THE INTERNATIONAL REVIEW OF WEATHER, CLIMATE AND HYDROLOGY TECHNOLOGIES AND SERVICES

Meteorological

TECHNOLOGY INTERNATIONAL

FULL PREVIEW OF THE LARGEST EVER **METEOROLOGICAL TECHNOLOGY WORLD EXPO 2017**, OCTOBER 10-12 AMSTERDAM

SOLAR ATTRACTION

Can we forecast magnetic storms to prevent catastrophe?

TOP OF THE CROPS

Sensors, drones and data modeling are helping farmers protect valuable crops and increase yields

SMARTER SATELLITES

Experts assess the technology on board the latest weather satellites and reveal their value to meteorology

Radiometer Physics
A Rohde & Schwarz Company

Remote Sensing for Weather and Climate

FMCW Cloud Radars

Radiometer Physics GmbH (RPG) has developed a line of polarimetric solid-state radars operating at 94 and 35 GHz for continuous cloud and precipitation observations.

- Accurate absolute calibration, hardware monitoring
- High spatial, temporal, and Doppler resolution
- Built-in passive radiometric channel for LWP estimation
- Rain mitigation system for keeping the radomes dry
- Data products: full spectra, moments, spectral polarimetry
- Optional scanning unit for volumetric processing
- Automated data exchange with RPG radiometers
- Turbulence, wind shear, fog, and cloud observations
- Particle size distribution, rain intensity, ice microphysics

Profiling Radiometers

The RPG-HATPRO (Humidity And Temperature PROfiler) is becoming the radiometer of choice for meteorological networks and forecasting systems all around the world.

- 14 channels (22 to 31 GHz, 51 to 58 GHz, 183 GHz optional)
- Superior direct detection technology: EMI / EMC, parallel
- Network suitable, control + data flow via Ethernet
- Data products: IWV, LWP, T + RH profiles, stability indices
- Better boundary layer T-profiling than radio-soundings
- Full-sky scanning (350 directions in less than 5 minutes)
- Ground-based: complementing the satellite view!
- All-weather proof, reliable, robust… proven!
- IR radiometer extension for cloud base height detection

Scintillometers

RPG is the only commercial supplier for scintillometers observing in the microwave spectral region.

- Microwave scintillometer RPG-MWSC operates at 160 GHz
- Synchronous observation of sensible and latent heat fluxes (combined with optical Large Aperture Scintillometer)
- Designed for automated networks
- Network suitable, control + data flow via Ethernet

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AHEAD IN THE CLOUDS

A cost-effective new radar is making it easier than ever to understand the structure of clouds

By using its 40 years of experience in high-frequency design and more than a decade's insight into microwave profiling radiometer development, Radiometer Physics GmbH (RPG) of Meckenheim, Germany, has designed an innovative and cost-effective cloud radar for the detection and analysis of scatterers, of any type, above 10µm in size.

The new radar can observe small cloud drops and ice particles, fog, liquid and solid precipitation, and even non-meteorological scatterers such as insects and pollen. Operating at a 94GHz (W-band) frequency, it reaches higher sensitivity with a smaller form factor than X and Ka-band radars. Its small size and low weight mean that RPG's new system is suitable for use on airborne and shipborne measurement platforms. With a recently developed scanning unit, the cloud radar can scan both in azimuth and elevation for 3D cloud and precipitation observations. It delivers a unique set of data products, which is of great value to a wide range of organizations, among them national weather and rescue services, water management organizations, airports, agriculture companies and research institutes.

THE CONCEPT

Conventional meteorological radars, based on high-power vacuum tubes, estimate the distance to the target from the time delay between the transmitted pulse and reflected signals. However, RPG uses the frequency modulated, continuous wave (FMCW) concept, which means that the radar emits an uninterrupted microwave signal. The frequency of the signal is changed linearly over time in saw-tooth steps, known as chirps. The signal is formed digitally and amplified by a solid-state transmitter. The radar receiver compares frequencies of the transmitted and the returned signals. The frequency difference is proportional to the distance to atmospheric scatterers.

An embedded 89-GHz direct-detection channel provides the functionality of a passive microwave radiometer within the antenna pattern of the radar's main beam. This clooud radar is the first one which is able to measure the integrated liquid water signal with the same field-of-view as the radar reflectivity.

Digital signal formation and processing give the instrument spatial resolution down to a few meters, which is important for the analysis of small-scale cloud microphysics and cloud dynamics. Its high transmission power and state-of-the-art receiver components also provide great sensitivity. The radar easily detects even the thinnest ice clouds at a height of 12km. Low peak power meets the electromagnetic compatibility requirements critical for applications in urban areas.

DRY ANTENNAS

Accurate absolute calibration is crucial in the quantitative characterization of cloud particles and precipitation. The radar was designed to provide precise characterization

Photo: Hillary Sanctuary/École Polytechnique Fédérale de Lausanne, Switzerland

of all components in the transmission and reception parts of the system.

A common issue with radar systems is that wet antennas reduce sensitivity. A wet radome could also spoil the quality of the the cloud radar's passive channel. RPG therefore went to great lengths to provide dry antennas during operation, by covering the transmit and receiver antennas with radomes featuring a hydrophobic coating. Strong fans provide airflow of 1m³/sec to prevent water from accumulating on the antenna radomes. This is the first radar to benefit from dry antennas in all weather conditions, even strong rain. The RPG radar uses internal monitoring of transmitter power, absolute receiver calibration with liquid nitrogen reference, and Dicke-switch stabilized radiometric receivers to calculate calibration parameters. The current design is a step toward 0.5dB accuracy (10-15%) in radar reflectivity.

With a digitally controlled synthesizer as a chirp generator, RPG makes use of a variety of chirp sequences optimized for typical standard observation modes. These observation modes can be selected according to the target of interest: low-level fog measurements require different chirps from observations targeting high-level ice clouds, for instance. The chirp sequences are reprogrammable during operation and can be optimized by the user.

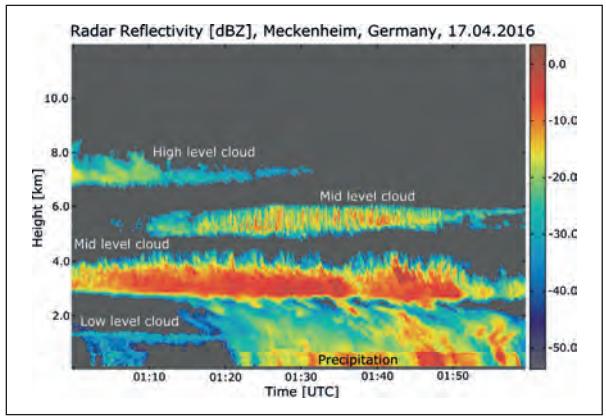

Figure 1: Example of radar reflectivity measurements

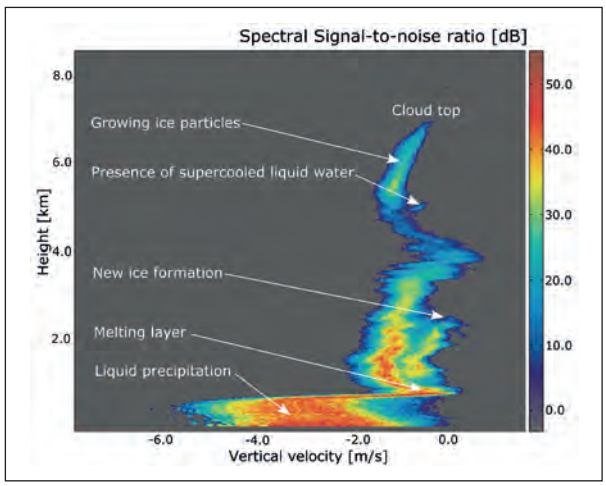

Figure 2: Vertical Doppler spectral profile, Meckenheim, Germany, April 23, 2016, 01:38 UTC

DATA PROCESSING AND PRODUCTS

The radar processing combines all advanced observational techniques such as Doppler processing, comprehensive scan pattern analysis, and radar polarimetry. The data output of the RPG cloud radar contains Doppler velocity distributions and additionally derived parameters such as spectral width, skewness and kurtosis. Thanks to the very low system noise, complex features of the Doppler spectra are clearly identifiable.

Modern meteorological radars are polarimetric. In general, cloud particles are non-spherical and aligned nearly horizontally. Therefore, scattering of the horizontal polarization is often more intense than the vertical one. The scattering differences between two polarizations depend on the particle's phase, liquid or ice, air inclusions, shape and orientation.

Radar polarimetry has been widely used by the precipitation radar community for the improved detection of weather phenomena, efficient classification and quantitative characterization of precipitation. Nevertheless, the polarimetric approach is not intensively employed in cloud radars. The RPG radar provides a set of products similar to that used in weather radar networks. Based on polarimetric observations, the cloud radar can provide a detailed classification of atmospheric scatterers into several classes, including liquid precipitation, melting particles, dendrites, hail, ice columns and aggregates. Cloud radar polarimetry is also suitable for removing non-meteorological scatterers. Atmospheric plankton, such as insects and pollen, often hamper reliable detection of low-level clouds and fog, which are characterized by low reflectivity values.

The RPG cloud radar's processing is based on a combination of Doppler and polarimetric measurements. The novel RPG cloud radar's processing is based on a combination of Doppler and polarimetric measurements. This allows for a precise estimation of liquid precipitation intensity. The radar can measure a drop-size distribution for conversion into rain rate

APPLICATIONS

Its accuracy means the new instrument can be used for the calibration of other radar systems, such as pulsed magnetron based radars, where hardware performance depends on environmental conditions and ageing components. Operating nearly the same frequency as many satellite-based cloud radars, the RPG radar is a good reference for data evaluation.

The radar is also a valuable tool for airports. First, it detects the areas of limited visibility by providing continuously vertical profiles of clouds. Second, the radar equipped with the scanning unit can deliver vertical profiles of wind direction and velocity to indicate windshears, which are a risk to aviation safety. Third, its Doppler capabilities mean the cloud radar can quantitatively characterize turbulence in the atmosphere. Fourth, the radar can identify areas in the atmosphere featuring tiny liquid drops at temperatures below 0°C. These drops freeze when they come into contact with the aircraft surface, leading to accumulation of ice, increasing mass and negatively impacting an aircraft's performance. Finally, its high sensitivity and scanning capabilities make the radar suitable for fog nowcasting.

Performing continuous azimuthal scans, the radar can be used for local short-term forecasts of clouds and precipitation for early warning systems and disaster prevention. Given the large populations in metropolitan regions, such an approach may very well foster new activities in the nowcasting community. Catching the early stages of convection will help to improve forecast quality.

The new radar can also be combined with the RPG-HATPRO profiling radiometer to provide temperature and humidity profiles for use in weather modification projects. The radiometer can identify potential seeding areas, while the radar can track the evolution of precipitation to provide an estimation of seeding efficiency.

RPG's new cloud radar offers the highest-quality insights into cloud structure at a low price. Research and operational teams looking into cloud behavior and structure now have at their disposal a thoughtfully-designed, flexible tool. ▮