Climate Application: Aerosol Direct Radiative Forcing

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Background Information

- SW – shortwave
- LW - longwave

Figure 1

Just Right!
Background Information

- AOD – Aerosol optical depth
  \[ \tau = \int_z^\infty k_{abs} \rho_a \, dz \]

- ADRE – Aerosol direct radiative effect
  \[ \text{ADRE} = (F_{aer,up} - F_{aer,down}) - (F_{0,up} - F_{0,down}) \]
  \[ F_{aer,up} = \text{Upward Flux with aerosols} \]
  \[ F_{aer,down} = \text{Downward Flux with aerosols} \]
  \[ F_{0,up} = \text{Upward Flux without aerosols} \]
  \[ F_{0,down} = \text{Downward Flux without aerosols} \]

- FE – Aerosol forcing efficiency
  \[ FE = \frac{d \text{ADRE}}{d \tau} \]
Background Information

- Aerosols increase scattering of SW radiation
- Aerosols can decrease outgoing LW radiation
Eastern China (20-40°N, 110-125°E) between March and October 2009

\[ ADRE = F_{0,TOA} - F_{aer,TOA} \]

- TOA – top of the atmosphere
- Normalization of \( F_{aer,TOA} \) – due to effects of solar zenith angle, water vapor, surface albedo, and Sun-Earth distance

**On the use of a satellite remote-sensing-based approach for determining aerosol direct radiative effect over land: a case study over China**

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Clouds and the Earth’s Radiant Energy System (CERES) on Terra
- Latitude, longitude, $F_{\text{aer,TOA}}$, 550 nm AOD, and precipitable water

Aerosol Robotic Network (AERONET)
- Single scattering albedo (SSA)

MODerate Imaging Spectroradiometer (MODIS) Land Cover Type Climate Modeling Grid product (MCD12C1)
- Identify in-land water bodies
- Provide SW broadband black-sky albedo $\rightarrow$ input for UVSPEC radiative transfer model

UVSPEC
- Determine ADRE diurnal variation and model $F_{0,\text{TOA}}$ for later comparison
Figure 5.
- Left – without normalizing
- Right – after normalizing

(Sundström, et al., 2015)
Application Papers – Sundström, et al.

- Figure 12.
  - Top row – instantaneous median ADRE
  - Middle row – 24hr averaged median ADRE
  - Bottom row – median AOD
Application Papers – Peris-Ferrús, et al.

- Western Mediterranean during a dust storm on June 23, 2008
- Heating rate profile, Aerosol Heating Rate (AHR), and surface and TOA ADRE
  - \[ ADRE = F_{aer}(z) - F_0(z) \]
  - \[ \frac{\Delta T(z)}{\Delta t} = -\frac{g}{c_p} \frac{\Delta F_{net}(z)}{\Delta p} \]
  - \[ AHR = \left( \frac{\Delta T(z)}{\Delta t} \right)_{AER} - \left( \frac{\Delta T(z)}{\Delta t} \right)_0 \]

Heating rate profiles and radiative forcing due to a dust storm in the Western Mediterranean using satellite observations

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**Highlights**

- We analyze the radiative impact of a dust storm through satellite observations and detailed radiative transfer modeling.
MODIS on Aqua
  - Retrievals of AOD and Angström exponent
Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) on CALIPSO
  - Retrievals of aerosol extinction profile
AERONET
  - Aerosol size distribution, SSA, and asymmetry parameter
MODerate spectral resolution atmospheric TRANsmission (MODTRAN) radiative transfer model
  - Inputs: aerosol extinction profile, asymmetry parameter, and AOD
Table 3.
- Instantaneous surface and TOA ADRE and FE
- Gray – land-sea surface pixels

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<th>SW FE (Wm⁻²)</th>
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(Peris-Ferrús, 2017)
Application Papers – Peris-Ferrús, et al.

- Figure 6.
  - 36 – 38°N
    - a) extinction profiles
    - b) AHR in SW
    - c) AHR in LW

(Peris-Ferrús, 2017)
Data Processing so far...

- Solar Insolation (W/m$^2$), TOA SW Upward Flux (W/m$^2$), and AOD
  - Spatially averaged
  - CERES and MODIS (filtered for dust AOD)
- Sahara Desert in 2016
  - Excludes February 19$^{th}$ – 27$^{th}$
Data Processing so far...

- Time series of Solar Insolation, TOA SW Upward Flux, and AOD
Data Processing so far...

- Scatter plot of AOD and TOA SW Upward Flux
- Linear fit between AOD and TOA SW Upward Flux

\[ FE = -97.6 \text{ W/m}^2/\text{unit of AOD} \]
\[ F_{0,\text{TOA}} = 79.8 \text{ W/m}^2 \]
Thank you!
References


- https://mynasadata.larc.nasa.gov/what-is-the-earths-radiation-budget/

