Weather Radar Establishes New Ground in Hydrology

Since its inception over sixty years ago, weather radar has gradually evolved from its crude beginnings in military applications into a leading-edge technology for tracking meteorological events. The last decade, however, has been marked by its most significant advance to date – dual polarization technology, which renders a signal accuracy that has now caught the attention of the field of hydrology.

As demand for fresh water continues to grow and supply remains largely static, there is a pressing need for governments around the world to have accurate, short- and medium-term precipitation forecasts to ensure adequate potable water sources for growing urban populations. At the same time, competing sectors like the ever-increasing agricultural and hydroelectric sectors are demanding an equal share of that limited water supply. Balancing these demands requires trustworthy hydrological information.

Beyond the demand for fresh water, public safety concerns present hydrologists with the most convincing reason for adopting weather radar. Flood Early Warning Systems do represent a sizeable CAPEX investment, but it is an investment that can yield significant dividends – not just in the lives saved, but also in mitigating economic losses due to flooding. One estimate from the US National Oceanic and Atmospheric Administration (NOAA) saw an annual six-fold return on a single investment in a Flood Early Warning System throughout the lifetime of the system. All of these weather radar uses for hydrology can be integrated into a comprehensive water management policy that yields cumulative socioeconomic effects.

Every year, over 140 million people worldwide see their lives disrupted or destroyed by flooding. For emerging economies that are often disproportionately affected by flooding, one single catastrophic flood can wash away thousands of homes and decades of infrastructure investment. The real tragedy is that in many instances these events were foreseeable. Estimates suggest that Flood Early Warning Systems can mitigate between 10% and 30% of economic losses due to flooding and save countless lives.

One of the greatest challenges for local and national governments in the coming decades will be ensuring adequate fresh water supplies for growing urban populations and the domestic agricultural production that will feed them. There is a growing acceptance of the effect that climate change may be having on local and regional weather patterns. If precipitation patterns are changing, authorities need to know how. With constant monitoring, farmers can optimize their irrigation, drainage, seeding, and pesticide applications and monitor water levels against overuse.

As society slowly moves away from a carbon-based economy, demand continues to grow for renewable energy resources. Hydropower has been the stalwart of this movement due to its high energy output. Naturally, the production of hydroelectricity is entirely dependent on the constant replenishing of water reservoirs. Operators, therefore, need real-time observation and forecast data to ensure they have the precipitation available for resupply.

Increased Spatial and Temporal Accuracy of Precipitation Measurement

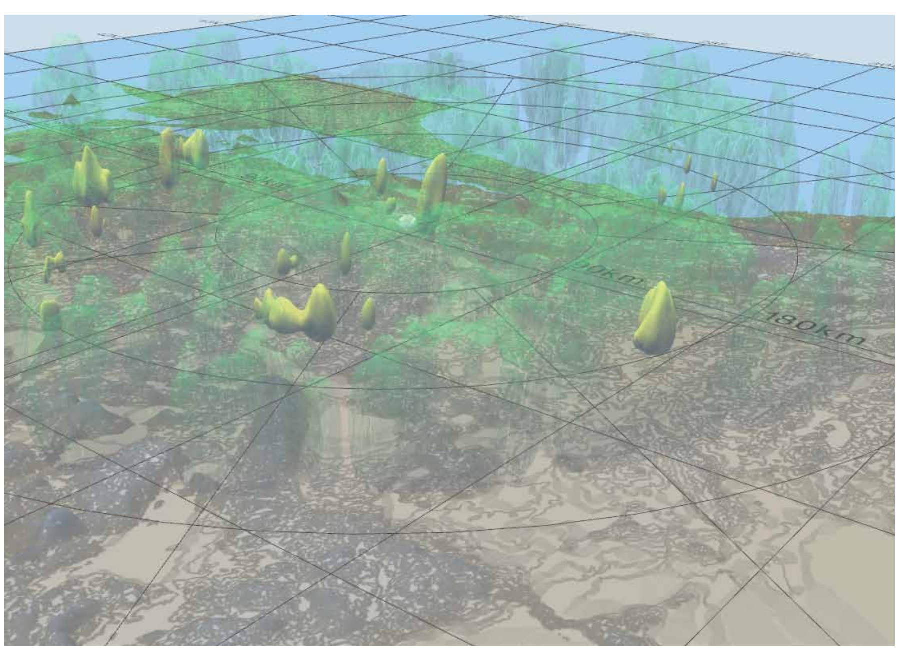
Hydrologic simulation models employ complex algorithms to simulate the many varied processes that occur in a watershed. These can include variables such as runoff volume estimation, solute transport, groundwater recharge, and flow and volume estimation. Efficient water resource management planning often depends heavily on the accuracy of hydrological models. For example, simulations of watershed response under changing hydrometeorological conditions are used to define optimal operation conditions of multi-purpose reservoirs, especially where conflicting priorities exist in water resource usage.

With Vaisala Sigmet Interactive Radar Information System IRIS™, it is possible to provide direct input feeds for both lumped and distributed hydrological modeling.

Hydrological models are usually calibrated by finding the optimal parameter values based on the relationship between model input, such as precipitation, and model output such as discharge. Better input data during model calibration will inevitably lead to improved hydrological forecasts.

Precipitation can be measured two ways – with weather radar and in the field with in-situ automatic hydrometeorological stations. Rain gauges typically measure precipitation with collector openings of only 10–20 cm wide, whereas weather radars measure precipitation remotely with, on average, a 1 km wide sampling volume. Comparatively speaking, weather radar provides excellent spatial and temporal resolution compared to point measurements. Both of these measurement technologies do of course have their own limitations, so the most accurate precipitation measurement is a combination of both in-situ and weather radar measurements – a method known as gauge adjustment.

Several advances in Vaisala's weather radar technology over the years – such as C-band dual polarization with attenuation correction – have significantly increased the accuracy of the data, making weather radar an increasingly essential tool for use in hydrology. Dual polarization technology helps users gain more accurate precipitation estimates, especially in severe and heavy precipitation cases, at considerably



Vaisala Sigmet Interactive Radar Information System IRIS™ offers tools to visualize and monitor your hydrological radar and surface observations.

Weather radar in heavy rain. Photo Courtesy of Jarmo Koistinen.

lower cost compared to the longer wavelength S-band radars. In the past, much earlier C-band weather radar suffered from attenuation in heavy precipitation causing significant underestimates in precipitation measurements. However, current dual polarization eliminates this concern while simultaneously yielding other crucial advantages.

Short Term Precipitation Forecasts

Weather radar can offer yet another key tool for hydrology – the ability to provide accurate, short-term quantitative precipitation forecasts (QPFs) which is of particular importance to flash flood forecasting. A rainfall rate forecast extending up to a few hours into the future is usually the most critical indicator in hydrology toward forecasting the potential risk of flooding and especially flash flooding. It is widely known that Numerical Weather Prediction models require spin-up times of up to 6 hours before they begin demonstrating a reasonable forecasting ability. Essentially, weather radar image extrapolation can be used to fill in the gap between observations and forecasts. The latest precipitation field can be extrapolated based on the calculated motion vector field allowing for precipitation forecasting in the range of 2–4 hours in advance in most cases. The ability to provide accurate short term precipitation estimates is particularly important for flash flood forecasting where Numerical Weather Prediction models may not be able to accurately represent precipitation fields with adequate spatial accuracy. When extrapolating weather radar data, the data quality plays a key role. For instance, the presence of ground clutter in the data runs the risk of faulty extrapolation and inaccurate forecasts – a major concern when applying this data to automatic flood alarm systems. The improvement to weather radar quality achieved by implementing dual polarization algorithms means you will avoid this common pitfall of conventional weather radars.

Hydrometeor Classification by HydroClass

A conventional weather radar transmits and receives only single polarized waves (usually horizontal). By contrast, state-of-the-art dual polarization radars transmit and receive radar signals on both the horizontal and vertical polarizations. The HydroClass™ (Hydrometeor Classification) software makes optimal use of these dual-channel measurements to deduce the types of scatterers present in the atmosphere, such as rain, hail, snow, graupel, and even non-meteorological targets such as insects, birds, and sea clutter. In addition to improving precipitation estimates, the ability for dual polarization radar to deduce and map types of scatterers significantly enhances its use in applications such as hydrological modelling.

Hydrometeor classification can prove to be a valuable source of supplemental information for certain hydrologic model types, along with measurements of snow pack accumulation in regions where snow is the primary cause of peak flow. Most hydrologic models and their associated snow pack accumulation and melt algorithms rely on a temperature index method to differentiate between incoming precipitation types – liquid rain or solid snow. Some snow pack accumulation and melt algorithms can be highly sensitive to this variable. The signal processing module of the Vaisala HydroClass™ software can be used to verify a hydrologic model's snow pack accumulation and melt algorithms performance. Moreover, the HydroClass product can also be used as an input variable in a hydrologic model's post-processing routines to correct for the hydrologic model's snow storage state – and thus improve the snow pack accumulation and melt driven peak flow forecasts.

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