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Determining cloud thermodynamic phase from Micropulse Lidar Network data

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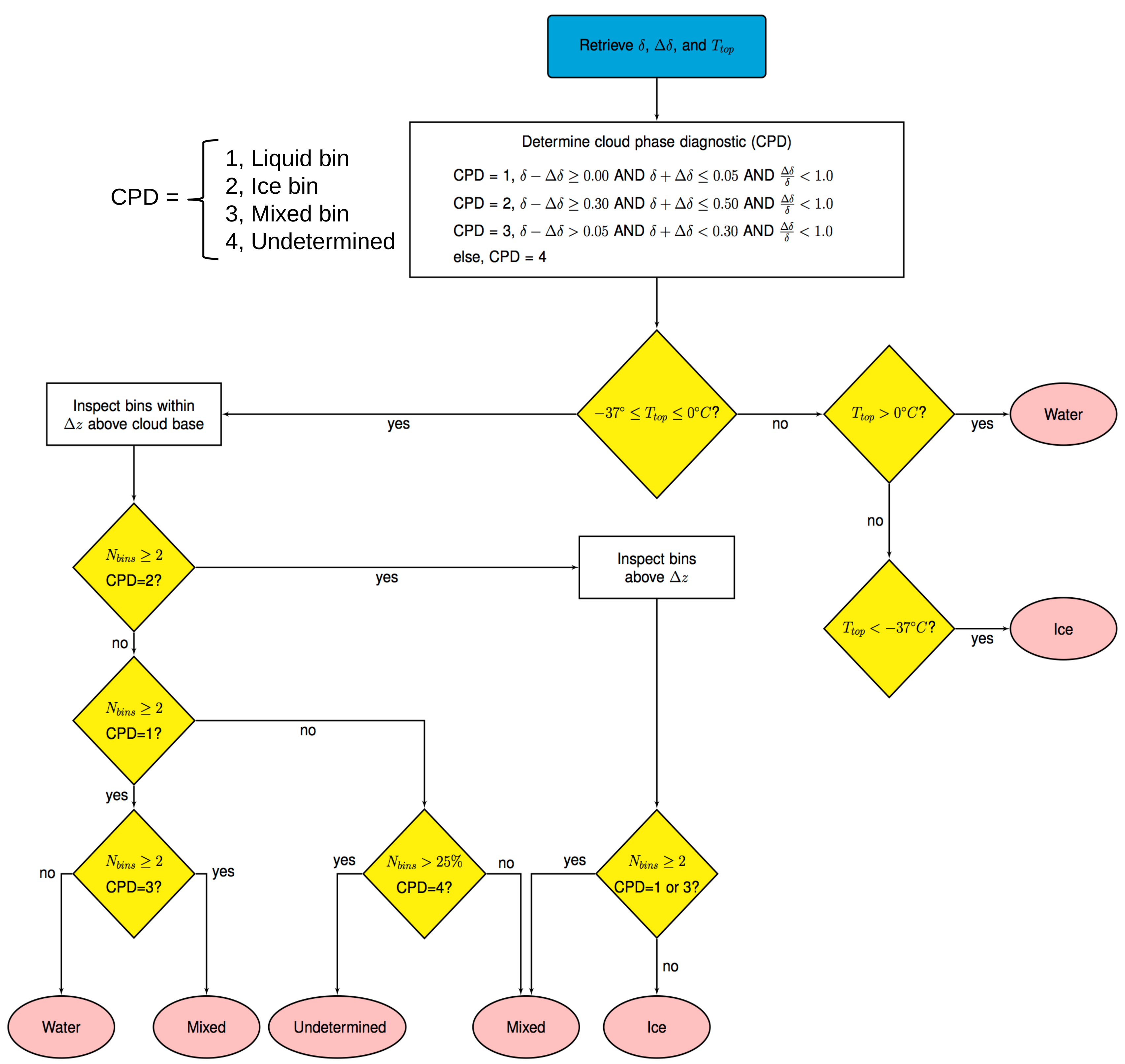
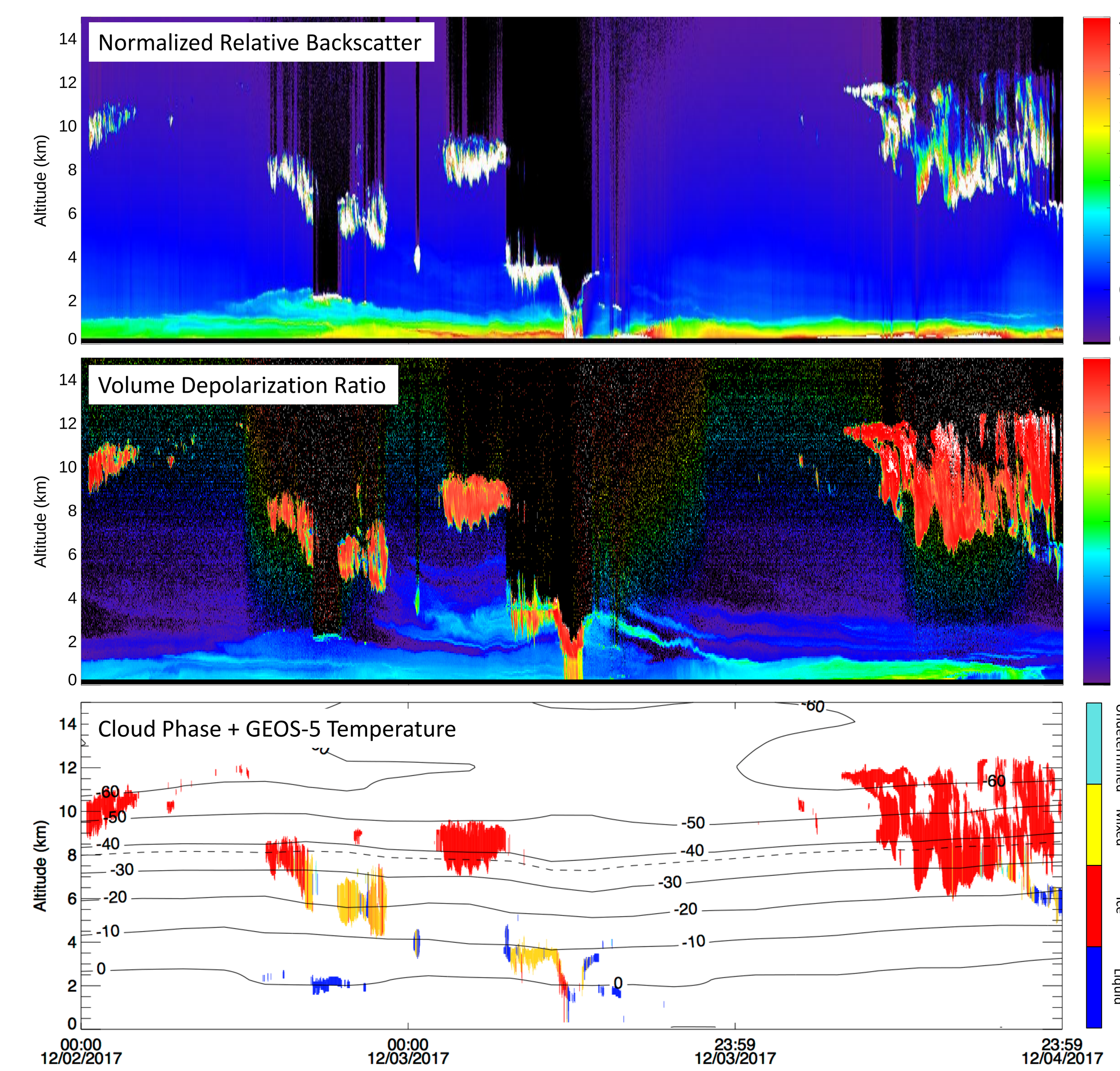
I. Introduction and Method

Lidars with polarization capabilities have recently been incorporated into the Micro Pulse Lidar Network (MPLNET; http://mplnet.gsfc.nasa.gov) which allows, for the first time, the ability to infer a cloud thermodynamic phase. Cloud retrievals from the NASA MPLNET (Lewis et al., 2016) and thermodynamic profiles from the Goddard Earth Observing System, version 5 (GEOS-5; http://gmao.gsfc.nasa.gov/products) are used to distinguish liquid water, mixed-phase, and ice water clouds based on the volume depolarization ratio (δ) and its uncertainty ($\Delta\delta$) and the cloud top temperature (T_{top}).



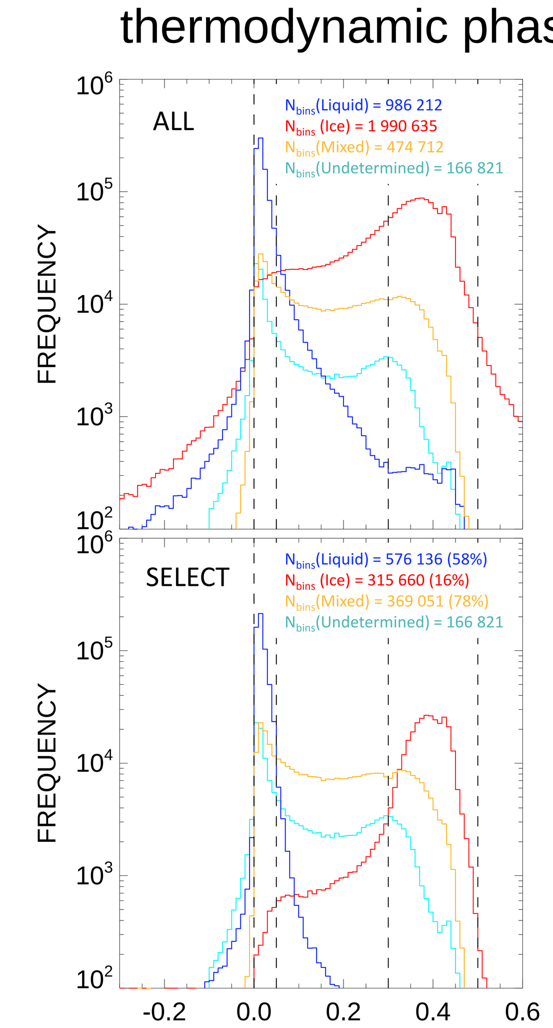
- The Micro Pulse lidar alternates between two modes, transmitting either linear or circularly polarized light and uses a single detector to identify depolarizing particles (Flynn et al., 2007).
- Cloud thermodynamic phase is determined solely using temperature for layers with cloud top temperatures above 0 ºC (liquid) and below -37 ºC (ice).
- Polarization measurements are used to determine the phase for layers with cloud top temperatures in the range of -37 ºC to 0 ºC by first assigning a cloud phase diagnostic (CPD) for each altitude bin within the cloud layer.
- To account for effects of multiple scattering, the search for ice-containing bins is limited to within a depth, Δz, which is determined by the transmittance within the cloud layer.

II. Results



The example above shows a three-day period at the NASA GSFC site. The temperature contours are from GEOS-5. The dashed contour line indicates the -37 ºC ice threshold suggested by Sassen and Campbell (2001) for detection of cirrus clouds.

The distributions of the volume depolarization ratio and CPD for each altitude bin and cloud top temperatures for each cloud layer detected at GSFC (01 Jun 2016 – 30 Nov 2017) are shown in the figures and tables below. Vertical dashed lines indicate thresholds used to determine cloud thermodynamic phase.

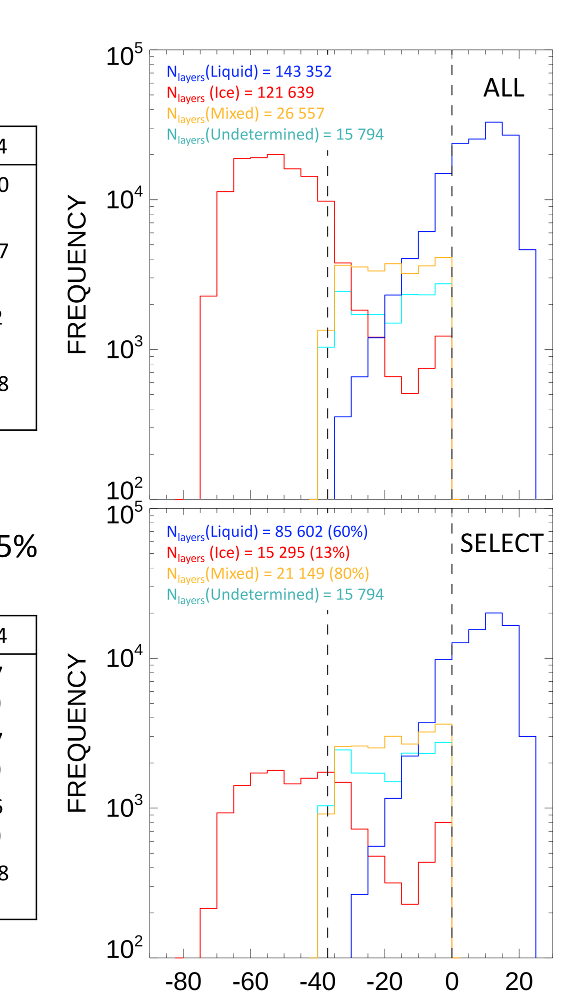


ALL – includes the full GSFC dataset

Cloud Phase	CPD = 1	CPD = 2	CPD = 3	CPD = 4
Liquid	721 606 **(73%)**	3 270 **(0.33%)**	88 706 **(9.0%)**	172 630 **(18%)**
Ice	29919 **(1.5%)**	777 166 **(39%)**	410 213 **(21%)**	773 337 **(39%)**
Mixed	84 061 **(18%)**	97 348 **(21%)**	219 661 **(46%)**	73 642 **(16%)**
Undetermined	12 565 **(7.5%)**	1 688 **(1.0%)**	27 990 **(17%)**	124 578 **(75%)**

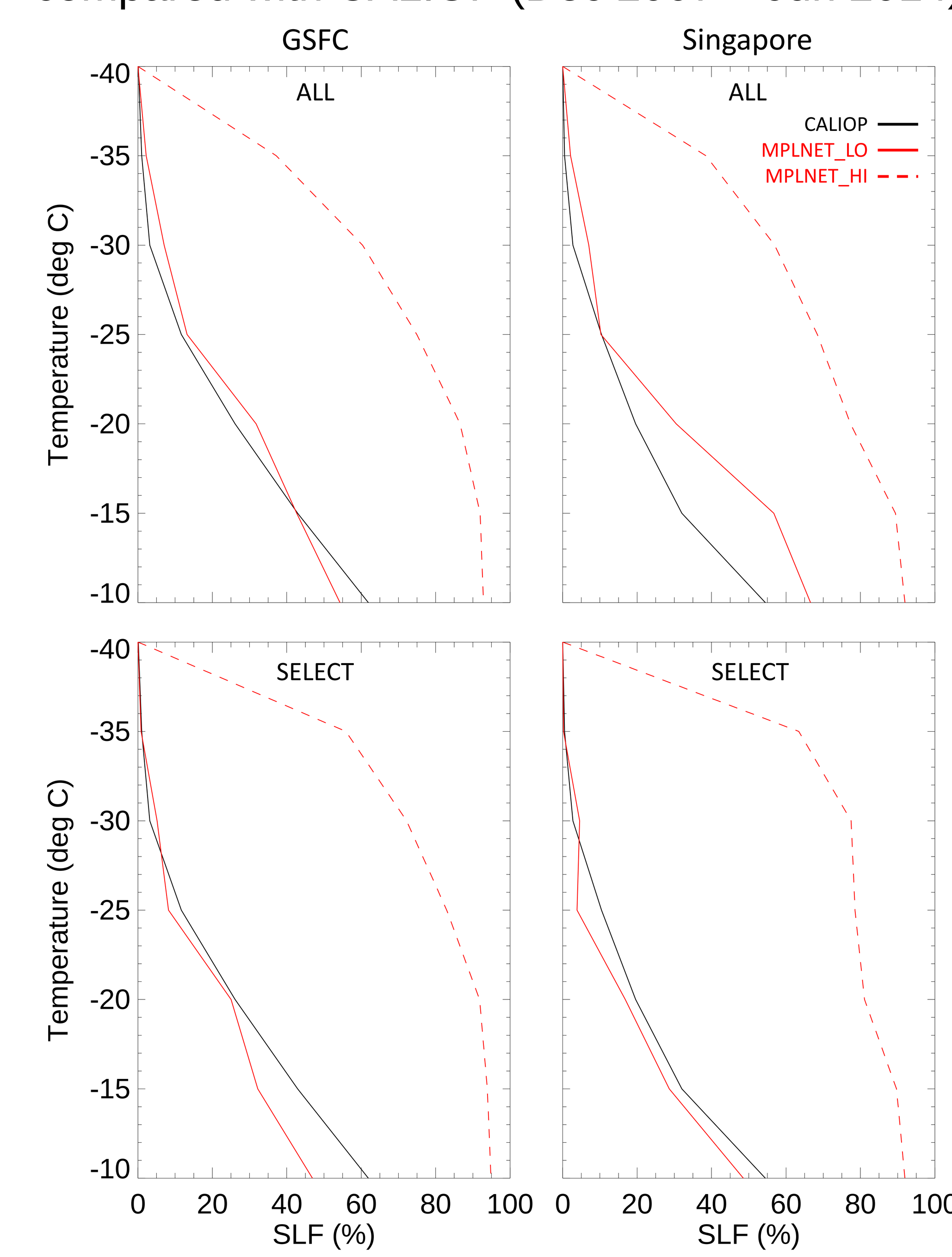
SELECT – removes cloud layers if more than 25% of CPD is mismatched with the cloud phase

Cloud Phase	CPD = 1	CPD = 2	CPD = 3	CPD = 4
Liquid	535 171 **(93%)**	4 **(0.0%)**	9 384 **(1.6%)**	31 577 **(5.5%)**
Ice	1 049 **(0.33%)**	268 175 **(85%)**	18 949 **(6.0%)**	27 487 **(8.7%)**
Mixed	73 130 **(20%)**	79 945 **(22%)**	185 750 **(50%)**	30 226 **(8.2%)**
Undetermined	12 565 **(7.5%)**	1 688 **(1.0%)**	27 990 **(17%)**	124 578 **(75%)**



III. Evaluation

Following the work of Tan et al. (2014), the supercooled liquid fraction (SLF) in the mixed phase regime (-10 ºC to -40 ºC; 5 Cº increments) is calculated at the GSFC (01 Jun 2016 – 30 Nov 2017) and Singapore (29 Jul 2017 – 30 Nov 2017) sites and compared with CALIOP (Dec 2007 – Jun 2014) within a 2.5º lat/lon grid box.



The CALIOP SLF uses the (NCEP)-Department of Energy (DOE) Reanalysis 2 air temperature at the CALIOP cloud top altitude. CALIOP does not specify mixed phase, so SLF is calculated:

$$SLF = \frac{Liquid}{Liquid + Ice}$$

The MPLNET SLF uses the GEOS-5 air temperature at the MPLNET cloud top altitude. A low and high SLF is calculated for MPLNET to account for mixed phase clouds:

$$SLF(LO) = \frac{Liquid}{Liquid + Ice + Mixed}$$

$$SLF(HI) = \frac{Liquid + Mixed}{Liquid + Ice + Mixed}$$

IV. Future Work

Coincident measurements with other instruments (e.g. radar and microwave radiometer) are needed to evaluate and improve the MPLNET cloud phase determination. The Alaska-Fairbanks site has recently added polarization capabilities which will allow future studies of mixed phase clouds.

References:

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