



ECRA General Assembly 2017

“Climate Change and Vulnerable Regions”

07-08 March 2017

Square Brussels Meeting Centre

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ECRA Collaborative Program

“Changes in the Hydrological Cycle”

Elisa Palazzi (CNR, Italy) & Ralf Ludwig (LMU, Munich)

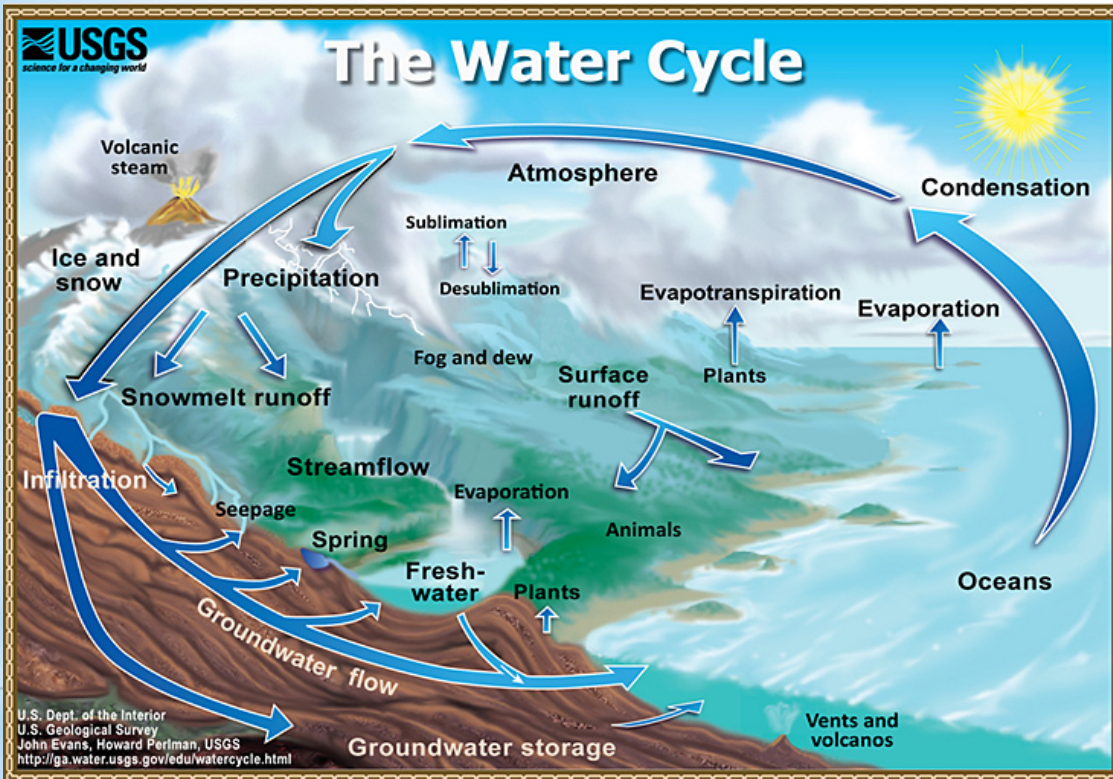
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Changes in the Hydrological Cycle

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, affect climate dynamics



Changes in the Hydrological Cycle

The components of the hydrological cycle react in a different way to climate change, sometimes **amplifying each other's action**, sometimes giving rise to **negative feedbacks**.

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.

Changes in the Hydrological Cycle

This Collaborative Programme
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.**

Changes in the Hydrological Cycle

Current needs

To provide unambiguous analysis of 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, predict future changes

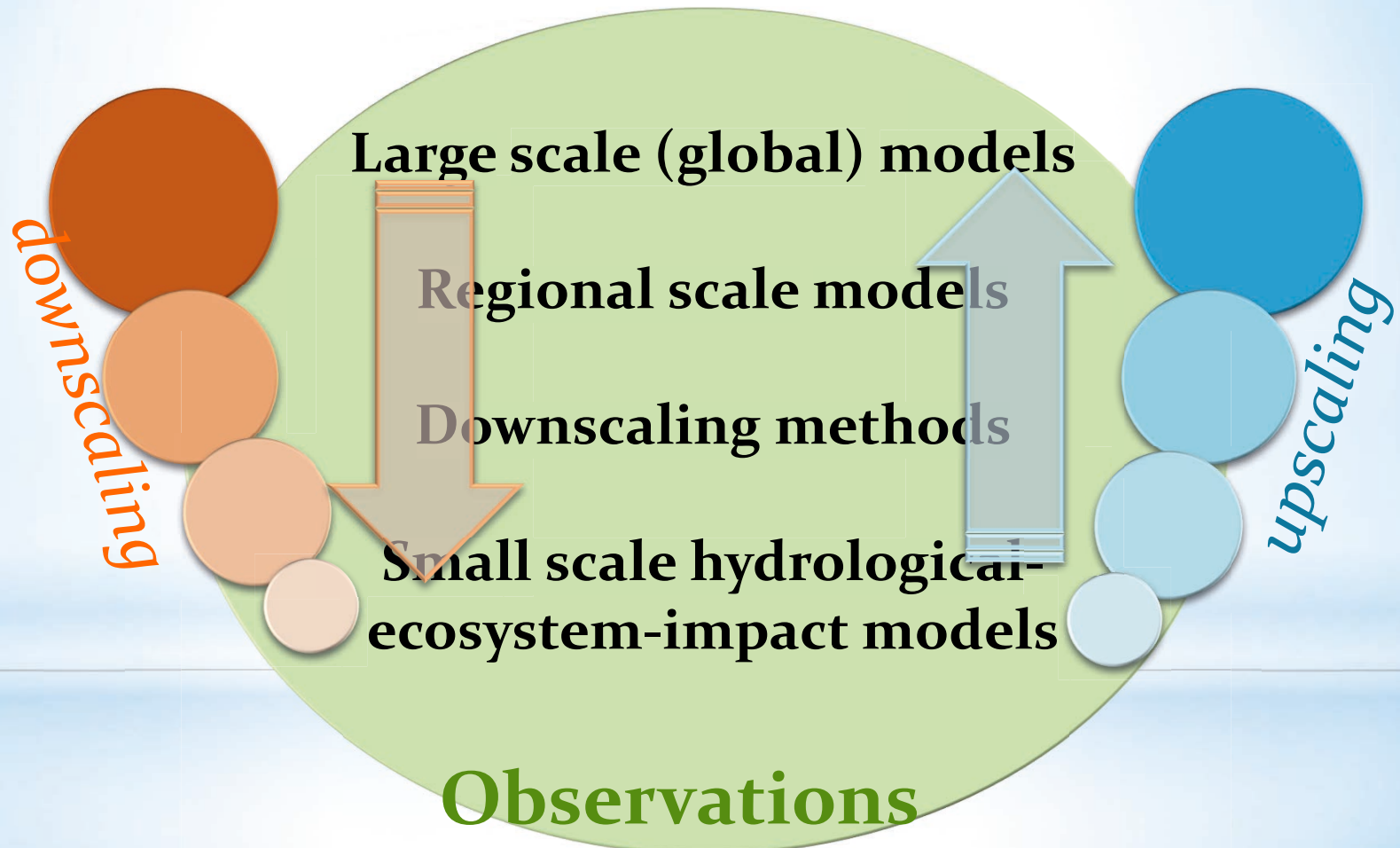
Changes in the Hydrological Cycle

Model uncertainties/weak points

- Hydrological processes are often only crudely represented in the models
- Future changes in some components, such as **precipitation**, **evapotranspiration**, **runoff**, and **precipitable water content** are not captured in detail and are affected by large uncertainties
- Detailed changes, especially in the terrestrial components of the hydrological cycle, are largely uncertain or are not tackled at all (**groundwater**, **snowmelt**, **permafrost hydrology**, and **wetlands**)
- Certain **anthropogenic influences are generally not considered** (irrigation, dams, river regulation, and agricultural land use changes and management).

Changes in the Hydrological Cycle

Cross-scale interactions



Changes in the Hydrological Cycle

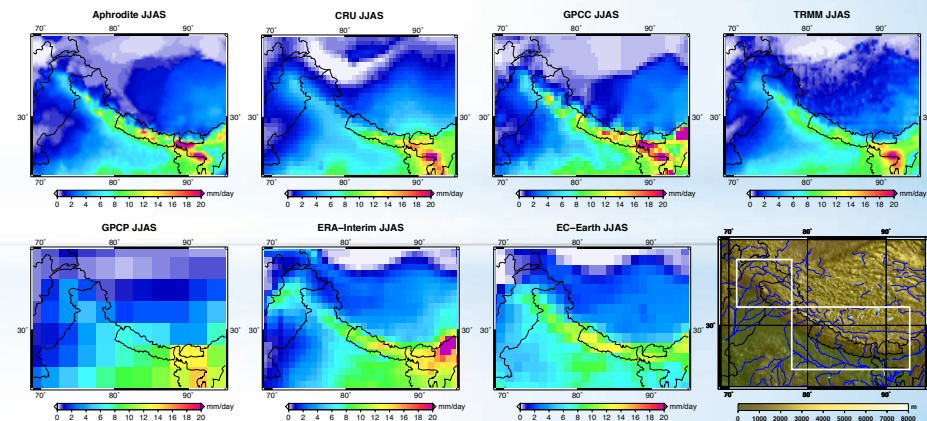
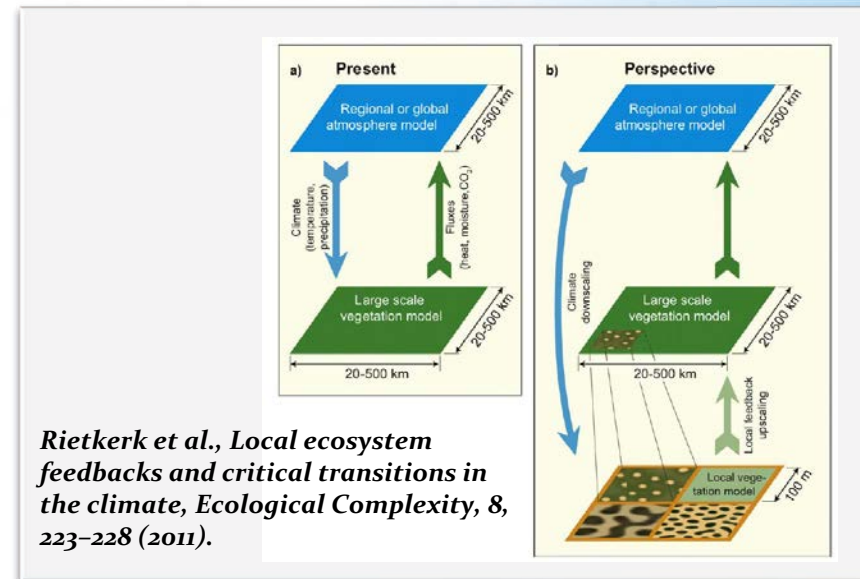
Core topics/tasks of the CP

Global precipitation changes and runoff

Interaction between climate and hydrological/land surface processes

Changes in the hydrological cycle of highly vulnerable regions (Mediterranean region and mountain areas)

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



Changes in the Hydrological Cycle

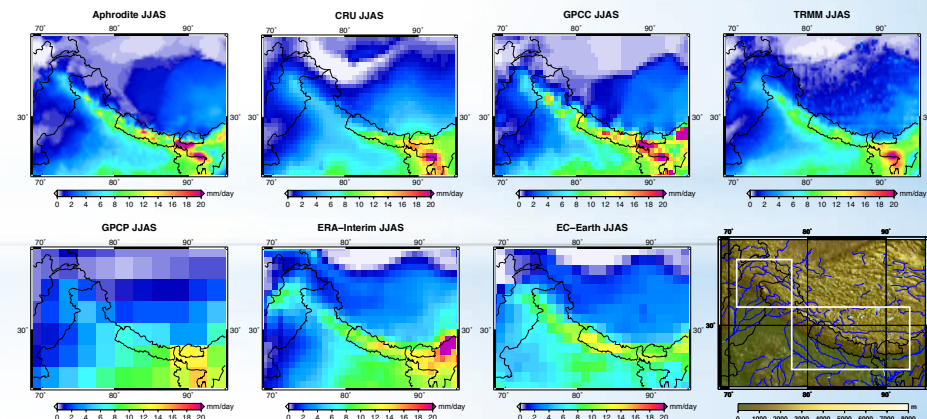
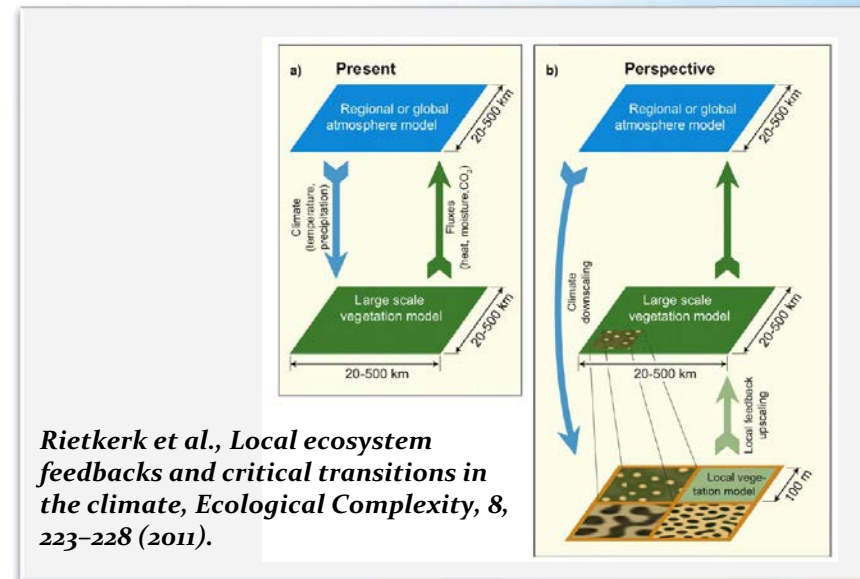
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Changes in the Hydrological Cycle

Example: Hydrological cycle in mountains

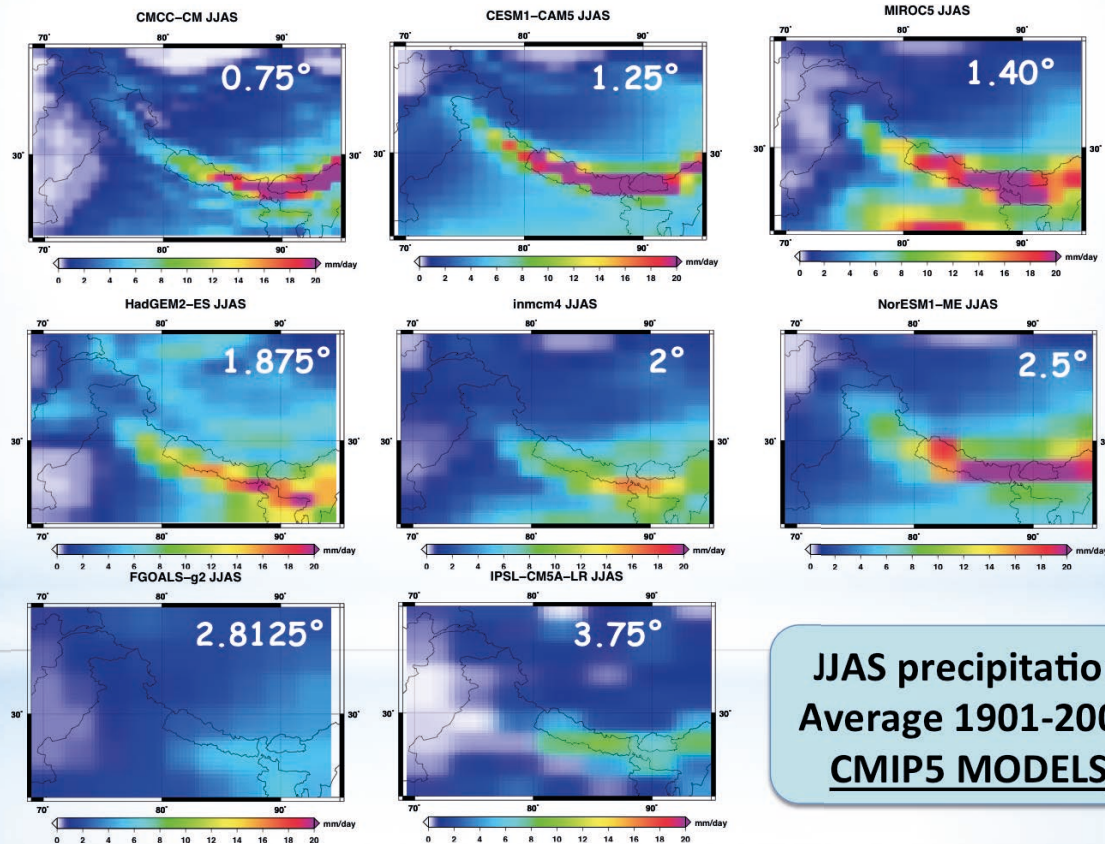
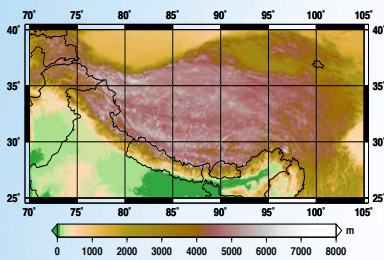
- *Glacier retreat, loss of water reservoirs*
- *Decrease of duration and thickness of snow cover and effects on ecosystems*
 - *Changes in precipitation*
- *Sub-surface water and changes in aquifers*
 - *Slope stability and landslides*
 - *Elevation Dependent Warming*

Changes in the Hydrological Cycle

In the mountains

Prediction of precipitation (uncertainty)

Topography of the Study Area



JJAS precipitation
Average 1901-2005
CMIP5 MODELS

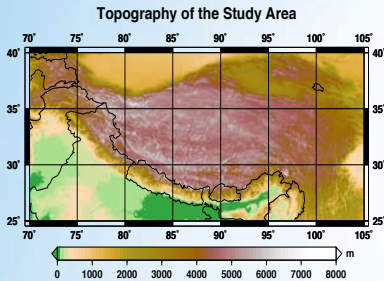
Models (CMIP5)

Changes in the Hydrological Cycle

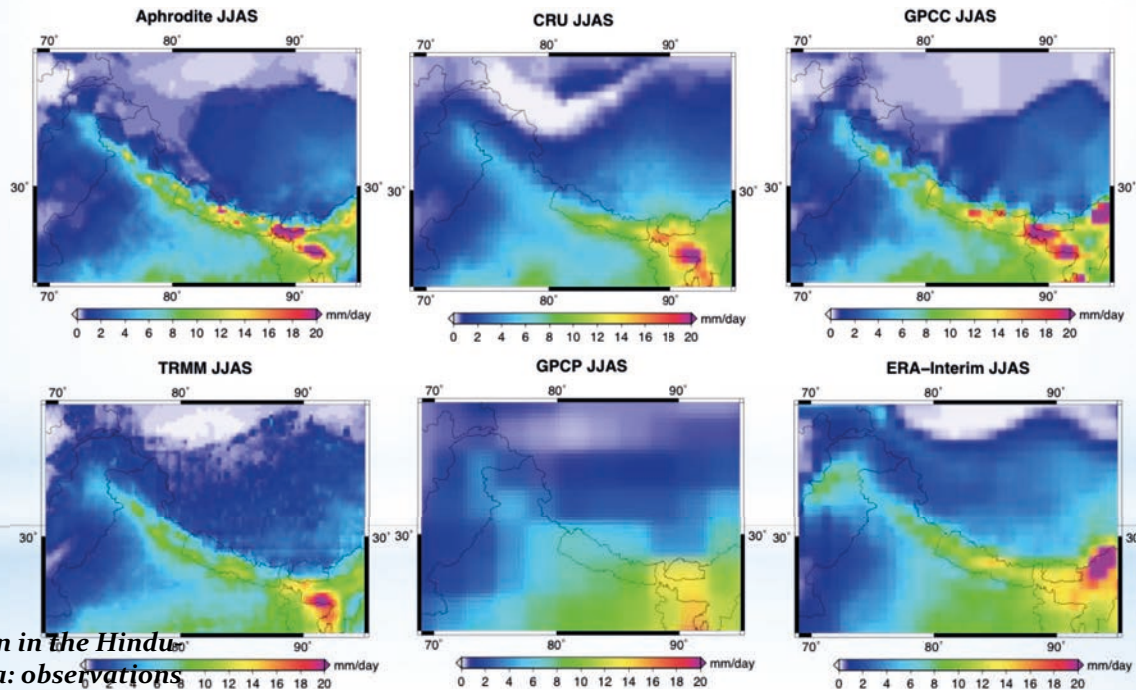
In the mountains

Prediction of precipitation (uncertainty)

Multiannual average 1998-2007



Observations



Gridded
station data

Satellite data

Merged data

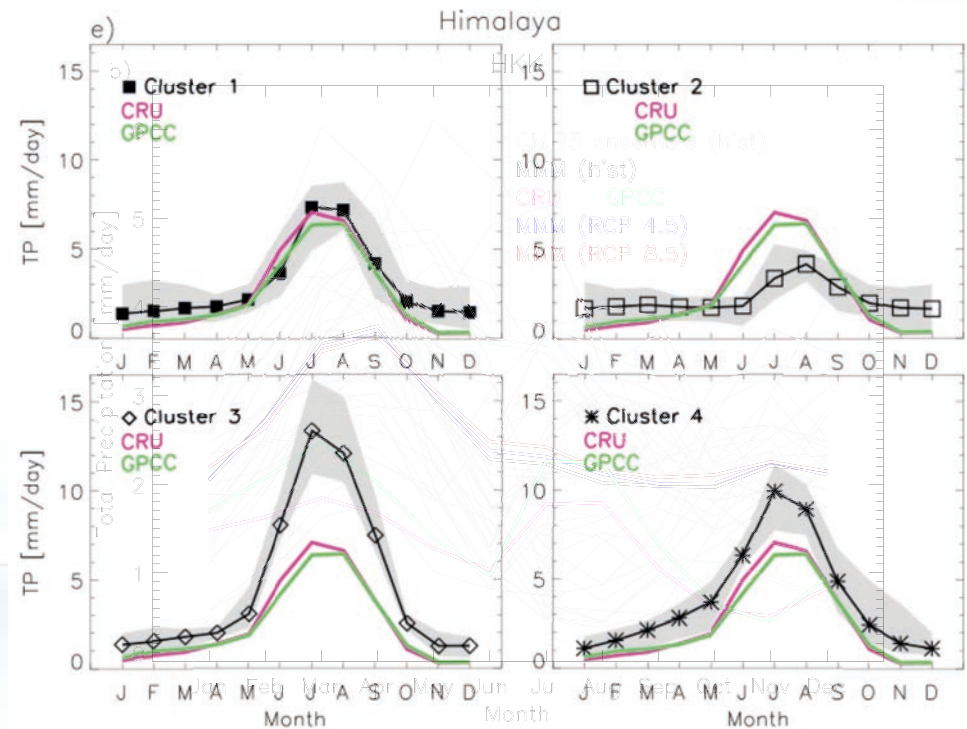
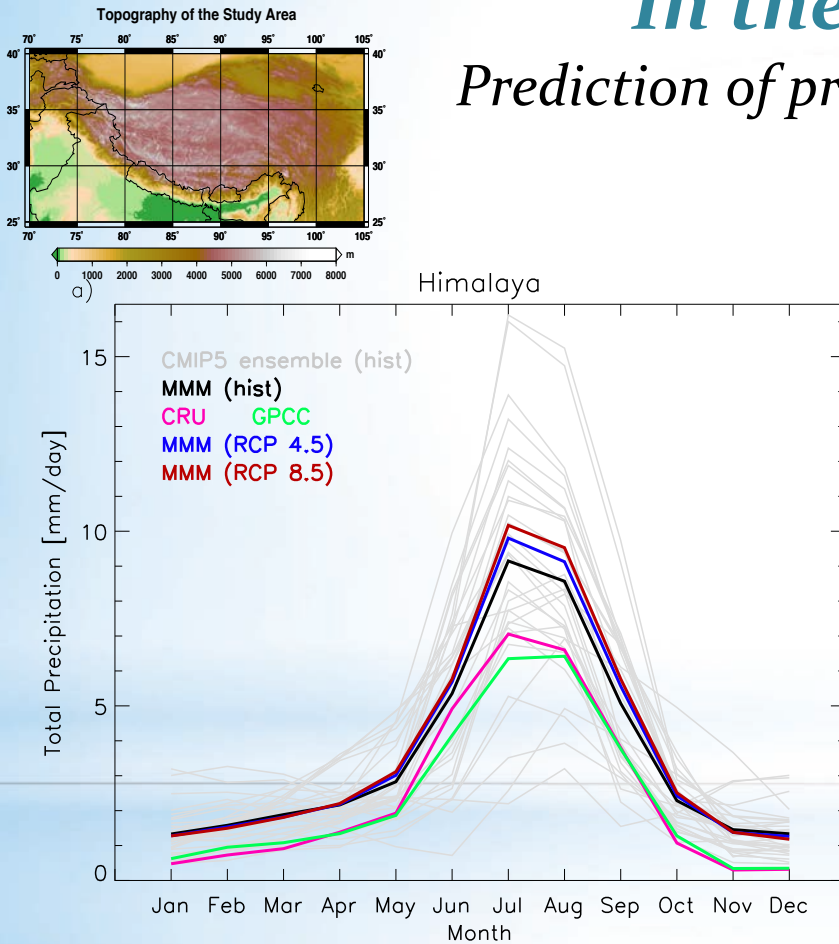
Reanalyses

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

Changes in the Hydrological Cycle

In the mountains

Prediction of precipitation (uncertainty)



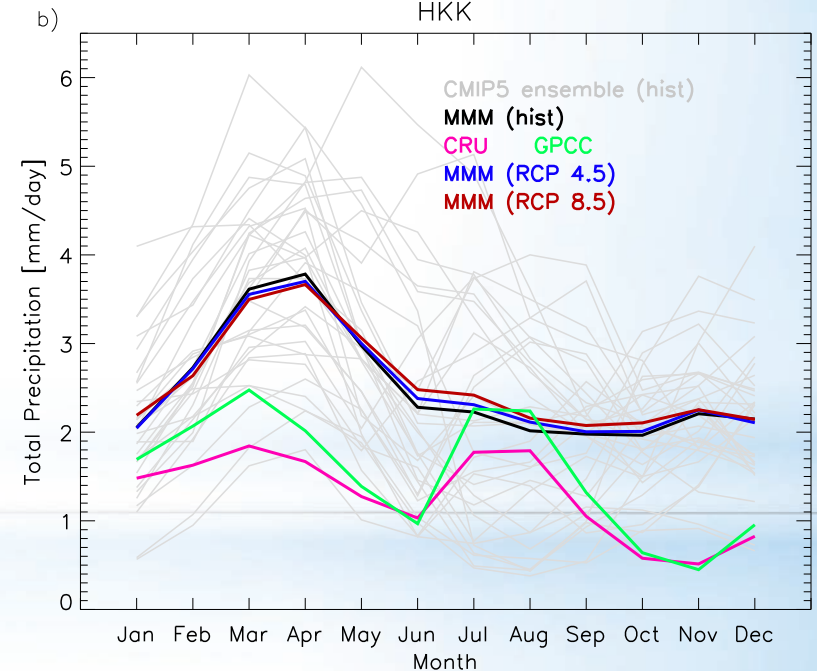
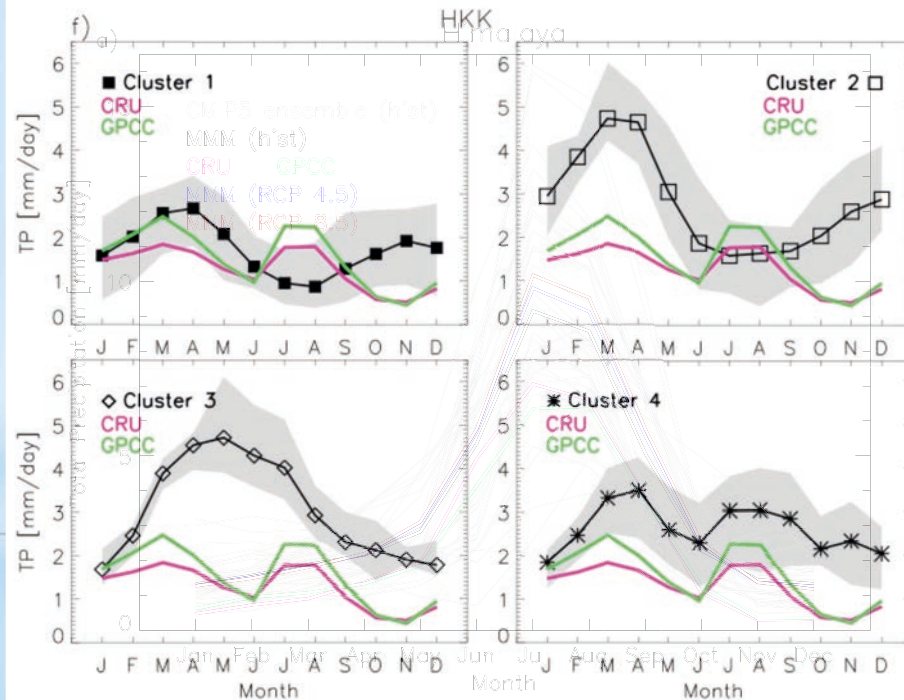
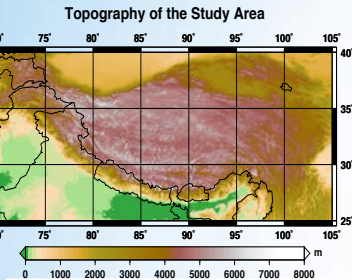
Changes in the Hydrological Cycle

In the mountains

Prediction of precipitation (uncertainty)

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

HKK

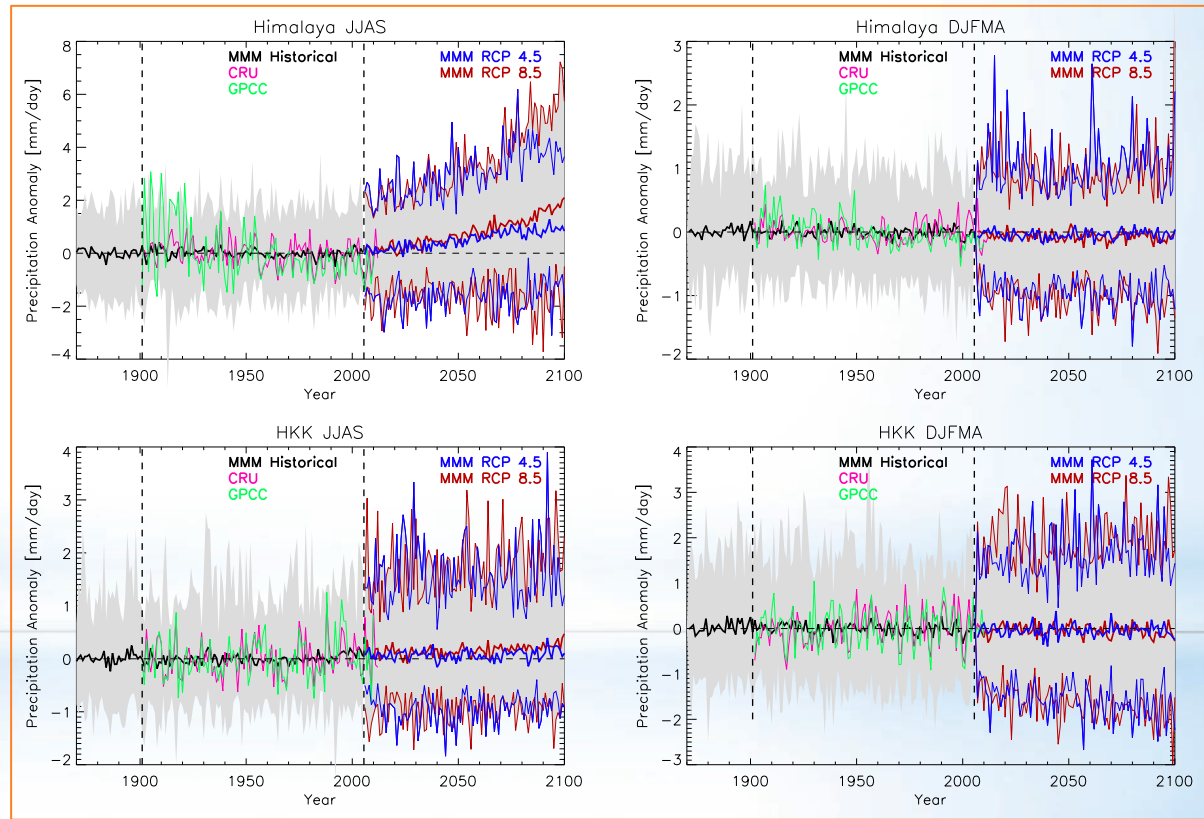
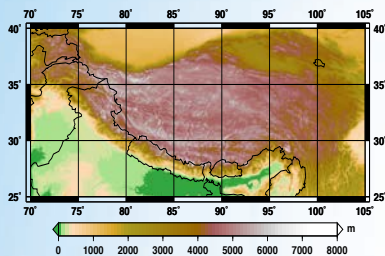


Changes in the Hydrological Cycle

In the mountains

Prediction of precipitation (uncertainty)

Topography of the Study Area

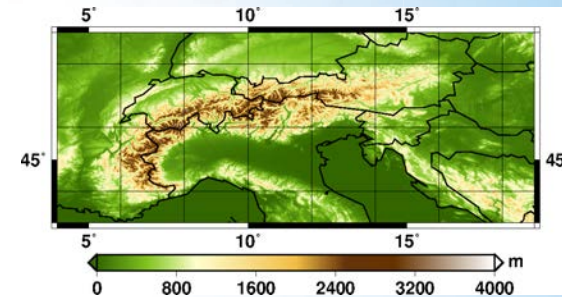


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Changes in the Hydrological Cycle

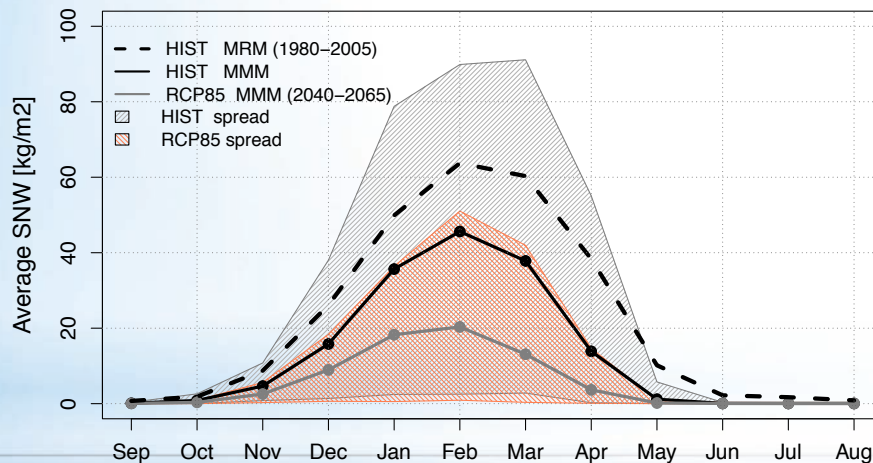
In the mountains

- Changes in snow resources



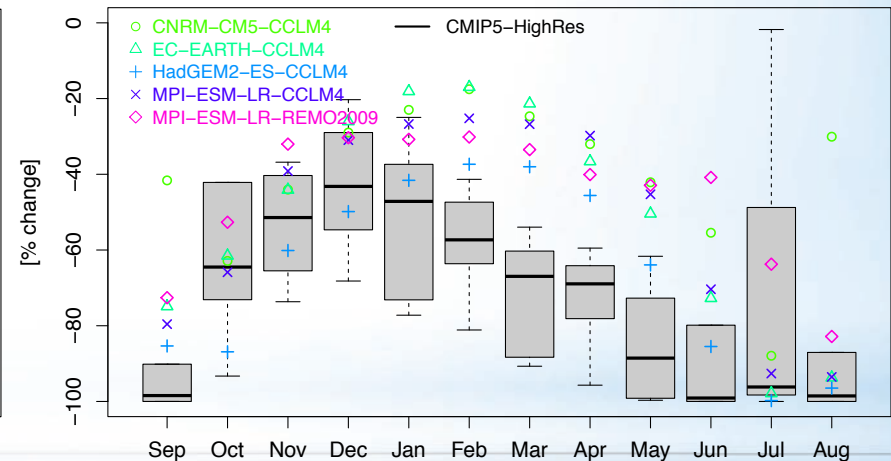
Terzago, S., von Hardenberg, J., Palazzi, E., and Provenzale, A.: Snow water equivalent in the Alps as seen by gridded datasets, CMIP5 and CORDEX climate models, *The Cryosphere Discuss.*, doi:10.5194/tc-2016-280, in review, 2017

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



(a)

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



(b)

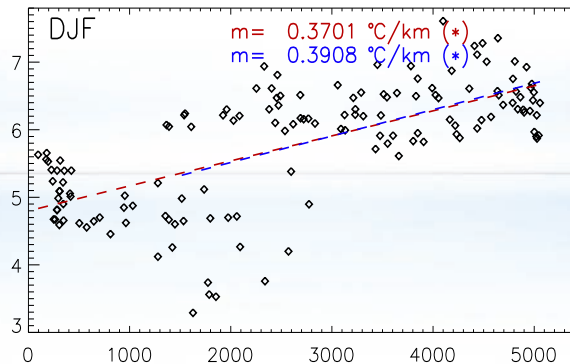
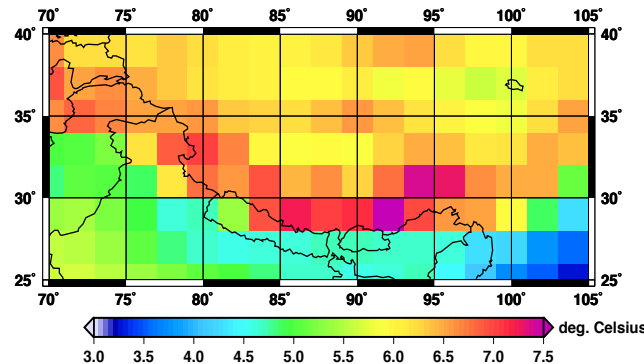
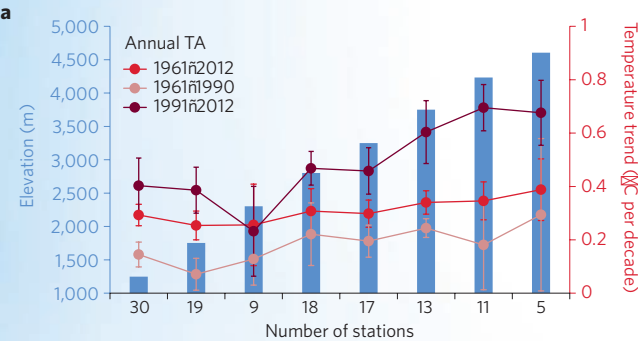
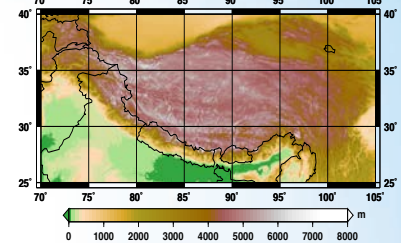
Annual cycle of snow water equivalent expected by mid 21st century in the RCP8.5 scenario compared to the baseline 1980–2005, as provided by the Hi-Res CMIP5 models. (b) Percent change in snow water equivalent (2040–2065 average with respect to the baseline) as in the Hi-Res CMIP5 GCMs (boxplot) and RCM simulations.

Changes in the Hydrological Cycle

In the mountains

- Elevation-dependent warming

Topography of the Study Area



- Snow-albedo feedback
- Increase in specific humidity and in downwelling longwave radiation (important at high elevations which are currently very dry)

- Higher aerosol concentrations

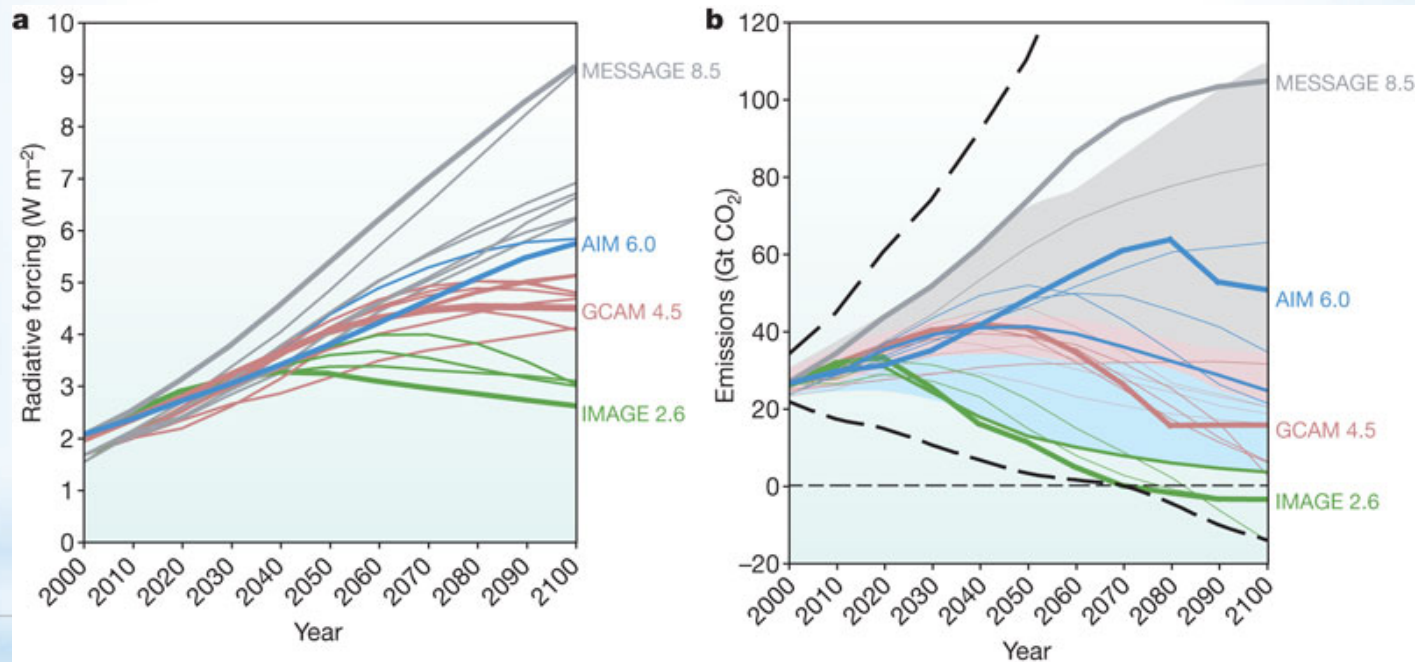
MRI 2015: Elevation-dependent warming in mountain regions of the world, *Nature Climate Change* 5, 424-430 (2015)
doi:10.1038/nclimate2563

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

Changes in the Hydrological Cycle

Uncertainty in the scenarios

Future simulations



RH Moss et al. Nature **463**, 747-756 (2010) doi:10.1038/nature08823

RCP 2.6, RCP4.5, RCP 6.0, RCP8.5

Changes in the Hydrological Cycle

Cross themes and research priorities

- ✓ *Performance and limitations of numerical models*

- ✓ *Working at the climate-hydro interface*

- ✓ *Impact-oriented research and societal challenges*

(see the Talk by A. Iglesias tomorrow on **Changes in environmental and agricultural risks in the Mediterranean**)

- ✓ *Climate hot-spots and vulnerable regions*

(Talk, E. Coppola on **Climate change impact on the hydrological cycle for the Alpine region**)

Changes in the Hydrological Cycle

Cross themes and research priorities

✓ Performance and limitations of numerical models

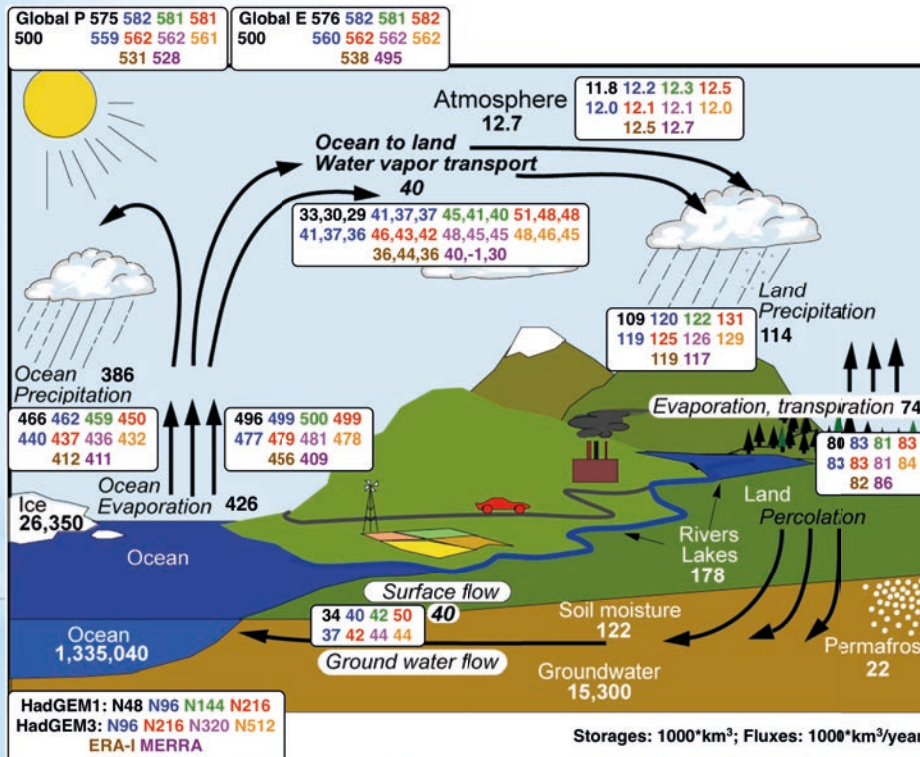


Figure adapted from Trenberth et al, 2007, 2011

- Classic GCMs too dependent on physical parameterisation because of **unresolved** atmospheric transports
- Role of **resolved** sea→land transport larger at high resolution
- **Hydrological cycle more intense at high resolution**

Equivalent resolution at 50N:

270 km

135 km

90 km

60 km

40 km

25 km

HadGEM at various resolutions

Changes in the Hydrological Cycle

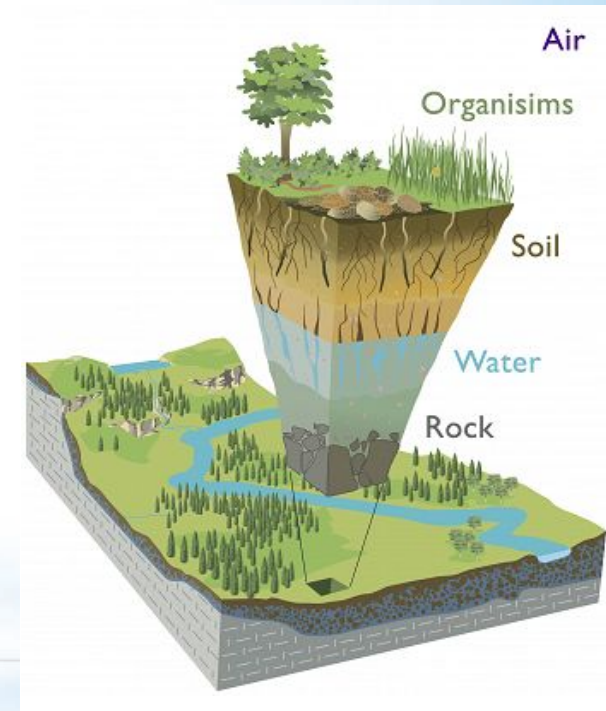
A new theme

The Earth critical zone (ECZ) -> a focus on geosphere-biosphere interactions

- **the veneer of our planet: from the top of the tree canopy to the bottom of drinkable water aquifers**

Multi-sectorial research, open questions:

- To what extent the ECZ functions have been influenced by its paleo-evolution
- What is the response of the ECZ to climate and land use changes
- What are the benefits coming from integration of new sensing technologies and models for simulating EVs



Talk by A. Provenzale tomorrow on “*Geosphere-biosphere-hydrosphere interactions in the earth critical zone - Lessons from European Protected Areas*”

Changes in the Hydrological Cycle

The international dimension

- *H2020 ECOPOTENTIAL (ECOPOTENTIAL: improving future ecosystem benefits through earth observations)*
- *H2020 CRESCENDO (Coordinated Research in Earth Systems and climate: experiments, knowledge, dissemination and outreach) -> Improve the process realism and future projection reliability of European Earth-System Models, while evaluating and documenting the performance quality of these models*
- *H2020 PRIMAVERA (PRocess-based climate sIMulation: AdVances in high resolution modelling and European climate Risk Assessment) -> Develop a new generation of well-evaluated high-resolution global climate models, capable of simulating and predicting regional climate with unprecedented fidelity*

Changes in the Hydrological Cycle

The international dimension

- **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 new Initiative of GEO/GEOSS
- **Belmont Forum CRA** “Mountain as Sentinels of Change”, Close Call, ongoing projects activities

Changes in the Hydrological Cycle

Challenges for the near future

- *Identify modes of operation besides meetings and discussions: specific topics cross-CP, joint technical papers, ... ?*
- *Identify funding sources (COST, H2020, etc) to make ideas and collaborations operational*

Changes in the Hydrological Cycle

Thank you!