HIAPER Cloud Radar (HCR)

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NCAR, Boulder, Colorado

NCAR maintains and deploys a suite of world-class remote sensing instruments (radars and lidars) in support of the atmospheric science community.

Develops innovative and state of the art “next-generation” remote sensors.
Motivation for Observational Instruments

Key scientific challenges:

When and where convection will be initiated?
How to improve accuracy of a NWP model in describing onset of precipitation process?
What factors control intensity and track of an hurricane?
How does convection influence UTLS chemistry?
How to parameterize aerosol and cloud interaction in an earth system model?

Dual Use: Instruments should be deployable on airborne and ground-based platforms
Motivation for Observational Instruments (cont.)

Aerosol and cloud:

Aerosol type: Particle composition, size and shape

Differences in cloud parametrizations lead to variations in climate model predictions
- cloud detection - optically thin clouds (-50 to -20 dBZ)
- cloud fraction without reference to opacity

Cloud microphysics
- Phase
- size
Depolarization by Regular Crystals and Drizzle*

SLDR*-45, Constant scale (top of each frame) Ze, Variable scale (bottom of each frame)

Data collected and processed NOAA ETL Boulder, Colorado.

(a) Ice crystals, melting level, drizzle
(b) Planar crystals (dendrites)
(c) Long columnar crystals
(d) Blocky columnar crystals
Retrieval of particle size (RES), LWC from Ka-band reflectivity and microwave Radiometer observations.
Comparison of liquid water content between radar/radiometer retrievals and in-situ measurements during WISPO4. In-situ measurements are from a liquid water probe on board the UND Citation research aircraft.
HCR Characteristics

- Scanning, airborne, W-band Doppler radar for Gulfstream V (GV) mid-altitude jet (51kft ceiling)
  - Phase A: system to be ready for test flights in summer 2010
  - Phase B: Adds Polarimetry (H-V), pulse compression - unfunded
  - Phase C: Adds Second wavelength (Ka-band) - unfunded
  - Initial system design incorporates electro-mechanical infrastructure of phases B and C
  - Radar electronics housed in unpressurized wing-mounted pod, with data archiving and real-time display inside aircraft

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>Spec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>94.46 GHz</td>
</tr>
<tr>
<td>Polarization</td>
<td>H</td>
</tr>
<tr>
<td>Peak Transmit Power</td>
<td>1.7 kW</td>
</tr>
<tr>
<td>Sensitivity @ 5 km</td>
<td>-28 dBZ</td>
</tr>
<tr>
<td>(60m volume size, 0dB SNR)</td>
<td></td>
</tr>
<tr>
<td>Antenna Diameter</td>
<td>0.305 m</td>
</tr>
<tr>
<td>Antenna Gain</td>
<td>46 dB</td>
</tr>
<tr>
<td>3 dB Beamwidth</td>
<td>0.7°</td>
</tr>
<tr>
<td>PRF</td>
<td>1 - 20 kHz</td>
</tr>
<tr>
<td>Range Resolution</td>
<td>30 - 150 m</td>
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</tbody>
</table>
Pod Based Radar System

Pod Layout

Pod:
- Length = 158.5”
- Diameter = 20”
- Payload = 800 lbs

Extended Interaction Klystron Amplifier (Eika)
- Based on the rugged, reliable Klystron
- Conduction cooled, similar to version produced for CloudSat
System Calibration

- **Absolute Calibration**
  - Corner reflector
  - Sea surface
  - Noise/signal sources used to measure gain and dynamic range of the receiver

- **Dynamic Calibration**
  - Transmitted signal continuously switched into the receiver during operation while the radar is “blind”
  - Noise floor measurement possible periodically during aircraft turns, etc.
GV HSRL Overview

Model of HSRL for operation on the NCAR GV

- Telescope can rotate to view up or down GV view port
- Wavelength: 532 nm
- Pulse repetition rate: 6 KHz
- Average power: up to 400 mW
- Range resolution: 7.5 m
- Telescope diameter: 40 cm
- Angular field of view 0.025 deg
- Filter bandwidth: 1.8 GHz

Support Electronics mounts to Base Frame
System optics bench
Base Frame mounts to seat tracks

Slide courtesy of Ed Eloranta
University of Wisconsin - Madison
Backscatter cross section as a function of time and altitude.

- Cirrus
- Water clouds with ice virga
- Boundary layer aerosols

Color scale showing the magnitude of aerosol backscatter cross section (1/(m sr)).

Date and end time of data.

Name of the instrument.
Depolarization ratio as a function of time and altitude.

Color scale showing the magnitude of the depolarization ratio.

Ice crystals and other irregularly shaped particles give 0.17 – 0.5 depolarization (yellow).

Mixtures of water and ice give depolarization values between pure water and ice (blue and cyan).

Water clouds with small optical depths have low depolarization (purple). Multiple scattering at larger optical depth increases the depolarization with the penetration depth (from purple to blue).
## HCR with High Spectral Resolution Lidar (HSRL)

<table>
<thead>
<tr>
<th>Physical parameters</th>
<th>Kinematics</th>
<th>Microphysics: Phase and size</th>
<th>Ice and/or liquid water content</th>
<th>Aerosol Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single wavelength HCR</strong></td>
<td>• Radial wind</td>
<td>• Good</td>
<td>• Larger uncertainty</td>
<td>Yes</td>
</tr>
<tr>
<td>With LIDAR</td>
<td></td>
<td>• Optically thin cloud</td>
<td>• Assumptions are needed</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dual-wavelength HCR</strong></td>
<td>• Radial wind</td>
<td>• Very good</td>
<td>• Lower uncertainty</td>
<td>Yes</td>
</tr>
<tr>
<td>with LIDAR</td>
<td></td>
<td>• Optically thin and thick clouds</td>
<td>• Optically thin and thick clouds</td>
<td></td>
</tr>
</tbody>
</table>
High Spectral Resolution Lidar

- GV HSRL Designed and built by University of Wisconsin - Madison
- Provides accurate measurement of optical depth, extinction and backscatter cross sections of aerosols and thin clouds
- Eye-safe at the exit port (532-nm wavelength operation)
- GV HSRL is already operational operation as ground based instrument
- To be used to in combination with HCR to measure:
  - cloud fraction, precipitation rate, scattering cross sections, particle shape
  - Scheduled for GV test flights in late 2009 early 2010

Measurements on 1-Oct of 2008 by the arctic HSRL and MMCR
Courtesy of University of Wisconsin