The GOES-R Aerosol Optical Depth Product

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Outline

- The nature of atmospheric aerosols
- Why do we care about them?
- Aerosol retrieval from space
- The GOES-R ABI aerosol retrieval
- Examples
- Quality of ABI aerosol data

Aerosols

Atmospheric aerosols are liquid or solid particles suspended in air.

- dust, smoke, haze
- size from a few nanometers to a few tens of micrometers

Stay aloft for about a week.

Heterogeneous distribution in space and time.

Natural and anthropogenic sources.

Sources


sea spray


volcanic eruptions


emission from vegetation

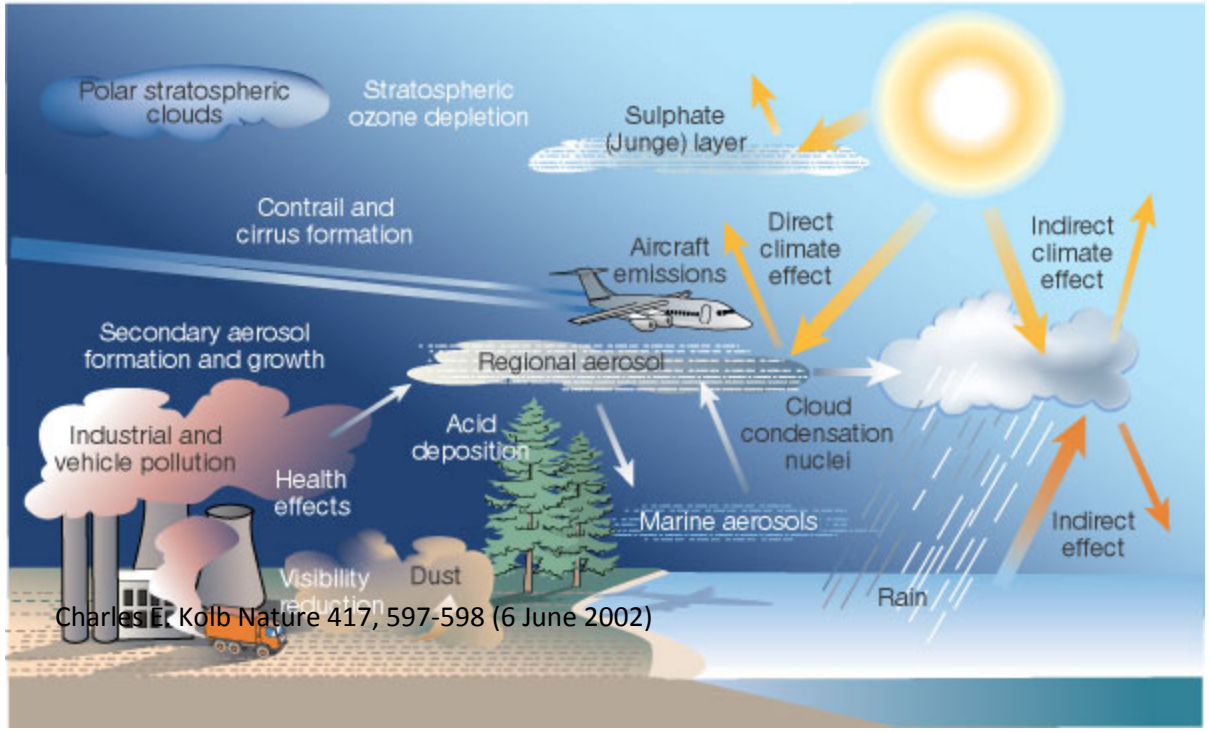

windblown dust


vehicle exhaust


wildfires


industrial emission

Aerosol effects

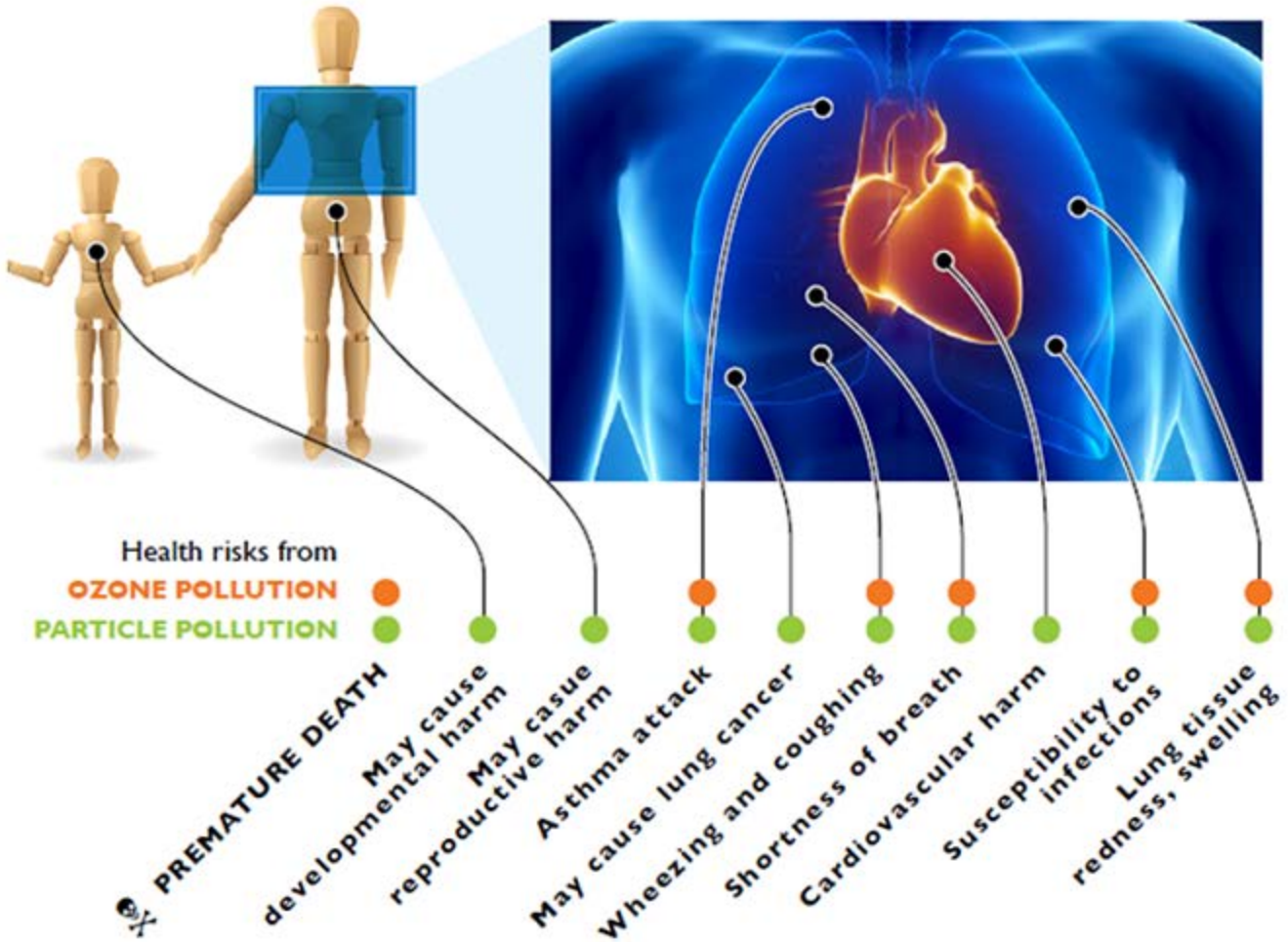


Charlas E. Kolb Nature 417, 597-598 (6 June 2002)

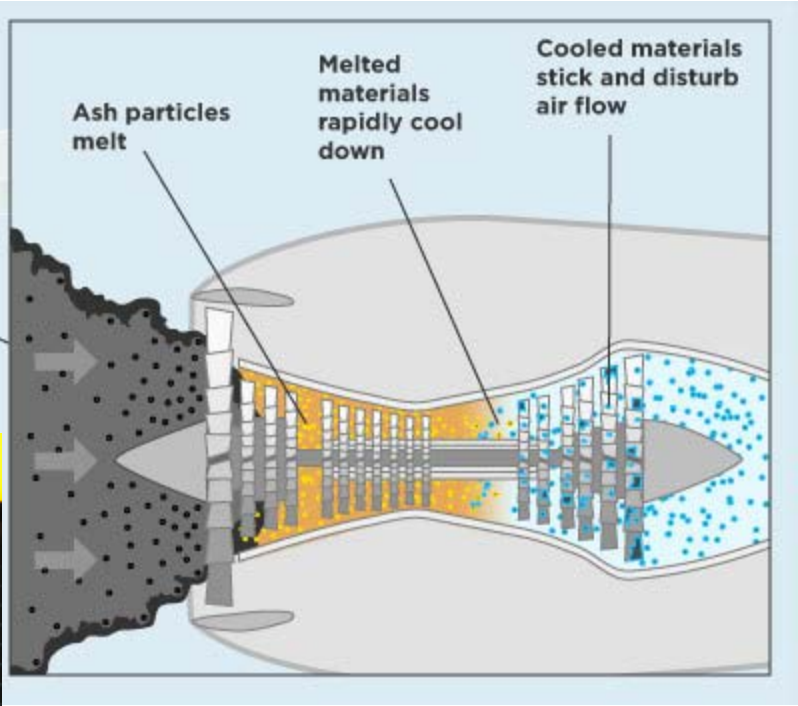
- radiation budget
- hydrologic cycle
- chemistry of atmosphere
- climate
- health
- aviation

Aerosol effects - Health

- PM10: diameter > 10 µm; eliminated through coughing.
- PM2.5: diameter < 2.5 µm; penetrates deep into the lungs.



Aerosol effects - Aviation

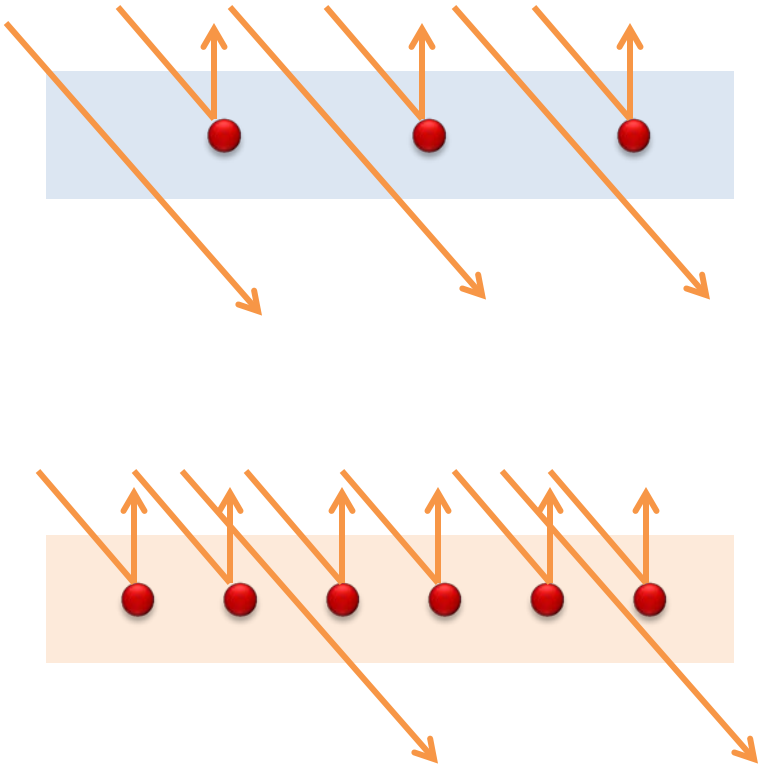


- reduces visibility
- volcanic ash can damage components (engine)

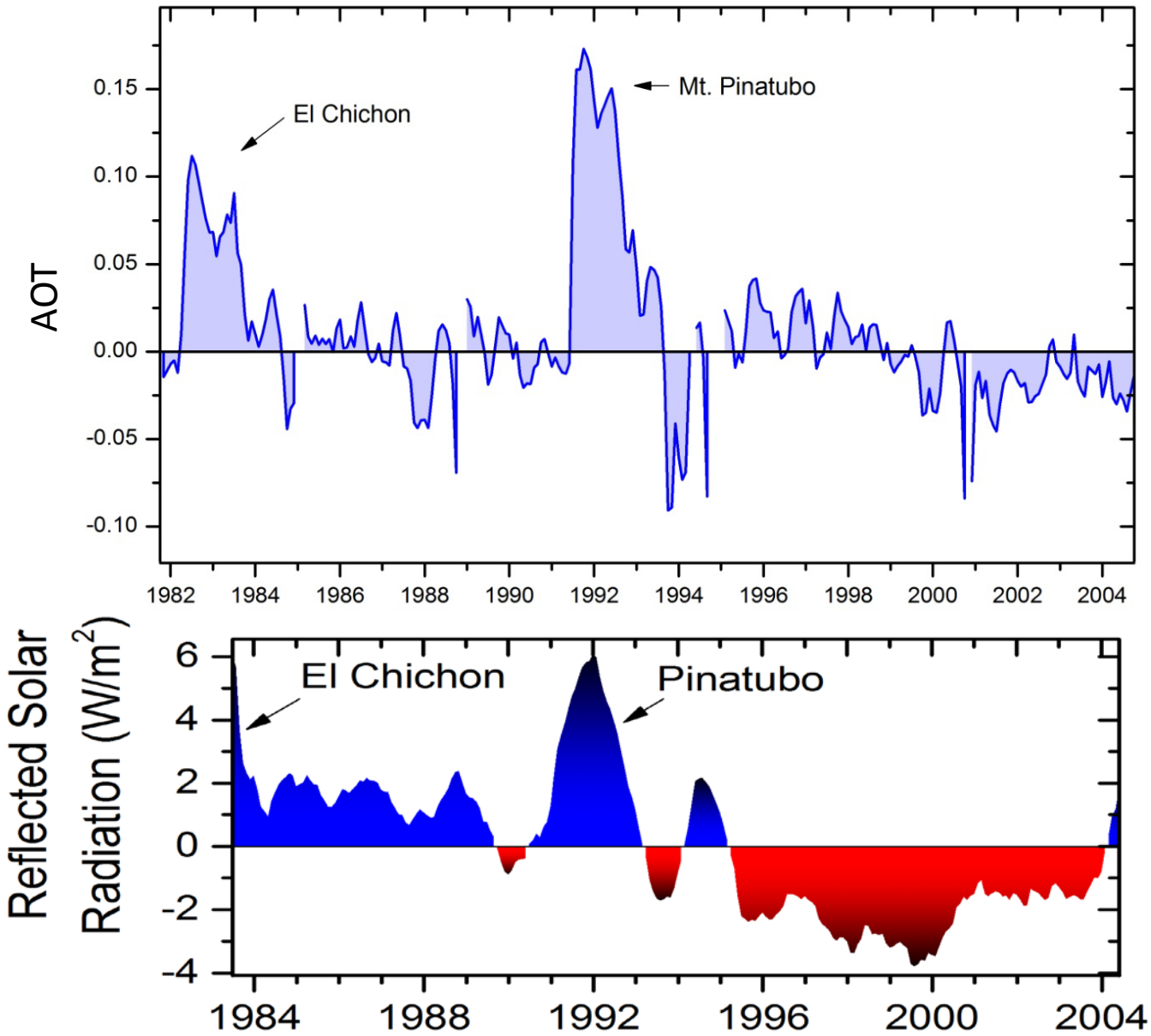
Aerosol effects – Radiation Budget

Direct effects:

- Aerosols mainly reflect solar radiation back to space → *increase the planetary albedo* → ***net cooling at the surface***
- Some aerosols also absorb solar radiation → *warming of the atmosphere* → ***net cooling at the surface***

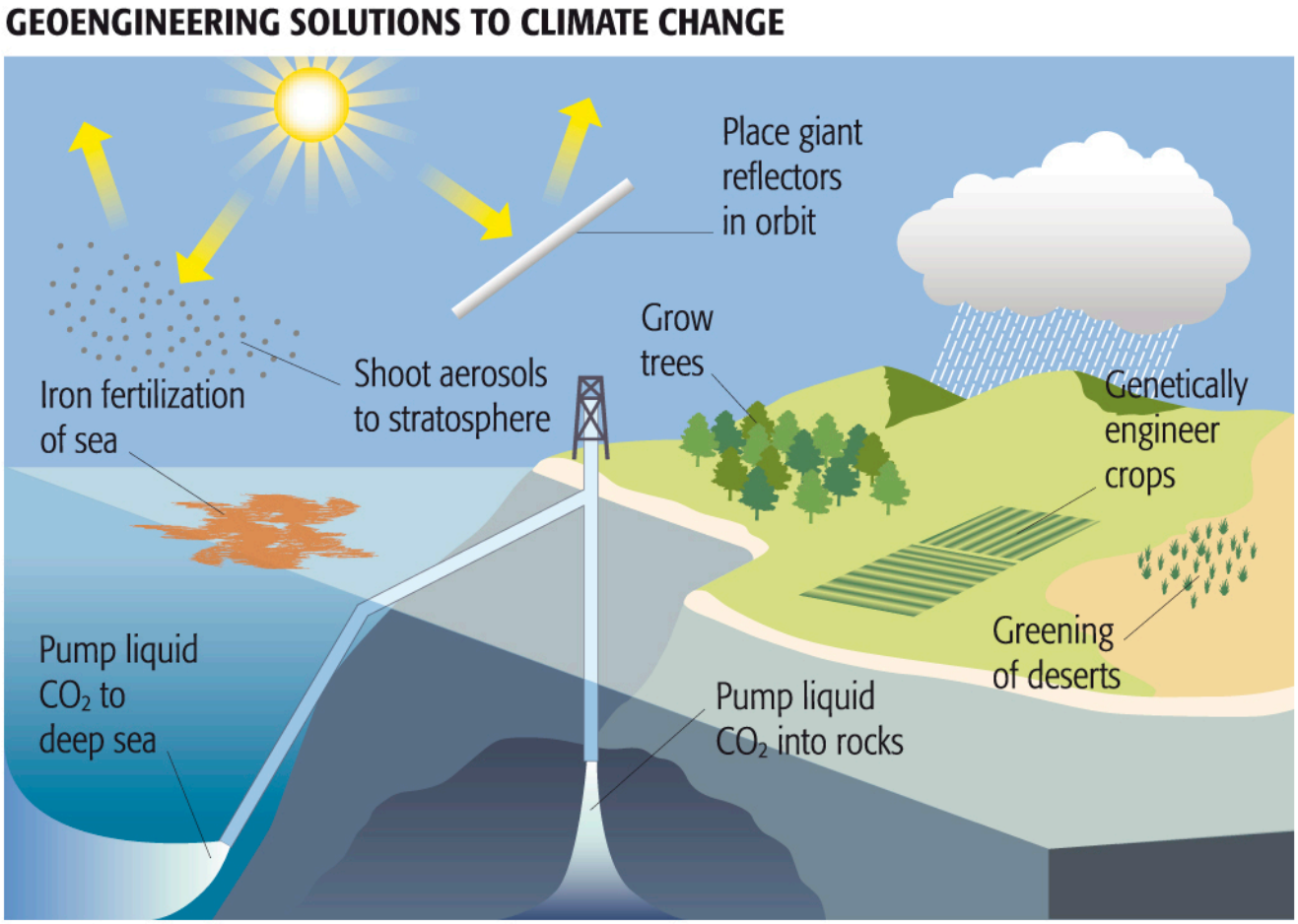


Solar radiation budget



Solar Radiation Management

Aerosol pumped high into the atmosphere reflects solar radiation back to space, thus reducing warming of lower atmosphere and surface.



Aerosol effects - Cloud

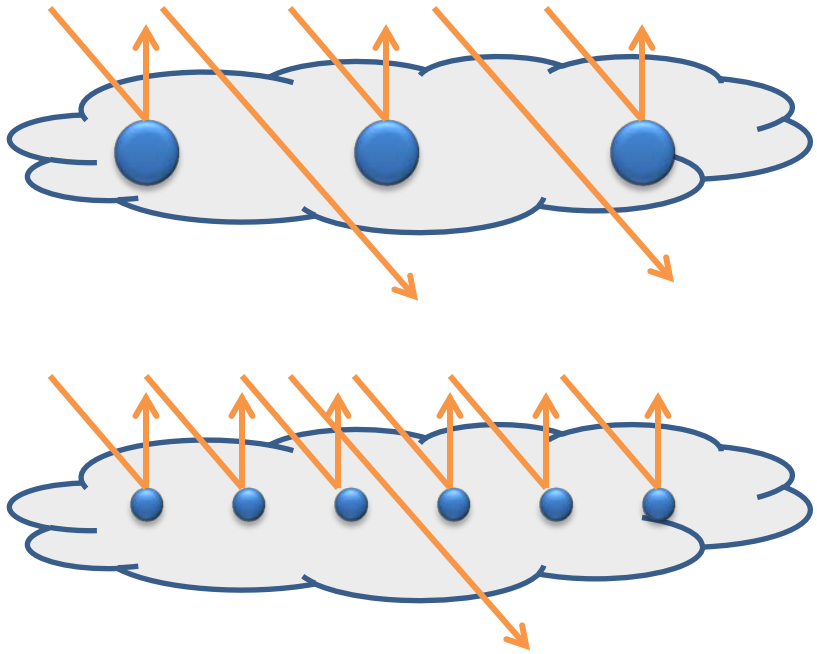
Indirect effects:

More aerosol provides an increase in the number of cloud condensation nuclei

→ *reduces cloud droplet size*

→ *increases cloud albedo*

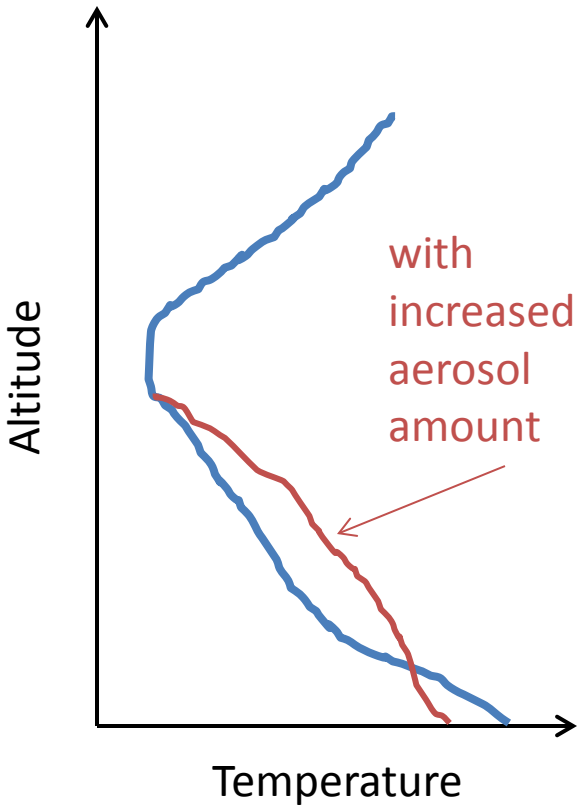
→ *cools surface*



Aerosol effects - Hydrology

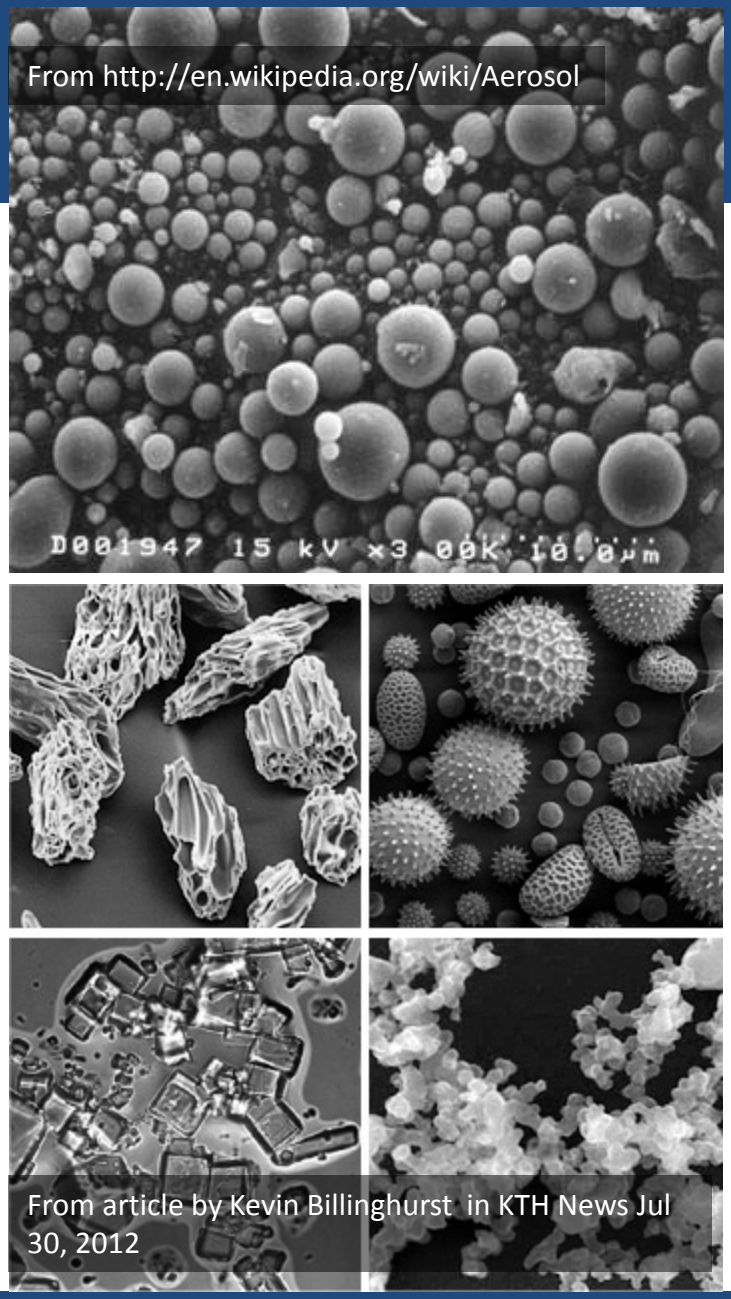
Indirect effects:

- Aerosol induced reduction in cloud droplet size may lead to *less precipitation*
- Increased solar absorption in "dirty" cloud droplets "dries" the cloud → *less precipitation*
- Heating the atmosphere and cooling the surface reduces the temperature gradient → *decline in evaporation and cloud formation*



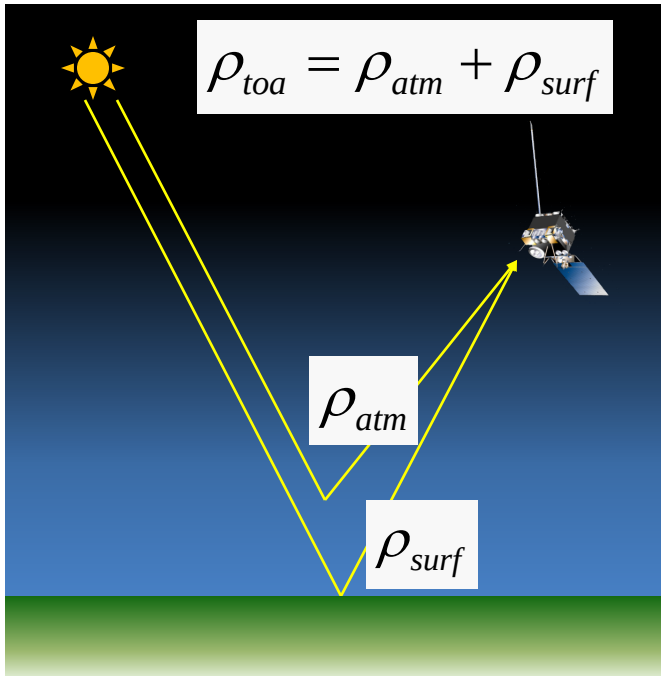
Aerosols

- Size, shape and chemical composition of aerosols vary significantly both in time and space (horizontal and vertical).
- In remote sensing, aerosol amount is expressed in **aerosol optical depth (AOD)** or **aerosol optical thickness (AOT)**.



AOD Retrieval - Physical Basis (1)

- The satellite-observed reflectance (ρ_{toa}) is the sum of atmospheric (ρ_{atm}) and surface components (ρ_{surf}).
- These components are the result of reflection, scattering by molecules and aerosols and absorption by aerosols and gases.
- The atmospheric component carries information about aerosol.
- The aerosol portion of the atmospheric component (*aerosol reflectance*) is determined by the amount and type (size, shape and chemical composition) of aerosol.



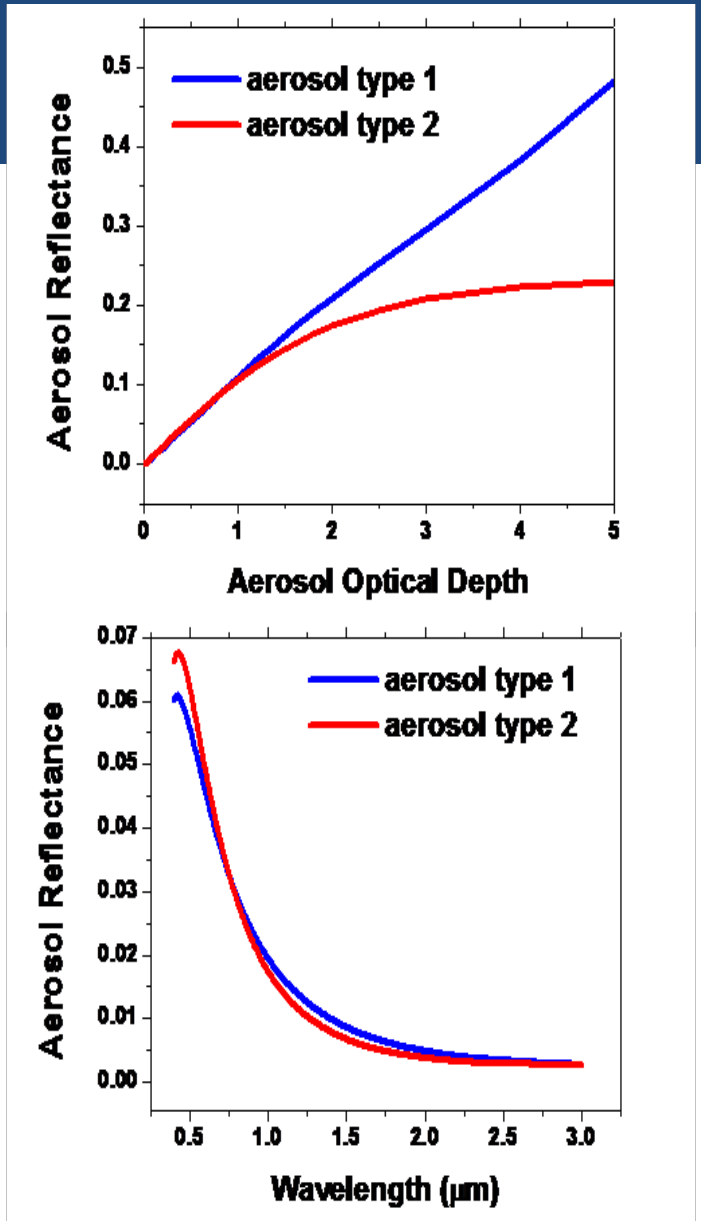
AOD Retrieval Physical Basis (2)

- Aerosol reflectance (ρ_A) increases with increasing amount of aerosol (as measured by AOD)

  → **for estimating AOD**

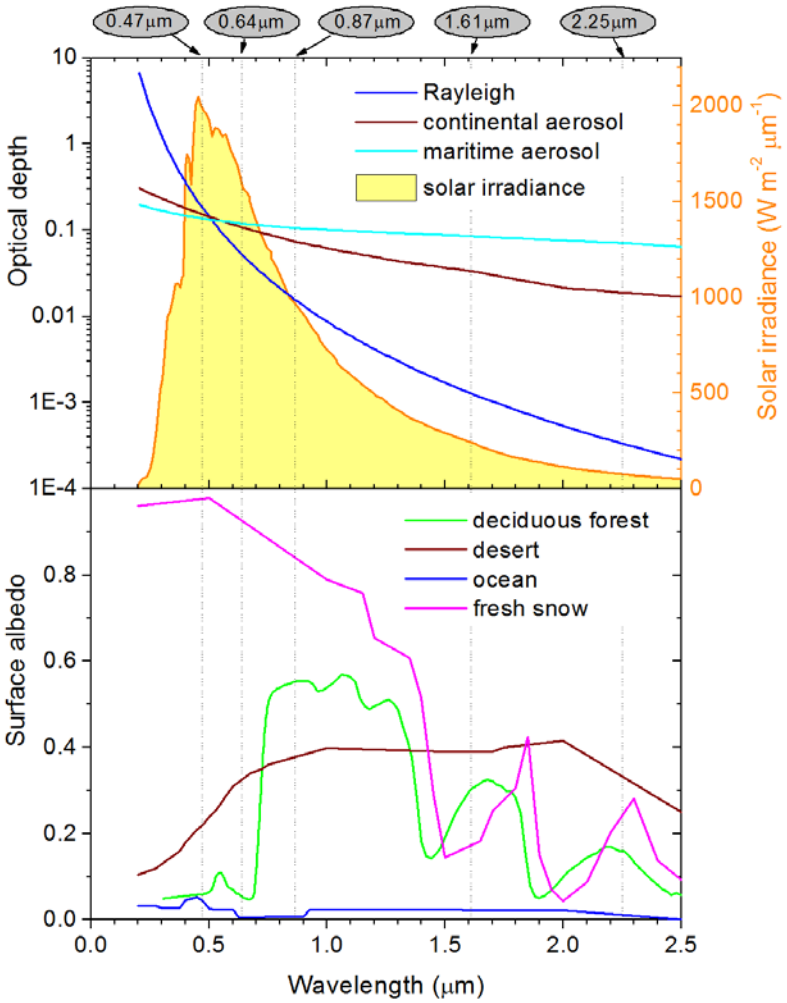
- The spectral dependence of aerosol reflectance is a function of aerosol type.

  → **for estimating aerosol type**

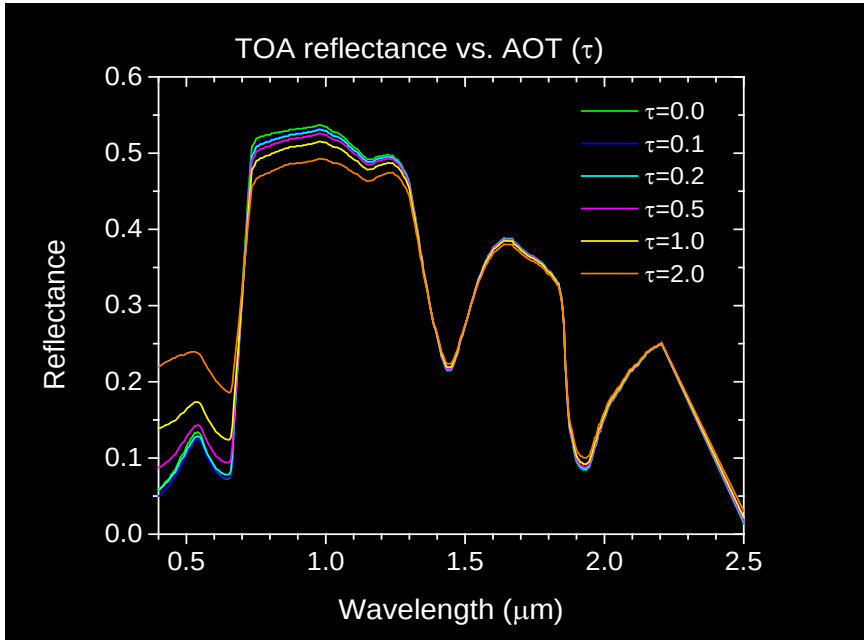


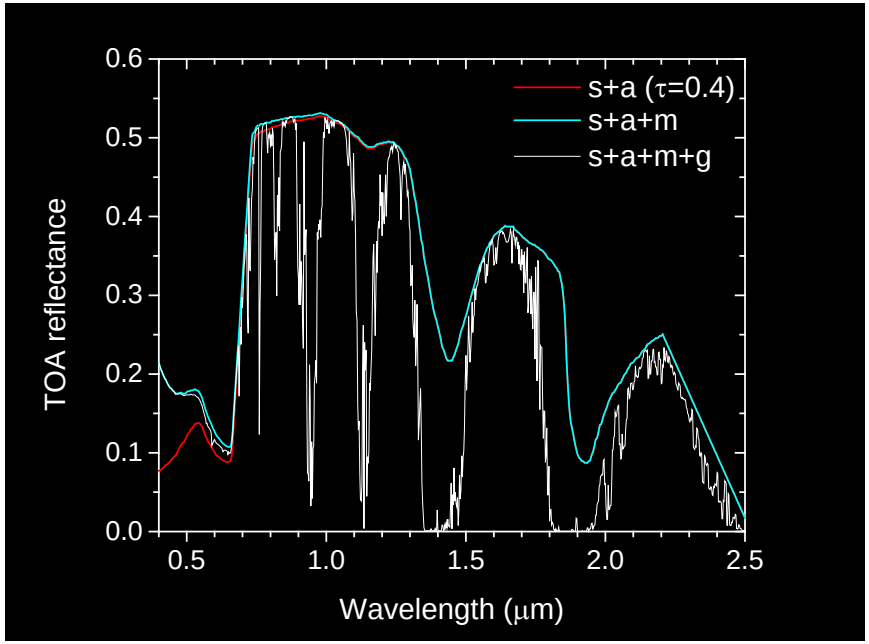
Aerosol Remote Sensing

- Done from clear radiances → *need good cloud screening*
- Aerosol signal is relatively low → *need good calibration*
- Surface contribution can be overwhelming → *need good description of surface*
- Aerosols have complex, spatially and temporally varying structure/composition
- Five unknowns (amount, real and imaginary refractive index, mean radius, and effective variance) even in the simplest case.



The Aerosol Signal

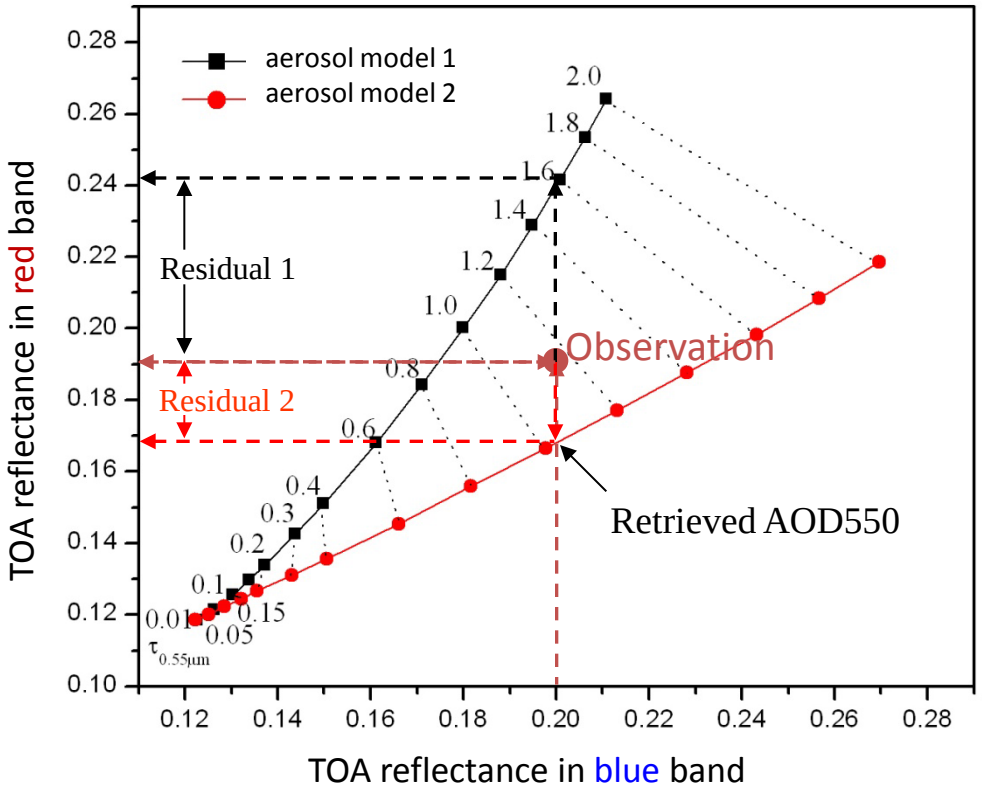




ABI Aerosol Algorithm

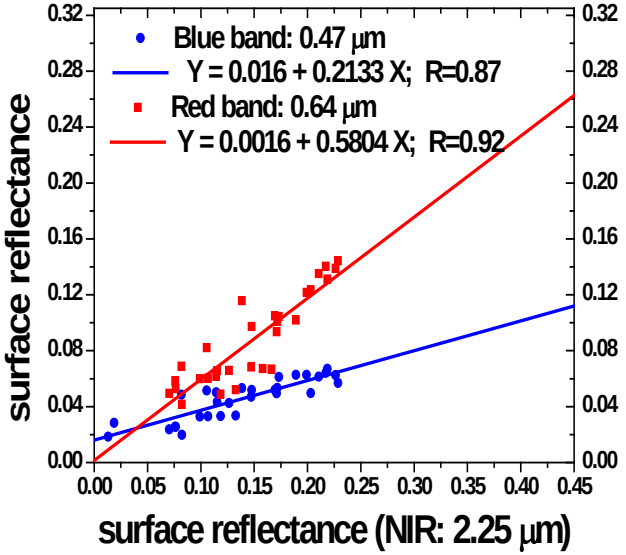
General features:

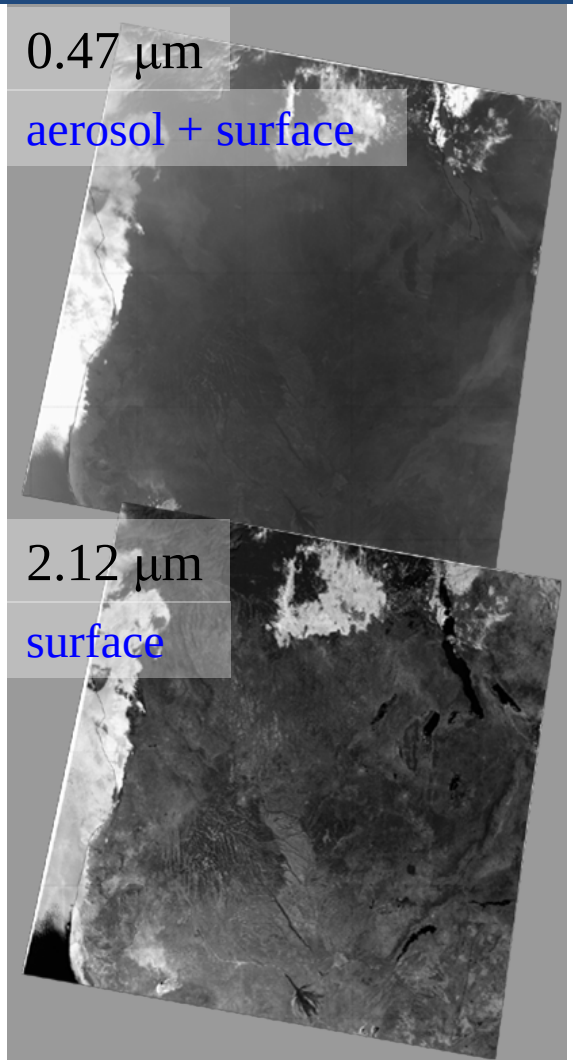
- Separates aerosol and surface signals by estimating surface reflectance in “blue” and “red” channels from that in SWIR for land.
- Models surface contribution for water.
- Uses multi-channel information.



Land Surface Reflectance

- AOD at 2.2 μm is generally small; allows seeing the surface.
- Over dark targets and dense dark vegetation surface reflectance across the solar spectrum is well correlated.
  - Vegetation has low reflectivity in the visible (0.47 and 0.64 μm) region due to chlorophyll absorption and in the 2.2 μm region due to absorption by liquid water.

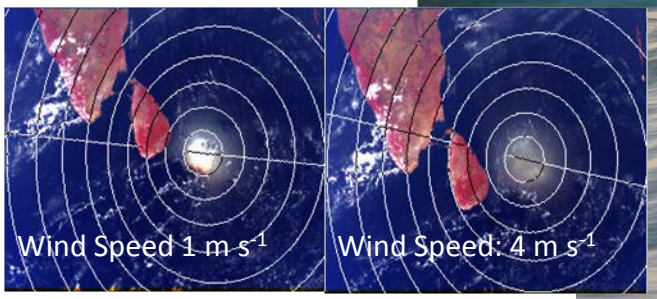


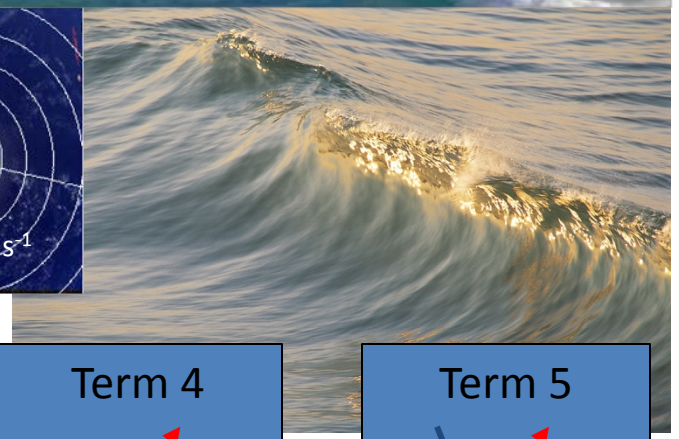


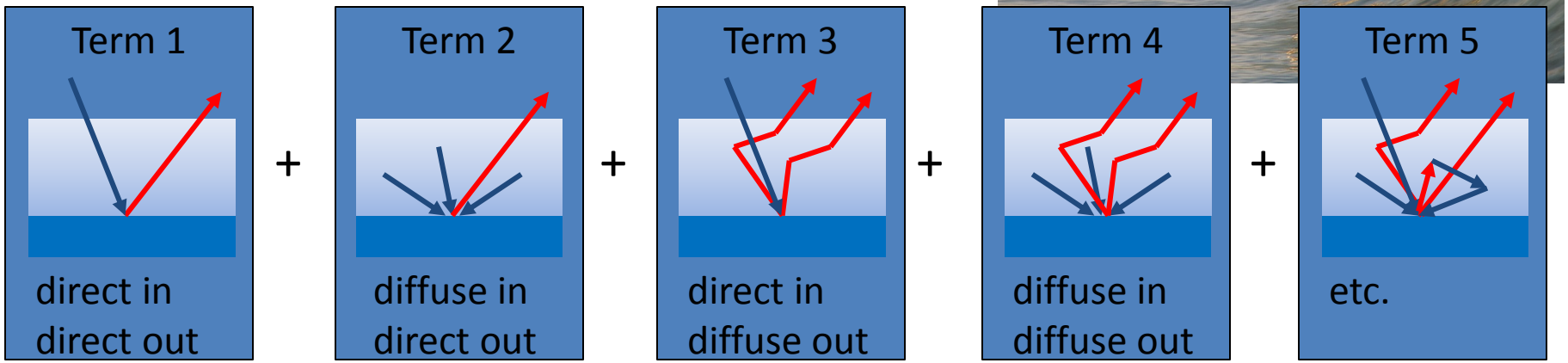
Ocean Surface Reflectance

Modeled as sum of three components:

- Whitecap
- Sunglint
- Radiation coming from under water



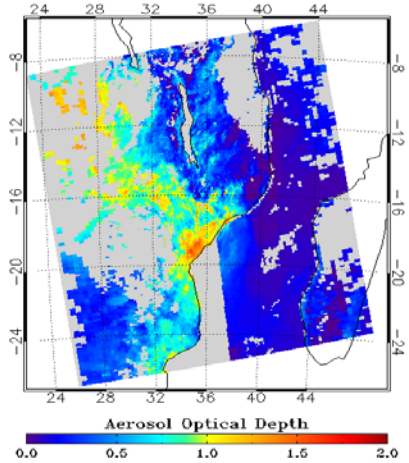




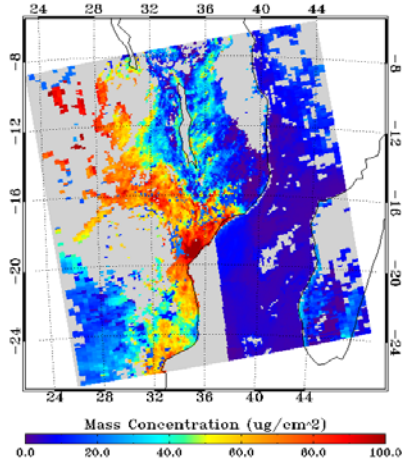
Example Output

MODIS Granule: Aqua, Sep 23, 2007, 11:20 UTC

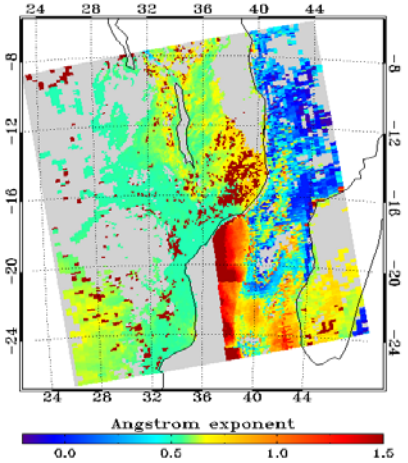
Aerosol Optical Depth (550nm)



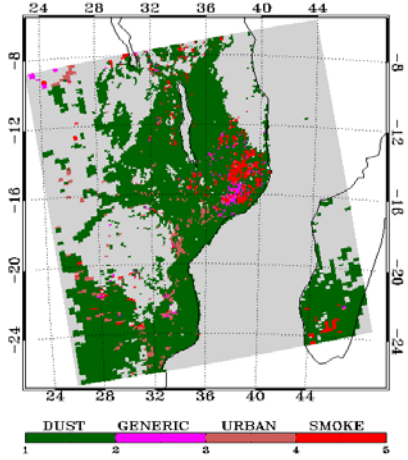
Suspended Matter



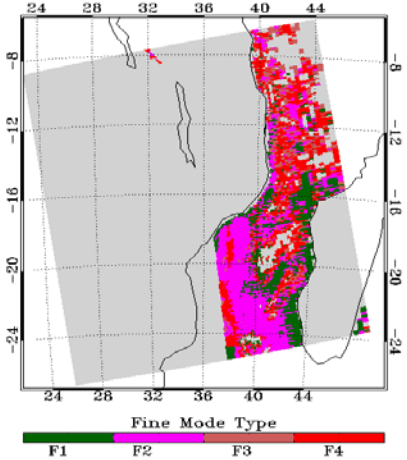
Ångström Exponent (470/860)

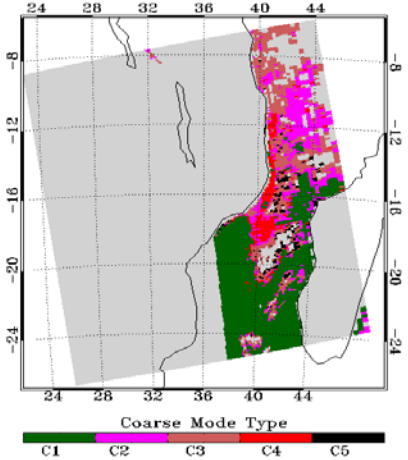


Land Aerosol Model

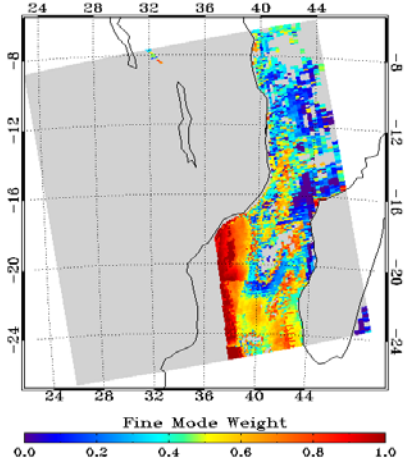


Ocean Aerosol Model (fine/coarse)

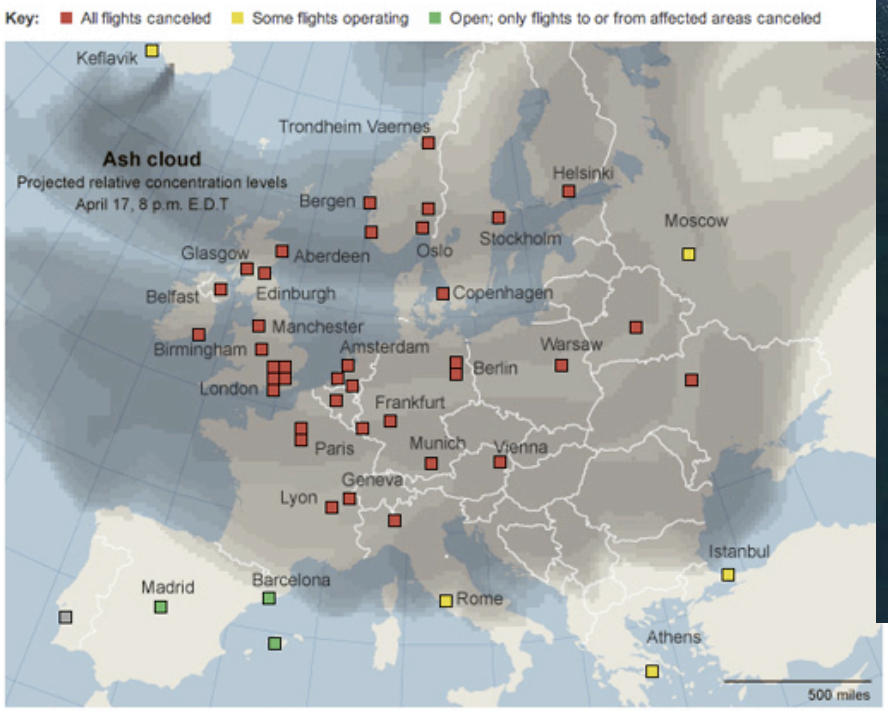


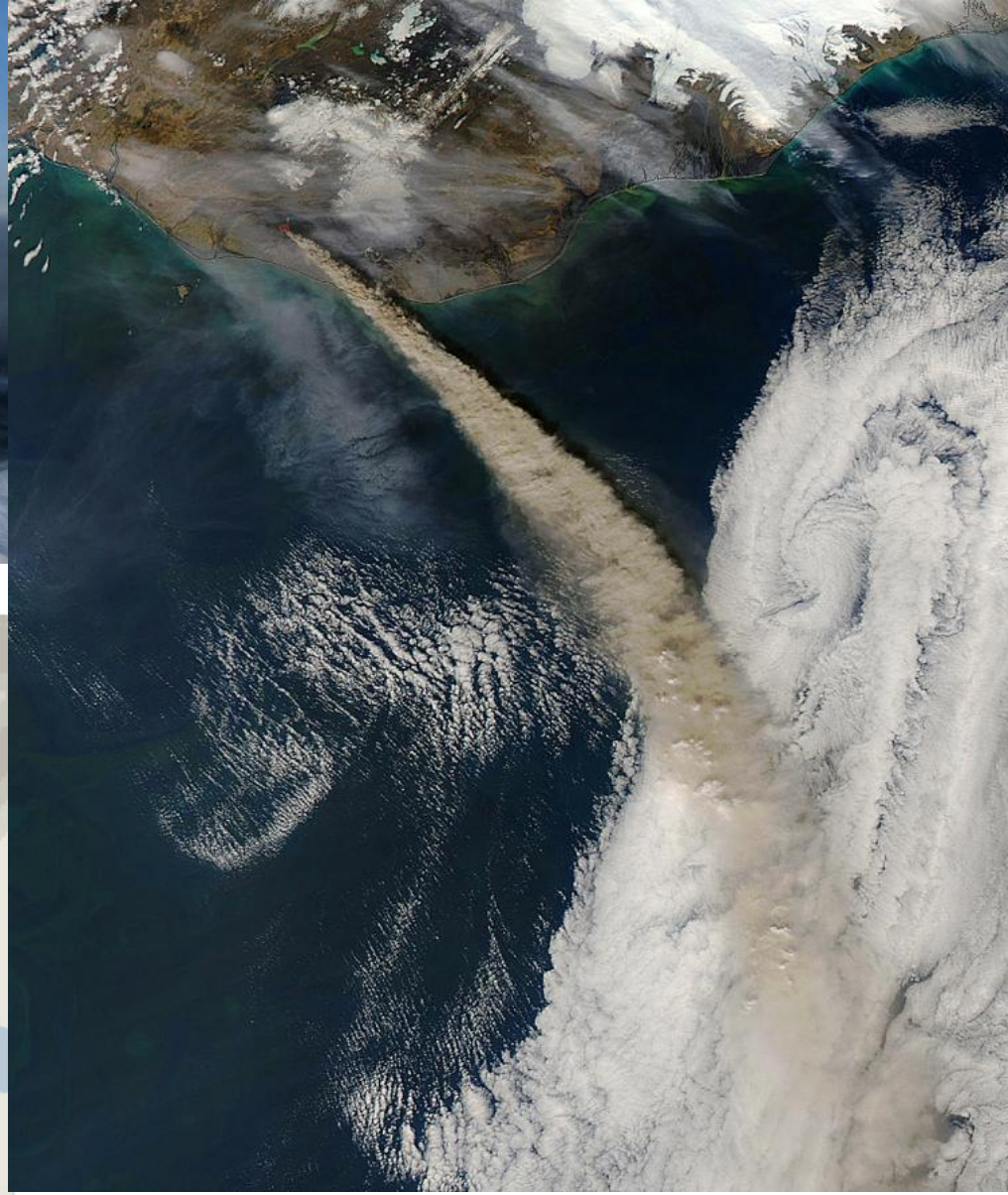


Ocean Fine-mode Weight



Eyjafjallajökull volcano April 17, 2010

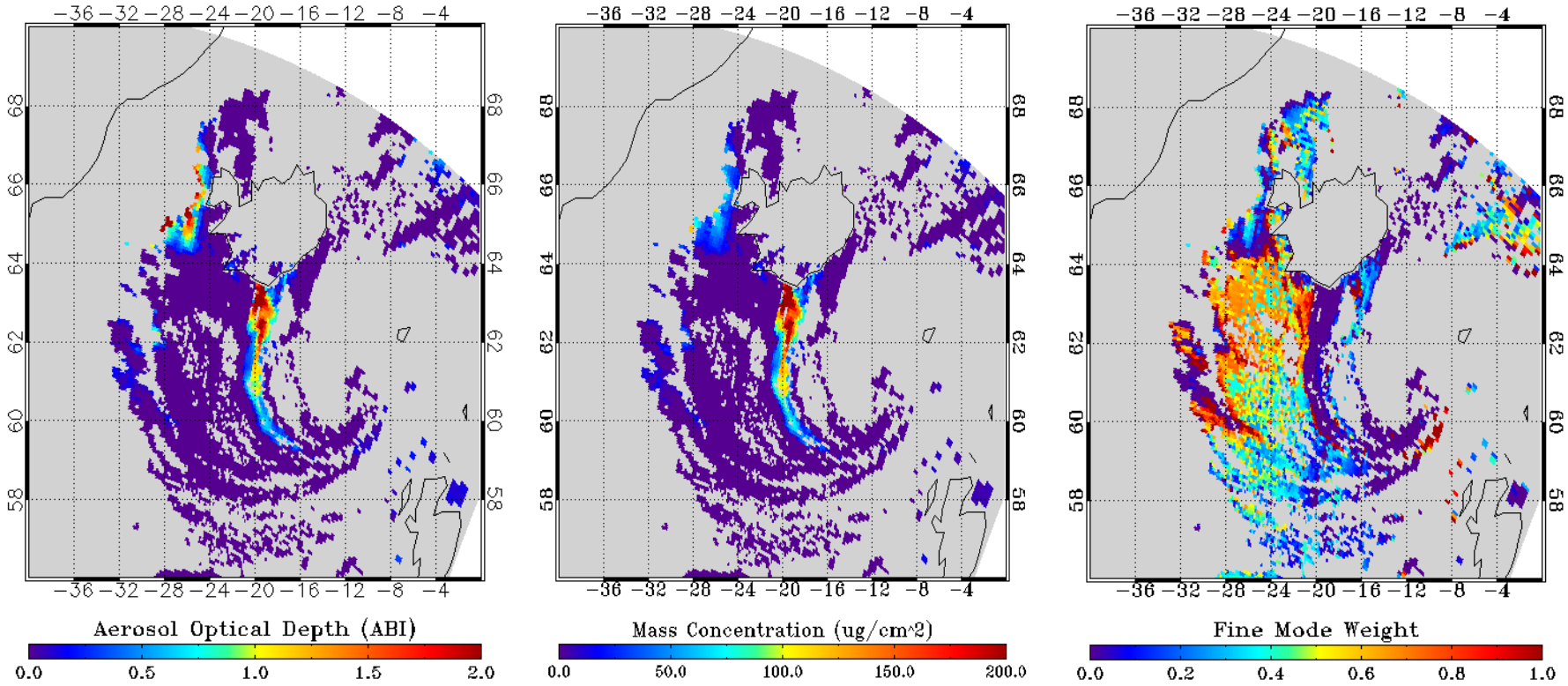




AQUA/MODIS image on May 8, 2010

Eyjafjallajökull Volcano
ABI Aerosol Retrieval Results

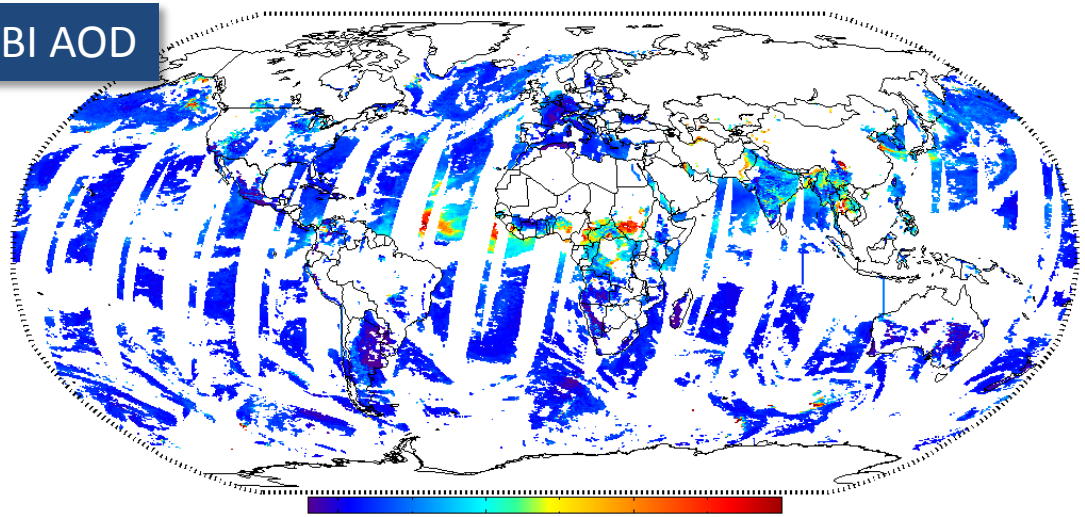
Terra/MODIS, 12:50 UTC

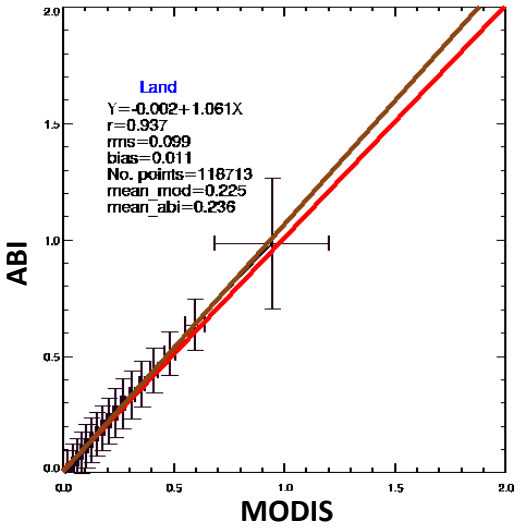


Comparison with MODIS

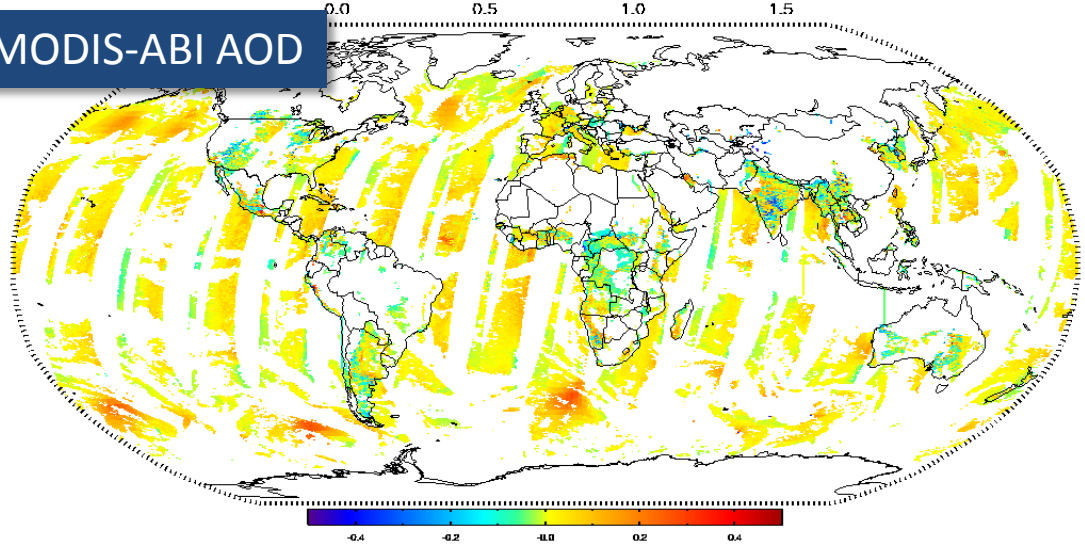
MODIS/Terra aerosol reflectances are used; 03/15/2012

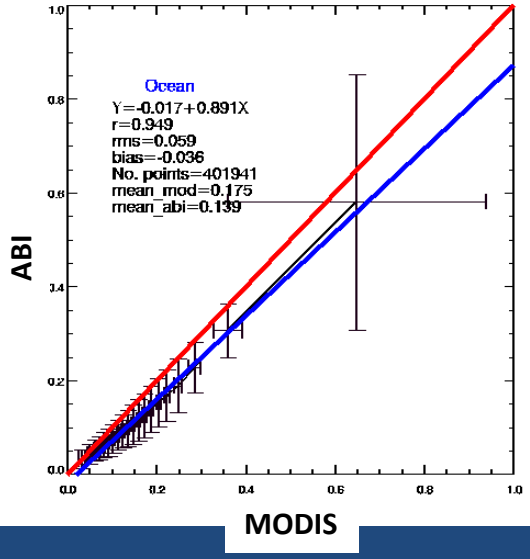
ABI AOD





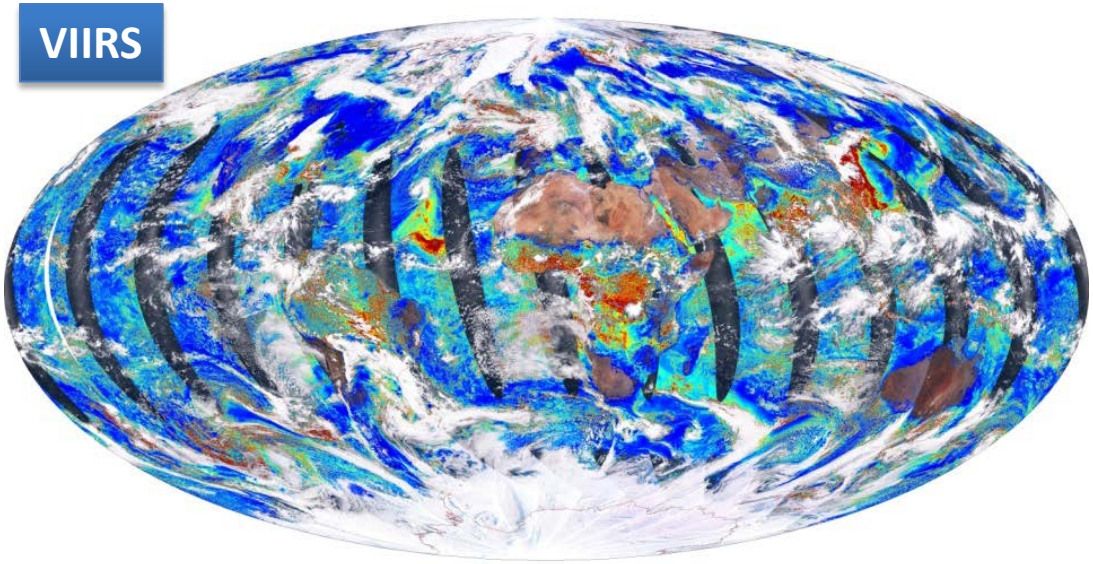
MODIS-ABI AOD





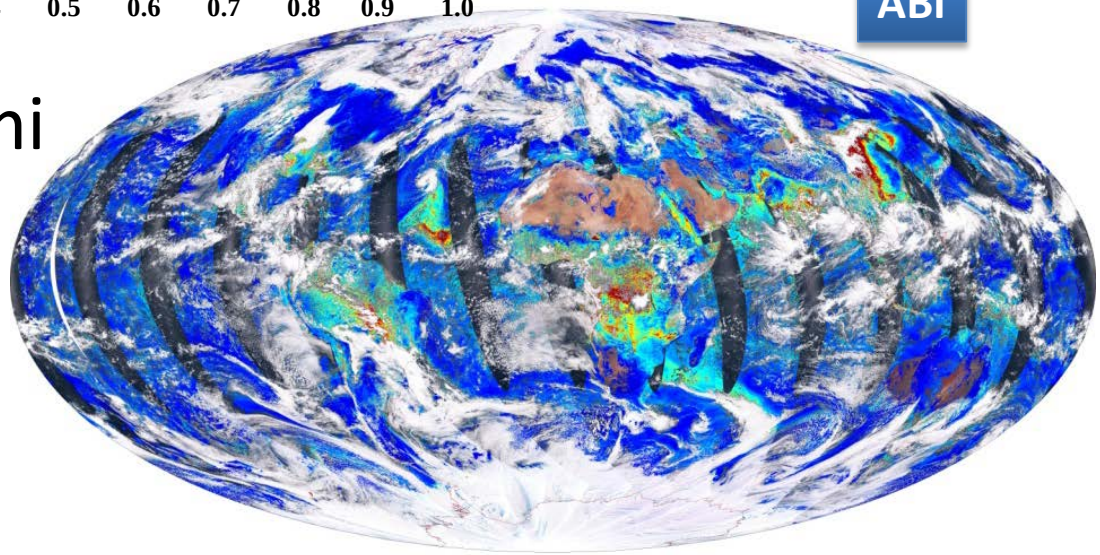
Comparison with AOD from S-NPP/VIIRS

VIIRS



-0.1 0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

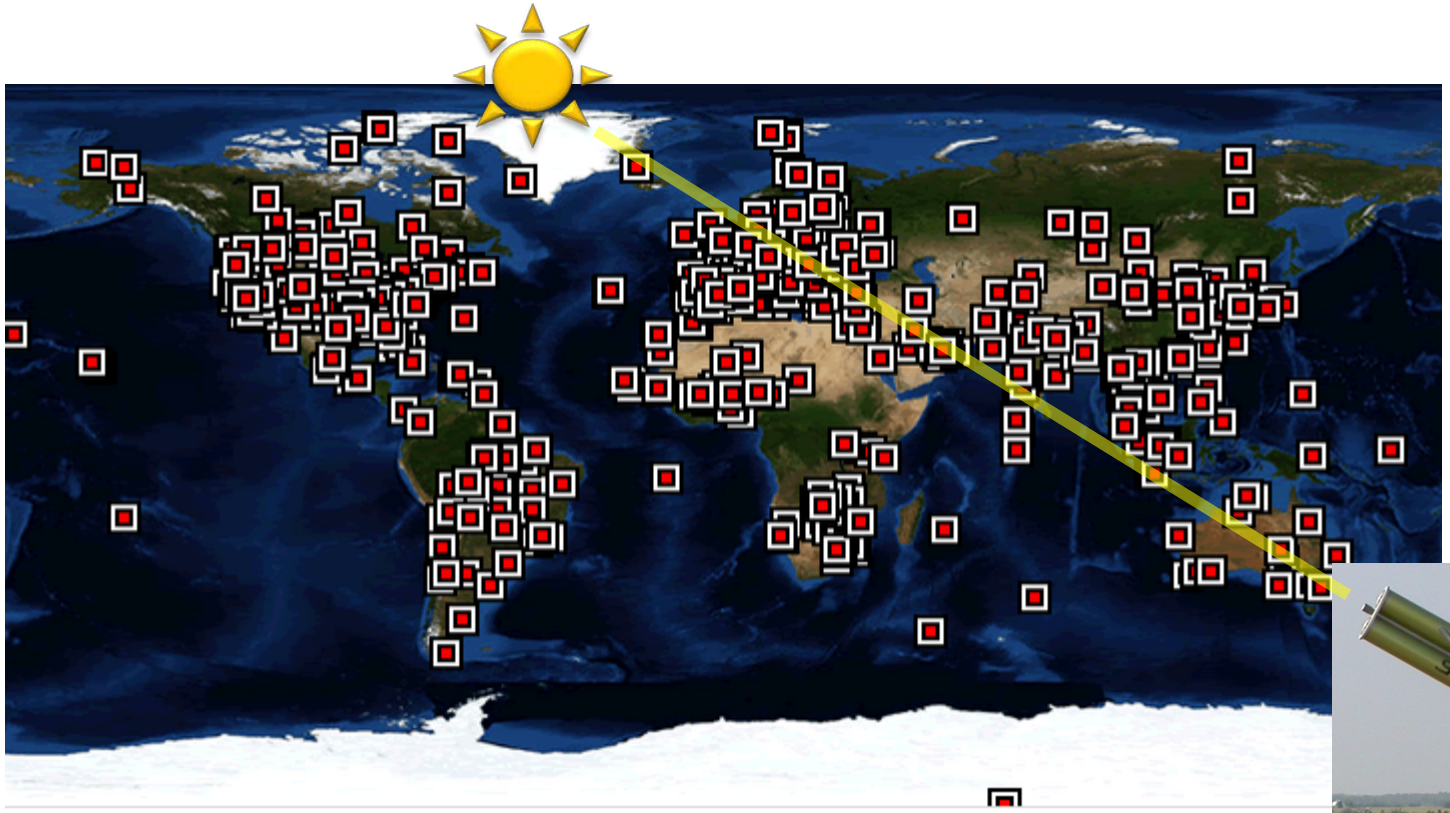
ABI



-0.1 0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

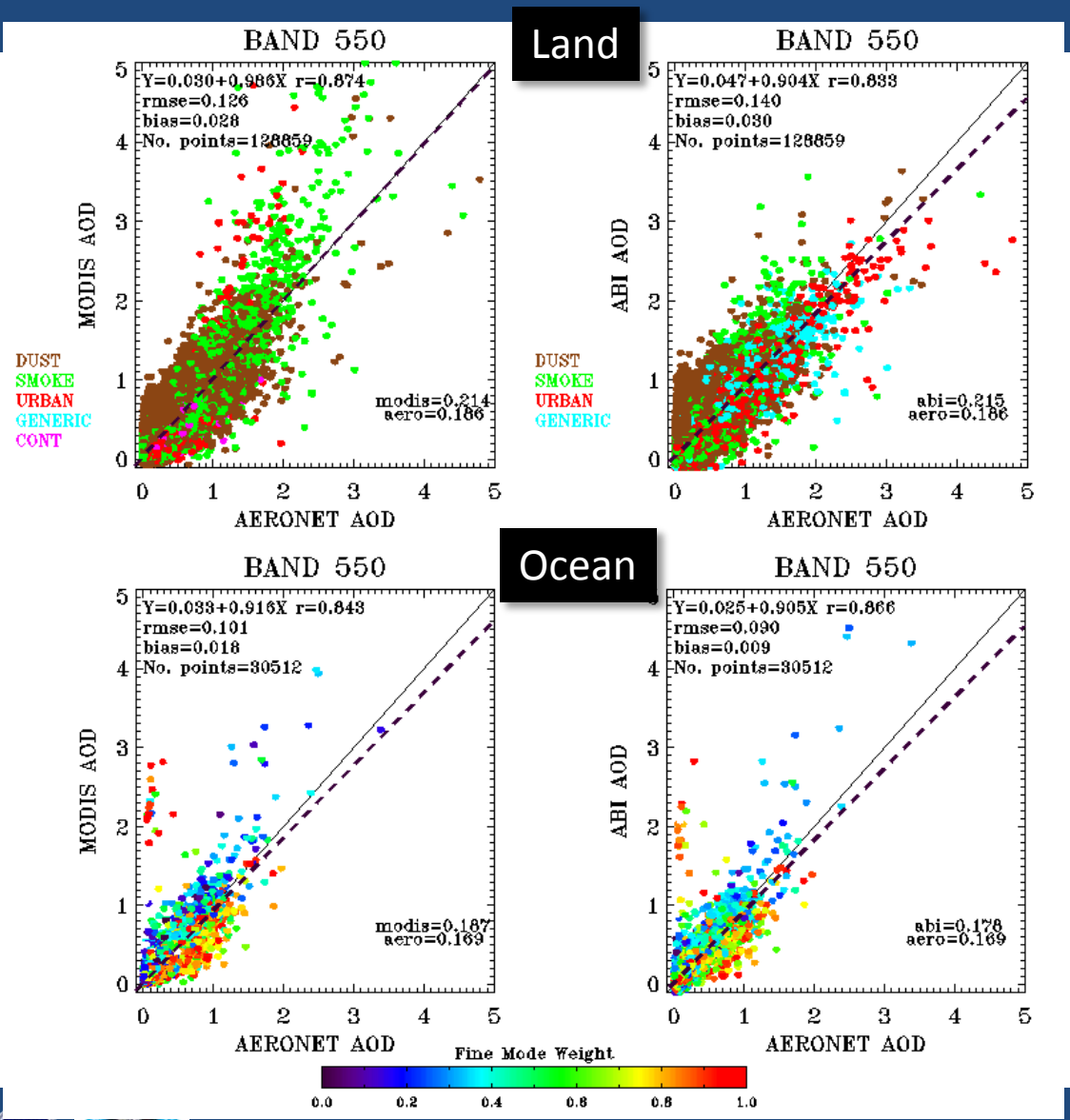
AOD from Suomi NPP/VIIRS input for 09/17/2013

AERONET



- AERONET: Aerosol Robotic Network (Holben et al., 1998)
- Error in AOD ~0.02 → “ground truth” for aerosol

Comparison with AERONET



- Retrievals are from MODIS Terra and Aqua from 2000-2009
- AOD at 550 nm
- Same overall performance of MODIS and ABI over land
- Slightly smaller overall ABI bias over water

Summary

- Aerosols, although tiny particles, can have a big effect on radiation, clouds, and precipitation.
- The GOES-R/ABI aerosol algorithm retrieves aerosol optical depth (a measure of the amount of aerosol in a vertical column).
- The GOES-R/ABI aerosol products are expected to have a performance comparable to those of products derived globally from polar orbiters (MODIS and VIIRS).

References

- GOES- R Advanced Baseline Imager (ABI) Algorithm Theoretical Basis Document for Suspended Matter/ Aerosol Optical and Aerosol Size Parameter NOAA/NESDIS/STAR, Version 2.0, September 25, 2010.
- **Holben** et al., 1998: AERONET - A federated instrument network and data archive for aerosol characterization, *Rem. Sens. Environ.,* **66**, 1-16.
- **Kahn**, R. A., H. Yu, S. E. Schwartz, M. Chin, G. Feingold, L. A. Remer, D. Rind, R. Halthore, and P. DeCola, 2009: Introduction, in *Atmospheric Aerosol Properties and Climate Impacts, A Report by the U.S. Climate Change Science* Program and the Subcommittee on Global Change Research. [Mian Chin, Ralph A. Kahn, and Stephen E. Schwartz (eds.)]. National Aeronautics and Space Administration, Washington, D.C., USA.
- **King**, M., Y. Kaufman, D. Tanré, and T. Nakajima, 1999: Remote sensing of tropospheric aerosols: Past, present, and future. *Bulletin of the American Meteorological Society*, 80, 2229-2259.
- **Remer**, L. A., M. Chin, P. DeCola, G. Feingold, R. Halthore, R. A. Kahn, P. K. Quinn, D. Rind, S. E. Schwartz, D. Streets, and H. Yu, 2009: Executive Summary, in *Atmospheric Aerosol Properties and Climate Impacts, A Report by the* U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [Mian Chin, Ralph A. Kahn, and Stephen E. Schwartz (eds.)]. National Aeronautics and Space Administration, Washington, D.C., USA.

Image Credits

- Atmospheric chemistry: Iodine's air of importance Charles E. Kolb Nature 417, 597-598(6 June 2002) doi:10.1038/417597a http://www.nature.com/nature/journal/v417/n6889/fig_tab/417597a_F1.html
- Scanning electron microscope images of atmospheric aerosol particles. http://en.wikipedia.org/wiki/Aerosol and http://www.redorbit.com/news/science/1579581/sahara_aerosol_discovery_useful_to_climate_change_studies/#y7duzOdQi1bwCgZZ.99
- Biomass burning aerosols over the Amazon during the 2005 dry season with embedded cumulus clouds. (From NASA Goddard)
- Bright yellow streamers of dust sweep off North Africa's Moroccan coast toward the Canary Islands; Terra MODIS image from February 17, 2004. Credit: Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC
- Smoke covers wide swaths of the Amazon. Photograph taken from an airplane in 2005. **Credit:** Ilan Koren, Weismann Institute.
- Fire burns near Cessnock, Australia, Friday, Jan. 18, 2013. (AP Photo/NSW Rural Fire Service, Kerry Lawrence.) The Huffington Post.
- NASA's Aqua satellite image of Iceland's Eyjafjallajokull volcano, May 8, 2010.
- Solar radiation management. http://www.mediaglobal.org/2011/03/15/geo-engineering-should-the-world-have-a-plan-b/
- Aviation and volcanoes. http://www.cnn.com/2011/WORLD/asiapcf/06/13/volcano.questions/index.html

Example with SEVIRI data

- **SEVIRI**: imager instrument onboard the European geostationary satellite Meteosat.
- AOD retrieved for March 5, 2007 at 7:15, 10:15, 12:15 and 15:15 UTC.
  - single channel over land
  - three-channels over ocean
  - note the sun-glint region