Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

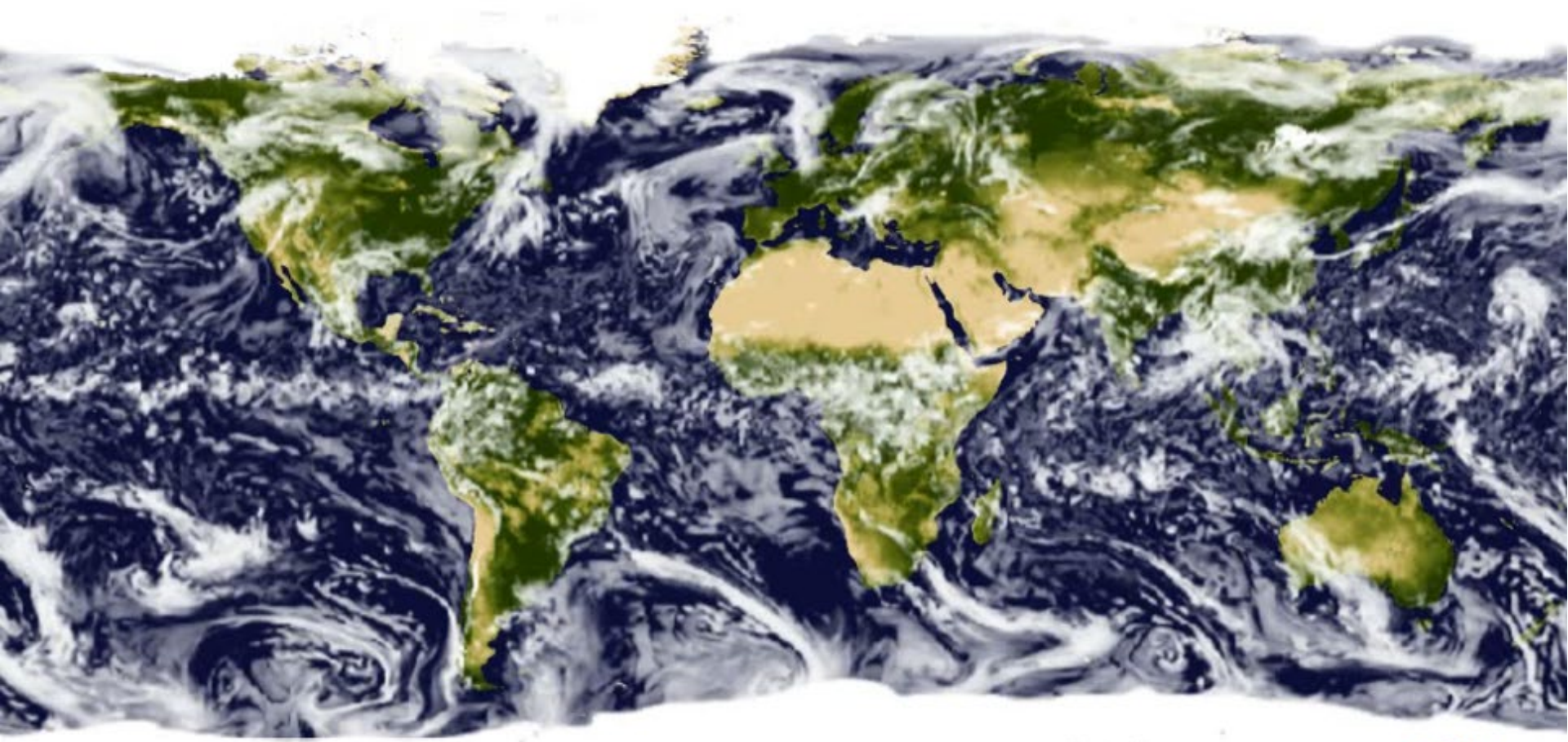
Swiss Confederation

Federal Department of Home Affairs FDHA
Federal Office of Meteorology and Climatology MeteoSwiss

MeteoSwiss

Current and future challenges in climate modelling and implications for future research in hydrology

Sven Kotlarski
Federal Office of Meteorology and Climatology MeteoSwiss



A global climate model!

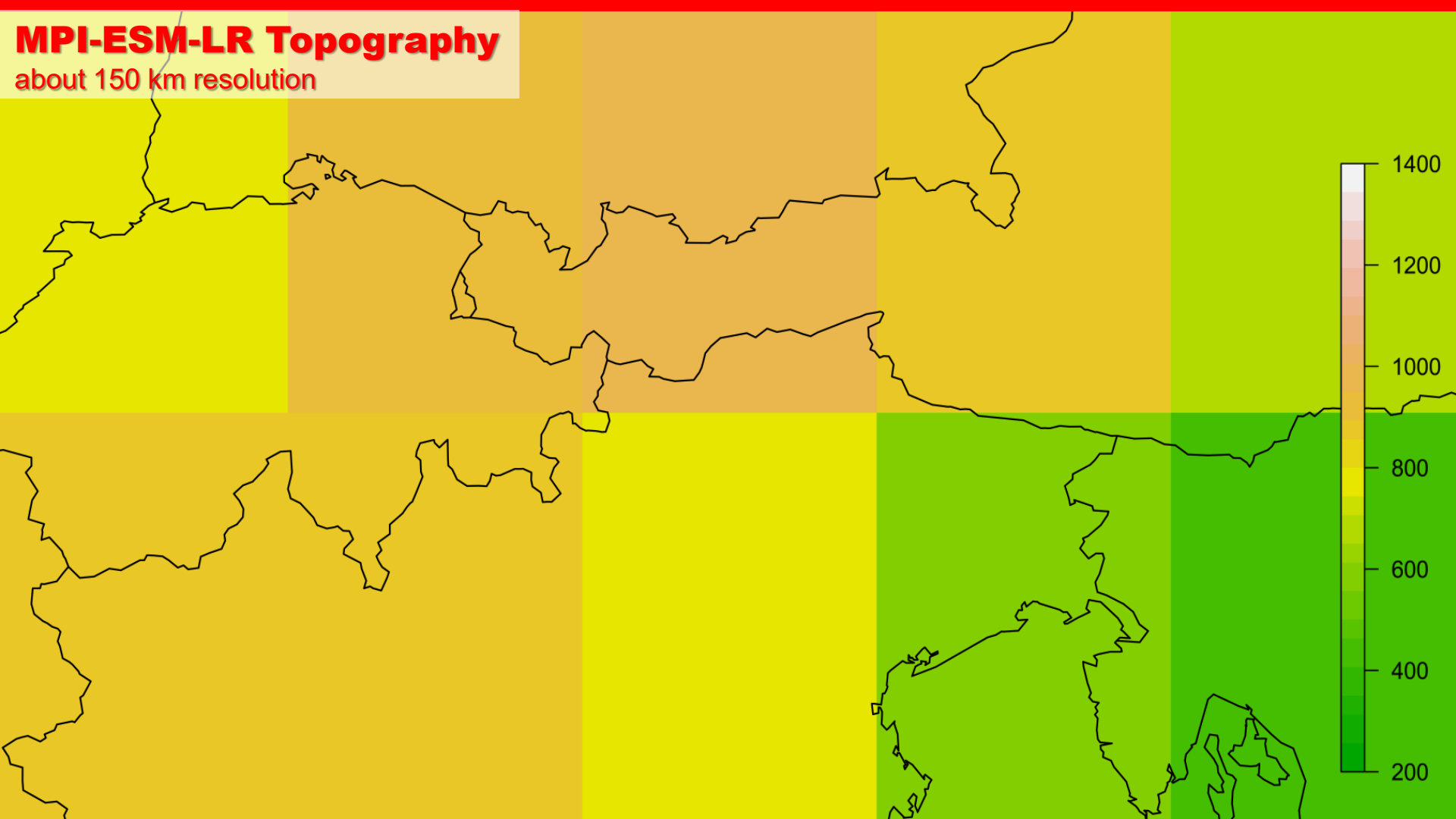
25 km resolution

C2SM
Center for Climate
Systems Modeling

What is the reality?

MPI-ESM-LR Topography

about 150 km resolution

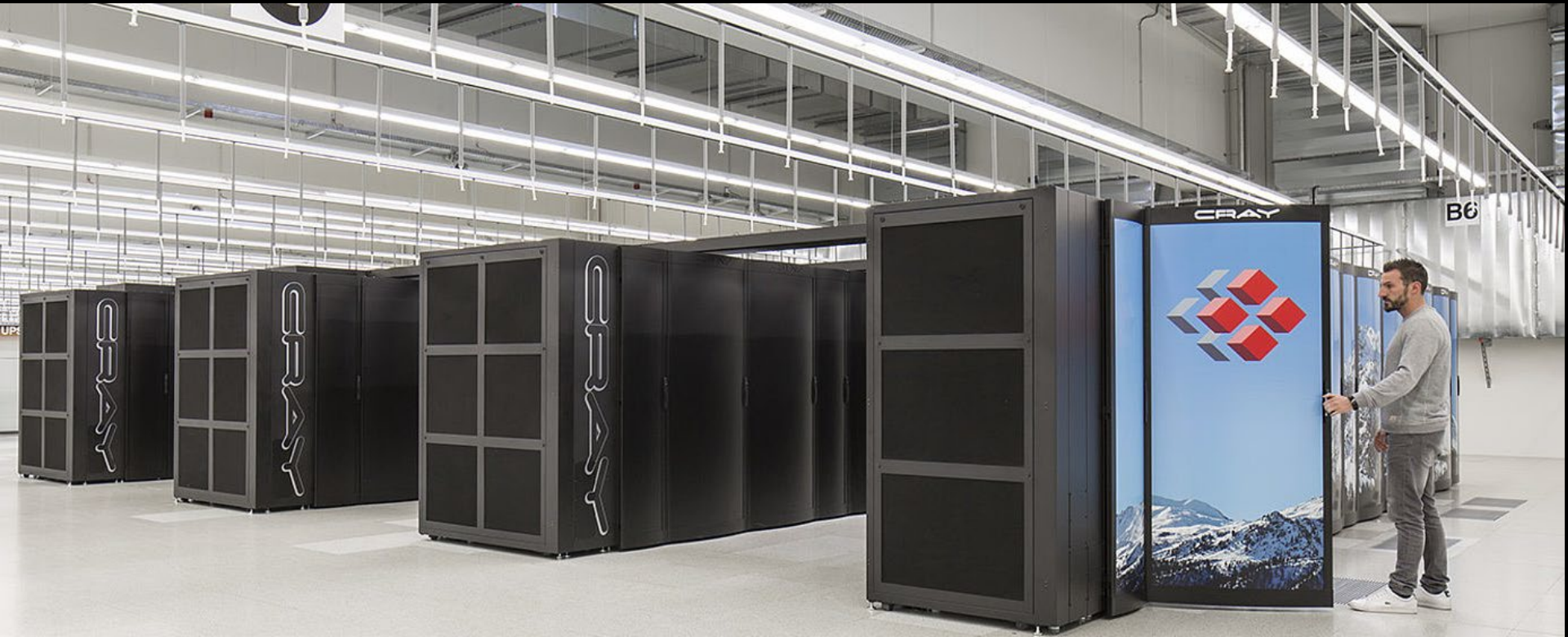


CSCS
Centro Svizzero di Calcolo Scientifico
Swiss National Supercomputing Centre

Piz Daint

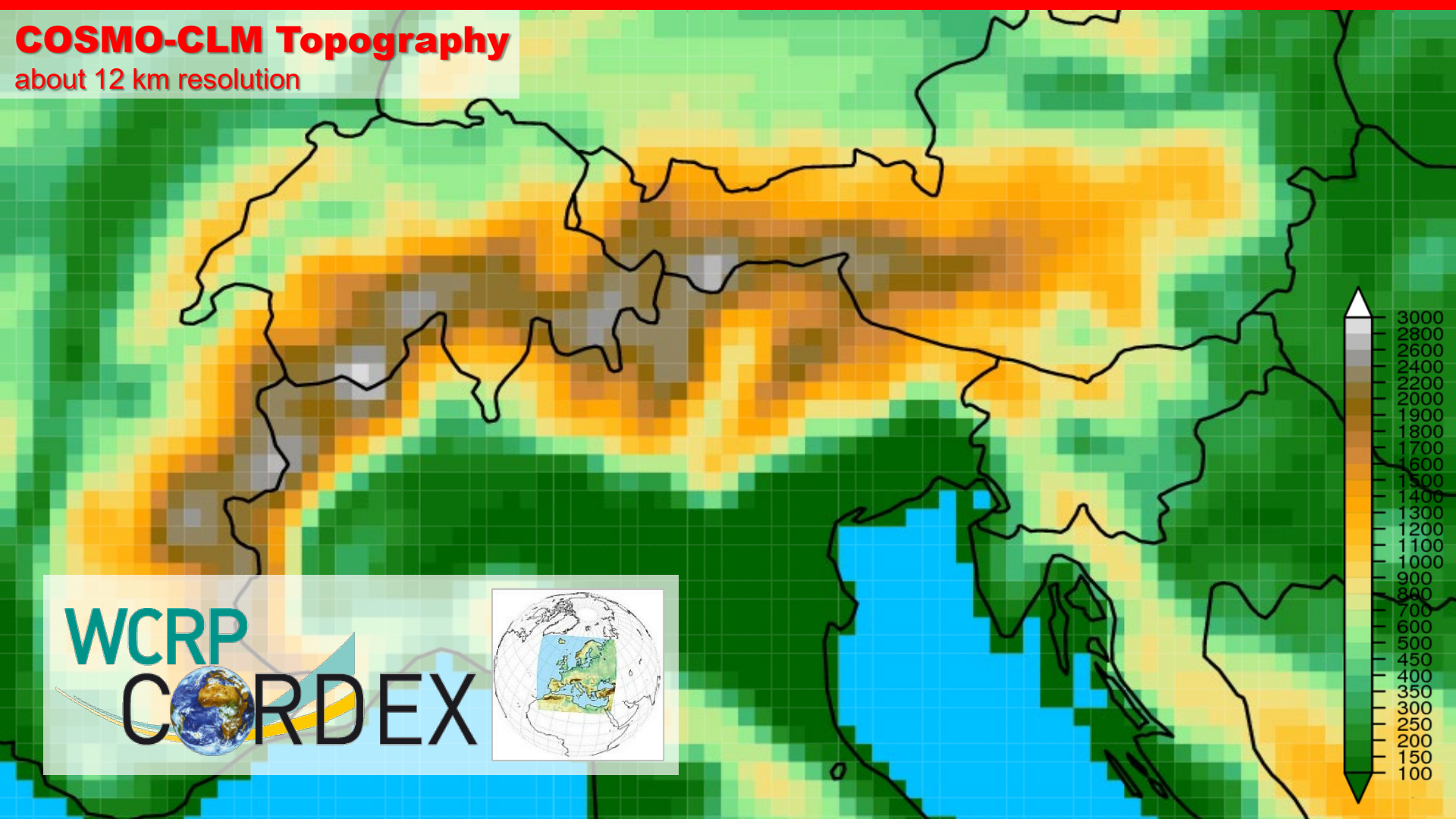
25 PetaFLOPS (25 000 000 000 000 000)

One of Europe's fastest HPC systems



COSMO-CLM Topography

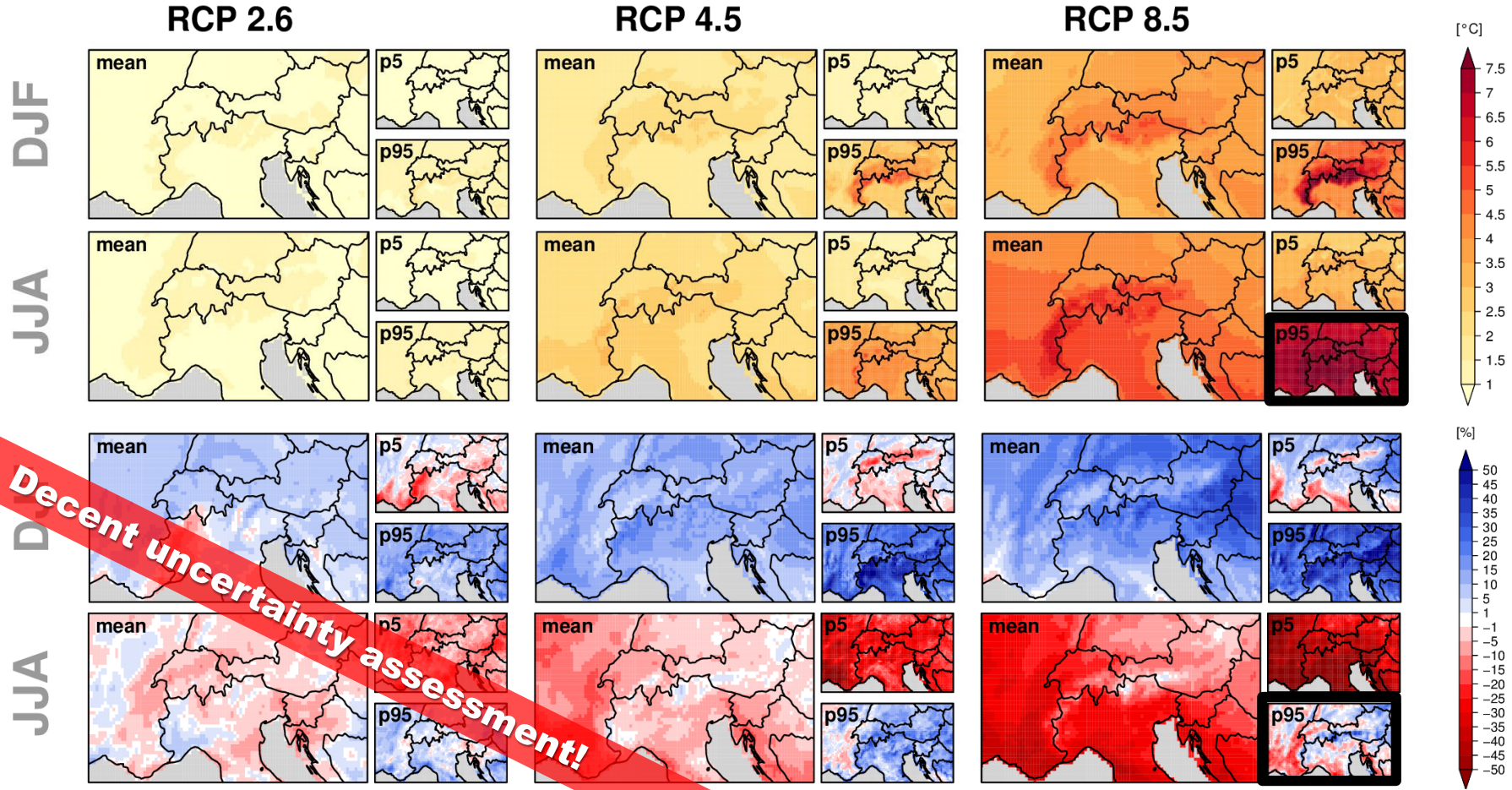
about 12 km resolution



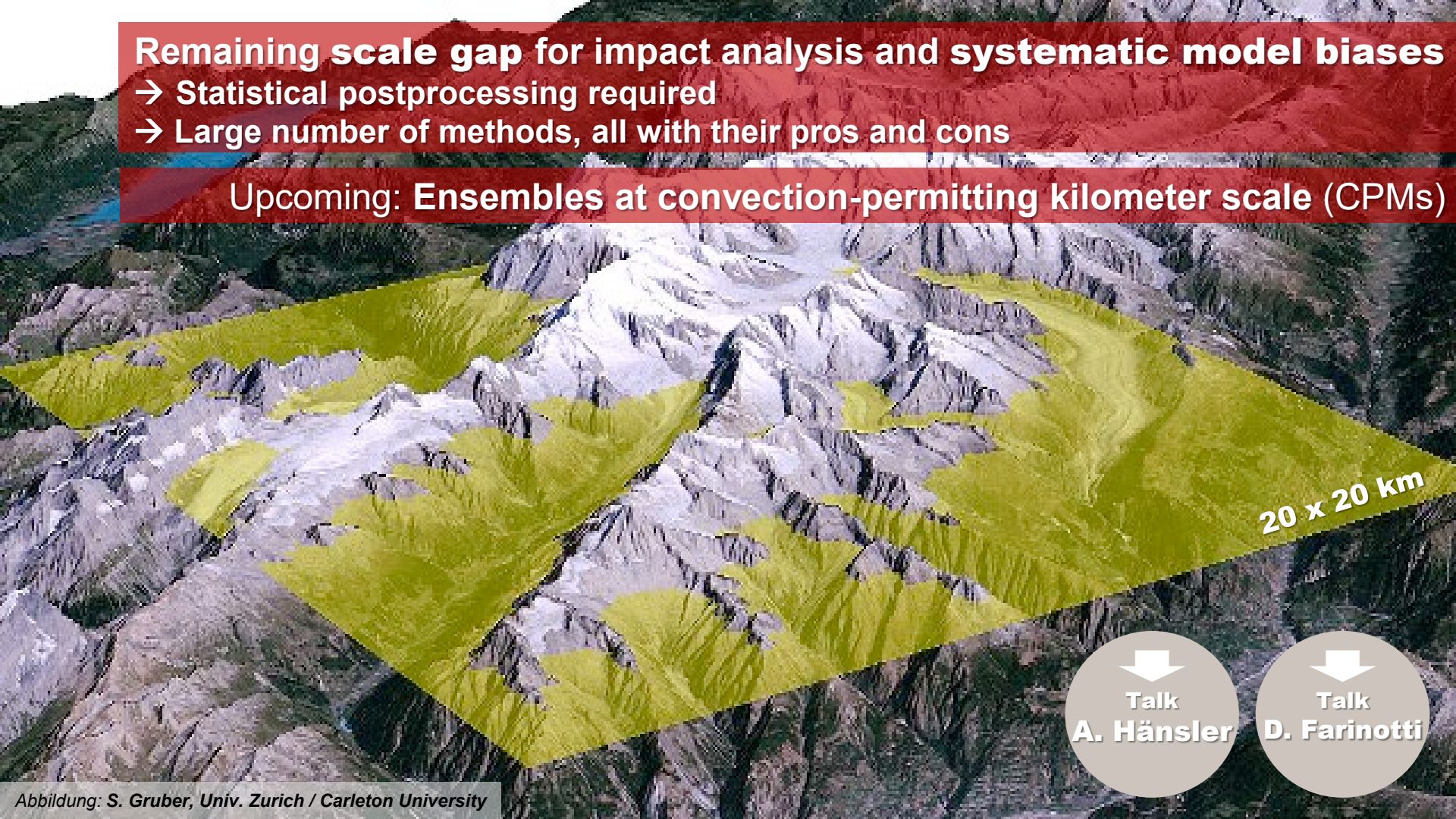
WCRP CORDEX

Alpine climate scenarios

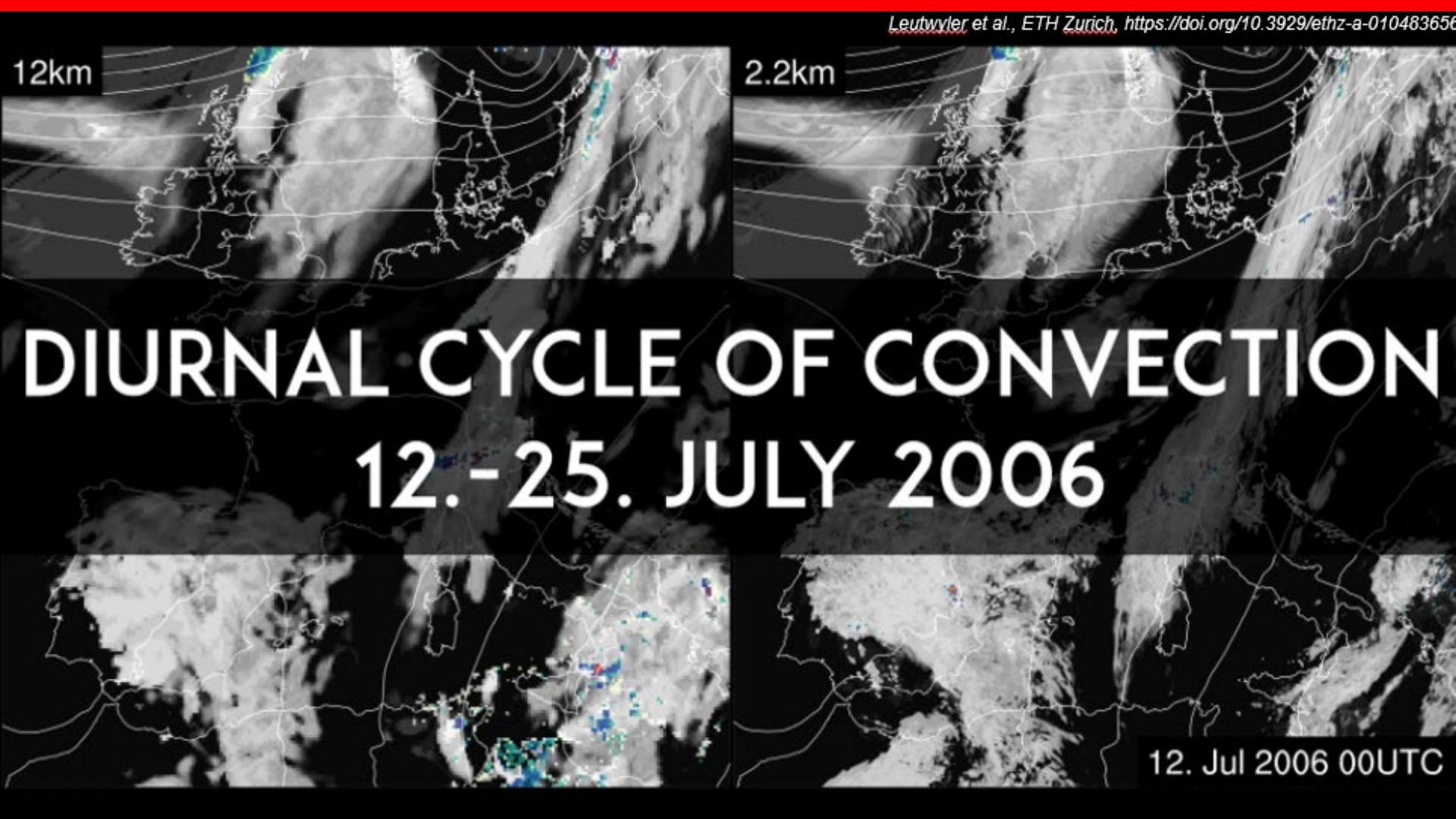
Change signals by end-of-century

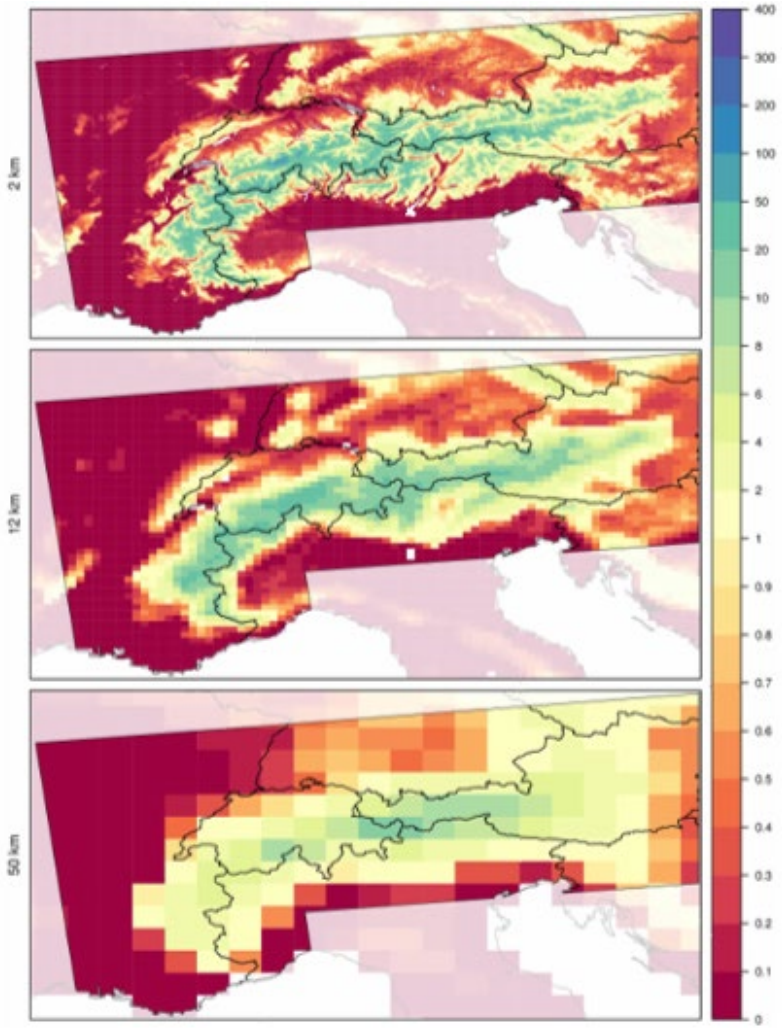


Kotlarski et al., Climate Dynamics, 2022


Remaining **scale gap** for impact analysis and **systematic model biases**
→ Statistical postprocessing required
→ Large number of methods, all with their pros and cons
Upcoming: **Ensembles at convection-permitting kilometer scale** (CPMs)
20 x 20 km
Talk
A. Hänsler
Talk
D. Farinotti
Abbildung: **S. Gruber, Univ. Zurich / Carleton University**

Leutwyler et al., ETH Zurich, https://doi.org/10.3929/ethz-a-010483656





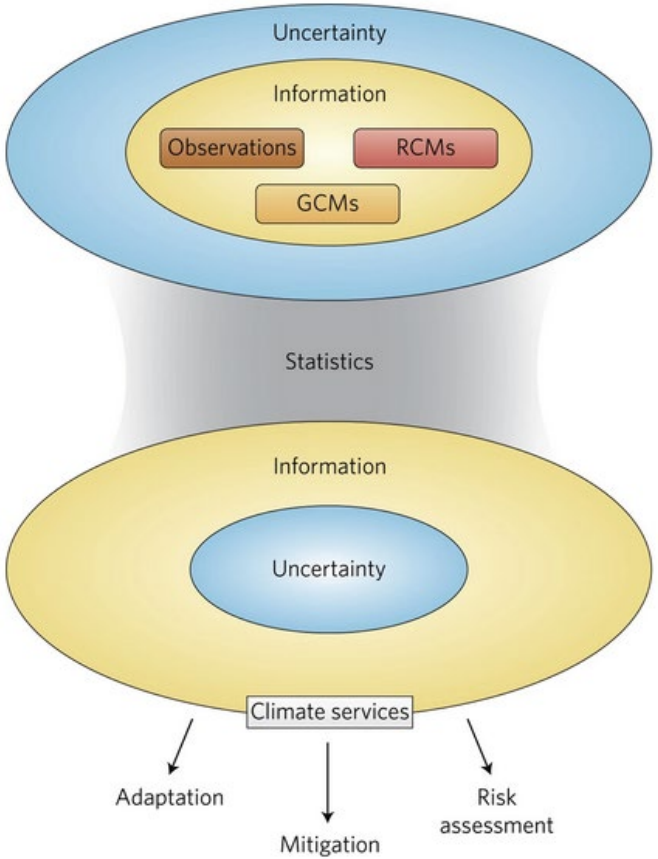
Simulated snow water equivalent [cm]
COSMO-CLM, year 2000

Source: Christian Steger (ETH Zürich)

Talk
W. Schöner

Is it just about resolution?

Climate Information Distillation

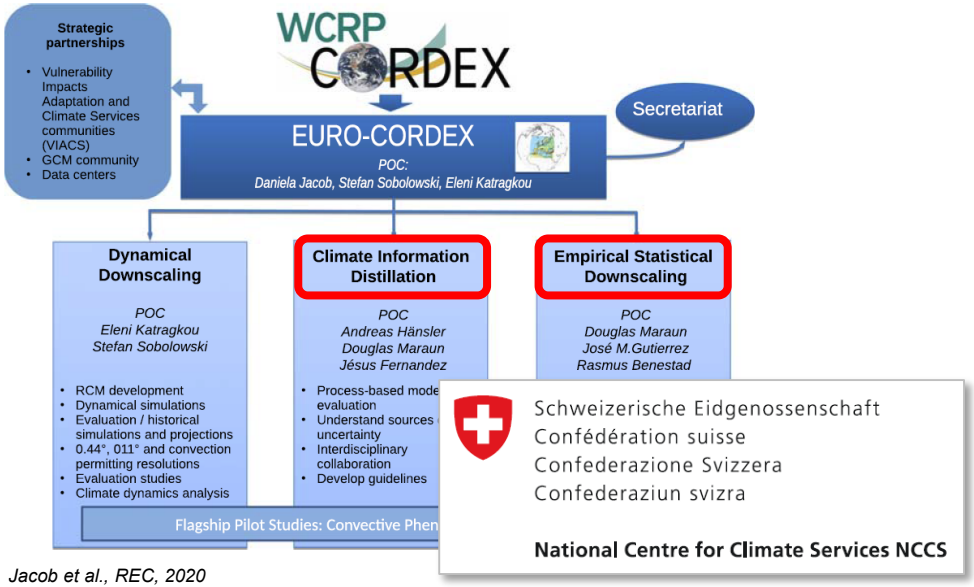


Benestad et al., Nature Climate Change, 2017

Models and observations provide us with a lot of information, but there are inherent large uncertainties.

Tailored statistical methods can carve out the relevant information, embracing the uncertainties.

Distilled information can feed into climate services and other applications (such as adaptation, mitigation and so on).



Jacob et al., REC, 2020

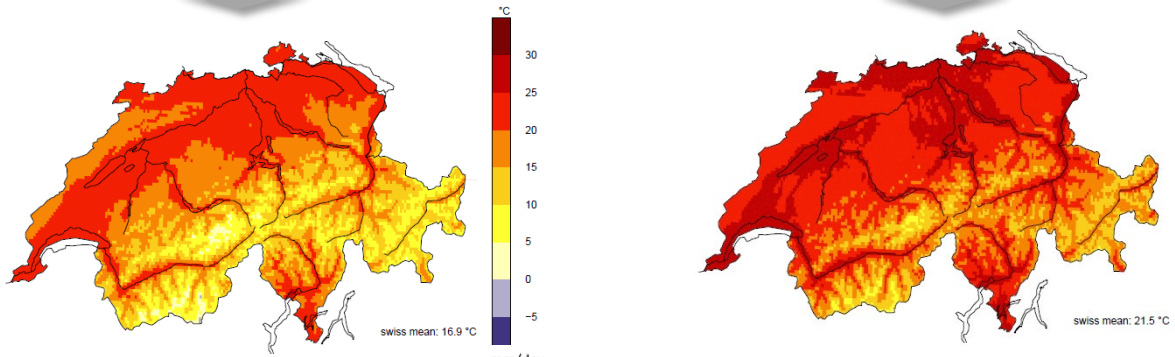
Storylines

"We define a storyline as a **physically self consistent unfolding of past events, or of plausible future events** or pathways. No a priori probability of the storyline is assessed; emphasis is placed instead on understanding the driving factors involved, and the plausibility of those factors." *Shepherd et al., Climatic Change, 2018*

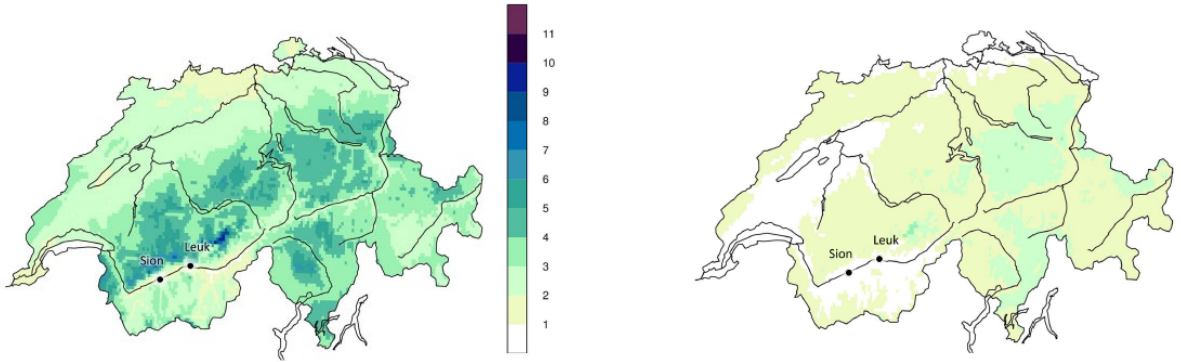
Summer 2003

Extreme end-of-century summer

Summer (JJA)
mean temperature

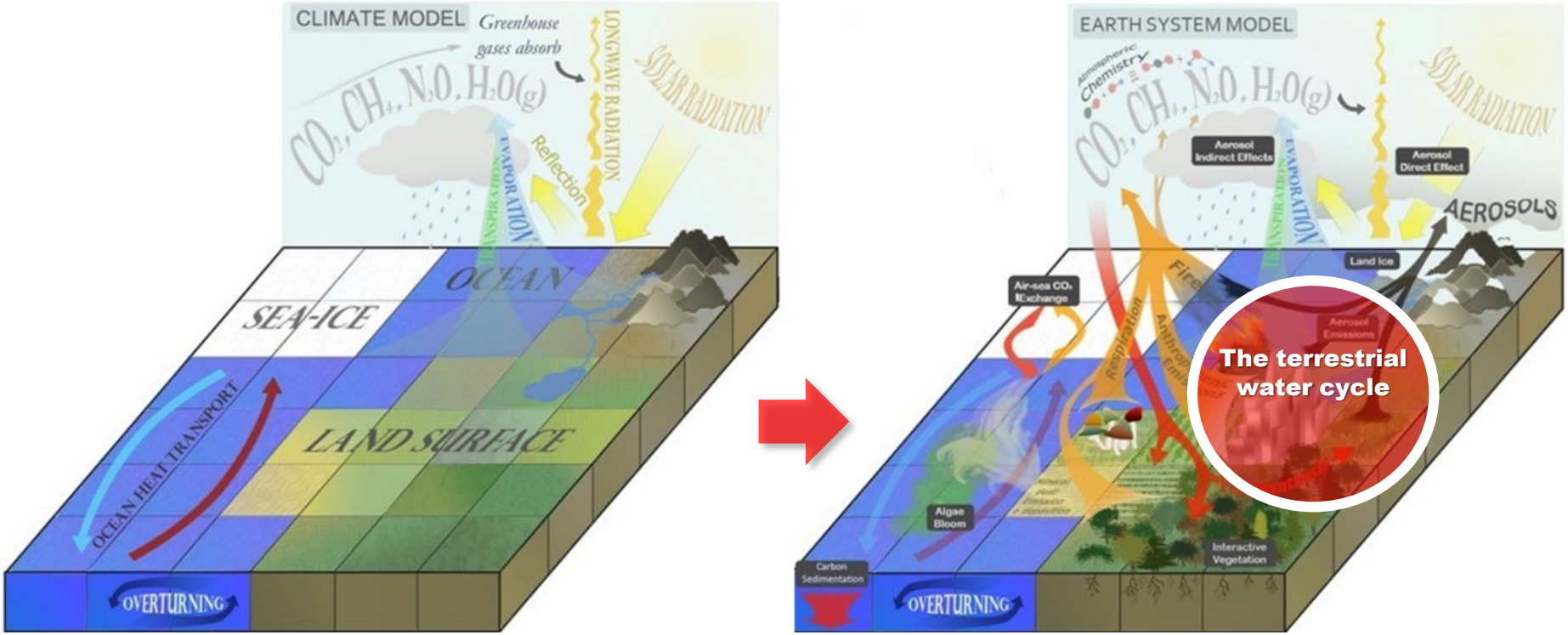


Summer (JJA)
mean precipitation



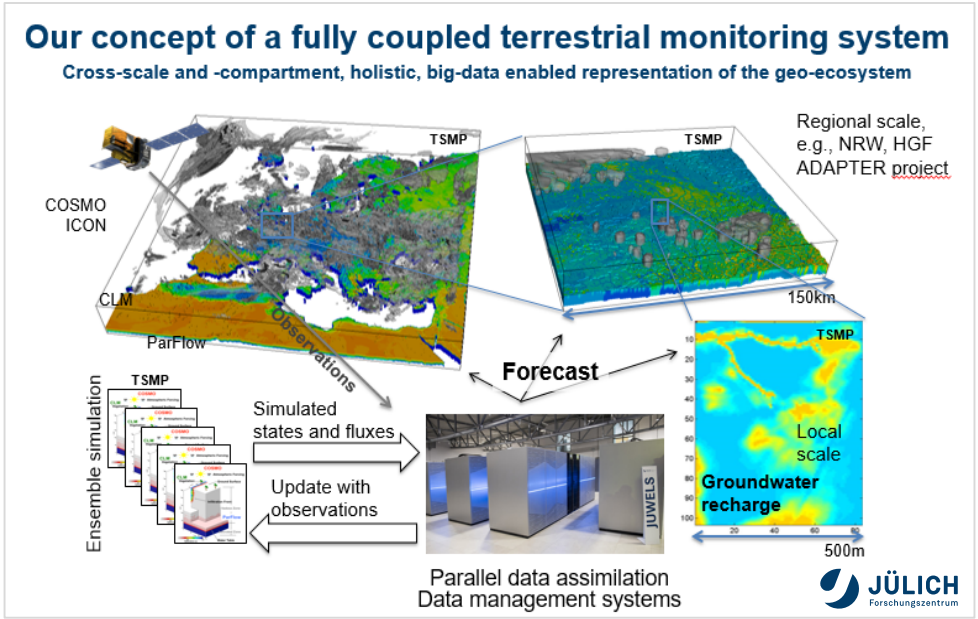
Mastai, 2022 (MSc thesis ETH Zurich/MeteoSwiss)

Regional Earth System Models

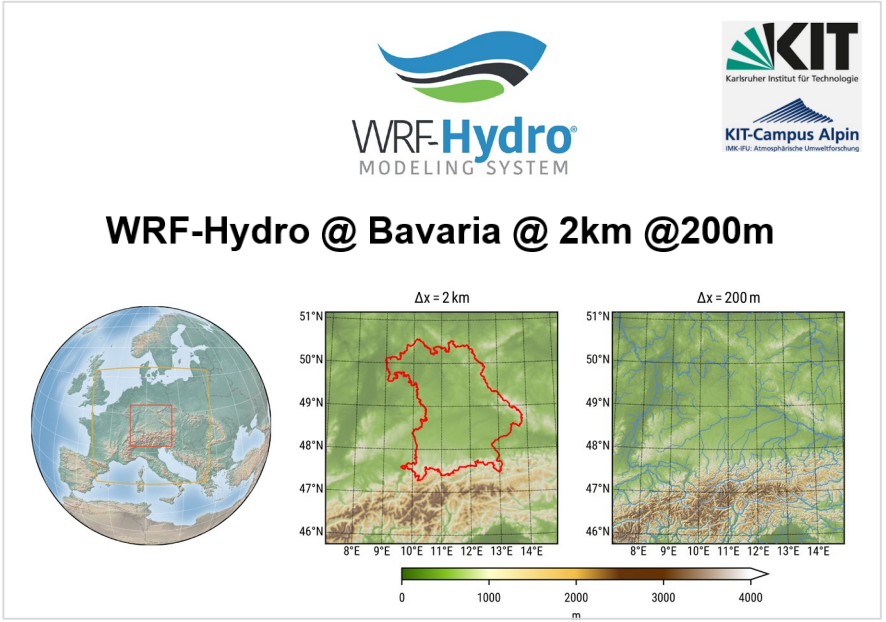


Source: Nature Education, 2013

Coupled Climate-Hydrology Modeling



Source: K. Goergen, S. Kollet, et al. (FZ-Jülich)



Source: H. Kunstmann (KIT Campus-Alpin / Univ. Augsburg)

Large ensembles and weather generators

Single model initial-condition large ensembles (SMILEs)
to sample **natural climate variability**

Earth Syst. Dynam., 12, 401–418, 2021
https://doi.org/10.5194/esd-12-401-2021

Earth System Dynamics
EGU

Large ensemble climate model simulations: introduction, overview, and future prospects for utilising multiple types of large ensemble

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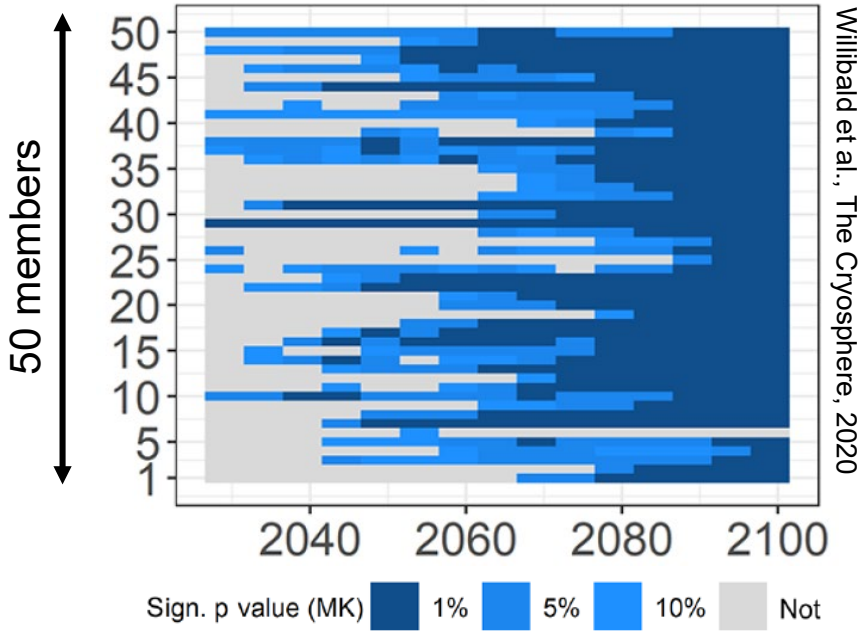
[1]Max Planck Institute for Meteorology, Hamburg, Germany
[2]Department of Geography, Ludwig-Maximilians-Universität, Munich, Germany
Correspondence: Nicola Maher (nicola.maher@colorado.edu)

Published: 22 April 2021

Abstract. Single model initial-condition large ensembles (SMILEs) are valuable tools that can be used to investigate the climate system. SMILEs allow scientists to quantify and separate the internal variability of the climate system and its response to external forcing, with different types of SMILEs appropriate to answer different scientific questions. In this editorial we first provide an introduction to SMILEs and an overview of the studies in the special issue "Large Ensemble Climate Model Simulations: Exploring Natural Variability, Change Signals and Impacts". These studies analyse a range of different types of SMILEs including global climate models (GCMs), regionally downscaled climate models (RCMs), a hydrological model with input from a RCM SMILE, a SMILE with prescribed sea surface temperature (SST) built for event attribution, a SMILE that assimilates observed data, and an initialised regional model. These studies provide novel methods, that can be used with SMILEs. The methods published in this issue include a snapshot empirical orthogonal function analysis used to investigate El Niño–Southern Oscillation teleconnections; the partitioning of future uncertainty into model differences, internal variability, and scenario choices; a weighting scheme for multi-model ensembles that can incorporate SMILEs; and a method to identify the required ensemble size for any given problem. Studies in this special issue also focus on RCM SMILEs, with projections of the North Atlantic Oscillation and its regional impacts assessed over Europe, and an RCM SMILE intercomparison. Finally a subset of studies investigate projected impacts of global warming, with increased water flows projected for future hydrometeorological events in southern Ontario; precipitation projections over central Europe are investigated and found to be inconsistent across models in the Alps, with a continuation of past tendencies in Mid-Europe; and equatorial Asia is found to have an increase in the probability of large fire and drought events under higher levels of warming. These studies demonstrate the utility of different types of SMILEs. In the second part of this editorial we provide a perspective on how three types of SMILEs could be combined to exploit the advantages of each. To do so we use a GCM SMILE and an RCM SMILE with all forcings, as well as a naturally forced GCM SMILE (nat-GCM) over the European domain. We utilise one of the key advantages of SMILEs, precisely separating the forced response and internal variability within an individual model to investigate a variety of simple questions. Broadly we show that the GCM can be used to investigate broad-scale patterns and can be directly compared to the nat-GCM to attribute forced changes to either anthropogenic emissions or volcanoes. The RCM provides high-resolution spatial information of both the forced change and the internal variability around this change at different warming levels. By combining all three ensembles we can gain information that would not be available using a single type of SMILE alone, providing a perspective on future research that could be undertaken using these tools.

When does mean winter snow depth change at Weissfluhjoch emerge from natural variability?

RCP8.5

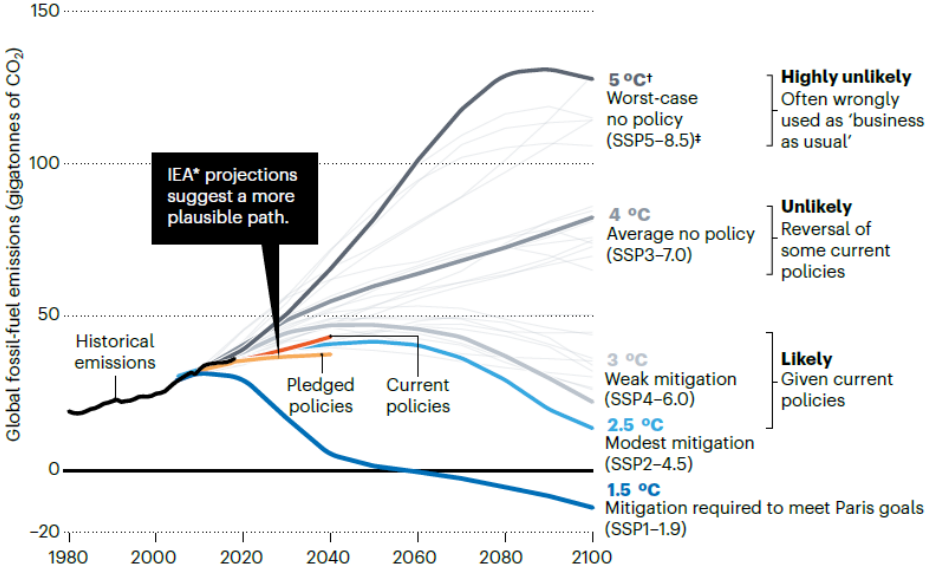


Talk
R. Ludwig

Interpretation of Emission Scenarios

POSSIBLE FUTURES

The Intergovernmental Panel on Climate Change (IPCC) uses scenarios called pathways to explore possible changes in future energy use, greenhouse-gas emissions and temperature. These depend on which policies are enacted, where and when. In the upcoming IPCC Sixth Assessment Report, the new pathways (SSPs) must not be misused as previous pathways (RCPs) were. Business-as-usual emissions are unlikely to result in the worst-case scenario. More-plausible trajectories make better baselines for the huge policy push needed to keep global temperature rise below 1.5 °C.



*The International Energy Agency (IEA) maps out different energy-policy and investment choices. Estimated emissions are shown for its Current Policies Scenario and for its Stated Policies Scenario (includes countries' current policy pledges and targets). To be comparable with scenarios for the Shared Socioeconomic Pathways (SSPs), IEA scenarios were modified to include constant non-fossil-fuel emissions from industry in 2018.
†Approximate global mean temperature rise by 2100 relative to pre-industrial levels.
‡SSP5–8.5 replaces Representative Concentration Pathway (RCP) 8.5.

Hausfather and Peters, Nature, 2020

D-A-CH Report on interpretation of the new SSP-RCPs


Empfehlungen
für die Charakterisierung
ausgewählter Klimaszenarien

Deutscher Wetterdienst
Wetter und Klima aus einer Hand
DWD
MeteoSchweiz
RheinlandPfalz
LANDESAMT FÜR UMWELT
Umwelt Bundesamt
KomPass
Internationales Institut für Angewandte Systemanalyse
IIASA www.iiasa.ac.at
ZAMG
LfU
Landesamt für Umwelt

Stand: 15. März 2022

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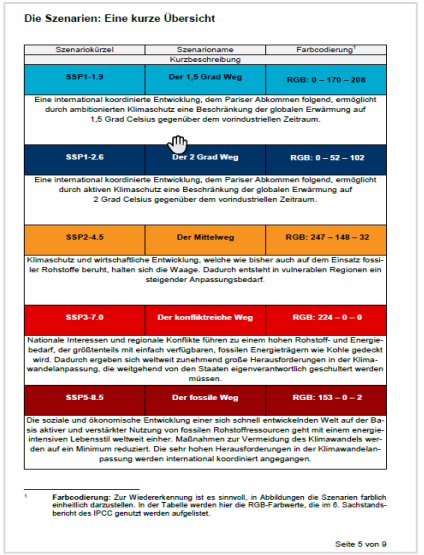
Die Szenarien: Eine kurze Übersicht

Szenariokürzel	Szenarioname Kurzbeschreibung	Farbcodierung[1]
SSP1-1.9	Der 1,5 Grad Weg	RGB: 0 – 170 – 208
Eine international koordinierte Entwicklung, dem Pariser Abkommen folgend, ermöglicht durch ambitionierten Klimaschutz eine Beschränkung der globalen Erwärmung auf 1,5 Grad Celsius gegenüber dem vorindustriellen Zeitraum.		
SSP1-2.6	Der 2 Grad Weg	RGB: 0 – 52 – 102
Eine international koordinierte Entwicklung, dem Pariser Abkommen folgend, ermöglicht durch aktiven Klimaschutz eine Beschränkung der globalen Erwärmung auf 2 Grad Celsius gegenüber dem vorindustriellen Zeitraum.		
SSP2-4.5	Der Mittelweg	RGB: 247 – 148 – 32
Klimaschutz und wirtschaftliche Entwicklung, welche wie bisher auch auf dem Einsatz fossiler Rohstoffe beruht, halten sich die Waage. Dadurch entsteht in vulnerablen Regionen ein steigender Anpassungsbedarf.		
SSP3-7.0	Der konfliktreiche Weg	RGB: 224 – 0 – 0
Nationale Interessen und regionale Konflikte führen zu einem hohen Rohstoff- und Energiebedarf, der größtenteils mit einfach verfügbaren, fossilen Energieträgern wie Kohle gedeckt wird. Dadurch ergeben sich weltweit zunehmend große Herausforderungen in der Klimawandelanpassung, die weitgehend von den Staaten eigenverantwortlich geschultert werden müssen.		
SSP5-8.5	Der fossile Weg	RGB: 153 – 0 – 2
Die soziale und ökonomische Entwicklung einer sich schnell entwickelnden Welt auf der Basis aktiver und verstärkter Nutzung von fossilen Rohstoffressourcen geht mit einem energieintensiven Lebensstil weltweit einher. Maßnahmen zur Vermeidung des Klimawandels werden auf ein Minimum reduziert. Die sehr hohen Herausforderungen in der Klimawandelanpassung werden international koordiniert angegangen.		

[1] **Farbcodierung:** Zur Wiedererkennung ist es sinnvoll, in Abbildungen die Szenarien farblich einheitlich darzustellen. In der Tabelle werden hier die RGB-Farbwerte, die im 6. Sachstandsbericht des IPCC genutzt werden aufgelistet.

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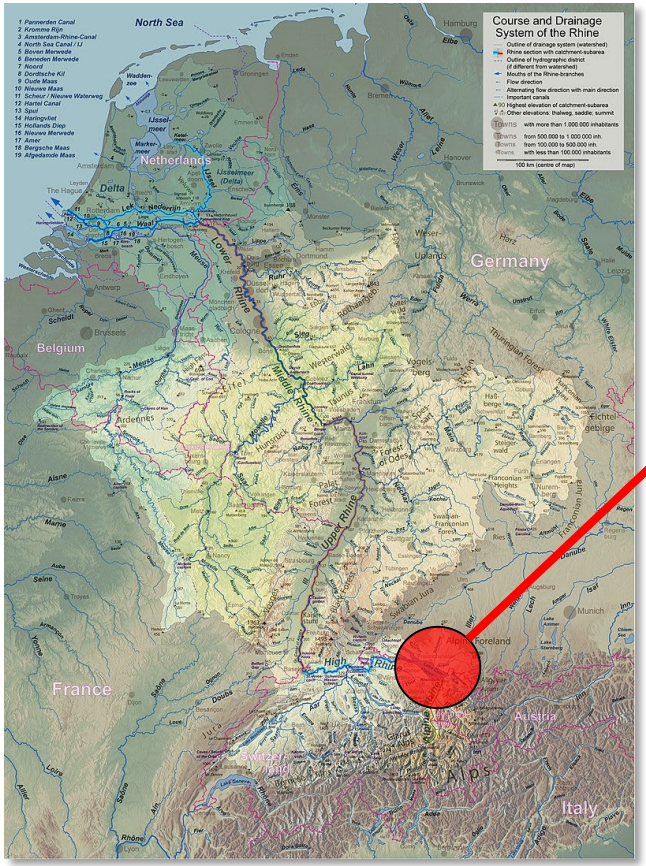
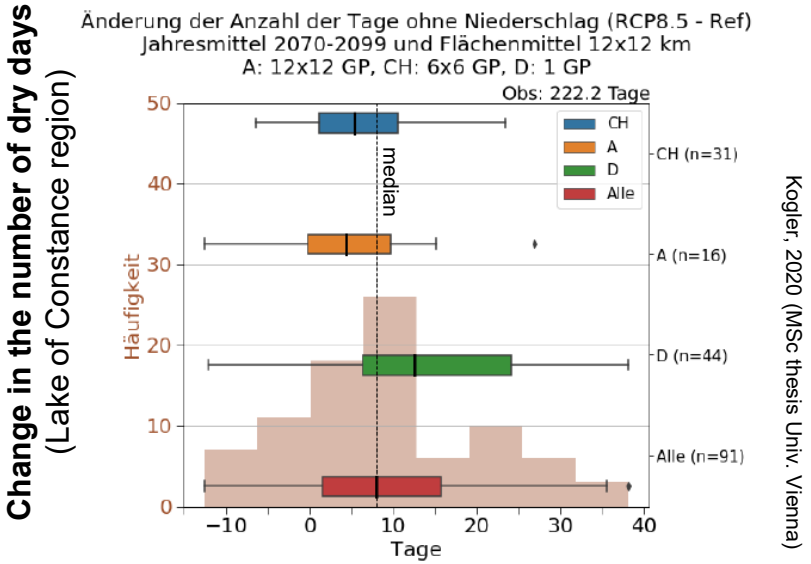
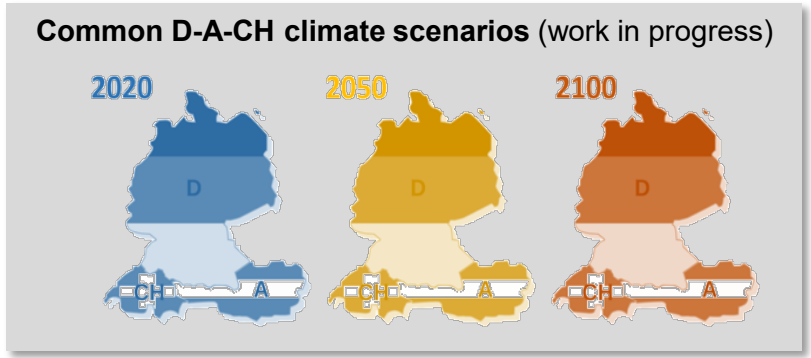
https://www.dwd.de/DE/klimaumwelt/klimawandel/klimaszenarien/ssp-generation.html

Transboundary Climate Scenarios



Source: en.wikipedia.org





Challenges ahead, but are (mostly?) known

- Research ongoing
- Don't forget *distillation and communication of limitations*
- Satisfying hydrologists as the *gold standard*
  → Co-production!

Thank You!