From radar image to flood warning

Real-time precipitation information at the highest spatial and temporal resolution possible is essential for short-term heavy precipitation, inundation and flood warnings.

In Switzerland, precipitation is measured continuously and automatically in real time at ground weather stations (see p. 20), and via weather radar. For ground weather stations in complex topography, these measured precipitation values are only representative for the local environment. The weather radar network of MeteoSwiss is comprised of five fully automatic radar stations with Doppler and Dual Polarisation technology, and records a detailed three-dimensional picture of all precipitation clouds and thunderstorms over Switzerland and its neighbouring areas (Fig. 35). A map of precipitation values on the ground can be derived from this information.

![Map of precipitation values in Switzerland](image)

A radar sends electromagnetic waves into the atmosphere. These are reflected back to the radar as precipitation clouds and thunderstorms, and the radar measures the received energy as a function of distance, azimuth, and angle of elevation. The back radiation comes not only from the so-called hydrometeors of rain drops, snowflakes, hail, sleet, and ice crystals, but also from aeroplanes, birds, and insects. When the radar wave arrives at a mountain, a part of this energy is also turned according to a fixed pattern and completes 20 rotations every five minutes. The data are transferred to a central computer from the five radar stations, compiled into comprehensive precipitation maps, further processed into hail and thunderstorm warnings, and sent to a variety of users. This group includes air traffic control, the service Protection Against Natural Hazards, the hydrology, insurance, and energy sectors, as well as many others. The radar products are updated every two and a half minutes, and have a spatial resolution of 1 km. A picture emerges of the changes in precipitation systems and thunderstorms over space and time (Fig. 36, upper right). Thanks to the application of Doppler and Dual Polarisation technology as well as sophisticated computer programs, radar can distinguish between the echoes of droplets, snowflakes, hail, ice crystals, insects, birds, aeroplanes, and mountains, and can even derive wind fields along with the intensity of precipitation in precipitation clouds.

For an optimal determination of precipitation amounts on the ground, radar data (Fig. 36, upper right) are statistically merged (Fig. 36, bottom left) in real time with measurements from ground stations (Fig 36, upper left). The combination of radar, satellite, lightning, and modelling data create the basis for short-term weather forecasts of rain, thunderstorms, and hail: so-called “now-casting”.

Precipitation forecasts for longer time periods (several hours to days) are based on the calculations of numerical weather-forecasting models. These models deliver comprehensive information about precipitation (Fig. 36, bottom right). Numerical weather-forecasting models solve the principle equations of the atmosphere and use observations through data assimilation (see p. 24) to obtain an optimal description of the state of the atmosphere for the initial conditions of the model calculations. Uncertainties remain, however, since observations are also faulty and cannot portray the state of the atmosphere in full detail. The impacts of these uncertainties on the model prediction can be quantified with the help of so-called “ensemble predictions”. For an ensemble prediction, many model predictions are calculated with slightly varying initial and boundary conditions. The difference between the individual ensemble forecasts provides information about the uncertainty of the forecast. The calculation of the model forecasts is conducted with the help of supercomputers; nevertheless, the necessary processing time is so high that only a limited number of forecasts can be calculated.

Heavy precipitation and floodwater warnings can be created with radar observations and information from weather models. This is how, for example, short-term warnings for heavy precipitation and flash floods depend on the combination of radar measurements of the past hours and the precipitation forecasts for the coming hours. Ensemble models are used to estimate uncertainties. These heavy-precipitation warnings are important for addressing local floods in cities or estimating the debris-flow risk in the mountains.

Floodwater warnings for the next few days depend on the precipitation calculations of weather-forecasting models. These calculations are passed on to numerical hydrological models (see p. 28), which calculate the transfer of precipitation water through the soil in rivers and streams (Fig. 37). The hydrological models are coupled with hydraulic models for the calculation of inundation areas (see p. 30). Hydrological models deliver better discharge forecasts if they are calibrated with outflow volumes. High-quality precipitation information (radar, CombiPrecip, and soil measurements) is essential for this. Figure 37 shows how the hydrological calculations vary for a...
period in May 2016, depending on which rain product is used for the simulation. In this specific case, CombiPrecip performs best compared to observations.

Fig. 36: Precipitation amount [mm] from 12 May 2016, 11:00 – 12:00 UTC, measured at the stations of the SwissMetNet (top left), estimated with radar (top right), estimated from a combination of station and radar data (CombiPrecip, lower left) and in the analysis of the weather forecasting model COSMO.

Fig. 37: Runoff simulation of Alp at Einsiedeln [m³/s] with the hydrological model PREVAH for the period of 8 – 17 May 2016. Three rain products were used for the simulations: interpolated SwissMetNet data (red), radar data (blue), and the CombiPrecip product (green).

The origins of MeteoSwiss

The history of the measurement network operated today in Switzerland begins in the early 1860s: at the time, the Swiss Academy of Natural Sciences organised meteorological observations in all parts of the country. Starting in December 1863, temperature and pressure, as well as daily precipitation and other values, were recorded at around 80 locations three times per day. The idea behind this was to be able to better describe climate with long-term means and extreme values. For the coordination of this project, an office in Zürich was arranged: the Swiss Central Meteorological Institute, the predecessor of the Federal Office of Meteorology and Climatology, MeteoSwiss.

In contrast to today, the institution was not initially responsible for issuing weather warnings. Its activities were limited to measuring the amount of rainfall, including the event of 1868. The spatial variability could only be imprecisely represented. In this context, the flood of 1868 – together with that of 1876 – provided the impetus for expanding the measurement network. In 1868, there were only 76 stations measuring precipitation; by 1900, there were 380.

More and more people began to ask whether the Central Meteorological Institute should also offer weather forecasts besides climatological data. Several countries, particularly seafaring nations, already possessed storm-warning services. Their central agencies received current weather-station data every morning by telegraph. They drew the high- and low-pressure areas onto a map of Europe and then predicted the weather development over the next hours, using past understandings of the relationship between air-pressure distribution and wind.

The first forecasts created in this way were controversial, because they lacked a solid scientific basis. However, their proponents argued that forecasts were greatly needed by agriculture and other weather-dependent sectors. The Swiss Federal Council supported this proposal, which enabled the Central Meteorological Institute to introduce its own forecasts. Starting in 1880, it published a daily weather report about current conditions and “prospects” for the following day. This new service prompted the Swiss Confederation government to take over responsibility for the Central Meteorological Institute from the Swiss Academy of Natural Sciences. Starting in 1881, the climate observations as well as weather forecasts were a governmental task in Switzerland.

Fig. 38: Excerpt from the first “Weather forecast of the Swiss Central Meteorological Institute” from 1 July 1880.