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Assessing climate change risks under uncertain conditions

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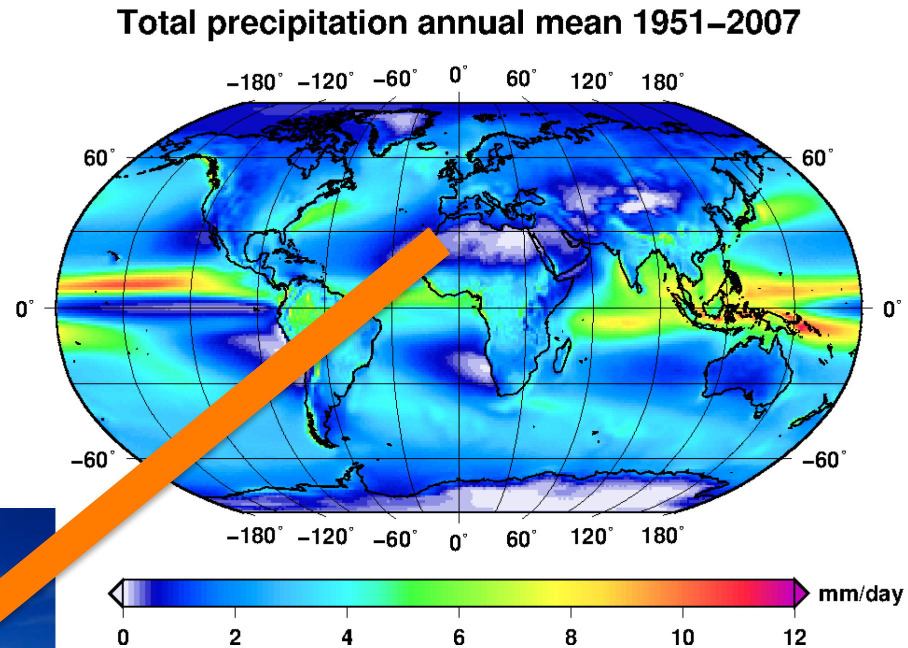
Climate change effects
on land surface processes
can lead to increased risk:

Floods and extreme events,
landslides, droughts, heat waves,
ecosystem functions and services,
food and energy production,
health, geopolitical instabilities

Most of these impacts are linked
with changes in the hydrological cycle

To estimate future risks, we need climate and impact models

Global Climate Models: The most advanced tools that are currently available for simulating the global climate system and its response to anthropogenic and natural forcings.



Impact models:
Basin response
Ecosystems
Glaciers and snow
Agriculture, Land surface

Problem:

Most climate change impacts take place at local scale

Global Climate Models currently provide climate projections spatial resolution between 40 and 100 km

So: **scale mismatch and need for climate downscaling**

Climate downscaling approaches:

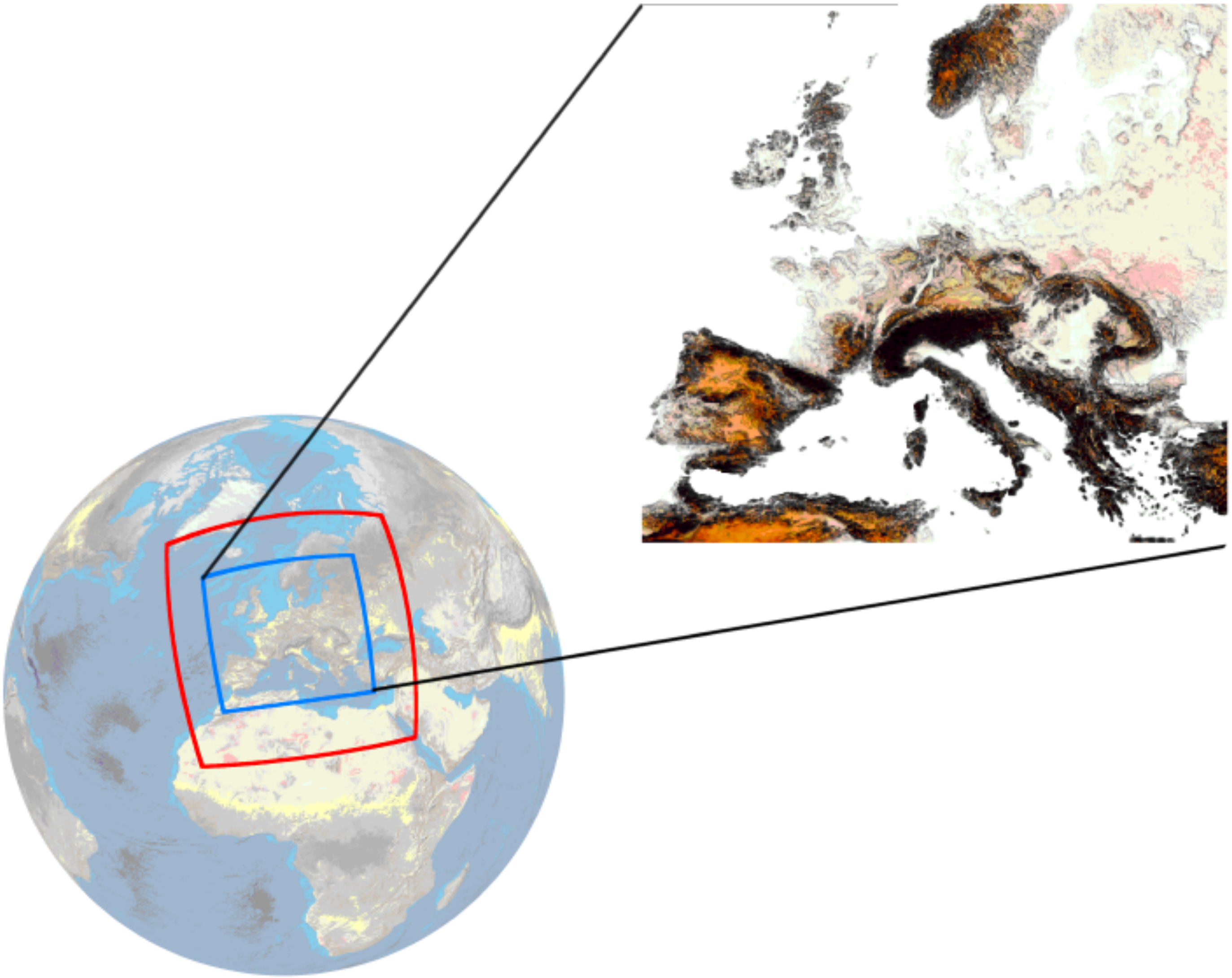
Dynamical downscaling

Regional Climate Models
(eg RegCM, Protheus)
Non-hydrostatic models
(eg COSMO-CLM, WRF)

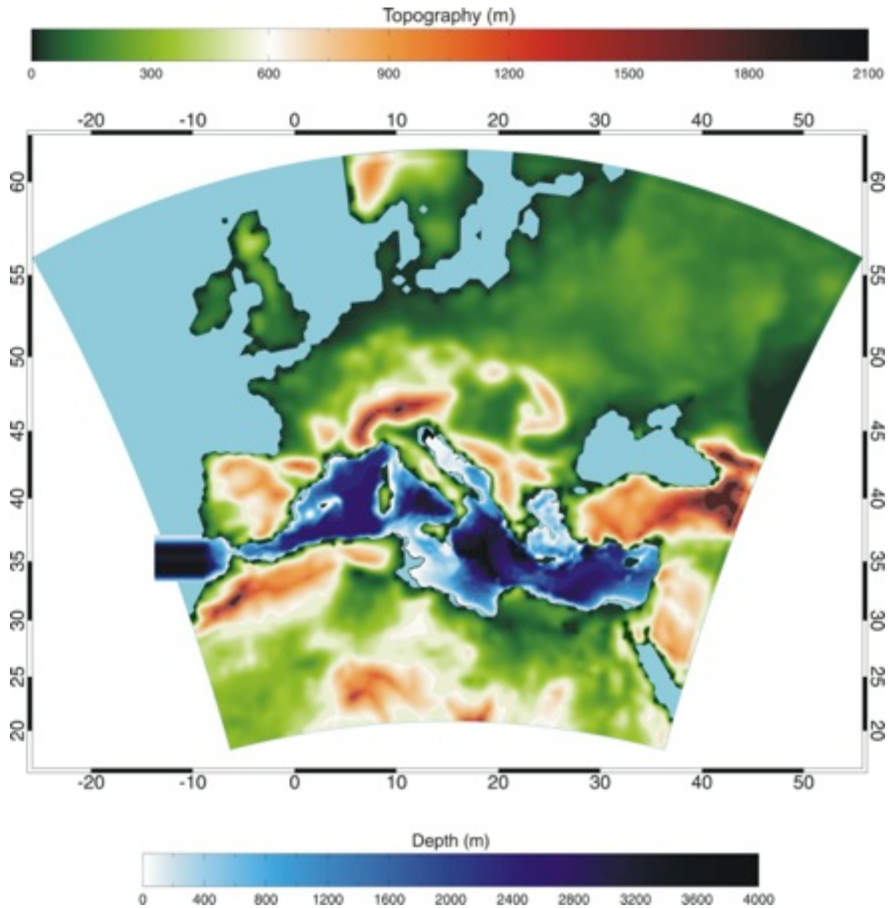
Statistical downscaling

Stochastic (rainfall) downscaling

Dynamical downscaling



Regional climate model "Protheus" – ICTP - ENEA UTMEA



Computational domain

"An Atmosphere-Ocean Regional Climate Model for the Mediterranean area: Assessment of a Present Climate Simulation". The Protheus Group, Clim. Dynamics. 2009

Components of the regional model

RegCM3

18 sigma vertical levels

30 Km horizontal resolution

BATS + IRIS

BATS: **Biosph.-Atmosph. Transfer Scheme**

IRIS: interactive RIvers Scheme

SST

OASIS 3
Freq. 6h

HF-WF-Wind

MedMIT

42 vertical levels

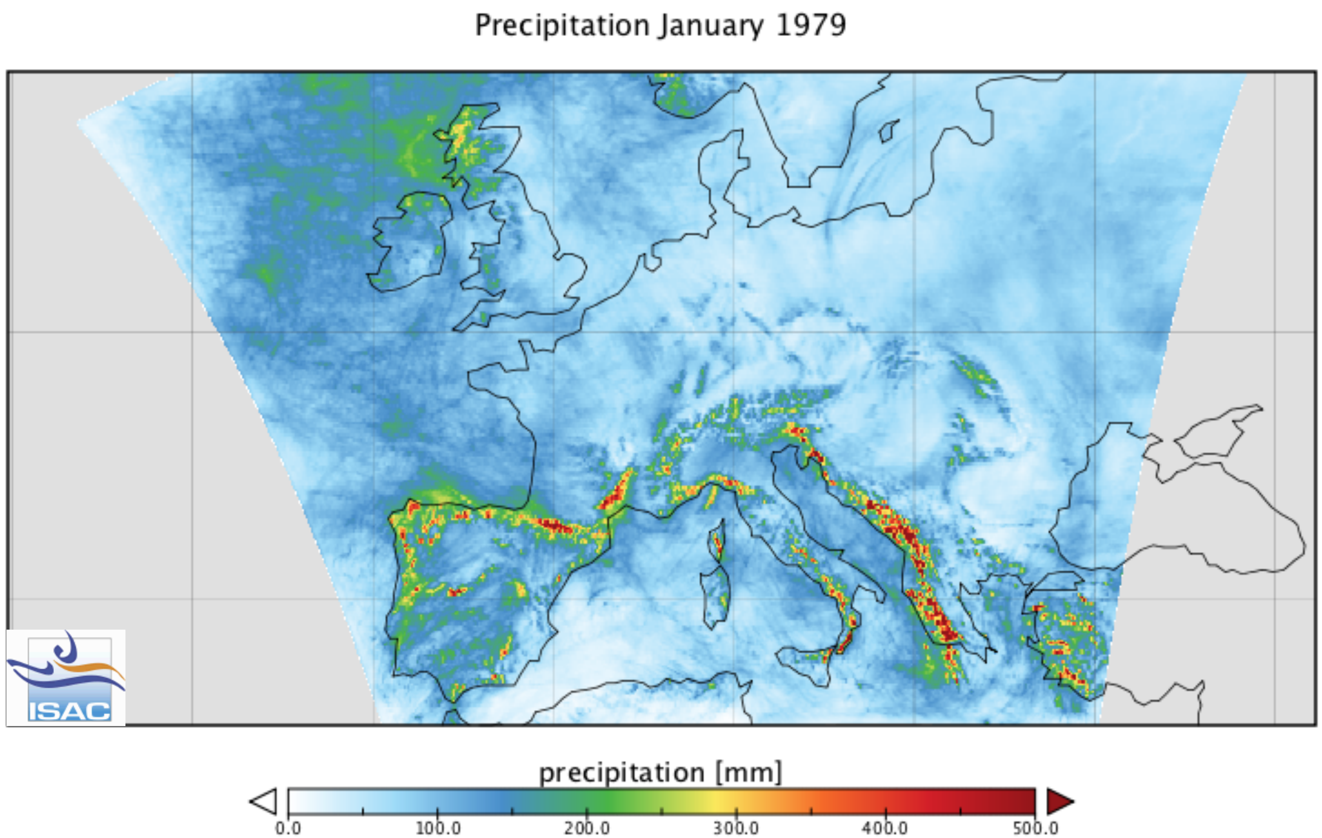
1/8° x 1/8° horizontal resolution

A collaboration between ICTP and ENEA UTMEA-CLIM

Non-hydrostatic RCMs: simulations with WRF

WRF - Weather Research & Forecasting Model
http://www.wrf-model.org/index.php

Climate simulations (30 years) with WRF at high spatial resolution (0.11° and 0.04°) nested into reanalyses (to be nested also into the EC-Earth GCM)



Total precipitation

from WRF climate simulations at 4 km January 1979

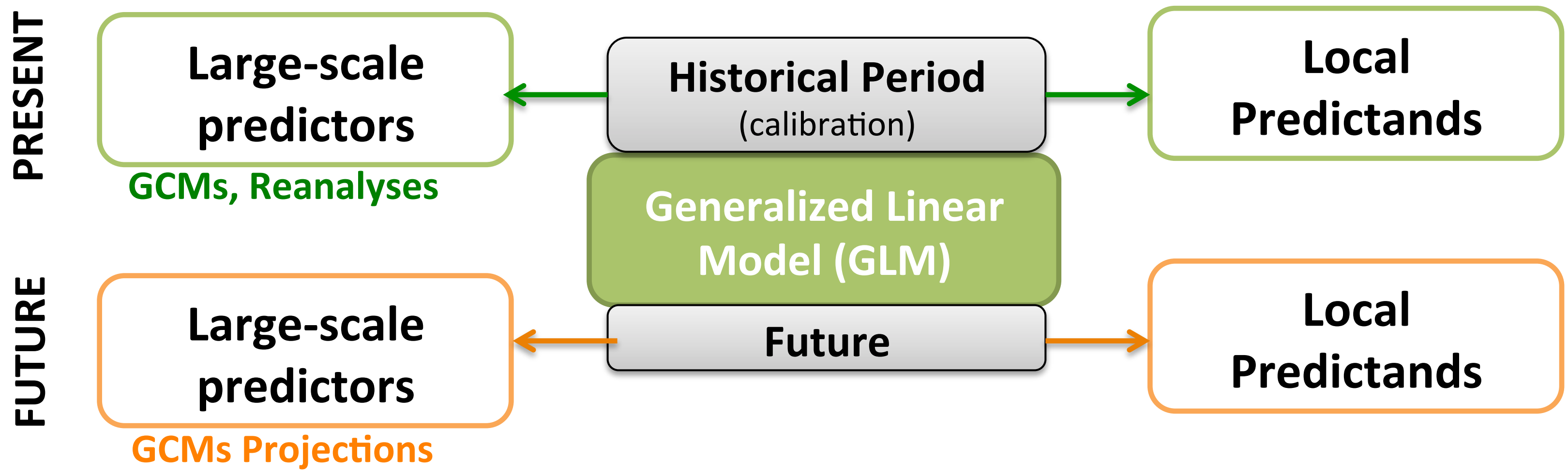
Simulations @ Leibniz-Rechenzentrum (LRZ)/ SuperMUC, Munich

Alexandre Pieri et al,
In preparation 2014

Statistical downscaling

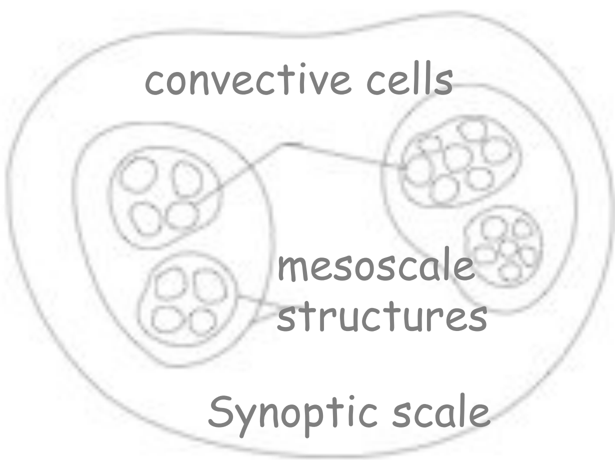
Find statistical relationships between large-scale climate features and fine-scale climate for a give region:

1. Find a large-scale predictor
2. Determine its relation with a predictand
3. Use the projected value of the predictor to estimate the future value of the predictand (assuming stationarity)



Stochastic downscaling

Highly intermittent fields such as rainfall can be difficult to handle with dynamical or statistical downscaling (no simple interpolation is possible).



- Highly **non-homogeneous phenomenon**

- Organized in **hierarchic structures (scaling property of rainfall)**

- **Highly intermittent in space and time** (alternating between dry and rainy periods).

An alternate approach is **stochastic downscaling** which leads to ensemble projections

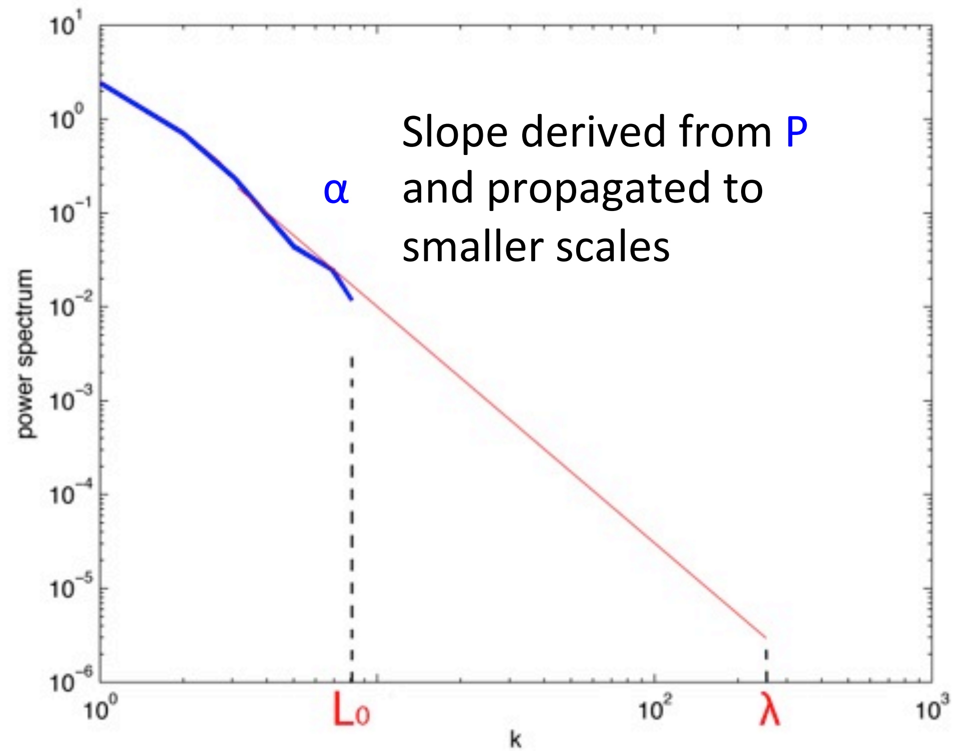
Stochastic downscaling

RainFARM (Rainfall Filtered Auto Regressive Model)

RainFARM uses simple statistical properties of large-scale rainfall fields, such as the **shape of the power spectrum,** and generates small-scale rainfall fields **propagating this information to smaller (unreliable/unresolved) scales, provided that the input field shows a (approximate) scaling behaviour**

—— P(X, Y, T), input field
L_0, T_0: reliability scales

SPATIAL Power spectrum of rainfall field



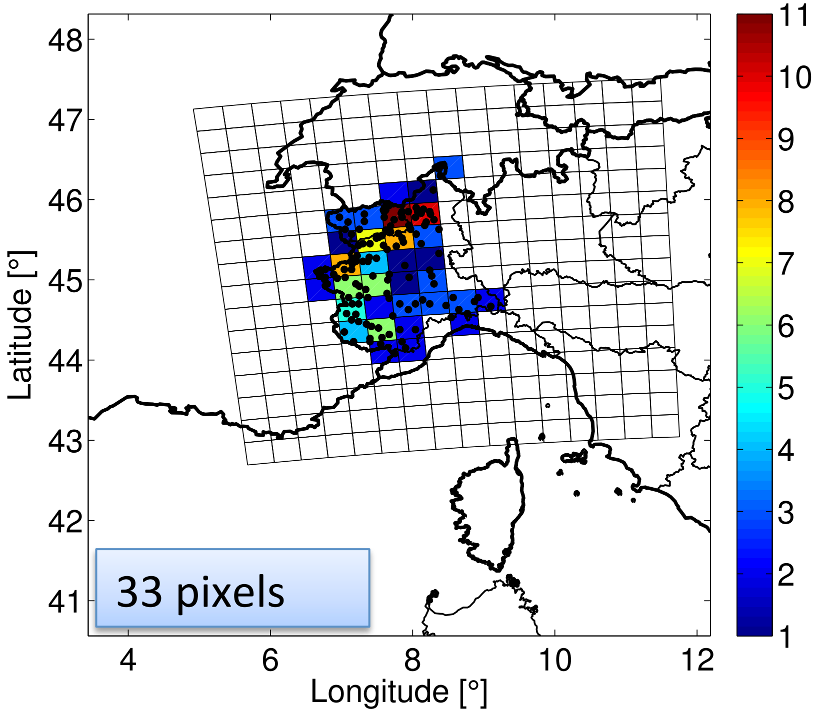
Stochastic downscaling

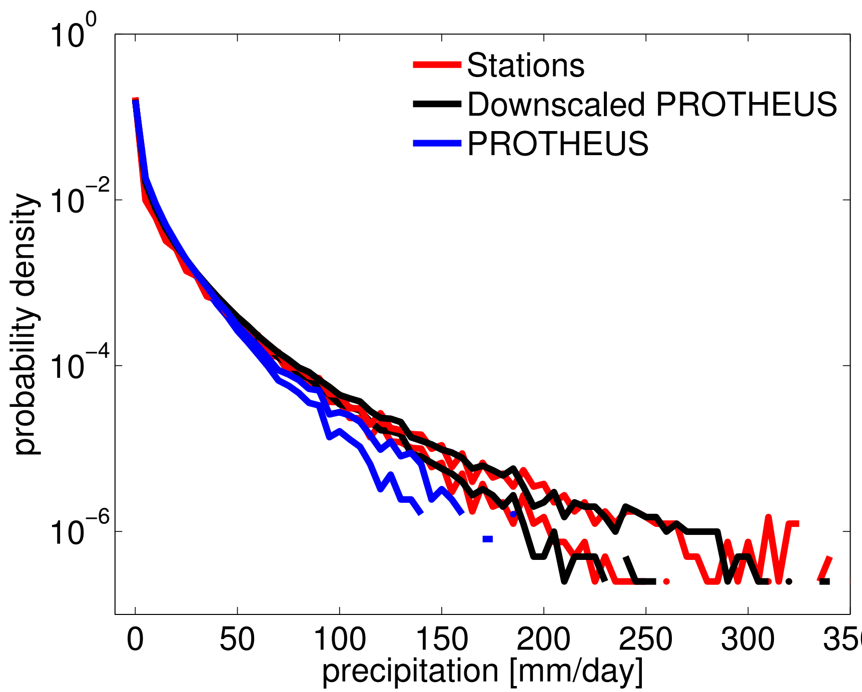
RainFARM (Rainfall Filtered Auto Regressive Model)

- 122 rain gauges
- 1958-2001
- Daily resolution
- Altitude max: 2526 m
- Altitude min: 127 m

D'Onofrio et al.,
J. Hydrometeor,
15, 830–843, 2014

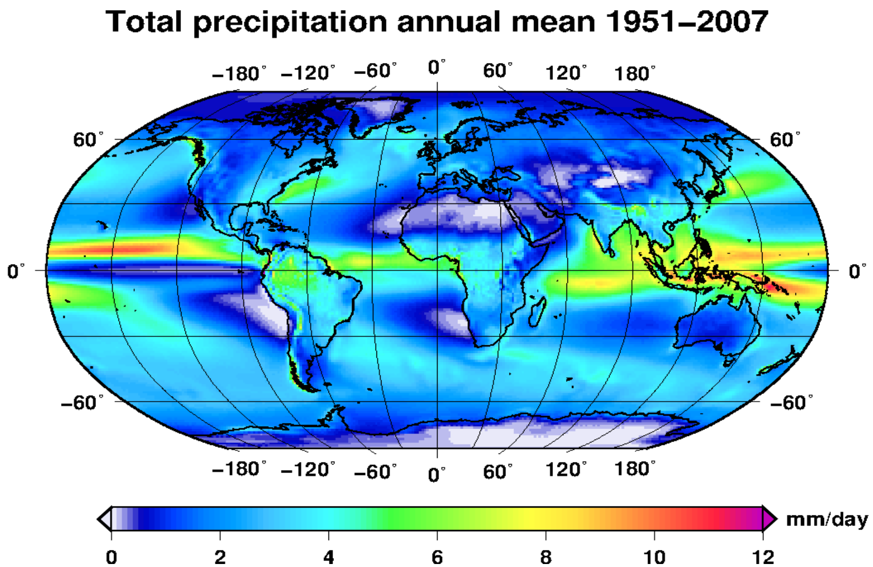
PROTHEUS: Δx≈30km



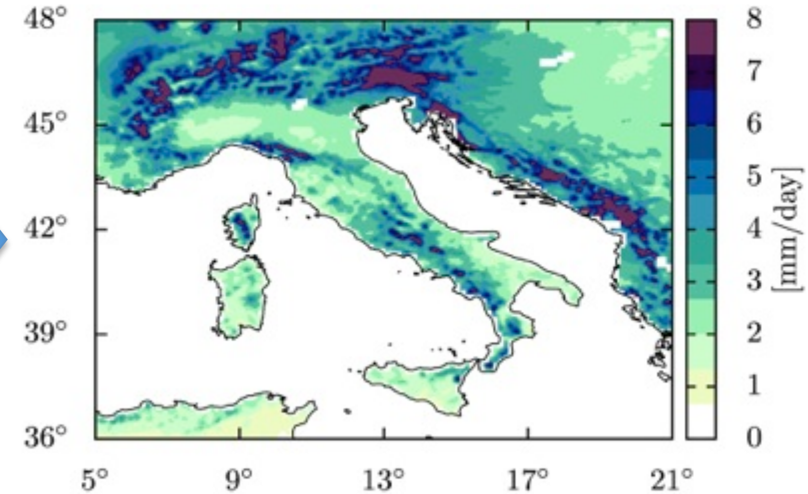


The downscaling-impact chain

Global climate model



Regional climate model



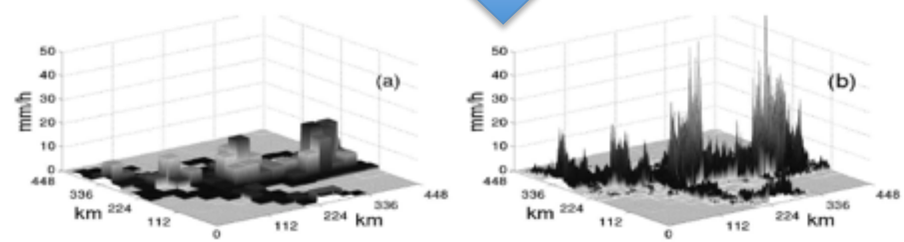


FIG. 10. (a) A snapshot of the forecasted rain field obtained from the LAM forecast and (b) one example of a downscaled field obtained by application of the RainFARM. The vertical scale indicates precipitation intensity (mm h^{-1}) and it is the same for the two fields.

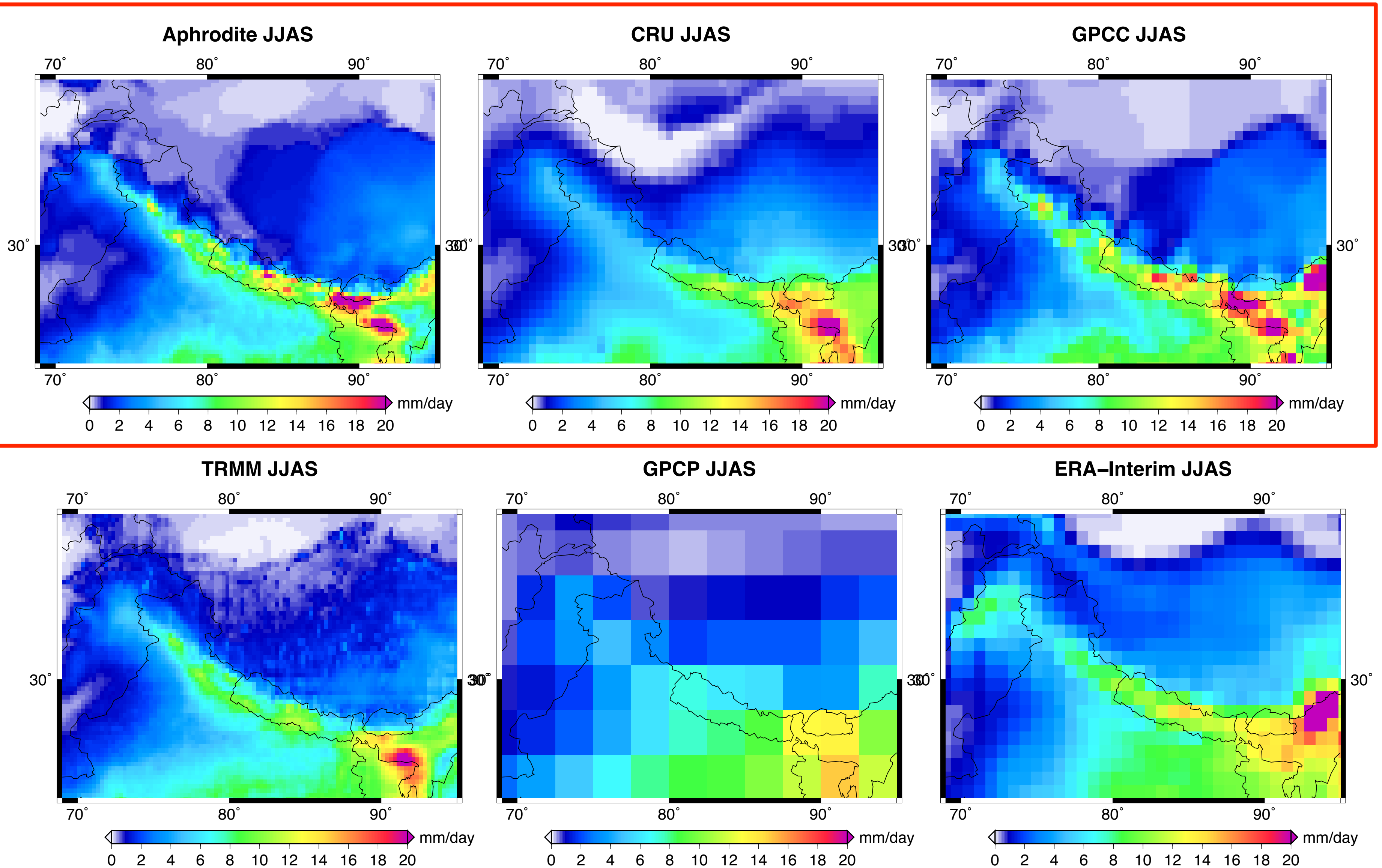
Statistical/stochastic downscaling

Impact on eco-hydrological processes


Troubles, oh troubles

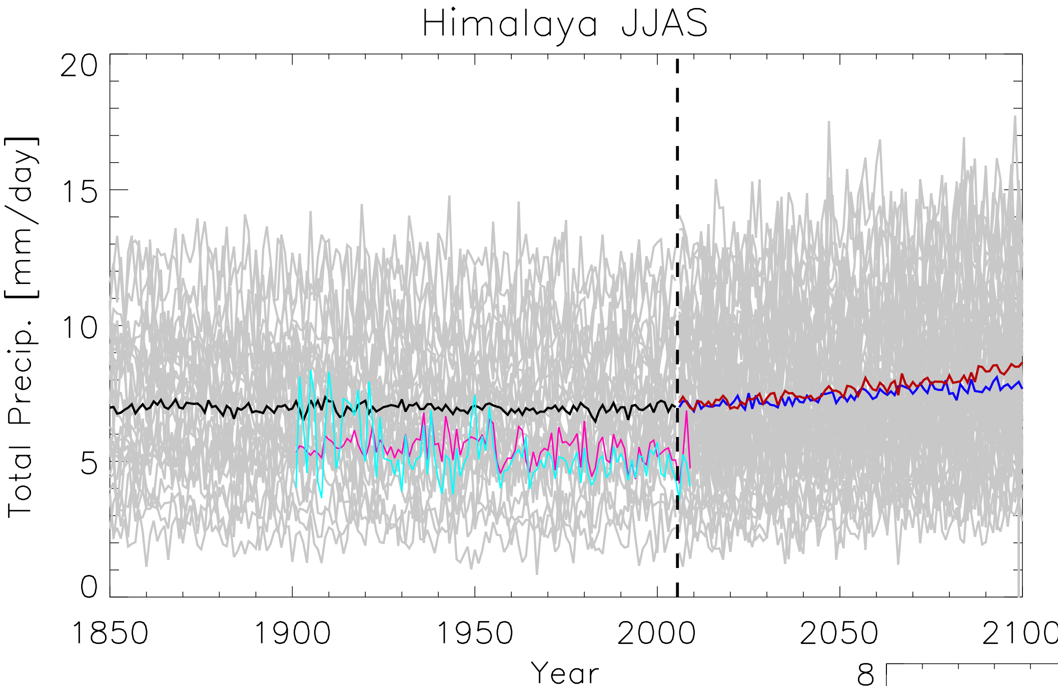
The chain of uncertainties: (1) data for model validation

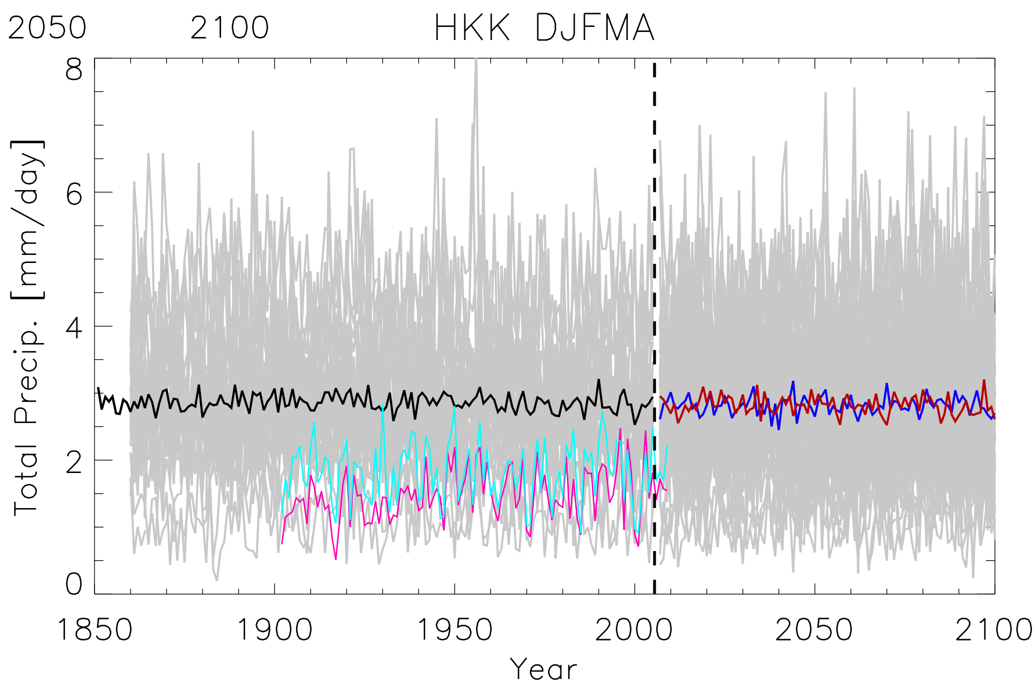
Summer precipitation (JJAS), Multiannual average 1998-2007



Palazzi E., von Hardenberg J., Provenzale A.: Precipitation in the Hindu-Kush Karakoram Himalaya: Observations and future scenarios, JGR 2013

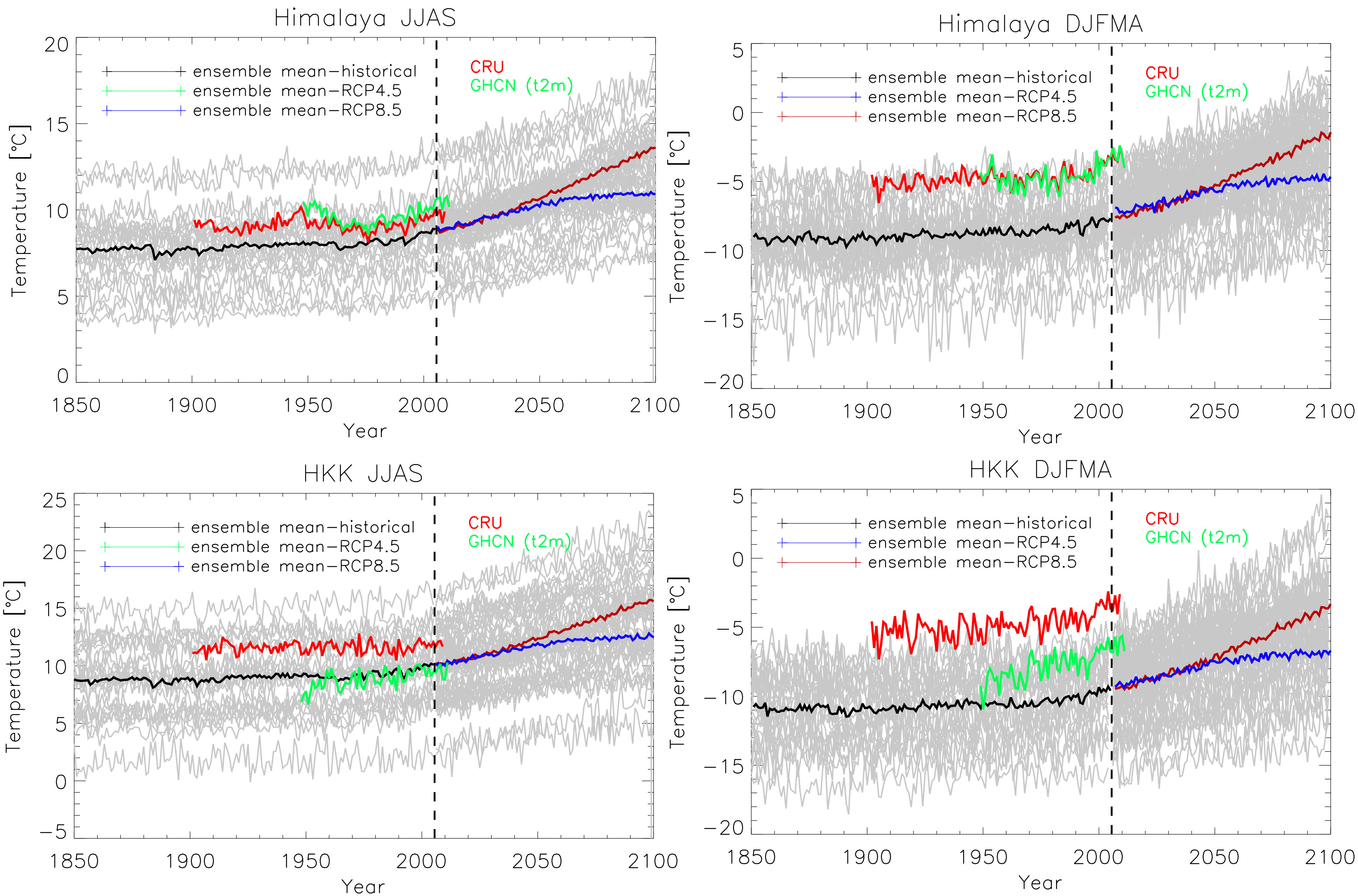
The chain of uncertainties: (2) spread between CMIP5 models



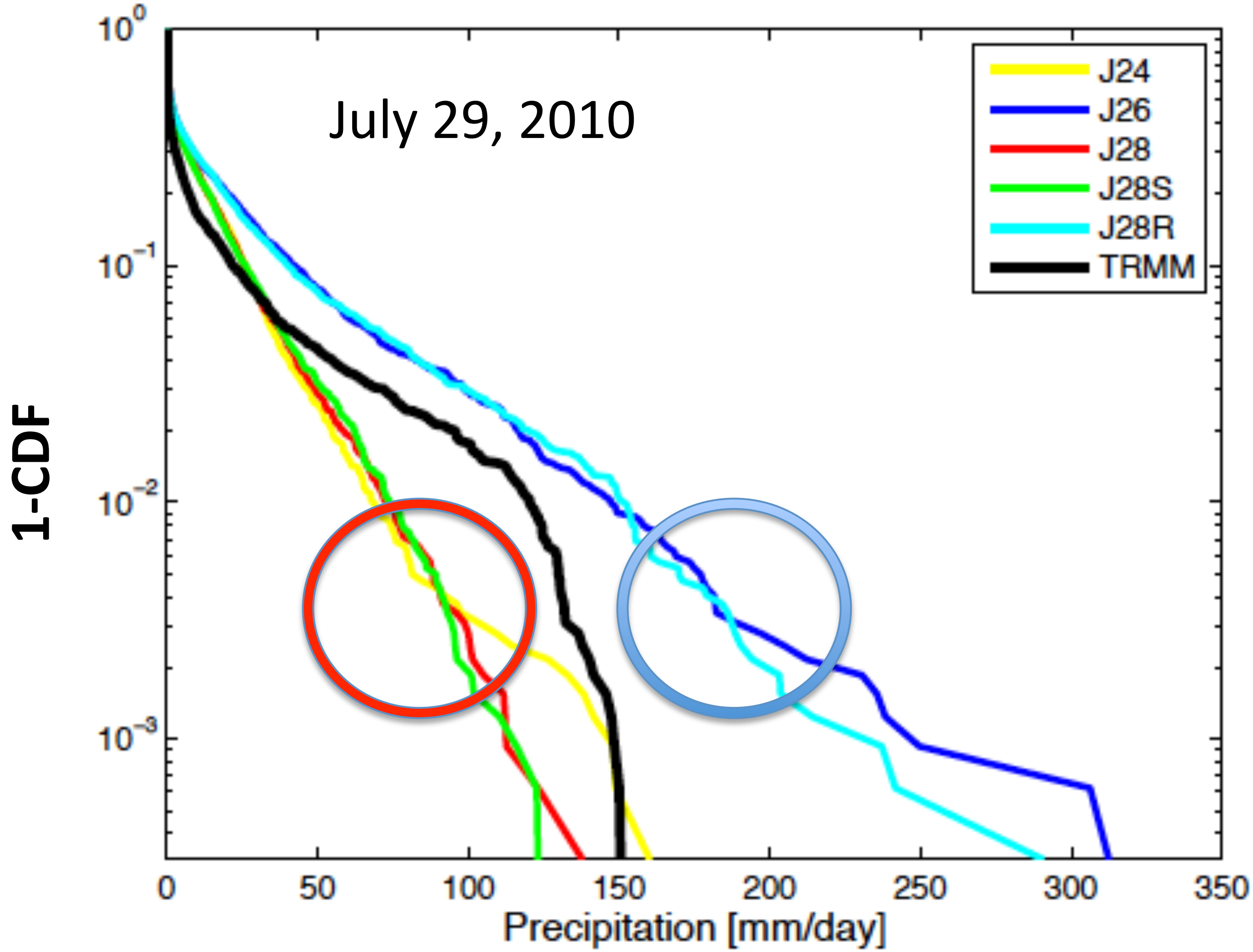


Palazzi E., von Hardenberg J., Terzago S., Provenzale A.: Precipitation in the Karakoram-Himalaya: A CMIP5 view, Climate Dynamics, 2014 (in press)

And the spread of CMIP5 temperatures

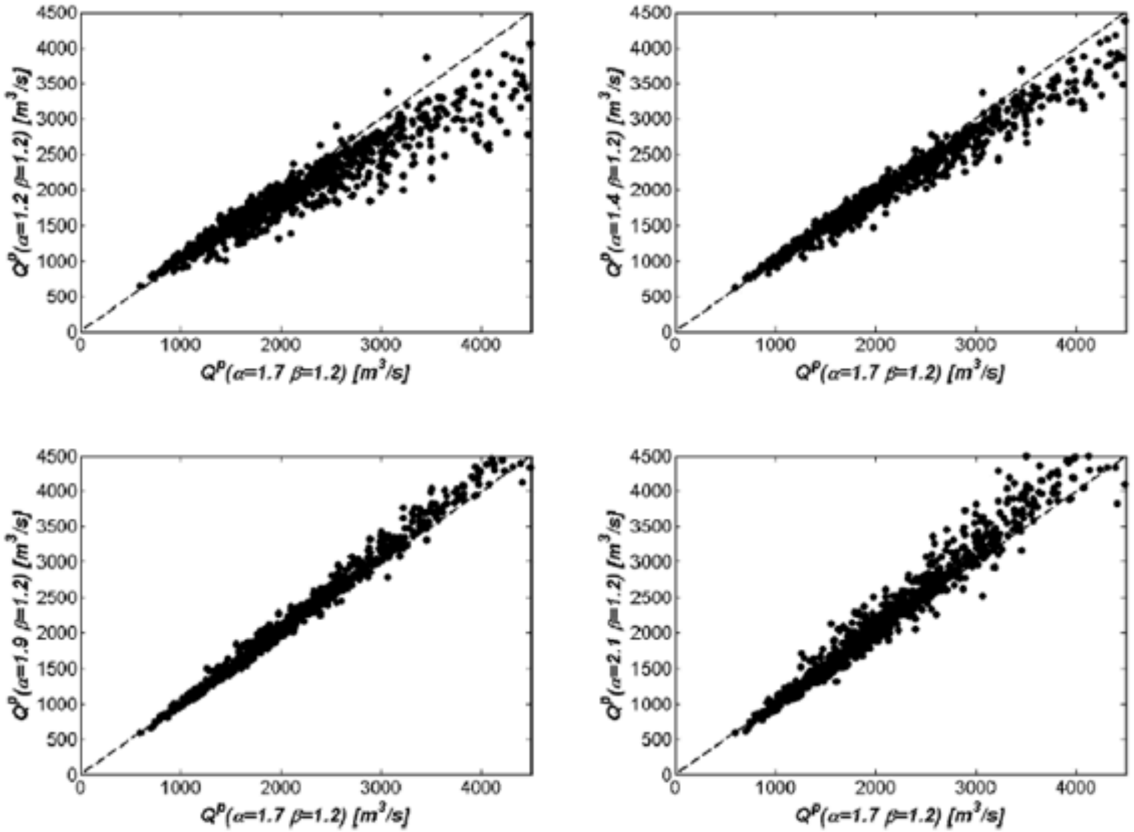


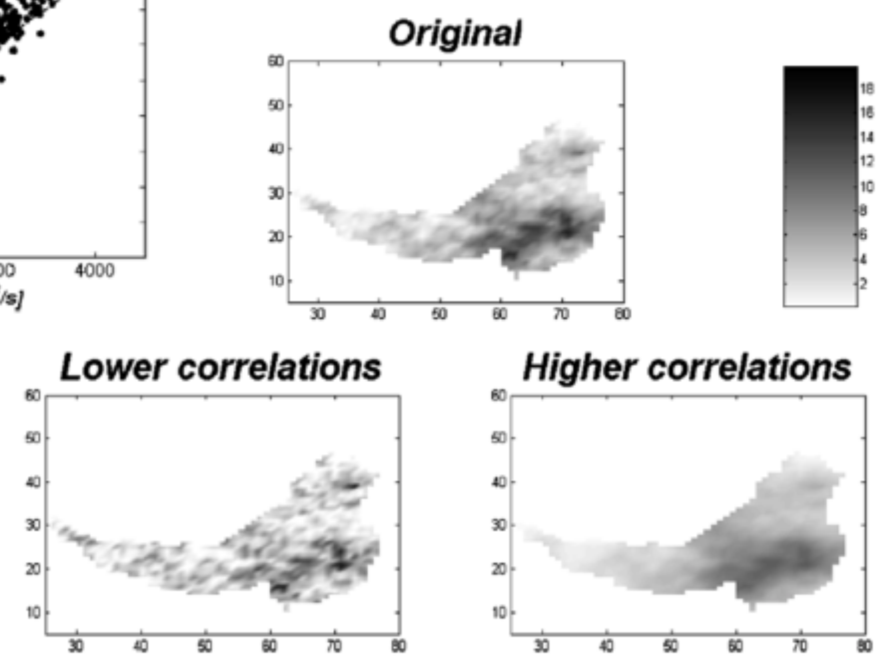
Precipitation statistics from WRF (Pakistan Flood 2010)



Francesca Viterbo et al., in preparation (2014)

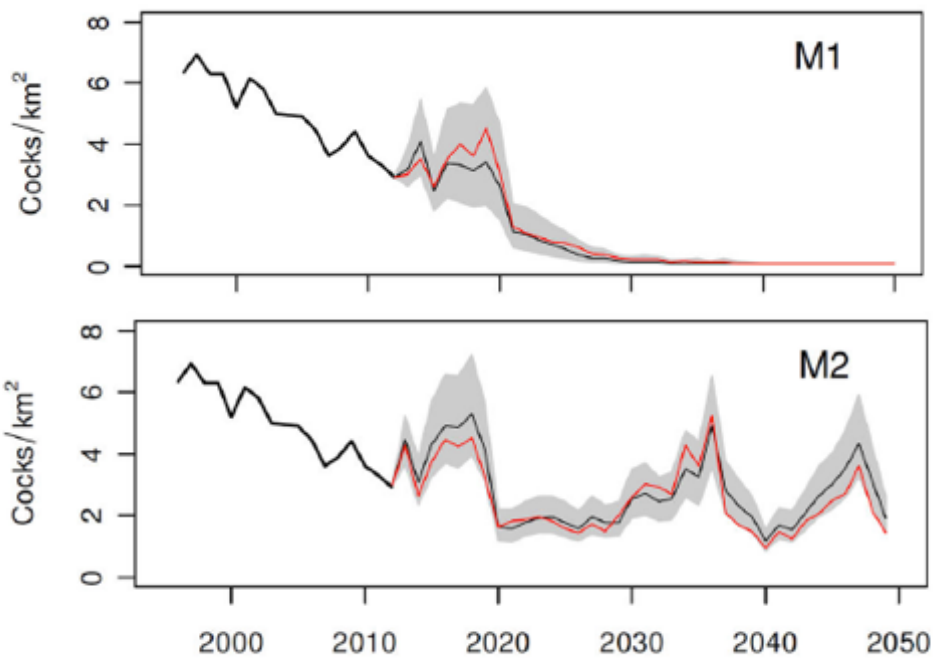
The chain of uncertainties: (3) downscaling

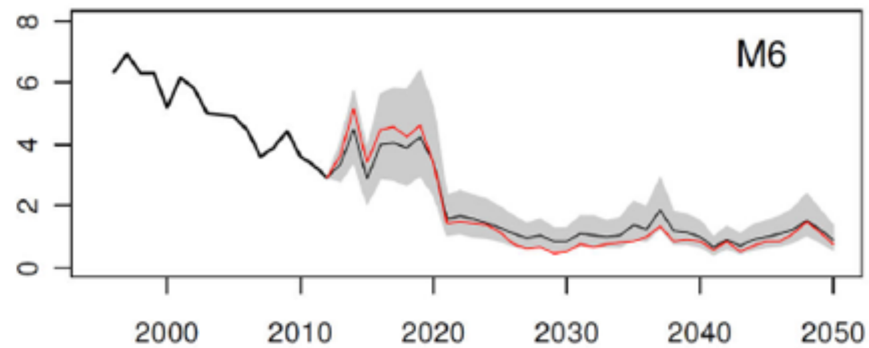




Gabellani, Boni, Ferraris,
von Hardenberg, Provenzale
Adv. Water Res. 2007

The chain of uncertainties: (4) local impact models





Model	Intercept	lnN_{t-1}	lnN_{t-2}	SE_{t-1}	SS_{t-1}	SP_t	$T(July)_{t-1}$	$P(July)_{t-1}$	$T(Jan\text{-}Mar)_t$	$T(Apr\text{-}May)_t$	var.	R^2	AICc
M1	-0.07±0.04			**-0.19±0.04**	**-0.18±0.04**						2	0.78	-50.53
M2	0.34±0.24		-0.25±0.14	**-0.19±0.04**	**-0.19±0.04**						3	0.83	-50.20
M3	-0.07±0.04			**-0.19±0.04**	**-0.18±0.04**			0.05±0.03			3	0.82	-49.28
M4	-0.07±0.04			**-0.19±0.04**	**-0.17±0.04**		-0.05±0.04				3	0.81	-48.51
M5	-0.07±0.04			**-0.20±0.04**	**-0.18±0.04**				-0.03±0.04		3	0.79	-47.28
M6	0.08±0.26	-0.10±0.16		**-0.18±0.04**	**-0.17±0.04**						3	0.78	-46.98

Simona Imperio, Radames Bionda, Ramona Viterbi, Antonello Provenzale,
Alpine rock ptarmigan, PLOS One, 2013

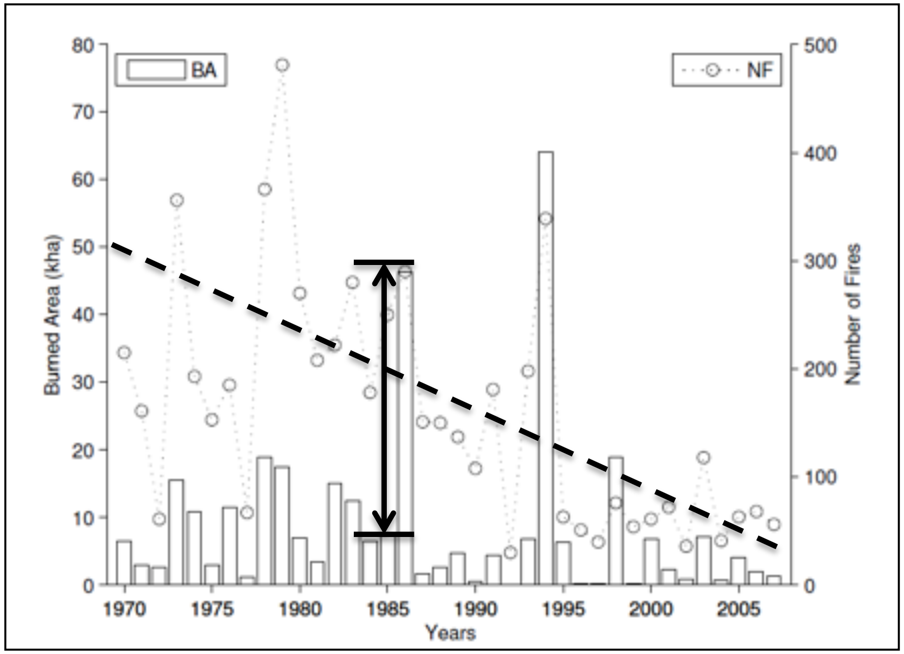
The chain of uncertainties: (4) local impact models

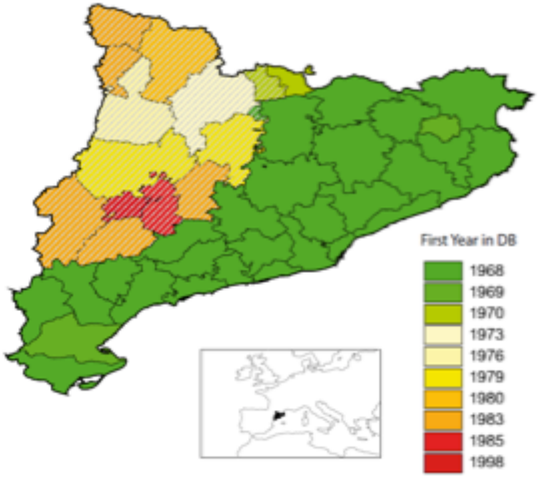
Climate change and forest fires

Long-term changes → human activities, climate trends.

The year-to-year changes in NF and BA are mainly related to **climate variability**.

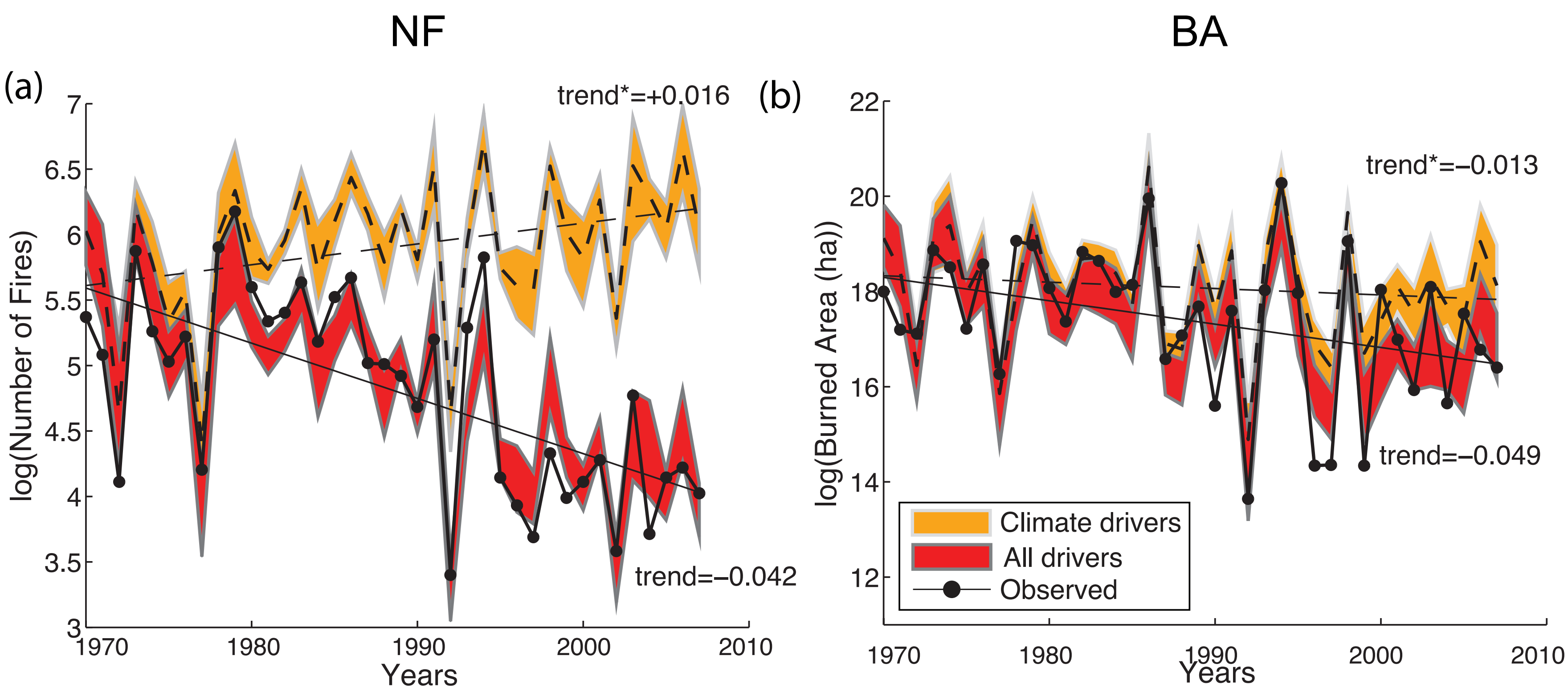
The climate acts mainly on two aspects: (i) **antecedent climate** → fuel to burn; (ii) **coincident climate**→ fuel flammability.





Turco et al. Climatic Change 2013, 2014, NHESS 2013

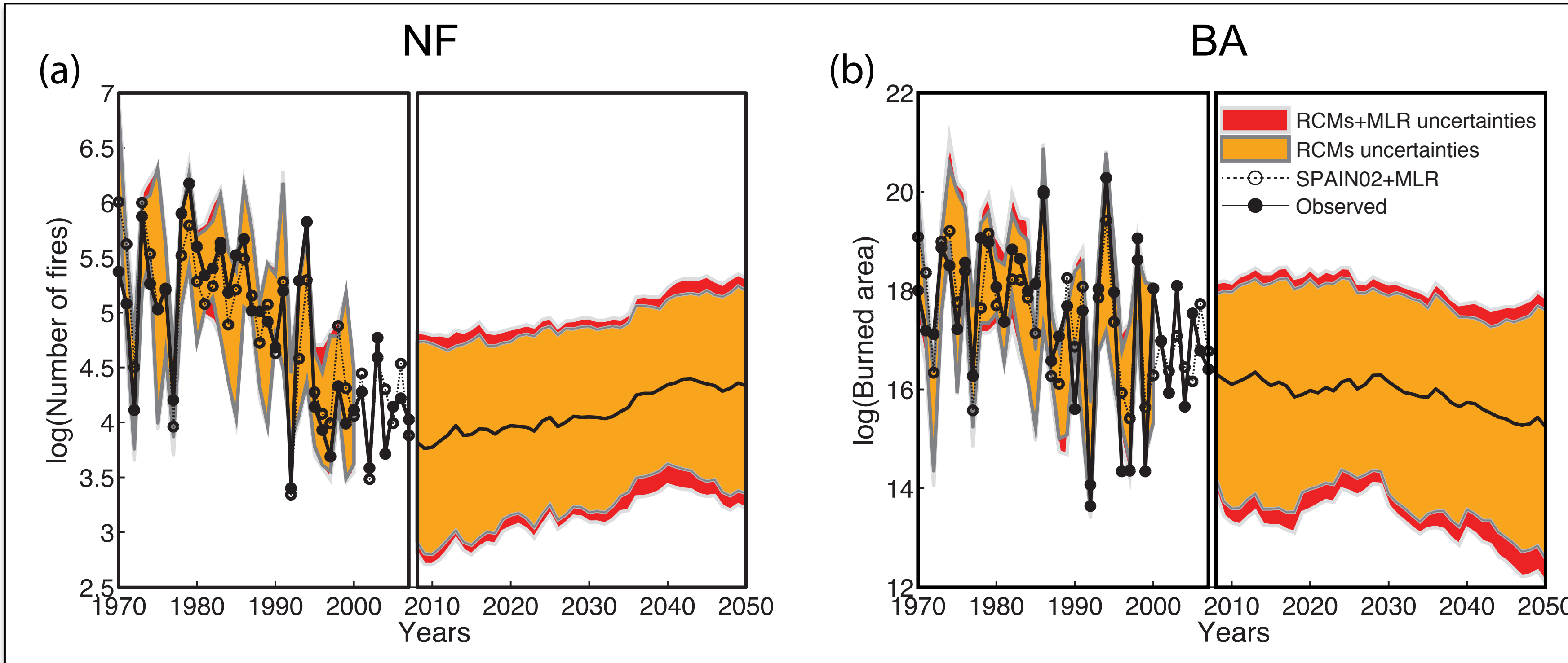
Fire response to climate trends



Uncertainty bands: includes 90% of the members of 1000 different bootstrap replicates

Climate drivers = both interannual variability and trend are driven by climate
All drivers= MLR considers the year-to-year climate variation + overall trend

Impact of future climate change on wildfires



- Future response depends on management strategies
- Uncertainty in RCM scenarios is larger than impact model uncertainties for forest fires

Conclusions (?)

Scale mismatch between climate models (and drivers) and land surface response: need for **downscaling** (and upscaling) and consideration of cross-scale interactions

Huge uncertainties in data, climate models, downscaling procedures, impact models: need for **ensemble approaches**, need for **uncertainty estimates**, need for **caution** in providing and interpreting results.

To address these issues,
Open-access EO and in situ data are essential

NextData
un sistema nazionale per la raccolta, conservazione, accessibilità e diffusione dei dati ambientali e climatici in aree montane e marine

ECRA
European Climate Research Alliance

We know a lot, but still not enough

**Application must be based on solid grounds:
further research and understanding
of climate and land surface systems
are necessary**

**The role of interdisciplinary approaches
In Geosciences is crucial: we need to think
In terms of Earth System Science**


Thank you for your attention!