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Meteorological Technology World Expo
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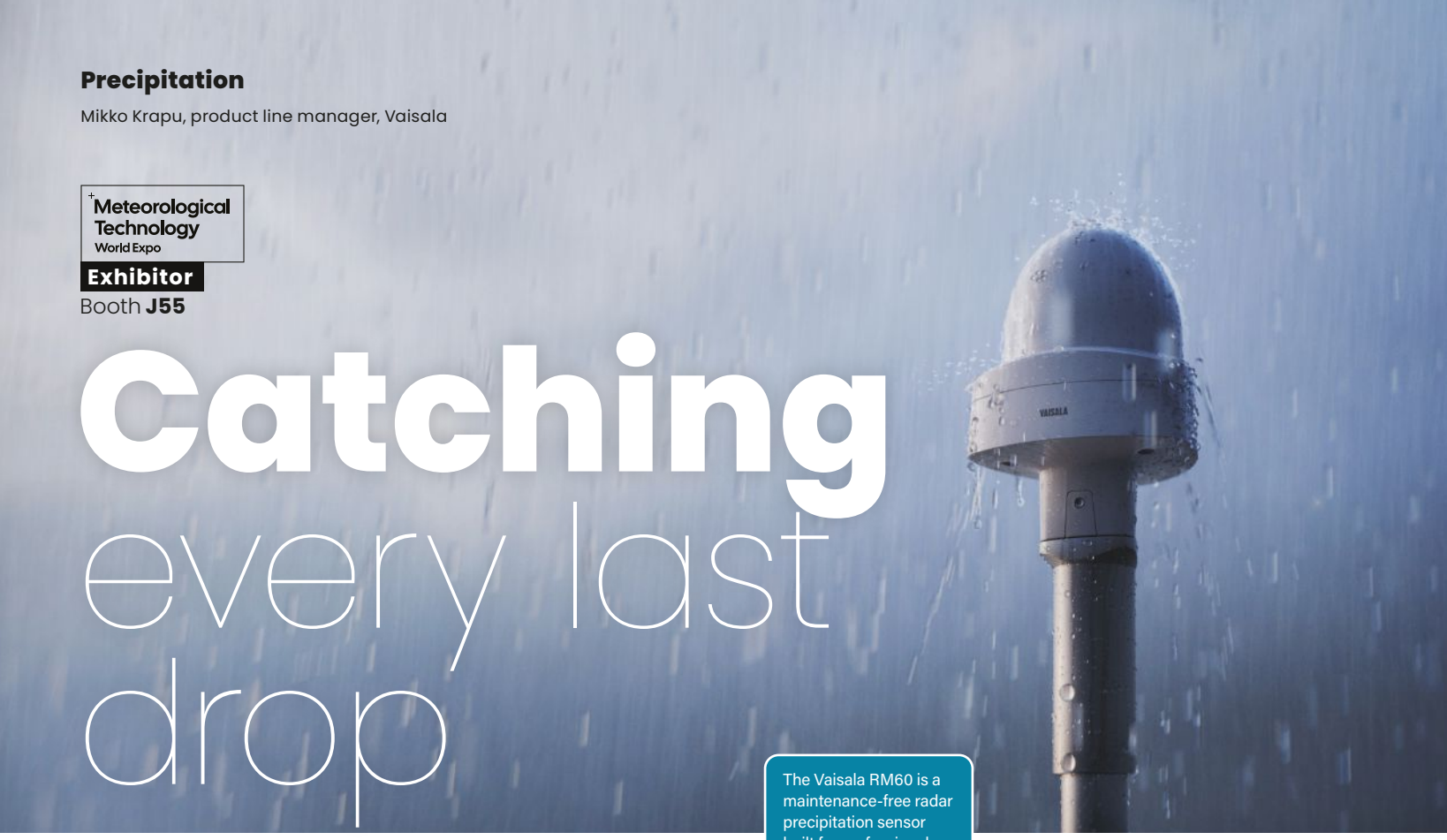
Catching every last drop



The Vaisala RM60 is a maintenance-free radar precipitation sensor built for professional precipitation networks

Precipitation underreporting has significant implications for flood warning systems, infrastructure design and climate-change monitoring. Vaisala takes a closer look at how network coverage and data quality can be greatly enhanced

Precipitation is a double-edged sword. Life on Earth depends on the fresh water it provides, but too much or too little precipitation has wide-ranging consequences. Extreme rainfall events can lead to catastrophic flash flooding; long periods without rainfall, on the other hand, can result in drought that threatens life and property. Both these extremes are becoming increasingly frequent due to accelerating climate change.

Accurate precipitation data is a vital input for flood warning systems, reservoir operations, hydrological models and the climate records used to assess how rainfall patterns are shifting. However, today's precipitation monitoring networks face two key problems. First, the data they gather often runs consistently low because of challenges with traditional mechanical collection methods. Second, coverage is severely lacking, particularly in locations that are vulnerable to flash floods and debris flows caused by extreme rainfall events.

The problem with traditional collection methods

In addition to lack of coverage, precipitation monitoring networks face a second significant challenge in the form of undercatch. The term undercatch refers to the systematic underestimation of precipitation by rain gauges, where the amount of precipitation measured by the gauge is less than the amount that actually reaches the ground.

Traditional mechanical methods for measuring precipitation, such as tipping buckets and weighing gauges, are affected by many kinds of error, including wind-induced undercatch. Wind-induced undercatch is caused by the airflow around the rain gauge being deformed by the gauge structure.

A study by Dunn et al. published in the Royal Meteorological Society journal *Weather*[1] estimates that for more modern tipping-bucket rain gauges, wind-induced undercatch generally reduces rainfall estimation by 5-46% depending on the gauge design, setup and ambient conditions. The study highlights that when precipitation is in frozen form, such as snow or hail, or when the gauge is installed in an exposed position, recorded precipitation may be less than one-third of the actual amount.

In summary, global precipitation networks are suffering from a lack of coverage due to too few gauges, and where gauges do exist, they often provide a woefully inaccurate picture of actual precipitation conditions. As the frequency and intensity of extreme precipitation events increases, the cost of the gap between recorded and actual precipitation grows with it.

Lack of coverage hinders climate-change impact assessment

Precipitation is becoming more unpredictable, and extreme events such as flash floods and droughts are increasing in both frequency and intensity. Notable recent examples from Europe include the flood events seen in Germany in 2021 and in southern Spain in 2024, which resulted in significant loss of life and damaging economic consequences. The ability to better predict, prepare for and monitor such events relies on high-quality precipitation data.

One of the biggest challenges facing precipitation monitoring networks today is the lack of coverage. A recent study published in *Nature*[2] highlights the problem of lack of coverage. The study reveals that only 13.4% of the global land surface meets World Meteorological Organization requirements for annual precipitation monitoring. This lack of coverage severely hinders assessment of the impacts of climate change.

13.4%
The proportion of global land surface that meets WMO requirements for annual precipitation monitoring

Why existing precipitation networks struggle

The problems facing existing precipitation networks based on mechanical gauges can be summarized as follows:

The maintenance trap: Mechanical measurement methods such as tipping buckets and weighing gauges need regular cleaning, calibration and service visits. On a network scale, this costly and time-consuming maintenance effort limits how large a network can grow.

Silent failures: When gauges fail, they cannot self-report. Silent failures such as clogged funnels and frozen mechanisms do not automatically generate system alerts, leading to gaps in the data. These gaps are often most consequential during severe weather events that drive operational decisions.

Wind-induced undercatch: Rain data being 'stolen' by wind is a huge problem in precipitation networks. Wind-induced undercatch is the dominant systematic error in precipitation measurement, and it is not an easy or cost-effective problem to correct. Installing shields, fences or rain pits adds cost and complexity that make standardized deployment impractical.

Missing details: Accumulation only tells part of the story. Conventional gauges can measure accumulation and calculate intensity but cannot give deep detail about precipitation events. Gathering data on precipitation type, drop size distribution or reflectivity requires separate instruments, and these come with their own maintenance needs and costs.

What today's precipitation networks need

Through widespread engagement with agencies who are responsible for operating precipitation networks around the world, Vaisala has identified four recurring themes in terms of what these networks should deliver. First, agencies need to be able to trust the data that precipitation networks provide, particularly during events that drive critical decisions, such as intense rainfall, winter storms and flash flood conditions. Real-time data during extreme events provides critical input for early flood warnings, dam operations and infrastructure design.

Second, agencies are seeking ground truth data that goes beyond accumulation. Deep detail about precipitation events – including real-time intensity and precipitation type – measurably improves forecasting and hydrological models.

Third, agencies want to be able to achieve network coverage wherever they need it, without hitting a maintenance ceiling, avoiding the maintenance trap that constrains how large a network can grow.

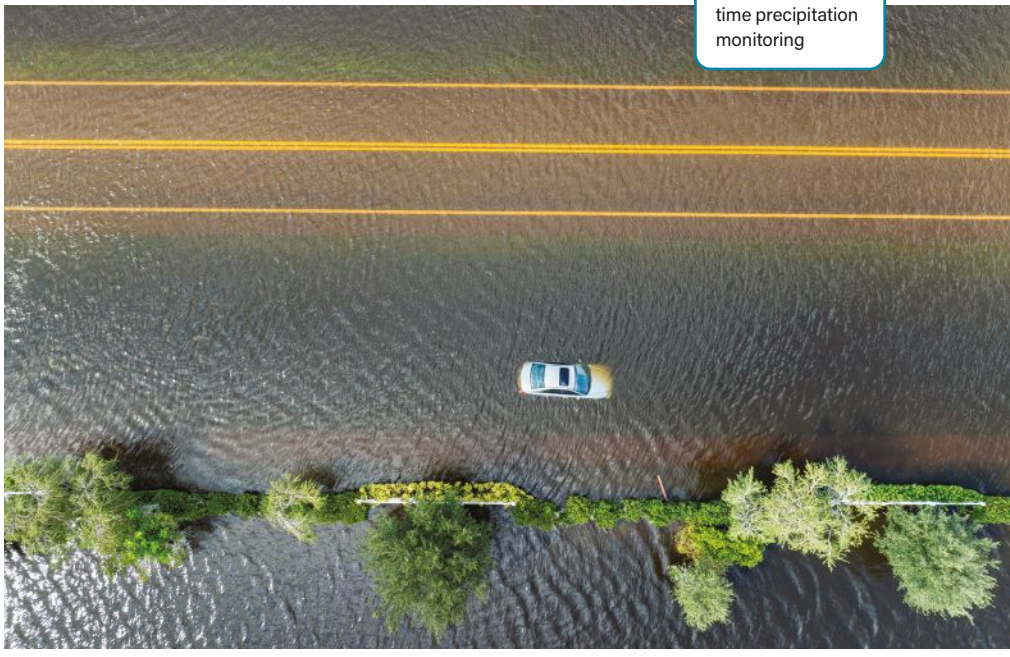
Finally, they want continuous precipitation records that are sufficiently homogeneous and stable to detect climate trends, and not fragmented by downtime and maintenance gaps caused by equipment failure or lack of coverage.

So, there are clear ambitions for the precipitation networks of the future, but how can these ambitions be achieved?

Closing the gap in two-tier network building

Precipitation is by its nature local, with conditions varying hugely between locations. For this reason, having a small number of high-quality reference stations is simply not sufficient to capture the full picture. The key here is density, and this is why virtually every network operating today is built in two tiers.

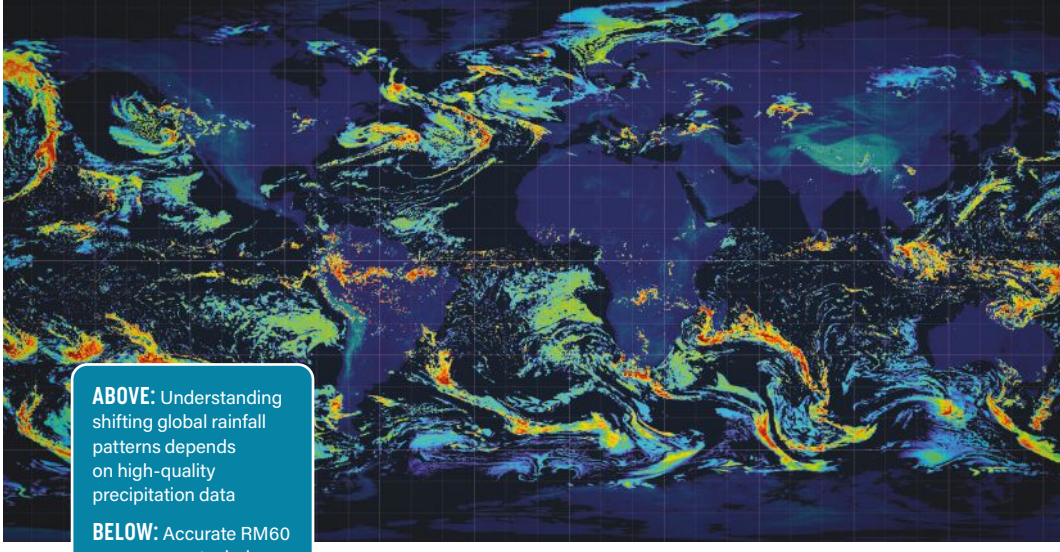
The first tier comprises reference stations, often with double-fenced weighing rain gauges. The second tier consists of supplementary precipitation networks. There are many more stations with wider coverage, but typically with unshielded tipping buckets with much lower accuracy. Additionally, there are manual observations



Flooded streets highlight the real-world stakes of accurate, real-time precipitation monitoring

by volunteers who measure water levels at scheduled times each day. This network is declining as volunteer numbers shrink, and it lacks the real-time availability, precision and data richness of automated systems.

Between these two tiers lie the known observation gaps, such as mountain slopes and other remote locations where data is needed but there is no coverage. Closing these gaps is the key to transforming precipitation networks and enabling advanced forecasting capabilities.



ABOVE: Understanding shifting global rainfall patterns depends on high-quality precipitation data

BELOW: Accurate RM60 measurements during an Atlantic storm (sustained winds 14m/s, gusts 23m/s)

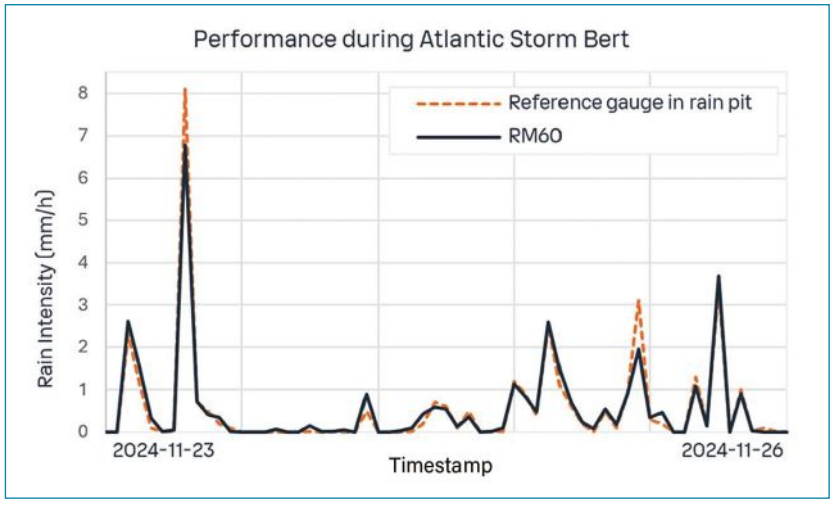
Introducing a new era in precipitation sensing

As a world leader in weather radar technology, Vaisala has built deep expertise in precipitation physics and measurement over several decades. With the introduction of the Forward Scatter Sensor FD70, Vaisala solved how to measure and analyze individual hydrometeors optically, creating a new level of understanding of precipitation.

Vaisala's PRECICAP Radar Precipitation Sensor RM60 represents the next step on this technology journey. PRECICAP is a vertically oriented Doppler radar that leverages two patented technologies. The first is near-field measurement, which – combined with the 61GHz frequency – enables precipitation to be resolved at the individual hydrometeor level. The second is narrow-beam geometry, which enables excellent accuracy even in high wind conditions without shields or fences.

How PRECICAP overcomes challenges

While conventional rain gauges collect and count rainfall mechanically, the RM60 uses patented Doppler radar technology to measure falling raindrops, snowflakes and hailstones individually as they pass through the air. Because the RM60 does not rely on catchment, it is not subject to the physical losses that affect conventional gauges. In practice, this means network operators gain more detailed data, with a complete picture of precipitation intensity, accumulation, type, drop size distribution and reflectivity factor.



Because the RM60 sensor requires no cleaning, it eliminates the maintenance ceiling that currently limits how large precipitation networks can grow. Sensors can be installed in any location where data is needed, plugging critical gaps in the network. Vertical fall speeds are measured in a narrow-beam volume directly above the sensor, eliminating wind impact. This enables a compact footprint and consistent data at the same time. Reliable data is delivered in all conditions, from light drizzle to intense rainstorms and heavy snow, without the need for sensor heating.

Feeding next-generation prediction models

AI is enabling predictions without traditional data assimilation and physical models, with precipitation and storm impacts being the primary use case. Quality in, quality out is a foundational concept in modeling, and it is magnified when using AI. If inputs are biased, smoothed, or mismatched, models learn those errors.

RM60 represents a significant development because it enables high-resolution ground networks that improve the relevancy and usefulness of AI. The technology provides consistent surface-based measurements with reduced reliance on radar-based estimates, with detailed information to learn from that goes beyond mere bulk accumulation. The result is trustworthy, representative data for AI systems to learn from.

The technology has been field-deployed since 2020, with dozens of units operating across a range of climates and environments. More than 700,000 hours of field data cover conditions from subarctic winters to tropical rainfall and high-wind Atlantic conditions.

In conclusion, Vaisala RM60 delivers better ground truth for precipitation networks and richer inputs for forecast models and hydrological simulations. The result is more complete, more trustworthy data for forecasters, hydrologists and infrastructure operators who depend on it, and ultimately for the communities whose safety depends on their work. ∎

References:
1) https://doi.org/10.1002/wea.7736
2) Precipitation observing network gaps limit climate change impact assessment, (Su J, Miao C, Zwiers F, et al., Nature 652, 119-125 (2026)

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To learn more, scan the QR code or visit:
www.vaisala.com