Estimating ensemble flood forecasts uncertainty:

A novel "Peak-box" approach for detecting multiple peak-flow events

Antonio Giordani[1,2], Massimiliano Zappa[2] and Mathias Rotach[1]

1 Department of Atmospheric and Cryospheric Sciences, Universität Innsbruck, Innrain 52f, 6020, Innsbruck, Austria

2 Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Zürcherstrasse 111, CH-8903, Birmensdorf, Switzerland

Correspondence: antonio.giordani2@studio.unibo.it

1. Introduction and goal

Why flood forecasting?

- floods can cause great loss of human and animal lives, and large damages to the environment and infrastructures
- severe events' frequency will increase under global warming

A key question ensemble flood forecasts try to answer is:

How high and when is the peak of the flood expected?

Arkansas River flood, 28 May 2019

Their interpretation is limited by the **large spread** they present ⇒ development of new tools is necessary
One of these is the **"Peak-box" approach** developed by Zappa et al. (2013):

- thought to guide the forecasters in decision-making
- based on peak timing and magnitude distributions of the runoff members
- received positive feedbacks within the hydrological community

BUT: it is limited for events presenting multiple runoff peaks (caused by intermittent rainfalls)!

For this reason our research question is:

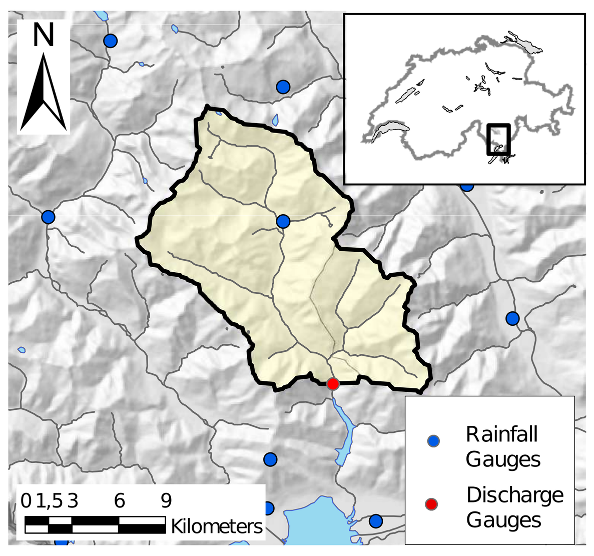
Is it possible to develop a "Peak-box" approach for detecting multiple flood peaks within the same forecast, and does it outperform the former method?

2. Models and study area

Simulations were run with a system formed by:

- **COSMO-E** as the forcing NWP: a high-resolution (2.2 km) limited-area 21-members EPS, running over the Alps twice daily
- **PREVAH** as hydrological model: a semi-distributed catchment model designed for mountainous environment, forced by COSMO-E's rainfall predictions

Period: Oct-Nov 2018 (including the **Vaia storm**).
Study area: the small **Verzasca** basin (186 km^2), in the Canton Ticino, Switzerland.

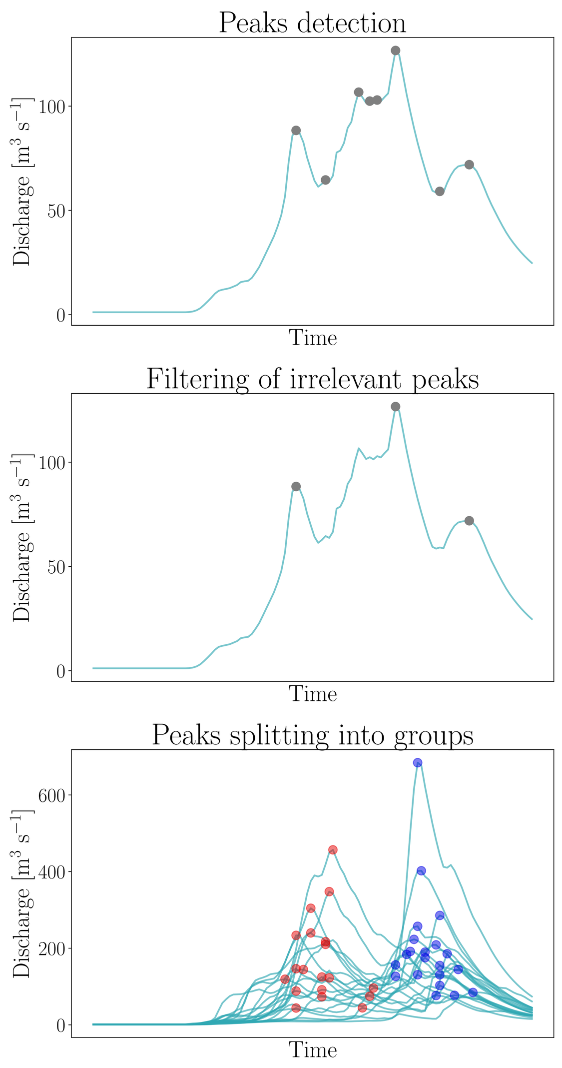


The Verzasca river catchment

4. The new Peak-Box for Multiple peak-flow events (PBM)

PBC unable to detect multiple peaks → development of PBM in **4 steps**:

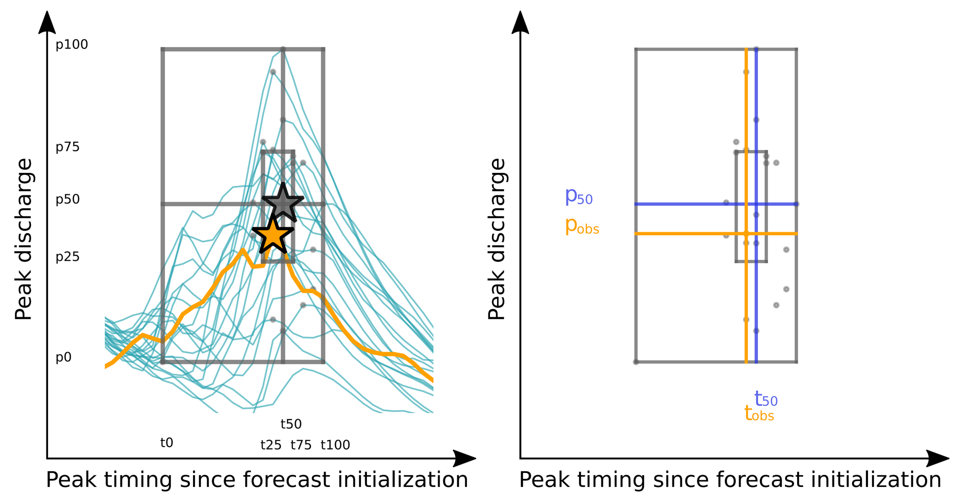
1. for every runoff member find all peaks with a certain **prominence** (measure of independence of a peak) → to filter out irrelevant peaks
2. use a threshold (T_{low}) to discard low peaks; when many peaks are very close in time (± 10 h), keep just the highest
3. apply a **K-means clustering** on the peaks population of the entire ensemble to separate them into groups related to different events
   → variables: peak timing and scaled peak runoff
   → # groups = mean # peaks among members
   → in 1 group only 1 peak for member is allowed
4. apply PBC procedure to every group to construct the boxes and verify the results



The Python script is freely available at https://github.com/agiord/peakbox

3. The Classic Peak-box (PBC)

As developed in Zappa et al. (2013):



4 elements of the peak-box: based on quantiles

- outer rectangle, "peak-box"
- inner rectangle, "IQR-box"
- median of the peak discharge, p_{50}
- median of the peak timing, t_{50}

Measures of agreement:

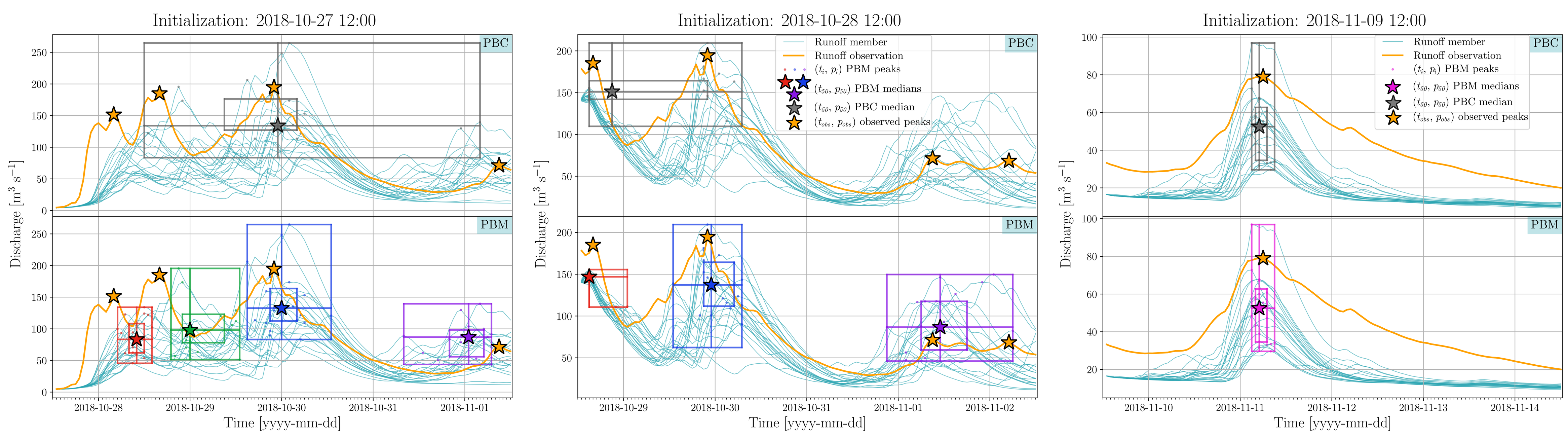
- Sharpness:

$$PB_{FULL} = (p_{100} - p_0) \cdot (t_{100} - t_0) \frac{3.6}{A} \quad [\text{mm}]$$

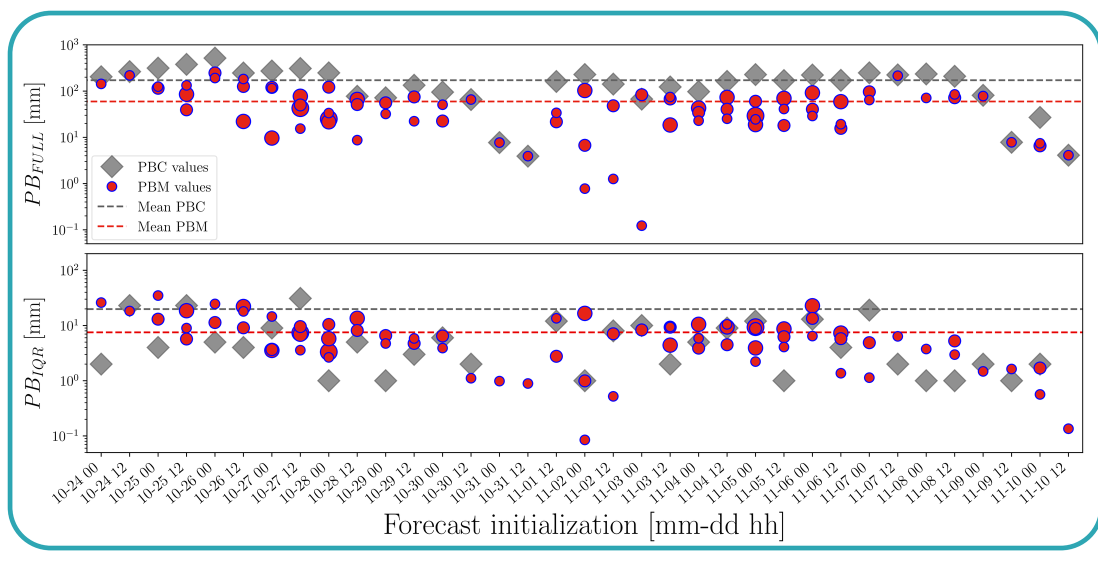
$$PB_{IQR} = (p_{75} - p_{25}) \cdot (t_{75} - t_{25}) \frac{3.6}{A} \quad [\text{mm}]$$

- Hit/miss score: $H_{PB} = \frac{\#\text{ hit peaks}}{\#\text{ observed peaks}}$

5. Results and Discussion: PBC vs PBM

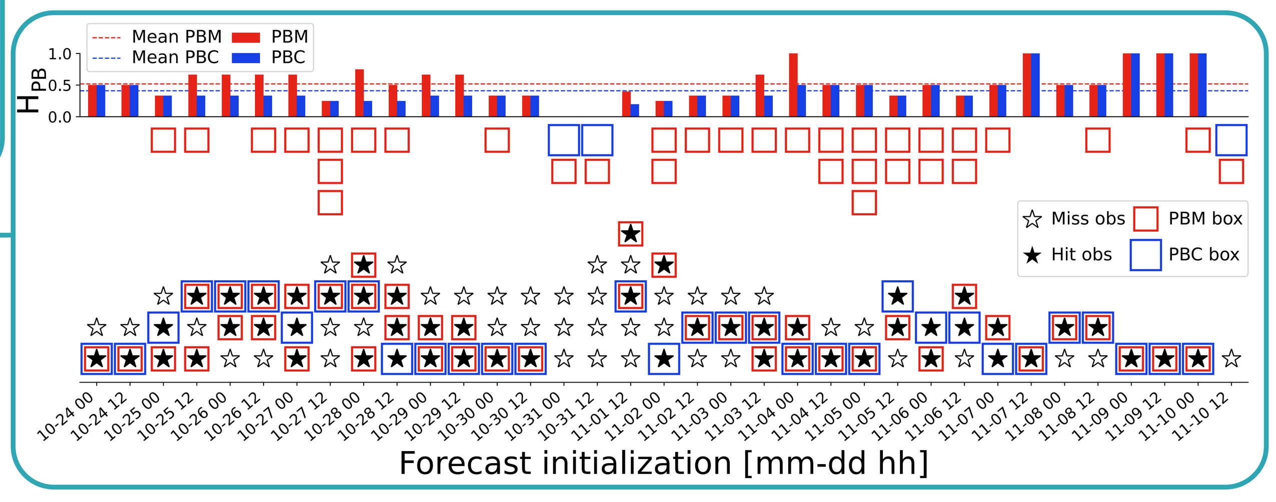


PBM successfully produces **more than one** sharp box when multiple peaks are present, while PBC creates one wide box not even always centered towards the main peak. PBM reduces to PBC for singular events.



Sharpness metric:
On average PBM produces peak-boxes and IQR-boxes that are **3 times sharper** than PBC.
The ability of PBM to produce sharp peak predictions does not depend from forecast leadtime.

Hit/miss score:
PBM successfully **hits 50%** of the observed peaks, while PBC just the 40%. PBM is able to hit more peaks when multiple events occur.



6. Conclusions

The former method (PBC) was found to be not reliable in case of multiple peak-flow events. On the other hand, the implementation of a new algorithm (PBM) designed to distinguish among events was successful: PBM produces more than one peak forecast when required, and peak estimations are sharper and more skillful than those of PBC.
Main limitation: PBM tested on a very limited sample of model initializations, a wider application to different basins, periods of the year and models shall be performed.

7. References

Zappa, M., F. Fundel and S. Jaun, 2013: A 'peak-box'approach for supporting interpretation and verification of operational ensemble peak-flow forecasts, Hydrological Processes, 27, (1), 117–131.

This poster is based on the thesis *Estimating ensemble flood forecasts uncertainty* by Antonio Giordani, and the research contents are submitted and under revision by MDPI's journal *Atmosphere*.