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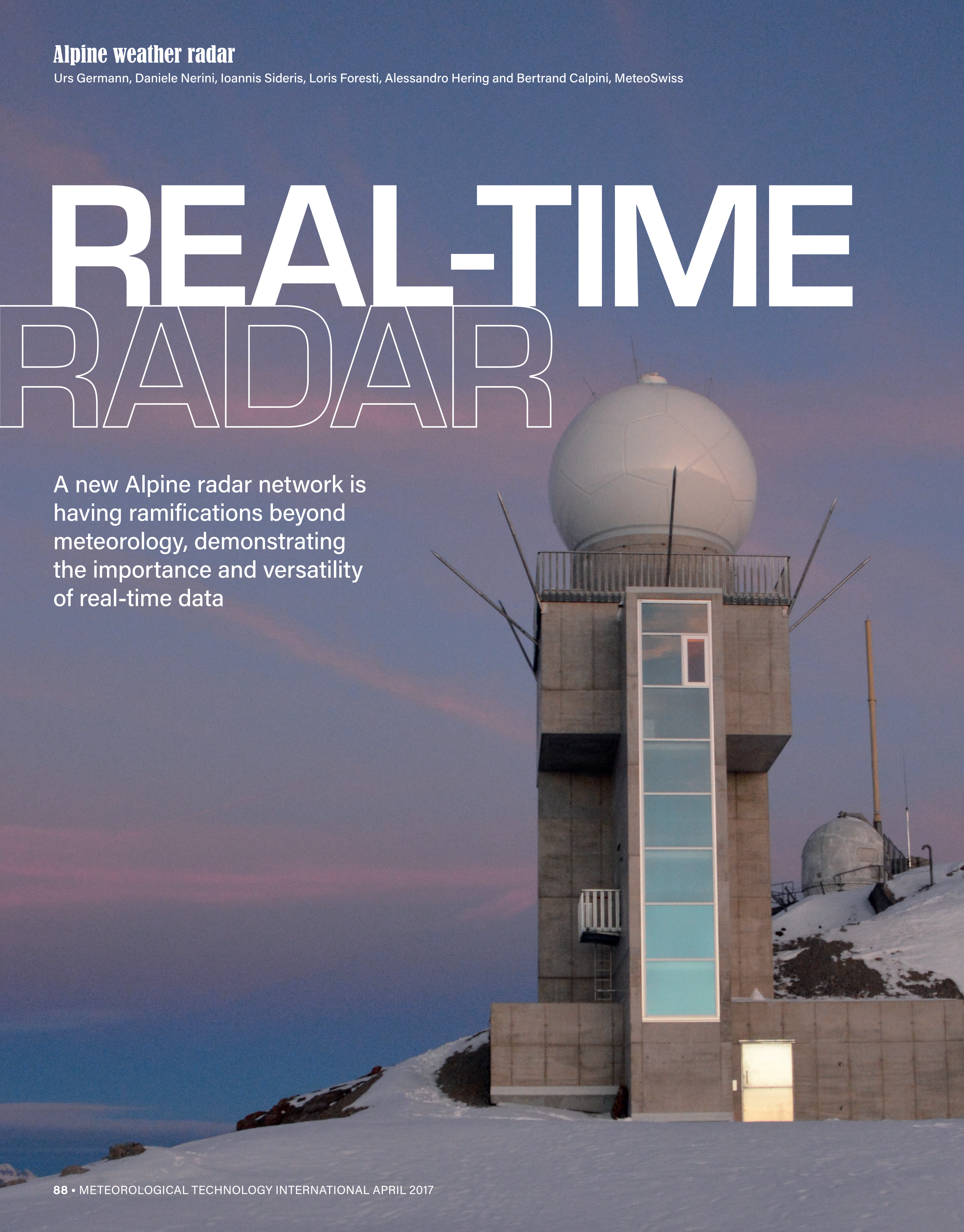
REAL-TIME RADAR

A new Alpine radar network is having ramifications beyond meteorology, demonstrating the importance and versatility of real-time data



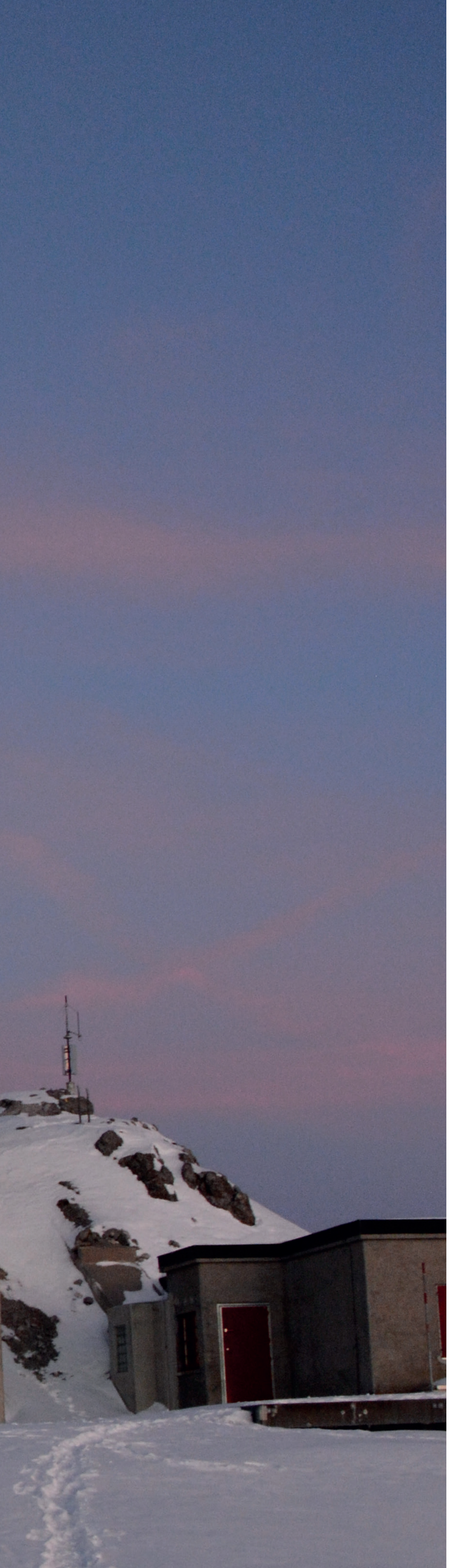


Figure 1: Weather radar on a mountain peak at 2,850m above sea level, southeastern Switzerland, installed in 2015 in close collaboration with Selex ES

MeteoSwiss operates a network of five dual-polarization Doppler weather radar stations that record precipitation and storms in real time, are fully automated and, between them, cover the whole of Switzerland. This new Alpine radar network is proving invaluable in some unexpected applications.

WORKING IN A WATER TUNNEL

At 5m wide, 3m high and 1.5km long, the water tunnel passes right below the center of Basel, northwestern Switzerland. The Birsig, a small river with a watershed of 82km^2, flows through the tunnel, entering the Rhine at Basel. Normal discharge is in the region of 1m^3/s, but in the presence of thunderstorms the water level can rise drastically in a short time. This is not normally a problem. The tunnel has a capacity of 68m^3/s and can thus withstand the discharge of an extreme precipitation event that might only happen once every 300 years.

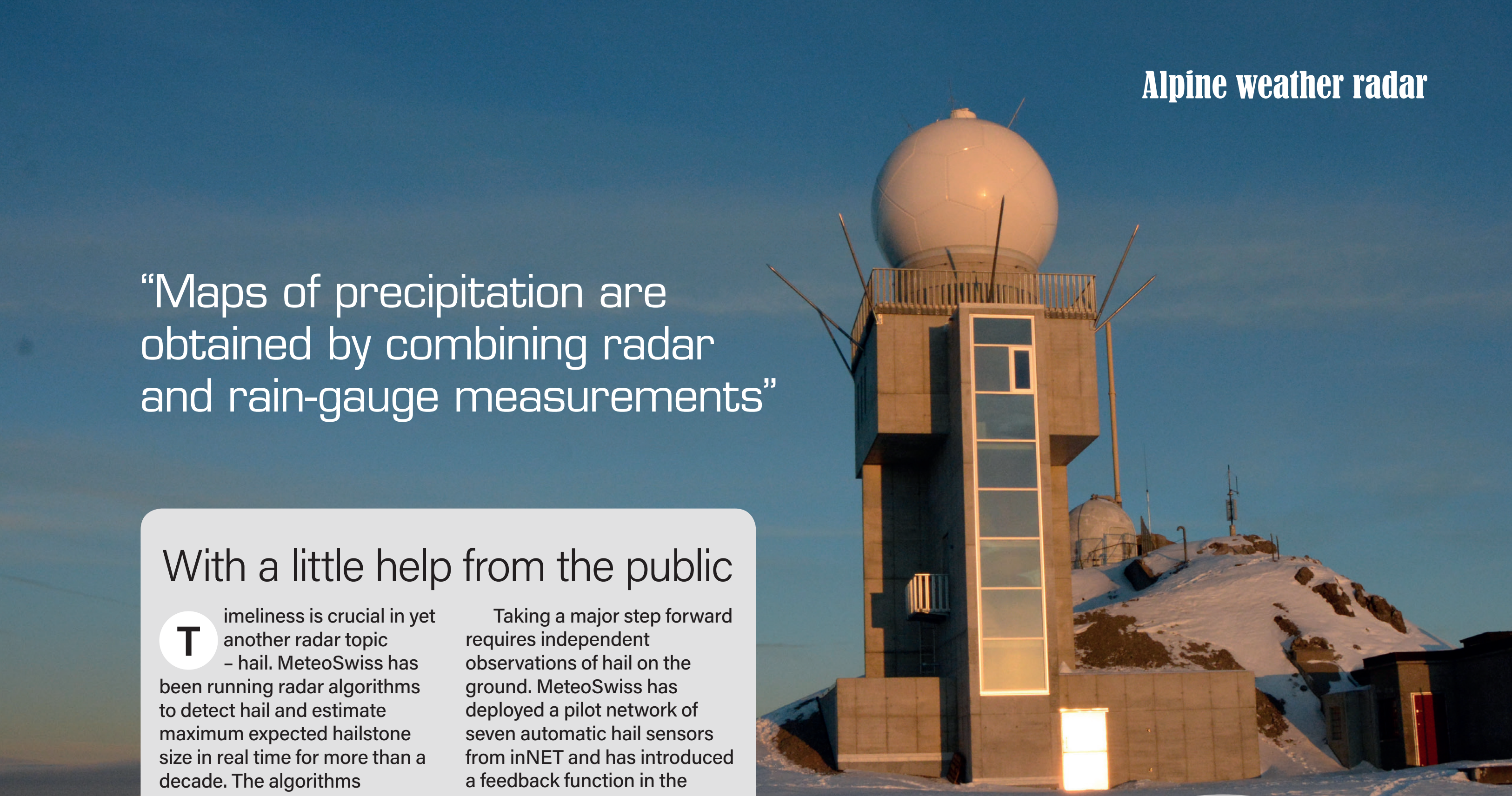
There are concerns, however, that driftwood and floating trash could block the tunnel, resulting in a devastating flooding of the old town of Basel, with potential damage estimated at CHF1.5bn (US$1.5bn). The municipal authority has therefore decided to intervene with a set of structural measures, both in and in front of the tunnel. To ensure the safety of the workers on the project, a system is required that can issue timely alerts, enabling them to get out of the tunnel in the case of heavy rainfall in the catchment.

The MeteoSwiss weather radar network is a possible solution here. Timeliness and reliability were among the top requirements for the design of the new radar network in Switzerland (see also *Peak Performance*, *MTI*, April 2015, p42). Within 60 seconds of the measurement being taken, the base products of the radar network are ready for distribution to the customer and the system performs continuous automatic calibration and monitoring of the hardware using more than 350 parameters per radar, reported and archived every 15 seconds.

A specific radar nowcasting system has been developed for the construction site in the Birsig tunnel. It combines rainfall amounts over the catchment fallen in the immediate past as seen by the radar, expected in the next hours as extrapolated from the radar, and predicted in the forthcoming days by the numerical weather prediction model COSMO (Consortium for Small-Scale Modelling). The algorithm issues an alert whenever one out of a series of combinations of rainfall criteria is fulfilled.

The criteria and thresholds are based on four years of radar and run-off observations in the Birsig watershed. With safety, the ideal is a probability of detection of 100%, but a high false alert rate will be accepted if necessary. The municipal authority integrated the radar nowcast with further technical and organizational measures to ensure safety at the construction site.

On August 17, 2016, the river level jumped from 2m^3/s to 7m^3/s within four minutes. With 2m^3/s the construction site is safe, whereas a run-off of 7m^3/s poses a considerable threat to the workers. Such a rapid increase in run-off leaves little time for those working in the tunnel. The nowcasting



> “Maps of precipitation are obtained by combining radar and rain-gauge measurements”

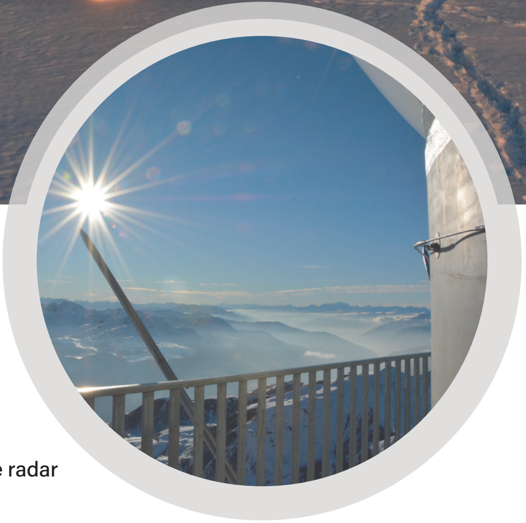
With a little help from the public

Timeliness is crucial in yet another radar topic – hail. MeteoSwiss has been running radar algorithms to detect hail and estimate maximum expected hailstone size in real time for more than a decade. The algorithms take advantage of the high vertical and temporal resolution of the radars scanning 20 elevation sweeps every five minutes and combine the four-dimensional radar information with temperature fields from COSMO.

The upgrade of the radar network to dual-polarization opens new opportunities to further improve hail products. The semi-supervised polarimetric hydrometeor identification scheme developed recently includes classes for ice hail, melting hail and graupel.

Taking a major step forward requires independent observations of hail on the ground. MeteoSwiss has deployed a pilot network of seven automatic hail sensors from inNET and has introduced a feedback function in the weather app for smartphones.

The results of the first two years of operations are encouraging. The sensors, which can measure the size of individual hailstones, have already captured a total of 800 hailstones on 20 hail days. Furthermore, through the app, the general public reported 27,000 observations of hail, including a rough estimate of the maximum size of hail. This combination of new technology and crowdsourcing is a unique way to refine the radar algorithms and gain more information on hail in real time.



A close-up of the radar in Figure 1

system identified the risk of a run-off wave and issued an alert more than one hour in advance. Fortunately the event took place in the evening when nobody was in the tunnel, but it was a good test for the alert system and a gratifying result for the intense collaboration between the municipal administration of Basel and the Federal Office of Meteorology and Climatology MeteoSwiss.

THE POWER OF BLENDING

For the Birsig case, a straightforward combination of radar and COSMO precipitation fields yielded satisfactory results. For other applications, however, a more sophisticated blending is required, ideally one that can integrate input from all available systems with the skill to predict precipitation for the given region and space-time scale. MeteoSwiss is working on a nowcast system that blends predictions of precipitation from a variety of sources in a seamless manner and generates an ensemble of time series of possible realizations.

Maps of precipitation over the most recent hours are obtained by combining radar and rain-gauge measurements with a cokriging with external drift technique developed for operational usage in a mountainous region. It is updated every 10 minutes. The latest map is then extrapolated in a Lagrangian frame to obtain nowcasts for the next few hours.

Over the Alps the extrapolated radar fields are modulated, using knowledge of orographic forcing obtained from machine learning and analogs from past radar archives. The radar nowcasts are combined with forecasts from COSMO.

For the small catchments in Switzerland, natural hazards are often related to the presence of thunderstorms, so it is crucial to accurately represent the presence and evolution of severe convective cells, taking into account the very latest observations at hand. The system under development will thus also integrate nowcasts of the radar, satellite and lightning data-based cell tracking systems, TRT (Thunderstorms Radar Tracking) and COALITION (Context and Scale Orientated Thunderstorm Satellite Predictors Development). The combination of such a diverse set of forecast systems is not trivial, but has large potential for practical real-time applications.

The system has two main tasks. First, it blends the diverse information of different forecast systems using an appropriate set of statistical parameters that describe the local properties of precipitation and the temporal evolution. Second, it generates in a stochastic manner an ensemble of time series of precipitation fields that are in agreement with the statistical properties obtained in the previous step. As with the Birsig application, timeliness is critical and the system has to integrate the latest observations and make the blended output in just a few minutes.

FROM NOISE TO RAINFALL

A core element of the nowcast system under development is the stochastic generation of time series of realistic precipitation fields. The fields must locally satisfy the set of statistical parameters. These parameters include the ratio between dry and wet areas, the conditional mean and variance of precipitation rates, the spatial auto-correlation structure and its anisotropy, the temporal auto-correlation, and additional moments or percentiles of the marginal distribution of precipitation rates, if necessary.

The generator starts from white noise and gradually adapts it with different filtering and transform functions until the resulting time series of fields satisfies the properties of precipitation as described by the statistical parameters. The generator is fully non-stationary; that is, the statistical properties can vary in space and time. For instance, it can reproduce convective cells at a certain location whereas there are no cells generated in a region nearby. Similarly, it can reproduce an anisotropic southwest-northeast alignment of rainfall cells in one region and isotropic structures in another. In other words, the parameters locally control how the noise is morphed into precipitation. This is particularly important in a mountainous region where precipitation properties depend on the location. First experiments with the stochastic generator have shown that it can produce precipitation fields barely distinguishable from real radar images with all the desired local properties, as predicted by the forecast systems.

The higher the confidence of the nowcast from Lagrangian radar extrapolation, COSMO and the other forecast systems on input, the more stringent the statistical parameters and consequently the more similar the members of the ensemble. If, on the other hand, the forecast confidence is low, the parameters leave leeway to the generator and the resulting spread of the ensemble will be large. ▮

Figure 2: The dual-polarization receiver is mounted on the back of the reflector, resulting in a substantial increase in data quality, sensitivity and a compact symmetric waveguide path (developed by Selex ES)

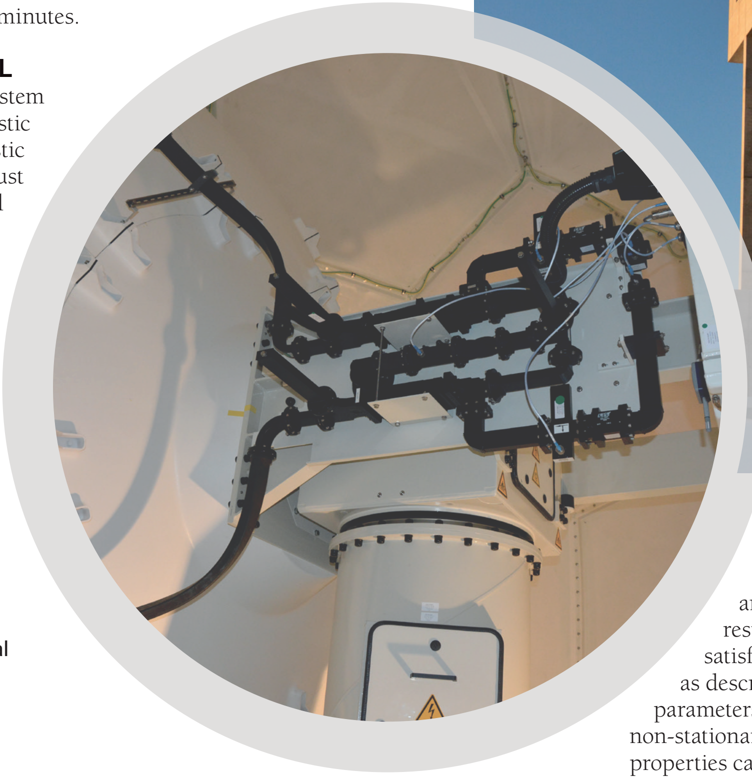


Figure 3: Example of stochastic generation of precipitation fields. Top: statistical parameters. Bottom: simulated precipitation fields that locally satisfy statistical parameters