

Direct aerosol radiative effect derived from CERES data products

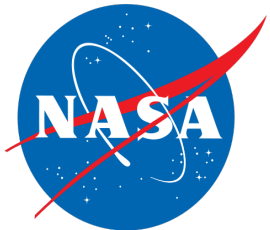
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Aerocenter Seminar
October 24, 2023



Outline of this talk

- Aerosols in CERES Edition 4.2 process
 - MATCH aerosol transport model
- Direct aerosol radiative effects derived from CERES observations
- Direct aerosol radiative effects derived from computed irradiances
 - TOA and surface
- Trend of direct aerosol radiative effect
- Plan to mitigate discontinuity in AOD derived from MODIS and VIIRS to extend the time period covered by Edition 4 products

Assimilating hourly MODIS AOD

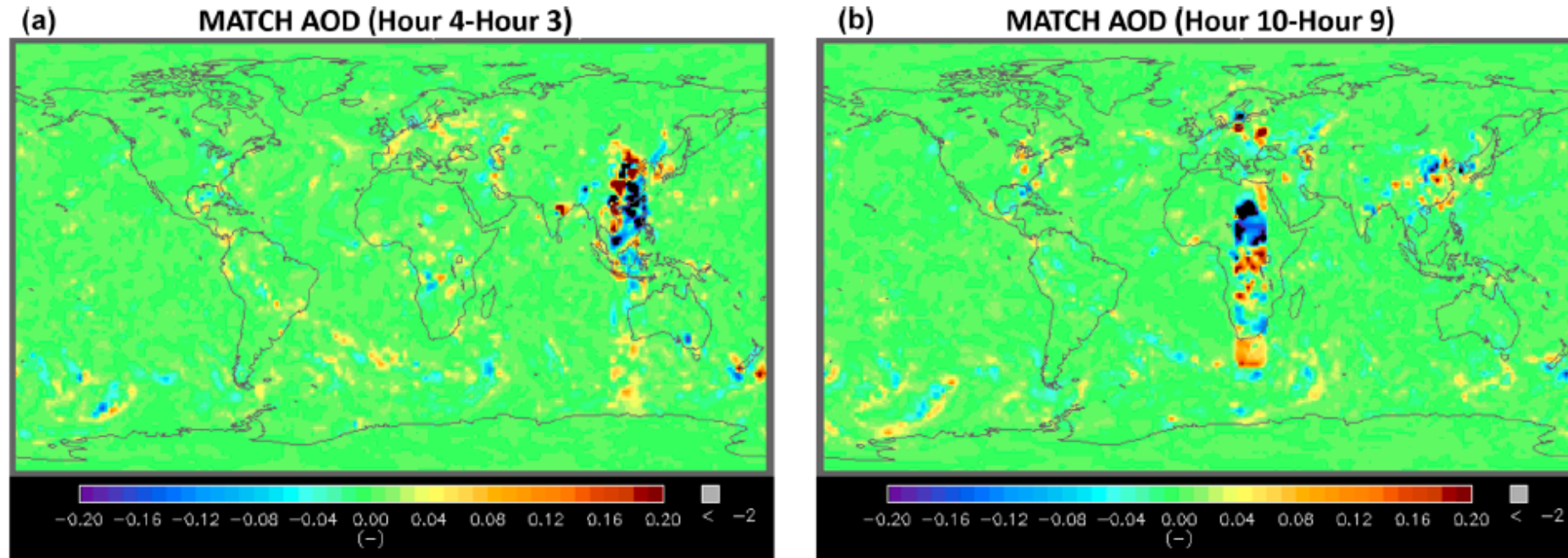
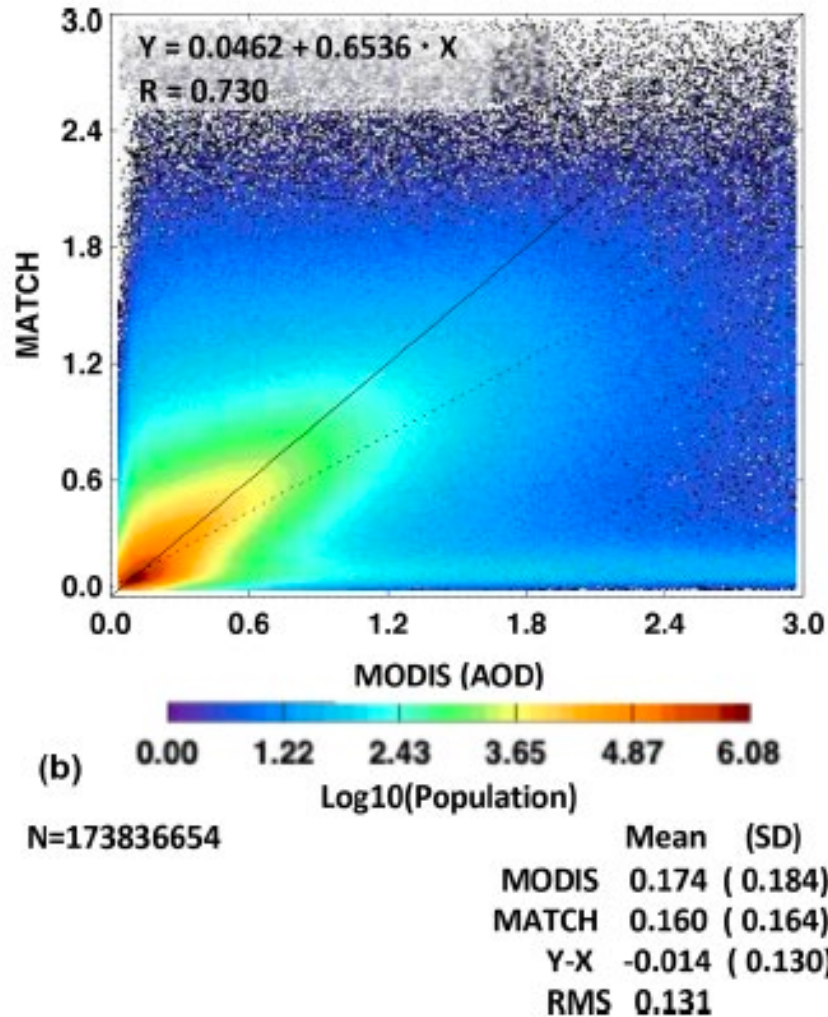


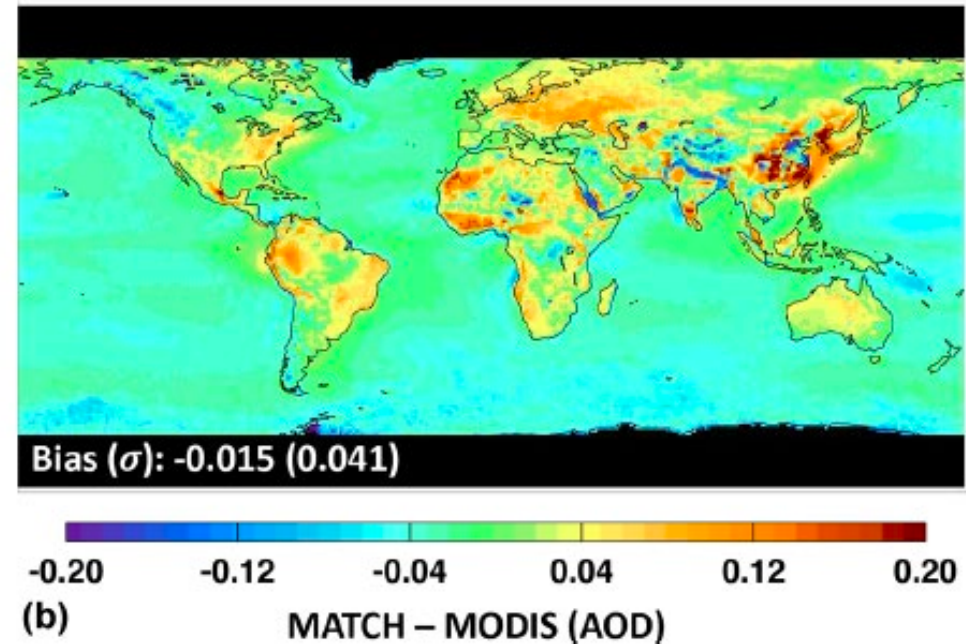
Figure 2. The difference in MATCH AOD due to the assimilation of MODIS AOD. Panel (a) shows 04:00 UT minus 03:00 UT on 1 February 2020, and panel (b) shows 10:00 UT minus 09:00 UT on 1 February 2020. AOD is adjusted at the local solar noon within the 15° longitudinal band by the MODIS AOD assimilation. Wind-blown dust and sea salt differences are also apparent outside the 15° longitudinal band.

Compute TOA, surface, and in atmosphere irradiance hourly

AOD compared with MODIS



Difference averaged from March 2000 to February 2020



Although MODIS AODs are assimilated, MATCH AODs are different because AOD for cloudy conditions are modeled AOD

Comparison with AERONET AOD

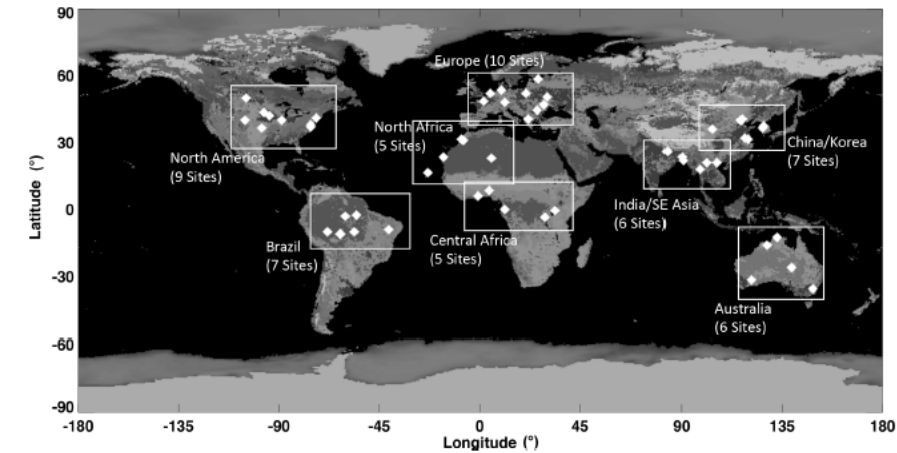
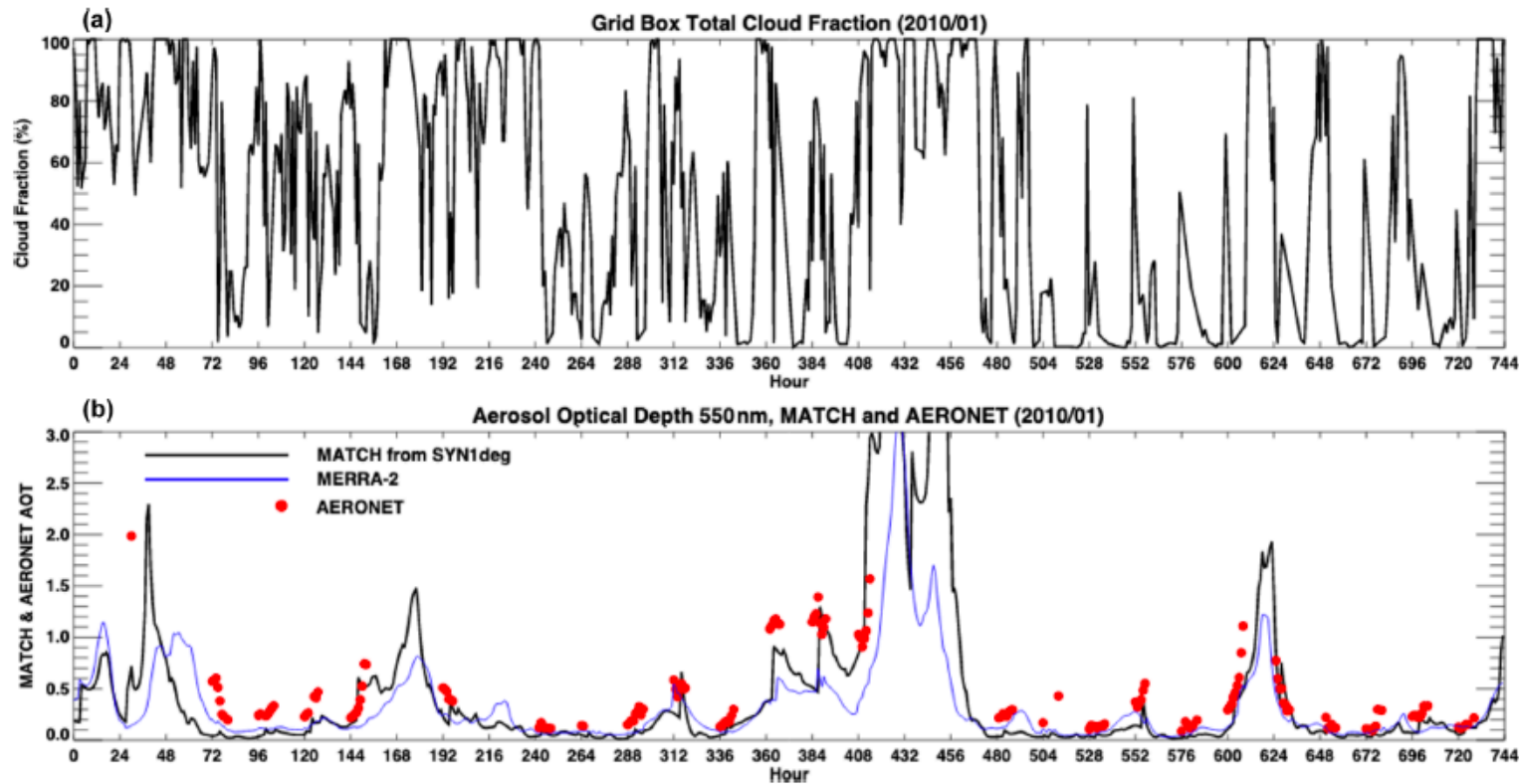
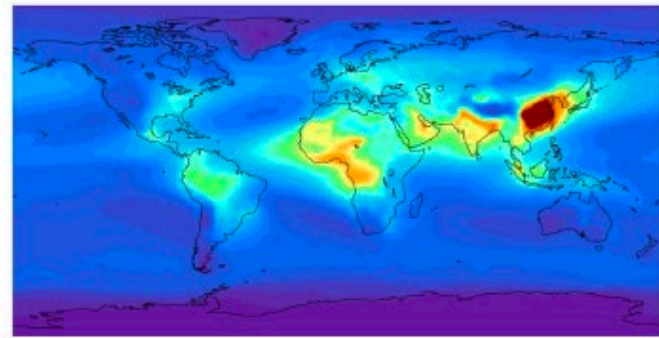


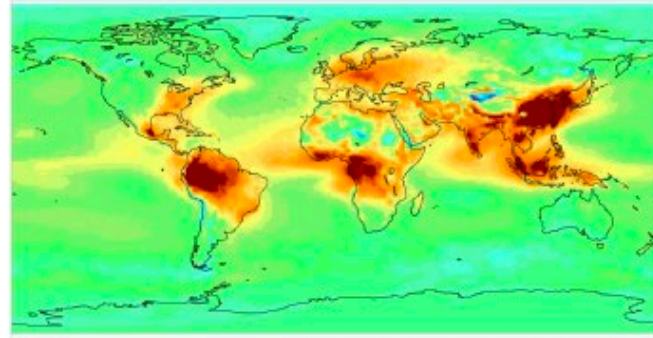
Figure 6. Hourly time series of the (a) grid box cloud fraction from the SYN1deg Edition 4.1 CERES product and (b) AOD. Results are from the grid box containing the AERONET Beijing (China) site. The black line represents MATCH, the blue line represents MERRA-2, and the red dots represent AERONET observations. MATCH and, to a lesser degree, MERRA-2 often have large increases in AOD when the cloud fraction nears 100 %.

Mean aerosol optical thickness

All-sky



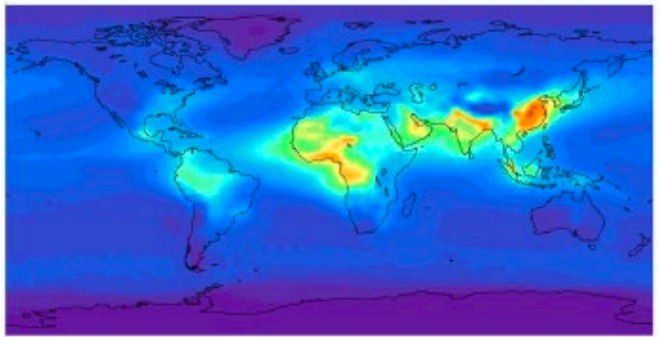
(a) MATCH AOD (All Sky, 2000-2020)



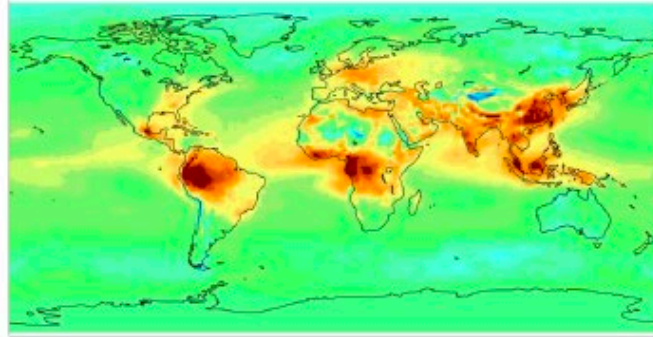
(b) MATCH-MERRA-2 AOD (All Sky, 2000-2020)

N= 64800 Glob mean(sd): 0.162 (0.116) Mn/Mx: 0.0004/ 1.1 N= 64800 Glob mean(sd): 0.024 (0.048) Mn/Mx: -0.198/ 0.485

Clear-sky fraction
weighted



(c) MATCH AOD (Clear Sky Weighted, 2000-2020)



(d) MATCH-MERRA-2 AOD (Clear Sky Weighted, 2000-2020)

N= 64800 Glob mean(sd): 0.136 (0.100) Mn/Mx: 0.0004/ 0.73 N= 64800 Glob mean(sd): 0.016 (0.038) Mn/Mx: -0.162/ 0.293

Fillmore et al. 2022

Optical properties

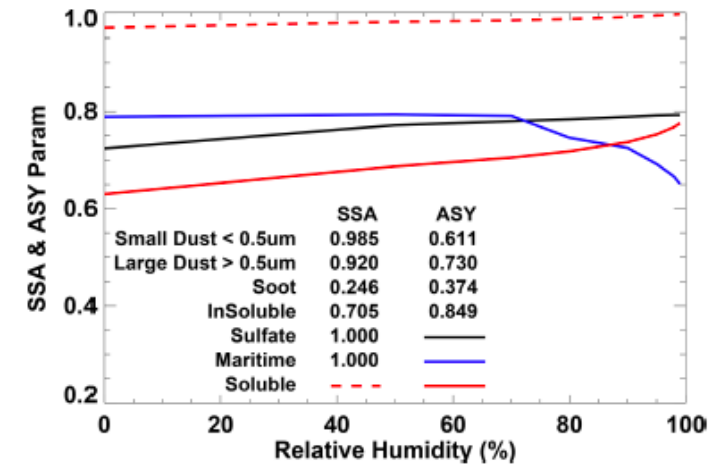
Table 2. Mapping of MATCH aerosol types into radiative transfer code.

Aerosol type
dependent
optical
properties

MATCH provide
mass mixing
ratio of 7
aerosol types

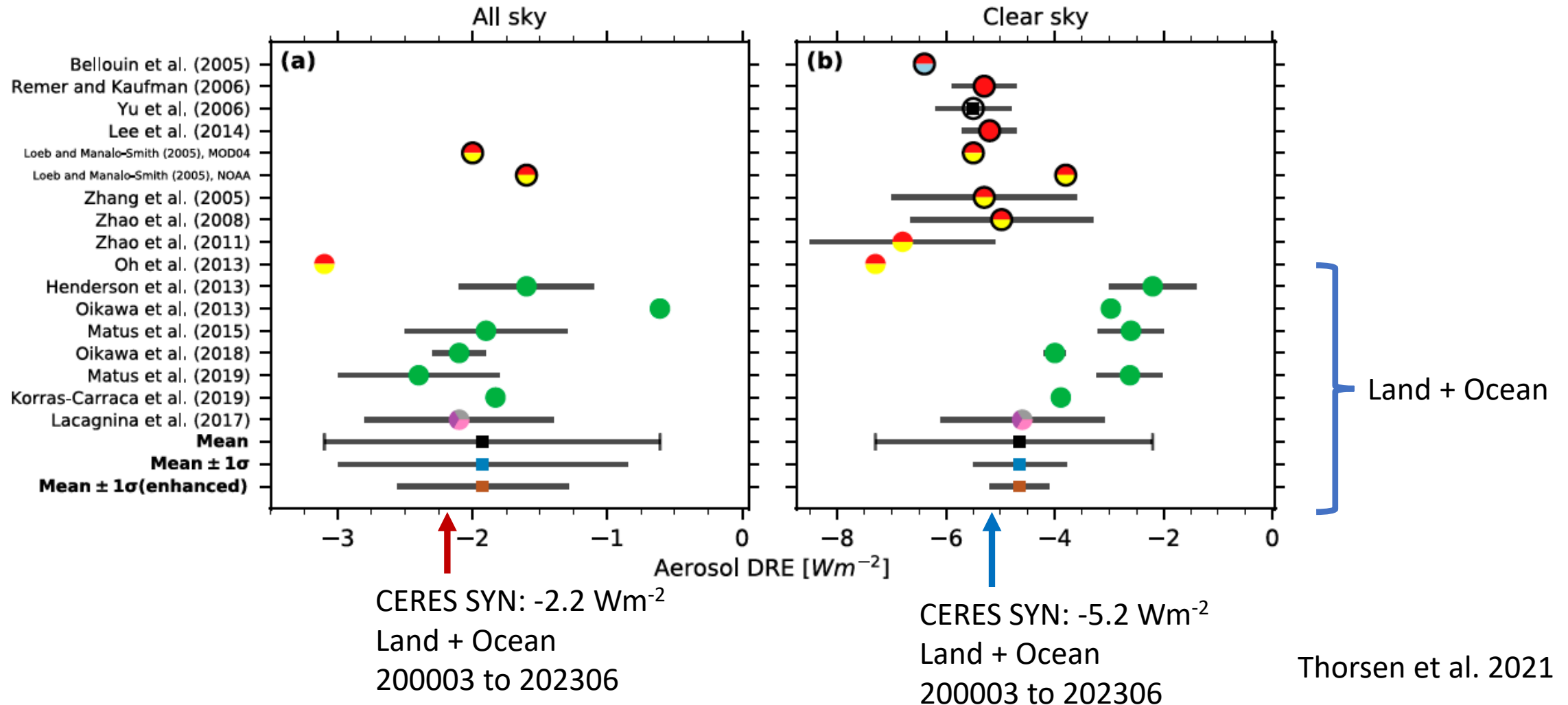
MATCH constituent	Langley Fu–Liou constituent	Langley Fu–Liou spectral properties
Sea salt	Maritime	d’Almeida (1991)
Hydrophobic organic carbon	Insoluble	OPAC
Hydrophilic black carbon Hydrophobic black carbon	Soot	OPAC
Hydrophilic organic carbon Tropospheric sulfate	Water soluble (WASO)	OPAC
Volcanic Stratospheric sulfate	Suspended organic (SUSO)	OPAC
Dust < 0.6 μm^*	“Small” dust	Sinyuk et al. (2003)
Dust 0.5–1.25 μm^* Dust 1.25–2.5 μm^* Dust 2.5–5.0 μm^*	“Large” dust	Sinyuk et al. (2003)

* Effective radius.

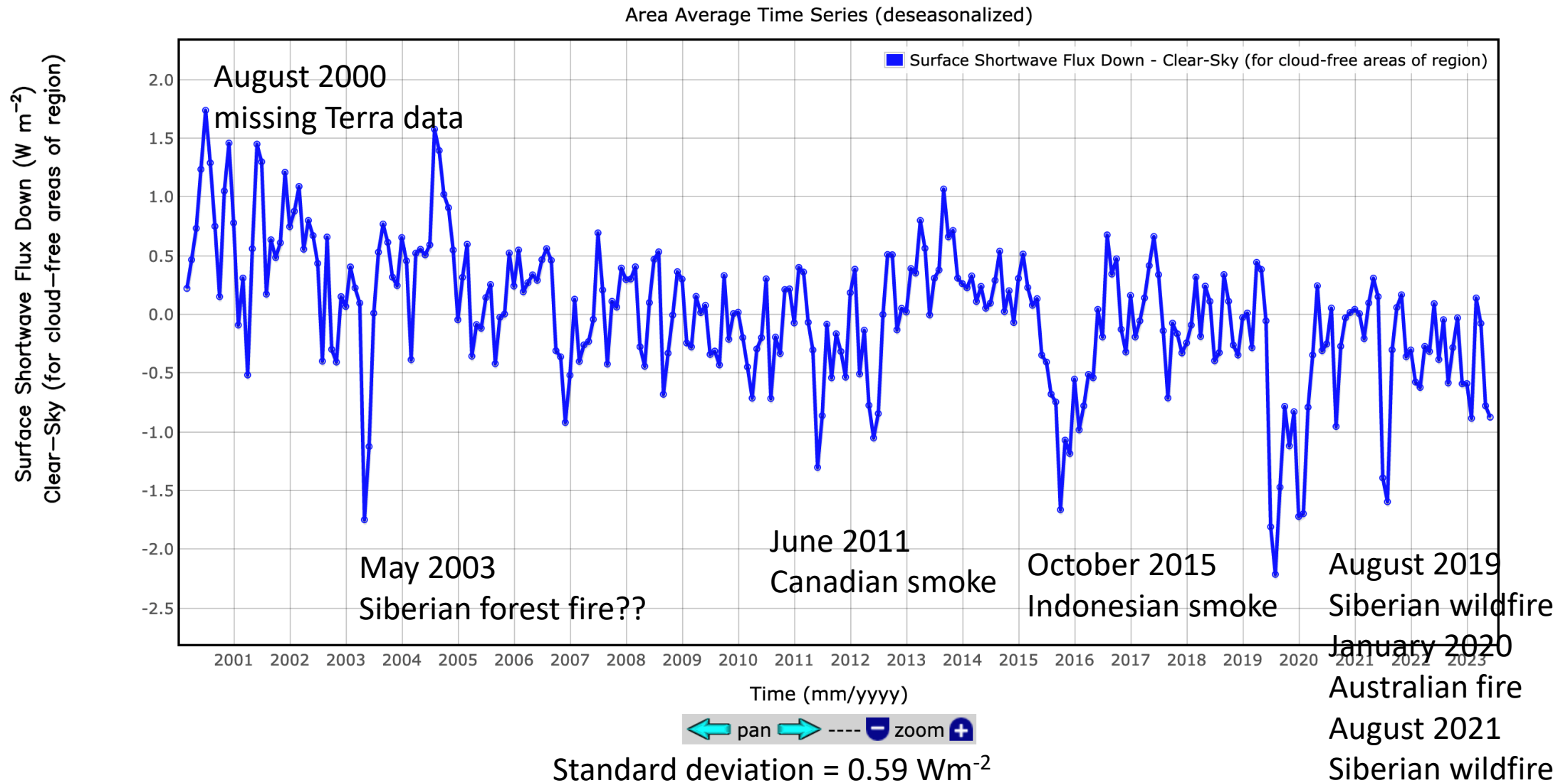


Global mean direct aerosol radiative effects

SYN1deg is used to produce EBAF



Global monthly surface clear-sky downward shortwave anomalies



Mean=0.00000 ; StdDev=0.60415 (W m⁻²) Number of month > 2 σ : 14 (out of 261)

Using Time Range: 3/2000-6/2023

Selected Region: [-90,0 to 90,360]

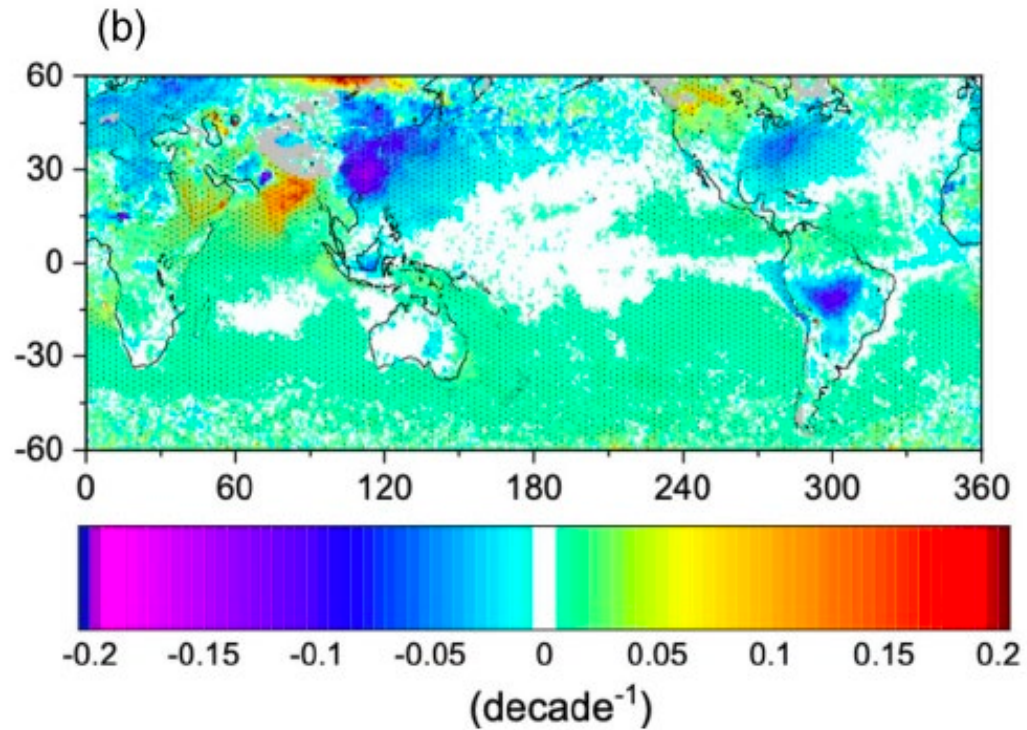
8 occurred after 2010 5 occurred after 2019

ADO trends

Loeb et al. 2021

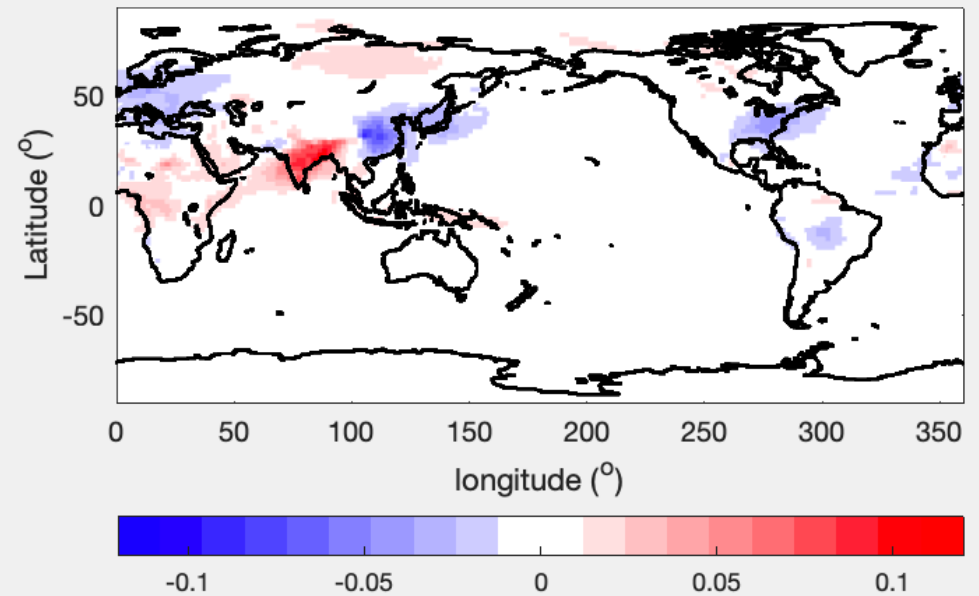
MODIS MYD08_M3.0.61 550 nm

Clear-sky AOD trend from July 2002 to April 2020



MATCH All-sky AOD trend

From March 2000 to June 2023



Trend of clear-sky TOA direct aerosol radiative effect derived from CERES observations

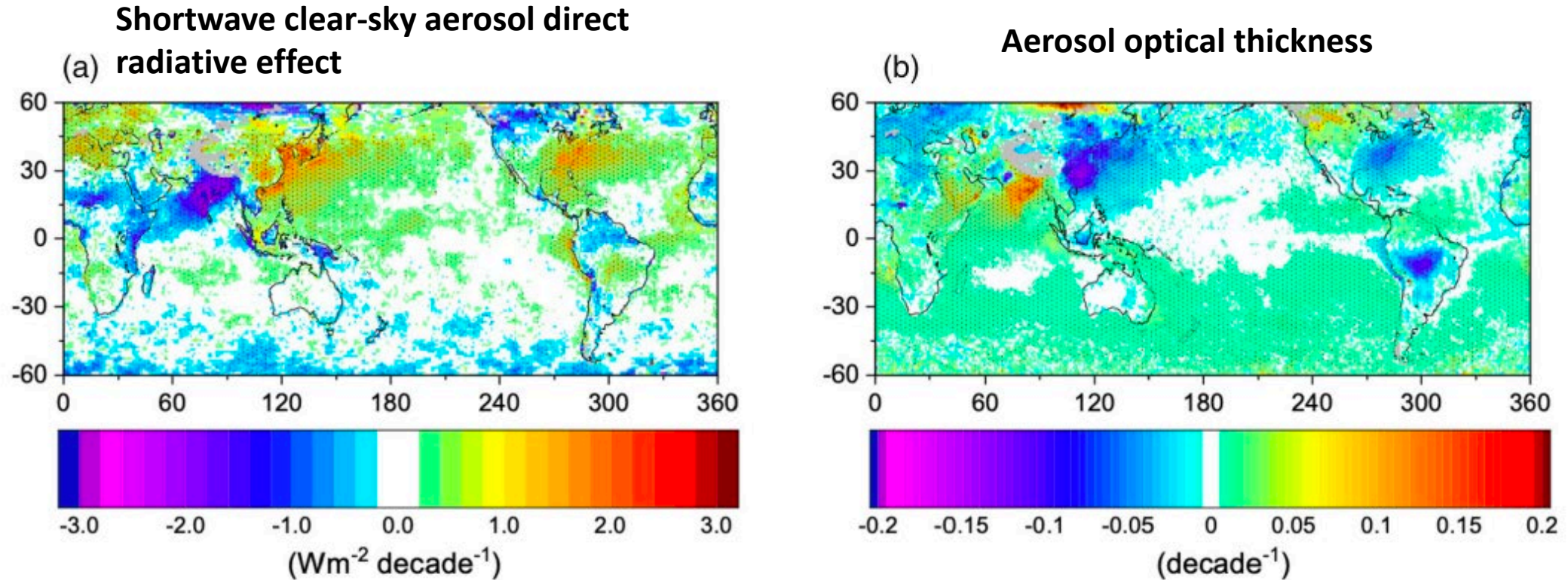
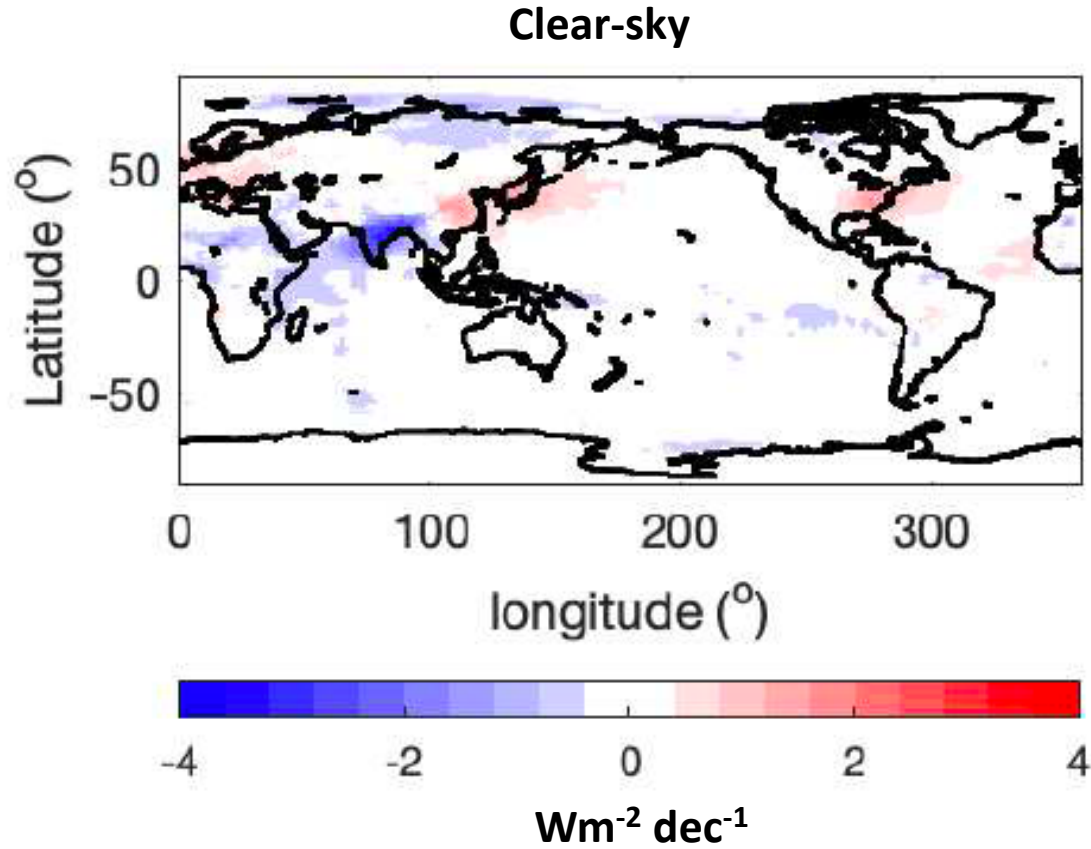


Figure 1. Trend in anomalies of (a) SW clear-sky ADRE and (b) AOD for 2002/07–2020/03. Stippled area exceeds 95% confidence interval. ADRE, aerosol direct radiative effects; AOD, aerosol optical depth.

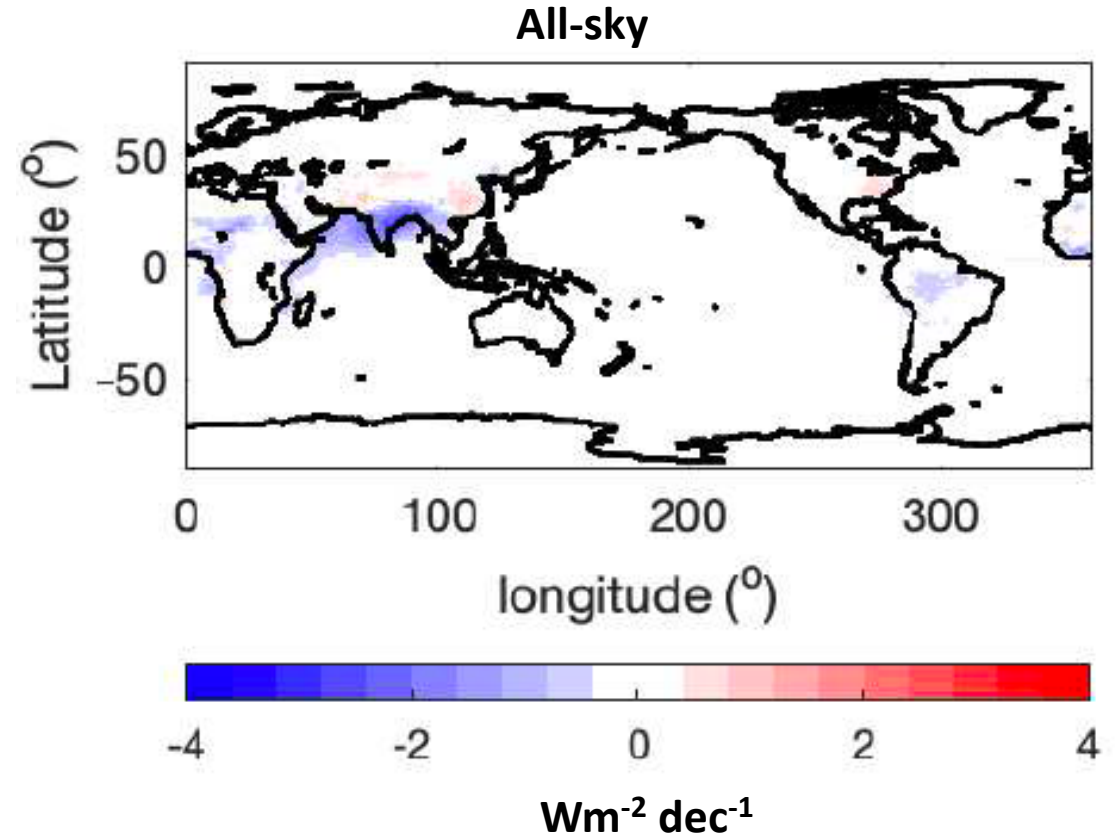
Loeb et al. 2020

$0.18 \pm 0.17 \text{ Wm}^{-2} \text{dec}^{-1}$

Trend of computed TOA Clear-sky and all-sky direct aerosol radiative effects



Clear-sky TOA shortwave direct aerosol radiative effect (clear-sky – pristine) from Ed. 4.1 SYN GEO



All-sky TOA shortwave direct aerosol radiative effect (all-sky – all-sky no aerosol) from Ed. 4.1 SYN GEO

Challenges

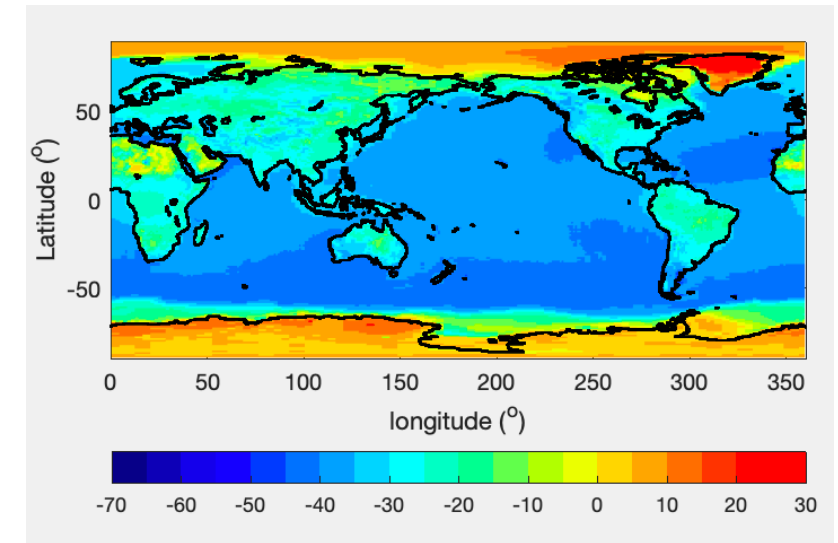
Aerosol type and optical properties

Table 15. Summary of the clear-sky radiative efficiency E_τ , defined as the aerosol radiative effect (Wm^{-2}) per unit aerosol optical depth (τ at 550 nm), in East Asia and Northwest Pacific.

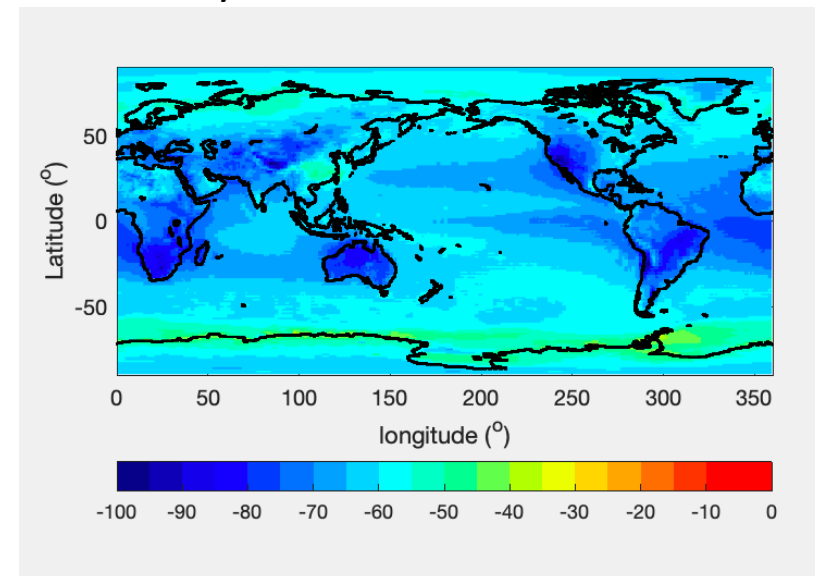
Region	Period	Source	E_τ	
			TOA	Surface
Zone 4 (ocean)	MAM	MODIS	-52	n/a
		CERES_A	-35	n/a
		CERES_B	-31	n/a
		MODIS_A	-44	-61
		Models	-25~-42	-45~-61
Northwest Pacific	April 2001	Seinfeld et al., 2004	-41	-71
Gosan, Korea	April, 2001	Bush and Valero, 2003	n/a	-80±11
Anmyon, Japan (ocean albedo)	Dust events (1998, 2000)	Kim et al., 2005	-26	-91
	Non-dust events (2000)		-22	-82
Gosan, Korea (ocean albedo)	Dust events (2001)		-21	-104
	Non-dust events (2001)		-29	-69
Amami-Oshima (ocean albedo)	Dust events (2001)		-12	-106
	Non-dust events (2000, 2001)		-18	-90
Zone 4 (land)	Fall	AERONET	-28	-82
		Models	-19~-27	-40~-54
Linan, East China (rural)	November, 1999	Xu et al., 2003	-33	-51
Dunhuang, China (desert)	April-July, 1998-2000	Kim et al., 2005	-9	-76
Yinchuan, China (urban)	September-December, 1997-2000		-16	-55
Sri-Samrong (SE Asia)	December-March, 1997-2000		-10	-63

Yu et al. 2006

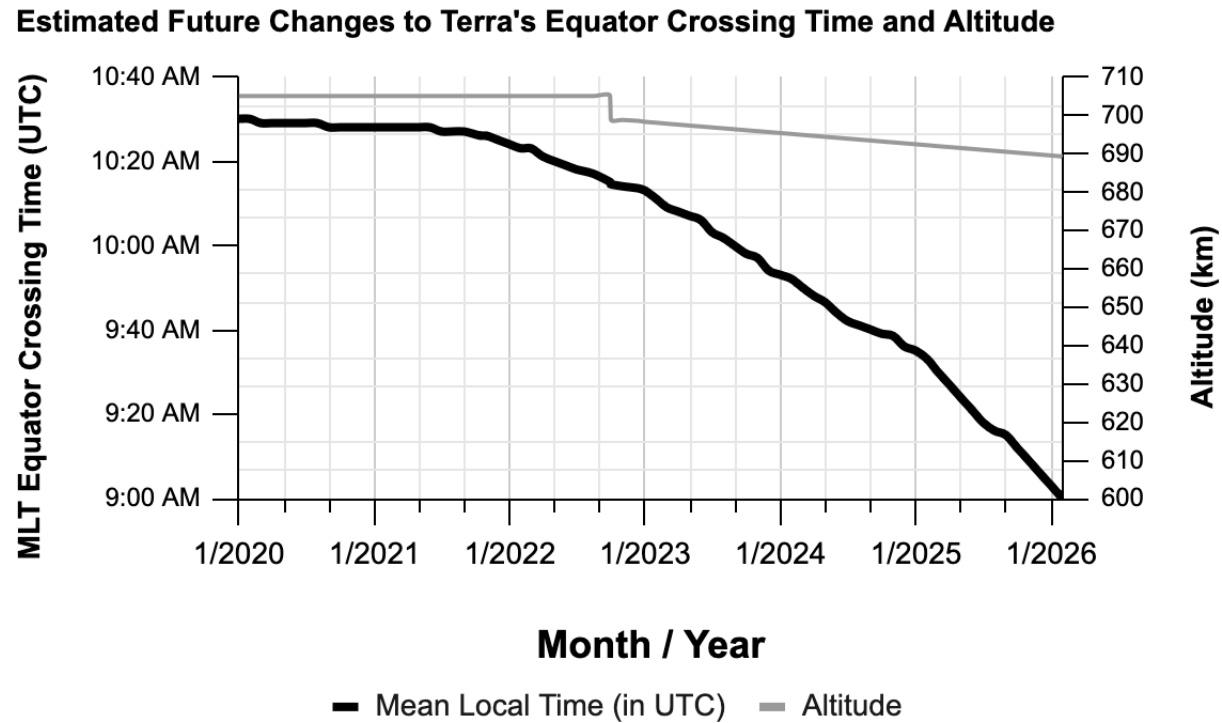
Clear-sky TOA DARE / 550 nm AOD



Clear-sky Surface DARE / 550 nm AOD



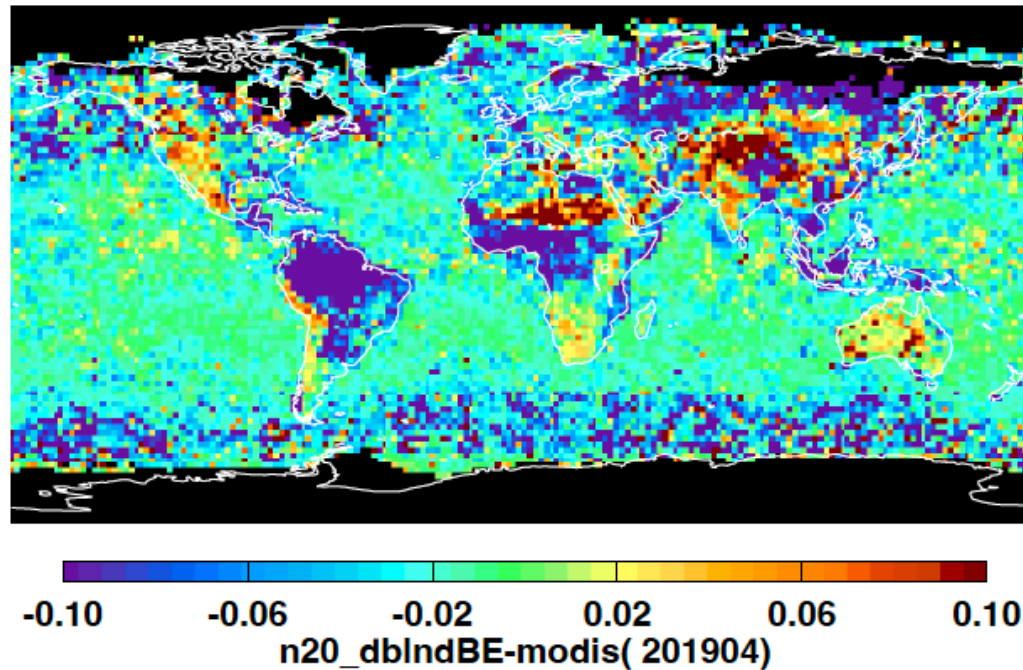
MODIS to VIIRS



Terra and Aqua are drifting.

We are using AOD derived from Terra and Aqua, but we need to switch to AOD derived from VIIRS on NOAA20

VIIRS – MODIS for April 2019



Difference of aerosol optical thickness derived from NOAA 20 VIIRS minus Terra+Aqua MODIS by the Dark Target and Deep Blue algorithms for April 2019. Dark Target aerosol optical thicknesses are used over ocean and land and best estimate of Deep Blue aerosol optical thicknesses are used over land.

We are working with Dark Target and Deep Blue teams to mitigate ADO discontinuity

N= 50107

Glb mean(sd): * -0.030 (0.086)

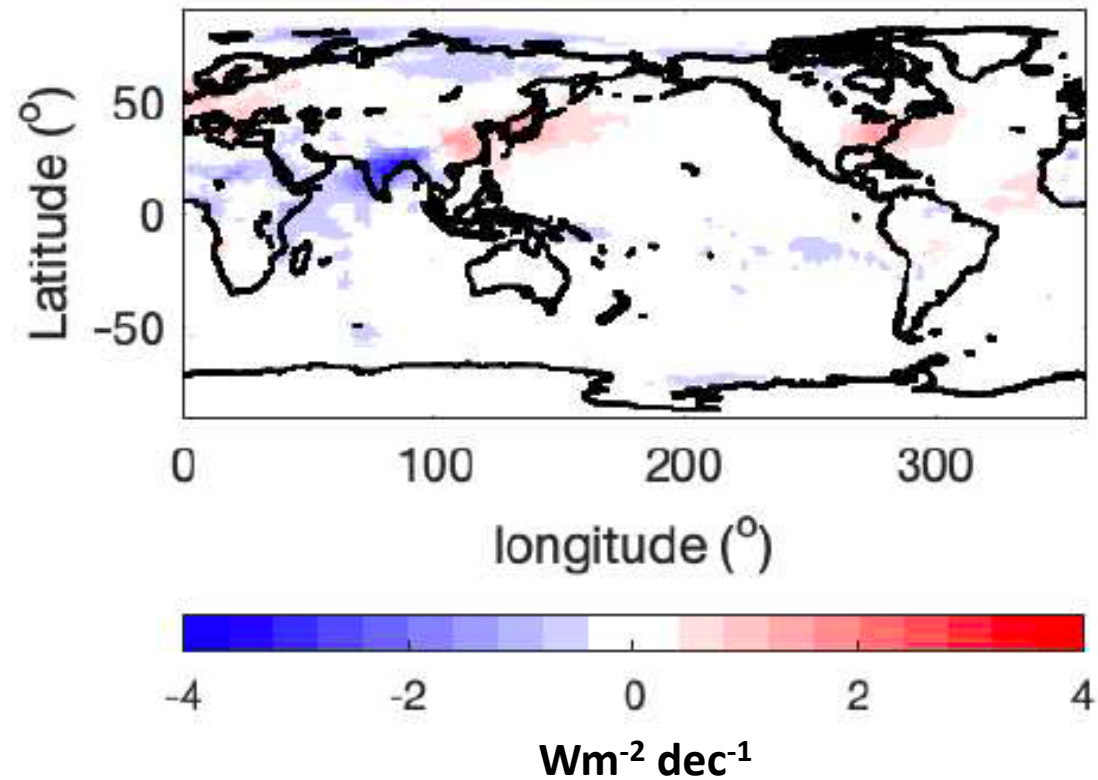
Mn/Mx: -2.66/ 1.18

Summary

- CERES team use aerosol optical thicknesses derived by Dark Target and Deep Blue teams
- CERES Edition 4 SYN1deg Level 3 product provide computed direct aerosol radiative effects for clear-sky and all-sky conditions
- Global mean direct aerosol radiative effects derived from SYN1deg product agree with observation-based estimate done in earlier studies.
- Frequency of occurrence of heavy aerosol loading events that affect the global mean clear-sky downward shortwave irradiance greater than 2-standard deviation is increasing
- Aerosol type and seamless transition of aerosol optical thickness that are derived from multiple imagers are challenging.

Backup slides

Aerosol and precipitation



Regional trend from GPCP

