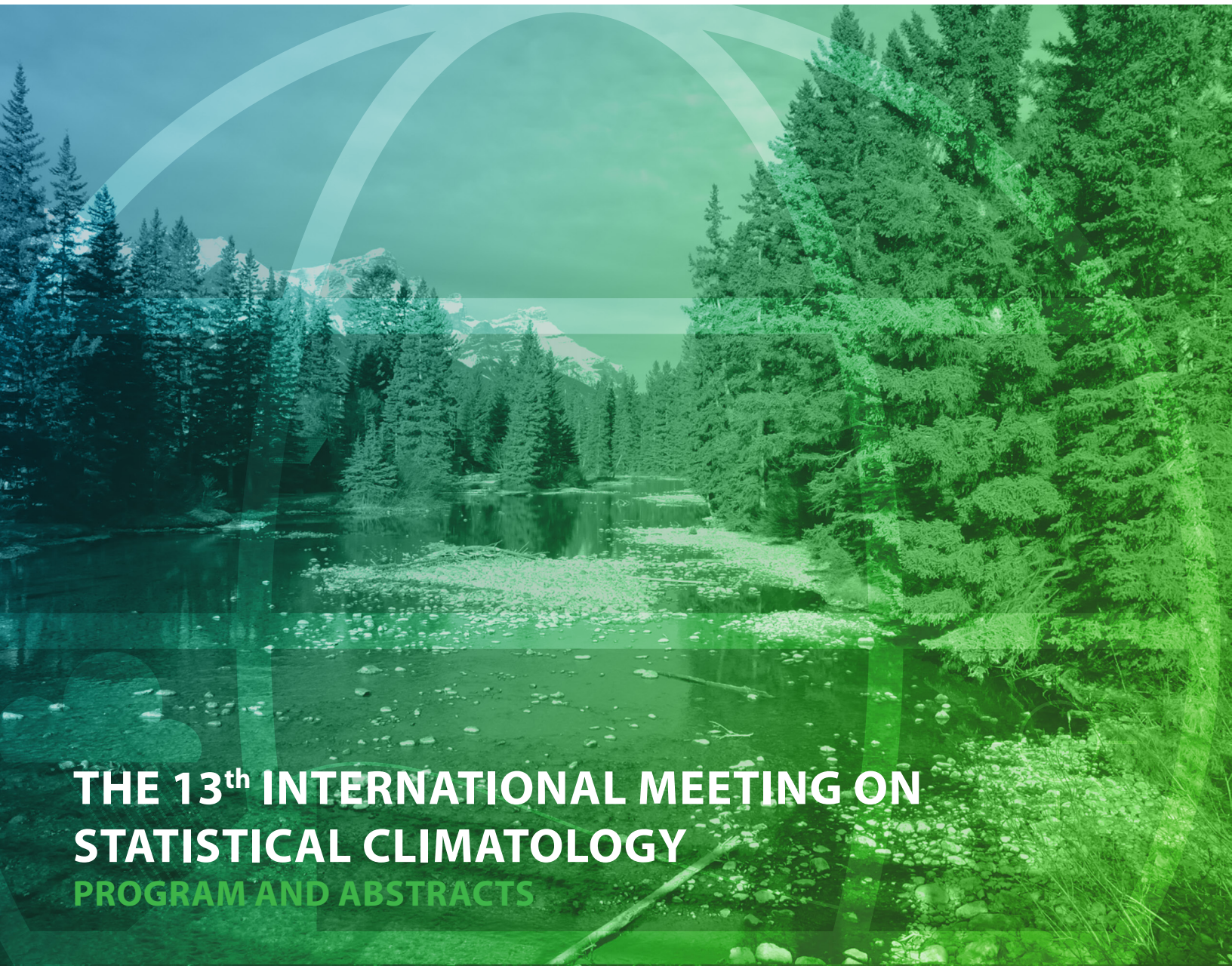

THE 13th INTERNATIONAL MEETING ON STATISTICAL CLIMATOLOGY

PROGRAM AND ABSTRACTS

JUNE 6-10, 2016 | CANMORE, ALBERTA

CANSSI INCASS

PACIFIC CLIMATE IMPACTS CONSORTIUM

WCRP World Climate Research Programme

Government of Canada

LOCATION AND CONTACT INFORMATION

Coast Canmore Hotel & Conference Centre, located at 511 Bow Valley Trail, Canmore, Alberta, T1W 1N7.

Phone: 403-678-3625 Fax: 403-678-5534

THE 13th INTERNATIONAL MEETING ON STATISTICAL CLIMATOLOGY

It is with great satisfaction that I welcome you to the 13th International Meeting on Statistical Climatology. These meetings are dedicated to the memory of the late Alan Murphy, who organized the first of these meetings in 1979 in Hachioji, Japan, and who was the initial chair of the IMSC Steering Committee that was established in 1987. The IMSC meetings have been held at roughly three year intervals since 1979, and were conceived as a place where climatologists, meteorologists and statisticians can share their experiences in applying statistical methods and reasoning to climatological and meteorological problems. The interaction between the meteorological and statistical sciences has increased substantially over the years, and resulted in continued improvement in the sophistication of statistical practice in climatology and meteorology. This is well reflected in this meeting, and also within the literature of all three disciplines and in assessments such as those of the IPCC; it would be nice to think that the IMSC series of meetings have contributed in at least some small way to that development.

The IMSC meetings have over their 37-year history always been the product of a grass roots community effort. This meeting is no exception – the mandate and impetus to hold the meeting stems entirely from the community that it serves. Therefore I wish to express the very sincere thanks of the Steering Committee to you, the participants, for your participation and continued interest in the IMSC. Secondly, I hope that you will join me in thanking the Program Committee lead by Dr. Xuebin for organizing an extremely stimulating and interesting program, and also sincerely thanking the local organizers at the Pacific Climate Impacts Consortium; both groups have worked extremely hard to make the meeting a success. We are deeply indebted to the members of both committees. Finally, we would like to express our deep appreciation to the sponsoring organizations, the Canadian Statistical Sciences Institute, Environment and Climate Change Canada, the Pacific Climate Impacts Consortium, and the World Climate Research Program, who have assisted by providing in-kind and cash support that has helped to enable the meeting. On behalf of everyone who has contributed to the preparations for this meeting, we hope that you will have an enjoyable and enriching week!

Yours sincerely,
Francis Zwiers, on behalf of the IMSC Steering Committee

PROGRAM OVERVIEW

TIME	JUNE 6	JUNE 7	JUNE 8	JUNE 9	JUNE 10
	REGISTRATION WILL BE OPEN ON SUNDAY, JUNE 5th 4:00-6:00 PM AND MONDAY- FRIDAY, 8:00-8:30 AM				
8:00	Breakfast 8:50: Opening and Introductions	Breakfast	Breakfast	Breakfast	Breakfast
9:00-	AM1: **CLIMATE AND WEATHER MODEL EVALUATION**	9:00: AM1: **THE DETECTION AND ATTRIBUTION MODEL INTERCOMPARISON PROJECT (DAMIP)** 10:00: AM1: **ADVANCED METHODS FOR EVALUATING WEATHER AND CLIMATE EXTREMES IN CLIMATE MODEL SIMULATIONS**	AM1: **WCRP EXTREME GC**	AM1: **STATISTICAL DOWNSCALING METHODS FOR SEASONAL TO CENTENNIAL PREDICTIONS AND PROJECTIONS**	AM1: **CLIMATE DATA HOMOGENIZATION AND CLIMATE TRENDS/ VARIABILITY ASSESSMENT**
10:30	Break	Break	Break	Break	Break
11:00	AM2: **THE ATTRIBUTION OF EXTREME WEATHER EVENTS AND THEIR IMPACTS TO EXTERNAL DRIVERS OF CLIMATE CHANGE**	AM2: **UNDERSTANDING CLIMATE VARIABILITY AND ITS TELECONNECTIONS UNDER GLOBAL WARMING**	AM2: **EXTREME VALUE THEORY AND ITS APPLICATION**	AM2: **NONLINEAR METHODS FOR CLIMATE EXTREMES** 12:00: **IMSC SCC Chair Invited Address**	AM2-P2: **THE DETECTION AND ATTRIBUTION MODEL INTERCOMPARISON PROJECT (DAMIP)** AM2-P2: **NONLINEAR METHODS FOR CLIMATE EXTREMES**
12:30	Lunch	Lunch	Lunch	Lunch	Lunch
1:30	PM1-P1: **UNDERSTANDING CLIMATE VARIABILITY AND ITS TELECONNECTIONS UNDER GLOBAL WARMING** PM1-P2: **STATISTICAL DOWNSCALING METHODS FOR SEASONAL TO CENTENNIAL PREDICTIONS AND PROJECTIONS**	PM1-P1: **WCRP GRAND CHALLENGE ON CLIMATE EXTREMES** PM1-P2: **STATISTICAL DOWNSCALING METHODS FOR SEASONAL TO CENTENNIAL PREDICTIONS AND PROJECTIONS**	PM1-P1: **CLIMATE AND WEATHER MODEL EVALUATION** PM1-P2: **NONLINEAR METHODS FOR CLIMATE EXTREMES**	PM1-P1: **ADVANCED METHODS FOR EVALUATING WEATHER AND CLIMATE EXTREMES IN CLIMATE MODEL SIMULATIONS** PM1-P2: **THE DETECTION AND ATTRIBUTION MODEL INTERCOMPARISON PROJECT (DAMIP)**	PM1-P1: **EXTREME VALUE THEORY AND ITS APPLICATIONS** PM1-P2: **CLIMATE DATA HOMOGENIZATION AND CLIMATE TRENDS/ VARIABILITY ASSESSMENT**
3:15	Break	Break	Break	Break	Conference ends: 3:15
3:45	PM2-P1: **THE ATTRIBUTION OF EXTREME WEATHER EVENTS AND THEIR IMPACTS TO EXTERNAL DRIVERS OF CLIMATE CHANGE ENDS: 5:30** PM2-P2: **CLIMATE AND WEATHER MODEL EVALUATION ENDS: 5:30**	**POSTER SESSION AND MIXER, WITH CASH BAR**	M2-P1: **STATISTICAL DOWNSCALING METHODS FOR SEASONAL TO CENTENNIAL PREDICTIONS AND PROJECTIONS** PM2-P2: **STOCHASTIC ANALYSIS OF THE HYDROLOGIC CYCLE**	PM2-P1: **EXTREME VALUE THEORY AND ITS APPLICATION** PM2-P2: **CLIMATE AND WEATHER MODEL EVALUATION**	

JUNE 6th, 2016

Time	
8:00-8:50	BREAKFAST
8:50-9:00	**OPENING AND INTRODUCTIONS**
9:00	Session AM1: **CLIMATE AND WEATHER MODEL EVALUATION** (VIEW ABSTRACTS) Chair: Barbara Casati
9:00-9:30	CURRENT STATUS AND RECENT ADVANCES IN FORECAST EVALUATION METHODS Barbara Brown, National Center for Atmospheric Research
9:30-10:00	AN INTERCOMPARISON OF A LARGE ENSEMBLE OF STATISTICAL DOWNSCALING METHODS FOR EUROPE: OVERALL RESULTS FROM THE VALUE PERFECT PREDICTOR CROSS-VALIDATION EXPERIMENT Douglas Maraun, University of Graz
10:00-10:30	COMPARING FORECAST SKILL Michael Tippett, Columbia University
10:30-11:00	BREAK
11:00	Session AM2: **THE ATTRIBUTION OF EXTREME WEATHER EVENTS AND THEIR IMPACTS TO EXTERNAL DRIVERS OF CLIMATE CHANGE** (VIEW ABSTRACTS) Chair: Francis Zwiers
11:00-11:30	ATTRIBUTING A SPECIFIC CLIMATE EVENT OR A CLASS OF CLIMATE EVENTS: CONTRASTS IN PURPOSE, IMPLICATIONS AND METHODS Alexis Hannart, Centre National de la Recherche Scientifique
11:30-12:00	TOWARDS AN "END-TO-END" ATTRIBUTION FRAMEWORK FOR BIOSPHERE VARIABILITY AND CHANGE Sebastian Sippel, Max Planck Institute for Biogeochemistry
12:00-12:30	CHANGES IN WINTER EXTREMES ATTRIBUTABLE TO HUMAN-INDUCED CHANGES IN ATMOSPHERIC FLOWS Robert Vautard, Institut Pierre Simon Laplace
12:30-1:30	LUNCH Note that the program splits into two sessions following lunch. These are listed as PM1-P1 and PM1-P2 below

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1:30	Session PM1-P1: **UNDERSTANDING CLIMATE VARIABILITY AND ITS TELECONNECTIONS UNDER GLOBAL WARMING** (VIEW ABSTRACTS) Chair: Seung-Ki Min
1:30-1:45	CMIP5 SIMULATION AND PROJECTION ON THE ASIAN-PACIFIC OSCILLATION Botao Zhou, China Meteorological Administration
2:00-2:15	UNDERSTANDING TELECONNECTIVE EFFECTS FROM EAST ASIA ON THE DROUGHT OVER THE CONTINENTAL UNITED STATES DURING SUMMER Sang-Wook Yeh, Hanyang University
2:15-2:30	DISRUPTION OF THE EUROPEAN CLIMATE SEASONAL CLOCK IN A WARMING WORLD Julien Cattiaux, CNRM, CNRS/Météo-France
2:30-2:45	INFLUENCE OF CLIMATE VARIABILITY ON EXTREME OCEAN SURFACE WAVE HEIGHTS ASSESSED FROM ERA-INTERIM AND ERA-20C REANALYSES Seung-Ki Min, Pohang University of Science and Technology
2:45-3:00	THE EFFECT OF THE PDO ON ANNUAL PEAK FLOWS IN WESTERN CANADIAN RIVERS Jeannine-Marie St-Jacques, Prairie Adaptation Research Collaborative
3:00-3:15	IMPACT OF TEMPERATURE AND PRECIPITATION EXTREMES ON FLOWERING DATES OF FOUR SHRUB SPECIES OVER GERMANY Jonatan Siegmund, Potsdam Institute for Climate Impact Research
1:30	Session PM1-P2: **STATISTICAL DOWNSCALING METHODS FOR SEASONAL TO CENTENNIAL PREDICTIONS AND PROJECTIONS** (VIEW ABSTRACTS) Chair: Xuebin Zhang
1:30-1:45	A NOVEL BIAS CORRECTION METHODOLOGY FOR CLIMATE IMPACT SIMULATIONS Sebastian Sippel, Max Planck Institute for Biogeochemistry
1:45-2:00	BIAS CORRECTING HEATING AND COOLING DEGREE DAYS Caroline Holmes, University of Edinburgh
2:00-2:15	EXAMINING THE SENSITIVITIES OF AIR QUALITY TO EXTREME AIR POLLUTION METEOROLOGY BY COMBINING STATISTICAL ANALYSIS WITH ATMOSPHERIC MODELLING Shiliang Wu, Michigan Technological University
2:15-2:30	INTER-COMPARISON OF STOCHASTIC WEATHER GENERATORS FOR THE SIMULATION OF BASIN-SCALE EXTREME PRECIPITATION IN THE CATSKILL MOUNTAINS, NEW YORK STATE, U.S. Nachiketa Acharya, City University of New York

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2:30-2:45	CONVECTIVE AND LARGE-SCALE PRECIPITATION CHARACTERISTICS IN REGIONAL CLIMATE MODEL SIMULATIONS IN CENTRAL EUROPE Jan Kysely, Czech Academy of Sciences
2:45-3:00	
3:00-3:15	AIR TEMPERATURE MODELLING : TRENDS, EXTREME VALUES, HEAT AND COLD WAVES Thu Huong Hoang, EDF and Quai Watier
3:15-3:45	BREAK Note that the program is split into two sessions following the break. These are listed as PM2-P1 and PM2-P2 below
3:45	Session PM2-P1: **THE ATTRIBUTION OF EXTREME WEATHER EVENTS AND THEIR IMPACTS TO EXTERNAL DRIVERS OF CLIMATE CHANGE** (VIEW ABSTRACTS) Chair: Xuebin Zhang
3:45-4:00	ATTRIBUTION OF EXTREME EVENTS IN ARCTIC SEA ICE EXTENT Megan Kirchmeier-Young, The Pacific Climate Impacts Consortium
4:00-4:15	MULTI-METHOD ATTRIBUTION ANALYSIS OF EXTREME PRECIPITATION IN BOULDER, COLORADO Jonathan Eden, Royal Netherlands Meteorological Institute (KNMI)
4:15-4:30	HOW MUCH RAINFALL EXTREMES ASSOCIATED WITH TROPICAL CYCLONES CAN BE ATTRIBUTABLE TO ANTHROPOGENIC INFLUENCES? Cheng-Ta Chen, National Taiwan Normal University
4:30-4:45	QUANTIFYING THE EFFECT OF OCEAN VARIABILITY ON THE ATTRIBUTION OF EXTREME CLIMATE EVENTS TO HUMAN INFLUENCE Daithi Stone, Lawrence Berkeley Lab
4:45-5:00	INVESTIGATION OF THE 2013 ALBERTA FLOOD FROM WEATHER AND CLIMATE PERSPECTIVES Bernardo Teufel, University of Quebec at Montreal
5:00-5:15	STOCHASTIC AND ANTHROPOGENIC INFLUENCES ON REPEATED RECORD-BREAKING TEMPERATURE EXTREMES IN AUSTRALIAN SPRING OF 2013 AND 2014 Ailie Gallant, Monash University
5:15-5:30	USING RELIABILITY TO QUANTIFY UNCERTAINTY IN EVENT ATTRIBUTION Fraser Lott, Met Office Hadley Centre

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3:45	Session PM2-P2: **CLIMATE AND WEATHER MODEL EVALUATION** (VIEW ABSTRACTS) Chair: Erich Fischer
3:45-4:00	BAYESIAN MODEL AVERAGING AND ITS APPLICATION TO AN EL NINO INDEX IN CMIP5 MODELS Pao-Shin Chu, University of Hawaii
4:15-4:30	IMPROVING SEASONAL CLIMATE PREDICTION BY MATHEMATICAL/STATISTICAL METHODS. Youmin Tang, University of Northern British Columbia
4:30-4:45	FINDING LOW CLIMATE SENSITIVITY GENERAL CIRCULATION MODELS THROUGH VERY LARGE PERTURBED PHYSICS ENSEMBLES Richard Millar, University of Oxford
4:45-5:00	TESTING CLIMATE MODELS FOR TIME-VARYING FORECAST ACCURACY USING INDICATOR SATURATION Felix Pretis, University of Oxford
5:00-5:15	QUANTIFYING MODEL PERFORMANCE USING DATA ASSIMILATION Alexis Hannart, National Center for Scientific Research (CNRS)
5:15-5:30	SPATIAL VERIFICATION OF SEA ICE PREDICTION BY USING BINARY IMAGE DISTANCE METRICS Barbara Casati, Meteorological Research Division, Environment and Climate Change Canada

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Time	
8:00-9:00	BREAKFAST
9:00	Session AM1: **THE DETECTION AND ATTRIBUTION MODEL INTERCOMPARISON PROJECT (DAMIP)** (VIEW ABSTRACTS) Chair: Michael Wehner
9:00-9:30	MULTI-MODEL DETECTION AND ATTRIBUTION WITHOUT LINEAR REGRESSION Aurélien Ribes, Météo France - CNRS
9:30-10:00	OVERVIEW OF DETECTION AND ATTRIBUTION MODEL INTERCOMPARISON PROJECT (DAMIP) Daithi Stone, Lawrence Berkeley National Laboratory
10:00	Session AM1: **ADVANCED METHODS FOR EVALUATING WEATHER AND CLIMATE EXTREMES IN CLIMATE MODEL SIMULATIONS** (VIEW ABSTRACTS) Chair: Jana Sillmann
10:00-10:30	HEAT EXTREMES IN CESM: HISTORICAL AND FUTURE BEHAVIOR Claudia Tebaldi, NCAR
10:30-11:00	BREAK
11:00	Session AM2: **UNDERSTANDING CLIMATE VARIABILITY AND ITS TELECONNECTIONS UNDER GLOBAL WARMING** (VIEW ABSTRACTS) Chair: Seung-Ki Min
11:00-11:30	MODES OF SST VARIABILITY IN CMIP MODEL SIMULATIONS Dietmar Dommenget, Monash University
11:30-12:00	TELECONNECTIONS, DROUGHTS AND GLOBAL WARMING Celine Bonfils, Lawrence Livermore National Laboratory
12:00-12:30	ASYMMETRICAL EVOLUTION BETWEEN EL NINO AND LA NINA MANIFESTED BY SEASON-RELIANT EOF METHOD Soon-Il An, Yonsei University
12:30-1:30	LUNCH Note that the program splits into two sessions following lunch. These are listed as PM1-P1 and PM1-P2 below
1:30	Session PM1-P1: **WCRP GRAND CHALLENGE ON CLIMATE EXTREMES** (VIEW ABSTRACTS) Chair: Gabi Hegerl
1:30-1:45	LAND-SURFACE COUPLING AND HEATWAVES IN THE CMIP5 MODELS Sarah Perkins-Kirkpatrick, , Climate Change Research Centre, UNSW Australia

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Time	
1:45-2:00	THE NEED FOR RELIABLE GRIDDED DAILY PRECIPITATION OBSERVATIONS FOR THE INVESTIGATION OF PRECIPITATION EXTREMES Steefan Contractor, University of New South Wales
2:00-2:15	ANALYSIS OF THE PROJECTED EXTREME TEMPERATURES AND PRECIPITATION AND ASSOCIATED SOIL HYDRIC CONDITIONS IN THE EAST-NORTHEAST OF ARGENTINA Vanesa Pántano, University of Buenos Aires
2:15-2:30	TEMPERATURE EXTREMES THEN AND NOW: WHAT CAN WE LEARN FROM THE 1930'S? Gabriele Hegerl, University of Edinburgh
2:30-2:45	LINKAGES BETWEEN SEASONAL WINTER TEMPERATURES AND SNOW COVER Klaus Wolter, University of Colorado at Boulder - CIRES and NOAA-ESRL-Physical Science Division
2:45-3:00	ESTIMATING FLOOD EXCEEDANCE PROBABILITIES IN ESTUARINE REGIONS Seth Westra, University of Adelaide
3:00-3:15	WHAT WEATHER FEATURES PRODUCE EXTREME PRECIPITATION GLOBALLY? Jennifer Catto, Monash University
1:30	Session PM1-P2: **STATISTICAL DOWNSCALING METHODS FOR SEASONAL TO CENTENNIAL PREDICTIONS AND PROJECTIONS** (VIEW ABSTRACTS) Chair: Megan Kirchmeier-Young
1:30-1:45	CONSTRUCTING HOURLY TEMPERATURE-WIND SCENARIOS FOR THE HUDSON BAY AREA: CHALLENGES AND METHOD. Patrick Grenier, Ouranos
1:45-2:00	IMPORTANCE-RANKING OF CLIMATE VARIABLES FOR PREDICTION OF DAMAGING STRAIGHT-LINE WINDS Ryan Lagerquist, University of Oklahoma, Cooperative Institute for Mesoscale Meteorological Studies
2:00-2:15	LINEAR AND NONLINEAR STATISTICAL DOWNSCALING OF SURFACE WIND VECTORS Yiwen Mao, University of Victoria
2:15-2:30	CAPTURING INTER ANNUAL VARIABILITY IN DOWNSCALED PRECIPITATION USING STOCHASTIC SEASONALITY Trevor Carey-Smith, National Institute of Water and Atmospheric Research
2:30-2:45	EVALUATING CLIMATE DOWNSCALING APPROACHES FOR THE NEXT GENERATION OF SWISS CLIMATE CHANGE SCENARIOS Jonas Bhend, MeteoSwiss

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Time	
2:45-3:00	HIGH-RESOLUTION MAPPING OF CLIMATE INDICES AND THEIR TRENDS ACROSS ALBERTA, CANADA Stefan Kienzle, University of Lethbridge
3:00-3:15	PROJECTED CHANGES IN PROBABLE MAXIMUM PRECIPITATION Xuebin Zhang, Environment Canada
3:15-3:45	BREAK
3:45-5:30	**POSTER SESSIONS**
NUMBER	TITLES AND SESSIONS
	THE ATTRIBUTION OF EXTREME WEATHER EVENTS AND THEIR IMPACTS TO EXTERNAL DRIVERS OF CLIMATE CHANGE (VIEW ABSTRACTS)
1	ALTERNATIVE APPROACHES TO ATTRIBUTING ANTHROPOGENIC INFLUENCES ON THE 2013 NEW ZEALAND DROUGHT Luke Harrington (Victoria University of Wellington)
2	POOREST COUNTRIES EXPERIENCE EARLIER ANTHROPOGENIC EMERGENCE OF DAILY TEMPERATURE EXTREMES Luke Harrington (Victoria University of Wellington)
3	A STATISTICAL ANALYSIS OF TROPICAL CYCLONE GENESIS Thomas Leahy (Imperial College London)
4	DIAGNOSING ANTHROPOGENIC CONTRIBUTIONS TO HEAVY COLORADO RAINFALL IN SEPTEMBER 2013 Pardeep Pall (Lawrence Berkeley National Laboratory)
5	THE C20C+ DETECTION AND ATTRIBUTION PROJECT: A NEW RESOURCE FOR ANALYSIS OF EXTREME WEATHER Daithi Stone (Lawrence Berkeley National Laboratory), et al.
	CLIMATE DATA HOMOGENIZATION AND CLIMATE TRENDS/VARIABILITY ASSESSMENT (VIEW ABSTRACTS)
6	REGIONAL CLIMATE INFORMATION FROM INSTRUMENTAL RECORDS IN DATA SPARSE AREAS OF NORTHERN BRITISH COLUMBIA Vanessa Noel Foord (BC Ministry of Forests, Lands, and Natural Resource Operations)
7	MONTHLY MEAN TEMPERATURES IN SE-EUROPE, VARIABILITY AND PERSISTENCE Haraldur Olafsson (University of Iceland and Icelandic Meteorological Office) and Dubravka Rasol

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Time	
3:45-5:30	**POSTER SESSIONS**

NUMBER	TITLES AND SESSIONS
8	THE EFFECT OF THE LOCATION OF STATIONS AND TEMPORAL VARIABILITY OF TEMPERATURE ON THE MAGNITUDE OF TRENDS Lucie Pokorna (Institute of Atmospheric Physics), et al.
9	DIFFERENCES IN TRENDS BEFORE AND AFTER HOMOGENIZATION OF CROATIAN TEMPERATURE DATA SETS Dubravka Rasol (Meteorological and Hydrological Service of Croatia)
10	THE CHARACTERISTIC FEATURES OF THE VARIABILITY OF AIR PRESSURE IN GDAŃSK, POLAND, IN THE PERIOD OF INSTRUMENTAL OBSERVATIONS, 1739-2012 Janusz Filipiak (University of Gdansk)
11	METEOROLOGICAL OBSERVATIONS IN 18TH CENTURY IN GDAŃSK, POLAND, AND THEIR APPLICABILITY TO STUDIES OF THE CLIMATE CHANGE Janusz Filipiak (University of Gdansk)
12	COMPARISON OF HOMOGENIZATION METHODS ON EXAMPLE OF CENTRAL EUROPEAN SERIES Petr Stepanek (Global Change Research Institute CAS), et al.
13	GLOBAL TEMPERATURE TREND BIASES AND STATISTICAL HOMOGENIZATION METHODS Victor Venema (University of Bonn)
14	HOMOGENIZATION PROJECT IN BRITISH COLUMBIA Yaqiong Wang (Pacific Climate Impacts Consortium, University of Victoria)
15	DATA QUALITY CONTROL OF VARIOUS METEOROLOGICAL ELEMENTS FOR NEBRASKA, USA Pavel Zahradníček (CzechGlobe - Global Research Institute, Czech Hydrometeorological Institute), et al.

3:45-5:30	**POSTER SESSIONS**

NUMBER	TITLES AND SESSIONS

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Time	
	STATISTICAL DOWNSCALING METHODS FOR SEASONAL TO CENTENNIAL PREDICTIONS AND PROJECTIONS (VIEW ABSTRACTS)
16	RESULTS FROM THE VALUE PERFECT PREDICTOR EXPERIMENT: PROCESS-BASED EVALUATION Emanuele Bevacqua (University of Graz), et al.
17	A REGRESSION-BASED STATISTICAL DOWNSCALING FOR MULTI AGRO-METEOROLOGICAL ELEMENTS AND THEIR COMPARISON WITH DYNAMICAL DOWNSCALING RESULTS Motoki Nishimori (National Institute for Agro-Environmental Sciences)
	WORLD CLIMATE RESEARCH PROGRAMME GRAND CHALLENGE ON CLIMATE AND WEATHER EXTREMES (VIEW ABSTRACTS)
18	USING OBJECTIVE CLASSIFICATION OF EXTRATROPICAL CYCLONES IN CLIMATE STUDIES Jennifer Catto (Monash University)
19	APPLYING COMPLEX NETWORKS TO EVALUATE PRECIPITATION PATTERNS OVER SOUTH AMERICA Catrin Ciemer (Potsdam Institut for Climate Impact Research, Germany)
20	SUMMER DAILY EXTREME PRECIPITATION IN CENTRAL-EASTERN ARGENTINA: POTENCIAL PREDICTORS Olga Penalba (University of Buenos Aires, Consejo Nacional de Investigaciones Científicas y Técnicas Argentina), et al.
21	STATISTICAL UNCERTAINTY OF EXTRA-TROPICAL CYCLONES OVER EUROPE DERIVED FROM A PROBABILISTIC CLUSTERING APPROACH USING REGRESSION MIXTURE MODELS Michael Walz (University of Birmingham), et al.
22	ASSESSING THE RISKS OF A CHANGING CLIMATE TO FOREST MANAGEMENT Trevor Murdock (The Pacific Climate Impacts Consortium), et al.
	UNDERSTANDING CLIMATE VARIABILITY AND ITS TELECONNECTIONS UNDER GLOBAL WARMING (VIEW ABSTRACTS)
23	THE PERIGEE YEAR AS A PRECURSOR TO EL NINO Albert Boehm
24	A SPATIAL-STATISTICAL APPROACH TO MODELING TELECONNECTIONS Joshua Hewitt (Colorado State University), et al.
25	THE CONTRIBUTION OF ATMOSPHERIC CIRCULATION TO DECADAL TRENDS IN NORTHERN HEMISPHERE TEMPERATURE Carley Elizabeth Iles (University of Edinburgh)

JUNE 7th, 2016

Time	
3:45-5:30	**POSTER SESSIONS**
NUMBER	TITLES AND SESSIONS
	ADVANCED METHODS FOR EVALUATING WEATHER AND CLIMATE EXTREMES IN CLIMATE MODEL SIMULATIONS (VIEW ABSTRACTS)
26	SIMULATION OF SEVERE HEAT WAVES IN REGIONAL CLIMATE MODELS: PAST BIASES AND FUTURE SCENARIOS Ondřej Lhotka (CzechGlobe)
27	CHANGES IN REGIONAL HEATWAVES AS A FUNCTION OF AVERAGE WARMING Sarah Perkins-Kirkpatrick, University of New South Wales
	EXTREME VALUE THEORY AND ITS APPLICATIONS (VIEW ABSTRACTS)
28	IDENTIFICATION OF HOMOGENEOUS REGIONS FOR ANALYSIS OF EXTREME PRECIPITATION EVENTS IN THE CZECH REPUBLIC WITH THE HELP OF NEURAL NETWORKS (KOHONEN MAPS) Stanislava Kliegrova (Czech Hydrometeorological Institute), et al.
29	OPTIMIZATION OF PROBABILITY ESTIMATES FOR MULTI-STATION PRECIPITATION DATA Isabella Osetinsky-Tzidaki (Israel Meteorological Service)
30	ESTIMATES OF EXTREME RAINFALL FREQUENCY IN URBAN AREAS FROM SPATIALLY DENSE OBSERVATIONS Lynne Seymour (University of Georgia), et al.
31	QUANTILE-BASED BIAS CORRECTION AND UNCERTAINTY QUANTIFICATION OF EXTREME EVENT ATTRIBUTION STATEMENTS Michael Wehner (Lawrence Berkeley National Laboratory)
32	STATISTICAL MODELLING OF DROUGHT AND HEAT WAVE COMPOUND EVENTS Martin Widmann (University of Birmingham), et al.

JUNE 8th, 2016

Time	
8:00-9:00	BREAKFAST
9:00-10:30	Session AM1: **WCRP GRAND CHALLENGE: UNDERSTANDING AND PREDICTING WEATHER AND CLIMATE EXTREMES - INTRODUCTION AND PANEL DISCUSSION** (VIEW ABSTRACTS) Chair: Gabi Hegerl
9:00-9:05	OVERVIEW OF THE WCRP GRAND CHALLENGE ON WEATHER AND CLIMATE EXTREMES Gabi Hegerl, The University of Edinburgh
9:05-9:15	DOCUMENT THEME: OBSERVATION OF WEATHER AND CLIMATE EXTREMES: OPPORTUNITIES, CHALLENGES, AND NEXT STEPS Ali Behrangi, National Aeronautics and Space Administration
9:15-9:25	UNDERSTANDING EXTREMES Robert Vautard, Institut Pierre Simon Laplace
9:25-9:35	THE CHALLENGE OF EVALUATING MODELS AND CONSTRAINING PROJECTIONS OF EXTREMES GIVEN ABUNDANT INTERNAL VARIABILITY – THE SIMULATE THEME Erich Fischer, ETH-Zurich
9:35-9:45	THE ATTRIBUTION OF EXTREME WEATHER TO EXTERNAL DRIVERS OF CLIMATE CHANGE IN THE CONTEXT OF THE WCRP GRAND CHALLENGE ON EXTREME EVENTS Francis Zwiers, The Pacific Climate Impacts Consortium
9:45-10:30	PANEL DISCUSSION ON THE WCRP GRAND CHALLENGE ON EXTREMES
10:30-11:00	BREAK
11:00	Session AM2: **EXTREME VALUE THEORY AND ITS APPLICATION** (VIEW ABSTRACTS) Chair: Seth Westra
11:00-11:30	MODELS FOR COMPLEX EXTREME EVENTS Anthony Davison, Ecole Poytechnique Federale de Lausanne
11:30-12:00	ON THE UNCERTAINTY OF GENERALIZED EXTREME VALUE ESTIMATES OF DAILY PRECIPITATION RETURN VALUES Michael Wehner, Lawrence Berkeley National Laboratory
12:00-1:30	IMSC AWARD PRESENTATION LUNCHEON Note that the program splits into two sessions following lunch. These are listed as PM1-P1 and PM1-P2 below

JUNE 8th, 2016

Time	
1:30	Session PM1-P1: **CLIMATE AND WEATHER MODEL EVALUATION** (VIEW ABSTRACTS) Chair: Barbara Casati
1:30-1:45	TOWARD A COMPREHENSIVE EVALUATION OF METEOROLOGICAL DROUGHT IN CMIP5 MODEL SIMULATIONS Ailie Gallant, Monash University
1:45-2:00	PREDICTIVE SKILL OF SEASONAL FORECASTS OF CLIMATE INDICES Jonas Bhend, MeteoSwiss
2:00-2:15	CLIMATE RESPONSES TO VOLCANIC ERUPTIONS ASSESSED FROM OBSERVATIONS AND CMIP5 MULTI-MODELS Seungmok Paik, POSTECH
2:15-2:30	STATISTICAL VERIFICATION OF WEATHER FORECASTING FOR DIFFERENT SEASONS Gerhard Reuter, University of Alberta
2:30-2:45	AN EMPIRICAL MODEL FOR PROBABILISTIC DECADAL PREDICTION: A GLOBAL ANALYSIS Jonathan Eden, Royal Netherlands Meteorological Institute (KNMI)
2:45-3:00	ANALYSIS OF ENSEMBLE QUALITY OF INITIALISED HINDCASTS IN THE GLOBAL COUPLED CLIMATE MODEL MPI-ESM Andre Dusterhus, Universität Hamburg
3:00-3:15	WINTER ATMOSPHERIC CIRCULATION OVER EUROPE AND THE NORTH ATLANTIC: AN EVALUATION Jan Stryhal, Charles University in Prague
1:30	Session PM1-P2: **NONLINEAR METHODS FOR CLIMATE EXTREMES** (VIEW ABSTRACTS) Chair: Andrea Toreti
1:30-1:45	A MODEL BASED ON PAIR-COPULA CONSTRUCTIONS TO ANALYZE AND REPRESENT COMPOUND FLOODING Emanuele Bevacqua, University of Graz
1:45-2:00	NONPARAMETRIC MULTIVARIATE BIAS CORRECTION OF CLIMATE MODEL OUTPUTS: MATCHING MARGINAL DISTRIBUTIONS AND INTER-VARIABLE DEPENDENCE STRUCTURE Alex Cannon, Environment and Climate Change Canada
2:00-2:15	HOMOGENEITY TESTING REVISITED Taha Ouarda, Institut National de la Recherche Scientifique
2:15-2:30	A FAST AND OBJECTIVE MULTIDIMENSIONAL KERNEL DENSITY ESTIMATION METHOD: FASTKDE Travis O'Brien, Lawrence Berkeley National Lab and University of California, Davis

JUNE 8th, 2016

Time	
2:30-2:45	GENERALIZED ADDITIVE MODELS (GAM) FOR THE SPATIO-TEMPORAL ASSESSMENT OF HYDRO-CLIMATIC VARIABLES Taha Ouarda, Institut National de la Recherche Scientifique
2:45-3:00	PROJECTION PURSUIT REGRESSION IN REGIONAL FREQUENCY ANALYSIS Fateh Chebana, Institut National de la Recherche Scientifique
3:00-3:15	NON-LINEAR DELINEATION FOR REGIONAL FREQUENCY ANALYSIS Dhouha Ouali, Institut National de la Recherche Scientifique
3:15-3:45	BREAK Note that the program is split into two sessions following the break. These are listed as PM2-P1 and PM2-P2 below
3:45	Session PM2-P1: **STATISTICAL DOWNSCALING METHODS FOR SEASONAL TO CENTENNIAL PREDICTIONS AND PROJECTIONS** (VIEW ABSTRACTS) Chair: Megan Kirchmeier-Young
3:45-4:00	CHANGES IN U.S. TEMPERATURE EXTREMES UNDER INCREASED CO2 IN MILLENNIAL-SCALE CLIMATE SIMULATIONS Whitney Huang, Purdue University
4:00-4:15	THE BCCAQ STATISTICAL DOWNSCALING TECHNIQUE AND ITS APPLICATION TO CANADA Trevor Murdock, The Pacific Climate Impacts Consortium
4:15-4:30	DOES QUANTILE MAPPING OF SIMULATED PRECIPITATION CORRECT FOR BIASES IN TRANSITION PROBABILITIES AND SPELL LENGTHS? Jan Rajczak, ETH Zurich
4:30-4:45	INDICES OF CANADA'S FUTURE CLIMATE FOR GENERAL AND AGRICULTURAL ADAPTATION APPLICATIONS Trevor Murdock, The Pacific Climate Impacts Consortium
3:45	Session PM2-P2: **STOCHASTIC ANALYSIS OF THE HYDROLOGIC CYCLE** (VIEW ABSTRACTS) Chair: Mohammad Reza Najafi
3:45-4:00	ASSESSMENT OF SOURCES OF UNCERTAINTY IN FORCED CHANGES OF MONTHLY MEAN AND DAILY EXTREME RAINFALL David Karoly, University of Melbourne
4:00-4:15	ENSEMBLE RECONSTRUCTION OF SEVERE LOW FLOW EVENTS IN FRANCE SINCE 1871 THROUGH STATISTICAL DOWNSCALING AND HYDROLOGICAL MODELLING Jean-Philippe Vidal, Hydrology and Hydrolics Research Unit, IRSTEA

JUNE 8th, 2016

Time	
4:15-4:30	CHANGES IN FLOOD REGIMES AS INFERRED FROM LONG RECORD GAUGING STATIONS Donald Burn, University of Waterloo
4:30-4:45	CHANGES TO STREAMFLOW PEAKS AT THE FALL-WINTER TRANSITION IN THE ROCKY MOUNTAINS OF NORTH AMERICA Paul Whitfield, University of Saskatchewan
4:45-5:00	A NEW FRAMEWORK FOR ANALYZING THE SCALING PROPERTIES OF INTERMITTENT PRECIPITATION Marc Schleiss, Princeton University
5:00-5:15	A MODEL-BASED APPROACH TO THE COMPUTATION OF AREA PROBABILITIES FOR PRECIPITATION EXCEEDING A CERTAIN THRESHOLD Bjoern Kriesche, Ulm University

JUNE 9th, 2016

Time	
8:00-9:00	BREAKFAST
9:00	Session AM1: **STATISTICAL DOWNSCALING METHODS FOR SEASONAL TO CENTENNIAL PREDICTIONS AND PROJECTIONS** (VIEW ABSTRACTS) Chair: Francis Zwiers
9:00-9:30	QUANTIFYING UNCERTAINTY IN THE PATTERN SCALING OF CLIMATE MODELS Doug Nychka, Institute for Mathematics Applied to Geosciences
9:30-10:00	USING NATURAL VARIABILITY UNCERTAINTY IN THE EVALUATION OF BIAS CORRECTION PERFORMANCE Blaise Gauvin St-Denis, Ouranos
10:00-10:30	PLENARY TALK: STATISTICAL DOWNSCALING OF TEMPERATURE IN A "PERFECT MODEL" FRAMEWORK: OVERALL PERFORMANCE AND TAIL PERFORMANCE John Lanzante, National Oceanic and Atmospheric Administration
10:30-11:00	BREAK
11:00	Session AM2: **NONLINEAR METHODS FOR CLIMATE EXTREMES** (VIEW ABSTRACTS) Chair: Alex Cannon
11:00-11:30	EVENT COINCIDENCE ANALYSIS: A NOVEL STATISTICAL APPROACH FOR QUANTIFYING SIMULTANEITIES IN (EXTREME) EVENT SEQUENCES Jonatan Siegmund, Potsdam Institute for Climate Impact Research
11:30-12:00	DISCRIMINATING DIFFERENT EL NINO AND LA NINA PHASES FROM EVOLVING CLIMATE NETWORKS Reik Donner, Potsdam Institute for Climate Impact Research
12:00-12:30	IMSC SCC Chair Invited Address: **OUR SHARED RESPONSIBILITY AS USERS OF STATISTICS AND CONSUMERS OF RESULTS FROM ITS APPLICATION IN THE CLIMATE SCIENCES** (VIEW ABSTRACT) Francis Zwiers, the Pacific Climate Impacts Consortium
12:30-1:30	LUNCH Note that the program splits into two sessions following lunch. These are listed as PM1-P1 and PM1-P2 below

JUNE 9th, 2016

Time	
1:30	Session PM1-P1: **ADVANCED METHODS FOR EVALUATING WEATHER AND CLIMATE EXTREMES IN CLIMATE MODEL SIMULATIONS** (VIEW ABSTRACTS) Chair: Jana Sillmann
1:30-1:45	A PERFORMANCE WEIGHTING PROCEDURE FOR GCMS BASED ON EXPLICIT PROBABILISTIC MODELS AND ACCOUNTING FOR OBSERVATION UNCERTAINTY Jean-Philippe Vidal, Irstea
1:45-2:00	QUANTIFYING CHANGES IN CLIMATE VARIABILITY AND EXTREMES: PITFALLS AND THEIR OVERCOMING Sebastian Sippel, Max Planck Institute for Biogeochemistry
2:00-2:15	PROJECTED CHANGES OF RAIN-ON-SNOW EVENTS OVER NORTH AMERICA BASED ON TWO CANADIAN REGIONAL CLIMATE MODELS Dae Il Jeong, Université du Québec à Montréal
2:15-2:30	CONSISTENCY OF EXTREME RAINFALL REPRESENTATION IN NUMERICAL SIMULATIONS AND HYDROLOGICAL DATASETS Ben Timmermans, Lawrence Berkeley National Lab
2:30-2:45	A NON-PARAMETRIC APPROACH FOR THE EVALUATION OF PRECIPITATION EXTREMES SIMULATED BY CLIMATE MODELS Andrea Toreti, European Commission
2:45-3:00	METHODS FOR CORRECTING BIASES IN LARGE MODEL ENSEMBLE EXPERIMENTS Friederike Otto (speaker to be announced), University of Oxford
3:00-3:15	COMPARING REGIONAL PRECIPITATION AND TEMPERATURE EXTREMES IN CLIMATE MODEL AND REANALYSIS PRODUCTS Oliver Angelil, University of New South Wales
1:30	Session PM1-P2: **THE DETECTION AND ATTRIBUTION MODEL INTERCOMPARISON PROJECT (DAMIP)** (VIEW ABSTRACTS) Chair: Daithi Stone
1:30-1:45	RAPID SYSTEMATIC ASSESSMENT OF THE DETECTION AND ATTRIBUTION OF REGIONAL ANTHROPOGENIC CLIMATE CHANGE Daithi Stone, Lawrence Berkeley National Laboratory
1:45-2:00	MULTI-MODEL ATTRIBUTION OF EXTREME TEMPERATURE CHANGES DURING 1951-2010 Yeon-Hee Kim, Pohang University of Science and Technology
2:00-2:15	IMPACTS OF LOCAL AND REMOTE ANTHROPOGENIC AEROSOLS ON THE 20TH CENTURY WEST AFRICA AND SOUTH ASIA MONSOONS Debbie Polson, University of Edinburgh

JUNE 9th, 2016

Time	
2:15-2:30	OBSERVED HEAVY PRECIPITATION INCREASE CONFIRMS THEORY AND EARLY MODELS Erich Fischer, ETH Zurich
2:30-2:45	EMERGENCE OF AN ANTHROPOGENIC INFLUENCE ON PRECIPITATION EXTREMES Andrew King, University of Melbourne
2:45-3:00	SIGNIFICANT ANTHROPOGENIC-INDUCED CHANGES OF CLIMATE CLASSES SINCE 1950 Qigang Wu, Nanjing University
3:00-3:15	OBSERVATIONALLY-CONSTRAINED PROJECTIONS OF WARMING UNDER RCP 2.6 AND THE FEASIBILITY OF LIMITING GLOBAL WARMING TO 1.5°C Nathan Gillett, Canadian Centre for Climate Modelling and Analysis
3:15-3:45	BREAK Note that the program is split into two sessions following the break. These are listed as PM2-P1 and PM2-P2 below.
3:45	Session PM2-P1: **EXTREME VALUE THEORY AND ITS APPLICATION** (VIEW ABSTRACTS) Chair: Seth Westra
3:45-4:00	THRESHOLD SELECTION FOR REGIONAL PEAKS-OVER-THRESHOLD DATA Martin Roth, Royal Netherlands Meteorological Institute
4:00-4:15	MODELING JOINTLY LOW, MODERATE AND HEAVY RAINFALL Philippe Naveau, LSCE-IPSL-CNRS-NCAR
4:15-4:30	ON THE STATISTICAL DISTRIBUTION OF HEATWAVES Jana Sillmann, Center for International Climate and Environmental Research - Oslo
4:30-4:45	EXTREME VALUE ANALYSIS OF OCEAN WAVES IN A CHANGING CLIMATE Erik Vanem, DNV-GL and University of Oslo
4:45-5:00	CHANGING TORNADO OUTBREAK VARIABILITY AND EXTREMES Michael Tippett, Columbia University
3:45	Session PM2-P2: **CLIMATE AND WEATHER MODEL EVALUATION** (VIEW ABSTRACTS) Chair: Barbara Brown
3:45-4:00	A SCALE-SEPARATION VERIFICATION APPROACH WHICH ACCOUNTS FOR THE UNEVEN SPATIAL DENSITY OF STATION OBSERVATION NETWORKS Barbara Casati, Environment and Climate Change Canada
4:00-4:15	SELF-ORGANIZING MAPS: A TOOL FOR EVALUATING CLIMATE MODELS BY ATMOSPHERIC STATE Aaron Kennedy, University of North Dakota

JUNE 9th, 2016

Time	
4:15-4:30	A SIMPLE WEIGHTING METHOD FOR COMBINING MULTIMODEL PROJECTIONS Ruth Lorenz, ETH-Zurich
4:30-4:45	A REGIME BASED CLIMATOLOGICAL ASSESSMENT OF WRF SIMULATED DEEP CONVECTION AND ASSOCIATED PRECIPITATION Brooke Hagenhoff, University of North Dakota
4:45-5:00	EVALUATING RAINFALL EXTREMES IN A CONVECTION-PERMITTING STRETCHED-GRID MODEL SIMULATION Tony Rafter, Commonwealth Scientific and Industrial Research Organisation
5:00-5:15	EVALUATION OF NOWCASTS OF AFTERNOON CONVECTIVE STORM INITIATION FROM TAIWAN AUTO-NOWCASTER Hui-Ling Chang, Central Weather Bureau, Taiwan

JUNE 10th, 2016

Time	
8:00-9:00	BREAKFAST
9:00	Session AM1: **CLIMATE DATA HOMOGENIZATION AND CLIMATE TRENDS/VARIABILITY ASSESSMENT** (VIEW ABSTRACTS) Chair: Lucie Vincent
9:00-9:30	GLOBAL CLIMATE MONITORING IN THE CONTEXT OF THE WMO ANNUAL STATEMENT ON GLOBAL CLIMATE John Kennedy, Met Office Hadley Centre
9:30-10:00	A GENERAL REGRESSION CHANGEPOINT TEST FOR TIME SERIES DATA Michael Robbins, RAND Corporation
10:00-10:30	HOMOGENIZATION OF THE GLOBAL TEMPERATURE Victor Venema, University of Bonn
10:30-11:00	BREAK Note that the program splits into two sessions following the break. These are listed as AM2-P1 and AM2-P2 below
11:00	Session AM2-P1: **THE DETECTION AND ATTRIBUTION MODEL INTERCOMPARISON PROJECT (DAMIP)** (VIEW ABSTRACTS) Chair: Daithi Stone
11:00-11:15	FLOW ANALOGUES FOR THE DETECTION AND ATTRIBUTION OF HEAT WAVES Aglae Jezequel, Institut Pierre Simon Laplace
11:15-11:30	ANTHROPOGENIC INFLUENCE ON THE FREQUENCY OF EXTREME TEMPERATURES IN CHINA Chunhui Lu, National Meteorological Information Center
11:30-11:45	ATTRIBUTION OF HUMAN INFLUENCE ON EXTREME TEMPERATURE CHANGES IN CHINA Hong Yin, National Climate Center
11:45-12:00	ROLE OF ANTHROPOGENIC FORCING IN THE EXTREME HIGH TEMPERATURE EVENTS IN CHINA Ying Sun, National Climate Center, China Meteorological Administration
12:00-12:15	SUPPRESSED MID-LATITUDE HOT SUMMER WEATHER BY ARCTIC SEA ICE LOSS DURING 1979-2012 Qigang Wu, Nanjing University

JUNE 10th, 2016

Time	
11:00	Session AM2-P2: **NONLINEAR METHODS FOR CLIMATE EXTREMES** (VIEW ABSTRACTS) Chair: Reik Donner
11:00-11:15	PROJECTING FUTURE EXTREME STREAMFLOW FOR THE FRASER RIVER: A NONSTATIONARY EXTREME VALUE ANALYSIS APPROACH Francis Zwiers, The Pacific Climate Impacts Consortium
11:15-11:30	DEVELOPMENT OF AN HOMOGENEOUS HYDROLOGICAL RECONSTRUCTION OVER FRANCE ON THE 20TH CENTURY TO EVALUATE THE LONG-TERM EVOLUTION OF EVAPOTRANSPIRATION IN CLIMATE MODELS Julien Boé, CECI, CERFACS – CNRS
11:30-11:45	A NEW APPROACH TO TESTING STATISTICAL SIGNIFICANCE OF TRENDS: ASSESSMENT ON SYNTHETIC DATA Radan Huth, Charles University
11:45-12:00	IDENTIFYING AND ATTRIBUTING COMMON DATA QUALITY PROBLEMS: TEMPERATURE AND PRECIPITATION OBSERVATIONS IN BOLIVIA AND PERU Stefan Hunziker, University of Bern
12:00-12:15	EXAMINING THE RELATIONSHIP BETWEEN SHORT-DURATION EXTREME PRECIPITATION AND SURFACE TEMPERATURE IN KOREA In Hong Park, Pohang University of Science and Techology
12:30-1:30	LUNCH Note that the program is split into two sessions following lunch. These are listed as PM1-P1 and PM1-P2 below
1:30	Session PM1-P1: **EXTREME VALUE THEORY AND ITS APPLICATIONS** (VIEW ABSTRACTS) Chair: Philipe Naveau
1:30-1:45	SPATIAL HIGH-DIMENSIONAL PEAKS-OVER-THRESHOLD MODELLING FOR EXTREME RAINFALL Raphaël de Fondeville, Ecole Polytechnique Federale de Lausanne
1:45-2:00	
2:00-2:15	AN APPLICATION OF MAX-STABLE PROCESSES TO MODELLING EXTREME DAILY RAINFALL IN SOUTH EAST QUEENSLAND, AUSTRALIA Kate Saunders, University of Melbourne
2:15-2:30	CALIBRATING MAX-STABLE MODELS OF RAINFALL EXTREMES AT MULTIPLE TIMESCALES Seth Westra, University of Adelaide

JUNE 10th, 2016

Time	
2:30-2:45	A RADAR-BASED REGIONAL EXTREME RAINFALL ANALYSIS IN SUPPORT OF A NEW AUTOMATIC ALERT SYSTEM IN SWITZERLAND Luca Panziera, University of Bern
2:45-3:00	ROBUST INCREASE IN CONCURRENT HOT AND DRY PERIODS AT THE GLOBAL SCALE Jakob Zscheischler, ETH Zurich
1:30	Session PM1-P2: **CLIMATE DATA HOMOGENIZATION AND CLIMATE TRENDS/VARIABILITY ASSESSMENT** (VIEW ABSTRACTS) Chair: Lucie Vincent
1:30-1:45	LONG-TERM TRENDS IN MARINE HEATWAVES SINCE 1900 Sara Perkins-Kirkpatrick, University of New South Wales
1:45-2:00	UPDATES TO HADISD AND CHANGES IN SUB-DAILY DISTRIBUTIONS Robert Dunn, Met Office Hadley Centre
2:00-2:15	INTEGRATING INCOMPLETE ANNUAL PRECIPITATION RECORDS INTO THE ESTIMATION OF ANNUAL MAXIMUM QUANTILES Alain Mailhot, INRS
2:15-2:30	REDUCING UNCERTAINTY IN THE LONG-TERM RECORD OF CLOUD OCCURRENCE AT THE ARM SOUTHERN GREAT PLAINS SITE Aaron Kennedy, University of North Dakota
2:30-2:45	A SIMPLE STATISTICAL METHOD FOR ESTIMATING THE EFFECT OF SYSTEMATIC ERRORS IN CLIMATE DATA SETS OF LONG-TERM SEA-SURFACE TEMPERATURE CHANGE John Kennedy, Met Office Hadley Centre
2:45-3:00	UNCERTAINTIES IN DAILY TEMPERATURE HOMOGENEITY ADJUSTMENTS ILLUSTRATED USING PARALLEL OBSERVATIONS Lucie Vincent, Environment and Climate Change Canada
3:00-3:15	SYSTEMATIC INVESTIGATION OF DAILY RAINFALL VARIABILITY FROM 1958 TO 2014 ACROSS AUSTRALIA Steefan Contractor, University of New South Wales
3:15	END OF MEETING

POSTER ABSTRACTS

THE ATTRIBUTION OF EXTREME WEATHER EVENTS AND THEIR IMPACTS TO EXTERNAL DRIVERS OF CLIMATE CHANGE

1. ALTERNATIVE APPROACHES TO ATTRIBUTING ANTHROPOGENIC INFLUENCES ON THE 2013 NEW ZEALAND DROUGHT

Luke Harrington (Victoria University of Wellington)

Previous studies evaluating anthropogenic influences on the meteorological drivers of drought have found mixed results, in part owing to the complex physical mechanisms which lead to the onset of drought, and differences in the characteristics and timescales of drought observed for different regions of the world. For a mid-latitude, temperate climate like New Zealand, strongly modulated by oceanic influences, summer droughts last on the order of three months, and are not strongly linked to persistent temperature anomalies, unlike more continental climates for example. Here, we consider a variety of alternative approaches to characterise the meteorological conditions conducive to extreme drought over the North Island of New Zealand, using the January-March 2013 event as a case study. Specifically, we consider the use of self-organising map (SOM) techniques in a multi-model (CMIP5) ensemble to capture changes in both circulation and precipitation deficits, on both seasonal and daily timescales, between two 41-year periods (1861-1901 and 1993-2033). In addition, we employ the use of data from the "weather@home" ANZ experiment to determine the relative contribution of greenhouse gases, ENSO and ozone changes on the likelihood of drought-conducive circulation patterns and seasonal precipitation deficits.

2. POOREST COUNTRIES EXPERIENCE EARLIER ANTHROPOGENIC EMERGENCE OF DAILY TEMPERATURE EXTREMES

Luke Harrington (Victoria University of Wellington)

Understanding how the emergence of anthropogenic warming signals from the noise of internal variability translates to changes in extreme event occurrence is of crucial societal importance. Here, we demonstrate that the inherently lower internal variability found at tropical latitudes results in the anthropogenic emergence of increased frequency in extreme daily temperatures to occur much earlier than for mid-to-high latitude regions. Consequently, the fraction of the global population in the lowest socio-economic quintile (based on 2010 GDP PPP per capita) experiences exposure to substantially more frequent daily temperature extremes (exceedances of the 99.9th percentile derived from 200 years of pre-industrial climate simulations) after much lower increases in both mean global warming and cumulative CO2 emissions. Further, the fractional difference in exposure between the wealthiest and poorest 20% of the global population increases for exponentially higher probability ratios with continued cumulative emissions. This further emphasises that, owing simply to how the global population is distributed geographically, the disparity in damages related to heat extremes between wealthy and poor countries will only worsen with continued CO2 emissions.

3. A STATISTICAL ANALYSIS OF TROPICAL CYCLONE GENESIS

Thomas Leahy (Imperial College London)

According to the Fifth IPCC assessment report, in the 21st ``the frequency of the most intense storms will increase substantially in some ocean basins". This poses a significant risk to the vulnerable regions. Whilst studies suggest that there will be an increase in intensity and decrease in frequency, it is still uncertain by how much. Quantifying this change in intensity and distribution of tropical cyclones is difficult. As a natural first step, we examine the starting points or genesis of tropical cyclones. This poster will give an insight into attributing and quantifying the influence of physical covariates on tropical cyclone genesis. Generalised Linear Modelling provides a statistical framework to understand the physical variables that contribute to the generation of tropical cyclones. An in depth understanding of the contributing factors to genesis is particularly vital in a potential future climate.

4. DIAGNOSING ANTHROPOGENIC CONTRIBUTIONS TO HEAVY COLORADO RAINFALL IN SEPTEMBER 2013

Pardeep Pall (Lawrence Berkeley National Laboratory)

The Colorado floods of September 2013 caused severe damage and fatalities, and resulted from prolonged heavy rainfall unusual for that time of year – both in its record-breaking amounts and associated weather systems. This situation challenges contemporary frameworks investigating the potential role of anthropogenic climate change in recent extreme weather events, because they struggle to connect large-scale meteorology with local weather processes. Here we use a novel part observational- part dynamical-model-based approach to investigate how the influence of anthropogenic climate drivers on the observed large-scale meteorological conditions might have affected Colorado rainfall. Subject to these imposed conditions, our simulations indicate anthropogenic drivers increased the magnitude of heavy northeast Colorado rainfall for the wet week in September 2013 by 30%, with the occurrence probability of a week at least that wet increasing by at least a factor of 1.3. We argue this increase resulted primarily from the additional moisture-carrying capacity of a warmer atmosphere – allowing more intense local convective precipitation that induced a dynamical positive feedback in moisture flow. Tailoring analysis tools to better tackle particular aspects of extreme weather events, as demonstrated here, should prove a useful addition to furthering understanding of the effects of anthropogenic climate change on severe weather.

5. THE C20C+ DETECTION AND ATTRIBUTION PROJECT: A NEW RESOURCE FOR ANALYSIS OF EXTREME WEATHER

Daithi Stone (Lawrence Berkeley National Laboratory), et al.

THE ATTRIBUTION OF EXTREME WEATHER EVENTS AND THEIR IMPACTS TO EXTERNAL DRIVERS OF CLIMATE CHANGE

Over the past decade there has been a remarkable growth in interest concerning the effects of anthropogenic emissions on extreme weather. However, research has been constrained by the lack of a public climate-model-based data product optimised for investigation of extreme weather in the context of climate change, relying instead on products designed for other purposes or on bespoke simulations designed for the particular study and not generally applicable to other extremes. The international Climate of the 20th Century Plus (C20C+) Detection and Attribution Project is filling this gap by producing the first large ensemble, multi-model, multi-year, and multi-scenario historical climate data product, specifically designed for resolving variations in the occurrence and characteristics of extreme weather from year to year and their differences from what might have been in the absence of anthropogenic emissions. Project status information and simulation output are available at http://portal.nersc.gov/c20c.Here we describe the experimental design of the first phase of the project, conducted with half a dozen atmospheric climate models, and discuss its various strengths and weaknesses with respect to various types of extreme weather. We also present analyses of the relative importance of climate model, estimate of anthropogenic ocean warming, spatial and temporal scale, and aspects of experimental design on estimates of how much emissions have affected extreme weather.

CLIMATE DATA HOMOGENIZATION AND CLIMATE TRENDS/VARIABILITY ASSESSMENT

6. REGIONAL CLIMATE INFORMATION FROM INSTRUMENTAL RECORDS IN DATA SPARSE AREAS OF NORTHERN BRITISH COLUMBIA

Vanessa Noel Foord (BC Ministry of Forests, Lands, and Natural Resource Operations)

Understanding regional climate and historical climate trends are very difficult in areas of complex terrain and limited weather observations. A method was developed in northern British Columbia, where weather observations are relatively sparse, to create regional climate summaries from available daily weather data from Environment Canada. Regional annual and seasonal summaries were created for precipitation, mean temperature, extreme maximum temperature and extreme minimum temperature. This information is used for local and regional level climate change impact assessment and adaptation studies, but may also be worthwhile for relating to gridded regional climate products. The benefits and limitations of the methodology are also discussed.

7. MONTHLY MEAN TEMPERATURES IN SE-EUROPE, VARIABILITY AND PERSISTENCE

Dubravka Rasol and Haraldur Olafsson, Presented by Haraldur Olafsson, (University of Iceland and Icelandic Meteorological Office)

Time series of up to 150 years of monthly mean temperatures from weather stations in coastal and inland Croatia have been homogenized and explored for persistence. Several interesting features are revealed: In general, there is strong temperature persistence between adjacent months in winter and summer, but much less in the spring and in the fall. It is particularly clear that a cold July is never followed by a warm August and a very warm January is never followed by a cold February. There is statistically significant persistence for more than one month in the winter and also from spring into the summer. A plausible explanation for the positive correlation in the winter may be related to snow on the ground. The snow is associated with cold spells and increases the albedo, contributing to the extension of the low temperatures. The summertime correlation may be related to the water content of the soil. A cold and rainy period results in wet soil and subsequently, relatively large part of the energy of the incoming solar radiation is consumed by evaporation, rather than sensible heating. In the spring, there is generally no snow on the ground and in the autumn, the air temperature is not as sensitive to the water content of the soil as in the summer. This may explain the low correlation in spring and autumn. Time series of up to 150 years of monthly mean temperatures from weather stations in coastal and inland Croatia have been homogenized and explored for persistence. Several interesting features are revealed: In general, there is strong temperature persistence between adjacent months in winter and summer, but much less in the spring and in the fall. It is particularly clear that a cold July is never followed by a warm August and a very warm January is never followed by a cold February. There is statistically significant persistence for more than one month in the winter and also from spring into the summer. A plausible explanation for the positive correlation in the winter may be related to snow on the ground. The snow is associated with cold spells and increases the albedo, contributing to extension of the low temperatures. The summertime correlation may be related to the water content of the soil. A cold and rainy period results in wet soil and subsequently, relatively large part of the energy of the incoming solar radiation is consumed by evaporation, rather than sensible heating. In the spring, there is generally no snow on the ground and in the autumn, the air temperature is not as sensitive to the water content of the soil as in the summer. This may explain the low correlation in spring and autumn.

8. THE EFFECT OF THE LOCATION OF STATIONS AND TEMPORAL VARIABILITY OF TEMPERATURE ON THE MAGNITUDE OF TRENDS

Lucie Pokorna (Institute of Atmospheric Physics), et al.

In a changing climate, temperature trends are of great importance among various indicators. Thanks to availability and good quality of temperature series, temperature trends are widely used to characterize the manifestation of climatic change from global to local scale. Although trends over large regions are usually based on areal mean temperature, local trends are computed from individual station series. In the latter, the geographical position of a station together with the specific conditions of a given place strongly affect the magnitude of trends. Both parametric and nonparametric methods were applied to station temperature series in Europe to demonstrate the differences between magnitudes of trends at individual stations. Using moving "subseasons" of different lengths, the variations of trends within the calendar year, at different altitudes, in various distances from the ocean and according to latitude are documented. We show that the leading factor determining the magnitude and the statistical significance of trends is the temporal variability of temperature. In the light of the results the question arises, what magnitude of trend is representative for the examined domain and whether the magnitude of trends is an appropriate characteristic when comparing the size of climatic change among various regions.

9. DIFFERENCES IN TRENDS BEFORE AND AFTER HOMOGENIZATION OF CROATIAN TEMPERATURE DATA SETS

Dubravka Rasol (Meteorological and Hydrological Service of Croatia)

Surface air temperature data sets used for temperature trend studies should be of the highest quality. In Croatia, very few stations have not had any influence that causes non-climatic changes in temperature data. Accordingly, homogenization of Croatian temperature data series is required before trends analyses. In this study monthly mean, maximum and minimum temperature data sets from 41 main and climatological meteorological stations were homogenized using the ACMANT method. The data series cover a period from 1961 to 2014. Prior to the homogenization process, the data were additionally quality controlled by the RClimDex extra-QC package. Here, the results of mentioned quality control and homogenization processes are presented as well as differences in trends of data sets before and after homogenization.

10. THE CHARACTERISTIC FEATURES OF THE VARIABILITY OF AIR PRESSURE IN GDAŃSK, POLAND, IN THE PERIOD OF INSTRUMENTAL OBSERVATIONS, 1739-2012

Janusz Filipiak (University of Gdansk)

Gdańsk pressure series spanning the period 1739-2012 has been reconstructed by joining air pressure observations of 15 local shorter series. A gap in the original daily data exists for the period 1849-1875, the data are presented in the form of five-day averages. Numerous errors were discovered during digitalization. Despite this the quality of observations can be regarded as good. Data have been corrected to provide a daily- and monthly-mean measures of atmospheric pressure in the unit of hPa at standard conditions. Some inconsistencies may still arise as the procedure of the homogenization of air temperature is not completed. Numerous breakpoints were identified in the homogenisation of the series and they cannot be always linked to known causes despite a reasonably detailed station history. Mean annual atmospheric pressure in Gdańsk in period 1739-2012 calculated on the basis of homogenized series was 1014.9 hPa. Mean seasonal means are equalled as follows: winter – 1015.2 hPa, spring – 1014.9 hPa, summer – 1014.2 hPa and autumn – 1015.4 hPa. Winter is characterized by the highest variability, what is connected to most intense cyclonic activity in this season. Thus in winter occur the highest daily maxima and lowest minima. Several cases of extremely deep cyclones with the pressure of less than 960 hPa were identified as well a few barometer readings exceeding 1045 hPa. It is also evident that annual minima occurs in summer and this season is also described as of the lowest value of standard deviation.

11. METEOROLOGICAL OBSERVATIONS IN 18TH CENTURY IN GDAŃSK, POLAND, AND THEIR APPLICABILITY TO STUDIES OF THE CLIMATE CHANGE

Janusz Filipiak (University of Gdansk)

Michael Christian Hanow, the physicist and meteorologist was probably the precursor of the thermometric measurements in 1739 in Gdańsk (former Danzig) in Poland. The measurements carried out four times a day concern the following elements: air temperature, atmospheric pressure, total precipitation, humidity and the direction of wind. Besides the detailed information on daily weather phenomena were collected. The measurements of atmospheric pressure, temperature and wind direction conducted twice a day, as well as notes on weather phenomena for the period from 1752 to 1789 can be found in Johann Eilhard Reinick's manuscript. Two other manuscripts contain the results of the measurements the atmospheric pressure, temperature and wind force spanning the period to 1811, when the measurements in accordance with the regulations of Societas Meteorologica Palatina started. The data were digitised and corrected for errors. Then the series was subjected to a preliminary statistical homogenisation procedure. The comparative analysis of the series from Gdańsk and homogenous data from Swedish stations Uppsala and Stockholm revealed some discrepancies. Although some problems connected to the interpretation of the origin of those differences appeared, the results of analysis of Gdańsk data did not reveal the errors in data. Jointly with Swedish series it provides

useful information about the variability of climate across Baltic Sea Basin in 18th century. Basing on the notes of botanist Gottfried Reyger presenting daily weather observations for the period 1722-1786 (the long-lasting weather chronicle of one man) there is a potential to extend the climatic series of Gdańsk up to 1722.

12. COMPARISON OF HOMOGENIZATION METHODS ON EXAMPLE OF CENTRAL EUROPEAN SERIES

Petr Stepanek (Global Change Research Institute CAS), et al.

13. GLOBAL TEMPERATURE TREND BIASES AND STATISTICAL HOMOGENIZATION METHODS

Victor Venema (University of Bonn)

In an accompanying presentation we show that well-homogenized national datasets warm more than temperatures from global collections averaged over the region of common coverage. Here we present additional work about possible causes of temperature trend biases and shortcomings of relative statistical homogenization methods. There are several possible causes of cooling biases, which have not been studied much. Siting could have improved. Increases in irrigation could lead to a spurious cooling trend. Early thermometer screen have a warm bias compared to Stevenson screens. Currently we are in a transition to Automatic Weather Stations. The net global effect of this transition is not clear at this moment. The latter two transitions are difficult to homogenize using relative statistical homogenization because the entire network is affected. In the Global Historical Climate Network (GHCNv3), homogenization does not change the global mean temperature much in these periods. Previous validation studies of statistical homogenizations unfortunately have some caveats. The main problem is that the used artificial datasets had a relatively large and too optimistic signal to noise ratio (SNR). Our recent work on multiple breakpoint detection methods shows that real-world SNRs may be as small as about 0.5. For these realistic cases, statistically significant breaks are identified, but the corresponding segmentation is about as good as a random segmentation. The joint correction method using a decomposition approach (ANOVA) can remove the bias when all breaks (predictors) are known. Any error in the predictors will, however, lead to a systematic undercorrection of any large-scale trend bias.

14. HOMOGENIZATION PROJECT IN BRITISH COLUMBIA

Yaqiong Wang (Pacific Climate Impacts Consortium, University of Victoria)

Non-climatic variations (such as changes of instrument, station relocation, changes in observing time and procedure, etc.) in climate data can lead to discontinuities, causing the inaccurate analysis of the climatic characteristics for a given location. Thus, data quality control and homogenization is the crucial first step before properly analyzing climate trend and extremes. In Canada, the most recent Adjusted and Homogenized Canadian Climate Data (AHCCD) from Environment and Climate Change Canada have been produced for four climate variables at various temporal resolution, such as adjusted surface air temperature for 338 locations (Vincent et al., 2012), adjusted precipitation dataset for over 450 locations (Mekis and Vincent, 2011). In British Columbia (B.C.), thousands of stations from non-ECC networks are available for quality control and homogenization.

In this project, homogenization of monthly temperature data for 79 stations from three networks (BCHydro, Ministry of Forests Lands and Natural Resource Operations Wildfire Management Branch and the Ministry of Transportation and Infrastructure) is based on a penalized maximum t-test with Quantile-Matching (QM) algorithm to detect inhomogeneities and make adjustments to the data (Wang et al. 2007, Wang 2008a, Wang 2008b). The homogenized product from the project will be made available to climate researchers through the Pacific Climate Impacts Consortium's (PCIC) data portal. Climate trends in the studied region (Northwest of B.C. and Vancouver Island) will be presented from the homogenized dataset and will be compared to those calculated from datasets without homogenization and the AHCCD data. After such evaluation, the preliminary results are expected to suggest an improvement in the ability of characterizing climate change with the homogenized datasets.

15. DATA QUALITY CONTROL OF VARIOUS METEOROLOGICAL ELEMENTS FOR NEBRASKA, USA

Pavel Zahradníček (CzechGlobe - Global Research Institute, Czech Hydrometeorological Institute), et al.

In recent years considerable attention has been paid to the analysis of daily weather data, especially when fully automated measurement and data acquisition systems became a norm. Without treating outliers properly, homogenization and consequent data analysis may render misleading results. Regarding data quality control within the ProClimDB software (www.climahom.eu), we devoted considerable time to developing the methodology of detecting outliers and automating the whole process over the large datasets of daily (sub-daily) data. This approach has been successfully tested on climatological data in Europe (Czech Republic, Slovakia, Austria, EC&D database etc.). Each dataset is specific especially in station network density. We tried to apply our method to data from various station networks in Nebraska, USA, and its neighboring states. Here the process of data quality control has been affected mainly by low station network density and we further encountered errors in unit conversion etc. The above-mentioned methods were adopted for these specific conditions. Tools that helped to better find and assess possible errors included interpolating various meteorological elements into maps in daily steps. This expert approach based on the inspection of spatial patterns enabled the detection of many other inconsistencies and improved the final database quality. One of the applications of

the cleaned data will be its input into the drought monitoring products useful for the state of and comparing these results with the current monitoring system. In our contribution, we will present the methodology of the data quality control with examples of its application on Nebraska datasets.

STATISTICAL DOWNSCALING METHODS FOR SEASONAL TO CENTENNIAL PREDICTIONS AND PROJECTIONS

16. RESULTS FROM THE VALUE PERFECT PREDICTOR EXPERIMENT: PROCESS-BASED EVALUATION

Douglas Maraun (University of Graz), et al.

Until recently, the evaluation of downscaled climate model simulations has typically been limited to surface climatologies, including longterm means, spatial variability and extremes. But these aspects are often, at least partly, tuned in regional climate models to match observed climate. The tuning issue is of course particularly relevant for bias corrected regional climate models. In general, a good performance of a model for these aspects in present climate does therefore not imply a good performance in simulating climate change.Therefore, VALUE has carried out a broad process-based evaluation study based on its perfect predictor experiment simulations: the downscaling methods are driven by ERA-Interim data over the period 1979-2008, reference observations are given by a network of 85 meteorological stations covering all European climates. More than 30 methods participated in the evaluation. In order to compare statistical and dynamical methods, only variables provided by both types of approaches could be considered. This limited the analysis to conditioning local surface variables on variables from driving processes that are simulated by ERA-Interim. We considered the following types of processes: at the continental scale, we evaluated the performance of downscaling methods for the major North Atlantic circulation patterns. At synoptic scales, we considered Lamb weather types for selected European regions. At regional scales we considered phenomena such as the Mistral, the Bora or the Iberian coastal jet. Such process-based evaluation helps to attribute biases insurface variables to underlying processes and ultimately to improve climate models.

17. A REGRESSION-BASED STATISTICAL DOWNSCALING FOR MULTI AGRO-METEOROLOGICAL ELEMENTS AND THEIR COMPARISON WITH DYNAMICAL DOWNSCALING RESULTS

Motoki Nishimori (National Institute for Agro-Environmental Sciences)

In this study, a multivariate multiple linear regression (MMLR) -based empirical statistical downscaling (ESD) method that comprehensively analyzed for seven surface predictands, daily averaged, maximum and minimum temperatures (Tm, Tx and Tn), precipitation (Pr), solar radiation (Sr), relative humidity (Rh) and wind speed (Ws), was applied over Japan by using atmospheric circulation factors derived by reanalysis dataset (JRA25) as predictors. The characteristics of this study are, first, to include not only major climate elements (Tm and Pr) but also agro-meteorological ones such as Sr, Rh and Ws for input to agricultural (crop) models. For example, Sr is the most important elements for agricultural production, but current regional climate models (RCMs) has the tendency to overestimate for Sr. In this ESD, linear regression equations to explain the anomaly of the predictands are different in wet and dry days. Thus, the physical interrelationships among these elements should be considered. Bias correction for the ESD-estimated value are also emphasized. Generally, downscaled data are adjusted to have the same variance as observed climate (scaling method), but the scaling method is, however, insufficient for the Pr. Weak rainfall tended to drizzle in the linear regression-based ESD, which is associated with significant overestimation of rainfall, especially in the dry season. Here, an additional bias correction technique, adjusting the number of the rainy days, was developed. As the result, this ESD method obtained the good estimation with observed climate, relative to the RCMs output driven by the same boundary conditions.

WORLD CLIMATE RESEARCH PROGRAMME GRAND CHALLENGE ON CLIMATE AND WEATHER EXTREMES

18. USING OBJECTIVE CLASSIFICATION OF EXTRATROPICAL CYCLONES IN CLIMATE STUDIES

Jennifer Catto (Monash University)

There has been a long tradition in attempting to separate extratropical cyclones into different classes depending on their cloud signatures, airflows, synoptic precursors, or upper-level flow features. Depending on these features, the cyclones may have different impacts, for example in their precipitation intensity. It is important, therefore, to understand how the distribution of different cyclone classes may change in the future. Many of the previous classifications have been performed manually. In order to be able to evaluate climate models and understand how extratropical cyclones might change in the future, we need to be able to use an automated method to classify cyclones. Extratropical cyclones have been identified in the Southern Hemisphere from the ERA-Interim reanalysis dataset with a commonly used identification and tracking algorithm that employs 850 hPa relative vorticity. A

clustering method applied to large-scale fields from ERA-Interim at the time of cyclone genesis (when the cyclone is first detected), has been used to objectively classify identified cyclones. The results are compared to the manual classification of Sinclair and Revell (2000) and the objectively identified classes shown in this presentation are found to match well. The clustering method has also been applied to climate model data to investigate the representation of the different cyclone classes.

19. APPLYING COMPLEX NETWORKS TO EVALUATE PRECIPITATION PATTERNS OVER SOUTH AMERICA

Catrin Ciemer (Potsdam Institut for Climate Impact Research, Germany)

The climate of South America exhibits pronounced differences between the wet- and the dry-season, which are accompanied by specific synoptic events like changes in the location of the South American Low Level Jet (SALLJ) and the establishment of the South American Convergence Zone (SACZ). The onset of these events can be related to the presence of typical large-scale precipitation patterns over South America, as previous studies have shown[1,2].The application of complex network methods to precipitation data recently received increased scientific attention for the special case of extreme events, as it is possible with such methods to analyze the spatiotemporal correlation structure as well as possible teleconnections of these events[3,4]. In these approaches the correlation between precipitation datasets is calculated by means of Event Synchronization which restricts their applicability to extreme precipitation events.In this work, we propose a method which is able to consider not only extreme precipitation but complete time series. A direct application of standard similarity measures in order to correlate precipitation time series is impossible due to their intricate statistical properties as the large amount of zeros. Therefore, we introduced and evaluated a suitable modification of Pearson's correlation coefficient to construct spatial correlation networks of precipitation. By analyzing the characteristics of spatial correlation networks constructed on the basis of this new measure, we are able to determine coherent areas of similar precipitation patterns, spot teleconnections of correlated areas, and detect central regions for precipitation correlation. By analyzing the change of the network over the year[5], we are also able to determine local and global changes in precipitation correlation patterns. Additionally, global network characteristics as the network connectivity yield indications for beginning and end of wet- and dry season. In order to identify large-scale synoptic events like the SACZ onset, detecting the changes of correlation over time between certain regions is of significant relevance. [1] Nieto-Ferreira et al. Quarterly Journal of the Royal Meteorological Society (2011)[2] Vera et al. Bulletin of the American Meteorological Society (2006)[3] Quiroga et al. Physical review E (2002)[4] Boers et al. nature communications (2014)[5] Radebach et al. Physical review E (2013)

20. SUMMER DAILY EXTREME PRECIPITATION IN CENTRAL-EASTERN ARGENTINA: POTENCIAL PREDICTORS

Olga Penalba (University of Buenos Aires, Consejo Nacional de Investigaciones Científicas y Técnicas Argentina), et al.

The main objective of this work was to explore climate and local indices as potential predictors of summer daily extreme precipitation in the center-east of Argentina. The purpose of this analysis was to perform a statistically model based on the relationship found in seasonal and monthly scale. In this region, the occurrence of extreme events has both social and economic relevance since it affect a wide variety of activities, such as agriculture and hydric activities, etc., in densely populated area. To this end, the intensity of seasonal and monthly mean daily extreme precipitation was used, estimated as the rate between the seasonal (December, January and February) and monthly cumulative precipitation, respectively, above the daily 75th percentile and the number of days that recorded this precipitation. Observed daily precipitation data of 30 weather stations of the database CLARIS-LPB for the period 1960-2012 was used. Different climate and regional indices were considered as potential predictors as well as local moisture conditions and temperature in the Atlantic Ocean in regions closer to the area of concern. The relationship between predictors and daily extreme precipitation was studied using the Pearson correlation coefficient with a phase shift up to 6 months prior.Different intra-seasonal signals were found, that led to perform the statistical modeling in a monthly time scale. The statistical modeling of the relationship between the selected predictors and predictand was made based on canonical-correlation analysis (CCA).Finally, the forecasting equation obtained by CCA was calibrated and validated using cross-validation technique.

21. STATISTICAL UNCERTAINTY OF EXTRA-TROPICAL CYCLONES OVER EUROPE DERIVED FROM A PROBABILISTIC CLUSTERING APPROACH USING REGRESSION MIXTURE MODELS

Michael Walz (University of Birmingham), et al.

Extreme winter wind storms are known to be amongst the most dangerous and loss intensive natural hazards in Europe. Due to only 50 years of high quality observational data, however, it is challenging to assess the statistical uncertainty of such sparse events just based on observations. Over the last decade seasonal ensemble forecasts have become vital in quantifying the uncertainty of weather prediction on seasonal timescales. In this study seasonal forecasts are used in a climatological context: By means of using of up to 51 ensemble members a broad, physically consistent statistical base can be created. With the aim of determining the statistical uncertainty of storms with diverse paths of progression, a clustering technique using regression mixture models is used to objectively assign storm tracks (either based on core pressure or on extreme wind speeds) to different clusters. This methodology allows for the entire life time of a storm to be taken into consideration. Three main clusters can be identified, each of which have their own particulate features. Storm features like average velocity and duration are calculated and compared for each

cluster. The main benefit of this clustering technique, however, is to evaluate if the clusters show different degrees of uncertainty, e.g. more (less) spread for tracks approaching Europe in an east-west direction (in a southwest-northeast direction). This statistical uncertainty is compared for different seasonal forecast

22. ASSESSING THE RISKS OF A CHANGING CLIMATE TO FOREST MANAGEMENT

Trevor Murdock (The Pacific Climate Impacts Consortium), et al.

Monthly and daily climate change time series allow assessing the frequency of occurrence of events that could affect forests. Southern British Columbia, Canada is projected to see increases in temperature of 2 to 4°C in all seasons and precipitation increase winter of 5 to 15% and a decrease in summer of 10 to 20%. Changes in daily extreme precipitation events, snow accumulation and melt and summer fire conditions were evaluated for increase in risk to forest infrastructure. The 80 km long In-SHUCK-ch forest service road runs by the Lillooet River and is surrounded by mountains up to 2000 m in elevation. Risks to road infrastructure and to a 20 km wide forested area either side of the road were evaluated for impacts of a changing climate. The 20-year return extreme maximum temperature for the area is projected to increase to 4±2°C by 2050s and 7±2°C in 2080s under rcp 8.5. The 20-year return 1- and 3-day annual maximum precipitation is projected to increase by 20 to 50% by 2050s. Increases in extreme precipitation will result in a need for larger stream crossings (culverts and bridges), and along with changes in freeze/thaw conditions and snow cover this will affect road surface maintenance. There will also be an increase in the risk of landslides and debris flows. An increase in fall and winter precipitation will not be sufficient to offset the effect of warming on the winter snow regime. A shorter snow season along with warmer summers and reduced precipitation result in an increase in the risk of forest fire. Warmer and dry weather will increase the frequency of drought stress conditions which will affect forest growth and likely increase the risk to insect infestations. By the 2080s, the current forest ecosystems will be exposed to climate conditions well outside of their current range.

UNDERSTANDING CLIMATE VARIABILITY AND ITS TELECONNECTIONS UNDER GLOBAL WARMING

23. THE PERIGEE YEAR AS A PRECURSOR TO EL NINO BY ALBERT BOEHM

Albert Boehm

At the AMS Meeting in Hartford, Glenn Brier presented the calculations of the moon's gravity on the earth's atmosphere. This effect is greatly is magnified when the moon in its elliptical orbit comes closest to the Earth. This point is called Perigee. From one Perigee to the next it is called the anomalistic month which is 27.5 days. Glenn performed a time series analysis of variance between the anomalistic month and the calendar month in which data is collected. He found the percent of variance accounted for by the anomalistic month was larger than the difference between summer and winter on the zonal index. Since the decrease in the zonal flow has been found to be a precursor to El Nino, a logical hypotheses is that a perigee year - a year with more than the average number of Perigees will also be a precursor to El Nino. This presentation will list the perigee years and also the strong El Nino years and test the hypotheses including significance. Furthermore, the North Atlantic oscillation also depends on the zonal index, so that others can check the effect of the Perigee Years on the North Atlantic oscillations.

24. A SPATIAL-STATISTICAL APPROACH TO MODELING TELECONNECTIONS

Joshua Hewitt (Colorado State University), et al.

Applying spatial-statistical models to teleconnection patterns, like the El Niño-Southern Oscillation (ENSO), poses a challenge given the assumptions inherent in spatial-statistical models regarding how different locations are related. In ENSO, tropical Pacific Ocean sea surface temperatures strongly influence temperature and precipitation in distant locations including North America, South America, and Southeast Asia. While teleconnection patterns are characterized by relationships between distant locations, standard spatial-statistical models assume distant locations are unrelated. We propose a spatial-statistical model that overcomes this limitation by drawing on ideas from spatially-varying intercept and coefficient models. We adopt a hierarchical Bayesian framework to statistically model teleconnections and estimate the effect of climatological variables in the Pacific Ocean on precipitation in the continental United States. We also develop computational techniques to allow tractable estimation of model parameters for large data sets.

25. THE CONTRIBUTION OF ATMOSPHERIC CIRCULATION TO DECADAL TRENDS IN NORTHERN HEMISPHERE TEMPERATURE

Carley Elizabeth Iles (University of Edinburgh)

The early twentieth century (1920s-1940s) was characterised by a warming period, concentrated particularly in the Arctic in winter. The causes of this Arctic warming are not completely understood but a combination of internal variability and external forcing has been suggested. Here we investigate the contribution of atmospheric circulation to this northern hemisphere warming trend.

We identify the atmospheric pressure patterns that occurred during this period using observational and reanalysis data. We then calculate their contribution to the observed winter temperature trends through an analogue technique in which similar atmospheric circulation patterns are identified in interannual variability across the whole twentieth century, and their relationship to northern hemisphere temperature calculated through regression. We also examine the contribution of other known atmospheric modes to northern hemisphere temperature during this period and for other periods of increasing and decreasing temperature, including the North Atlantic Oscillation/ Arctic Oscillation and the Cold Ocean Warm Land Pattern, which is associated with warm air advection from ocean to land in the northern hemisphere in winter.

ADVANCED METHODS FOR EVALUATING WEATHER AND CLIMATE EXTREMES IN CLIMATE MODEL SIMULATIONS

26. SIMULATION OF SEVERE HEAT WAVES IN REGIONAL CLIMATE MODELS: PAST BIASES AND FUTURE SCENARIOS

Ondřej Lhotka (CzechGlobe)

The recent summer of 2015 was punctuated by several severe heat waves in Central Europe, comparable to or exceeding (depending on particular characteristics and definitions) previous record-breaking events. In the first part of this study, we evaluate capability of regional climate models (RCMs) to capture such severe heat waves. RCMs from the EURO-CORDEX project driven by historical global climate model (GCM) runs in 12.5 and 50 km grids are analysed, and the simulated frequency of heat waves analogous to the 2015 event is compared to the E-OBS gridded data set. In the second part, time slices in which such events are projected to occur at least once per decade are identified in future scenarios from the same RCMs under RCP 4.5 and RCP 8.5 concentration pathways. We evaluate how the frequency of heat waves such as the 2015 event is linked to concentration scenarios, model resolution, and driving GCMs. The results contribute to better understanding of future severe heat wave projections and associated uncertainties.

27. CHANGES IN REGIONAL HEATWAVES AS A FUNCTION OF AVERAGE WARMING

Sarah Perkins-Kirkpatrick (University of New South Wales)

The landmark Paris Agreement of 2015 stated that efforts would be made to limit global warming from anthropogenic activity below 2oC compared to pre-industrial levels by the end of the 21st Century,. However, it has recently been demonstrated that a global mean warming of 2oC corresponds to larger regional changes in the hottest day of the year over land (Seneviratne et al., 2016), calling to question the prospect of this target for avoiding "dangerous" climate change. Furthermore, heatwaves, which are defined as prolonged extreme temperatures, arguably have greater impacts on many biophysical, industrial and ecological systems than extreme temperatures for a single day. In this study, we analyse how varying degrees of projected global warming throughout the 21st Century corresponds to changes in the intensity, frequency and duration of regional heatwaves for models participating in phase 5 of the Coupled Climate Model Intercomparison Project (CMIP5). We also investigate the consensus between models on the change in heatwave characteristics per global warming threshold, as well as any regional variations. Such work is important for gaining a deeper understanding on what average global temperature targets actually mean for high-impact events on more meaningful and impact-relevant scales.

EXTREME VALUE THEORY AND ITS APPLICATIONS

28. IDENTIFICATION OF HOMOGENEOUS REGIONS FOR ANALYSIS OF EXTREME PRECIPITATION EVENTS IN THE CZECH REPUBLIC WITH THE HELP OF NEURAL NETWORKS (KOHONEN MAPS)

Stanislava Kliegrova (Czech Hydrometeorological Institute), et al.

The study is the first step for an improvement of the probabilities of extreme precipitation events with a shorter duration above all (in minutes to hours) in the Czech Republic. A regional approach to the frequency analysis of heavy precipitation events has been shown as useful because the convetional approach (at site frequency analysis) tends to underestimate the quantiles, mainly for the sub-daily rainfall durations. The first (and very important) step of a regional approach is the identification of homogenous regions that should satisfy the condition that their frequency distributions of extreme precipitation amounts are the same except for a scaling factor (which is specific for every site). Cluster analysis is a common method of identifying homogeneous regions. Our study is focused on an application of Kohonen Self Organizing Maps (SOM) for the classification and on a comparison of results between „classical" cluster analysis and Kohonen SOM. Both types of cluster analysis were applied on „site characteristic" (longitude, latitude, elevation, mean annual precipitation, mean ratio of summer half-year to winter half-year precipitation and mean annual number of dry days) for meteorological stations in the Czech Rebublic. Results and differences are discussed.

29. OPTIMIZATION OF PROBABILITY ESTIMATES FOR MULTI-STATION PRECIPITATION DATA

Isabella Osetinsky-Tzidaki (Israel Meteorological Service)

A quick and flexible mapping of precipitation quantiles, including the high quantiles for hazard mapping, is based on probability estimates for multi-station data. These estimates are subject to modification with an arrival of each new observation. Fast algorithms for updating either the estimates or the distribution family itself have been developed in the Israel Meteorological Service (IMS) for both the Extreme Precipitation and Standard Precipitation Index mapping.The need for a complex approach arose from heterogeneity of precipitation regimes (sometimes even at adjacent points) of the Israeli rain stations located at the margins of various climatic zones (from Mediterranean through arid), and over complex topography (mountains, valleys, coastal plain and coastline across a small and narrow area). A spatial interpolation is not much of help, and one needs to proceed with data from as many stations as possible.The algorithms check on several probability distributions (Gamma, GEV, Weibull, Normal, Lognormal, Exponential) with two goodness-of-fit tests (Modified Anderson-Darling, Chi-Square) and simultaneously produce the optimal parameter estimates for each one of all (not-limited number) stations at each run.The algorithms provide, as well as optimal estimates, a graphical analysis (QQ-plot, PP-plot) that illustrates a comparison of the results from application of different distributions to each station time-series. A choice of the plotting position rule may play a critical role when comes a need for a manual intervention in the assignment of the optimal distribution family to a given station, e.g. while validating the model performance on a specific range of return periods.

30. ESTIMATES OF EXTREME RAINFALL FREQUENCY IN URBAN AREAS FROM SPATIALLY DENSE OBSERVATIONS

Lynne Seymour (University of Georgia), et al.

A method for estimating 24-hour rainfall totals associated with seven return periods between 1- and 1000-year is presented. The technique builds upon recent efforts to employ spatially dense rain gauge networks in an area-based calculation of rainfall frequency estimation. Specifically, this study uses stations from the Community Collaborative Rain, Hail and Snow (CoCoRaHS) network to estimate rainfall frequency in the Rocky Mountains Front Range region. For each site, the distribution of monthly maximum 24-hour rainfall totals was assembled by selecting the greatest daily rainfall total measured by either the local Global Historical Climatology Network (GHCN) station or any CoCoRaHS station within six km of the GHCN station. A gamma distribution was fit to the histogram of monthly maximums, and distributions of design values (the rainfall totals associated with each n-year return period) were estimated by repeatedly simulating 12 x n monthly maximums from the fitted gamma distribution. The distribution of all values for each return period is emphasized to communicate the uncertainty. The results are relevant for city planners tasked with designing infrastructure to withstand the range of extremes experienced across an entire urban area as well as a range of other stakeholders with interests affected by precipitation frequency.

31. QUANTILE-BASED BIAS CORRECTION AND UNCERTAINTY QUANTIFICATION OF EXTREME EVENT ATTRIBUTION STATEMENTS

Michael Wehner (Lawrence Berkeley National Laboratory)

We sample daily precipitation from a very large ensemble of climate model simulations to estimate the uncertainty in long period return values determined empirically and by fitted extreme value distributions. We find that even for very large datasets, confidence intervals using extreme value statistical methods are tighter than from empirical methods. We further investigate the uncertainty due to limited sample sizes as a function of both return period and sample size itself. We compare the uncertainty estimates obtained from parametric bootstrapping and non-bootstrap methods as well as investigate the difference in the uncertainty estimates using two different methods of fitting the extreme value distributions. Finally, we draw some conclusions about the size of climate model ensemble simulations required to robustly estimate extreme daily precipitation statistics.

32. STATISTICAL MODELLING OF DROUGHT AND HEAT WAVE COMPOUND EVENTS

Martin Widmann (University of Birmingham), et al.

Compound extreme events (CEs) are a combination of two or more contributing events which in themselves may not be extreme but through their joint occurrence produce an extreme impact. A focus of the CE:LLO project (Compound Events: muLtivariate statisticaL mOdelling) is to develop a multivariate statistical model to capture the dependence structure of the CE between drought and heat wave events in order to correctly describe the joint probabilities of these conditions and the resulting probability of their compound impact. We will show an application of Pair Copula Constructions (PCCs) to study the aforementioned CE. PCCs allow in theory for the formulation of multivariate dependence structures in any dimension where the PCC is a decomposition of a multivariate distribution into a product of bivariate components modelled using copulas. A copula is a multivariate distribution function which allows one to model dependence structure of given variables separately from the marginal behaviour. The Standardised Precipitation Evapotranspiration Index (SPEI) is used here to represent meteorological drought where local drought conditions are identified as those with an SPEI value below -1.0. As a first step we model the multivariate dependence structure of characteristics of local and large-scale drought events such as magnitude, duration and spatial extent, and calculate return levels for certain events. At a local scale, we initially find positive correlations between drought characteristics, though the degree of correlation as well as the computed return levels can vary considerably spatially. As a next step we introduce heat wave characteristics.

ORAL PRESENTATION ABSTRACTS

IMSC SCC CHAIR INVITED ADDRESS

OUR SHARED RESPONSIBILITY AS USERS OF STATISTICS AND CONSUMERS OF RESULTS FROM ITS APPLICATION IN THE CLIMATE SCIENCES

Francis W Zwiers

June 7th 12:00-12:30

Pacific Climate Impacts Consortium, University of Victoria" "Climate is defined by the Intergovernmental Panel on Climate Change ?as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years? Statistical methods are therefore central for climate studies, as they are for many other disciplines. These tools are used to describe the effects of variability and uncertainty on myriad measures that have been developed to characterize the climate. They also provide a context within which to evaluate differences in climate in space and time, and to infer information about the climate at locations or times that have not been sampled. That context for evaluation and inference includes the sampling, structural and distributional assumptions. These assumptions are required to develop effective diagnostics, and to determine their expected performance in repeated application under well understood, albeit necessarily idealized, conditions. Without such information to describe the reliability and sensitivity of statistical inference methods, it is impossible to assess the level of confidence that we can place in their results. Unfortunately, however, the routine application of statistical methods in climate research implies that users are often not fully aware of the limitations of the context that is implicit in their use. I will briefly discuss four examples illustrating topics where the statistical context appears to be understood and appreciated to different extents. The examples will draw from the body of research on climate change detection and attribution, the evaluation of extremes, and the characterization of the large-scale modes of climate variability. The first two areas have a relatively well-understood statistical framing and a reasonable understanding of limitations, while the latter remains problematic.

ADVANCED METHODS FOR EVALUATING WEATHER AND CLIMATE EXTREMES IN CLIMATE MODEL SIMULATIONS

HEAT EXTREMES IN CESM: HISTORICAL AND FUTURE BEHAVIOR

Claudia Tebaldi

June 7th AM1 10:00-10:30

"I will present results from a couple of recent studies that used a large ensemble of perturbed initial condition run with NCAR-DOE CESM1-CAM5 over the historical period and into the future using RCP8.5 as boundary conditions. The two studies explored current and future behavior of two types of heat extremes. One focused on current 20-year events and their changes in the future, with a global perspective; the other focused on record highs (and low) over the US. I will present overall results in terms of future projected changes in these quantities, focusing on the high signal to noise ratio in these results afforded by the large ensemble. In both cases comparison with observations (HadEx indices in the first case and GHCN station data in the second case) shows fairly significant biases both in climatological values and in trends, which cannot easily be blamed on internal variability because of the wide exploration of it that the large ensemble affords us. I will show some additional analysis that also explored how some of this behavior is common to the CMIP5 class of models (or not), and that looked into some related variables and processes in the attempt to pin down the sources of the disparity between model and observations.

A PERFORMANCE WEIGHTING PROCEDURE FOR GCMS BASED ON EXPLICIT PROBABILISTIC MODELS AND ACCOUNTING FOR OBSERVATION UNCERTAINTY

Jean-Philippe Vidal and Benjamin Renard

June 9th, PM1-P1 1:30-1:45

"In recent years, the climate modeling community has put a lot of effort into releasing the outputs of multimodel experiments for use by the wider scientific community. In such experiments, several structurally distinct GCMs are run using the same observed forcings (for the historical period) or the same projected forcings (for the future period). In addition, several members are produced for a single given model structure, by running each GCM with slightly different initial conditions.This multiplicity of GCM outputs offers many opportunities in terms of uncertainty quantification or GCM comparisons. In this presentation, we propose a new procedure to weight GCMs according to their ability to reproduce the observed climate. Such weights can be used to combine the outputs of several models in a way that rewards good-performing models and discards poorly-performing ones.

The proposed procedure has the following main properties:It is based on explicit probabilistic models describing the time series produced by the GCMs and the corresponding historical observations,It can use several members whenever available,It accounts for the uncertainty in observations,It assigns a weight to each GCM (all weights summing up to one),It can also assign a weight to the ?H0 hypothesis? that all GCMs in the multimodel ensemble are not compatible with observations.The application of the weighting procedure is illustrated with several case studies including synthetic experiments, simple cases where the target GCM output is a simple univariate variable and more realistic cases where the target GCM output is a multivariate and/or a spatial variable. These case studies illustrate the generality of the procedure which can be applied in a wide range of situations, as long as the analyst is prepared to make an explicit probabilistic assumption on the target variable. Moreover, these case studies highlight several interesting properties of the weighting procedure. In particular, they suggest that observation uncertainty plays a key role in the assignment of performance weights to competing GCMs. Roughly speaking, the weights move from ?weight =1 for a single model? to ?same weight for all models? with increasing observation uncertainty. This behavior is consistent with intuition (highly uncertain observations make it more difficult to distinguish well- and poorly-performing GCMs), and emphasizes the importance of reliably quantifying the uncertainty in the observed historical climate."

QUANTIFYING CHANGES IN CLIMATE VARIABILITY AND EXTREMES: PITFALLS AND THEIR OVERCOMING

Sebastian Sippel, Jakob Zscheischler, Martin Heimann, Friederike E. L. Otto, Jonas Peters, Miguel D. Mahecha
June 9th, PM1-P1 1:45-2:00
"Hot temperature extremes have increased substantially in frequency and magnitude over past decades. Yet in recent years these unusual events have exceeded the range of historical variability, implying major impacts upon human societies. A widely used approach to quantify this phenomenon is standardizing temperature data relative to the local mean and variability of a reference period. Here we demonstrate both analytically and empirically that the standardization of temperature time series leads to exaggerated estimates of the increase in present and future temperature variability and extremes. For example, the occurrence of ""2-sigma extremes"" would be overestimated by ÷48.2% compared to a given reference period of 30 years with time-invariant Gaussian distributed data. In general, limited sample sizes lead to systematically heavier tails in the distribution outside the reference period inducing, if taken at face value, an overestimation of extremes. We develop an analytical correction that reveals that this overestimation of changes in extreme temperatures and variability prevails in recent studies. Our analyses lead to a revision of earlier reports: For instance, we show that there is no evidence for a recent increase in temperature variability in low-variance regions. However, despite the correction we still confirm the non-ambiguous increase in temperature extremes in the Northern hemisphere. In conclusion, we provide an analytical pathway to describe changes in variability and extremes in climate observations and model simulations."

PROJECTED CHANGES OF RAIN-ON-SNOW EVENTS OVER NORTH AMERICA BASED ON TWO CANADIAN REGIONAL CLIMATE MODELS

Dae Il Jeong and Laxmi Sushama
June 9th, PM1-P1 2:00-2:15
This study evaluates the changes in Rain-on-snow (ROS) characteristics (i.e., frequency, amounts, and runoff) for the future 2041-2070 period with respect to the current 1976-2005 period over North America using six simulations, based on two Canadian RCMs, driven by two driving GCMs for RCP4.5 and 8.5 emission pathways. Projected changes to extreme runoff caused by the changes of the ROS characteristics are also evaluated. All simulations suggest general increases in ROS days in late autumn, winter, and early spring periods for most Canadian regions and northwestern USA for the future period, due to an increase in rain days in a warmer climate. Future ROS runoff is expected to increase more than future ROS amounts during snowmelt months as ROS events usually enhance runoff, given the land state and associated reduced soil infiltration rate and also due to the faster snowmelt rate occurring during these events. The simulations also show that ROS events usually lead to extreme runoff over most of Canada and north-western and -central USA in the January-May snowmelt months for the current period and these show no significant changes in the future climate. However, the future ROS to total runoff ratio will significantly decrease for western and eastern Canada as well as north-western USA for these months, due to an overall increase of the fraction of direct rainfall generated runoff in a warmer climate. These results indicate the difficulties of flood risk and water resource managements in the future, particularly in Canada and north-western and -central USA.

CONSISTENCY OF EXTREME RAINFALL REPRESENTATION IN NUMERICAL SIMULATIONS AND HYDROLOGICAL DATASETS

Ben Timmermans, Travis O'Brien and Michael Wehner

June 9th, PM1-P1 2:15-2:30

Understanding extreme weather is imperative to society, particularly given the growing body of evidence suggesting that the characteristics of weather extremes are changing. Given this imperative, it is crucial that climate models accurately simulate such extremes. Model evaluation efforts typically focus on average conditions. However, if (as has been observed) the relationship between average and extremes is non-trivial, it is necessary to evaluate our models more rigorously with respect to extremes.To this end, we examine the correspondence between observed and simulated extreme precipitation in the Community Earth System Model. The simulations were performed under the ILIAD framework, which runs a large, multiresolution ensemble of five-day reforecasts to achieve a long-term dataset in which simulated weather events correspond to observed weather events. We quantitatively compare simulated and observed precipitation extremes by applying statistical methods from bivariate extreme value theory that quantify tail dependence.Similarly, observational datasets are often developed with a focus on the mean, and it has been shown that there is large uncertainty in the tails of these datasets. Therefore, in order to make definitive statements about model fidelity, it is necessary to also understand the uncertainty in observations; to date, uncertainty in observed extremes has received little formal scrutiny. Towards understanding this uncertainty, we apply bivariate statistical methods to observations: the Maurer et al. 2002 and Chen et al. 2008 precipitation datasets, which are derived from the same original station observations using different gridding algorithms. The impact on model evaluation of discrepancy between the datasets is discussed."

A NON-PARAMETRIC APPROACH FOR THE EVALUATION OF PRECIPITATION EXTREMES SIMULATED BY CLIMATE MODELS

Andrea Toreti and Philippe Naveau

PM1-P1 2:30-2:45

"The evaluation of precipitation extremes simulated by climate models is still a challenging issue. Here, a non-parametric approach specifically designed for extremes is proposed. The method is tested and then applied to observations and CMIP5 simulations over the Euro-Mediterranean region. Results support the existence of a scaling relationship among models and between models and observations in terms of conditional mean of the extremes. However, the rescaled tails of modeled precipitation show significant differences when compared with observations. Concerning future projections, models show an intensification of heavy precipitation associated with a change in the conditional mean of extremes. More complex changes in the upper tails are not identified at the mid-century, while a lack of model agreement prevents drawing definitive conclusions for the end of the century."

METHODS FOR CORRECTING BIASES IN LARGE MODEL ENSEMBLE EXPERIMENTS

Friederike Otto

June 9th, PM1-P1 2:45-3:00

Advanced methods for evaluating weather and climate extremes in climate model simulations. "Extreme event attribution with large ensembles of AGCM and RCM simulations is aiming at estimating the role of external drivers on the change in risk of an event occurring. The method has become more available and more popular in recent years, with weather@home being one of the largest projects amongst them. Here we address two major issues that are impacting the attribution statement of any given model experiment and how we are tackling them within the weather@home framework: (1) Model biases due to inadequate representation of dynamical and physical processes. (2) Attribution biases due to incorrect representation of the counterfactual (i.e. natural) world. We provide an overview of systematic model biases, from a physical as well as dynamical point of view, and which methods we are applying to remedy the problem. Particular emphasis is given to the correct representation of spatio-temporal patterns in order to reduce the tendency to provide overconfident attribution results. AGCM experiments are forced with observed SSTs which are not available for a counterfactual world. We describe the current method of setting up our natural SSTs so that they encompass what is believed to be natural variability. Also, the role and importance of external low-frequency natural and early anthropogenic external drivers is discussed in the context of counterfactual SSTs."

COMPARING REGIONAL PRECIPITATION AND TEMPERATURE EXTREMES IN CLIMATE MODEL AND REANALYSIS PRODUCTS

Sarah Perkins-Kirkpatrick, Oliver Angelil, Lisa Alexander, Daithi Stone, Michael Wehner, Markus Donat and Hideo Shiogama

June 9th, PM1-P1 3:00-3:15

A growing eld of research aims to characterise the contribution of anthropogenic emissions to the likelihood of extreme weather events. These analyses can be sensitive to the shapes of the tails of simulated distributions. If tails are found to be unrealistically short or long, the anthropogenic signal emerges more or less clearly respectively, from the noise of possible weather. This renders the estimated anthropogenic contribution to the event likelihood inaccurate. Here we compare the chance of daily precipitation and temperature extremes generated by two Atmospheric Global Climate Models typically used for event attribution, with distributions from ve reanalysis products. The chance of extremes are compared for area-averages over grid cell (1.9 resolution { constrained by National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) Reanalysis 2) and regional (2 106 km2) sized spatial domains. Results suggestthe models simulate the chance of precipitation extremes equally well as the chance of temperature extremes. In most cases, return periods of extremes from the modelled data fall within the spread of return periods from the reanalyses, except over a handful of cases one such being temperatureextremes over Africa. Large discrepancies amongst all datasets emphasise the importance of using multiple reanalysis and/or observation products, as well as multiple models in event attribution studies."

THE ATTRIBUTION OF EXTREME WEATHER EVENTS AND THEIR IMPACTS TO EXTERNAL DRIVERS OF CLIMATE CHANGE

ATTRIBUTING A SPECIFIC CLIMATE EVENT OR A CLASS OF CLIMATE EVENTS: CONTRASTS IN PURPOSE, IMPLICATIONS AND METHODS

Alexis Hannart

June 6th, AM2 11:00-11:30

"Providing causal assessments on weather and climate events is an important research topic in the climate sciences at present. A crucial difficulty in this field regards the very framing of the causal question. Should the causal question focus on an individual, specific event? Or should it focus instead on a general class of events? But first and foremost, what is an event? What is a specific event? What is a class of events? And, accordingly, what does causality mean for each of these? Climate scientists sometimes appear to have diverging meanings in mind for these central notions. The debate thus suffers in our view from weak semantics, lack of clear definitions for the very words ?event? and ?cause?, and consequently lack of clear distinction between attributing a specific event and attributing a class of events. We propose an attempt to clarify this debate by: (i) proposing simple definitions for ?specific event?, ?class of events? and ?cause? that are adapted from probabilistic causal theory; (ii) shedding light on the stringent contrast in nature, purpose and method between attributing a specific climate event and attributing a class of events; (iii) arguing that both types of climate event attribution studies are relevant and useful but for distinct reasons. Coauthors (alphabetic order): M. Ghil (Institut Pierre Simon Laplace, CNRS and Dept. of Atmospheric and Oceanic Sciences, UCLA), P. Naveau (Institut Pierre Simon Laplace, CNRS), F. Otto (Environmental Change Institute, University of Oxford), S. Seneviratne (Institute for Atmospheric and Climate Science, ETH Zurich), F. Zwiers (Pacific Climate Impacts Consortium, University of Victoria)."

TOWARDS AN ""END-TO-END"" ATTRIBUTION FRAMEWORK FOR BIOSPHERE VARIABILITY AND CHANGE

Sebastian Sippel, Matthias Forkel, Friederike E. L. Otto and Miguel D. Mahecha

June 6th, AM2 11:30-12:00

Climate is a major driver of variability and extremes in the functioning of terrestrial ecosystems. A changing climate might thus induce substantial changes in the biosphere's carbon and water cycling, often implying previously unseen extreme conditions. However, these ecosystem impacts occur typically through various complex pathways and are thus often not straightforward to quantify, predict or attribute to specific drivers. Here, we introduce a novel framework for attributing changes in biosphere variability and extremes to changes in the underlying climatological drivers. The attribution scheme uses a large ensemble of climate-impact simulations in conjunction with a statistical approximation of the system. The latter allows to directly infer the contribution of a changing climate driver to changes in the system's output and extremes. We demonstrate our approach using a large ensemble of process-oriented ecosystem model simulations for a transient period (1986-2010) and six eco-physiologically distinct European regions that broadly cover major European vegetation types. This allows us to isolate the dominant climatological drivers of transient changes in ecosystem variability and extremes on a seasonal time scale. However, land surface model simulations of carbon

and water fluxes are inherently uncertain and rely strongly on issues such as model structure and parametrization. Hence, in order to complement process-oriented model simulations, we derive a data-driven climate-impact mapping for major semi-natural vegetation types in the six European regions. Subsequently, we generate a statistical ensemble of ecosystem impacts and conduct a data-driven attribution analysis. The latter reveals that changes in early season variability and extremes in the biosphere are predominantly driven by warming spring temperatures. In conclusion, a robust biosphere ""end-to-end"" attribution framework allows to detect and quantify the dominant climate-induced contemporary changes in the functioning of terrestrial ecosystems."

CHANGES IN WINTER EXTREMES ATTRIBUTABLE TO HUMAN-INDUCED CHANGES IN ATMOSPHERIC FLOWS

Robert Vautard

June 6th, AM2 12:00-12:30

Changes in atmospheric flow patterns are difficult to detect in observations, and also to attribute to human influence from model experiments. This is mainly due to the multi-dimensional character of flows. However, trends in the occurrence of small specific flows may significantly alter the odds of extreme weather conditions (temperature, precipitation). Using a flow analogy formalism, applied to observations or large model ensembles, we show from a few examples how mean and extreme winter weather have changed in the last decades or due to human influence on atmospheric dynamics. The examples taken are the winter temperatures or precipitations in several areas of the Northern mid-latitudes."

ATTRIBUTION OF EXTREME EVENTS IN ARCTIC SEA ICE EXTENT

Megan Kirchmeier-Young

June 6th, PM2-P1 3:45-4:00

Extreme minima in Actic sea ice extent (SIE) have widespread implications, covering sectors from ecosystems to commerce. Of particular interest is the quantification of the athropogenic influence on extreme Arctic SIE events, like those in 2007 and 2012. This is accomplished by comparing the probabilities of a specific SIE value under forcing scenarios with and without the anthropogenic component through metrics such as the Fraction of Attributable Risk (FAR) and the Risk Ratio. We utilize two large-ensembles for this analysis. CanESM2 and CESM1 both provide ensembles of a size (50 and 30, respectively) large enough to realize a wide range of internal variability and to provide robust estimates of the event probabilities. Using several different metrics to define the events in question, it will be shown robustly that an extreme SIE minimum of the magnitude seen in 2012 is consistent with a scenario including anthropogenic influence, but is extremely unlikely in a scenario excluding anthropogenic influence. Hence, the 2012 Arctic sea ice minimum provides a counterexample to the often-quoted idea that individual extreme events cannot be attributed to human influence.

MULTI-METHOD ATTRIBUTION ANALYSIS OF EXTREME PRECIPITATION IN BOULDER, COLORADO

Jonathan Eden, Geert Jan van Oldenborgh and Friederike Otto

June 6th, PM2-P1 4:00-4:15

Understanding and attributing the characteristics of extreme events that lead to societal impacts is a key challenge in climate science. Detailed analysis of individual case studies is particularly important in assessing how anthropogenic climate change is changing the likelihood of extreme events and their associated risk at relevant spatial scales. While climate model simulations provide an important basis for such analysis, reliable assessment of long term changes in extreme events is limited by models? inherent errors and biases. Here, we conduct a comprehensive multi-method attribution analysis of the heavy precipitation that led to widespread flooding in Boulder, Colorado in September 2013. Using extreme value analysis of, first of all, historical observations, we assess the influence of anthropogenic climate change on the likelihood of one- and five-day precipitation events across the Boulder area. The same analysis is extended to the output of a 16-member coupled model ensemble, following rigorous evaluation of the model skill in representing the processes responsible for extreme precipitation events in this region. Preliminary analysis using both observation- and model-based methods suggests that an event of this magnitude is around 20% more likely as a result of anthropogenic climate change. Recently, emphasis has been placed on the importance of model evaluation and bias correction in attribution studies. Further analysis will thus focus on sophisticated bias correction and downscaling techniques and their potential added value for application in attribution analysis. We also highlight the benefit of a multi-method approach in addressing event-specific attribution questions, particularly with regard to the quantification of uncertainty."

HOW MUCH RAINFALL EXTREMES ASSOCIATED WITH TROPICAL CYCLONES CAN BE ATTRIBUTABLE TO ANTHROPOGENIC INFLUENCES?

Cheng-Ta Chen and Shih-How Lo

June 6th, PM2-P1 4:15-4:30

The rainfall extremes and strong winds associated with tropical cyclones lead to significant damages and lost to where they make landfalling. Upward trend in term of financial lost was indicated for the past few decades from the report of major reinsurance firms. Whether the past anthropogenic warming played a significant role in such extreme event and their changes remained very controversial. On one hand, people argue it's nearly impossible to attribute an individual extreme event to global warming. On the other hand, the increase of heavy rainfall is consistent with the expected effects of climate change on tropical cyclone. To diagnose possible anthropogenic contributions to the odds of heavy rainfall associated with tropical cyclone, we adapt an existing event attribution framework of modeling a "world that was" and comparing it to a modeled "world that might have been" for that same time but for the absence of historical anthropogenic drivers of climate. The analysis was applied to Typhoon Morakot (2009) as an example. There was more than 2000 mm rainfall occurred over southern Taiwan when a category 1 Typhoon Morakot pass through Taiwan in early August 2009. Entire village and hundred of people were buried by massive mudslides induced by record-breaking precipitation. One limitation for applying such approach to high-impact weather system is that it will require models capable of capturing the essential processes lead to the studied extremes. Using a cloud system resolving model that can properly simulate the complicated interactions between tropical cyclone, large-scale background, topography, we first perform the ensemble "world that was" simulations forced by the high resolution ECMWF YOTC analysis. We then re-simulate, having adjusted the analysis to "world that might have been conditions" by removing the regional atmospheric and oceanic forcing due to human influences estimated from the CMIP5 model ensemble mean conditions between all forcing and natural forcing only historical runs. Thus our findings are highly conditional on the driving analysis and adjustments therein, but the setup allows us to elucidate possible contribution of anthropogenic forcing to changes in the likelihood of heavy rainfall associated tropical cyclone.

QUANTIFYING THE EFFECT OF OCEAN VARIABILITY ON THE ATTRIBUTION OF EXTREME CLIMATE EVENTS TO HUMAN INFLUENCE

Daithi Stone

June 6th, PM2-P1 4:30-4:45

In recent years, the climate change research community has become highly interested in describing the influence of anthropogenic emissions on extreme weather events, commonly termed ?event attribution.? Limitations in the observational record motivate the use of climate models to estimate anthropogenic influence, while computational limitations motivate the use of uncoupled, atmosphere-only climate models with prescribed ocean conditions. In this approach, large ensembles of high-resolution simulations can be obtained and used to estimate anthropogenic risk; however, fixing the ocean state does not account for the long-term internal variability of the climate system. This source of uncertainty is extremely important, as large internal variability can lead to qualitatively different conclusions about anthropogenic influence.In this work, we develop a hierarchical Bayesian model to estimate the changing risk over time of extreme weather events due to anthropogenic influences. Unlike related approaches in event attribution, the model allows us to quantify the internal variability present in statements of risk, after adjusting for long-term trends. Furthermore, based on the magnitude of this variability, we develop a metric that allows climate change scientists to identify event types and regions of the globe for which single-year atmosphere-only climate simulations are sufficient for assessing the true risk. The methodology is illustrated by exploring extreme temperature and precipitation events for the northwest coast of South America and northern-central Siberia."

INVESTIGATION OF THE 2013 ALBERTA FLOOD FROM WEATHER AND CLIMATE PERSPECTIVES

Bernardo Teufel, Gulilat Tefera Diro, Kirien Whan, Shawn Milrad, Dae Il Jeong, Arman Ganji, Oleksandr Huziy, Katja Winger, John Gyakum, Ramon de Elia, Francis Zwiers and Laxmi Sushama

June 6th, PM2-P1 4:45-5:00

During 19-21 June 2013 a heavy precipitation event affected southern Alberta and adjoining regions, leading to severe flood damage in numerous communities and resulting in the costliest natural disaster in Canadian history. This flood was caused by a combination of meteorological and hydrological factors, which are investigated from weather and climate perspectives with the fifth generation Canadian Regional Climate Model (CRCM5). Results show that the contribution of orographic ascent to precipitation was important, exceeding 30% over the foothills of the Rocky Mountains. Another contributing factor was evapotranspiration from the land surface, which is found to have acted as an important moisture source and was likely enhanced by antecedent rainfall that increased soil moisture over the northern Great Plains. Event attribution analysis suggests that human induced greenhouse gas increases may also have contributed by causing evapotranspiration rates to be higher than they would have been under pre-industrial conditions. Frozen and snow-covered soils at high elevations are likely to have played an important

role in generating record streamflows. Results point to a doubling of surface runoff due to the frozen conditions, while 25% of the modelled runoff originated from snowmelt. The estimated return time of the 3-day precipitation event exceeds 50 years over a large region, and an increase in the occurrence of similar extreme precipitation events is projected by the end of the 21st century. Event attribution analysis suggests that greenhouse gas increases may have increased 1-day and 3-day return levels of May-June precipitation with respect to pre-industrial climate conditions. However, no anthropogenic influence can be detected for 1-day and 3-day surface runoff, as increases in extreme precipitation in the present-day climate are offset by decreased snow cover and lower frozen water content in soils during the May-June transition months, compared to pre-industrial climate.

STOCHASTIC AND ANTHROPOGENIC INFLUENCES ON REPEATED RECORD-BREAKING TEMPERATURE EXTREMES IN AUSTRALIAN SPRING OF 2013 AND 2014

Ailie Gallant and Sophie Lewis

June 6th, PM2-P1 5:00-5:15

We examine the contribution of synoptic and interannual processes and anthropogenic warming to repeated record-breaking warmth in the Australian spring of 2013 and 2014. Climatic conditions similar to those in 2013 and 2014 have occurred in the past, the regional and large-scale interannual processes associated with these extreme temperatures were not unusual, and the repetition of the very warm temperatures is likely to be a function of stochastic interannual variability. However, analysis using observations and climate model simulations shows that without an anthropogenically-driven warming trend, it is unlikely that the 2013 and 2014 temperature anomalies would have been consecutively record-breaking. Climate models demonstrate that the likelihood of consecutive record-breaking spring temperatures similar to 2013 and 2014 changes from < 1% in simulations using natural forcing only, to between 11% and 25% for the period 2006-2020 using simulations containing both natural and anthropogenic forcings.

USING RELIABILITY TO QUANTIFY UNCERTAINTY IN EVENT ATTRIBUTION

Fraser C Lott, Omar Bellprat, Peter A Stott and Antje Weisheimer

June 6th, PM2-P1 5:15-5:30

Event attribution assesses the climate-change-induced shift in the probabilities of classes of events. It typically calculates this shift from ensembles of climate simulations, with and without anthropogenic change. It is, however, difficult to quantify the uncertainty due to the probabilities (and thus the shift) being different between simulations and observations, since an event is only observed once, and the world without climate change is never observed.Reliability diagrams are typically used in seasonal forecasting to compare simulated probabilities of classes of event to their observed climatological frequencies. To extend this to attribution, the climatological period can be divided into pre- and post-change, and their individual reliabilities may be ascribed to simulations with natural forcings only, and with all known climate forcings, respectively.Preliminary work is presented showing how these reliabilities may then be converted into a bounded recalibration factor, which provides an error bar for the simulated probabilities around a new central estimate. Evidence is examined as to whether this estimate constitutes an improvement upon the original simulated value, and alternative methods of calculation are discussed. "

CLIMATE DATA HOMOGENIZATION AND CLIMATE TRENDS/VARIABILITY ASSESSMENT

GLOBAL CLIMATE MONITORING IN THE CONTEXT OF THE WMO ANNUAL STATEMENT ON GLOBAL CLIMATE

John Kennedy

June 10th, AM1 9:00-9:30

Climate defines, at a fundamental level, the way that we live. In order to understand our vulnerability to variation and changes in the climate around the world, we need to continually update our knowledge of what has happened and is happening in the climate system. Climate monitoring is the process of gathering and synthesising this information. Reports such as the WMO annual statements on global climate and the BAMS State of the Climate, draw together a wide range of often disparate information covering all aspects of the climate from the many countries and other centres around the world. Some of the longest climate records extend over centuries of time, during a period marked by rapid changes in technology. The WMO annual statement will be used as a starting point for describing some of the challenges - data gathering, data quality, homogenisation and consistent processing among them - associated with climate monitoring and introducing some of the mechanisms that are being introduced to help provide more consistent and reliable information."

A GENERAL REGRESSION CHANGEPOINT TEST FOR TIME SERIES DATA

Michael Robbins

June 10th, AM1 9:30-10:00

This presentation relays the development of a test for a single changepoint in a general setting that allows for correlated time series regression errors, a seasonal cycle, time-varying regression factors, and covariate information. A changepoint statistic is constructed from likelihood ratio principles and its asymptotic distribution is derived. The statistic can be used to test for a change in any desired subset of regression coefficients. The asymptotic distribution of the changepoint statistic is shown to be invariant of the seasonal cycle and the covariates should the latter obey some simple limit laws; however, the limit distribution depends on any time-varying factors. A new test based on ARMA residuals is developed and is shown to have favorable properties with finite samples. Driving our work is a changepoint analysis of the Mauna Loa record of monthly carbon dioxide concentrations. This series has a pronounced seasonal cycle, a non-linear trend, heavily correlated regression errors, and covariate information in the form of climate oscillations. In the end, we find a prominent changepoint in the underlying trend that occurred in the early 1990s, often attributed to the eruption of Mount Pinatubo, and a changepoint in the seasonal oscillations that occurred separately from the change in trend."

HOMOGENIZATION OF THE GLOBAL TEMPERATURE

Victor Venema

June 10th, AM1 10:00-10:30

The global land temperature trend may be biased due to remaining inhomogeneities. Well-homogenized national datasets on average clearly show more warming than global collections (GHCN, CRUTEM, GISTEMP, etc.) when averaged over the region of common coverage. We will present the temperature trend differences for several dozen national temperature series. This finding makes research into statistical homogenization more pressing. We have estimates for the uncertainties due to remaining inhomogeneities from numerical validation studies. We urgently need analytic work on the uncertainties in a certain dataset or station that is based on the inhomogeneities found and the network characteristics. Recent improvements in the quality of homogenization were largely due to the introduction of multiple breakpoint methods that can work with inhomogeneous reference series. These multiple breakpoint methods, however, do not have an optimal method yet to determine the number of breaks whose position can be accurately determined. The joint homogenization of all series simultaneously promises an optimal solution of the problem that also the reference stations have inhomogeneities. Also work on the selection of the best correction model (annual, seasonal, monthly, daily of the only the means or also of the higher moments) is needed. The homogenization of daily data is even harder. Only inhomogeneities in the mean, but not in the variability around the mean are used. Corrections in the variability are applied deterministically, while many error sources are not perfectly predictable. The correction of daily data should probably be treated similarly to downscaling.

LONG-TERM TRENDS IN MARINE HEATWAVES SINCE 1900

Sara Perkins-Kirkpatrick,

June 10th, PM1-P2 1:30-1:45

Several marine heatwaves (MHWs) have occurred over the past two decades, devastating regional ecosystems globally. These events have caused observable destruction to local marine ecology, species range extensions and contractions, and measurable economic impacts on fisheries. While it has been suspected that MHWs, like other extreme events, are becoming increasingly prominent as the climate warms, there has been no test of this hypothesis. Here we use extensive historical records of daily satellite observations, daily in-situ measurements, and gridded monthly in-situ SSTs, along with a recently developed MHW definition, to reveal significant global trends in marine heatwaves over the past century. Both the frequency and duration of MHWs has doubled since 1900, resulting in a four-fold increase in the global number of annual MHW days. These increases were generally consistent with average sea surface warming, as determined from a simple stochastic climate model, although notable regions were identified where trends in MHW characteristics were greater than that explained by the trend in the mean alone. Interestingly, we did not detect any significant global increase in the intensity of MHWs which was unexpected when set against the significant background global warming. Therefore, we concluded that rising mean temperatures had a stronger impact on trends in MHW frequency and duration than on intensity. Continued increases in MHWs, as anticipated with accelerated warming of the Earth during the 21st Century, will have serious implications for marine ecosystems, biodiversity and major industries fisheries, aquaculture, and tourism.

UPDATES TO HADISD AND CHANGES IN SUB-DAILY DISTRIBUTIONS

Robert J.H. Dunn

June 10th, PM1-P2 1:45-2:00

We present updates to HadISD, a sub-daily, multi-variable, quality-controlled land-surface product for the study of extremes. It comes complete with homogeneity information on the major meteorological variables. We will outline the improved station merging procedure along with changes in some of the quality control tests that have been included in the update to version 2.0.0.2015. We will also outline planned future developments to the update cycle.To demonstrate one value of such a dataset, we will present an analysis of the changes observed over time in the mean, standard-deviation, skew and kurtosis of measurements of observed and derived meteorological variables on a sub-daily basis. Building on the work of Donat & Alexander (2012) and Cavanaugh & Shen (2014) we will show whether changes in these statistical moments depend on the time of day, as well as the season and location. We will also study the changes in thequantiles of the distribution on a sub-daily basis.

INTEGRATING INCOMPLETE ANNUAL PRECIPITATION RECORDS INTO THE ESTIMATION OF ANNUAL MAXIMUM QUANTILES

Alain Mailhot and Guillaume Talbot

June 10th, PM1-P2 2:00-2:15

Missing data are an important issue since long time series are often needed, for example for trend analysis or the estimation of extreme rainfall quantiles. It is therefore necessary to define selection criteria (e.g. percentage of missing data is less than a given value over a given period) and values associated to this period are considered missing if these criteria are not met. This loss of information can even be more dramatic for the estimation of annual extreme rainfall. The annual completeness of the data record must be checked and the likelihood of capturing the annual maximum values must be assessed. For example, Environment Canada uses expert judgment to determine if a year is complete and also imposes that more than 180 days of observations are available during the yearly recording period (typically from April to October). In this study, we propose an approach that explicitly and formally takes into consideration annual incompleteness of precipitation records in the statistical treatment of annual maxima series. Incomplete years were assimilated to censored data. The approach was tested on stations belonging to the Canadian Second Generation Adjusted Daily Precipitation Dataset. Annual daily maximum series were fitted to the Generalized Extreme Distribution (GEV) and the impact of including incomplete years in the statistical analysis was assessed. Estimated GEV parameters and confidence intervals on these parameters were estimated and compared to the situation where only complete years are considered and to the case where a criterion similar to the one of Environment Canada is applied.

REDUCING UNCERTAINTY IN THE LONG-TERM RECORD OF CLOUD OCCURRENCE AT THE ARM SOUTHERN GREAT PLAINS SITE

Aaron David Kennedy, Xiquan Dong and Baike Xi

June 10th, PM1-P2 2:15-2:30

The Atmospheric Radiation Measurement (ARM) program operates multiple locations across the globe with over a decade of actively-sensed cloud observations. Unfortunately, these instruments can misbehave and introduce instrument downtime into the record, harming the ability to perform trend analyses or perform faithful evaluations of climate model cloud fields. The purpose of this talk is to describe activities to a) quantify uncertainty due to instrument downtime and b) reduce this uncertainty using a novel application of atmospheric state cluster analysis. Instrument uncertainty at the ARM Southern Great Plains (SGP) site from 1997-2010 will be quantified using bootstrapping. The result of this technique is the 95% confidence interval of cloud occurrence for each month. Early in the record, many months have high uncertainty due to lidar downtime. Under the notion that cloud occurrence is related to the large-scale atmospheric state, the long duration of the instrument record is taken advantage of. Utilizing atmospheric variables from a reanalysis, typing of atmospheric states is performed using Self Organizing Maps (SOMs). This record of atmospheric states is combined with instrument data (when operational) to understand what cloud scenes are expected for each state. This information is then used to fill in the instrument record when data is missing. The result of this technique is a large reduction in uncertainty, even when uptime is 0%. This unique property allows for an estimate of cloud occurrence prior to the existence of the ARM SGP site.

A SIMPLE STATISTICAL METHOD FOR ESTIMATING THE EFFECT OF SYSTEMATIC ERRORS IN CLIMATE DATA SETS OF LONG-TERM SEA-SURFACE TEMPERATURE CHANGE

John Kennedy

June 10th, PM1-P2 2:30-2:45

One of the larger uncertainties ? perhaps the largest ? in assessing long-term change in global temperature is that associated with systematic errors in measurements of sea surface temperature. Estimating the size of the systematic errors is difficult because measurements from ships have large random errors, the vessels themselves move constantly, vital metadata are often missing or unreliable and high quality reference measurements are few. We report the results of a simple analysis which combines information about the covariance of errors in ship measurements with a simple interpolation scheme. The analysis produces estimates of global biases at times from around 1950 when reference oceanographic data are available. At all times, it can produce estimates of locally varying systematic errors in SST measurements, in some cases estimating the biases for individual ships. The method is tested using independent high-quality data in the modern period."

UNCERTAINTIES IN DAILY TEMPERATURE HOMOGENEITY ADJUSTMENTS ILLUSTRATED USING PARALLEL OBSERVATIONS

Lucie Vincent, Ewa Milewska and Xiaolan Wang

June 10th, PM1-P2 2:45-3:00

In this study, we compare the uncertainties associated with a few approaches for producing homogeneity adjustments. The comparison is carried out using parallel observations over a 5-year period at 88 locations across Canada. At each location, daily maximum and minimum temperatures were observed at twoparallel sites over the same 5-year period. They were selected because their observations are often joined in time in order to produce a long time series useful for climate trends studies. The adjustments are based on the seasonal means of the daily temperature differences between both sites, on monthly means differences interpolated to calendar days, and on quantiles matching adjustments estimated with 12 quantile categories. The adjusments are also produced using neighbouring stations which can be located several kilometers away. The uncertainties are represented by the root-mean-square-error (RMSE) between the original (or adjusted) daily temperatures of site 1 and original temperatures of site 2. The results indicate that the daily temperatures of the two sites (or site and neighbour) need to be highly correlated in order to substantially improve the adjustments of the temperature extremes."

SYSTEMATIC INVESTIGATION OF DAILY RAINFALL VARIABILITY FROM 1958 TO 2014 ACROSS AUSTRALIA

Steefan Contractor, Lisa Alexander and Markus Donat

June 10th PM1-P2 3:00-3:15

In order to understand changes in daily precipitation variability in Australia we investigated changes in the probability distribution function (PDF) over the period 1958 to 2014. To determine whether there have been changes over time we compared quantiles over 2 periods, 1958 to 1985 and 1986 to 2013. We only focused on wet days since dry days dominate over higher quantiles. Mid and upper quantiles as well as various quantile based summary statistics such as median, interquartile range (IQR) and Yule-Kendell skewness measure (SM) are compared across the two periods. These relative changes or differences are then attributed to either location, scale or shape change of the distribution by transforming the distribution accordingly and once again examining the relative changes. Our findings suggest that the number of wet days have increased particularly in the East and West coast, the median and IQR have increased across most areas and so have the extremes in the form of upper quantiles. To test the robustness of the result, the analyses will be repeated using multiple long term precipitation grids available. The next step involves the application of this technique to global datasets.

CLIMATE AND WEATHER MODEL EVALUATION

CURRENT STATUS AND RECENT ADVANCES IN FORECAST EVALUATION METHODS

Barbara G Brown

June 6th, AM1 9:00-9:30

Forecast evaluation has been an important ? and often controversial ? topic in meteorology practically since the first weather forecasts were issued more than 100 years ago. While many verification methodologies have persisted through much of this history, the last few decades have seen a renaissance in the development of new approaches, as well as greater understanding of capabilities that have existed since the early days of forecasting. In recent times, not only has the variety of forecasts and observations expanded, but the needs for verification information have grown immensely ? from early efforts to evaluate the performance of

?simple? yes/no forecasts, to new methods for probabilistic and ensemble forecasts, and the development of spatial forecast evaluation methods and approaches to evaluate forecasts in terms of users? applications of forecast information. This talk will consider this recent evolution of forecast evaluation methods and will describe some of the new developments that are potentially relevant for evaluation of climate and other types of projections and forecasts. Specifically, the new probabilistic and spatial methods and their application will be described and new indices for evaluation of extreme events will be considered. In addition, existing issues and future directions will be addressed.

AN INTERCOMPARISON OF A STATISTICAL DOWNSCALING METHODS FOR EUROPE: OVERALL RESULTS FROM THE VALUE PERFECT PREDICTOR CROSS-VALIDATION EXPERIMENT

Douglas Maraun, Jose Manuel Guti, Gutierrez Manuel, Martin Widmann, Sven Kotlarski, Elke Hertig, Joanna Wibig, Ole R"ssler and Radan Huth

June 6th, AM1 9:30-10:00

VALUE is an open European network to validate and compare downscalingmethods for climate change research. A key deliverable of VALUE is thedevelopment of a systematic validation framework to enable theassessment and comparison of both dynamical and statisticaldownscaling methods. Several experiments have been designed to isolatespecific points in the downscaling procedure where problems mayoccur. The list of downscaling experiments includes 1)cross-validation with perfect predictors, 2) GCM predictors ?alignedwith EURO-CORDEX experiment? and 3) pseudo reality predictors. In thiscontribution we describe the overall results from Experiment 1),consisting of a European wide 5- fold cross-validation usingpredictors from ERA-Interim to downscale precipitation andtemperatures (minimum and maximum) over a set of 86 ECA&D stationsrepresentative of the main geographical and climatic regions inEurope. Over 40 methods representative of the main approaches (MOS andPerfect Prognosis, PP) and techniques (linear scaling, quantilemapping, analogs, weather typing, linear and generalized regression,weather generators, etc.) were submitted. This constitutes the largestand most comprehensive to date intercomparison of statisticaldownscaling methods. Here, we present an overall validation, analyzingmarginal and temporal aspects to assess the intrinsic performance andadded value of statistical downscaling methods at both annual andseasonal levels.

COMPARING FORECAST SKILL

Michael Tippett

June 6th, AM1 10:00-10:30

The problem of comparing the skill of different forecasts arises in a number of contexts, especially in model development and multi-model forecasting. Unfortunately, standard statistical tests for comparing correlation skill or mean square error are not valid when the skill is computed on a common period or with a common set of observations, because the resulting skill measures are not independent (e.g., forecasts tend to bust at the same time). In fact, applying these tests when the skill measures are not independent leads to serious biases. Rigorous tests for skill differences do exist, but their application in weather and climate prediction is surprisingly rare. I discuss a few of these tests, including the sign test, the Wilcoxon Signed-Rank test, the Morgan-Granger-Newbold test, and a permutation test. Moreover, I propose a new skill comparison test based on random walks that allows the evolution of skill differences to be visualized. Finally, I propose a new multivariate test that rigorously identifies patterns that explain the largest differences in mean square error between two forecasts. These new skill comparison tests are illustrated with a range of weather, seasonal, and climate forecasts.

COMPARING FORECAST SKILL

Timothy DelSole

June 6th, AM110:00-10:30

The problem of comparing the skill of different forecasts arises in a number of contexts, especially in model development and multi-model forecasting. Unfortunately, standard statistical tests for comparing correlation skill or mean square error are not valid when the skill is computed on a common period or with a common set of observations, because the resulting skill measures are not independent (e.g., forecasts tend to bust at the same time). In fact, applying these tests when the skill measures are not independent leads to serious biases. Rigorous tests for skill differences do exist, but their application in weather and climate prediction is surprisingly rare. I discuss a few of these tests, including the sign test, the Wilcoxon Signed-Rank test, the Morgan-Granger-Newbold test, and a permutation test. Moreover, I propose a new skill comparison test based on random walks that allows the evolution of skill differences to be visualized. Finally, I propose a new multivariate test that rigorously identifies patterns that explain the largest differences in mean square error between two forecasts. These new skill comparison tests are illustrated with a range of weather, seasonal, and climate forecasts.

BAYESIAN MODEL AVERAGING AND EVALUATION OF CMIP5 MODELS

Pao-Shin Chu and Christopher T. Holloway

June 6th PM2-P2 3:45-4:00

Climate or climate change simulations based on a single climate model or an ensemble of climate models will always have uncertainty.In order to describe the uncertainties and improve the possible range of climate variability a statistical post-processing method that combines climate model simulations and observations is used. In this study, we apply a Bayesian model averaging (BMA) to evaluate historical simulations from an ensemble of ten CMIP5 models to produce a skill-based weighted multi-model ensemble average. Uncertainties, weights, and variances for the historical experiments are estimated from a training period in reference to the National Centers for Environmental Prediction-National Center for Atmospheric Research (NCEP-NCAR) reanalysis datasets from 1950-2005. The weights are the estimated posterior distribution probabilities and represent the simulation skill of each model relative to others. The expectation-maximization (EM) algorithm is used to find the maximum likelihood estimates for BMA weights, based on simulated vertically integrated Kinetic Energy (KE), area averaged over the Central North Pacific (170øW-150øW, 13øN-28øN). Taylor diagrams and probability density functions for KE reveal that the BMA method successfully produces more accurate and reliable results of the current climate relative to the commonly used, equal-weighted multi-model ensemble average. Future changes of climate under global warming from the ensemble RCP8.5 experiments are projected using the weights derived during the training period. We conclude that that the BMA is an effective tool for describing uncertainties since it accounts for the skill of individual models in order to generate a more credible range of current climate variability."

IMPROVING SEASONAL CLIMATE PREDICTION BY MATHEMATICAL/STATISTICAL METHODS

Youmin Tang

June 6th PM2-P2 4:15-4:30

In this talk, we will present some progresses in improving seasonal climate predictions by using more advanced mathematical methods. The first example is to rely on the basic properties of stochastic theory to develop an efficient technique for the extraction of climatically relevant singular vectors (CSV) in the presence of weather noise. Emphasis is placed on the applications of the CSV in seasonal climate predictions and to construct optimal ensemble climate predictions. The results indicates that the CSVs can well characterize the optimal error growth of the climate predictions and lead to better ensemble predictions than traditional time lag (TLE) method. The second example is to apply for the information theory to quantify the potential climate predictability. It is found that the information-based measures such as relative entropy and multiple information can better characterize the real predictability than the traditional methods of signal-to-noise ratio. At last, our recent progress in the state estimate of state-space models is discussed with applications of Bayesian-based algorithms. A simplified algorithm of Sigma-point Kalman filter is develop to deal with the state estimation of high-dimensional systems like atmospheric and oceanic general circulation models.

FINDING LOW CLIMATE SENSITIVITY GENERAL CIRCULATION MODELS THROUGH VERY LARGE PERTURBED PHYSICS ENSEMBLES

Richard Millar, William Ingram and Myles Allen

June 6th PM2-P2 4:30-4:45

Estimates of the magnitude of GMST response to a doubling of atmospheric carbon dioxide (equilibrium climate sensitivity or ECS) remains uncertain over a broad range between 1.5-4.5K. Whilst observationally-based energy balance estimates of the climate response are consistent with ECS < 2K, general circulation models (GCMs) do not sample ECS < 2K in either multi-model ensembles or broad perturbed physics ensembles (PPEs). Whether this there is a hard physical limit to ECS at 2K, or whether GCM ensembles are simply not diverse enough to sample the full plausible climate response space is currently unclear. We construct a statistical emulator of HadCM3 climate response space, in which a linear-regression based model of the ECS is built from perturbations to GCM sub-gridscale parameters. This emulator is trained on existing HadCM3 GCM PPEs and is used to search for regions of HadCM3 parameter space that are consistent with ECS < 2K, whilst also maintaining radiatively balanced preindustrial climates. We find a set of GCMs with ECS between 1.5K and 2K, driven primarily by negative feedbacks in tropical low cloud with GMST warming, associated with changes in convective drying of the boundary layer proportional to the strength of this process in the preindustrial control climate. Achieving low ECS is associated with reduced model fidelity relative to the standard version of the model, but fidelity reductions are not sufficient to strongly rule out a low ECS of between 1.5-2K in the real climate system.

TESTING CLIMATE MODELS FOR TIME-VARYING FORECAST ACCURACY USING INDICATOR SATURATION

Felix Pretis

June 6th PM2-P2 4:45-5:00

The observational-tracking or forecast performance of climate models may vary over time - projections can track some observed periods successfully and fail during others. This paper proposes a formal test for time-varying forecast accuracy to detect periods

of model failure based on step-indicator saturation (SIS) building on Pretis, Mann, & Kaufmann (2015, Climatic Change). Time-varying forecast performance can be used to identify unique periods of model failure (e.g. the ?warming hiatus?) in hindcasts or forecasts, and provide insights into the causes of these failures. The propodes SIS test adds a full set of break functions at every point in time to a statistical model of the prediction errors - the difference between observed and modelled values ? and removes all but significant ones through model selection. The results - in the form of detected shifts - can be used to assess the timing and magnitudes of any predictive biases in ensemble means for a single model, as well as assess the relative performance of competing models. By only relying on observed and projected values, the test is model-independent where the underlying models (used to create the projection itself) may be unknown. The test is also robust to autocorrelation, which is of particular importance to evaluating projections from simulations in which auto-correlated prediction errors may misleadingly be interpreted as a forecast bias. Simulations confirm the approximate properties of the test and an application considers time-varying climate hindcast accuracy. Code to implement the procedure is made freely available as an R-package.

QUANTIFYING MODEL PERFORMANCE USING DATA ASSIMILATION

Alexis Hannart

June 6th PM2-P2 5:00-5:15

In statistics, the goodness-of-fit between some observations and some theoretical model used to represent them is often quantified by using the very general concept of likelihood. We argue that likelihood is also a relevant metric when it comes to evaluating the performance of large numerical weather or climate models in representing observed data. Indeed, these models may be viewed as high dimensional nonlinear state-space models, a convenient statistical setting which allows to account for the physics of the system (i.e. the numerical model itself) as well as numerical and observational errors. Mathematically speaking, deriving the likelihood under this setting comes with a difficulty as it requires to integrate out the state vector, a daunting task which is usually intractable. However, different approaches were recently proposed to circumvent this issue in order to yield an estimate of the likelihood, for instance under the Gaussian assumptions at stake in Data Assimilation (DA). The latter DA schemes present the advantage to be already used operationally at NWP centers for state estimation. Further, several authors have shown that in a DA context, likelihood can be obtained as a by-product of standard state estimation routines. We lay out the details of such a calculation and illustrate the use of a DA-based, likelihood quantification of model performance in the context of a low dimensional chaotic model (Lorenz 95), as well as an intermediate complexity atmospheric model (Speedy).Coauthors: Marc Bocquet, Alberto Carrassi, Sammy Metref.

SPATIAL VERIFICATION OF SEA ICE PREDICTION BY USING BINARY IMAGE DISTANCE METRICS

Barbara Casati, Jean-Francois Lemieux, Gregory Smith, Paul Pestieau, Angela Cheng

June 6th PM2-P2 5:15-5:30

Sea-ice is characterized by a coherent spatial structure, with sharp discontinuities and linear features (e.g. leads and ridges), the presence of spatial features (e.g. ice shelves and islands), and a multi-scale spatial structure (e.g. agglomerates of floes of different sizes). Traditional point-by-point verification approaches do not account for this complex spatial structure and the intrinsic spatial correlation existing between nearby grid-points. This leads to issues (such as double penalties), and an overall limited diagnostic power (e.g. traditional scores are insensitive to distance errors). In this work we explore the use of binary image distance metrics of the Hausdorff and Baddeley family for the spatial verification of sea-ice prediction. These metrics account for the field intrinsic spatial structure, and are shown to be sensitive to overlapping and similarities in shape and extent of observed and predicted sea-ice packs. Moreover, these metrics are sensitive to the distance of observed versus predicted sea-ice edge, and can provide distance errors in physical terms (i.e. km). The verification statistics are shown be robust, informative and meaningful for user-relevant applications. We illustrate the application of several binary image distance metrics for the verification of the Canadian Regional Ice Prediction System. The binary image distance metrics reveal to be a suitable set of complementary measures for the verification of sea-ice prediction, with respect to the traditional categorical scores.

TOWARD A COMPREHENSIVE EVALUATION OF METEOROLOGICAL DROUGHT IN CMIP5 MODEL SIMULATIONS

Ailie Gallant and Sophie Lewis

June 8th PM1-P1 1:30-1:45

Historical and future increases in global temperatures are likely to impact the hydrological cycle, including drought. However, the ability of climate models to simulate drought, either in terms of precipitation or soil moisture, is not well understood. In particular, the accuracy of the frequency, severity and duration of simulated meteorological drought has rarely been explored previously, al-

though changes in precipitation are arguably more important than changes in evaporation in a future climate.We explore the consistency of meteorological drought between observations and climate model simulations from the CMIP5 experiments using the Standardised Precipitation Index in combination with the lower tails of precipitation distributions. Significant precipitation deficits occurring on time scales of 3, 6, 12 and 24 months are examined. A comparison of the models and observations highlight differences in the shapes of the lower tails of the SPI and precipitation distributions. Systematic biases are present in the precipitation distribution that affect drought and these vary seasonally, geographically and with the timescale on which drought is examined. These biases are usually result in too much precipitation across the globe, associated with the well known ""drizzle"" problem.

PREDICTIVE SKILL OF SEASONAL FORECASTS OF CLIMATE INDICES

Jonas Bhend, Irina Mahlstein and Mark Liniger

June 8th PM1-P1 1:45-2:00

Seasonal forecasting sits at the interface between weather forecasting and climate prediction. Limited predictive skill and the related inherent uncertainty of climatic conditions a few months ahead require seasonal forecasts to be framed probabilistically and to be assessed very carefully. Current operational forecast and re-forecasts available for the recent past on the other hand make systematic verification of seasonal forecasts possible. We employ novel verification scores for ensemble forecasts that are unbiased with respect to ensemble size to study predictive skill of seasonal forecasts of climate indices. We analyze the behavior of two archetypes of indices: counts of events such as the number of dry days and accumulated threshold exceedances such as degree days. As a specific application, we find that the predictive skill of forecasts of heating and cooling degree days and of consecutive dry days is generally lower than the skill of seasonal mean temperature and rainfall forecasts respectively. By use of a toy model we demonstrate that this reduction in skill is more pronounced for skillful forecasts and thresholds at the tail of the statistical distribution. Spatial aggregation generally improves the predictive skill. We conclude that processing of direct model output to derive climate indices in combination with spatial aggregation can be used to render still skillful and from an application perspective even more useful seasonal forecasts of user-relevant quantities.

CLIMATE RESPONSES TO VOLCANIC ERUPTIONS ASSESSED FROM OBSERVATIONS AND CMIP5 MULTI-MODELS

Seungmok Paik and Seung-Ki Min

June 8th PM1-P1 2:00-2:15

This study analyzes climate responses to four volcanic eruptions that occurred since 1960s using observations and CMIP5 multi-model datasets. Changes in climate variables over the global land are examined using a composite analysis. Observations exhibit consistent decreases in temperature, humidity and precipitation following eruptions, which are reasonably captured by CMIP5 historical simulations. The observed precipitation decrease is significant but the CMIP5 models considerably underestimate it, as reported by previous studies. In order to explore important physical processes determining climate responses to volcanic forcing, a surface energy budget is analyzed together with inter-model relationship between variables. Interestingly, precipitation is found to have the significant correlation with latent heat flux (r= -0.50) and vertical motion at 500 hPa level (r = 0.68), which changes are also underestimated by models. Further, by comparing precipitation minus evaporation over land and ocean, which is significantly correlated with vertical motion (r = -0.73), it is found that monsoon circulation decreases after volcanic eruptions but CMIP5 models substantially underestimate it. Our results suggest that this dynamic response related to monsoon circulation weakening can be critical factors for models' underestimation of precipitation reduction following eruptions. The observed responses of temperature and precipitation extremes to volcanic eruptions and the corresponding performances of CMIP5 multi-models will be discusses as well.

STATISTICAL VERIFICATION OF WEATHER FORECASTING FOR DIFFERENT SEASONS

Gerhard Wilhelm Reuter and Clark Penelly

June 8th PM1-P1 2:15-2:30

The verification of weather prediction models remains a challenge, particulalrly for precipitation. In this talk we will show results from different statistical verifications scheme of day 1weather predictions using the Weather Research and Forecsating (WRF) Model for southern Alberta. The analyis includes minimum and maximum temperatures, humidity, surface pressure, wind speed, daily rainfall accumualtions, and snowfall amounts. The emphasis is quantifying the on seasonal differences of the WRF model skill statistics.

AN EMPIRICAL MODEL FOR PROBABILISTIC DECADAL PREDICTION: A GLOBAL ANALYSIS

Emma Suckling, Ed Hawkins, Geert Jan van Oldenborgh and Jonathan Eden

June 8th PM1-P1 2:30-2:45

Empirical models, based on the statistics of past events and on observed statistical relationships, are useful tools for seasonal-to-decadal climate prediction. They not only serve as benchmarks for comparison against dynamical models, but may also be useful as informative tools in their own right or in combination with other forecast systems. A new global empirical decadal forecast system has been developed, and its hindcast skill evaluated for surface air temperature and precipitation for lead times of one to ten years ahead. It is based on a multiple linear regression approach and has been designed to produce ensemble output comparable to dynamical models. The model is semi-operational in the sense that forecasts have been produced for the coming decade and have contributed to the Decadal Forecast Exchange project. The potential to improve the skill of the model further and to expand the range of surface variables predicted, by exploiting observed land-sea teleconnections, will also be discussed."

ANALYSIS OF ENSEMBLE QUALITY OF INITIALISED HINDCASTS IN THE GLOBAL COUPLED CLIMATE MODEL MPI-ESM

Andre Dusterhus

June 8th PM1-P1 2:45-3:00

For medium range climate predictions, on interannual to decadal time scales, both initial and boundary conditions are thought to influence the climate state, because the ocean is expected to have a much larger deterministic timescale than the atmosphere. The climate model needs to resemble the observed climate state and its tendency at the start of the prediction. This is realised by incorporating observations into both the oceanic and atmospheric components of the climate model leading to an initialised simulation.Here, we analyse the quality of an initialised ensemble generated with the global coupled Max Planck Institute for Meteorology Earth System Model (MPI-ESM). We initialise for every year for the time period 1960 to 2014 an ensemble run out to 10 years length. In this context, the initialisation of the oceanic component of the model ensemble is thought to impact the model state within the first years of prediction, however, it remains poorly known, for how much longer this impact can be detected. In our approach we focus on the analysis of the probability density function (PDF) and the spread-error-ratio of the ensemble to access the predictive skill of the ensemble. We apply this firstly to the comparison of the initialised ensemble with the uninitialised one and in a second step to the comparison of the initialised ensemble and re-analysis products.

WINTER ATMOSPHERIC CIRCULATION OVER EUROPE AND THE NORTH ATLANTIC: AN EVALUATION

Jan Stryhal,

June 8th PM1-P1 3:00-3:15

An analysis of winter atmospheric circulation over Europe and the North Atlantic is carried out based on five reanalysis datasets (ERA-40, NCEP/NCAR, JRA-55, ERA-20C, and 20CRv2) and outputs of thirty-two CMIP5 GCM historical runs (1961–2000). Research on atmospheric circulation has been quite common in Europe and includes e.g. analyses of circulation properties and trends in both observed and simulated climates and links between the large-scale circulation and local climate elements. In many cases, however, studies have been restricted to but one research method or one set of data, which might have led to inaccurate findings. Therefore, to achieve reliable results, eight distinct computer-assisted classification methods were consecutively used to define circulation types and to classify both reanalyzed and simulated daily mean sea-level pressure patterns. The GCM ensemble median in most cases shows an overestimation of circulation types with (south)western advection over Europe, and over- and underestimation of cyclonic and anticyclonic types, respectively, both in their frequency and persistence and the spatial extent of the respective pressure systems. The size and significance of these biases are, however, considerably dependent on the chosen classification method, domain, and even the reanalysis dataset.

A SCALE-SEPARATION VERIFICATION APPROACH WHICH ACCOUNTS FOR THE UNEVEN SPATIAL DENSITY OF STATION OBSERVATION NETWORKS

Barbara Casati, Vincent Fortin and Laurence Wilson

June 9th PM2-P2 3:45-4:00

Forecasts defined over spatial domains are often characterized by a coherent spatial structure and the presence of features. Verification methods ought to account for this intrinsic spatial structure. However, when station observations are used for the verification, this task becomes particularly challenging because of the variation in spatial density and scale representativeness of the observation network across the domain. This study addresses some of the issues related to the verification of spatial (precipitation) forecasts against observations unevenly distributed in space. A wavelet-based approach to reconstruct a precipitation field from

sparse gauge observations is introduced. The reconstructed field preserves the observed value at the observation location, represents the coherent spatial structure characterizing the field, and accounts for the network density, so that more details are shown where the observation network is more dense. The wavelet reconstructed fields are used to perform a scale-oriented verification. Different scale components are isolated by a 2D Haar wavelet transform. Scales not represented in the observations are disregarded in the forecast prior to verification. Continuous verification statistics are then evaluated on each scale. Forecast and observation scale structure, the scale dependency of the bias error, and the no-skill to skill transition scale are analyzed. The sensitivity of the scale-separation verification statistics to the network density, and the effects of including satellite clear-sky data in the wavelet reconstruction are also illustrated.

SELF-ORGANIZING MAPS: A TOOL FOR EVALUATING CLIMATE MODELS BY ATMOSPHERIC STATE

Aaron David Kennedy

June 9th PM2-P2 4:00-4:15

By their design, climate models simulate an alternate reality of weather conditions. When aggregated over periods of time, these weather states form the climate. Averaged properties (precipitation, cloud cover, etc.) are then typically compared to observations to determine model performance. These gross comparisons can hide model errors, and lead to less insight into the physical mechanisms responsible for these problems. High-temporal output is becoming more common for climate models and more rigorous assessments are now possible. This work will showcase examples of climate model evaluation utilizing a clustering technique known as the Self Organizing Map (SOM). After discussing the choices that must be made by the user to implement this type of assessment, SOMs will be used to identify historical atmospheric patterns from reanalyses across the Northern and Southern Plains of the United States. Historical simulations from the Coupled Model Intercomparison Project (CMIP5) will then be analyzed to determine a) how they simulated the observed distribution of atmospheric states, and b) how properties such as precipitation and cloud cover varied by these patterns. This assessment will provide insight into how errors are partitioned between the dynamic and physical (parameterized) components of these models.

A SIMPLE WEIGHTING METHOD FOR COMBINING MULTIMODEL PROJECTIONS

Ruth Lorenz

June 9th PM2-P2 4:15-4:30

The statistical theory of extreme values has only rarely been applied to model heatwaves. Choosing a probability distribution to represent the heatwaves intensity at various durations is a topic of interest in climate research. Recent studies have shown that the annual frequency and lenght of heatwaves can be modeled by a Poisson and a Geometric distribution, respectively. Here a set of probability distributions (log-normal, Gamma, and GEV) are evaluated on their ability to reproduce the statistics of the Heat Wave Magnitude Index daily (HWMId) capturing both the duration and magnitude of heatwaves into a single number. Our analyses are based on historical and future climate simulations from a 50-member ensemble of the CanESM2 model developed at the Canadian Centre for Climate Modelling and Analysis (CCCma). Using a single model large ensemble enables us to assess uncertainties with regard to natural climate variability and parameter estimation.

A REGIME BASED CLIMATOLOGICAL ASSESSMENT OF WRF SIMULATED DEEP CONVECTION AND ASSOCIATED PRECIPITATION

Brooke Hagenhoff, Aaron Kennedy, Xiquan Dong, Baike Xi and Jingyu Wang

June 9th PM2-P2 4:30-4:45

This study will evaluate deep convection and associated precipitation in a multi-year database of Weather Research and Forecasting (WRF) simulations over the Northern and Southern Great Plains of the United States. These WRF simulations were run daily in support of the NOAA Hazardous Weather Testbed (HWT) by the National Severe Storms Laboratory (NSSL) for operational forecasts. The thousands of simulations allow for a unique, climatological assessment of convection by weather regime. Evaluating model skill by synoptic pattern allows for an understanding of how model performance varies with particular atmospheric states and will aid forecasters with pattern recognition. To conduct this analysis, a competitive neural network known as the Self-Organizing Map (SOM) will be used. SOMs allow the user to represent atmospheric patterns in an array of nodes that represent a continuum of synoptic categorizations. North American Regional Reanalysis (NARR) data will be used during the warm season (April-August) to perform the synoptic typing over the study domains. Model simulations will be evaluated using observed precipitation provided by the National Centers for Environmental Prediction (NCEP) Stage IV precipitation analysis and archived radar data such that stratiform/convective classifications can be made.

EVALUATING RAINFALL EXTREMES IN A CONVECTION-PERMITTING STRETCHED-GRID MODEL SIMULATION

Tony Rafter, Marcus Thatcher and Kim Nguyen

June 9th PM2-P2 4:45-5:00

CSIRO Oceans & Atmosphere The relatively coarse resolution (minimum ~100km) of global climate models means that they are unable to directly resolve extreme rainfall events, though they are likely able to simulate the large-scale dynamical environments that cause them. The use of convection-permitting or convection-resolving models to downscale the future climate scenarios produced by GCMs provides a pathway to produce dynamically-based projections of future rainfall extremes, albeit for limited areas. To evaluate the potential to produce regional dynamically-based projections of future rainfall extremes, the use of a convection-permitting model ? the non-hydrostatic CSIRO Cubic-Conformal Atmospheric Model (CCAM) run at 2km resolution ? was evaluated in its ability to produce a realistic climatology of rainfall, from means to multi-year extremes, compared to observational datasets. A quasi-observational simulation was performed over a domain covering the Australian city of Sydney for the period 1980-2012, using the ERA Interim reanalysis to provide the external forcing. Output was then compared to the Australian Water Availability Project (AWAP) 0.05 degree gridded rainfall data set. The distribution of simulated rainfall over the domain?s land-based points reveals a reasonably good match, with errors possibly attributable to the interpolation method used in AWAP dampening its extremes. Spatially the 95th and 99th percentile and GEV-derived annualised recurrence interval rainfall extremes correspond extremely well to AWAP, although again simulated values appear higher than the gridded AWAP product, and this is further accentuated the more extreme the event. These results provide encouragement that providing projections of rainfall extremes using this CCAM configuration is feasible.

EVALUATION OF NOWCASTS OF AFTERNOON CONVECTIVE STORM INITIATION FROM TAIWAN AUTO-NOWCASTER

Hui-Ling Chang

June 9th PM2-P2 5:00-5:15

At present, nowcasts of afternoon convective storm initiation (ACSI) is still a challenging task. This is because important mesoscale boundary characteristics, such as the frontal edges of sea-land breeze and anabatic-katabatic winds, cannot be resolved by observations and become unavailable for the model initial fields. However, such information is critical for accurate forecasts of ACSI in dynamical models. One way to overcome this problem is to use a statistical forecasting method such as Taiwan Auto-NowCaster (TANC) developed by Central Weather Bureau (CWB) in Taiwan. This study evaluates the 1-h nowcasts of ACSI from TANC based on Fuzzy Logic. Verification results show that TANC displays obvious overforecasting, but has excellent discrimination.The sensitivity of probability threshold (Pt) on forecast performance suggests an optimal value for Pt is 0.6. Relative to forecasting other weather systems (e.g., Mei-yu front or typhoon), the uncertainty in nowcasts of exact location or timing of ACSI is large. Because of this difficulty, various spatial (+/- 1-4 km) and temporal (+/- 6-18 min) windows of ACSI have been considered in operational applications. If a spatial/temporal window of +/- 4 km/18 min is allowed, the threat score and Kuiper score can reach 0.17 / 0.19 and 0.59 / 0.65, respectively. The nonparametric Mann-Whitney test suggests that we are 90% confident that the TANC significantly surpasses the competitive STMAS (Space and Time Multiscale Analysis System)-WRF model, which serves as an improtant reference for short-range (0-6 h) forecasts at CWB.

THE DETECTION AND ATTRIBUTION MODEL INTERCOMPARISON PROJECT (DAMIP)

MULTI-MODEL DETECTION AND ATTRIBUTION WITHOUT LINEAR REGRESSION

Aurélien Ribes

June 7th AM1 9:00-9:30

Conventional D&A statistical methods involve linear regression models where the observations are regressed onto expected response patterns to different external forcings. These methods do not use physical information provided by climate models regarding the expected response magnitudes to constrain the estimated responses to the forcings. As an alternative to this approach, we propose a new statistical model for detection and attribution based only on the additivity assumption. We introduce estimation and testing procedures based on likelihood maximization. As the possibility of misrepresented response magnitudes is removed in this revised statistical framework, it is important to take the climate modelling uncertainty into account. In this way, modelling uncertainty in the response magnitude and the response pattern is treated consistently. We show that climate modelling uncertainty can be accounted for easily in our approach. We then provide some discussion on how to practically estimate this source of uncertainty, and on the future challenges related to multi-model D&A in the framework of CMIP6/DAMIP."

RAPID SYSTEMATIC ASSESSMENT OF THE DETECTION AND ATTRIBUTION OF REGIONAL ANTHROPOGENIC CLIMATE CHANGE

Daithi Stone, Gerrit Hansen and Mark Risser

June 9th PM1-P2 1:30-1:45

While the detection and attribution of climate change is well established as a field of research, it has yet to be formulated in an algorithmic form which permits wide-spread and rapid, yet accurate, assessment of the degree to which anthropogenic emissions have influenced regional climate. Even detailed investigations rarely go beyond a statistical comparion of (a posteori) predicted and observed climate change, without considering the importance of uncertainties extraneous to the experimental specifications. In this talk we present the development of an algorithm which, in essence, predicts the conclusion of an IPCC-like expert assessment of confidence in the detection and in the attribution of observed climate change to anthropogenic emissions. The algorithm considers the diversity of observational and climate model data sources, the observational measurement density, the region size, and the accuracy of the physical representation within climate models. Through standard regression analysis, it also considers whether the simulated anthropogenic climate change signal is visible in the observed record, whether the simulated and observed magnitudes are consistent, whether the natural signal is detected, whether there is evidence of missing forcings, and, for attribution, whether emissions have played a major role in observed variations. The possibility of further development within the context of a Bayesian decision model will also be discussed.In this talk, insights from deployment of this algorithm on a number of aspects of regional climate change will be demonstrated, including identification of factors that are currently limiting our ability to develop confident assessments. For instance, it appears that existing rules of thumb concerning the detectability of climate change ignore the full range of sources of uncertainty."

MULTI-MODEL ATTRIBUTION OF EXTREME TEMPERATURE CHANGES DURING 1951-2010

Yeon-Hee Kim, Seung-Ki Min, Xuebin Zhang, Francis Zwiers and Lisa V. Alexander, Markus G. Donat and Yu-Shiang Tung

June 9th PM1-P2 1:45-2:00

This study conducts an attribution analysis of extreme temperature changes based on updated observation (HadEX2) and multi-model climate simulation (CMIP5) datasets for an extended period of 1951-2010. Using an optimal fingerprinting technique, we compare observed changes in annual extreme temperature indices of coldest/warmest night and day (annual minimum/maximum of daily minimum and maximum temperatures) with those from multi-model simulations that were integrated under ALL (natural-plus-anthropogenic) and NAT (natural-only) forcings. Results show that anthropogenic (ANT) signals are robustly detected in the observed increase in global means of the four indices of extreme temperatures. The detected ANT signals are clearly separable from the response to NAT forcing. ANT signal are also detected in continental-scale, more robustly in warm extremes. All these results support previous HadEX/CMIP3-based results, indicating that detection results are insensitive to the used of difference observed and model dataset. It is demonstrated that detection results further improve when removing the influence of two major modes of natural internal variability (Arctic Oscillation and Pacific Decadal Oscillation) from observations, especially in cold extremes over Northern mid-latitudes."

IMPACTS OF LOCAL AND REMOTE ANTHROPOGENIC AEROSOLS ON THE 20TH CENTURY WEST AFRICA AND SOUTH ASIA MONSOONS

Debbie Polson

June 9th PM1-P2 2:00-2:15

Precipitation in monsoon regions has large seasonal variability associated with a strong land-sea temperature contrast and seasonal wind reversals and studies have shown that anthropogenic aerosols are a key driver of historical changes in summer monsoon precipitation in the Northern Hemisphere (Polson et al. 2014). The reduction in precipitation in both the West African (Held et al. 2005) and Asian monsoons during the latter half of the 20th century, has been linked to increasing emissions of anthropogenic aerosols (Lau and Kim, 2006; Bollasina et al., 2011; Guo et al., 2015). Here we apply detection and attribution methods to investigate changes in the West African and South Asian monsoons separately and identify the aerosol source regions that are most important for explaining the observed changes. Historical climate model simulations are used to derive fingerprints of aerosol forcing for different regions of the globe. Comparing model changes with observations show that the changes over the 20th century in West African monsoon precipitation were mainly driven by remote aerosol emissions from North America and Europe, while changes in South Asian monsoon precipitation were most strongly influenced by local aerosol emissions.

Polson D et al. 2014 GRL41, 6023?6029. Held I et al. T 2005 PNAS 102, 17891?17896 Lau KM and Kim KM 2006 GRL 33 L21810, 1944-8007 Bollasina MA et al. 2011 Science 334, 502?505 Guo L et al. 2015 Atmospheric Chemistry and Physics 15 6367?6378

OBSERVED HEAVY PRECIPITATION INCREASE CONFIRMS THEORY AND EARLY MODELS

Erich Fischer and Reto Knutti

June 9th PM1-P2 2:15-2:30

Environmental phenomena are often first observed, and then explained or simulated quantitatively. The complexity and diversity of processes, the range of scales involved, and the lack of first principles to describe many processes make it challenging to predict conditions beyond the ones observed. Here we use the intensification of heavy precipitation as a counterexample, where seemingly complex and potentially computationally intractable processes to first order manifest themselves in simple ways: the intensification of heavy precipitation is now emerging in the observed record across many regions of the world, confirming both theory and a variety of model predictions made decades ago, before robust evidence arose from observations.We compare the heavy rainfall intensification over the US and Europe across observational data sets, GCMs and RCMs and demonstrate that largely independent of resolution observations and models consistently show an increased frequency of very wet days. Overall this increases confidence in the model-based large-scale attribution statements on precipitation extremes.

EMERGENCE OF AN ANTHROPOGENIC INFLUENCE ON PRECIPITATION EXTREMES

Andrew King, David Karoly and Markus Donat

June 9th PM1-P2 2:30-2:45

Precipitation extremes are changing due to the anthropogenic influence on the climate, however, relatively few recent extreme rain and snowfall events can be directly attributed to human-induced climate change. This analysis investigates the role of anthropogenic forcings in recent and future extreme precipitation events by employing a modification on the commonly used Fractional Attributable Risk (FAR) methodology and using CMIP5 natural- and all-forcings simulations.We will estimate when attribution statements will be possible for extreme wet months, seasons and years as well as investigating emergence in maximum one- and five-day precipitatiion indices. This will be done across the globe and also for specific regions where there has been interest in the role of climate change in recent extreme events.The results of this work will show when the fingerprint of human-induced climate change emerges in precipitation extremes.

SIGNIFICANT ANTHROPOGENIC-INDUCED CHANGES OF CLIMATE CLASSES SINCE 1950

Qigang Wu and Duo Chan

June 9th PM1-P2 2:45-3:00

Anthropogenic forcings have contributed to global and regional warming in the last few decades and likely affected terrestrial precipitation. Here we examine changes in major K"ppen climate classes from gridded observed data and their uncertainties due to internal climate variability using control simulations from Coupled Model Intercomparison Project 5 (CMIP5). About 5.7% of the global total land area has shifted toward warmer and drier climate types from 1950-2010, and significant changes include expansion of arid and high-latitude continental climate zones, shrinkage in polar and midlatitude continental climates, poleward shifts in temperate, continental and polar climates, and increasing average elevation of tropical and polar climates. Using CMIP5 multi-model averaged historical simulations forced by observed anthropogenic and natural, or natural only, forcing components, we find that these changes of climate types since 1950 cannot be explained as natural variations but are driven by anthropogenic factors.

OBSERVATIONALLY-CONSTRAINED PROJECTIONS OF WARMING UNDER RCP 2.6 AND THE FEASIBILITY OF LIMITING GLOBAL WARMING TO 1.5°C

Nathan Gillett

June 9th PM1-P2 3:00-3:15

The recently-signed Paris Agreement mandates signatories to "pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels". Is limiting global warming to 1.5°C possible, given what we know about the physical climate system and plausible emissions scenarios? RCP 2.6 has the lowest forcing of the RCPs assessed in the IPCC Fifth Assessment Report and while it is associated with relatively rapid emissions reductions, it is considered plausible. While only approximately 30% of CMIP5 model simulations project less than 1.5°C warming relative to 1870 over the 21st century, the CMIP5 models have an average Transient Climate Response (TCR) which is above the best estimate from observations. TCR is strongly correlated with warming in RCP 2.6 at the end of the 21st century. When an observationally-constrained estimate of TCR derived from a detection and attribution analysis is used to constrain projected warming under RCP 2.6, the estimated probability of limiting warming to below 1.5°C under this scenario increases to approximately 50%."

FLOW ANALOGUES FOR THE DETECTION AND ATTRIBUTION OF HEAT WAVES

Aglae Jezequel

June 10th AM2-P1 11:00-11:15

The detection and attribution of extreme events to climate change relies on the comparison of a probability density in a factual world – a world similar to ours, including climate change – to a counterfactual one – with pre-industrial conditions. Because of the rarity of extreme events, long time series are needed to produce statistically significant results. Most attribution studies simulate both worlds, which uses a lot of computation time and limits the number of cases that can be investigated. We explore how flow analogues can simulate a large number of events from relatively short (70 to 100 years) data samples and hence produce results very quickly, for a recent heat wave case study. We will focus on temperature simulations for heatwaves over Europe. Analogues are days which have similar atmospheric circulations to the days of interest. We can use them to reconstruct virtual temperatures for a given dynamical state, close to the studied event, and create a conditional probability density. Depending on the data base from which we pick analogues, we can compare different types of world. We use different periods from reanalysis data as well as an ensemble of CMIP5 models for different experiments (pre-industrial, historical, RCP4.5 and RCP8.5). This allows us to identify the role played by dynamics (i.e. the atmospheric circulation) in the occurrence of the event and to assess conditional probability densities. We will discuss perspectives of using this method not only on temperature, but also on indices closer to impacts of extreme temperatures.

ANTHROPOGENIC INFLUENCE ON THE FREQUENCY OF EXTREME TEMPERATURES IN CHINA

Chunhui Lu

June 10th AM2-P1 11:15-11:30

Using an optimal fingerprint method and a newly homogenized observational dataset as well as simulations conducted with the new generation of climate models, anthropogenic influence on the frequency of the temperature extremes in China were detected. Four indices, including the percentage of days above the 90th percentile and the percentage of days below the 10th percentile of daily minimum (Tn90p and Tn10p, respectively) and maximum (Tx90p and Tx10p, respectively) temperatures were investigated from 1958 to 2012. We found that temperature response to the anthropogenic-plus-natural (ALL) forcing could be robustly detected in the frequency changes of daytime (Tx10p and Tx90p) and nighttime (Tn10p and Tn90p) extremes. The responses to anthropogenic and natural forcings could be separated from two-signal detection analyses in all indices. The human influence on the frequency changes of temperature extremes is very clear in China even at a sub-national scale, including Eastern and Western China, while the NAT signal alone cannot explain these changes."

ATTRIBUTION OF HUMAN INFLUENCE ON EXTREME TEMPERATURE CHANGES IN CHINA

Hong Yin

June 10th AM2-P1 11:30-11:45

An attribution analysis of extreme temperature change in China is conducted using homogenized daily observation and multi-model climate simulation datasets from Coupled Model Intercomparison Project Phase 5 (CMIP5) during 1958-2012. We compare the observed and multi-model simulated spatial temporal changes in annual warmest day and night (TXx and TNx) and coldest day and night (TXn and TNn) based on an optimal fingerprinting method. We find that the anthropogenic (ANT) influence can be robustly detected in annual extreme temperature changes in China. The ANT signal is clearly separable from the response to natural-only (NAT) forcing in the two-signal analysis. The NAT signal is also can be detected for TXx and TNx indices.

ROLE OF ANTHROPOGENIC FORCING IN THE EXTREME HIGH TEMPERATURE EVENTS IN CHINA

Ying Sun

June 10th AM2-P1 11:45-12:00

The attribution of two extreme high temperature events in china were respectively conducted based on single- and two-step attribution methods. The spring of 2014 was the third warmest springin Northern China since reliable observations were established in the late 1950s.We used a two-step attribution method to investigate the relative contribution from natural and human caused forcings to this event and found that the anthropogenic forcing may have contributed to an 11-fold increased in the chance of the 2014 spring extreme high temperature event in Northern China.The 2015 summer was very hot in Western China with new records for the daily maximum temperature in many stations in the region. The regional average of annual maxima of daily maximum (TXx) and daily minimum temperatures (TNx) reached their historical highs. It is interesting to find that anthropogenic influence can be directly detected in the extreme indices themselves at such a small regional scale. So the human influence can be estimated directly on the output of the optimal detection results. The results show that anthropogenic forcing may increase the occurrence of such events by 15-fold for TXx and 9-fold for TNx.

SUPPRESSED MID-LATITUDE HOT SUMMER WEATHER BY ARCTIC SEA ICE LOSS DURING 1979-2012

Qigang Wu

June 10th AM2-P1 12:00-12:15

Since the 1980s, rapid Arctic warming, sea ice decline, and weakening summer circulation have coincided with an increasing number of extreme heatwaves and other destructive weather events in the Northern Hemisphere (NH) mid-latitudes in summer. Recent papers disagree about whether such high-impact events are related to Arctic warming and/or ice loss. Here we use atmospheric model ensemble simulations to attribute effects of sea ice loss and other factors on observed summer climate trends during 1979-2012. The ongoing greenhouse gas buildup and resulting sea surface temperature (SST) warming outside the Arctic explains nearly all land warming and a significant portion of observed weakening zonal winds in the NH mid-latitudes. However, sea ice loss has induced a negative Arctic Oscillation (AO)-type circulation with significant summer surface and tropospheric cooling trends over large portions of the NH mid-latitudes, which reduce the warming and might reduce the probability of regional severe hot summers.

EXTREME VALUE THEORY AND ITS APPLICATIONS

MODELS FOR COMPLEX EXTREME EVENTS

Anthony Davison

June 8th AM2 11:00-11:30

The last few years have seen very rapid advances in modelling complex extreme events, such as extreme spatial rainfall, windstorms and the like. Much of this advance has been based on the use of max-stable processes for modelling maxima, but more recent work has concerned peaks over thresholds modelling, which is known to be more efficient in simpler settings. It turns out that it is both more efficient and somewhat easier in complex settings also. This talk will survey recent advances in this area, with special reference to modelling extreme rainfall.

ON THE UNCERTAINTY OF GENERALIZED EXTREME VALUE ESTIMATES OF DAILY PRECIPITATION RETURN VALUES

Michael Wehner, Soyoung Jeon and Christopher Paciorek

June 8th AM2 1:30-12:00

Extreme event attribution characterizes how anthropogenic climate change may have influenced the probability and magnitude of selected individual extreme weather and climate events. Attribution statements often involve quantification of the fraction of attributable risk (FAR) or the risk ratio (RR) and associated confidence intervals. Many such analyses use climate model output to characterize extreme event behavior with and without anthropogenic influence. However, such climate models may have biases in their representation of extreme events. To account for discrepancies in the probabilities of extreme events between observational datasets and model datasets, we demonstrate an appropriate rescaling of the model output based on the quantiles of the datasets to estimate an adjusted risk ratio. Our methodology also accounts for various components of uncertainty in estimation of the risk ratio. In particular, we present an approach to construct a one-sided confidence interval on the lower bound of the risk ratio when the estimated bounds on the risk ratio include infinity.

THRESHOLD SELECTION FOR REGIONAL PEAKS-OVER-THRESHOLD DATA

Martin Roth, Geurt Jongbloed and Adri Buishand

June 9th PM2-P1 3:45-4:00

A hurdle in the peaks-over-threshold approach for analyzing extreme values is the selection of the threshold. A method is developed to reduce this obstacle in the presence of multiple, similar data samples. This is for instance the case in many environmental applications. The idea is to combine threshold selection methods into a regional method. Regionalized versions of the threshold stability and the mean excess plot are presented as graphical tools for threshold selection. Moreover, quantitative approaches based on the bootstrap distribution of the spatially averaged Kolmogorov?Smirnov and Anderson?Darling test statistics are introduced. It is demonstrated that the proposed regional method leads to an increased sensitivity for too low thresholds, compared to methods that do not take into account the regional information. The approach can be used for a wide range of univariate threshold selection methods. We test the methods using simulated data and present an application to rainfall data from the Dutch water board Vallei en Veluwe.

MODELING JOINTLY LOW, MODERATE AND HEAVY RAINFALL

Philippe Naveau, R. Huser, P. Ribereau and A. Hannar

June 9th PM2-P1 4:00-4:15

In statistics, extreme events are often defined as as excesses above a given large threshold. This definition allows hydrologists and flood planners to apply Extreme-Value Theory (EVT) to their time series of interest. Even in the stationary univariate context, this approach has at least two main drawbacks. First, working with excesses implies that a lot of observations (those below the chosen threshold) are completely disregarded. The range of precipitation is artificially shopped down into two pieces, namely large intensities and the rest, which necessarily imposes different statistical models for each piece. Second, this strategy raises a non-trivial and very practical difficultly: how to choose the optimal threshold which correctly discriminates between low and heavy rainfall intensities.To address these issues, we propose a statistical model in which EVT results apply not only to heavy, but also to low precipitation amounts. Our model is in compliance with EVT on both ends of the spectrum and allows a smooth transition between the two tails, while keeping a low number of parameters. In terms of inference, we have implemented and tested two classical methods of estimation ikelihood maximisation and probability weighed moments. Last but not least, there is no need to choose a threshold to define low and high excesses. The performance and flexibility of this approach are illustrated on simulated and hourly precipitation.

ON THE STATISTICAL DISTRIBUTION OF HEATWAVES

Jana Sillmann

June 9th PM2-P1 4:15-4:30

The statistical theory of extreme values has only rarely been applied to model heatwaves. Choosing a probability distribution to represent the heatwaves intensity at various durations is a topic of interest in climate research. Recent studies have shown that the annual frequency and lenght of heatwaves can be modeled by a Poisson and a Geometric distribution, respectively. Here a set of probability distributions (log-normal, Gamma, and GEV) are evaluated on their ability to reproduce the statistics of the Heat Wave Magnitude Index daily (HWMId) capturing both the duration and magnitude of heatwaves into a single number. Our analyses are based on historical and future climate simulations from a 50-member ensemble of the CanESM2 model developed at the Canadian Centre for Climate Modelling and Analysis (CCCma). Using a single model large ensemble enables us to assess uncertainties with regard to natural climate variability and parameter estimation.

THE IMPACT OF CLIMATE CHANGE ON THE DISTRIBUTION OF PRECIPITATION EXTREMES IN WESTERN CANADA

Andre Richard Erler

June 9th PM2-P1 4:30-4:45

An analysis of precipitation extremes in western Canada is presented, based upon station observations and high-resolution climate projections.The climate projections employed here are comprised of a small initial condition ensemble of CESM projections that have been downscaled to 10 km resolution using WRF in two configurations.Using model data and observations, it is first demonstrated that the spatial and temporal variability of extremes follows that of the mean climate. Furthermore, if seasons are analyzed seperately, this is true for the climate change response as well.In order to characterize the distribution of seasonal extremes reliably, it is necessary to pool data from different stations. However, western Canada is a highly heterogeneous region and characterized by complex topography. To overcome this challenge, a new pooling methodology is introduced, which is based on clustering stations with a similar precipitation climatology.Using Extreme Value Theory and this new pooling technique, it is shown that the regional model (WRF) can match the observed distribution after simple linear bias-correction. The global model (CESM), on the other hand can only match the distribution in summer.It is further demonstrated that Global Warming induced changes in the distribution of winter extremes can be explained solely by a linear scaling of intensity, while changes in summer precipitation extremes involve a change in the shape of the distribution. The latter is a change towards heavier tails and appears to be associated with an increase in the fraction of convective precipitation.

EXTREME VALUE ANALYSIS OF OCEAN WAVES IN A CHANGING CLIMATE

Erik Vanem

June 9th PM2-P1 5:00-5:15

The extreme wave climate is of great interest in a number of ocean engineering applications, including the design and operation of ships and offshore structures. Typically, the return values of certain met-ocean parameters such as significant wave height are of particular importance. There exist many methods for estimating such return values, including the initial distribution approach, the block maxima approach and the peaks-over threshold approach. In a climate change perspective, projections of such return values to a future climate are of great importance for risk management and adaptation purposes. In this presentation, various non-stationary GEV-models for significant wave height are explored that account for trends and shifts in the extreme wave climate due

to climate change. The models are used to investigate whether there are trends in the data within each period. Moreover, it will be investigated whether there are significant inter-period shifts or trends in the extreme wave climate from the historical period to the future periods. The results suggest that intra-period trends are not statistically significant and that it might be reasonable to ignore these in extreme value analyses. However, statistical significant inter-period changes are detected. Hence, the accumulated effect of a climatic trend may not be negligible over longer time periods. Interestingly enough, such statistically significant shifts are not detected if stationary extreme value models are fitted to each period separately. Therefore, the non-stationary extreme value models with inter-period shifts in the parameters are proposed as an alternative for extreme value modelling in a climate change perspective.

CHANGING TORNADO OUTBREAK VARIABILITY AND EXTREMES

Michael K. Tippett, Joel E. Cohen and Chiara Lepore

June 9th PM2-P1 5:15-5:30

Tornadoes kill people and damage property each year in the US and around the world. The largest impacts come from ""out-breaks"" consisting of multiple tornadoes close in time. Here we find an upward trend in the annual mean number of tornadoes per US tornado outbreak for the period 1954-2014. Moreover, the variance of this quantity is increasing more than four times as fast as the mean. This finding indicates that the distribution of the number of tornadoes is shifting to the right (increasing mean) and that higher percentiles of the distribution are shifting faster than the mean (increasing variance). This picture of increasing outbreak severity is supported by quantile regression and means that the frequency of the most extreme tornado outbreaks is increasing. Additionally, we find that the mean and variance of the number of tornadoes per outbreak vary according to Taylor?s power law of fluctuation scaling (TL), and we discuss the implications this behavior on the suitability of parametric models. We compare these findings with ones based on time-varying extreme value distributions for annual maxima. Tornado-related atmospheric quantities show similar power-law scaling and trends which we compare with some known climate signals.

SPATIAL HIGH-DIMENSIONAL PEAKS-OVER-THRESHOLD MODELLING FOR EXTREME RAINFALL

Raphael de Fondeville and Anthony Davison

June 10th PM1-P1 1:30-1:45

Classical spatial models for extremes rely on block maxima, but this approach is limited by computational considerations to a few dozen variables (Wadsworth and Tawn, 2013; Huser and Davison, 2014). In order to get a better understanding of extremal dependence and reduce model uncertainties, exploitation of gridded datasets is necessary. Generalized Pareto processes (Dombry and Ribatet, 2015)based on a peaks-over-threshold approach focus on single events, generalize the notion of exceedance to more complex extreme events, and have simpler mathematical expressions. For spatial modelling, we focus on the Brown--Resnick model, which relies on classical Gaussian models widely used in applications, and investigate how to perform high-dimensional peaks-over-threshold inference. We apply our methods to fit a model for extreme rainfall over Florida on a grid with 3600 locations for two types of exceedances: locally intense and areal cumulated rainfall. We can then use the model to generate new extreme events with unobserved intensity and spatial pattern. This is joint work with Professor Anthony Davison.Dombry, C. and Ribatet, M. (2015). Functional Regular Variations, Pareto Processes and Peaks Over Thresholds. Statistics and Its Interface, 8(1):9?17.

Huser, R. and Davison, A. C. (2014). Space-time Modelling of Extreme Events. Journal of the Royal Statistical Society: Series B, 76(2):439?461.

Wadsworth, J. L. and Tawn, J. A. (2013). Efficient Inference for Spatial Extreme Value Processes Associated to Log-Gaussian Random Functions.Biometrika, 101(1):1?15."

A COPULA BASED MULTIVARIATE SPATIAL MODEL WITH APPLICATIONS TO WEEKLY AIR POLLUTANT EXTREMES IN PEARL RIVER DELTA

Ka Shing Chan

June 10th PM1-P1 1:45-2:00

Department of Information Systems, Business Statistics and Operations Management" "Air pollution problem is a high priority concern in many cities. Poor air quality increases the risk of life-threatening conditions and burdens the public health care systems. A general approach to model extreme spatial events is through the generalized extreme value distributions with spatially varying parameters. In the literature, this approach is mostly used to capture spatial dependence for only one type of event. This limits the applications to air pollutant data as different pollutants may chemically interact with each others. In this paper, we extend the spatial GEV models and the Bayesian hierarchical models to a multivariate setting based on copulas so that our model is capable to handle both the spatial dependence and the dependence among multiple pollutants. We apply our proposed model to analyze weekly maxima of nitrogen dioxide, ozone, respirable suspended particles (PM10) and fine suspended particles (PM2.5) collected in Pearl River Delta in southern China."

AN APPLICATION OF MAX-STABLE PROCESSES TO MODELLING EXTREME DAILY RAINFALL IN SOUTH EAST QUEENSLAND, AUSTRALIA

Kate Saunders

June 10th PM1-P1 2:00-2:15

In Australia, we know the El Ni¤o Southern Oscillation (ENSO) to be a large scale climate driver that affects mean and total rainfall. While we know that ENSO also affects Australian rainfall extremes, we have not yet quantified the size of this effect. In this research, we fit a max-stable process to the daily annual maxima rainfall observed at gauges in South East Queensland, Australia. The annual maxima were taken over the non-calendar year July to June to avoid splitting the Australian wet season in two. To include the effect of ENSO in our model, the Southern Oscillation Index (SOI) was included as a temporal covariate. The preferred model included SOI as a temporal covariate in both location and scale parameters. The result demonstrates that the marginal distributions are both shifted and scaled conditional on the SOI, and therefore the exceedance level associated with a given tail probability is also conditional on the SOI.

CALIBRATING MAX-STABLE MODELS OF RAINFALL EXTREMES AT MULTIPLE TIMESCALES

Seth Westra, Phuong Dong Le and Michael Leonard

June 10th PM1-P1 2:15-2:30

Understanding the probabilistic behaviour of extreme rainfall events is critical to estimate the risk of flooding. The majority of engineering design is based on estimates of the probability of extreme rainfall known as the Intensity-Duration-Frequency relationship (IDF). IDF curves are estimated at each rain gauge and are subsequently interpolated for application to ungauged locations. The pointwise nature of IDF estimates leads to difficulties, especially at sub-daily timescales, due to the sparseness of sub-daily extreme rainfall data. As a result there is greater uncertainty when estimating sub-daily extreme rainfall. By using a model that incorporates dependence between spatial extremes as well as across multiple timescales, there is considerable potential to improve estimates of extreme rainfall.The aim of this research is to develop a max-stable model of extreme rainfall that has both spatial dependence as well as dependence across timescales. This provides a general framework for modelling multivariate extremes with spatial dependence for just a single duration extreme rainfall. To achieve dependence across multiple timescales, Koutsoyiannis et al. (1998) proposed a mathematical framework which expresses the parameters as a function of timescale. This parameterization is important because it allows data to be incorporated from daily rainfall stations to improve estimates at sub-daily timescales. The approach therefore addresses the issue of sparseness for sub-daily stations by exploiting the denser network of daily stations.A case study in the Hawkesbury-Nepean catchment near Sydney is used, having 82 daily gauges (>50 years) and 13 sub-daily gauges (>24 years) over a region of 300 km x 300 km. The max-stable model incorporates spatial dependence by fitting parameters simultaneously, as well as considering covariates such as latitude, longitude and elevation. Models were fitted for the case of sub-daily gauges and daily gauges separately, and an additional model was fitted for the timescale-dependent case. A comparison of the model results for the sub-daily case and the timescale-dependent case shows significant improvement to the subdaily estimates due to the density of the daily network.

A RADAR-BASED REGIONAL EXTREME RAINFALL ANALYSIS IN SUPPORT OF A NEW AUTOMATIC ALERT SYSTEM IN SWITZERLAND

Luca Panziera Alexis Berne Marco Gabella and Olivia Romppainen-Martius

June 10th PM1-P1 2:30-2:45

The continuous growth of weather radar archivesoffers an unique opportunity to investigate the statistical properties ofprecipitation in space and time. In this study, quality-checkedquantitative precipitation estimates produced by MeteoSwiss by combining radarand rain-gauge measurements for the period 2005-2015 are employed toinvestigate the influence of different spatial and temporal scales on the statistics of heavy precipitation in Switzerland. Regional monthly maxima of rainfall are fitted to GEVdistribution and return levels for precipitationaccumulations measured over several spatial and temporal scales are derived. The spatial distribution of extremes in Switzerland is thus analyzed,permitting the identification of regional differences in the behavior of heavyrainfall. A comparison with point rain gauge-derived extreme rainfallstatistics is also conducted. This study provides the scientific framework necessaryto identify optimal thresholds of precipitation accumulations for a nowcastingsystem recently developed at MeteoSwiss and specifically designed to issueheavy rainfall alerts over pre-defined geographical regions."

ROBUST INCREASE IN CONCURRENT HOT AND DRY PERIODS AT THE GLOBAL SCALE

Jakob Zscheischler and Sonia Isabelle Seneviratne

June 10th PM1-P1 2:45-3:00

Ongoing climate change is largely affecting the frequency and magnitude of climate extremes in many areas of the world. Most studies investigating extreme events focus on a single variable such as extreme temperature, drought, and heavy precipita-

tion. Often however, it is compound extremes that have the strongest impacts on ecosystems and society. For example, extreme rainfall in combination with high soil moisture causes floods with severe impacts. Similarly, droughts combined with extreme hot temperatures have particularly devastating impacts on ecosystem functioning.The magnitude of an extreme event can be reflected in its return period. Recently, the concept of copulas has been adapted to estimate multivariate return periods of drought extent and duration, peak flow and peak volume, and extreme precipitation events at nearby stations. We use this concept and estimate bivariate return periods of concurrent hot and dry, and concurrent cold and wet periods of 3 months length on gridded temperature and precipitation data from 1901 onwards. We find a strong increase of concurrent dry and hot periods over the recent decades, in particular in the northern hemisphere. At the same time we detect a decrease in concurrent wet and cold periods. Further we demonstrate that bivariate return periods are equally strongly driven by temperature and precipitation at the local scale. If return periods are aggregated in space, however, the influence of temperature becomes more important whereas the influence of precipitation weakens. Averaged globally, temperature is the main driver of bivariate return periods while the influence of precipitation is negligible.

NONLINEAR METHODS FOR CLIMATE EXTREMES

A MODEL BASED ON PAIR-COPULA CONSTRUCTIONS TO ANALYZE AND REPRESENT COMPOUND FLOODING

Douglas Maraun, Emanuele Bevacqua, Mathieu Vrac, Martin Widmann and Colin Manning

June 8th PM1-P2 1:30-1:45

Compound events (CEs) are multivariate extreme events in which the individual contributing events might not be extreme themselves, but their joint - correlated - occurrence causes an extreme impact. We develop a multivariate statistical model to represent and analyze the physical mechanisms driving CEs, and to quantify the risk associated with these events, both in present day and future climate. The model is based on Pair-copula construction theory, which has the advantage of building joint probability distributions modeling the marginal distributions separately from the dependence structure among variables. Moreover, the dependence structure is decomposed into two-dimensional copula, some of which are conditional. Practically, the application of this theory gives high flexibility in building multivariate probability distribution functions. Furthermore, this model allows to analyze the individual contributing variables underlying the CE separately to their dependence structure. Here, we apply the model for studying Compound Floods (joint storm surge and high runoff) in Ravenna, Italy. We show that the apparently weak dependence observed among Sea level and River discharge has to be considered because it determines a relevant increase of the risk associated with flooding, with respect to the independent case. Furthermore, we show how the model can be applied to future climate inserting predictors into the statistical model as additional conditioning variables. Through conditioning the simulation of the statistical model on the predictors obtained for future projections from Climate Models, both the change of the risk and characteristics of compound floods for the future can be analyzed.

NONPARAMETRIC MULTIVARIATE BIAS CORRECTION OF CLIMATE MODEL OUTPUTS: MATCHING MARGINAL DISTRIBUTIONS AND INTER-VARIABLE DEPENDENCE STRUCTURE

Alex Cannon

June 8th PM1-P2 1:45-2:00

Climate models are representations of the coupled atmosphere-ocean-land-cryosphere system. Despite continued improvements in the simulation of relevant physical processes, systematic biases remain, e.g., models may be too hot or cold, wet or dry, etc. Development of statistical bias correction techniques for climate model outputs has thus become an active area of research. By definition, all bias correction algorithms blend information from a climate model with historical observations. In a sense, the choice of algorithm sets the state of 'knobs' that control whether marginal distributions, inter-variable/spatial dependence structure, and temporal sequencing are informed more by the climate model or observations. The majority of algorithms, such as quantile mapping, are univariate in nature. They are used to correct systematic biases in a single climate model variable at a time. Inter-variable dependence structure is typically ignored, which can have an impact on subsequent calculations that depend on multiple climate variables (e.g., fire weather indices, hydrological models, and others). Furthermore, some algorithms may modify future projected trends from the underlying climate model without a physical basis. As a means of illustrating some of these assumptions/characteristics, a new multivariate bias correction (MBC) algorithm - a multidimensional analogue of univariate quantile mapping - is discussed. MBC corrects (rank) correlation dependence structure, with marginal distributions constrained to match observed distributions via quantile mapping. Following previous work, the quantile mapping corrects systematic distributional biases relative to historical observations and, to the extent possible subject to this correction, preserves projected future trends from the climate model.

HOMOGENEITY TESTING REVISITED

Pierre Masselot, Fateh Chebana, Taha B.M.J. Ouarda

June 8th PM1-P2 2:00-2:15

Regional frequency analysis (RFA) is commonly used to estimate quantiles (representing the hydrologic risk) at an ungauged site. Before modeling, regions should be constituted and be homogeneous. Therefore, their homogeneity should be tested, usually through the Hosking-Wallis (HW) test. Though this test is useful and powerful, it presents some drawbacks such as estimating a subjectively chosen parametric distribution and a poorly justified rejection threshold. In the present work, these drawbacks are addressed through the use of a nonparametric framework for the HW test. In addition, the computation of a statistically justified p-value is proposed instead of the original rejection threshold. The proposed nonparametric methods and the original HW test are compared through a simulation study. Results show that permutation methods and the bootstrap are more powerful than the original HW test. The nonparametric tests are also easier to implement and needs less time to perform.

A FAST AND OBJECTIVE MULTIDIMENSIONAL KERNEL DENSITY ESTIMATION METHOD: FASTKDE

Travis Allen O'Brien, Karthik Kashinath, Nicholas R. Cavanaugh, William D. Collins and John P. O'Brien

June 8th PM1-P2 2:15-2:30

Numerous facets of scientific research implicitly or explicitly call for the estimation of probability densities. Histograms and kernel density estimates (KDEs) are two commonly used techniques for estimating such information, with the KDE generally providing a higher fidelity representation of the probability density function (PDF). Both methods require specification of either a bin width or a kernel bandwidth. While techniques exist for choosing the kernel bandwidth optimally and objectively, they are computationally intensive. A solution for objectively and optimally choosing both the kernel shape and width has recently been developed by Bernacchia and Pigolotti (2011, J. Roy. Met. Soc. B). While this solution theoretically applies to multidimensional KDEs, it has not been clear how to practically do so. We introduce a method for extending the Bernacchia-Pigolotti KDE to multidimensions. We combine this multidimensional extension with a recently-developed computational improvement to their method that makes it computationally efficient: a 2D KDE on 105 samples only takes 1 second on a modern workstation. We show that this fast and objective KDE method, which we call the fastKDE method, retains the excellent statistical convergence properties that have been demonstrated for univariate samples. fastKDE exhibits statistical accuracy comparable to state-of-the-science KDE methods publicly available in R and produces KDEs orders of magnitude faster. fastKDE does an excellent job of encoding covariance information for bivariate samples. We show that this property allows for direct calculation of conditional PDFs from the fastKDE, and we demonstrate this on climate data analysis problems."

GENERALIZED ADDITIVE MODELS (GAM) FOR THE SPATIO-TEMPORAL ASSESSMENT OF HYDRO-CLIMATIC VARIABLES

Taha Ouarda

June 8th PM1-P2 2:30-2:45

Generalized Additive Models (GAM) are introduced and adapted to the estimation of hydro-climatic variables at sites where no data is available. GAMs are extensions of the generalized linear models which generalize regression methods by defining a general link between predictors and the response variable and by allowing non-normal residuals. GAMs provide more power in modeling non-linear natural processes through a number of non-parametric smooth functions. GAMs allow for a large flexibility in the shapes of the relationships between variables and the distribution of output variables. Despite their success in other fields, GAMs have not been extensively used in hydro-climatology. After a presentation of the theoretical background of GAMs, their application to the estimation of the direct, diffuse and global solar irradiance at ungauged sites, through remotely sensed data is presented. Six thermal channels of the SEVIRI instrument onboard Meteosat Second Generation as well as the solar zenith angle, time, day number and eccentricity correction are used as explanatory variables. The performance of the GAM model is compared to ensemble of artificial neural network based models, and deterministic models commonly used by the renewable energy community to model irradiance at ungauged sites. Results indicate that GAM outperforms the other models and provides explicit physical explanations of the relations between irradiance variables and explanatory variables. A second application for the estimation of flood quantiles at ungauged sites is also presented. GAM is again compared to commonly used approaches. The results of the second application confirm the advantages of the GAM model.

PROJECTION PURSUIT REGRESSION IN REGIONAL FREQUENCY ANALYSIS

Fateh Chebana, Martin Durocher and Taha Ouarda

June 8th PM1-P2 2:45-3:00

The aim of this talk is to treat nonlinearity and problematic stations in Regional Flood Frequency Analysis (RFFA). To this end, the Projection Pursuit Regression (PPR) is considered. The latter is a family of regression models that applies smooth functions on

intermediate predictors to fit complex patterns. The PPR approach can be seen as a hybrid method between the Generalized Additive Model (GAM) and the Artificial Neural Network (ANN). Hence, PPR combines their advantages where, first it has the structure of a GAM to describe nonlinear relations between hydrological variables and other basin characteristics, and second, PPR can consider interactions between basin characteristics to improve the predictive capabilities in a similar way to ANN, but simpler. The methodology developed in the present study is applied to a case study represented by hydrometric stations from Southern Quebec, Canada. The model performance is compared to eight other methods available in the literature for the same dataset. It is shown that flood quantiles are mostly associated to a dominant intermediate predictor, which provides a parsimonious representation of the nonlinearity in the flood generating processes. When using the same basin characteristics, the results indicate that the simpler structure of PPR does not affect the global performance and that PPR is competitive with the best existing methods in RFFA. Particular attention is also given to the performance resulting from the choice of the basin characteristics and the presence of problematic stations.

NON-LINEAR DELINEATION FOR REGIONAL FREQUENCY ANALYSIS

Dhouha Ouali, Fateh Chebana and Taha Ouarda

June 8th PM1-P2 3:00-3:15

The complexity of the hydrological processes has long been recognized. Despite this, relatively few approaches were designed to account for the nonlinear relationships between hydrological variables and catchment characteristics. Recently, a number of nonlinear tools have received attention in regional frequency analysis (RFA) applications in particular for estimation purposes. In this talk, the focus is to investigate nonlinearity related aspects in the RFA of hydrological variables for the first RFA step, namely the delineation of homogeneous regions. To this end, non-linear canonical correlation analysis (NL-CCA) is considered. In order to illustrate the usefulness of this approach in RFA, a comparative study between NL-CCA and the linear canonical correlation analysis (CCA) is carried out using three different databases from North America. Results show that, when associated to the multiple linear regression model, the NL-CCA is the most appropriate since it provides best performances and a more realistic description of the physical processes involved, even though it is relatively more complex than the linear one."

EVENT COINCIDENCE ANALYSIS: A NOVEL STATISTICAL APPROACH FOR QUANTIFYING SIMULTANEITIES IN (EXTREME) EVENT SEQUENCES

Jonatan Frederik Siegmund

June 9th AM2 11:00-11:30

For many research questions in climatology as well as in various related areas, variables of interest are of binary or quasi-binary nature. Prominent examples include sequences of climate extremes. However, there are only few appropriate statistical tools for the analysis of interdependencies among such kinds of event sequences. Here, we introduce the novel statistical approach of event coincidence analysis (ECA), which allows quantifying simultaneities of events in two sequences. With its build-in options to define additional parameters like time lag and temporal tolerance window, ECA naturally distinguishes between two types of coincidence rates allowing to separately test for 'trigger' and 'precursor' phenomena in observational time series, thereby establishing an intuitive yet not statistically rigorous notion of causality between pairs of event sequences. Beyond the original ECA framework for the analysis of bivariate recordings, we further present conditional event coincidence analysis (CECA), a thorough multivariate extension of ECA which explicitly accounts for the presence or absence of events in additional covariates. We demonstrate the application of ECA and CECA to different case studies linking extremes in the productivity of terrestrial ecosystems with such of various meteorological variables. An easy-to-handle implementation of the basic functionality is provided within a new R package CoinCalc, which additionally includes a hierarchy of different significance tests.

DISCRIMINATING DIFFERENT EL NINO AND LA NINA PHASES FROM EVOLVING CLIMATE NETWORKS

Reik Donner

June 9th AM2 11:30-12:00

El Nino, the positive phase of the El Nino southern oscillation (ENSO), exhibits into two different types (Eastern Pacific (EP) and central Pacific (CP)). These types may be distinguished from each other by different signatures in the Pacific sea surface temperature or corresponding EOF fields, but up to now no generally applicable criterion has been introduced.In this work, we present a method based on evolving climate networks constructed from daily global surface air temperature fields to distinguish EP and CP events by utilizing a simple scalar-valued measure, the so-called climate network transitivity. From a one-year running window analysis we obtain the time-evolution of this measure and show that it displays a strong peak during EP events, whereas its value during CP events is close to the baseline observed during normal periods. Despite its simplicity we give an intuitive interpretation of this behavior based on the high synchronization of Pacific sea-surface temperatures during El Nino events. Our method classifies correctly all commonly defined El Ninos between 1951 and 2010 and displays high consistency with works that applied EOF

analysis as a tool to discriminate between both El Nino flavors.Ultimately, we apply our framework to La Nina events and show that a similar discrimination into two types is possible and reasonable. Thus, our framework provides a powerful formalism to systematically detect and categorize different types of ENSO periods complementing existing tools of statistical climatology.

PROJECTING FUTURE EXTREME STREAMFLOW FOR THE FRASER RIVER: A NONSTATIONARY EXTREME VALUE ANALYSIS APPROACH

Rjesh Shrestha, Alex Cannon, Markus Schnorbus and Francis Zwiers

June 10th AM2-P2 11:00-11:15

Historically high extreme streamflow on the lower Fraser River has the potential to cause significant damage due the high concentration of infrastructure and human activity in the region. Using a combination of process-based and statistical modelling, we project that small (e.g. 2-20 year return period) extreme streamflow events will decrease in intensity, that the intensity of intermediate events (e.g. 40-60 year return period) will remain essentially unchanged, and that events of historic intensity (e.g. 100-200 year return period) will intensify modestly. [Extreme streamflow on the Fraser typically occurs in late spring/ early summer and is dependent on snow storage in the basin. Projected increases in winter precipitation would, all else being equal, increase the snow storage. Warming, however, tends to moderate this impact by reducing the fraction of winter precipitation stored as snow and shortening the period of snow storage]. The analysis in this paper is performed using an extreme value analysis technique that allows for nonstationarity in annual extreme streamflow by relating extreme streamflow with antecedent winter and spring precipitation and temperature. The study uses an extensive suite of existing simulations with the Variable Infiltration Capacity (VIC) hydrologic model driven by Coupled Model Intercomparison Project Phase 3 (CMIP3) climate simulations to train and evaluate the nonlinear and nonstationary Generalized Extreme Value conditional density network (GEVcdn) model of Fraser River streamflow extremes, and subsequently applies the model to project changes in Fraser River extremes under CMIP5 based climate change scenarios.

DEVELOPMENT OF AN HOMOGENEOUS HYDROLOGICAL RECONSTRUCTION OVER FRANCE ON THE 20TH CENTURY TO EVALUATE THE LONG-TERM EVOLUTION OF EVAPOTRANSPIRATION IN CLIMATE MODELS.

Julien Bo, Gildas Dayon and Remy Bonnet

June 10th, AM2-P2 11:15-11:30

Major inter-model uncertainties exist in the simulated long-term evolution of evapotranspiration over Europe, on the entire historical period. The necessary evaluation of climate models in this context requires a long term (i.e. from 1900 to present-days) estimation of evapotranspiration. This is a challenging issue, as the direct measurements of evapotranspiration are extremely short and scarce. In this work, we use hydrological modelling over France with a forced soil-vegetation-atmosphere transfer scheme coupled to a routing scheme to obtain long term reconstructions of evapotranspiration. The major difficulty in this context given the scarcity of meteorological observations in the first half of the 20th century is to construct the meteorological forcing (e.g.: precipitation, temperature etc.) at the high resolution required for hydrological modelling, on a long period and with a good temporal homogeneity. We describe a new statistical approach whereby the results of a statistical downscaling method applied to long-term atmospheric reanalyses (NOAA 20CR and ECMWF ERA20C) are corrected thanks to sparse but long-term and homogenized precipitation and temperature series, to obtain the long-term atmospheric forcing at the 8km resolution over France necessary for hydrological modelling. The reconstructed forcing is evaluated against long-term homogenized precipitation and temperature series, and simulated river flows are compared to few long-term observed series. The added value of the use of homogenized series in the reconstruction method is discussed. Finally, it is shown how our long-term reconstructions are useful to evaluate CMIP5 models and that despite some difficulties, this approach shows promises.

A NEW APPROACH TO TESTING STATISTICAL SIGNIFICANCE OF TRENDS: ASSESSMENT ON SYNTHETIC DATA

Radan Huth and Martin Dubrovsk

June 10th, AM2-P2 11:30-11:45

A common approach to assessing statistical significance of trends in climate elements is to conduct separate tests at all individual sites. Trends that are not significantly different from zero are frequently not considered as relevant, and a large amount of information may thus be lost. We argue that it is reasonable to assume that the prevalence of one sign of trends at individual sites is indicative of the significance of that trend (significance meaning here a high confidence in the trend not being zero), regardless of the (in)significance of individual local trends. Our idea of significance testing builds on this premise: We propose to count sites (stations or gridpoints) with a trend of a given sign (positive or negative) and to quantify whether the number of sites with that trend sign may or may not have occurred due to chance. In this contribution we examine the feasibility of the proposed way of significance testing on synthetic data, which are produced by a multi-site stochastic generator. The synthetic dataset, mimicking an array of stations and/or gridpoints, is constructed assuming a given structure of the data time series and its length. This struc-

ture is characterized by (i) spatial separation (density of the station network), (ii) temporal and spatial autocorrelation structure, and (iii) a spatial pattern of the trend magnitude. The test statistic is defined as the number of sites with the trend of a given sign, and its probabilistic distribution is determined from multiple realizations of the synthetic dataset, in which no trend is imposed at each site (that is, any trend is a result of random fluctuations only). The procedure is then evaluated on the synthetic dataset in which a spatially uniform non-zero trend is imposed. A sensitivity analysis is conducted for various combinations of the trend magnitude, variance, and temporal and spatial autocorrelation.

IDENTIFYING AND ATTRIBUTING COMMON DATA QUALITY PROBLEMS: TEMPERATURE AND PRECIPITATION OBSERVATIONS IN BOLIVIA AND PERU

Stefan Hunziker, S. Gubler, J. Calle, I. Moreno, M. Andrade, F. Velarde, L. Ticona, G. Carrasco, Y. Castell, C. Oria Rojas, S. Br"nnimann, M. Croci-Maspoli, T. Konzelmann and M. Rohrer

June 10th, AM2-P2 11:45-12:00

Assessing climatological trends and extreme events requires high-quality data. However, for many regions of the world, observational data of the desired quality is not available. If the data still contains undetected errors and quality problems after quality control (QC), a consequence may be misleading and erroneous results. A region which is seriously affected by observational data quality problems is the Central Andes. At the same time, climatological information on ongoing climate change and climate risks are of utmost importance in this area due to its vulnerability to extreme events and climatic changes. Beside data quality issues, the lack of metadata and the low station network density complicate quality assessment, and hence, appropriate use of the data. Errors and data problems may occur at any point of the data generation chain, e.g. due to unsuitable station configuration or siting, poor station maintenance, erroneous instrument reading, or inaccurate data digitalization and post processing. Different measurement conditions in the predominantly conventional station networks in Bolivia and Peru compared to the mostly automated networks e.g. in Europe or Northern America may cause different types of errors. A comprehensive amount of Bolivian and Peruvian maximum and minimum temperature and precipitation in-situ measurements was analyzed to detect and describe common data quality problems. Furthermore, station visits and reviews of the original documents were done. The resulting information allows to define appropriate QC-strategies, and it enables to decide whether the use of time series containing data problems is yet accurate for specific purposes.

EXAMINING THE RELATIONSHIP BETWEEN SHORT-DURATION EXTREME PRECIPITATION AND SURFACE TEMPERATURE IN KOREA

In Hong Park and Seung-Ki Min

June 10th AM2-P2 12:00-12:15

Extreme precipitation events exert devastating impacts on human society, and it is imperative to advance our understanding of their changes under global warming. Recent studies have reported that extreme sub-daily precipitation intensities generally increase with temperature at a rate of higher than capable water vapor constraint according to the Clausius?Clapeyron (C-C relationship) in many land areas. In this study we analyze sub-daily precipitation-temperature relationship in Korea using station observations during 1980-2014. Results show that shorter time-scale and more extreme precipitations exhibit higher sensitivity to temperature increase with hourly extreme precipitations displaying a stronger than the C-C rate (so-called super C-C), consistent with previous findings. It is notable that super C-C rate in Korea starts from 20°C, at higher temperature than in other regions. We demonstrate that this characteristic occurs due to a relatively low fraction of convective type precipitation in Korea, compared to other mid-latitude regions. Analysis of individual precipitation type reveals that intensity of extreme stratiform precipitation follows the C-C rate while convective precipitation intensity follows double C-C rate above 12°C, well consistent with the case of other regions. Importantly, proportion of convective rainfall is found to increase dramatically from 20°C, resulting in the overall super C-C relation. This indicates that convective rainfall plays a critical role in extreme precipitation scaling in Korea.

STATISTICAL DOWNSCALING METHODS FOR SEASONAL TO CENTENNIAL PREDICTIONS AND PROJECTIONS

A NOVEL BIAS CORRECTION METHODOLOGY FOR CLIMATE IMPACT SIMULATIONS

Sebastian Sippel

June 6th PM1-P2 1:30-1:45

Understanding, quantifying and attributing the impacts of extreme weather and climate events in the terrestrial biosphere is crucial for societal adaptation in a changing climate. However, climate model simulations generated for this purpose typically exhibit biases in their output that hinder any straightforward assessment of impacts. To overcome this issue, various bias correction strate-

gies are routinely used to alleviate climate model deficiencies, most of which have been criticized for physical inconsistency and the nonpreservation of the multivariate correlation structure. In this study, we introduce a novel, resampling-based bias correction scheme that fully preserves the physical consistency and multivariate correlation structure of the model output. This procedure strongly improves the representation of climatic extremes and variability in a large regional climate model ensemble, which is illustrated for summer extremes in temperature and rainfall over Central Europe. Moreover, we simulate biosphere–atmosphere fluxes of carbon and water using a terrestrial ecosystem model driven by the bias-corrected climate forcing. The resampling-based bias correction yields strongly improved statistical distributions of carbon and water fluxes, including the extremes. Our results thus highlight the importance of carefully considering statistical moments beyond the mean for climate impact simulations. In conclusion, the present study introduces an approach to alleviate climate model biases in a physically consistent way and demonstrates that this yields strongly improved simulations of climate extremes and associated impacts in the terrestrial biosphere. A wider uptake of our methodology by the climate and impact modelling community therefore seems desirable for accurately quantifying changes in past, current and future extremes.

EXAMINING THE SENSITIVITIES OF AIR QUALITY TO EXTREME AIR POLLUTION METEOROLOGY BY COMBINING BIAS CORRECTING HEATING AND COOLING DEGREE DAYS

Caroline Holmes

June 6th PM1-P2 1:45-2:00

Socioeconomic impacts of climate variability and change can be quantified by temperature indices. Heating and cooling degree days (HDD and CDD), defined as the sum of deviations below (HDD) or above (CDD) a threshold, are measures of the temperature-driven component of energy demand for heating and cooling in buildings. In a warming climate, HDD is expected to decrease and CDD to increase, and accurate projections of both are important. However, other authors have demonstrated that for temperature indices relevant to crop yield, inappropriate bias correction strategies can yield very unrealistic results. We obtain daily temperatures from HadRM3-PPE, the eleven-member perturbed parameter ensemble of the regional climate model HadRM3 generated for UK Climate Projections 2009 (UKCP09). In these simulations, considerable regionally and seasonally varying temperature biases exist over the UK, for example cold winter bias over Scotland. Assuming that temperature distributions are Gaussian (after removing the seasonal cycle), expected degree days can be calculated as an analytical function of the mean and variance. We investigate the behaviour of this function given values derived from observations and from HadRM3–PPE in past and future periods. Using this analytical approach, we show that when the degree day threshold is in the relevant tail of the temperature distribution (degree days are rare), applying bias correction methods to the index rather than the underlying distribution introduces large errors. These results are broadly applicable in demonstrating the cases in which bias correction of underlying data is particularly important.

EXAMINING THE SENSITIVITIES OF AIR QUALITY TO EXTREME AIR POLLUTION METEOROLOGY BY COMBINING STATISTICAL ANALYSIS WITH ATMOSPHERIC MODELLING

Shiliang Wu and Pei Hou

June 6th PM2-P1 2:00-2:15

Besides affecting the mean values of various meteorological variables, a critical implication of climate change is to alter the frequency and intensity of a suite of extreme meteorological events. Some of these extreme events such as heat waves, temperature inversion and atmospheric stagnation have important implications for atmospheric chemistry and air quality. There have been many studies on the potential impacts of climate change on air quality, but they have generally focused on the impacts associated with the changes in the mean values of air pollution meteorological variables such as temperature, humidity, precipitation, etc. The long-term evolution of extreme air pollution meteorology and the potential impacts on air quality have not been investigated. In this study, we show that the occurrences of these extreme air pollution meteorological events have increased considerably in the past six decades on the global scale, especially over the continental regions. Based on observational data, we find strong sensitivities of air quality, including both the average concentrations and high pollution episodes, to these extreme events. Significant seasonal and spatial variations in the sensitivity of air quality to each extreme event have also been identified.

INTER-COMPARISON OF STOCHASTIC WEATHER GENERATORS FOR THE SIMULATION OF BASIN-SCALE EXTREME PRECIPITATION IN THE CATSKILL MOUNTAINS, NEW YORK STATE, U.S.

Nachiketa Acharya, Allan Frei, Jie Chen and Emmet M. Owens

June 6th PM1-P2 2:15-2:30

This study is to examine the performance of a set of stochastic weather generators with different levels of complexity to simulate extreme precipitation characteristics for watersheds located in the Catskill Mountains in southeastern New York State, USA, which contribute about 90% of New York City's drinking water supply. The analysis is performed on basin mean precipitation for each

of six basins. To generate the precipitation occurrence, three Markov chain models with 1st, 2nd and 3rd order are evaluated. To generate precipitation magnitude we evaluate 7 distribution models, including five parametric distributions, one resampling technique based on k-nearest neighbor, and one 2nd order polynomial-based curve fitting method. The five parametric distributions include three single distributions (exponential, gamma and skewed-normal) and two compound distributions (a mixed exponential distribution and a hybrid exponential and generalized Pareto (EXPP) distribution).The performance of all Markov chain models in terms of simulating average and extreme wet days and dry/wet spell lengths are comparable. Precipitation magnitude distribution models are evaluated using two parallel approaches: extreme event indices associated with large precipitation events, and recurrence intervals based on the Generalized Extreme Value (GEV) distribution. The exponential and gamma distributions consistently underestimate extremes while EXPP distribution and curve fitting method overestimate extremes. The skewed-normal, mixed exponential, and k-nearest neighbor based resampling distributions most accurately simulate the observed extremes.

CONVECTIVE AND LARGE-SCALE PRECIPITATION CHARACTERISTICS IN REGIONAL CLIMATE MODEL SIMULATIONS IN CENTRAL EUROPE

Jan Kyselý, Zuzana Rulfová, Martin Hanel, Romana Beranová

June 6th PM1-P2 2:30-2:45

We evaluate biases in characteristics of convective (subgrid) and large-scale precipitation in an ensemble of RCM simulations for recent climate in Central Europe. We find that characteristics of total precipitation are often better simulated than are those of convective and large-scale precipitation analyzed separately. Extremes are underestimated for convective precipitation while they tend to be slightly overestimated for large-scale precipitation, which results in a relatively good simulation of extremes in total precipitation amounts. For convective extremes, the effect of areal averaging (as estimated by area reduction factors) is small in comparison to the identified biases. The biases of convective precipitation depend little on horizonal resolution of the RCM simulations, and increased resolution tends to improve mainly large-scale precipitation characteristics due to better representation of orography. Since the biases influence spatial and temporal patterns of precipitation, they are important with respect to hydrological effects, too. By examining diurnal cycles of hourly precipitation, we further show that the RCMs do not capture some of the basic features typical for observed data, including a relationship to daily temperature. As a consequence of misrepresentation of underlying physical mechanisms, distributions of subdaily precipitation extremes are severely distorted in the RCMs. Climate change scenarios for the late 21st century show increasing proportion of convective precipitation and generally increasing intensity of both convective and large-scale precipitation in Central Europe, but they have to be interpreted with caution.

AIR TEMPERATURE MODELLING : TRENDS, EXTREME VALUES, HEAT AND COLD WAVES

Thu Huong Thi Hoang, Sylvie Parey and Augustin Touron

June 6th PM1-P2 3:00-3:15

Temperatures which represents the bulk of the temperatrue distribution as well as the observed extreme values and heat/cold waves. We first try to remove the deterministic partsof the signal, mean and variance trends, seasonalities in the mean and variance, to make the variable as stationary as possible. The trends are removed using the non parametric Loess method, with a bandwidth chosen in an optimal way. Then a SFAR model (seasonal functional autoregressive model) is used to fit the detrended and deseasonalized variable under extreme constraints based on the extreme theory of the continuous-time diffusion with inaccesible boundaries. The model represents well the normal and extreme values but tends to underestimate extreme waves. Different approaches are used to improve this aspect: modifying the correlation between extreme values, using mixed models. The study is realized in different stations in France using the datasets ECA&D. The final model with these improvements gives quite promising results.

CONSTRUCTING HOURLY TEMPERATURE-WIND SCENARIOS FOR THE HUDSON BAY AREA: CHALLENGES AND METHOD

Patrick Grenier

June 7th PM1-P2 1:30-1:45

A climate scenario is typically constructed by merging information from an observation-based product and a numerical climate model simulation. The former sets some of the statistical properties of the climate scenario over a recent-past reference period, while the latter dictates long-term trends of the same or other statistical properties. Such procedure also often addresses the mismatch in spatial or temporal resolution between available products and needed scenarios. Moreover, users often need several variables, which raises the issue of physical coherence. Here a specific case study is used to illustrate some of the challenges faced by providers of climate services when connecting user needs with scientific data. The objective here is to build plausible scenarios for surface temperature (T_2m) and wind components (u_10m, v_10m) at an hourly resolution and over the Hudson Bay area during 1979-2100. CFSR reanalysis are used as the observation-based reference product (1979-2010). This is a defensible choice, but

as the region is poorly covered with in situ data, there is no guarantee of a perfect match with the climatology really experienced. Moreover, hourly resolution of the product is appealing, but the diurnal structure is found to present non-realistic climatic peaks near 0, 6, 12, and 18 UTC, suggesting assimilation-based artifacts. The challenge of designing a meaningful method for constructing climate scenarios also includes obtaining plausible spatial and inter-variable correlations, and covering the uncertainty in the long-term change.

IMPORTANCE-RANKING OF CLIMATE VARIABLES FOR PREDICTION OF DAMAGING STRAIGHT-LINE WINDS

Ryan Lagerquist, Amy McGovern, Travis Smith, Michael Richman and Valliappa Lakshmanan

June 7th PM1-P2 1:45-2:00

Thunderstorms in the United States cause over 100 deaths and 10 billion USD insured damages per year. Many of these losses are caused by straight-line (non-tornadic) winds. Storm-scale winds are non-linearly related to many meteorological variables and are not adequately predicted by numerical models, which has motivated the use of machine learning (ML) in this domain. We have developed a suite of ML models that predict the occurrence of damaging straight-line winds (> 50 kt), on a storm-by-storm basis, at lead times up to one hour. These models use three types of input: archived radar grids from the Multi-year Reanalysis for Remotely Sensed Storms (MYRORSS), proxy soundings from the Rapid Refresh (RAP) model, and surface wind observations from both Storm Prediction Center (SPC) reports and weather stations. First, storm cells are identified and tracked from the MYRORSS data. Then wind observations are linked (causally attributed) to nearby storm cells. Then four types of features are calculated for each storm cell: properties of radar fields; properties of the storm-cell shape; basic storm information (area, speed, etc.); and sounding indices (CAPE, shear, lapse rates, etc.). ML models (mainly random forests and logistic regression) are trained on these features to predict damaging winds. Then several methods (mainly J-measure ranking and sequential forward selection) are used to rank feature importance for the ML models. Relationships between top-ranked features (e.g., lapse rates, wind shear, precipitable water) and climate ? and their implications for damaging straight-line wind climatology in the future ? will be discussed."

LINEAR AND NONLINEAR STATISTICAL DOWNSCALING OF SURFACE WIND VECTORS

Yiwen Mao and Adam Monahan

June 7th PM1-P2 2:00-2:15

Predictability of surface wind vectors by statistical downscaling (SD) from free-tropospheric predictors and based on linear transfer functions (TF) varies with directions of projection; such anisotropy renders predictability of zonal and meridional components alone insufficient to fully reveal the characteristics of predictability of surface wind vectors by SD methods. This study considers whether predictive anisotropy is an artifact of linear regression models used as the TF. We compare predictive characteristics of surface wind vectors by SD based on linear TF and nonlinear TF (i.e. neural network, support vector machine and tree regression) using a large dataset of surface meteorological stations across the globe. Our results show that the predictability of surface wind vectors resulting from nonlinear SD is not necessarily better than the corresponding linear predictability. These results indicate that predictive anisotropy is not an artifact of linear SD."

CAPTURING INTER ANNUAL VARIABILITY IN DOWNSCALED PRECIPITATION USING STOCHASTIC SEASONALITY

Trevor Carey-Smith and Peter Thomson

June 7th PM1-P2 2:15-2:30

A hidden seasonal switching model for daily rainfall over a region is described where season onset times are stochastic and can vary from year to year. The model allows seasons to occur earlier or later than expected and have varying lengths. This stochastic seasonal variation accommodates considerably more of the observed intra-annual rainfall variability than can be represented using seasonal models with standard fixed seasons.Methods used to estimate season onset probabilities from multi-year and multi-site data are described. Relationships between season onset probabilities and large scale climate drivers such as the ENSO are explored leading to the application of stochastic seasonality to the downscaling of climate model simulations.

EVALUATING CLIMATE DOWNSCALING APPROACHES FOR THE NEXT GENERATION OF SWISS CLIMATE CHANGE SCENARIOS

Sven Kotlarski, Andreas Fischer, Denise Keller, Ole R"ssler, Jonas Bhend and Mark A. Liniger

June 7th PM1-P2 2:30-2:45

A new suite of national Swiss climate scenarios "CH2018" is currentlybeing prepared and expected to be released in 2018. CH2018 exploits the latestCMIP5 and CORDEX climate projections and employs empirical-statisticaldownscaling and bias correction (ESDBC) techniques to produce climate scenariosfor the local scale. The applied ESDBC techniques should overcome certainlimitations of the previous delta-change-based CH2011 scenarios. We herepresent a preparatory evaluation of several ESDBC methods over thetopographically complex terrain of Switzerland following a cross validationprotocol for the historical period. The analyzed

methods comprise quantilemapping (QM) variants and a new implementation of a Richardson-type multi-siteweather generator (WG). We compare their skill in reproducing the local multi-variateand spatio-temporal climate variability. Projected change patterns for the 21stcentury are compared to the raw climate model output and to the CH2011 delta-changeapproach. Additionally, the effect of the choice of downscaling method on dischargeis evaluated by driving a hydrological model with ESDBC outputs for ameso-scale pre-Alpine catchment.The results reveal an overall satisfying performance of ESDBC, thoughspecific aspects such as spatial climate variability on sub-regional scales canbe misrepresented. An important added value with respect to the delta changeapproach is identified in terms of changes in temporal climate variability and,for the case of QM, in changes of extremes. These findings provide importantguidance for impact modellers regarding the proper choice of downscalingproducts. Additionally, the results shed light on the design and implementationof validation protocols of downscaling approaches.

HIGH-RESOLUTION MAPPING OF CLIMATE INDICES AND THEIR TRENDS ACROSS ALBERTA, CANADA

Stefan Kienzle

June 7th PM1-P2 2:45-3:00

The changes in 43 climate indices were mapped for the Province of Alberta. The research is aimed at providing systematic knowledge to satisfy the recognized requirement for "Better climate information for a better future", as coined by The Third World Climate Conference. It is a computational challenge to organize and transform the vast amount of climatic data into relevant information for climate change impact studies. With the recent advent of a Canada-wide climate time series, spanning the period 1950-2010 at a spatial resolution of 10km by 10km, a complete, long-term, and spatially consistent climate dataset became available (Tmin, Tmax, P), which served as a keystone in the calculation of a wide range of climate indices. To cover the entire Province of Alberta, 6833 time series were analysed to detect trends for 43 climate indices using the non-parametric Mann–Kendall and Sen Slope tests. A publicly available and interactive webpage was created to show maps of Alberta and enable the query of changes, trends and annual variations, currently available at albertaclimaterecords.com. Results include annual, seasonal and many other temperature and precipitation indices. Results provide a compelling picture of overall warming and changes of weather extremes, such as the warming of winters, or the highly significant declines in frost days or days below -20°C. Contrary, the number of summer days or heat waves has significantly increased, as have the length of the growing season or the number of growing degree days.

PROBABLE MAXIMUM PRECIPITATION RESPONSE TO PROJECTED CLIMATE CHANGE OVER NORTH AMERICA

Mark W. Shephard, Guilong Li, Xuebin Zhang, Jason N.S. Cole, Yanjun Jiao, and John Scinocca

June 7th PM1-P2 3:00-3:15

The Probable Maximum Precipitation (PMP) is used in the design specifications of infrastructure (i.e. dams, reservoirs, flood diversion tunnels) that may last for at least 50 to 100 years. This study examines RCM simulated responses of main meteorological factors that influence the PMP calculation, including precipitable water and precipitation efficiency, under the Representative Concentration Pathways (RCP) 4.5 and 8.5 scenarios. The maximum daily precipitable water is projected to increase everywhere at the rate close to the rate determined with the Clausius-Claperyron equation when scaled with local temperature change. Precipitation efficiency is projected to decrease, especially in the west coastal regions. The resulting PMP responses have a spatial pattern of an increase everywhere else. The projected change in annual maximum one-day precipitation (Rx1day) has similar spatial pattern, except it is projected to decrease over Mexico. The magnitude of projected changes in PMP and Rx1day increases towards more remote future and is larger under the RCP8.5 than RCP4.5 for the same future period. The projected relative changes in PMP and Rx1day are of similar magnitude with a median value around 4%/K local temperature increase. The uncertainty in the magnitude of projected changes is large with much larger uncertainty associated to PMP projections. Given the projected large increase in temperature, increase in PMP and Rx1day can be substantial over most of North America. These can be important guidance for the future design.

CHANGES IN U.S. TEMPERATURE EXTREMES UNDER INCREASED CO2 IN MILLENNIAL-SCALE CLIMATE SIMULATIONS

Michael Stein, David McInerney, Whitney Huang , Shanshan Sun and Elisabeth Moyer

June 8th PM2-P1 3:45-4:00

Changes in extreme weather may produce some of the largest societal impacts from anthropogenic climate change: present-day weather damages are dominated by rare events that happen only every several decades or more. However, it is intrinsically difficult to estimate changes in those rare events from the short observational record. We therefore look for insight to climate models where we can generate long simulations. In this work we use millennial runs from the Community Climate System Model version 3 (CCSM3) in equilibrated pre-industrial and possible future (700and 1400 ppm CO2) conditions to examine both how extremes change and how well these changes can be estimated as a function of run length. We estimate changes to distributions of future

temperature extremes (annual maxima/minima) in the contiguous United States by fitting generalized extreme value (GEV) distributions. Using 1000-year pre-industrial and future time series, we show that the magnitude of warmextremes largely shifts in accordance with mean shifts in summertime temperatures, and their distribution does not otherwise change significantly. In contrast, cold extremes warm more than mean shifts in wintertime temperatures, with changes in spread and skewness at inland locations that lead to substantial changes in tail behavior. We then examine uncertainties that result from using shorter model runs. In principle, GEV modeling allows us to predict infrequent events using timeseries shorter than the recurrence frequency of those events. To investigate how well this approach works in practice, we estimate 20-, 50-, and 100-year extreme events using segments of varying length. We find that even with GEV modeling, time series that are of comparable length or shorter than the return period of interest can lead to very poor estimates. These results suggest caution when attempting to use short observational time series/model runs to infer infrequent extremes.

THE BCCAQ STATISTICAL DOWNSCALING TECHNIQUE AND ITS APPLICATION TO CANADA

Trevor Murdock, Alex Cannon and Stephen Sobie

June 8th PM2-P1 4:00-4:15

Bias-Correction/Constructed Analogues with Quantile mapping (version 2) is a hybrid downscaling algorithm that combines outputs from two other established downscaling methods, BCCA and QMAP. On its own QMAP performs well in terms of long-term temporal sequencing/distribution of extremes, but produces overly smoothed spatial fields on a day-by-day basis. On the other hand, BCCA performs poorly in terms of the distribution of extremes, but produces daily fields with more realistic spatial structure. BCCAQ is a hybrid of the two methods which retains the strengths of each method while also addressing "Huth's paradox" where models that are calibrated based on short-term variability fail to project realistic long-term trends. Finally, Quantile Delta Mapping (Cannon et al. 2015), which distinguishes BCCAQ v2 from BCCAQ is applied. This method preserves (relative) changes from the driving model at each quantile and greatly reduces inflation of large changes that occurs in some cases (particularly extreme precipitation).

DOES QUANTILE MAPPING OF SIMULATED PRECIPITATION CORRECT FOR BIASES IN TRANSITION PROBABILITIES AND SPELL LENGTHS?

Jan Rajczak, Sven Kotlarski and Christoph Schar

June 6th PM2-P1 4:15-4:30

Climate impact studies constitute the basis for the formulation of adaptation strategies. Usually such assessments apply statistically post-processed output of climate model projections to force impact models. Increasingly, time series with daily resolution are used, which require high consistency, for instance with respect to transition probabilities (TPs) between wet and dry days and spell durations. However, both climate models and commonly applied statistical tools have considerable uncertainties and drawbacks.In this presentation, we compare the ability of (1) raw regional climate model (RCM) output, (2) bias-corrected RCM output, and (3) a conventional weather generator (WG) that has been calibrated to match observed TPs to simulate the sequence of dry, wet, and very wet days at a set of long-term weather stations across Switzerland. The study finds systematic biases in TPs and spell-lengths for raw RCM output, but a substantial improvement after bias correction using the deterministic quantile-mapping technique. For the region considered, bias-corrected climate model output agrees well with observations in terms of TPs as well as dry and wet spell durations. For the majority of cases (models and stations) bias-corrected climate model output is similar in skill to a simple Markov-chain stochastic weather generator. We find strong evidence that bias-corrected climate model simulations capture the atmospheric event sequence more realistically than a simple WG.

INDICES OF CANADA'S FUTURE CLIMATE FOR GENERAL AND AGRICULTURAL ADAPTATION APPLICATIONS

G. Li, X. Zhang, A.J. Cannon, T. Murdock, S. Sobie, F.W. Zwiers, K. Anderson and B. Qian

June 8th PM2-P1 4:30-4:45

The development of adaptation measures often requires high-resolution future scenarios of impact-relevant climate indices. This study examines various climate indices based on statistically downscaled daily values of maximum and minimum temperatures and precipitation amounts at ~10 km resolution over Canada using simulations from 12 GCMs. Indices computed from the original GCM data have large discrepancies when compared with the observations, but those computed from the downscaled data reproduce the observed features well. Additionally, future projections based on the downscaled data have a smaller spread than those based on the original GCM data. We consider future projections based on the RCP4.5 and RCP8.5 emission scenarios. Overall, the projected changes in temperature-related indices are consistent with warming and those in precipitation-related indices are consistent with an increase in both precipitation frequency and intensity. Specifically, the number of hot days and hot nights, the length of growing season and frost-free period, the available heat units during the growing season, and the number of

cooling degree-days are all projected to increase. Conversely, the number of cold days and cold nights, and the number of heating degree-days are projected to decrease. A noticeable exception is a projected decrease in the length of the growing season for cool season crops in Ontario and the Prairies due to earlier termination of the growing season by higher temperatures. The number of days with precipitation and the number of days with heavy precipitation are projected to increase, especially towards the more distant future.

QUANTIFYING UNCERTAINTY IN THE PATTERN SCALING OF CLIMATE MODELS

Doug Nychka

June 9th PM1-P2 9:00-9:30

Pattern scaling has proved to be a useful way to extend and interpret Earth system model (i.e. climate) simulations. In the simplest case the response of local temperatures is assumed to be a linear function of the global temperature. This relationship makes it possible to consider many different scenarios of warming by using simpler climate models to infer global temperatures and then translating those results locally based on the scaling pattern deduced from a more complex model. We expect the scaled pattern to be uncertain because the linear relationship for each model grid box is only determined by limited number of model experiments. In addition there will be spatial dependence among adjacent model grid boxes so the uncertainty in the scaling pattern must include this spatial correlation. This work explores a methodology using spatial statistics to quantify how the pattern varies across an ensemble of model runs. The key is to represent the pattern uncertainty as a Gaussian process with a spatially varying covariance function. We found that when applied to the NCAR/DOE CESM1 large ensemble experiment we are able to reproduce the heterogeneous variation of the pattern among ensemble members. Moreover much these local statistical computations are embarrassingly parallel and the analysis can be accelerated by parallel tools within the R statistical environment.

USING NATURAL VARIABILITY UNCERTAINTY IN THE EVALUATION OF BIAS CORRECTION PERFORMANCE

BlaiseGauvin St-Denis

June 9th AM1 9:30-10:00

It is not trivial to demonstrate that a bias correction or downscaling method of climatic variables provides a good representation of future climate conditions, or if one method is preferable over another. One aspect that is often omitted from the analysis is uncertainty contribution from natural variability. Multi-member ensembles of climate models show that 30-year climate statistics, notably in precipitation extremes, can take a wide range of values only due to natural variability. By design, climate models are not meant to reproduce exactly the observed climate but a climate within this natural variability. Therefore the identification of biases in models, before and after correction, should allow for this range of plausible climates. Natural variability estimations from various multi-member ensembles are investigated and compared to related estimates from long observational records. With these estimates, various bias correction methods are then compared to see whether their differences fall within natural variability uncertainty. For statistics where natural variability is large, more consideration should be given to its consequence on climate projections in contrast to refinement of bias correction methods.

STATISTICAL DOWNSCALING OF TEMPERATURE IN A "PERFECT MODEL" FRAMEWORK

John Lanzante

June 9th AM2 10:00-10:30

Evaluation of the performance of empirical statistical downscaling (ESD) techniques for use in climate change applications represents a challenging exercise. One of the largest uncertainties pertains to the implicit "statistical stationarity" assumption. To what extent do relationships derived during an historical period apply to a future period that has experienced considerable climate change? One way to address this problem is through the use of a "Perfect Model" experimental design. We repurpose output from a General Circulation Model (GCM) to serve as data for both "observations" and "model", the latter after suitable transformation. In this way we obtain the crucial missing piece of "observations for the future". To further accentuate the effects of climate change, we examine temperature (a sensitive variable) and include high-emissions scenarios far into the future. One focal point is the amount of degradation in ESD performance in historical (1979-2008) cross-validation vs. that during the future (2086-2095). Over the conterminous United States overall ESD performance tends to diminish non-linearly as the simulated climate warms. Also, degradation varies from ESD method-to-method, seasonally, and geographically. Another focal point of evaluation involves the tails of distributions. Based on the Peaks Over Threshold (POT) philosophy we evaluate counts of exceedances over percentile-based thresholds. Employing some existing statistical tests, with some novel modifications, we seek to test two distinct hypotheses:

(1) differences between data treatments (dependent samples) and (2) differences between epochs (independent samples). Our interest is piqued by the fact that some of the most commonly used ESD methods often employ rather simple ad-hoc approaches in the tails.

STOCHASTIC ANALYSIS OF THE HYDROLOGIC CYCLE

ASSESSMENT OF SOURCES OF UNCERTAINTY IN FORCED CHANGES OF MONTHLY MEAN AND DAILY EXTREME RAINFALL

David Karoly, Andrew King and Mitchell Black

June 8th PM2-P2 3:45-4:00

There are large uncertainties in projected changes in rainfall in response to anthropogenic climate change or in response to sea surface temperature variations associated with El Ni¤o. These uncertainties are associated with chaotic atmospheric variability, with chaotic ocean variability, and with uncertainties in the response to the specified forcing. We use approaches based on analysis of variance to assess the relative importance of these different sources of uncertainty in simulated changes in regional rainfall in tropical Australia for both the wet season mean and daily extreme rainfall. We compare the observed rainfall variations with climate model simulations from the CMIP6 coupled model ensemble for all forcings and for natural forcings alone, to estimate the uncertainties from all sources, as well as simulations from individual coupled models with large ensembles, to estimate the uncertainties due to internal atmospheric and oceanic variability. We also use very large ensembles of simulations with atmospheric GCMs with specified observed sea surface temperatures, with different initial conditions, to estimate the uncertainties due to internal atmospheric variability alone, and with perturbed physics parameters in the model to estimate the uncertainties in the model response. We find that although there are very large uncertainties in changes of seasonal mean and daily rainfall extremes due to internal variability alone, the uncertainties in the response to the forcings between different climate models is also an important source of uncertainty. Using a single model, even with very large ensembles of simulations, may underestimate the uncertainties in the response to a forcing.

ENSEMBLE RECONSTRUCTION OF SEVERE LOW FLOW EVENTS IN FRANCE SINCE 1871 THROUGH STATISTICAL DOWNSCALING AND HYDROLOGICAL MODELLING

Jean-Philippe Vidal, Laurie Caillouet, Eric Sauquet, Alexandre Devers and Benjamin Graff

June 8th PM2-P2 4:00-4:15

This work presents a study of severe low flow events that occurred from 1871 onwards for a large number of near-natural catchments in France. It aims at assessing and comparing their characteristics to improve our knowledge on historical events and to provide a selection of benchmark events for climate change adaptation purposes.The historical depth of streamflow observations is generally limited to the last 50 years and therefore offers too small a sample of severe low flow events to properly explore the long-term evolution of their characteristics and associated impacts. In order to overcome this limit, this work takes advantage of a 140-year ensemble hydrometeorological dataset over France based on: (1) a probabilistic precipitation and temperature downscaling of the Twentieth Century Reanalysis over France (Caillouet et al., 2015), and (2) a continuous hydrological modelling that uses the high-resolution meteorological reconstructions as forcings over the whole period. This dataset provides an ensemble of 25 equally plausible daily streamflow time series for a reference network of stations in France over the whole 1871-2012 period. Severe low flow events are identified based on a combination of a fixed threshold and a daily variable threshold. Each event is characterized by its deficit, duration and timing by applying the Sequent Peak Algorithm. The procedure is applied to the 25 simulated time series as well as to the observed time series in order to compare observed and simulated events over the recent period, and to characterize in a probabilistic way unrecorded historical events. The ensemble aspect of the reconstruction leads to address specific issues, for properly defining events across ensemble simulations, as well as for adequately comparing the simulated characteristics to the observed ones.This study brings forward the outstanding 1921 and 1940s events but also older and less known ones that occurred during the last decade of the 19th century. For the first time, severe low flow events are qualified in a homogeneous way over 140 years on a large set of near-natural French catchments, allowing for detailed analyses of the effect of climate variability and anthropogenic climate change on low flow hydrology.Caillouet, L., Vidal, J.-P., Sauquet, E., and Graff, B. (2015) Probabilistic precipitation and temperature downscaling of the Twentieth Century Reanalysis over France, Clim. Past Discuss., 11, 4425-4482, doi:10.5194/cpd-11-4425-2015

CHANGES IN FLOOD REGIMES AS INFERRED FROM LONG RECORD GAUGING STATIONS

Donald Burn and Paul Whitfield

June 8th PM2-P2 4:15-4:30

Data from long term hydrometric reference streamflow gauging stations are used to examine changes that have occurred, or are continuing to occur, in flood regimes from natural watersheds in Canada and adjacent areas in the United States. Stations with a data record that spans most of the past century are examined herein; 20 reference sites are from the Canadian Reference Hydrometric Basin Network (RHBN) and nine sites are from the U.S. Geological Survey (USGS) Hydro-Climatic Data Network (HCDN).

There reference networks were specifically developed to assist in the identification of the impacts of climate change; stations included are considered to have good quality data and were screened to avoid the influences of regulation, diversions, or land use change. Peaks over threshold (POT) data are extracted from daily flow data for each watershed and changes to the magnitude, timing, and duration of threshold exceedences are investigated. Seasonal statistics are used to explore changes in the nature of the flood regime based on changes in the timing of flood threshold exceedences. We explore changes in the nature of the flood regime based on changes in the timing of grouped flood threshold exceedenaces. A variety of measures are used to infer flood regime shifts including from a nival regime to a mixed regime and a mixed regime to a more pluvial-dominated regime. The flood regime at many of the subject watersheds demonstrates a decreased prevalence of nival flood responses."

CHANGES TO STREAMFLOW PEAKS AT THE FALL-WINTER TRANSITION IN THE ROCKY MOUNTAINS OF NORTH AMERICA

Paul Whitfield

June 8th PM2-P2 4:30-4:45

The Rocky Mountains have experienced substantial warming at all elevations and latitudes in North America, though changes to annual and seasonal precipitation volumes are not consistent. Increased fall and early winter temperatures are expected to cause a transition in precipitation from snowfall to rainfall, particularly at the elevations, latitudes and times of year where historical air temperatures have been near 0 C and might also result in an increase in the frequency of rain-on-snow events. A longer snow-free period also increases the potential for convection and intense storms in the former fall-winter transition period. In warmer conditions, precipitation events can result in runoff generation and increase soil moisture, depending on antecedent conditions, in contrast to colder conditions where early winter precipitation occurs as snowfall and contributes to the accumulation of the seasonal snowpack. In many published studies, changes in the autumnal climate and hydrology are visually obvious, but not statistically significant because of the substantial variability in timing and magnitude of runoff events and the use of statistical techniques that cannot resolve these changes. In this study an alternative approach is presented; runoff events are separated from the streamflow records using a baseflow filter and are compared to rainfall and snowfall changes during this period. The results show substantial changes in fall and early winter hydrometeorology and streamflow across the Rocky Mountains. Significant trends in the magnitude, frequency, and duration of these runoff events were assessed with respect to generating processes; changes were more frequent than expected by chance alone. The spatial distribution of these events reflects regional and elevational changes in hydrological processes and shows important increases in the frequency and magnitude of rainfall and rain-on-snow events which leads to an increase in the number of autumnal floods.

A NEW FRAMEWORK FOR ANALYZING THE SCALING PROPERTIES OF INTERMITTENT PRECIPITATION

Marc Schleiss

June 8th PM2-P2 4:45-5:00

We investigate the temporal scaling properties of intermittent precipitation using the recently introduced concept of inter-amount times (IATs) and 10-60 years of rain gauge data from the US Climate Reference Network (USCRN) and Historical Climatology Network (USHCN). The results show that IATs can be modeled by a multifractal process with spatially varying scaling parameters depending on the local rainfall climatology. We show that at large scales (e.g., more than 30-50~mm) IATs are approximately stationary, uncorrelated and Log-Normally distributed. Based on these results, we propose a new method for computing intensity-duration-frequency curves, identifying regions with potentially hazardous rainfall patterns and assessing the regional changes in precipitation intermittency over the last 60 years."

A MODEL-BASED APPROACH TO THE COMPUTATION OF AREA PROBABILITIES FOR PRECIPITATION EXCEEDING A CERTAIN THRESHOLD

Bjoern Kriesche, Reinhold Hess and Volker Schmidt

June 8th PM2-P2 5:00-5:15

In meteorology it is important to compute the probabilities of certain precipitation events occurring. There are a number of operational numerical and statistical methods for estimating the probability that precipitation occurs at a fixed location (a point probability). However, there are no widely applicable techniques for estimating the probability of precipitation occurring anywhere in a geographical region (an area probability). Such probabilities are of great interest for the generation of automated weather warnings, e.g., to assess the risk of a flooding which might happen if a certain amount of precipitation occurs anywhere in a dedicated warning area. Recently, we proposed a model-based approach to the computation of area probabilities for the occurrence of precipitation, which is based on a non-stationary stochastic model for precipitation cells. In this talk we present a generalization of the existing method to the computation of area probabilities for precipitation exceeding a certain threshold. For that purpose, the stochastic model for precipitation cells is extended to model precipitation amounts by assigning a randomly scaled response

function to each cell. We derive formulas for the expectation and variance of random point precipitation amounts in our model, which are used for an algorithmic fitting of model parameters based on sequences of available point probabilities. We describe how area probabilities for precipitation exceeding some threshold can be estimated by repeated simulation of the proposed model. Finally, the results are verified by comparing the generated area probabilities with precipitation measurements obtained from radar data.

EVALUATING THE EFFECT OF HISTORICAL CLIMATE CHANGE ON HIGH AND LOW FLOW CONDITIONS OF GUMARA WATERSHED, UPPER BLUE NILE BASIN, ETHIOPIA

Gashaw Gismu Chakilu

June 8th PM2-P2 5:30-5:45

Climate and land cover change are very important issues in terms of global context and their responses to environmental and socio-economic drivers. The dynamic of these two factors is currently affecting the environment in unbalanced way including watershed hydrology. In this paper the impact of historical climate change on stream flow specifically on extreme flow events were evaluated through application of Soil and Water Assessment Tool (SWAT) model in Gumara watershed, Upper Blue Nile basin Ethiopia. Mann-Kendall trend test was used for climate trend analysis. The period between1973-1982 was taken as baseline and 2004-2013 was used as change study. Both temperature and rainfall showed increasing trend. The efficiency of SWAT model was determined by Nash-Sutcliffe (NS) and Relative Volume error (RVe) and their values were 0.66 and 0.72% for calibration and 0.64 and 1.23% for validation respectively. The high flow has been identified using Annual Maximum (AM) method and the low flow was also identified by using Seven Day Sustained minimum annual flow of the river. The impact of climate change was more significant on high stream flow than low flow of the catchment. Due to climate change, when the high flow was increasing by 17.08%, the low flow was decreasing by 6%. The overall results of the study indicated that Climate change is more responsible for stream flow during wet season than dry season. Keywords: - Climate, High flow, Low Flow, SWAT, Gumara, Blue Nile, Ethiopia.

UNDERSTANDING CLIMATE VARIABILITY AND ITS TELECONNECTIONS UNDER GLOBAL WARMING

CMIP5 SIMULATION AND PROJECTION ON THE ASIAN-PACIFIC OSCILLATION

Botao Zhou

June 6th PM1-P1 1:30-1:45

"The performance of 33 CMIP5 models in simulating the summer Asian-Pacific Oscillation (APO) pattern was evaluated and its change under the RCP4.5 and RCP8.5 scenarios was projected. The results show that most of the individual models have good capacity to simulate the climate mean state of the spatial structure of the summer APO pattern, while have poor skill in modeling its secular trend and interannual variability. The multimodel ensemble mean (MME) generally outperforms the individual models. It not only well reproduces the spatial distribution of the observed APO pattern, but also reasonably captures the observed negative trend and interannual variability of the APO. The MME projects a decrease in the APO intensity toward the end of 21st century under both the RCP4.5 and the RCP8.5 scenarios. Large differences in projected change under the two forcing scenarios start to emerge about in the 2040s, with larger decreasing under the RCP8.5 than that under the RCP4.5. Over the course of the second half of the 21st century, the APO pattern will shift eastward slightly in addition to the weakening in intensity as compared to the 1950-2005 mean climate. For the individual models, the majority of models agree on the sign of projected decreasing change in the APO intensity and also exhibit a stronger change under the RCP8.5 scenario than under the RCP4.5 scenario.

UNDERSTANDING TELECONNECTIVE EFFECTS FROM EAST ASIA ON THE DROUGHT OVER THE CONTINENTAL UNITED STATES DURING SUMMER

Sang-Wook Yeh, Rokjin Park and Minjoong Kim

June 6th PM1-P1 2:00-2:15

Extremes of the hydrological cycle, such as flooding and droughts, have devastating effects on human society and the environment and their future change is one of primary concerns for eco-systems. Here we present an evidence that the sulfate aerosol forcing in China not only alters the regional hydrological cycle but also affects the precipitation variability over the continental United States via atmospheric teleconnections. We use a global climate model with a transient sulfate forcing to reproduce the observed precipitation changes in southeastern China for 1985-2010. We find that the increase in regional sulfate forcing causes an

increasing trend of summer precipitation in southeastern China and is also responsible for less precipitation in the central United States via the Rossby wave-train signal crossing over the Pacific. This finding is beyond our conventional view on aerosol forcing, which has been considered importantly as regional forcing but resulting changes are global."

DISRUPTION OF THE EUROPEAN CLIMATE SEASONAL CLOCK IN A WARMING WORLD

Julien Cattiaux

June 6th PM1-P1 2:15-2:30

Temperatures over Europe are largely driven by the strength and inland penetration of the oceanic westerly flow. The wind influence depends on season: blocked westerlies, linked to high-pressure anomalies over Scandinavia, induce cold episodes in winter but warm conditions in summer. Here we propose to define the onset of the two seasons as the calendar day where the daily circulation/temperature relationship switches sign. We have assessed this meteorologically-based metric using several observational datasets and we provide evidence for an earlier onset of the summer date by ~10 days between the 1960s and 2000s. Results from a climate model show that internal variability alone cannot explain this calendar advance. Rather, the earlier onset can be partly attributed to anthropogenic forcings. The modification of the zonal advection due to winter snow earlier disappearance over Eastern Europe, which reduces the degree to which climate has continental properties, is mainly responsible for the present-day and near-future advance of the summer date in Western Europe. Our findings are in line with phenological-based trends (earlier spring events) reported for many living species over Europe, for which we provide an alternative interpretation to the traditionally evoked local warming effect. Based on the Representative Concentration Pathway 8.5 scenario, which assumes that greenhouse gas emissions continue to rise throughout the twenty-first century, a summer advance of ~20 days compared to preindustrial climate is expected by 2100, while no clear signal arises for winter onset."

INFLUENCE OF CLIMATE VARIABILITY ON EXTREME OCEAN SURFACE WAVE HEIGHTS ASSESSED FROM ERA-INTERIM AND ERA-20C REANALYSES

Seung-Ki Min

June 6th PM1-P1 2:30-2:45

Extreme ocean surface wave heights significantly affect coastal structures and offshore activities, and impact many vulnerable populations of low lying islands. Therefore, better understanding of ocean wave height variability plays an important role to potentially reduce risk in such regions. In this study, global impacts of various natural climate variability such as El Niño-Southern Oscillation (ENSO), North Atlantic Oscillation (NAO), and Pacific Decadal Oscillation (PDO) on extreme significant wave height (SWH) are analyzed using ERA-Interim (1980-2014) and ERA-20C (1952-2010) reanalysis data sets for December-January-February (DJF). The non-stationary Generalized Extreme Value (GEV) analysis is used to determine the influence of natural climate variability on DJF maxima of SWH (Hmax), wind speed (Wmax), and mean sea level pressure gradient amplitude (Gmax). The major ENSO influence on Hmax is found over the northeastern North Pacific (NP) with increases during El Niño and decreases during La Niña, and its counter responses are observed in coastal regions of the western NP, which are consistently observed in both Wmax and Gmax responses. The Hmax response to the PDO occurs over similar regions in the NP as associated with ENSO, but with much weaker amplitude. Composite analysis of different ENSO and PDO phase combinations reveals stronger [weaker] influences when both variability modes are of the same [opposite] phase. Furthermore, significant NAO influence on Hmax, Wmax, and Gmax is observed throughout Icelandic and Azores regions in relation to changes in atmospheric circulation patterns. Overall, the response of extreme SWH to natural climate variability modes is consistent with seasonal mean responses.

THE EFFECT OF THE PDO ON ANNUAL PEAK FLOWS IN WESTERN CANADIAN RIVERS

Jeannine-Marie St-Jacques, Sunil Garappu, David Sauchyn and Kyle Hodder

June 6th PM1-P1 2:45-3:00

We analyzed annual peak flow series from 127 naturally-flowing or naturalized streamflow gauges across western Canada to examine the impact of the Pacific Decadal Oscillation (PDO) on annual flood risk, which has been previously unexamined in detail. Using Spearman?s rank correlation ? and permutation tests on quantile-quantile plots, we show that higher magnitude floods are more likely during the negative phase of the PDO than during the positive phase. Flood frequency analysis (FFA) stratified according to PDO phase suggests that higher magnitude floods may also occur more frequently during the negative PDO phase than during the positive phase. Our results hold throughout much of this region, with the upper Fraser River Basin (the pathway of the proposed Northern Gateway petroleum pipeline from near Edmonton, Alberta to coastal Kitimat, British Columbia), the Columbia River Basin and the North Saskatchewan River Basin particularly subject to this effect. We also present spectral analysis results based upon tree-ring data and CMIP3 pre-industrial control runs demonstrating that the PDO has likely had strong regional hydrological impacts for several hundred years. Hence, the impact of the PDO on peak flows in this region is most likely longstanding

and will continue to be important in the near future. Our results add to other researchers? work questioning the wholesale validity of the key assumption in FFA that the annual peak flow series at a site is independently and identically distributed. Hence, knowledge of large-scale climate state should be considered prior to the design and construction of infrastructure."

IMPACT OF TEMPERATURE AND PRECIPITATION EXTREMES ON FLOWERING DATES OF FOUR SHRUB SPECIES OVER GERMANY

Jonatan Siegmund

June 6th PM1-P1 3:00-3:15

Ongoing climate change is known to cause an increase in the frequency and amplitude of local temperature and precipitation extremes in many regions of the earth. While gradual changes in the climatological conditions are known to strongly influence plant flowering dates, the question arises if and how extremes specifically impact the timing of this important phenological phase. In this study, we systematically quantify simultaneities between meteorological extremes and the timing of flowering of four shrub species across Germany by means of event coincidence analysis, a novel statistical tool that allows assessing whether or not two types of events exhibit similar sequences of occurrences. Our systematic investigation supports previous findings of experimental studies by highlighting the impact of early spring temperatures on the flowering of wildlife plants. In addition, we find statistically significant indications for some long-term relations reaching back to the previous year.

MODES OF SST VARIABILITY IN CMIP MODEL SIMULATIONS

Dietmar Dommenget

June 7th AM2 11:00-11:30

The natural sea surface temperature (SST) variability in the global oceans is evaluated in simulations of the Climate Model Intercomparison Project Phase 3 (CMIP3) and CMIP5 models. In this evaluation, we examine how well the spatial structure of the SST variability matches between the observations and simulations on the basis of their leading empirical orthogonal functions-modes. Here we focus on the high-pass filter monthly mean time scales and the longer 5 years running mean time scales. We will compare the models and observations against simple null hypotheses, such as isotropic diffusion (red noise) or a slab ocean model, to illustrate the models skill in simulating realistic patterns of variability. Some models show good skill in simulating the observed spatial structure of the SST variability in the tropical domains and less so in the extra-tropical domains. However, most models show substantial deviations from the observations and from each other in most domains and particularly in the North Atlantic and Southern Ocean on the longer (5 years running mean) time scale. In many cases the simple spatial red noise null hypothesis is closer to the observed structure than most models, despite the fact that the observed SST variability shows significant deviations from this simple spatial red noise null hypothesis. The CMIP models tend to largely overestimate the effective spatial number degrees of freedom and simulate too strongly localized patterns of SST variability at the wrong locations with structures that are different from the observed. However, the CMIP5 ensemble shows some improvement over the CMIP3 ensemble, mostly in the tropical domains. Further, the spatial structure of the SST modes of the CMIP3 and CMIP5 super ensemble is more realistic than any single model, if the relative explained variances of these modes are scaled by the observed eigenvalues.

TELECONNECTIONS, DROUGHTS AND GLOBAL WARMING

Celine Bonfils

June 7th AM2 11:30-12:00

A "super El Ni¤o" with above-normal precipitation over California is providing some drought relief in the region. We argue that ENSO is not always be a source of relief in the future in regions where the mean change in terrestrial aridity/moistening in response to greenhouse warming becomes larger than the expected range of current variability. We use a suite of state-of-the-art climate model simulations to identify the regions where a projected change in aridity exists, and consider whether this change is large enough to overwhelm the effect of local drying/moistening associated with ENSO variability. By the end of the 21st century, warming is expected virtually everywhere, independent of the phase of ENSO. In contrast, expectations regarding the net anomalies in regional precipitation are less evident, because changes in the mean state and variability are governed by a number of different, spatially-complex mechanisms. Here, we provide a comprehensive assessment of the relative contributions to future drought from changes in moisture supply and demand. We also investigate the competing effects of mean changes and ENSO variability in terms of ameliorating or exacerbating drought. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. This work is released as LLNL-ABS-675905.

ASYMMETRICAL EVOLUTION BETWEEN EL NINO AND LA NINA MANIFESTED BY SEASON-RELIANT EOF METHOD

Soon-Il An and Ji-Won Kim

June 7th AM2 12:00-12:30

The El Nino is frequently followed by La Nina but the opposite case rarely happens. Here, we manifested such asymmetric evolution feature between El Nino and La Nina by applying the season-reliant empirical orthogonal function (S-EOF) analysis to tropical Pacific sea surface anomalies. S-EOF effectively detects major modes of climate variability regulated by annual cycle. The first S-EOF mode of tropical Pacific sea surface anomalies represents El Nino/La Nino evolution from an initial state to mature state, and the second S-EOF mode represents the turnabout feature of El Nino/La Nina. The asymmetricities in El Nino-La Nina evolution are measured by linear regression coefficients between the principal components of two leading modes for El Nino and La Nina, respectively. We found that the asymmetricity of El Nino is significantly larger than that of La Nina. However, the difference in the asymmetricities between El Nino and La Nina keeps changing in various timescales including decadal and trend. Possible causes on varying asymmetricity are also discussed in this study."

WCRP GRAND CHALLENGE ON CLIMATE EXTREMES

OVERVIEW OF THE WCRP GRAND CHALLENGE ON WEATHER AND CLIMATE EXTREMES

Gabi Hegerl

June 8th AM1 9:00-9:05

This short talk introduces the grand challenge on climate extremes, which has inspired this session. The grand challenge aims to improve the observational support for changing extremes. It also encourages research strands that support understanding the mechanisms involved in extremes (for example, land surface feedbacks and changes in circulation), further the evaluation and simulation of changes in extremes, and the attribution of long term changes in extremes as well as of individual extremes.

DOCUMENT THEME: OBSERVATION OF WEATHER AND CLIMATE EXTREMES: OPPORTUNITIES, CHALLENGES, AND NEXT STEPS

Ali Behrangi and Lisa Alexander

June 8th AM1 9:00-9:15

This talk will review existing capabilities and challenges in the observation of weather and climate extremes, highlighting a few important areas of future research. An important question is: Are existing observations sufficient to underpin the assessment of extremes? Observations provide crucial underpinning but are often not well-constrained and critical gaps exist in the amount, quality, consistency and availability, especially for extremes. Satellite data have enabled global observation of extremes over the last few decades, but the relatively short record of data is a limiting factor. Furthermore, large differences in temporal and spatial scales of in situ and remote sensing observations exist that have to be addressed in order to provide an integrated and comprehensive analysis of extremes. Using a few examples we highlight some areas of research and community efforts for advancing our current observing tools and data requirements for analysis of weather and climate extremes.

UNDERSTANDING EXTREMES

Sonia I. Seneviratne, Olivia Martius, and Robert Vautard

June 8th PM1-P1 9:15-9:25

A range of mechanisms can lead to the occurrence of extreme events such as heat waves, droughts or floods. Recent investigations have shown that the interaction between large-scale drivers and regional-scale (in particular land) feedbacks or forcings can be critical. For instance soil moisture-temperature feedbacks amplify heat waves in many regions, and were shown to play an important role in recent extreme hot events, such as the 2003 European heat wave, the 2010 Russian heatwave, or the 2012/2013 Australian summer. Moisture evaporated from the land was also identified as a major contributor to the precipitation events that led to the Pakistan floods in 2010 and the floods in Germany in 2013. Warm sea surface temperatures, combined with specific atmospheric circulation are known to drive heavy rains such as in Mediterranean regions. Additionally forcing from land cover and land use changes can be important for either amplifying or damping extreme events. Similarly, the role of the tropical SST anomalies, melting Arctic sea ice, changes in storm tracks and weather extremes in Eurasia needs to be clarified. These changes can affect the frequency, intensity and the pathways and persistence of individual weather systems such as cyclones, anticyclones and fronts, large-scale weather regimes and teleconnection patterns. Processes acting to trigger, favour duration or terminate persistent weather regime patterns need to be better understood, as well as their changes with increased greenhouse gases (baroclinic

waves interactions, diabatic processes, tropical-extratropical interactions). For progress to occur, the link between dynamical meteorology and climate needs to be strengthened. Finally, there is an additional need to understand which events lead to specific impacts and which features of given events are most relevant to these impacts.
A better quantification of these processes, thanks to interactions between research communities working both on large-scale atmospheric drivers and regional land-atmosphere feedbacks is essential to reduce uncertainties in projections, improve sub-seasonal to decadal predictability of extremes as well as the attribution of past trends and single events. The role of internal climate variability for the occurrence of extremes also needs to be carefully evaluated, in particular for past recent trends and in order to assess their contribution to projections' uncertainty.
In this presentation, the current planned activities under this theme will be discussed. This entails mechanistic model-based experiments assessing the respective role of different external drivers, initial conditions and feedback processes in the development of climate extremes, as well as the development and assessment of statistical methods and models to detect changes in extreme events, their characteristics and clustering, including multivariate and complex extremes. Connection between large-scale circulation and individual, sometimes small-scale events will be strengthened using 'storylines'.
References:
Alexander, L.V., X. Zhang, G. Hegerl, and S.I. Seneviratne, 2015: Implementation plan for WCRP Grand Challenge on Understanding and Predicting Weather and Climate Extremes. (available from: http://wcrp-climate.org/images/documents/grand_challenges/WCRP_Grand_Challenge_Extremes_Implementation_Plan_v20150203.pdf)
Zhang, X., G. Hegerl, S.I. Seneviratne, R. Stewart, F.W. Zwiers, and L.V. Alexander, 2013: WCRP Grand Challenge: Understanding and Predicting Weather and Climate Extremes. White paper of the WCRP. (available from http://wcrp-climate.org/images/documents/grand_challenges/GC_Extremes_v2.pdf)

THE CHALLENGE OF EVALUATING MODELS AND CONSTRAINING PROJECTIONS OF EXTREMES GIVEN ABUNDANT INTERNAL VARIABILITY – THE SIMULATE THEME

Erich Fischer

June 8th AM1 9:25-9:35

Weather and climate extremes often have major socio-economic or ecological impacts. Thus, it is vital to quantify their present-day return periods and to predict their future occurrence. Numerical climate models from convection-permitting models and large-eddy simulations to earth system models are promising tools to improve our understanding of the underlying physical mechanisms, to quantify the present-day likelihood of extremes informing risk assessments and ultimately to provide projections on future changes in frequency, intensity, duration and spatial extent of extremes. However, to this end their skill in representing different types of extremes first needs to be rigorously evaluated, a task that is notoriously difficult given the limited availability of observations and the high internal variability. Within the SIMULATE theme of the WCRP Grand Challenge on Climate Extremes we propose different pathways to advance the representation of extremes in numerical models. We suggest that besides purely statistical approaches of extreme statistics also process-based evaluation of extremes as well as the dissection of individual events based on observations, reanalysis and models should receive more attention. Furthermore, we see a major potential for model evaluation to feed into observational constraints on multi-decadal projections of extremes. We here review first steps in this direction and discuss possible ways forward.

THE ATTRIBUTION OF EXTREME WEATHER TO EXTERNAL DRIVERS OF CLIMATE CHANGE IN THE CONTEXT OF THE WCRP GRAND CHALLENGE ON EXTREME EVENTS

Friederike Otto

June 8th AM1 9:35-9:45

It is now widely accepted that "extreme event attribution" is possible, albeit in a probabilistic sense and recognizing the role of multiple causal factors. Annual assessments of the role of climate change in individual classes of weather and climate events are being compiled using a range of approaches (e.g., Herring et al.,2015). There is increasing interest in using event attribution in risk assessment, and public communication to address questions of rebuilding and relocation after disasters. In order for the science to inform the latter, only attributing the role of climate change on meteorological hazards is likely insufficient and the relative roles of hazard and vulnerability need to be included when assessing impacts. While this risk-based approach is probably most relevant in the context of the WCRP grand challenge's mandate to provide 'actionable information' it needs to be related to an alternative approach, the so called storyline (Shepherd 2016) based on in-depth analysis of a single, unique, event. Here I will introduce the basic ideas and discuss examples where one method r the other might provide the most relevant information. Only if we, as the scientific community, understand the potential and limitations and come to a common language to discuss them attribution can truly unfold its potential to improve our understanding of extreme events and aid in short term predictions.

Herring S. C., M. P. Hoerling, J. P. Kossin, T. C. Peterson and P. A. Stott (2015). Explaining Extreme Events of 2014 from a Climate Perspective. Bulletin of the American Meteorological Society 96(12), S1–S172.
Shepherd T. G. (2016) A Common Framework for Approaches to Extreme Event Attribution Curr. Clim. Change Rep. 2, 28–38.

LAND-SURFACE COUPLING AND HEATWAVES IN THE CMIP5 MODELS

Sarah Perkins-Kirkpatrick, Ruth Lorenz and Peter Gibson

June 7th PM1-P1 1:30-1:45

Heatwaves, defined as prolonged periods of extreme temperatures, have disastrous impacts on many biophysical, industrial and ecological systems. Regional and global projections from state-of-the-art climate models indicate increasing observed trends in heatwave frequency, intensity and duration will continue to at least the end of the 21st Century, especially under conditions where little is done to mitigate anthropogenic impacts on the climate. Furthermore, there is an increasing body of literature demonstrating the importance of the land surface in priming and exacerbating heatwave conditions. Specifically, reduced antecedent soil moisture increases the likelihood of very extreme and prolonged heatwaves, as demonstrated for numerous European events. But how well do the state-of-the-art climate models simulate this important process, particularly in relation to heatwaves? How do climate models differ in their simulation of land-surface feedbacks and antecedent soil moisture, and corresponding influence on heatwaves? By calculating soil moisture-temperature coupling indices during heatwaves, we will investigate these questions for models participating in phase 5 of the Coupled Climate Model Intercomparison Project (CMIP5). We will use coupling indices that can be derived from observations and CMIP5 data to advance our knowledge about how different models represent soil moisture-temperature. Results of this work will be beneficial in determining the reliability of heatwave projections, specifically in diagnosing whether the underpinning dynamics are appropriately represented, and how they may influence future changes in heatwaves.

THE NEED FOR RELIABLE GRIDDED DAILY PRECIPITATION OBSERVATIONS FOR THE INVESTIGATION OF PRECIPITATION EXTREMES

Nicholas Herold, Steefan Contractor, Lisa Alexander and Markus Donat

June 7th PM1-P1 1:45-2:00

A thorough understanding of the changes in rainfall extremes in the past is needed for making reliable projections in the future. These past extremes can be investigated using gridded observations of daily rainfall. Despite the availability of several observationally constrained datasets of daily precipitation based on rain-gauge measurements, remote-sensing and/or reanalyses, we demonstrate a large disparity in the global land mean of daily precipitation intensity. Surprisingly, the magnitude of this spread is similar to that found in CMIP5 models. Even when comparing interpolated data based on the same network of in situ stations, there exists uncertainty due to varying interpolation methods. For example in Australia, our results show a large spread in the upper quantiles between the various datasets compared, indicating that substantial uncertainty exists in extremes from various gridded datasets. These large uncertainties within observations critically underpins our understanding of rainfall extremes in the past and in turn projections into the future. Through the results presented here we aim to contribute to the themes in WCRP grand challenge on climate extremes."

ANALYSIS OF THE PROJECTED EXTREME TEMPERATURES AND PRECIPITATION AND ASSOCIATED SOIL HYDRIC CONDITIONS IN THE EAST-NORTHEAST OF ARGENTINA

Vanesa Cristina Pantano, Olga Clorinda Penalba

June 7th PM1-P1 2:00-2:15

Climate extremes influence on soil hydric conditions causing an economic impact in the agriculture production in the east-northeast of Argentina (South America) which can be mitigated by anticipating potential changes. The objective of this work is to statistically analyze projections in mean and extreme values of the main meteorological variables participating in soil-atmosphere interaction, and associated impact on soil hydric conditions. Firstly, projected monthly maximum and minimum temperatures and precipitation by the end of this century were analyzed using seven Global Climate Models selected from CMIP5, under two emission scenarios (RCP4.5 and RCP8.5). Since changes are projected to occur on both mean and extreme values, they were quantified based on probabilistic intervals considering the entire frequency distribution. Secondly, media and standard deviation were tested while model uncertainty was assessed through the relation between signal (change) and noise (model variability). Finally, projected changes were applied to observed series for each probabilistic interval, as input variables for the water balance model in order to obtain consequent soilhydric condition. Temperatures and precipitation are projected to increase in a higher rate for extreme high and low values, respectively. Temperatures show higher statistical significance, better agreement between models and lower model uncertainty than precipitation. Soil response to these changes show that projected increased tempera-

tures reduce the impact of extreme high precipitation but favors deficit conditions, especially in the western zone where potential evapotranspiration becomes more important. This contributes to the design of strategies of adaptation to eventually attenuate the vulnerability of the agriculture production."

TEMPERATURE EXTREMES THEN AND NOW: WHAT CAN WE LEARN FROM THE 1930S?

Gabriele Hegerl, Tim Cowan and Ioana Colfescu

June 7th PM1-P1 2:15-2:30

During the 1930s the US saw some of the all time records in terms of heat occur. This presentation looks at the synoptic situation involved in hot and cold events and compares it between the early 20th century and the present, then focuses on hot events in 1934 and 1936 to evaluate what processes contributed to the really strong extreme events. Heat waves started early in the summer, often following a dry spring. The role of ocean SSTs as well as circulation is discussed, but preliminary analyses do not indicate a clear pattern linking heat waves and sst patterns that is replicated by climate models. The presentation will also discuss cold extremes eg the cold wartime winters in Europe and to what extent the pressure patterns involved in hot and cold events have changed between the 1930s and the recent period.

LINKAGES BETWEEN SEASONAL WINTER TEMPERATURES AND SNOW COVER

Klaus Wolter and Jon Eischeid

June 7th PM1-P1 2:30-2:45

It has long been known that mid-latitude boundary layer temperatures experience systematic cooling under the presence of snow cover. Prompted by the exceptionally cold Midwestern winter of 2013-14, thisinvestigation surveys the geographical extent to which this mechanism still explains much of the statistical variance of seasonal winter temperatures in the Northern Hemisphere. We are comparing observational with coupled model (CESM-1) results to assess the reproducibility of the former in the latter. To the extent possible, we also evaluate trends in observed and modeled snow cover and temperatures to assess the evolving nature of this coupling, in particular to identify ?tipping point regions? where we might expect reduced winter temperature variability in the near future due to reduced chances of long-lasting snow cover occurrences.

ESTIMATING FLOOD EXCEEDANCE PROBABILITIES IN ESTUARINE REGIONS

Seth Westra, Michael Leonard and Feifei Zheng

June 7th PM1-P1 2:45-3:00

lood events in estuarine regions can arise from the interaction of extreme rainfall and storm surge. Determining flood level exceedance probabilities in these regions is complicated by the dependence of these processes for extreme events. A comprehensive study of tide and rainfall gauges along the Australian coastline was conducted to determine the dependence of these extremes using a bivariate logistic threshold-excess model. The dependence strength is shown to vary as a function of distance over many hundreds of kilometres indicating that the dependence arises due to synoptic scale meteorological forcings. It is also shown to vary as a function of storm burst duration, time lag between the extreme rainfall and the storm surge event. The dependence estimates are then used with a bivariate design variable method to determine flood risk in estuarine regions for a number of case studies. Aspects of the method demonstrated in the case studies include, the resolution and range of the hydraulic response table, fitting of probability distributions, computational efficiency, uncertainty, potential variation in marginal distributions due to climate change, and application to two dimensional output from hydraulic models. Case studies are located on the Swan River (Western Australia), Nambucca River and Hawkesbury Nepean River (New South Wales).

WHAT WEATHER FEATURES PRODUCE EXTREME PRECIPITATION GLOBALLY?

Jennifer L. Catto and Andrew Dowdy

June 7th PM1-P13:00-3:15

Extreme precipitation (defined as above the 99th percentile) has been examined previously in relation to a number of different weather events. Such events include cyclones, fronts, and thunderstorms. However, previous studies have not examined various combinations of these weather events, which highlights the potential for an improved understanding of what causes extreme precipitation. Here we make use of objective cyclone and front identification methods and a global dataset of lightning strikes, to examine different combinations of cyclone, front and thunderstorm events to provide a comprehensive climatological examination of observed extreme precipitation events throughout the world. This method allows a number of novel concepts to be explored, with results showing that the highest risk of extreme precipitation occurs for a type of ?triple storm? event characterised by the simultaneous occurrence of a cyclone, front and thunderstorm. The physical properties of the various different combinations

of weather systems are examined in relation to the occurrence of extreme precipitation. Preliminary evaluation of these features in climate models is also presented. The results presented here are intended to lead to better preparedness for the impacts of extreme precipitation throughout the world including in relation to disaster risk reduction in both current and future climates.