European Climate Research Alliance

General Assembly 2015

"New knowledge for risk reduction"

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Collaborative Programme

Changes in the Hydrological Cycle

Prediction of precipitation (uncertainty) under different climate change scenarios

Uncertainty in climate modeling of precipitation: from data to downscaling

Elisa Palazzi, **ISAC-CNR**

Silvia Terzago and Jost von Hardenberg, **ISAC-CNR**
Antonello Provenzale, **IGG-CNR**

25-26 March 2015, Brussels

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

Model uncertainties/weak points

- Hydrological processes are often only crudely represented in the models

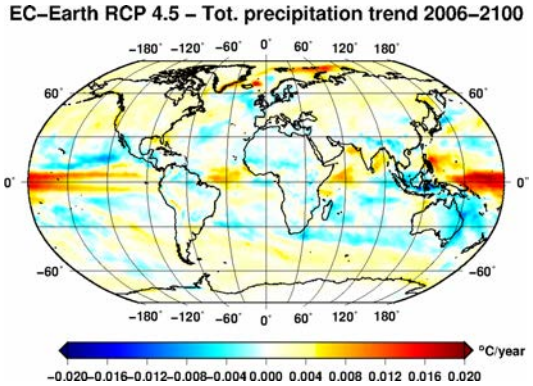
- Future changes in some components, such as precipitation, evapotranspiration, runoff, and precipitable water content are not captured in detail and are affected by large uncertainties

- 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).

From large to small scales (and back)

- Climate projections from global climate models are available at coarse resolutions (~80-120 km)

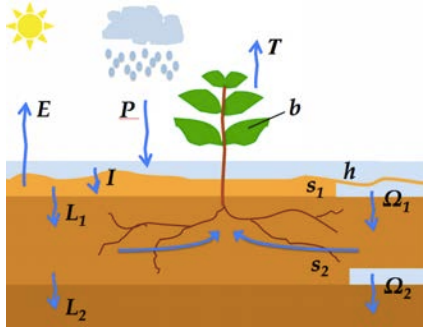


- Impacts on ecosystems, hydrology, risks, surface processes act mostly at local scales

→ Scale mismatch and need for downscaling

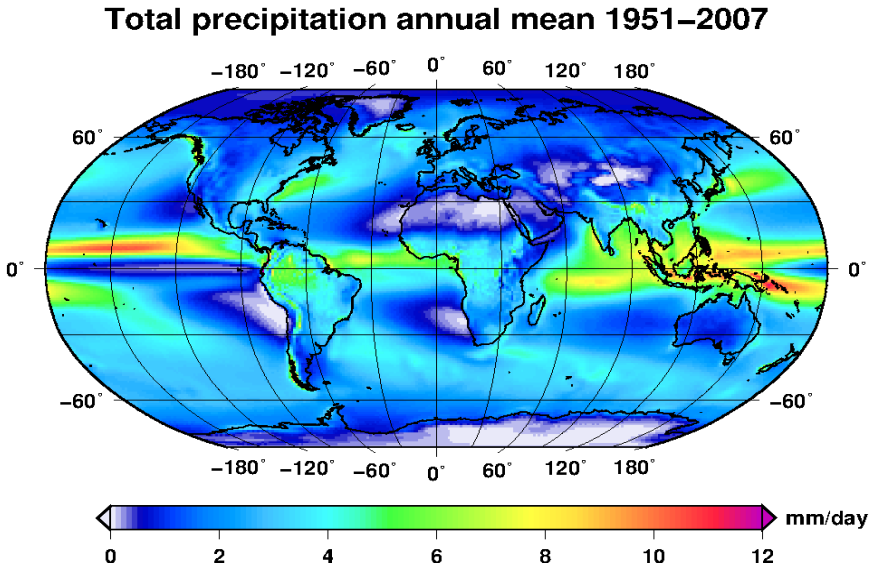
- Local surface processes may feed back on large scales

→ need for upscaling

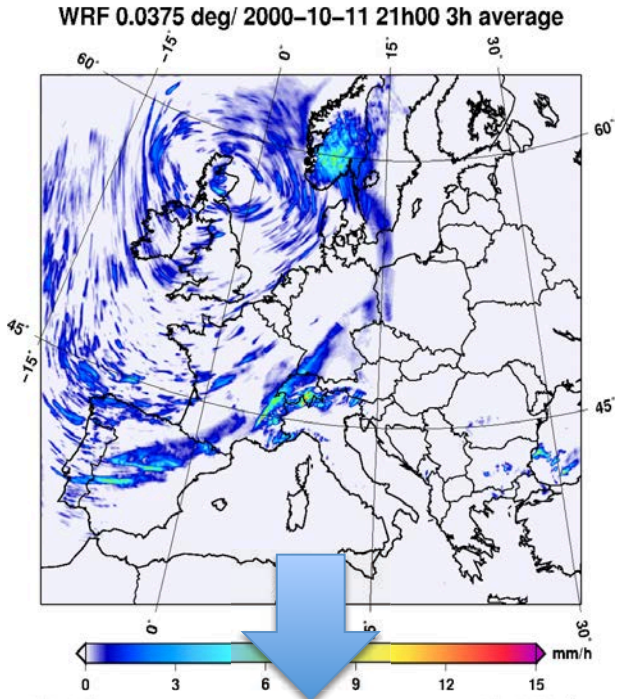


The downscaling modelling chain

Global climate model



Regional climate model



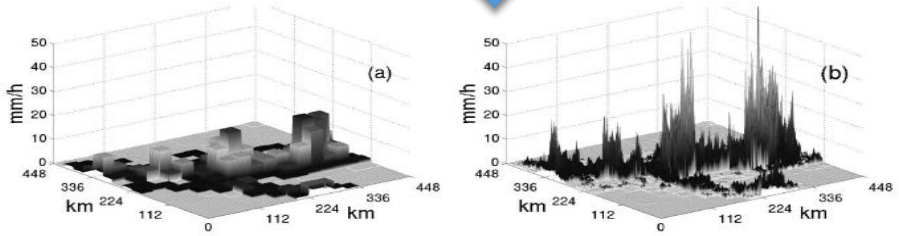


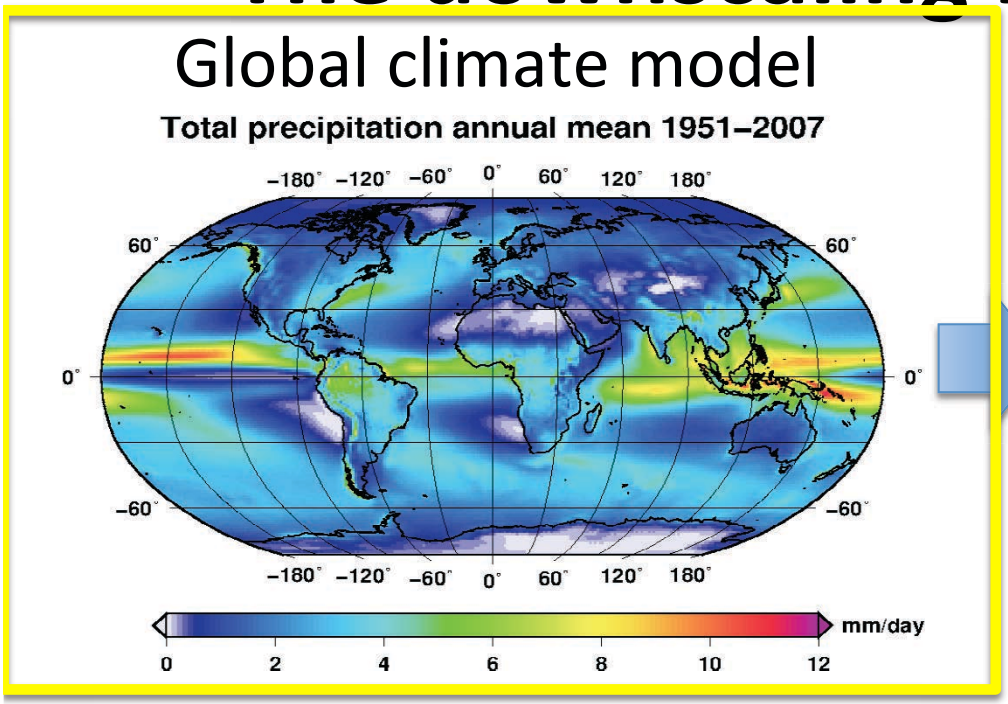
FIG. 10. (a) A snapshot of the forecasted rain field obtained from the LAM forecast and (b) one example of a downscaled field obtained by application of the RainFARM. The vertical scale indicates precipitation intensity (mm h^{-1}) and it is the same for the two fields.

Impact on eco-hydrological processes

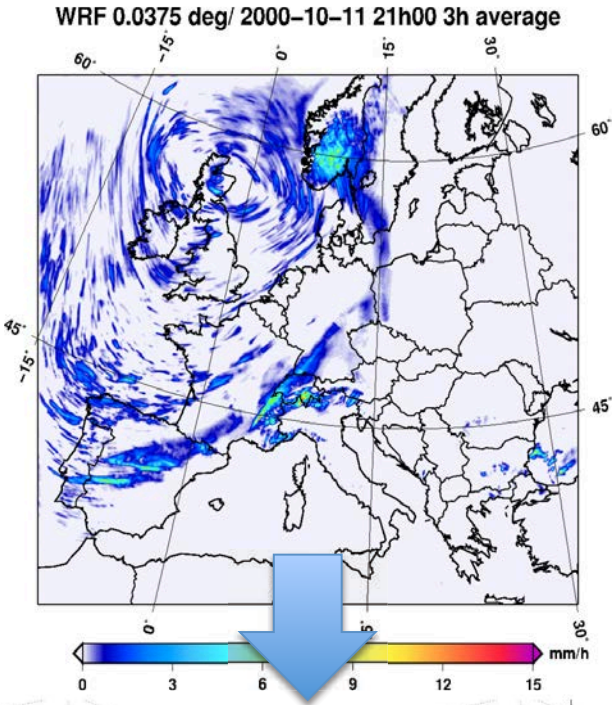
Statistical/stochastic downscaling

The downscaling modelling chain

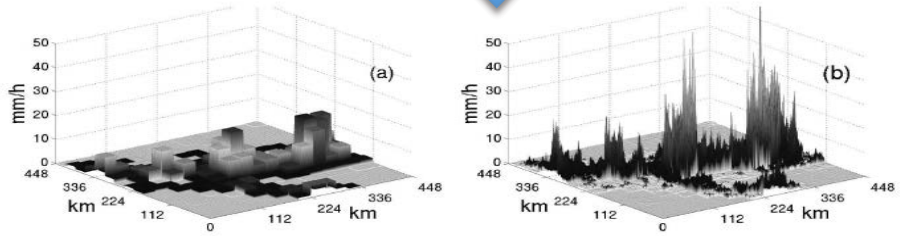
Global climate model



Regional climate model



Impact on eco-hydrological processes



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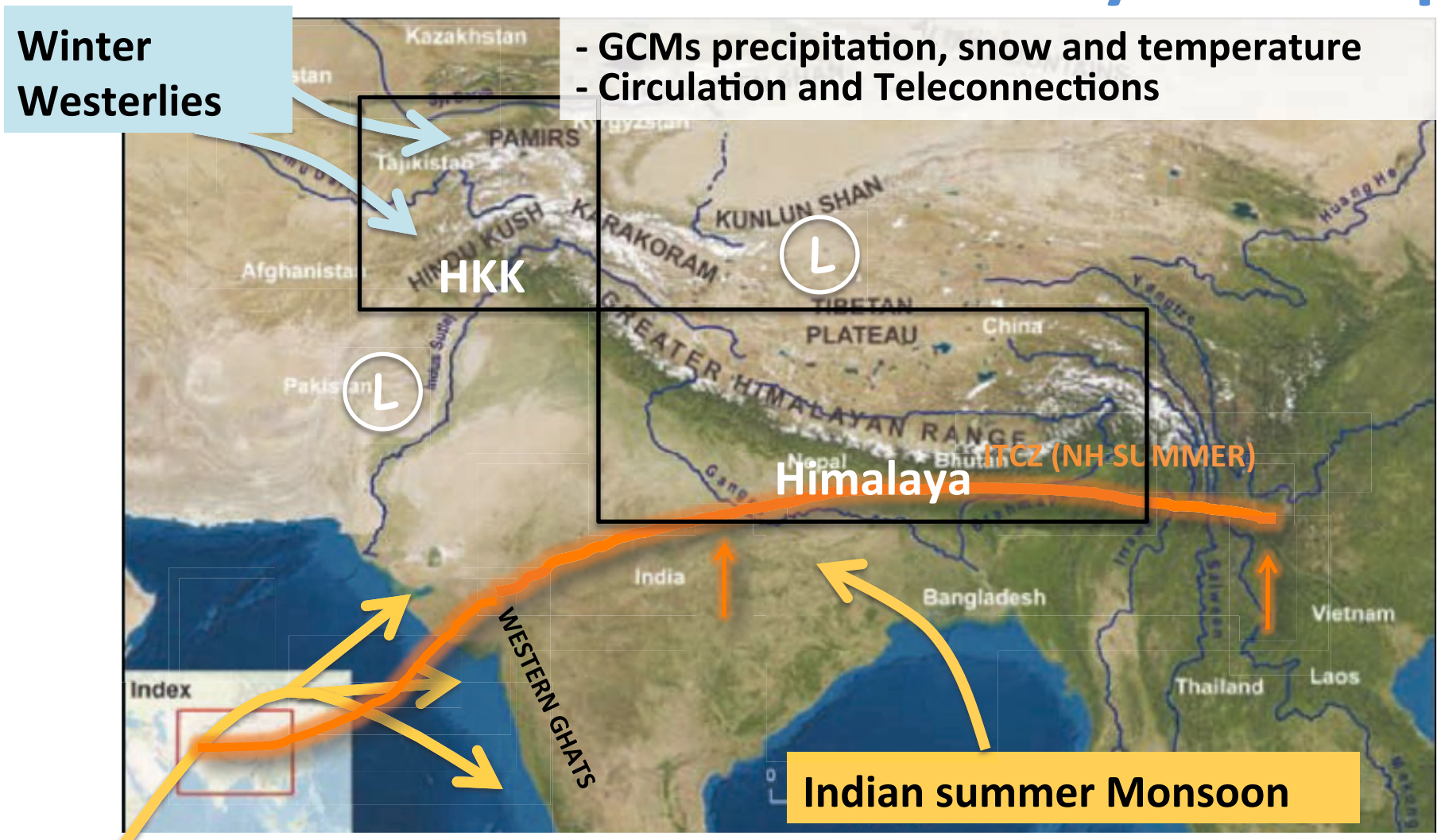
Statistical/stochastic downscaling

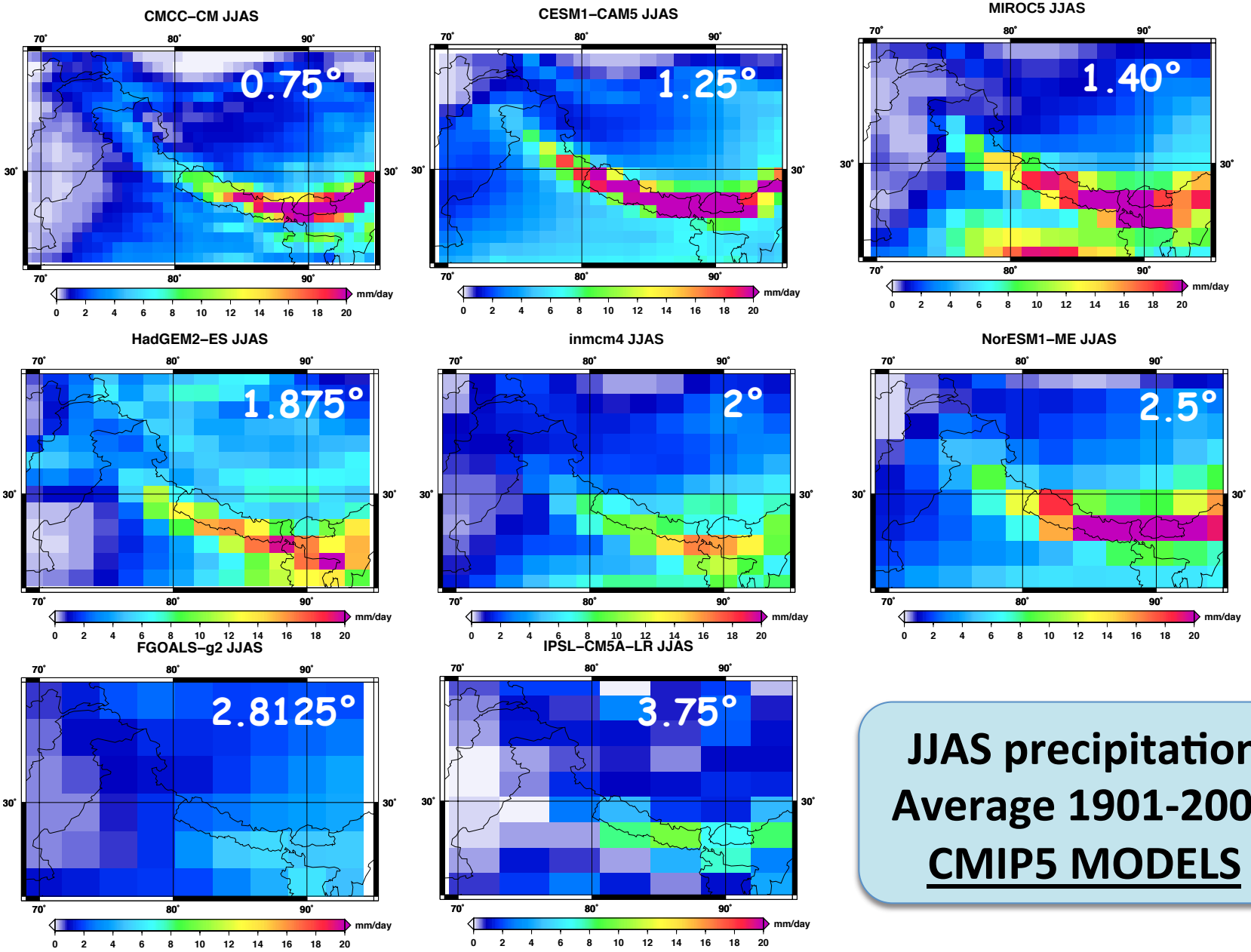
Hindu-Kush Karakoram Himalaya: example



** Palazzi, E., J. von Hardenberg, and A. Provenzale. 2013. Precipitation in the Hindu-Kush Karakoram Himalaya: Observations and future scenarios, J. Geophys. Res. Atmos., 118, 85–100*

** Filippi, L., Palazzi, E., von Hardenberg, J. & Provenzale, A. 2014. Multidecadal Variations in the Relationship between the NAO and Winter Precipitation in the Hindu-Kush Karakoram. Journal of Climate (2014). doi: 10.1175/JCLI-D-14-00286.1,*

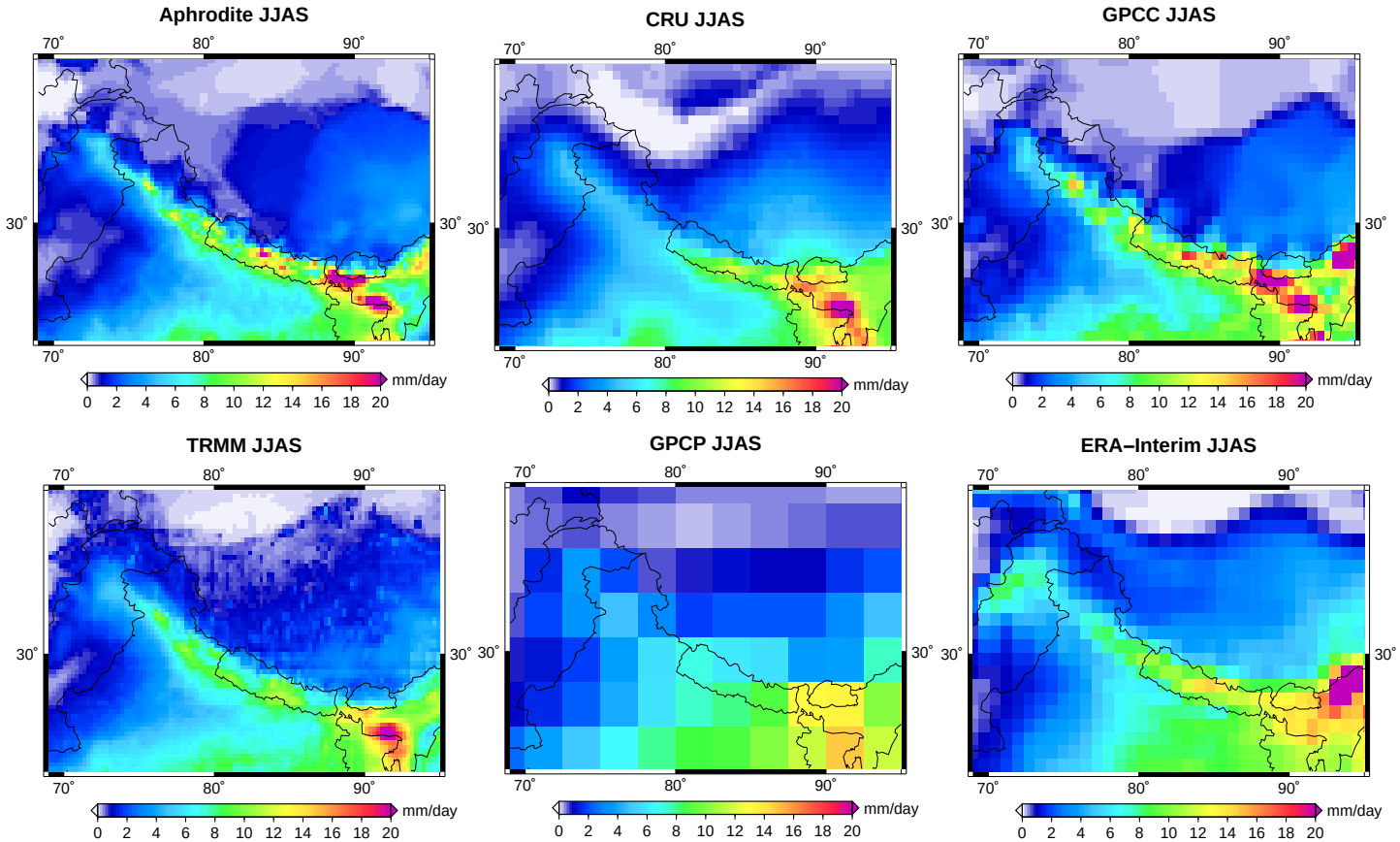
HKKH precipitation: example



JJAS precipitation
Average 1901-2005
CMIP5 MODELS

HKKH precipitation: example

JJAS precipitation, Multiannual average 1998-2007



Gridded station data

Satellite data

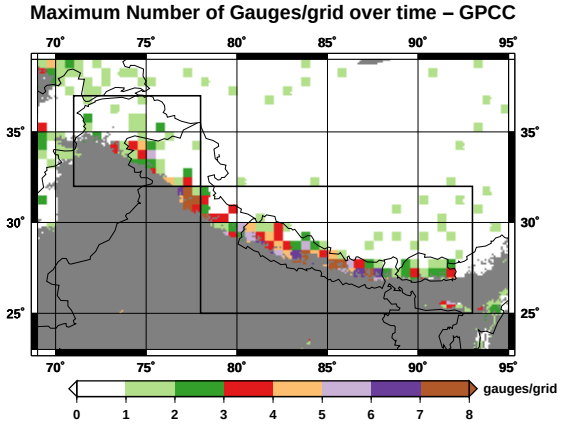
Merged data

Reanalyses

Palazzi, E., J. von Hardenberg, and A. Provenzale. 2013. Precipitation in the Hindu-Kush Karakoram Himalaya: Observations and future scenarios, J. Geophys. Res. Atmos., 118, 85–100, doi: 10.1029/2012JD018697

Precipitation datasets & issues

Maximum number of gauges/pixel (1901-2013). Elevation > 1000 m a.s.l.



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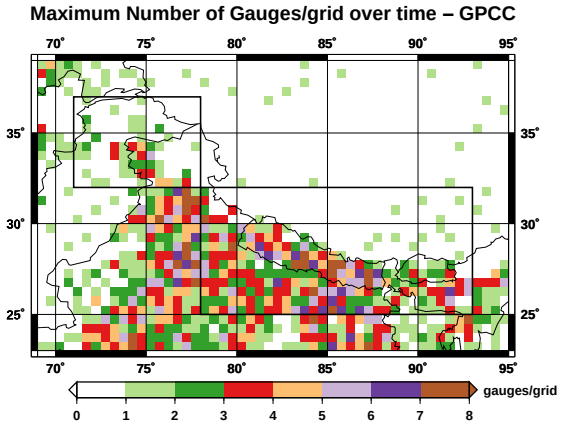
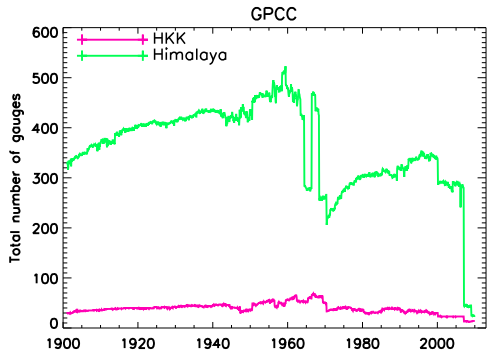
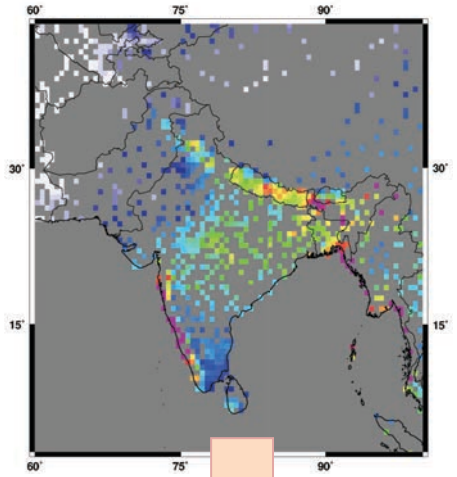
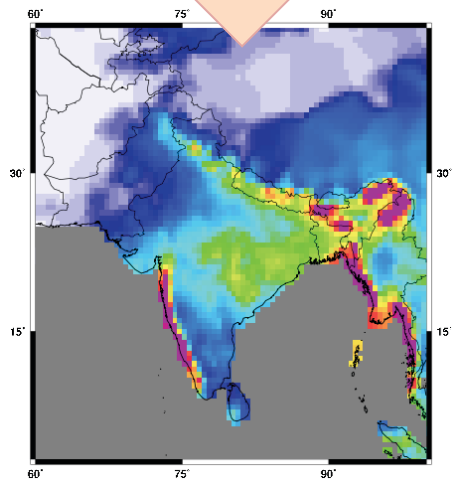


Time series of the total number of gauges in the HKK and Himalaya



GPCC raw



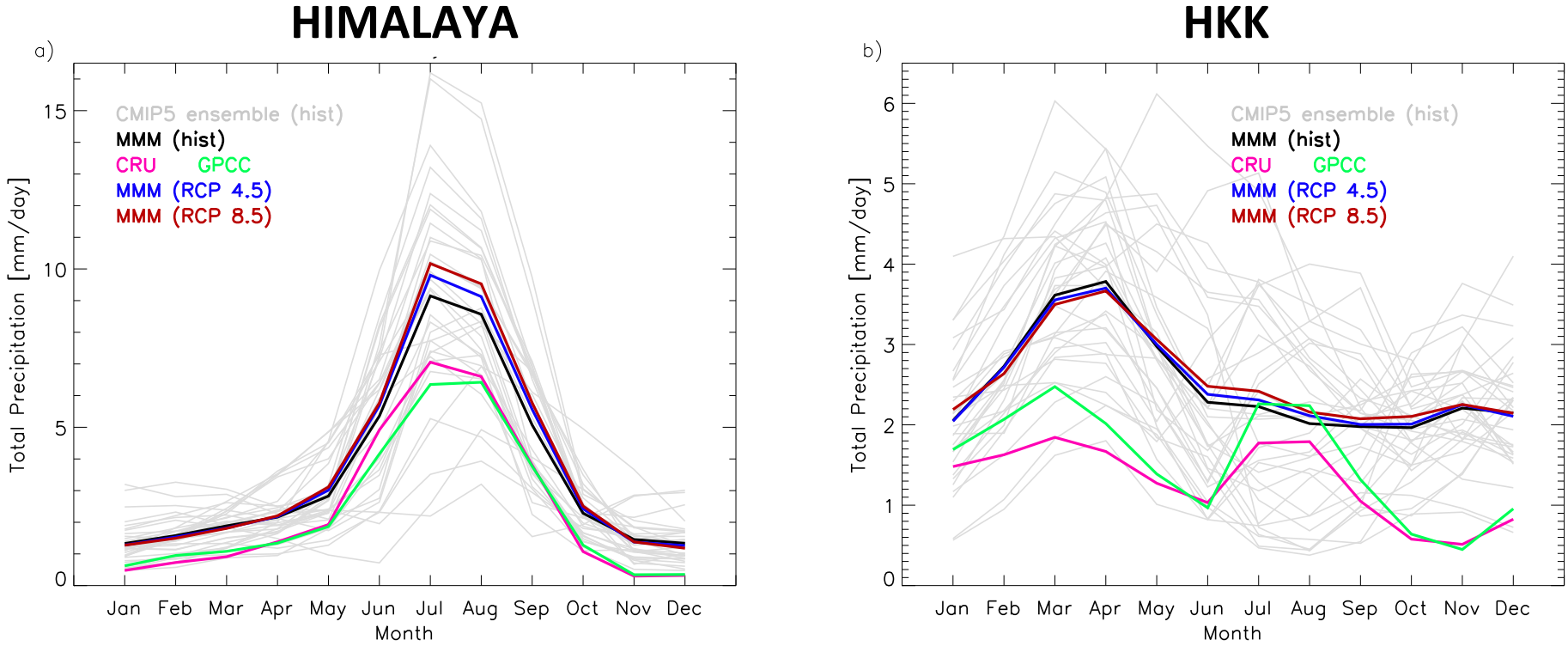


GPCC interpolated

GPCC Gridded dataset

HKKH precipitation: example

Annual Cycle

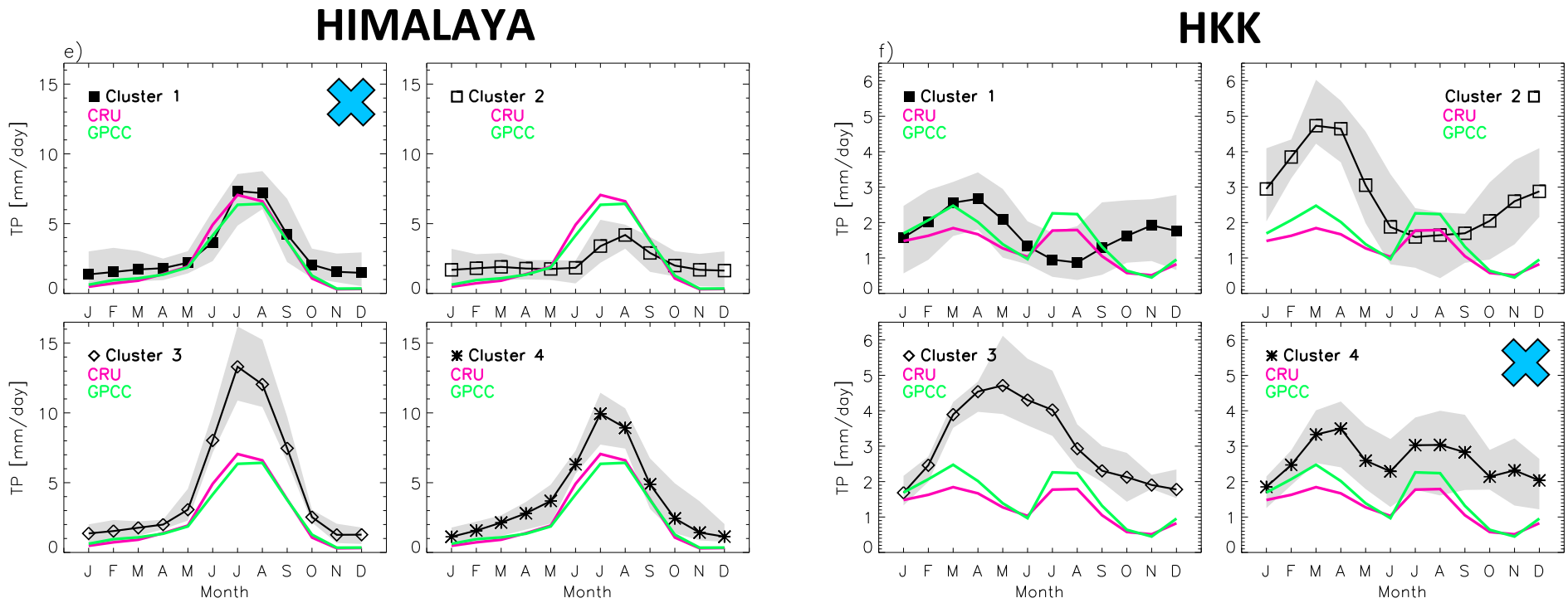


Is there one model, or group of models, that provides the *best results* in terms of precipitation annual cycle in one or both regions?

Palazzi E., J. von Hardenberg, S. Terzago, A. Provenzale. 2014. Precipitation in the Karakoram-Himalaya: A CMIP5 view, Climate Dynamics, doi: 10.1007/s00382-014-2341-z

HKKH precipitation: example

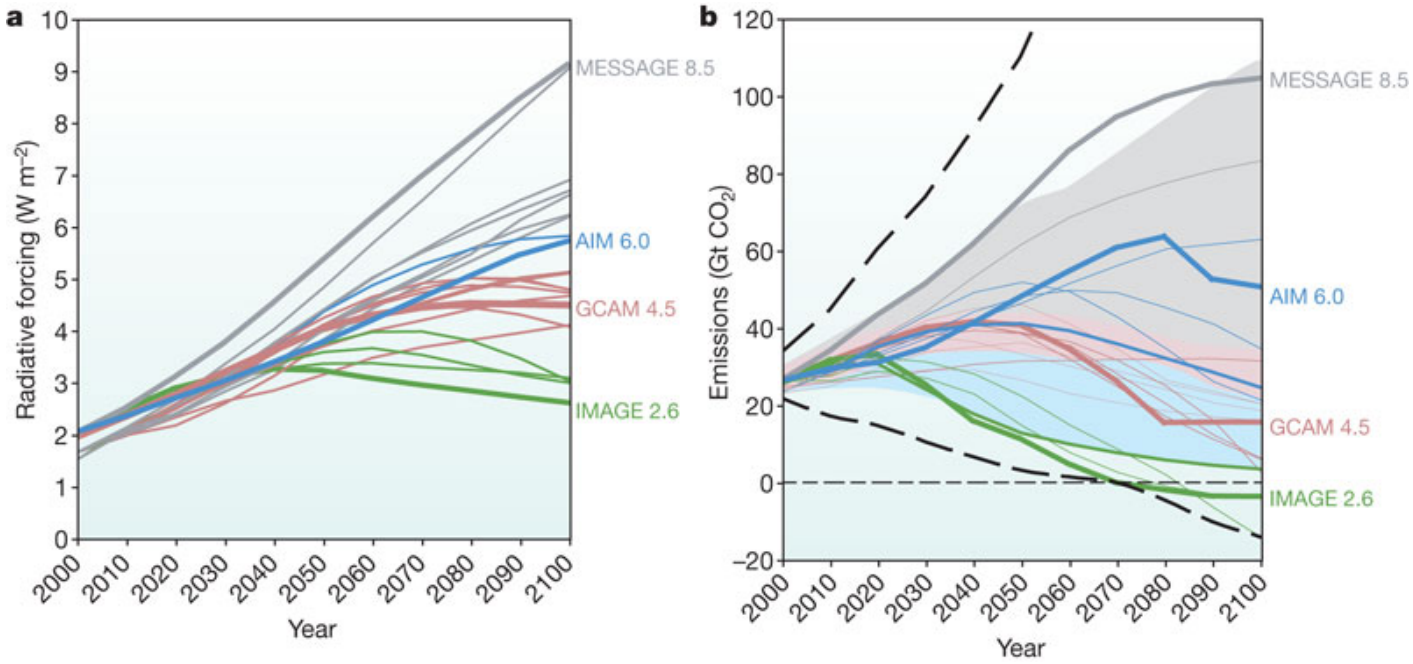
Annual Cycle



Are there any model features that have emerged as those providing the *best results*?

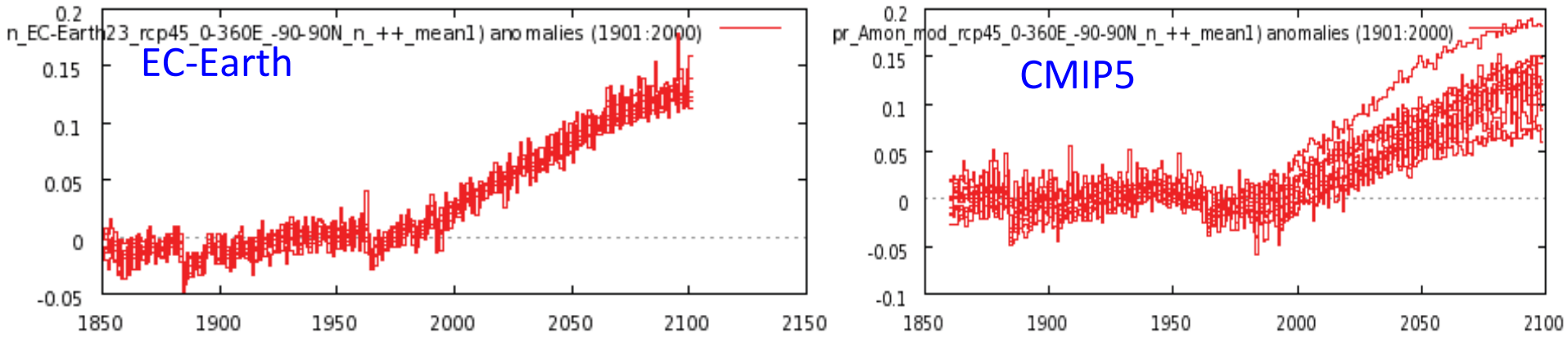
Palazzi E., J. von Hardenberg, S. Terzago, A. Provenzale. 2014. Precipitation in the Karakoram-Himalaya: A CMIP5 view, Climate Dynamics, doi: 10.1007/s00382-014-2341-z

CMIP5 and Representative concentration pathways



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

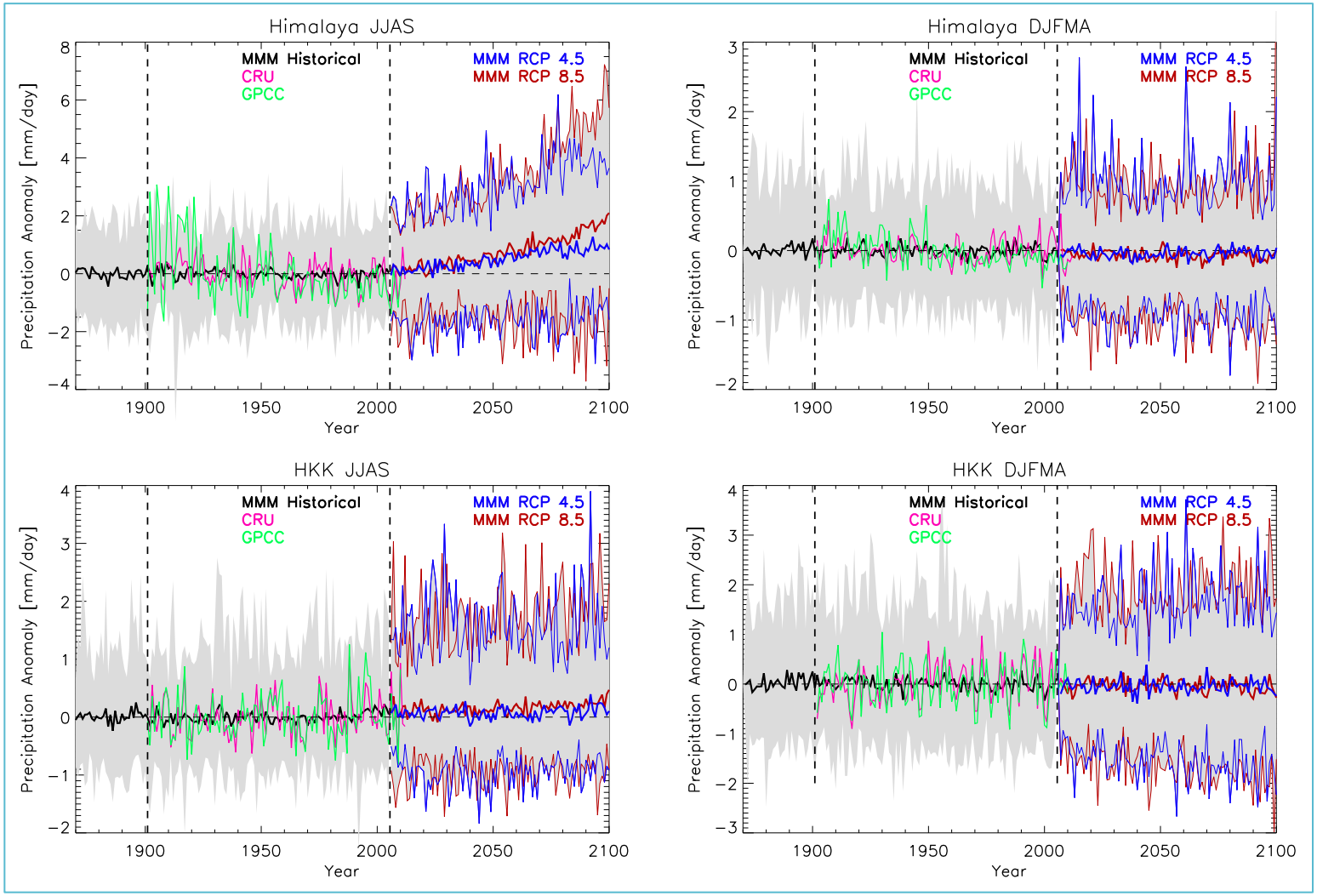
Global Precipitation (RCP 4.5)



HKKH precipitation: example

Long-term trends

CMIP5 Multi-model ensemble



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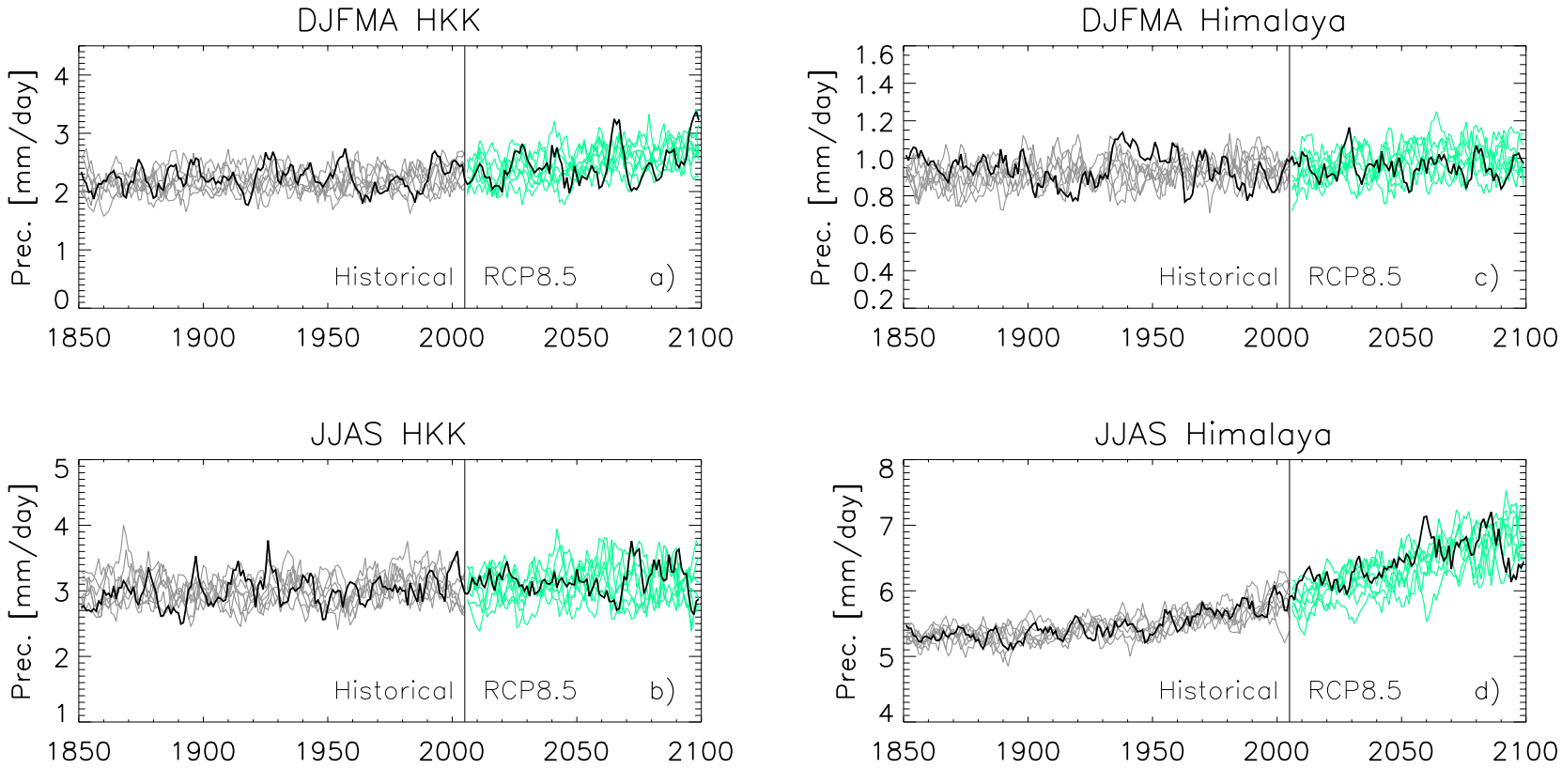
HKKH precipitation: example

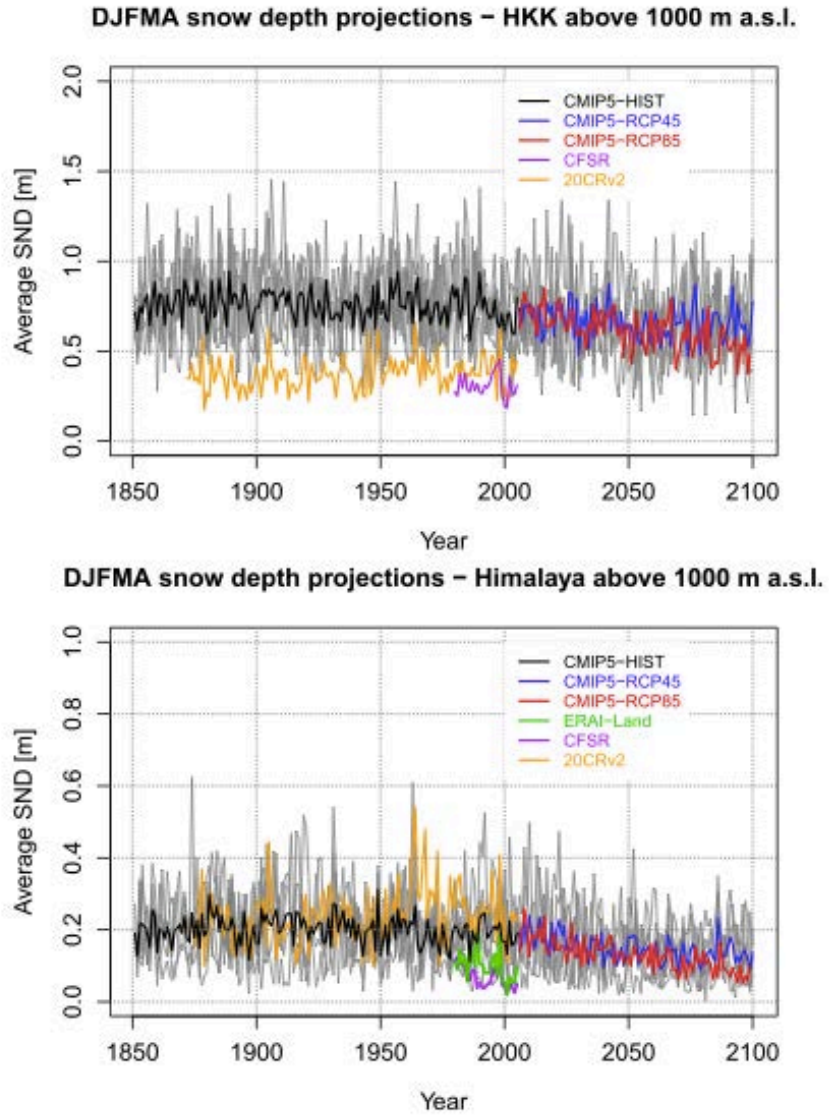
Long-term trends

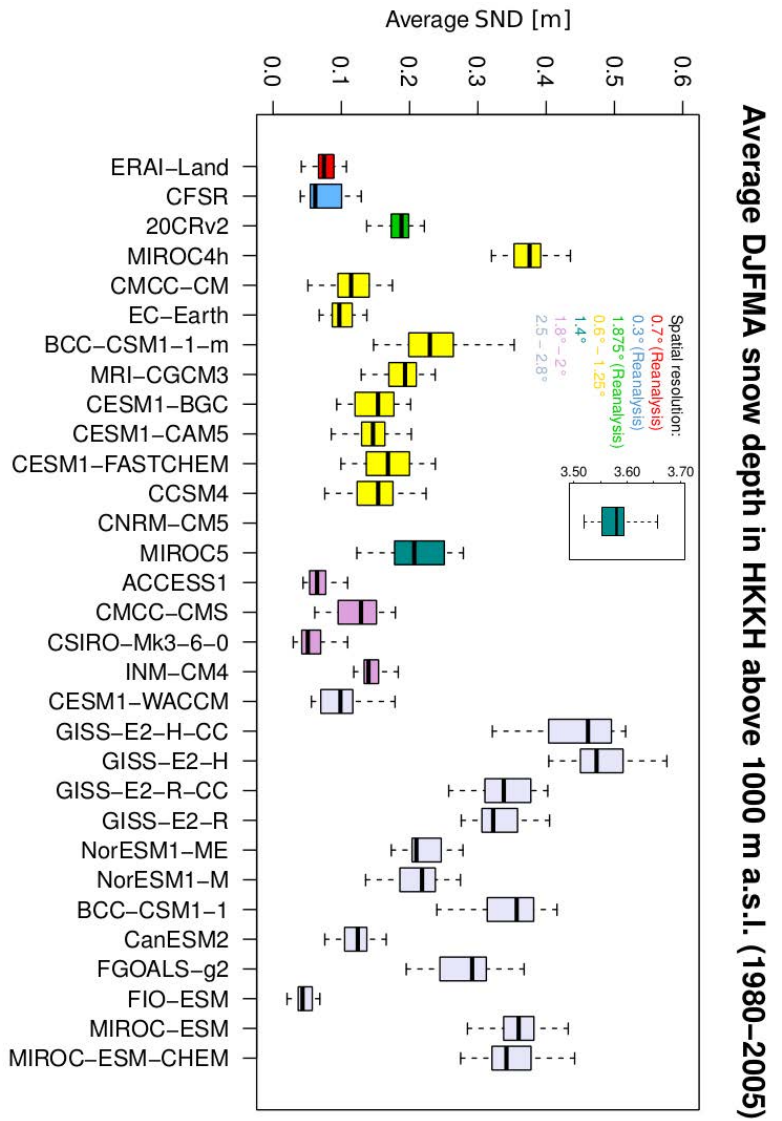
EC-Earth multi-member ensemble



Palazzi, E., J. von Hardenberg, and A. Provenzale. 2013. Precipitation in the Hindu-Kush Karakoram Himalaya: Observations and future scenarios, J. Geophys. Res. Atmos., 118, 85–100, doi: 10.1029/2012JD018697

HKKH snowpack: example

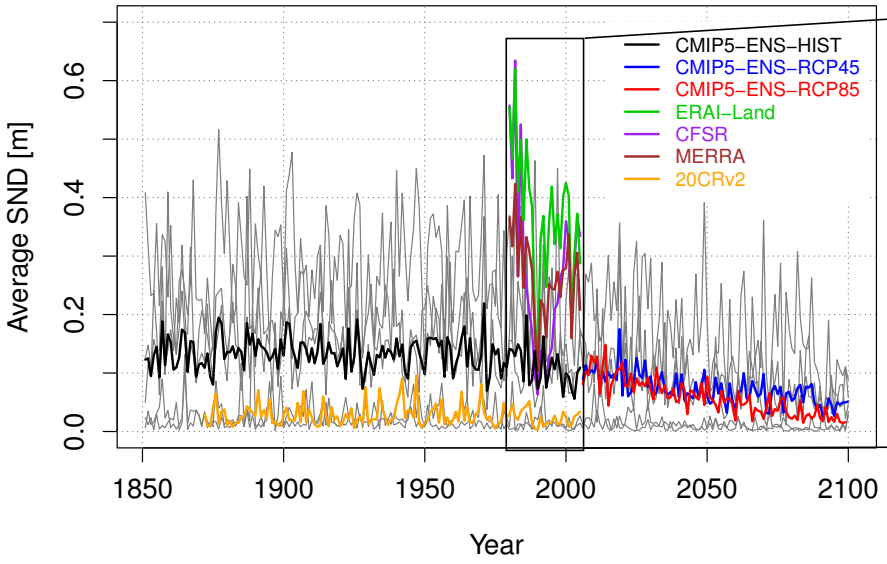




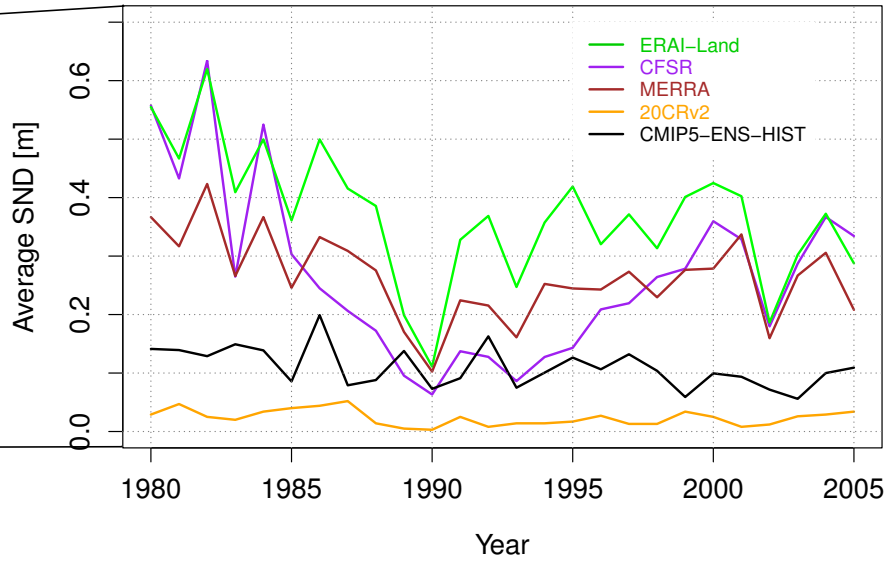
Terzago, S., J. von Hardenberg, E. Palazzi, and A. Provenzale (2014), Snowpack changes in the Hindu-Kush Karakoram Himalaya from CMIP5 Global Climate Models, J. Hydrometeorol., 15 (6), 2293-2313

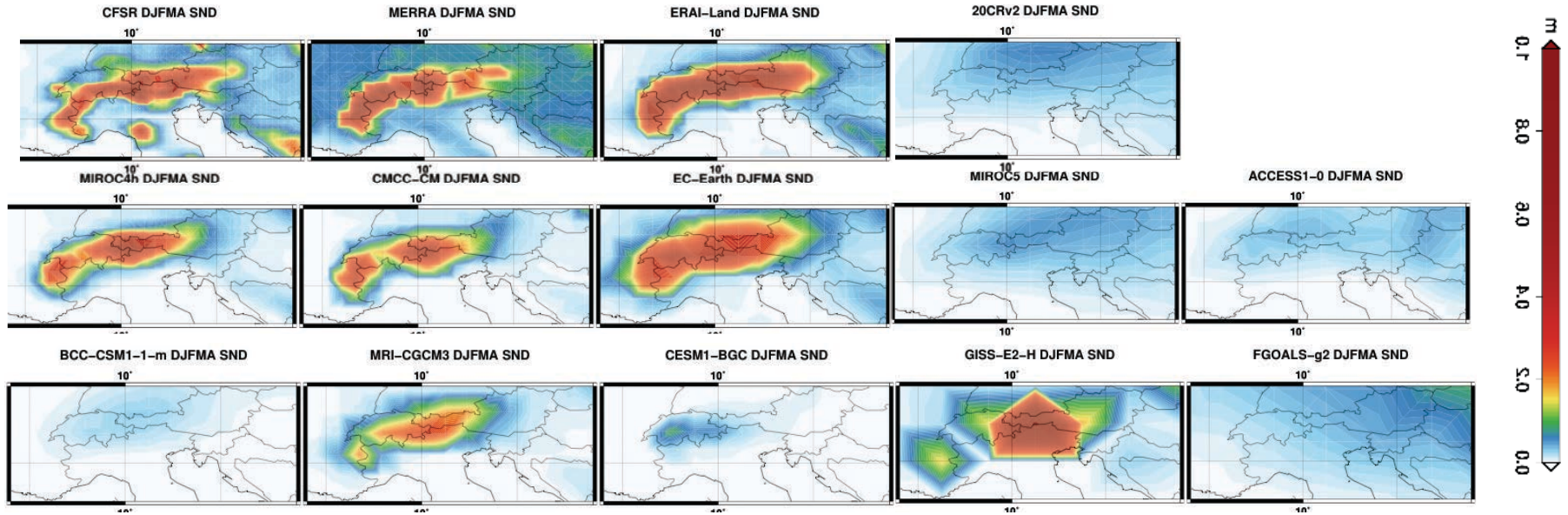
Snow depth in the Alps: example

DJFMA snow depth projections – Alps above 1000 m a.s.l.



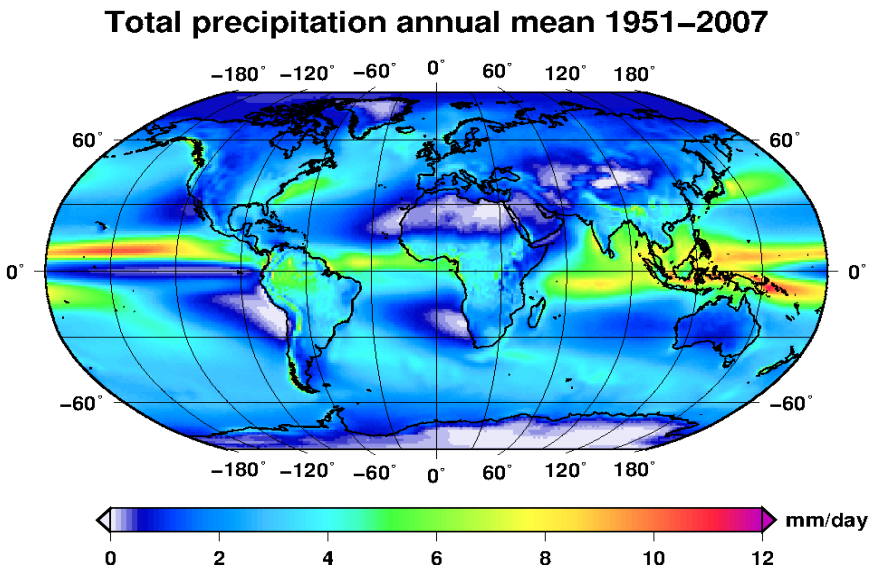
DJFMA snow depth reanalyses – Alps above 1000 m a.s.l.



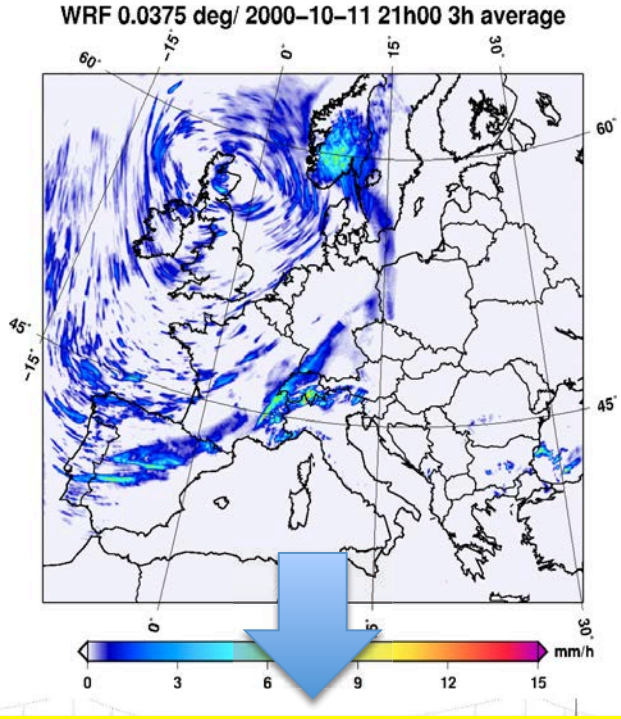


The downscaling modelling chain

Global climate model



Regional climate model



Impact on eco-hydrological processes

Statistical/stochastic downscaling

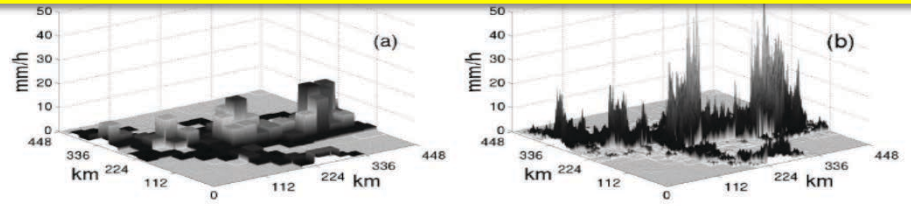
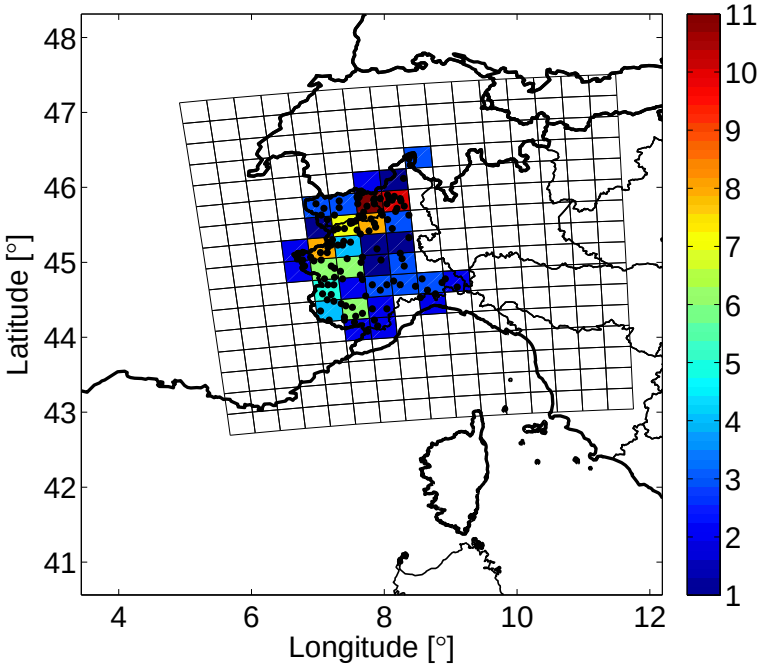


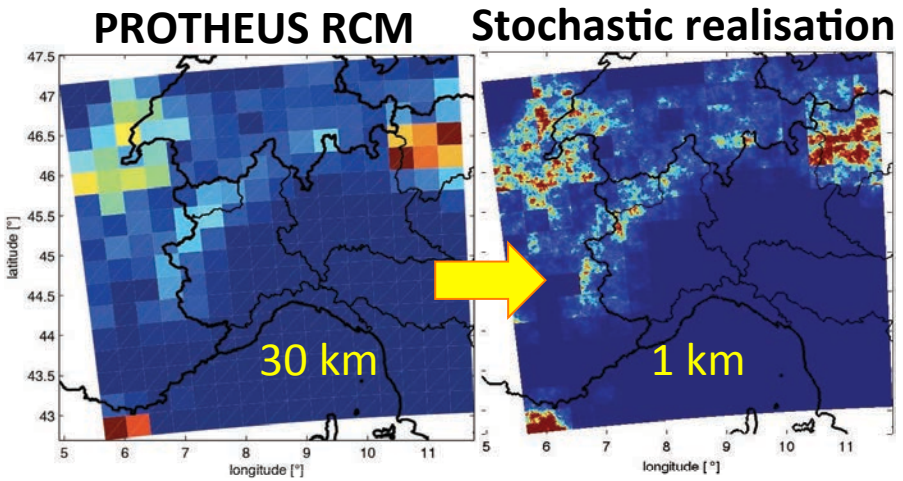
FIG. 10. (a) A snapshot of the forecasted rain field obtained from the LAM forecast and (b) one example of a downscaled field obtained by application of the RainFARM. The vertical scale indicates precipitation intensity (mm h^{-1}) and it is the same for the two fields.

Stochastic rainfall downscaling (RainFARM)

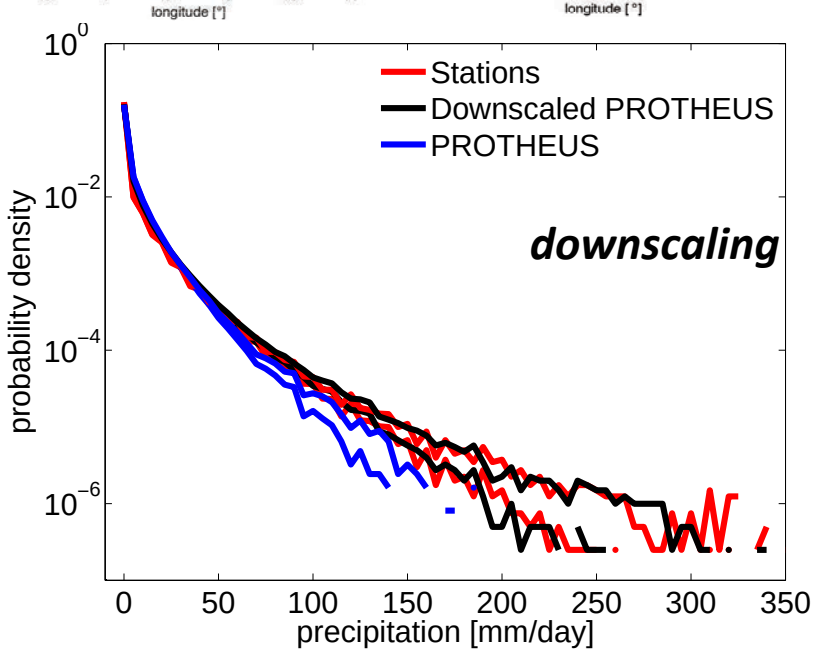
D D'Onofrio, E Palazzi, J von Hardenberg, A Provenzale, S Calmanti., Stochastic rainfall downscaling of climate models. J. Hydrometeor, 15, 830–843, 2014

Piedmont-Velle d'Aosta Regions



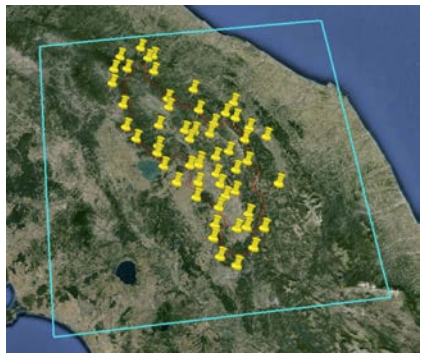


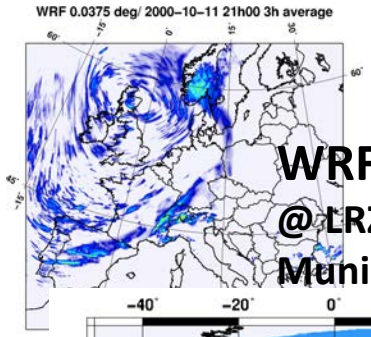
Daily precipitation PDFs of the **PROTHEUS RCM** (30 km), **individual rain gauges** and **DOWNSCALED PROTHEUS fields.** *The two lines for each PDF indicate the 5th and 95th percentile for each class.*



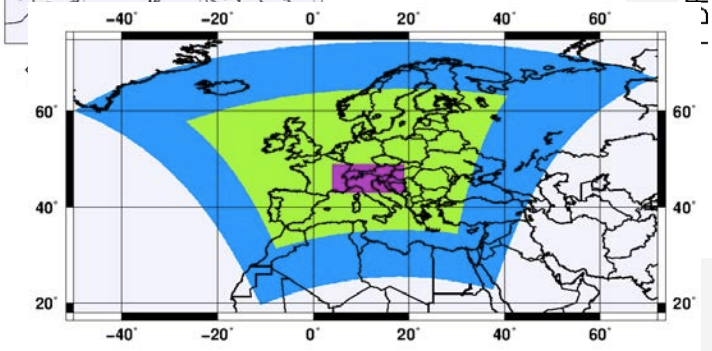
Stochastic rainfall downscaling (RainFARM)

Upper Tiber Basin region

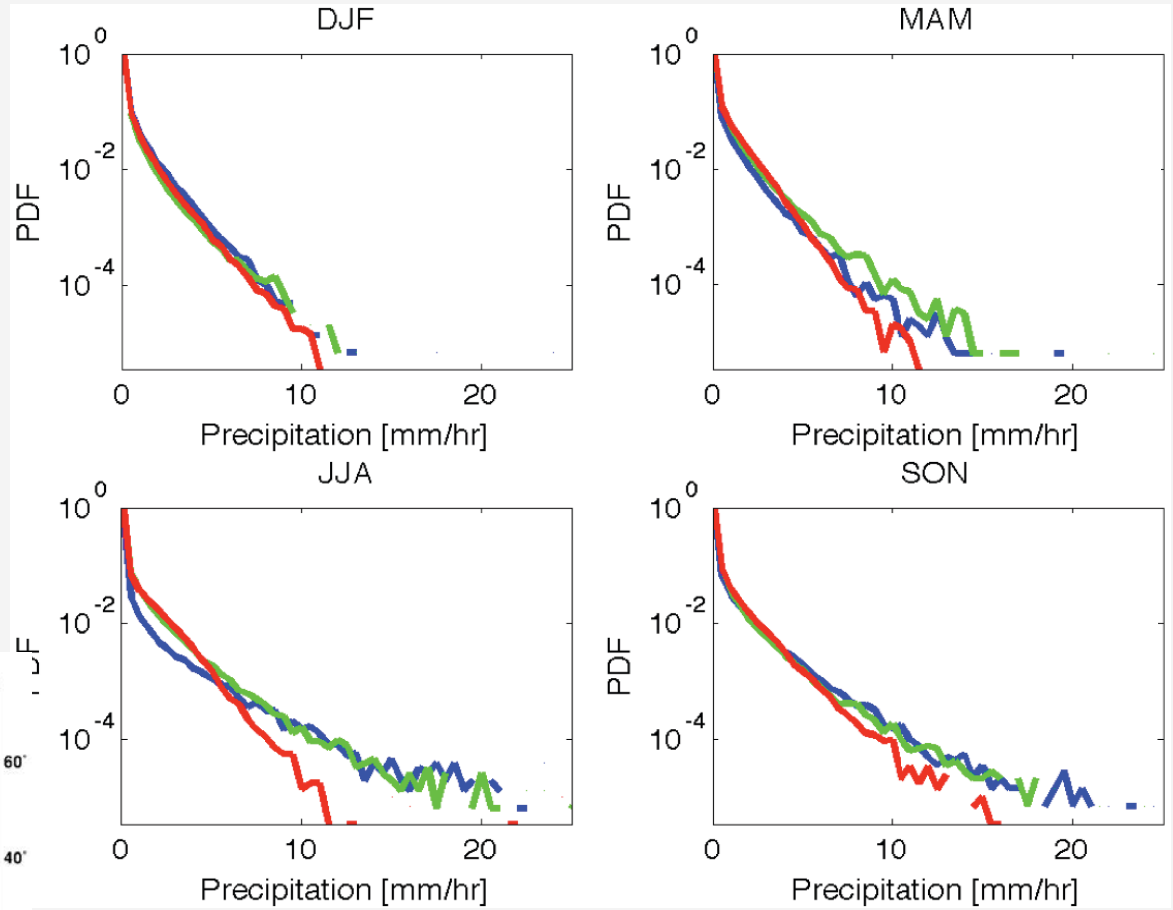




WRF Simulations @ LRZ/SuperMUC Munich



OBSERVATIONS **WRF RCM 11 km** **Downscaled WRF 1 km**



Precipitation PDFs (2003-2014)

Open questions

- *The problem of scales:* ***mismatch between the resolution of climate models and the scales needed for land surface dynamics***

The two sides of the same coin: **downscaling** and **upscaling**

Dynamical downscaling
Statistical/stochastic downscaling

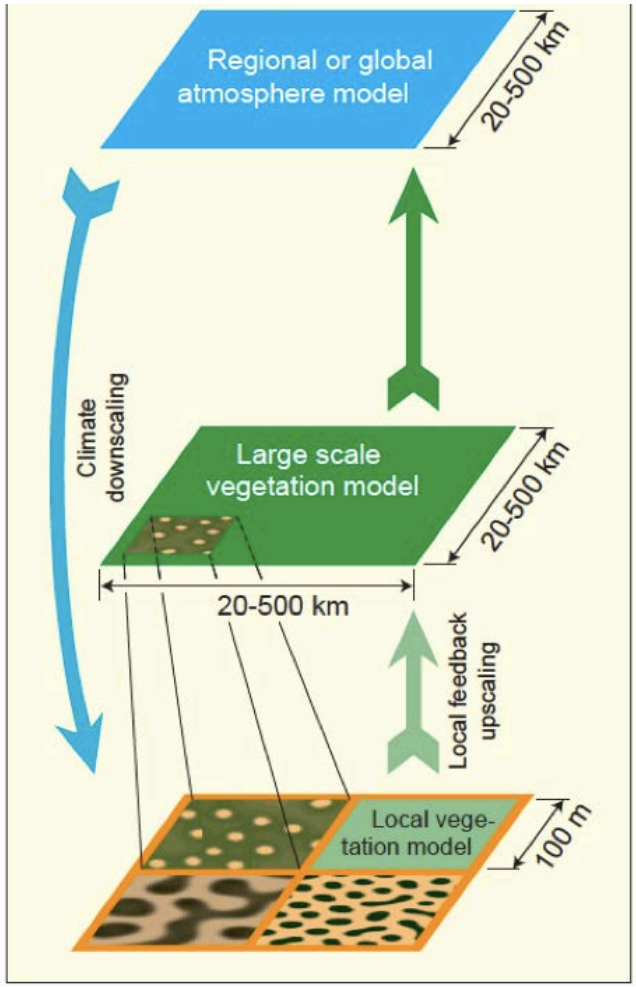
- **Hydrological modelling**
- **Impact models**
- **Representing better the interaction between climate and hydrological/land surface processes**

- **Representing better the interaction between land surface dynamics and regional/ continental climate dynamics**
- **Development of parameterizations of small-scale processes such as multiple steady states of vegetation**

Needs and perspectives

- **Coupling of feedback at multiple scales** in climate models (including local feedbacks) is an essential step to better understand and predict global climate changes

- A modelling framework that can operate **both in downscaling and upscaling modes** would provide the necessary capabilities for addressing scaling issues



Rietkerk, M. et al. (2011)
Ecological Complexity 8 (3):223-228

Thank you !

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European Climate Research Alliance

General Assembly 2015

"New knowledge for risk reduction"

Elisa Palazzi

e.palazzi@isac.cnr.it

25-26 March 2015, Brussels

Additional

CP: Changes in the Hydrological Cycle

CP Inter-linked tasks

Global precipitation changes and runoff
Aerosols and the hydrological cycle
Hydrological cycle and precipitation in mountain areas
Changes in the hydrological cycle in the Mediterranean region
Interaction between climate and hydrological/land surface processes

Hydrological cycle and precipitation in mountain areas

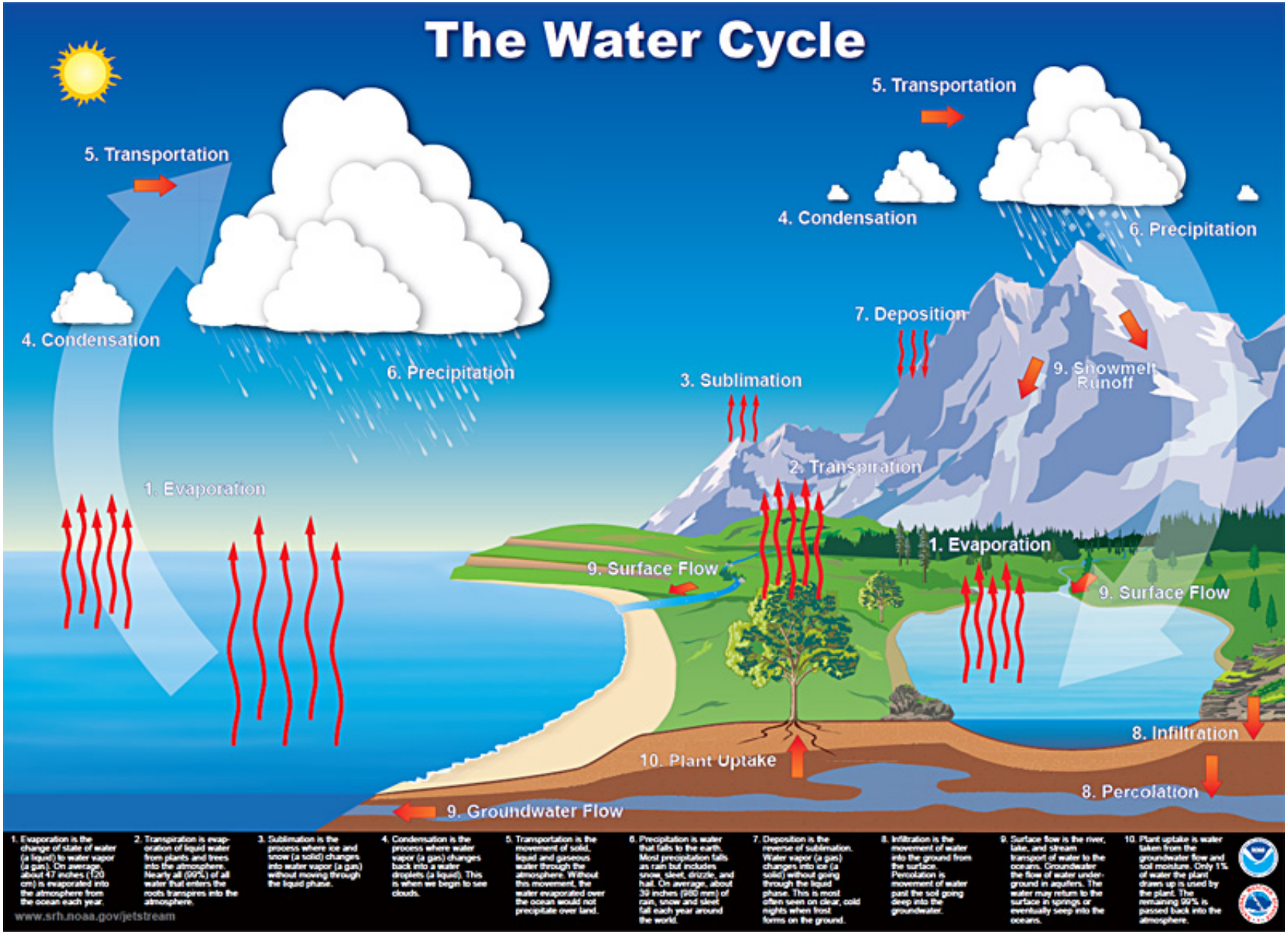
Precipitation

- **Precipitation**

Strong intermittency at all scales, **strong orographic dependence, hard to measure** (either by ground stations, radars or satellites), **hard to model**

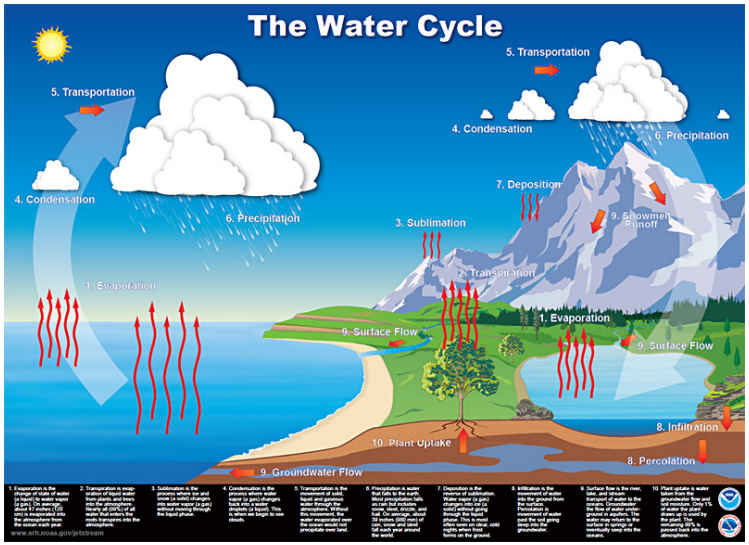
- **Snow:** Uncertainties in observations and models
- **Temperature:** e.g. Elevation Dependent Warming

The global hydrological cycle



http://www.srh.noaa.gov/

Changes in the Hydrological Cycle



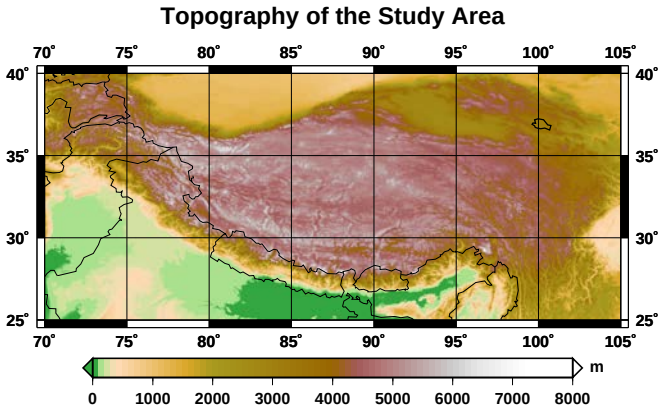
(e.g., vegetation feedbacks are positive)

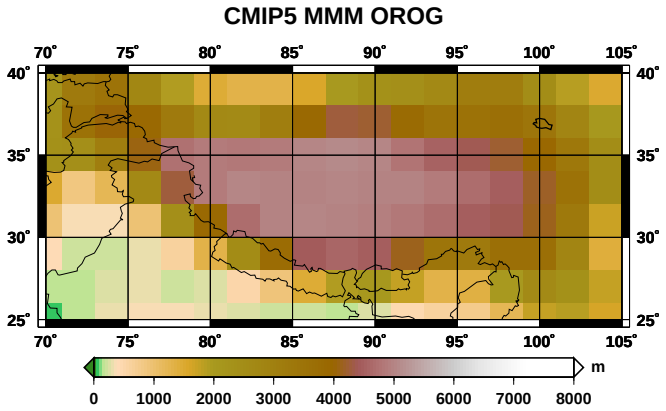
All the components of the hydrological cycle react in different ways to climate change, **sometimes amplifying each other's action (positive feedbacks)**, **sometimes giving rise to negative feedbacks**.

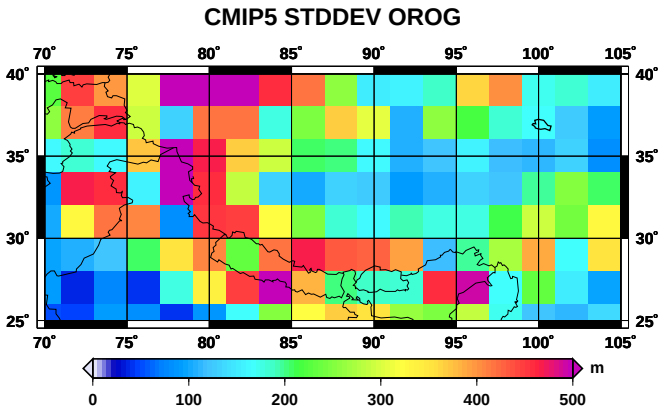
Feedbacks can connect small to large scales

Variations in the hydrological cycle often take place at **regional or even local scale** but can trigger **modifications that have an effect at larger scales** possibly leading to regional or even global changes in the water cycle

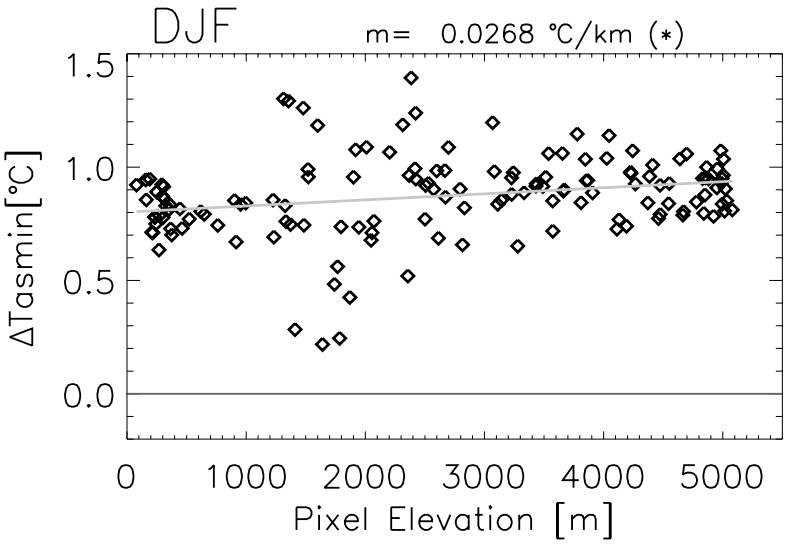
HKKH temperature (EDW): example



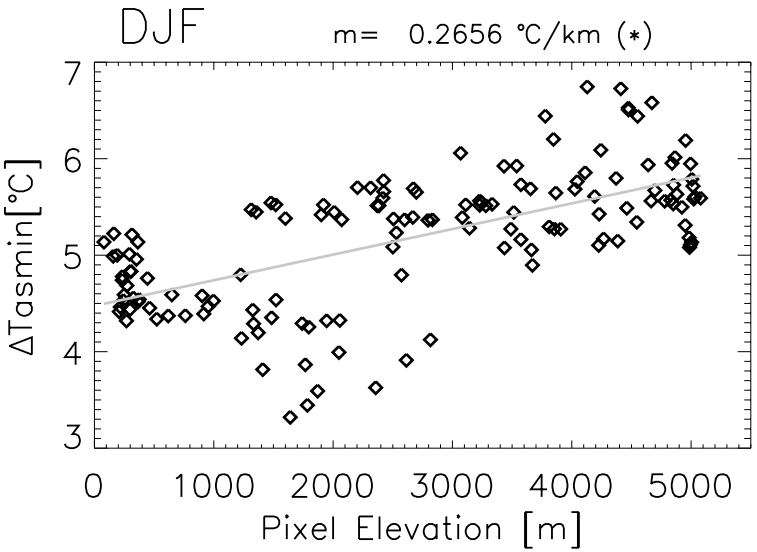




CMIP5 MMM T MIN (1986-2005)-(1901-1920)

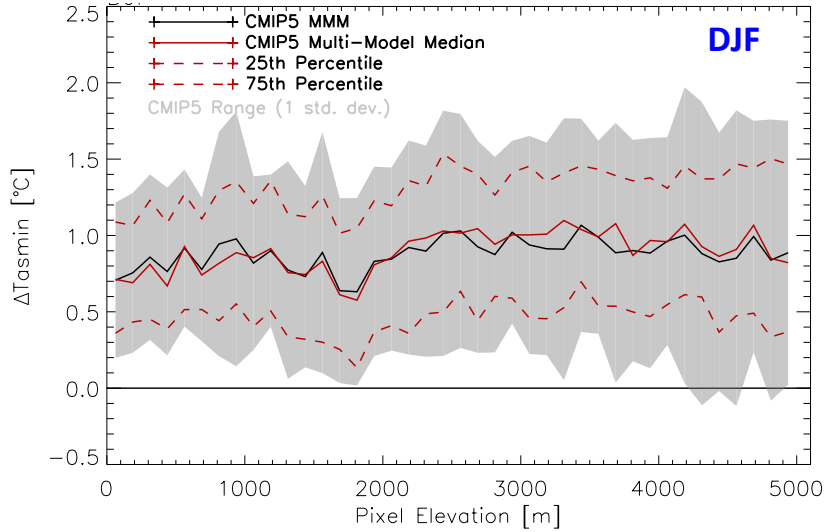


CMIP5 MMM T MIN (2081-2100)-(2006-2025)

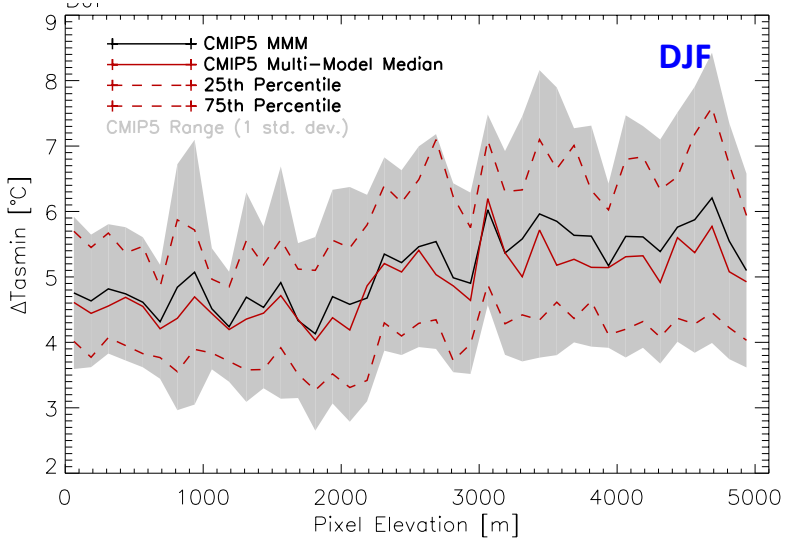


HKKH temperature (EDW): example

CMIP5 MMM T MIN (1986-2005)-(1901-1920)



CMIP5 MMM T MIN (2081-2100)-(2006-2025)



Historical	**1901-2005**	**DJF**	**MAM**	**JJA**	**SON**
	T MIN	**0.027**	**0.043**	**0.051**	**0.050**
	T MAX	**0.012**	**0.012**	**0.026**	**0.056**
Projection	**2006-2100**	**DJF**	**MAM**	**JJA**	**SON**
	T MIN	**0.266**	**0.174**	**0.153**	**0.155**
	T MAX	**0.185**	**0.120**	**0.203**	**0.295**

Slope of the linear regression (°C/Km) describing the changes in T MIN and T MAX as a function of the ELEVATION (CMIP5 MMM). RED: statistically significant values (p<0.05).