A Complete Time History of Clouds and Cloud Properties Over the CRYSTAL-FACE Eastern Ground Site

Matthew Shupe, Timothy Schneider
Sergey Matrosov, Duane Hazen
Taneil Uttal
The NOAA Portable Cloud Observatory (NPCO)

• **35-GHz Millimeter Cloud Radar (MMCR) – Up 98% of time**
  * CRYSTAL-specific operation modes
  * Up to 45-meter, 10-second resolution
  * Provides reflectivity, velocity, spectral width
  * Records full Doppler spectra for each mode

• **Microwave Radiometer (MWR) – Up 93% of time**
  * 20.6, 31.65, and 90 GHz channels
  * Brightness temperatures used to derive LWP and PWV

• **IR radiometer**
  * Provides IR sky brightness temperatures (10.6-11.3 µm)

• **Near real-time internet display**
  * Radar & radiometer measurements on web within an hour
  * Derived cloud microphysical products on the web

• **Has been deployed on land and ship on 6 projects in 3 years**
What do NPCO observations provide?

1) **Cloud Identification** → cloud occurrence, cloud vertical distribution, cloud type identification, continuous record of cloudiness, cloud temperature (with soundings).

2) **Cloud microphysics and extinction retrievals** → Apply multiple retrieval techniques (see Matrosov et al. poster) to retrieve profiles of size, water content, and extinction for cloud ice and liquid. Exploring the use of Doppler spectra in cloud retrievals.

3) **Radiative transfer modeling** → Run radiative transfer codes using retrieved microphysics to produce heating rate and flux profiles (see Shupe et al. poster). Thermodynamic state parameters are derived from Miami soundings.
Cloud Identification

CRystal-FACE
Cloud Occurrence [%]

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>52</td>
</tr>
<tr>
<td>Ice Present</td>
<td>41</td>
</tr>
<tr>
<td>Liquid Present</td>
<td>12</td>
</tr>
<tr>
<td>Mixed-phase</td>
<td>4</td>
</tr>
<tr>
<td>Rain/Drizzle</td>
<td>20</td>
</tr>
<tr>
<td>&gt; 5 km</td>
<td>42</td>
</tr>
<tr>
<td>1 to 5 km</td>
<td>24</td>
</tr>
<tr>
<td>&lt; 1 km</td>
<td>25</td>
</tr>
</tbody>
</table>

July cloud fraction per 45-m radar range gate

July 8, July 9, July 10

Graph shows cloud fraction variation with height and time.
Cirrus cloud microphysics retrievals

- Use a suite of retrieval techniques: radar-radiometer, radar moments, and empirical reflectivity. Reasonable agreement between techniques.
- Need more aircraft validation and a broader inter-comparison of techniques (i.e. Mace retrievals).
- See Matrosov et al. poster
Anvil cirrus properties

Observed ~32 hours of anvil cirrus and over 150 hours of total cirrus during the month of July.

Anvil statistics

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_{\text{mean}}$ [$\mu$m]</td>
<td>110</td>
<td>100</td>
</tr>
<tr>
<td>IWC [g/m$^3$]</td>
<td>0.06</td>
<td>0.2</td>
</tr>
<tr>
<td>IWP [g/m$^2$]</td>
<td>85</td>
<td>110</td>
</tr>
<tr>
<td>Ext [km$^{-1}$]</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
Anvil cirrus properties

Distribution of particle size with height in atmosphere

July 17

July 18

July 19
New use of radar Doppler spectra: Mixed-phase clouds
Mixed-phase cloud retrieval from Doppler spectra on July 29th

- Liquid (lifting)
- Ice (falling)

Liquid cloud base

- Height [km]
- Spectral Width [m s⁻¹]
- Velocity [m s⁻¹]
Retrieved liquid and ice water content profiles

Water Content by phase, 07/29/02, CRYSTAL

MPL cloud base

- All, IWP= 55.8
- Ice, IWP= 55.4
- Liquid, LWP=309.0
- LWP_{ETL}=230.0, LWP_{NASA}=347.6
Heating Rate Calculations

07/29/02, Mixed-phase

LW

SW
Summary

- NPCO data stream was continuous for the CRYSTAL month, showing full time-height cross-sections of the atmosphere, the evolution of cloud systems over time, and the diurnal cycle.
- Measurements and retrievals can be used to characterize cloud properties, to validate satellite retrievals/observations, and to assess models.
- A new technique has been developed for using Doppler spectra.
- Need coincident aircraft measurements to validate techniques (i.e. tie-down points for the continuous data record).

Future work

- Collaborate with Eastern ground team to fix calibration issues (pre 7/14).
- Assess quality of microphysical retrievals to ensure consistency.
- Reprocess all products with updated information.
- Science!! Use radar spectra and multiple radar frequencies in retrievals (with others from the ground site team), further characterize microphysical and radiative properties of cirrus, more satellite intercomparisons.