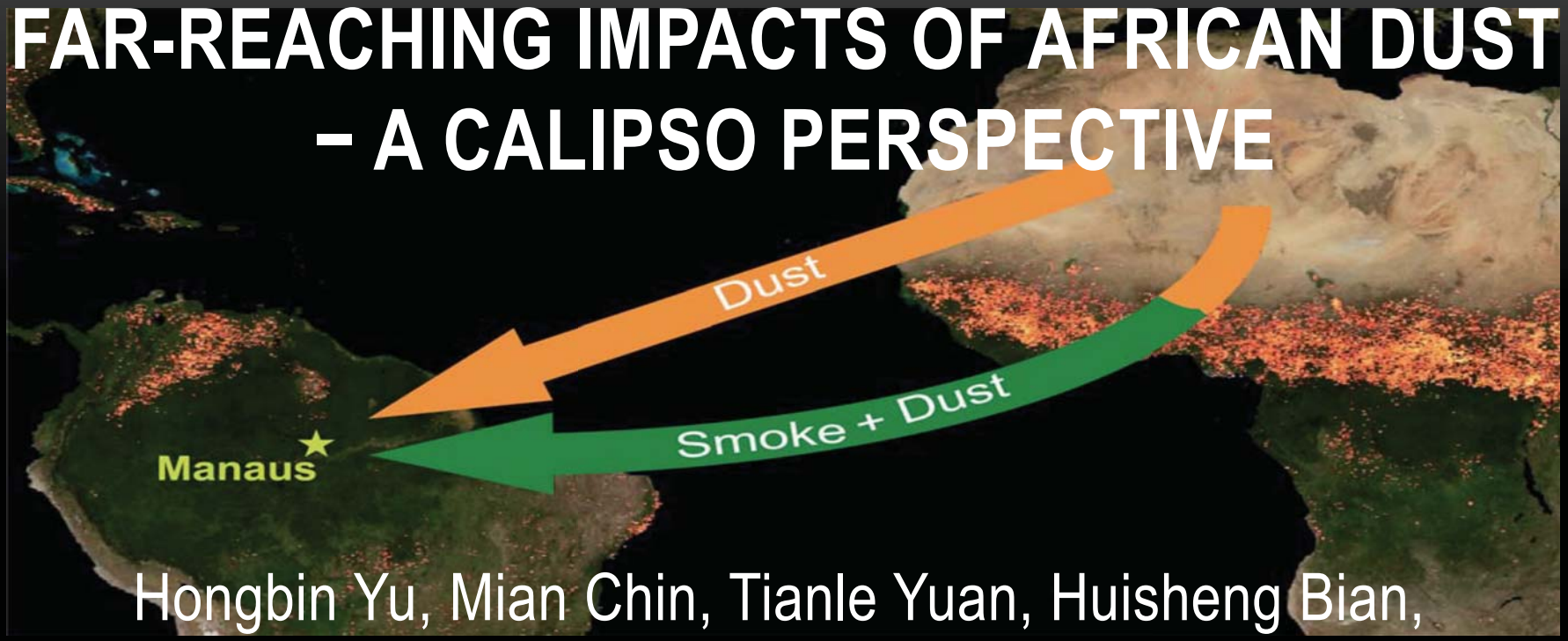
FAR-REACHING IMPACTS OF AFRICAN DUST – A CALIPSO PERSPECTIVE



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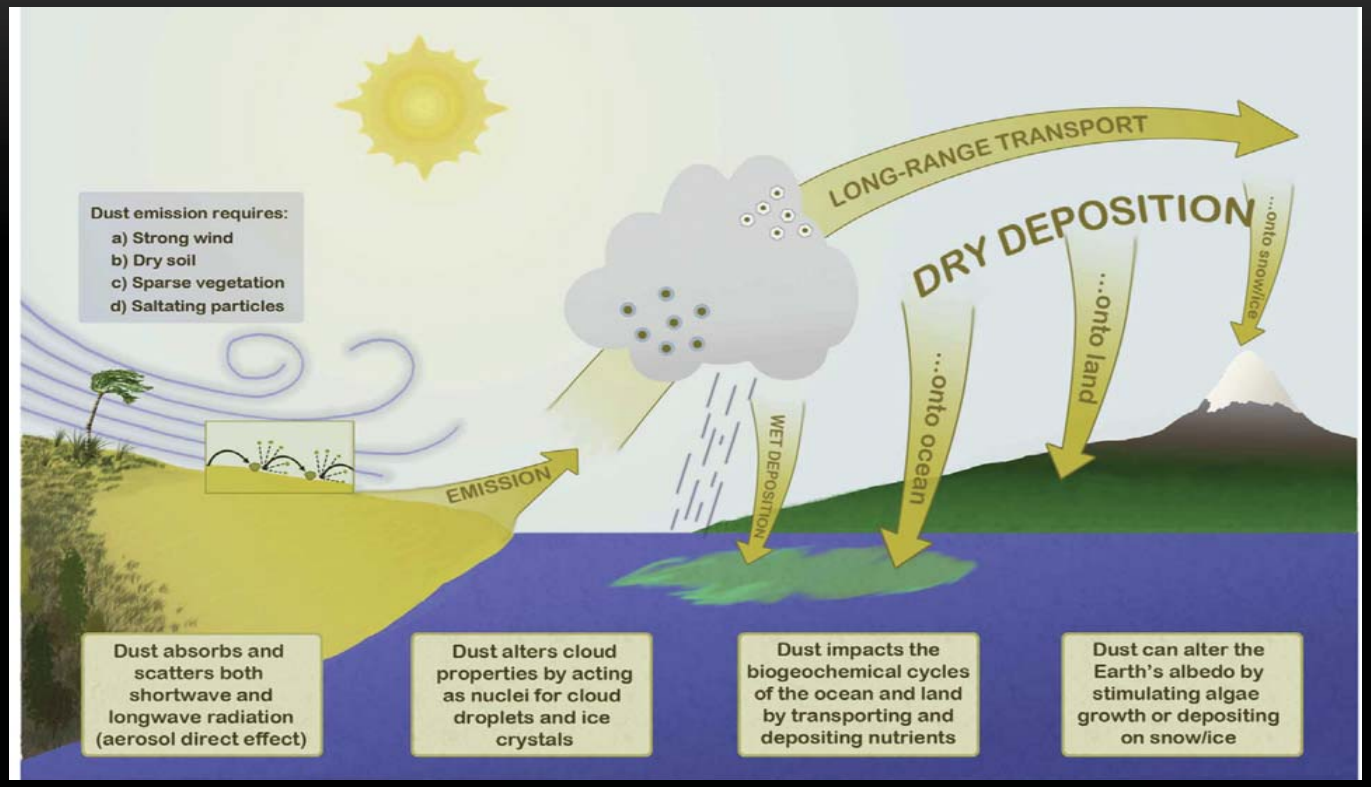
May 14, 2014

DUST IMPACTS ON CLIMATE



(Mahowald et al., Aeolian Research, 2014)

- The impacts are far-reaching because of long-range transport.
- Satellites can play an important role in assessing these impacts because of routine sampling over a global scale.

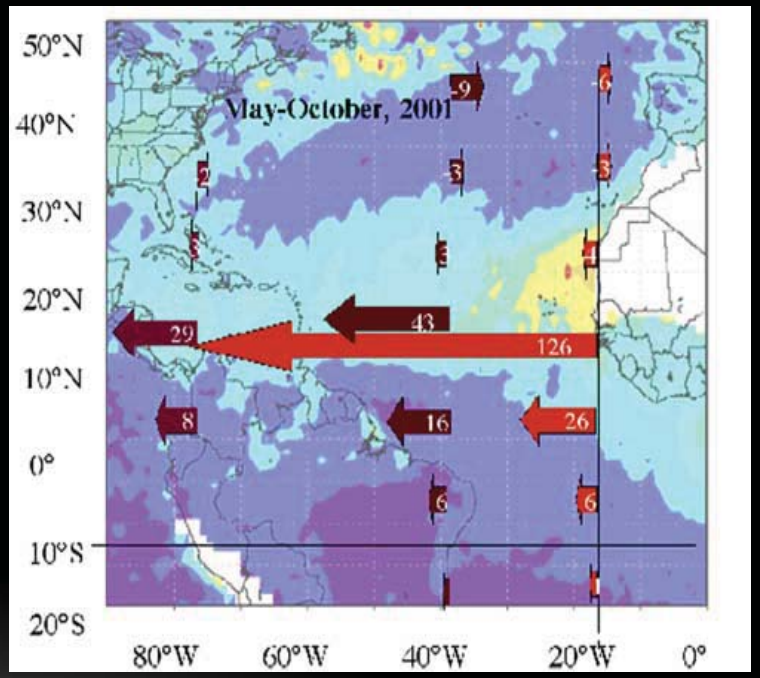
JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 110, D10S12, doi:10.1029/2003JD004436, 2005

Dust transport and deposition observed from the Terra-Moderate Resolution Imaging Spectroradiometer (MODIS) spacecraft over the Atlantic Ocean

Y. J. Kaufman,[1] I. Koren,[2,3] L. A. Remer,[1] D. Tanré,[4] P. Ginoux,[5] and S. Fan[5]

- The study provides important insights into aerosol transport, deposition, and impacts (e.g., dust fertilizing Amazon rainforest).

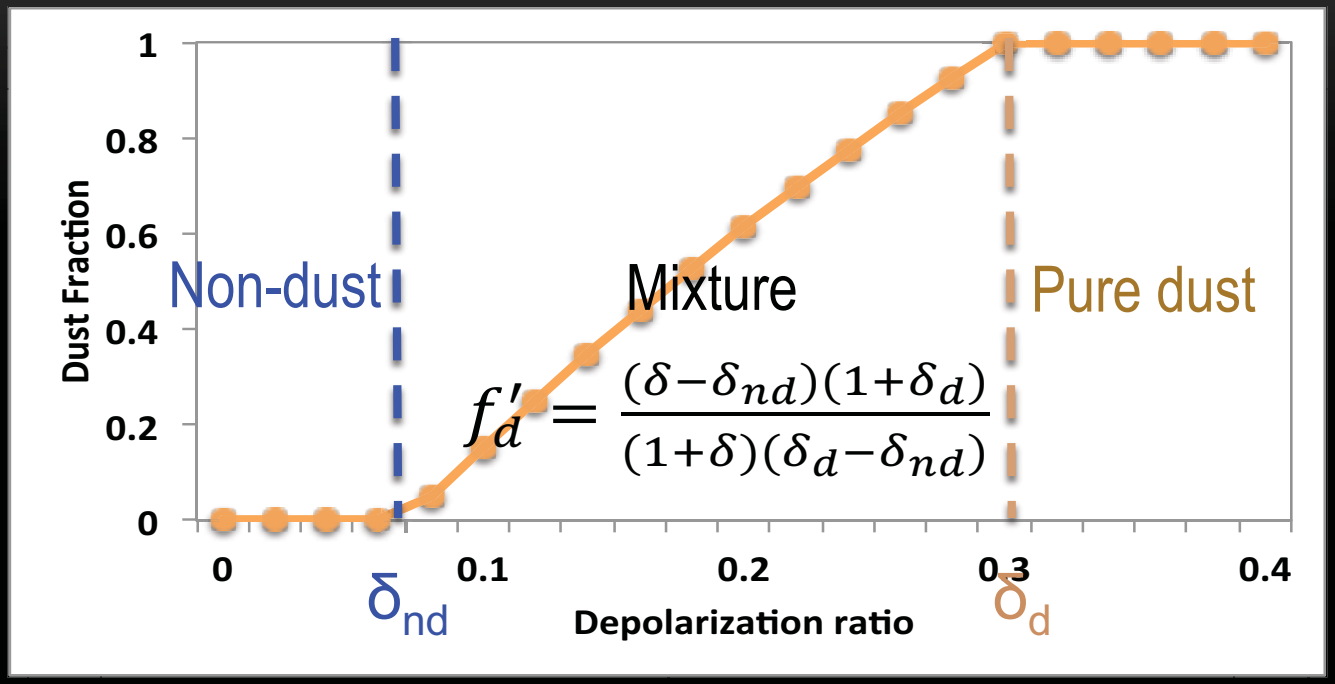
- It has some limitations:
  - Uncertainty of MODIS observations
  - Assumption of dust transport height (700mb in summer, 850mb in winter)
  - Estimate of zonal flux only



- Our objective is to provide an independent estimate of trans-Atlantic dust transport and deposition with 7-year records of CALIOP observations.
  - 3D distributions of aerosol backscatter and extinction: more realistic transport height
  - Particulate depolarization ratio: separating dust from non-dust aerosol
  - Above-cloud aerosol profiles: new information additional to clear-sky aerosol

Only nighttime data with high data quality are used.

SEPARATING DUST FROM NON-DUST AEROSOL

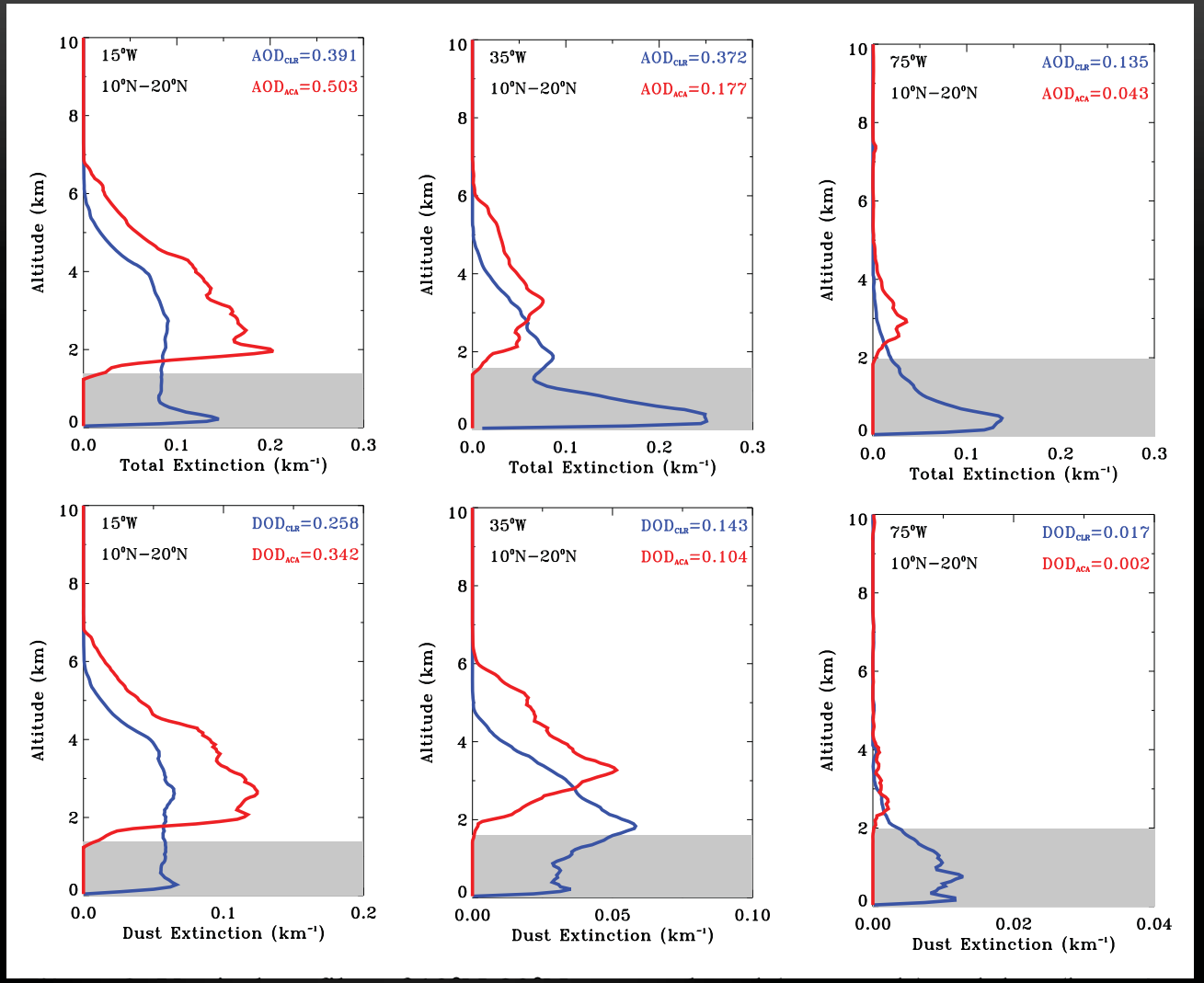


- **Low-Dust-Fraction (LDF)** scenario: $\delta_d = 0.30$, $\delta_{nd} = 0.07$
- **High-Dust-Fraction (HDF)** scenario: $\delta_d = 0.20$, $\delta_{nd} = 0.02$

We use both LDF & HDF scenarios to provide a range of dust mass flux estimate.

TOTAL AEROSOL

DUST



2012 MAM
LDF scenario

BLUE: clear-sky **RED:** above-cloud

Shaded Gray Area: average cloud top

ESTIMATE OF DUST MASS FLUX FROM CALIOP MEASUREMENTS

Dust backscatter/extinction profile from CALIOP (CSA & ACA)

Extinction (1/m) = Mass Conc. (g/m^3) * MEE (=0.37 m^2/g)

MEE (Mass Extinction Efficiency)

Profile of Dust Mass Concentration (m) (CSA & ACA)

$$FLUX_{all} = FLUX_{csa}\,(1 - f_{aca}) + FLUX_{aca}\,f_{aca}$$

MERRA reanalysis wind field

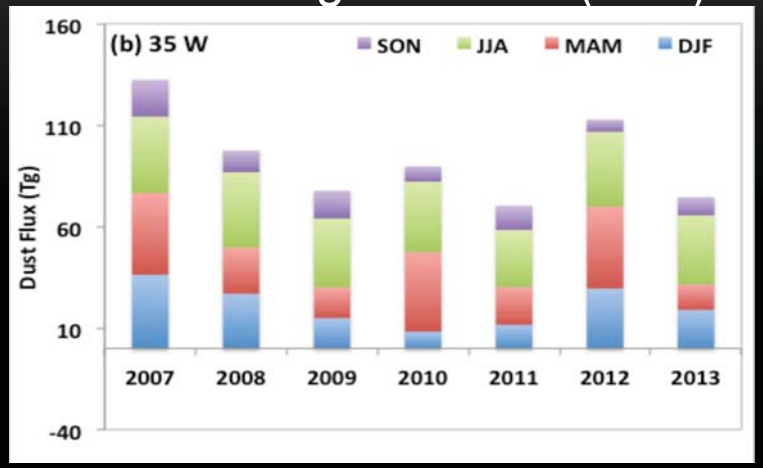
Dust Mass Flux

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

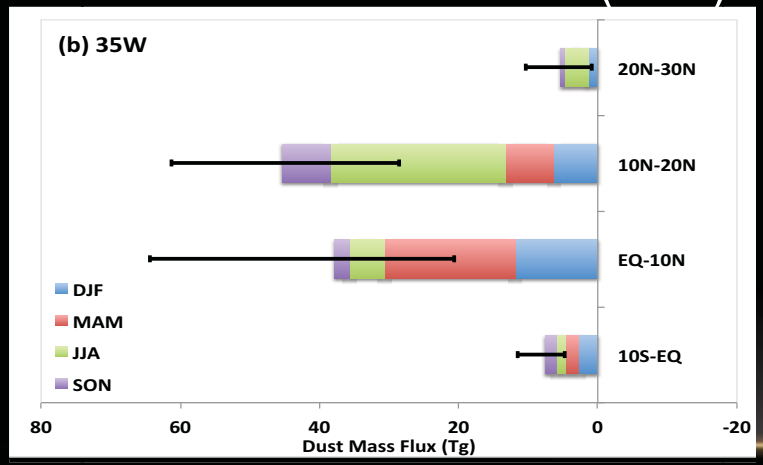
(CSA & ACA)

CALIOP ESTIMATE OF ZONAL DUST FLUX

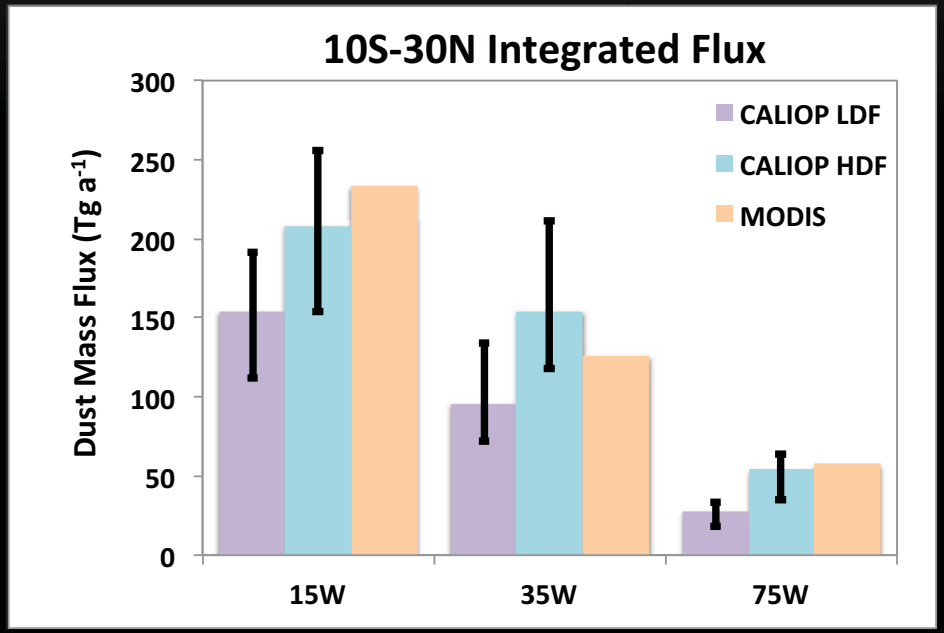
10S-30N integrated flux (LDF)



Latitudinal distribution (LDF)



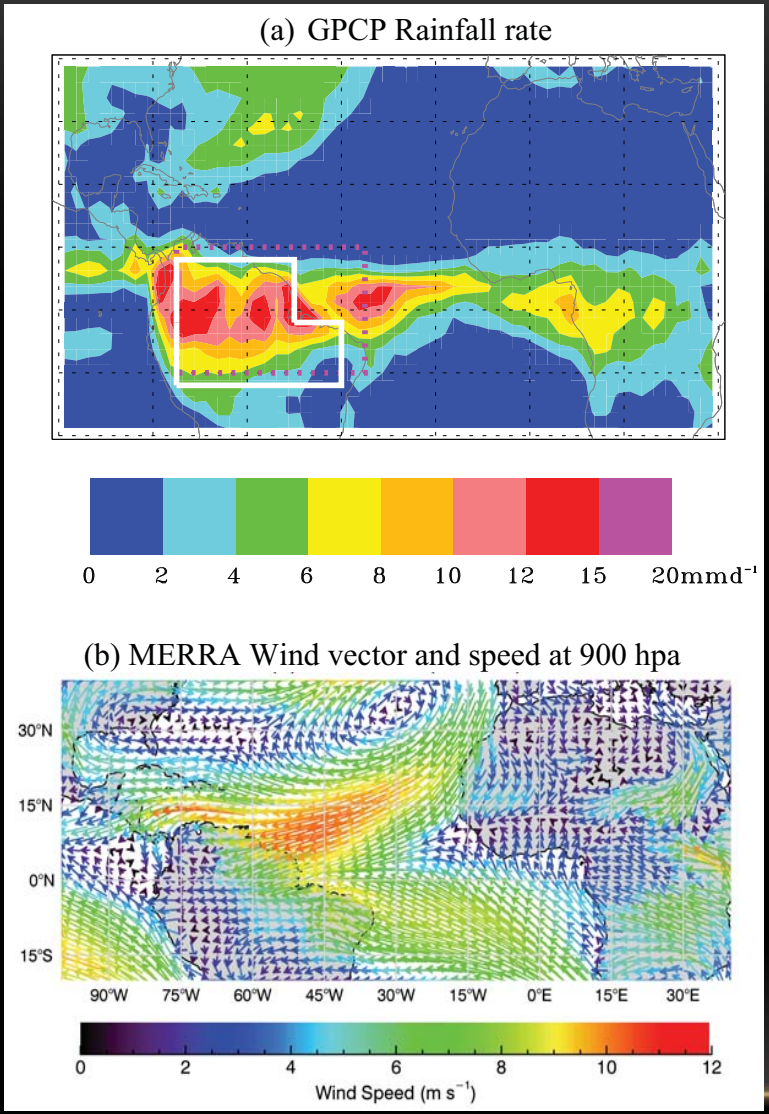
CALIOP vs MODIS



MODIS-based dust mass flux agrees favorably with CALIOP estimates

Error bar indicates the range over the 7-year period.

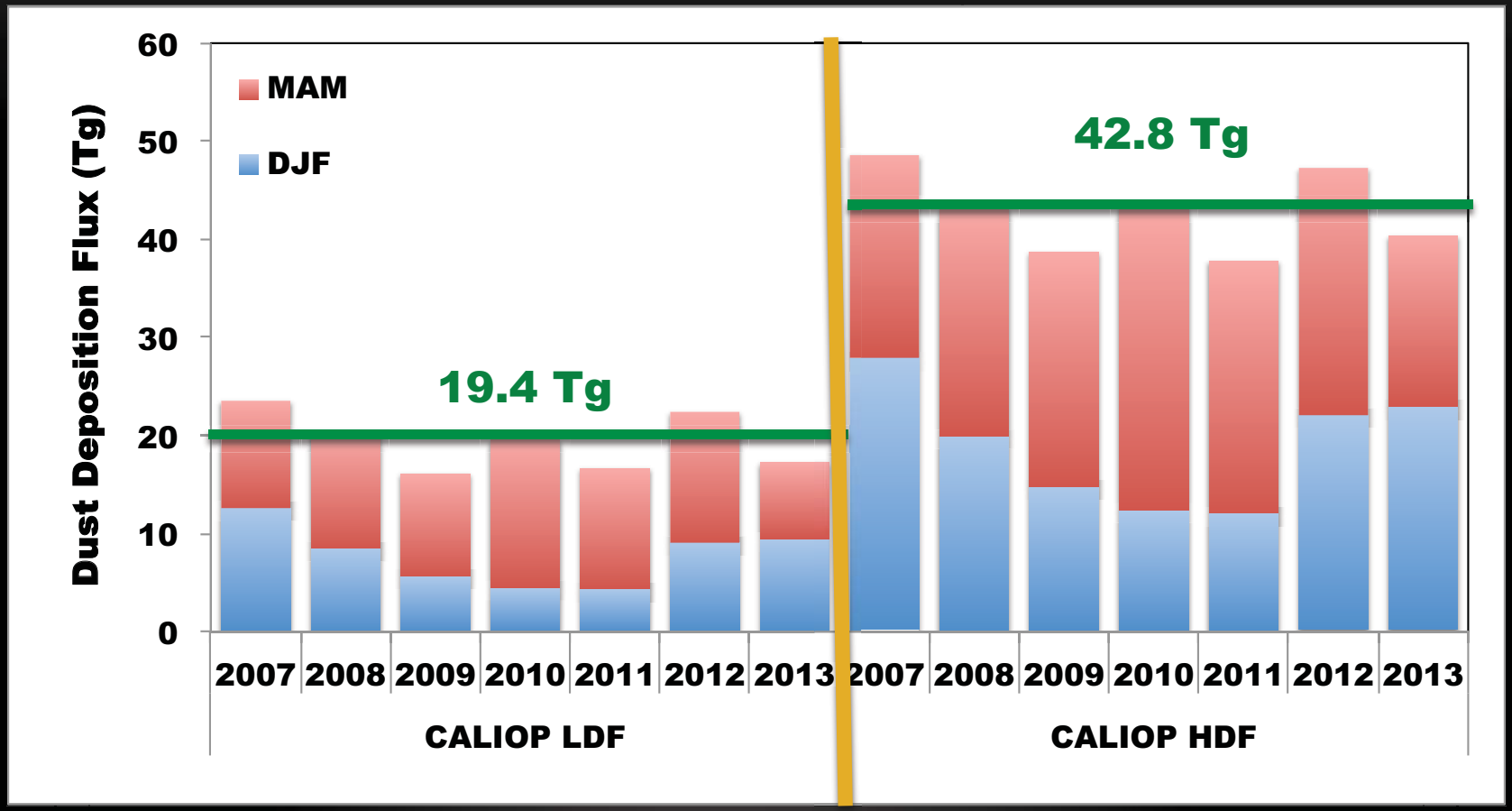
ESTIMATE OF DUST DEPOSITION TO THE AMAZON



- Kaufman et al. [2005] used the zonal dust flux difference between 35W and 75W to estimate the dust deposition into the Amazon, i.e., 50 Tg a^{-1}.

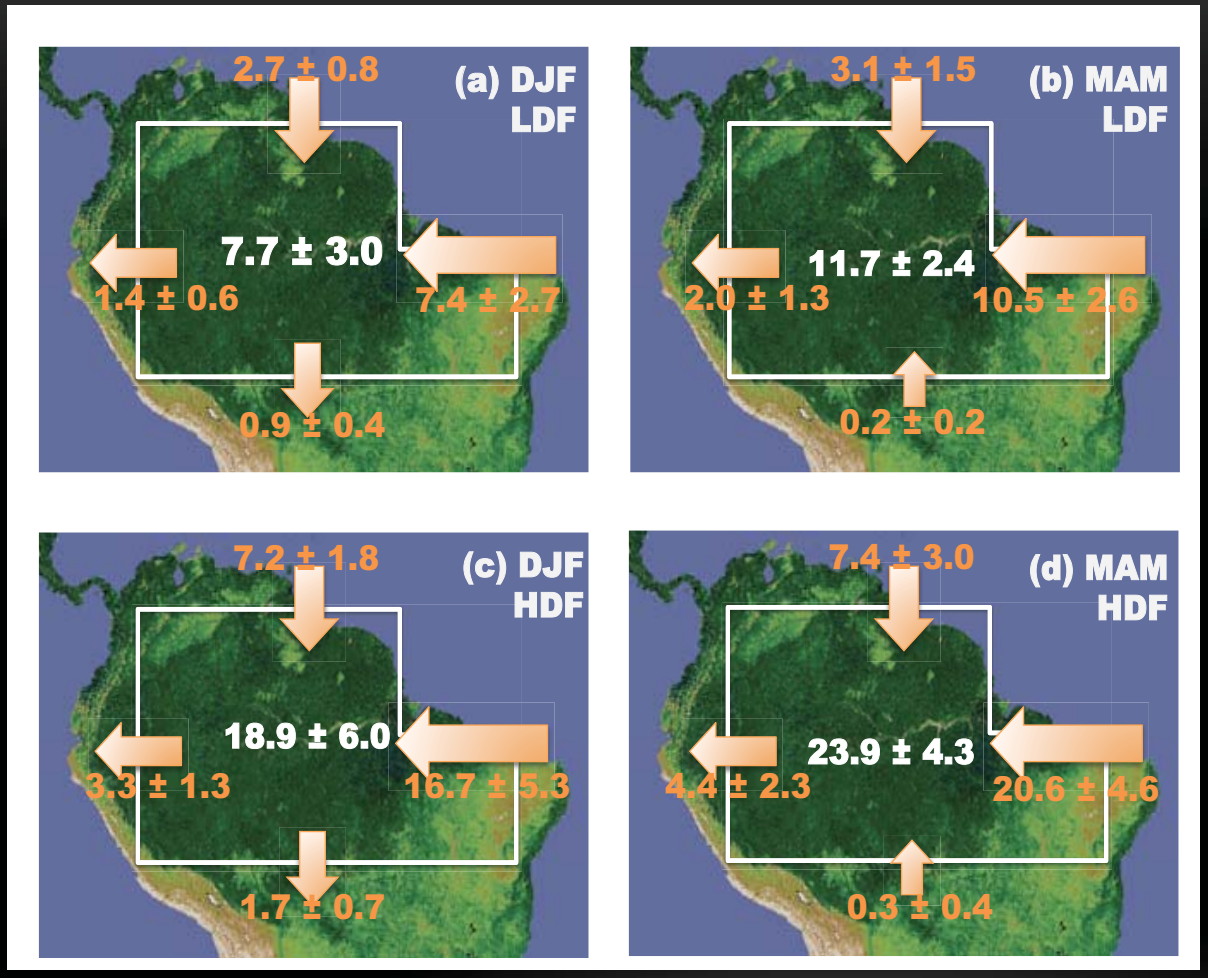
- Two major issues:
  - The region **(red-dotted boundaries)** is bigger than the Amazon *(including oceanic area with intense precipitation)*, which introduced a high bias to the estimated dust deposition in the basin.
  - **Meridional transport** is not accounted for, which introduced a low bias to the dust deposition estimate.

DUST DEPOSITION INTO THE AMAZON: SEASONAL & INTERANNUAL VARIATIONS



In boreal summer and fall (JJA & SON), the estimated deposition is around zero)

BUDGET OF DUST FLOW INTO THE AMAZON

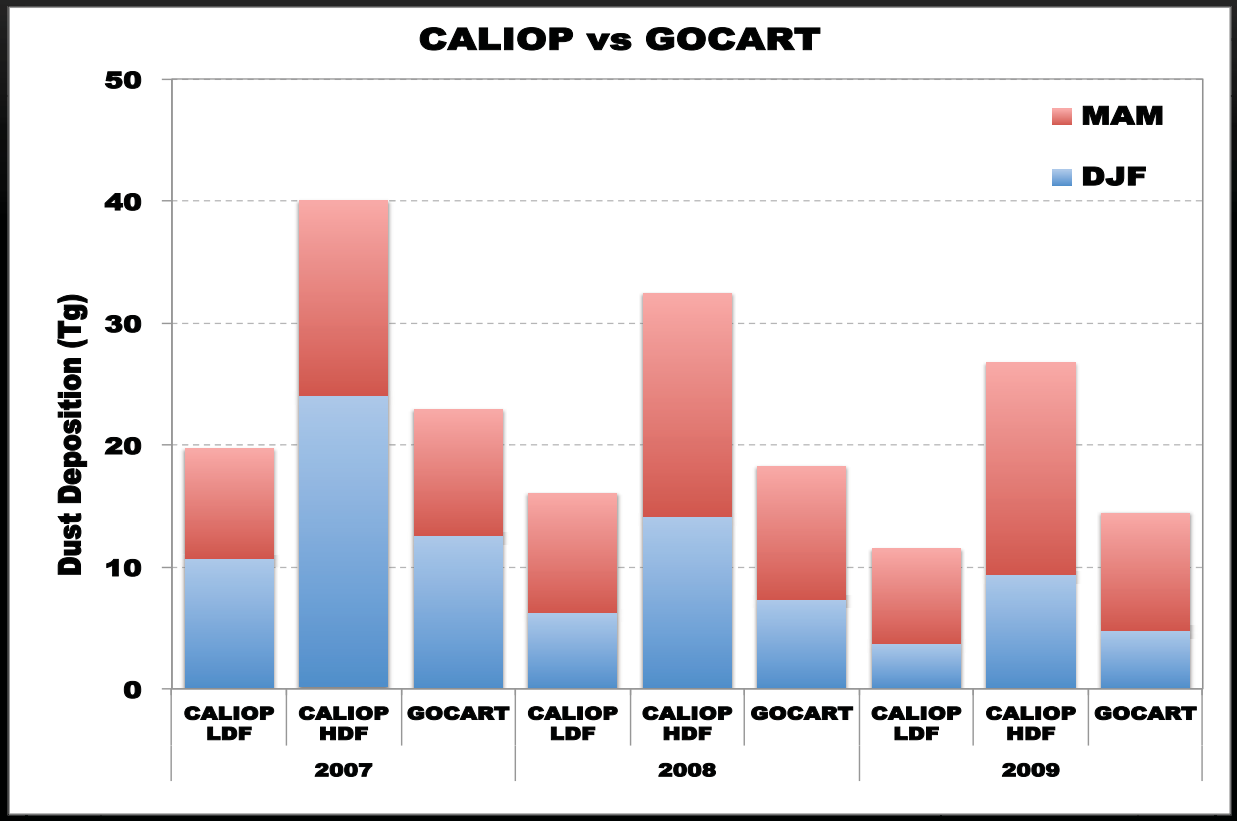


- **24 - 48 Tg:** dust import from E & N.
- **30 - 44%:** meridional to zonal flux ratio
- **19 - 43 Tg:** dust deposition

CALIOP 7-year average

The estimated dust deposition is small in boreal summer and fall.

DUST DEPOSITION INTO AMAZON: CALIOP VS. GOCART



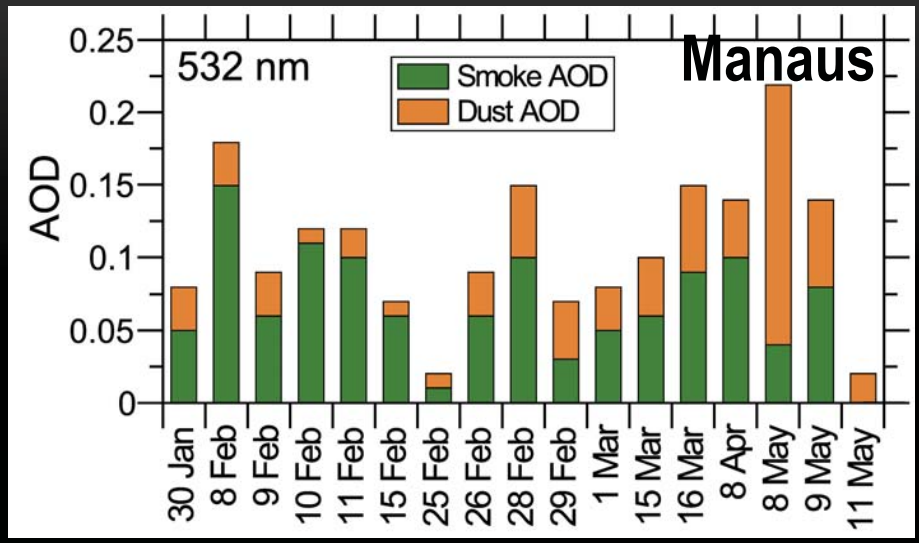
GOCART simulated dust deposition is about 10-20% higher than the CALIOP estimate in the low-dust-fraction (LDF) scenario.

IMPLICATION FOR BIOGEOCHEMICAL CYCLE

- The productivity of Amazon rainforest is constrained by phosphorous.
- P input associated with African dust
  - Dust deposition: 19 ~ 43 Tg a^{-1} or 20 ~ 45 kg ha^{-1} a^{-1}
  - 1 g dust = 780 µg P (780 ppm)
  - P input: 0.015 ~ 0.033 Tg P a^{-1} or **16 ~ 35 g P ha^{-1} a^{-1}**
- Some numbers in the context *[Vitousek and Sanford, 1986; Mahowald et al., 2005]*
  - 10-22% of total deposition of 161 g P ha^{-1} a^{-1}
  - 2-order of magnitude lower than P cycling of 1400~4100 g$Pha^{-1}a^{-1}$
  - comparable to hydrological loss rate of 8 ~ 40 g P ha^{-1} a^{-1}
- African dust is important for the health of Amazon rainforest on the long run.

POTENTIAL INFLUENCES ON RADIATION AND CLOUDS

- The imported African dust will interact with radiation and clouds when the basin has low level of aerosol (AOD = 0.03) in wet season ("green ocean").
- African smoke also comes to the Amazon and would affect radiation and clouds.



Baars et al. (2011)

African smoke and dust were detected in 32% of days with available lidar observation (clear sky) over the 5-month period near Manaus.

SUMMARY

We estimated from 7-year records of CALIOP measurements that

- 24 - 48 Tg of African dust are imported to the basin during boreal winter and spring. The meridional flux is significant, which accounts for 30-44% of the zonal flux.
- 19 - 43 Tg dust is deposited in the basin.
- African dust provides phosphorous of 6 ~ 35 g P ha^{-1} a^{-1} to the Amazon rainforest, which largely offsets the hydrological loss of P.
- African dust (and smoke) would influence radiation and clouds in the Amazon during the wet season, which needs to be investigated.

Thank you for your attention!

Questions?