Climate Change and Hydrological Extreme Events

Risks and Perspectives for Water Resources Management in Bavaria and Québec

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gefördert durch
Bayerisches Staatsministerium für Umwelt und Verbraucherschutz

A short history of collaboration

Q-BIC³ - Québec-Bavaria collaboration on climate change since 2006…

Bavarian Environment Agency

OURANOS

UNIVERSITÉ LAVAL

Développement durable, Environnement et Lutte contre les changements climatiques

Québec

McGill

INRS UNIVERSITÉ DE RECHERCHE

ÉTS Le génie pour l'industrie

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

lrz Leibniz-Rechenzentrum der Bayerischen Akademie der Wissenschaften

A short history of collaboration

Central Theme:

Research towards adapting to climate change

Major topics:

- Water balance
- River basin management
- Dam and reservoir management
- Natural hazards (floods/droughts)

Goals:

Understanding the course and impacts of climate change in Québec and Bavaria

- Develop tools and methods to support decision makers
- Train young researchers in this domain
- Communicate results to scientific community and users

Overview & Acknowledgements

Runtime:	05/2015 – 08/2019
Partners:	LMU, Ouranos, ETS, INRS, LRZ, MELCC-DEH, Bavarian Environmental Agency
Funding:	Bavarian State Ministry for the Environment and Consumer Protection
Acknowledge-ments:	ESCER centre at Université du Québec a Montréal (www.escer.uqam.ca) and Environment and Climate Change Canada for providing CRCM5
	Environment and Climate Change Canada CCCMA for making available the CanESM2 Large Ensemble simulations
	Gauss Centre for Supercomputing (www.gauss-centre.eu) for providing computing time on the GCS Supercomputer SuperMUC at LRZ (www.lrz.de)

Bavarian State Ministry of the Environment and Consumer Protection

Environment and Climate Change Canada

Leibniz-Rechenzentrum der Bayerischen Akademie der Wissenschaften

UQÀM

GCS Gauss Centre for Supercomputing

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Background

Major flood events in Québec
1996/2011/2017/2019

Major flood events in Bavaria
1999/2002/2005/2013/2016

« Extreme precipitation events over most of the mid-latitude land masses and over wet tropical regions will *very likely* become more intense and more frequent. » - IPCC AR5 report

Research objectives

Provide unprecedented high-resolution climate model datasets to …

- Confirm knowledge on whether and how climate change contributes to higher magnitudes and frequencies of extreme events
- Distinguish between the effects of internal variability and a ‘clear’ climate change signal
- Improve methods to analyse hydro-meteorological extreme events and provide robust estimates of HQx floods

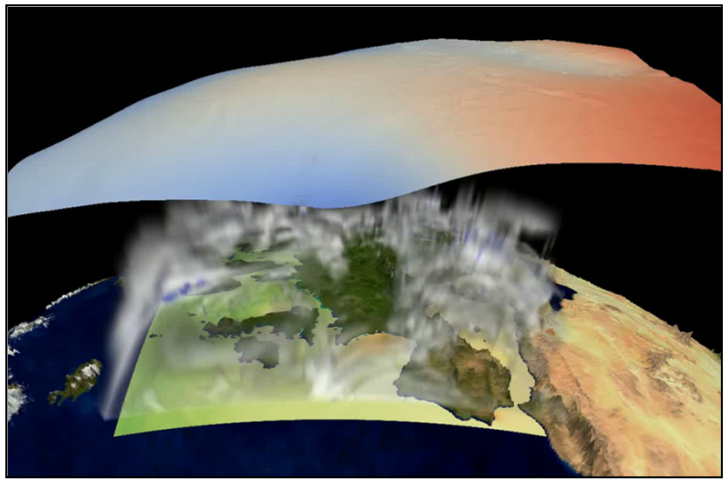
ClimEx…

- employs High Performance Computing (HPC) to produce a large scale single model ensemble (CanESM2-CRCM5, 50 members), resulting in a high-resolution (0.11°, up to 1h), transient climate dataset (1951-2100) under RCP8.5 (7500 model years)
- will provide, for the first time, a statistically robust analysis and comparison of extremes under climate variability and climate change

HPC challenges and implementation

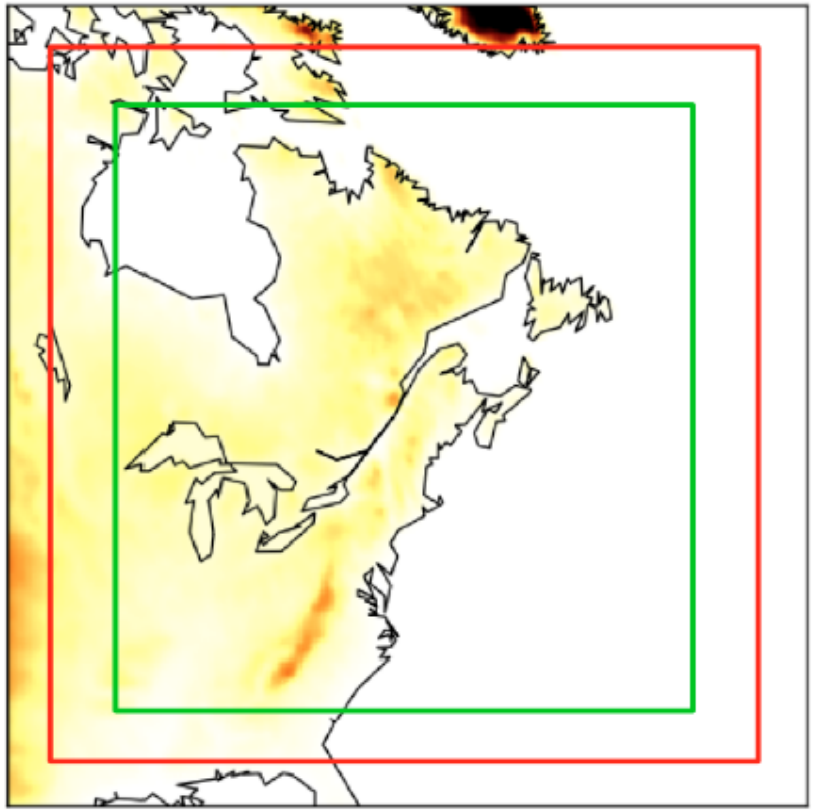
Experiment requires great computing power, storage and IT expertise

- GCS project granted in 2016
  (88 MCPU-h, 500 Tbyte)
- Climate simulations lasted one year!
- Data storage and sharing
- Visualization of model results
- Science communication

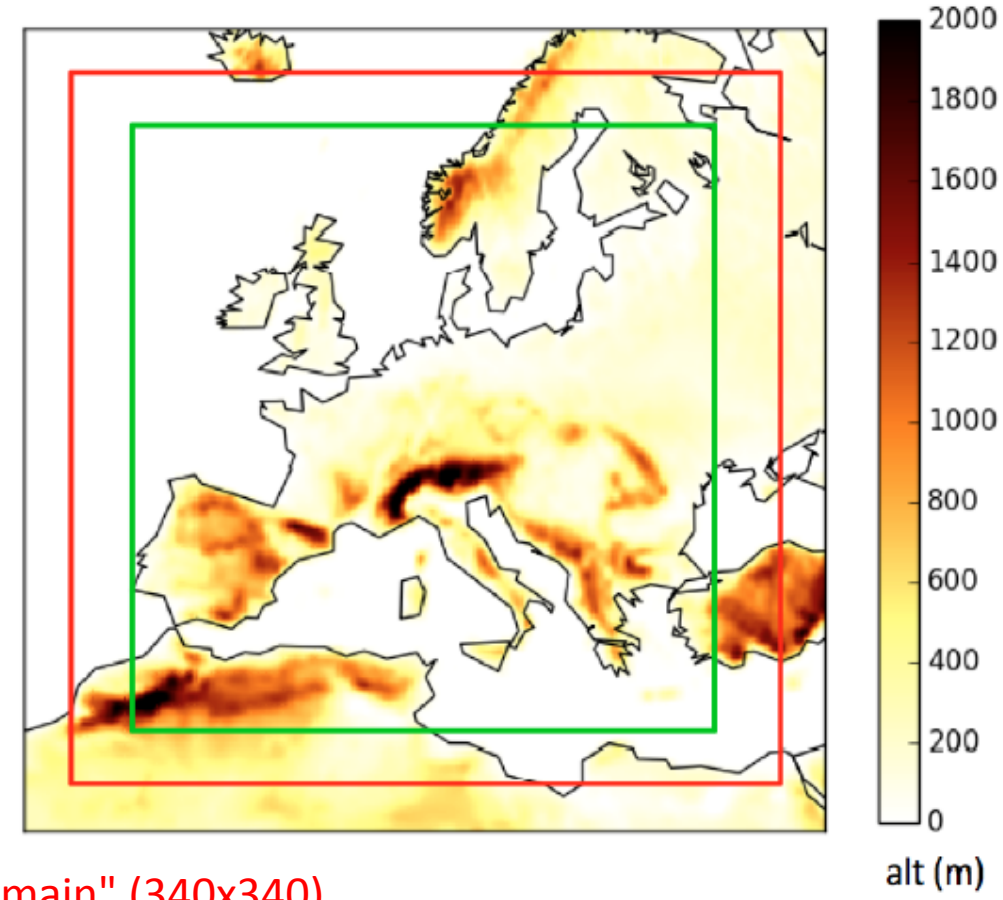


Case studies - Climate model domains

North American Domain



European Domain

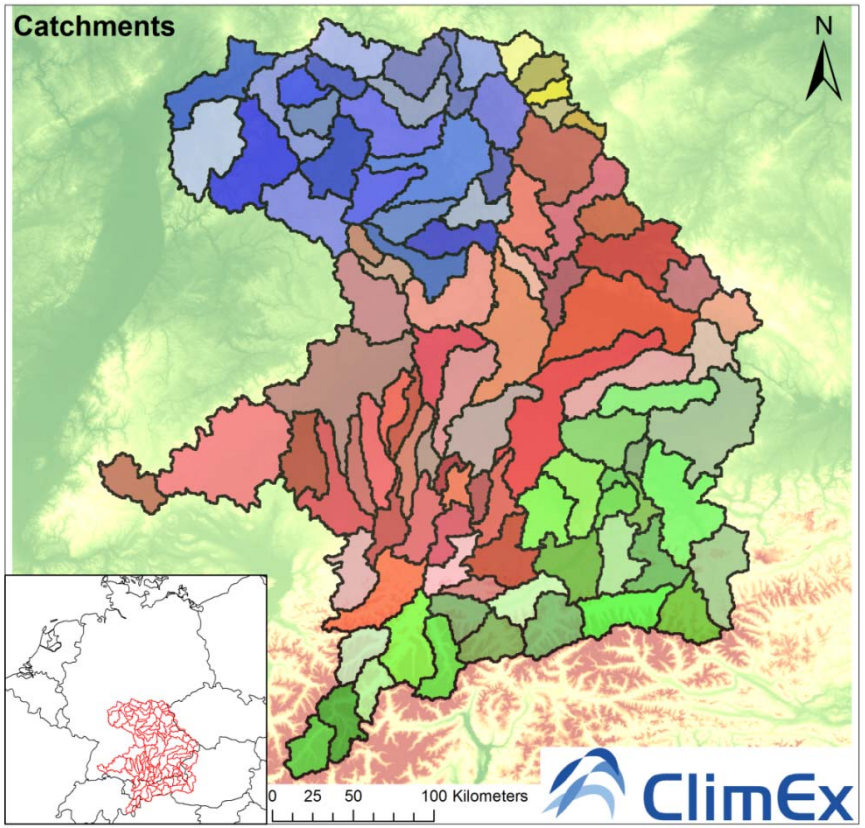


"free domain" (340x340)
"analysis domain" (280x280)

Case studies - Hydrological model domains

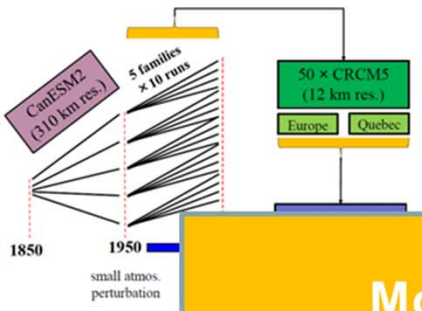
On which spatial and temporal scales do we need to investigate hydrometeorological extreme events?

- Challenge:
  Investigate the variability and climate change dependency of extreme events in 98 Bavarian river basins (~100.000 km²)
- Goal:
  Improved process understanding and provisioning of measures for water resources management and river authorities to reduce extreme risks
- Conduct:
  Hydrological simulations using WaSiM, 500m and 3h resolution (driven by 50 members CRCM5, 1950-2100)

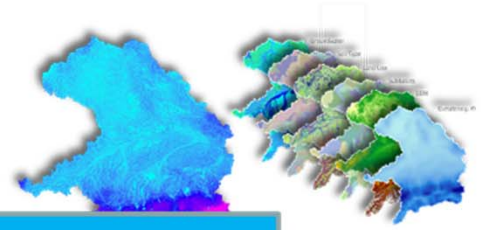


Hydrological Bavaria

Project structure

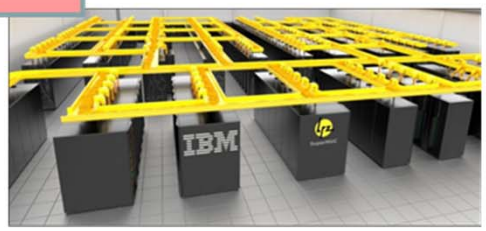


Module A: CLIMATE

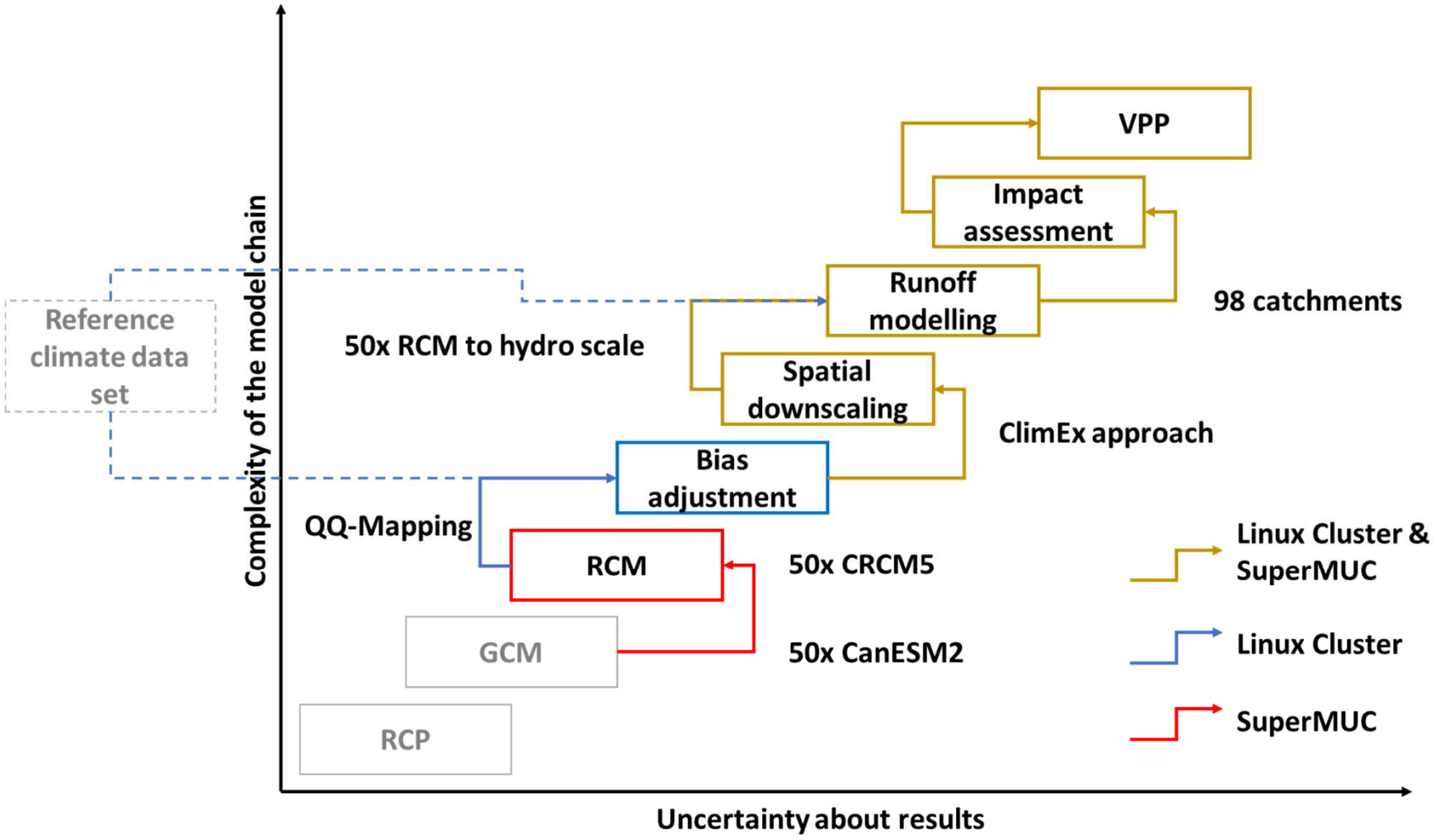


Module B: HYDRO

Module Z: Information Technology / Super Computing

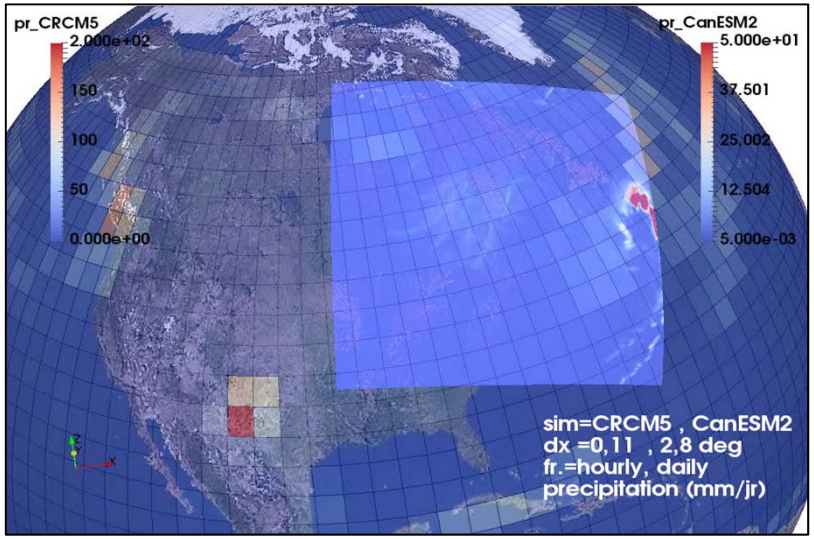


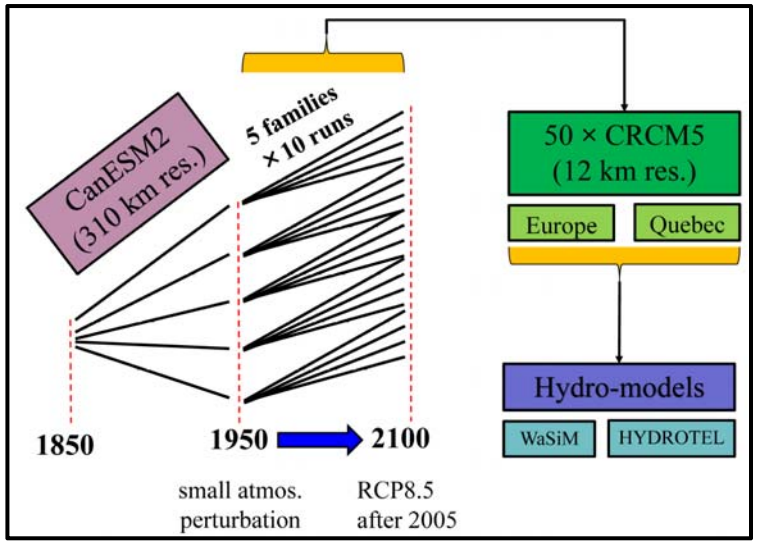
Project structure - workflow

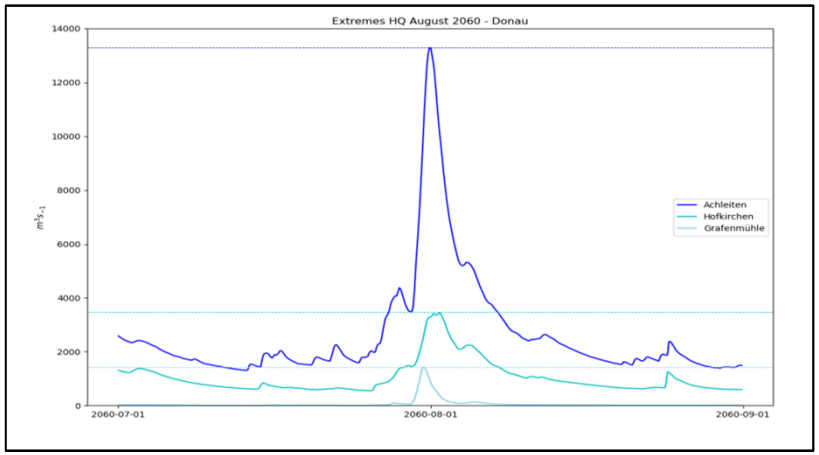


Climate variability, climate change and extremes

…in a model chain using a Large Scale Single Model Ensemble?





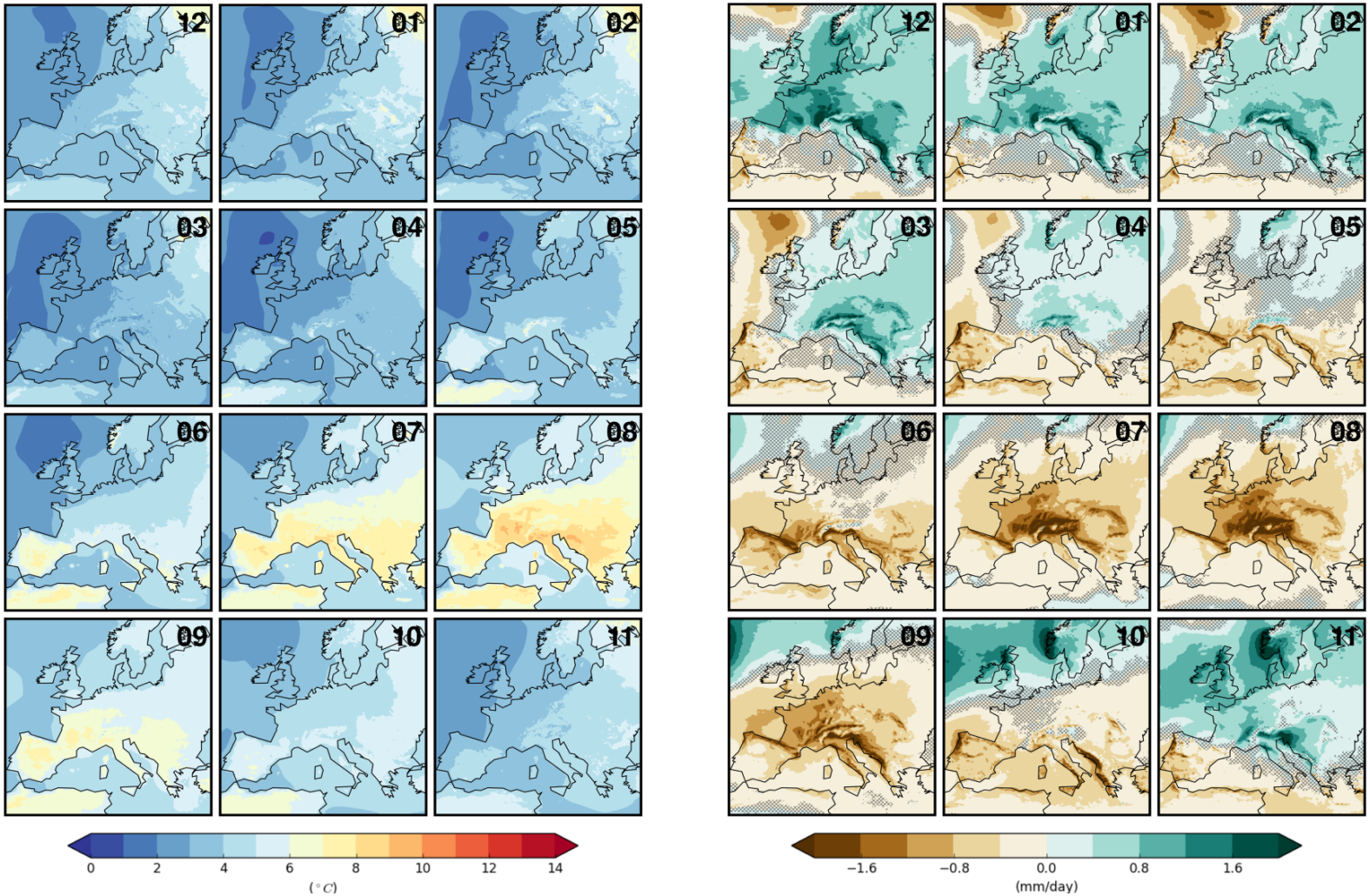


50 model members → 50 time series

[i.e. to estimate the robustness of natural variability in the time frame of 1981-2010, we possess not 30 but 1500 (model) years]

Estimation of rare extreme events in a given time period becomes much more robust…

Climate change – Temp & Precip in Europe



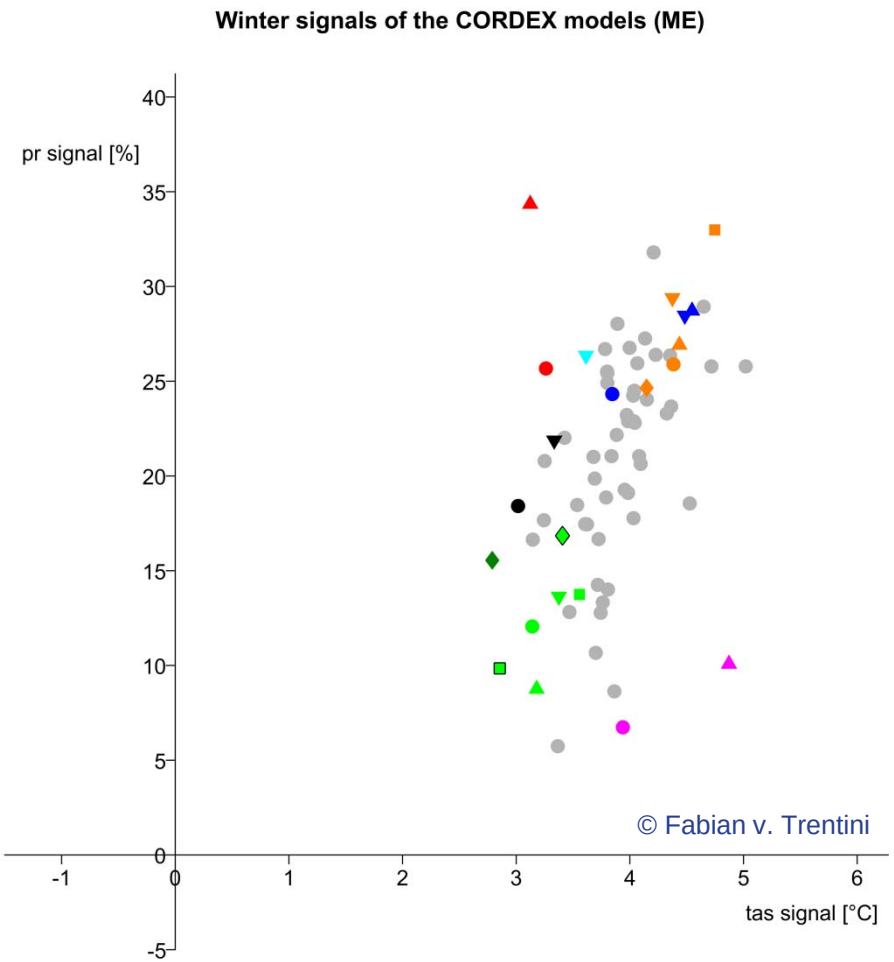
Monthly change of temperature and precipitation (2080-2099 vs. 2000-2019)
(50 member mean)

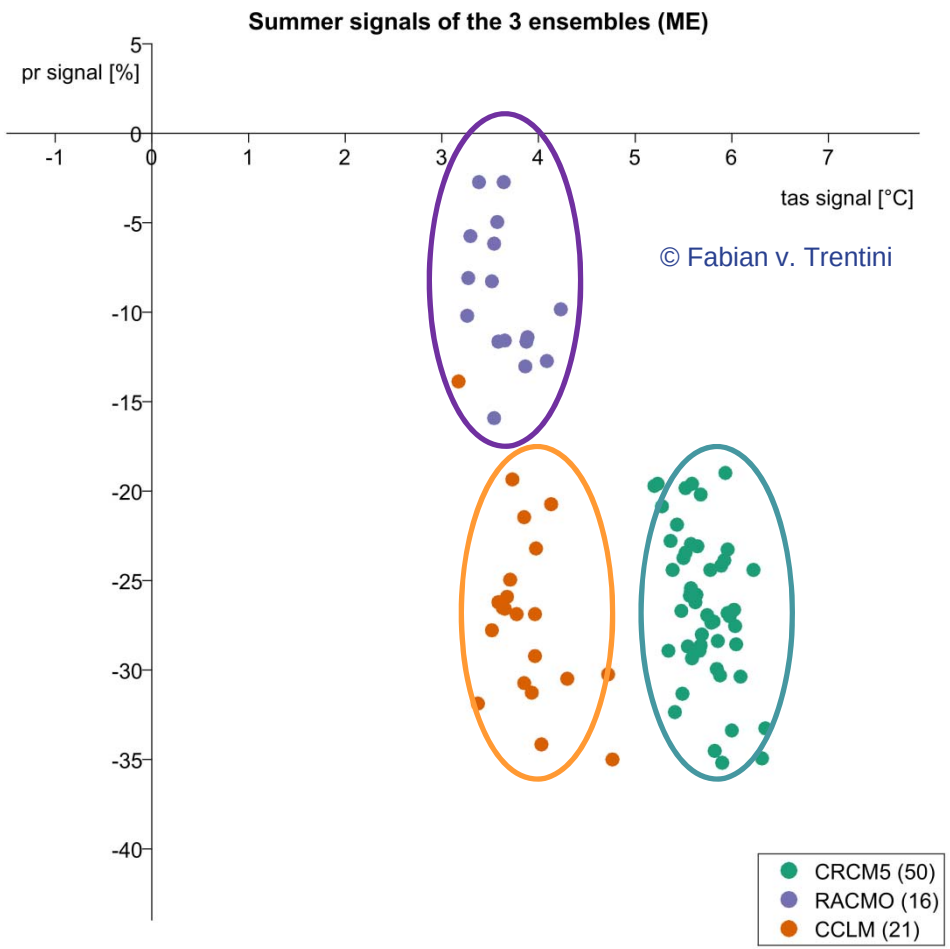
Leduc et al. (2019)

Does the data make sense? Is it valid?

How are CRCM5 signals comparing to other climate model experiments?

Relative signals of precipitation and temperature in 2070-99 compared to 1980-2009 (CEUR)





Does the data make sense? Is it valid?

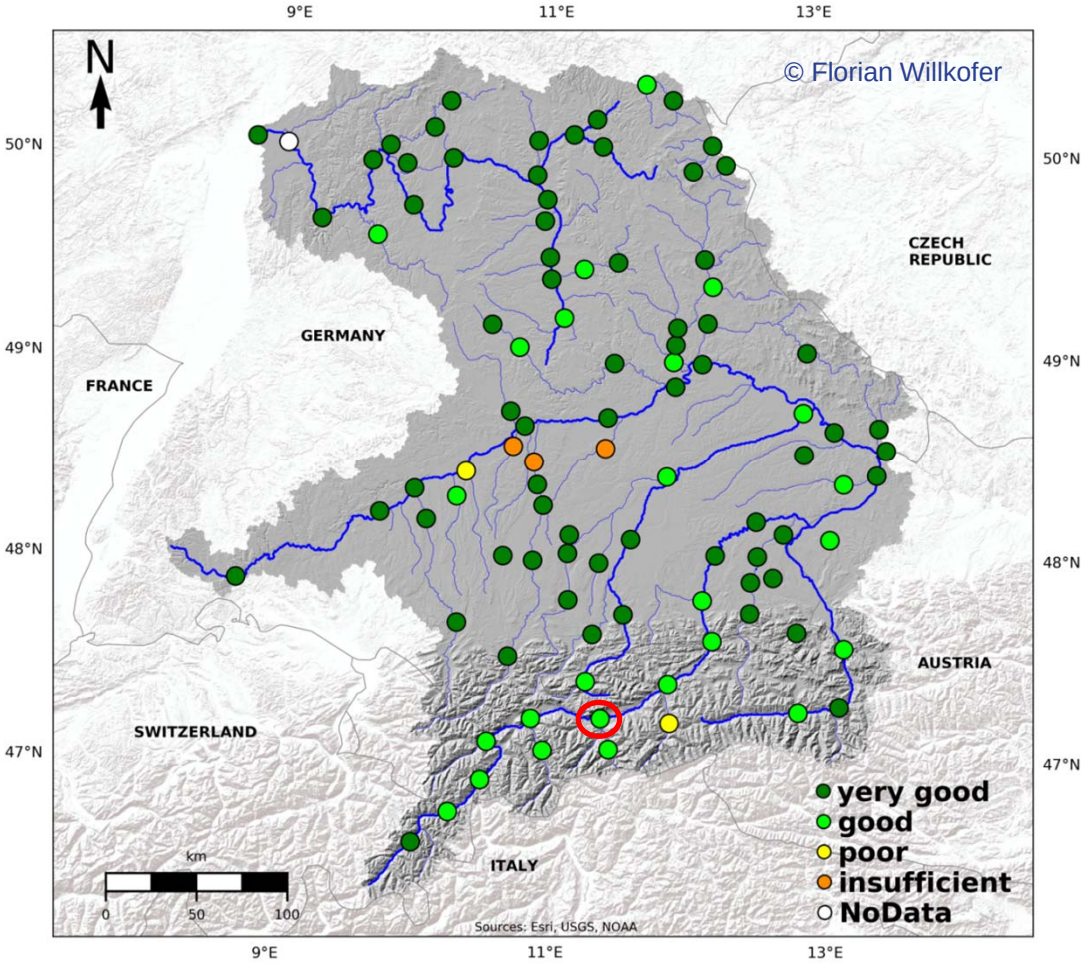
Can we use the hydrological model WaSiM for climate change impact analyses?

Evaluation of model performance

- WaSiM is spatially explicit and "physically based"
- global calibration applied, i.e. one setup for 98 gauges
- model performance "good" to "very good" for most gauges
- weaker results related to management practices (gauges are marked for further analysis)

- **Analysis of extreme events and its causes in future periods**

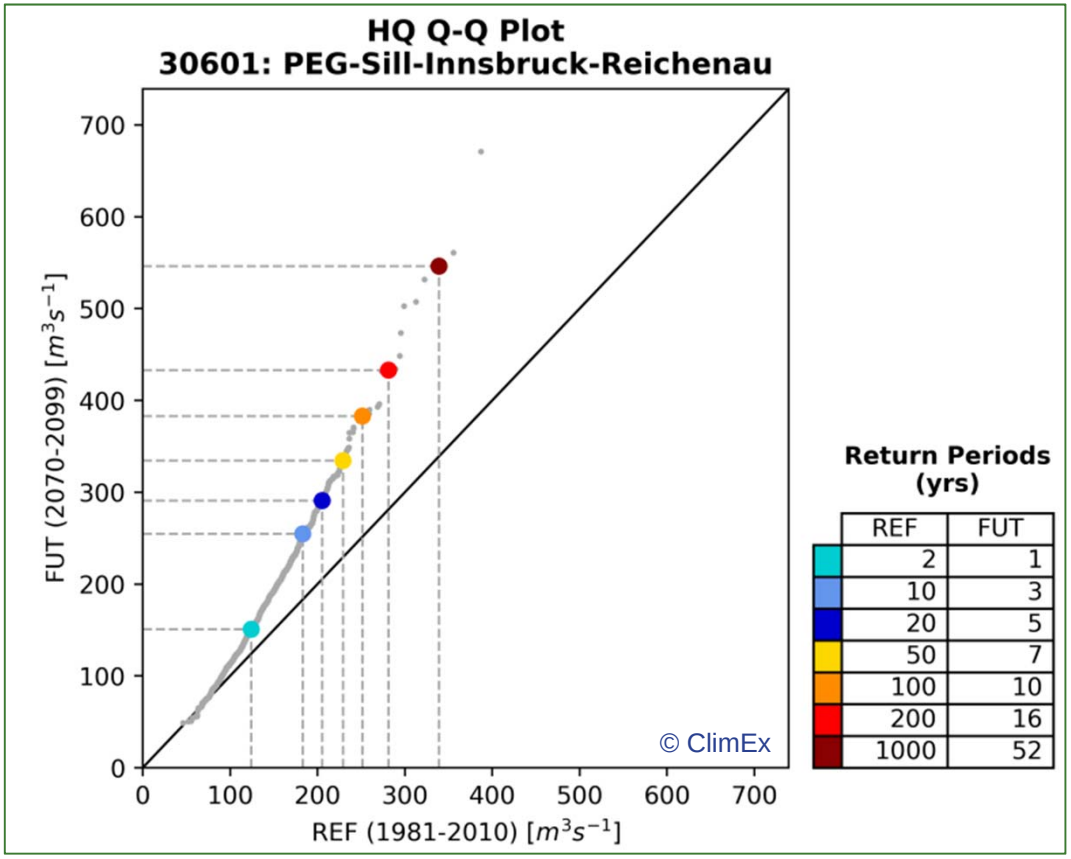
Model performance for the reference period (1981-2010)



Changes of extremes - compound events under climate change

An example of a gauge at the Inn river – long term perspective

Under future climatic and hydrological conditions, there is a severe increase in intensity and frequency of extreme flood events!



	REF	FUT
	2	1
	10	3
	20	5
	50	7
	100	10
	200	16
	1000	52

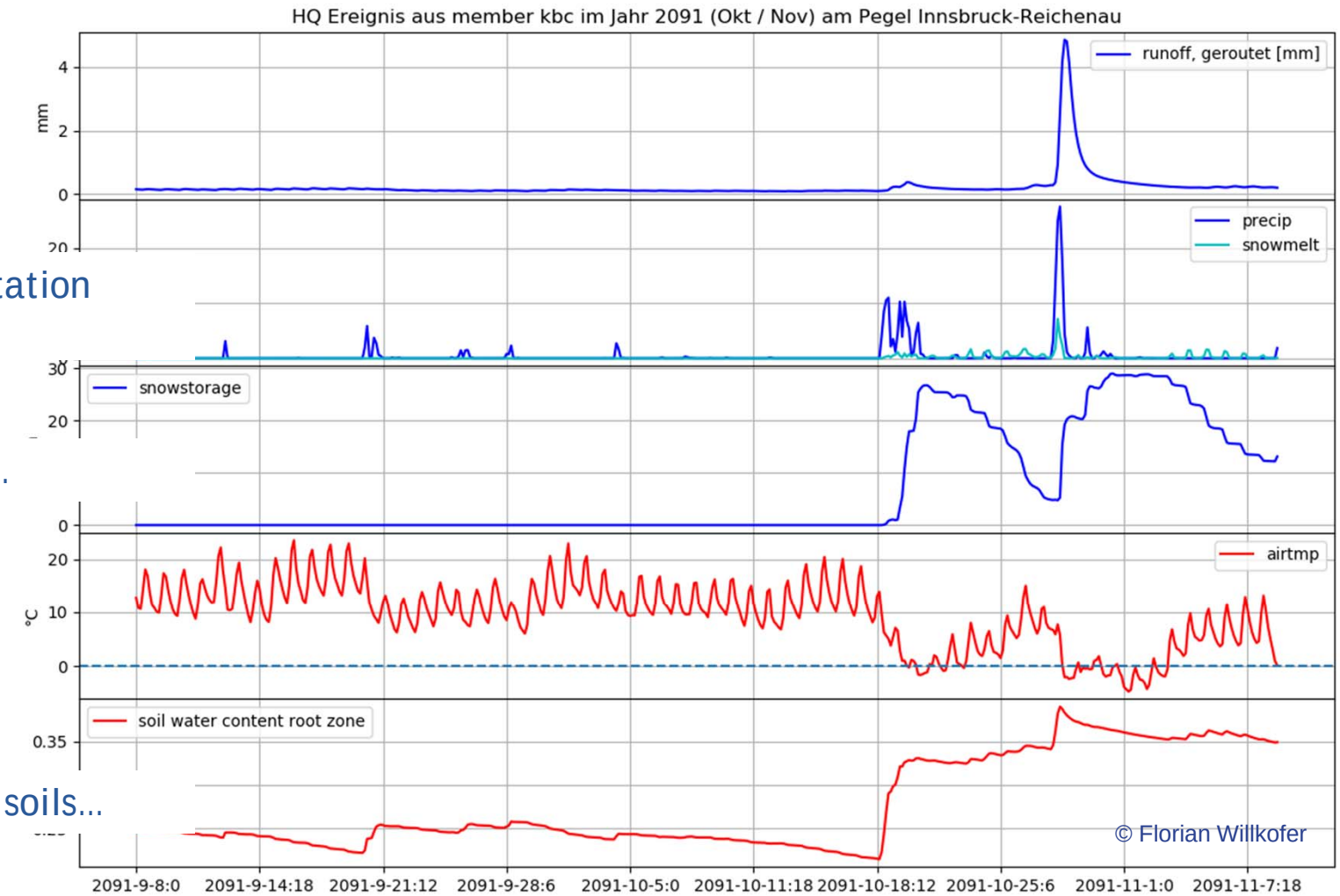
Changes of extremes - compound events under climate change

An example of a gauge at the Inn river – single extreme event triggered by…

Heavy precipitation falling on…

melting snow…

and saturated soils…



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Key messages

ClimEx …

- employs HPC to analyze *climate variability* and *climate change* over Eastern North America and Europe
- provides robust estimates for the dynamics of hydrometeorological extremes in Québec and Bavaria
- delivers simulation and visualization tools to support water resources management and civil security
- makes data and results available to the scientific community and stakeholders
- uses data from a sensitive climate model under an extreme climate change scenario

Bavaria 2013

Québec 2017

Québec 2019

Bavaria 2016

Program and
Logistical Information

Program of the Symposium

06 May 2019 – ClimEx Policy Day Bavarian Academy of Sciences	
13.00 – 13.45	Welcome and Introduction
13.45 – 14.30	Keynote by Prof. Friederike Otto
14.30 – 15.00	Coffee Break
15.00 – 17.00	ClimEx – Results
17.00 – 18.00	Tea Time & Poster Session & Visualization
18.00 – 19.00	Panel Discussion (Dr. M. Altmayer) Friederike Otto, Felix Finkbeiner, Martin Grambow, Peter Höppe, Ralf Ludwig
19.00 –	Reception

- "Angry weather? How to find out to what extent climate change is affecting extreme weather."
- Eight short talks to highlight some of the ClimEx findings
- Visit the posters & sign-up for parallel workshops on Tuesday!
- "Ist der Zug schon abgefahren? – Klimawandel, Extremereignisse und was wir (noch) dagegen tun können."

Program of the Symposium

An in-depth view on ClimEx results

Four parallel workshops to discuss scientific advance and novel applications of ClimEx and related data

Sign-up for guided tours to SuperMUC-NG (identification required)

07 May 2019 – ClimEx Science Day Leibniz Rechenzentrum		
08.30 – 08.40	Welcome	
08.40 – 10.30	A scientific view on ClimEx data and applications	
10.30 – 11.00	Coffee Break	
11.00 – 12.45	Parallel Workshops	A – Large Model Ensembles B – Climate Services and Science Communication C – Hydrologische Extreme und Anpassung in der Wasserwirtschaft D – Klimawandel und erneuerbare Energien
12.45 – 13.45	Lunch Break	
13.45 – 14.15	Parallel Workshops - Summary	
14.15 – 15.15	Synthesis and Outlook	
15.15 – 16.00	Network Café and Farewell	
16.00 – 17.00	Guided Tours to SuperMUC-NG (on demand)	

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