Flash-flood Alert System using Ensemble Radar Prediction and Rainfall-runoff Simulation

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Abstract:

Increasingly intense rainfall events are causing serious damages to infrastructures and endangering human lives. To better protect them, early warning systems can be set up to evacuate people, move and protect cars or protect infrastructure by installing flood barriers. However, warnings must be issued with sufficient lead times (tens of minutes) before the flood event occurs in order to be useful.

Deterministic forecasts based on the advection of precipitation radar measurements can anticipate flash flood precipitation. However, these systems are subject to considerable uncertainties, especially for extreme convective events that tend to cause flash floods. These uncertainties include the growth and decay of the storm cell, as well as the estimation of the cell's displacement. The use of these deterministic forecasts leads to low detection probabilities for localized intense precipitation events. The generation of ensemble precipitation forecasts improves on deterministic forecasts by proposing several precipitation scenarios, some of which may lead to higher discharge forecasts.

As part of the Radar4Infra project, a flash flood forecasting and alert system based on NowPrecip1.0 radar forecast (Sideris et al., 2020) is being developed for several small catchments. This system builds on recent improvements of the weather radar network and data processing (Germann et al., 2022), sophisticated nowcasting algorithms (Sideris et al., 2020) and a state-of-the-art rainfall-funoff model adapted for Alpine catchments (Jordan, 2007). More precisely, it consists of a radar precipitation forecast, with a spatial resolution of 1 km^2, a temporal resolution of 10 min, a forecast horizon of 6 hours and a forecast update rate of 10 min. This forecast is then introduced into the Routing System rainfall-runoff simulation model (Schäfli et al., 2005; Jordan, 2007), also with a 10 min temporal resolution. The rainfall-runoff simulation model is calibrated on flow measurements, with input data from rain gauges or precipitation fields (CPCH from MeteoSwiss, Sideris et al., 2014).

The methodology (Figure 1) followed consists of evaluating the quality of deterministic flow forecasts using the "probability of detection" and "false alarm ratio" indicators, calculated at several flow thresholds (Cosson, 2023). These benchmark forecasts are then compared with NowPrecip ensemble forecasts. The latter are derived from preliminary tests carried out by MeteoSwiss for a few selected flood events.
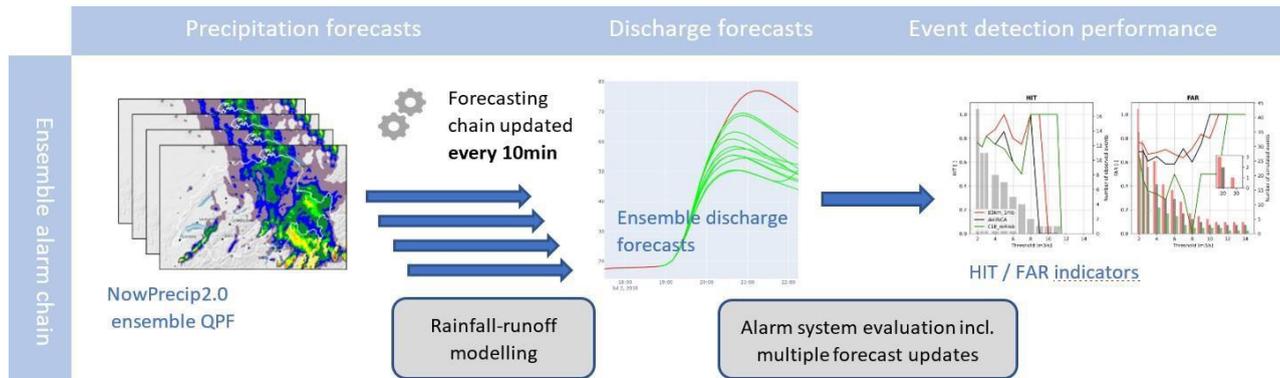
Figure 1. Schematic representation of the flash flood forecasting and alert system, with the hydro-meteorological cascade for one forecast update.

It is difficult to quantify the performance of these forecasts, as the number of flash flood events with flow measurements is very limited. Moreover, there is never more than one documented event per catchment. The comparison is therefore qualitative, with an assessment of the detection lead time and the maximum discharge forecast.

Figure 2 shows the example of hindcasts for the Anniviers event of July 2nd, 2018 (left, catchment area 88 km^2 in the Swiss Alps), and the Cressier event of June 22nd, 2021 (right, catchment area 4.5 km^2 in the Jura region), in Switzerland. In both cases, the rainfall-runoff model is able to reproduce the flood peak when using observed precipitation at rainfall gauges. In the Anniviers example, only the "NowPrecip2.0 RZC-based" ensemble forecast is available. The system predicted, at 7.00pm, a peak flow occurring at 8.50 pm, i.e. almost two hours ahead of time, while the watershed response time was only one hour in this situation. In the Cressier example, the "NowPrecip2.0 RZC-based" ensemble forecast was not able to predict the peak discharge, but the 7.20 pm run predicted a smaller flood, with a peak flow occurring at 8.20pm. In that case, the response time of the catchment area is only 20min. Moreover, the deterministic NowPrecip1.0 RZC-based forecast was not able to predict any flood discharge at all. Thanks to the ensemble generation including different motion fields, some of the members can produce rainfall on the catchment area, leading to improved flood forecasts.
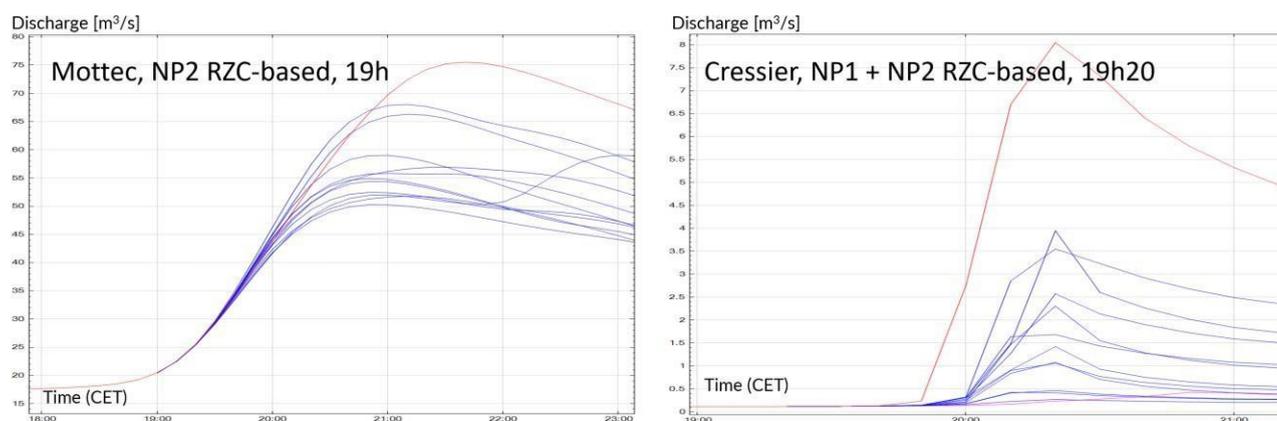

Figure 2. Flood event of Mottec (left) and Cressier (right). Comparison of observed discharge (in red), deterministric NowPrecip1.0 forecast (pink, right) and ensemble NowPrecip2.0 forecasts (blue)

In conclusion, the research carried out in this project seems to be heading towards improved flash flood forecasting capability, achieved mainly through ensemble generation and improved storm cell growth models with NowPrecip2.0.

Acknowledgements

References

Cosson, C., 2023. Ensemble approach for flash flood forecasting in alpine watersheds", unpublished Ms Thesis, LTE-EPFL and Hydrique Ingénieurs, Lausanne, Switzerland

Germann, U., Boscacci, M., Clementi, L., Gabella, M., Hering, A., Sartori, M., Sideris, I. V., & Calpini, B., 2022. Weather radar in complex orography. Remote Sensing, 14 (3), 503, 40pp, https://doi.org/10.3390/rs14030503

Jordan, F., 2007. Modèle de prévision et de gestion des crues, Optimisation des opérations des aménagements hydroélectriques à accumulation pour la réduction des débits de crue, Ph.D. thesis 3711, Laboratory of Hydraulic Construction, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

Schaefli, B., Hingray, B., Niggly, M. & Musy, A., 2005. A conceptual glacio-hydrological model for high mountainous catchments" Hydrol. Earth Syst. Sc. Disc., 2, 73-117.

Sideris, I. V., Gabella, M., Erdin, R. & Germann, U., 2014. Real-Time Radar–Rain-Gauge Merging Using Spatio-Temporal Co-Kriging with External Drift in the Alpine Terrain of Switzerland. Quarterly Journal of the Royal Meteorological Society 140, 1097–1111.

Sideris, I. V., Foresti, L., Nerini, D., Germann, U., 2020. NowPrecip: Localized Precipitation Nowcasting in the Complex Terrain of Switzerland. Quarterly Journal of the Royal Meteorological Society 2020, 146 (729), 1768–1800. https://doi.org/10.1002/qj.3766.