In a (hydro)class of its own

Richard Passarelli
Sigmet Product Line Manager
Vaisala
Westford, MA, USA

Realizing the full potential of dual-polarization radars

A conventional weather radar transmits and receives only a single polarization, usually horizontal. State-of-the-art dual polarization radars transmit and receive both horizontal and vertical polarization. The IRIS/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, chaff and sea clutter. In addition to the improvements in precipitation estimation that are achieved with a dual-polarization radar, the ability to deduce and map the types of scatterers greatly enhances the power of a dual-polarization radar for applications such as:

- Hail detection
- Lightning hazard potential forecasting
- Highway snow removal
- Airport terminal operation
- Rain/snow line demarcation
- Melting height detection
- Weather modification for hail mitigation
- Insurance industry claims verification
- Military detection of chaff
- Data quality improvement by elimination of non-meteorological targets
- Improved precipitation forecasting
- Hydrological modeling

Data acquisition and processing

The dual-polarization data for HydroClass™ is acquired by either a Sigmet RVP7 or RVP8 Digital IF Receiver and Signal Processor running under Interactive Radar Information System IRIS/Radar or another application program. The measured parameters are:

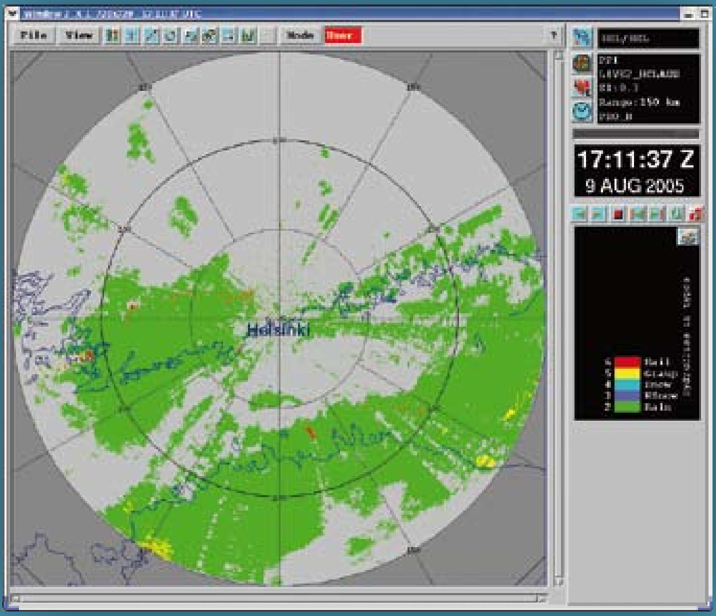
- dBZH – the reflectivity at horizontal polarization
- dBZV – the reflectivity at vertical polarization
- ZDR – The ratio of ZHZV expressed in dB
- RHOHV – the normalized cross-correlation magnitude between the H and V co-polar channels
- PHIDP – the differential phase between the H and V co-polar channels
- LDR – (optional) the linear depolarization ratio for transmitting H and receiving H and V.

This input data is used to classify the precipitation type. The processing may be carried out in either of two places depending on the customer requirements:

1) RVP8 HydroClass ™ Processing: in this case the processing is done directly in the RVP8 and the class assignments are output in real-time for each range bin (similar to output of velocity or reflectivity). This approach is well-suited to applications where IRIS software is not used since the particle type can be displayed directly by the customer's display software.

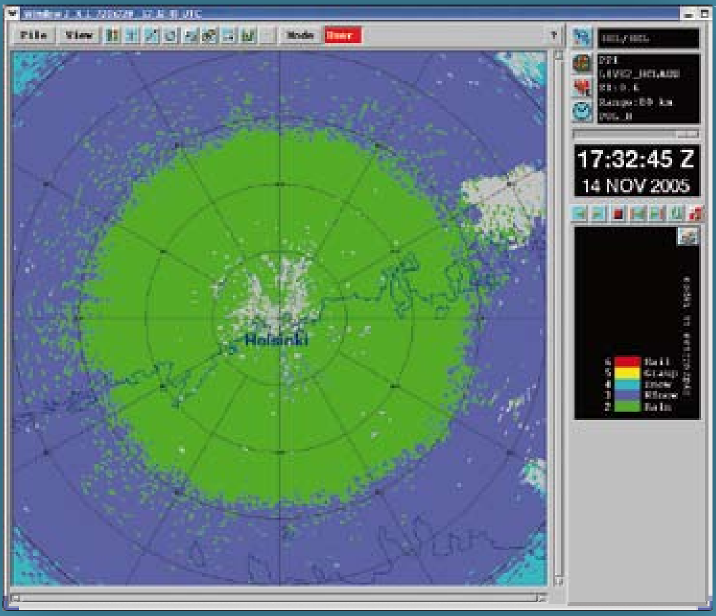
2) IRIS HydroClass™ Processing: In this case, the dual polarization data from the RVP8, or a third party processor, is passed to an IRIS/Radar or an IRIS/Analysis system that is enabled with the HydroClass™ features option. The results of the algorithm are color-coded maps of precipitation classification categories which can be output to and displayed on other IRIS workstations and IRIS/Web clients. Output of .GIF and other standard image formats is also supported.

›››



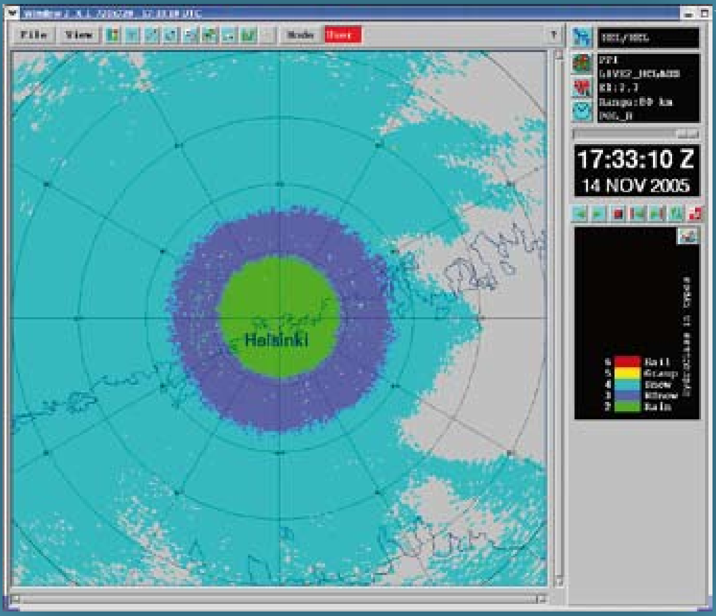
Case 1: August 9, 2005: Helsinki summer convection with hail

In this case, there is convective precipitation occurring over Finland and Estonia to the south. Rain (green) was the predominant form of precipitation. Hail (red) was detected in the more intense areas of convection along with some graupel or small hail (yellow). Note that there was extensive lightning on this day which is consistent with the detection of hail. AWS stations in the Helsinki Testbed area indicated showers of hail/graupel mixed in with the rain. Also of note is the absence of sea clutter as the color scale has been selected not to show non-meteorological targets.



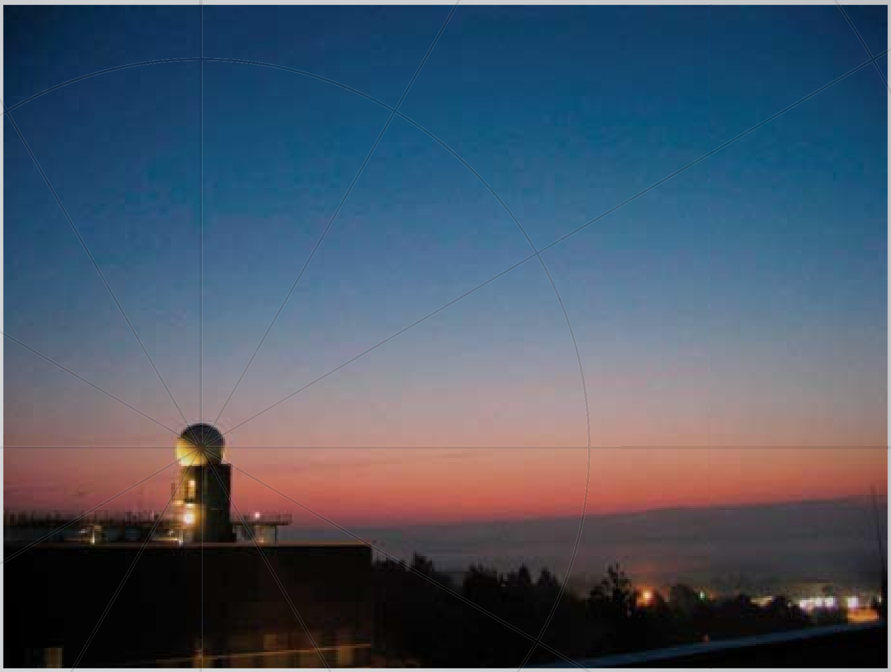
Case 2: November 14, 2005: Helsinki winter stratiform precipitation

This is a widespread, moderate stratiform rain situation with the melting level height at about 1500 m. Rain is observed within 60 km of the radar transitioning to wet snow as the beam enters into the melting level at ranges beyond 60 km. This is verified by the melting layer study in the next case.



Case 3: November 14, 2005: High elevation angle example of melting layer at Helsinki

This case is an excellent example of the well-known vertical structure of stratiform precipitation. At an elevation angle of 2.7 degrees, the further ranges correspond to higher beam heights. At far range (high altitude), there is snow transitioning to wet snow below the 0°C layer which on this day was at approximately 1500 m. Below the melting layer, the precipitation transitions from wet snow to moderate rain. The wet snow transition corresponds to a melting layer depth of approximately 400 m.



Vaisala weather radar prototype in Kumpula, Helsinki. (Photo courtesy of Harri Hohti, FMI)

HydroClass™ uses a fuzzy logic approach that is based on research studies published in scientific literature by recognized experts.

The science behind it all

HydroClass™ uses a fuzzy logic approach that is based on research studies published in scientific literature by recognized experts in the field such as Bringi and Chandrasekar (2000), Straka et al (2000), Liu and Chandrasekar (2000), Zrnic et al (2000), Lim et al. (2005). Throughout the development and testing of HydroClass™, Prof. Chandrasekar of Colorado State University, and co-author of the definitive textbook on dual-polarization techniques for weather radar, served as a consultant.

The signatures of specified hydrometeor classes are quantified as a set of membership functions (MBF) that take the measured dual-polarization parameters obtained at each bin as input. The melting layer height is also used as input, either from an external source or deduced by the melting layer detection algorithm. The strength of each hydrometeor class is then expressed as the outcome (rule strength) of an inference function which takes the MBF values as input. The membership functions and the inference rule strength function formalize the meteorological interpretation encoded in the classification method.

The classification results are presented by labeling each bin with the hydrometeor class that is most compatible with the observations, i.e. by choosing the class of highest rule strength. A threshold parameter is used to specify bins for which the class is ambiguous, e.g., for non-meteorological targets.

The classification schemes described by Lim et al. (2005) and Liu and Chandrasekar (2000) are used for identifying hydrometeor classes among signals known to consist of hydrometeors ("weather"). The algorithms can be tuned for different locales and radar wavelength. For non-meteorological targets, such as ground clutter, sea clutter or chaff, the classification method of Schuur et al. (2003) is used.

In the IRIS software, alerts can be configured using the WARN product to signal the presence of specific targets such as large hail. This provides the best radar method for unambiguous hail detection. In addition, non-meteorological targets can be "masked" in the data to exclude them from subsequent product generation and analysis.

Examples from the Helsinki Testbed

The examples presented here are from the Helsinki Testbed radar system. This is a C-Band dual-polarization Klystron system with a 1 degree antenna beamwidth. The STAR mode (simultaneous transmit and receive of H and V) is used to collect the other dual polarization parameters. The examples cover both summer and winter precipitation. ■

References:

BRINGI V.N. AND V. CHANDRASEKAR, 2001: *Polarimetric Doppler Weather Radar, Principles and Applications,* Cambridge University Press. 636 p.

ZRNIC. D.S., J.M. STRAKA, A.V. RYZHKOV, Y. LIU AND J. VIVEKANDAN, 2000: *Testing a Procedure for Automatic Classification of Hydrometeor Types,* J. of Atmospheric and Oceanic Tech, 18, 892 – 913.

LIU H. AND V. CHANDASEKAR, 2000: *Classification of Hydrometeors Based on Polarimetric Radar Measurements: Development of Fuzzy Logic and Neuro-Fuzzy Systems, and In Situ Verification,* J. of Atmospheric and Oceanic Tech. 17, 140 – 164.

STRAKA J.M., D.S. ZRNIC AND A.V. RYZHKOV, 2000: *Bulk Hydrometeor Classification and Quantification Using Polarimetric Radar Data: Synthesis of Relations,* J. of Applied Meteorology. 39, 1341 – 1372.

LIM, S., V.CHANDRASEKAR, AND V.N BRINGI, 2005: *Hydrometeor Classification System Using Dual-Polarization Radar Measurements: Model Improvements and In Situ verification.* IEEE Transactions on Geoscience and Remote Sensing 43, 792 – 801.

SCHUUR T. ET AL. 2003: *Observations and Classification of Echoes with Polarimetric WSR-88D Radar NOAA, Norman, Oklahoma;* University of Oklahoma *(report available at http://www.cimms.ou.edu~schuur/jpole)*