Temporal Variations, Radiative Forcing, and Radiative Heating Rates of Absorbing Aerosols Above Clouds

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Background and Motivation

- Quantifying absorbing aerosol within and above clouds, including optical properties, radiative effects, and heating rates remains to be a challenge.
- Geostationary satellite enable the assessment of the diurnal variation of aerosols above clouds, which a key aspect of investigation.
- Radiative transfer models (RTM) provide a theoretical framework of aerosol optical depth (AOD) and cloud optical depth (COD) retrieval, radiative forcing and radiative heating rates calculations.

Methodology

- Radiative transfer models are used to retrieve aerosol and cloud optical properties and assess the direct radiative forcing and radiative heating rates.
- The diurnal variation is assessed by the simultaneous AOD/COD retrieval from solar channels (0.64 and 0.81µm) from SEVIRI based on color ratio technique pioneered by Jethva et al. (2013, IEEE).

SEVIRI 21 August 2013 (11Z)

Aqua 21 August 2015

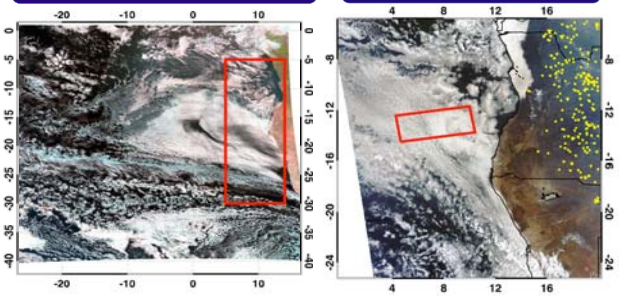

Fig. 1. RGB images over the southeast Atlantic when absorbing aerosols are present above clouds.

CALIOP 19 August 2009

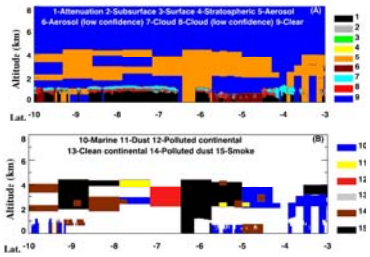

Fig. 2. (top) CALIOP Vertical Feature Mask and (bottom) aerosol subtype during an aerosol above/within clouds event (Chang and Christopher, submitted to QJRMS).

Radiative Transfer Model

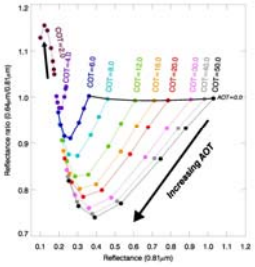

Fig. 3. The LUT showing the simultaneous AOD/COD retrieval from SEVIRI bands (Chang and Christopher, Accepted in IEEE).

RTM input parameters			
µm	SSA	Asy	AOT
0.44	0.84	0.64	0.45
0.67	0.79	0.52	0.20
0.86	0.76	0.46	0.12
1.02	0.75	0.45	0.08

Aerosol-cloud Diurnal Variations

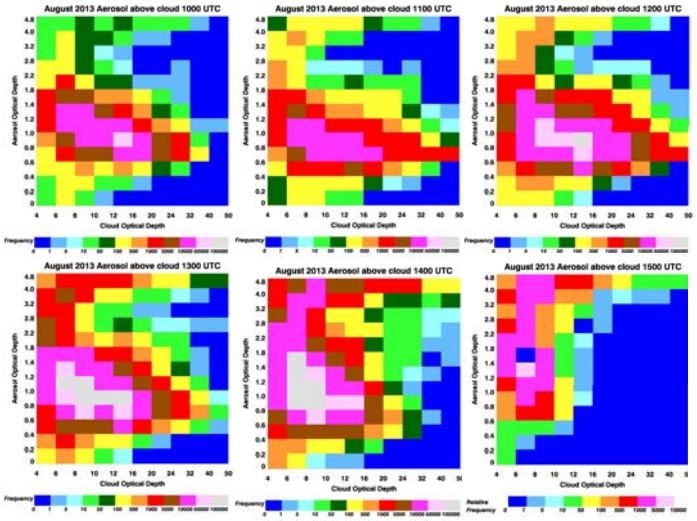

Fig. 4. Temporal and frequency distributions of AOD/COD pair (SZA<55) for aerosols above clouds for August 2013 from SEVIRI.

- For August 2013 near coast of southern Africa, highest AOD and COD pair are 0.8-1.0 and 12-16, respectively.
- Above-cloud AOD increases throughout the day, particularly in the afternoon hours.
- Below aerosol COD decreases during throughout the day.
- Homogeneous stratocumulus cloud fields indicate a minor changes in the reflectance values.

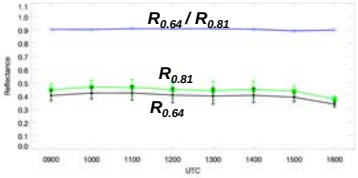

Fig. 5. Diurnal variations of reflectance and color ratio for absorbing aerosols above clouds on from 0900-1600UTC on 21 August 2015 from SEVIRI.

Summary and Future Work

- Above-cloud AOD increases throughout the day, particularly in the afternoon hours, while below-aerosol COD decreases in the afternoon.
- The critical COD occurs near COD=4, where TOA fluxes remain almost constant with increasing AOD. Aerosols induce scattering effects below the critical COD and absorbing effects above the critical COD.
- A long-term climatological trend along with A-Train collocation would be essential for more accurate understanding of aerosols above clouds.
- Field experiments including ORACLES, CLARIFY-2016, and LASIC will be important for the quantification and satellite validation of aerosols above and within clouds (e.g., radiative effects, heating rate profile, microphysical properties, and optical properties).

Radiative Forcing and Radiative Heating Rates

- Radiative fluxes depend more on the single scattering albedo than the asymmetry parameter.
- The critical COD occurs near COD=4, where TOA fluxes remain almost constant with increasing AOD. Aerosols induce scattering effects below the critical COD and absorbing effects above the critical COD.
- Radiative forcing become more positive with above-cloud AOD.

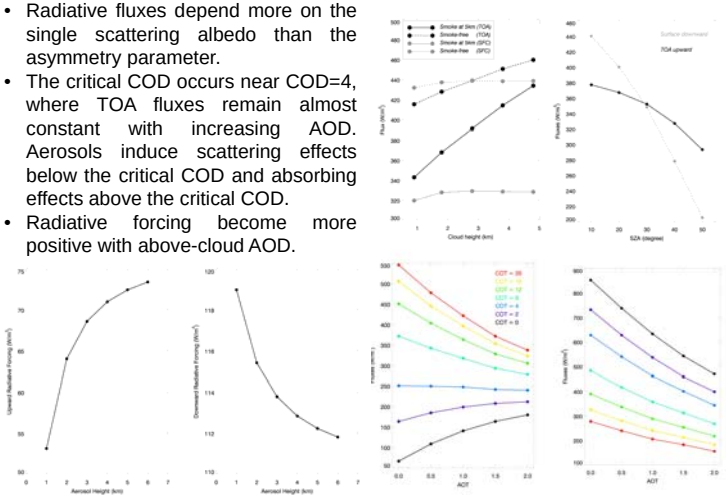

Fig. 6. Radiative forcing and fluxes under various aerosol-cloud scenarios.

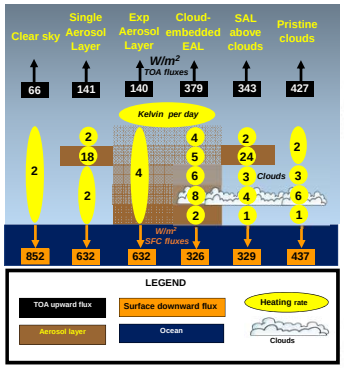

Fig. 7. Schematic of radiative fluxes and heating rates for aerosol above/within cloud cases.

TOA (down) ~1122Wm^{-2}, COS(SZA)=0.82, COS(VZA)=0.90, AOD(550nm)=1.0, COD(550nm)=10.0 r_c=10µm

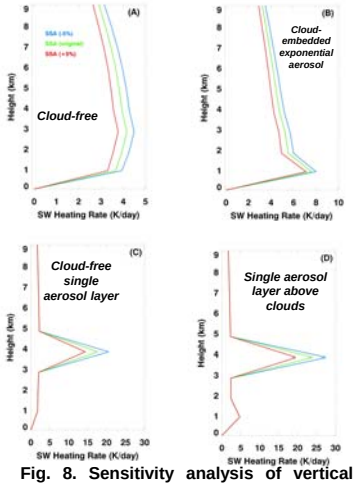

Fig. 8. Sensitivity analysis of vertical heating rates for various single scattering albedo.

Further Readings

- Chang, I. and S. A. Christopher, Identifying absorbing aerosols above clouds from the Spinning Enhanced Visible and Infrared Imager coupled with NASA A-Train multiple sensors. IEEE Transactions on Geoscience and Remote Sensing (Accepted).
- Chang, I. and S. A. Christopher, Impacts of vertical distributions of absorbing aerosols and clouds on the direct radiative forcing and radiative heating rates. Submitted to the Quarterly Journal of the Royal Meteorological Society.

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