GEO-CAPE Aerosol Science Objectives

GEO-CAPE Aerosol Subgroup

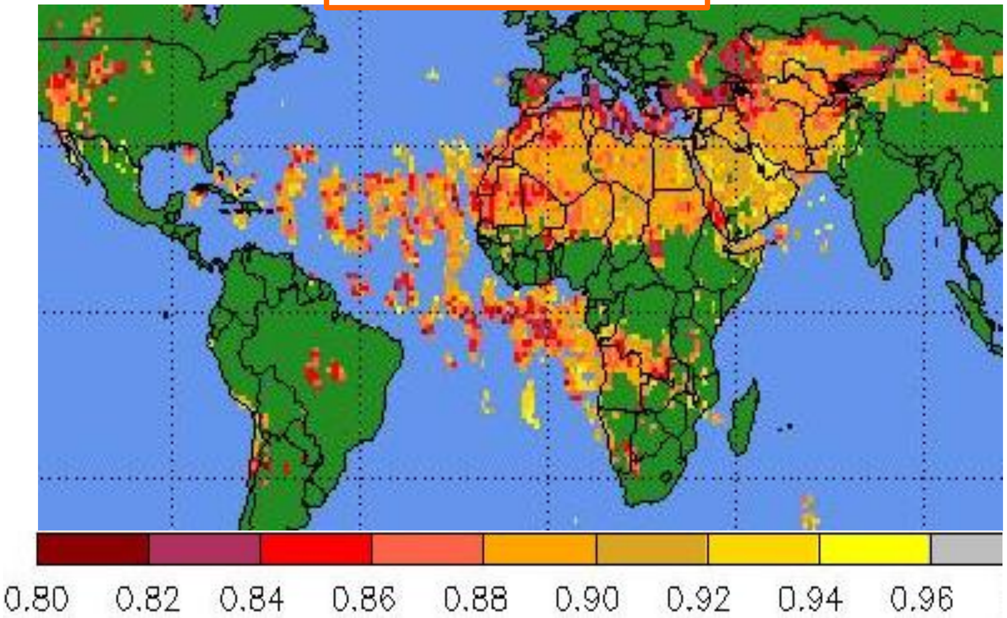
GEO-CAPE Workshop
September 2009

Aerosol studies with GEO-CAPE

- The GEO-CAPE mission can provide a unique opportunity in advancing our understanding on aerosol processes and aerosol effects on climate and air quality, especially when it is synergistically combined with other satellites and models
- Major advantages of GEO-CAPE:
  - Retrieval of aerosol properties at near UV to visible wavelengths to provide aerosol absorption and SSA
  - Concurrent measurements of aerosols and precursors (e.g., SO_2, NO_2, VOCs)
  - Ocean color measurements relevant to aerosol studies
  - Super high spatial resolution (100-300 m) in coastal areas (land and ocean) for enhanced studies (e.g. pollution transport from /circulation near Megacities)

Aerosol absorption and SSA from UV instrument OMI

SSA Sept. 2006



AAOD Sept. 2007

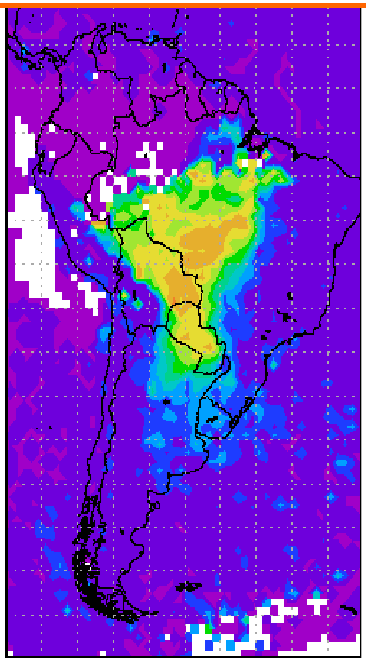
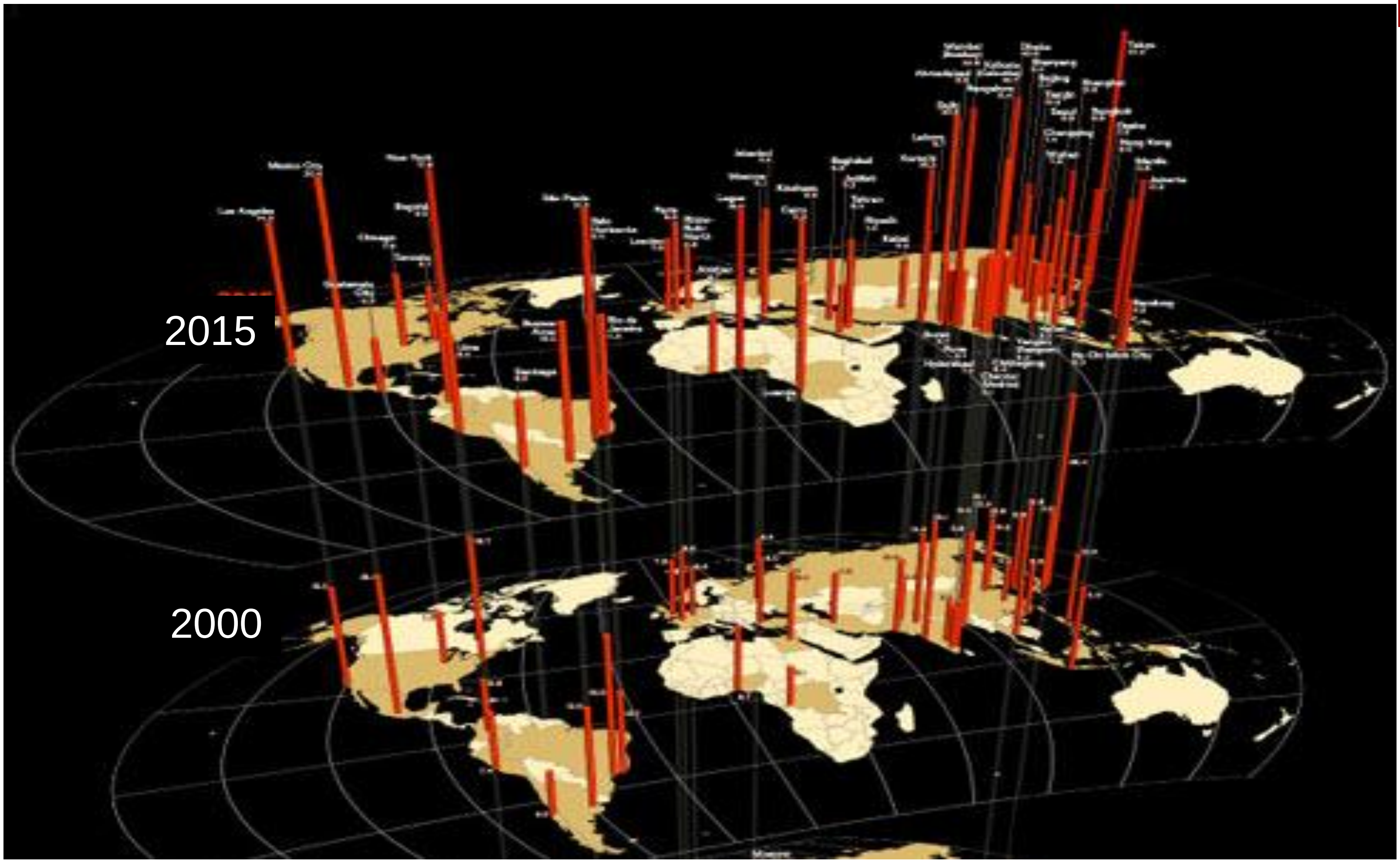


Figure from Omar Torres, Hampton University

Most megacities are located near the coastal area



Source/© 2002 National Geographic Society (provided by Hongbin Yu)

Related future missions of GOES-R and ACE:

- GOES-R (NOAA):
  - Geostationary over North and South America and adjacent oceans (may have GOES-R East and West)
  - 16-channels (MODIS-like) from 470 nm to 13.3 μm
  - Spatial resolution: 0.5 km in VIS, 1 km in NIR, 2 km in IR (thus better cloud screening/measurements capability than GEO-CAPE over land at 8 km)
  - Operational

- ACE (NASA):
  - Global coverage (instantaneous once a day)
  - More detailed aerosol property measurements (AOD, vertical profile, size, phase function, refractive indices, absorption, etc.)
  - Related measurements: clouds, precipitation, ocean color

Synergy is key to achieve the GEO-CAPE aerosol objectives

- Synergy among LEO and GEO
  - ACE for more detailed aerosol properties vertical distributions, and long-range transport
- Synergy among GEO and GEO
  - GEOS-R for clouds (due to better spatial resolutions) and spectrally extended aerosol data, and possible joint retrieval for particle shape or plume height
  - GEO from Asia, Europe, and North America for expanded spatial coverage of diurnal variation data
- Synergy among atmospheric and space measurements
  - Ground-based and aircraft measurements for validation, constraints, additional detailed information
- Synergy among measurements and models
  - Use model to analyze/interpret measurements and use measurements to improve models

Example: GEO-CAPE and GOES-R synergy on aerosol retrieval

- Joint retrieval from observations collected from dual viewing angles and multiple scattering angles to
  - characterize non-spherical dust particles
  - derive wind speed and stereo height of aerosol plume

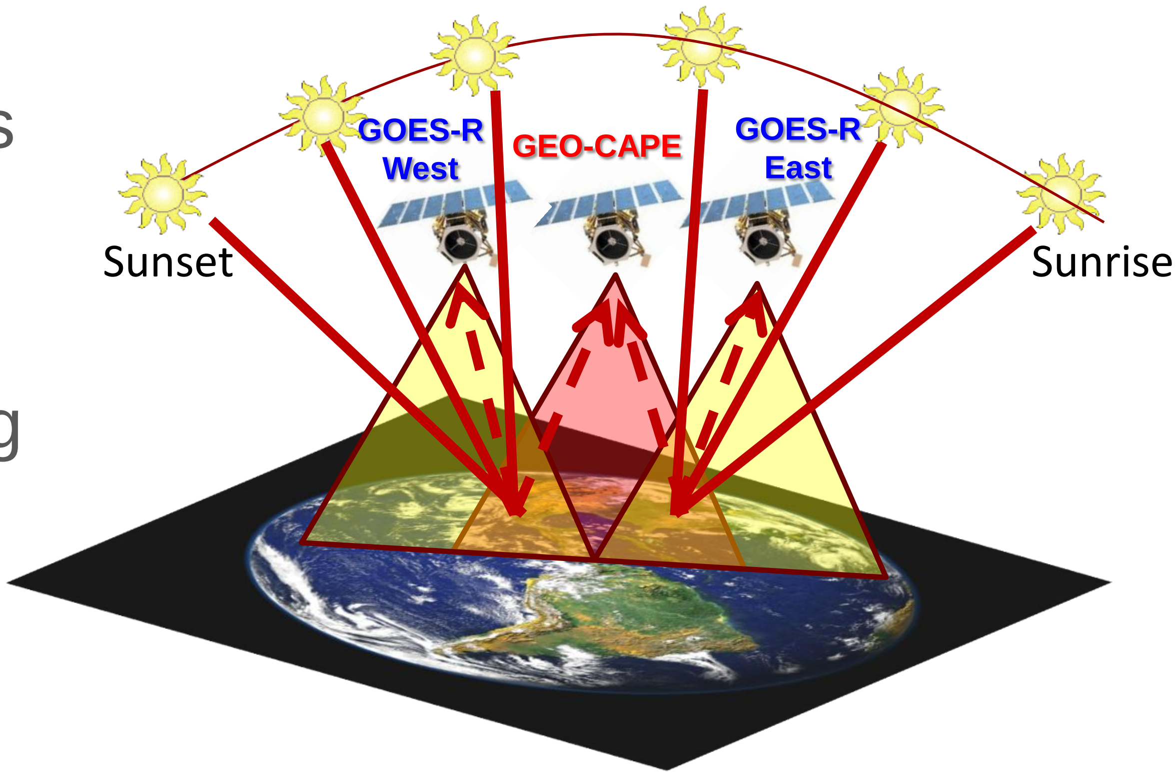


Figure from Jun Wang, U. Nebraska – See poster for details

Four major scientific objectives (not in priority order):

1. To better derive aerosol (and precursor) **emissions** (*STM P1*)
2. To better understand atmospheric **processes** that determine the variability of aerosols (*STM P2*)
3. To better estimate aerosol **effects on climate and weather** (*STM P4*+)
4. To better assess aerosol **environmental impacts** (*STM Px?*)

Objective1: Emissions

- Q1: Quantitatively, what are the temporal variations of biomass burning, dust, volcanic, anthropogenic (e.g. fossil fuel SO_2, ship), and biogenic emissions?
- Q2: What are the controlling factors (e.g., meteorological condition) of these emissions?

Example: Diurnal variation of biomass burning emission

Diurnal fire sizes for various ecosystems derived based on the GOES fire data, 2002-2005

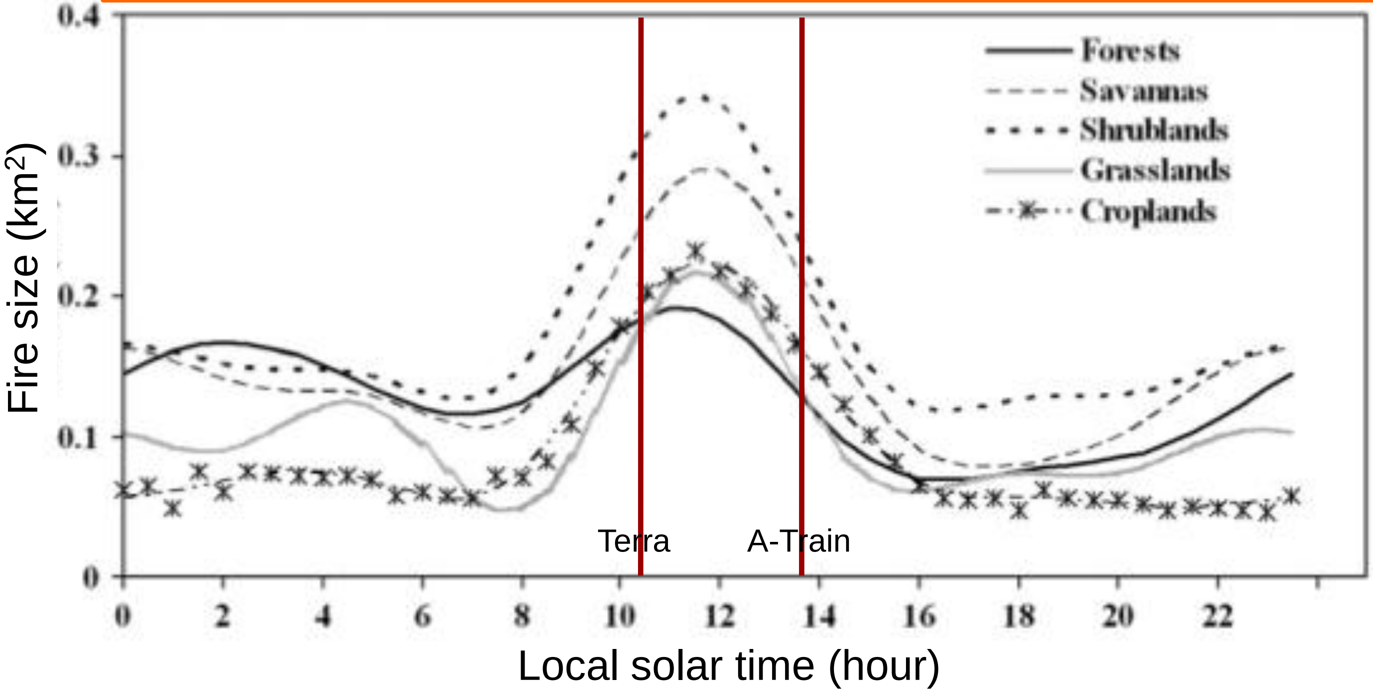
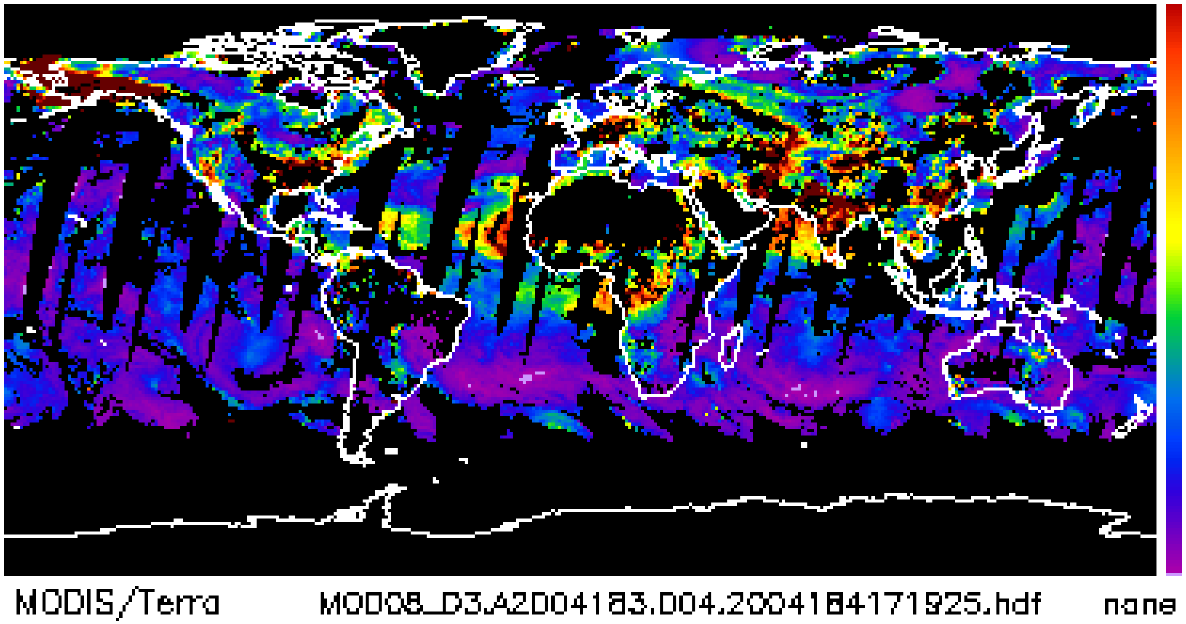


Figure from Zhang and Kondragunta, RSE 2008

Example: MODIS fire radiative power (FRP) for smoke

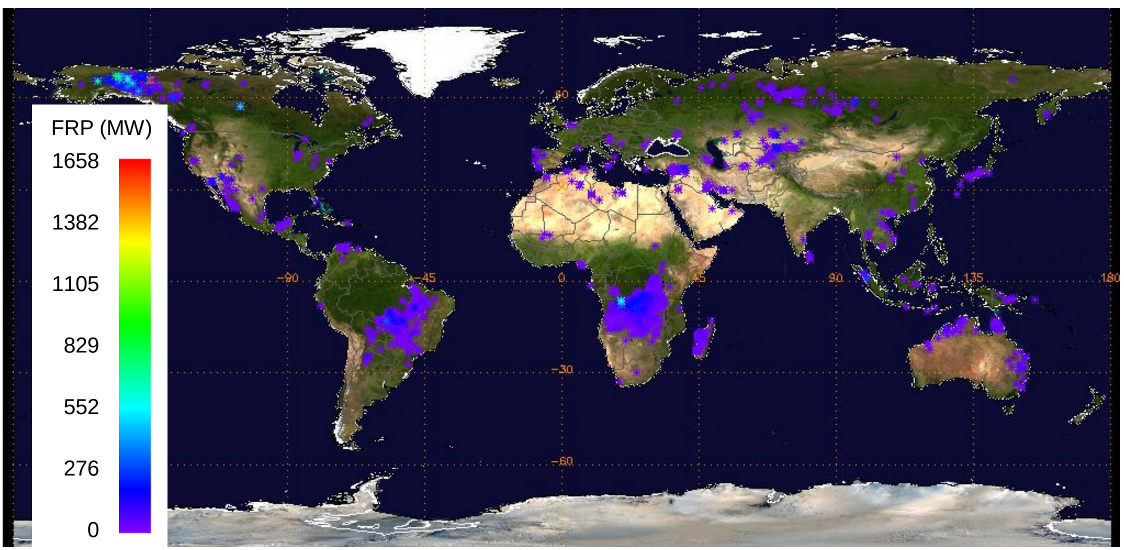
MODIS Measurements of AOD July 1, 2004

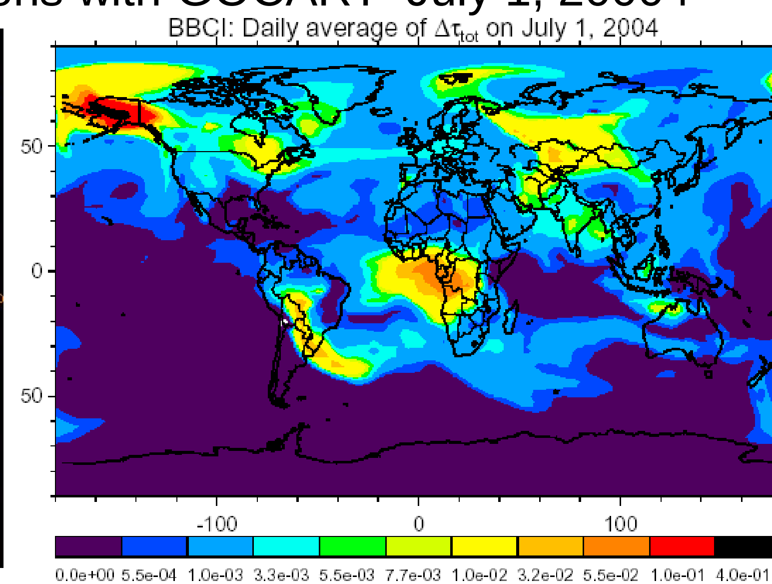


- It is extremely important to characterize fires quantitatively to improve smoke emissions in models and to enhance accurate evaluation of smoke impacts
- FRP is directly related to fire strength, biomass consumption, and smoke emission

Slide from Charles Ichoku, NASA GSFC

MODIS FRP used in simulation of smoke emissions with GOCART July 1, 20004

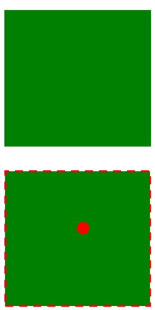




Fire detection

- Advantages of FRP for estimating burned biomass and smoke emissions: quantitative, more direct, fewer assumptions, less uncertainty, higher accuracy, wide range of scales: spatial (local, regional, and global) and temporal (real-time, daily, monthly, etc.)
- The MIR (~4 µm) channel is ideal for detection and measurement of radiative energy of active fires covering < 10
- Sp

Veg Only
(300 K)



Veg +
1%
Fire

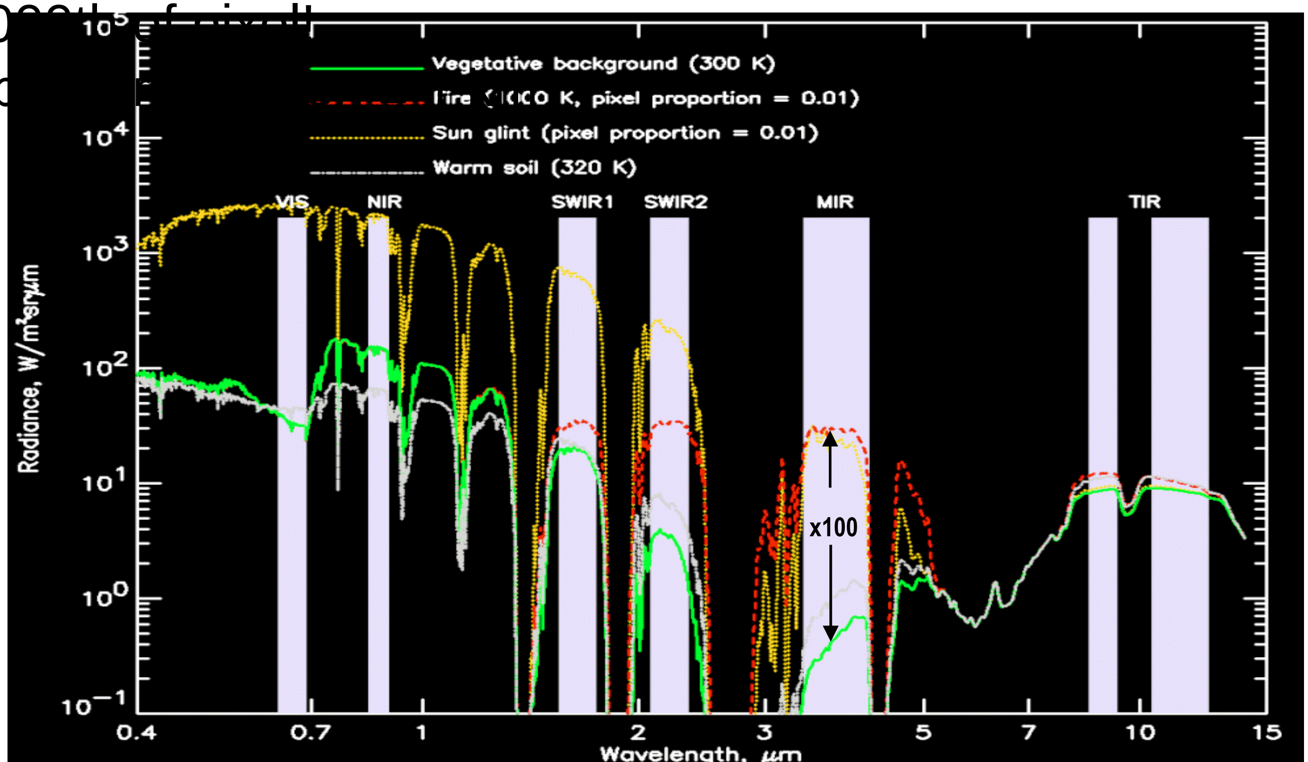


Figure from Zhukov et al., 2006 (provided by Martin Wooster)

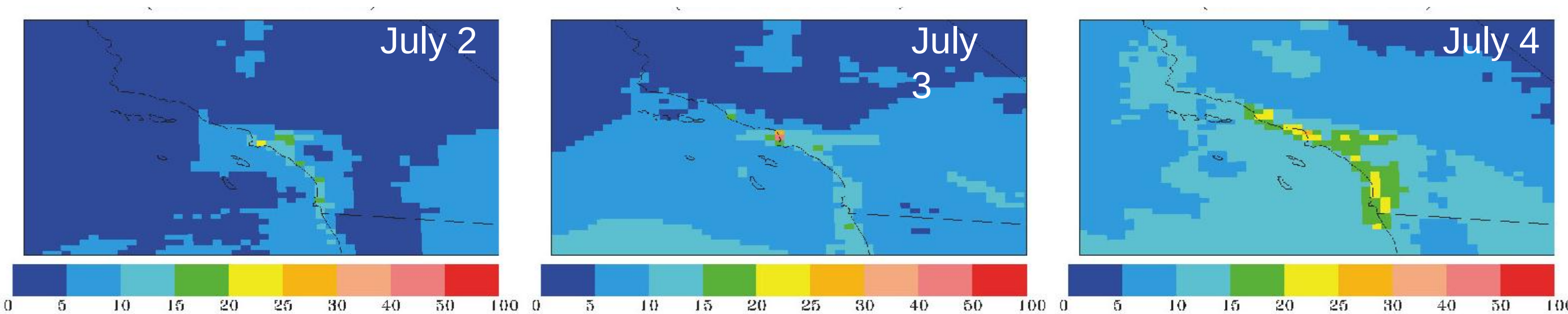
Objective 2: Processes

- Q1: How do transport, boundary layer process, convection, meso-scale circulation, chemical evolution, and deposition determine the aerosol distribution over temporal scales from hourly to daily and spatial scales from local to regional?
- Q2: Can we quantify the deposition and aerosol mass flux into and out of the regional atmosphere, partitioned by type, and as a function of time?
- Q3: What are the relative importance of emission, long-range transport, and meso-scale circulation on local and regional pollution levels at a temporally resolved scale?

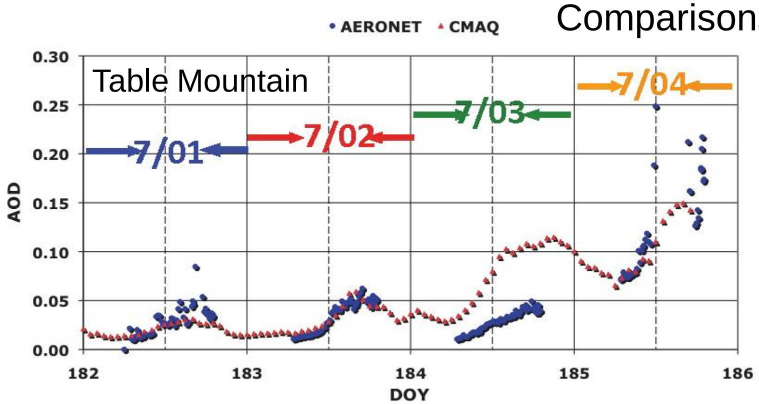
Example: Effects of coastal circulation on pollution levels (and vise versa)

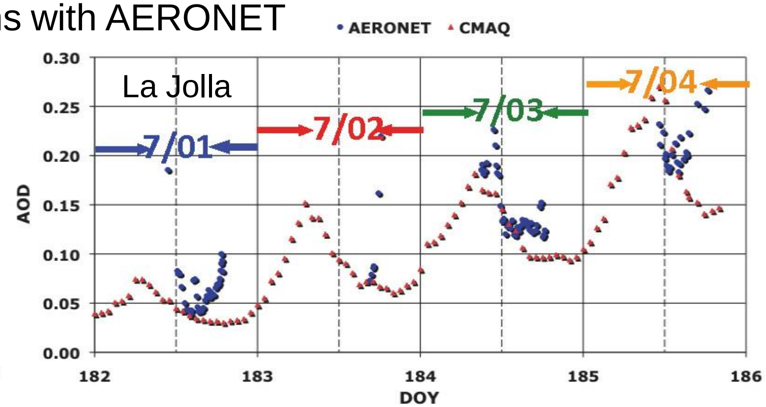
CMAQ simulation (4 km res) of AOD over SW US, 7/2-7/4/2007

18 UT



Comparisons with AERONET





Aerosol accumulation from July 2 to July 4 results mainly from recirculation (occurrence of return flow of sea breeze on July 3 & 4, due to weaker background wind).

Figure from Hongbin Yu, NASA GSFC (see poster)

Example: Dust transport and deposition

- Using MODIS AOD and NCEP winds, Kaufman et al. (2005) estimated the amount of dust transport from Sahara and deposited to the Atlantic, Amazon, and Europe
- With high frequency geostationary satellite observations, such transport and deposition can be estimated with much higher confidence

May – September

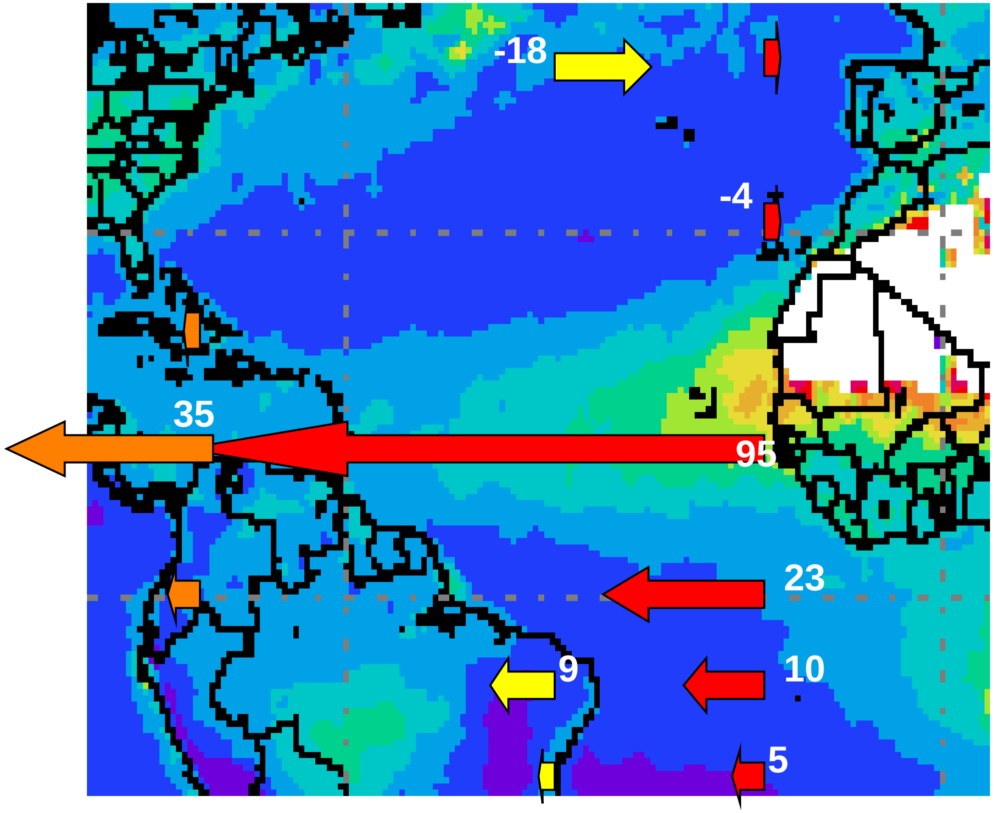


Figure from Kaufman et al., JGR 2005

Objective 3: Effects on climate and weather

- Q1: What is the diurnal variation of AOD, absorption, and aerosol direct radiative forcing at TOA, atmospheric column, and at the surface?
- Q2: How can the aerosol radiative forcing above and below the clouds be estimated from the high spatial and temporal resolution measurements from geostationary satellites?
- Q3: How can the aerosol-cloud interactions be better understood with the geostationary satellite observations of aerosol properties and cloud evolution?
- Q4: Can the aerosol impact on weather (e.g. hurricane) be better assessed with the combination of geostationary satellite observations from GEO-CAPE, GOES-R, European geostationary satellite, and polar-orbiting satellites?

Example: Effect of diurnal sampling on monthly mean AOD

- Monthly mean AOD from GOES AOD retrievals at 10:30 and 13:30 LST
  - lot of gaps
  - large areas with extreme values

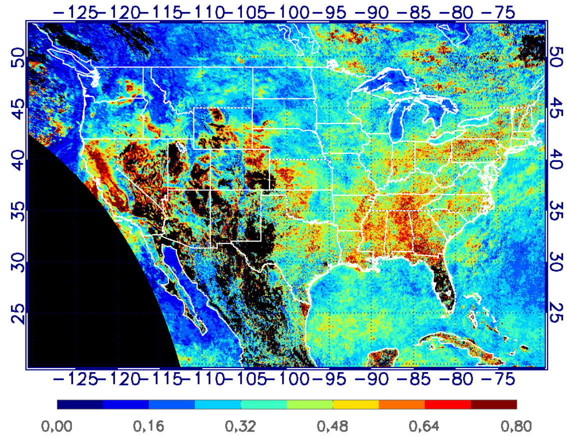
- Monthly mean AOD from half-hourly GOES AOD retrievals ("geo") for July 2008
  - less gaps
  - smoother AOD field

- Regional errors in monthly mean AOD from "polar" is as large +/- 0.3 or higher

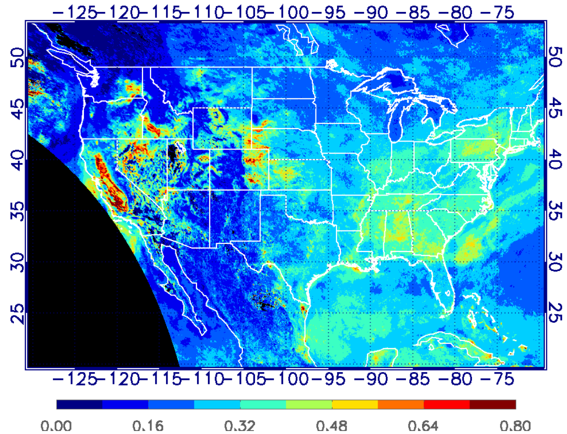
- AERONET data shows similar pattern

Monthly mean AOD	AERONET GSFC	GASP
"geo"	0.29	0.32
"polar"	0.51	0.4

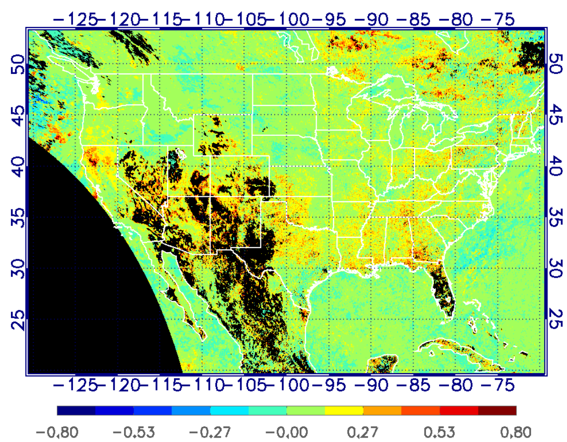
Slide from Shobha Kandragunta, NOAA



(a) Monthly avg AOD sampled at 10:30 and 13:30 LST



(b) Monthly avg AOD sampled from half-hourly GOES



Difference (a) – (b)

Example: Temporal variations of AOD and TOA flux over Amazon

AOD and SW TOA flux from the GOES-8 data during Amazon biomass burning season, July 20-August 31,1998

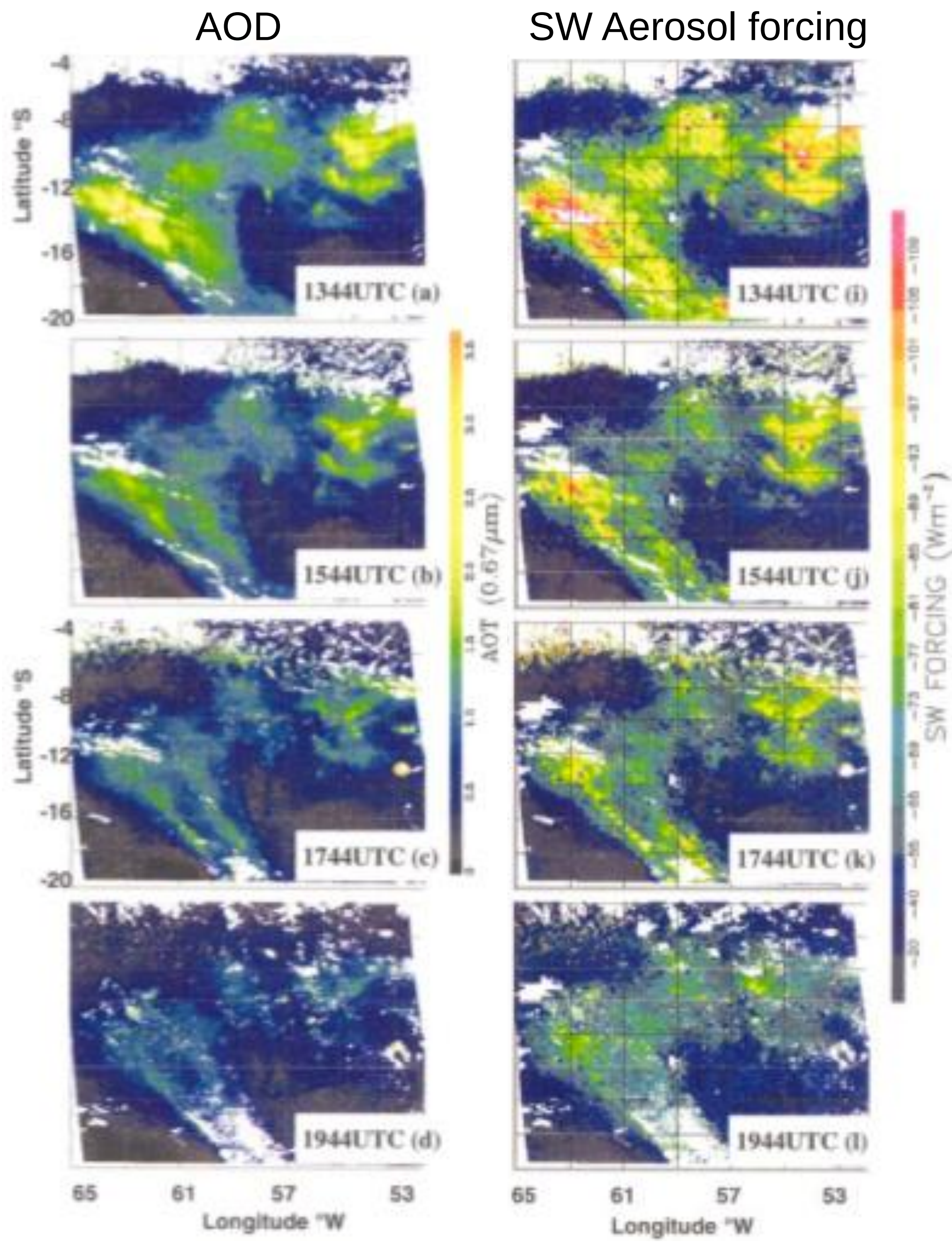
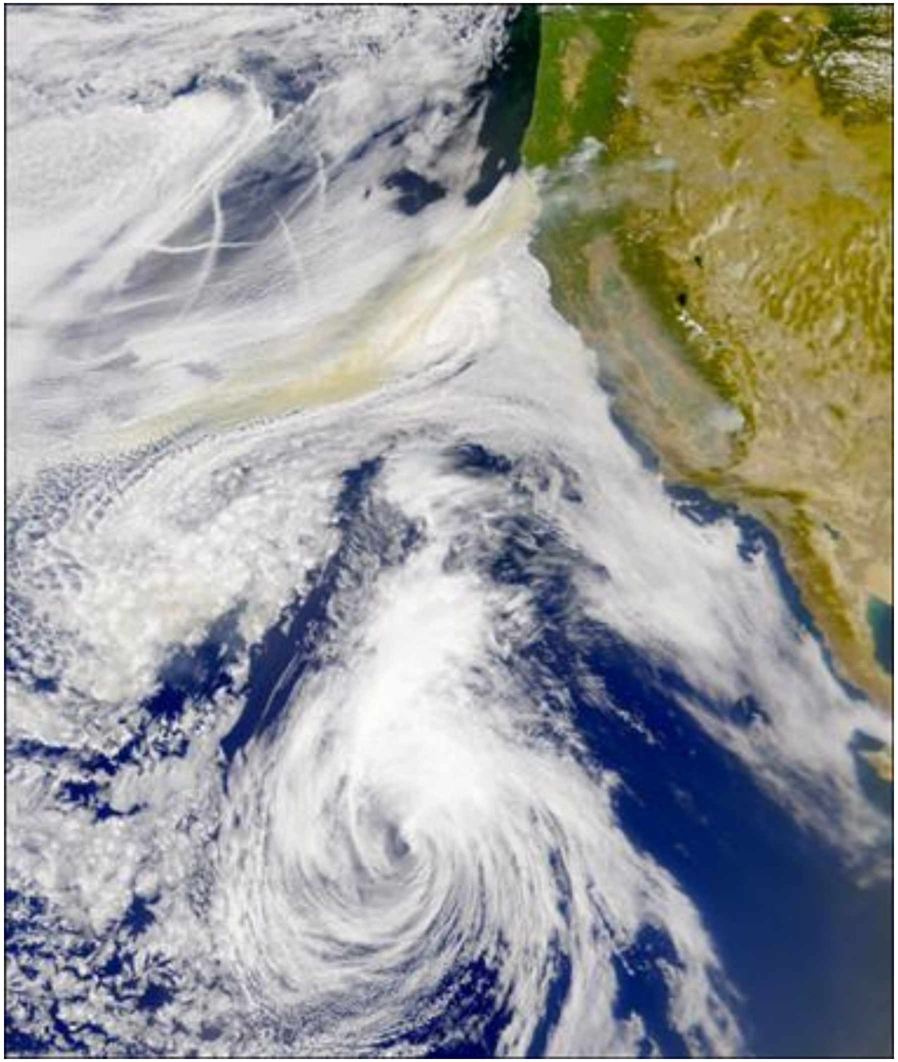


Figure from Christopher and Zhang, JAS 2002

Example: Aerosol and clouds



This photograph shows ship tracks (upper left) produced by emission of soot and sulfur from diesel engines which act as cloud condensation nuclei. It also shows smoke from biomass burning (upper central, brownish) which is mixing with clouds.

From: http://www.geog.cam.ac.uk/research/projects/aerosolsclimate/

Example: Aerosol effects on cloud

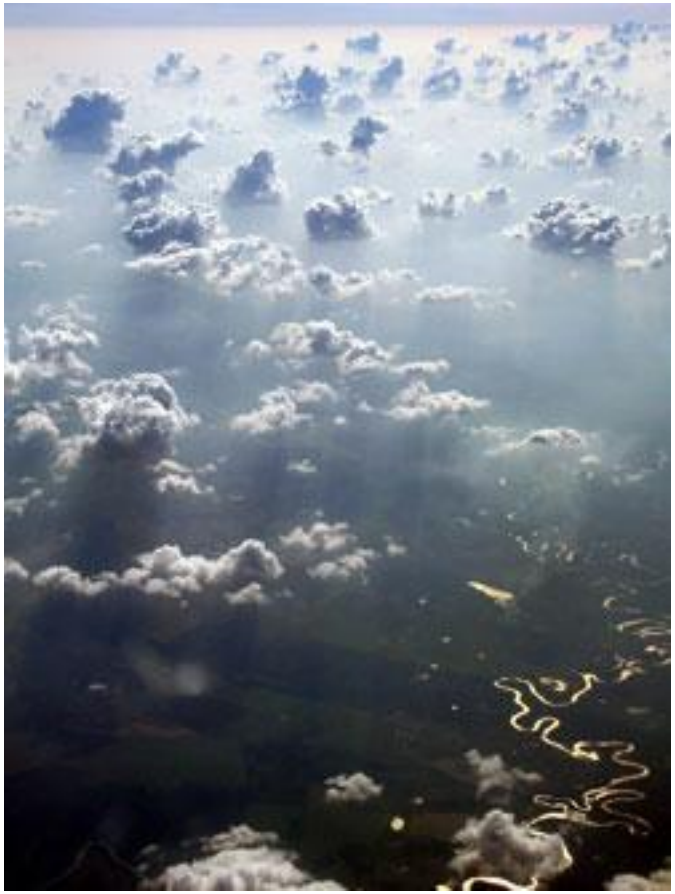
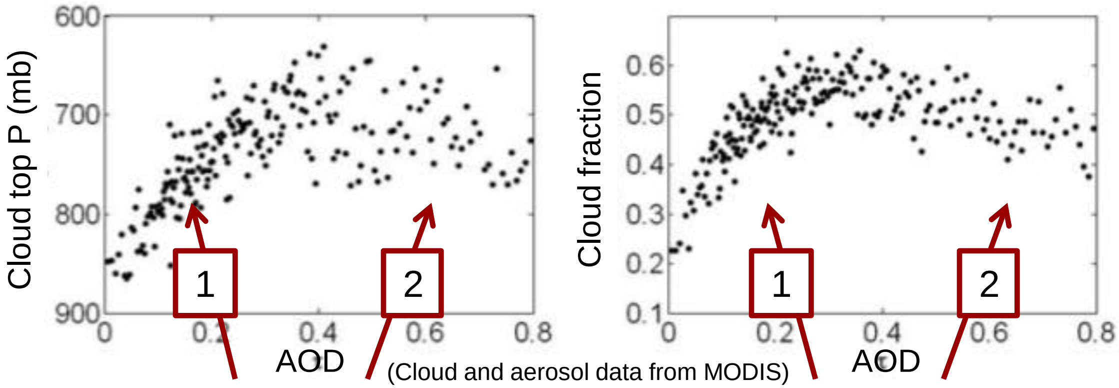


Photo by Ilan Koren, Weizmann Inst., Isaeral



(Cloud and aerosol data from MODIS)

(1) Aerosol can invigorate clouds, increasing cloud heights and fraction (microphysical effects)
(2) Aerosol can also inhibit clouds, decreasing cloud heights and fraction (result of aerosol absorption)

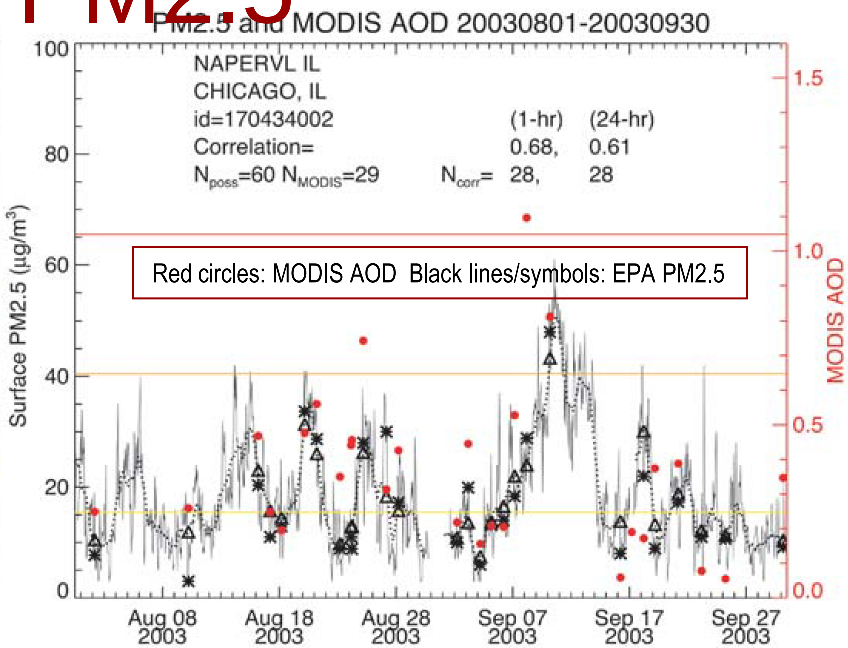
From Koren et al., Science 2008

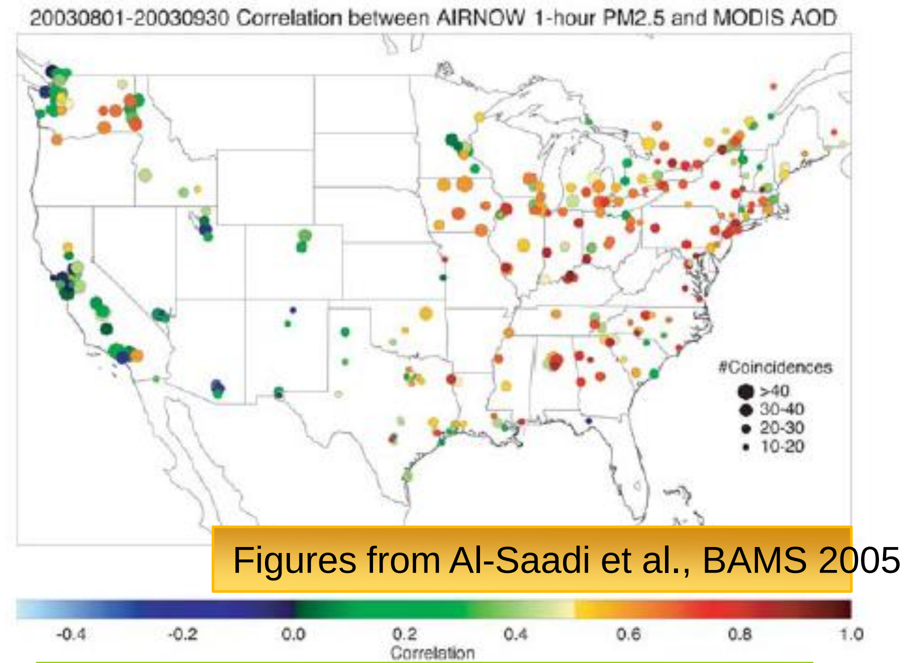
High temporal frequency measurements of cloud and aerosols from GEO should help provide a better understanding of aerosol-cloud interaction (also required: sufficient spatial resolution)

Objective 4: Environmental impacts

- Q1: How can the high temporal frequency aerosol measurements be used to monitor and forecast air quality/visibility in the viewing area?
- Q2: Can assimilation of GEO-CAPE data, together with the surface measurement data, improve the air quality forecasts?
- Q3: From the GEO-CAPE, European geostationary satellite, and ocean color measurements, can aerosol (e.g. dust, nitrate) deposition to the ocean (coastal region or away from coast) and associated effects on ocean biology be quantified?
- Q4: What is the impact of extreme events, such as wild fires, dust outbreaks, urban/industrial pollution, volcanic eruptions, on the local and regional aerosol levels?

Example: MODIS AOD and EPA PM2.5





Figures from Al-Saadi et al., BAMS 2005

PM2.5 varies significantly from hour to hour, MODIS cannot provide information on the high variability of PM2.5 during the day

Correlation coefficients of AOD and PM2.5 vary significantly (higher in E. US, lower in W. US), and slopes change too (not shown).

High temporal resolution data from geostationary satellites, ground-based measurements, and meteorological information will help better understand/quantify these relationships

Example: Dust deposition and ocean productivity

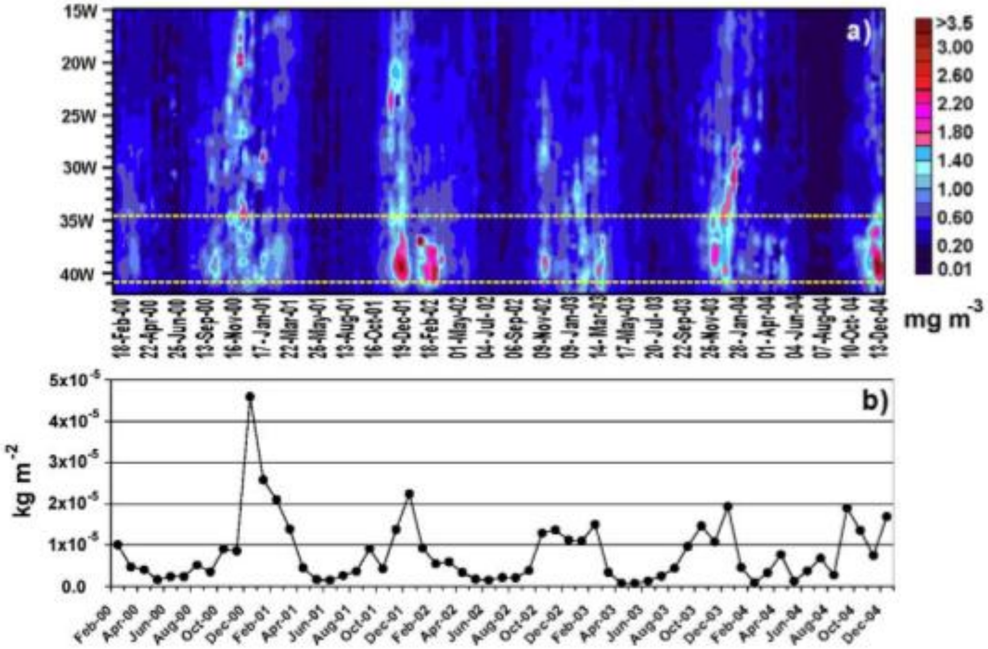
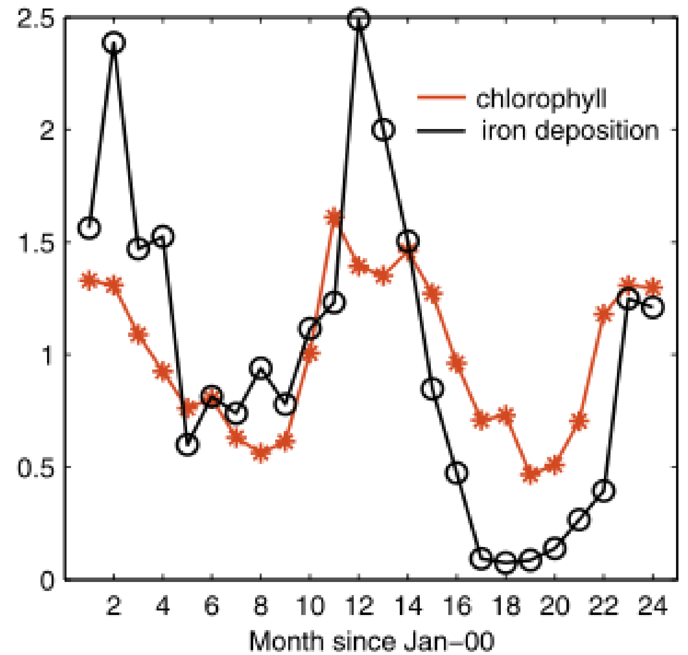


Figure 6. (a) Latitudinally averaged (49°S to 54°S) MODIS-observed [Chl *a*] and (b) model-predicted monthly averaged fluxes of mineral dust near South Georgia Island (49°S–54°S, 35°W–41°W). Horizontal dashed lines indicate the approximate area near the Island where the dust fluxes are averaged.



Using 5 years of MODIS ocean Chl *a* data and the MATCH model dust deposition calculation, Meskhidze et al. (2007) suggested that dust deposition to the ocean contributed to promote ocean productivity (although the upwelling of nutrient-rich waters appeared to be the major source of bioavailable Fe).

Using 2 years of SeaWiFS ocean Chl *a* data and the GOCART model dust deposition calculation in the southern ocean, Erickson et al. (2003) suggested that the phytoplankton production was controlled mainly by the supply of Fe from dust.

Next steps:

- Refine science objectives
- Define approaches and requirements
- Enhance the aerosol part in the atmospheric STM
- Case studies to demonstrate concepts using existing data and models