Climate Application: Aerosol Direct Radiative Forcing

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SIOG 135/236

Spring 2018

Background Information

- SW – shortwave
- LW - longwave

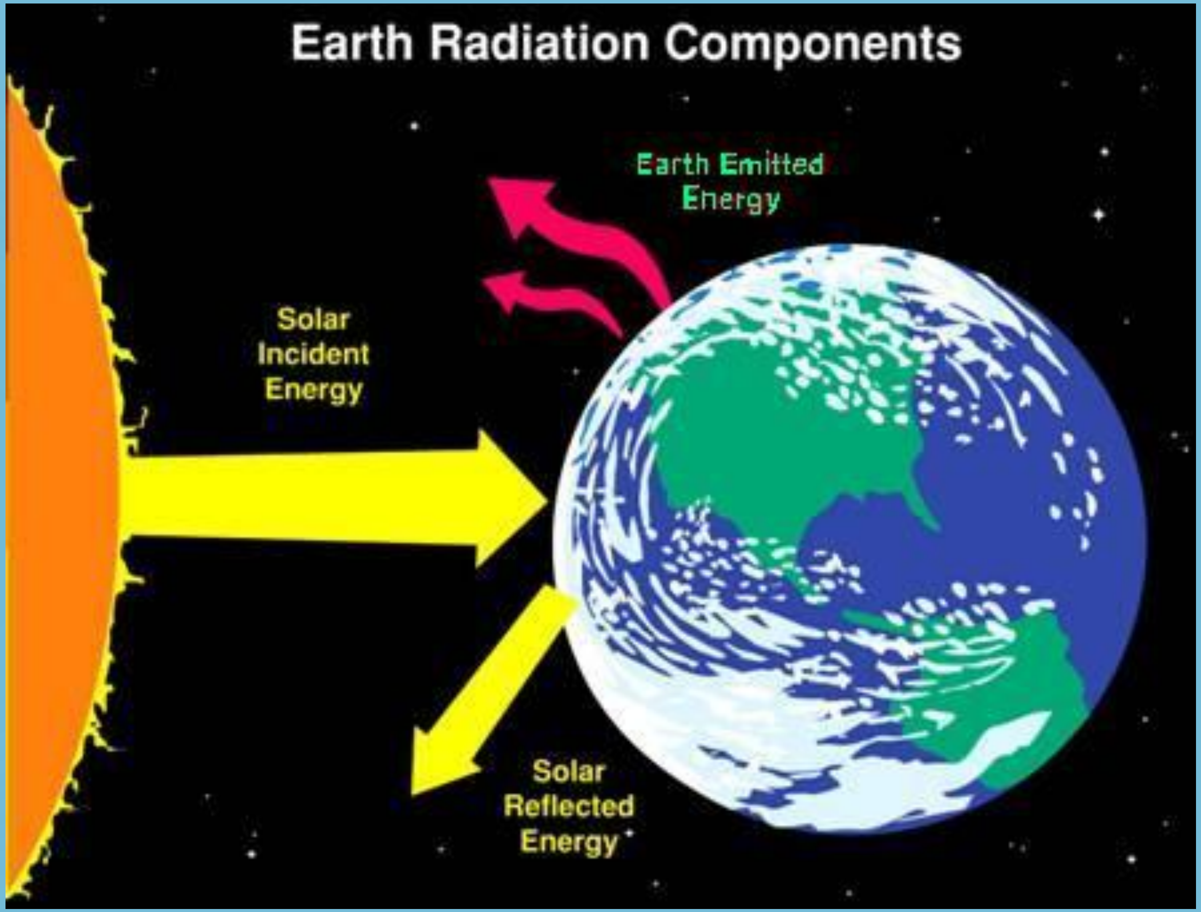

Figure 1.

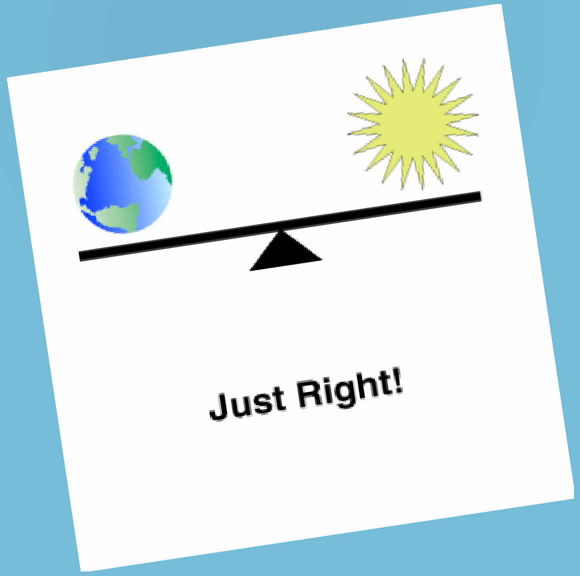

Figure 2.

Background Information

- AOD – Aerosol optical depth
  - $\tau = \int_z^\infty k_{abs} \rho_a dz$
- ADRE – Aerosol direct radiative effect
  - $ADRE = (F_{aer,up} - F_{aer,down}) - (F_{0,up} - F_{0,down})$
  - $F_{aer,up}$ = Upward Flux with aerosols
  - $F_{aer,down}$ = Downward Flux with aerosols
  - $F_{0,up}$ = Upward Flux without aerosols
  - $F_{0,down}$ = Downward Flux without aerosols
- FE – Aerosol forcing efficiency
  - $FE = \frac{d\ ADRE}{d\tau}$

Background Information

- Aerosols increase scattering of SW radiation

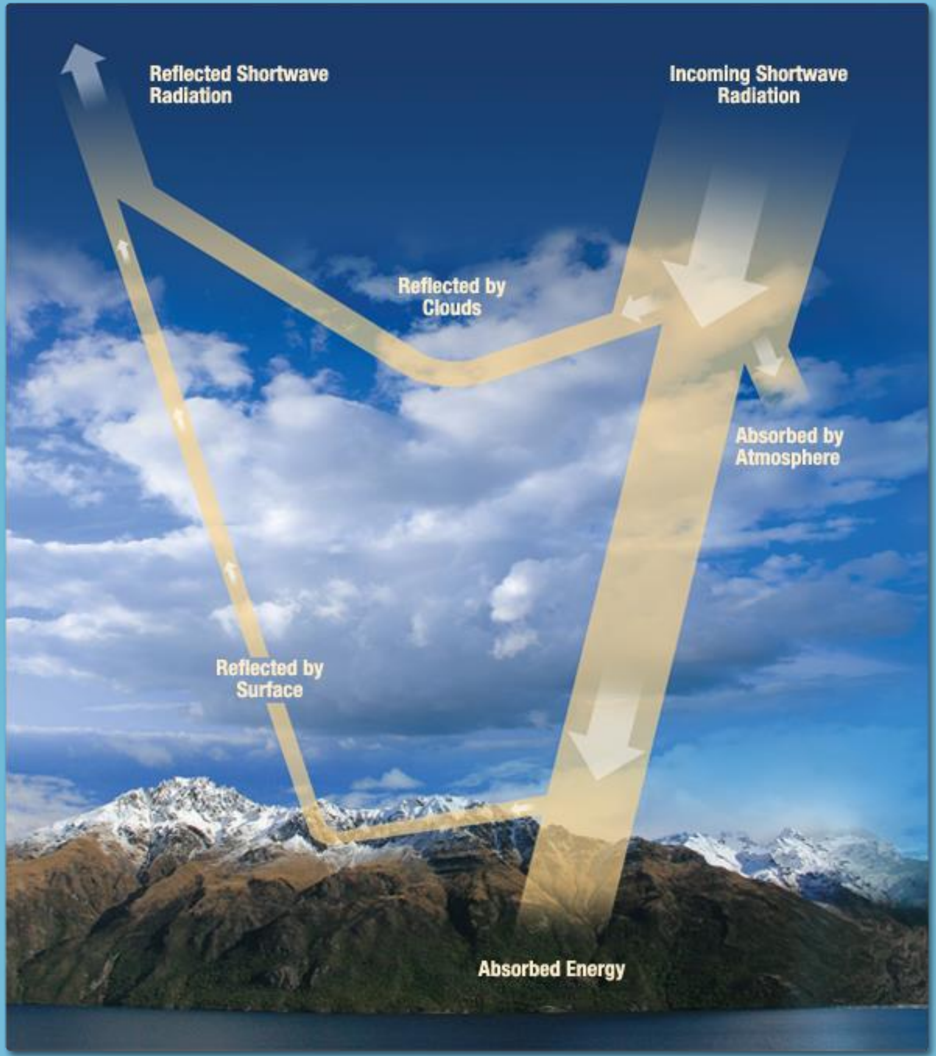

Figure 3.

- Aerosols can decrease outgoing LW radiation

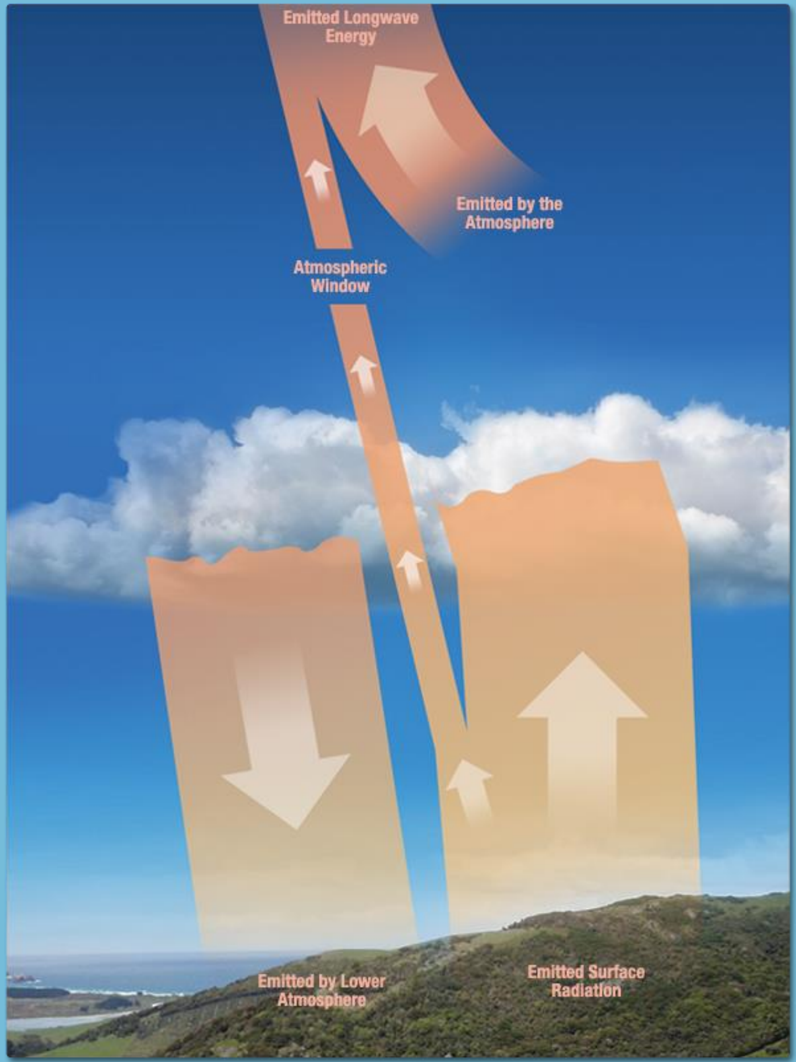

Figure 4.

Application Papers – Sundström, et al.

- 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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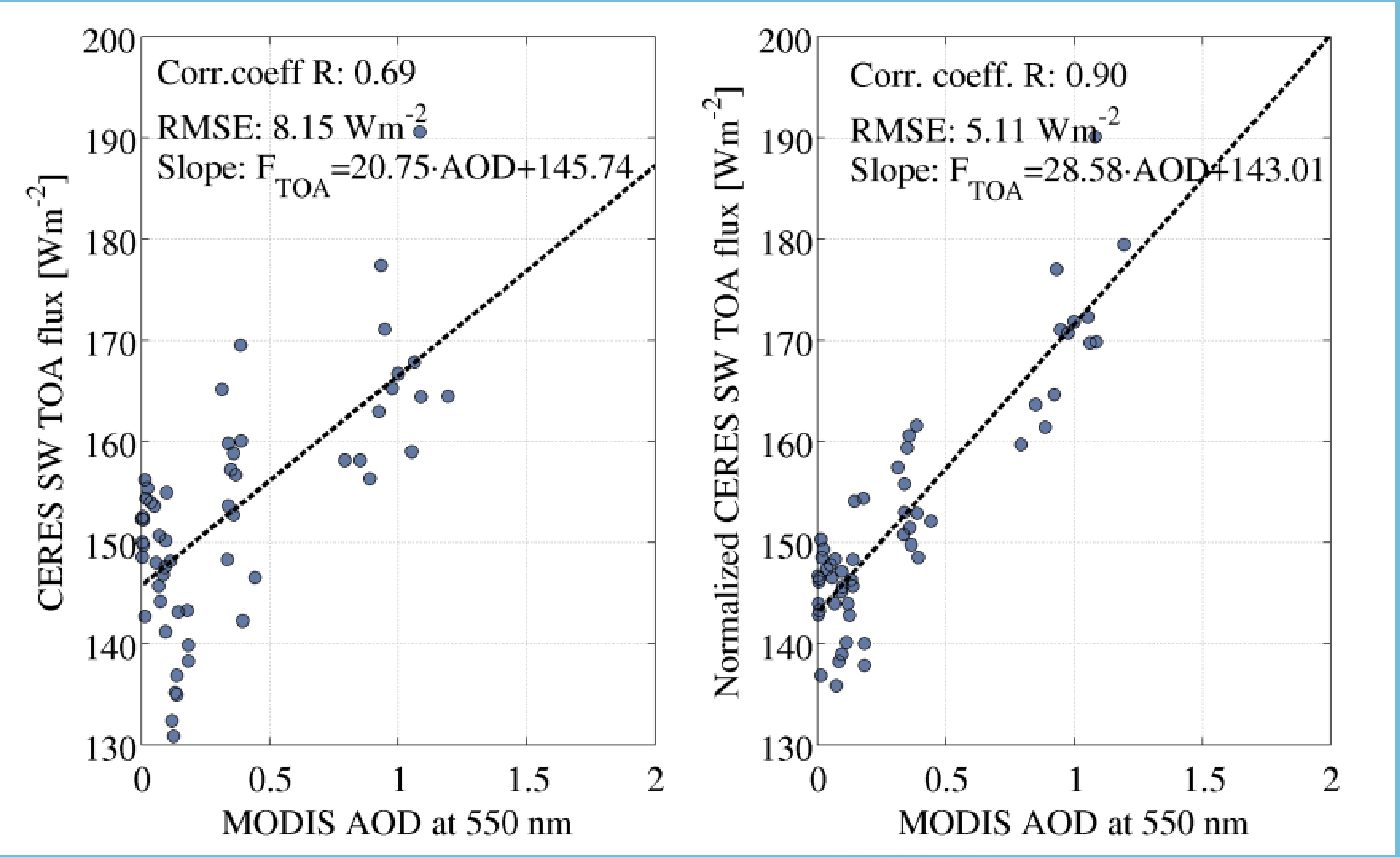
Application Papers – Sundström, et al.

- Clouds and the Earth's Radiant Energy System (CERES) on Terra
  - Latitude, longitude, $F_{aer,TOA}$, 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 → input for UVSPEC radiative transfer model
- UVSPEC
  - Determine ADRE diurnal variation and model $F_{0,TOA}$ for later comparison

Application Papers – Sundström, et al.

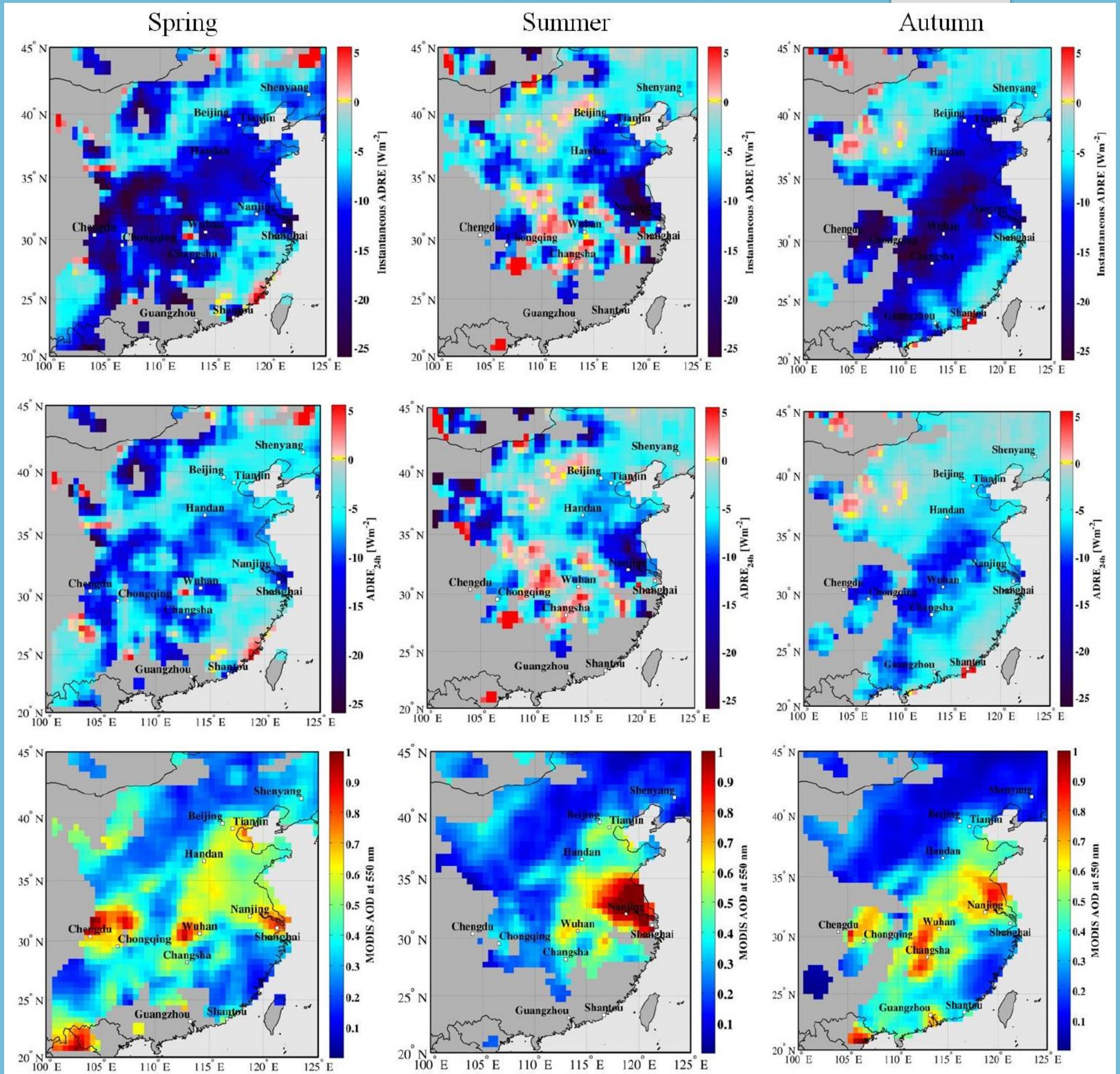
- Figure 5.
  - Left – without normalizing
  - Right – after normalizing



(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



(Sundström, et al., 2015)

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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H I G H L I G H T S

- We analyze the radiative impact of a dust storm though satellite observations and detailed radiative transfer modeling.

Application Papers – Peris-Ferrús, et al.

- 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

Application Papers – Peris-Ferrús, et al.

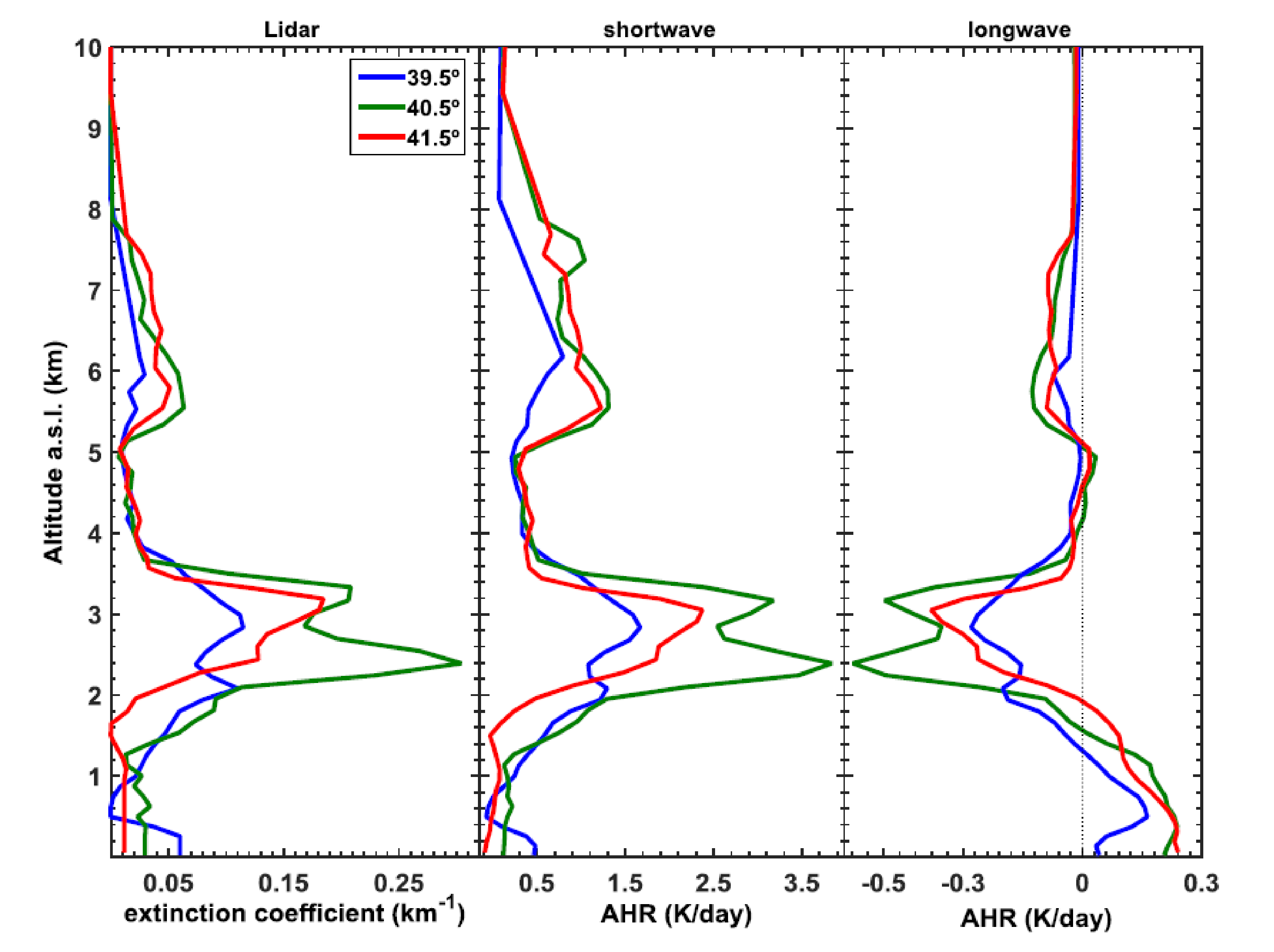
- Table 3.
  - Instantaneous surface and TOA ADRE and FE
  - Gray – land-sea surface pixels

	Surface				TOA			
	SW		LW		SW		LW	
Latitude (ºN)	ARF (Wm^{-2})	FE (Wm^{-2})	ARF (Wm^{-2})	FE (Wm^{-2})	ARF (Wm^{-2})	FE (Wm^{-2})	ARF (Wm^{-2})	FE (Wm^{-2})
36.5	-59.2	-169.1	10.1	28.9	-7.3	-20.9	5.5	15.8
37.5	-97.2	-190.6	13.7	27.0	-23.9	-46.9	4.8	9.4
38.5	-111.6	-214.6	13.9	26.9	-27.8	-53.4	5.4	10.4
39.5	-55.1	-183.7	7.8	26.3	-10.4	-34.6	3.4	11.6
40.5	-101.0	-198.0	12.0	23.8	-22.3	-43.7	6.5	12.8
41.5	-61.2	-185.5	7.4	23.5	-9.6	-29.1	4.9	15.4

(Peris-Ferrús, 2017)

Application Papers – Peris-Ferrús, et al.

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



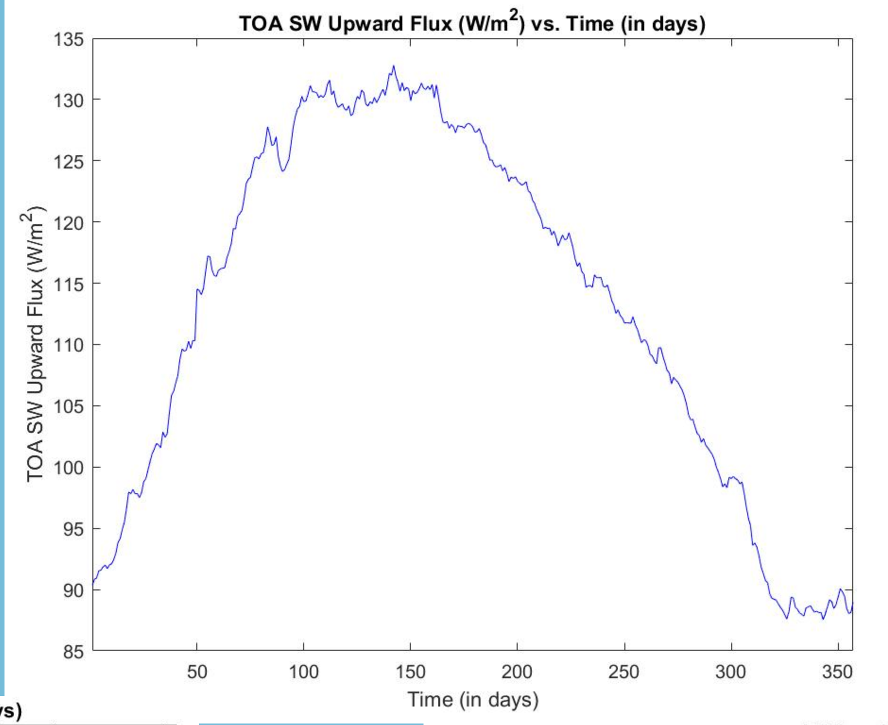
(Peris-Ferrús, 2017)

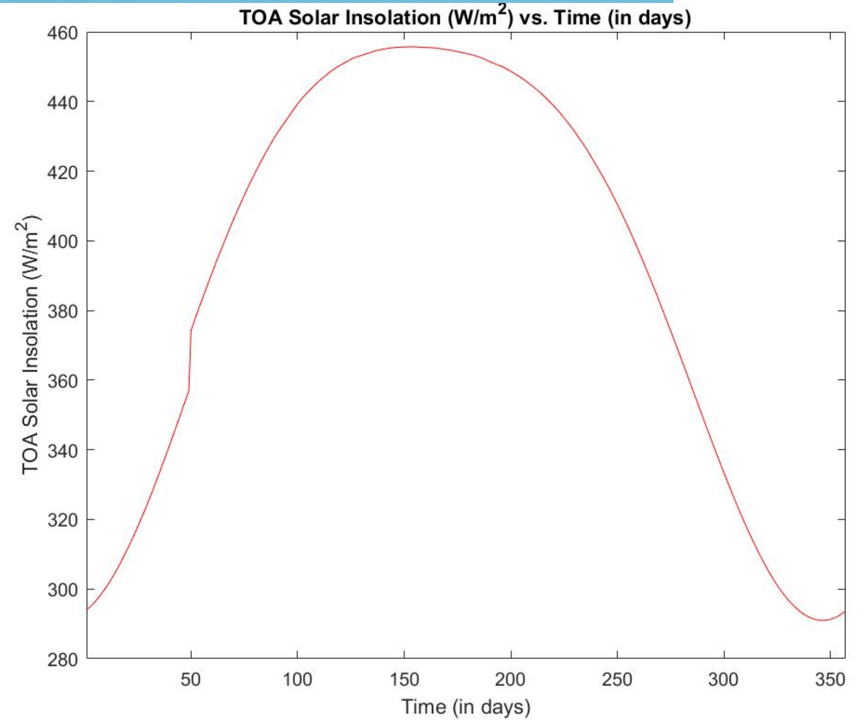
Data Processing so far…

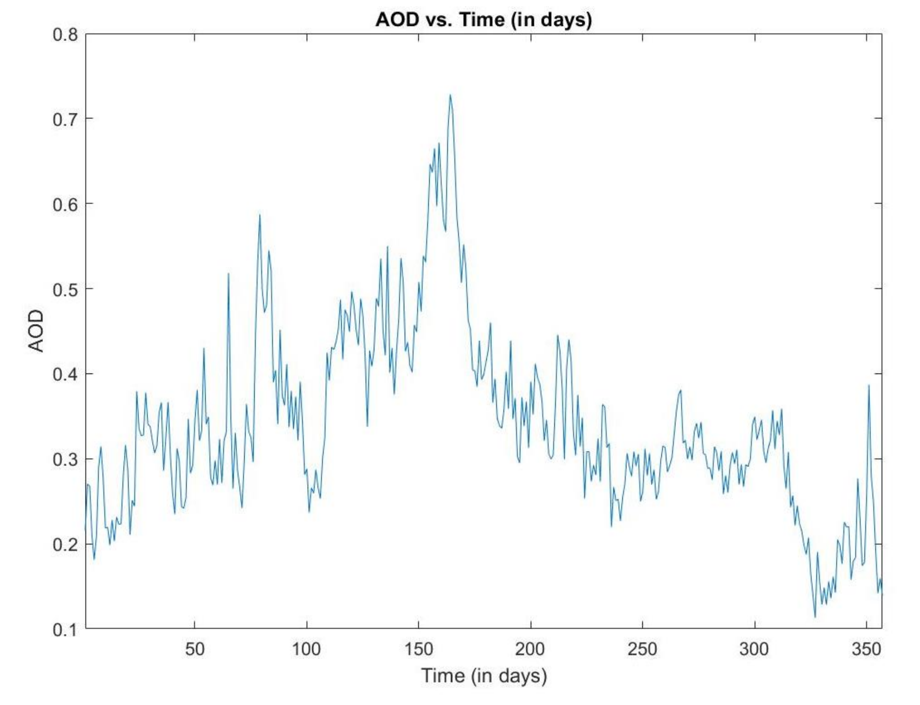
- Solar Insolation (W/m^2), TOA SW Upward Flux (W/m^2), and AOD
  - Spatially averaged
  - CERES and MODIS (filtered for dust AOD)
- Sahara Desert in 2016
  - Excludes February 19th – 27th

Data Processing so far…

- Time series of Solar Insolation, TOA SW Upward Flux, and AOD



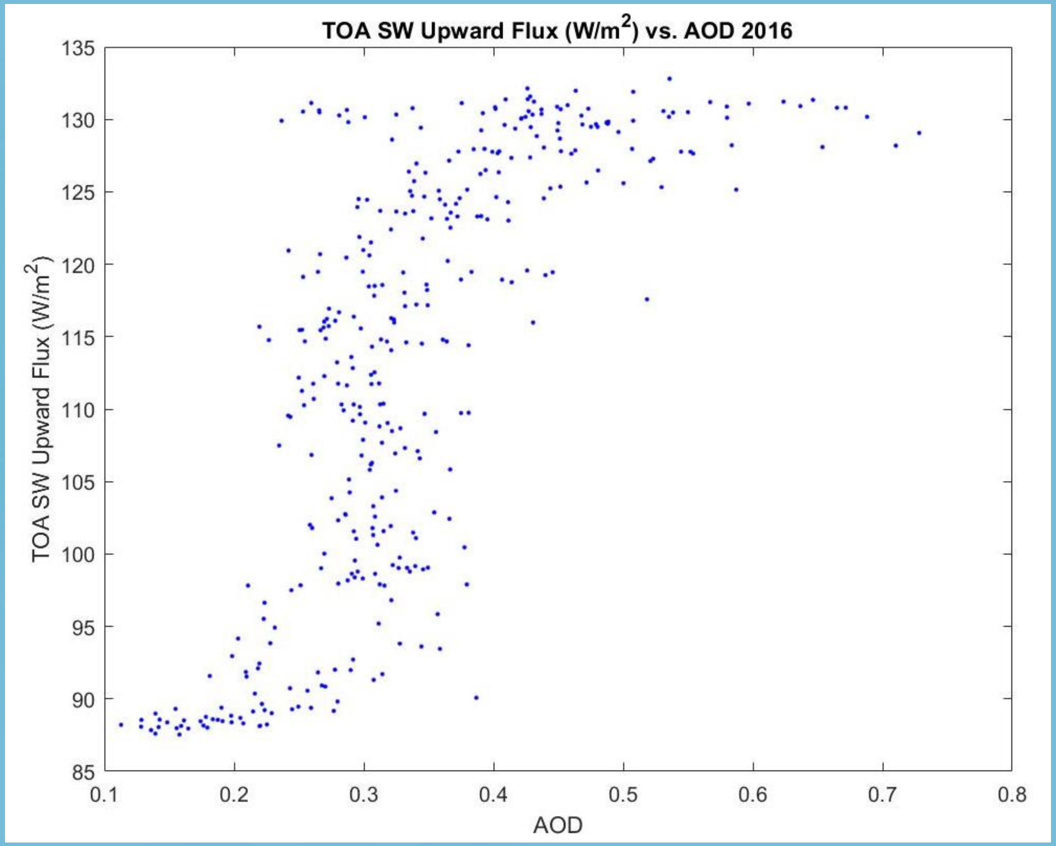


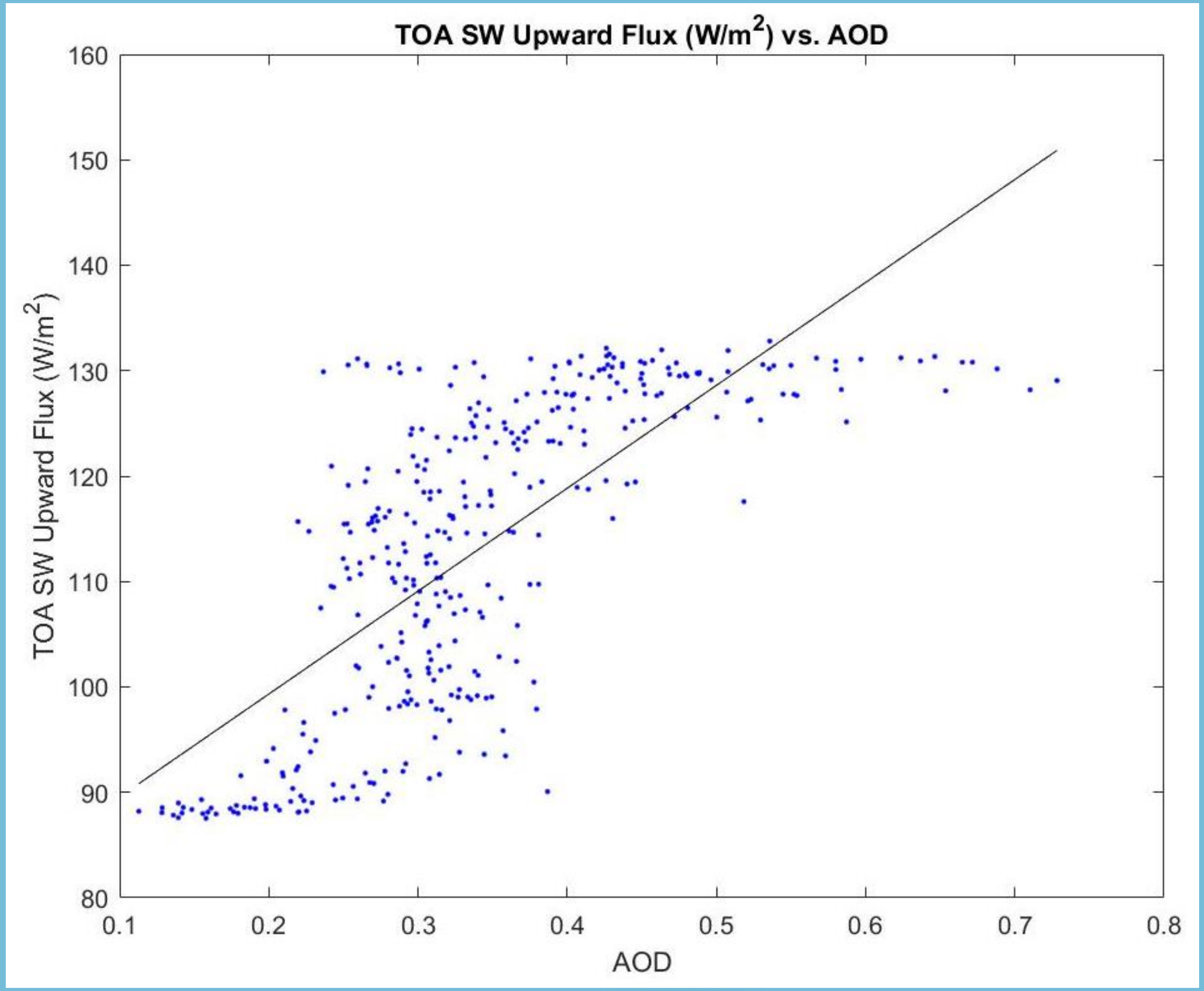


Data Processing so far…

FE = -97.6 W/m^2/unit of AOD
$F_{0,TOA}$ = 79.8 W/m^2

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





Thank you!

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