P2.1 An Overview of NOAA/ETL's Scanning K_a-band Cloud Radar

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The NOAA/K Cloud Radar

Clouds play a vital role in climate by virtue of their ability to transform water phase and radiant energy in the atmosphere. However, clouds have received disproportionately little consideration in hydrological cycle studies because their properties have been difficult to assess quantitatively. The accelerated development of millimeter-wave "cloud" radars in the last decade now allows unprecedented high-resolution remote-sensing observations of the three-dimensional structure, kinematics, and composition of clouds from the ground, from research aircraft, and (soon) from satellites.

Using wavelengths more than ten times shorter than those of storm surveillance radars, such as NEXRAD, cloud radars readily detect the tiny ice crystals and cloud droplets that comprise non-precipitating clouds. The main drawback is that these short-wavelength signals are severely attenuated by rain. However, they are essentially unattenuated by dry snow. Thus, in addition to their use for observing non-precipitating and weakly precipitating clouds, millimeter-wave radars are excellent for studying snowstorms across mountain and urban watersheds.

NOAA/ETL has been a leader in cloud radar advances. The capabilities of its venerable **NOAA/K** radar, originally used in the early 1980s, have been continually enhanced. It was one of the first cloud radars to add Doppler, scanning, and dual-polarization to further extend the realm of cloud measureables. This radar provides observations of the intricate structure and airflow patterns of clouds within a radius of about 20 km. Its polarization and scanning capabilities are used together to identify and distinguish hydrometeor types within clouds. When combined with simultaneous microwave and infrared radiometer observations, the vertical profiles of cloud particle size, concentration, and mass content can also be retrieved.

Photo of NOAA/K radar's offset Cassegrain antenna. The rotatable phase retarding plate that controls the transmitted polarization is located on the sub-reflector arm just above the 1.4-m parabolic dish.

A Versatile Cloud Research Tool

Major Capabilities:

*Doppler
* Dual-polarization
* Scanning
* Transportable

Primary Uses:

* Observations of clouds, drizzle, snowstorms,and very light rain.
*Structure * Kinematics * Particle Types
* Microphysical properties when combined with other remote sensors

Recent Offspring Inspired by NOAA/K

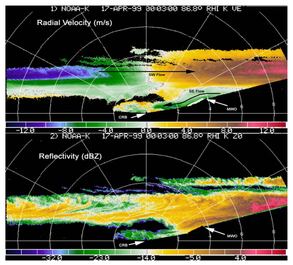
* The **MMCR** - Unattended, vertical cloud-profiling radars for the U.S. Dept. of Energy's ARM program climate research. Five sites worldwide.

* **GRIDS** – An unattended, ultra-high sensitivity polarized cloud radar with microwave radiometer of Federal Aviation Administration to detect and warn of aircraft icing conditions at airports. This design is based on award-winning[#] research conducted with NOAA/K.

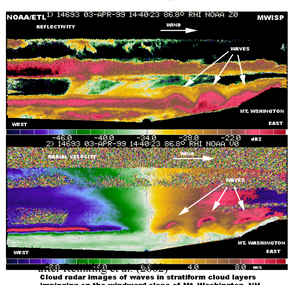
[#]**NOAA Gold Medal Award – 2001** for research and instrument development to detect aircraft icing conditions by remote sensing.

Cloud Structure and Kinematics

Doppler cloud radars reveal cloud structure and airflow in fine-scale detail, as shown in these examples from NOAA/K.

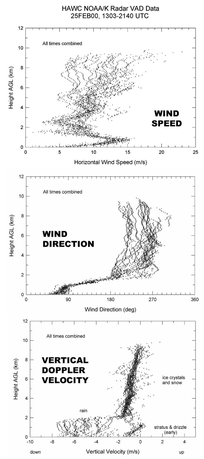


RHI scans through cloud layers at Mt. Washington, NH, showing downslope flow (top) and waves (bottom) on different days on the eastern slope.

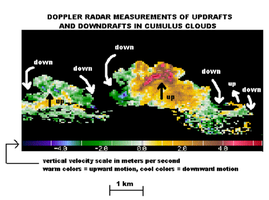


Cloud radar images of waves in stratiform cloud layers impinging on the windward slope of Mt. Washington, NH.

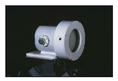
Vertical velocity patterns (right) in small Arizona cumulus clouds.



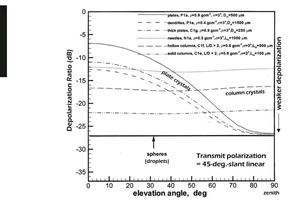
Wind profiles (above) from VAD analysis of PPI scans for an 9-h period in a deep winter storm near Boston. In lower altitudes, the cloud produced drizzle followed by rain.

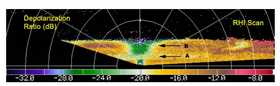


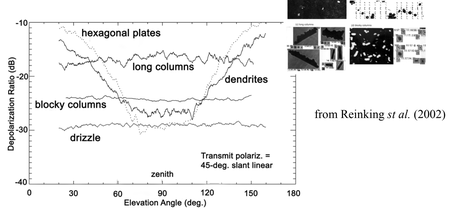
Identifying Hydrometeor Types



NOAA/K's unique phase retarding plate apparatus (above) allows the transmitted polarization to be selected and varied. The depolarization ratio (DR) measured by the radar from returned signals contains information about particle shapes. Backscatter theory (top right) shows distinctly different patterns for various cloud particle types as a function of the radar's elevation angle. These patterns are used to identify the dominant particle type at each altitude, as in the RHI scan observations (right) through a winter cloud. Numerous comparisons with *in situ* sampling (below) have validated DR signatures for several particle types.

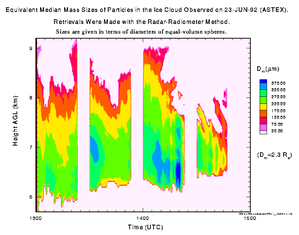






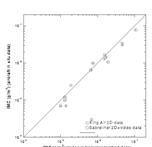
from Reinking *st al.* (2002)

Radar + Radiometer Retrievals of Microphysical Properties



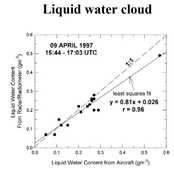
In methods developed at ETL, simultaneous vertically pointing measurements by cloud radar and radiometers can be used to estimate vertical profiles of cloud microphysical parameters, including hydrometeor median size, total concentration, and mass content. These retrieval techniques use radar + infrared radiometer for ice clouds, such as cirrus (above) and radar + microwave radiometer for liquid clouds, such as stratus. Comparisons with *in situ* sampling by aircraft show excellent agreement (below) when the retrieval assumption conditions are met.

Ice cloud



from Martosov et al. (1998)

Liquid water cloud



from Frisch et al. (2000)

NOAA/K Radar Characteristics

Frequency: 34.66 GHz (wavelength = 8.6 mm)
Transmit Power: 80 kW peak; 40 W avg.
Transmitter: magnetron
Antenna A1: 1.2-m diameter offset Cassegrain
Antenna A2: 1.6-m diameter center-feed
Beam Width: 0.3 – 0.5 deg., circular
Pulse Length: 0.25 microsec
Resolution: 37.5 m
PRF: selectable (2000/s typical), double pulse method is used to extend Nyquist.
Scans: PPI, RHI, sector, fixed-beam, co-plane, all with elevations through zenith and below horizon.
Scan Rates: up to 30 deg/sec.
Sensitivity: approx. –30 dBZ at range of 10 km
Polarizations: RHC, LHC, and ellipticals with QWP, H, V, and tilted linear with HWP on antenna A1;
H or tilted linear on antenna A2.
Doppler Processing: pulse pairs or time series/Doppler spectra
Data System: VME-based with DSP and SPARC

Platform: 15-m flatbed trailer, or 2 seatainers.

Diverse Deployments

NOAA/K and part of the Mt. Washington Icing Sensors Project research team in New Hampshire, 1999.

The NOAA/K radar and its optional larger antenna (A2) participating in a study of cloud electrification at Cape Canaveral, Florida, 2001.

NOAA/K on a cliff high above the Oregon coastline during a field experiment to study ocean surface and internal waves, 1995.