Liquid-Top Mixed-Phase Cloud Detection from Shortwave-Infrared Satellite Radiometer Observations

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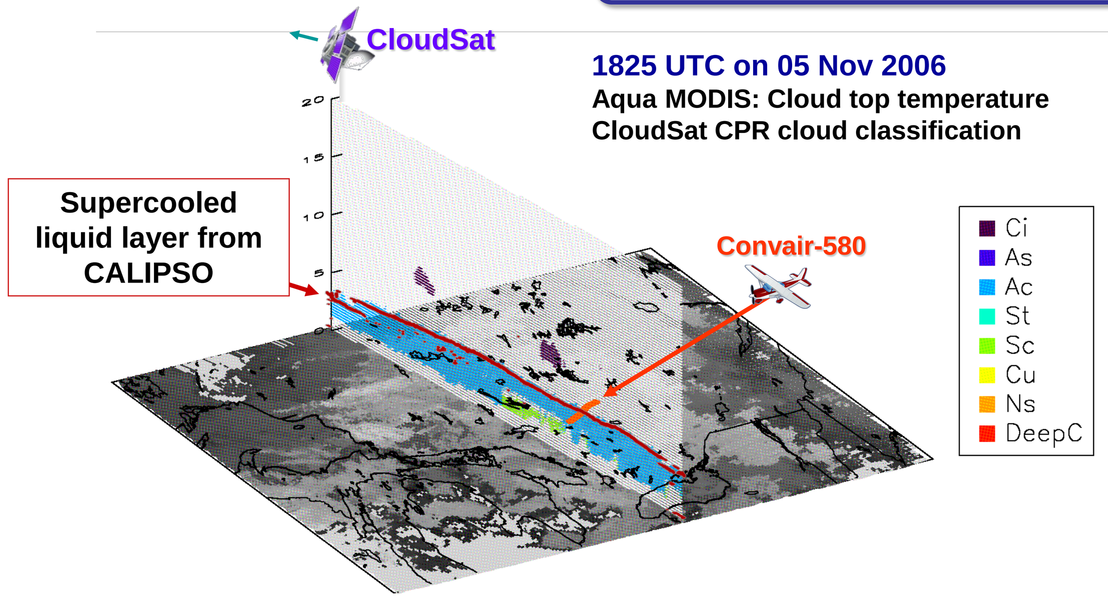
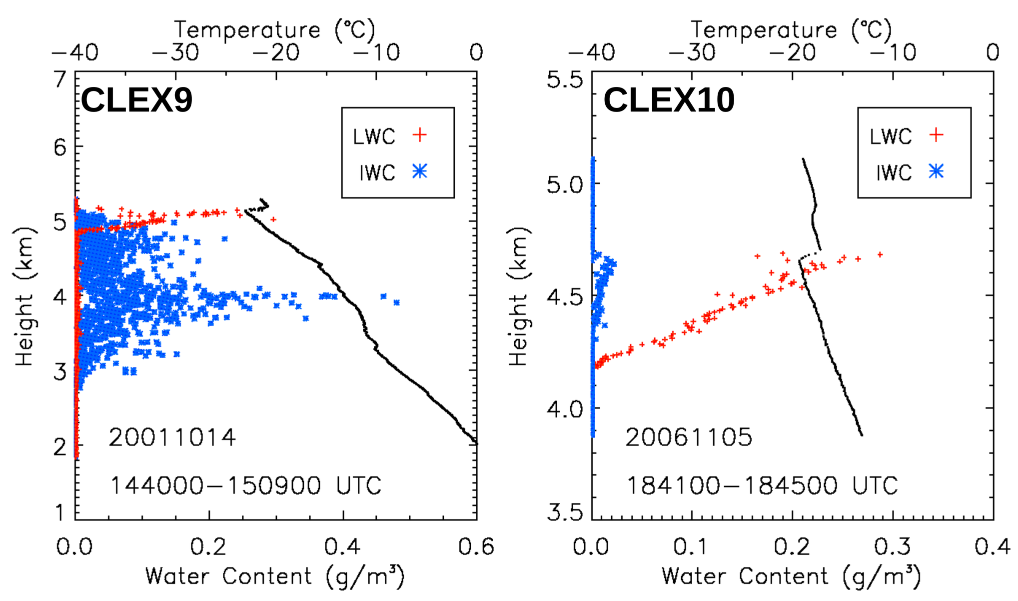
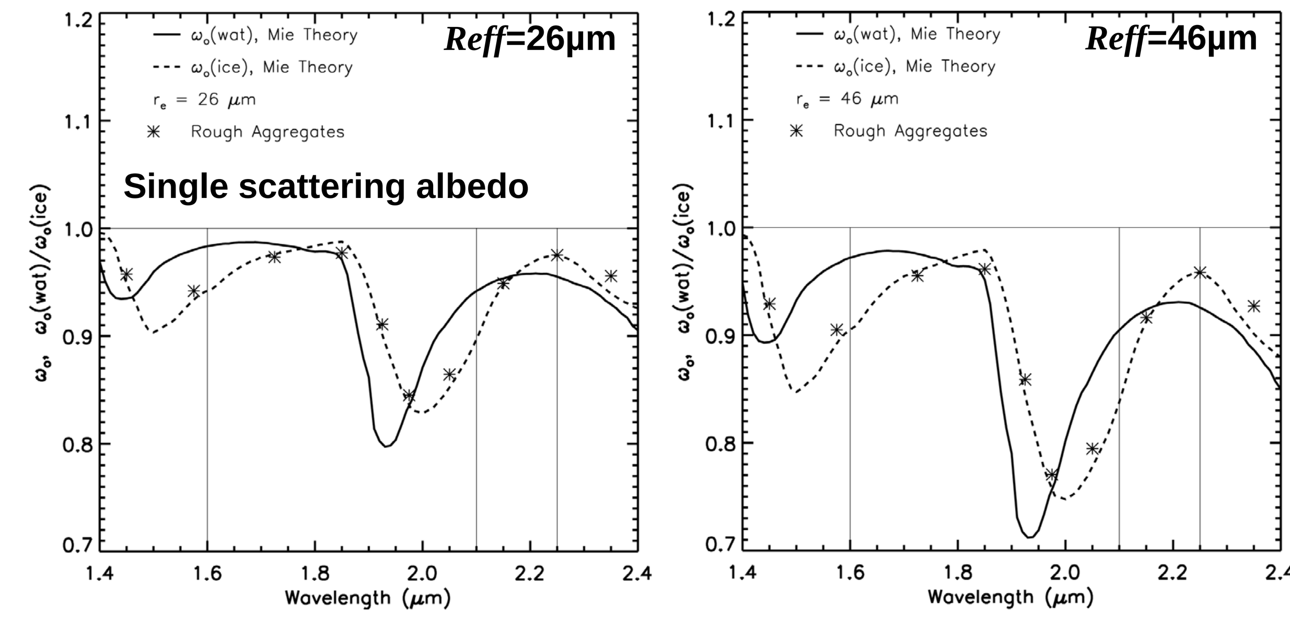
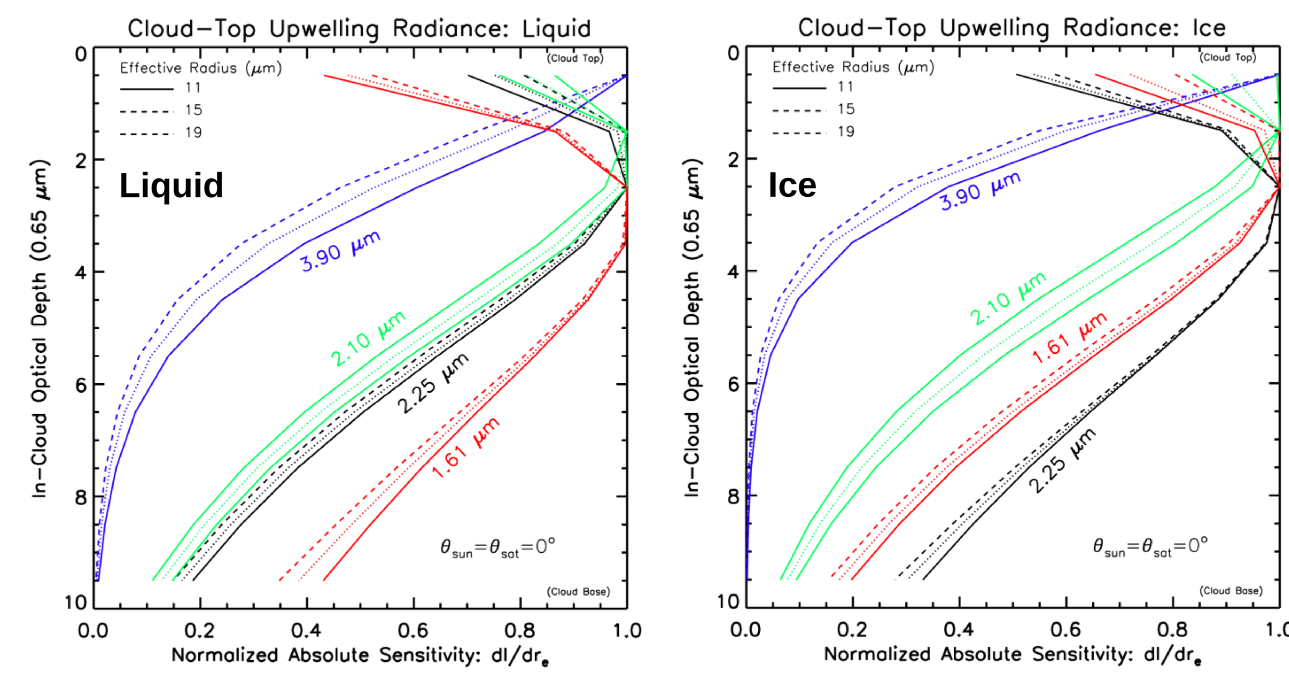
Introduction





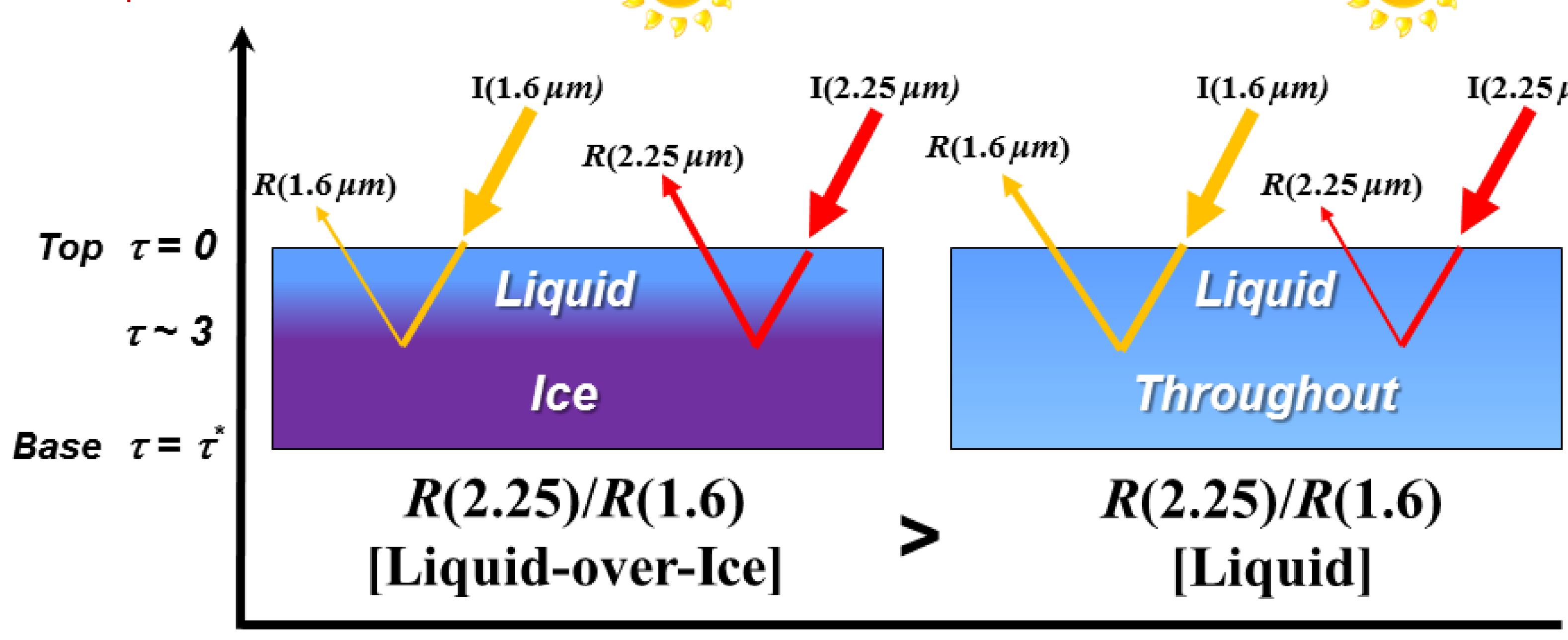
- Satellite-derived information on cloud phase comes from narrow bands in the shortwave- and thermal-infrared traditionally, with sensitivity biased strongly toward cloud top. However, this may be an important limitation for assessing cloud phase characteristics in particular for clouds which often exist in the liquid phase at temperatures below 0˚C at their tops but a predominantly ice phase residing below (*In-situ* observations).
- We describe a physical basis for the detection of liquid-top mixed-phase (LTMP) clouds from passive satellite radiometer observations. The algorithm makes use of reflected sunlight in narrow bands (1.6 and 2.25 μm) to optically probe below liquid-topped clouds and determine phase. Detection is predicated on differential absorption properties between liquid and ice particles for varying sun/sensor geometry and cloud optical properties.
- This algorithm utilizes spectral bands available on VIIRS, Himawari AHI and the future GOES-R ABI that will enable daytime monitoring with potential applications to aviation and the validation of NWP models.



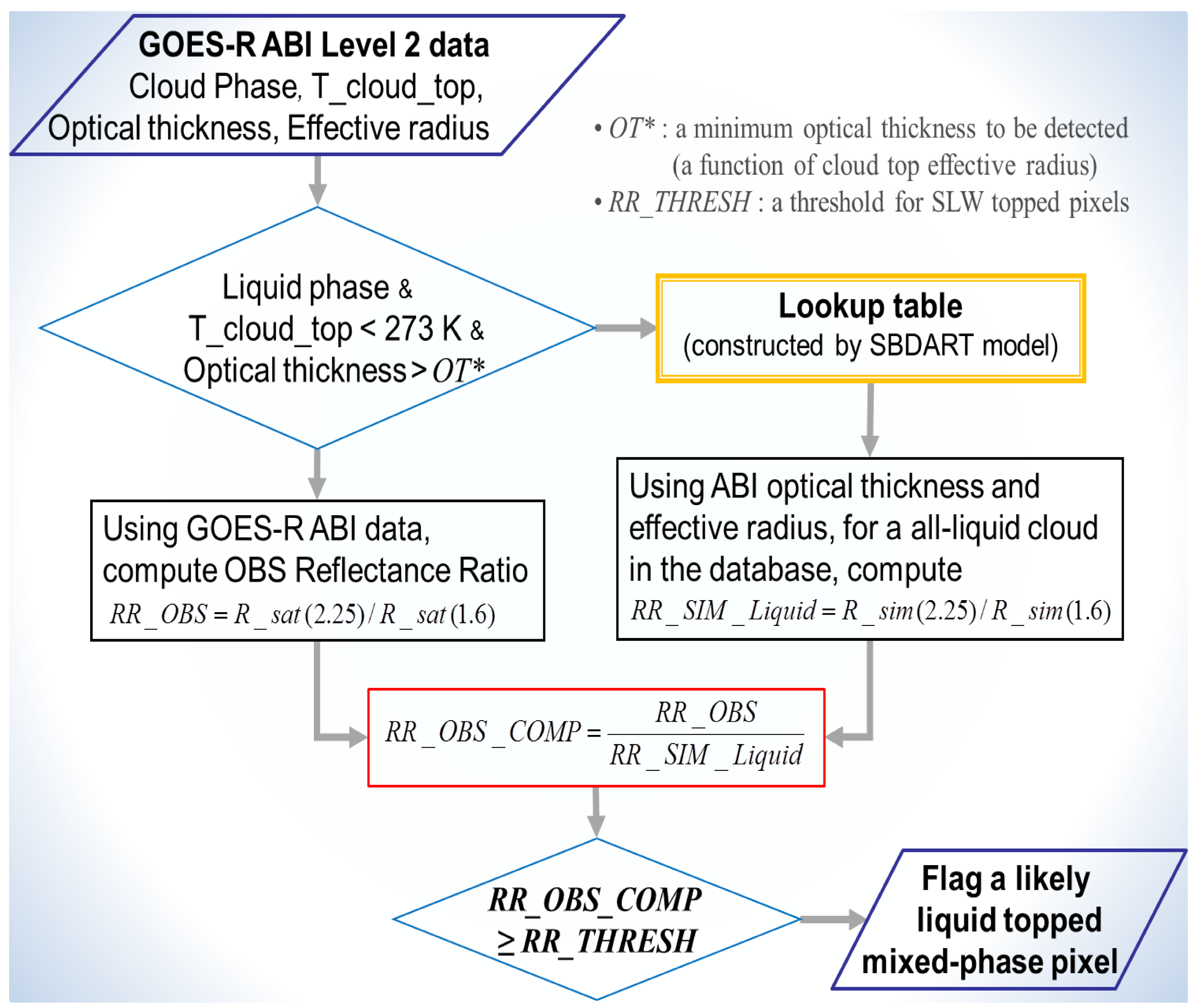


A Multispectral Satellite Detection Algorithm for 'Supercooled Liquid-Top Mixed-Phase' Clouds

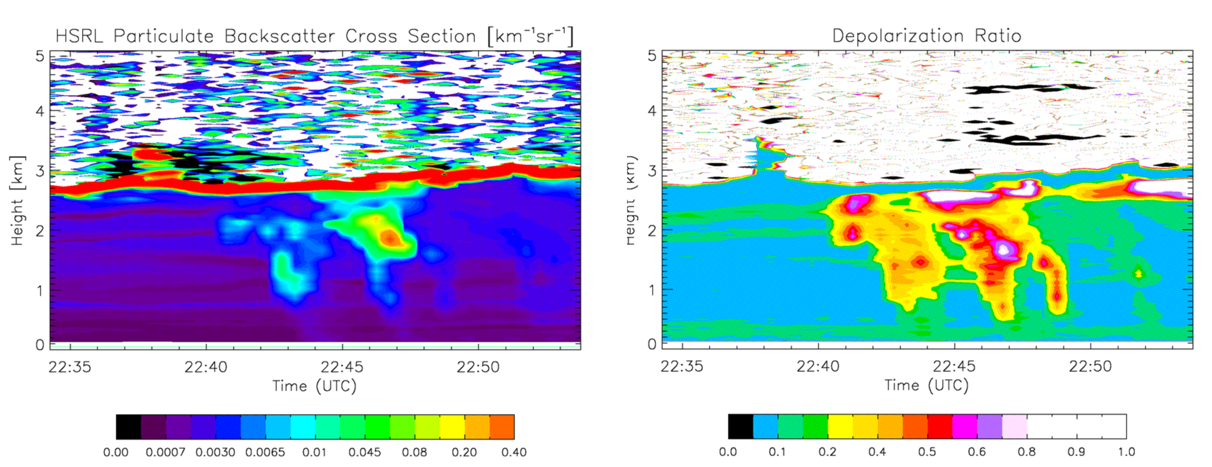
Differential radiative properties for liquid and ice phases at SWIR bands



Flow chart of the LTMP cloud detection algorithm

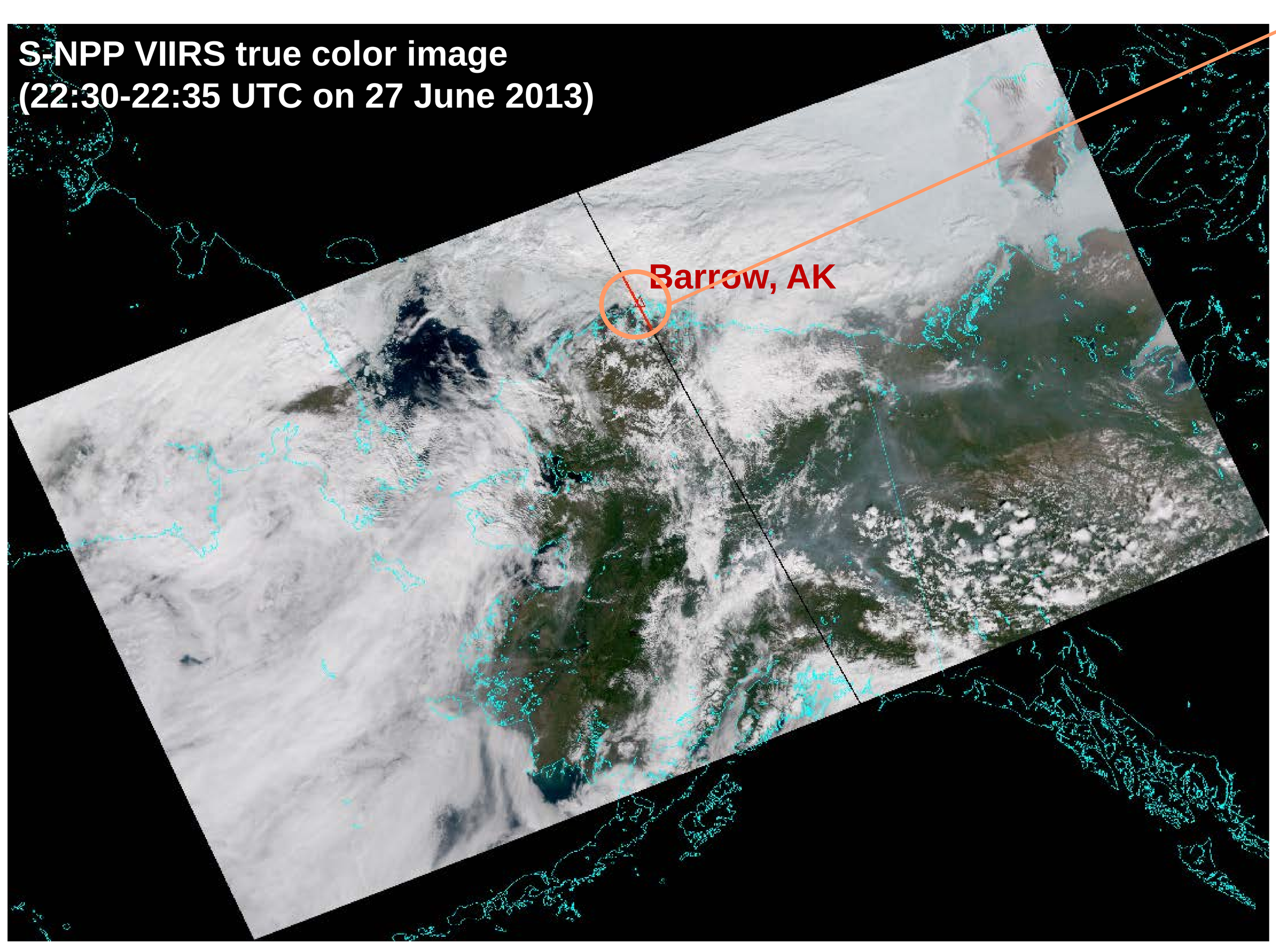


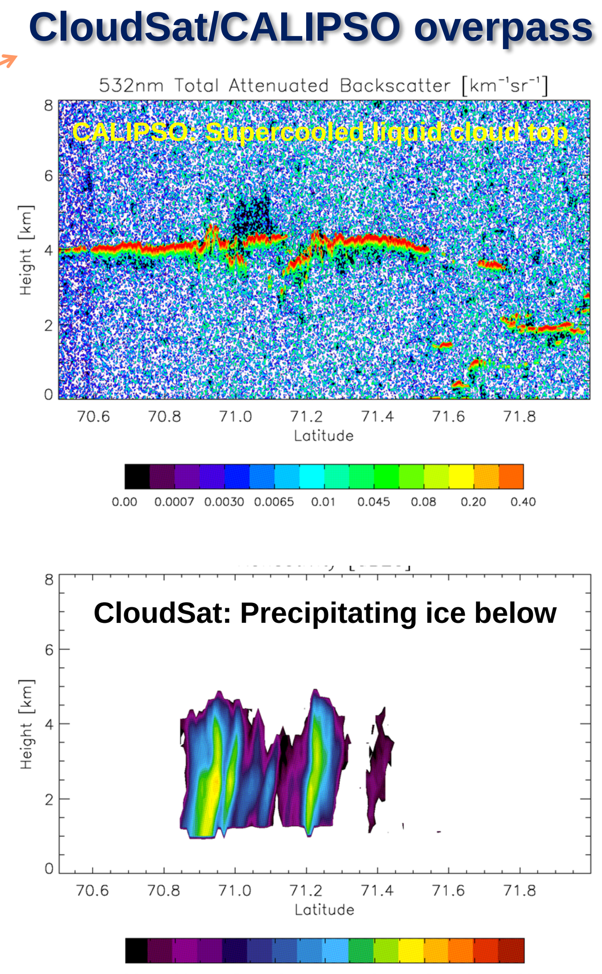
Case Study Analysis with S-NPP VIIRS Data

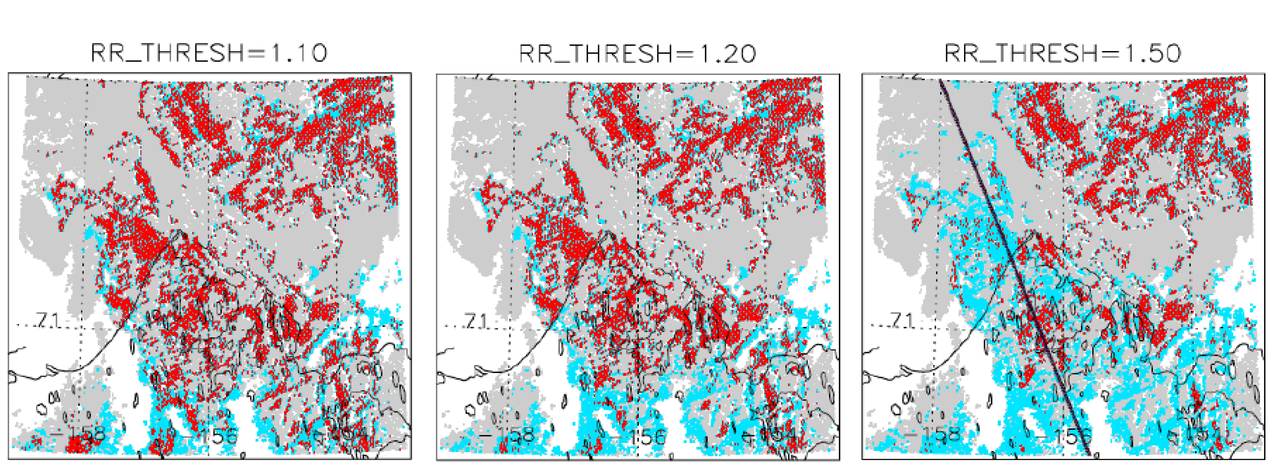


Time series of attenuated backscatter and depolarization ratio observed from the upward-pointing ARM NSA (Barrow, AK) HSRL instrument on 27 June 2013.

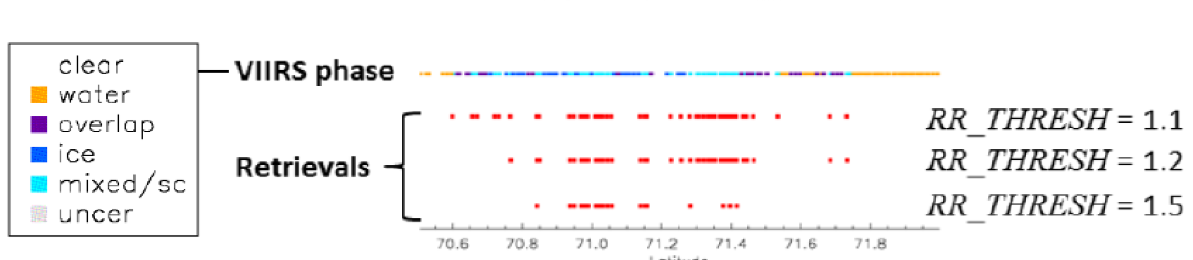
CloudSat/CALIPSO overpass







Detection algorithm performance test
LTMP detection algorithm applied to the VIIRS supercooled/mixed phase pixels for various RR_THRESH with positive-detection LTMP clouds in red, supercooled liquid-only (negative detection) in cyan, and unconsidered clouds in gray.



Cross sections of cloud phase and the corresponding detection results extracted along the CloudSat/CALIPSO ground track (black line in the upper-right panel).

Summary

- The physical basis for a daytime detection algorithm of clouds with liquid-top and mixed-phase or pristine ice below cloud top has been presented. This algorithm was designed toward applications on the ABI sensors of the next-generation GOES-R series and JMA Himawari-8/9 AHI sensors.
- The algorithm takes advantage of differential optical properties of liquid and ice phase cloud particles using SWIR bands whose weighting functions peak below cloud top and below levels of sensitivity for conventional cloud top phase discrimination techniques.
- LUTs for the algorithm are based on SBDART radiative transfer calculations for the idealized two-layer cloud scenario composed of various liquid/ice phase fraction, cloud optical thickness, cloud top effective radius, and sun/sensor geometry.
- The LTMP flag is identified using the departure of reflectance ratios between the observed cloud and an idealized all-liquid cloud (having the same cloud/geometry bulk properties) from cloud-property-dependent threshold values.
- The ARM/NSA case study and WRF model simulations (*not shown here*) of LTMP cloud systems reveal both capabilities and limitations of the current algorithm but show promising potential of the algorithm.
- In future work, we will explore various subsets of the spectrum providing optimal phase sensitivity (e.g. 2.25/2.13 μm) which can be applied to hyperspectral sensors such as ABI and AHI.

Miller, S. D., Y. J. Noh, and A. K. Heidinger, 2014: Liquid-top mixed-phase cloud detection from shortwave-infrared satellite radiometer observations: A physical basis. *J. Geophys. Res.*,119, DOI: 10.1002/2013JD021262.

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