

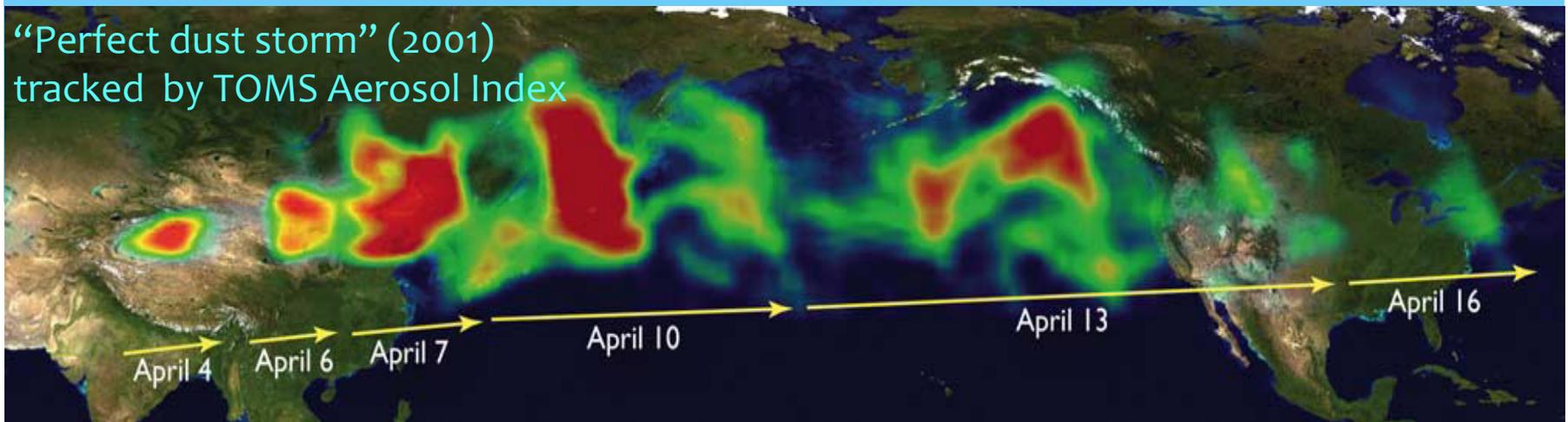
Assessing Aerosol Intercontinental Transport and Climate Impacts From Satellites and Models

Hongbin Yu

Univ. of Maryland, NASA Goddard Space Flight Center

Yan Zhang, Lorraine Remer, Mian Chin, Huisheng Bian, Qian Tan, Ralph Kahn, Ali Omar, Tianle Yuan, Zhibo Zhang, Jun Wang, Juying Warner

“Perfect dust storm” (2001)
tracked by TOMS Aerosol Index

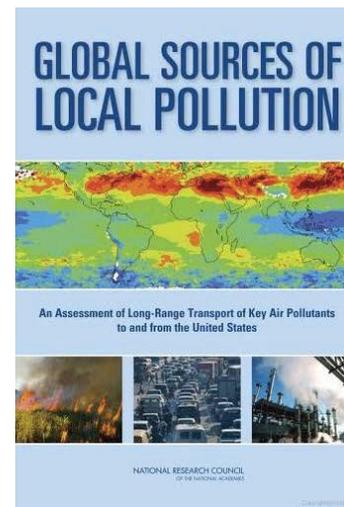
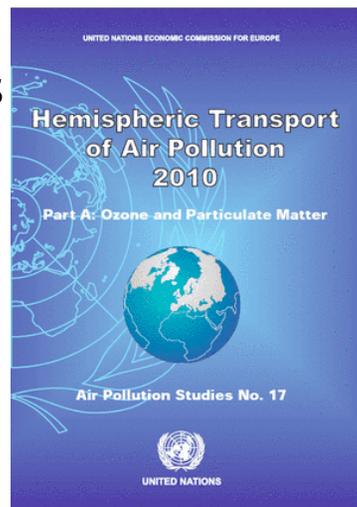


Aerosol Intercontinental Transport (ICT) Is Gaining Increasing Attention From Both Science & Policy-making Communities

Many types of aerosols have lifetimes long enough for intercontinental transport

- ❑ widespread – dust, pollution, smoke across the Pacific, Atlantic
- ❑ convincing – satellite images, in-situ measurements, modeling
- ❑ having important implications – air quality, climate change, water supply

United Nations
Economic
Commission
for Europe
HTAP Task
Force



National
Academy of
Science
Expert
Review

Satellite Perspective of Aerosol Intercontinental Transport: From Qualitative Tracking to Quantitative Characterization

(Yu, Remer, Kahn, Chin, Zhang, Atmos. Res., 124, 73-100, 2013)

- Models are essential but are subject to large uncertainties. We need observations.

- Satellite measurements have advantages over aircraft and surface-based measurements:
 - ✓ global coverage
 - ✓ frequent sampling (~daily)
 - ✓ whole atmos. column & somewhat altitude-resolved

- EOS satellites offer aerosol loading (AOD) and type (size, shape,...) measurements needed for ICT study. But they alone are not sufficient and need to be supplemented by in-situ measurements and models.

TERRA/AQUA PROJECT OBJECTIVES

- * To estimate aerosol mass fluxes via intercontinental transport (ICT) with satellite measurements (i.e., go beyond plume tracking with pretty images and be more quantitative)
- * To assess radiative/climate impacts of aerosol ICT with models constrained by satellite measurements

Five Major Tasks

- ❑ **Task 1:** Estimated trans-Pacific dust transport mass fluxes with MODIS and CALIOP
- ❑ **Task 2:** Assessed the relative contribution of intercontinental transport vs. domestic production with satellite measurements
- ❑ **Task 3:** Analyzed HTAP multi-model source-receptor simulations for the contribution of ICT to regional direct radiative forcing
- ❑ **Task 4:** Integrated CALIOP/OMI/MODIS observations to analyze above-cloud aerosols (*Yan Zhang's poster*)
- ❑ **Task 5:** Explored multi-sensor characterization of aerosol types (*Yan Zhang's poster*)

Major Results from the Tasks

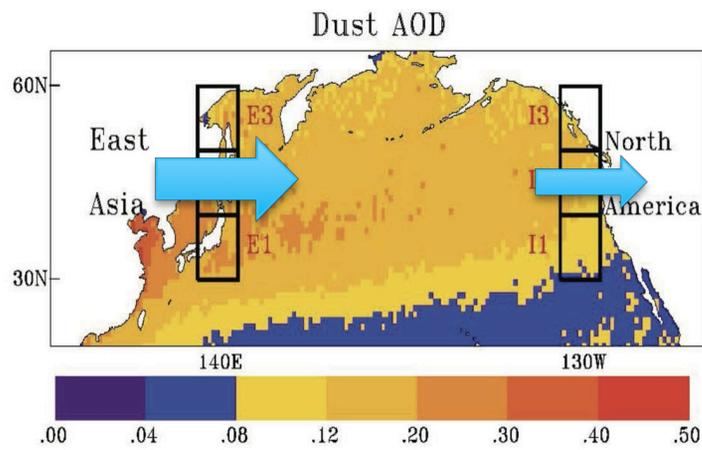
- ❑ **Task 1:** Estimated trans-Pacific dust transport mass fluxes with MODIS and CALIOP
- ❑ **Task 2:** Assessed the relative contribution of intercontinental transport vs domestic production and implications for climate and air quality
- ❑ **Task 3:** Analyzed HTAP multi-model source-receptor simulations for the contribution of intercontinental transport to regional direct radiative forcing
- ❑ **Task 4:** Integrated CALIOP/OMI/MODIS observations to analyze above-cloud aerosols
- ❑ **Task 5:** Explored multi-sensor characterization of aerosol types

MODIS AOD & fine-mode fraction are used to derive AOD for dust & combustion aerosol

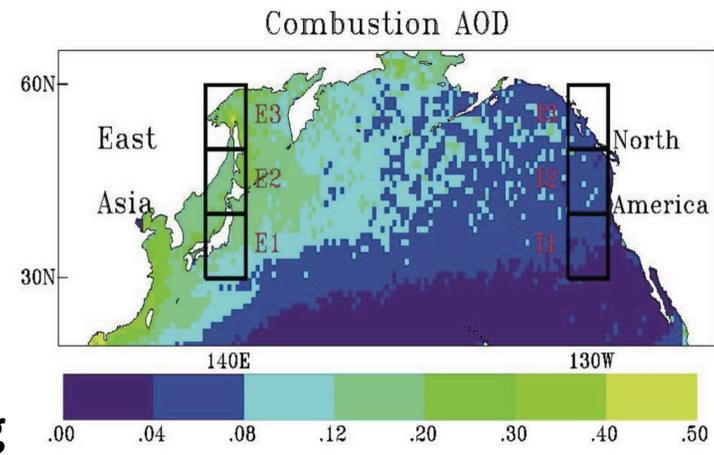
Total AOD: $\tau = \tau_{\text{dust}} + \tau_{\text{comb.}} + \tau_{\text{marine}}$

Fine-mode AOD: $f\tau = f_{\text{dust}}\tau_{\text{dust}} + f_{\text{comb.}}\tau_{\text{comb.}} + f_{\text{marine}}\tau_{\text{marine}}$

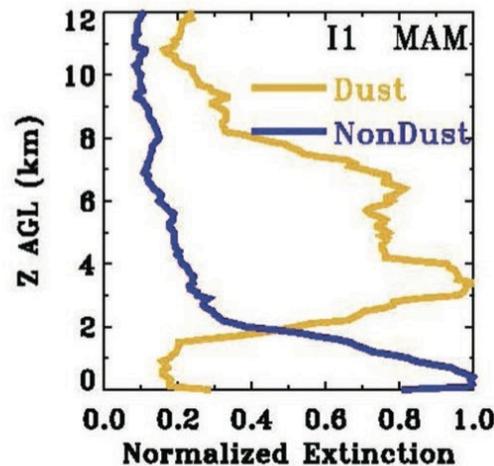
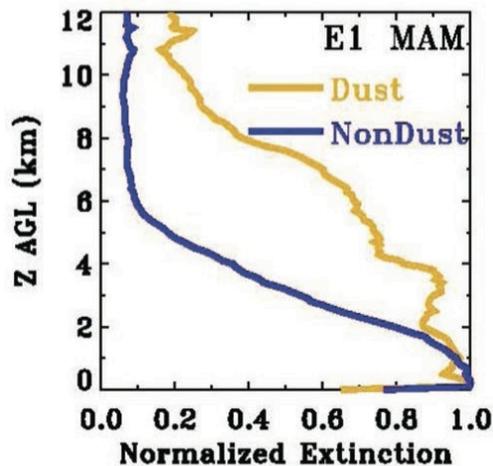
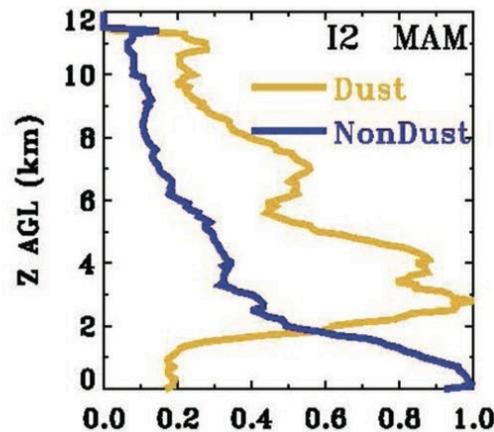
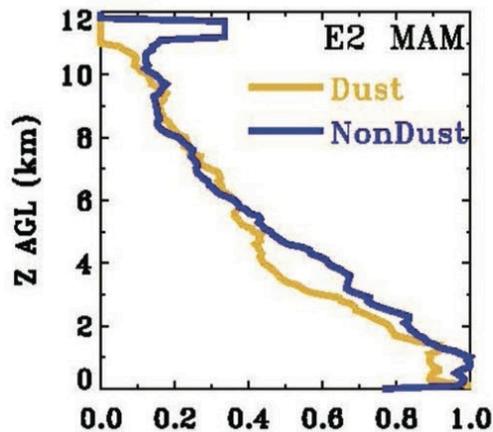
τ_{dust} and τ_{comb} are inferred from τ & f , with assumptions about f_{dust} , $f_{\text{comb.}}$, f_{marine} & τ_{marine} (Kaufman et al., 2005; Yu et al., 2009)



spring



CALIPSO Lidar Profiles are Used to Distribute MODIS AOD in the Vertical



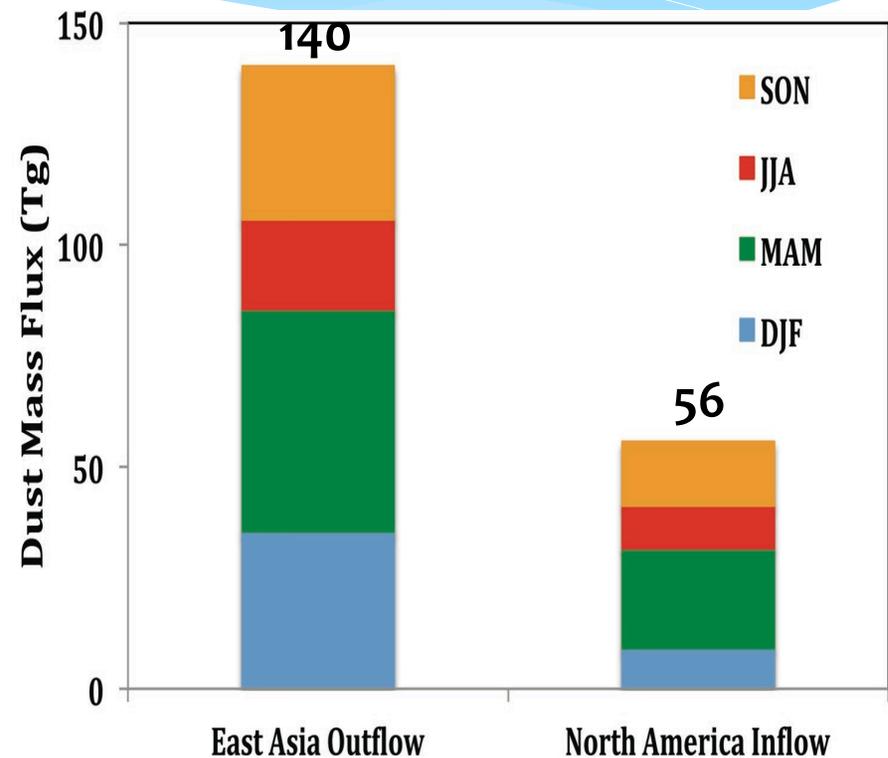
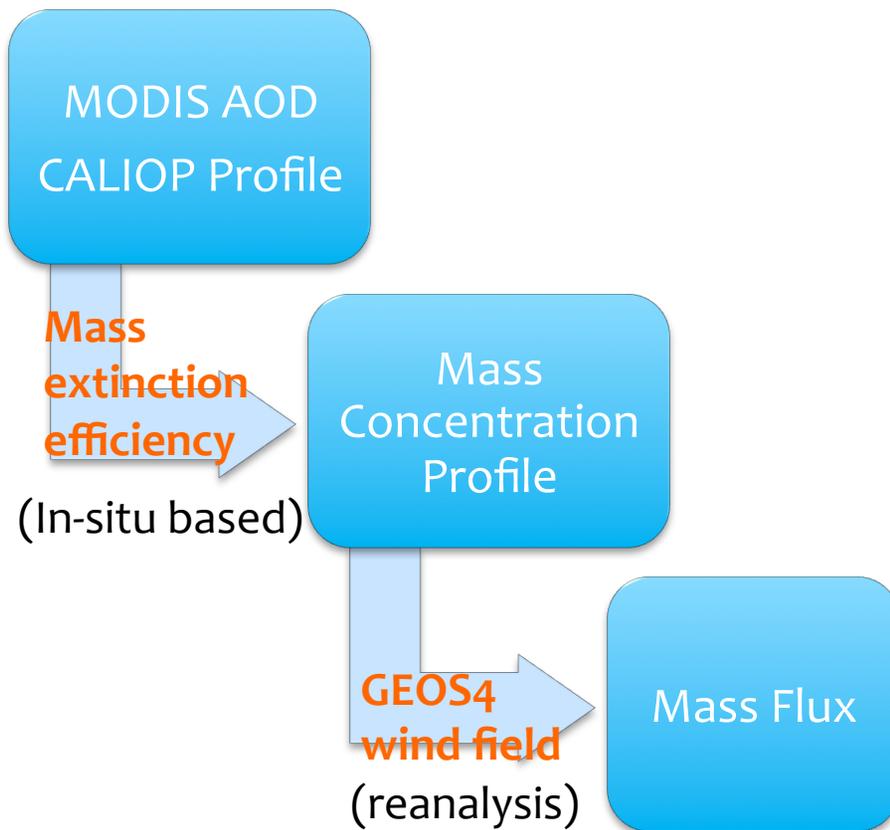
East Asia Export

N. America Import

- 4-yr (2007-2010) springtime climatology
- **Dust** is separated from other aerosols using measured particle depolarization
- Dust in low levels doesn't transport far

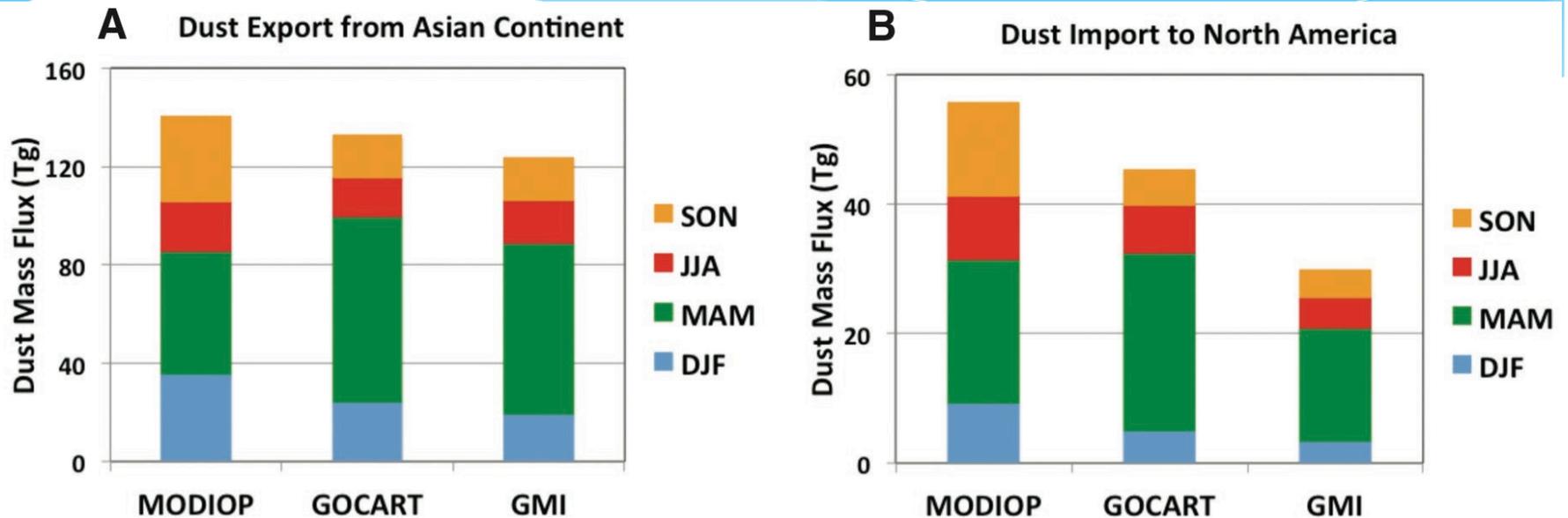
Trans-Pacific Dust Transport is Estimated from the Satellite Measurements

Vertically integrated dust mass flux



Estimated uncertainty: ~50%

Models vs Observations

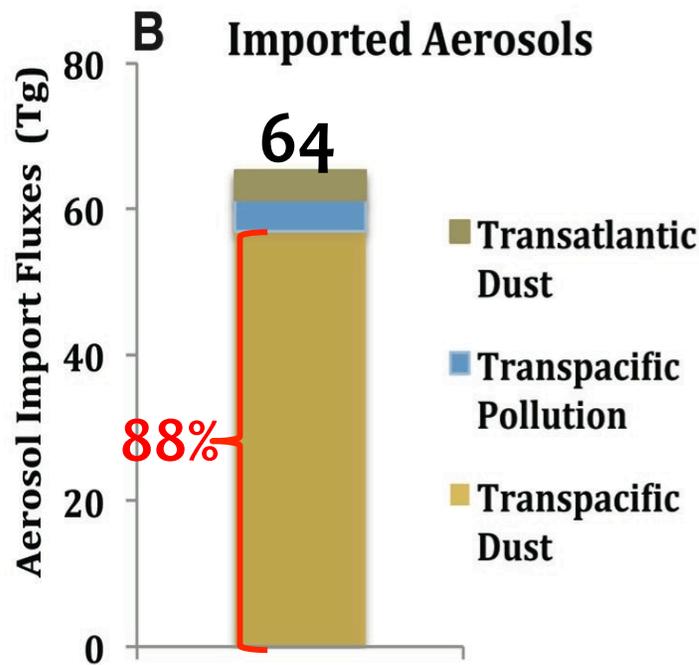


- Dust mass fluxes from GMI and GOCART models are lower than the satellite estimate, in particular for GMI simulated North America inflow.
- GMI implements a more efficient washout than GOCART does.

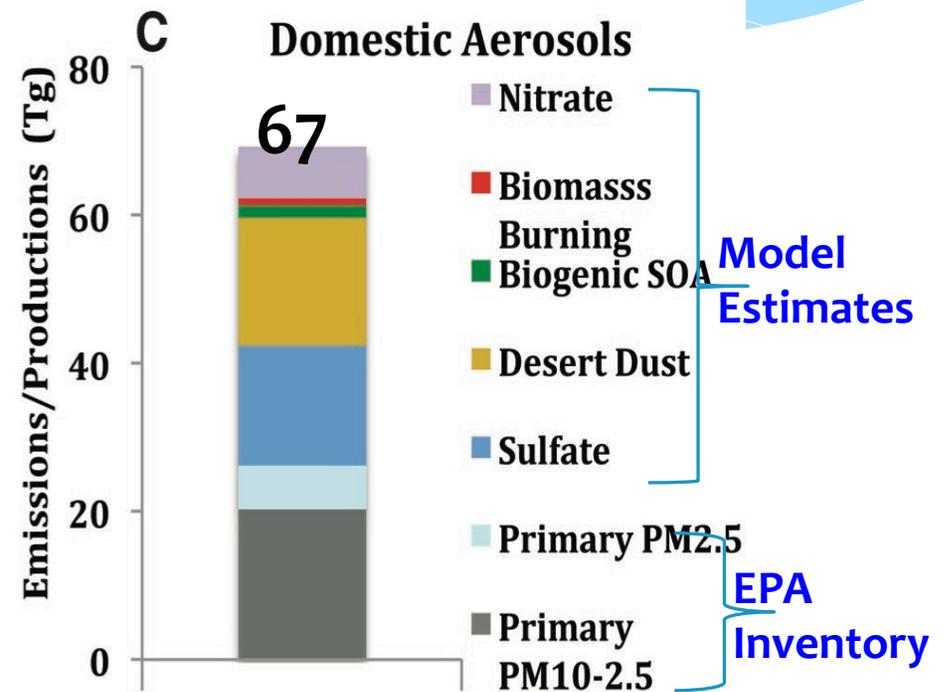
Major Results from the Tasks

- ❑ **Task 1:** Estimated trans-Pacific dust transport mass fluxes with MODIS and CALIOP
- ❑ **Task 2:** Assessed the relative contribution of intercontinental transport vs domestic production and implications for climate and air quality
- ❑ **Task 3:** Analyzed HTAP multi-model source-receptor simulations for the contribution of ICT to regional direct radiative forcing
- ❑ **Task 4:** Integrated CALIOP/OMI/MODIS observations to analyze above-cloud aerosols
- ❑ **Task 5:** Explored multi-sensor characterization of aerosol types

Aerosol Import is Comparable with Domestic Emissions in North America

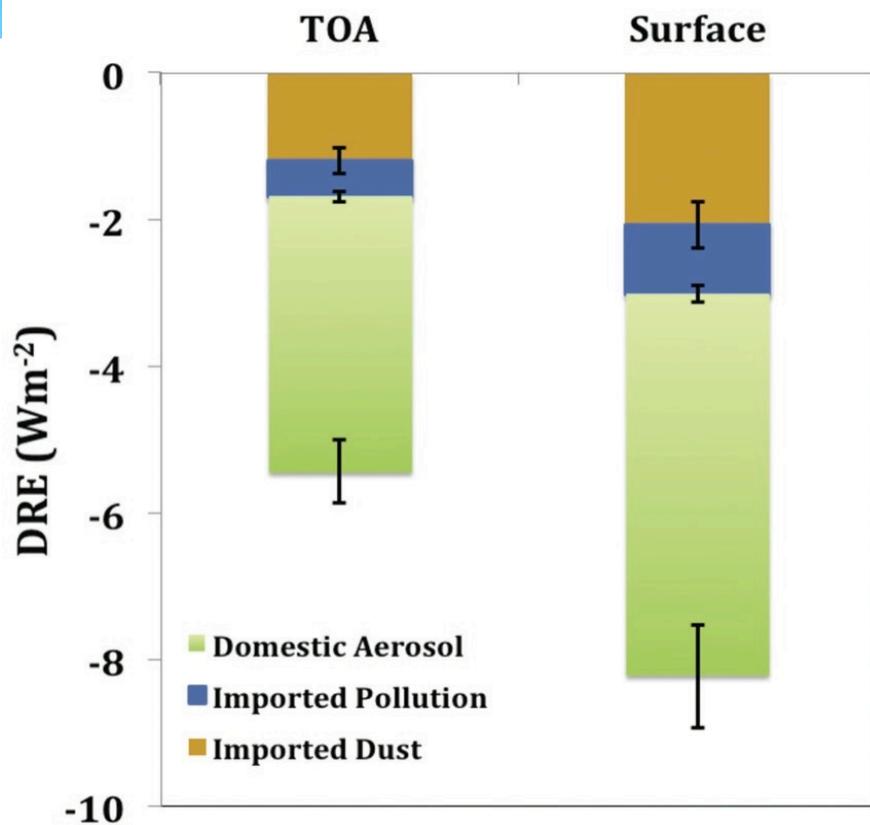


Transatlantic dust: [Kaufman et al. \(2005\)](#)
Transpacific pollution: [Yu et al. \(2008\)](#)



(Yu et al., Science, 2013)

Implications: Weather & Climate

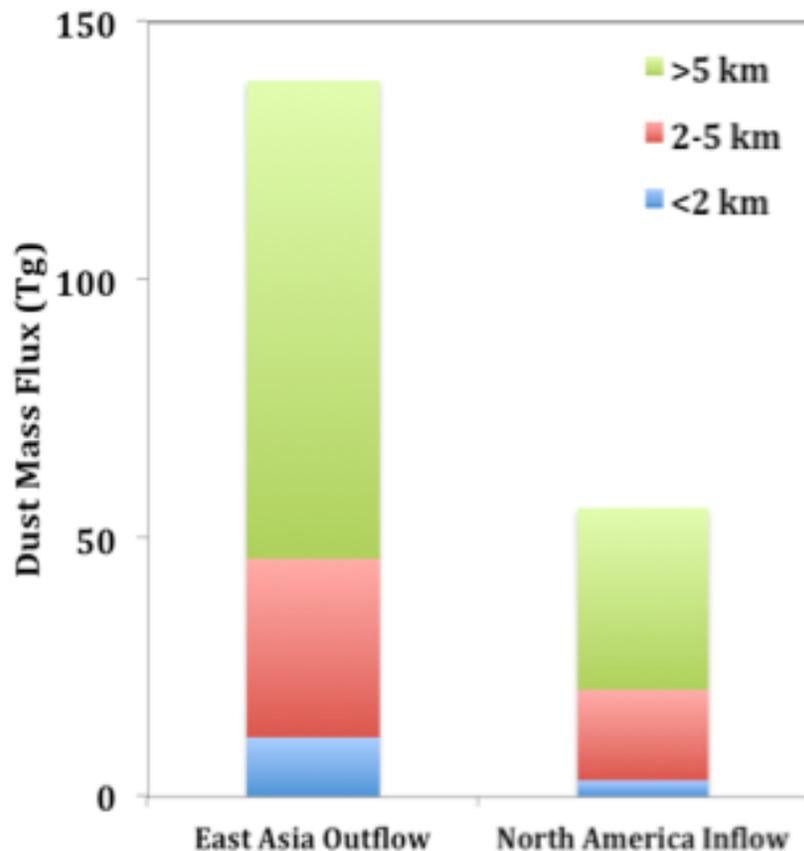


- ❑ The imported aerosols contribute about 1/3 of **solar diming** caused by aerosol scattering & absorption
- ❑ Other potential impacts
 - ❑ Changing atmospheric stability & circulations
 - ❑ Seeding clouds & changing rainfall patterns (CalWater)
 - ❑ Speeding snow melt

(Yu et al., Science, 2013)

High—flying dust may have limited impact on air quality

MODIS + CALIOP

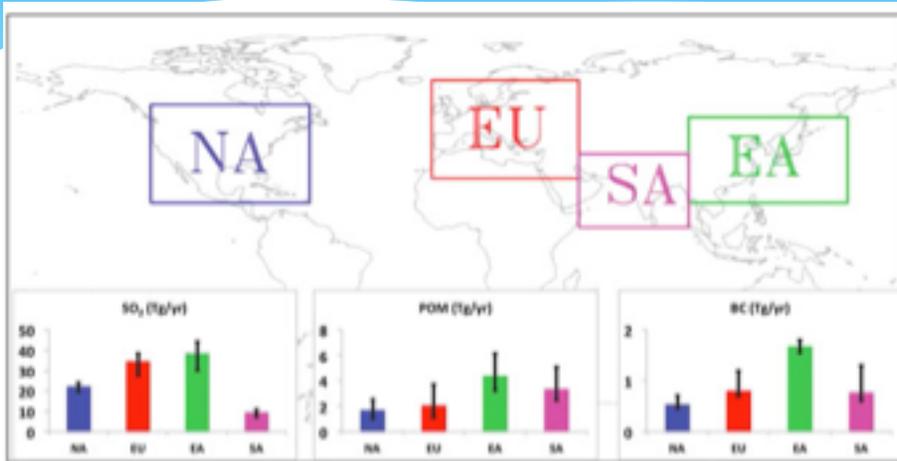


- ❑ Only ~5% of dust enters North America via the lowest 2km.
- ❑ So air quality impact is likely to be only significant in the western part & during intense events.

Major Results from the Tasks

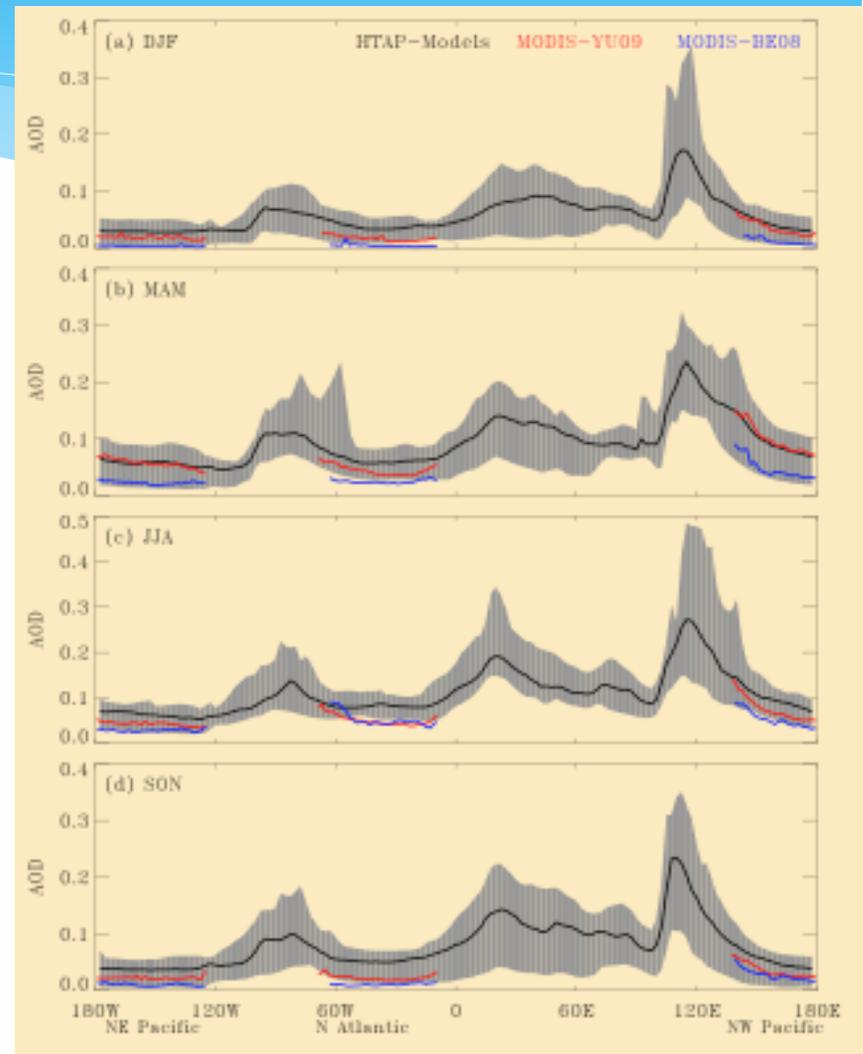
- ❑ **Task 1:** Estimated trans-Pacific dust transport mass fluxes with MODIS and CALIOP
- ❑ **Task 2:** Assessed the relative contribution of intercontinental transport vs domestic production and implications for climate and air quality
- ❑ **Task 3:** Analyzed HTAP multi-model source-receptor simulations for the contribution of ICT to regional direct radiative forcing
- ❑ **Task 4:** Integrated CALIOP/OMI/MODIS observations to analyze above-cloud aerosols
- ❑ **Task 5:** Explored multi-sensor characterization of aerosol types

HTAP Source/Receptor Relationship Experiments



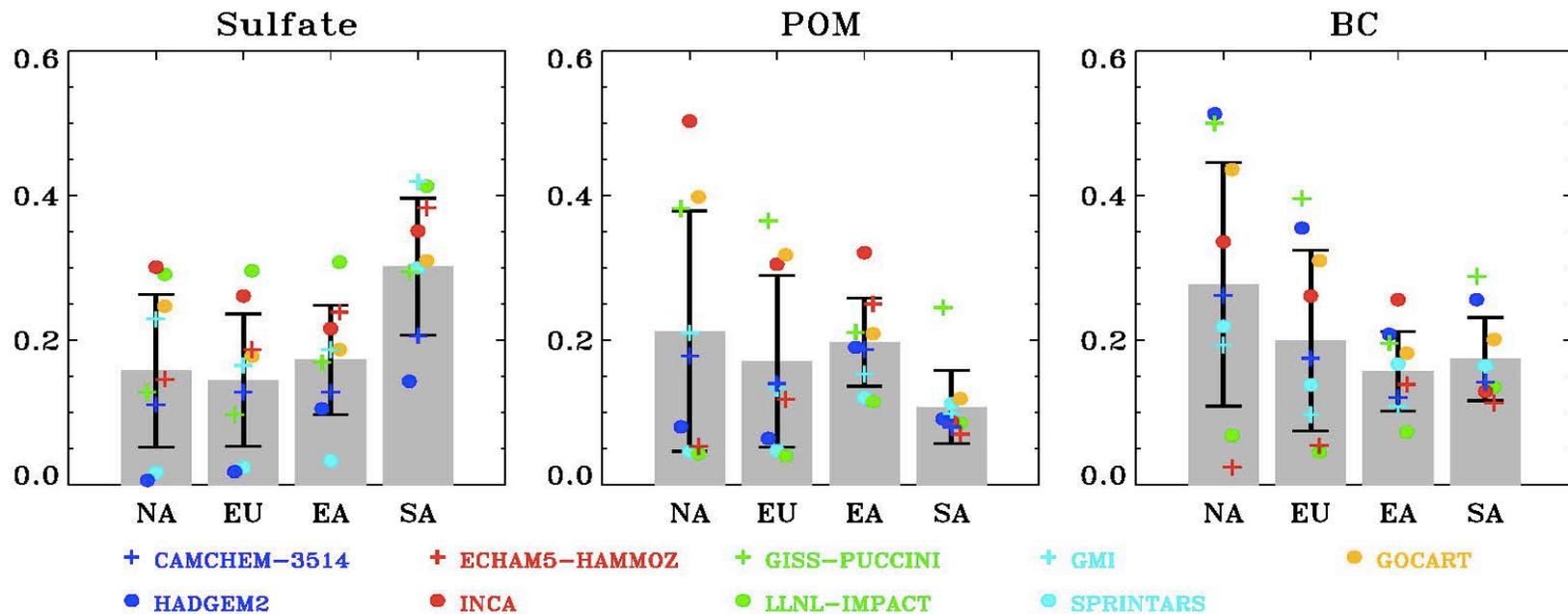
HTAP phase I modeling experiments

- * 9 aerosol models
- * 1 baseline run
- * 4 perturbation runs (each representing 20% reduction of anthropogenic emissions in one major pollution region, i.e., NA, EU, EA or SA)



(Yu et al., JGR 2013)

AOD fractional contributions by foreign aerosols via ICT



NA – North America; EU – Europe; EA – East Asia; SA – South Asia

The ICT contributions are significant (e.g., 10-30% 9-model median)
But large model spread exists

(The analysis also contributed to the HTAP assessment report)

(Yu et al., JGR 2013)

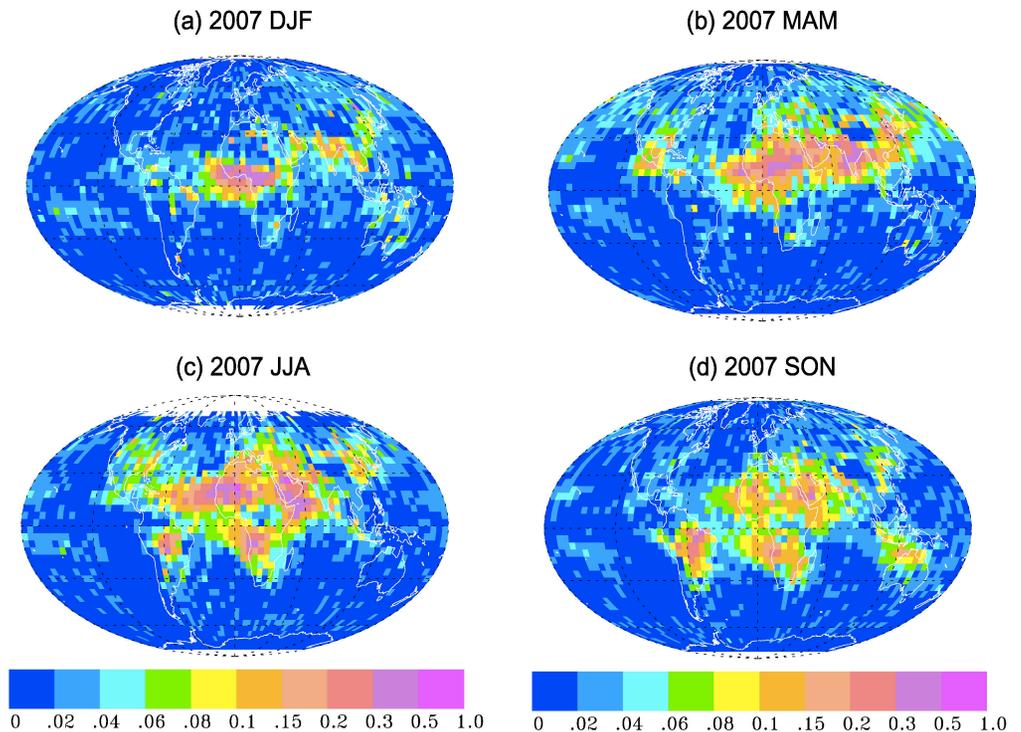
Major Results from the Tasks

- ❑ **Task 1:** Estimated trans-Pacific dust transport mass fluxes with MODIS and CALIOP
- ❑ **Task 2:** Assessed the relative contribution of intercontinental transport vs domestic production and implications for climate and air quality
- ❑ **Task 3:** Analyzed HTAP multi-model source-receptor simulations for the contribution of ICT to regional direct radiative forcing
- ❑ **Task 4:** Integrated CALIOP/OMI/MODIS observations to analyze above-cloud aerosols
- ❑ **Task 5:** Explored multi-sensor characterization of aerosol types

Satellite observations of above-cloud aerosols are emerging [1]

- ❑ Aerosol intercontinental transport often occurs above clouds.
- ❑ One inherent assumption in previous studies: cloud-free AOD can be representative of that in cloudy condition.
- ❑ Satellite observations of above-cloud aerosols are emerging.....

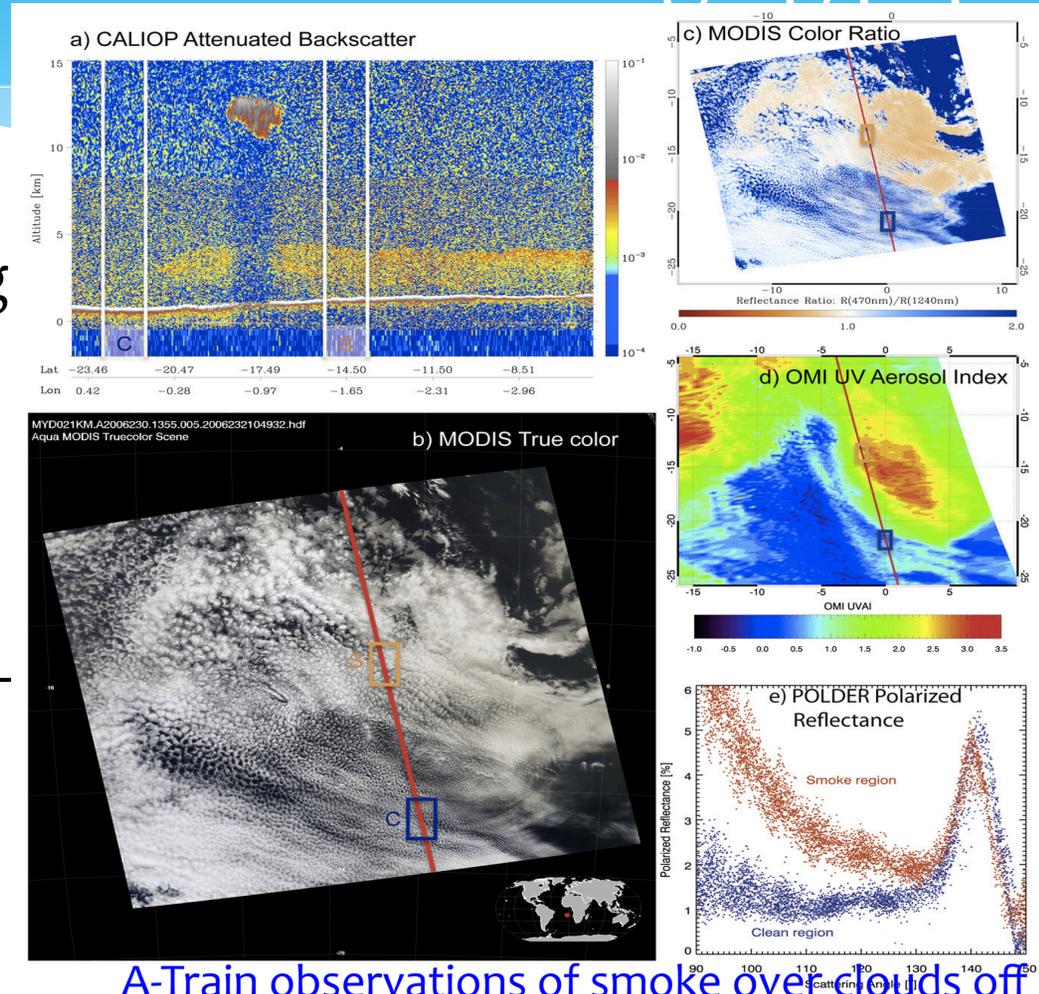
CALIPSO lidar can measure aerosols above low-level clouds



Satellite observations of above-cloud aerosols are emerging [2]

EOS passive sensors also show promising capability of measuring above-cloud aerosols:

- Waquet et al. (2009) – POLDER
- Torres et al. (2012) - OMI
- Jethava et al. (2013) – MODIS

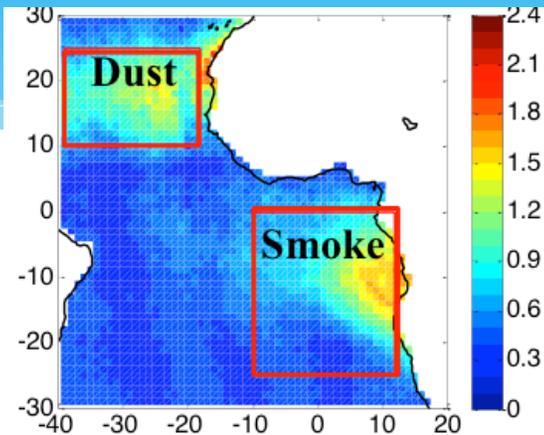


A-Train observations of smoke over clouds off the coast of SW Africa (8/18/2006)

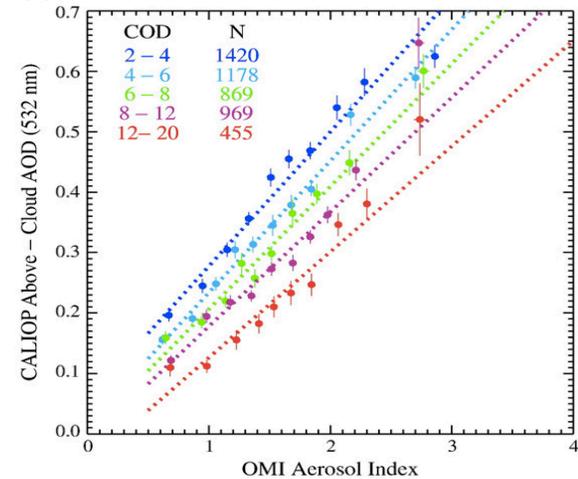
Yu & Zhang, Atmos. Environ. - New Directions, 2013

OMI-CALIOP-MODIS integration

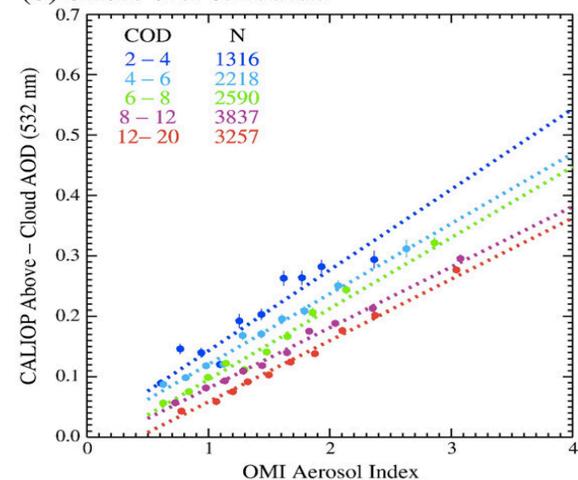
- ❑ CALIOP: ACAOD at very narrow swath
- ❑ OMI: Aerosol Index (AI, semi-quantitative) with wide swath



(a) Dust over N. Atlantic



(b) Smoke over S. Atlantic



The relationships between co-located CALIOP ACAOD and OMI AI, stratified by MODIS cloud albedo, suggest a potential of using OMI AI and MODIS clouds to empirically derive ACAOD over extensive regions.

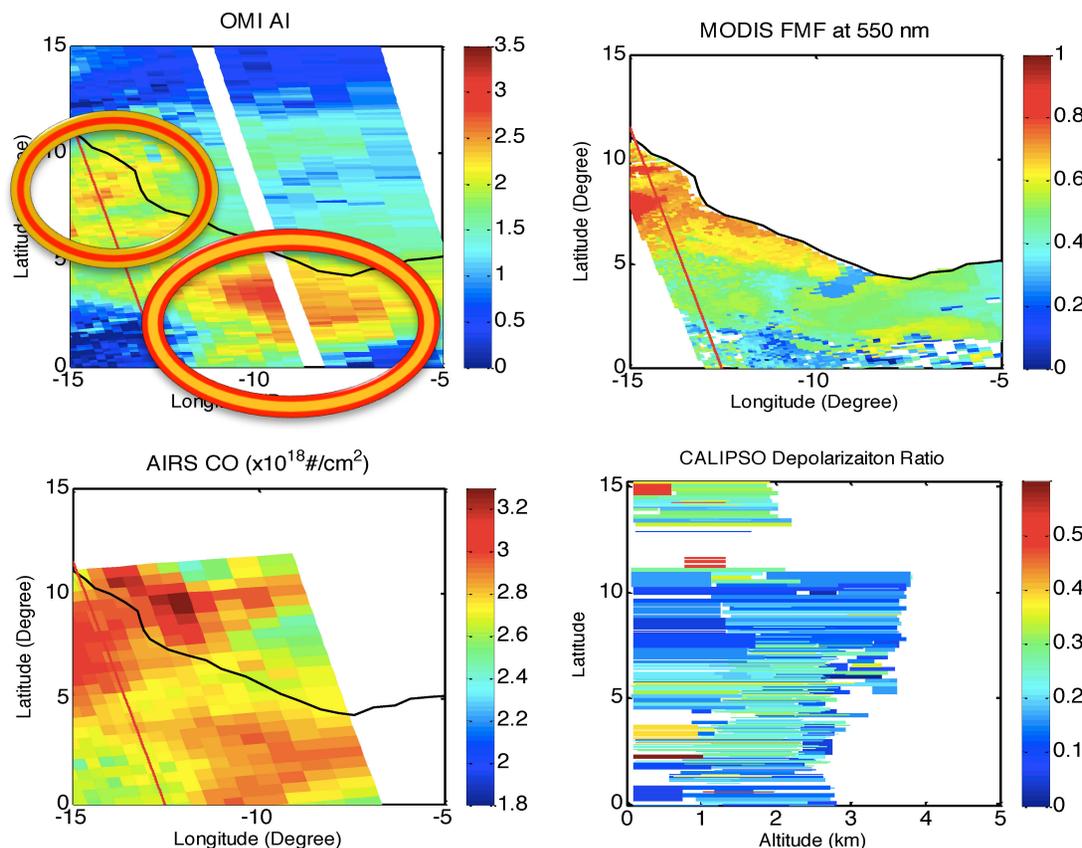
Please check Yan Zhang's poster

Yu et al., Remote Sens. Environ., 2012

Major Results from the Tasks

- ❑ **Task 1:** Estimated trans-Pacific dust transport mass fluxes with MODIS and CALIOP
- ❑ **Task 2:** Assessed the relative contribution of intercontinental transport vs domestic production and implications for climate and air quality
- ❑ **Task 3:** Analyzed HTAP multi-model source-receptor simulations for the contribution of ICT to regional direct radiative forcing
- ❑ **Task 4:** Integrated CALIOP/OMI/MODIS observations to analyze above-cloud aerosols
- ❑ **Task 5:** Explored multi-sensor characterization of aerosol types

EOS A-Train synergy offers more robust characterization of aerosol type



Gulf of Guinea (January 31, 2008)

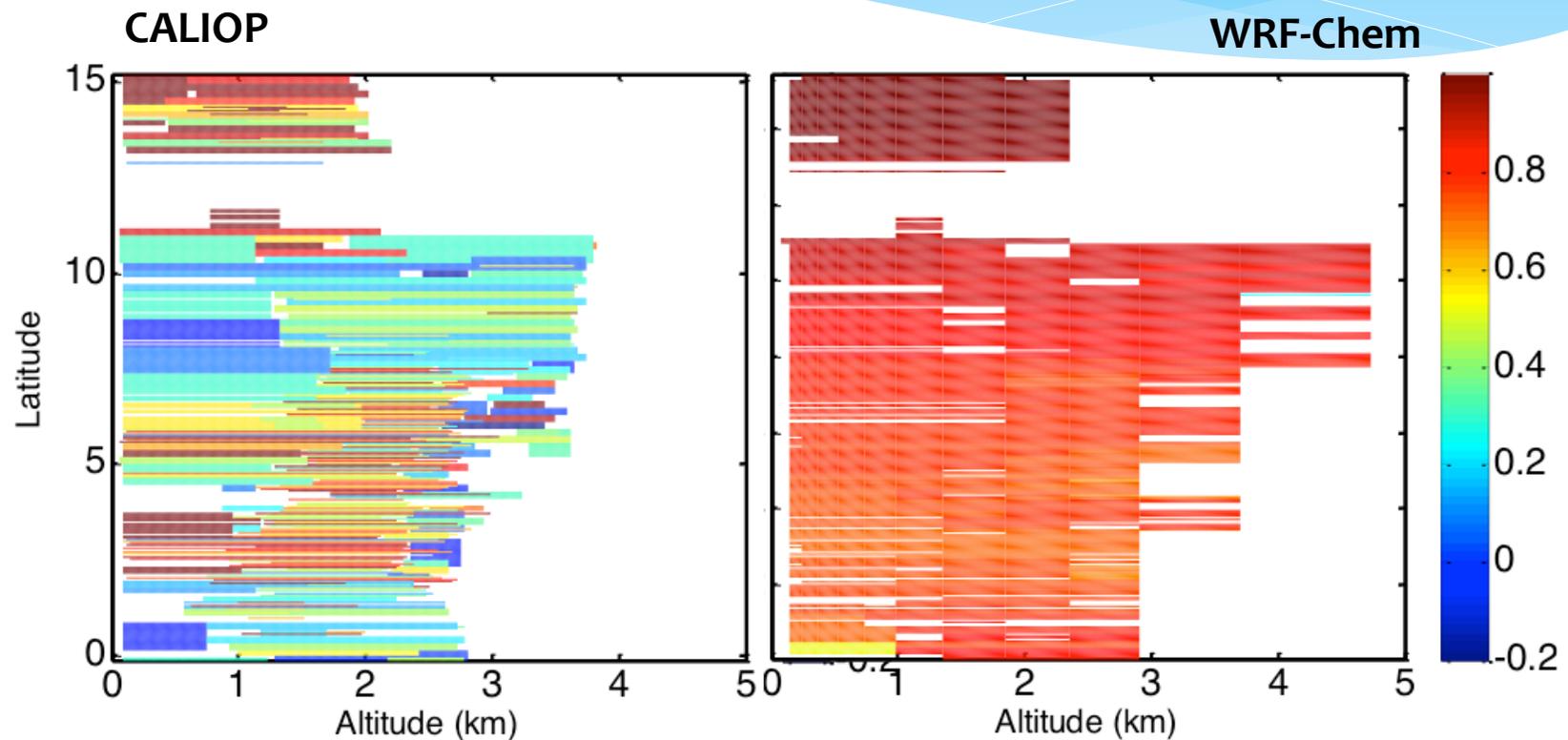
Please check Yan Zhang's poster

Size and shape-based aerosol type characterization can be cross examined with CO and traced to source locations through the back-trajectory analysis.

Dust dominated plume in the south
VS.
Smoke dominated plume in the north

Different Stories: satellite vs model

Altitude-resolved dust fraction (in terms of extinction) along the CALIPSO track



Please check Yan Zhang's poster

(Courtesy of Jun Wang for providing WRF-Chem results)

SUMMARY

- We used EOS multi-sensor measurements to estimate that
 - aerosol import to the air shed over North America amounts to 64 Tg/year
 - 88% of the import is trans-Pacific dust
- The imported aerosol column amount is nearly equivalent to the domestic production of 67 Tg/year
- The import could have significant impacts on regional climate and weather; but air quality impact is likely to be less significant because of high-flying dust.
- A multi-model assessment suggests that intercontinental transport (ICT) contributes significantly to regional aerosol direct effect; however large model-spread exists.
- Future efforts are needed to gain better understanding of aerosol ICT.
 - Using emerging above-cloud aerosol measurements
 - Exploring A-Train multi-sensor synergy to improve aerosol characterization
 - Estimating Asian aerosol transport to the Arctic
 - Understanding interannual variations of ICT on a decadal time scale
 - Contributing to HTAP phase II assessment

List of Publications

- ① Yu, H., L. Remer, M. Chin, H. Bian, Q. Tan, T. Yuan, and Y. Zhang (2012). Aerosols from Overseas Rival Domestic Emissions over North America, **Science**, **337**, 566-569. (highlighted by NASA <http://www.nasa.gov/topics/earth/features/dust-imports.html> and numerous media, just last Friday in The Baltimore Sun)
- ② Yu, H., et al. (2012). An Integrated Analysis of Aerosol above Clouds from A-Train Multi-sensor Measurements, **Rem. Sens. Environ**, **121**, 125-131.
- ③ Yu, H., L. A. Remer, R. A. Kahn, M. Chin, and Y. Zhang (2013). Satellite perspective of aerosol intercontinental transport: from qualitative tracking to quantitative characterization, **Atmos. Res**, **124**, 73-100.
- ④ Yu, H., and Z. Zhang (2013). New Directions: Emerging satellite observations of above-cloud aerosols and direct radiative forcing, **Atmos. Environ**, **72**, 36-40.
- ⑤ Yu, H., et al. (2013). A multi-model assessment of the influence of regional anthropogenic emission reductions on aerosol direct radiative forcing and the role of intercontinental transport, **J. Geophys. Res**, **118**, 700-720.
- ⑥ Collins, W., M. M. Fry, H. Yu, J. S. Fuglestvedt, D. T. Shindell, and J. J. West (2013). Global and regional temperature-change potentials for near-term climate forcers, **Atmos. Chem. Phys**, **13**, 2471-2485. (“Short-term impacts”, *Nature Climate Change*, **3**, 310, April 2013)

A story in the Baltimore Sun (last Friday)

Home → Collections → Maryland

Ads By Google



The Nature Conservancy
Protecting nature. Preserving life.

Earth Day April 22

Your donation will help protect the lands and waters for generations to come. [Donate](#)



AdChoices

Tracking the long-distance travels of dust

Scientists find huge plume from overseas, eye climate effect

April 12, 2013 | By Arthur Hirsch, The Baltimore Sun

Spring stirs pollen, and also dust — high-flying dust that's blown thousands of miles to reach North America in greater amounts than scientists have known before, with potential impact on the climate and air quality.

Mineral dust rises from dry expanses in Asia, Africa and the Middle East, rides upper atmospheric winds for days across the Pacific Ocean to the West Coast of the United States and beyond. More than two miles up, it can reach Maryland, where scientists at [College Park](#), Greenbelt and Catonsville have been tracking its global travels with satellite-based instruments in a way they say is more accurate and covers a longer period of time than previous studies.

[f Recommend](#) 0 [e](#) [p](#) [t](#) [+](#)

1 [J](#) 0

[t Tweet](#) [Submit](#) [g +1](#)

