Cloud Thermodynamic Phase

Introduction

The global spatial and diurnal distribution of cloud properties is a key issue for understanding the hydrological cycle, and critical for advancing efforts to improve numerical weather models and general circulation models. Satellite data provides the best way of gaining insight into global cloud properties. In particular, the determination of cloud thermodynamic phase is a critical first step in the process of inferring cloud optical and microphysical properties from satellite measurements. It is important that cloud phase be derived together with an estimate of the confidence of this determination, so that this information can be included with subsequent retrievals (optical thickness, effective particle radius, and ice/liquid water content).

In this product, we combine three different and well documented approaches for inferring cloud phase into a single algorithm. The algorithm is applied to data obtained by the MODIS (MODerate resolution Imaging Spectroradiometer) and POLDER3 (Polarization and Directionality of the Earth Reflectance) instruments. It has been shown that this synergistic algorithm can be used routinely to derive cloud phase along with an index that helps to discriminate ambiguous phase from confident phase cases.

General Principle

The approach proposed in this study is based on the synergy between the POLDER-3/Parasol (POLarization and Directionality of the Earth Reflectances) and MODIS/Aqua (MODerate resolution Imaging Spectroradiometer) instruments operating in the framework of the A-Train mission.

The potential of using polarization measurements of the reflected shortwave radiation to infer cloud phase has been clearly demonstrated using POLDER observations (Goloub et al., 2000; Riedi et al., 2001). The MODIS instrument provides information on cloud phase using two methods that rely on spectral measurements in the visible, shortwave to midrange infrared, and thermal infrared (Platnick et al., 2003). However, both the instruments and the specifically designed retrieval algorithms have limitations that need to be understood and recognized to prevent drawing misleading conclusions from analysis of the data products. Fortunately, limitations from one instrument can partly be mitigated by capabilities available from the other, as has been demonstrated by Riedi et al, 2010.

The rationale for merging the three afore mentioned methods is twofold. First, because each method has its own limitations, it is not always possible to provide a definitive phase determination based on a single technique. By implementing multiple approaches, the phase information content can be improved.

The second reason is that when all three methods provide a “reliable” answer, a general agreement between them provides a higher confidence level in the retrieval. When they disagree, this information is again useful because it provides guidance for focused attention and potential for identification of multilayer situations or mixed phase clouds.

In a first step, the algorithm is designed to compute a cloud phase index from each of the three individual methods. All algorithms are applied on POLDER and MODIS measurements at a spatial resolution of 6 km × 6 km corresponding to POLDER level 1 full resolution data with MODIS radiances being collocated and averaged over each corresponding POLDER pixel (see Fig. 2 from Riedi et al, 2010). In a second step the algorithm merges the individual decision using a logical decision tree (see Fig. 4 from Riedi at al, 2010) that has been built from a careful statistical analysis of each method strengths and weaknesses (see Zeng et al, 2013).

The resulting product (see Fig. 10 from Riedi et al, 2010) provides a semi-continuous index ranging from confident liquid to confident ice instead of the usual discrete classification of liquid phase, ice phase, mixed phase (potential combination of ice and liquid particles), or simply unknown phase clouds. The index value provides simultaneously information on the phase and the associated confidence. This approach is expected to be useful for cloud assimilation and modeling efforts while providing more insight into the global cloud properties derived from satellite data.

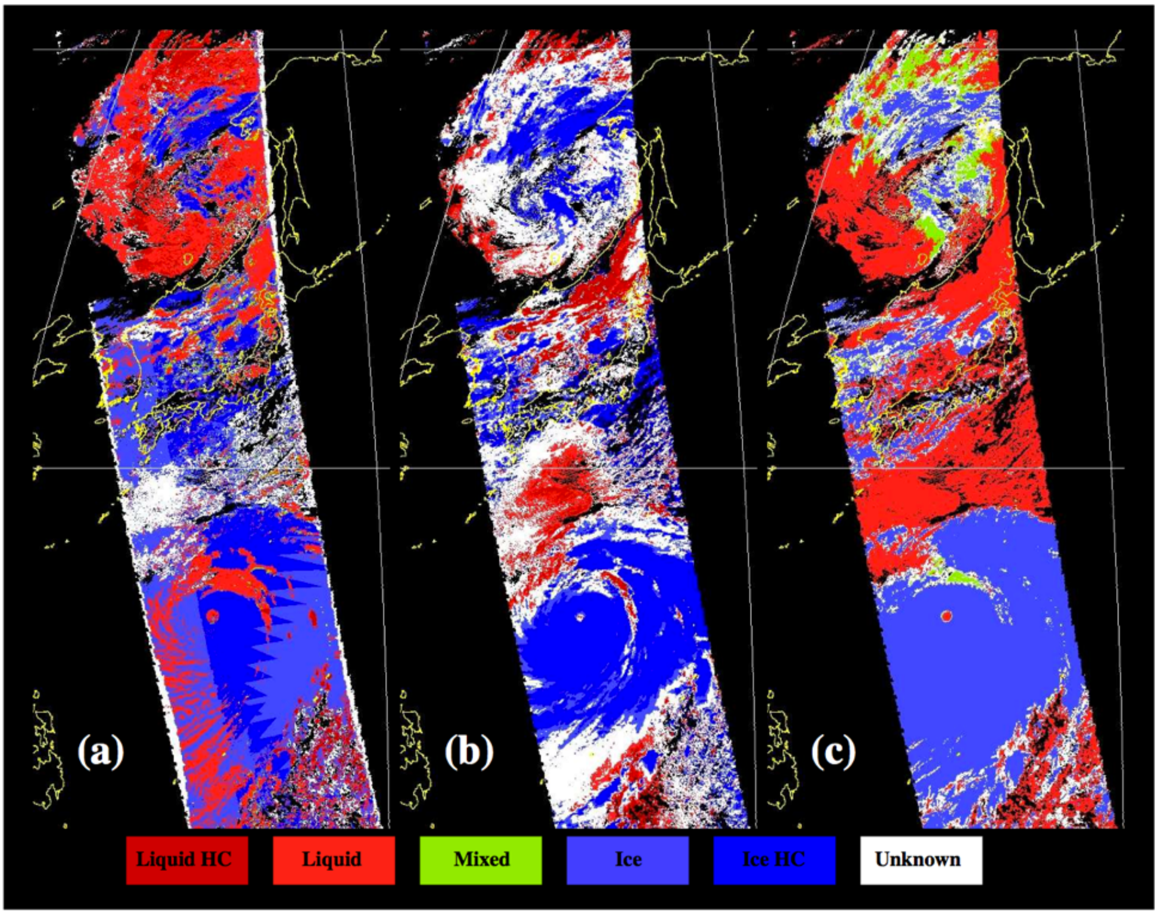

Fig. 3. Results of the partial cloud phase index retrieved from **(a)** POLDER polarization algorithm, **(b)** MODIS SWIR based algorithm and **(c)** MODIS bispectral IR algorithm.

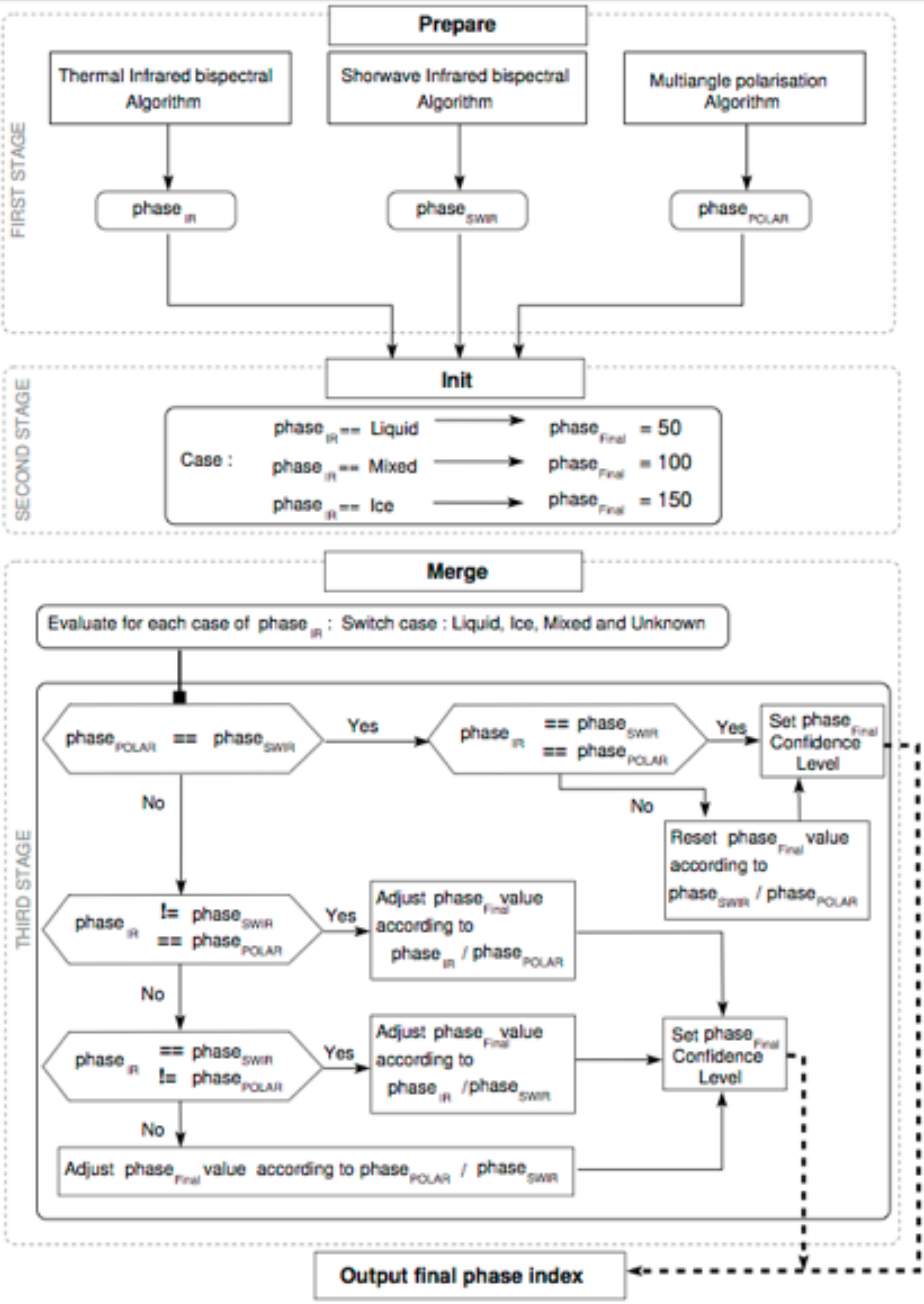

Fig. 4. Flowchart of the merging algorithm and decision tree used to produce the final cloud phase index.

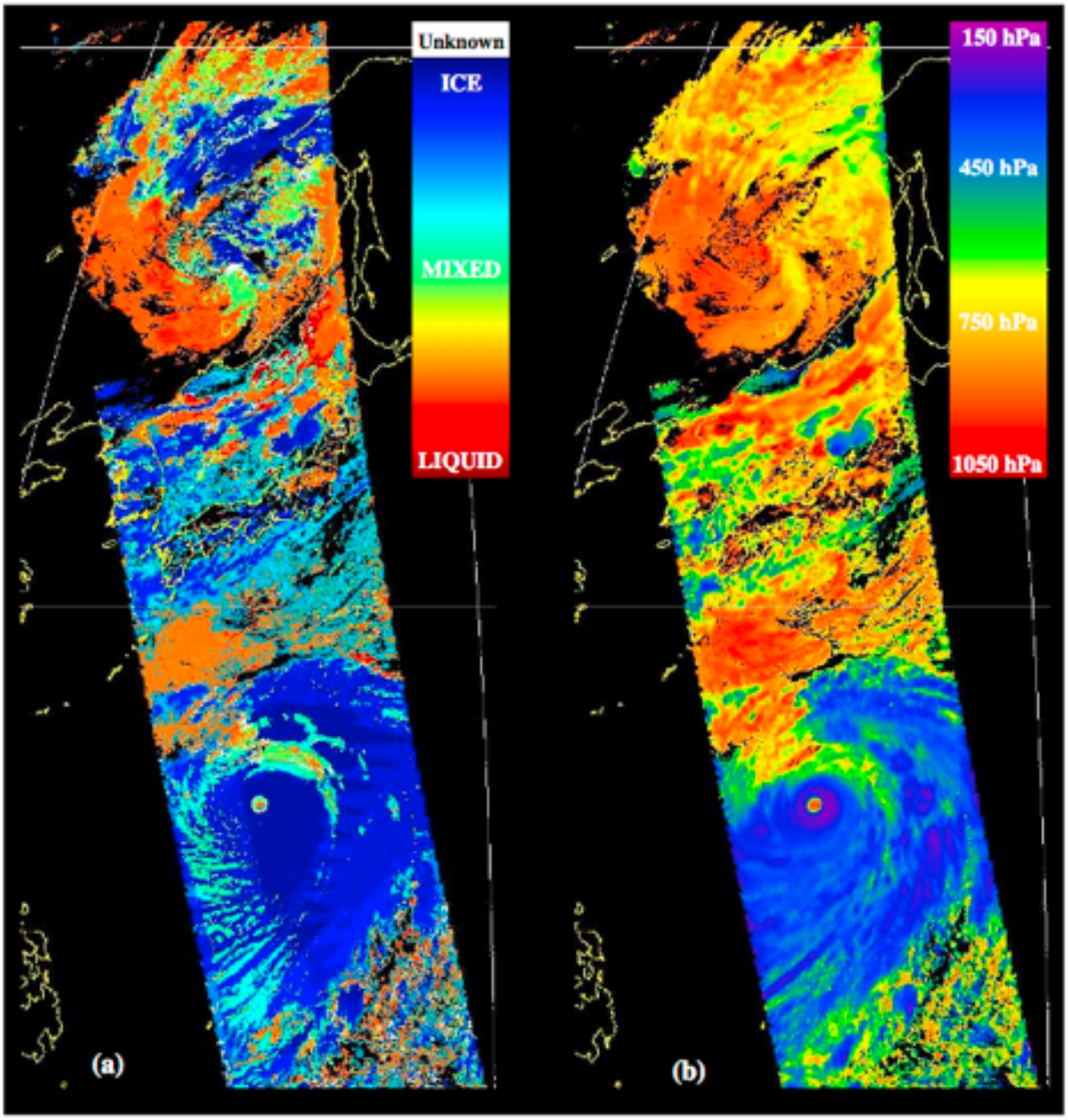

Fig. 10. **(a)** Results of the final cloud phase index retrieved from a combination of POLDER and MODIS data. **(b)** Cloud top pressure derived from POLDER oxygen A-Band method.

Contact

Any questions should be directed to J. Riedi (Jerome.riedi@univ-lille1.fr)

Reference

Riedi, J., Marchant, B., Platnick, S., Baum, B. A., Thieuleux, F., Oudard, C., Parol, F., Nicolas, J.-M., and Dubuisson, P.: Cloud thermodynamic phase inferred from merged POLDER and MODIS data, Atmos. Chem. Phys., 10, 11851-11865, doi:10.5194/acp-10 11851-2010, 2010.

Zeng, S., Riedi, J., Parol, F., Cornet, C., and Thieuleux, F.: An assessment of cloud top thermodynamic phase products obtained from A-Train passive and active sensors, Atmos. Meas. Tech. Discuss., 6, 8371-8411, doi:10.5194/amtd-6-8371-2013, 2013.