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Identification of synoptic precursors to extreme precipitation events in the Swiss Alps by the analysis of backward trajectories

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One of the most expensive natural disasters in Switzerland consists in floods related to heavy precipitation. Moreover, the occurrence of heavy rains may induce landslides and debris flows as it was observed during the three major precipitation events that occurred recently in the Swiss Alps (August 1987, September 1993 and October 2000). Even though all these inclement weather conditions took place under a southerly circulation, especially in autumn, not all southerly circulations lead to heavy precipitation. Although many studies have been carried out to understand them, they are still very difficult to forecast, due to the complexity of the phenomena involved. In consequence, the forecasting of extreme events still contains important uncertainties, especially in an alpine environment. The numerical models struggle to take into account the complexity of this environment strongly influence by different local-scale specific behaviors. Therefore, this work aims to identify simple synoptic precursors to such events throughout backward trajectories of the air masses.

Various existing tools were used to run the trajectories. Among them, we tested tools such as the Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT), a simple Matlab script developed at the University of Lausanne named HorTraj and the METeorological data Explorer (METEX). The implemented methods in these models are different: while HYSPLIT and METEX use a Lagrangian Particle Dispersion Model, HorTraj uses the fully implicit algorithm of Merril. Since these tools can be used with various datasets, the trajectories are processed with different ones such as the NCEP/NCAR Reanalysis I & II or the ERA reanalysis. Moreover for each tool and dataset, various methods can be used to calculate the altitude of the air masses. As a result, multiple combinations of tools, datasets and methods are available. Therefore, this work is separated in two parts. The first one tested and compared as many combinations of tools, datasets and methods as possible. For the second part, in order to reduce the number of models to be assessed, we removed those models yielding to similar results. Then, the selected models were used to search simple precursors leading to heavy precipitations. Based on deviations analysis, we preliminary observed that the larger differences between trajectories result mainly from the dataset used rather than the model.

Then, we processed 10 days backward trajectories for the Binn station (Wallis, Switzerland), which is a gauging station that often measures big amount of rain. As for the validity domain, we selected all the days between 1961 and 2014 that were characterized by a southerly circulation in autumn. Backward trajectories offer a way to understand some characteristics of air masses inducing heavy precipitation. For example, specific humidity can be retrieved all along the trajectories. Therefore, the origin of moisture contributing to heavy precipitation, and the role of the different weather systems in transporting moisture towards the Alps can be determined with the help of a Lagrangian moisture source diagnostic. According to the first results, moisture sources for heavy precipitation in autumn are mainly located on the western Mediterranean.

An identification of simple synoptic precursors is by then attempted throughout analysis made on the resulting trajectories.