Regional climate modeling and flood risk maps: an integrated hydrological and hydraulic approach

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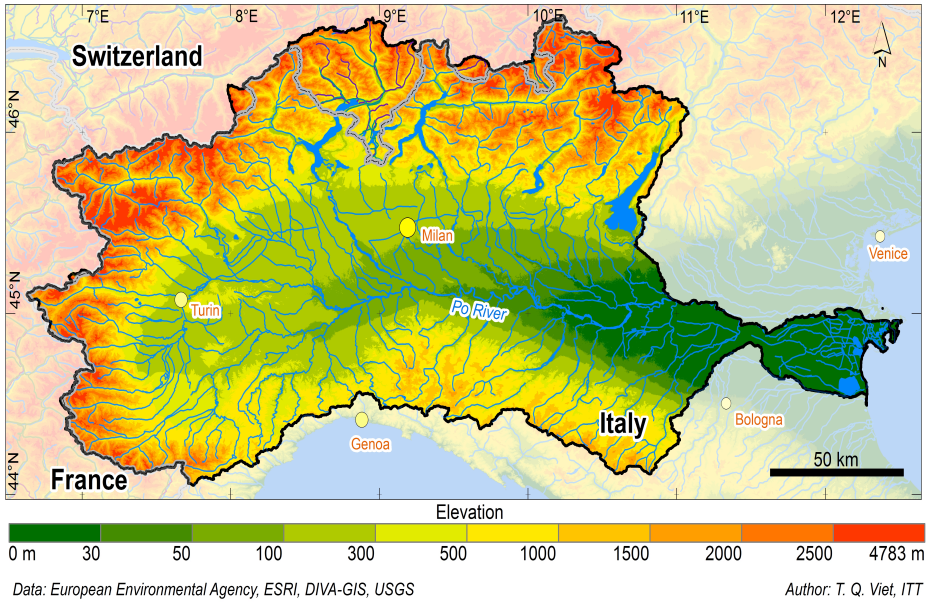
Allianz

* Example of concrete application to show how climate model results can be used by the stakeholders;
* An integrated hydrological (CHyM) and hydraulic (CA2D-par) approach over the Po river basin (Italy);
* Production of flood risk maps using observational and modeled data.

The goal

To produce FLOOD RISK MAPS over the Po river basin associated to different Return Periods.



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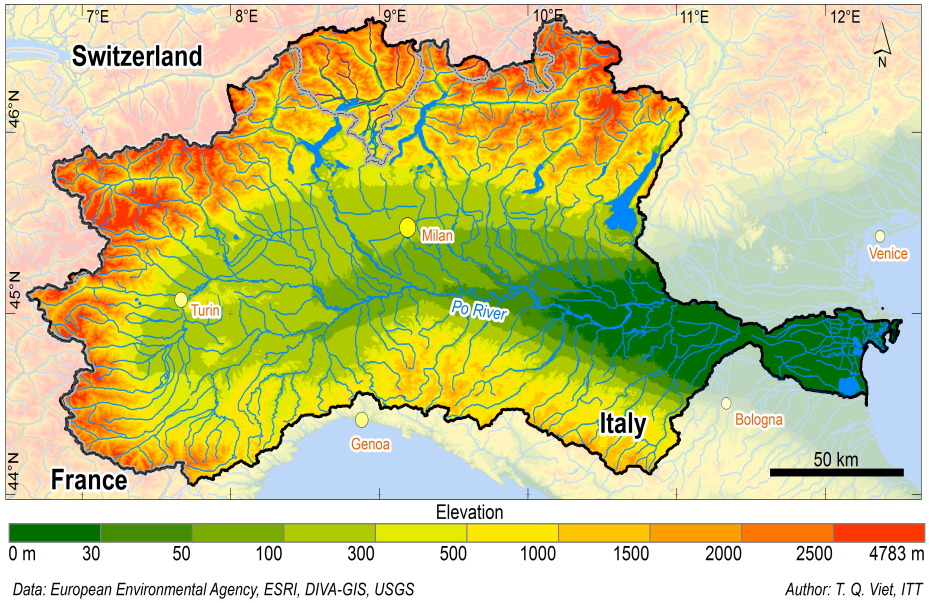

(= inverse of the probability that the event will be exceeded in any one year)

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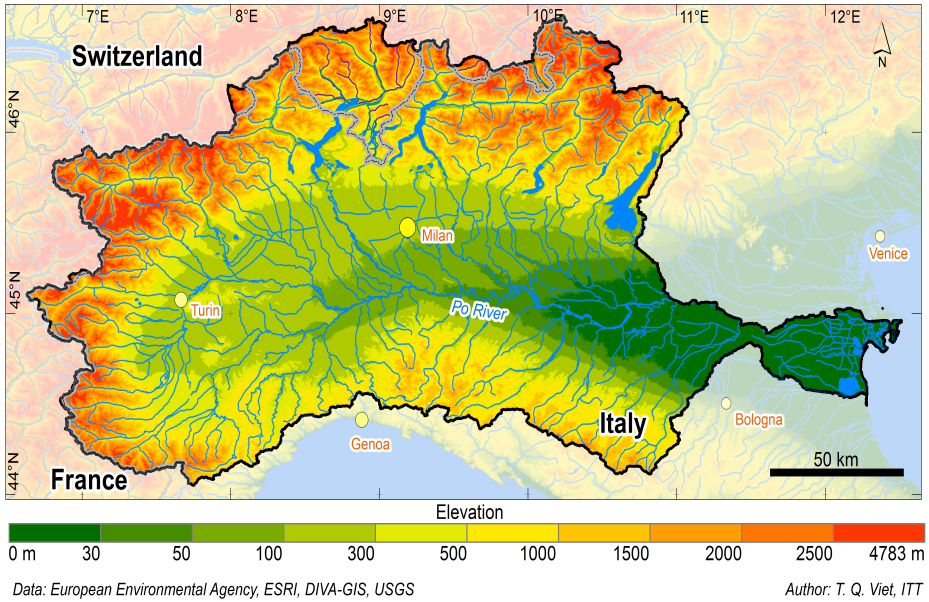
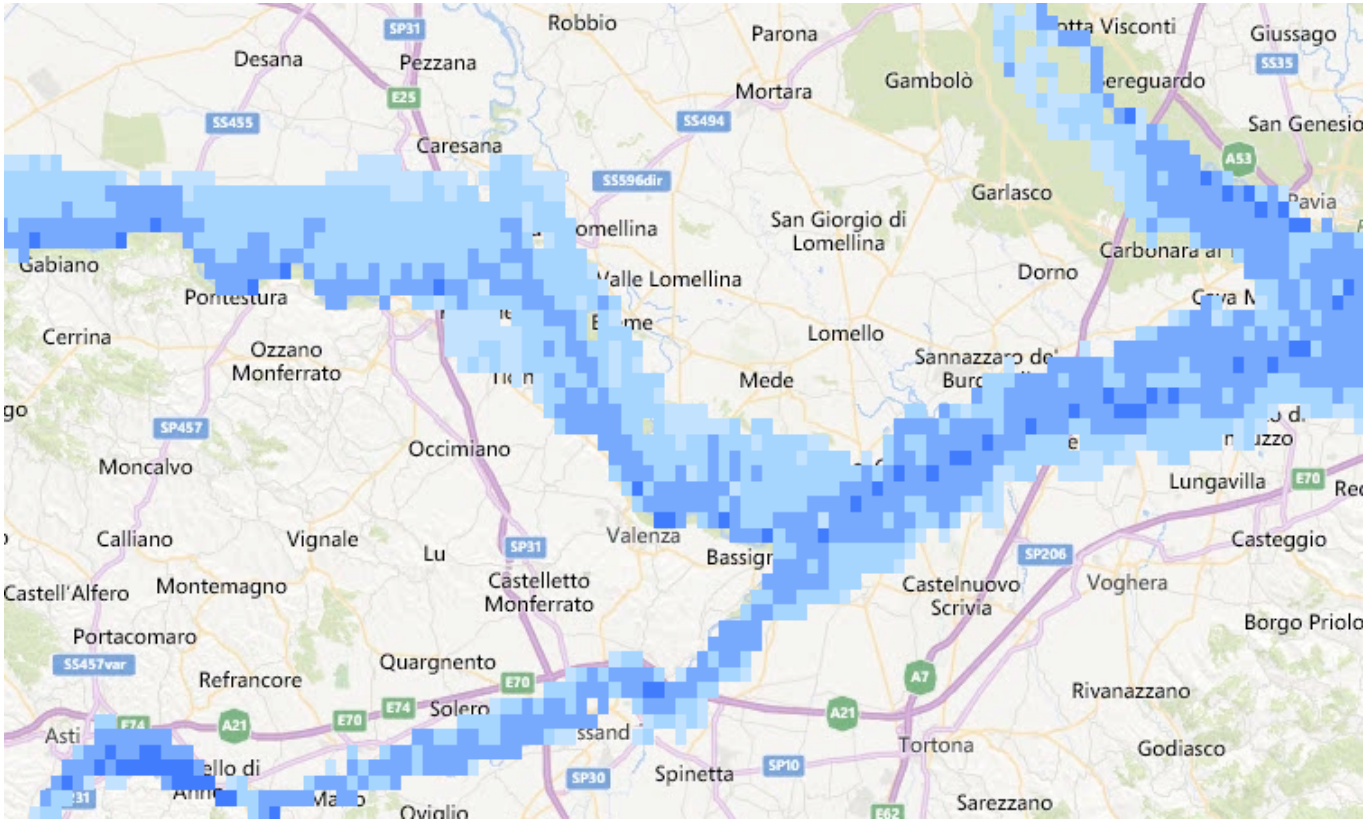


A 10-year flood has a 1/10 = 0.1 (or 10%) chance of being exceeded in any one year

A 50-year flood has a 0.02 (or 2%) chance of being exceeded in any one year

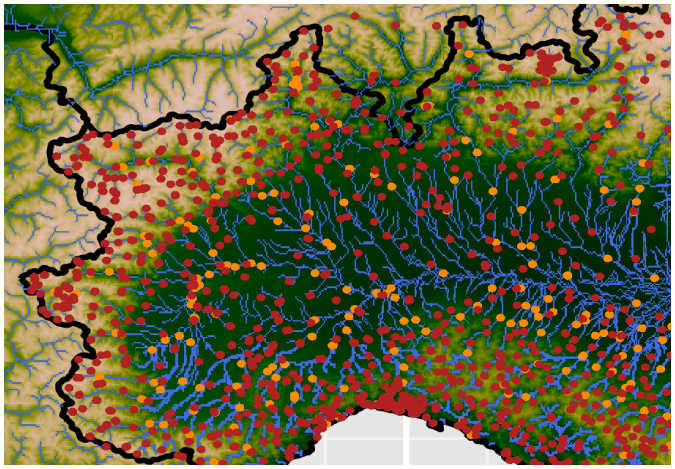
T=500 years

T=100 years

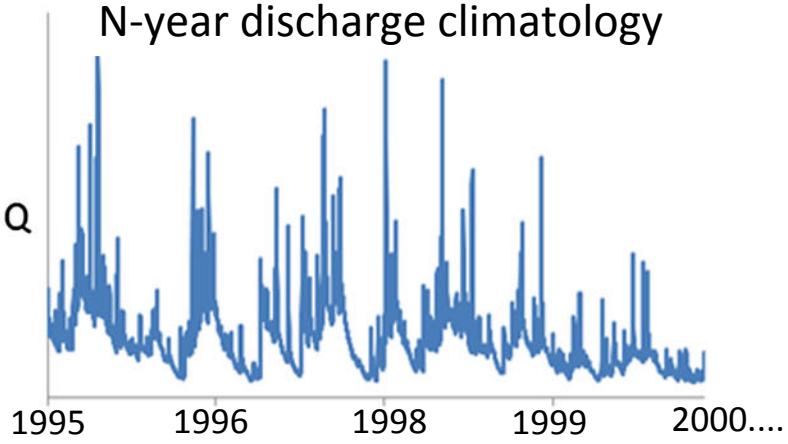


The method:

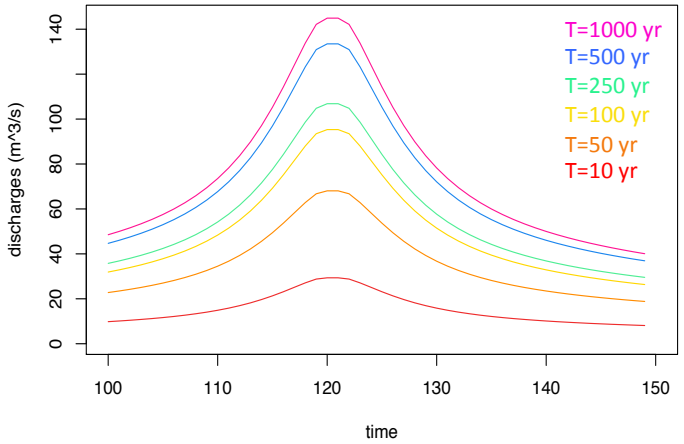
Discharge and Precipitation data



CHyM hydrological model or stations data (Coppola et al., 2003)



Statistical Flood Frequency analysis

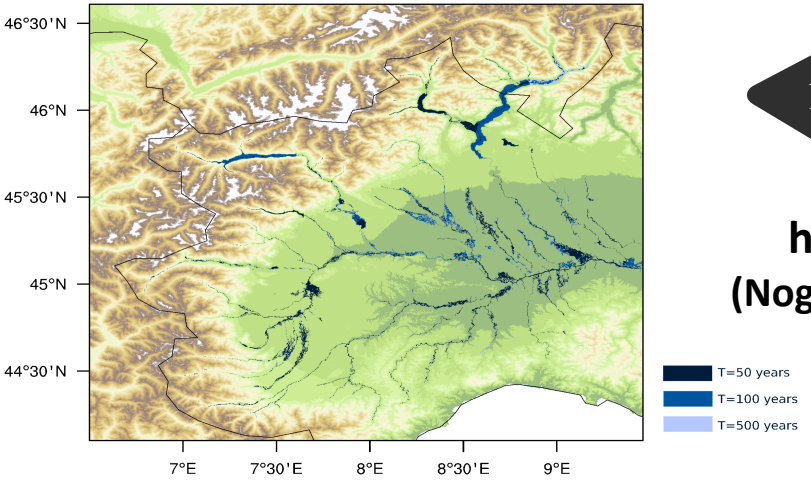


Synthetic Design Hydrograph (SDH)

(Maione et al., 2003; Beirlant et al. 2004; Alfieri et al. 2014; ...)

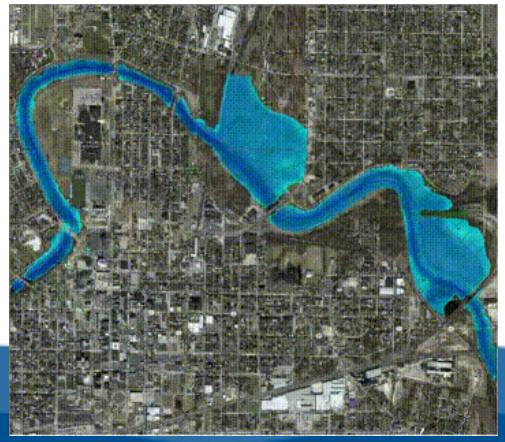
CA2D_par hydraulic model (Nogherotto et al., 2018)

Flood hazard maps



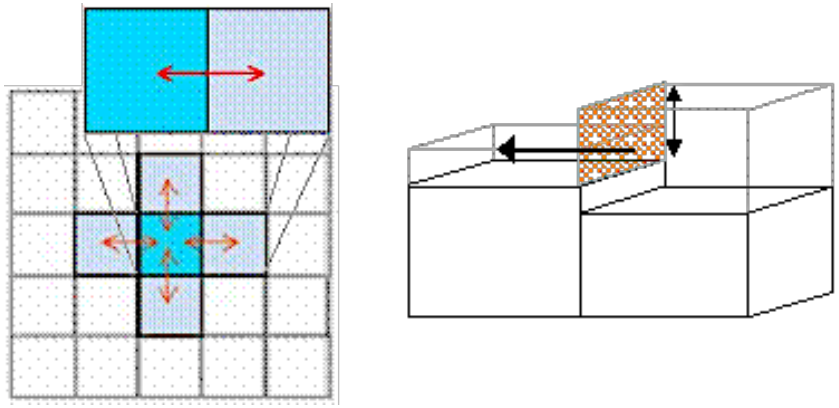
CA2D-par

* Hydraulic model used to simulate the flow on the floodplain;
* Flow is controlled by topography and friction;
* Capable of simulating grids up to 10^6 cells for dynamic flood events;
* Predicts water depths in each grid cell at each time step (over fluvial, coastal and estuarine floodplains).



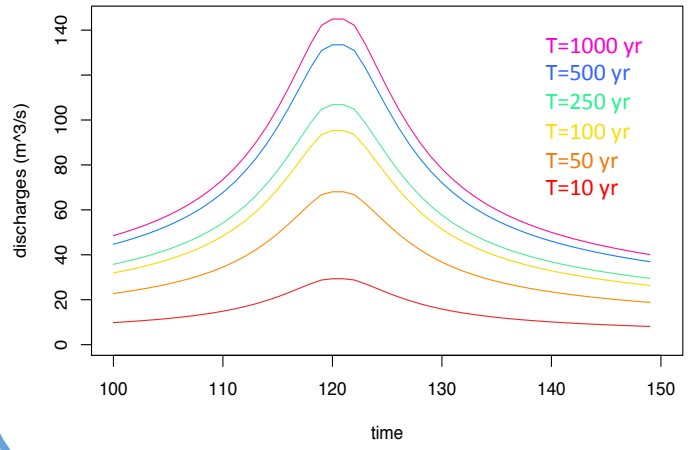
CA2D-par

Floodplain flows are described in terms of continuity and momentum equations, discretized over a grid of square cells



Assumed that the flow between two cells is simply a function of the free surface height difference between those cells, the grid scale Manning's friction coefficient for the floodplain and the local water acceleration.

Synthetic Design Hydrograph



CA2D-par

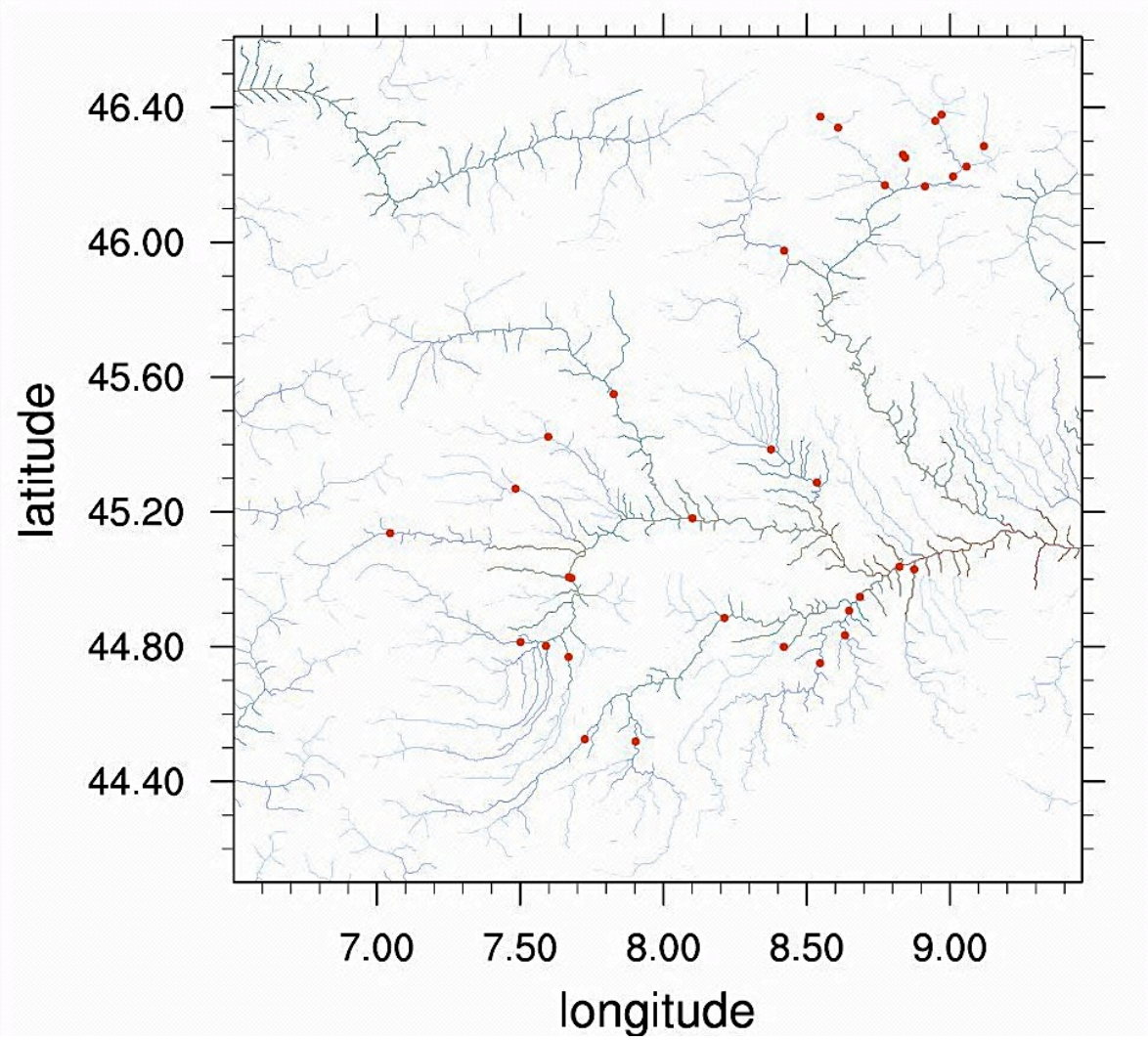
HydroSHEDS vf DEM 90 m

B. Lehner et al (2008)

River widths & depths

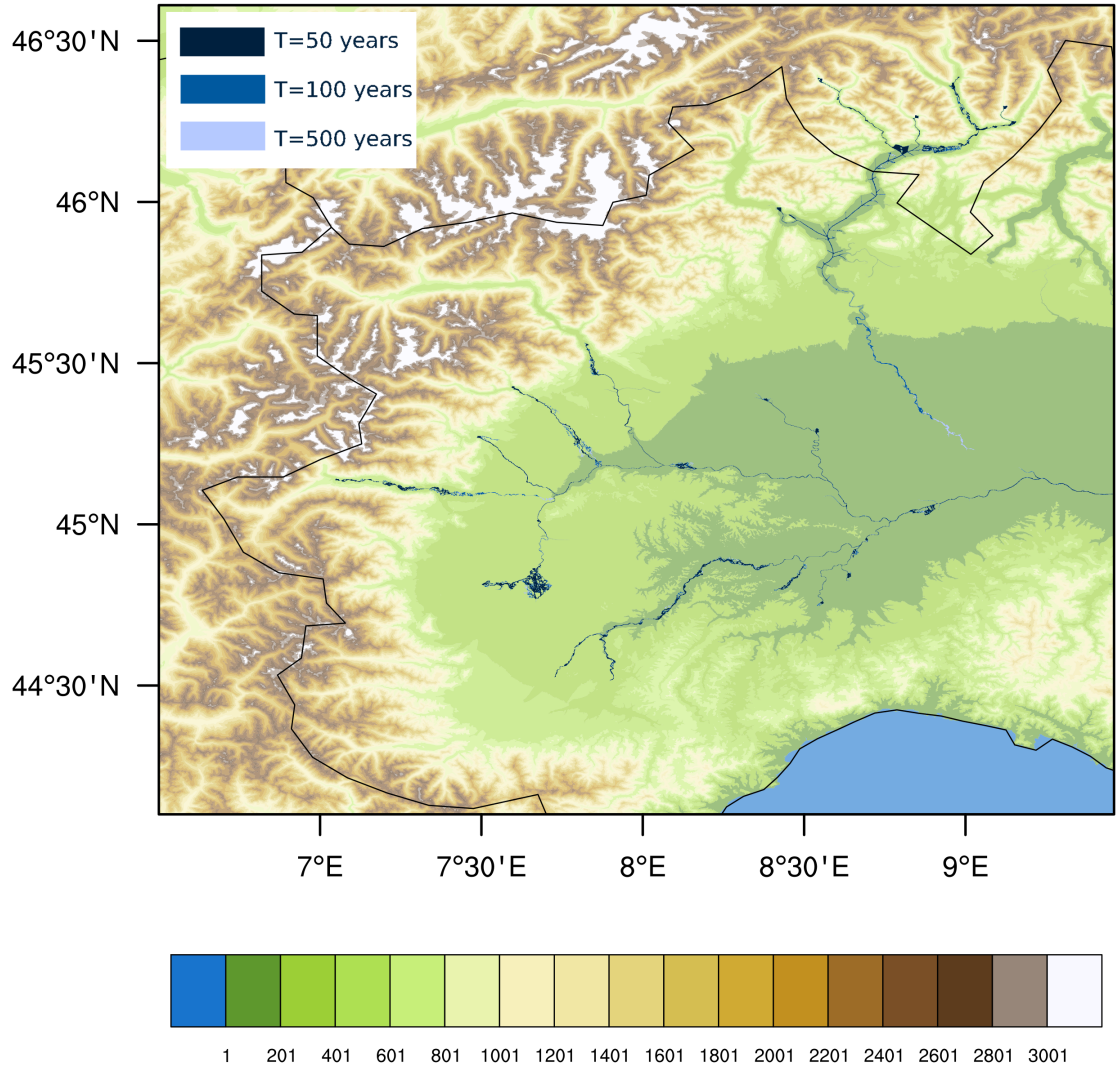
K. Andreadis et al (2013)

The available observations



* **DEM** 90 m resolution
* 34 stations
* 34 simulations using CA2D-par

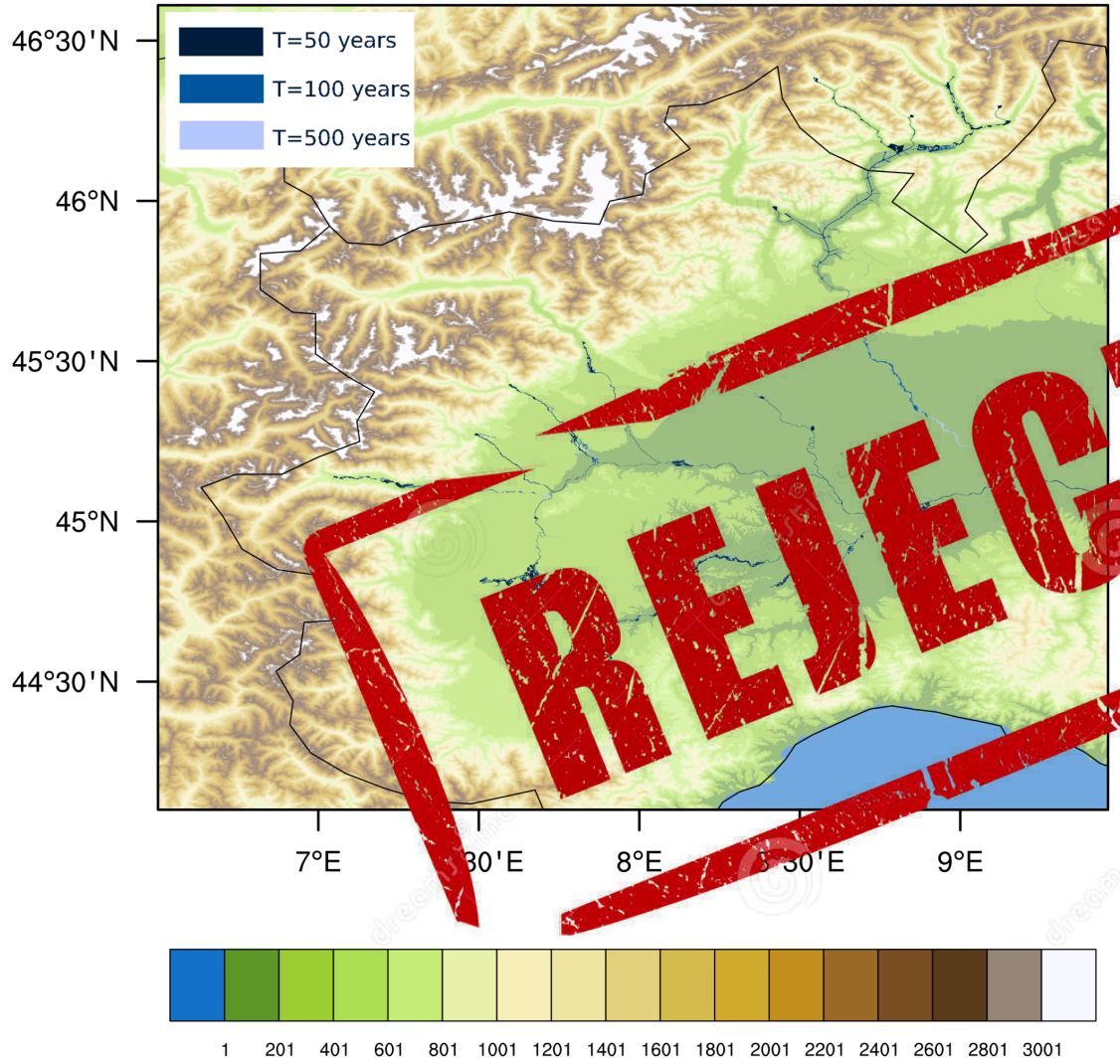
Flood with available observations



The network of the observational stations is not dense enough to simulate the river flow.

Observations are not sufficient to produce the flood maps.

Flood with available observations



REJECTED

The network of the observational stations is not enough to simulate the river flow.

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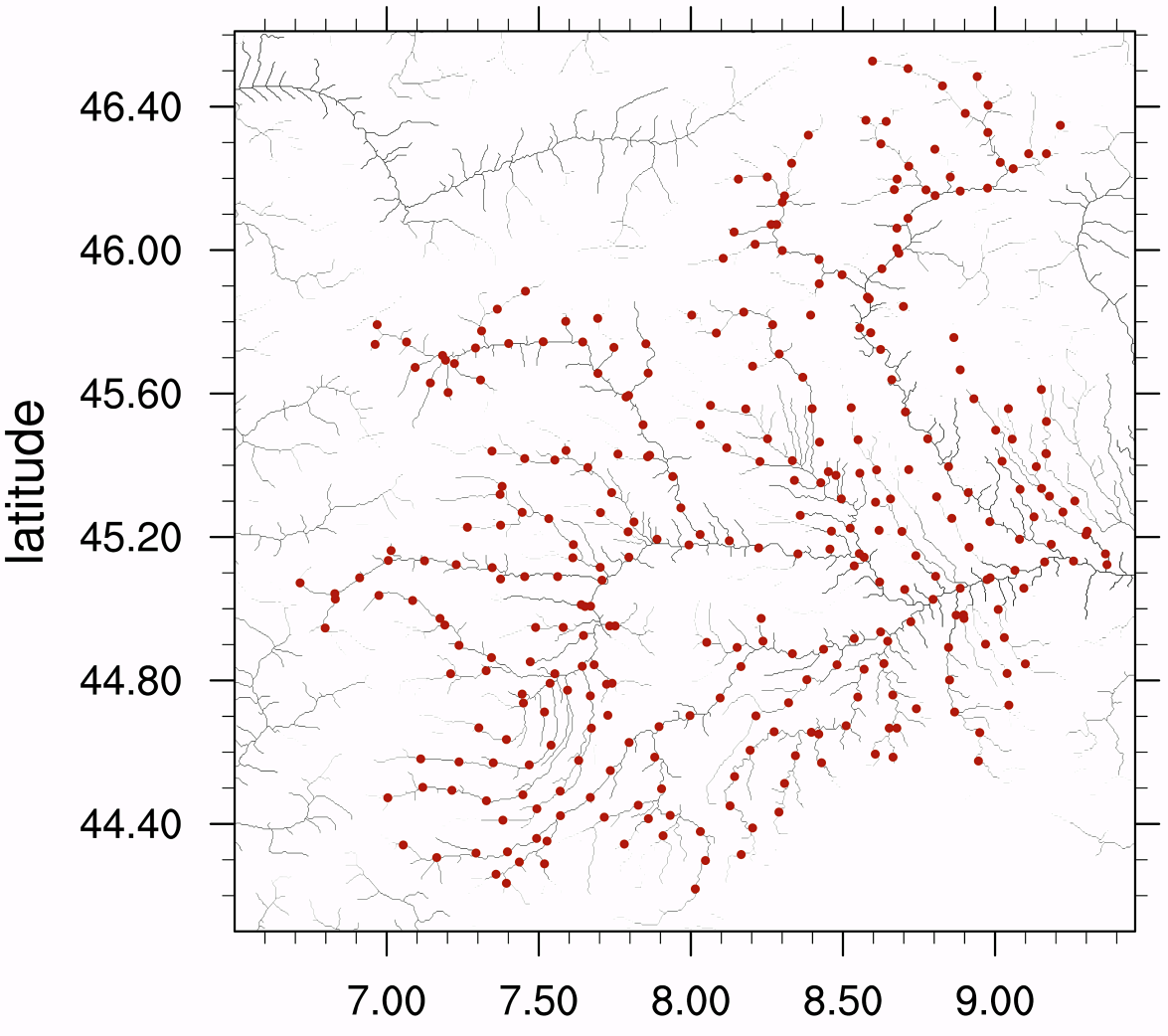
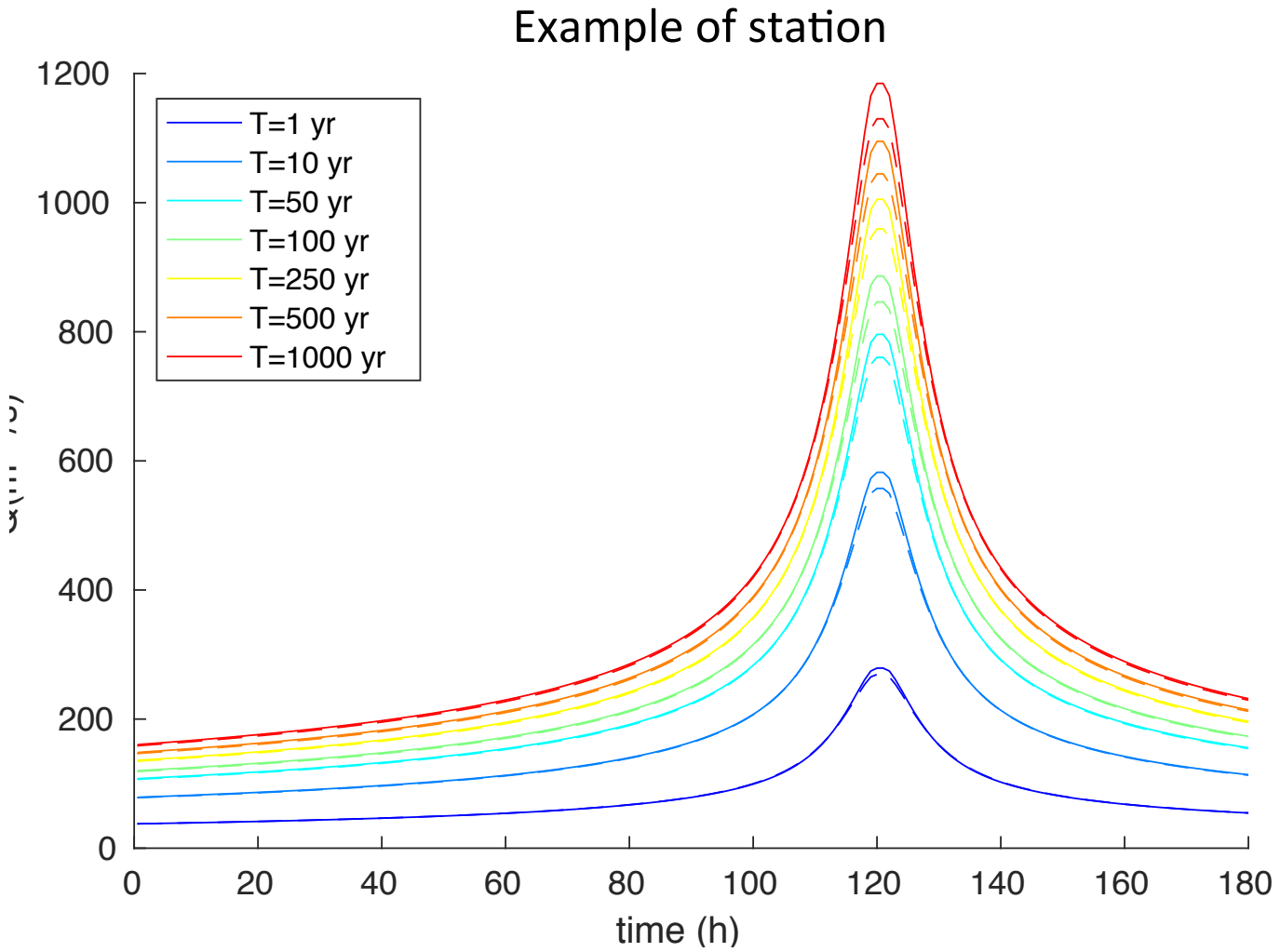
CHyM: the “virtual” stations

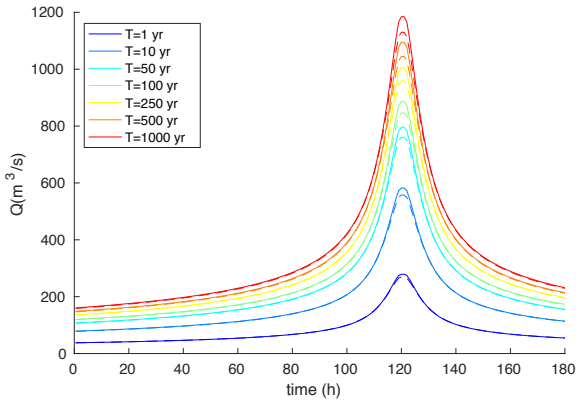


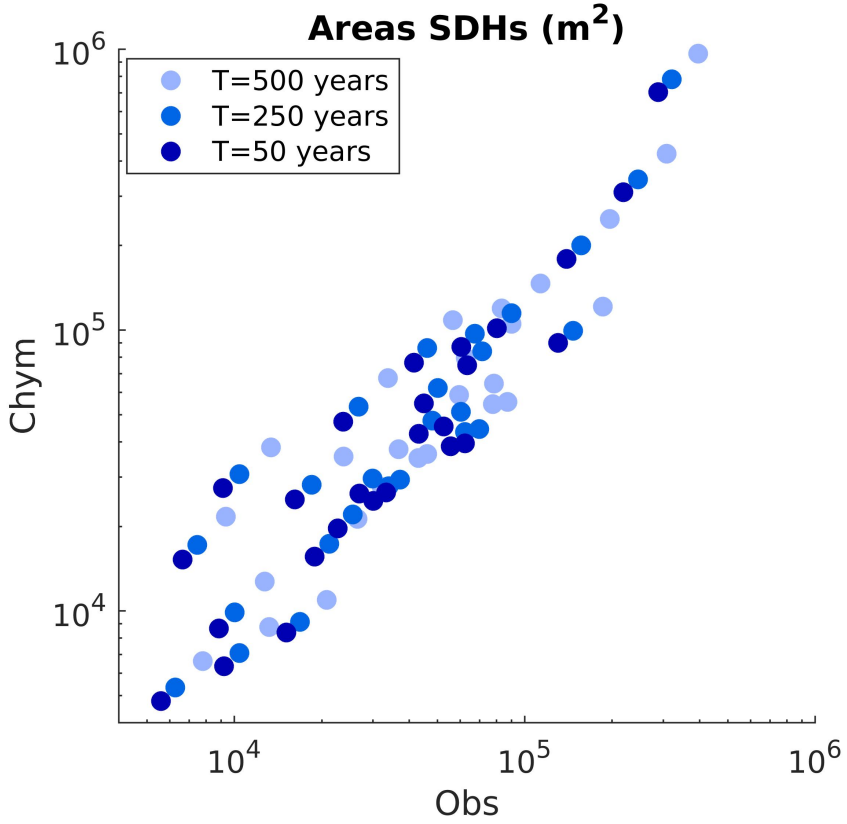
We have created a new set of virtual stations (one every 10 km) along the river network and run CA2D_par for each station with data from the hydrological model CHyM.

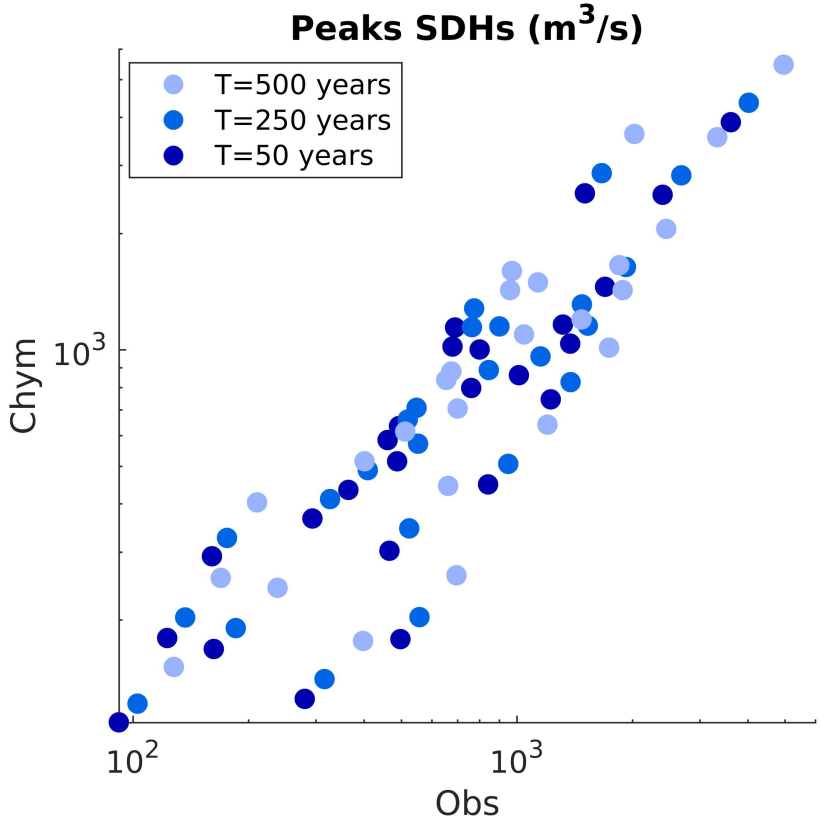
Example: observations vs model



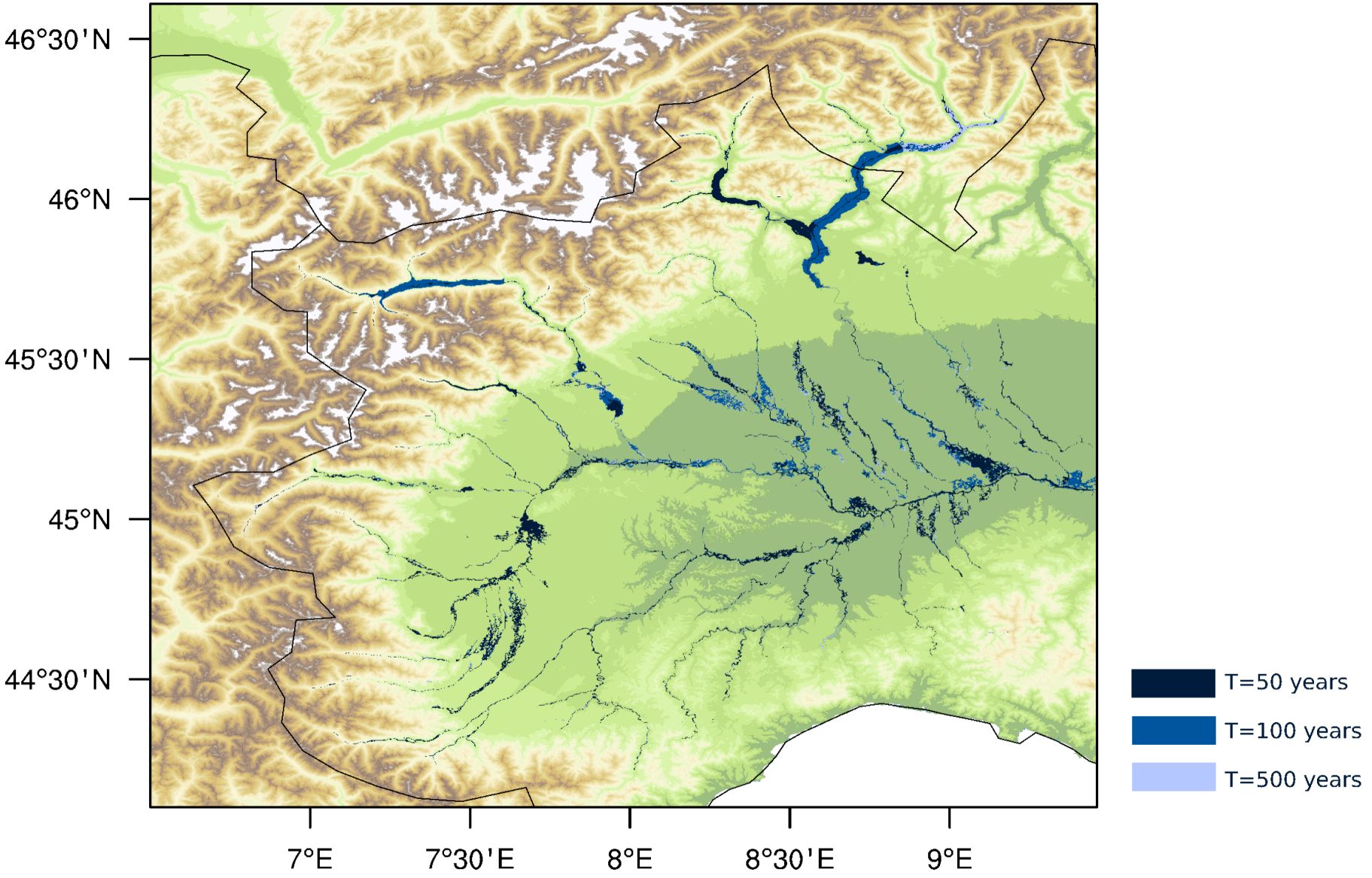
Example: observations vs model







Flood map over Po Western Basin



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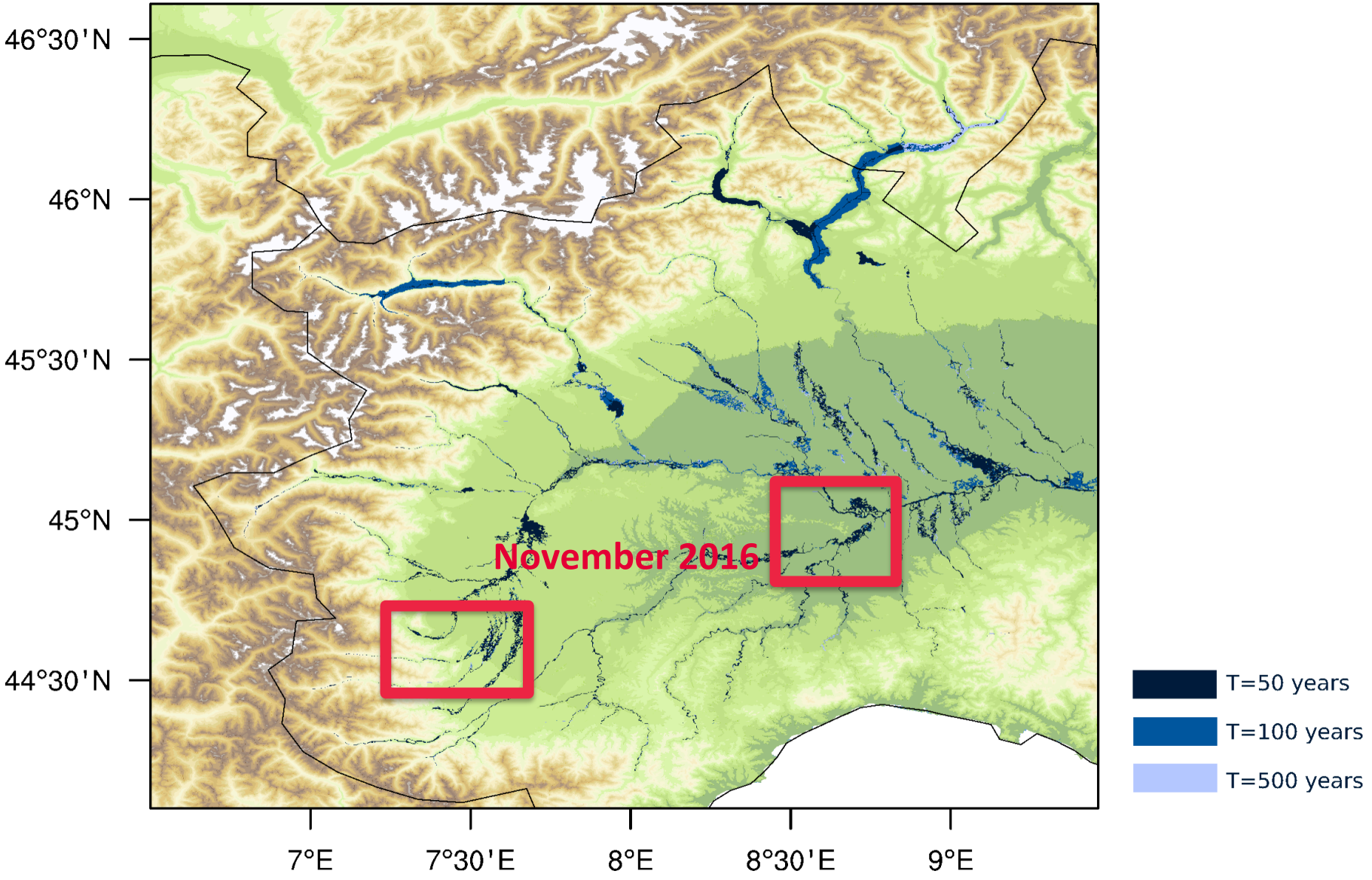
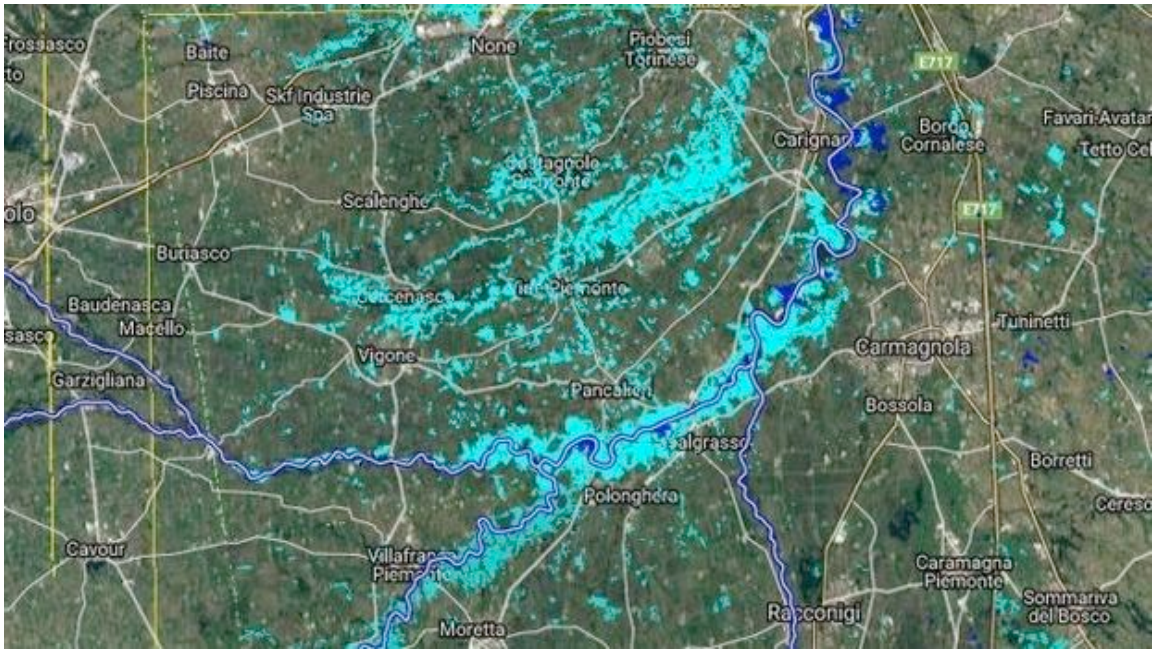


Observed flood from CosmoSkyMed satellite



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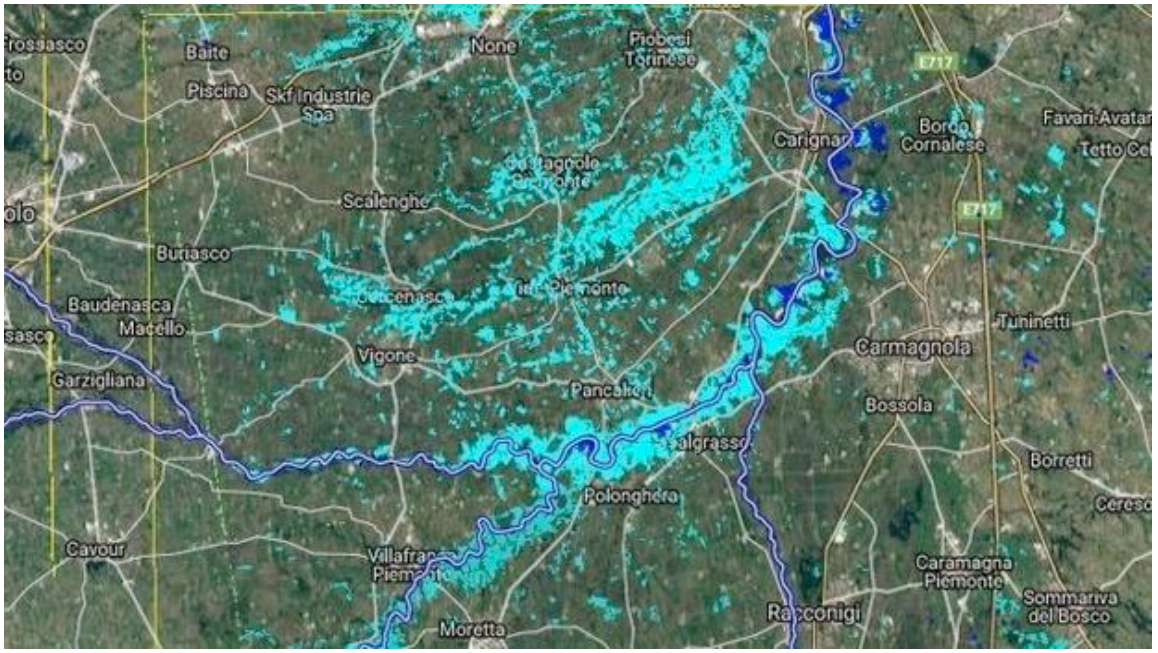
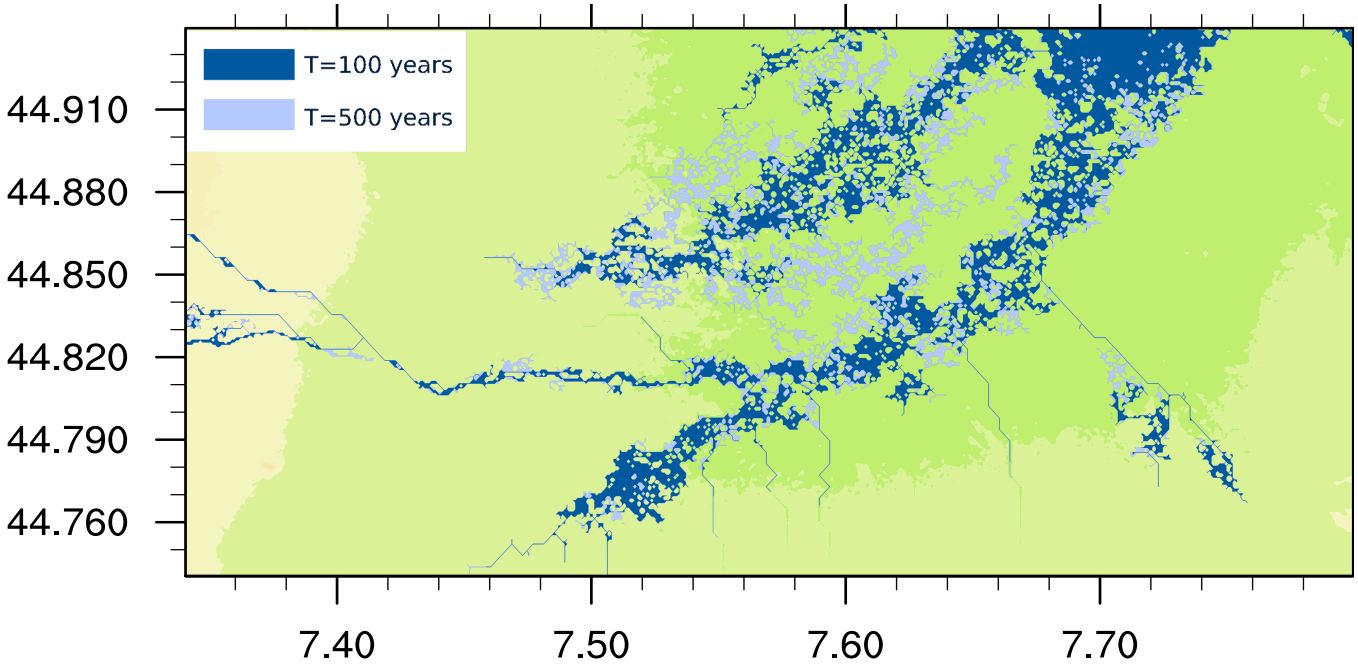


Modeled flood



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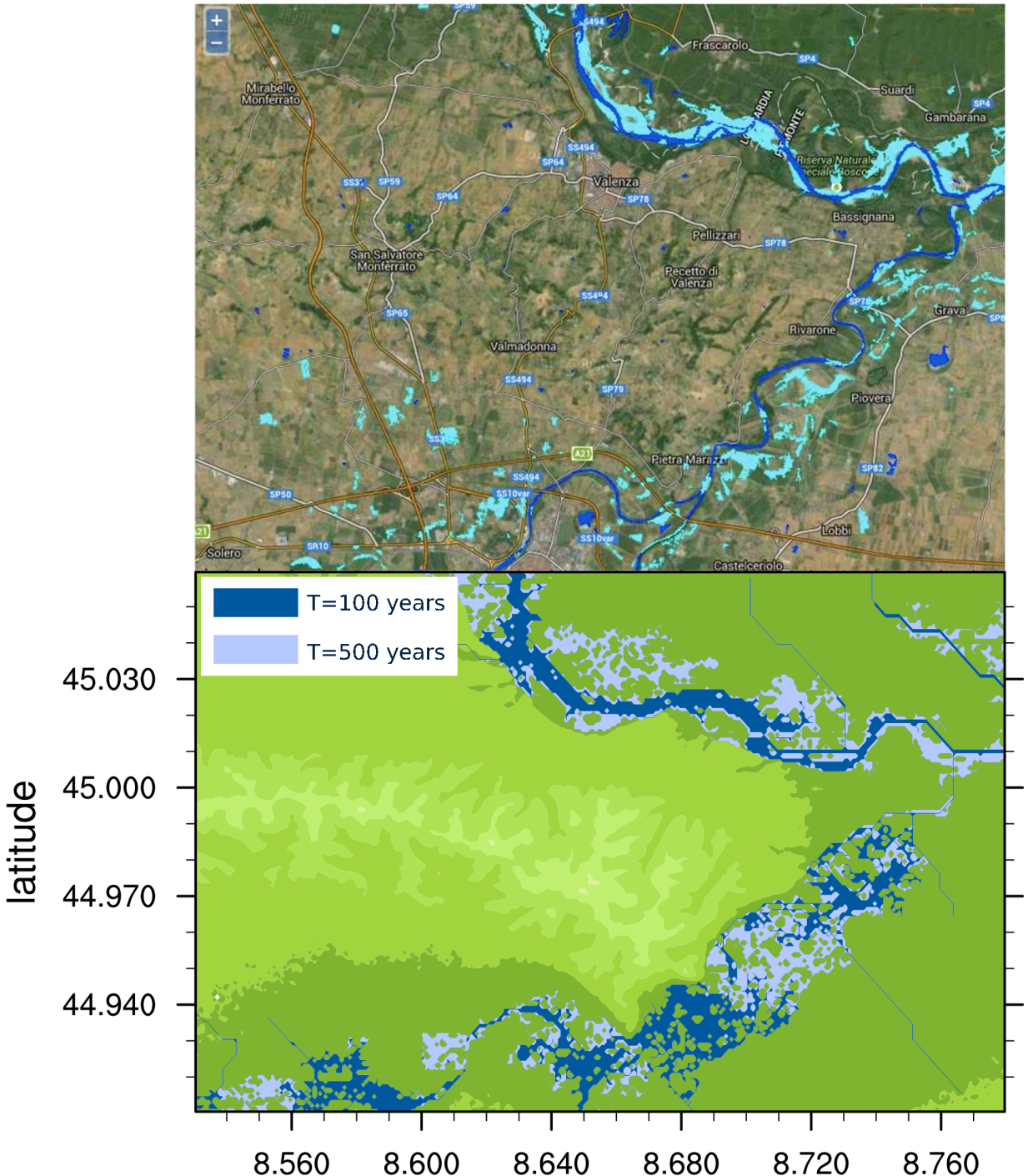
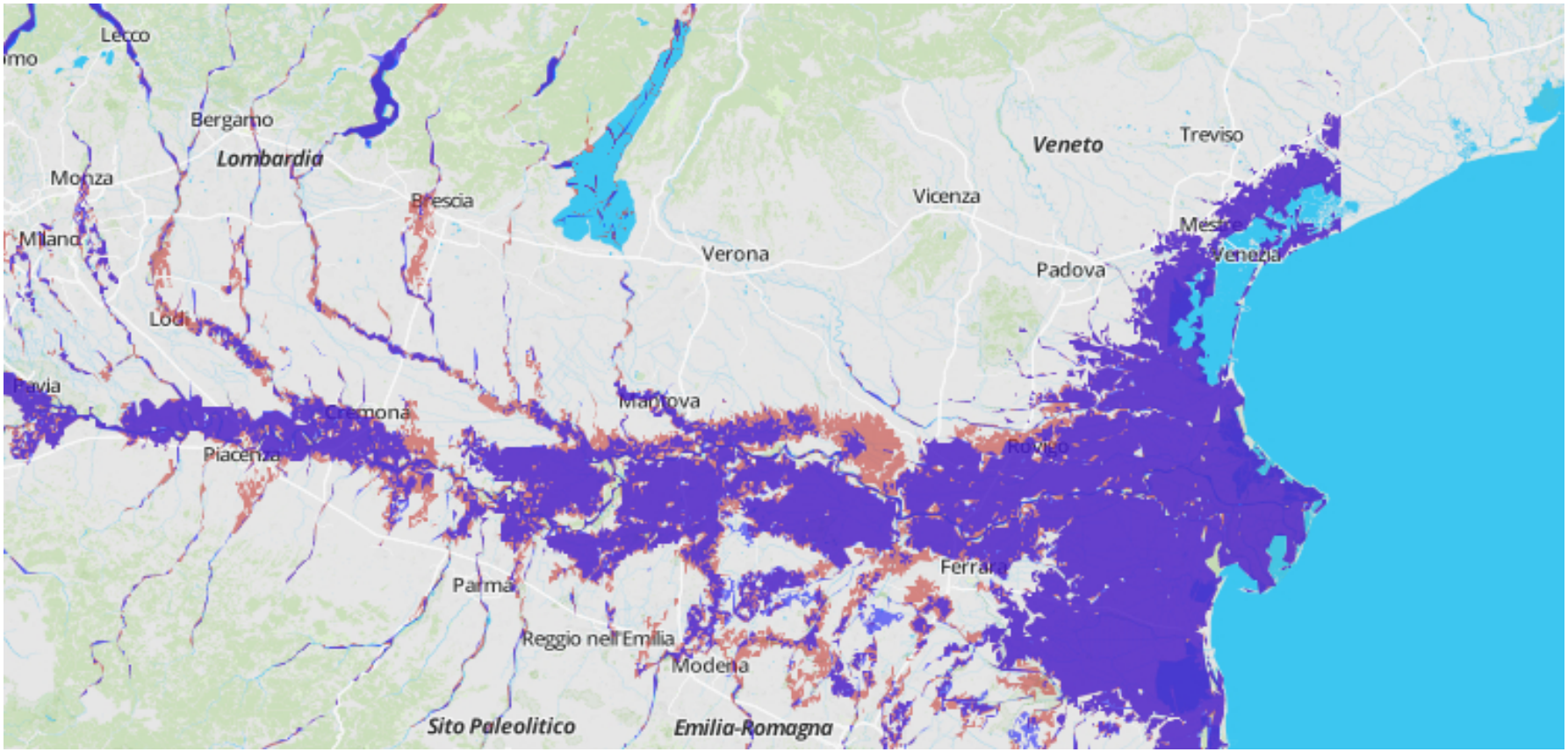
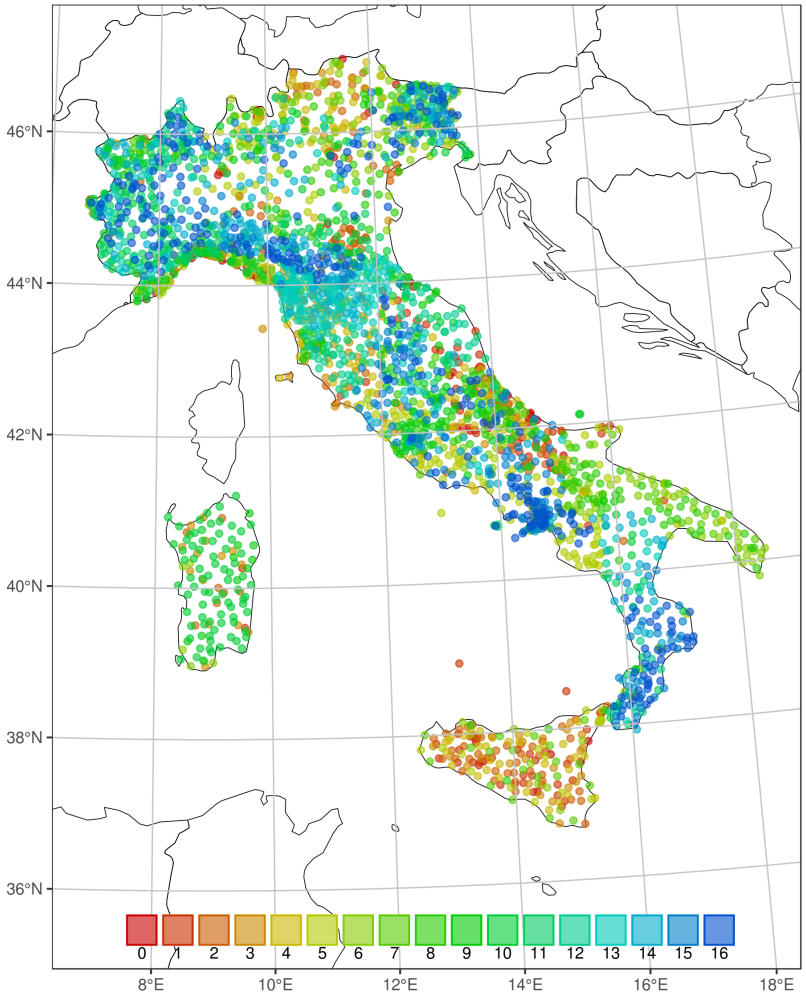


The entire Po Basin

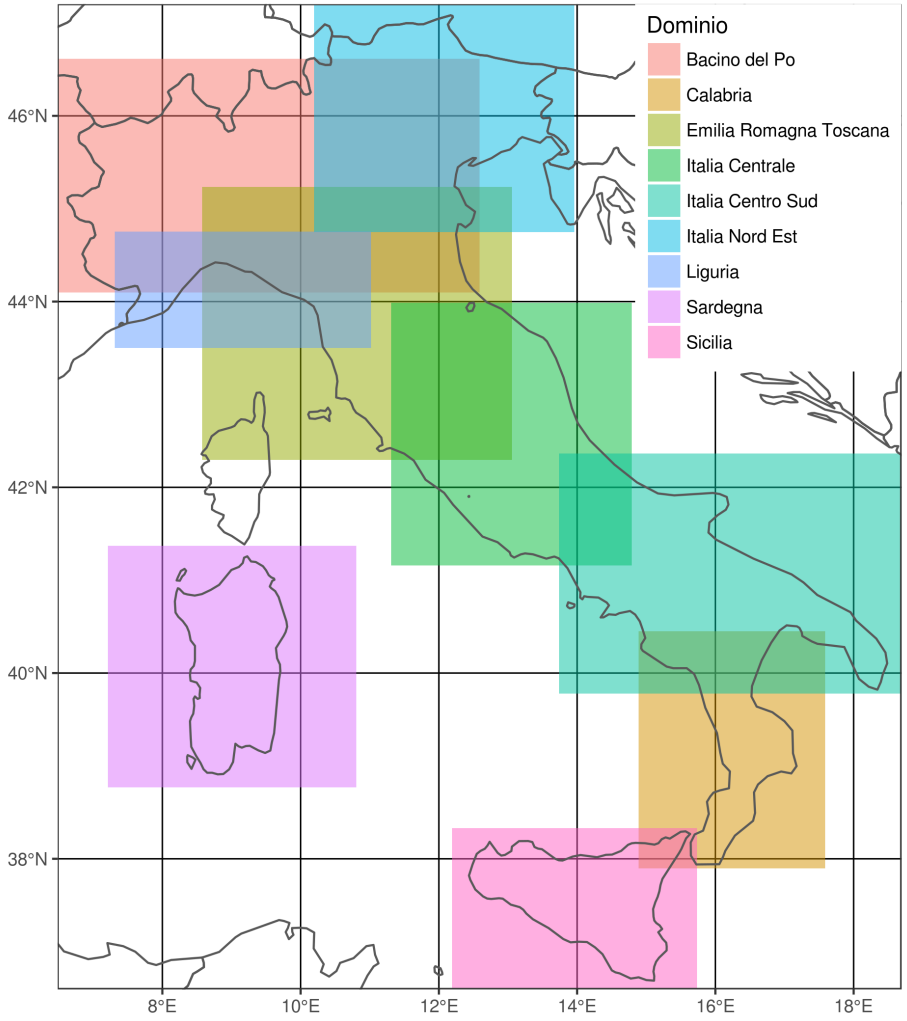


T=100 yr
T=500 yr

The other regions



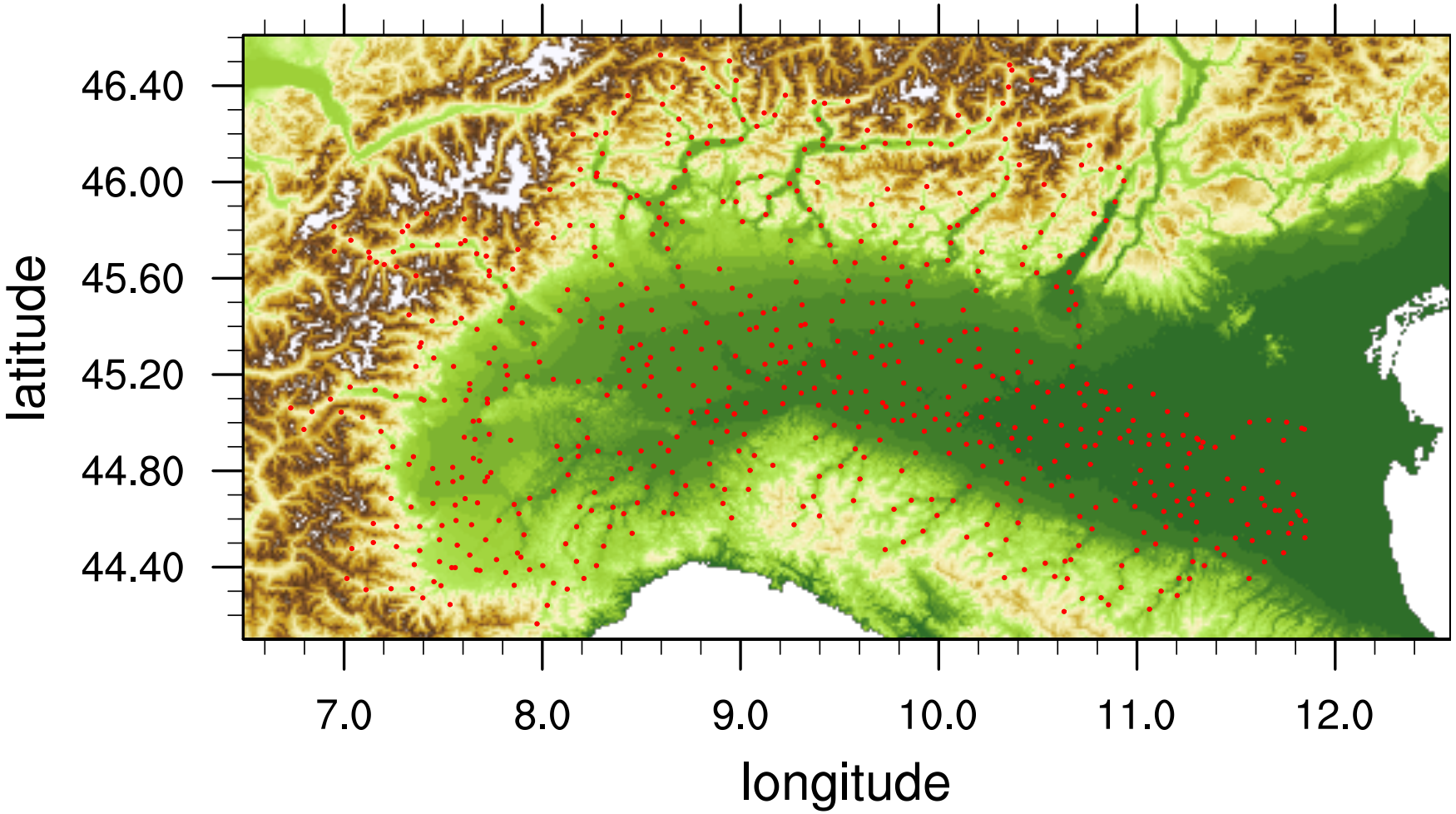
Temporal coverage



Use of RegCM4 regional climate model data

* CHyM increases spatial coverage and allows the use of observational data of precipitation;
* The use of a regional climate model guarantees a complete spatial and an extended temporal coverage;
* Validation station by station is complicated, model's error is more uniform and easier to correct.

Use of RegCM4 regional climate model data



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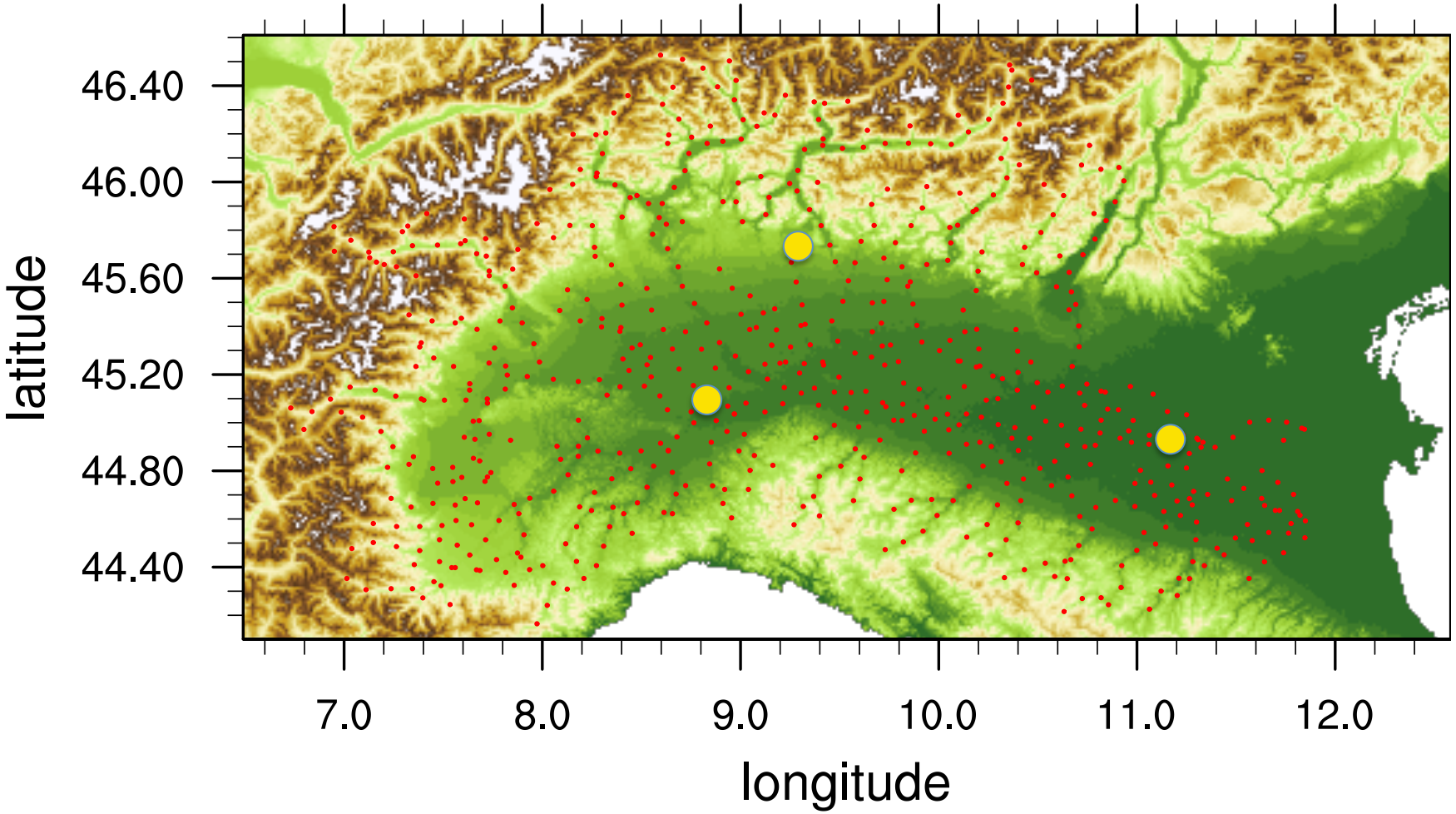

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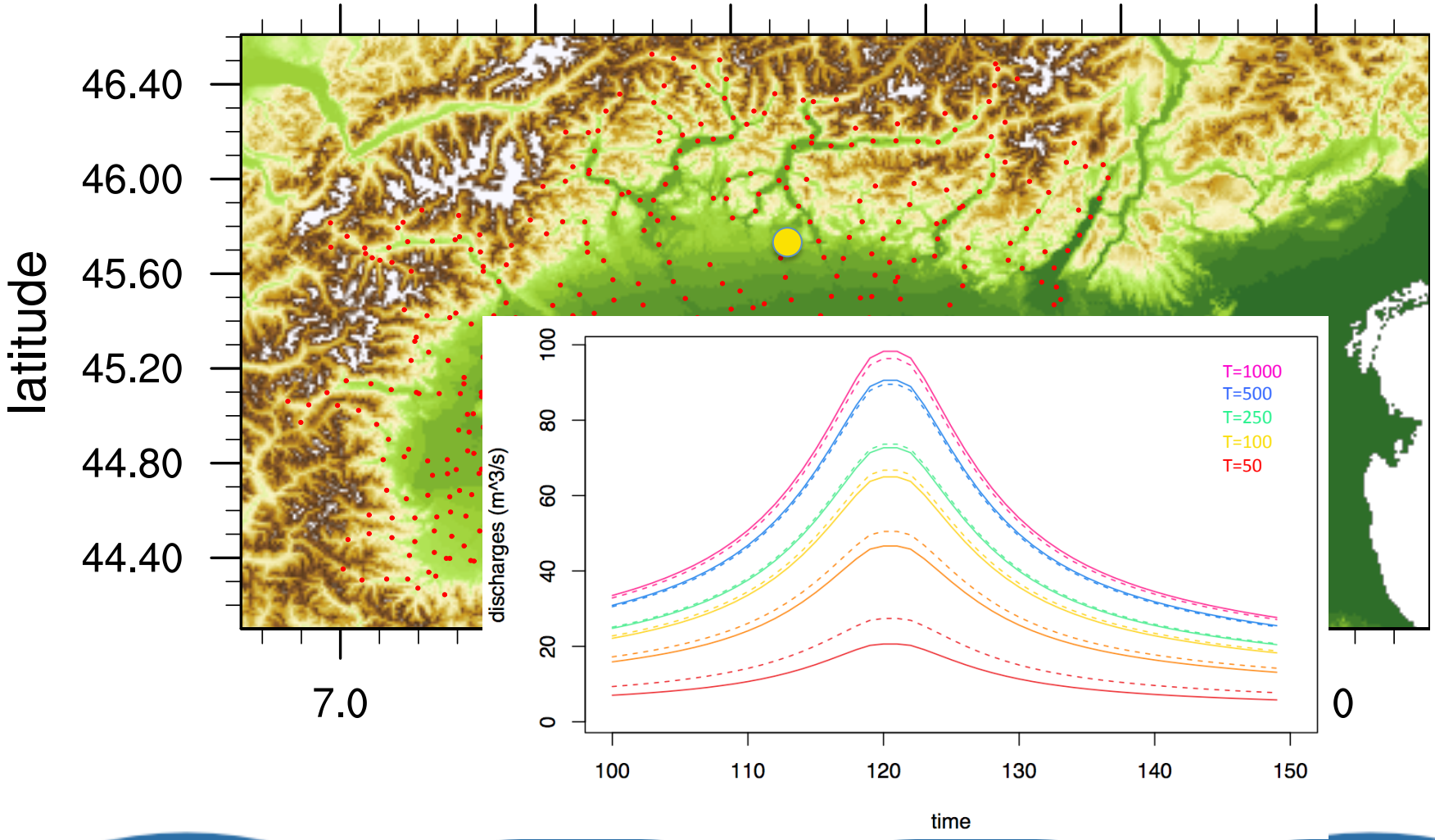

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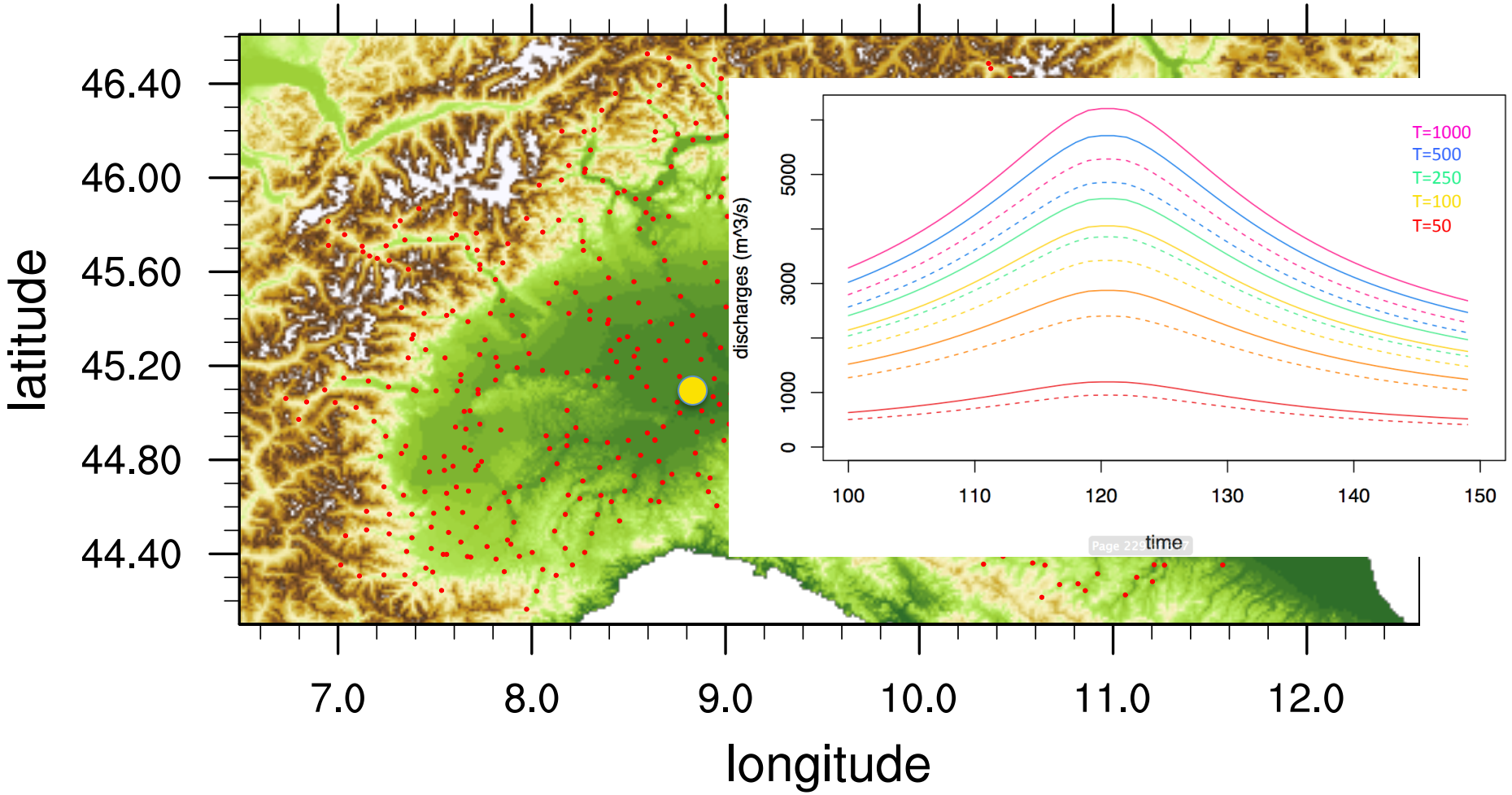

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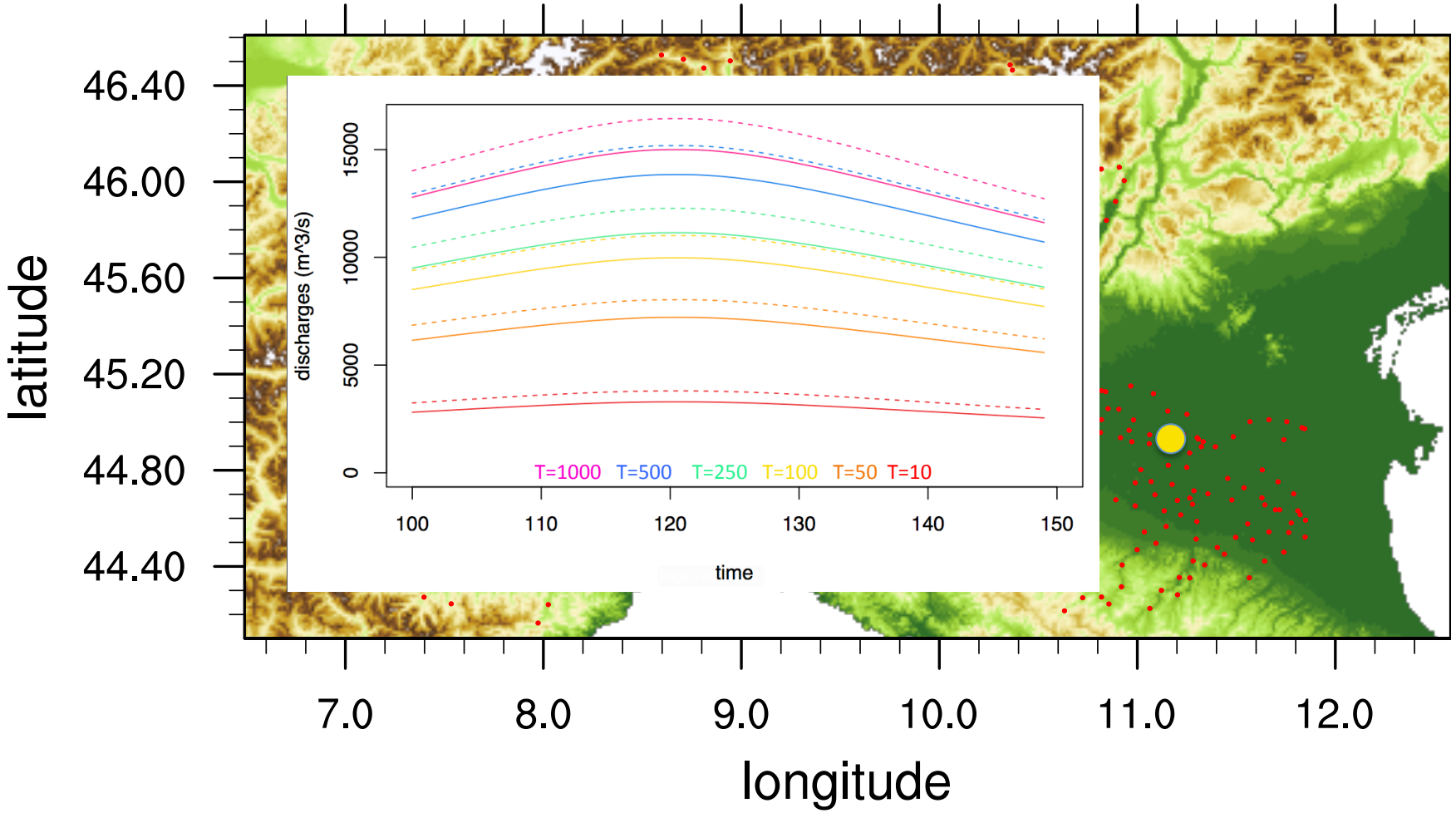

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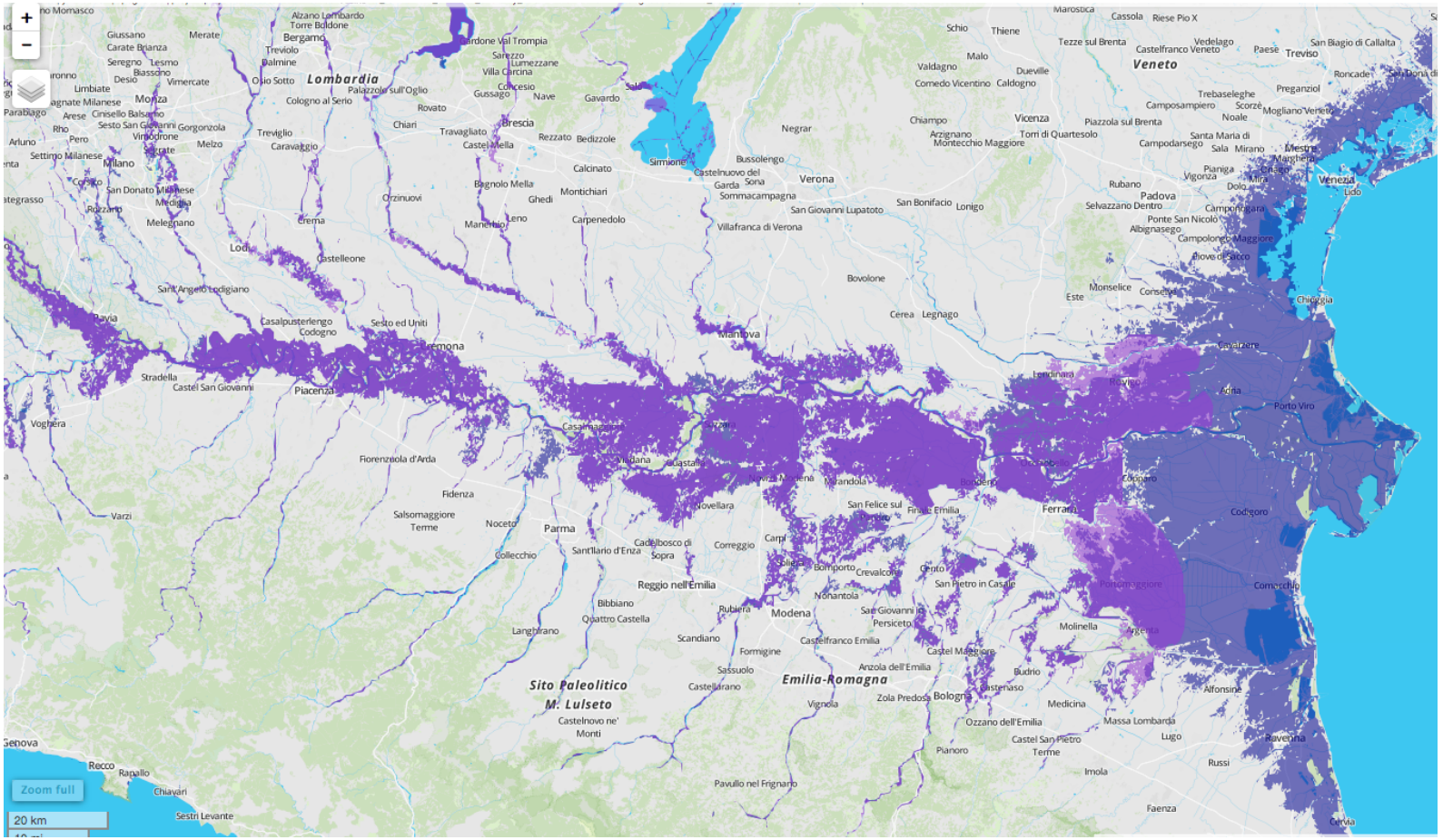


A=9124,08 km^2 T=100 yr, RegCM

A=8056,62 km^2 T=100 yr, Obs

Conclusions

* RegCM4 is able to reproduce the Po river flood extent obtained using CHyM and the observational data with an error of 11,7%;

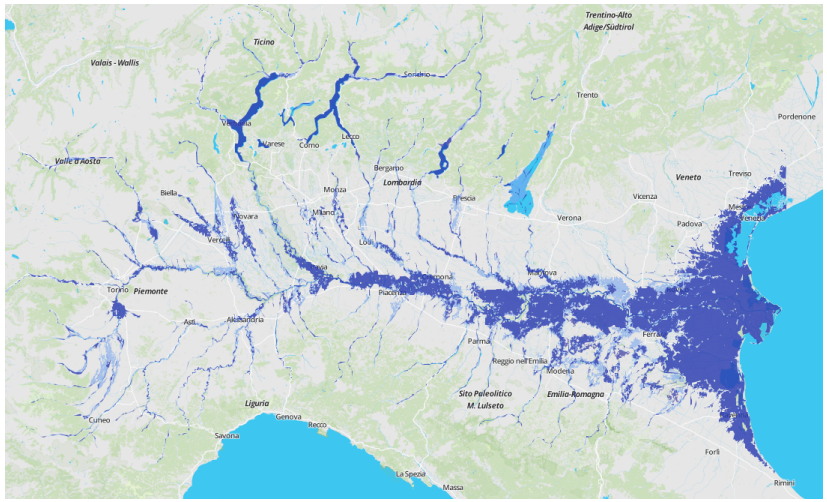
* We can now use the regional climate model with climate scenario's data to project flood patterns in the future and evaluate the impact of climate change on river flood risk!

* R. Nogherotto, A. Fantini, F. Raffaele, E. Coppola, F. Giorgi. “An integrated hydrological and hydraulic modelling approach for the flood risk assessment over Po river basin: a case study for the ALLIANZ Insurance Company”, *in preparation*

* Andreadis, Konstantinos M., Guy J-P. Schumann, and Tamlin Pavelsky. "A simple global river bankfull width and depth database." *Water Resources Research* 49.10 (2013): 7164-7168.

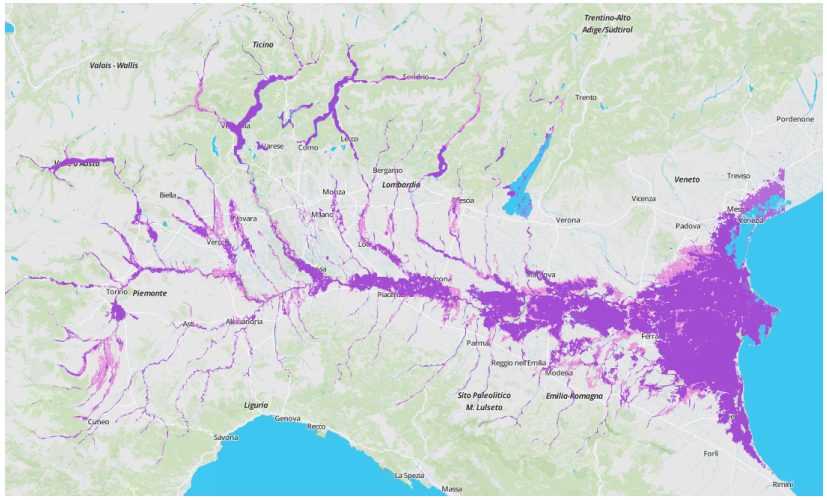
* Lehner, Bernhard, Kristine Verdin, and Andy Jarvis. "New global hydrography derived from spaceborne elevation data." *Eos, Transactions American Geophysical Union* 89.10 (2008): 93-94.

Use of RegCM4 regional climate model data



T=100 yr, RegCM

T=500 yr, RegCM



T=100 yr, Obs

T=500 yr, Obs

Example varying discharges