

# Overview of a Prototype CALIPSO LIDAR Level 2 Cloud Phase Discrimination Algorithm

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## Overview

A new cloud phase discrimination method, based on work done by Yongxiang Hu [Hu et al, 2009], has been incorporated into CALIPSO's Selective Iterated Boundary Locator (SIBYL) algorithm for the version 3.0 data release. Primarily, the algorithm relies on the relationship between the layer integrated volume depolarization ratio (IVDR) and 532nm integrated attenuated backscatter (IAB) to both identify the phase and, if an ice cloud, the orientation of the cloud particles. This information will be provided to the user version 3.0 data by a change in the reporting of phase types; ice is now split between horizontal ice (replacing ice phase) and randomly oriented ice (replacing mixed phase). Secondary relationships are used to fine tune the results. These include cloud micro-physical properties (temperature), lidar measurements (color ratio) the affect of adjoining layers (application of a spatial coherence function), and internal data quality measures (use of CAD scores).

## Phase Decision Tree

The phase of the detected layer is determined by a block of if statements contained within the algorithm. Figure 4 provides a descriptive measure of each decision block, which cluster together key parameters and from these assume both the type of cloud and the confidence on should apply to that cloud grouping. The resulting phase and phase quality assurance flags for each of these groupings are also shown; unknown, water, horizontal oriented ice (HOI), or randomly oriented ice (ROI).

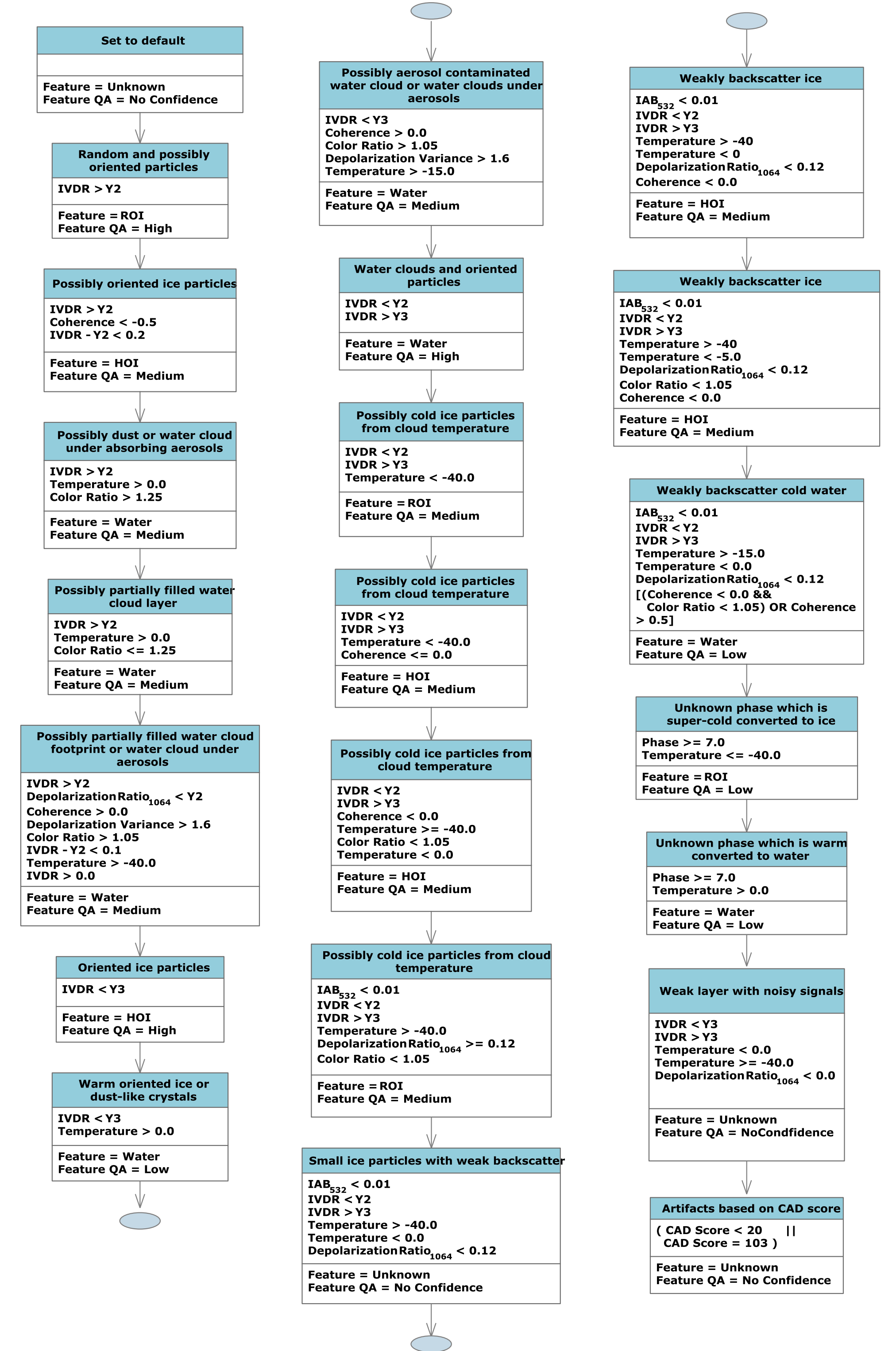


Figure 4: Cloud phase algorithm decision tree. Y2 is the random particle – water boundary, while Y3 is the water-horizontally oriented ice boundary.

## Depolarization / Backscatter Relationship

The algorithm assumes that there is a positive correlation between IVDR and IAB for water clouds and a negative correlation for ice clouds. For ice clouds, high IAB and low IVDR are identified for horizontally oriented plates while low IAB and high IVDR are identified for randomly oriented particles. Figure 1 shows how this relationship is used in the algorithm, where defined boundaries (red and blue lines) separate the different regimes. Figures 2 and 3 show the IVDR-IAB relationship for the four separate regimes, using a months' worth of Lidar L2 cloud layer data. Determination of phase is not STRICTLY determined by the IVDR and IAB relationship (see figure 4 for flow diagram), but distributions do show the predominate distribution. Figure 3 also shows the separation between HOI with a high confidence, and HOI with less confidence.

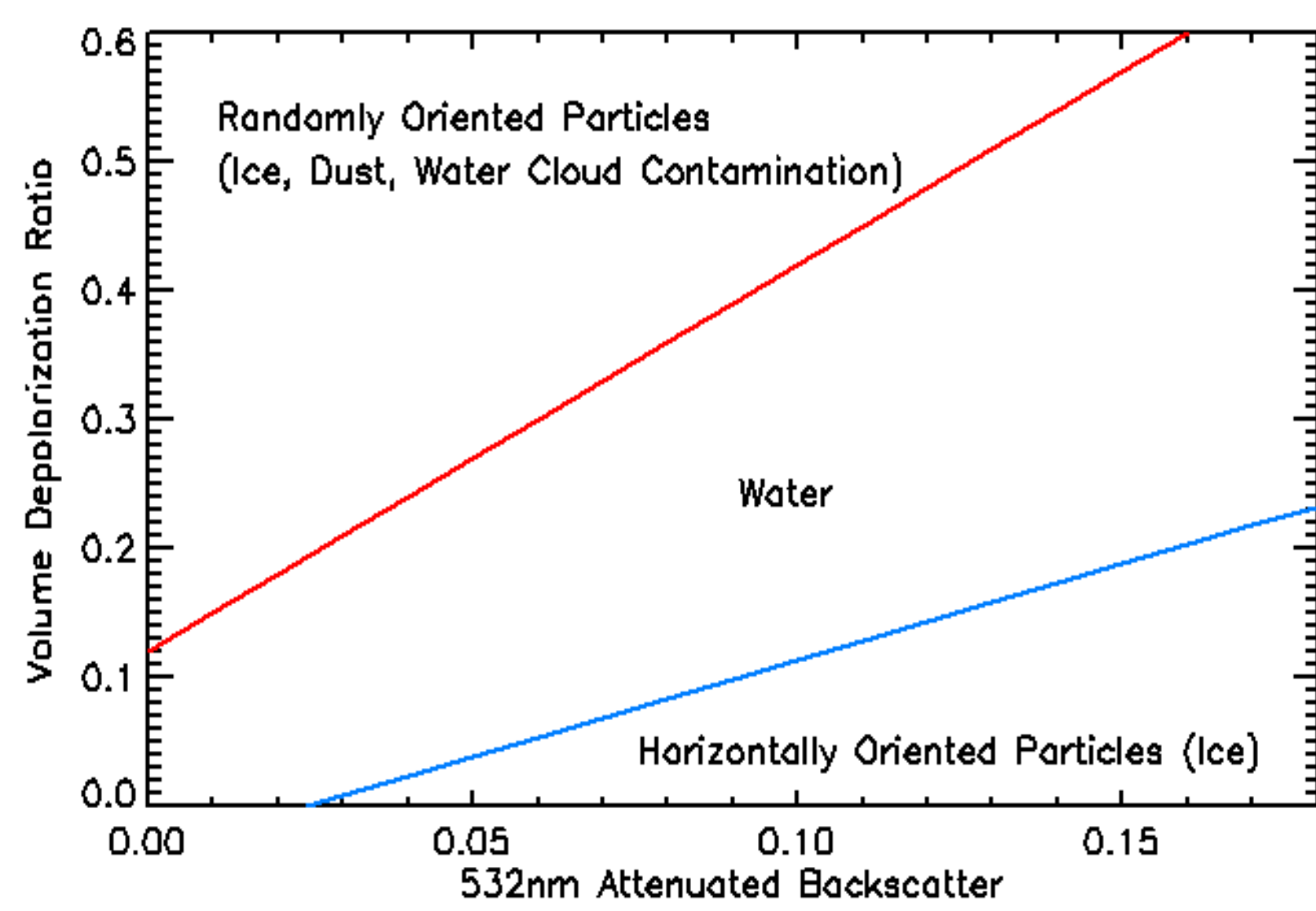


Figure 1: Relationship between 532nm integrated attenuated backscatter and integrated volume depolarization ratio for determining cloud phase.

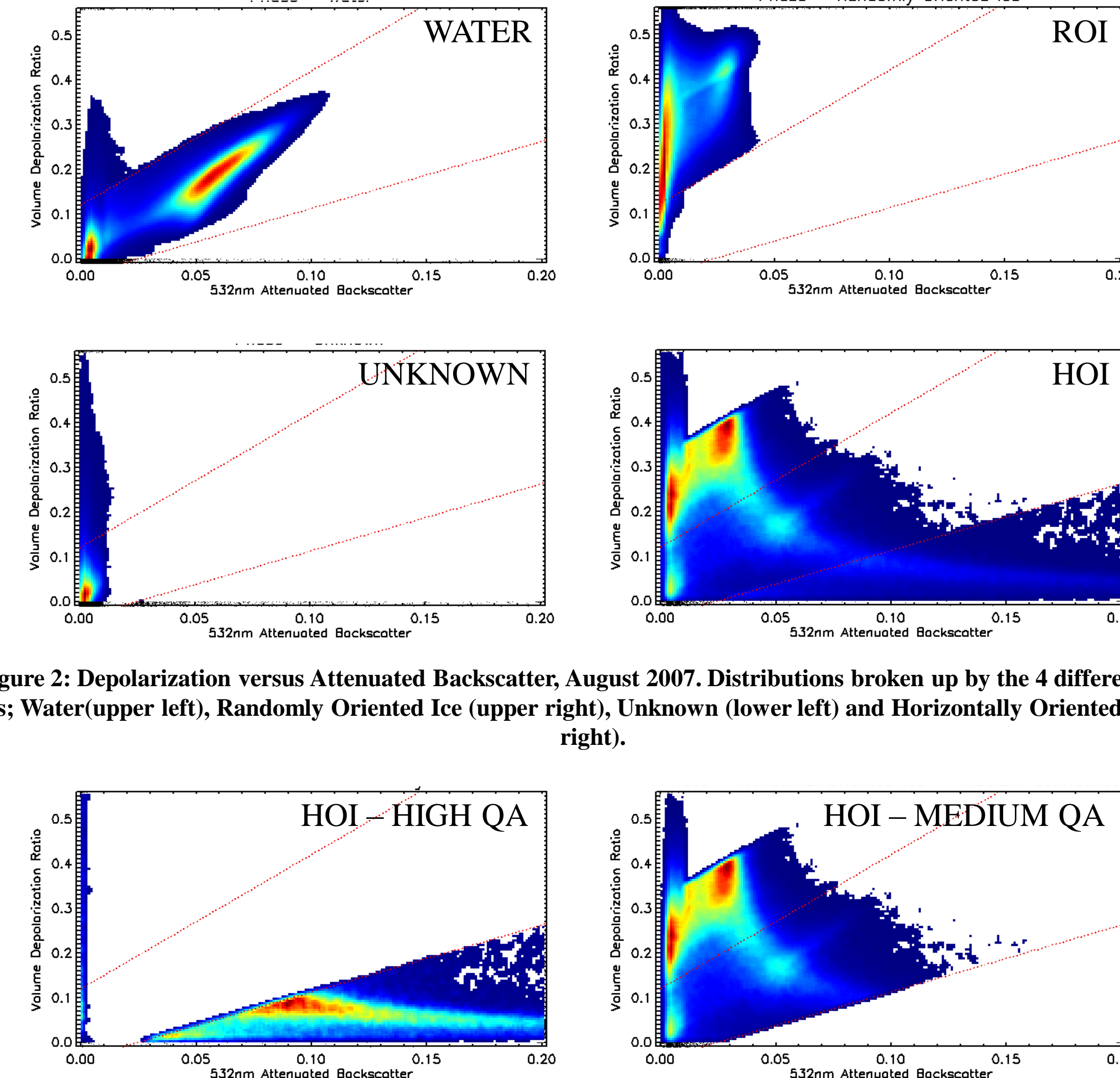


Figure 2: Depolarization versus Attenuated Backscatter, August 2007. Distributions broken up by the 4 different phase types; Water(upper left), Randomly Oriented Ice (upper right), Unknown (lower left) and Horizontally Oriented Ice (lower right).

Figure 3: Horizontally Oriented Ice for High (left) and Medium (right) phase values.

## Version 2.0 anomaly: cloud underneath attenuating layer

Stemmler and Anderson (University of Washington) provided CALIPSO with several cases which a liquid water cloud was misclassified as ice underneath aerosol layers. In each of these cases they compared CALIPSO with MODIS data to verify that these underlying clouds should be water, postulating that the overhead aerosol layer attenuates the signal enough to alter our interpretation of the layer. Re-ran this case with the new phase discrimination, which now re-classifies the underlying cloud from ice to water (as seen in lower right portion of figure 5).

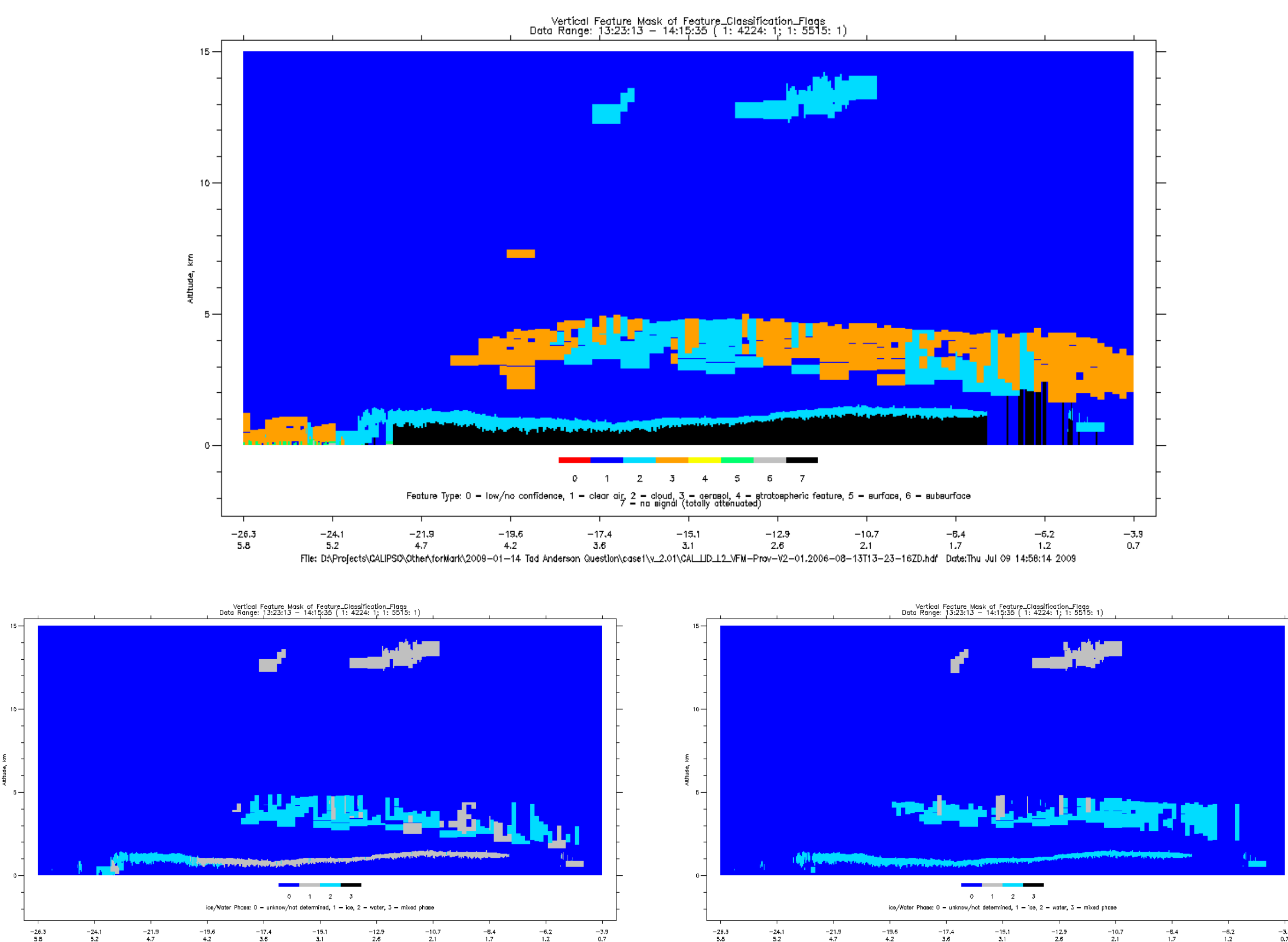


Figure 5: Vertical feature mask images for v2.01 layer type (upper), ice/water phase for v2.01 (lower left), and ice/water phase from the new phase algorithm (lower right).

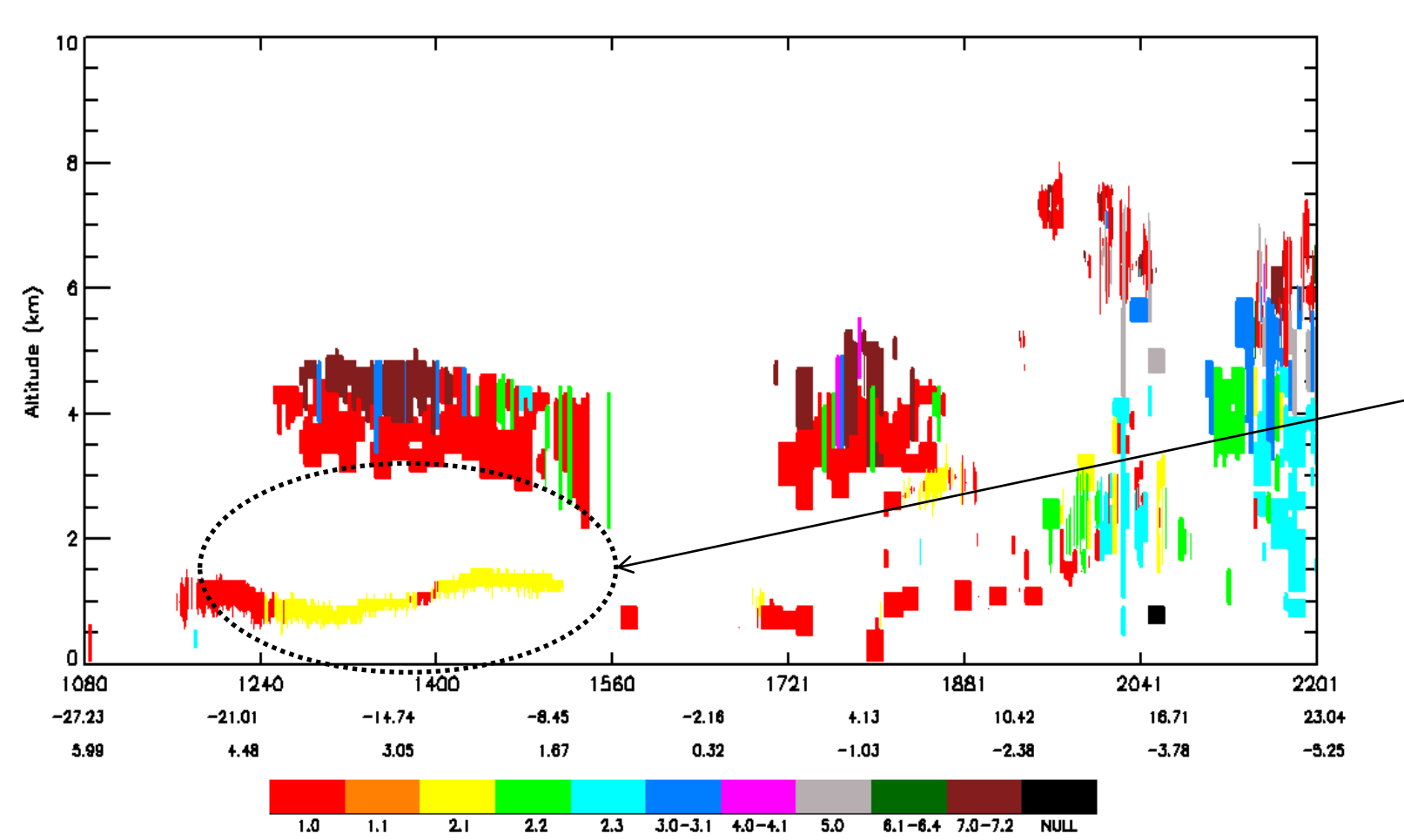


Figure 6: Ice/Water phase for 5km cloud layer file. Numbers correspond to the case blocks in figure 3 – each corresponding to a specific cloud regime.

Isolated the differing case blocks for each layer in the scene. The underlying cloud (yellow) corresponds to "Possibly dust or water cloud under absorbing aerosols", indicative of a layer in which the 532nm signal has been reduced in relation to 1064nm (color ratio > 1.25), is warm (temperature > 0.0), and is a randomly oriented particle (IVDR > ROI-water boundary). All describe the layer, and is why this is set as a water cloud, but with a reduced quality score (set to medium).

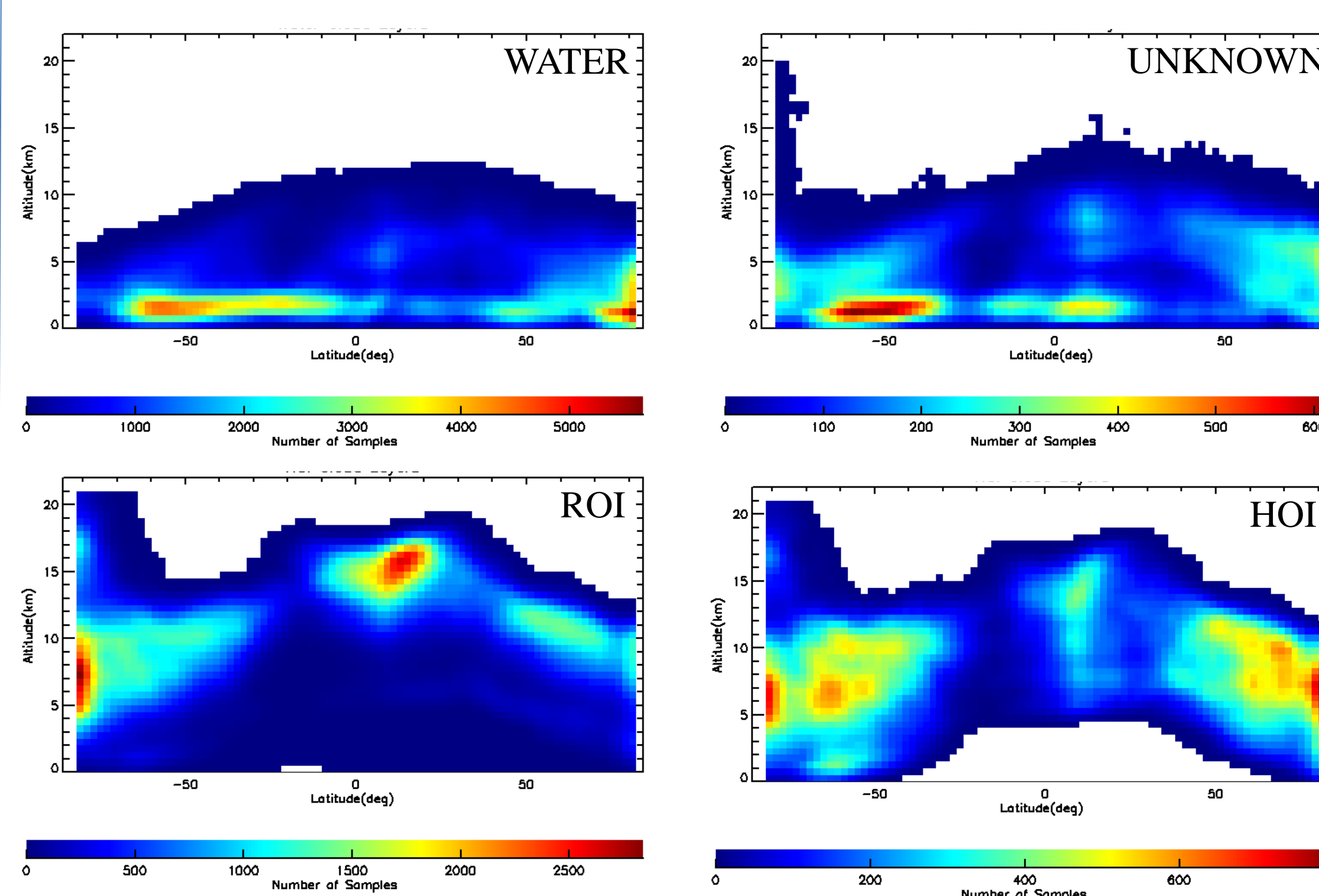


Figure 7: Cloud ice/water phase for August 2007 using the new phase algorithm.

	Fraction	Median Top	Std Top	Median Depth	Std Depth
Water	0.44	2.03	2.09	0.65	0.52
Unknown	0.07	3.37	2.65	0.53	0.99
ROI	0.33	10.47	3.91	1.75	1.91
HOI	0.14	8.03	3.64	2.21	2.06

Isolated common features between old and new phase algorithm (from 5km cloud layer files) for August 1-15, 2007. Focusing only on those layers which changed phase, one can see that there has been a marked improvement. Zonal distributions shows an increased segregation of ice and water clouds; increase in ice and unknown clouds in high latitudes and high altitudes, increase in low level water clouds (seen in figure 9).

## Version 2.0 versus the new algorithm

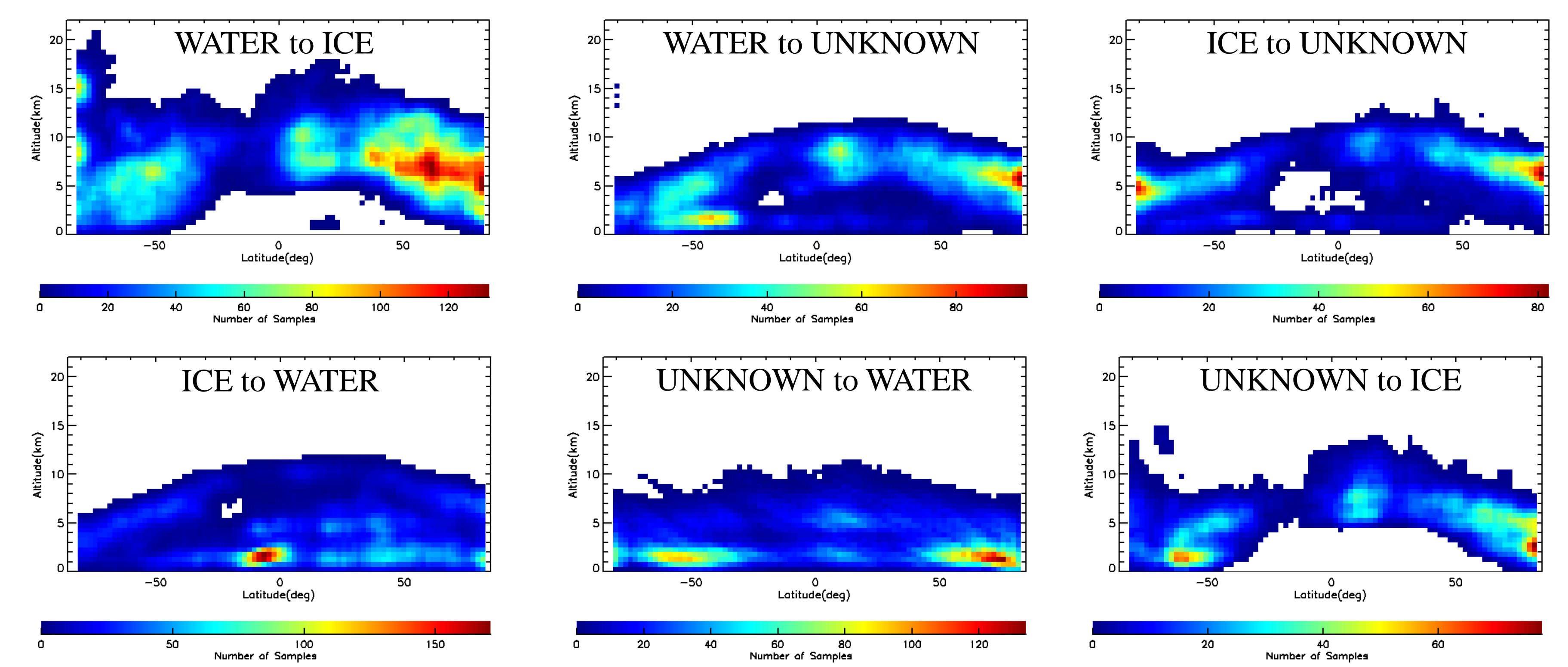


Figure 9: August 1-15, 2007 common cloud layers between version 2.0 and the new algorithm for various phase changes.

## Zonal distribution of phase types

Zonal distribution of ice/water phase consistent with expected distributions. Water clouds, constituting a majority of all observations, are confined to lower atmosphere. Ice (both ROI and HOI) are at both higher altitudes and higher latitudes, with more of a preponderance of ROI occurring for elevated clouds (cirrus) and HOI at lower altitude clouds (figure 7).

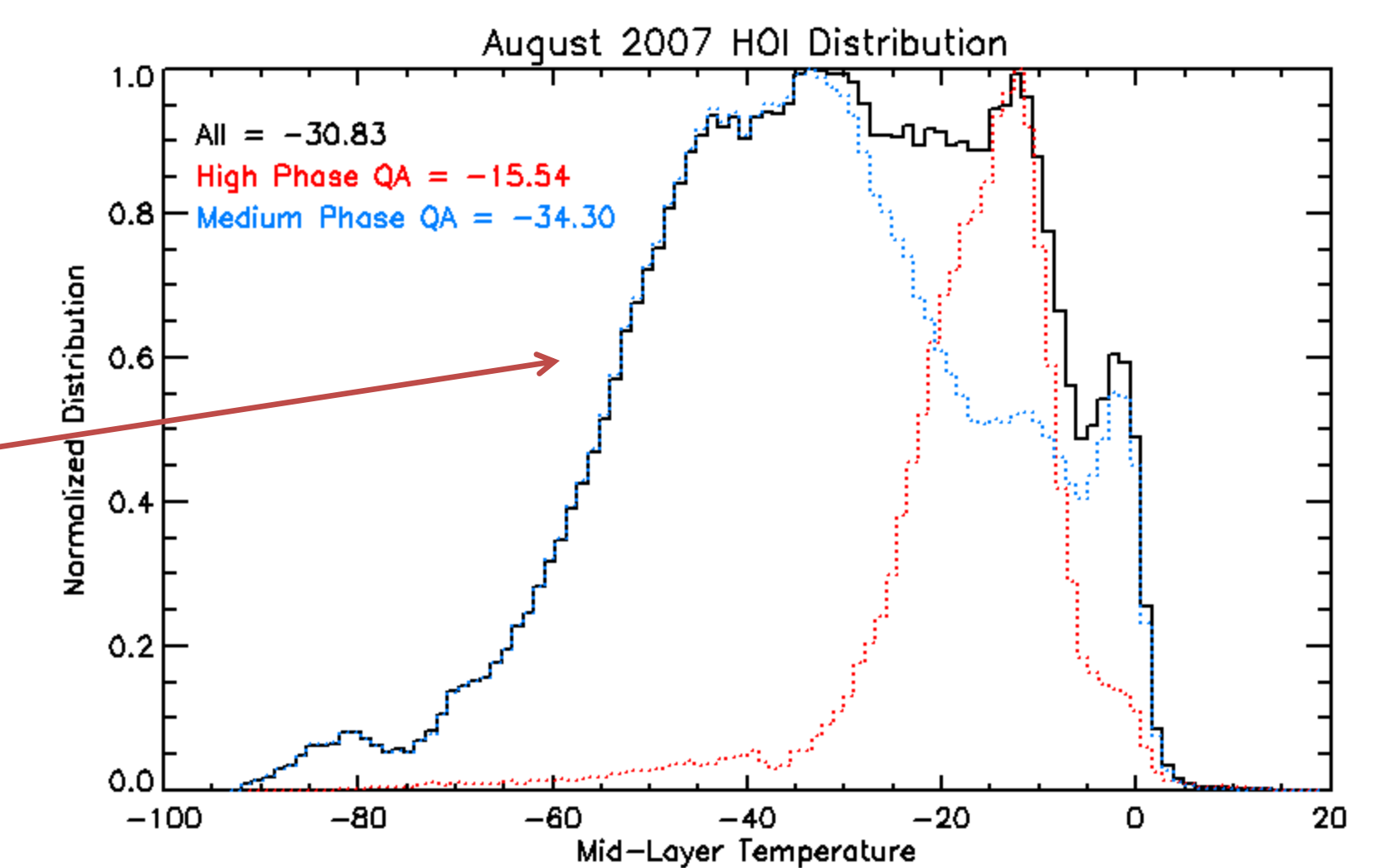


Figure 8: HOI distribution as a function of temperature.

Figure 8 shows the distribution of mid-layer cloud temperature for all HOI clouds, but divided based on medium and high phase QA. High phase QA clouds shows a narrow distribution centered on -15.5 degrees centigrade, a more "realistic" distribution than those HOI clouds with a lower phase QA. **This may require reclassification of these "medium" range HOI clouds.**