How Well Does NASA GEOS Model Perform in Simulating Dust Deposition into the Tropical Atlantic Ocean?

Hongbin Yu

NASA Goddard Space Flight Center

Huisheng Bian, Qian Tan, Mian Chin, Dongchul Kim, Paul Ginoux

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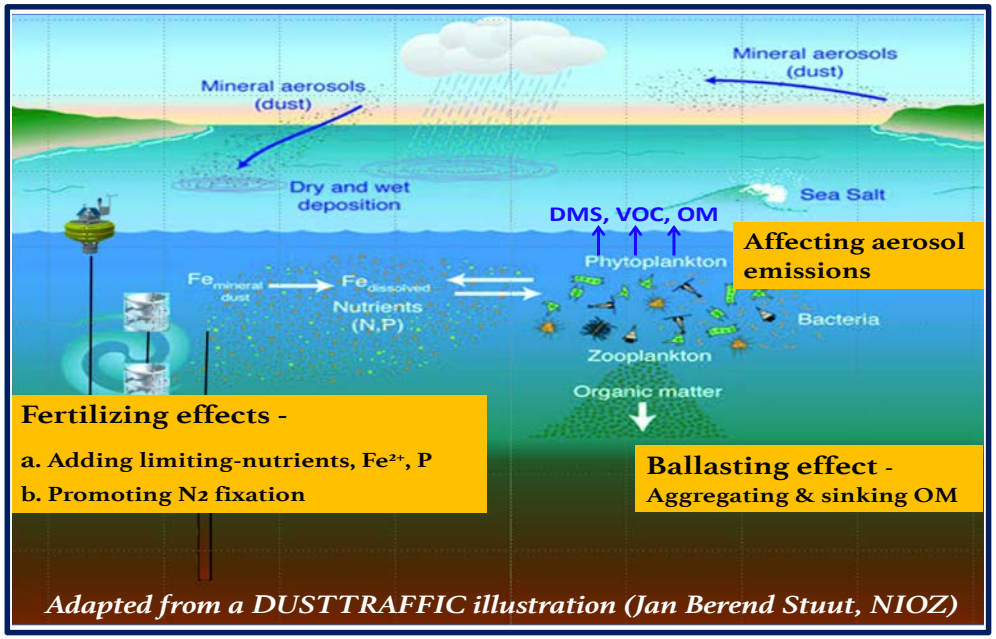
Motivation

- Dust deposition is crucial for understanding the dust impacts on ocean biogeochemical cycle & climate change.



Current Status

- Observations are ***scarce & over short periods***, esp. in remote oceans.
- Model simulations are ***very uncertain:***
  - Most of dust processes are ***highly parameterized*** without adequate obs. constraints, e.g., scavenging, emissions.
  - Data assimilation, being widely used to constrain aerosol loading (AOD), ***does not constrain*** the dust deposition.

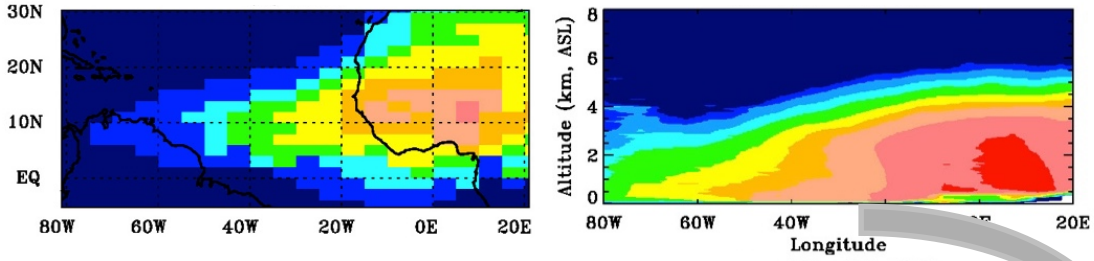
Objectives

- **Explore the use of satellite routine measurements to estimate:**
  - dust deposition (DD) into tropical Atlantic Ocean
  - loss frequency (LF) of dust *(i.e., how efficient dust is removed)*

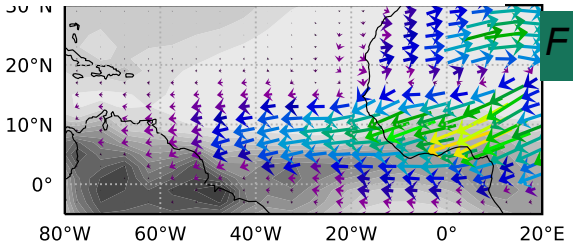
- **Compare GEOS simulations against satellite and in-situ observations to understand:**
  - *How does the model differ from the observations of dust deposition?*
  - *How do dust processes, e.g., transport/removal vs. emissions, contribute to model-observation agreement or discrepancy in the dust deposition?*

Estimation of Dust Deposition from Satellites

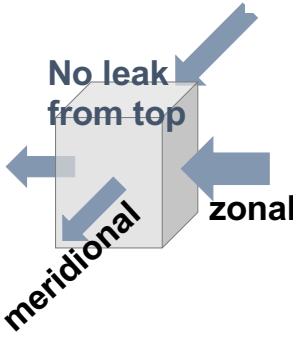
Monthly-aggregated dust 3-D distributions



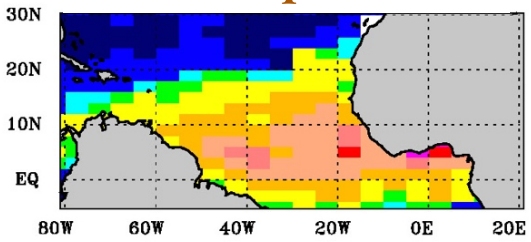
Zonal & meridional dust fluxes



$$F = \int m(z)u(z)\,dz$$



Dust deposition



"Mass Balance"

- Daily snapshot doesn't represent dust deposition
- The method only derives monthly bulk deposition *(hourly/daily processes accounted for, but not resolvable)*

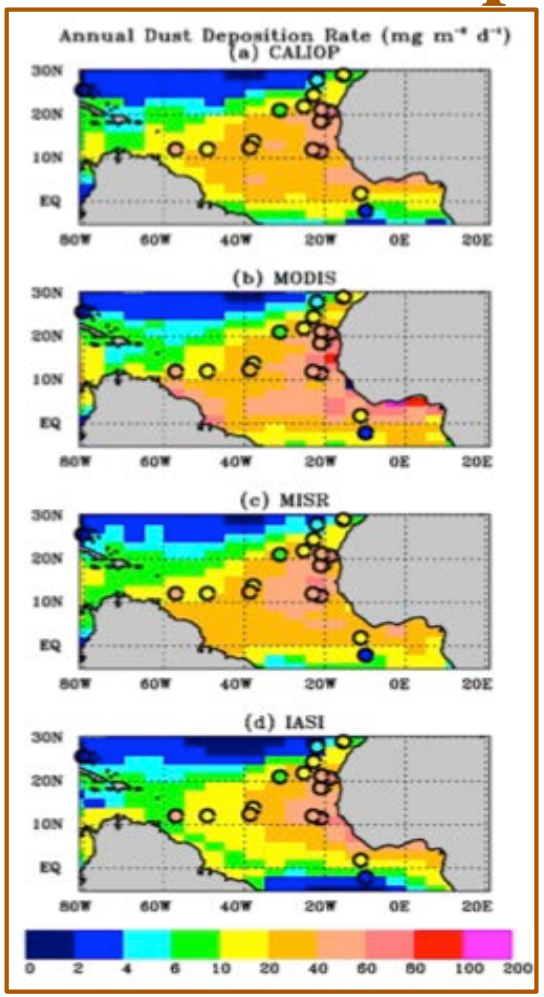
2007-2016 data

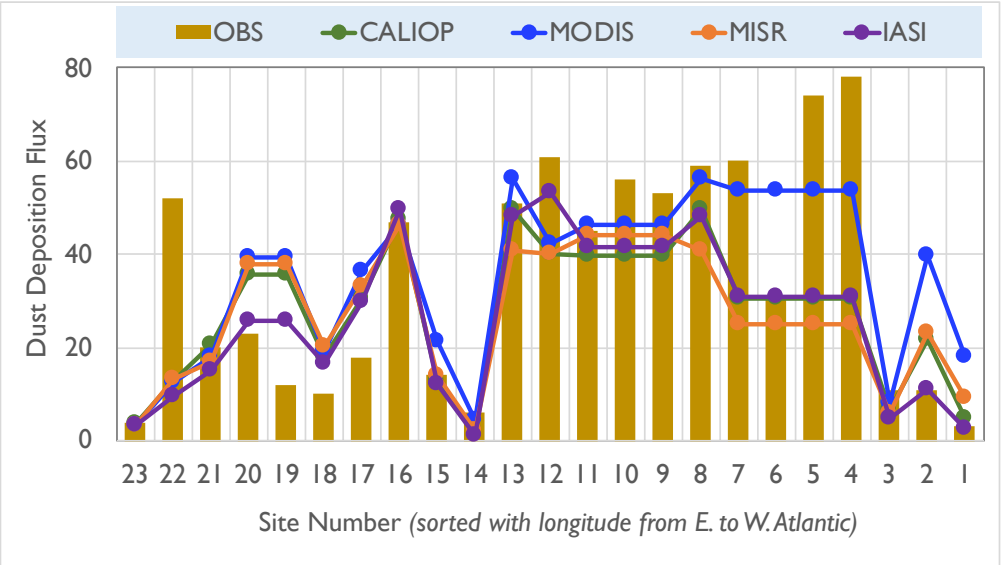
- **CALIOP**
- **MODIS**
- **MISR**
- **IASI**

} **CALIOP**

Yu et al., Estimates of African dust deposition along …… JGR 2019, accepted

Dust Deposition: Satellite vs In Situ

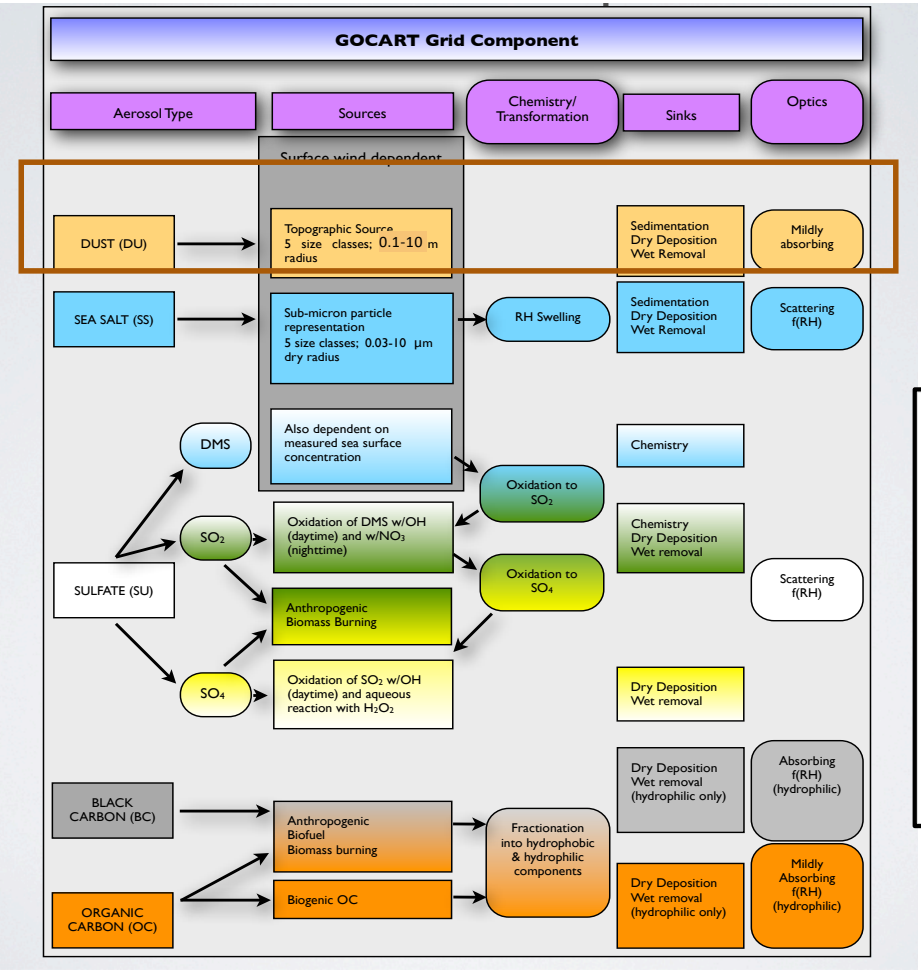




Ocean: *In-situ Obs.* = 1.26 * CALIOP
= 0.98 * MODIS
= 1.29 * MISR
= 1.32 * IASI

Yu et al., *Estimates of African dust deposition along the trans-Atlantic transit using the decade-long record of aerosol measurements from CALIOP, MODIS, MISR, and IASI. J. Geophys. Res., 2019, accepted.*

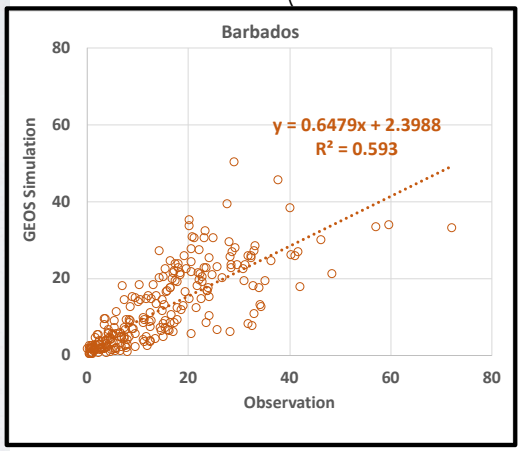
GEOS Dust Simulations

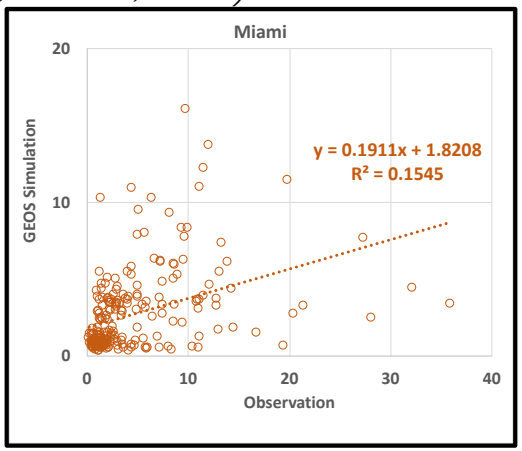


- ❑ MERRA-2 meteorology
- ❑ 1°x1° horizontal resolution
- ❑ 72 vertical layers
- ❑ 1995-2016 runs

Barbados & Miami dust data (1996-2016)

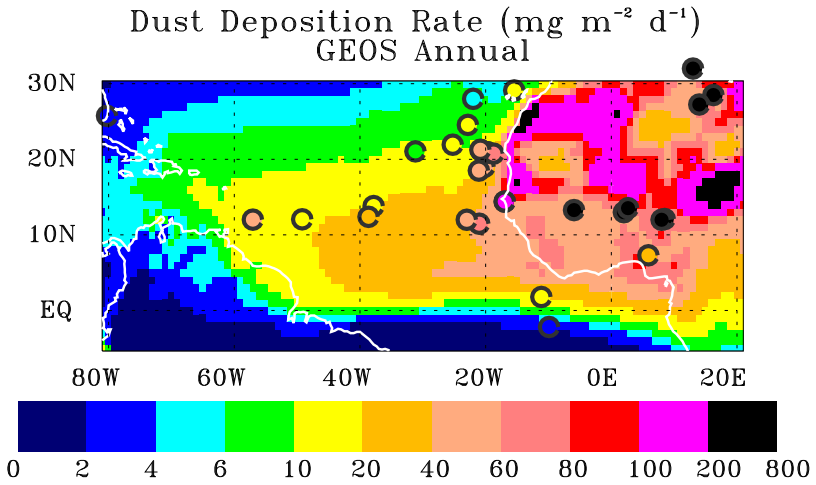
(Zuidema et al., BAMS, 2019)

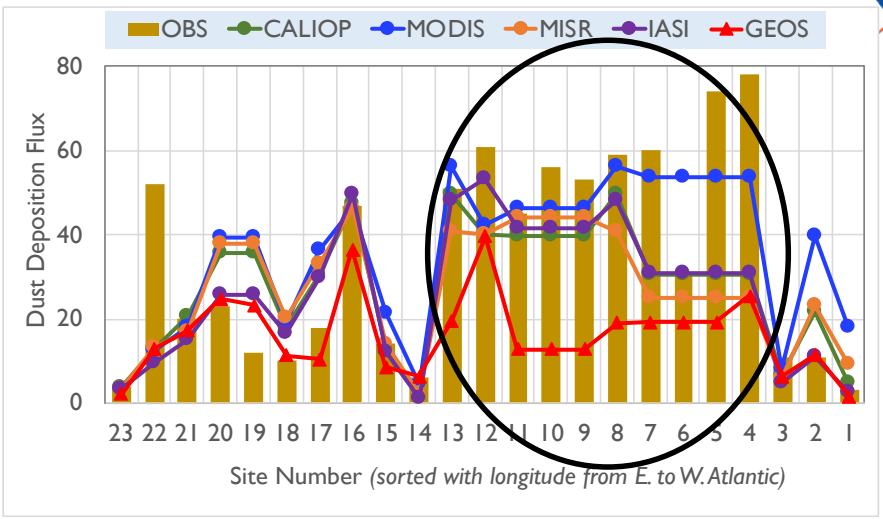




GEOS substantially underestimates surface dust observed in Caribbean Basin – by 5x in Miami and 35% in Barbados

Dust Deposition: GEOS vs Observations [1]



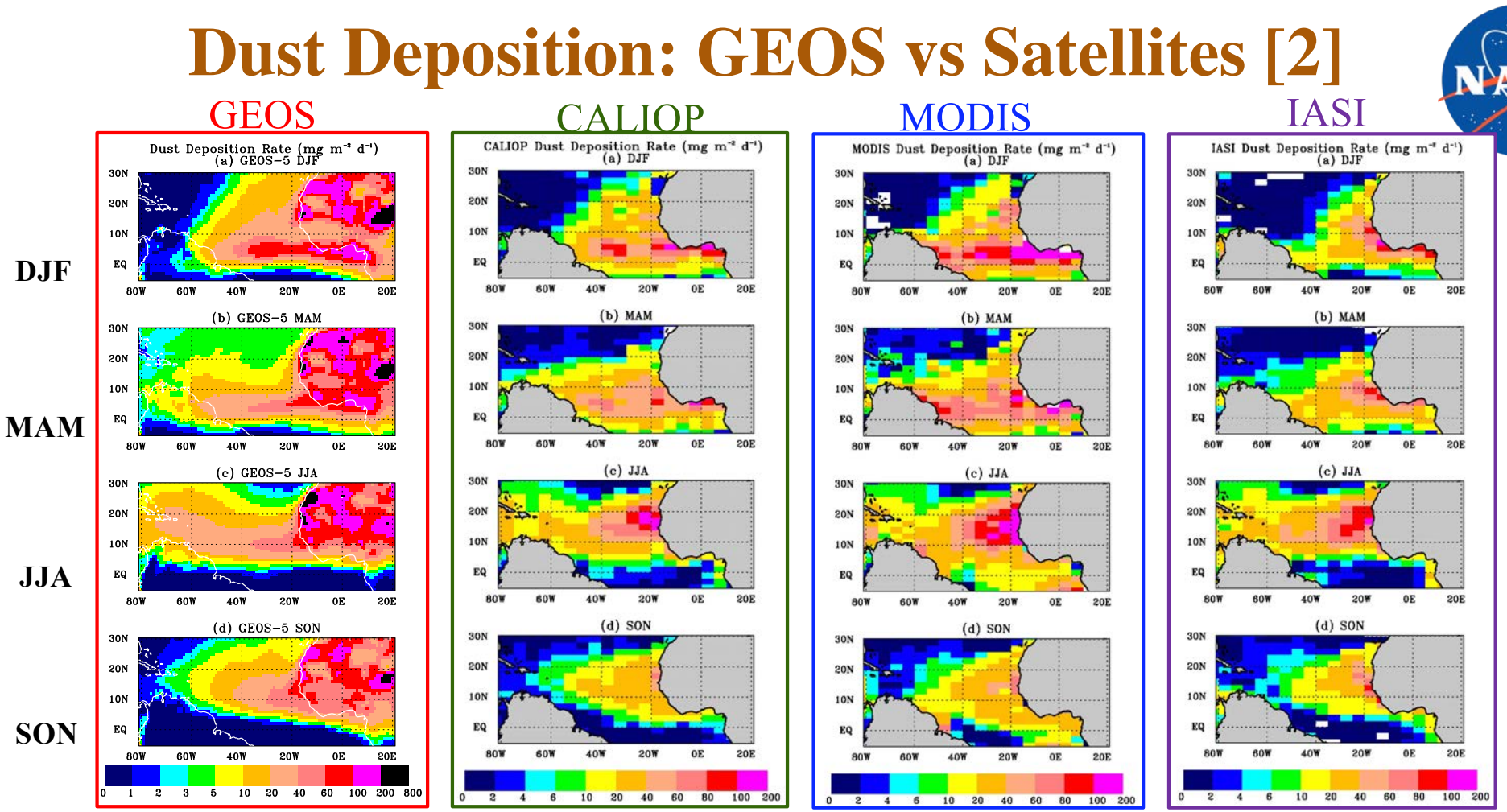


GEOS underestimates dust deposition over coastal ocean *(4-13)* and land

Ocean: *in-situ Obs.* = **2.14 * GEOS**

land: *in-situ Obs.* = **5.29 * GEOS**

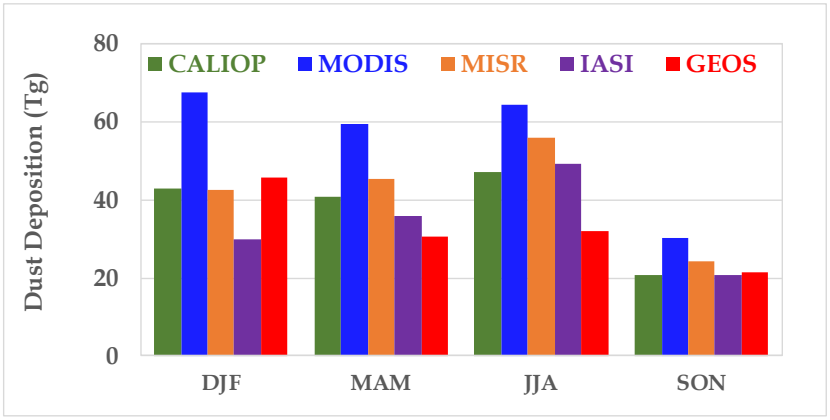
Dust Deposition: GEOS vs Satellites [2]

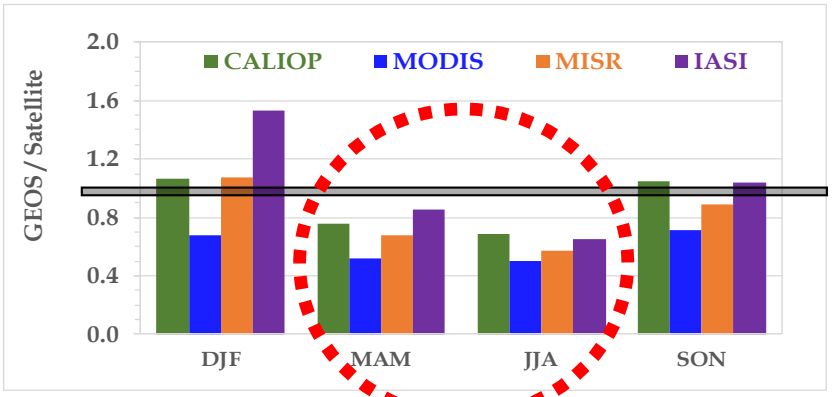


generally similar patterns, but clear difference in summer

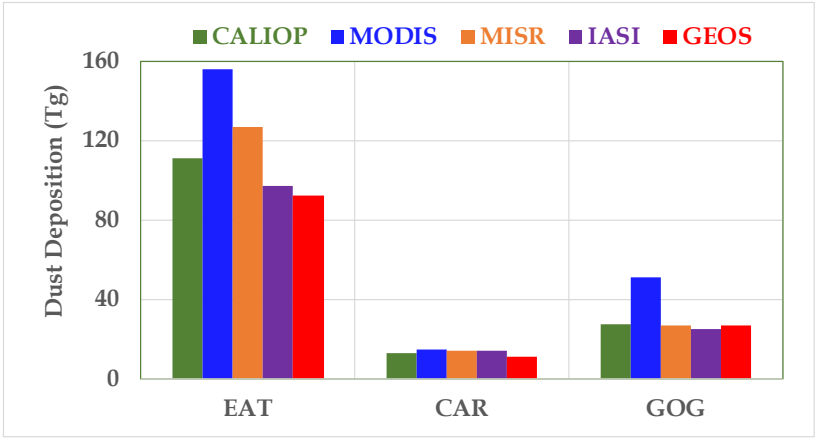
Dust Deposition: GEOS vs Satellites [3]

EAT + GOG + CAR





	GEOS	CALIOP	MODIS	MISR	IASI
Dust Deposition (Tg)	132	152	222	168	136



- *Consistently smaller in summer & spring*
- *Differences are larger near the African coast than in Caribbean Basin.*

What We Have Learned:

The GEOS simulation of **dust deposition** into tropical Atlantic Ocean is close to the low bound of satellite-based estimates.

- consistently smaller in summer & spring
- greater underestimate near the African coast than in Caribbean Basin

Next Steps:

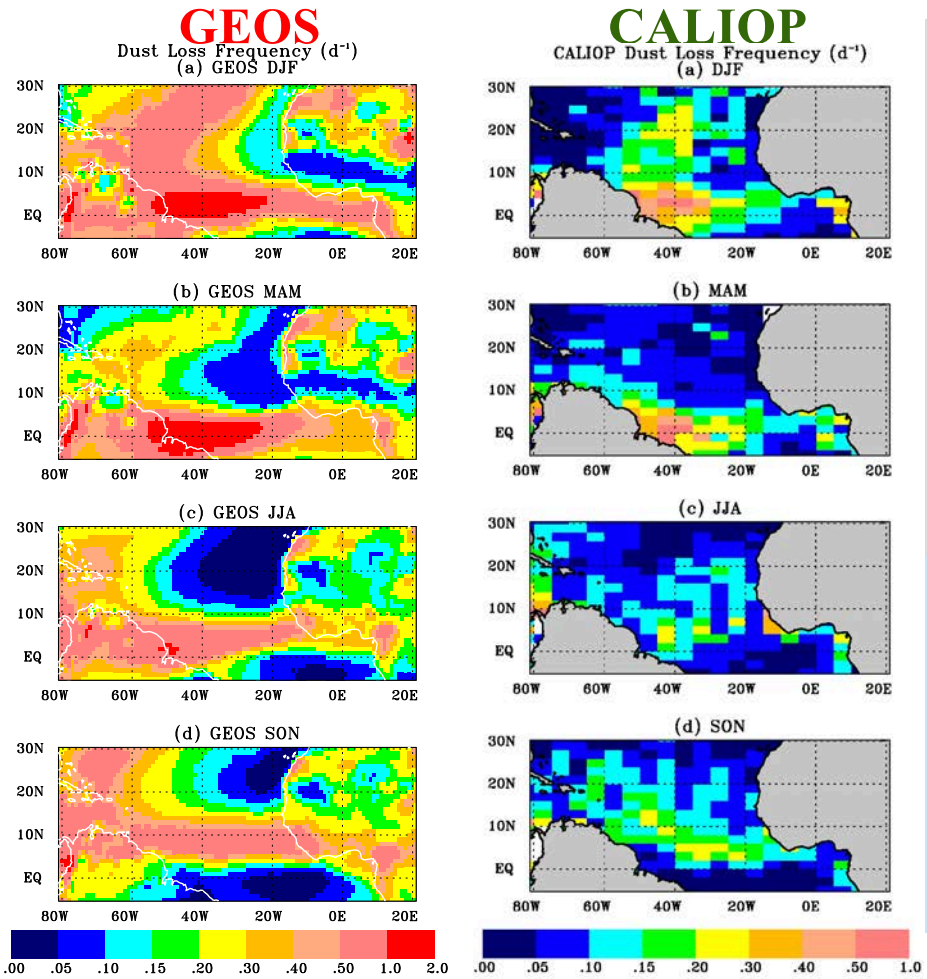
We examine how two dust processes, i.e., **(1) transport/removal**, and **(2) emissions**, contribute to the dust deposition estimates.

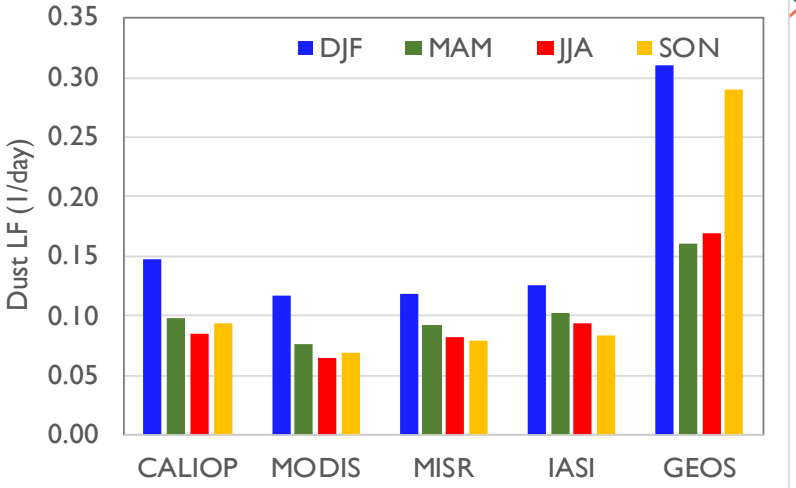
To isolate transport/removal processes from dust emissions:

Loss Frequency (LF)*[1/day]*=[Dust Deposition Rate] ÷ [Dust Mass Loading=DOD/MEE]

- less sensitive to assumed dust MEE (more accurate than dust deposition)

Dust Loss Frequency: GEOS vs Satellites [1]

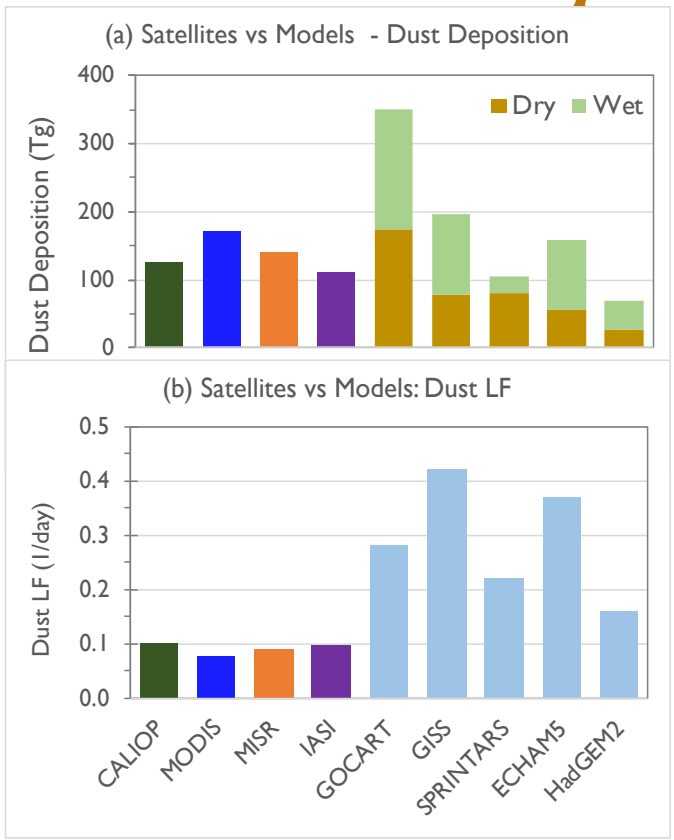




Pronounced differences between the satellites and GEOS model:

- *GEOS model > Satellites*
- *much larger in winter & fall than in spring & summer*

Dust Loss Frequency: AeroCom vs Satellites



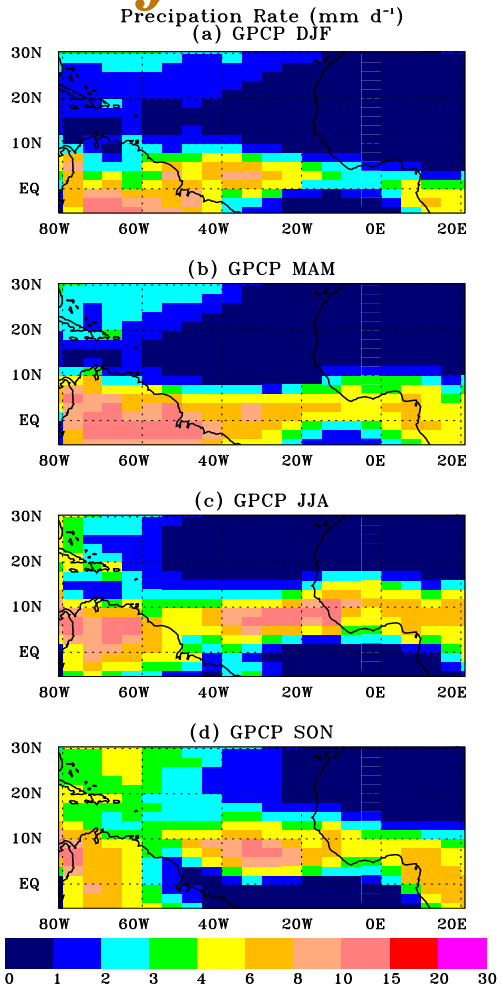
AeroCom Models from Kim et al. (2014)

<u>The large model-satellite LF discrepancy alludes to possible model deficiencies</u>

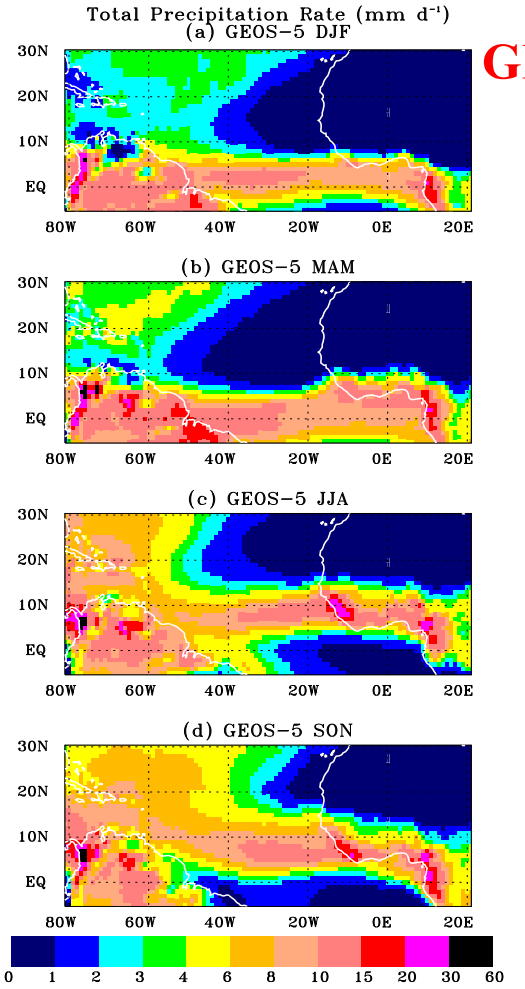
- ***Rainfall may be too intense?***
- ***Altitude of dust layer may be too low?***
- *Scavenging coefficient may be too high?*
- *Settling & dry deposition may be too fast?*

Model's rainfall is more intense than GPCP

GPCP



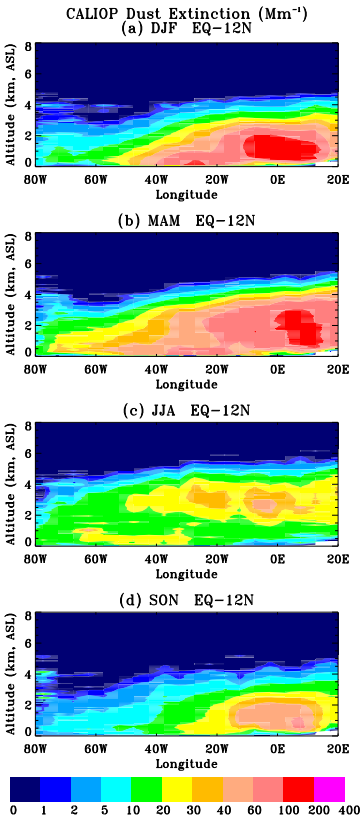
GEOS



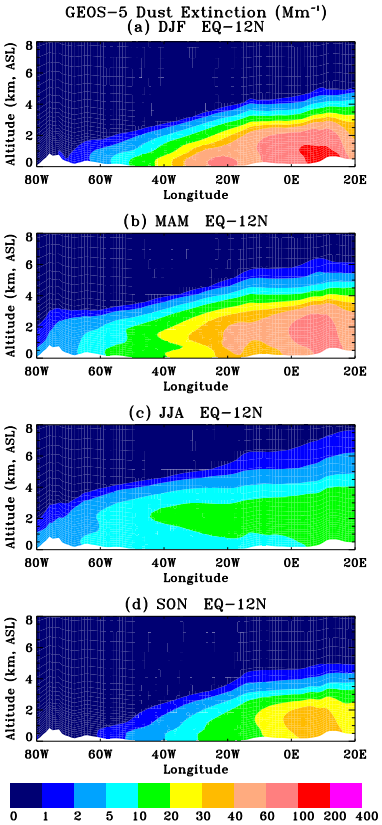
GEOS dust profiles show reasonably good agreement with CALIOP observations

[EQ-12N]

CALIOP

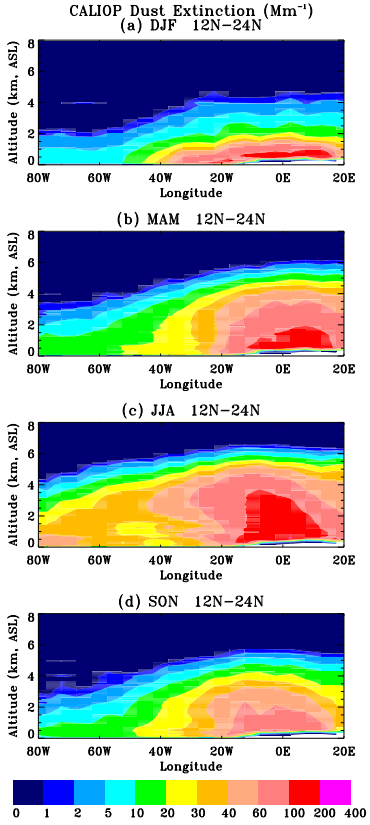


GEOS

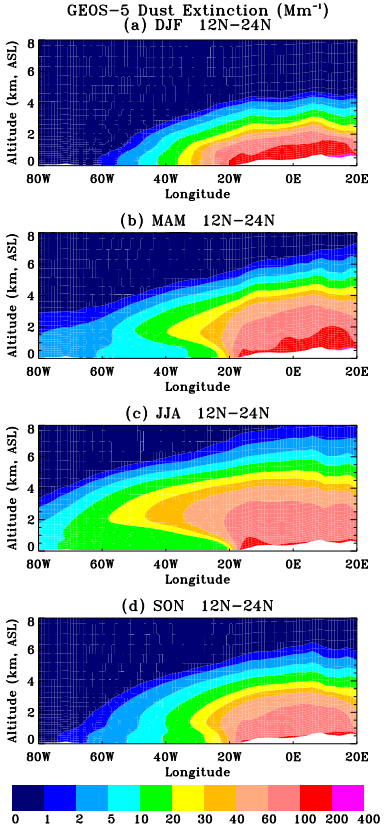


[12-24N]

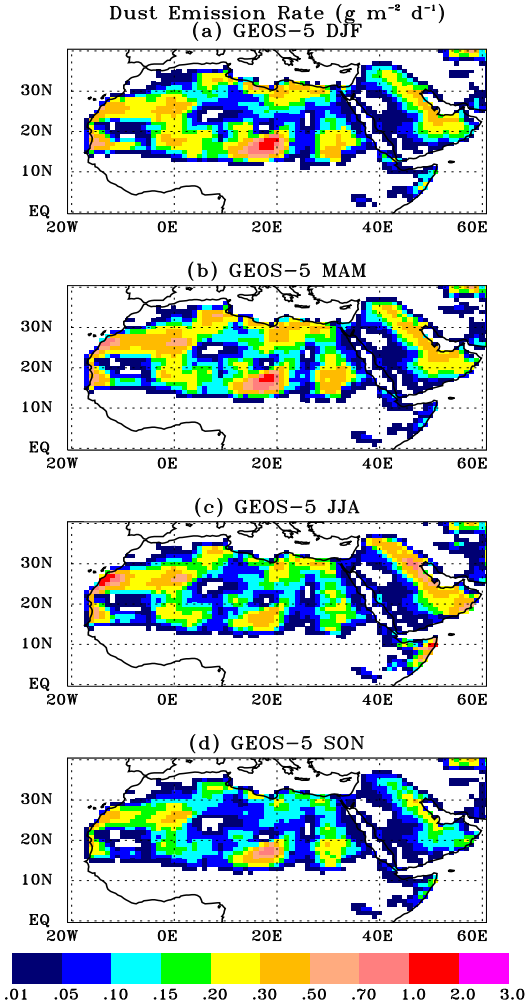
CALIOP



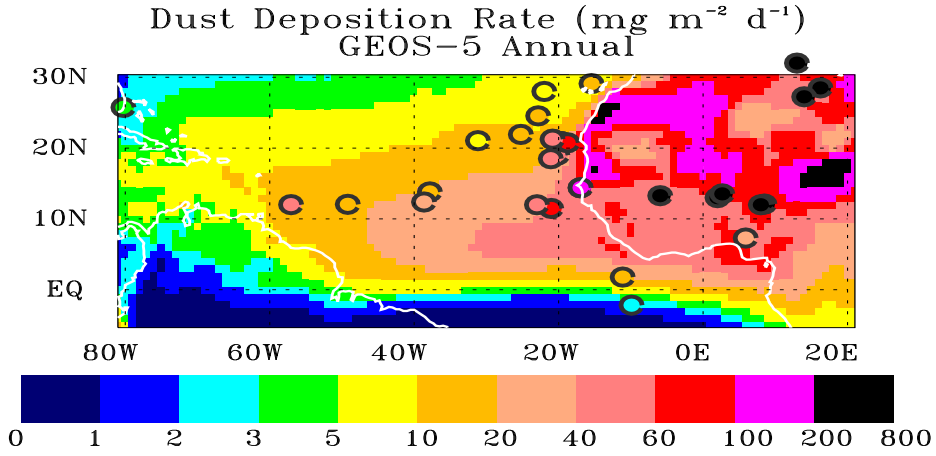
GEOS



How Well Does GEOS Represent Dust Emissions? [1]

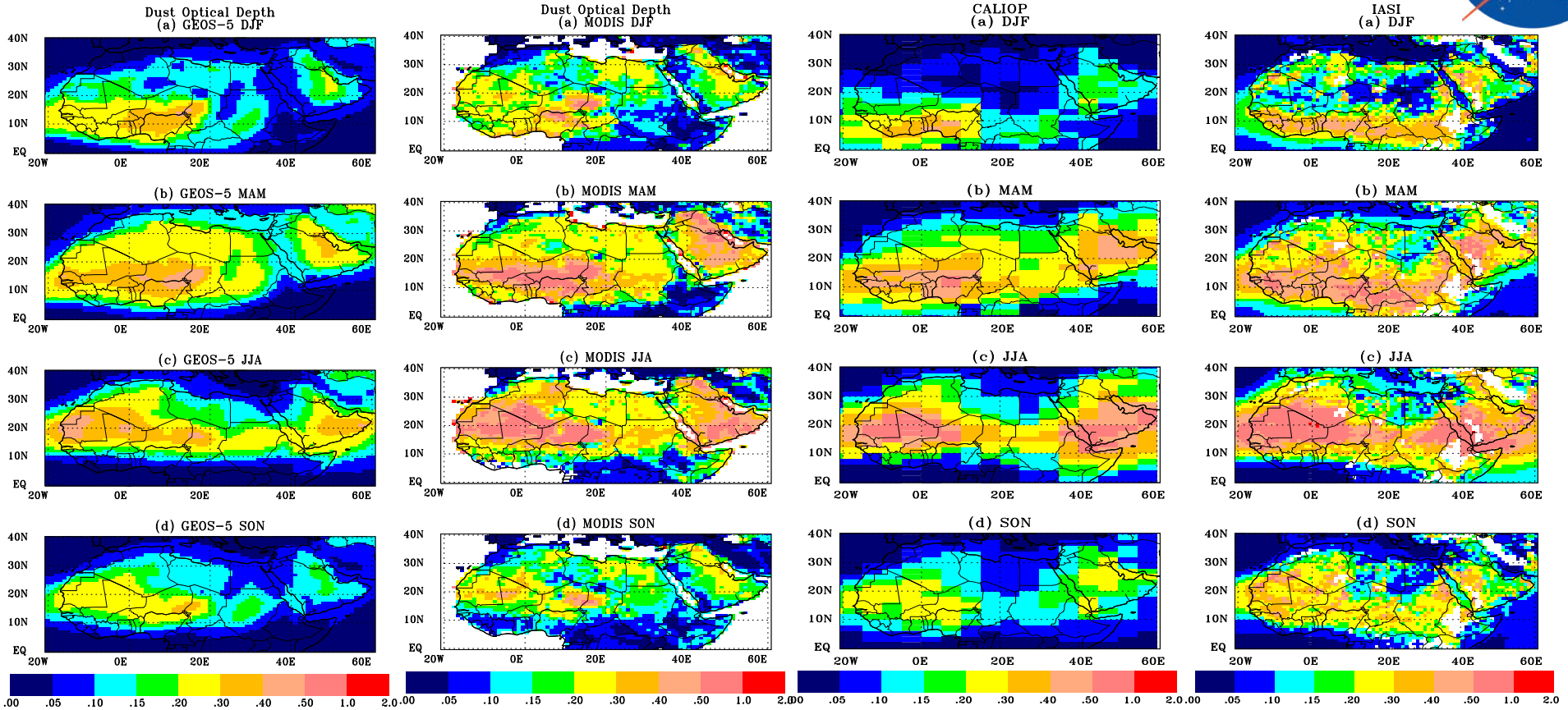


- *Does the model capture major dust sources?*
- *Are magnitudes of dust emissions biased high or low?*



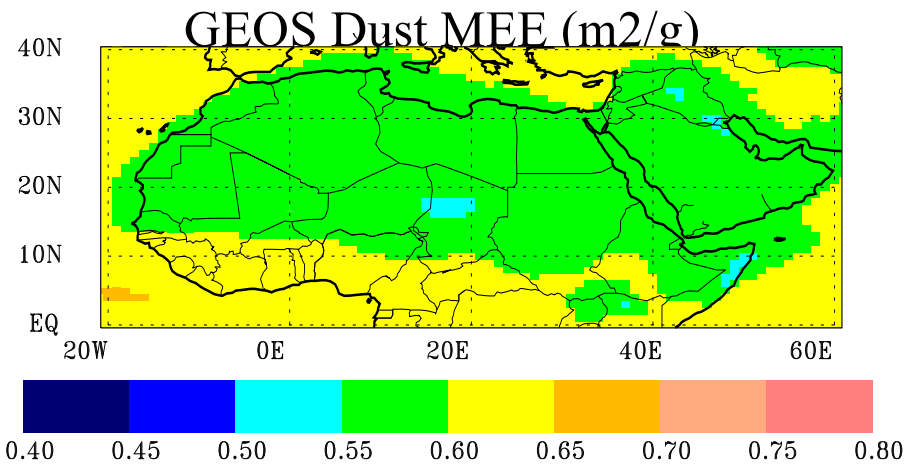
Over land, the model underestimates dust deposition by a factor of 5, suggesting a substantial underestimate of emissions (magnitude & size range).

How Well Does GEOS Represent Dust Emissions? [2]

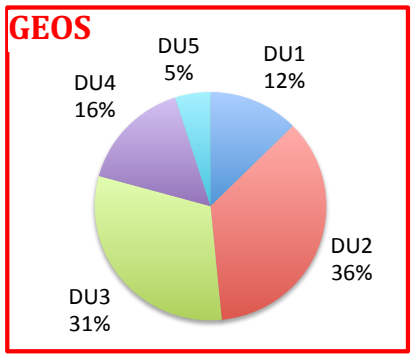


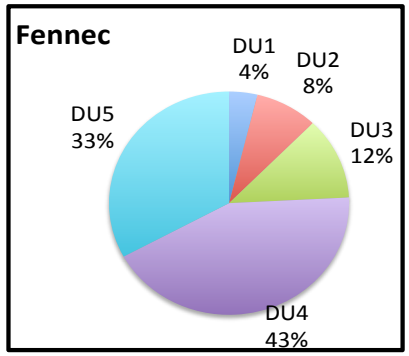
How Well Does GEOS Represent Dust Emissions? [3]

- *The model is mass-based, while satellites are extinction-based*
- *DOD = [Mass Loading] * MEE*
- *It is necessary to understand potential bias in MEE.*



DU1-DU2-DU3 $0.2<D_e<6.0\mu m$
DU4-DU5 $6.0<D_e<20\mu m$





- ❑ The PSD is biased to fine particles & Particles >20μm excluded
- ❑ Model MEE is biased high & Emissions are more low-biased than DOD

Conclusions

- ***Based on a comparison with the 10-year climatology of dust deposition*** from CALIOP, MODIS, MISR, and IASI measurements
  - *The GEOS dust deposition is close to the low bound of satellite estimates*
  - *Consistently smaller in summer & spring; larger difference near the African coast than in Caribbean Basin*

- The model-satellite differences in dust deposition are a ***compensation*** of the model's
  - ***underestimate of dust emissions*** *- needs size-resolvable emissions*
  - ***but overestimate of dust removal efficiency*** *– needs to reduce the model's rainfall overestimate before adjusting the model's scavenging parameters.*


Thank You