Paris, 16 and 17 October 2012
Workshop IS-ENES

STOCHASTIC RAINFALL DOWNSCALING role of RCMs

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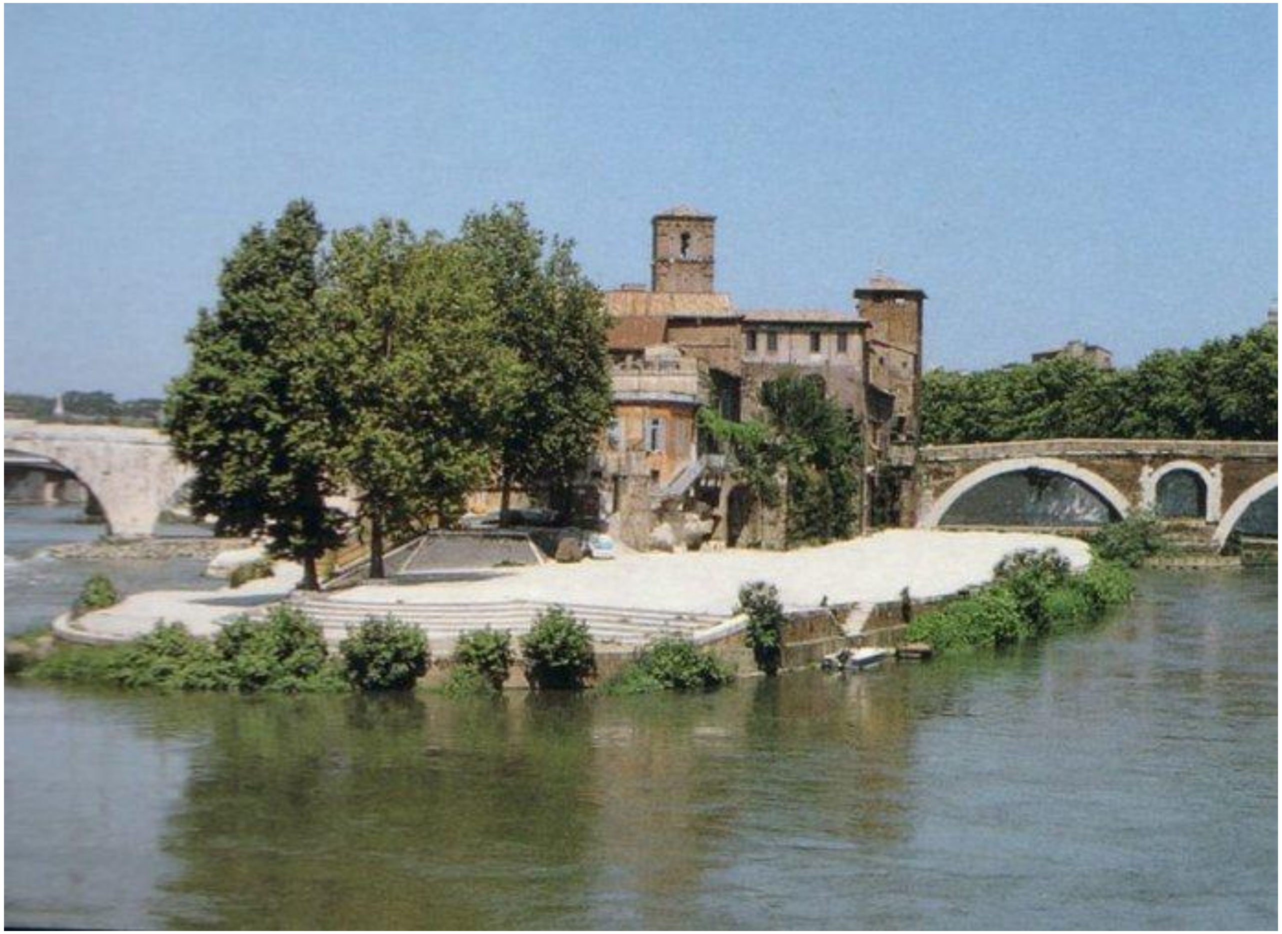
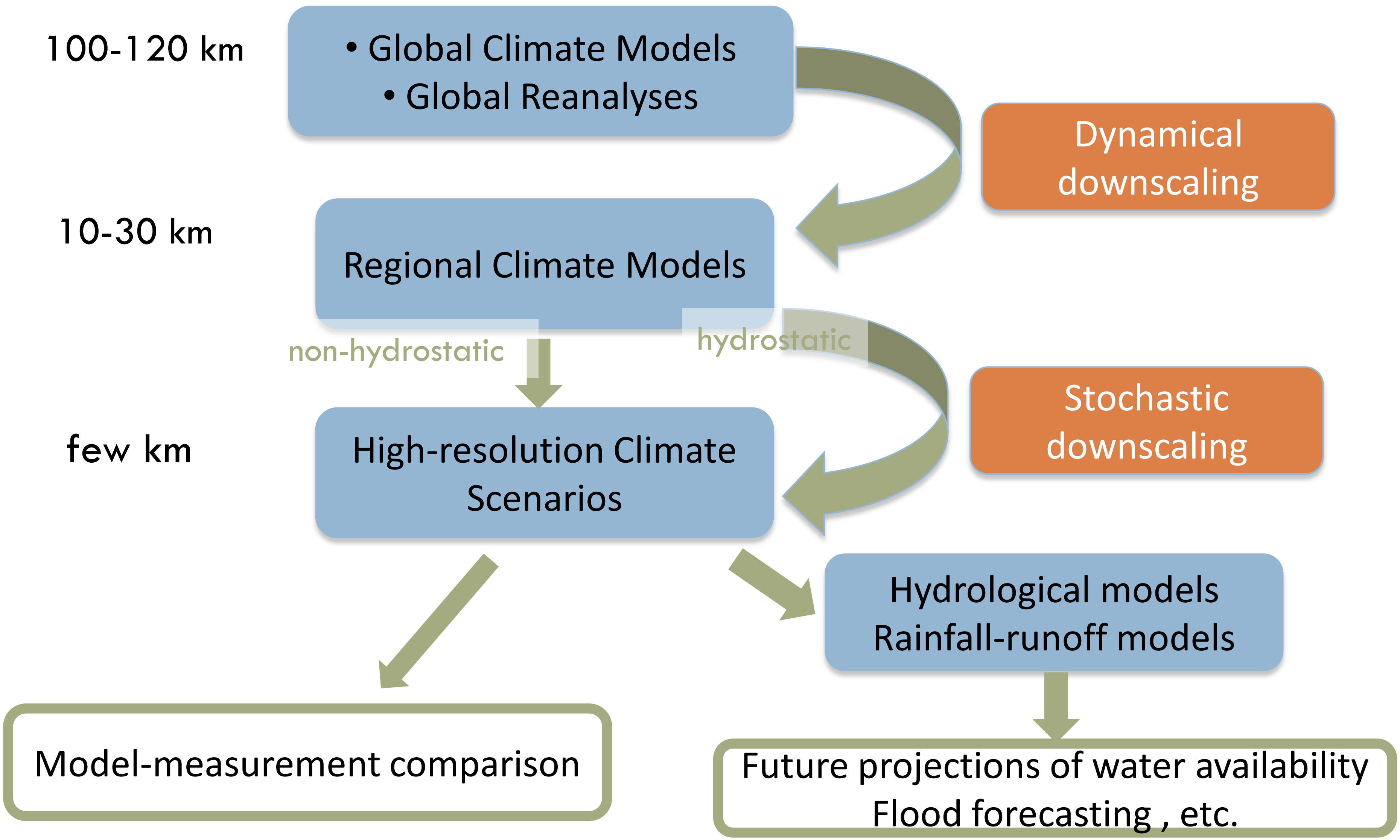
E. Palazzi and A. Provenzale



Modelling chain: bridging the gap



Upscaling: PROTHEUS vs averaged raingauge data

Spatially averaged over all model pixels (also true for each pixel)

	Average P (mm/day)	P intensity (mm/day)	Zeros (%)
Model data	3.7	7.0	46.8
Observed data	2.7	7.8	64.4
	Total precipitation	Precipitation intensity	Dry days

$p_0 = 0.1$ mm/day

PROTHEUS overestimates the total precipitation but underestimates precipitation intensity and the number of dry days. **Precipitation in the model is more frequent than in the observations**. There is a strong correlation between the interannual variability of model data and observed data.

RainFARM downscaling procedure

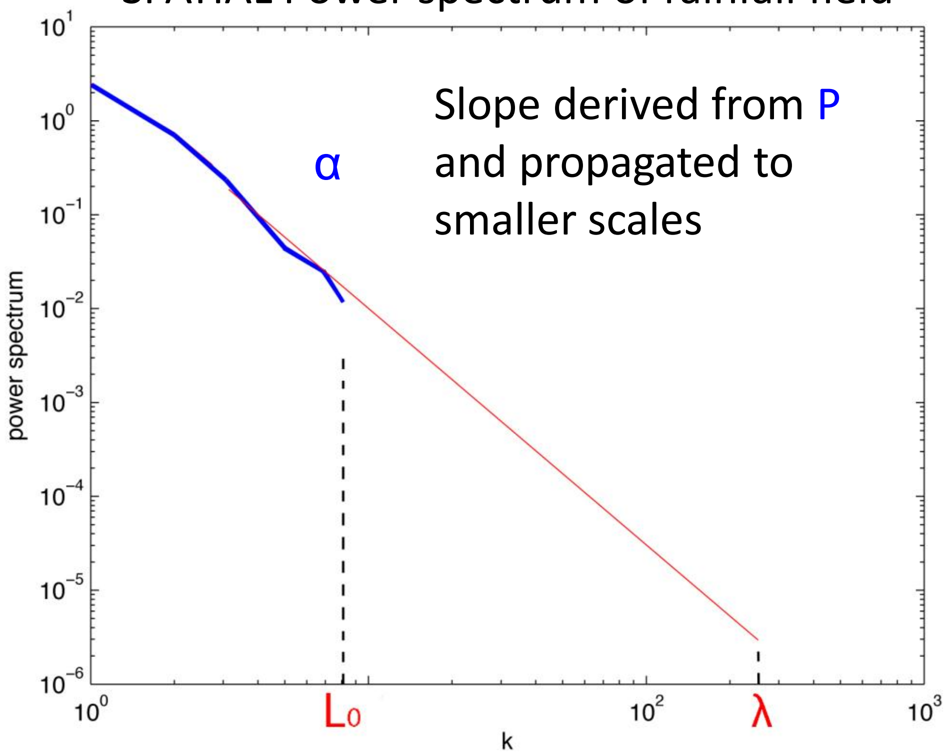
RAINFarm: Rainfall Filtered Auto Regressive Model

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

$r(x,y,t)$, output field, resolution λ, τ

Belongs to the family of "Metagaussian models", based on the nonlinear transformation of a linearly correlated stochastic field, obtained by extrapolating to small scales the power spectrum (i.e., the spatial logarithmic slope) of the original field (provided that the input field shows a approximate scaling behavior)

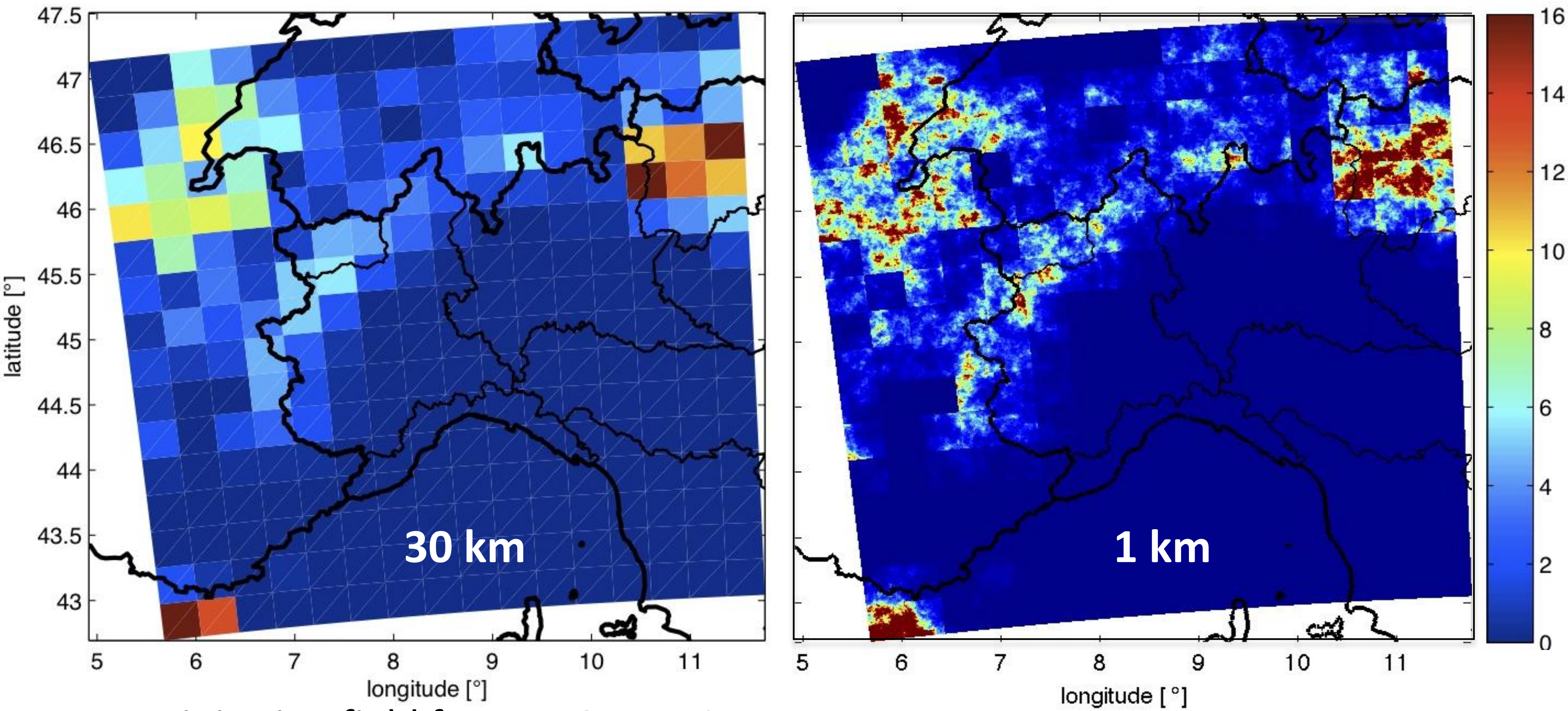
SPATIAL Power spectrum of rainfall field



Rebora et al., J. Hydrometeorol., 2006

RainFARM downscaling: example

Example SON 1958



Precipitation field from PROTHEUS

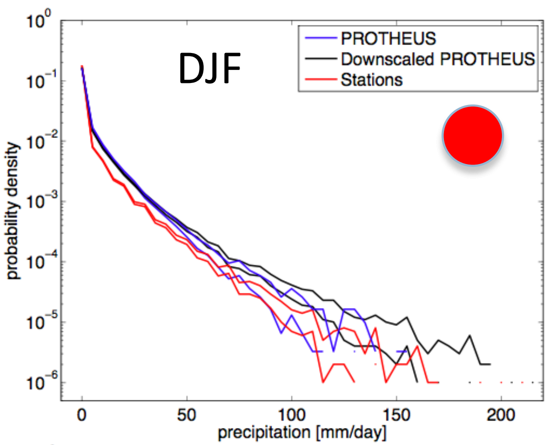
Stochastic realization of the PROTHEUS downscaled field, obtained with RainFARM

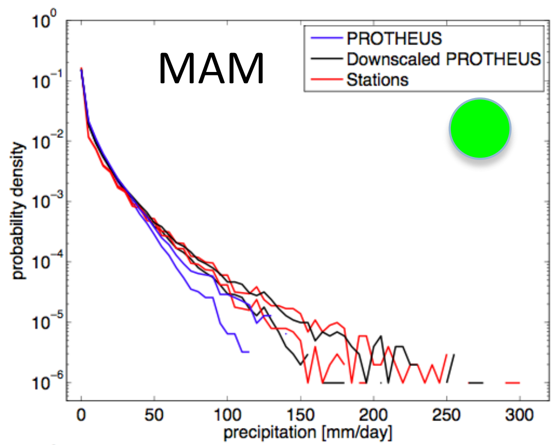
Downscaling: Downscaled PROTHEUS vs individual raingauge data

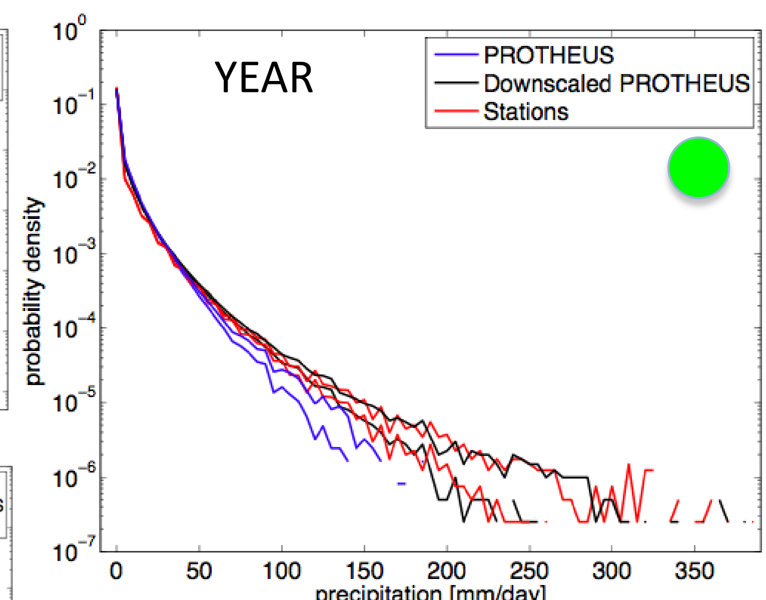
GOOD

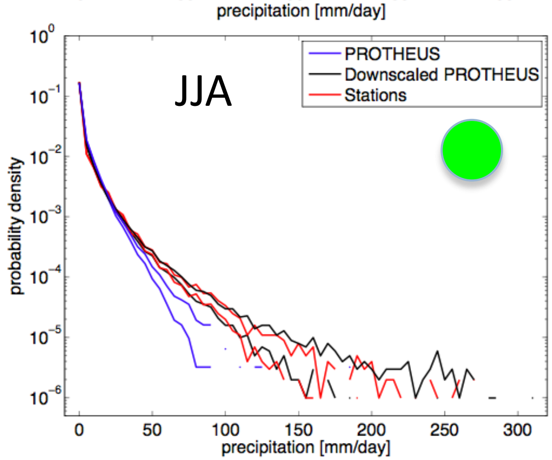
LESS GOOD

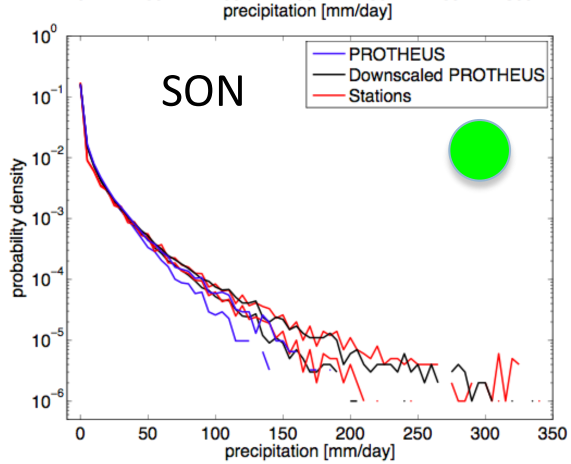
PDFs of total precipitation











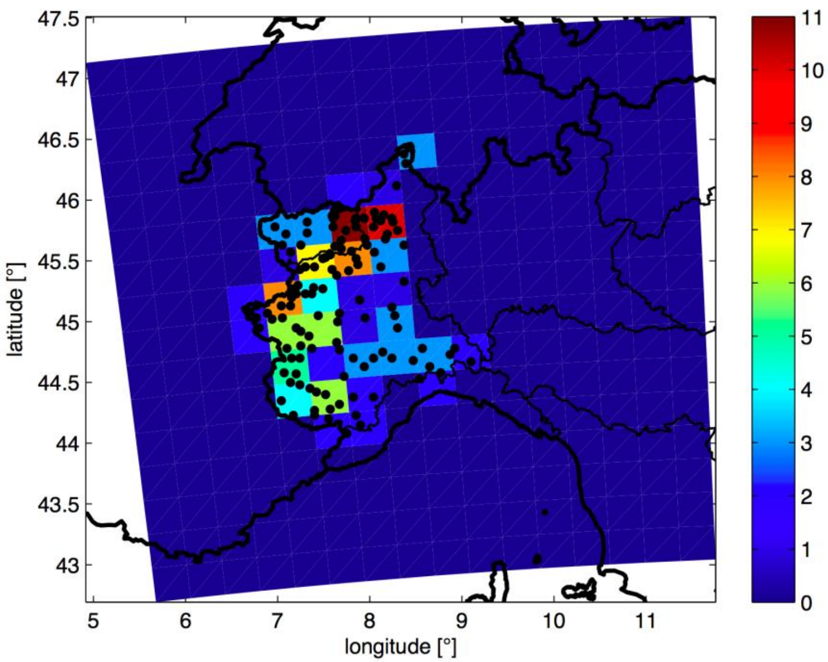
N_0_model = 47% (70%)
N_0_obs = 72%

P_0 = 0.1 (2) mm/day

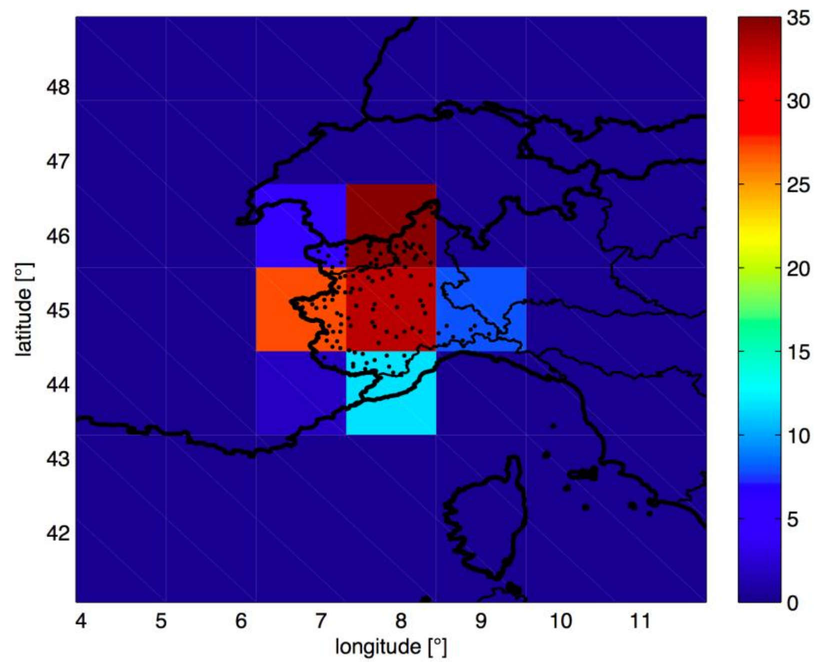
Rain-gauge network

Ciccarelli et al., *Global and Planetary Change*, 2008

PROTHEUS



ERA40



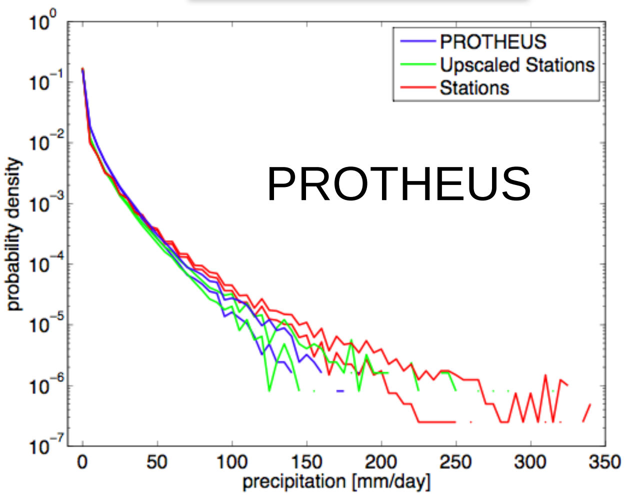
33 PROTHEUS pixels

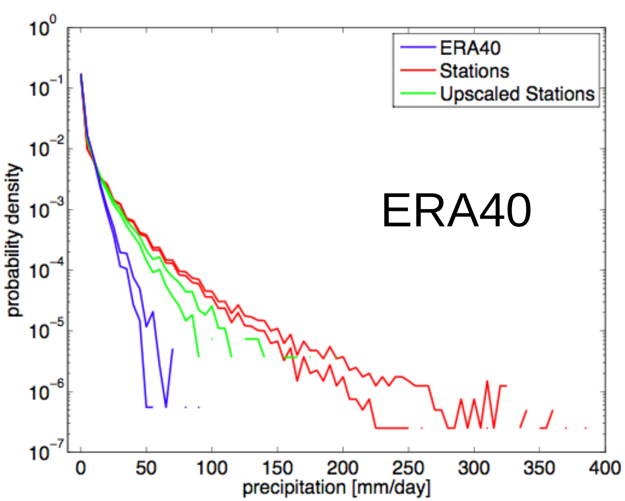
- 122 rain gauges
- 1958-2001
- Altitude max: 2526 m
- Altitude min: 127 m
- Daily resolution

7 ERA40 pixels

PROTHEUS vs ERA40

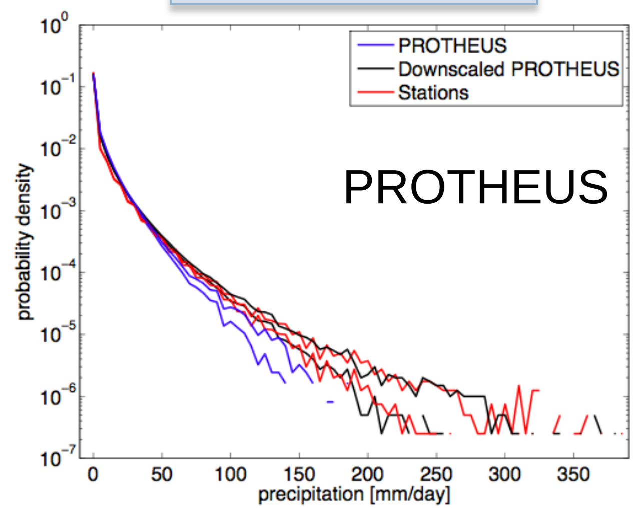
UPSCALING

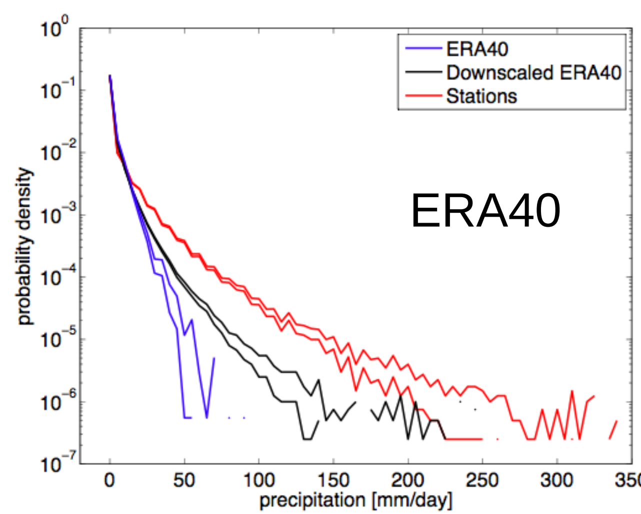




Application to PROTHEUS (30 km res.) and to ERA40 (100 km res.): need for dynamical downscaling prior to further stochastic downscaling

DOWNSCALING





Summary & conclusions

- The **high-resolution** precipitation fields obtained by downscaling the PROTHEUS output reproduce well the seasonality and the amplitude distribution of the observed rain gauge precipitation during most of the year, including the **extreme events**.

- However, the RainFARM stochastic downscaling procedure cannot correct the model outputs at large scale, such as the disagreement in the frequency of precipitation events in PROTHEUS in winter.

- **Limits** of RainFARM: does not account for the **orography** (it can matter inside the box) and **does not correct biases**

Contacts

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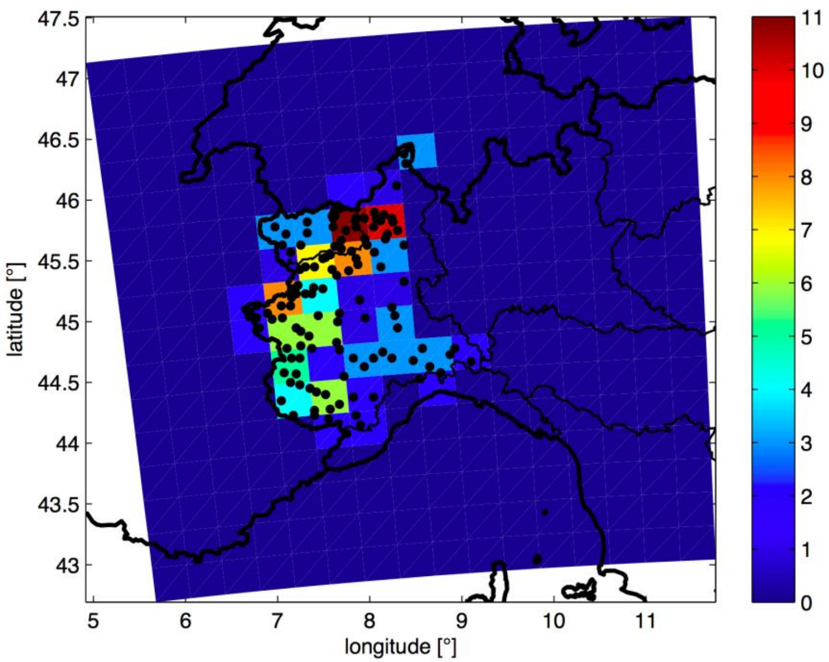
Rain-gauge network

Ciccarelli et al., *Global and Planetary Change*, 2008

PROTHEUS



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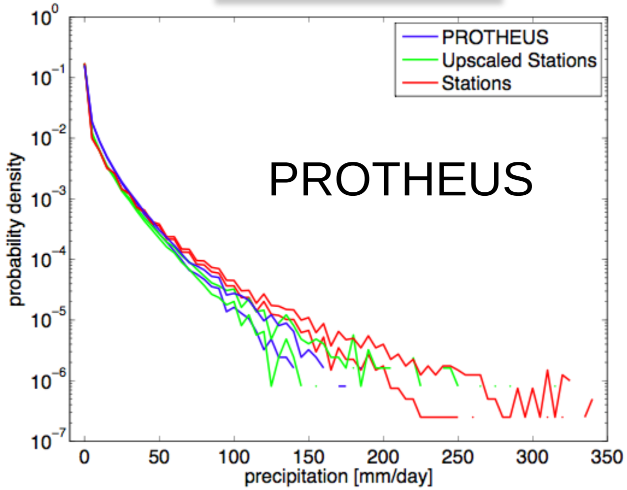
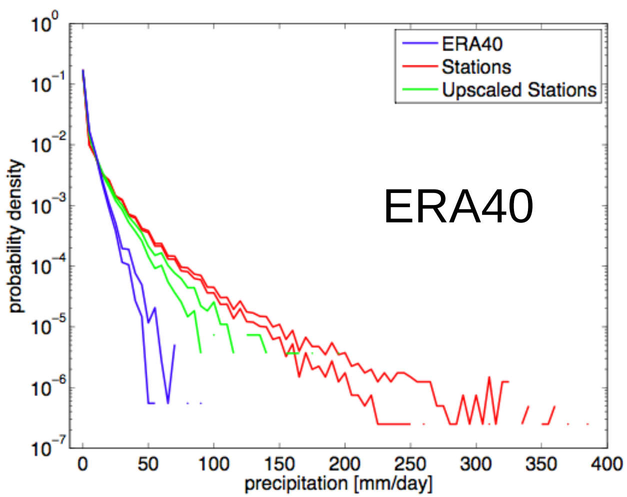
PROTHEUS vs ERA40 downscaling

UPSCALING





Additional: RAINFarm procedure

- $P(X,Y,T)$ $\quad L_0 \leq (X,Y) \leq L_{max} \quad T_0 \leq T \leq T_{max}$ Input field
- $\hat{P}(K_x, K_y, \Omega)$ $\quad (K_x, K_y) \leq \dfrac{\pi}{L_0} \quad \Omega \leq \dfrac{\pi}{T_0}$ Fourier spectrum
- $|\hat{P}|^2; \alpha\,;\, \beta$ -Space-time power spectrum (exponential behavior), with slopes α, β
  - extrapolation to small scales
- $\hat{g}(k_x, k_y, \omega) = |\hat{g}(k_x, k_y, \omega)| exp(i\phi)$
  $|\hat{g}(k_x, k_y, \omega)|^2 = ({k^2}_x + {k^2}_y)^{-\alpha/2} \omega^{-\beta}$ Fourier spectrum, ϕ are random phases
- $g(x,y,t)$ $\quad \lambda \leq (x,y) \leq L_{max} \quad \tau \leq t \leq T_{max}$ g: gaussian field obtained by inverting $\hat{g}$
- $\tilde{r}(x,y,t) = e^{g(x,y,t)}$ Systhetic precipitation field, obtained by a nonlinear tranformation of g

Additional: RAINFarm procedure

- The synthetic field is forced to be equal to the original field P, when aggregating on L_0 and T_0 scales → creation of $\tilde{R}$ so that:

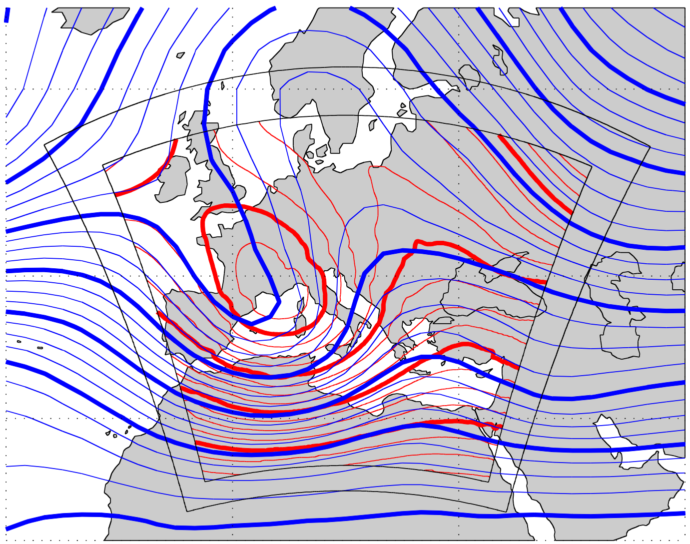
$$r(x,y,t) = \tilde{r}(x,y,t)\frac{P(X,Y,T)}{\tilde{R}(X,Y,T)}$$

Aggregating on L_0 , T_0

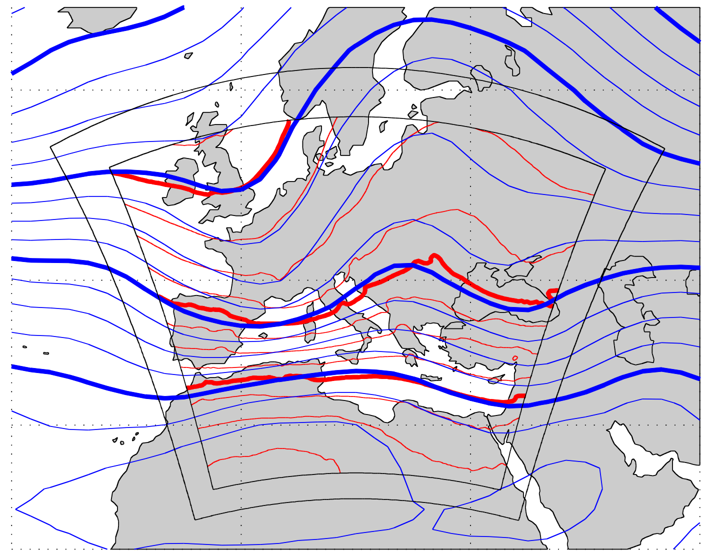
R = P

Additional: large scale bias

Winter



Summer



Composite 500hPa isobars during *intense rainfall* events at the weather station of Torino Caselle: ERA40 (blue) and PROTHEUS (red). *Intense rainfall* is defined as daily rainfall (observed) > 20mm.

The black boxes represent the PROTHEUS domain. The area between the inner and outer box is where PROTHEUS is nudged to the lateral boundary conditions.

Methodology

The method used to bridge the scale gap between coarse-scale climate model outputs and point-scale observed data is are averaging (upscaling) the raingauge data at the scale of the model or, vice versa, interpolating the model to the gauge positions (downscaling).

- ***Upscaling approach***: comparison between PROTHEUS/ERA40 and the raingauge data averaged over the PROTHEUS/ERA40 pixels (one observed time series for each pixel)

- ***Downscaling approach***: comparison between the downscaled PROTHEUS/ERA40 and data from the individual raingauges