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The Analogs method in the framework of severe rainfall forecasting in the Swiss Alps

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Introduction

This study is part of the MINERVE (Modélisation des Intempéries de Nature Extrême du Rhône Valaisan et de leurs Effets) project, which aims at creating a model for real-time flood risks management on the Rhône river. Flood forecasting allows us to reduce flood peaks by means of water retention in dams, but it implies that we need to anticipate at best the location and amount of forthcoming precipitation.
Our objective is to provide statistical precipitation forecasts by means of the Analogs method, in parallel to the COSMO model, in order to extend the information on which decisionmakers build up their choices. The Analogs method enables us to refer to past events and to identify determining elements in the atmospheric circulation.
The model is currently in its calibration stage and should be operational this year.

Study area

The study area is the alpine Rhône catchment in Switzerland. The calibration results will be illustrated on two precipitation gauging stations (Fig. 1) that are sensitive to different atmospheric synoptic circulations. The Marecottes station is sensitive to intense westerlies, while Binn is highly sensitive to south circulation.

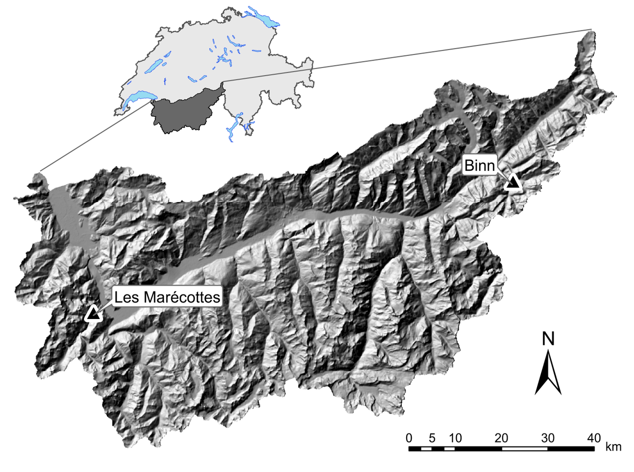

Fig. 1 : Location map of the study area and of the two meteorological stations of interest in the Swiss Alps (source : Swisstopo)

Datasets

The predictor datasets are the NCEP/NCAR Reanalyses (2.5° resolution, 17 atm. levels) (Kalnay et al. 1996) (Fig. 3). The predictands are precipitation time series measured by the MeteoSwiss stations network, on the period 1962-2007 (Fig.2)

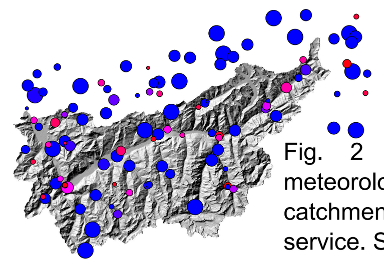
Fig. 2 : Location of the meteorological stations in the catchment (Blue are stations in service. Size = archive length)

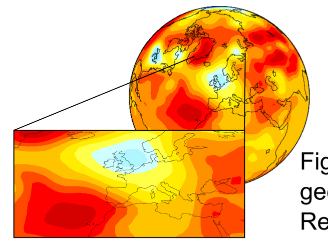
Fig. 3 : Illustration of a geopotential height in the Reanalyses dataset

The Analogs method

The Analogs method is a statistical adaptation method. It aims at forecasting daily precipitation (the predictand) on the basis of the synoptic atmospheric circulation. Its main hypothesis is that similar situations in term of atmospheric circulation are likely to lead to similar local meteorological conditions (Lorenz 1969, Bontron & Obled 2005).
The real-time forecasting (Fig. 4) is made of the following steps. (1) Atmospheric data processed by a GCM (Global Circulation Model) are acquired and (2) compared to the Reanalyses archive over a certain spatial window. The analogy is processed on different variables as subsampling steps. (3) The N days that are the most similar are extracted and (4) the observed precipitation for those days provide the empirical conditional distribution specific to the target day.

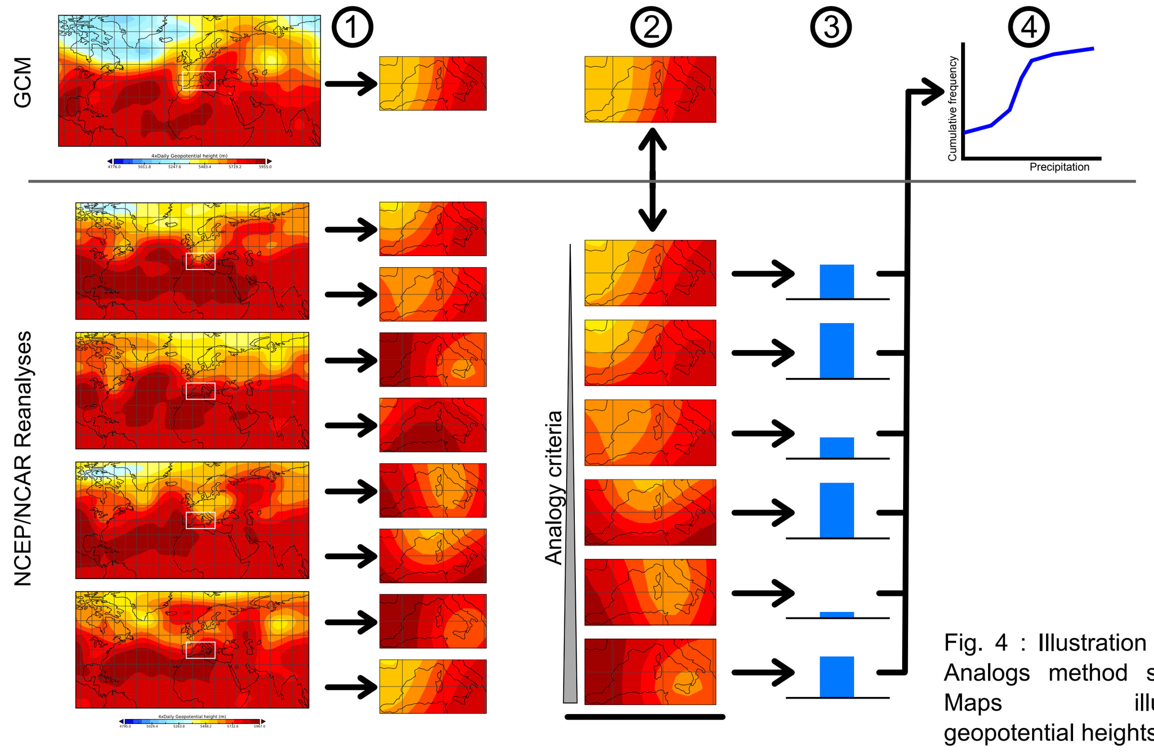

Fig. 4 : Illustration of the Analogs method stages. Maps illustrate geopotential heights.

The calibration of the method consists in identifying variables on a certain domain and at a certain time that best explain the observed precipitation at a region or station scale. The first predictor is the geopotential height. A comparison in terms of gradients (S1 criteria) is used to account for air masses flow (Teweles & Wobus, 1954). The second common predictor is the humidity information integrated by means of the relative humidity and the precipitable water.
Calibration of the method is done on the basis of the NCEP/NCAR Reanalyses, in a perfect forecast framework. A forecast score (CRPS) is calculated to characterize the predictor relevance (Matheson & Winkler 1976) for every day of the archive (1962-2007). The calibration aims at optimizing the parameters for the whole series.

Climatic considerations

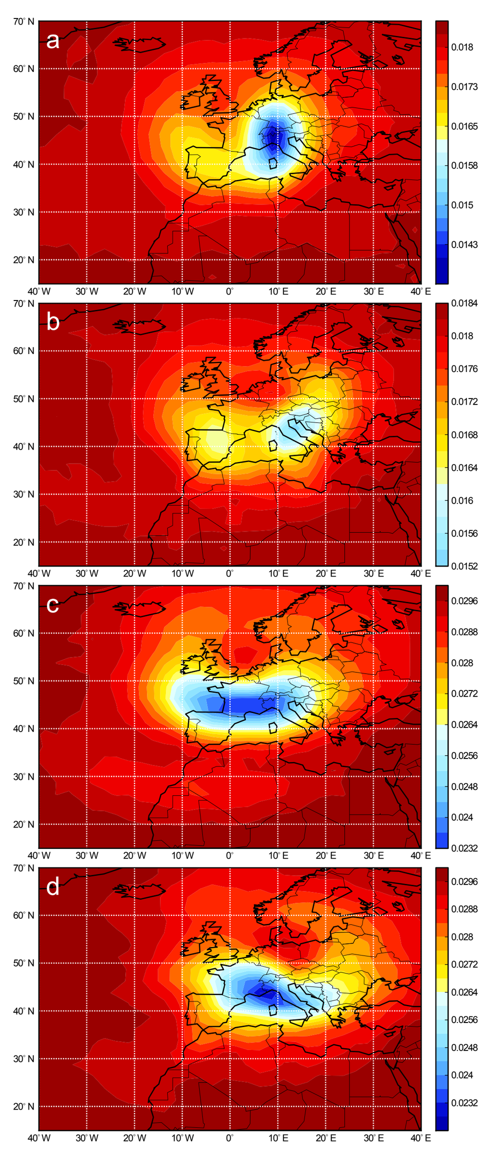
Fig. 5 : Relevance maps (a) for the 500 hPa level at dt=0h and (b) 1000 hPa at dt=-6h for the Binn station, and (c) at 500 hPa level at dt=0h and (d) 1000 hPa at dt=-6h for the Marécottes station. Values are the CRPS scores.

The relevance map is a spatial display of the forecasting capacity of every grid cell of a predictor. It allows seeing where the atmospheric circulation is of importance to determine the precipitation at the station.
Relevance maps for Binn (Fig. 5ab) and for Les Marécottes (Fig. 5cd) are consistent with the isobaric back trajectories for days with important precipitation at the stations (Fig. 6). It means that the predictors are the most relevant where the atmospheric circulation is critical for the stations. Another illustration of this tendency is given by the wind roses in Figure 7.

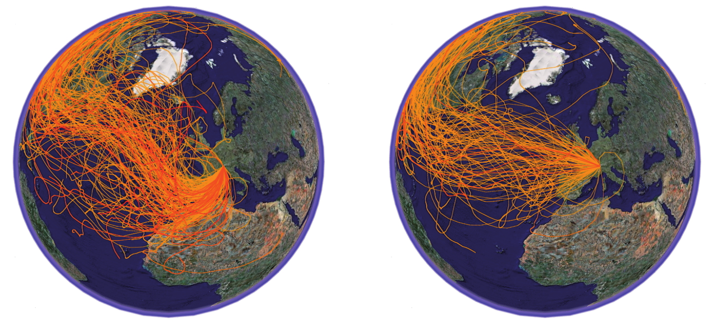
Fig. 6 : Isobaric back trajectories on the 500 hPa level for days with precipitation superior to 50 mm (left) at the Binn and (right) Marécottes station. Trajectories are processed on the velocity fields of the Reanalyses (source: GoogleEarth).

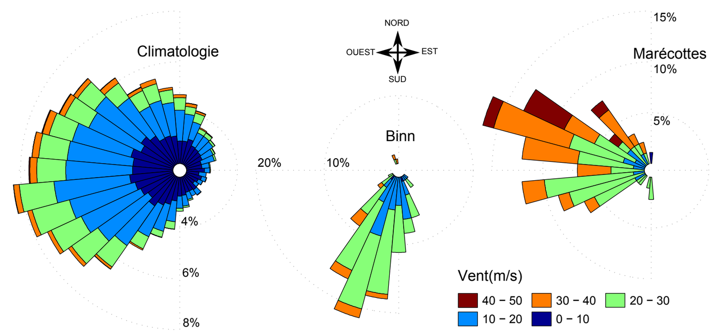

Fig. 7 : Wind roses at the 500 hPa level for the climatology and for the days with precipitation superior to 50 mm at the Binn and Marécottes station.

Calibration results

The calibration procedure results in optimal parameters describing e.g. the spatial windows (Fig. 8) for the different consecutive steps of the method. An illustration of a forecasted time-series in the calibration period is given in Figure 9 for the Binn station considering (left) the geopotential heights only and (right) these in combination with humidity. A forecast is synthesized by means of the 30, 60 and 90 percentiles. One must consider the 90 percentile for severe precipitation events.

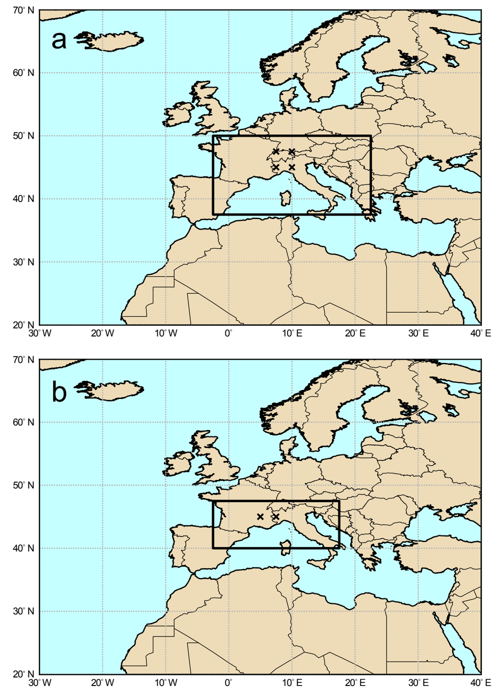
Fig. 8 : Illustration of the optimal spatial windows for (a) the Binn station and (b) the Marécottes station. Rectangles are for geopotential heights on both 500hPa and 1000hPa levels, and crosses are for humidity variables.

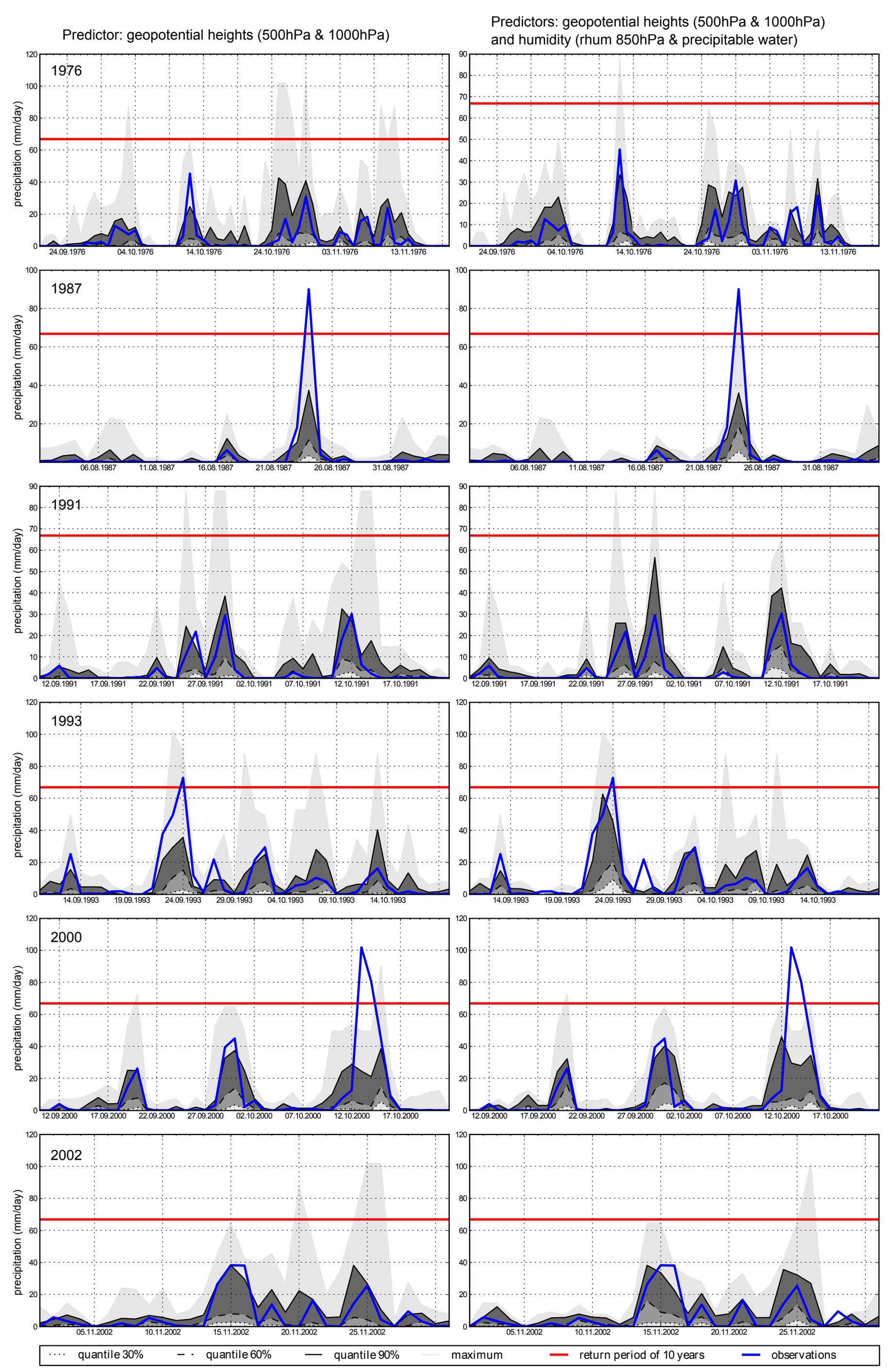

Fig. 9 : Examples of calibrated forecasts of some famous major precipitation events in the Binn region (perfect forecasting framework). Left column is processed with the geopotential height fields only, while the humidity variables were added for the right column.

Discussion and conclusions

The different regions in the Swiss Alps are sensitive to different meteorological situations. As a consequence, predictors vary from a sub-region to another. During calibration of the method, in order to find the optimal spatial windows on the geopotential heights, it appeared that those locations correspond to features in the atmospheric circulation of situations giving severe precipitation. For those events, the atmospheric circulation diverges from the climatology in a recurrent way.
The modeled time-series in the calibration period show a good consistency with the observed precipitation. The signal is significant, and the forecasted amounts are satisfying in general, except for the 1987 and 2000 events. Generally, the humidity information improves the forecasts.

Perspectives

The method shows a great potential in calibration. This potential will certainly be reported on real-time forecasts, at least for the first days, when GCM forecasts are relevant.
The calibration was done on the whole archive. It would be wise next to consider a validation period independent from the calibration.
Other calibration tests will focus on severe events only, to improve their accuracy. Some parameters still need to be calibrated, such as the time of the predictor. Other atmospheric variables will next be considered.

Aknowledgements

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