A Validation for Retrieving Cloud Optical and Microphysical Properties in the IR Region using MODIS and AIRS

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I. Study

Cloud property retrievals performed within the infrared (IR) spectrum introduce challenges not prevalent in current retrieval processes that utilize solar and near-infrared wavelengths, yet IR radiance observations are critical for any nighttime retrieval method. Radiances measured at top of atmosphere (TOA) are sensitive to multiple input parameters, including skin temperature, vertical temperature and water vapor profiles, cloud height and physical thickness, and gaseous absorption due to O_3, CO_2, CH_4, and N_2O for example. Furthermore, employing a lookup table approach to retrieve cloud properties, such as effective size and optical thickness based on brightness temperature differences derived from simulated radiances, may inherit or intensify errors from specified input parameters. This study provides a validation for cloud property retrievals using selected MODIS IR channels and AIRS profile information by:

- Determining the expected variability in radiance simulations at 8.5-, 11.0- and 12.0-µm for cloud-free atmospheric profiles.
- Simulating TOA radiances at 8.5-, 11.0- and 12.0-µm for atmospheric profiles containing a single cirrus cloud layer, and determining the expected variability in radiance calculations.
- Comparing the difference of simulated and MODIS observed radiances (MODIS channels 29, 31 and 32) to the difference of input parameters from AIRS and MODIS for various pixels.

II. Model

A model has been developed to simulate radiances for user-specified clear and cloudy sky MODIS pixels. MODIS level-2 cloud product (collection 5) provides the simulations with geolocation and viewing geometries. AIRS level-2 standard retrieval product supplies profile data and cloud top properties.

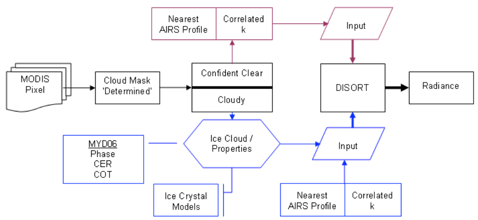

Figure 1. Model for Clear-Sky and Cloudy MODIS Pixel Simulations

- Clear-sky simulation steps in Figure 1 are shown with red borders. For each MODIS pixel flagged as "confident clear", the nearest AIRS pixel is located for atmospheric profile data. Atmospheric gaseous absorption is calculated using the correlated k-distribution method.
- Cloudy sky simulation steps in Figure 1 are shown with blue borders. Pixels flagged as "cloudy" are then filtered for ice cloud only. MODIS level-2 cloud product provides cloud effective radius (CER) and cloud optical thickness (COT), while ice crystal models are provided by Baum et al. AIRS provides profile data along with cloud top pressure to determine the cloud layer height.

III. Case Simulations

Figure 2 shows a MODIS daytime granule (MYD021KM.2005343.2320) in the central Pacific, December 9, 2005, the simulated clear-sky area, and the simulated cloudy sky (cirrus) region.

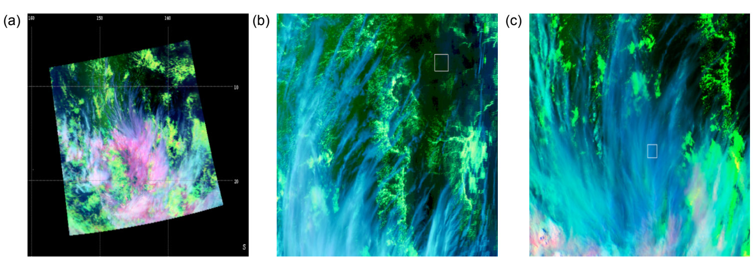

Figure 2. An RGB image with 0.65-µm radiance represented in red, 2.13-µm radiance represented in green, and 11.0-µm radiance represented in blue (a) enhancement of clear-sky case area (b) and enhancement of cloudy case area (c)

IV. Clear-Sky Results

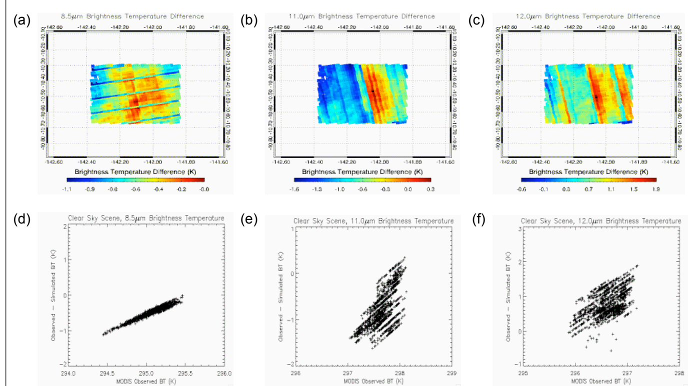

Figure 3. Brightness temperature differences (observed - simulated) at (a) 8.5-, (b) 11.0-, and (c)12.0-µm for clear-sky region with corresponding scatter plots (d), (e), and (f).

Discussion

Figure 3 shows simulated radiances under-estimate observed values by MODIS at 8.5- and 11.0-µm, but over-estimate at 12.0-µm. Figure 4 shows the four regions in the simulation which use different AIRS pixels. The AIRS pixel boundaries correlate well with the sharp cutoff in accuracy within the simulation area, showing clear sensitivity to the temperature and water vapor profiles in clear-sky simulations. This is an expected result as the AIRS profile (pixel) is an average over a 40km X 40km area at nadir.

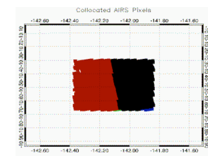

Figure 4. Shaded areas show AIRS profile coverage from the four AIRS pixels in the simulation area.

V. Cloudy Sky Results

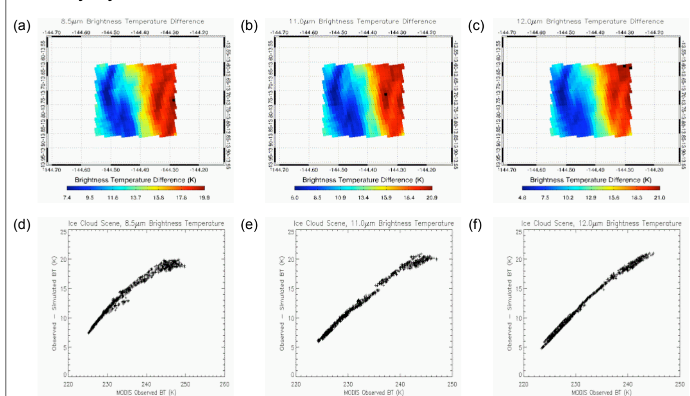

Figure 5. Brightness temperature differences (observed - simulated) at (a) 8.5-, (b) 11.0-, and (c)12.0-µm for cloudy sky region with corresponding scatter plots (d), (e), and (f).

Discussion

Figure 5 shows simulated radiances for all wavelengths under-estimate MODIS observations. The accuracy of the simulated brightness temperature varies with varying optical thickness. For thicker cirrus, the cloud radiates nearly as a blackbody, where observed minus simulated BT differences may be accounted for by error in cloud layer placement or physical thickness. For optically thinner cirrus, much larger differences are present as transmission of radiation to TOA appears to be inhibited.

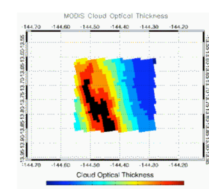

Figure 6. MODIS level-2 Cloud Optical Thickness.

VI. On-going Research

Differences between observed and simulated radiances must be explained and minimized before acceptable IR retrievals can be achieved. Crucial tasks include to:

- Investigate sensitivities to simulated radiances at TOA to input parameters such as skin temperature, temperature profile, and water vapor profile.
- Determine and mitigate the effects of AIRS spatial resolution.
- Incorporate more accurate method to improve cloud layer placement and physical thickness.
- Determine thresholds of cloud effective radius and cloud optical thickness for importance in regards to IR cloud radiative forcing.

A theoretical case study is under development and will be applied to MODIS data in order to resolve these differences and create a new retrieval method.

VII. Acknowledgements

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VIII. References

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