Flood risk in the Alps: Implications of rainfall and temperature variations on hydrological extremes

Flood risk in the Alps: implications of rainfall and temperature variations on hydrological extremes

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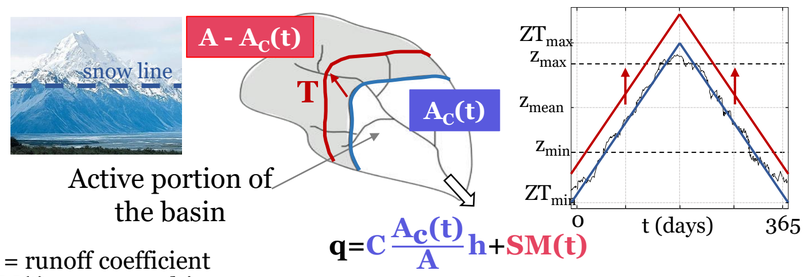
The context

- Knowing how a mountain basin will respond following a precipitation event is important for the purposes of flood risk management and mitigation.
- The response of mountain basins is closely linked to the conformation of the catchment area and to the fluctuation of snow depth over months or years.
- Rising temperatures that have occurred in recent decades and are expected to increase further will affect the formation and magnitude of floods in the mountains.

The model

The FloodAlp model [1], based on the derived distribution approach, produces a **simplified flood frequency curve** as a function of the annual variation of the snow-covered portion of the basin, based on how **the seasonal variation of the snow line** affects the **distribution of elevations in the basin**.

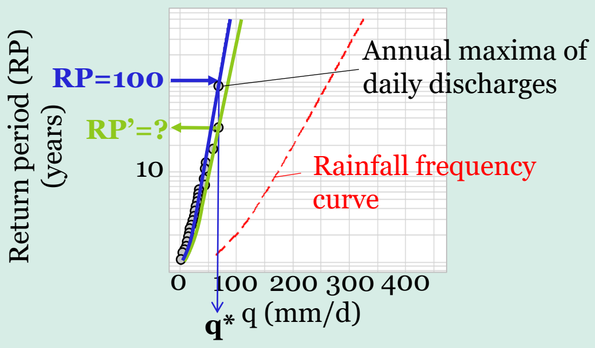


$$q = C\frac{A_C(t)}{A}h + SM(t)$$

C = runoff coefficient
SM(t) = snow melting
h = rainfall depth (Poisson representation)

Computation of the future flood frequency curve

— Current flood frequency curve
— Future flood frequency curve



Return Period Ratio $\mathbf{RPR} = \frac{RP}{RP'}$

Right-shift of the flood frequency curve → Increase of the frequency of exceedance of the current 100-year Flood (RPR>1)

24 simplified climate change scenarios

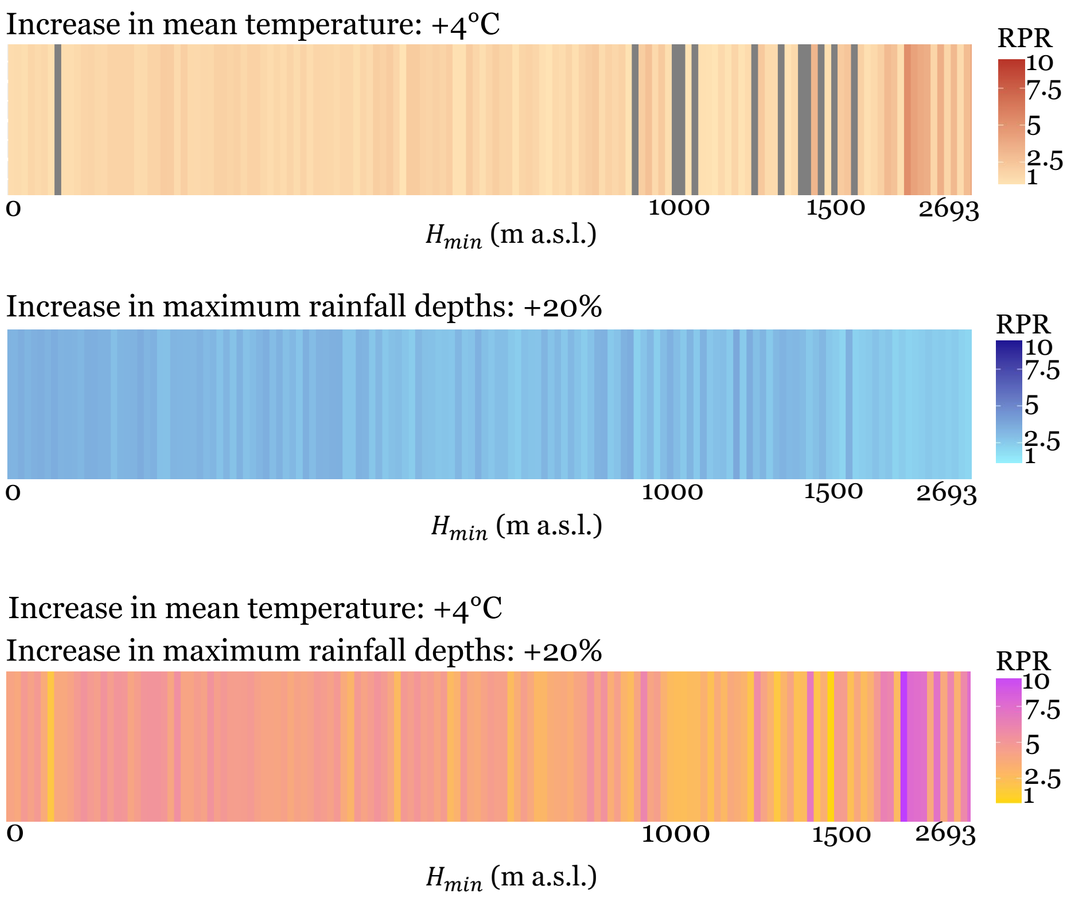
Increment of mean temperature
+1.5°C +2°C +3°C +4°C

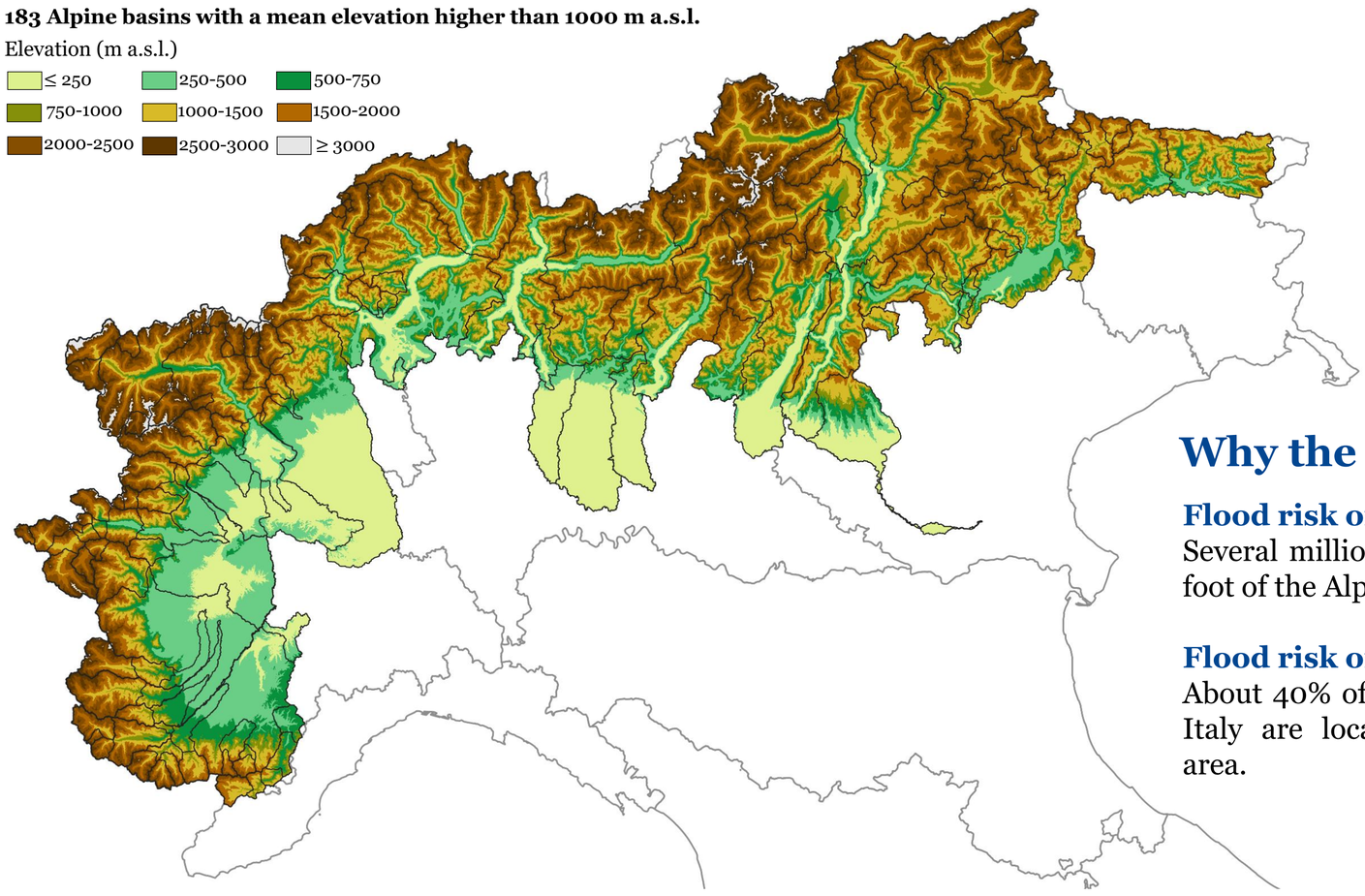
Increment of maximum rainfall depth*
+5% +10% +15% +20%

Combined increments of temperature and rainfall depths

*Changes in the number of rainfall events per year can also be simulated.

Variability of the potential increase of flood frequency in the Alpine basins





Why the Alps?

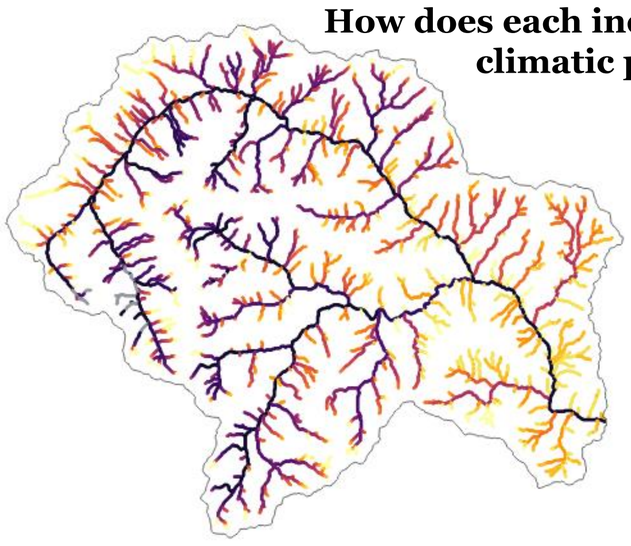
Flood risk on people
Several million people live at the foot of the Alps.

Flood risk on infrastructures
About 40% of the Large Dams in Italy are located in the Alpine area.

High-resolution zoom on the Chisone basin (North-Western Alps) [2]

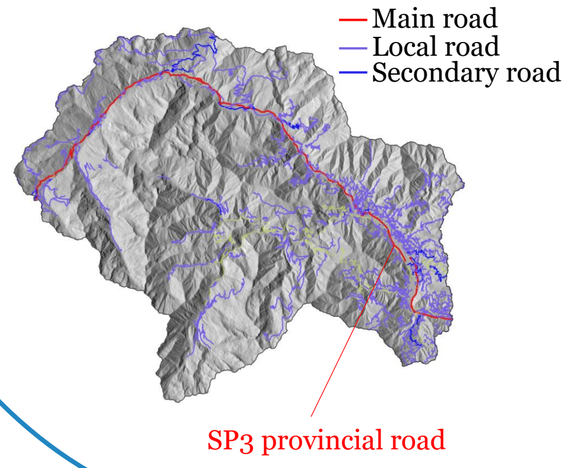
Analysis performed over **12.000 sub-basins** extracted from a DEM at a **50 m spatial resolution**, following the streams every 50 m.

How does each individual stream would respond to the climatic perturbations implemented?

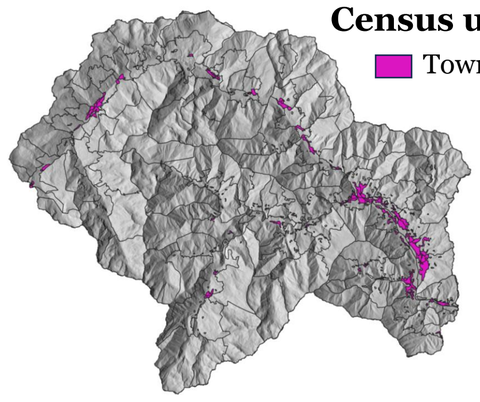


The RPR values are higher moving along the main river channel than along the tributaries

Road network



Census units



Summary

- The increased frequency of flooding due to changes in temperature and rainfall characteristics can have serious implications for infrastructure and human safety in the Alps.
- In absolute terms, alterations in temperature have a more pronounced effect on reducing the return period of the current 100-year flood compared to changes in precipitation intensity.
- High sensitivity of the Alpine basins to rising temperatures at elevations above 1500 m a.s.l. Lower regions, as expected, are however highly vulnerable to intensified precipitation.
- Due to a combined hypothetical increase of 4°C in mean temperature and 20% in maximum rainfall depth **the current 100-year flood may become up to 9 times more frequent**.

References

[1] Allamano, P.; Claps, P.; Laio, F. An analytical model of the effects of catchment elevation on the flood frequency distribution, *Water Resour. Res.* 2009, 45, W01402.
[2] Monforte, I., Evangelista, G., Claps, P. Flooding risk from global warming in Alpine basins: an estimate along stream network. Presented at the *5th EWaS (Efficient Water Systems) International Conference, Naples, 12-15 July 2022*.

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