ECRA Collaborative Program

Changes in the hydrological cycle

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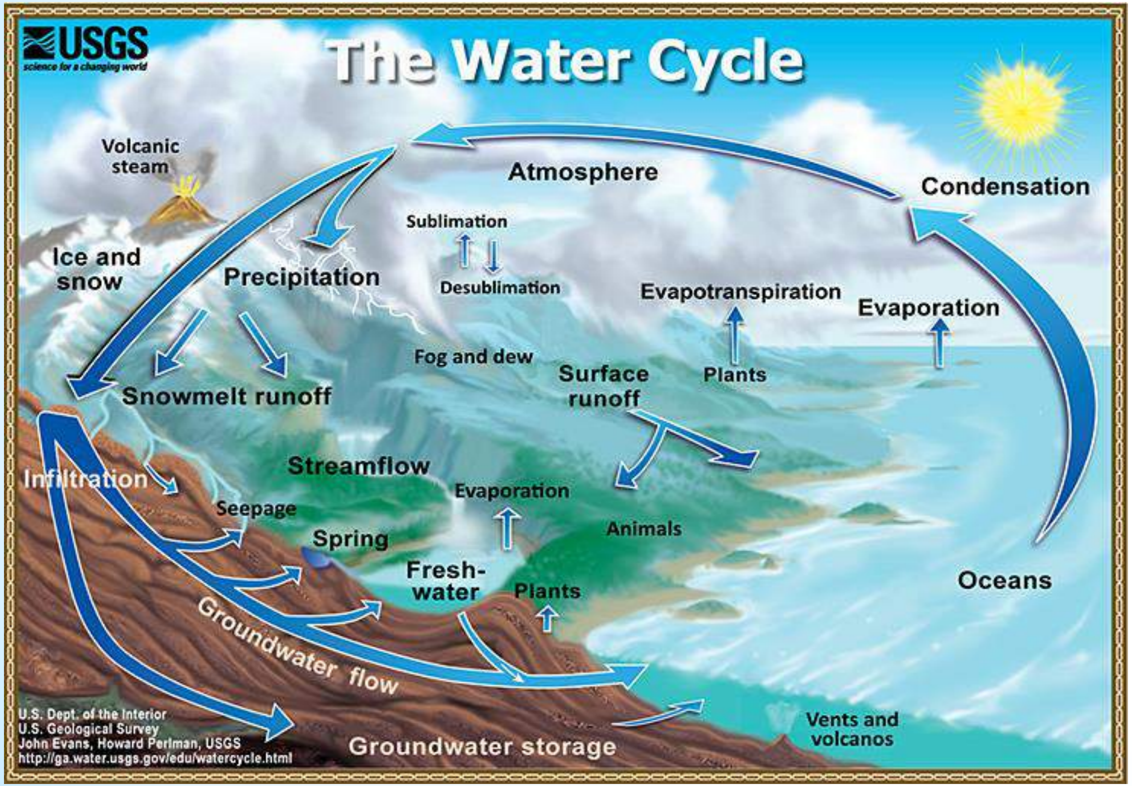
Changes in the hydrological cycle



Changes in the hydrological cycle are due to

- *Climate change*
- *Changes in ocean and atmospheric circulation*
- *Changes in atmospheric composition*
- *Changes in the land use / land cover*
- *Changes in terrestrial and marine vegetation*
- *Changes in subsurface water distribution*

and, in turn, they affect climate dynamics

Changes in the hydrological cycle

The components of the hydrological cycle react in a different way to climate change, sometimes amplifying sometimes dampening each other's action → **feedback loops**.

Variations in the hydrological cycle often take place at **regional and local scales** (such as variations in ecosystem composition or runoff processes) but can **trigger modifications at larger scales** possibly leading to global changes in the water cycle → **cross-scale interactions**

Changes in the hydrological cycle-CP

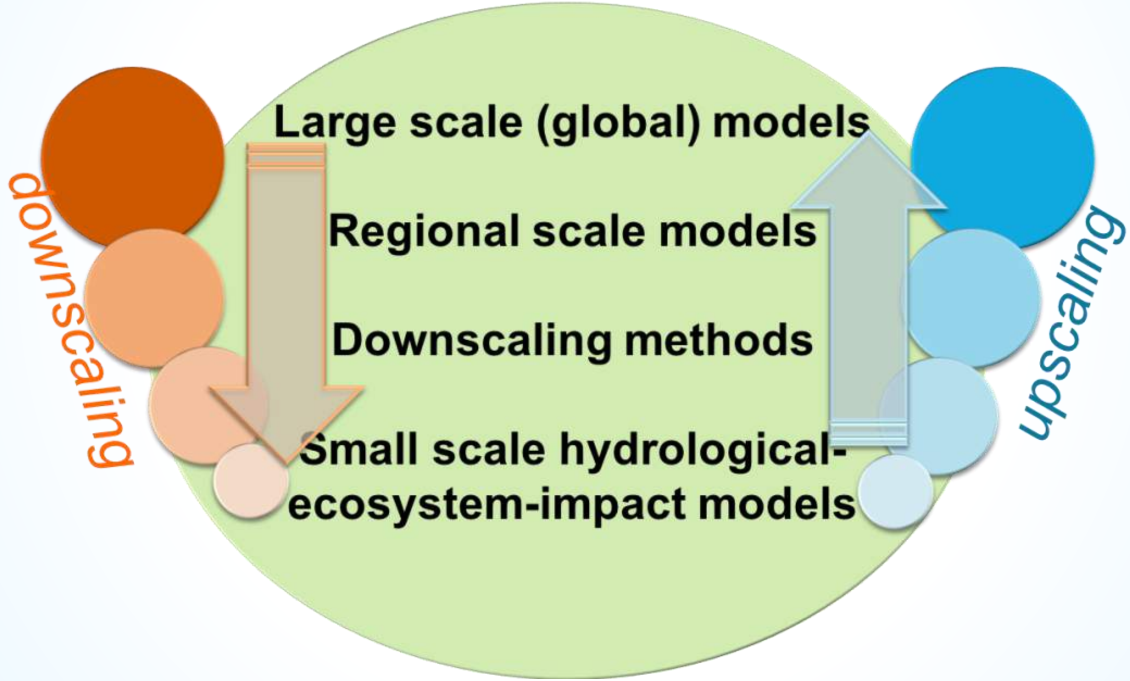
This CP fosters the study of

changes in the hydrological cycle and its impacts at global and regional scales

and aims at

- **improving the scientific understanding of hydrological processes under modified climatic conditions and of their effects**
- **adopting a multi- and trans- disciplinary perspective**

Changes in the hydrological cycle-CP



Selected topics of the CP

Interaction between climate and hydrological/land surface processes

Changes in the hydrological cycle of hot-spot regions (Mediterranean region and mountain areas)

Assessing the impacts of natural variability and climate change on precipitation and runoff

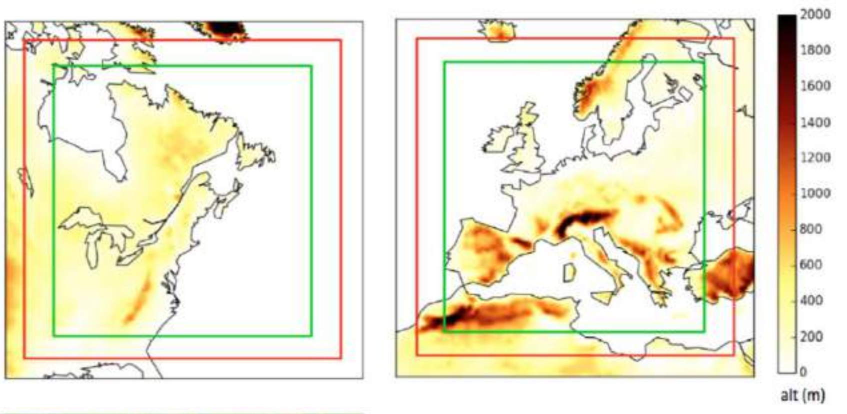
- large scale single-model ensembles
- changes in precipitation (volumes, extremes)
- changes in weather patterns

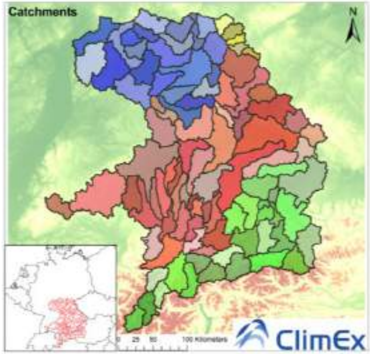
→ non-linear impacts on runoff and other feedbacks on/with hydrological quantities

Topic-Hydrological Impact

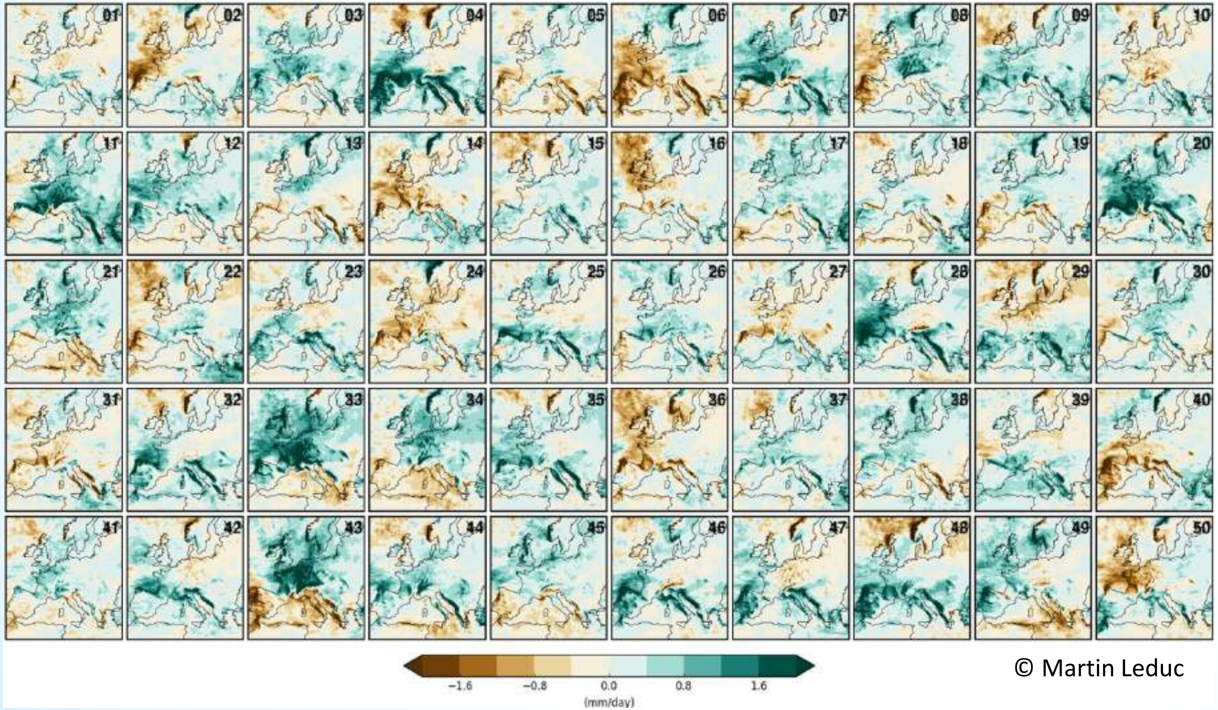
Example: The ClimEx-project (www.climex-project.org)

- 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 extremes events and provide robust estimates of floods and droughts





Topic-Hydrological Impact



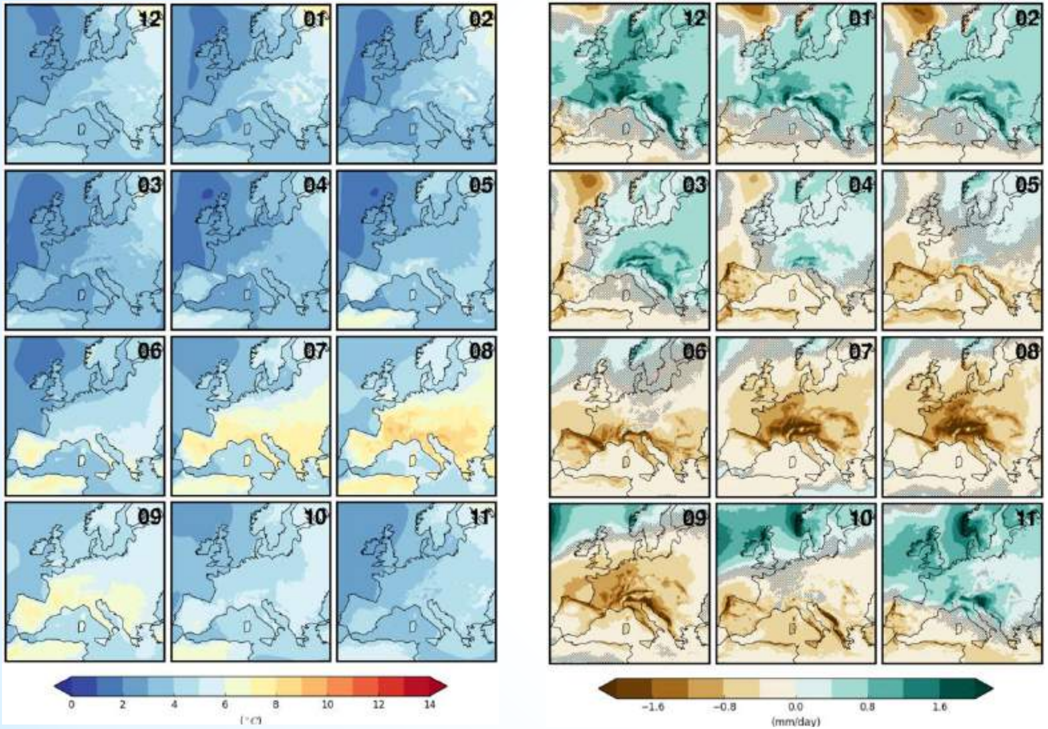
50 possible future changes for PRC (in %) between 2020-2039 and 2000-2019 over Europe from CanESM2-CRCM5 at a 12-km resolution

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°), transient climate dataset (1951-2100)

ECRA European Climate Research Alliance CP-CHC Collaborative Programme Changes in the Hydrological Cycle

ECRA European Climate Research Alliance

Topic-Hydrological Impact



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

Mean monthly signals from the large ensemble:

- strong temperature increase in all months, particularly during summer months over central and southern Europe
- Strong precipitation increase in the winter
- Extreme precipitation decline, particularly during summer months over central and southern Europe

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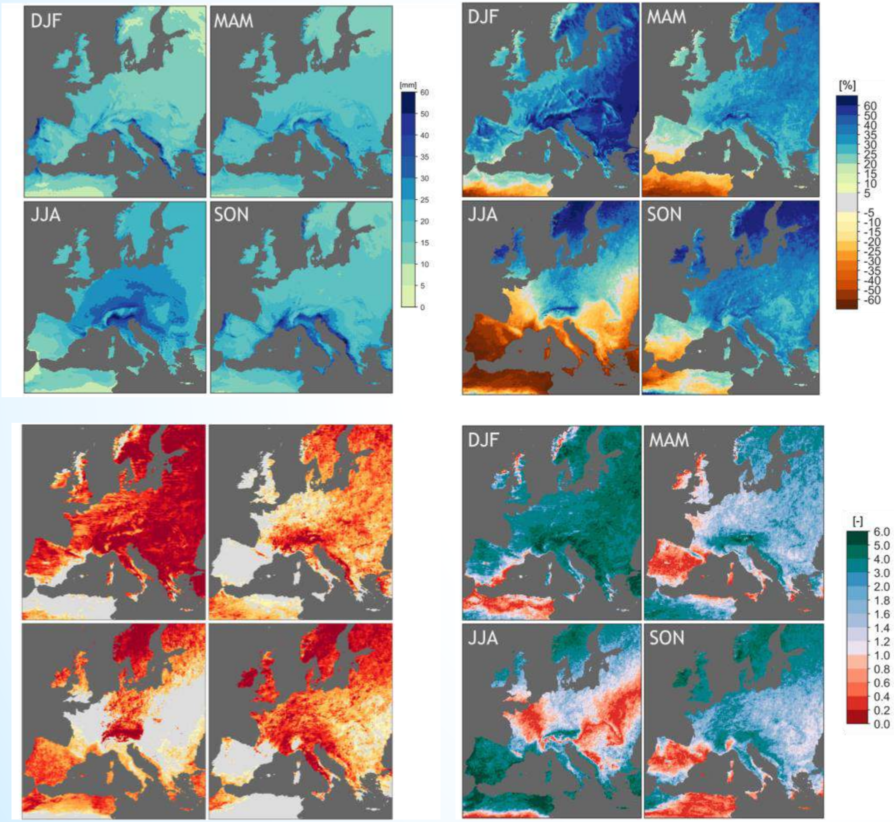
Collaborative Programme Changes in the Hydrological Cycle

Topic-Hydrological Impact



© Raul Wood

Maximum 3h-precipitation (Rx3h)

a) seasonal distribution over Europe (reference period 1980-2009)

b) climate change signal (%) (future period 2070-2099)

c) strong geographical differences in S/N – Ratio (2070-2099)

d) calculation of Time of Emergence (when S/N >1)

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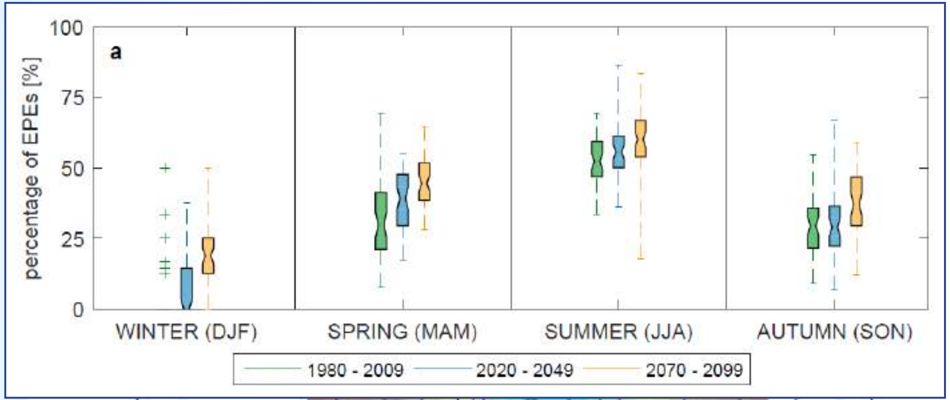
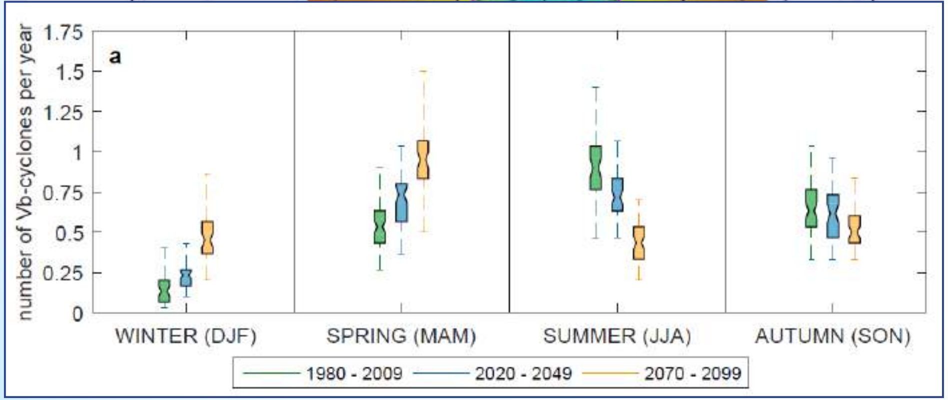
Topic-Hydrological Impact

Using Machine Learning to Detect Weather Patterns – e.g. Vb-cyclones



Increasing relevance for extreme precipitation events (EPE) linked to Vb-tracks in all seasons



Significant seasonal shifts of Vb-related EPEs from summer to spring

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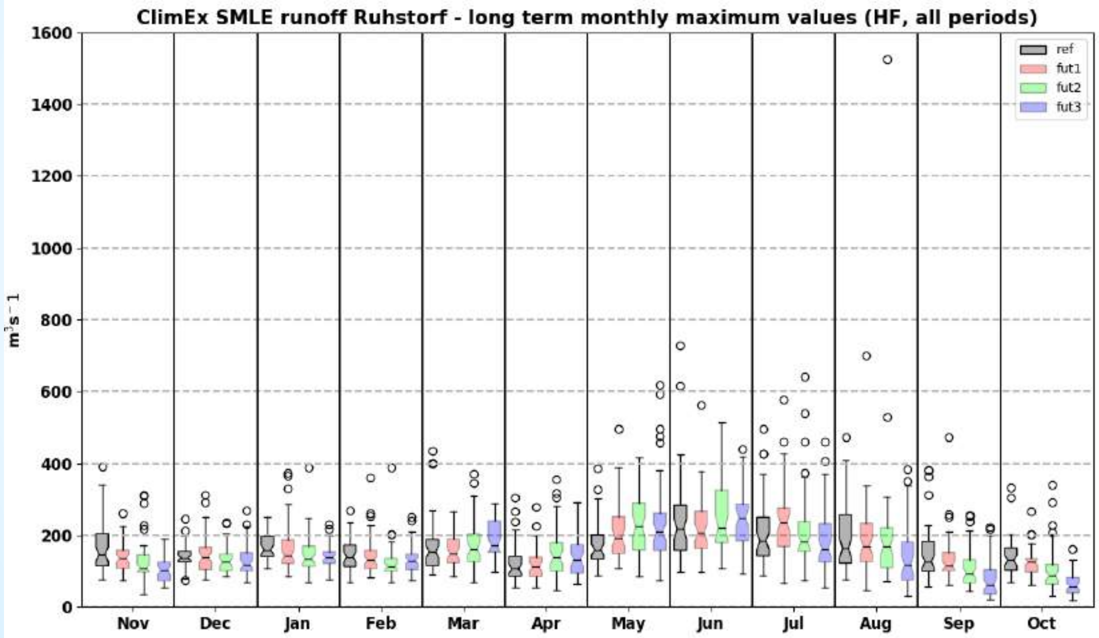
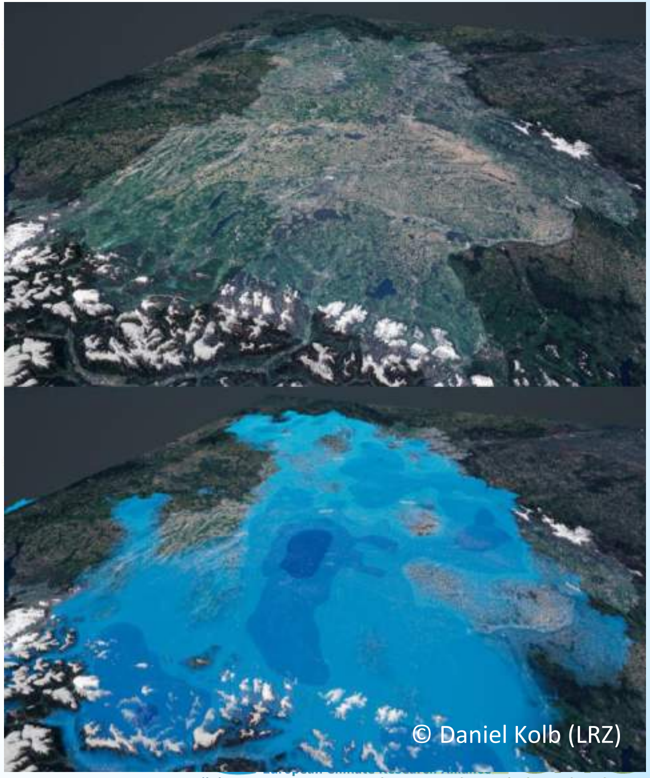
Topic-Hydrological Impact

Hydrological model application – detection of extreme flood events…



© Florian Willkofer



Example: River Rott (Ruhstorf = 1049 km²);
MQ 9.2 m³/s - MHQ 124 m³/s - HQ 295 m³/s HQ20 250 m³/s

Selected topics of the CP

Interaction between climate and hydrological/land surface processes

Changes in the hydrological cycle of hot-spot regions (Mediterranean region and mountain areas)

Changes in the Hydrological cycle in mountains

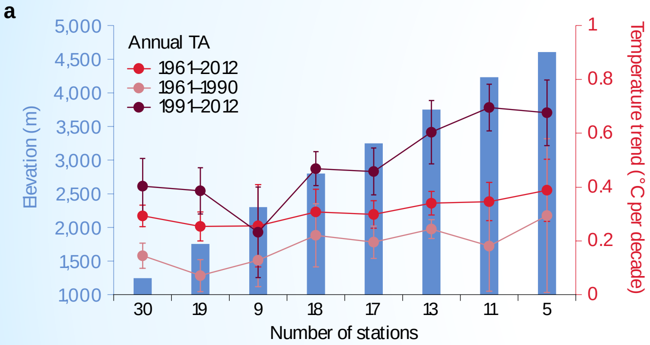
- Elevation Dependent Warming
- Changes in precipitation (phase, extremes)
- Sub-surface water and changes in aquifers

Impacts

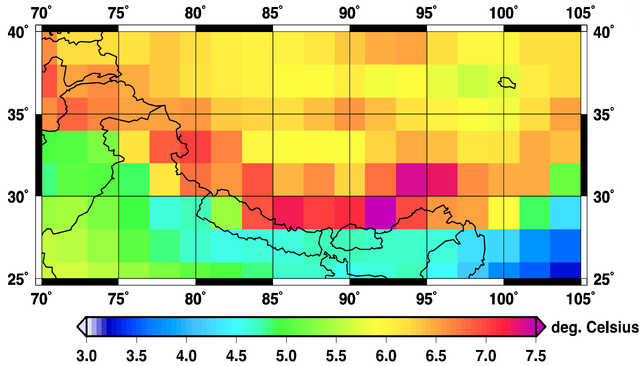
- Glacier retreat, loss of water reservoirs
- Decrease of duration and thickness of snow cover and effects on ecosystems and river runoff
- Permafrost degradation

Topic-Mountains

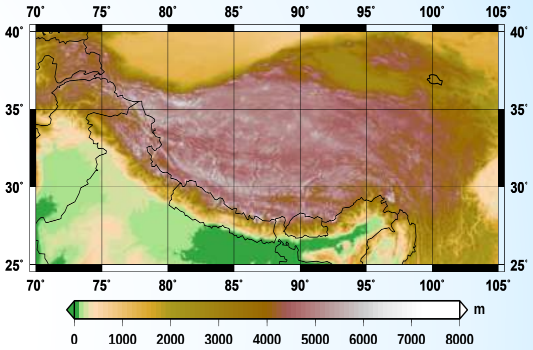
Elevation-Dependent Warming

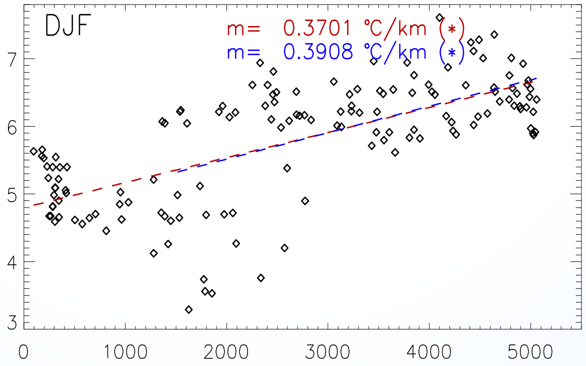


Pepin et al 2015: Elevation-dependent warming in mountain regions of the world, Nature Climate Change 5, 424–430 (2015) doi:10.1038/nclimate2563



Topography of the Study Area





- **Snow-albedo feedback**
- **Increase in specific humidity and in downwelling longwave radiation** (important in dry high elevations)

Palazzi, E., Filippi, L. & von Hardenberg, J. Clim Dyn (2016). doi:10.1007/s00382-016-3316-z

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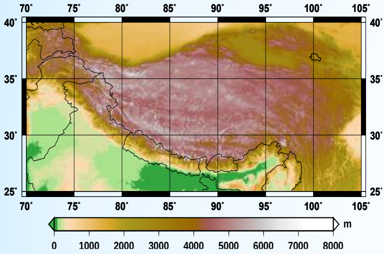
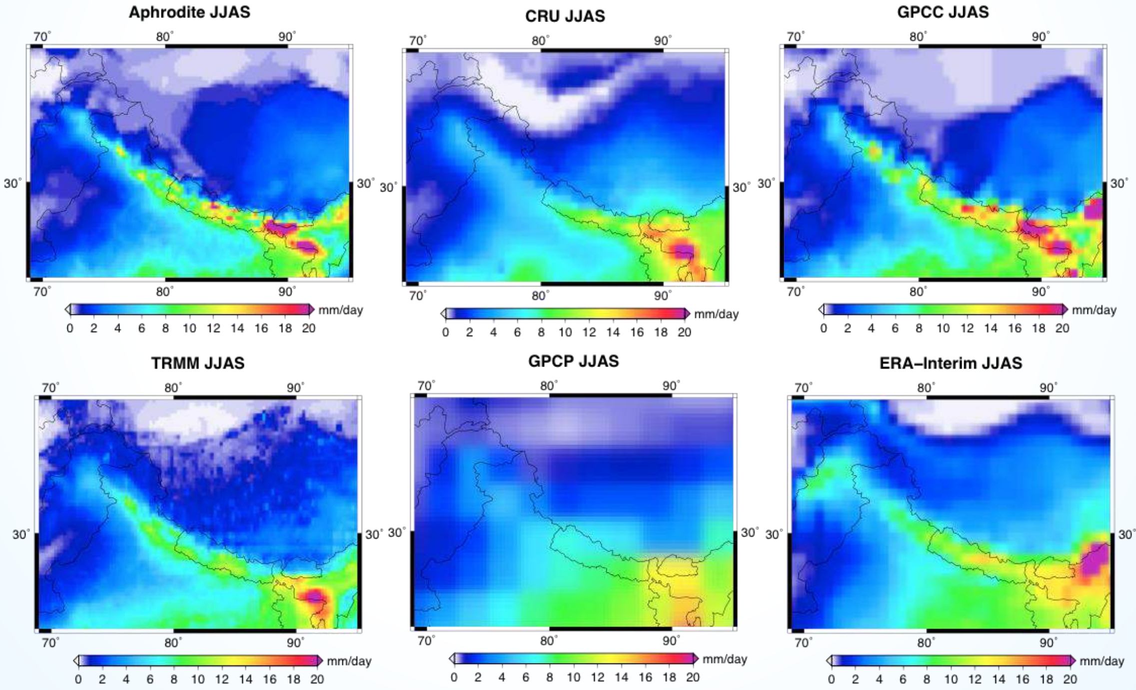
Topic-Mountains

Precipitation

Topography of the Study Area



Multiannual average 1998-2007



Observations

Gridded station data

Satellite data

Merged data

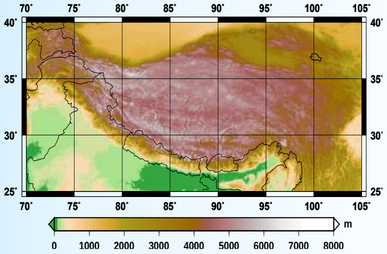
Reanalyses

Palazzi et al., "Precipitation in the Hindu-Kush Karakoram Himalaya: observations and future scenarios", JGR (2013).

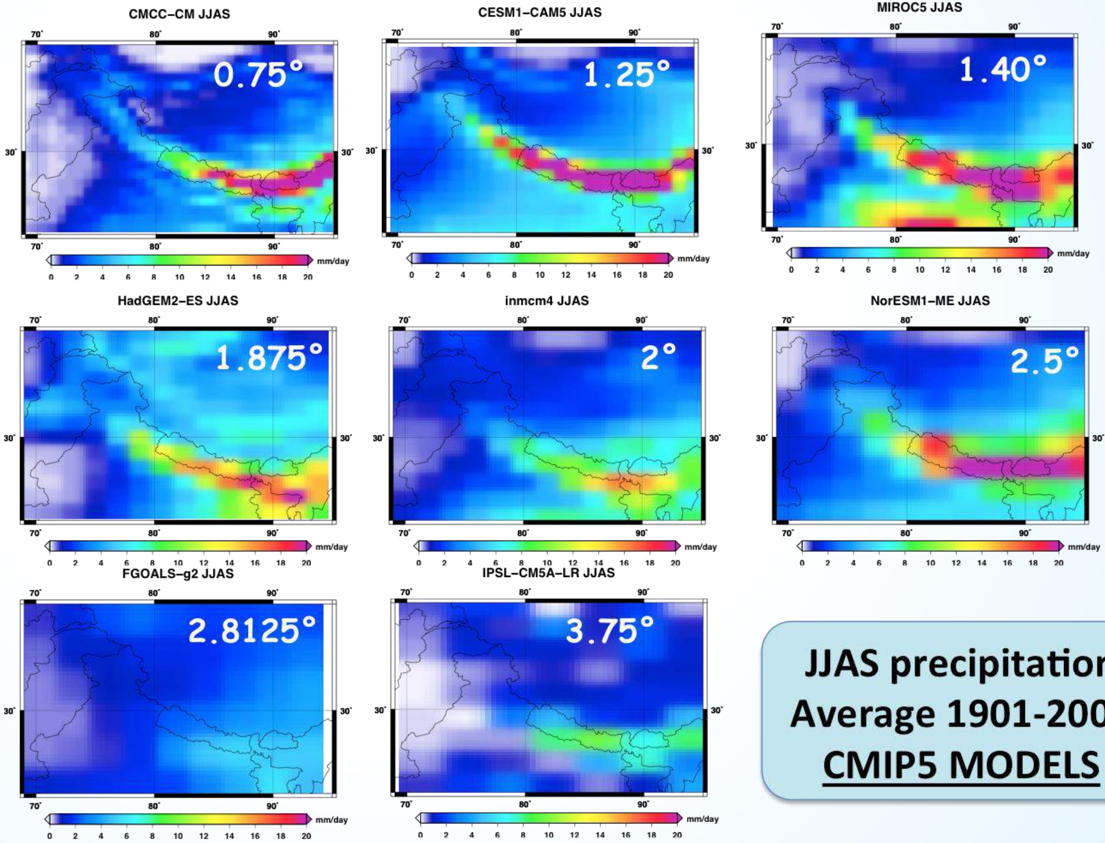
Topic-Mountains

Precipitation

Topography of the Study Area



CMIP5 Models

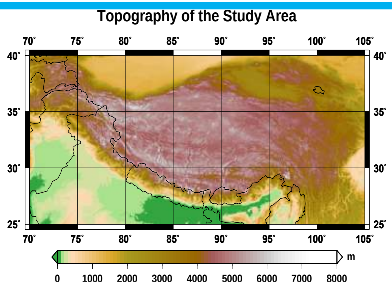


JJAS precipitation
Average 1901-2005
CMIP5 MODELS

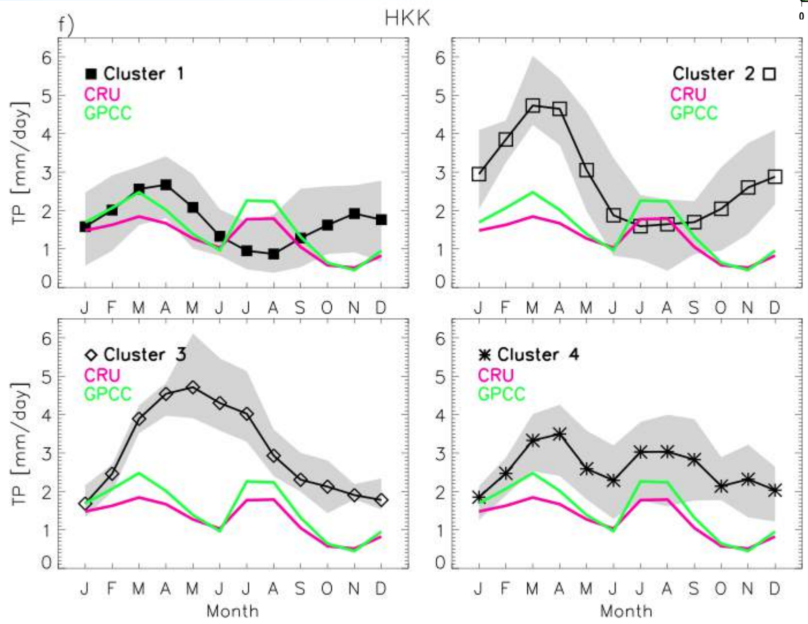
Topic-Mountains

Precipitation

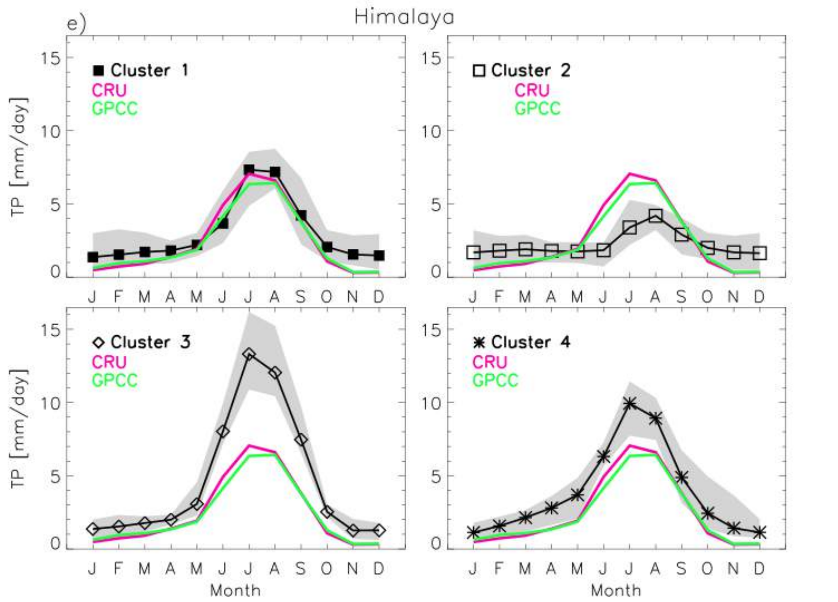
Palazzi, E., von Hardenberg, J., Terzago, S., Provenzale, A.. Clim Dyn (2015) 45: 21. doi:10.1007/s00382-014-2341-z



Hindu-Kush Karakoram

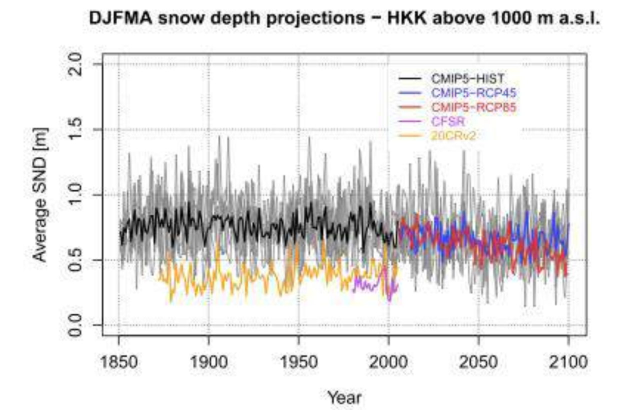


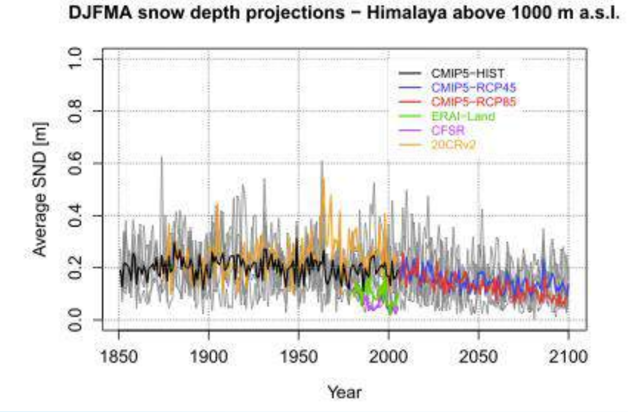
Himalaya

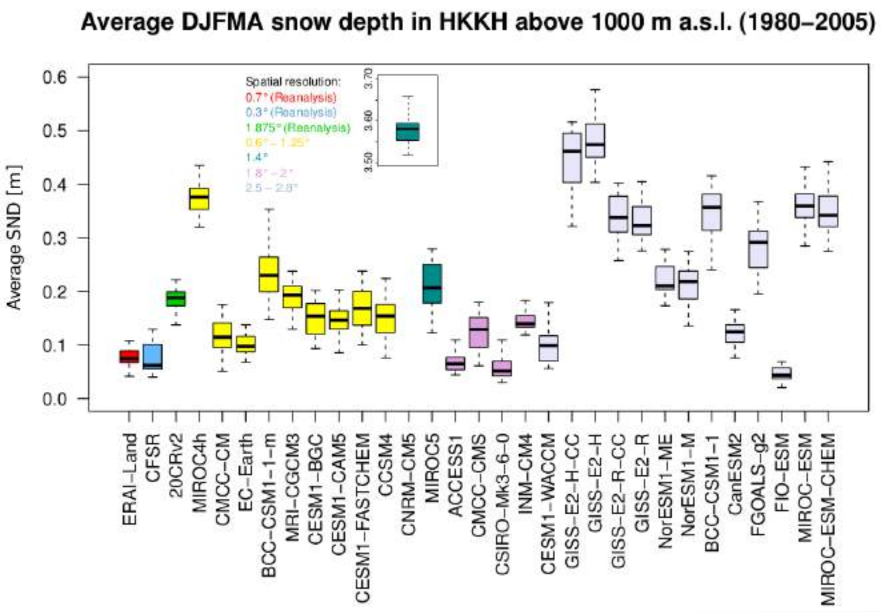


Topic-Mountains

Snow water equivalent





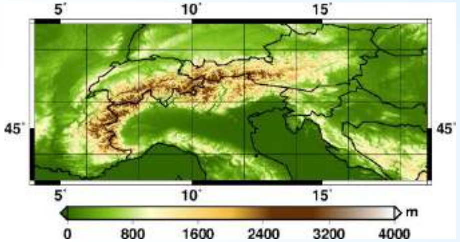


Terzago, S., J. von Hardenberg, E. Palazzi, and A. Provenzale (2014), Snowpack changes in the Hindu-Kush Karakoram Himalaya from CMIP5 Global Climate Models, J. Hydrometeorol., 15 (6), 2293-2313

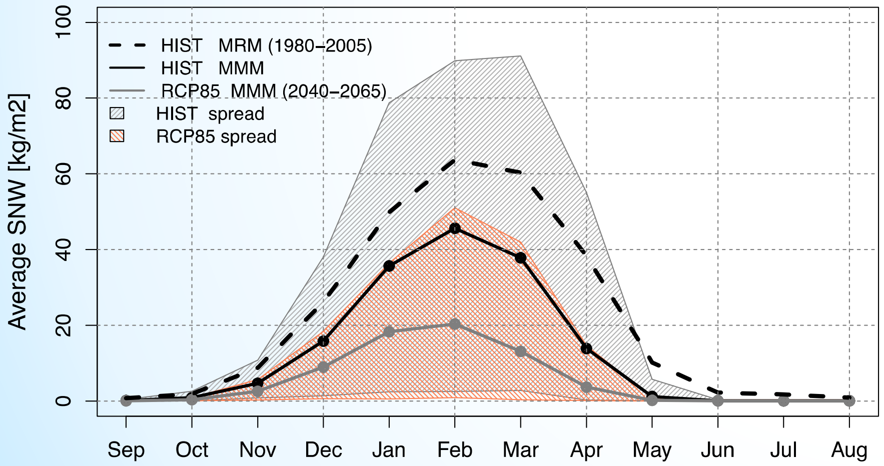
Topic-Mountains

Snow

Terzago, S., von Hardenberg, J., Palazzi, E., and Provenzale, A.: Snow water equivalent in the Alps as seen by gridded datasets, CMIP5 and CORDEX climate models, The Cryosphere Discuss., doi:10.5194/tc-2016-280, in review, 2017

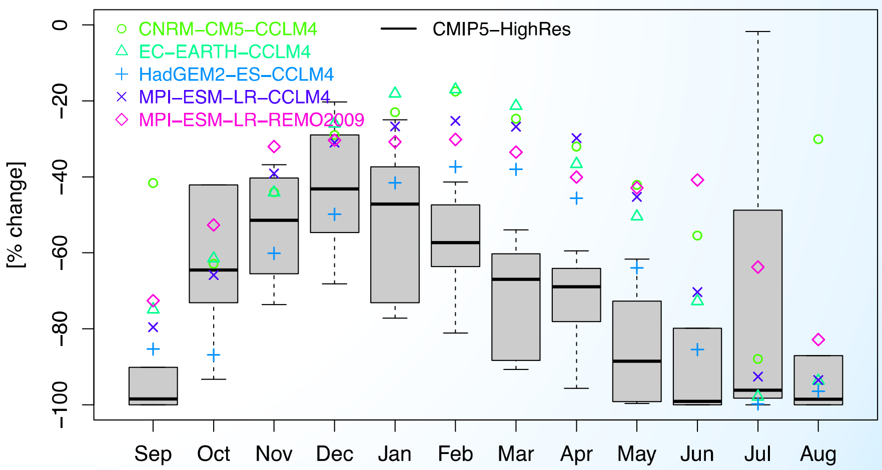


Future SNW annual cycle (2040–2065, RCP8.5)



(a)

SNW % change (2040–2065, RCP8.5) – GCMs vs RCM



(b)

Current needs

To analyse the changes and uncertainties in the global water cycle we require **global data sets**

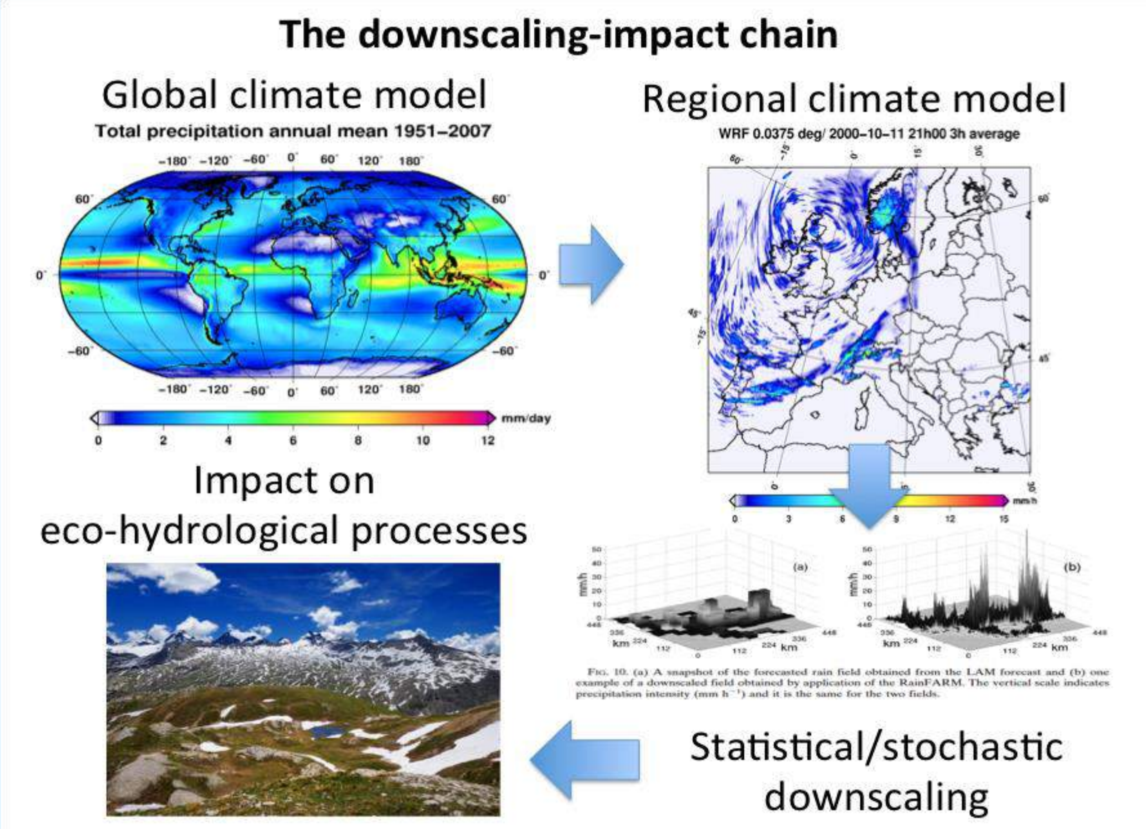
- **Long-term in-situ observations and satellite data**

- **Numerical models of the climate system**

to test and improve our understanding of the physical processes that drive the climate system, identify feedbacks, make future projections

Observations and models have strengths and uncertainties → integrated approach

Modelling chain and uncertainties



- Propagation of the uncertainty along the modelling chain

- The role of observations

International links, connections

H2020 ECOPOTENTIAL (ECOPOTENTIAL: improving future ecosystem benefits through earth observations)

H2020 CRESCENDO (Coordinated Research in Earth Systems and climate: experiments, knowledge, dissemination and outreach)

H2020 PRIMAVERA (PRocess-based climate sIMulation: AdVances in high resolution modelling and European climate Risk Assessment)

International links, connections

Copernicus "Development of C3S software for data analysis from climate models"

GMES (Global Monitoring of the Environment and Security, EC+ESA+EEA)

GEO-GNOME (The Global Network for observation and information in the mountain environments), a GEO/GEOSS Initiative (2017-2019**)**

Belmont Forum CRA "Mountain as Sentinels of Change"

Contribution to COST Action proposal CATCH-ME "Dynamically **C**oupled ocean **AT**mospheri**C**-**H**ydrologic **M**odeling for **E**nhanced Predictions"

International links, connections

Sessions/meetings @EGU 2019 of interest for this CP

SMI13 SPLINTER MEETING organized by Elisa Palazzi and Ralf Ludwig
Changes in the Hydrological Cycle - a Collaborative Programme of the European Climate Research Alliance (ECRA)
Convener: Elisa Palazzi | Co-convener: Ralf Ludwig, **Wed, 10 Apr, 19:00–20:00, Room 2.61**
CL4.30

Mountain climatology and meteorology
Co-organized as AS4.47/CR1.13/HS11.22
Convener: Sven Kotlarski | Co-conveners: Andreas Gobiet , Elisa Palazzi , Wolfgang Schöner , Stefano Serafin , Ivana Stiperski, Tue, 09 Apr, 10:45–12:30 (poster) and 16:15–18:00 (oral)

Large Ensemble Climate Model Simulations: Exploring Natural Variability, Change Signals and Impacts
Co-organized as AS4.35/CL3.08/HS4.1.4
Convener: Nicola Maher | Co-conveners: Ralf Ludwig , Emma Aalbers , Sebastian Milinski
Wed, 10 Apr, 08:30–12:30 (oral) and 14:00–15:45 (poster)