Retrieval of Aerosol Optical Properties under Thin Cirrus from MODIS

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Cirrus Correction to TOA Reflectance

Retrieval of aerosol optical properties using shortwave bands from passive satellite sensors, such as MODIS, is typically limited to cloud-free areas. However, if the clouds are thin enough (i.e. thin cirrus) such that the satellite-observed reflectance contains signals under the cirrus layer, and if the optical properties of this cirrus layer are known, the TOA reflectance can be corrected for the cirrus layer to be used for retrieving aerosol optical properties.

To this end, we first correct the TOA reflectances in the aerosol bands (0.47, 0.55, 0.65, 0.86, 1.24, 1.63, and 2.12 μm for ocean algorithm and 0.412, 0.47, and 0.65 μm for deep blue algorithm) for the effects of thin cirrus using 1.38 μm reflectance and conversion factors that convert cirrus reflectance in 1.38 μm band to those in aerosol bands. It was found that the conversion factors can be calculated by using relationships between reflectances in 1.38 μm band and minimum reflectances in the aerosol bands (Gao et al., 2002). Refer to the example in the figure.

Then, the cirrus-corrected reflectance can be calculated by subtracting the cirrus reflectance from the TOA reflectance in the optically thin case. A sensitivity study suggested that cloudy-sky TOA reflectances can be calculated with small errors in the form of simple linear addition of cirrus-only reflectances and clear-sky reflectances.

In this study, we correct the cirrus signals up to TOA reflectance at 1.38 μm of 0.05 where the simple linear addition is valid without extensive radiative transfer simulations. When each scene passes the set of tests shown in the flowchart, the scene is corrected for cirrus contamination and passed into aerosol retrieval algorithms.

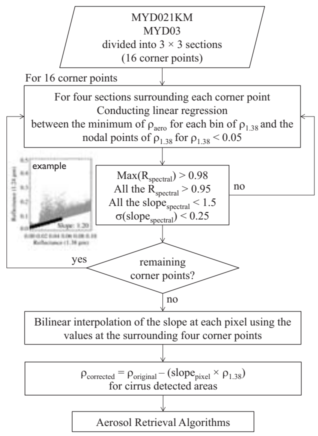

Figure 1. Flowchart of the TOA reflectance correction for thin cirrus signals.

Retrieval Results

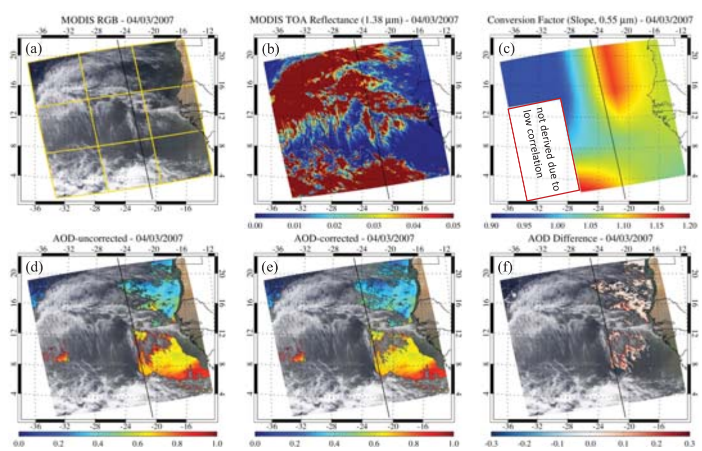

Figure 2. (a) MODIS RGB image, (b) TOA reflectance at 1.38 μm, (c) $\rho_{1.38}$-to-aerosol band conversion factors at 0.55 μm, (d) AOD without cirrus correction, (e) AOD with cirrus correction, and (f) AOD correction magnitude (AOD-uncorrected – AOD-corrected). Data for the MODIS granule collected at 15:05 UTC on 4 March 2007. The black line represents the CALIOP observation track.

Evaluation

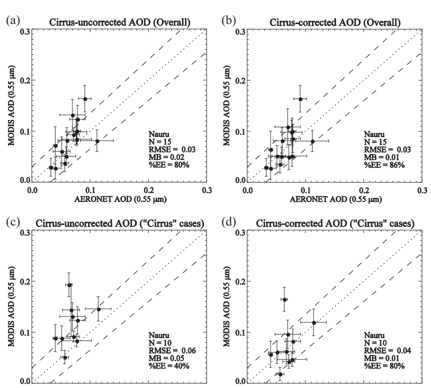

Figure 3. Comparisons of MODIS AODs against AERONET observations at Nauru site for the cases of (a) AOD-uncorrected overall data, (b) AOD-corrected overall data, (c) AOD-uncorrected cirrus-present cases, and (d) AOD-corrected cirrus-present cases. The solid, dotted, and dashed lines represent the linear least square regression, 1:1, and MODIS expected error (EE) lines, which is defined as ±(0.03 + 0.05 × AOD), respectively. The statistics shown are the number of data points (N), root-mean-squared error (RMSE), mean bias (MB), and the percentage within the expected error (%EE).

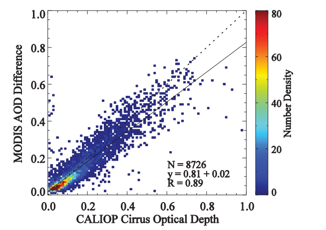

Figure 4. Scatter density plot between CALIOP COD and MODIS AOD correction magnitude over the eastern tropics for the period from 1 March 2007 to 31 May 2007.

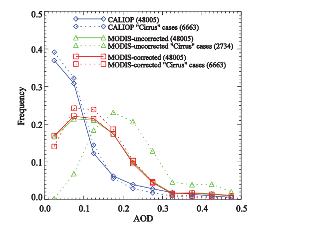

Figure 5. Normalized frequency distribution of CALIOP AOD and MODIS AOD data sets for different conditions. The same data coverage and period as used in Figure 4.

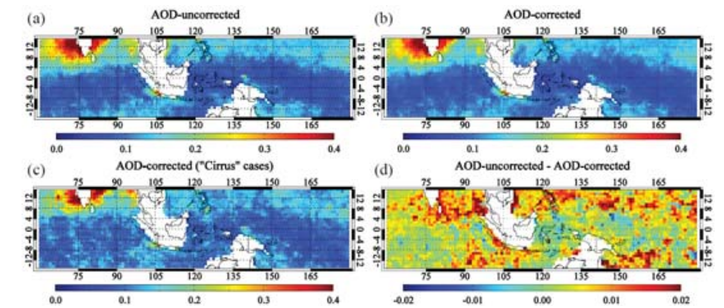

Figure 6. Spatial distribution of seasonal mean AOD for (a) AOD-uncorrected, (b) AOD-corrected, (c) AOD-corrected for cirrus-present cases, and (d) seasonal mean AOD difference over the eastern tropics for the period from 1 March 2007 to 31 May 2007.

Application to Deep Blue Algorithm

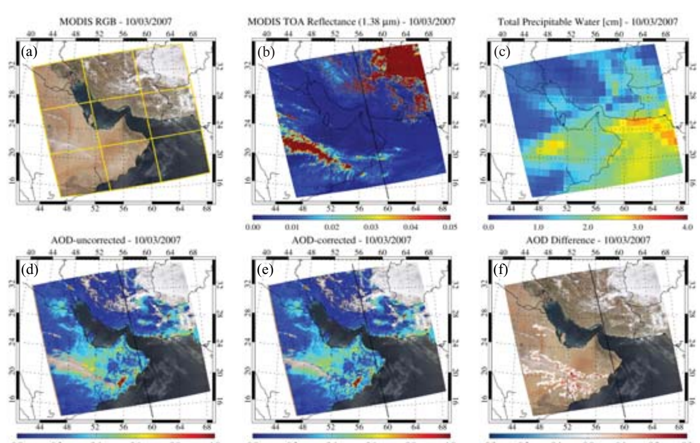

Figure 7. (a) MODIS RGB image, (b) TOA reflectance at 1.38 μm, (c) total precipitable water vapor, (d) AOD without cirrus correction, (e) AOD with cirrus correction, and (f) AOD correction magnitude. Data for the MODIS granule collected at 09:35 UTC on 10 March 2007. The black line represents the CALIOP observation track.

Discussion

- A strategy for retrieving aerosol optical properties under thin cirrus coverage is presented.
- The method can be applied to both bright and dark surfaces as long as columnar water vapor amount is sufficient to screen the surface signal.
- However, strong spatial inhomogeneity of land surfaces sometimes cause poor correlation between reflectances in 1.38 μm and aerosol bands, such that the method becomes not applicable.
- Improvements in the linear assumption are underway by conducting sophisticated radiative transfer calculations to extend the applicability to thicker cirrus clouds and to achieve better accuracy.

Acknowledgements

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References

Gao, B.-C., P. Yang, W. Han, R.-R. Li, and W. J. Wiscombe (2002), An algorithm using visible and 1.38-μm channels to retrieve cirrus cloud reflectances from aircraft and satellite data, *IEEE Trans. Geosci. Remote Sens.*, *40*(8), 1659–1668.

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