Group „Climate and Water Cycle“

Main research areas:
- radiation and water cycle
- high-resolution climate modeling
- representation of convection and turbulence
- climate change scenarios and impacts
- extreme events

Tools:
- global climate models (Δ=100-200km)
- regional climate models (12km-50km)
- convection-resolving models (1-2km)
- large-eddy simulation models (100m-2km)
- data analyses: radiation, precipitation, satellite products

Christoph Schär , ETH Zürich, February 2016

http://www.iac.ethz.ch/groups/schaer

Some ongoing key issues

Linkage between energy and water cycles

Solar radiation budgets and their changes in climate models and observations (dimming / brightening)

Numerical representation of convection and turbulence

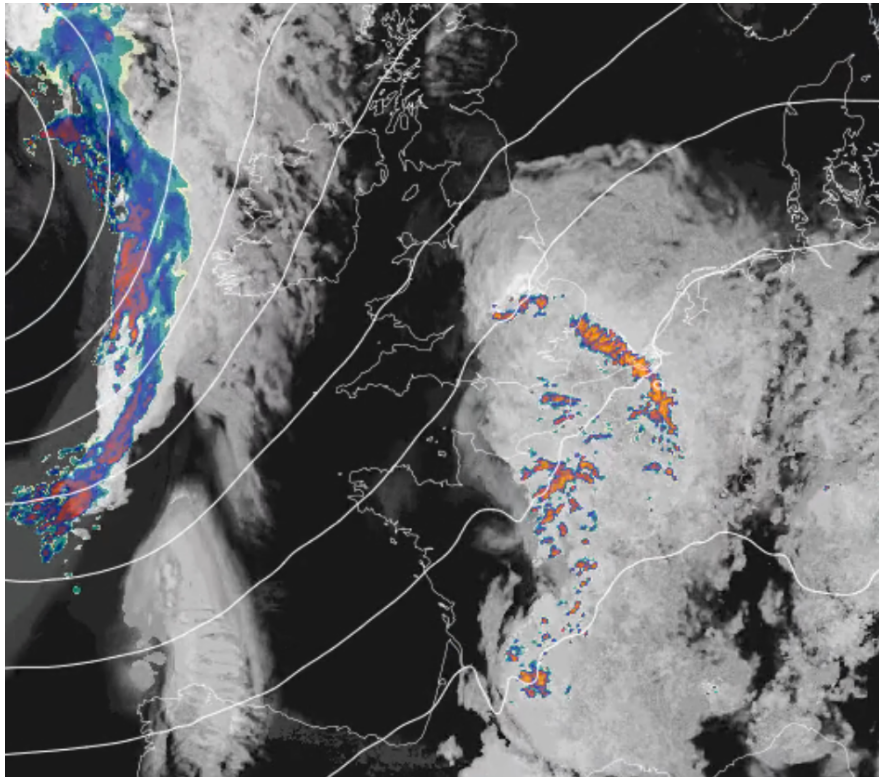
Development of new modeling capabilities:
- convection-resolving (Δ = 2 km), and
- large-eddy simulation modeling (Δ < 2 km)

Continental to Alpine-scale climate projections, with a focus on heat waves and heavy precipitation events over Europe

=> Following topics are ordered from small to large scale

Kilometer-scale simulations on Graphics Processing Units (GPUs)

Δ=2 km: Development for climate mode



Goals: Resolve convection on European scales with kilometer-scale simulations using GPUs.

MSc project will be embedded in an on-going effort to transfer and run the state-of-the-art weather and climate model COSMO to GPUs.

Requirements: Knowledge of FORTRAN or C++, motivation to learn tools related to HPC & GPUs.

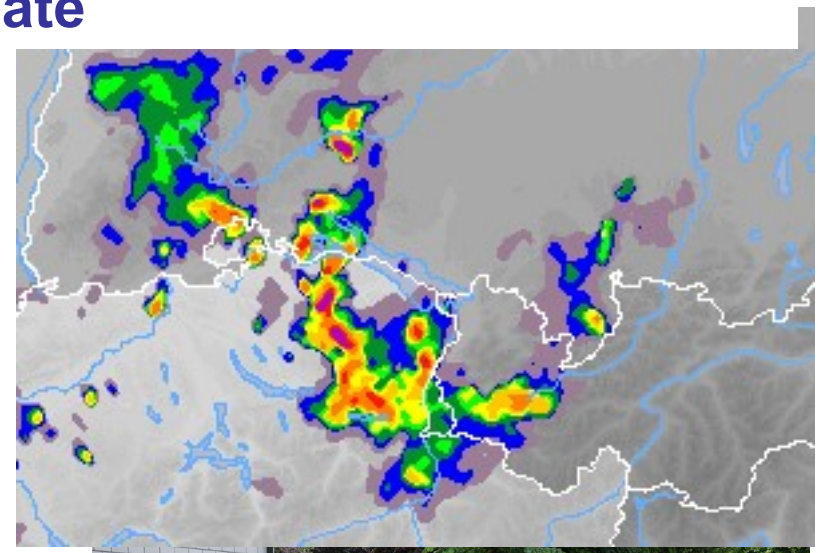
Supervisors: Oliver Fuhrer (MeteoSwiss) and David Leutwyler (ETH)

Clouds and precipitation in a simulation of July 2006

Piz Daint supercomputer @ CSCS

Δ=2 km:

Anatomy of heavy precipitation events in a changing climate



Analysis of high-resolution climate simulations over the Alps with Δ=2km.

Goal: Investigate the environment in which heavy precipitation events develop:

- Weather patterns
- Atmospheric conditions (humidity, stratification, CAPE/CIN, …)
- Changes of precipitation events

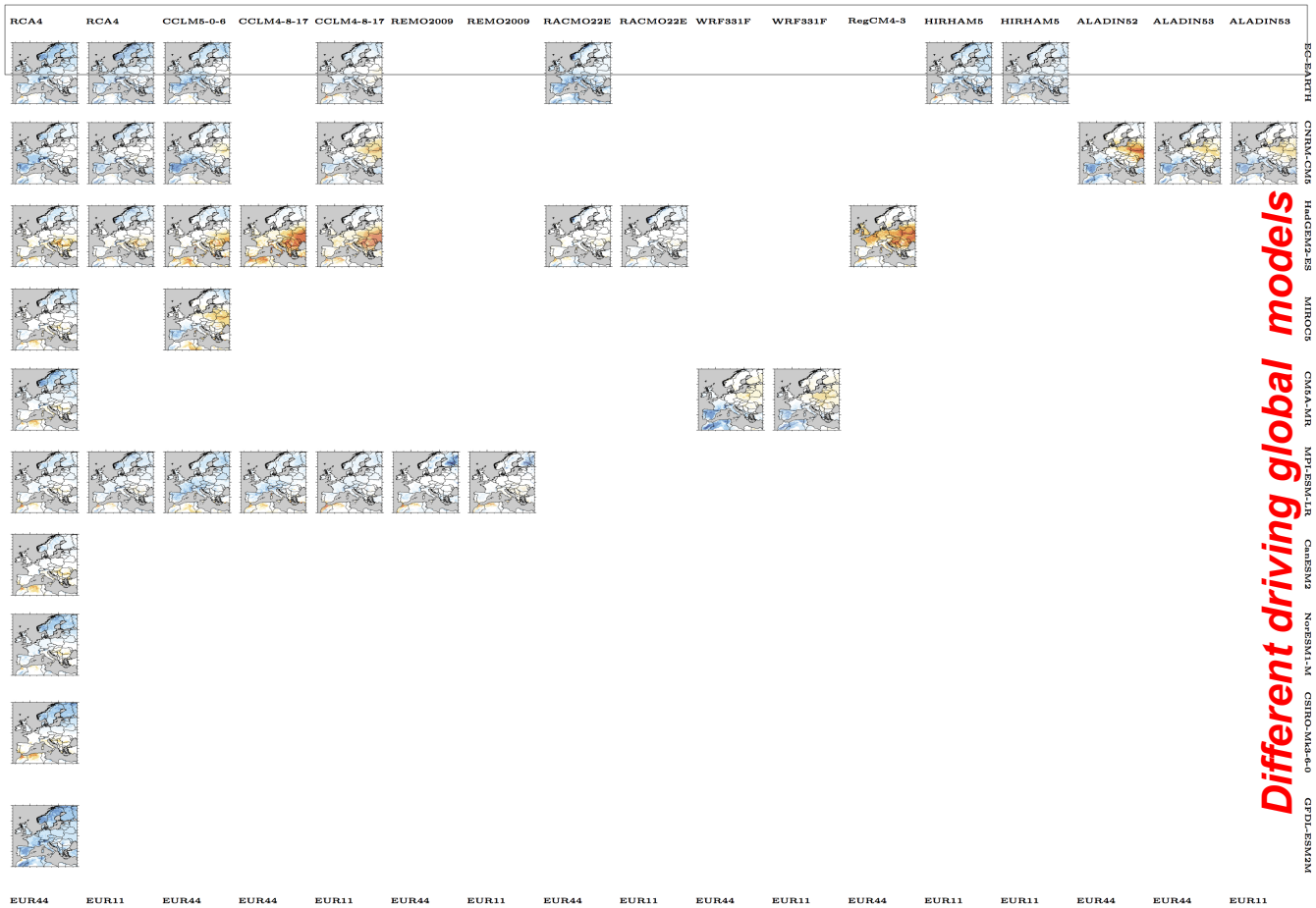
in a changing climate

Contact: Linda Schlemmer, Nikolina Ban (Start of the thesis: January 2018)

Δ=12 km: Analysis of a large ensemble of simulations

EURO-CORDEX regional climate model projections over Europe

Simulation matrix



Data:

- EURO-CORDEX (www.euro-cordex.net) provides new regional climate scenarios for the 21st century at resolutions of 12 km and 50 km.
- Large number of simulations are becoming available, among these some ETH simulations

Possible research topics:

Several different topics on validation and climate change projections

Contact: Silje Lund Sørland

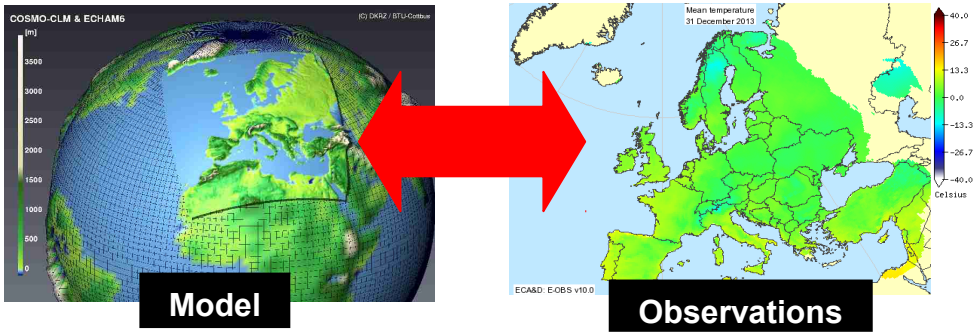
Δ=12 km: Analysis of a large ensemble of simulations

Changes in summer temperature variability over Europe

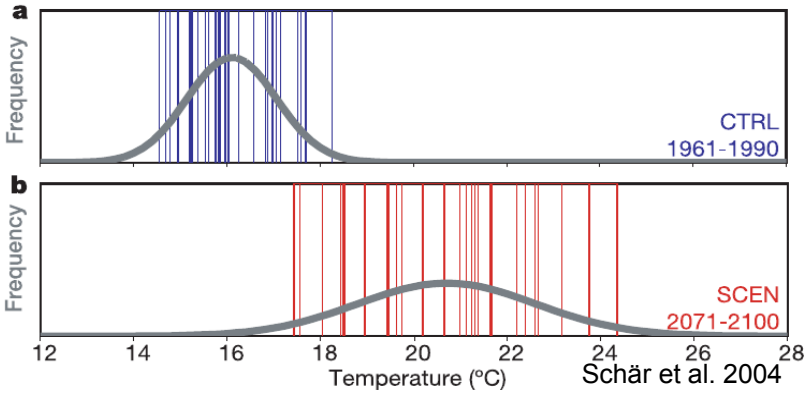
Motivation: Strong influence of European summer temperature variability on human society (crop yields, energy production...)

Main objectives:

1. Asses the performance of the new EURO-CORDEX multi model ensemble in simulating European temperature variability



2. Analyse the change signal of temperature variability in the 21th scenario simulations.

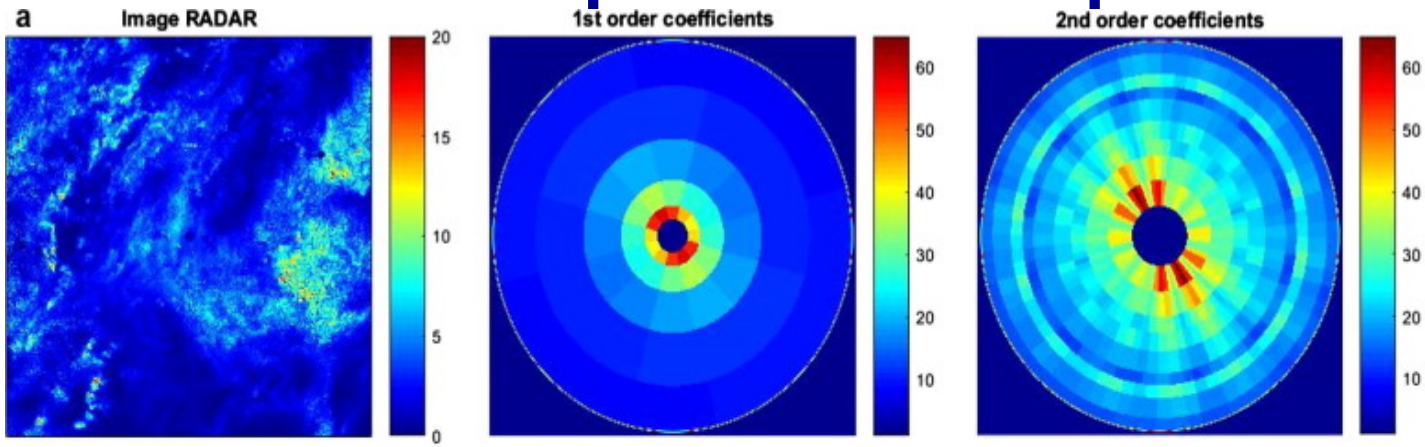


Schär et al. 2004

The work would mainly consist of data analyses using Matlab or Python and cdo (cf. Fischer et al. 2012)

Supervision: Nico Kröner, Jan Rajczak, Daniel Lüthi, Christoph Schär

Δ=12 km: How well do climate models reproduce the rainfall spatial and temporal structures?



Classification of rainfall radar images using the scattering transform (Lagrange et al., in press)

Spatial and temporal structures of rainfall at the mesoscale are often characterized using weather radar systems. Climate models are used to simulate the rainfall structure in a changing climate.

Main objectives of the MSc thesis

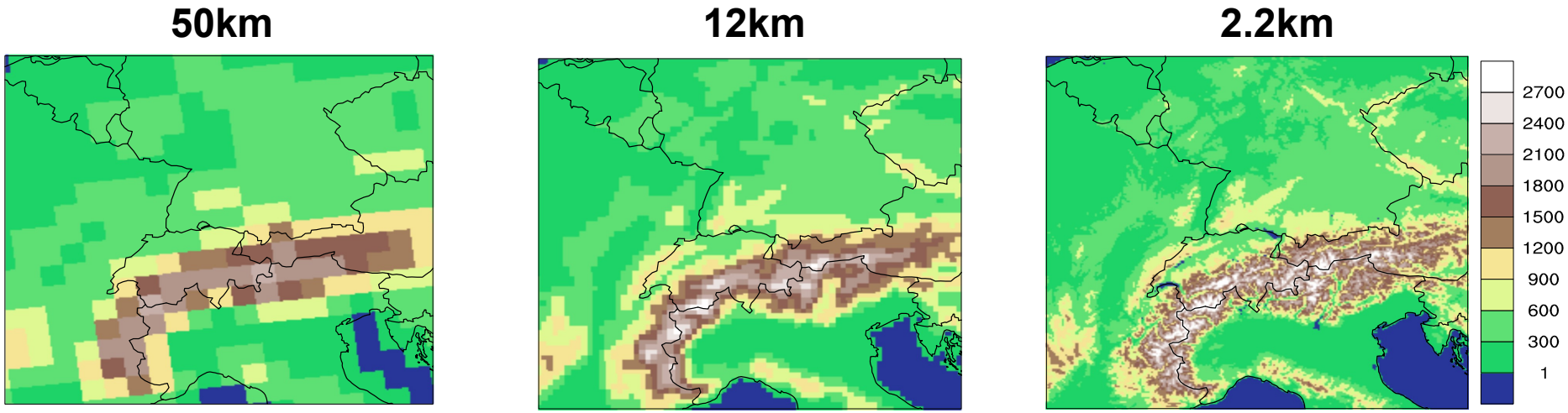
1. Evaluating the climate models ability in reproducing the rainfall structure for current climate.
2. Evaluating changes of future rainfall structure in Switzerland from regional climate model simulations.

Methods and data

1. Data to be used include: MeteoSwiss weather radar system, EURO-CORDEX multi model ensemble and a high-resolution climate model (e.g. Ban et al. JGR 2014; GRL 2015).
2. Rainfall spatial and temporal structures will be analysed using traditional statistical techniques and recent scattering transform methods.
3. The work would mainly consist of data analyses using Matlab.

***Contact: N. Peleg* (nadav.peleg@sccer-soe.ethz.ch), *P. Burlando* (paolo.burlando@ethz.ch), *C. Schär* (schaer@env.ethz.ch)**

Investigating the added value of an increased RCM resolution



Added value is expected with increased spatial resolution for precipitation, temperature, wind, snow dynamics and other near surface parameters.

A set of climate simulations with horizontal resolution of 50km, 12km and 2.2km has been performed and is available in our group (see e.g., Ban et al., 2014 JGR, Ban et al., 2015 GRL, Leutwyler et al., 2016).

DRIVING DATA	RESOLUTION		
Evaluation 1998-2007 (ERA-INTERIM)	50km	12km	2.2km
GCM historical 1991-2000 (MPI-ESM-LR)	50km	12km	2.2km
GCM RCP8.5 2081-2090 (MPI-ESM-LR)	50km	12km	2.2km

Several potential master thesis topics,

- **What is the added value of an increased horizontal resolution on elevation-dependent parameters (temperature, snow, etc.)?**
- **How does the projected climate change signal compare between different resolutions?**
- **What can coarse-resolution simulations tell us about high-elevation changes?**

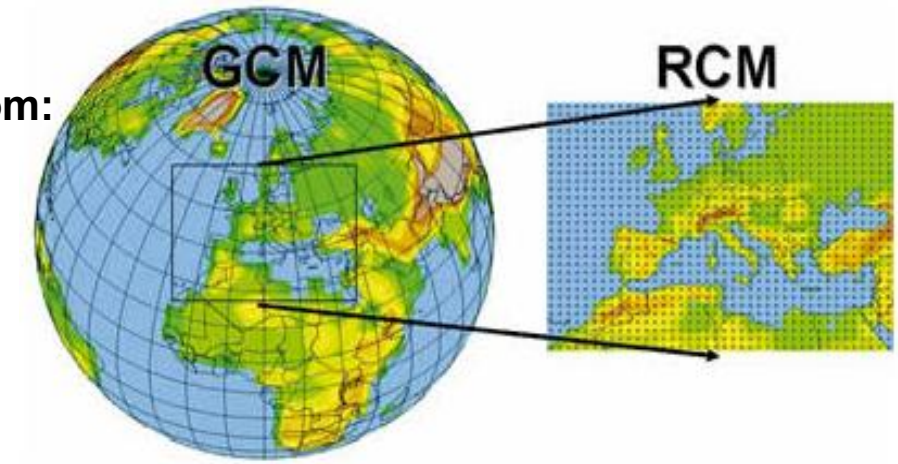
<u>Supervisors</u>: Silje Soerland, Nikolina Ban, Daniel Lüthi, Sven Kotlarski, Christoph Schär

Δ=50 km: Investigating internal variability in a millennium simulation

Motivation:

The uncertainty in regional climate prediction comes from:

- **scenario uncertainty**
- **model uncertainty**
- **internal variability**



Data:

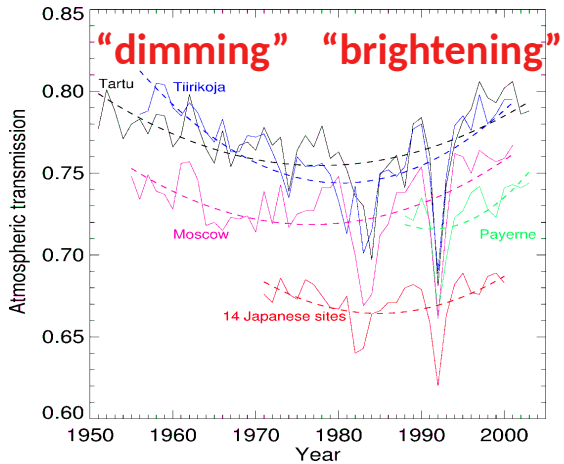
- **A GCM is dynamical downscaled for 1000 years over Europe, with the regional model COSMO-CLM at 50km horizontal resolution.**
- **The simulation is from an experiment where all the forcings (this includes natural, GHG and aerosol forcings) are kept fixed at levels of 1850 (the preindustrial level). *i.e. the simulation shows what we should expect from internal variability alone.***

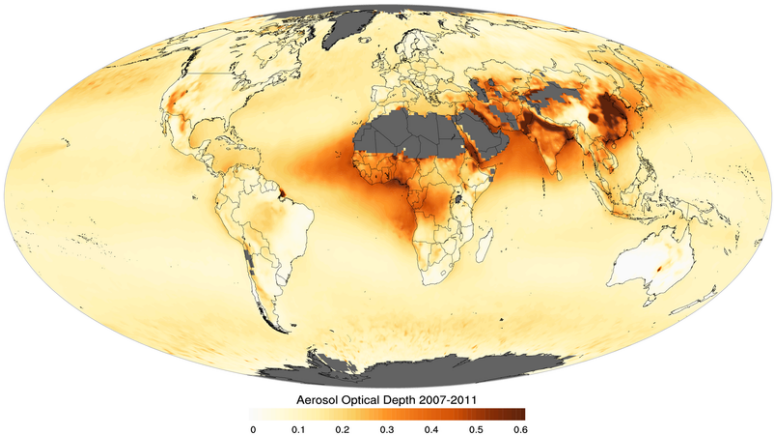
Possible research topics:

- **Evaluation of the millennium simulation: How is the climate in the millennium simulation?**
- **Comparing the millennium simulation with traditional transient climate simulations (historical and future scenario, i.e. 1950-2100). Does projected climate change exceed what we would expect from internal variability over the last centuries?**

Contact: Silje Lund Sørland, Jan Rajczak, Christoph Schär

Global scale: Earth radiation budget & climate change





Motivation:

Radiation budget is a main determinant of surface climate and climate change

Different topics:

- Solar radiation budgets and their changes in climate models and observations ("dimming / brightening")
- Continental scale energy budgets and their changes

Models and data to be studied:

- Regional / Global Climate Models used at ETH
- Regional / Global Climate Models used in IPCC AR5
- ECMWF/NCEP Reanalyses
- Surface and satellite radiation observations

Supervisors: Martin Wild, Doris Folini

Global scale: Radiation & climate change:
How is climate change affecting solar power generation?

Motivation: Solar power is a crucial technology for clean and sustainable energy with tremendous growth rates. But how will it be affected by climate change?

Objectives and methods:

- Projected change of surface insolation on monthly basis in Europe, based on climate models used at ETH IAC and IPCC AR5
- Input projections into PV generation model used at ETH IED (www.renewables.ninja)
- Determine implications for planning the European energy transition: how will variability change, and thus e.g. requirements for storage or transmission?

Supervisors: Martin Wild, Doris Folini, Stefan Pfenninger (IED Climate Policy)