Lidar Depolarization 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 stratus clouds.

- **Parallel Channel**: Admits light which has been backscattered with polarization “parallel” to the polarization of the transmitted beam (i.e. polarization unchanged by scatterers in the atmosphere).
- **Perpendicular 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 Factor (d)** measurements are made using two polarization-dedicated measurement channels. In the CRL these are both measured using the same PMT, with a Licol Polator (a linear polarizer) rotating in front of the PMT on each laser shot.

**How can we ensure these equations are realistic for the CRL lidar?**

A more complete matrix derivation of the depolarization parameter is developed. It accounts for more possible instrument contributions.

**Derivation of the depolarization equations**

We can describe light as a Stokes vector \([4\times4]\) and any optical components as \([4\times4]\) matrices.

\[
\begin{align*}
\text{Transmitted light vector:} \\
I_{\text{transmitted}} &= (G_{\text{transmitted}})I_{\text{Laser}} \\
&= (M_0)I_{\text{Laser}} \\
\end{align*}
\]

**Instrument Matrix (or matrices):**

- For the receiver channel (Figure 4), we specify the polarizer and PMT (photomultiplier tube) optics as another Mueller matrix for each polarization position, and the rest of the upstream optics as another Mueller matrix (beam splitters, LWP filters, etc.).

Here are the instrument matrices for the Parallel channel:

\[
\begin{align*}
M_0 &= \begin{bmatrix}
1 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 \\
0 & 0 & 1 & 0 \\
0 & 0 & 0 & 1 \\
\end{bmatrix} \\
M_1 &= \begin{bmatrix}
\cos^2 \theta & \sin \theta \cos \theta & 0 & 0 \\
\sin \theta \cos \theta & \cos^2 \theta & 0 & 0 \\
0 & 0 & 1 & 0 \\
0 & 0 & 0 & 1 \\
\end{bmatrix} \\
M_2 &= \begin{bmatrix}
\cos^2 \phi & 0 & \sin \phi \cos \phi & 0 \\
0 & 1 & 0 & 0 \\
\sin \phi \cos \phi & 0 & \cos^2 \phi & 0 \\
0 & 0 & 0 & 1 \\
\end{bmatrix} \\
M_3 &= \begin{bmatrix}
1 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 \\
0 & 0 & 1 & 0 \\
0 & 0 & 0 & 1 \\
\end{bmatrix} \\
\end{align*}
\]

We find that equations [1] and [2] are precisely valid ONLY in the case where:

\[M_0 = M_1 \quad \text{and} \quad M_0 = M_2\]

Calibrations assuming these conditions are called the “simple calibration method” in this poster.

**Simulation**

An assessment of the measurements shown in Figure 11 (at right) shows that the terms \(M_0 = M_2 \neq 0\) for the CRL lidar. This is demonstrated by the symmetry in the measurement (i.e. the values at \(\theta = 0.25\phi\) equal those at \(\theta = 0.75\phi\) for both the parallel and perpendicular channels).

**Combine to find a single equation**

Equations 13 and 14 both contain all three calibration constants, but they also include the \(G_{\text{transmitted}}\), which we do not particularly want. If we combine the equations 13 and 14, and make the simplification from above, we can make a third equation which includes only constants we seek:

\[ \frac{S_{\theta}^p}{S_{\theta}^p + S_{\theta}^s} = \frac{M_0 \cos 2\theta + M_2 \sin 2\theta}{1 + M_2 \cos 2\theta} \]

**Fitting equation 15**

Many combinations of \(M_0\) and \(M_2\) were used to find the weighted-least-squares best fit to [15].

**Results of fitting**

- \(M_0 = 0.756 \pm 0.01\)
- \(M_2 = 0.788 \pm 0.01\)
- \(M_0 = 0.978 \pm 0.01\)

**Effects on depolarization ratio measurements**

These effects are SMALL for the CRL lidar, smaller than uncertainty in \(d\). A comparison between the light of lidar measurement at the CRL is given in the top-right panel of this poster to show the negligible effect of a more complete calibration method versus a simple calibration.

**Determing the calibration constants**

\(M_0/M_0\), \(M_1/M_1\) and \(M_2/M_2\)

**References**


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