Evaluating the MODIS C6 multilayer cloud detection and phase algorithms through comparisons with CALIOP and CloudSat

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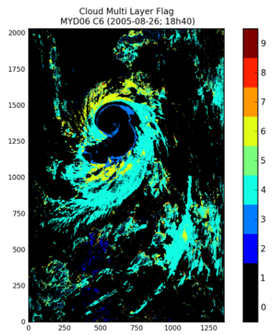
I - Introduction

Modis L2 multilayer cloud detection is stored in a SDS and QA bit (Wind et al. 2010; MODIS C6 User Guide):

- Multilayer cloud SDS = 0 (no cloud detected)
- Multilayer cloud SDS = 1 (monolayer)
- Multilayer cloud SDS = [2-9] (multilayer)

Based on 4 independent tests and only when Modis cloud optical thickness > 4:

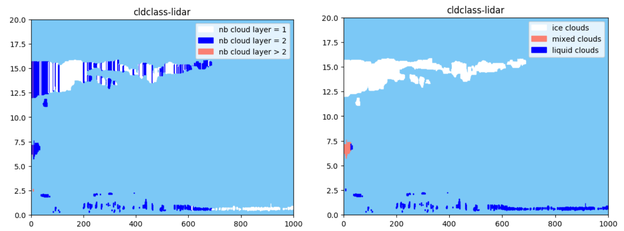
- IR and SWIR cloud phase diff.+1 (QA1)
- Delta precipitable water+2 (QA2)
- Delta precipitable water with cloud at 900mb+2 (QA3)
- Pavolonis-Heidinger (P-H test) + 3 (added in C6) (QA5)
- Note that COT diff test is not used anymore +1 (QA4)



II - Data Preparation

To evaluate MODIS C6 multilayer cloud a colocated dataset over the year 2008 has been created using Cloudsat and Caliop products:

- Cldclass-lidar (cloud mask & phase)
- Caliop 5km cloud layer product (cloud optical thickness)



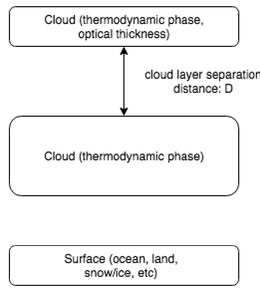
III - Modis multilayer and phase detection

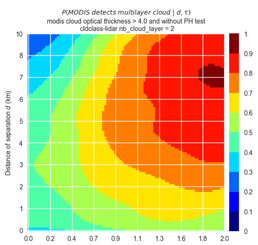
Three main parameters have been used to evaluate modis multilayer clouds:

- cloud layer separation distance: d (cldclass-lidar)
- cloud optical thickness upper layer (caliop 5km cloud layer products)
- cloud layer thermodynamic phase (cldclass-lidar)

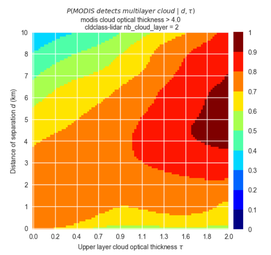
Only two cloud layer cases have been considered (two different phase and/or two separate cloud layers)

Probability that Modis detects a multilayer cloud given the separation distance d and the upper layer cloud optical thickness (regardless the cloud thermodynamic phase) :

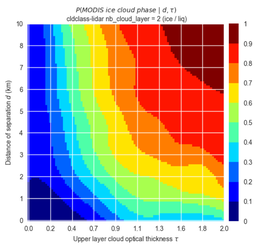




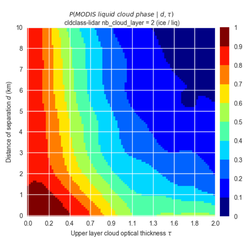
(Left Fig.) With the Pavolonis & Heidinger test turned off. The test is really sensitive to multilayer clouds even when the separation distance is low (Right Fig.)



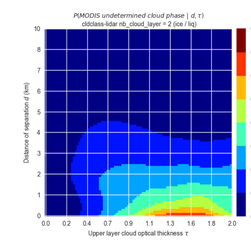
Impact of multilayer cloud on Modis cloud thermodynamic phase detection. Example for ice overlapping liquid clouds



Probability of Modis ice cloud phase given the separation distance d and the upper layer cloud optical thickness



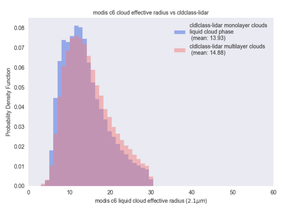
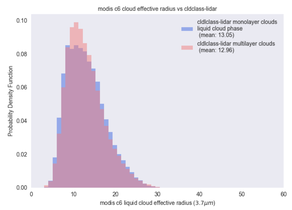
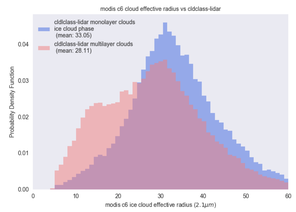
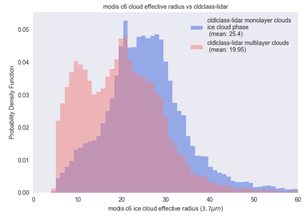
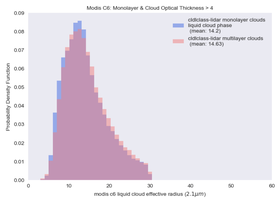
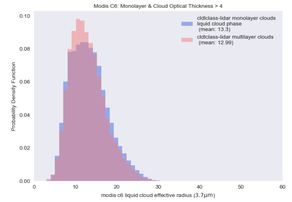
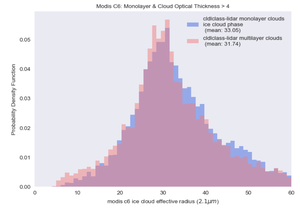
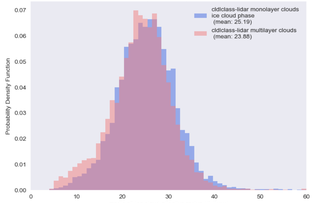
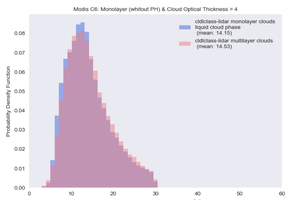
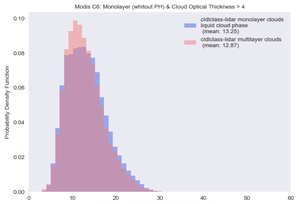
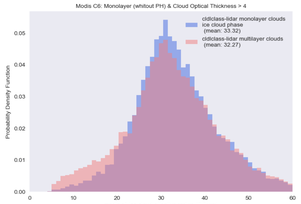
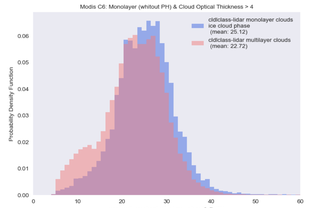
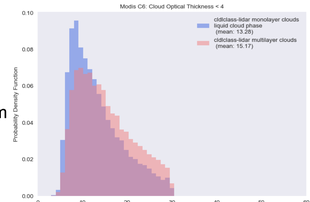
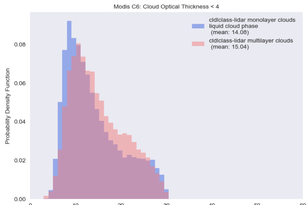
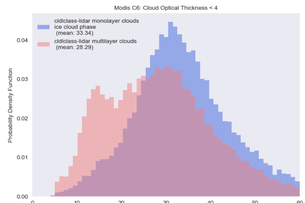
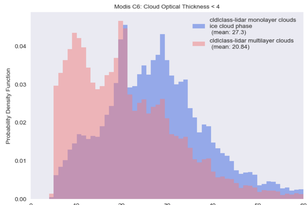
Probability of Modis liquid cloud phase given the separation distance d and the upper layer cloud optical thickness



Probability of Modis Undetermined cloud phase given the separation distance d and the upper layer cloud optical thickness

IV - Impact of multilayer clouds on MODIS cloud effective radius retrievals

Modis cloud effective radius differences for monolayer and multilayer cloud pixels according to CloudSat and Caliop

	Liquid Cloud Effective Radius		Ice Cloud Effective Radius	
	2.1 micron	3.7 micron	2.1 micron	3.7 micron
A) All multilayer clouds (regardless cloud phase, distance of separation or optical thickness) (blue = monolayer; red = multilayer; according to cloudsat & caliop) => important impact, especially for ice cloud effective radius				
B) Removing cloudy pixels flagged as multilayer clouds by Modis (and cloud optical thickness > 4) => Most of the cloud effective radius impacted by the multilayer clouds have been removed.				
C) same as above without using Pavalonis & Heidinger multilayer cloud detection test =>				
D) Modis cloud optical thickness lower than 4 where Modis multilayer cloud detection algorithm do not attempt to discriminate monolayer and multilayer clouds				

V - Conclusions

The main goal of MODIS multilayer cloud discrimination algorithm is not to detect all multilayer clouds but to detect multilayer clouds that can affect the cloud optical products (such as the cloud effective radius or optical thickness): (1) Modis multilayer cloud detection improve with the separation distance of the cloud layers and the upper layer cloud optical thickness (2) Strong impact on multilayer clouds on cloud effective radius retrievals (in particular for ice clouds) (3) Modis multilayer cloud classification can be used to filter multilayer clouds that affects cloud effective radius

VI - References

(1) Wind et al. 2006: Multilayer Cloud Detection with the MODIS Near-Infrared Water Vapor Absorption Band (2) Pavolonis and Heidinger 2004: Daytime Cloud Overlap Detection from AVHRR and VIIRS (3) Platnick et al. 2017: The MODIS Cloud Optical and Microphysical Products: Collection 6 Updates and Examples From Terra and Aqua (4) Marchant et al. 2016: MODIS Collection 6 shortwave-derived cloud phase classification algorithm and comparisons with CALIOP