**Thin liquid layers in Arctic tropospheric clouds during the 2012 Canadian Arctic ACE Validation Campaign**

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**Depolarization Ratio** measurements allow liquid droplets to be discerned from frozen particles in clouds. Liquid droplets can exist well below 0 °C, so this is an interesting quantity to examine in cold Arctic clouds.

The transmitted lidar laser pulse is linearly polarized. The depolarization ratio measures the depolarizing effect of the cloud particles on the backscattered laser photons.

**Figure 1, at left:** CRL lidar at DPAL (Zero-Altitude PEARL Auxiliary Lab) in Eureka, Nunavut in the Canadian High Arctic (80°N, 86°W). The CRL is able to operate both day and night.

This project is part of the larger CANDAC (Canadian Network for the Detection of Atmospheric Change) project at PEARL (Polar Environment Atmospheric Research Laboratory).

**Figure 2, below** Radiosonde temperature plot corresponding to the time indicated in Figure 4, below. Despite temperatures below 0 °C, liquid layers persist within the cloud. This is possible down to about -40 °C (at which point droplets freeze homogeneously).

**Figure 3, above** Thin liquid layers in Arctic tropospheric clouds during the 2012 Canadian Arctic ACE Validation Campaign. The surrounding ice cloud is orange and red. Figure 3, above Thin liquid layers persist for upwards of an hour. The layers are easily visible using the “parallel” and “polarization-insensitive” channels. The calibration is not yet perfect, but is adequate to show the value of this unconventional measurement method.

**Take-home points:**
1) The high time resolution of the CRL measurements is of importance for identifying these cloud types as their morphology is variable on timescales of several minutes, and some layers are < 15 m in vertical extent.
2) The high signal rates using the “polarization-insensitive” and “parallel” channels (instead of a low-count-rate “perpendicular” channel, see boxes below) leads to useful measurements. This method is an idea worth pursuing.

**Figure 4, above** Context plot for Figure 3, showing the large icy cloud which hosts the liquid layers. This cloud persisted for 5 hours.

**Figure 5, above** Understanding depolarization ratio values. Some ice crystal shapes (at warmer temperatures) can have low δ, so there is a range of cutoff values reported in the literature. Here, we use 30% to indicate ice.

**With the CRL, we have tried this new way:**

**Depolarization Ratio** measurements can also be made using one polarization-sensitive channel and one polarization-insensitive channel, as shown by CRL 2012 and 2013 measurements.

- **Parallel Channel:** One channel is for light which has been backscattered with polarization “parallel” to the polarization of the transmitted beam (i.e. polarization unchanged by the scatterers in the atmosphere).
- **Perpendicular Channel:** The other channel admits light whose plane of polarization is now perpendicular to that of the transmitted beam (i.e. from interaction with some non-spherical atmospheric scatterers).
- **Depolarization Ratio:** Calculated using the following equation, in which k is a calibration constant measured using a fully unpolarized light source:

  \[ \delta = k \frac{\text{Parallel}}{\text{Perpendicular}} \]

**Advantages** to this method include: 1) **low signal rates in the perpendicular channel** (especially apparent in the CRL setup, which has some upstream depolarization-era optics which are strongly polarizing), 2) The need to install two dedicated polarization channels or specialized equipment such as a rotating polarizer, to allow both parallel and perpendicular measurements.

**Drawbacks** to this method include:

- **Low signal rates in the perpendicular channel**
- **Specialized equipment** or additional moving parts.

**Calibrations and Analyses** are currently underway, and will explicitly demonstrate the new technique’s validity.

**The 2013 Canadian Arctic ACE Validation Campaign:** Based on the encouraging results from 2012, an expanded investigation of this new depolarization technique was carried out in 2013.

Thirty-five days of measurements were made using both techniques simultaneously. Calibrations and analyses are currently underway, and will explicitly demonstrate the new technique’s validity.