Uncertainties in an observation-based estimate of the global aerosol direct radiative effect

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Estimating the Aerosol Direct Radiative Effect (DRE)

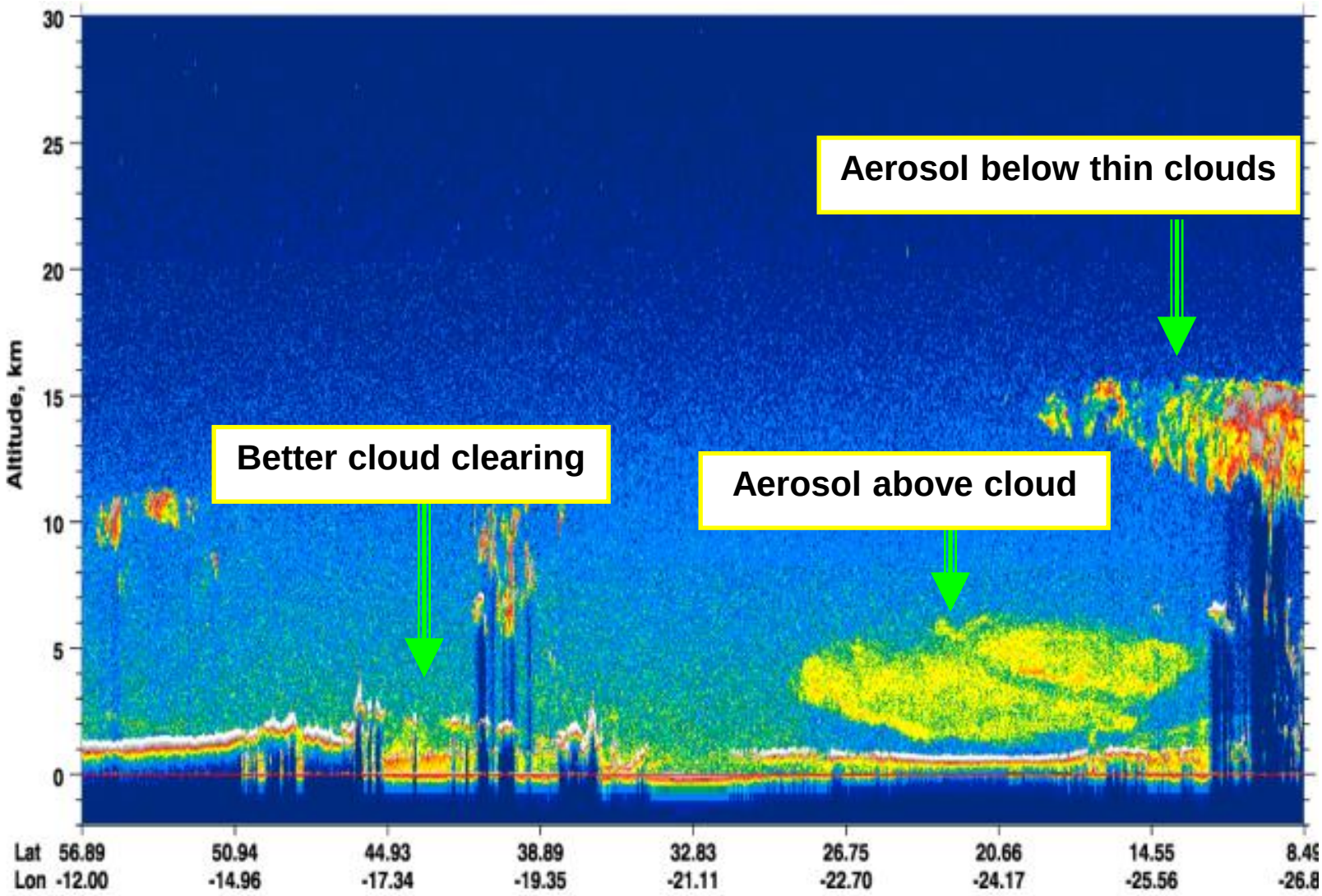
- Models take a 'bottom-up approach'
  - "Infinite" complexity in modeling ERFari from first principles
  - Multiple aerosol emissions sources, secondary production, aerosol nucleation, internal mixing, …
  - Models are poor at simulating cloud cover, relative vertical locations of aerosol and cloud

- "A recurring question is whether current aerosol models adequately cover the full range of uncertainties" in aerosol radiative forcing

  - Samset, Myhre, and Schulz, Nat Clim Chng, 2014

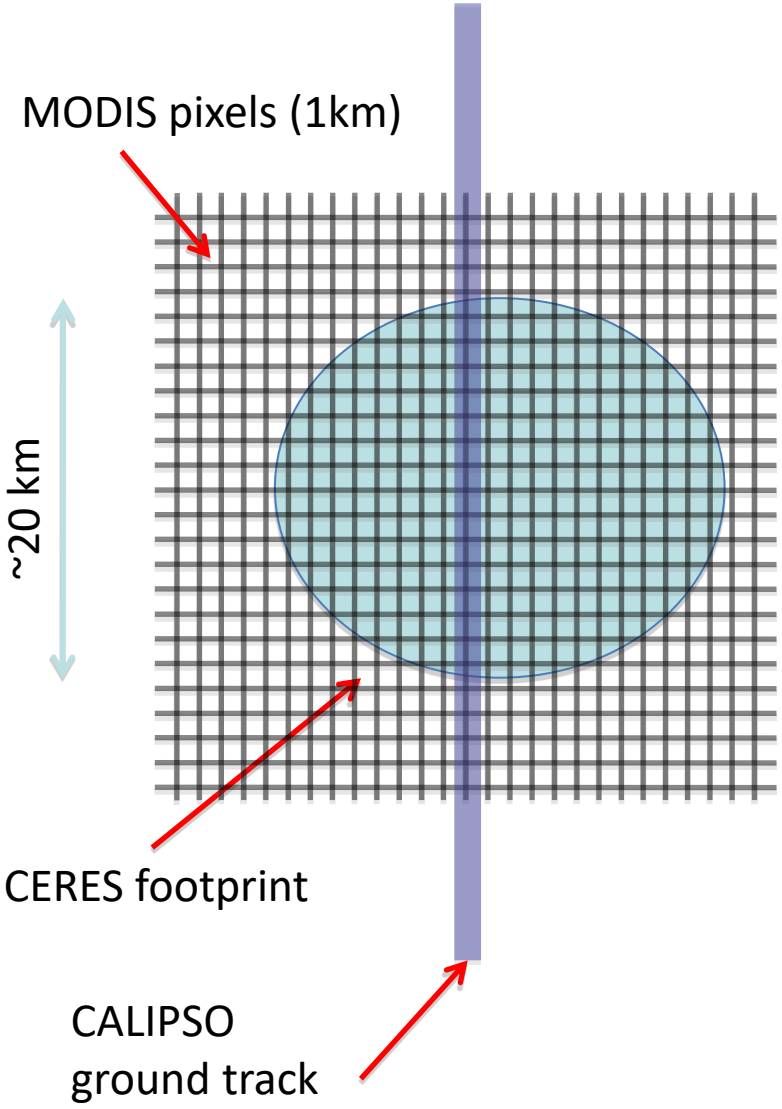
- Satellite observations can provide global 'top-down' estimates, but:
  - Satellite observations have their own limitations
  - Estimates from passive sensors: clear-sky only, typically ocean-only
  - Retrieval uncertainties related to cloud masking, cloud 3D effects

CALIOP can estimate missing cloudy-sky aerosol effects



The CERES, CALIPSO, CloudSat, MODIS (C3M) Product

C3M computes radiative fluxes from merged A-train data sets



Aerosol & cloud profiles
TOA radiative fluxes
Spectral surface albedo

↓

Radiative transfer calculations → Irradiance

↓

Irradiance-to-Flux Conversion
Instantaneous-to-Diurnal Conversion

↓

SW and LW radiative
flux profiles

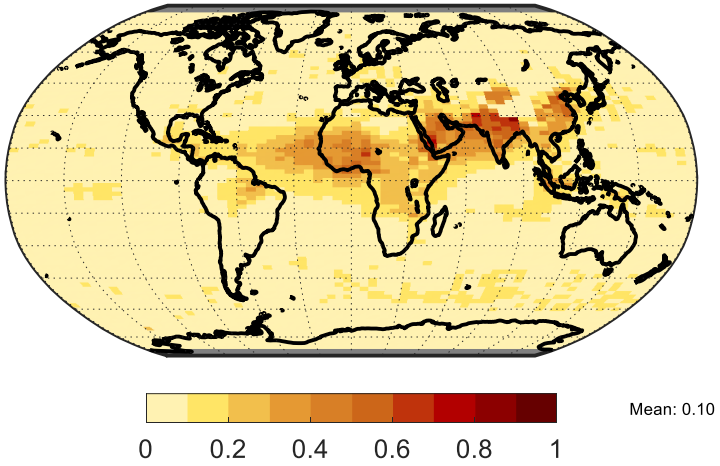
(Kato et al., 2010)

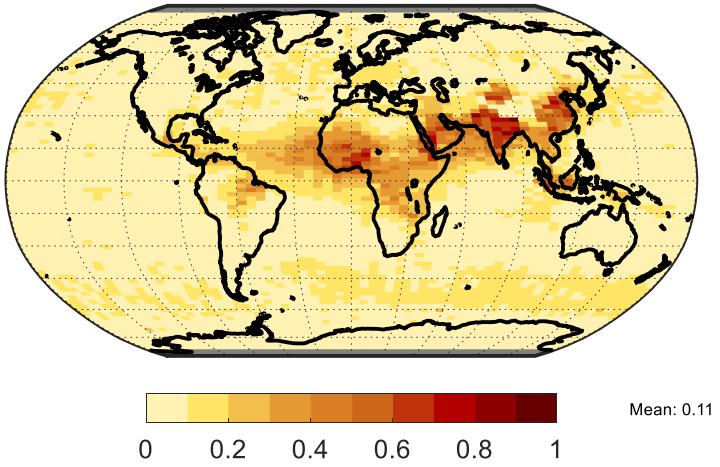
Method

aerosol 3D distribution (532 nm extinction coefficient)		**aerosol type**		**spectral optical properties**
CALIOP	→	“Dust” from CALIOP	→	Tegen and Lacis, 1996
+ MATCH in gaps (assimilates MODIS AOD)		Non-dust types from MATCH		OPAC (Hess, 1998)

C3M Release D uses AOD from V4.5

CALIOP Level 3 AOD, V4-20





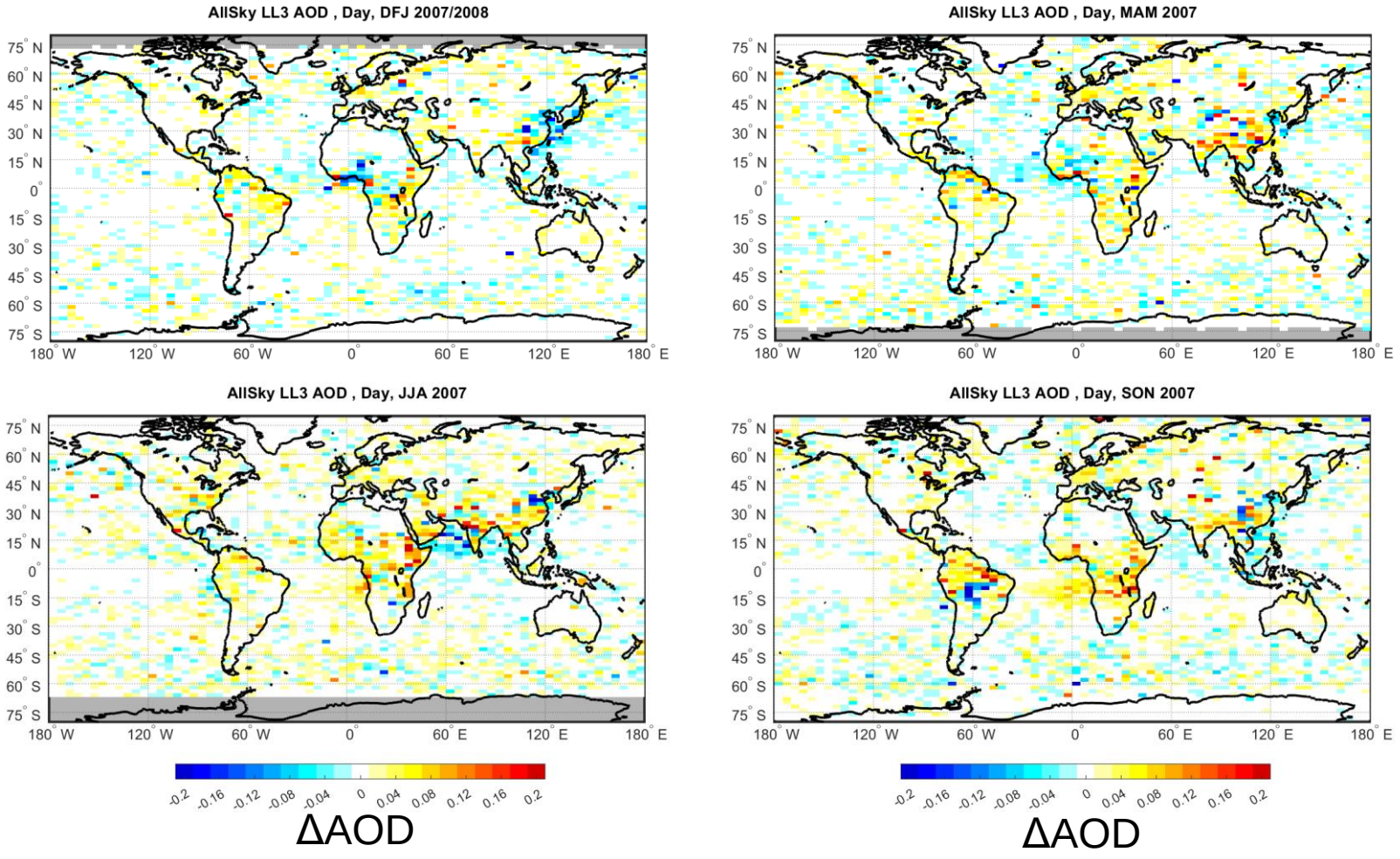
Global AOD, all-sky

V3	V4.2	V4.5
0.094	0.116	0.119

V4.2 (most recent L3) vs. V4.5 (C3M)

Day

ΔAOD (V4.5 – V4.2)



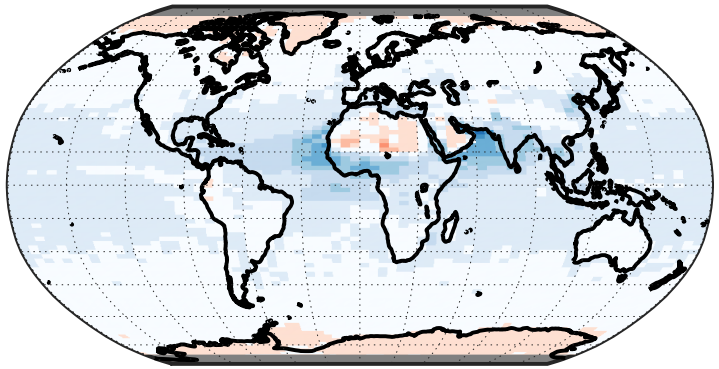
Aerosol DRE, Daytime

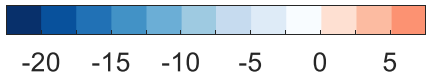
(2007-2010 and 2013-2015)

C3M Rel-D2

C3M Rel-B

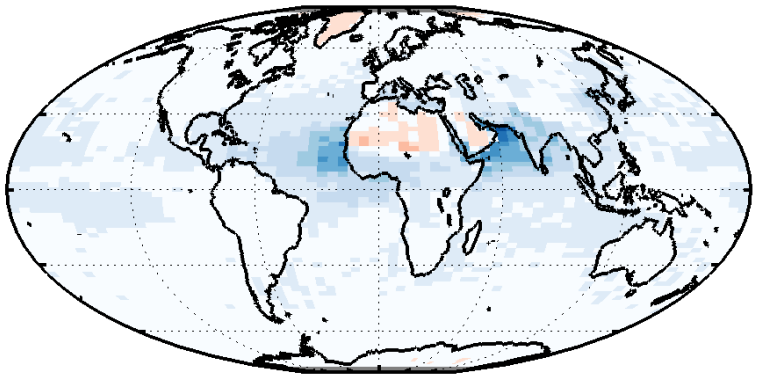
All-sky Aerosol SW DRE

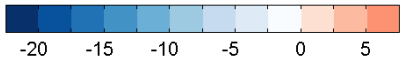




-2.68 W/m²

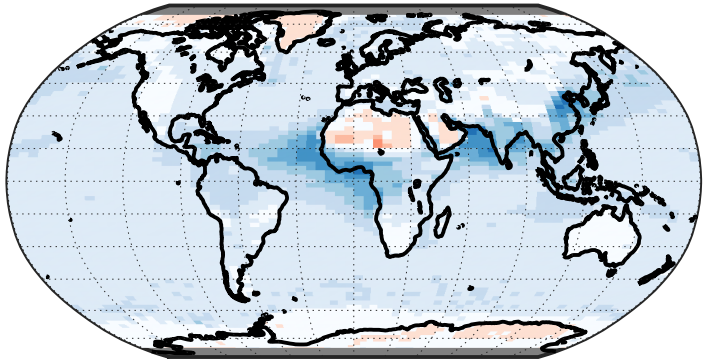
All-Sky Aerosol SW DRE

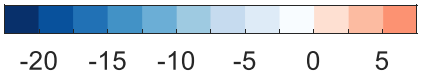




-2.34 W/m²

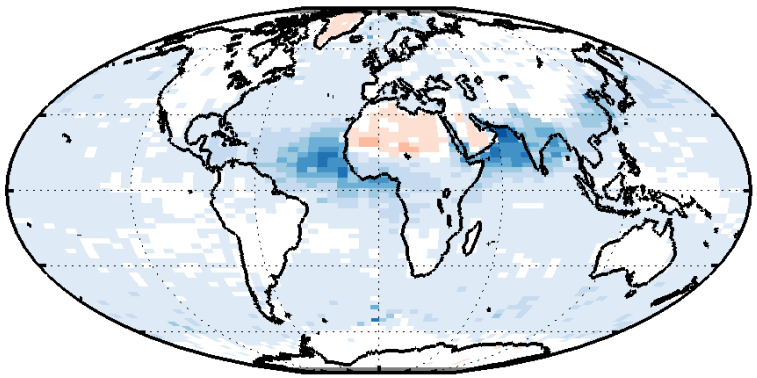
Clear-sky Aerosol SW DRE

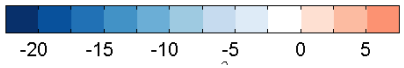




-4.2 W/m²

Clear-Sky Aerosol SW DRE



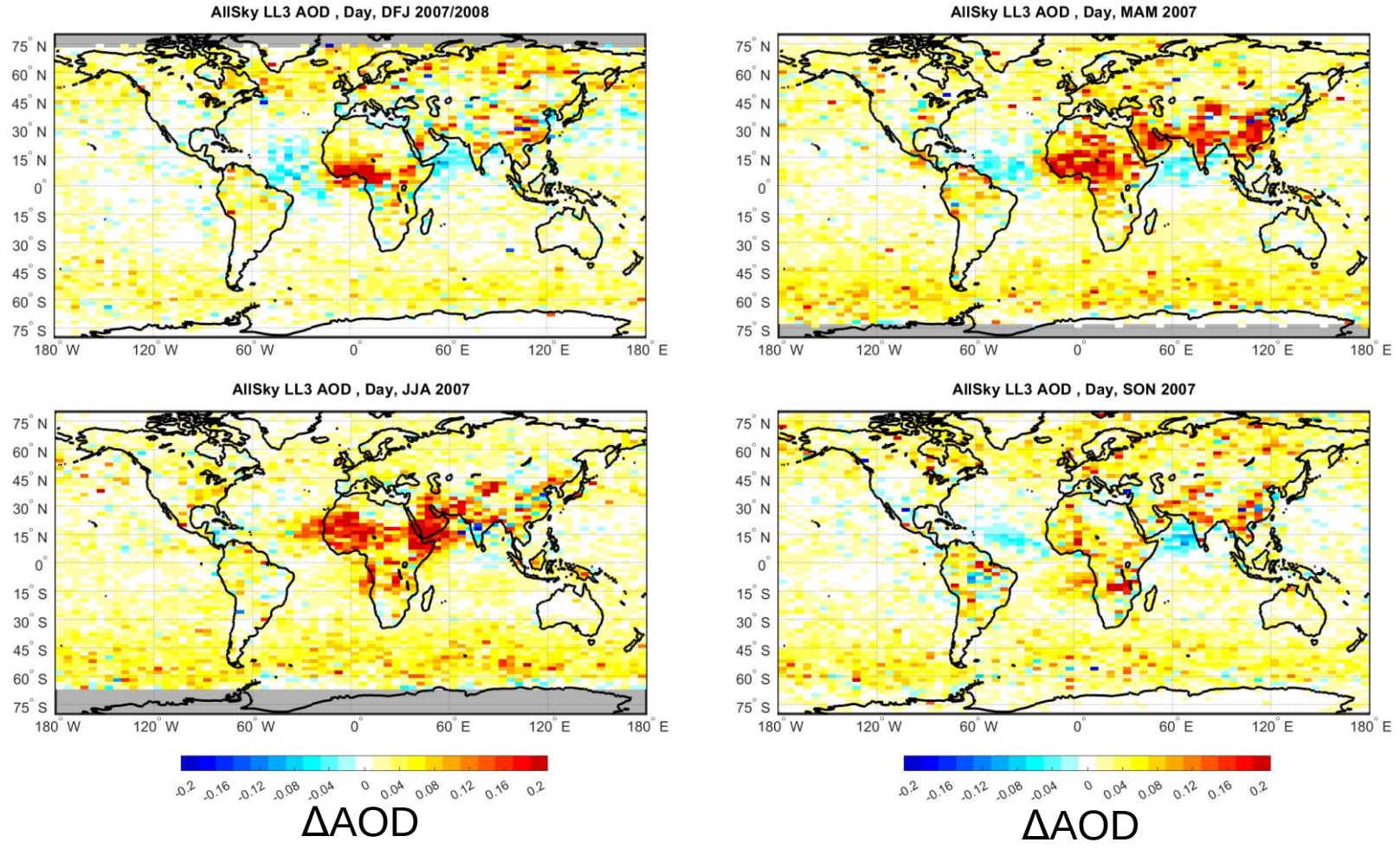


-3.30 W/m²

AOD is main driver of DRE differences

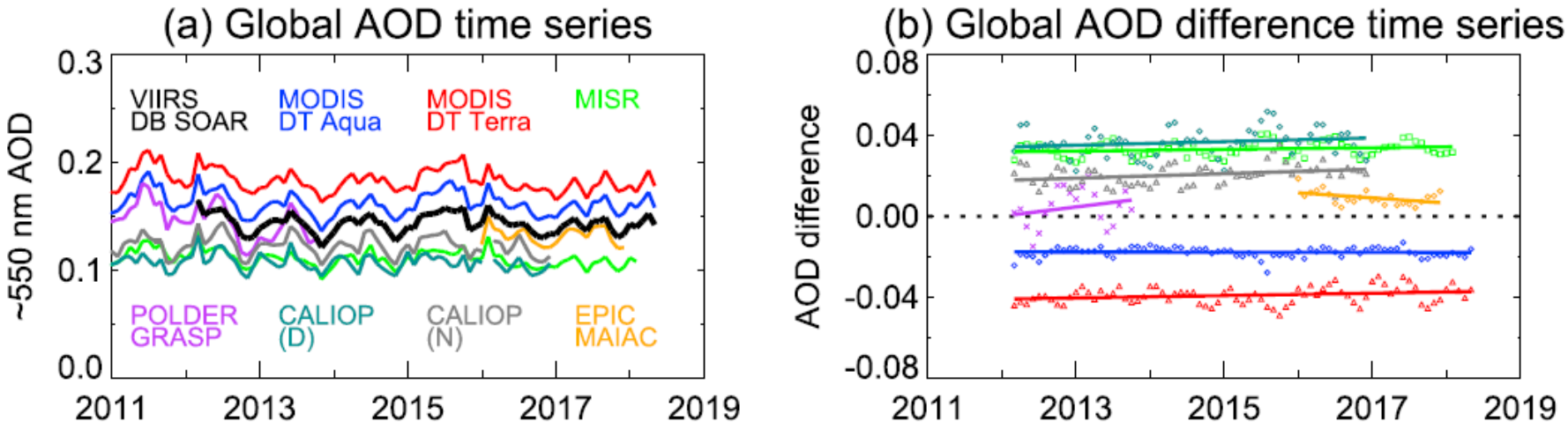
Day

ΔAOD (V4.5 – V3)



Where do V3 and V4 stand vs passive sensors?

Over-ocean time series from seven different sensors

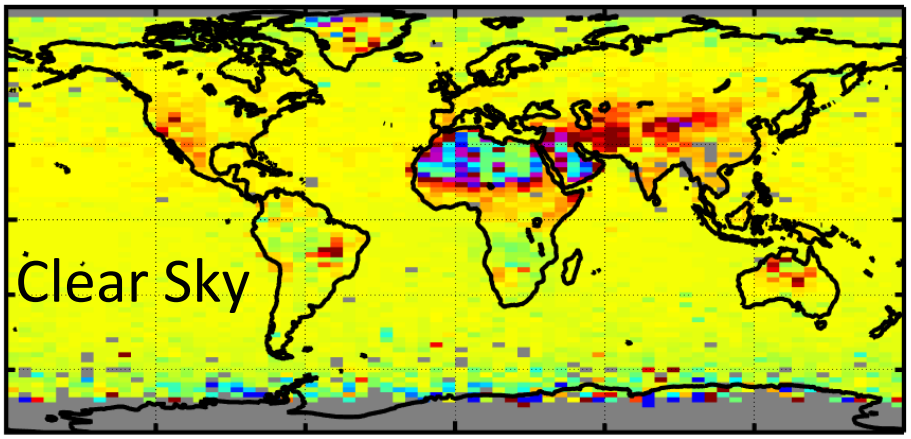


(Sayer et al, JGR, 2018)

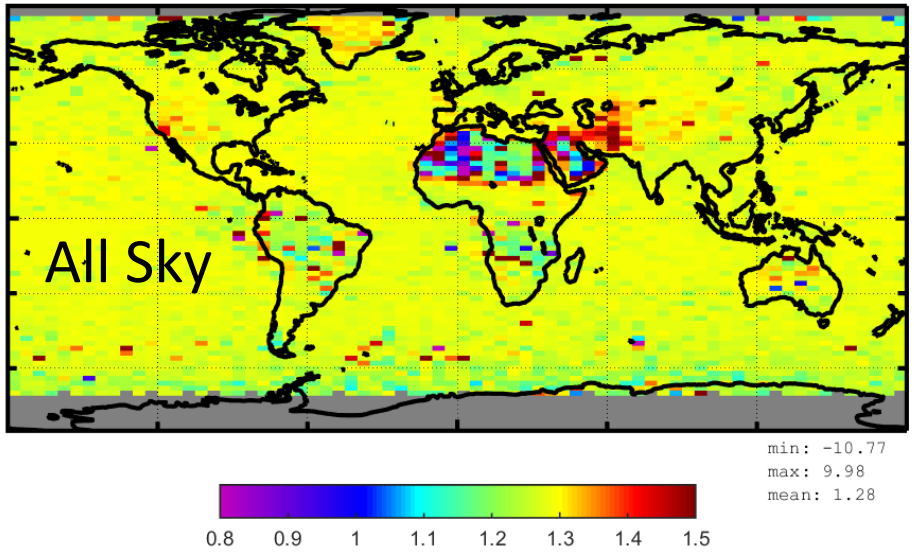
Figure 13. Time series (left column) of (a, b) AOD near 550 nm and (c, d) AE and VIIRS-other AOD and AE differences (right column), for over-water data from the period 2011–2018. The straight lines in the right panels are the linear fits to the monthly difference time series.

2016 Sensitivity study: AOD

Mean Aug 2008 Clear-Sky TOA Aerosol Direct Radiative Forcing ($\Delta F^{clrSky}_{daily}$) Modified/Control



Mean Aug 2008 All-Sky TOA Aerosol Direct Radiative Forcing ($\Delta F^{allSky}_{daily}$) Modified/Control



Effect of 30% AOD increase

DRE (1.3 x AOD) / DRE (control)

	DRE (W/m^2)	
	Control	1.3 x AOD
Clear-sky	-3.44	-4.44
All-sky	-2.18	-2.81

Global mean change ~ 30%

Regional deviations depend on:

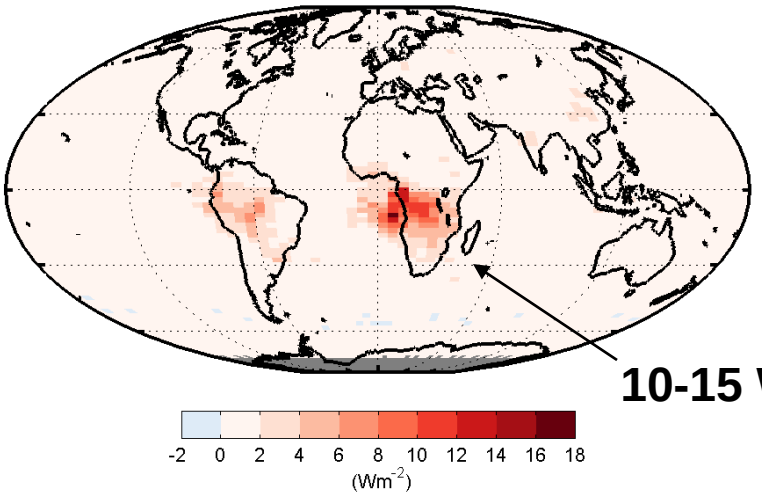
- surface albedo
- cloud cover
- aerosol type (absorption)

Sensitivity Experiment: aerosol absorption

- AAOD is the next largest uncertainty
- Aerosol types in C3M = dust, sea salt, BC, soluble, insoluble
- SSA of species corresponding to smoke (or pollution) adjusted to investigate differences in aerosol absorption

SSA of 'smoke' reduced by ~ 0.03 :

DRE difference, Aug 2008
(ω_o reduced − control)



Summary

- All-sky CALIOP aerosol profiles offer the opportunity to reduce current uncertainties by quantifying aerosol radiative effects in cloudy skies
- Can quantify impact of cloud-masking of aerosol
  - All-sky DRE < Clear-sky DRE
- Differences between DRE estimates largely explained by differences in retrieved AOD and assumptions on aerosol absorption

- But … anthropogenic fraction is likely the largest uncertainty in estimating aerosol *climate* forcing