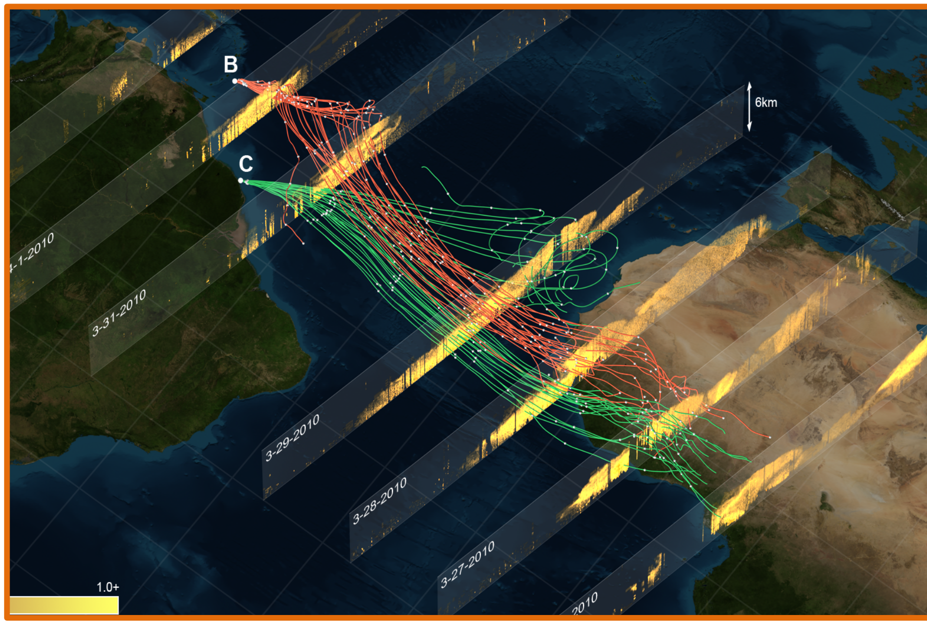


Satellite-based Estimates of Dust Deposition into Tropical Atlantic Ocean

Hongbin Yu [a], Mian Chin [a], Qian Tan [b], Zhibo Zhang [c], Qianqian Song [c], Dongchul Kim [a, d], Huisheng Bian [a, c], Tianle Yuan [a, c]

[a] NASA Goddard Space Flight Center, [b] Bay Area Environmental Research Institute, [c] University of Maryland Baltimore County, [d] Universities Space Research Association

Acknowledgements:

CALIOP – David Winker, Ali Omar

MODIS – Robert Levy, Lorraine Remer

MISR – Ralph Kahn, Olga Kalashnikova

IASI – Laurent Crepeau, Virginie Capelle, Alain Chedin

MERRA2 – Cynthia Randles, Arlindo da Silva

FENNEC – Claire Ryder

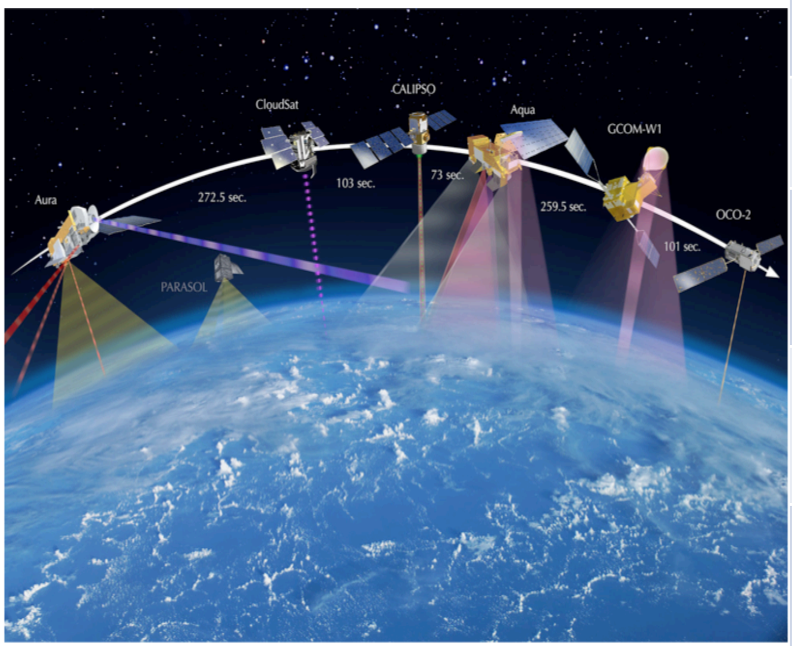
NASA support under the CALIPSO/CloudSat Science Team

Motivation & Objectives

- Dust deposition is believed to play important roles in ocean biogeochemical cycles, carbon sequestrations, and climate change.
  - **direct fertilizing effect**—providing essential nutrients Fe, P etc.
  - **indirect fertilizing effect**—promoting nitrogen fixation
  - **ballasting effect**—aggregating & sinking particulate organic carbon (POC)
- Observations of dust deposition are rare and model simulations are highly uncertain.
- **Objectives:** **(1)** to estimate the dust deposition into Atlantic Ocean from satellite measurements of aerosol 3-D distributions; **(2)** to evaluate model simulations.

A-Train (+other) provides several capabilities of observing global dust from space

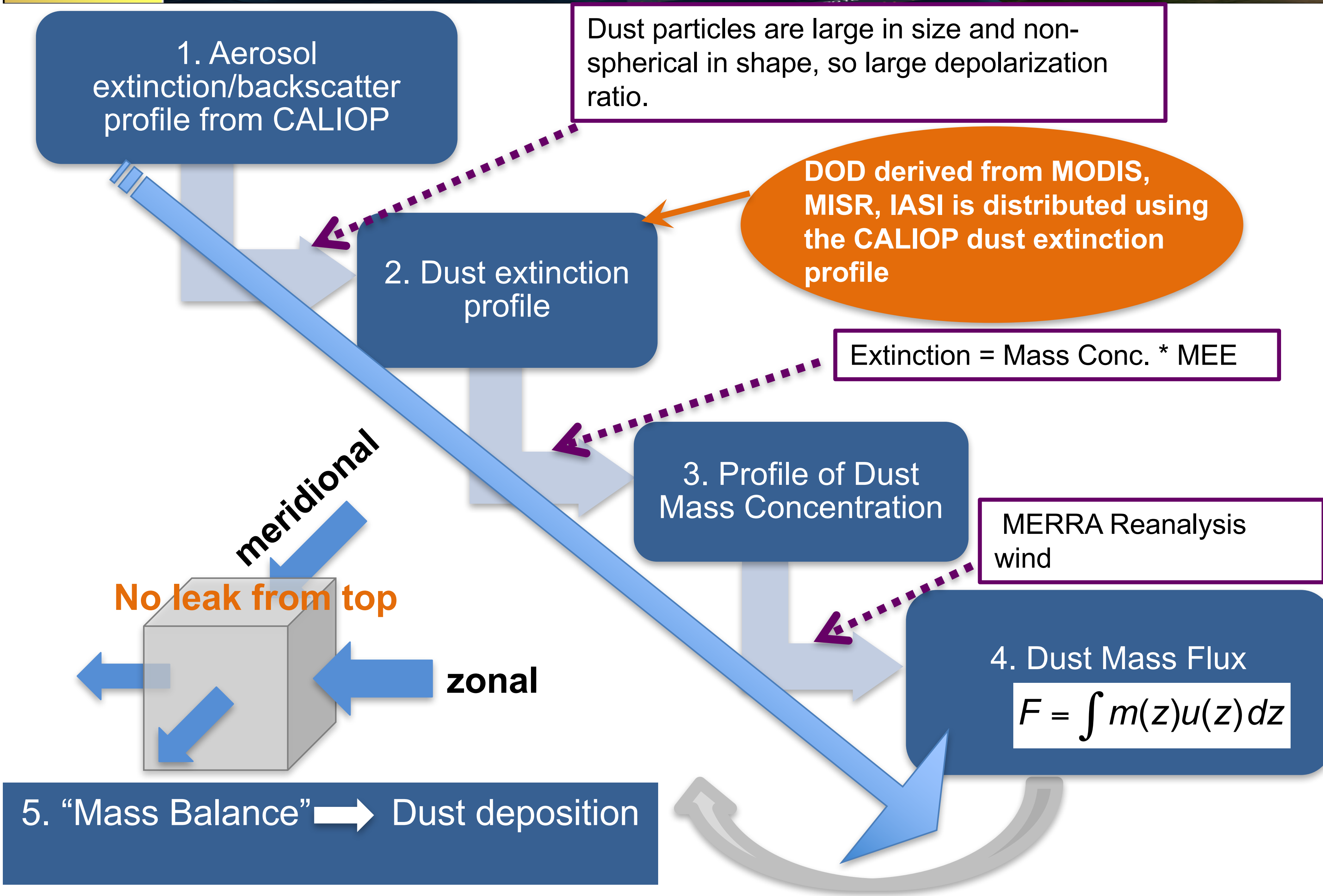
- Dust, generally large and non-spherical particles, can be separated from other types based on A-Train(+other) measurements.
- A synergy of these measurements can characterize the dust transport in 3-D *(passive + active)*



Sensor	Technique	Observables
CALIOP CATS	polarization lidar	Vert. profiles & particle shape
MODIS	multiple wavelengths	AOD & particle size
MISR	multi-angle, multiple wavelengths	AOD & particle shape
IASI **AIRS**	thermal IR	AOD at 10um & height info
POLDER	multi-angle, multiple wavelengths, polarization	AOD & particle shape

** POLDER GRASP data will be analyzed in near future*

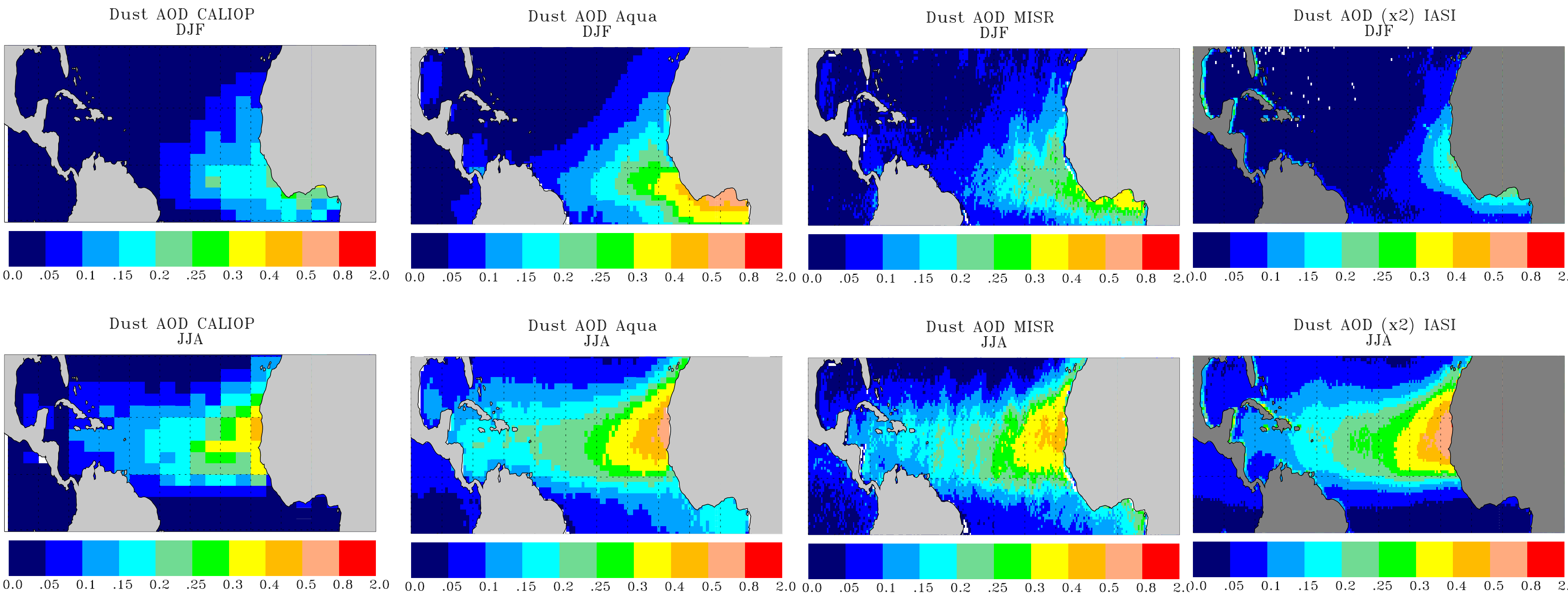
Step-by-step Estimation of Dust Transport & Deposition



Yu et al., Remote Sens. Environ., 2015 & Yu et al., Geophys. Res. Lett., 2015

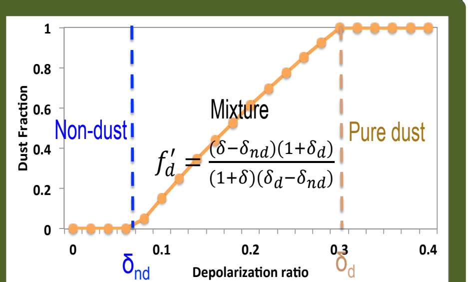
Dust Optical Depth Derived from Satellites

CALIOP | **MODIS** | **MISR** | **IASI (x2)**



CALIOP

$DOD = AOD*f_d$



MODIS

$DOD = [AOD(f_c-f)-AOD_m(f_c-f_m)]/(f_c-f_d)$

f – fine-mode fraction

d – dust; m – marine;

c – combustion

MISR

$DOD = AOD*f_{non-sph}$

$f_{non-sph}$: non-spherical fraction from multi-angle observations

IASI (x2)

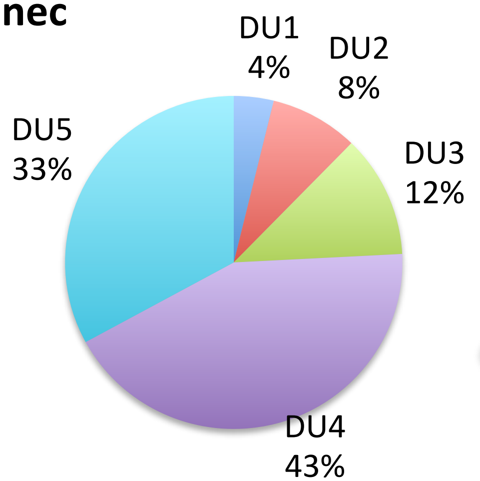
$DOD = AOD_{10um}$

thermal infrared channels only sensitive to elevated coarse particles.

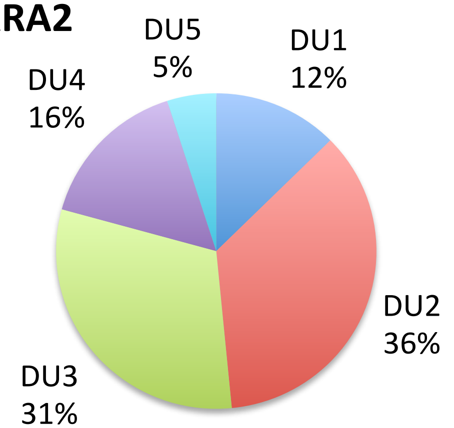
Dust Mass Extinction Efficiency (MEE)

Size distribution

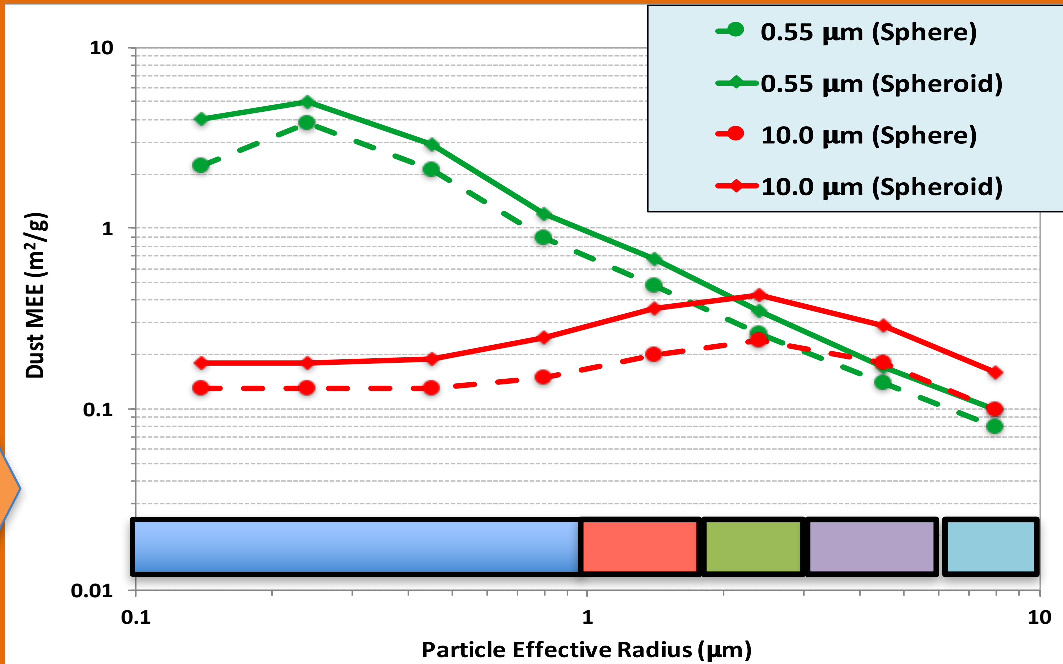
Fennec

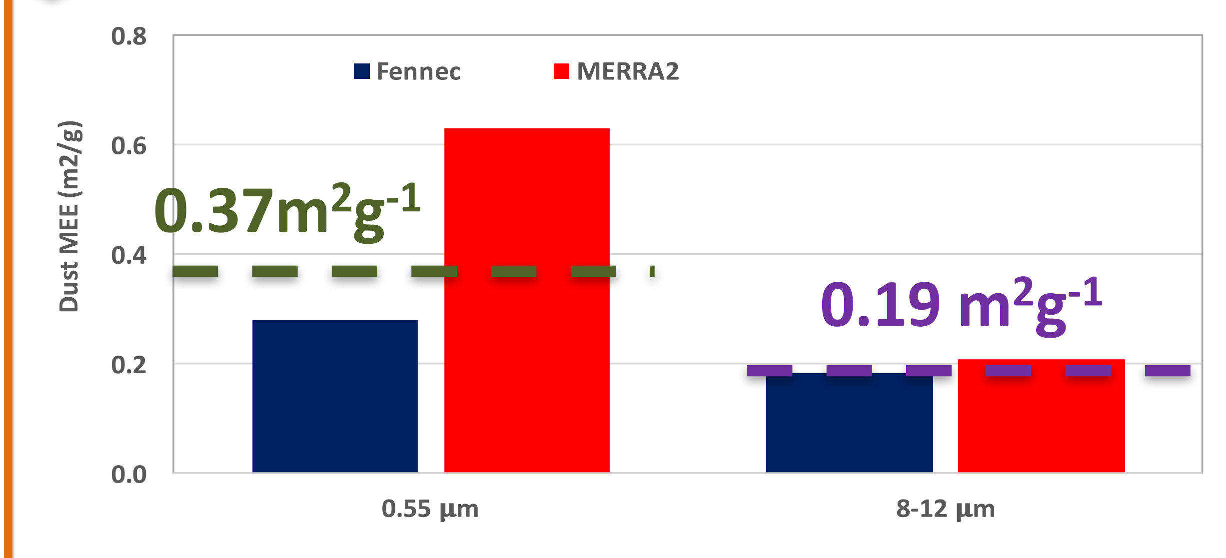


MERRA2

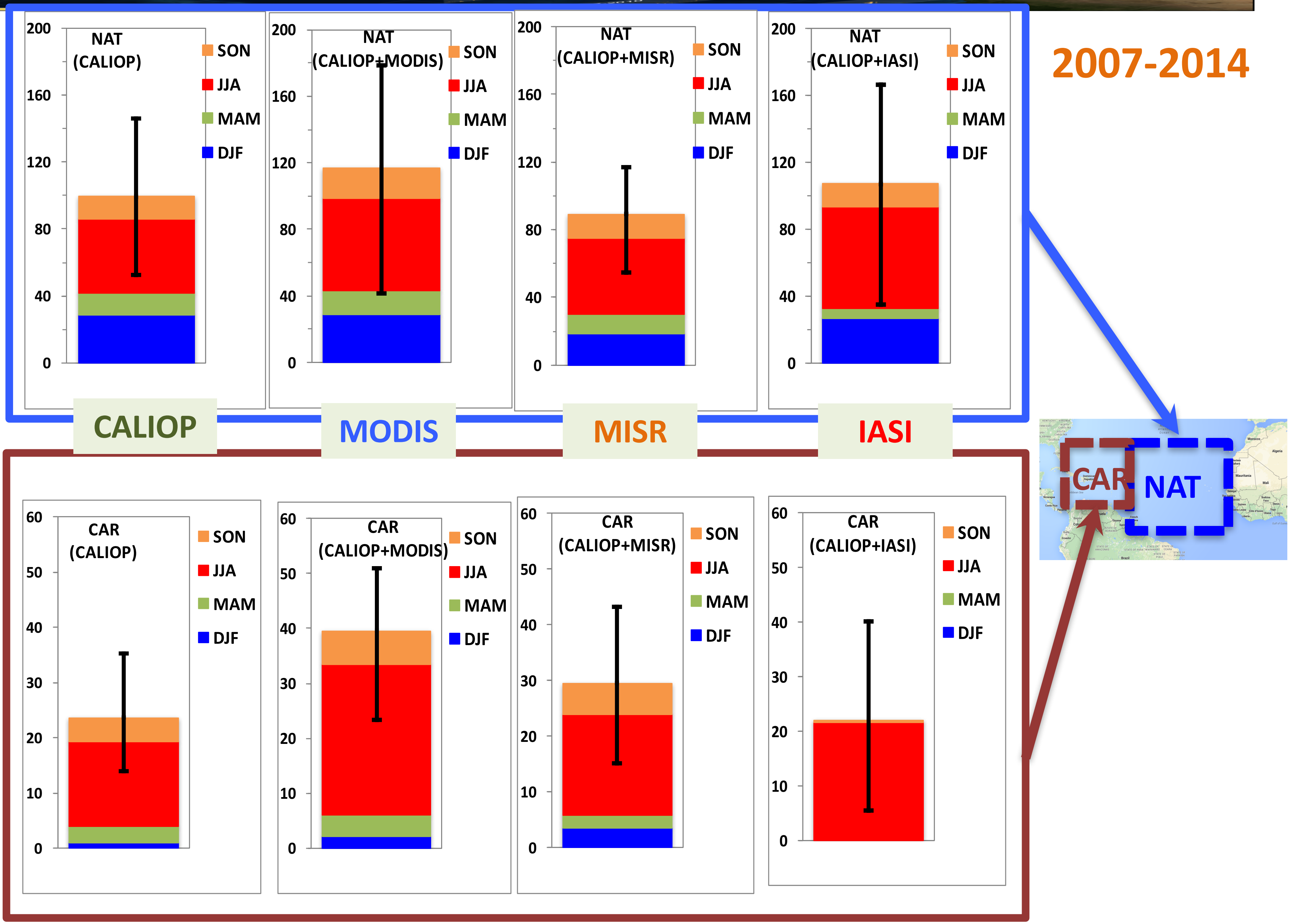


MERRA2 biases to fine particles (R_e < 3 µm, DU1-DU2- DU3)

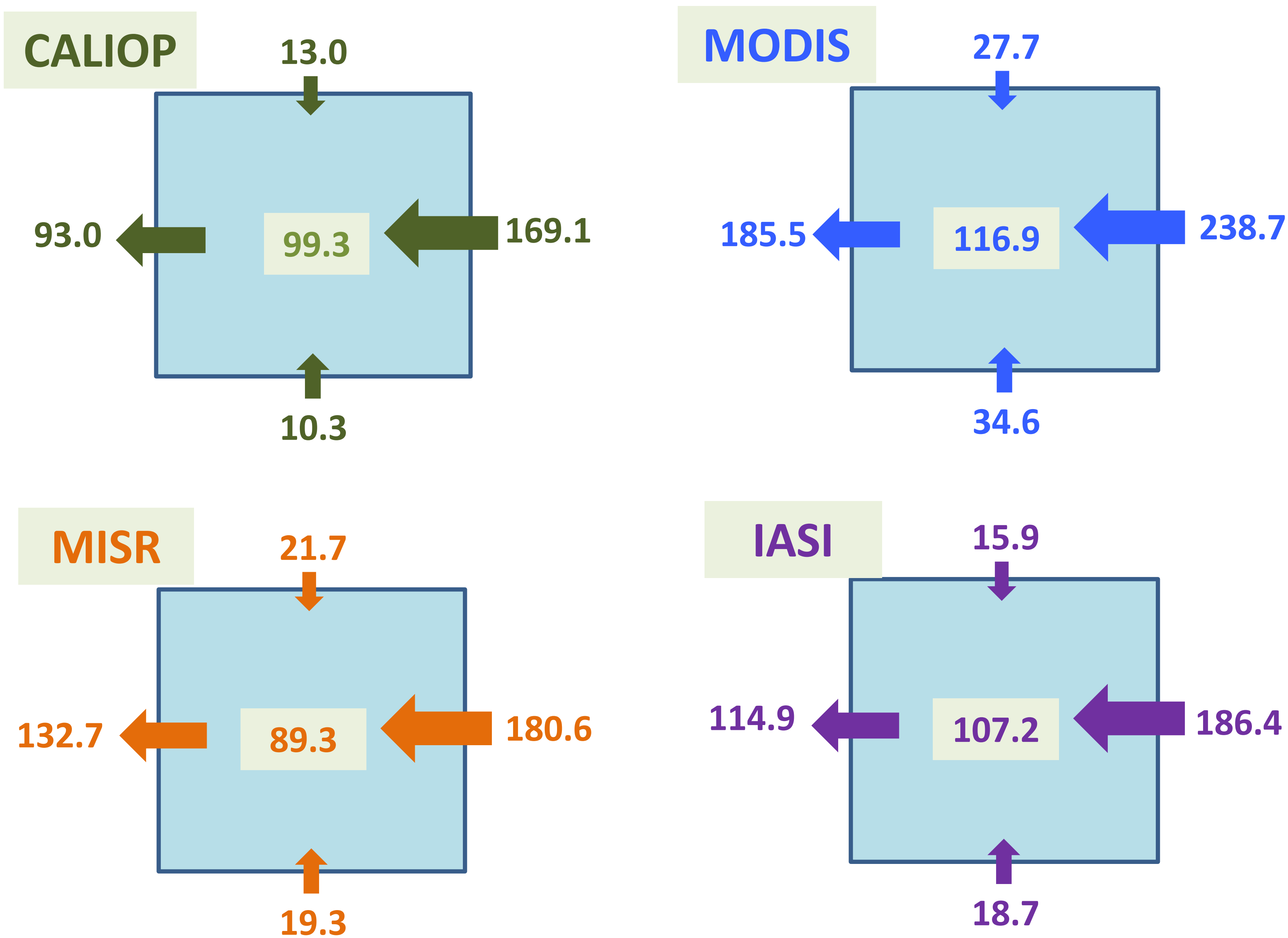




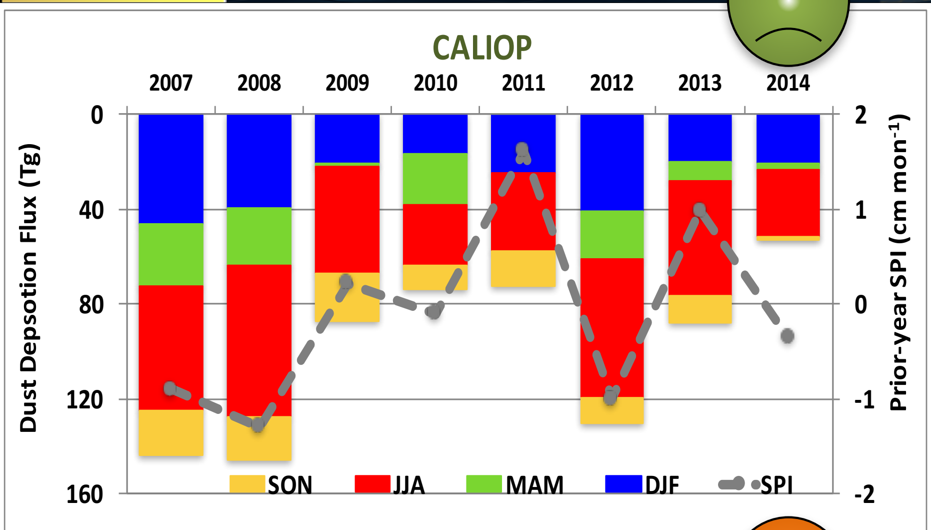
Satellite-Based Estimates of Dust Deposition (Tg)

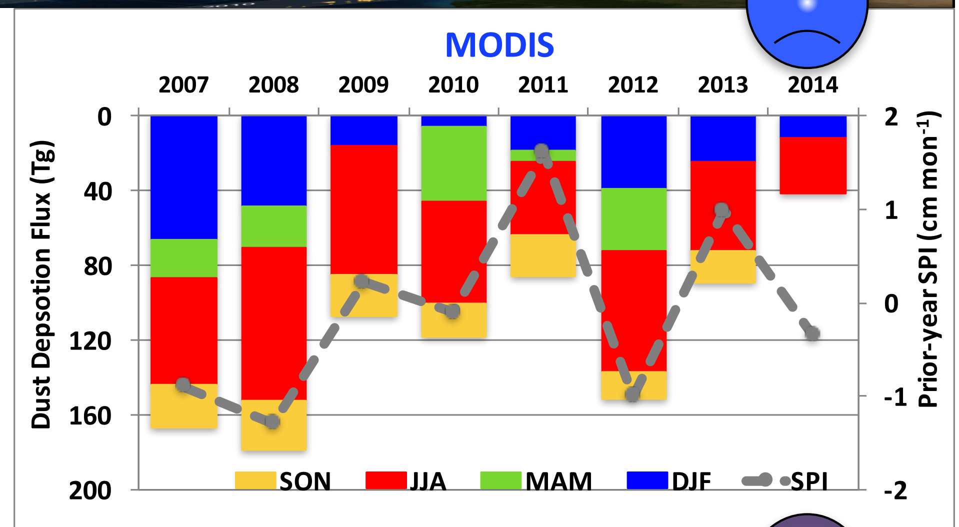


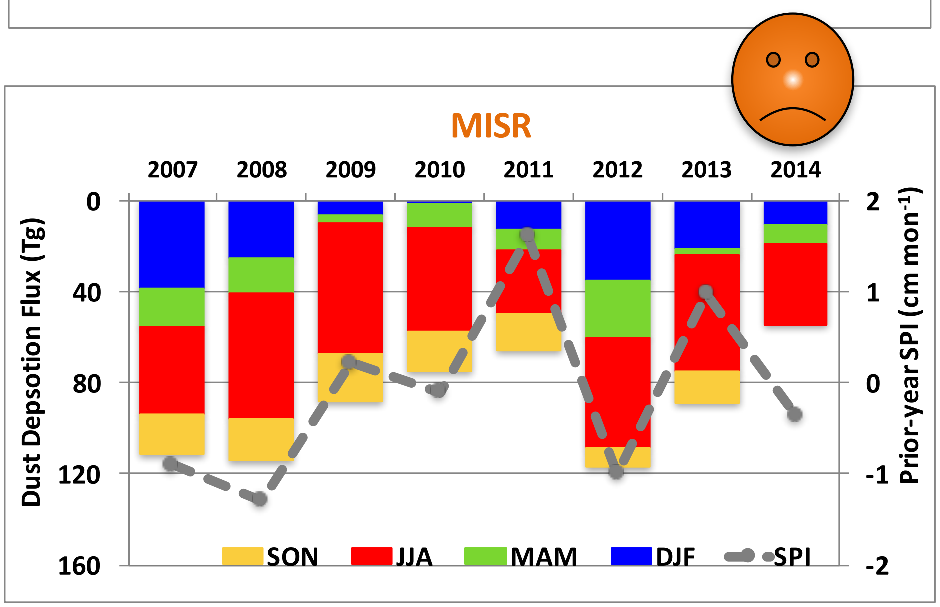
Budget of Dust Transport -NAT



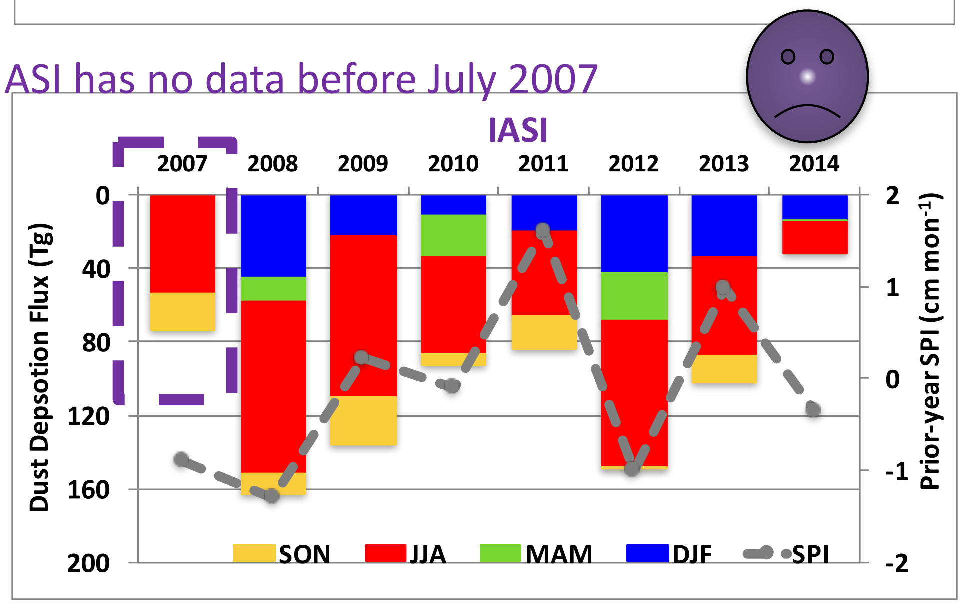
Interannual Variations of Dust Deposition [1]







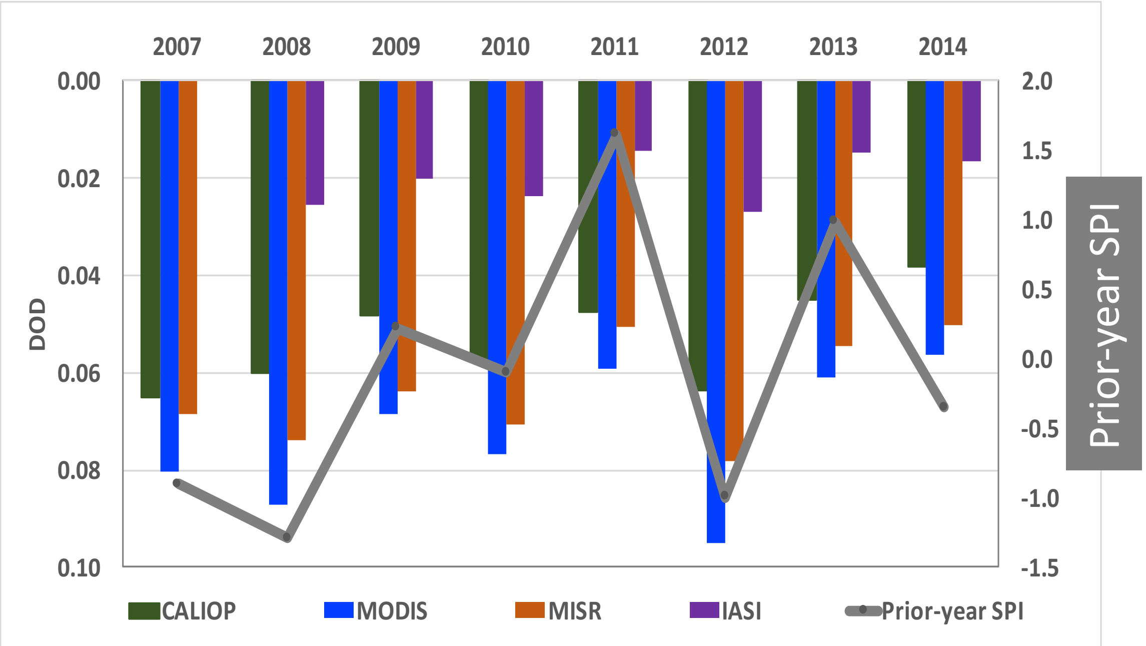
IASI has no data before July 2007

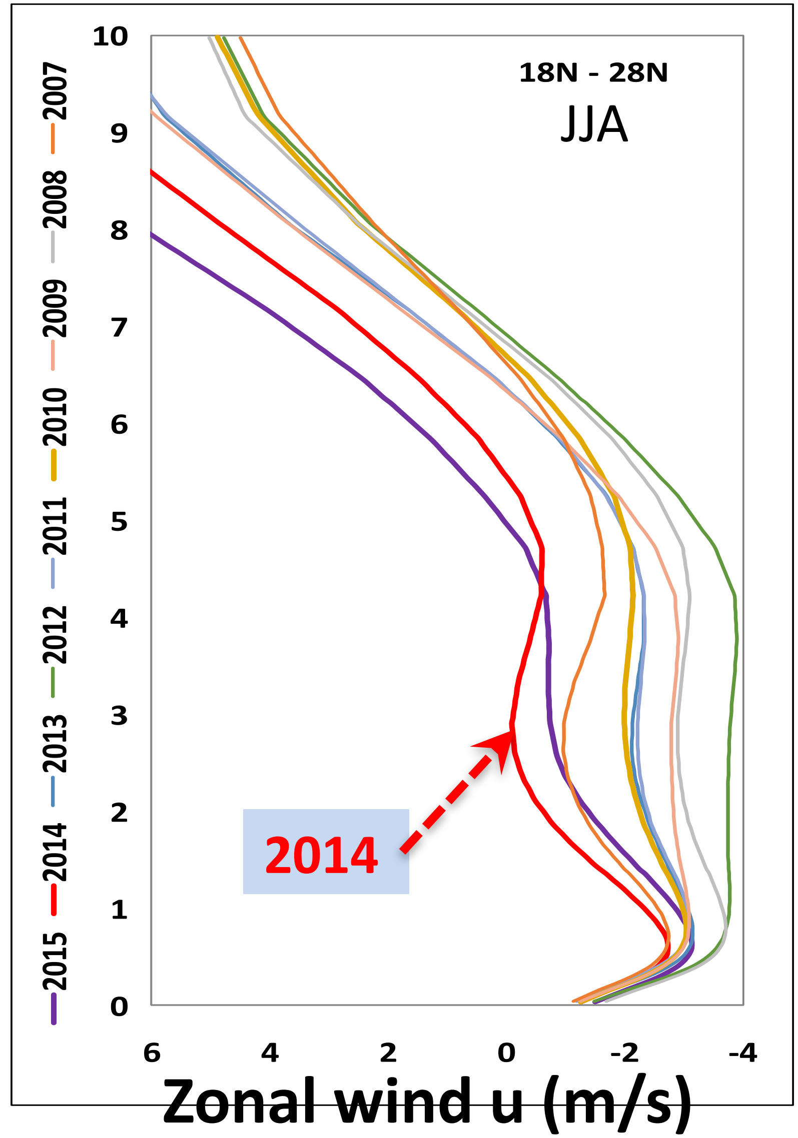


- ❑ Negative correlation with prior-year Sahel rainfall Index (SPI).
- ❑ 2014 is kind of outlier.

R	CALIOP	MODIS	MISR	IASI
2007-2014	-0.67	-0.65	-0.63	-0.44
2007-2013	-0.86	-0.96	-0.87	-0.85

Interannual Variations of Dust Deposition [2]





R	CALIOP	MODIS	MISR	IASI
2007-2014	-0.63	-0.77	-0.76	-0.84
2007-2013	-0.89	-0.94	-0.94	-0.96

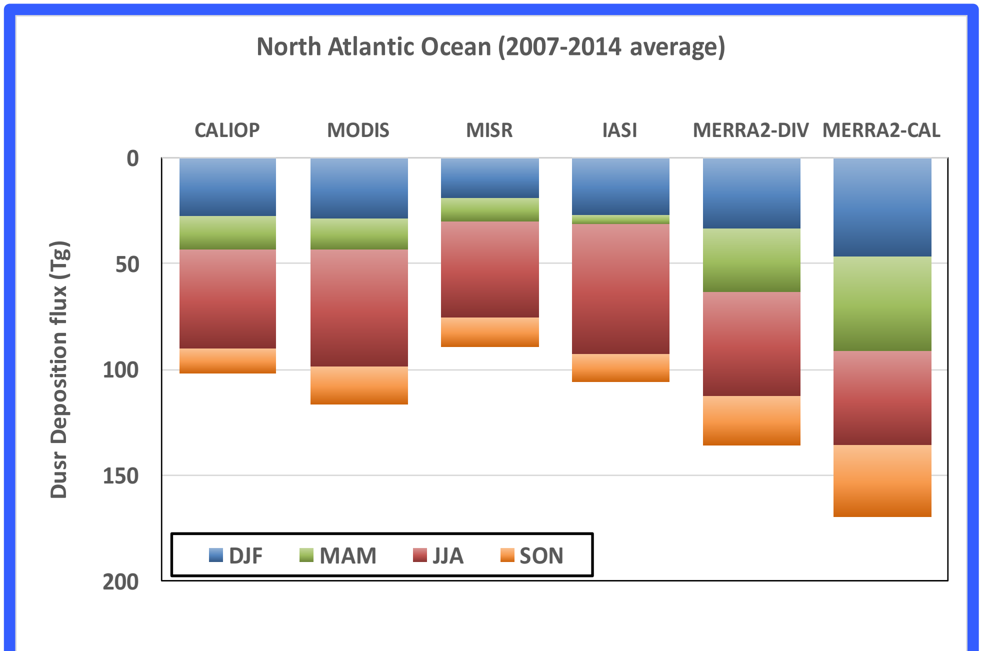
- Tighter negative correlation between DOD and prior-year SPI.
- The easterly was substantially weakened in 2014.

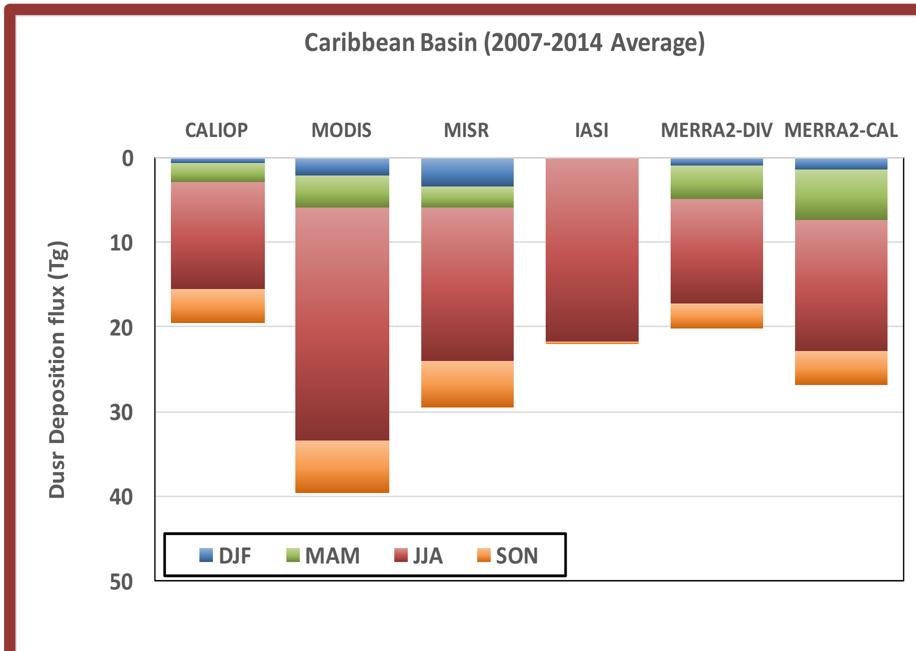
Dust Deposition: Satellites vs MERRA2

<u>Two MERRA2 estimates of dust deposition</u>

- **CAL**– based on para. of dry & wet removals **(*mass imbalance*)**
- **DIV** – the **"mass balance"** method *(similar to satellite estimates)*

<u>Data assimilation *doesn't* constrain the deposition, but could even *exacerbate* the bias of dust deposition (due to imperfect representations of dry and wet removals)</u>





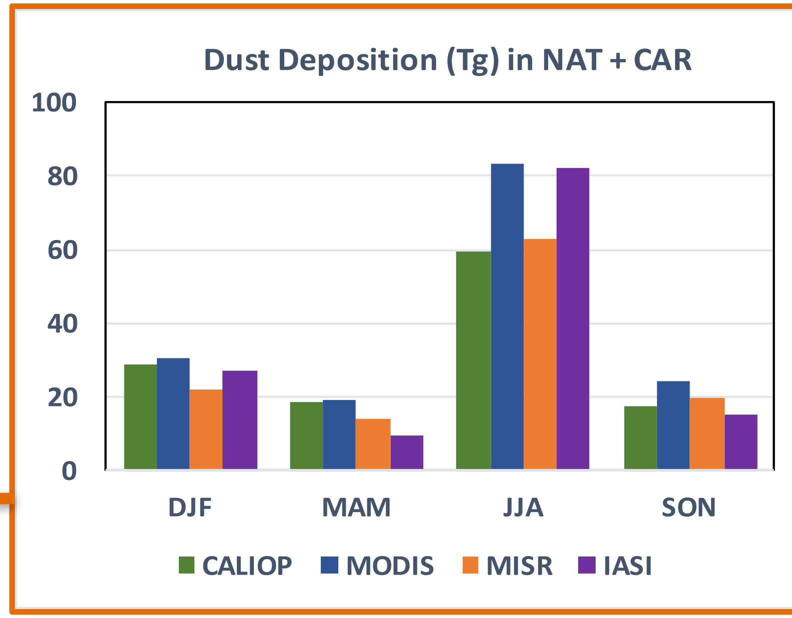
Dust Loss Frequency (LF) from Satellites

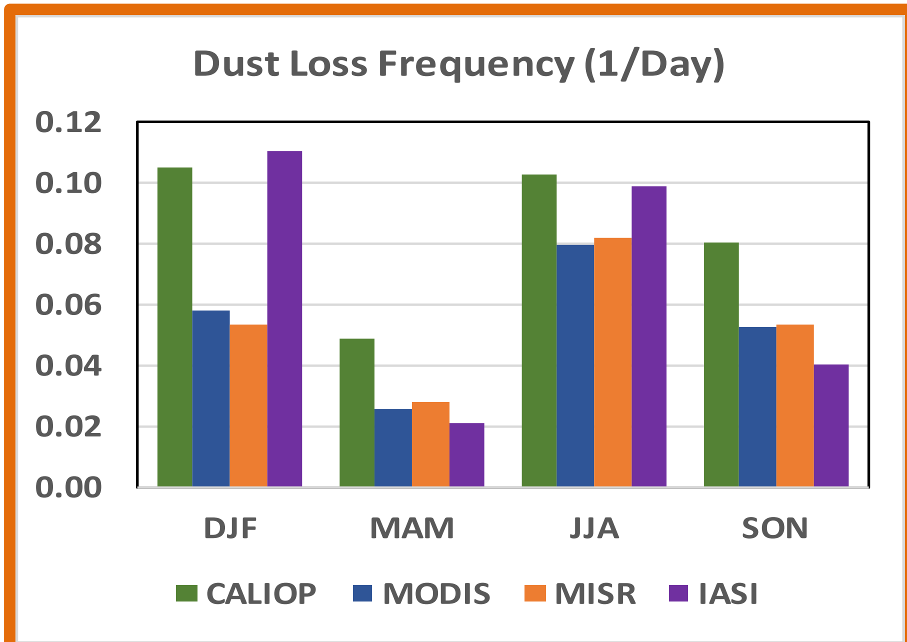
Dust Loss Frequency (LF) (1/day) =

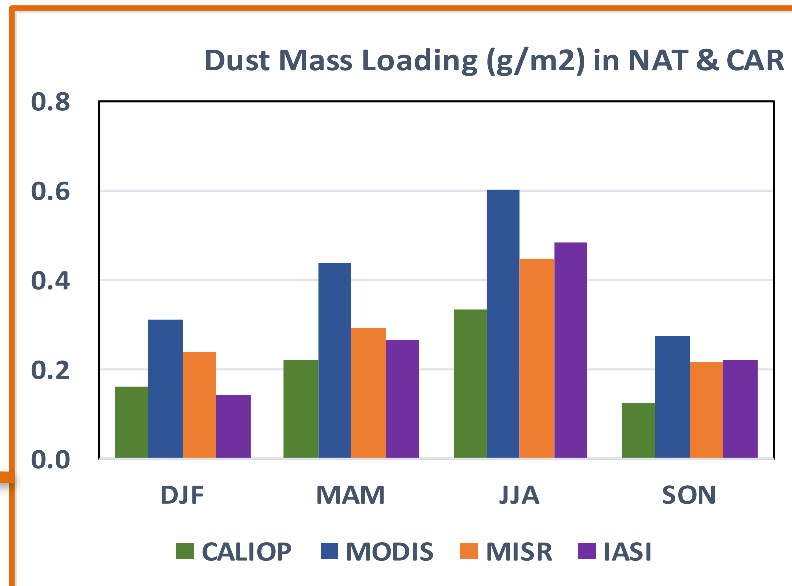
[Dust Deposition Flux Rate] (g/m²/day)

÷ [Dust Mass Loading=DOD/MEE] (g/m²)

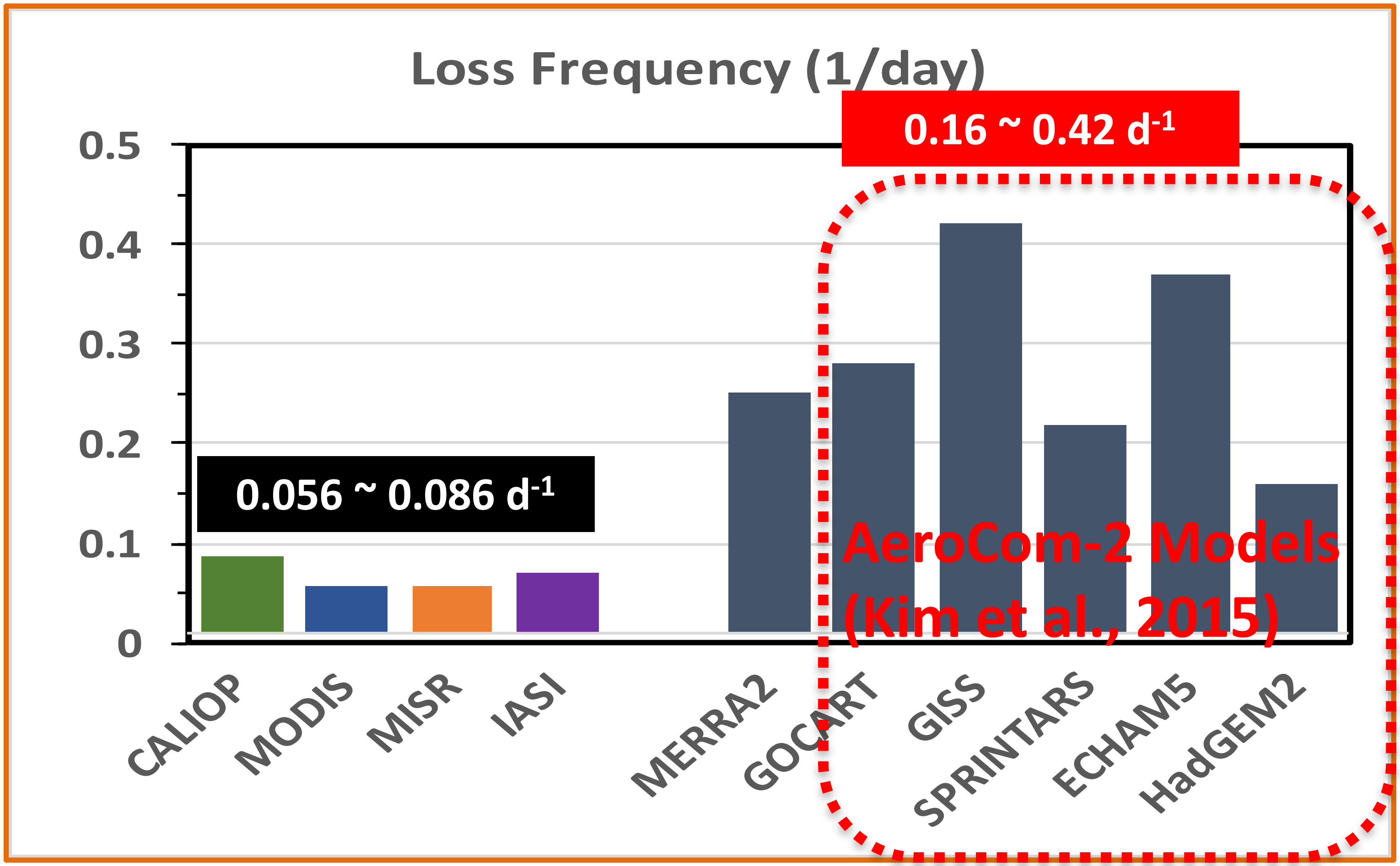
**** LF is not sensitive to dust MEE***







Dust Loss Frequency: Satellites versus Models



Models' loss frequency is more than a factor of 2 greater than that derived from the satellite observations.

Summary

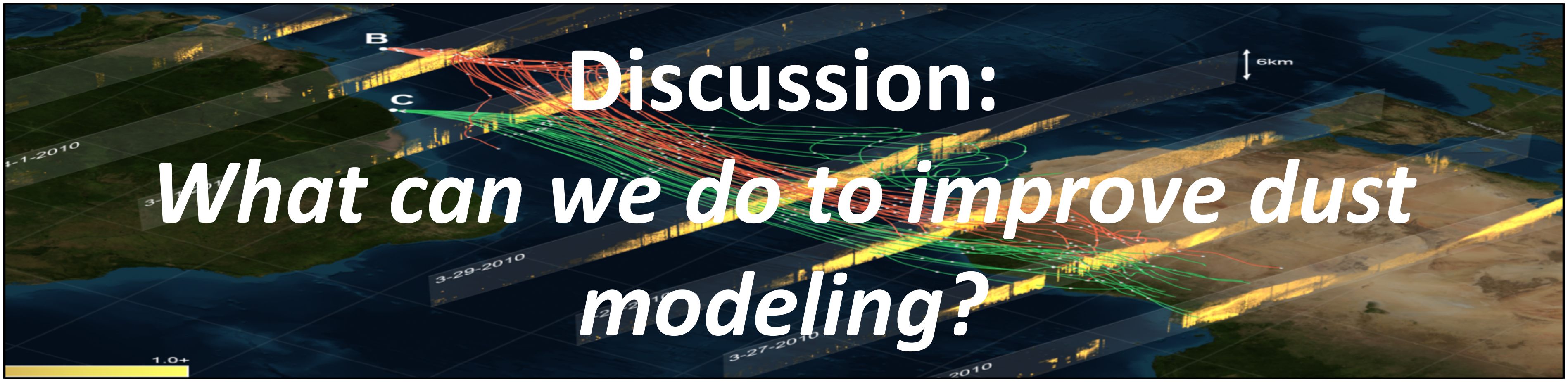
We have used 2007-2014 observations from CALIOP, MODIS, MUSR, and IASI to quantify dust deposition into tropical Atlantic Ocean and Caribbean Basin.

- The 8-year average dust deposition is **90 ~117 Tg** (North Atlantic) and **22 ~ 40 Tg** (Caribbean Basin).
- The dust deposition shows **negative correlation** *(R = -0.85 ~ -0.96)* with prior-year Sahel rainfall anomaly (e.g., SPI) over 2007-2013. But the correlation was substantially degraded by **2014** when the easterly was substantially weakened (further investigation needed).
- We estimated the regional dust loss frequency (LF) of **0.056 ~ 0.086 d^{-1}** from the satellite observations (<u>not sensitive to MEE</u>), which is at least a factor of 2 smaller than model simulations of **0.16 ~ 0.42 d^{-1}**.

Discussion

Michael Schulz offered some guidance on dust discussion:

- What is the recommendation for the dust modelling?
- For evaluating the models ?
- What should global aerosol models be able to simulate dust properly?
- Any recommendation how to parameterize?
- Good examples?



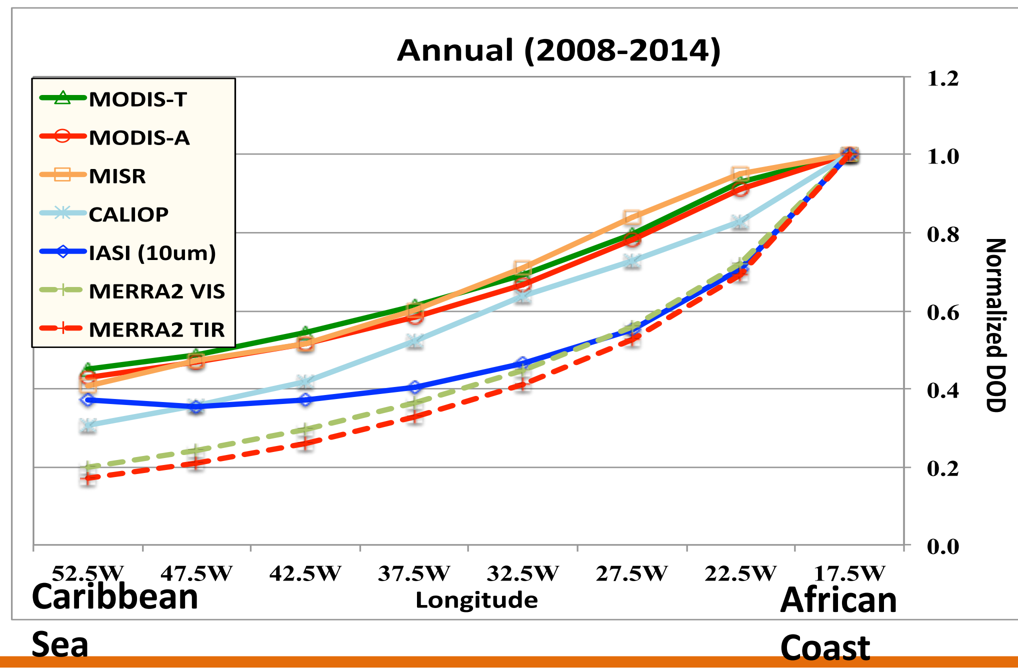
Discussion:
What can we do to improve dust modeling?

- Proposed Activity: Use recently available data sets to comprehensively evaluate model simulations of trans-Atlantic dust transport, deposition, and direct effect on SW and LW radiation.
  - Assimilation of satellite observations is a powerful tool to constrain dust loading in the atmosphere; but it doesn’t necessarily improve model representations of dust processes.
  - Previous AeroCom dust activities have largely focused on global perspective.
  - More datasets are emerging over Saharan desert and the trans-Atlantic transit.

Emerging Datasets [1]: Satellites and Ground-based Networks

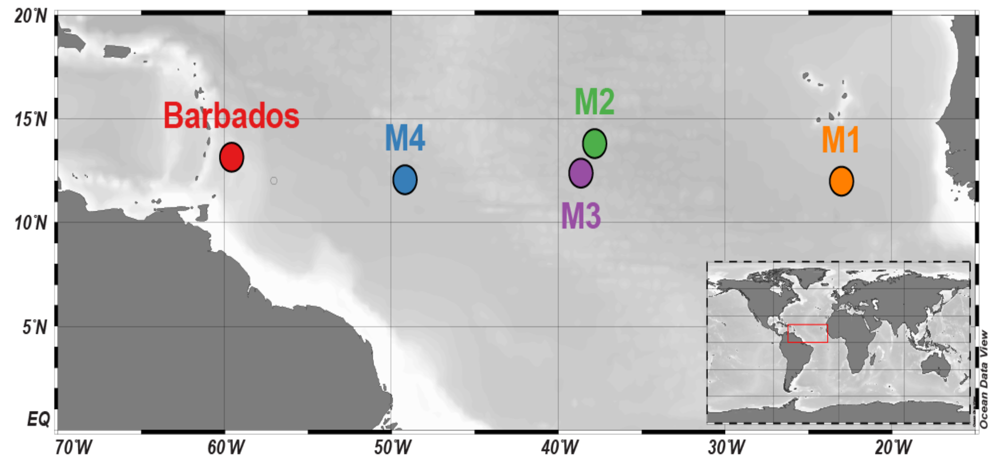
- **Ground-based networks**
- **Satellites**
  - Emissions inferred from PARASOL
  - Dust optical depth (0.55um & 10 um)
  - Dust vertical profiles
  - Dust transport & deposition (including loss frequency)

Decrease of DOD along the trans-Atlantic transit (normalized with that of African coast)

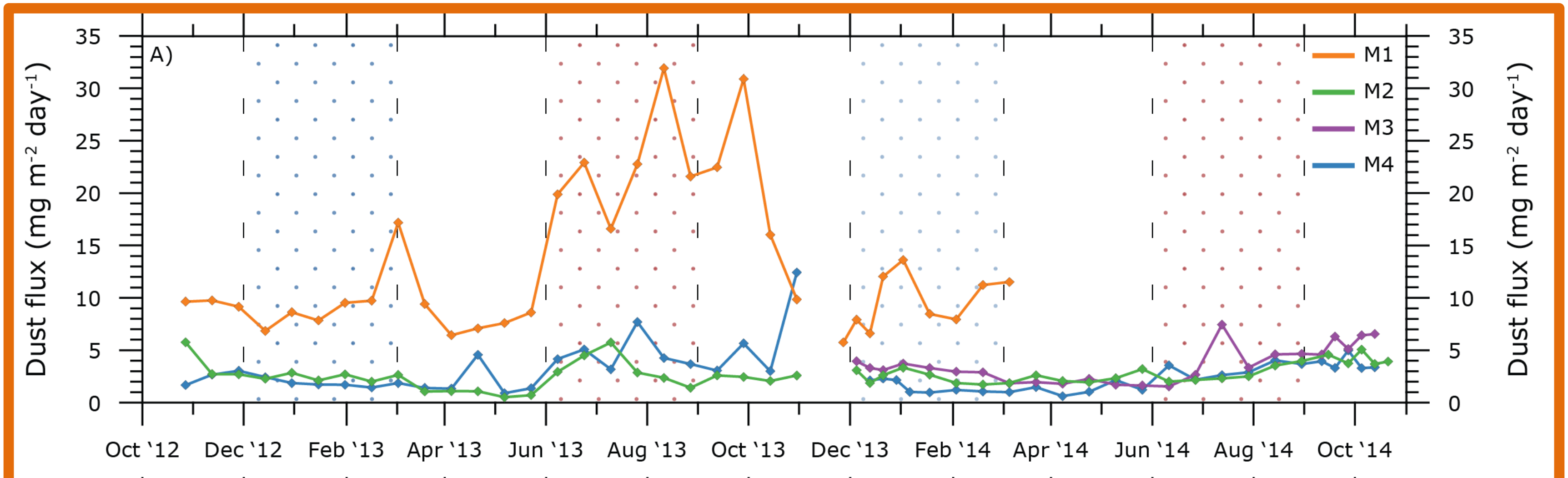


Emerging Datasets [2]: Field Campaigns
Dust Deposition from DUSTTRAFFIC

- **PI: Jan-Berend Stuut**
- **Multi-year project *(since late 2012)***
- **Sediment-trap sampling stations M1-4 , ~1200m deep, every 8-16 days**
- **Biogenic constituents are chemically removed**

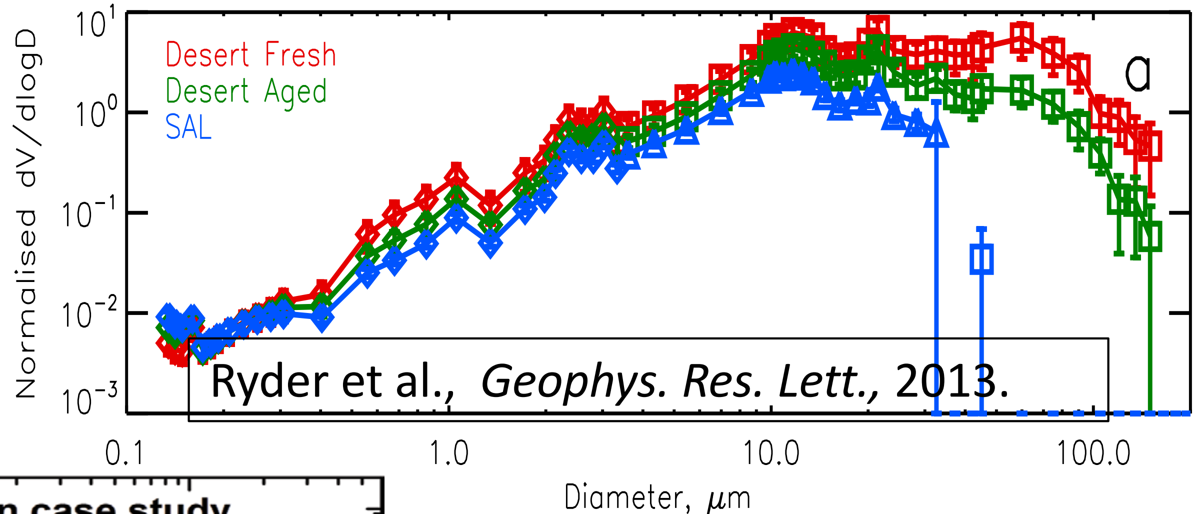


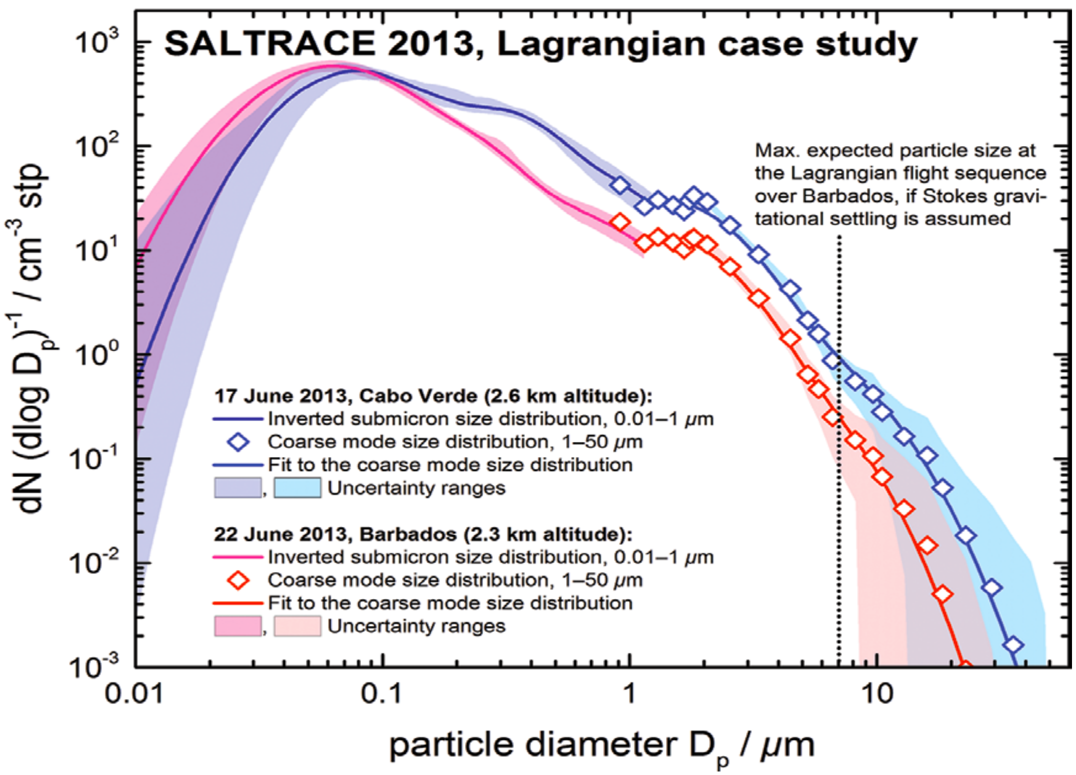
Courtesy of Michelle van der Does



Emerging Datasets [3]: Field Campaigns FENNEC & SALTRACE

FENNEC Campaign (2010)





SALTRACE: The Saharan Aerosol Long-Range Transport and Aerosol–Cloud-interaction Experiment (2013-2014)

Weinzierl et al., *BAMS*, 2017