# Analysis of the precipitation and streamflow extremes in Northern Italy using high resolution reanalysis dataset Express-Hydro

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## Introduction

The characterization of the hydrometeorological extremes, both in terms of rainfall and streamflow, in a given region plays a key role in the environmental monitoring provided by the flood alert services. In last years meteorological simulations (both near real-time and historical reanalysis) were available at increasing spatial and temporal resolutions, making possible long-period hydrological reanalysis in which the meteo dataset is used as input in distributed hydrological models.

In this work, a very high resolution meteorological reanalysis dataset, namely Express-Hydro (CIMA, ISAC-CNR, GAUSS Special Project PR45DE), was employed as input in the hydrological model Continuum in order to produce long time series of streamflows in the Liguria territory, located in the Northern part of Italy. The original dataset covers the whole Europe territory in the 1979-2008 period, at 4 km of spatial resolution and 3 hours of time resolution.

Analyses in terms of comparison between the rainfall estimated by the dataset and the observations (available from the local raingauges network) were carried out, and a bias correction was also performed in order to better match the observed climatology. An extreme analysis was eventually carried on the streamflows time series obtained by the simulations, by comparing them with the results of the same hydrological model fed with the observed time series of rainfall.

## Case Study

**DATASET Express-Hydro**
(CIMA, ISAC-CNR, GAUSS Special Project PR45DE)

**Period:** 1979 - 2008
**Spatial resolution:** 4 km
**Time resolution:** 3 hours
**Area covered:** Europe ( see Figure 2)

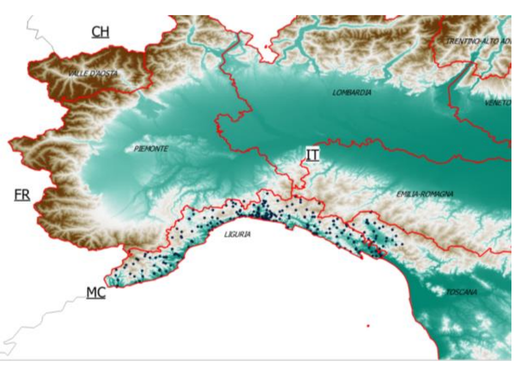

**Figure 1.** Study area. Red lines represent the regions of Italy, dots represent the meteorological gauge network of Liguria region of Italy. Digital elevation model evidences the morphology of the region.

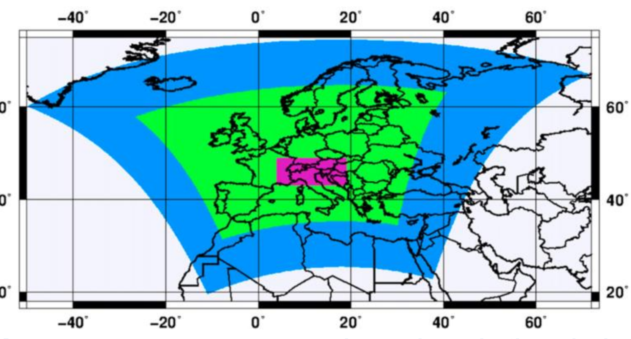

**Figure 2.** European domain defined in CORDEX (0.118; blue) and the IER (0.0378; green) used for the high-resolution integration. The Great Alpine Region (GAR) used for some of the diagnostics is displayed in purple.
Courtesy of Pieri, A. B., von Hardenberg, J., Parodi, A., & Provenzale, A. (2015). Sensitivity of Precipitation Statistics to Resolution, Microphysics, and Convective Parameterization: A Case Study with the High-Resolution WRF Climate Model over Europe. Journal of Hydrometeorology, 16(4), 1857-1872

## BIAS Correction and downscaling

The Express-Hydro dataset was employed as meteorlogical input with and without BIAS correction in order to better fit the observations available from the ground gauges network. The BIAS correction was performed on monthly basis by correcting the climatological rainfall cumulate with the corresponding observed variable (previously interpolated with IDW method):

$$P_x = \frac{\sum_{i=1}^{N} \frac{P_i}{d_i^{\,2}}}{\sum_{i=1}^{N} \frac{1}{d_i^{\,2}}}$$

*Inverse Distance Weight (IDW) interpolation*
($P_i$ is the observed rainfall at the $i$-th raingauge, $d_i$ is the distance between the i-th raingauge and the location $x$ in which the rainfall $P_x$ is desired, and $N$ is the number of raingauges)

$$P_{corr,x} = P_{EH,x}\,\frac{PM_{OBS,x}}{PM_{EH,x}}$$

*BIAS Correction*
($x$ is the location, $P_{EH,x}$ the original, unmodified value of 3-hour rainfall height in the cell $x$, $PM_{OBS,x}$ is the observed average rainfall monthly cumulate for the current month in the cell $x$, $PM_{EH,x}$ is the Express-Hydro average rainfall monthly cumulate for the current month in the cell $x$, and $P_{corr,x}$ is the desired BIAS-corrected 3-hour rainfall height in the cell $x$)

### Downscaling

In order to take into account of subgrid spatial patterns of the precipitation, the Rainfarm spectral downscaler (Rebora, N., L., Ferraris, J. H., Hardenberg and Provenzale, A.: Rainfall downscaling and flood forecasting: a case study in the Mediterranean area. *Nat. Hazards and Earth Syst. Sci.*, **6**, 611-619, 2006) was applied to the rainfall maps, The basic idea is that the spatial-temporal Fourier spectrum of the precipitation field, estimated at large scale from a meteorological model prediction, follows the functional form:

$$\left|\hat{g}(k_x, k_y, \omega)\right|^2 \propto (k_x^2 + k_y^2)^{-\alpha/2}\,\omega^{-\beta}$$

where $k_x$ and $k_y$ are the x and y spatial wavenumbers, $\omega$ the temporal wavenumber (frequency), while a and b represent two parameters of the model. The spectrum is then extended over larger wave numbers/frequencies thus allowing for the generation of a spatial-temporal field at a higher resolution.

## Hydrological simulations and results

### Distribution of the annual maximum discharge (AMD)

The adopted approach to evaluate the goodness of the results is comparing the distribution of the ADM with the observations. The simulated ADM were fitted with a General Extreme Value (GEV) distribution. In Figures 3a-c the modelled and observed sample ADM distributions are compared in different sections, together with the GEV obtained by modelled ADM with 95% confidence intervals. For each station both the results obtained with and without rainfall bias correction are reported.

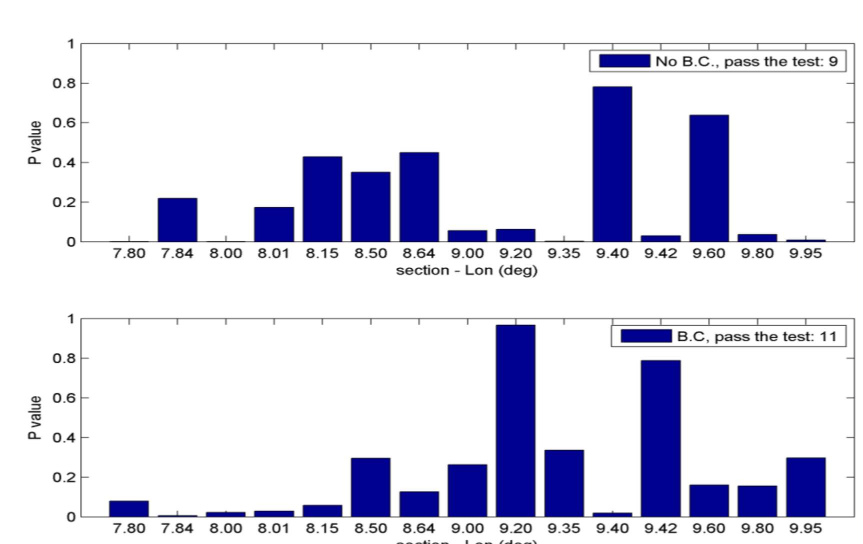



**Figure 4.** Kolmogorov Smirnov test with significance 95% done on AMD. On x axis the longitude of the basin centroid is reported while y axis shows the Pvalue of the test for each section

### Continuum hydrological model

The hydrological simulations were performed with the *Continuum* model (Silvestro, F., Gabellani, S., Delogu, F., Rudari, R., Boni, G.: Exploiting remote sensing land surface temperature in distributed hydrological modelling: the example of the Continuum model. Hydrol. Earth Syst. Sci., 17, 39-62, 2013. doi:10.5194/hess-17-39-2013), a continuous distributed hydrological model that strongly relies on a morphological approach and in which all of the main hydrological phenomena are modeled in a distributed way. In this work the model was implemented with a spatial resolution of 0.005 deg (about 480 m) with a timestep of 60 min.

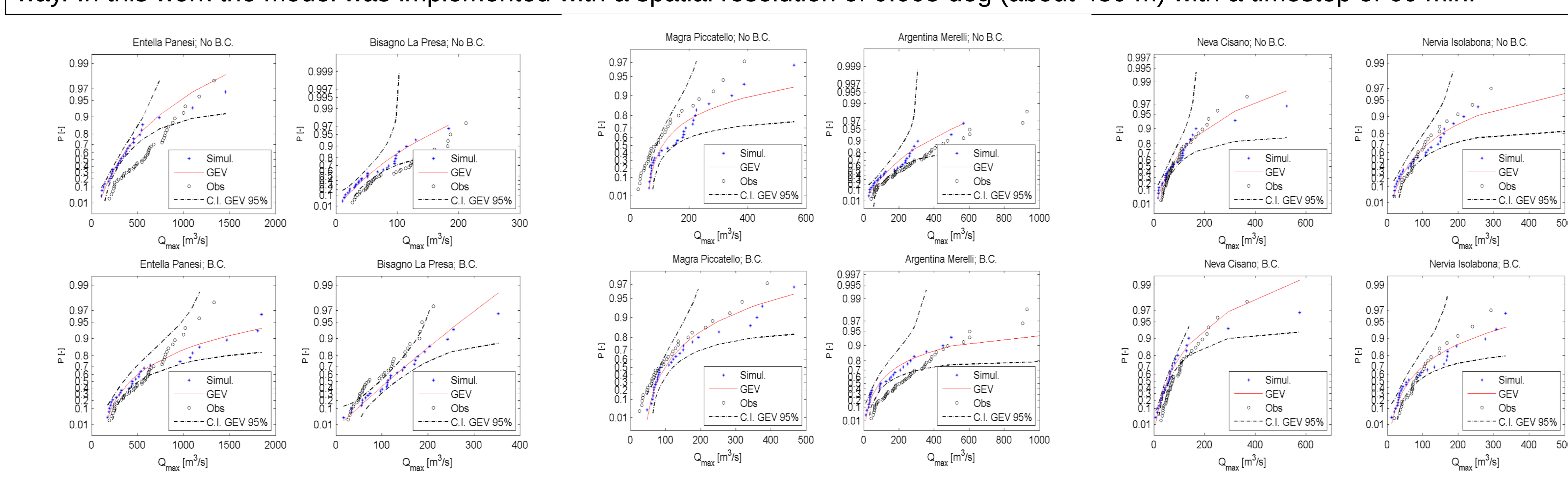



**Figure 3.** Distribution of AMD for Entella closed at Panesi (364 km$^2$) and Bisagno closed at La Presa (34 km$^2$) (panel a), for Magra closed at Piccatello (78 km$^2$) and Argentina closed at Merelli (188 km$^2$) (panel b) and for Neva closed at Cisano (123 km$^2$) and Nervia closed at Isolabona (122 km$^2$) (panel c). Blue dots are the simulated AMD, black dots are observed AMD, red line is the GEV fitted on simulated AMD while dotted line are confidence intervals with 95% significance. Upper panels show results without rainfall bias correction, bottom panels show results with rainfall bias correction.

### Regional analysis of the annual maximum peak flows

A comparison was made following a distributed approach through a regionalisation method that defines a hierarchical approach based on a non-dimensional random variable $X_0 = X/\mu_x$, where $\mu_x$ is the local gauge station mean. Index flood is estimated even where observations were not available with support of rainfall regional frequency analysis and rainfall-runoff modelling in order to allow quantile estimation in each point of the region. The final index flood is given by:

$$Q_{index} = f(Area, longitude)$$

$$Q(T) = K(T) \cdot Q_{index}$$

where T is the return period and K(T) is defined by the non-dimensional regional growth curve (unique for the whole region). To compare quantiles, the following ratio was employed (ideal value = 1):

$$Ratio(T) = \frac{Q(T)_{Model}}{Q(T)_{Reg}}$$

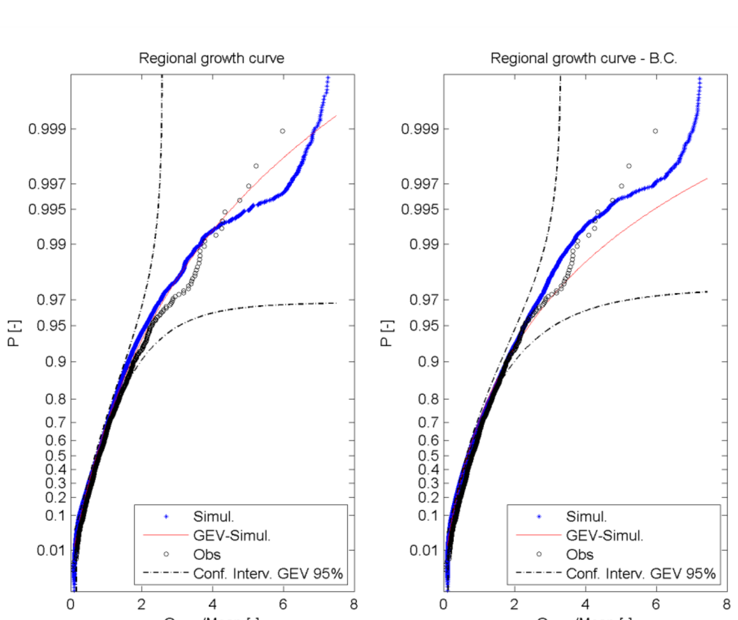



**Figure 5.** **S**ample growth curve obtained by model chain (blue dots) compared with observations (black dots). Red line is the GEV distribution fitted on modeled values while dotted lines are the confidence intervals with significance 90%.

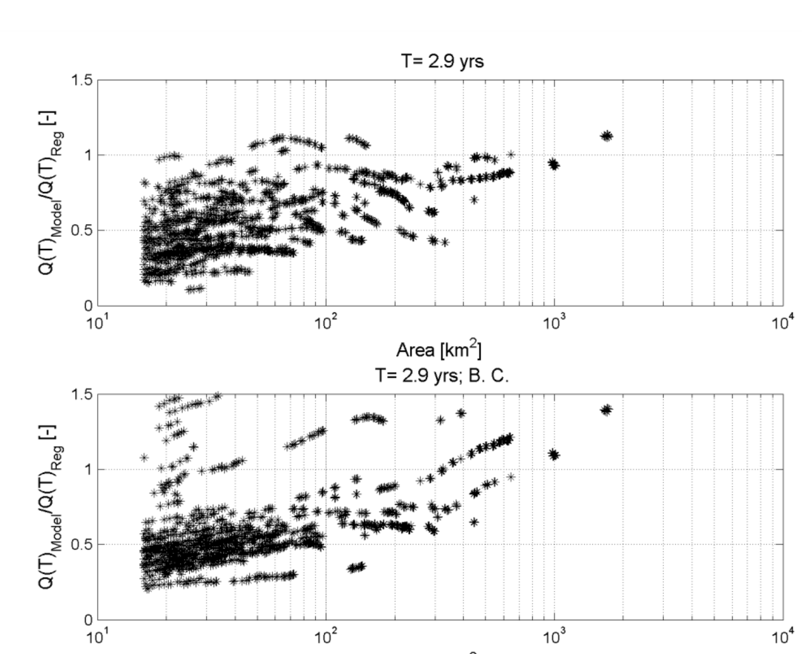



**Figure 6.** Ratio(T) as a function of drainage area. T=2.9 yrs corresponds to index flow. Upper panel shows results without rainfall bias correction, lower panel (B.C.) with rainfall bias correction.

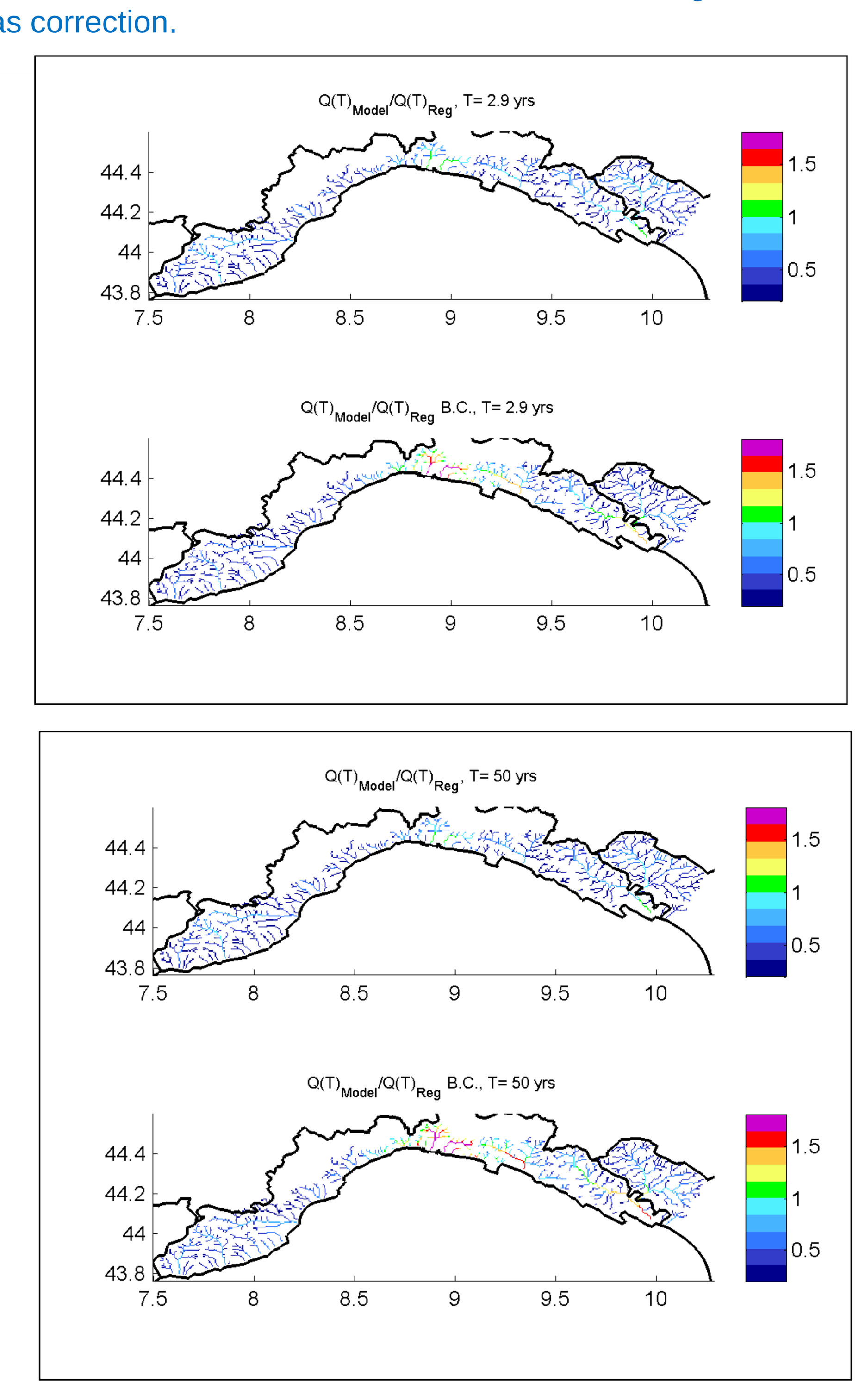

**Figure 7.** Maps of Ratio(T). Upper panel shows results without rainfall bias correction, lower panel (B.C.) with rainfall bias correction. Panel a: T=2.9 yrs, panel b: T=50 yrs.

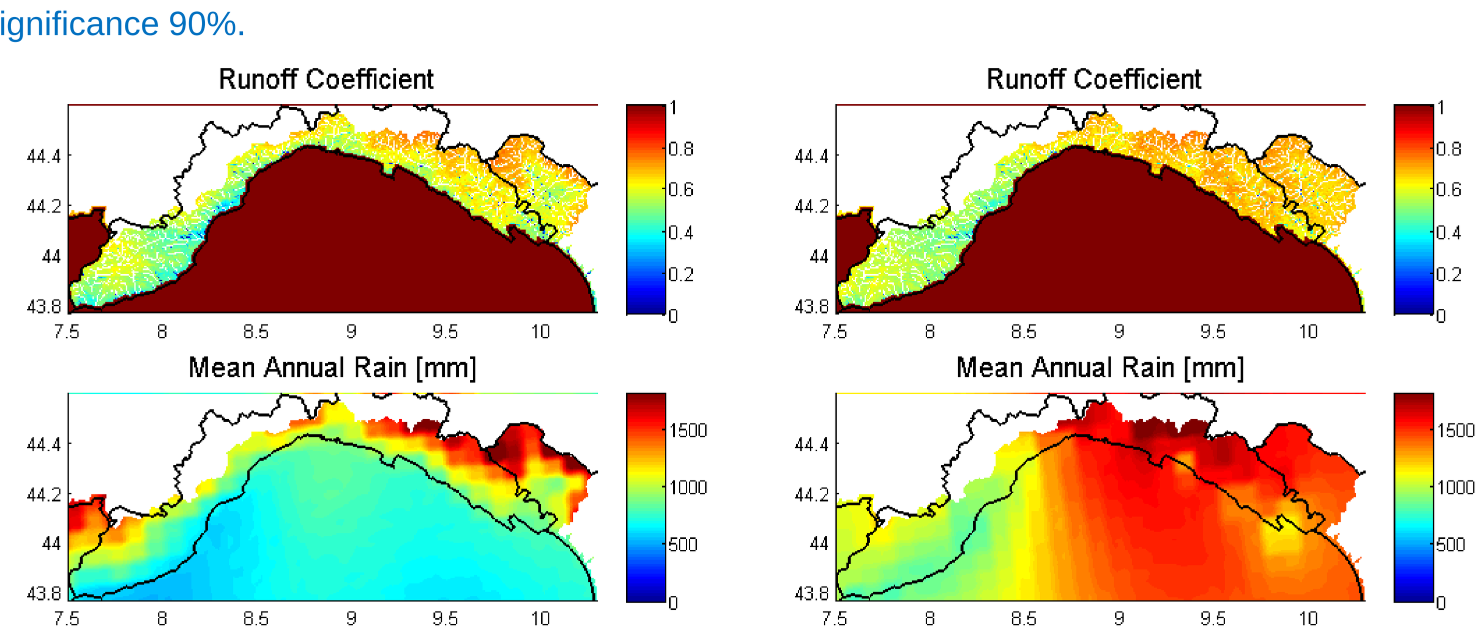



**Figure 8.** Maps of distributed Runoff coefficient (top) and mean annual rainfall from Express-Hydro (bottom). Panel a: without bias correction, panel b: with bias correction.