Paper #

Detection of Aerosol Signal from Geostationary Satellite Visible Imagery

Anand K. Inamdar[1] & Ken Knapp[2]

[1]Cooperative Institute for Climate and Satellites (CICSNC), NOAA/NCDC, Asheville, [2] NOAA/NCDC, Asheville NC 28801

Introduction

Aerosols play an important role in the earth system through their direct interaction with solar radiation altering the energy budget and affecting the weather patterns. Aerosols generated from wildfires, dust episodes and biomass burning also impact the human health. Further, observations at AERONET sites indicate diurnal variations of aerosol optical depth ranging between 10 – 20 % which significantly influence the radiative forcing and aerosol interaction with humidity and clouds (Holben et al 1998). During the past decades, aerosol retrieval has been confined to polar orbiters such as the Advanced Very High Resolution Radiometer (AVHRR) and Moderate Resolution Imaging Spectroradiometer (MODIS) instruments, etc. and mostly over the oceans. The present study aims to build upon the earlier attempts (Knapp 2002; Knapp et al 2005) to use geostationary orbits and extend the study in time and space covering the entire suite of geostationary satellites available through the International Satellite Cloud Climatology Project (ISCCP) B1 data since 1979. The visible channel of the ISCCP B1 data have been recently re-calibrated (Inamdar & Knapp, 2011) to Moderate Resolution Imaging Spectroradiometer (MODIS) standard through match-up with the Advanced Very High Resolution Radiometer (AVHRR) PATMOS-x data set (Heidinger et al 2010). With the added advantage of higher temporal resolution, geostationary data offers better potential for aerosol retrieval which will aid in monitoring of the pollutant transport from biomass burning, forest fires and aviation. The study reported here outlines the development of the strategy and results presented are preliminary in nature.

This study proposes to extend aerosol retrieval over the global land surfaces employing the re-calibrated GEO Visible Imagery from the ISCCP B1 data (1979-present).

Aerosol Signals in GEO Imagery

The signal received by a satellite consists of contributions from the surface, the intervening atmosphere, Rayleigh scattering by molecules and scattering and absorption by aerosols. The aerosol retrieval potential for any region can be assessed through comparing response of cloud-free satellite observations to changes in measured AOD. Knapp (2002) looked at aerosol signals at over 30 stations in North America during the period June to August 2001, through collocating observations from GOES-8 with measurements of AOD over AERONET sites.

In the present study, we extend the analyses to other important aerosol regions of the world as shown in the accompanying Figures 1 - 5.

Comparison of calibrated GEO visible reflectance in ISCCP B1 data with colocated measurements of AERONET AOD in diverse regions of the world indicate presence of an aerosol signal.

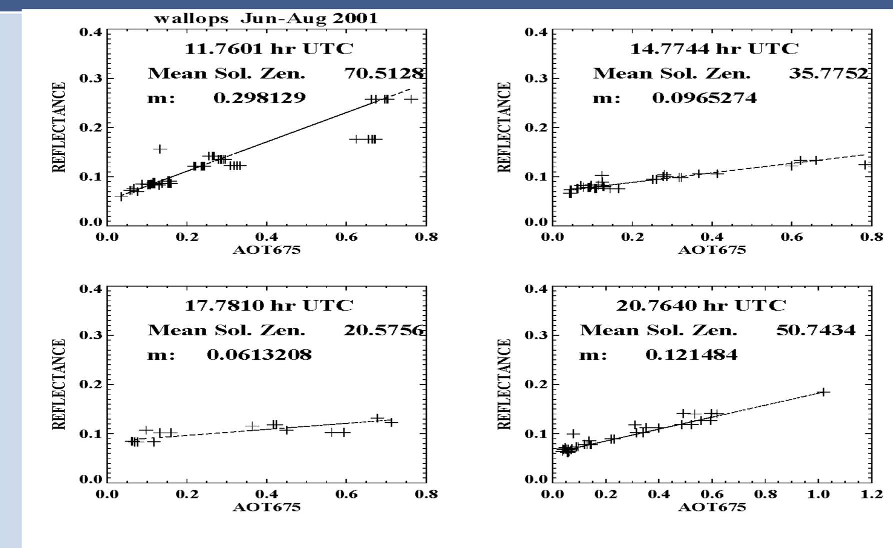


Fig.1 GOES-8-observed visible reflectance against AERONET Level 2 AOD at 0.67 µm at different times of the day at the Wallops site. It demonstrates the diurnal variation of the the regression slope, m, which is higher for higher solar zenith angles and the linear correlation is very good at all times of the day.

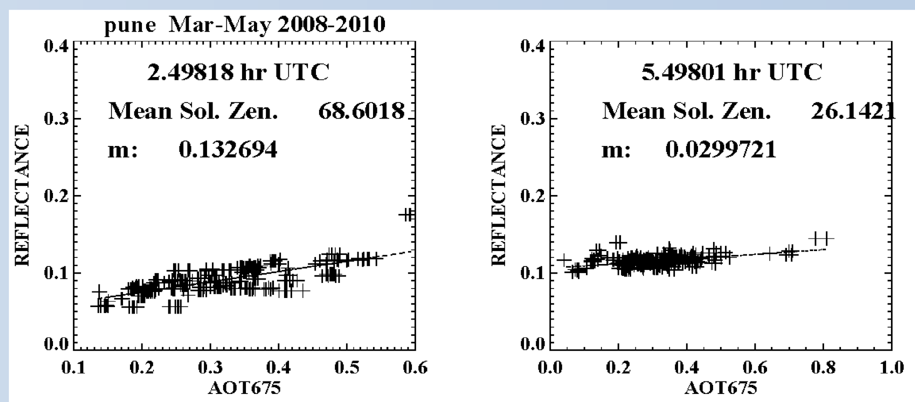


Fig. 2. Meteosat-7 visible reflectance versus AERONET AOD at Pune station in India. Pune is a fast-growing urban center, about 100 km inland of the West Coast of India. The city has experienced rapid industrialization with about 120 % growth in vehicular population during the last decade. The aerosols consist of water-soluble, soil, marine and soot.

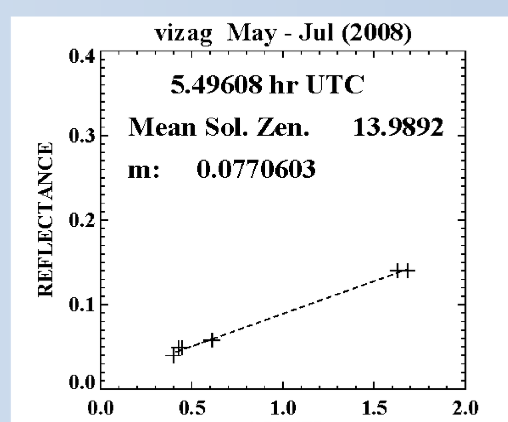


Fig. 3. Same as in Fig. 2, but for Vishakhapatnam, a coastal industrialized city in the east coast off Bay of Bengal. Absorbing black carbon is an important constituent.

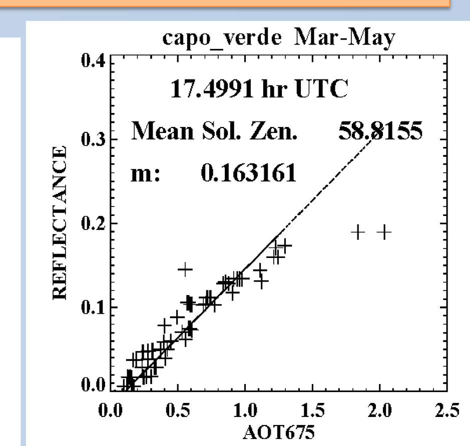


Fig. 4. Meteosat-observations of vis reflectance against AOD. Cape Verde is on west coast of Africa directly in the path of Saharan dust. Combination of high surface reflectivity and absorbing dust can make aerosol retrieval challenging.

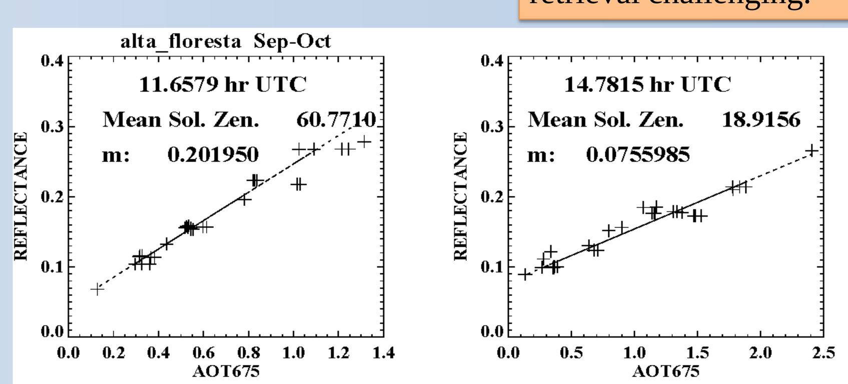


Fig. 5. Alta Floresta (South America) experiences prolific deforestation fires and agricultural burning during Sep – Oct period. This contributes to high loading of biomass burning aerosol over much of South America with AOD's exceeding 1. With darker underlying surface, these regions offer the best potential for aerosol retrieval.

Evaluation of Surface Reflectance

The presence of aerosol signals in GEO imagery alone, as shown in Figs. 1-5, is not sufficient for successful retrieval of aerosols. One must account for the effect of atmospheric gases, Rayleigh scattering and surface reflectance. Estimation of surface reflectance in advance is crucial in the satellite remote sensing of AOD. GEO imagery (especially pre-GVAR satellites prior to GOES-8) do not have the sophistication of polar orbiting sensors like MODIS, AVHRR, MISR, etc with their multiple channel configuration. Surface reflectances have been obtained from GEO satellites employing 30-day clear-sky composites of visible imagery with Second Simulation of the Satellite Signal in the Solar Spectrum (6S) code (Knapp et al 2005), through assuming a background aerosol signal. This method has limitations due to uncertainties relating to the aerosol optical properties themselves and in situations where the surface optical characteristics are rapidly varying.

Studies have shown that the presence of an additional mid-infrared 3.75 µm channel (Kim et al 2008; Kaufman et al 1994) greatly assists in the estimation of surface reflectance and aerosol retrieval. An advantage of this channel is that it is sensitive to the surface reflectance but least sensitive to aerosols, except for dust type aerosols.

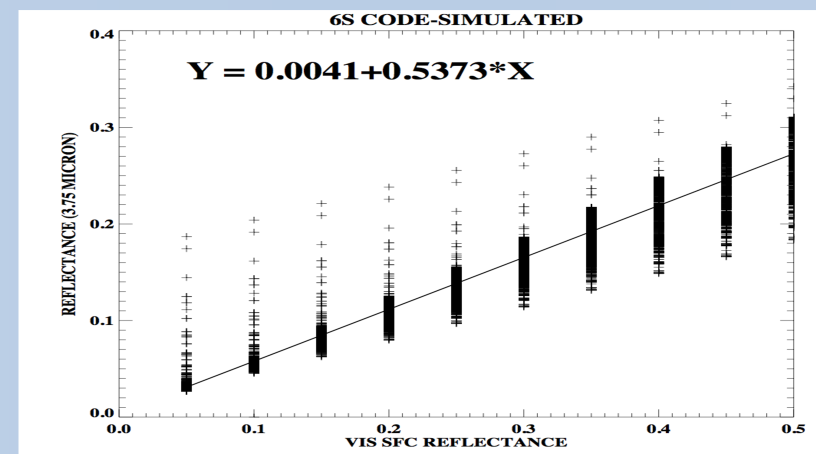


Fig. 6. Response of the AVHRR 3.75 µm reflectance to varying AOD for a range of surface reflectance (0 – 0.5 in steps of 0.05), incident solar zenith angles (0- 70^0, in intervals 5^0), view zenith angles (0-70^0 in steps of 5^0) and relative azimuth (0-180^0, in steps of 10^0), simulated from the 6S code.

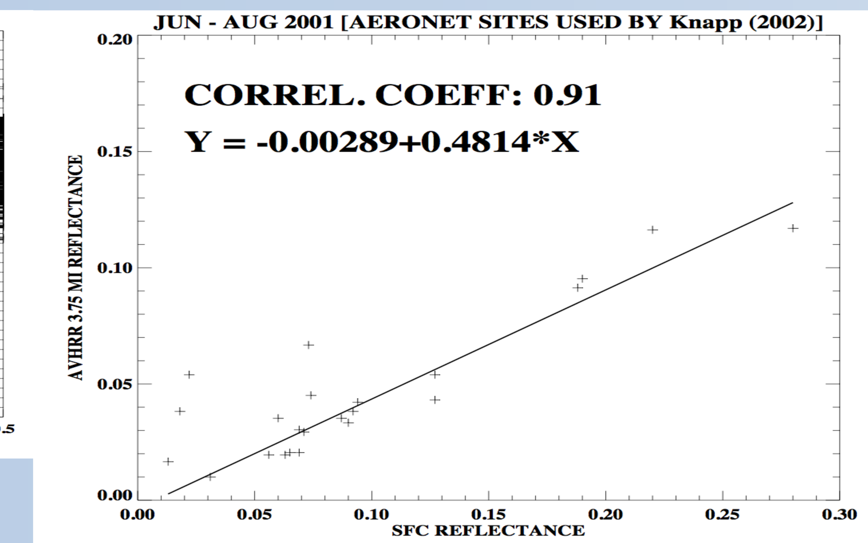
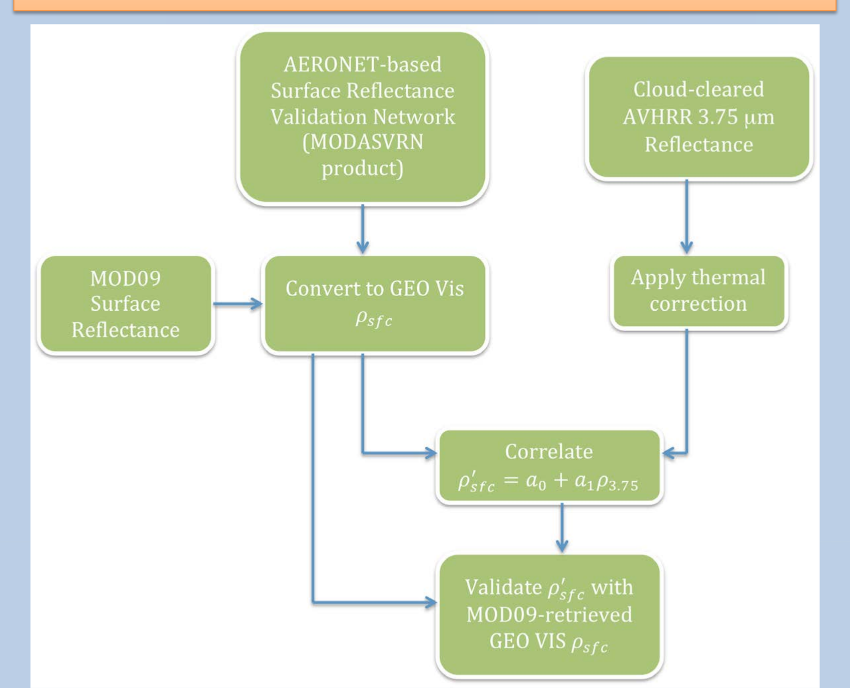


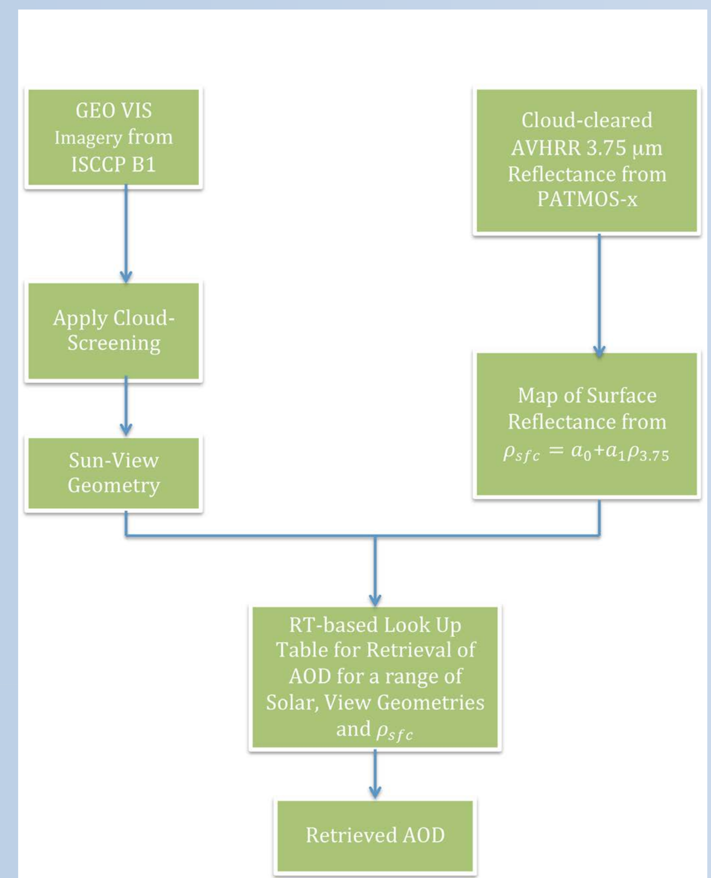
Fig. 7. Observed AVHRR 3.75 µm reflectance (after correcting for surface thermal emission) at the North American AERONET sites that were used in the study by Knapp (2002) against 6S-retrieved visible surface reflectance.

Results from both theoretical and observation-based studies (over the North American regions) indicate a great potential for the retrieval of GEO visible surface reflectance from the mid-IR channel.

Retrieval and Validation Plan for Surface Reflectance



Schematics of Aerosol Retrieval



Conclusions

- There is potential for aerosol retrieval over diverse regions of the globe using the re-calibrated ISCCP B1 data.
- Presence of a single visible channel in GEO satellites for aerosol retrieval over land poses additional difficulties in separating the aerosol signature from that due to ground reflection. Here we explore use of an additional mid-IR channel (3.75 µm) available on AVHRR.
- Results from both radiative transfer simulation and observations show consistent correlations between the reflective part of the mid-IR channel and surface reflectance.
- Availability of long time series of observations from both GEO and AVHRR satellites make them useful for processing long-term climate data records of AOD.

Future Work

Perform extensive validation of the surface reflectance estimated from the mid-IR AVHRR channel over diverse regions of the globe.

Perform retrievals of aerosol over different regions and validate with AERONET AOD's and MODIS-retrieved aerosols, and other LEO satellite sensors.

Acknowledgements

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References:

Inamdar, A. K., and K. R. Knapp, 2011: Assessment of calibration performance of the geostationary satellite imager visible channel in the ISCCP B1 data, Proceedings of the 92nd AMS Annual Meeting, New Orleans, Jan 25 2011.

Kaufman, Y. J., and L. A. Reemer, 1994: Detection of forests using mid-IR reflectance: an application for aerosol studies. IEEE Trans. Geoscience and Remote Sensing, 32, 672-683.

Kim, J., J. M. Yoon, M. H. Agn, B. J. Sohn, and H. S. Lim, 2008: Retrieving aerosol optical depth using visible and mid-IR channels from geostationary satellite MTSAT-1R., International J. Remote Sensing, 29, 6181-6192. reflectance (0-0.5),solar zenith (0-70^0), view zenith (0-70^0), and relative azimuth (0-180^0) angles.

Knapp, K. R., 2002: Quantification of aerosol signal in GOES-8 visible imagery over the U. S., J. Geophys. Res., 107, 10.1029/2001JD002001.

Knapp, K. R., R. Frouin, S. Kondragunta and A. Prados, 2005: Toward aerosol optical depth retrievals over land from GOES visible radiances: determining surface reflectance, International J. Remote Sensing, 26:18, 4097-4116.