Aerosols Observations from Satellites

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ARSET - AQ

Applied Remote Sensing Education and Training – Air Quality

A project of NASA Applied Sciences

Aerosol Optical Depth

- AOD - Aerosol Optical Depth
- AOT - Aerosol Optical Thickness

These optical measurements of light extinction are used to represent aerosol amount in the entire column of the atmosphere.

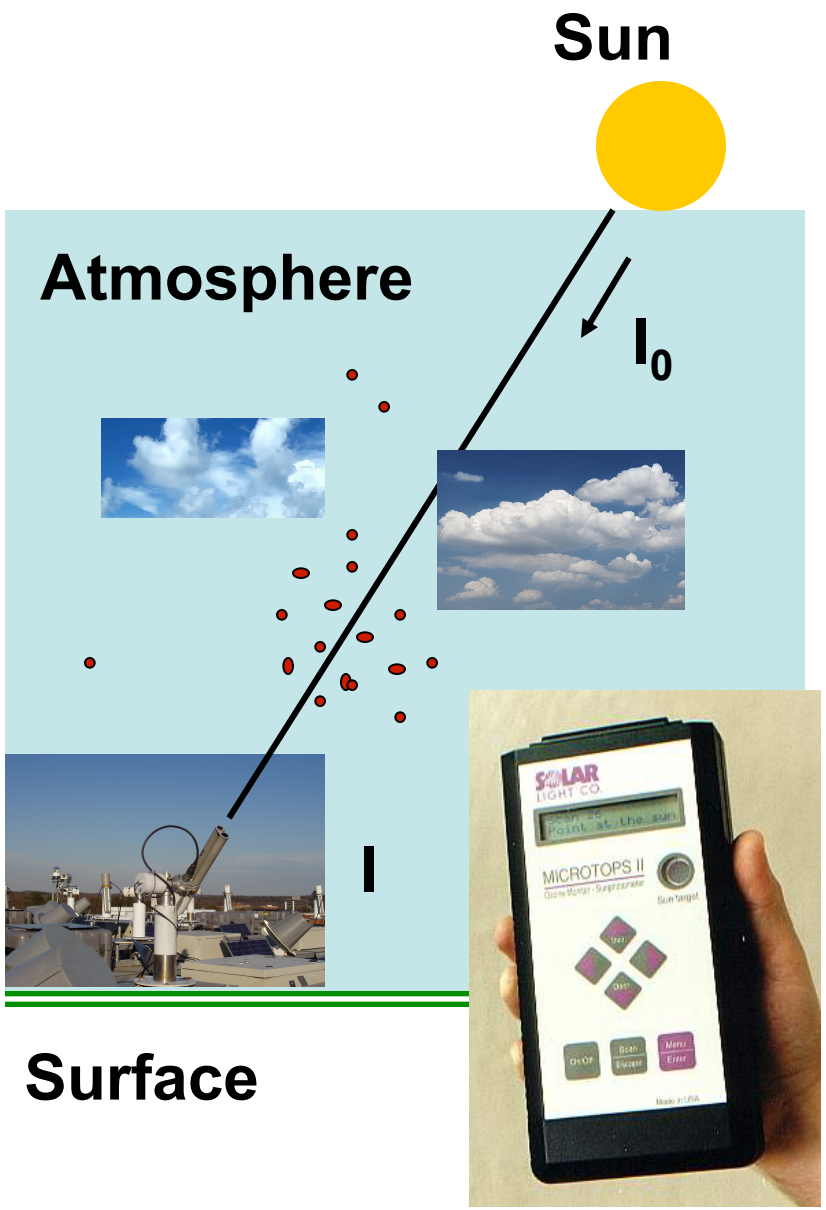
Moderate AOD ~0.40
Near Mt. Abu, India

Photo courtesy of Brent Holben

Visibility and PM2.5

Pictures taken from a same location at same time of day, on two different days

Optical Depth



The optical depth expresses the quantity of light removed from a beam by scattering or absorption during its path through a medium.

optical depth τ as

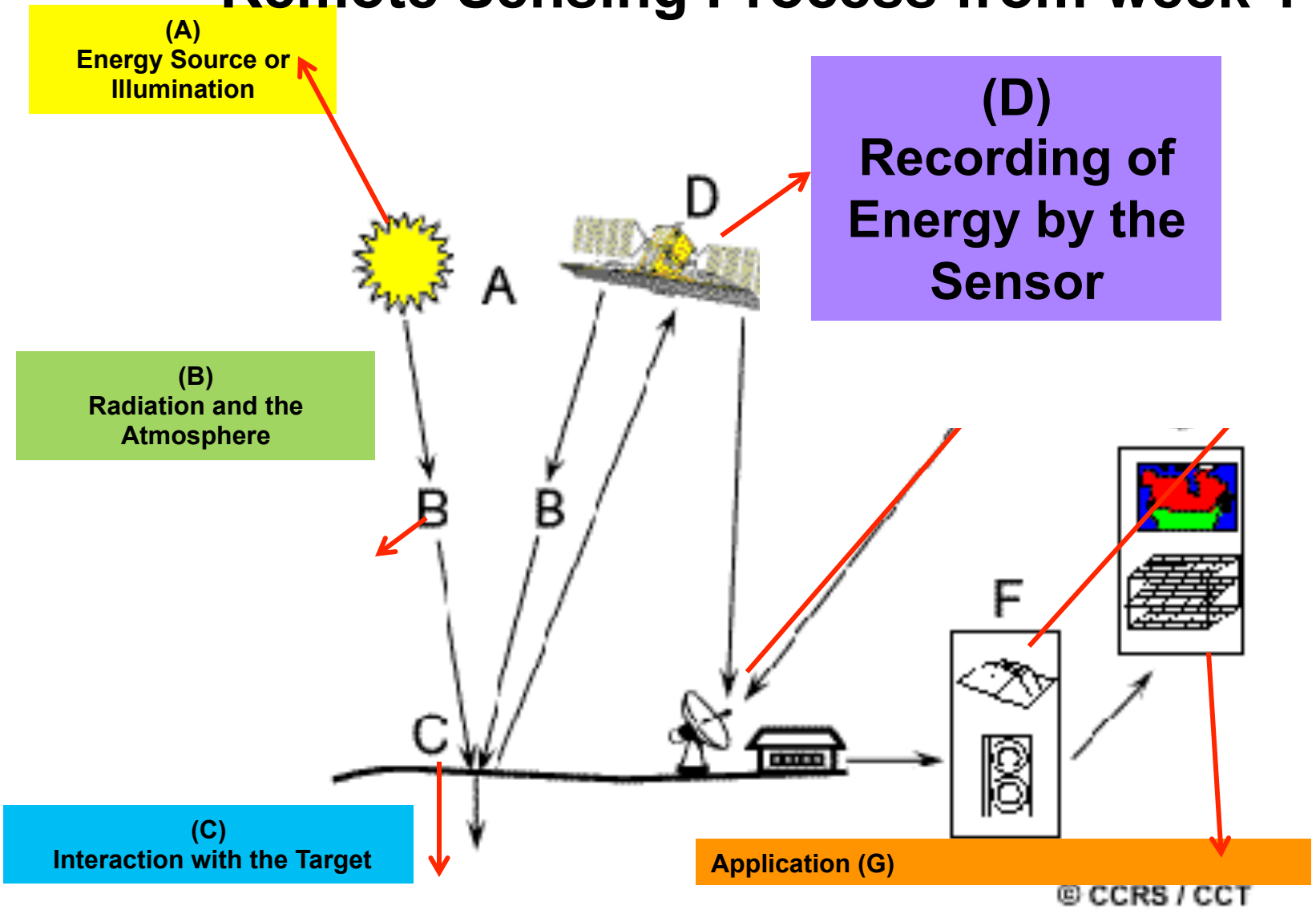
$$I = I_0 e^{-m\tau}$$

$$m = \sec\theta_0$$

$$\tau = \tau_{Rayl} + \tau_{aer} + \tau_{gas}$$

Aerosols from Satellite

Remote Sensing Process from week 1

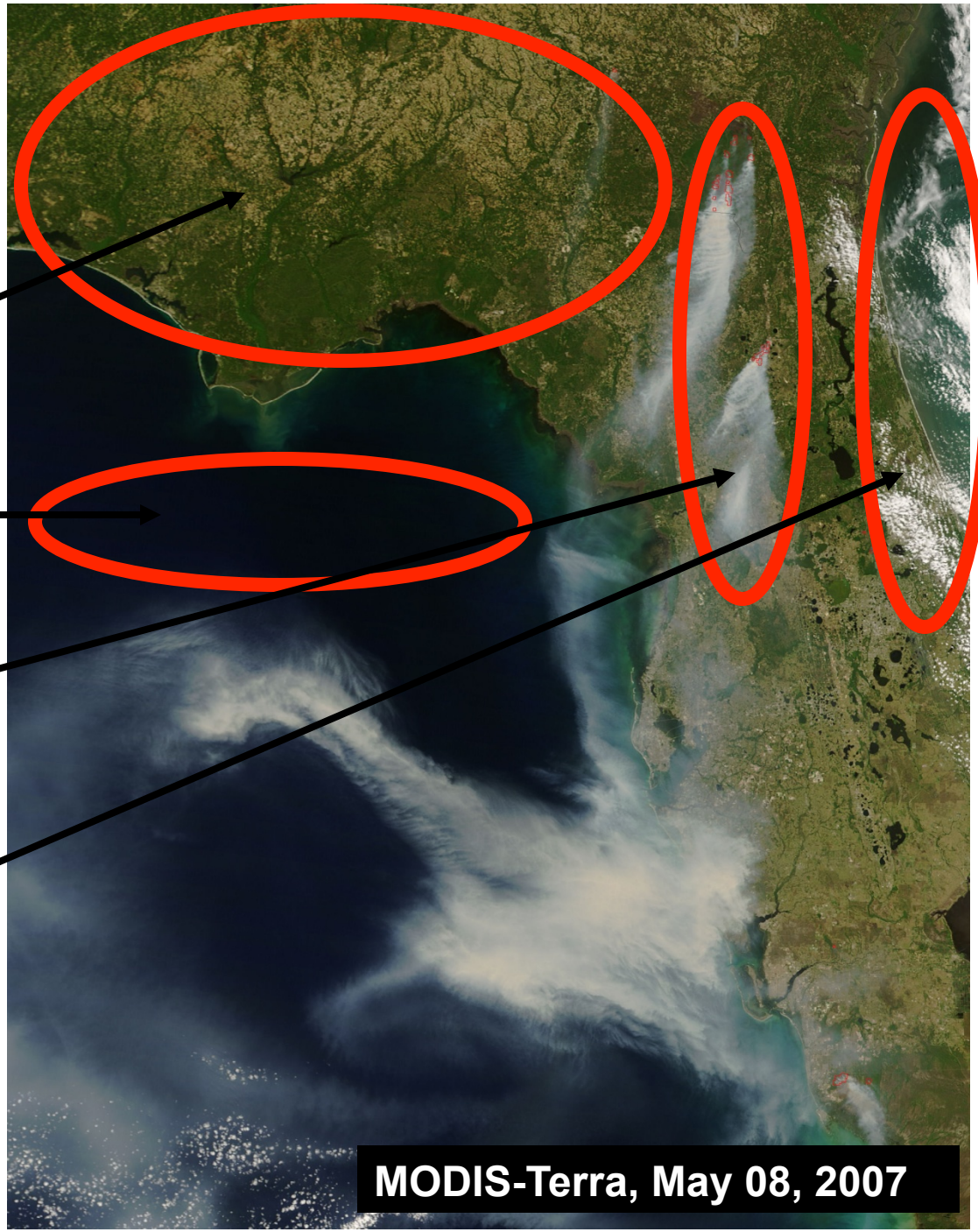


Reference:
CCRS/CCT

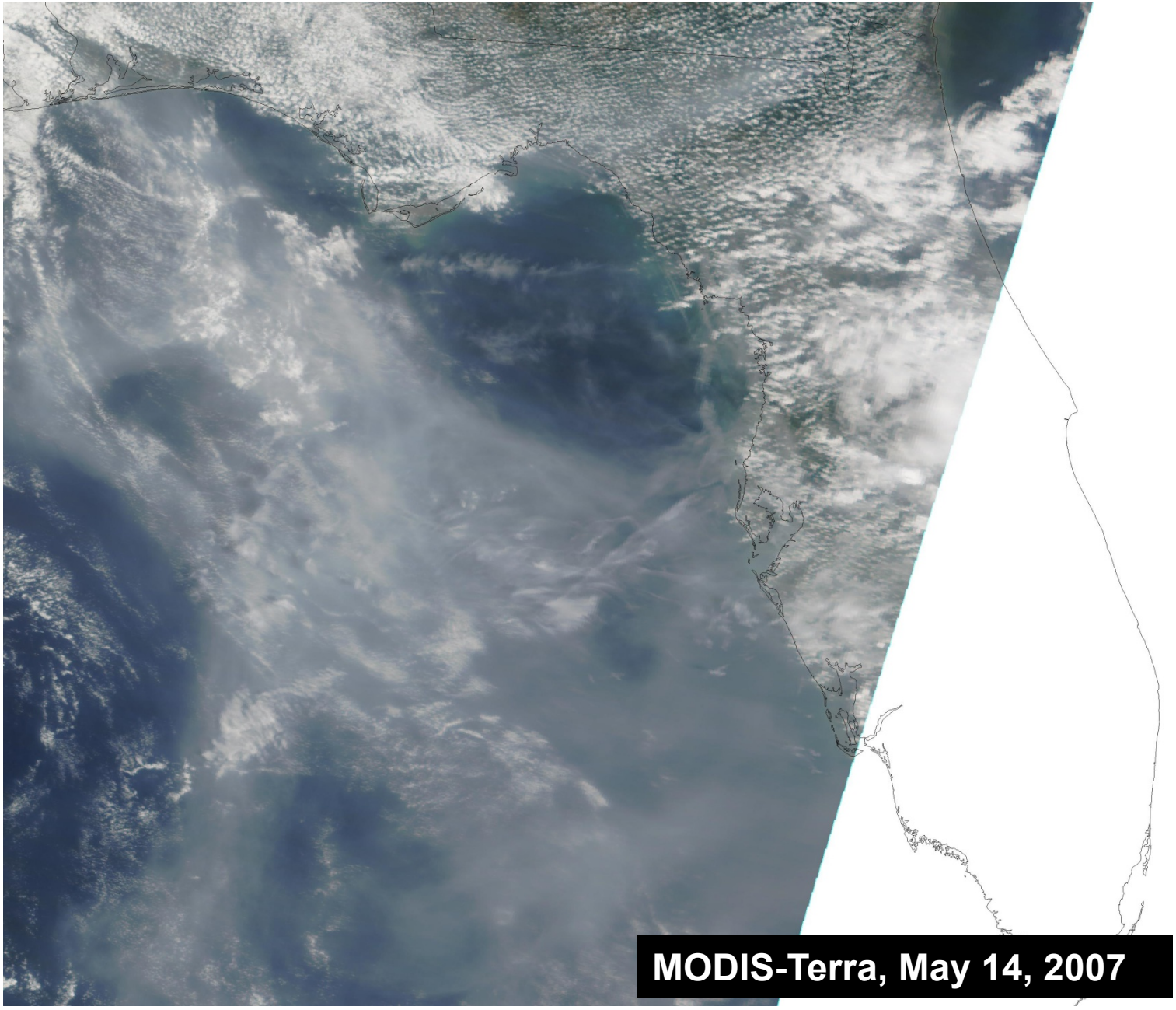
Aerosol Retrieval

Start with aerosol detection …

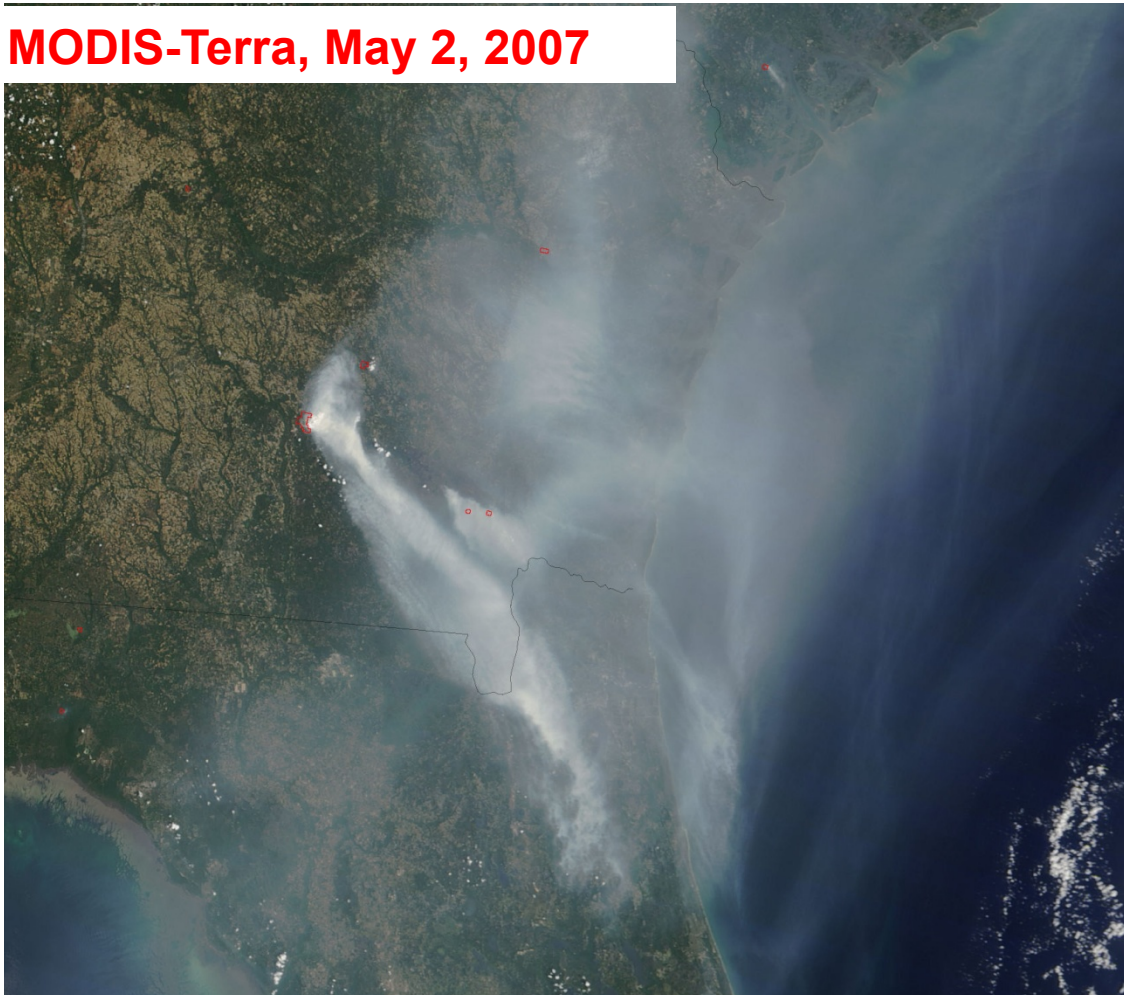
Satellite Observations & Pollution

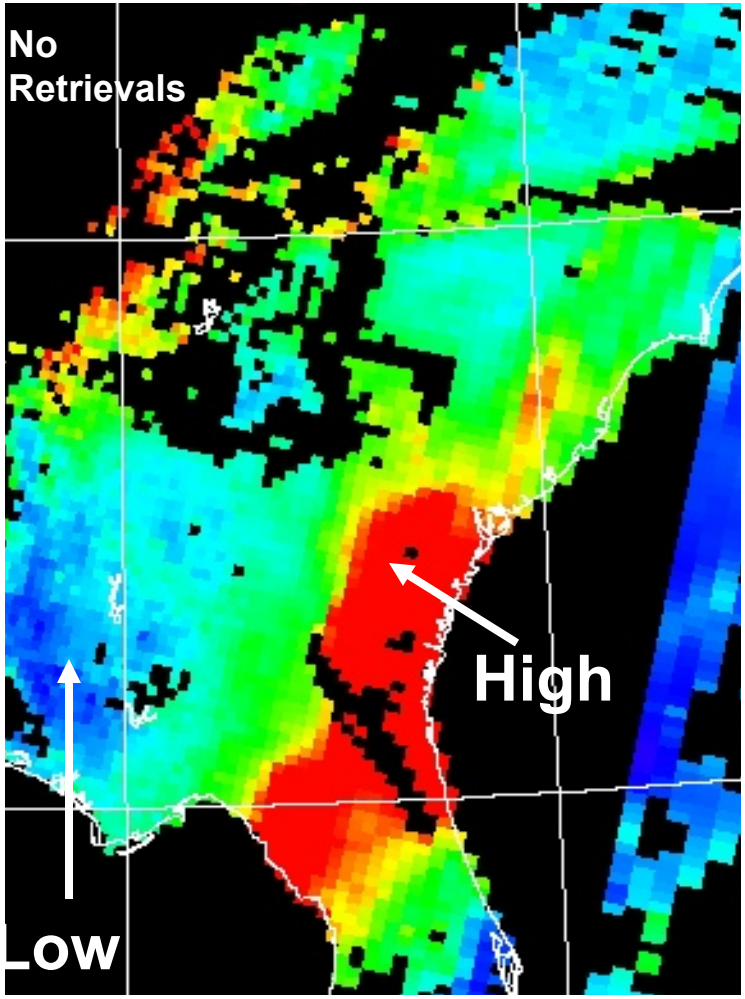


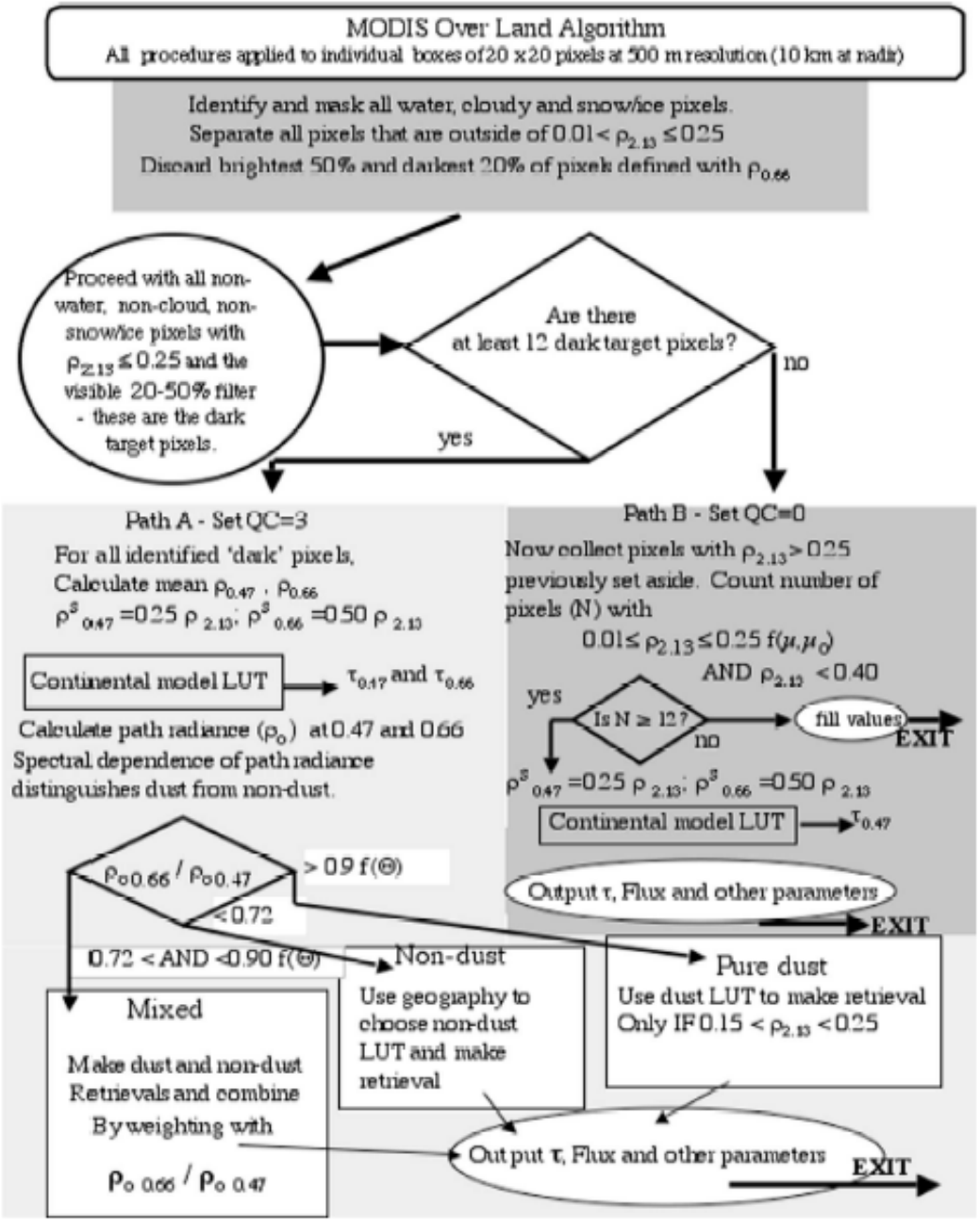
Complex Image: Smoke & Clouds



Radiance -to- Aerosol Products







Aerosol retrieval algorithm is a complex inversion scheme where assumptions are made in simulating satellite observations with advance radiative transfer calculations to retrieve atmospheric aerosol properties

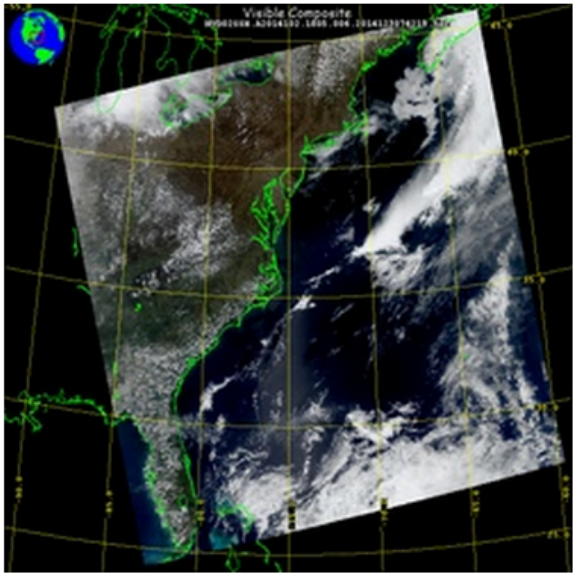
Remer et al., 2005, Levy et al., 2013

Data Levels

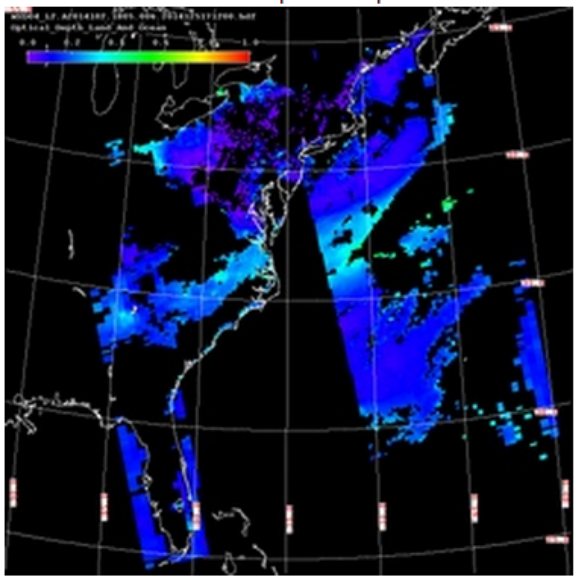
Levels of Data

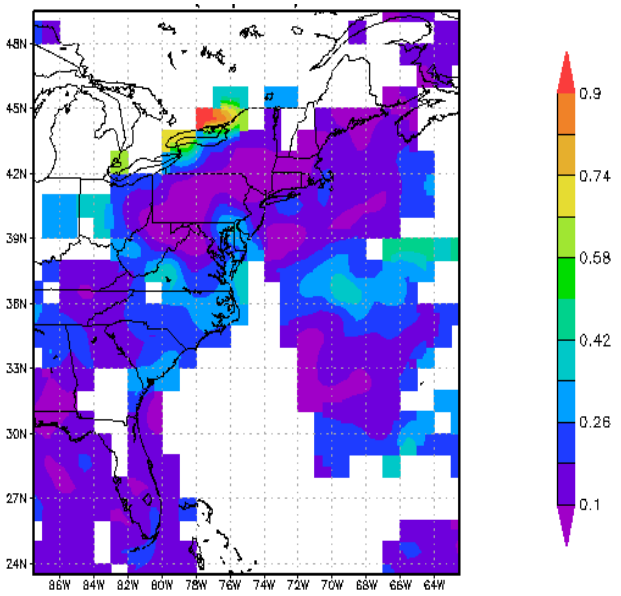
April 12, 2014

RGB



Aerosol Optical Depth





Level 1B

Calibration to Radiance

→

Level 2

Aerosol Retrieval Algorithm

→

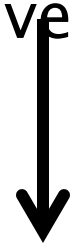
Level 3

Spatial & Temporal Averaging

Data Product Hierarchy

Level 1 Products – Raw data with and without applied calibration.
– **NO AEROSOL DATA**

Level 2 Products – Geophysical Products
– **AEROSOL DATA**



Level 3 Products – Globally gridded geophysical products
– **AEROSOL DATA**

Satellites for air quality data

- **MODIS (Terra and Aqua)**
  - AOD: columnar aerosol loading – can be used to get particulate matter mass concentration

- **MISR (Terra)**
  - Columnar aerosol loading in different particle size bins
  - in some cases aerosol heights

- **OMI (Aura)**
  - Absorbing aerosols
  - Trace gases

- **VIIRS (NPP)**
  - Aerosol Optical Depth, Aerosol Type

Instrument Capabilities for Air Quality

Sensor Measurement Resolution

MODIS –	**250m-1 KM Resolution**
MISR-	**275m- 1.1 KM Resolution**
OMI –	**13 x 24 KM Resolution**
VIIRS –	**750 m**

Satellite Aerosol Products

InInI	MODIS	MISR	OMI	VIIRS
Strengths	Coverage Resolution Calibration Accuracy	Calibration Accuracy Particle shape Aerosol height for thick layer or plume	Indication of absorbing or scattering particles	Coverage Resolution Calibration Smaller bow-tie effect
Weaknesses	Bright Surfaces* Ocean glint Non-spherical particles	Coverage	Resolution Cloud contamination	Bright Surfaces* Ocean glint
Main Products	AOD Ocean – 5 wavelengths Land – 3 wavelengths Fine Fraction* *Ocean only	AOD 4 wavelengths Spherical/ Non-spherical ratio Particle Size (3 Bins)	AOD AAOD Aerosol Index	AOD Aerosol Type
Product Resolution (level 2 and at Nadir)	10 Km 3 Km	17.6 Km	13 X 24 Km	0.75 km 6 km
Product Levels	2	2	2	2
Global Level 3 Aggregates	Daily 8 Day 30 Day	Monthly 3 Month Annual	Daily Monthly	Daily Monthly

MODIS

MODIS – MODerate resolution Imaging Spectroradiometer

Newer Earth-observing satellite remote sensing instruments typically make observations at many discrete wavelengths or wavelength bands.

36 wavelength bands covering the wavelength range 405 nm (blue) to 14.385 μm (infrared)

MODIS Products

(MOD for Terra/MYD for Aqua)

MOD01 Level-1A Radiance Counts
MOD02 Level-1B Calibrated Geolocated Radiances
-also Level 1B "subsampled" 5kmX5km pro
MOD03 Geolocation Data Set
MOD04 Aerosol Product
MOD05 Total Precipitable Water
MOD06 Cloud Products
MOD07 Atmospheric Profiles
MOD08 Gridded Atmospheric Product (Level 3)
MOD09 Atmospherically-corrected Surface Reflectance
MOD10 Snow Cover
MOD11 Land Surface Temperature & Emissivity
MOD12 Land Cover/Land Cover Change
MOD13 Vegetation Indices
MOD14 Thermal Anomalies, Fires & Biomass Burning
MOD15 Leaf Area Index & FPAR
MOD16 Surface Resistance & Evapotranspiration
MOD17 Vegetation Production, Net Primary Productivity
MOD18 *Normalized Water-leaving Radiance
MOD19 Pigment Concentration
MOD20 Chlorophyll Fluorescence
MOD21 *Chlorophyll_a Pigment Concentration
MOD22 Photosynthetically Active Radiation (PAR)
MOD23 Suspended-Solids Conc, Ocean Water
MOD24 Organic Matter Concentration
MOD25 Coccolith Concentration
MOD26 *Ocean Water Attenuation Coefficient
MOD27 Ocean Primary Productivity
MOD28 *Sea Surface Temperature
MOD29 Sea Ice Cover
MOD32 Processing Framework & Match-up Database
MOD33 Gridded Snow Cover
MOD34 Gridded Vegetation Indices
MOD35 Cloud Mask
MOD36 Total Absorption Coefficient
*MOD37 Ocean Aerosol Optical Thickness
MOD39 Clear Water Epsilon
MOD43 Albedo 16-day L3
MOD44 Vegetation Cover Conversion

Few more things to know about MODIS DATA

MOD - Terra product
MYD - Aqua product

- All MODIS products come in HDF format

- In HDF format each file contains both data and metadata

- SDS - Each parameter within a MODIS HDF file is referred to as an SDS (Scientific Data Set)

- An SDS must be referenced precisely according to name when analyzing the data with your own computer code.

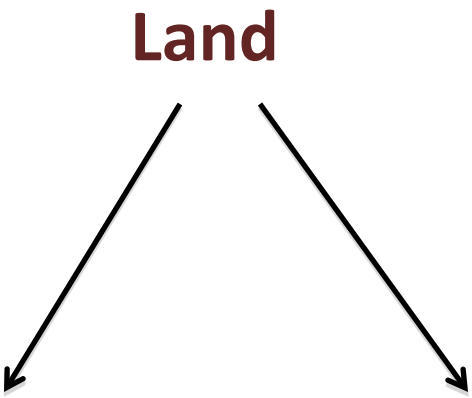
Things that change with each instrument

And therefore you need to learn!

- **Calibration accuracy.**
- **Quality Assurance – product creators estimate**
- **of the quality of the data.**
- **Data formats.**
- **Product Resolutions.**
- **How level 3 products are created from level 2**
- **temporally and spatially.**

MODIS Aerosol Products

Three Separate Algorithms

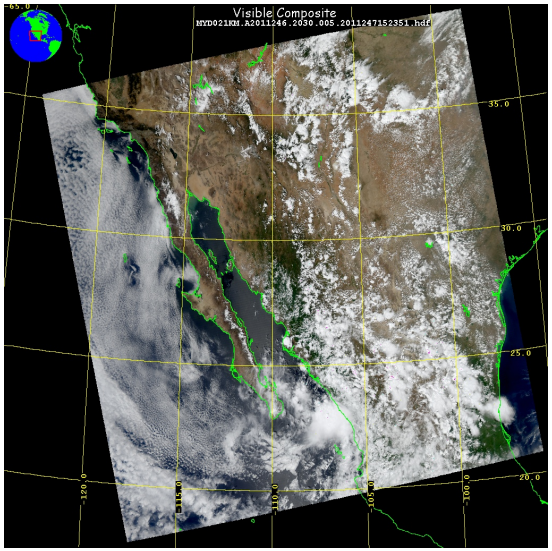


Dark Target

Deep Blue – Used over bright land surfaces

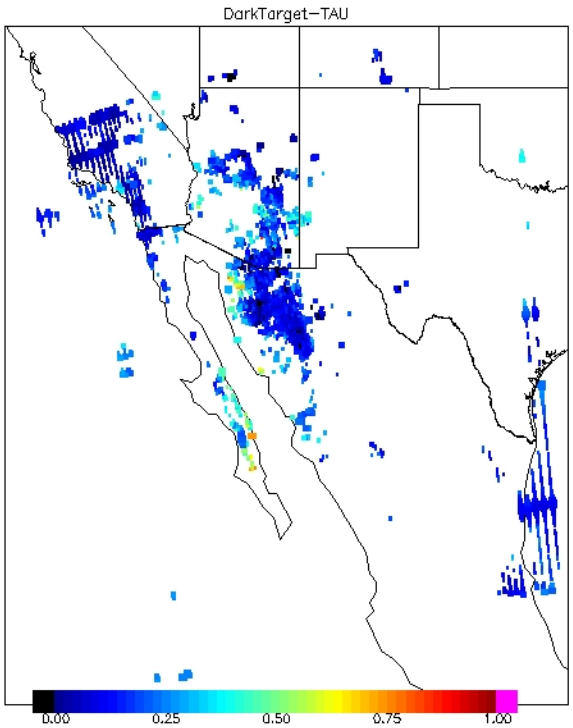
Currently the dark target and deep blue products are separate. When both are available the user must select which one to use

In collection 6 there will be a joint product that uses an automated procedure to select the appropriate product.

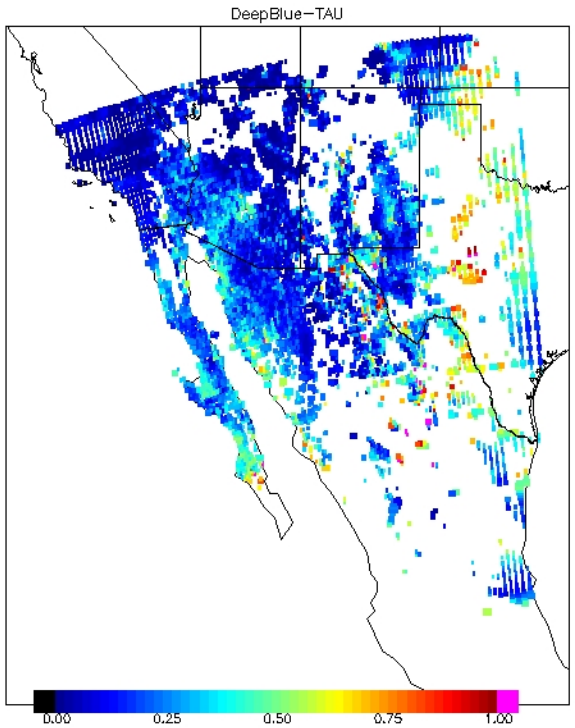


MODIS Aerosol Products

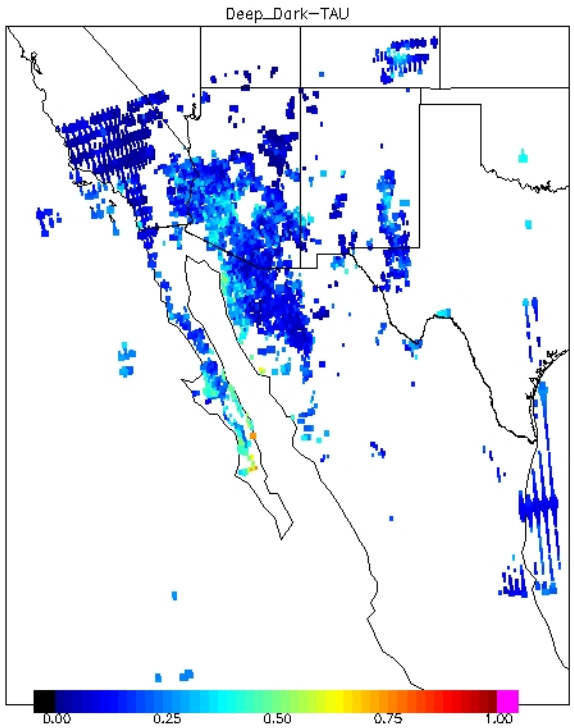
Two Algorithms



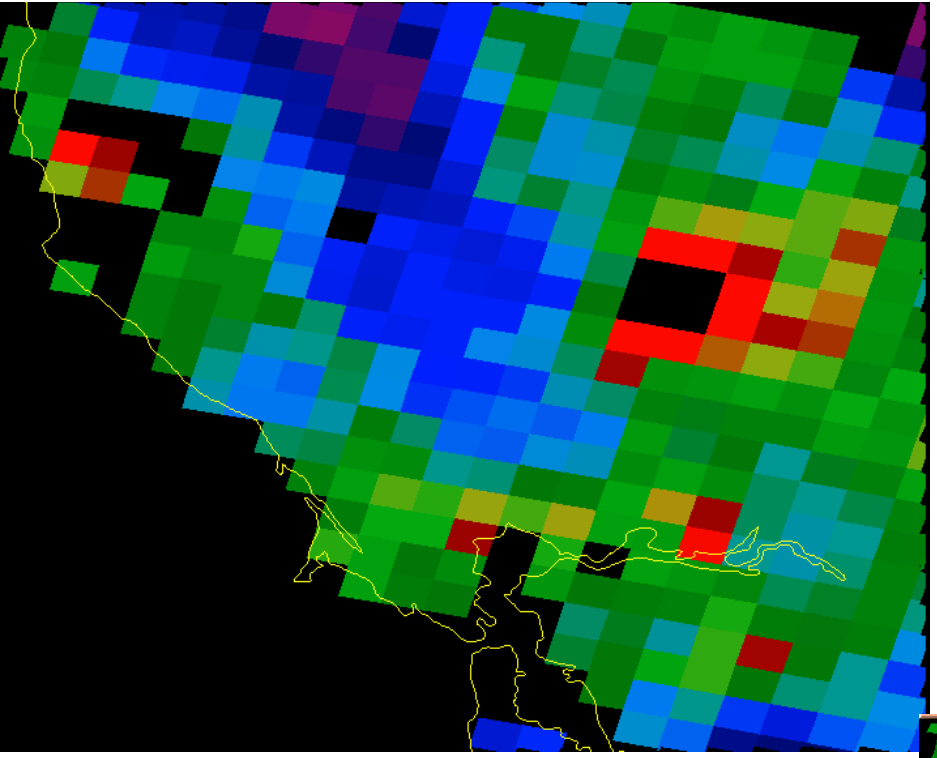
Dark Target



DeepBlue



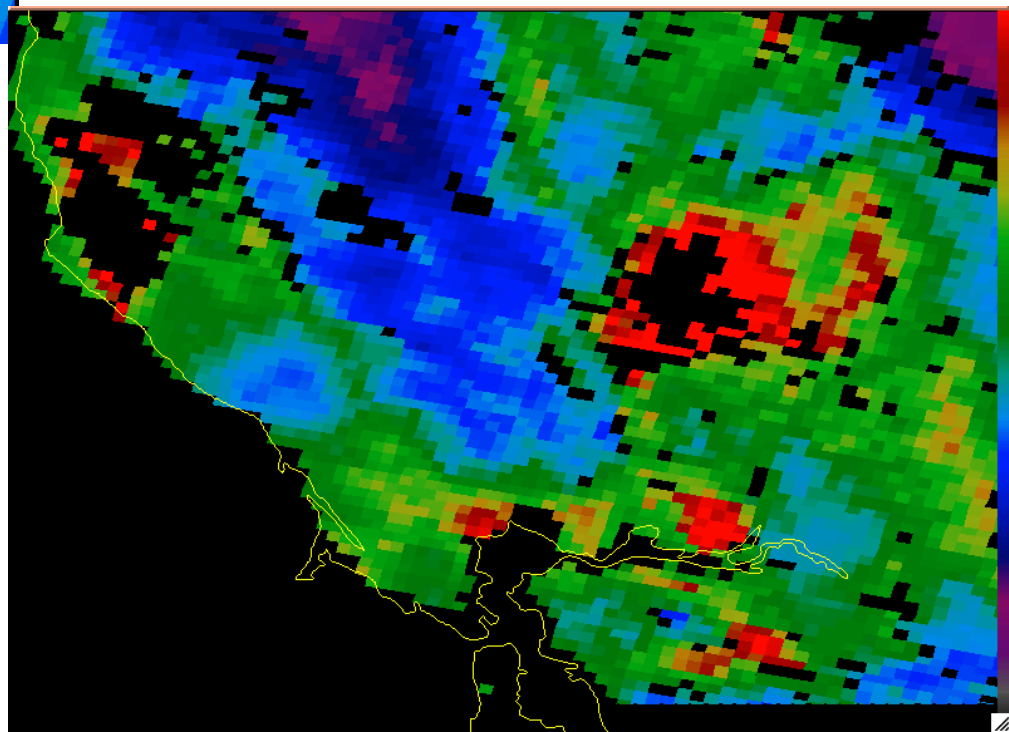
Deep_Dark_Combined



MODIS 10 KM

vs

3 KM Products



Quality Assurance is Extremely Important!!

QA indicates the confidence in the quality of the retrieval.

Quality_Assurance_Ocean
Scale is 0 - 3

Recommend Ocean QA above 1, 2, 3

Factors:
Number of pixels
Error fitting
How close to glint

Quality_Assurance_Land
Scale is 0 - 3

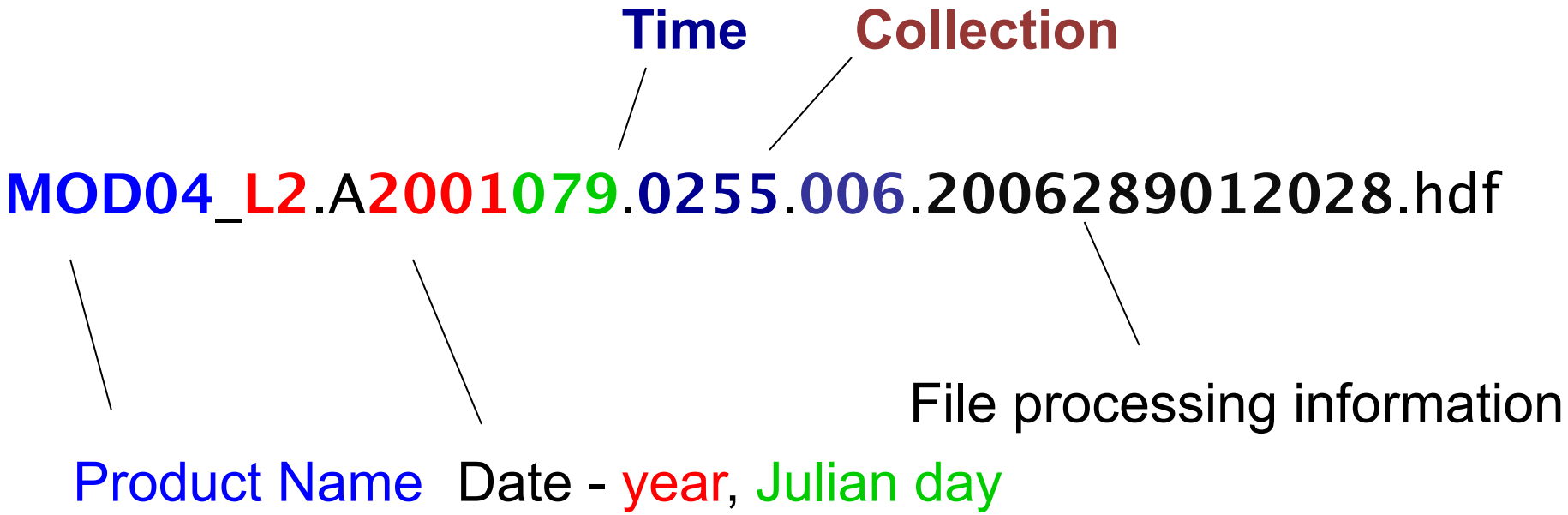
Recommend Land QA of 3

Factors:
Number of pixels
Error fitting
Surface reflectance

Understanding a MODIS File Name

Terra - MOD04
Aqua - MYD04

3 km Product Name
MOD04_3K



HDFLook, Panoply, IDL, Python, Fortran, Mat Lab etc. can be used to read the data

MODIS Aerosol Parameters (SDS)

Optical_Depth_Land_And_Ocean
(with recommended quality flags over land and ocean)
Over Land QA = 3, Over Ocean QA = 1, 2, 3

Dark_Target_Deep_Blue_Optical_Depth_550_Combined
(Deep Blue & Dark Target Algorithm merged product)

Dark_Target_Deep_Blue_Optical_Depth_550_Combined_QA
(Quality Flag associated with DD product)

Reference:

http://www.atmos-meas-tech.net/6/2989/2013/amt-6-2989-2013.html

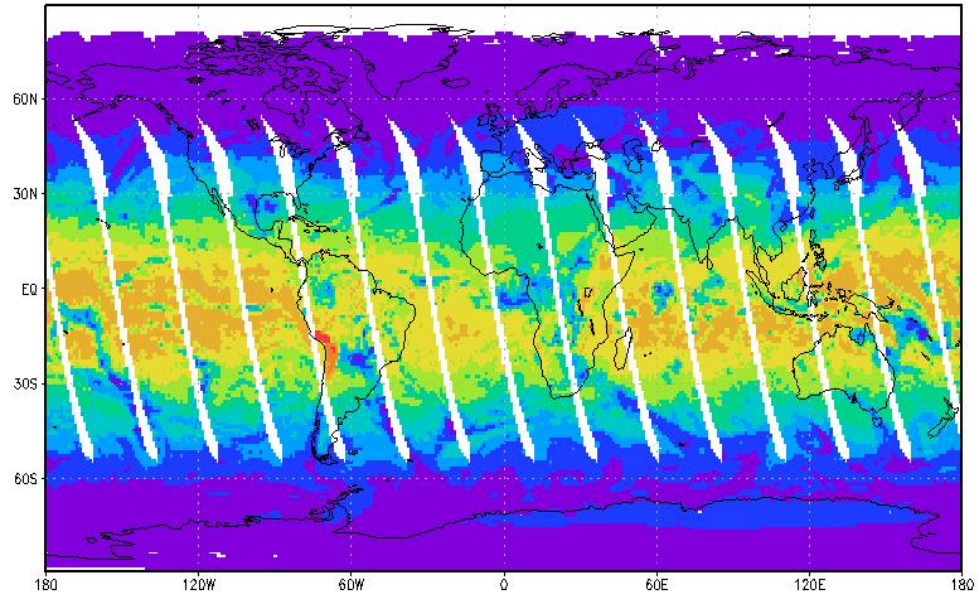
Access to MODIS Aerosol Products

- **NASA LAADSWEB. Searchable data base, FTP access**
  http://ladsweb.nascom.nasa.gov/index.html
- **MODIS-Atmos Site: Complete RGB archive and Level 3 product imagery.**
  http://modis-atmos.gsfc.nasa.gov/
- **Giovanni – web tool for imagery visualization and analysis**

  http://gdata1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=MODIS_DAILY_L3

OMI

Ozone Monitoring Instrument (OMI)



One of four sensors on the EOS-Aura platform (OMI, MLS, TES, HIRDLS)

An international project:
Holland, USA, Finland
Launched on 07-15-04

Instrument Characteristics

- **Nadir solar backscatter spectrometer**
- **Spectral range 270-500 nm (resolution~1nm)**
- **Spatial resolution: 13X24 km footprint**
- **Swath width: 2600 km (global daily coverage)**

Retrieval Products

Column Amounts
- **Ozone (O_3)**
- **Nitrogen Dioxide (NO_2)**
- **Sulfur Dioxide: (SO_2)**
- **Others**

Aerosols

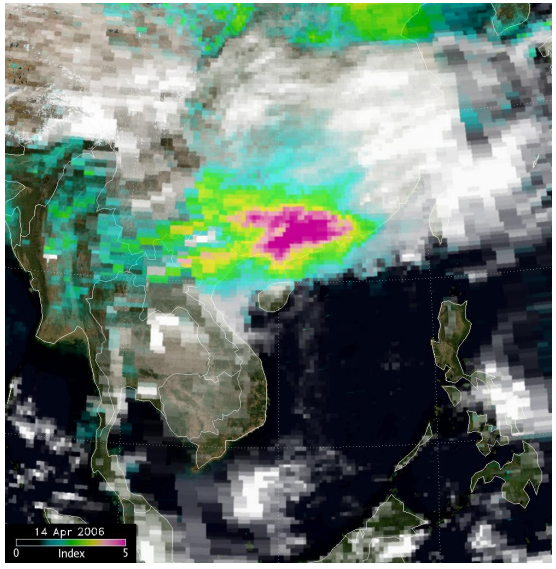
Applications of the Aerosol Index

-Validation tool for transport models

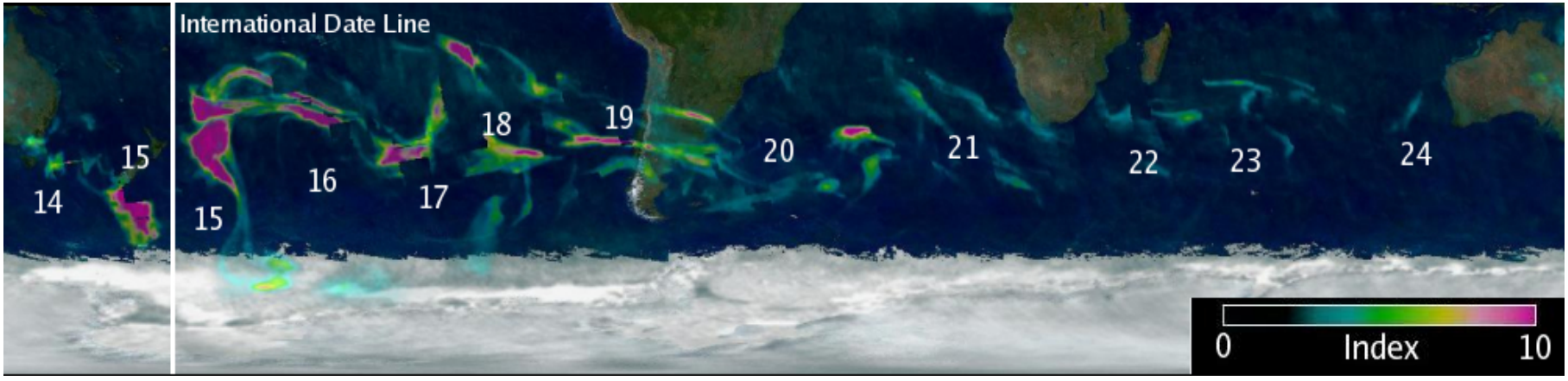
-Separation of carbonaceous from sulfate aerosols

-Identification of aerosols above PBL (i.e., PBL aerosols are not detectable by AI)

-Tracking of aerosol plumes above clouds and over ice/snow



Aerosol s over clouds:
April 14, 2006



Transport around the globe of a high altitude smoke layer generated by the Australian fires in December 2006. Numbers indicate the day of the month.

OMI data site

http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI

Version 003 OMI Level 2, Level 2G, Level-3 and Climatology Products			
Short Name & Data Access			Product Description
Level-2 Orbital Swath (Nadir pixels 13x24 km)	Level-2G Global Binned (0.25x0.25 or 0.125x0.125 deg)	Level-3 Global Gridded (0.25x0.25 or 1x1 deg)	
Aerosols			
OMAERUV	OMAERUVG	OMAERUVd	OMI/Aura Near-UV Aerosol Optical Depth and single Scattering Albedo
OMAERO	OMAEROG	OMAEROe	OMI/Aura Multi-Wavelength Aerosol Optical Depth and single Scattering Albedo

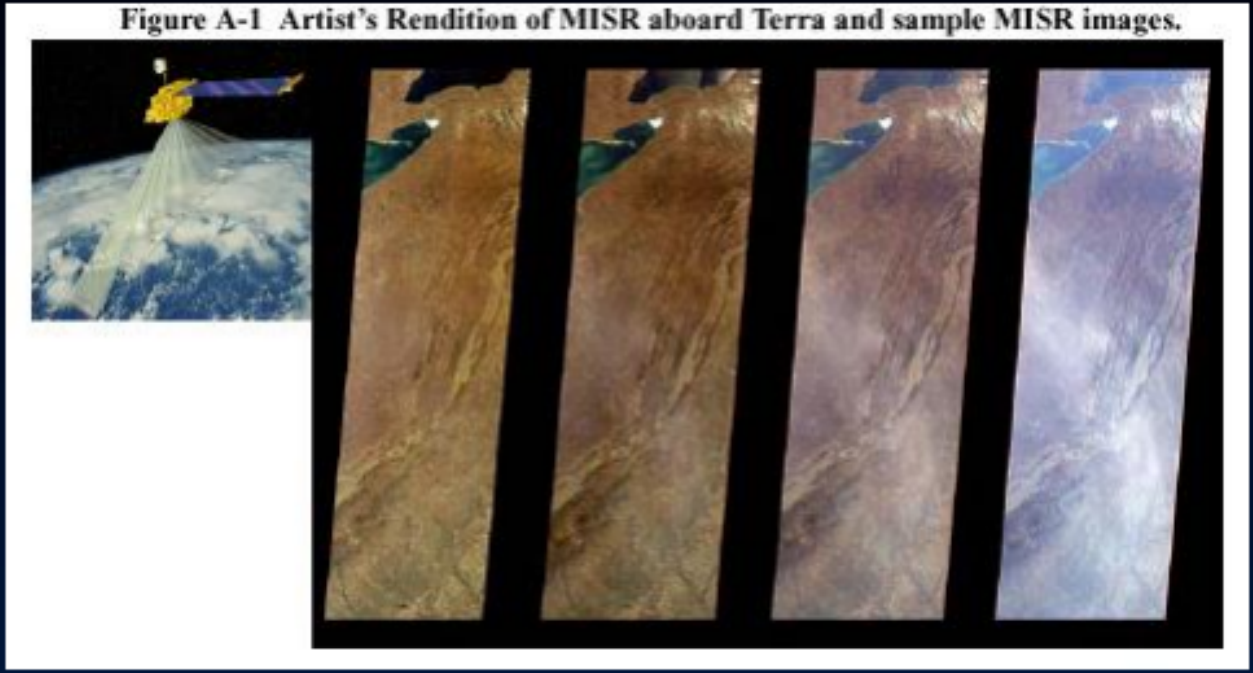
OMI-Aura_L2-OMAERUV_2011m1024t0521-o38692_v003-2011m1024t115317.he5

Product name

YYYYmMMDDtHHMM

MISR

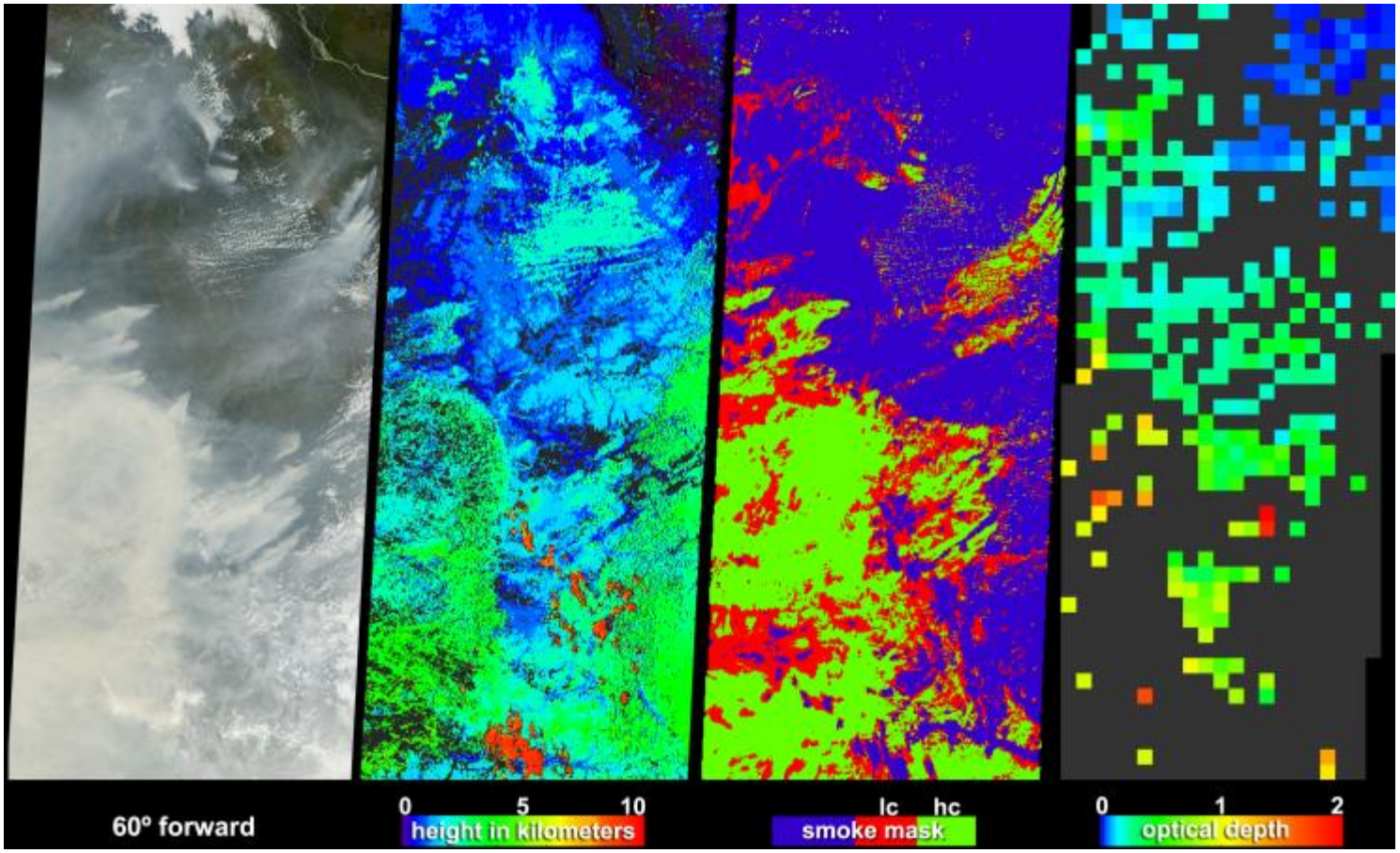
MISR Background



Four MISR images over Appalachain Mountains
Nadir, 45.6 deg, 60.0 deg, 70.5 deg forward viewing cameras

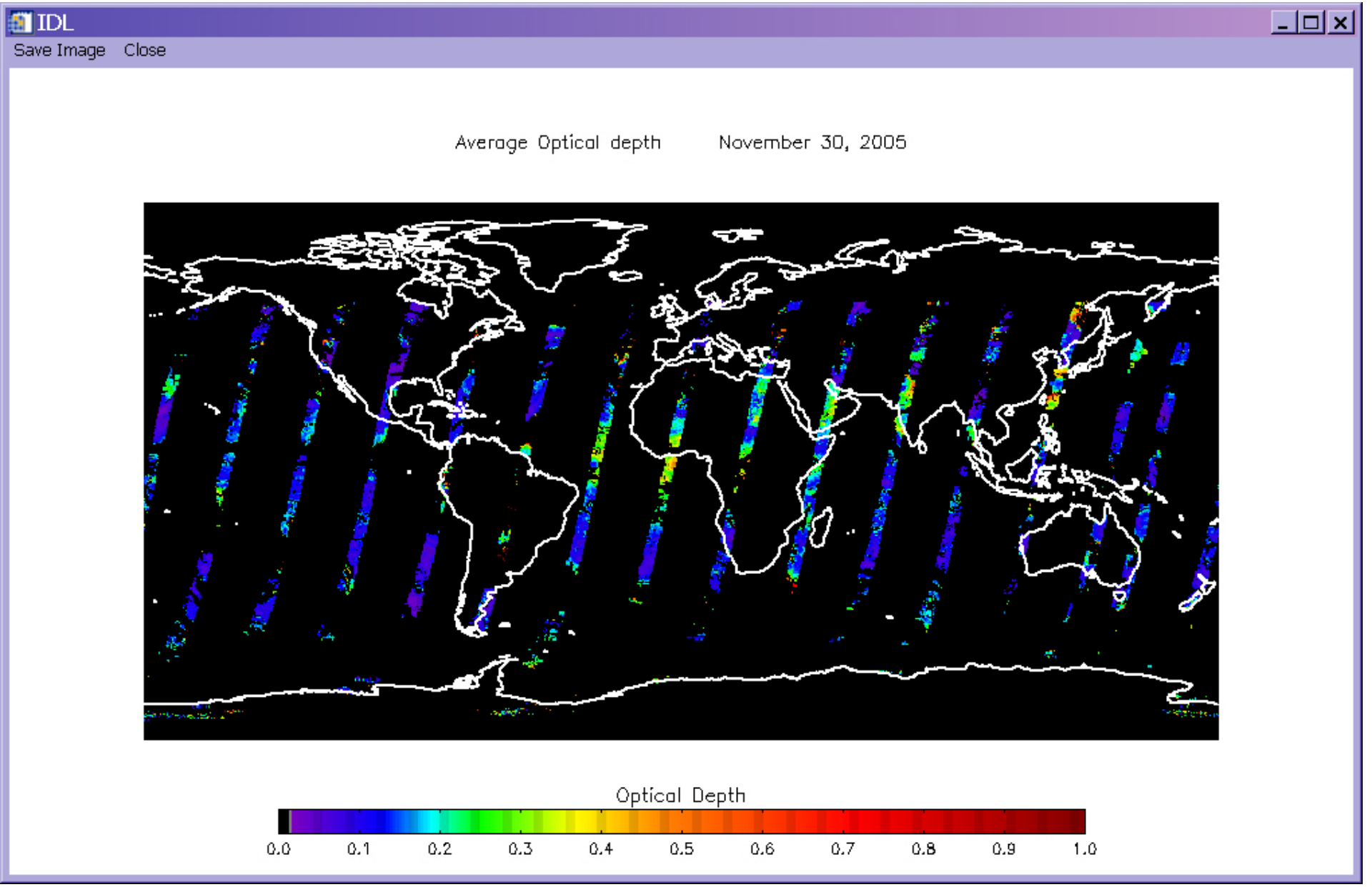
Angular observations (which are not available in MODIS) makes MISR capable of providing additional information on particle size, shape and aerosol height under specific cases

Aerosol Heights from MISR



Smoke Signals from the Alaska and Yukon Fires - July 2004

MISR Level 3 Tool



Level 2 & 3 aerosol

1 file = one orbit - about 98 min Data

17.6x17.6 km^2 , 0.5x0.5, and 1x1deg, daily, monthly, seasonal

MISR_AM1_AS_AEROSOL_P028_O002510_F12_0022.hdf

RegBestEstimateSpectralOptDepth (AOD – 4 wavelengths)
RegBestEstimateSpectralOptDepthFraction (AOD fraction for small, medium, large, spherical, and non-spherical particles)

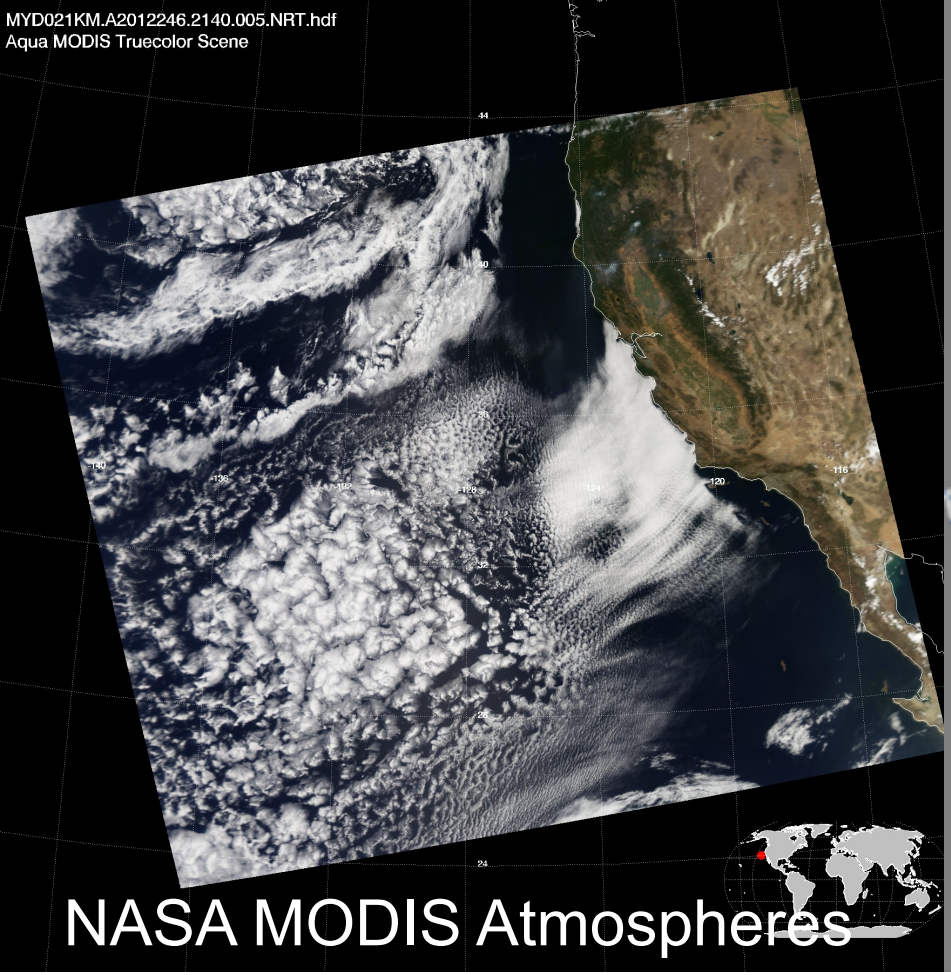
Data access and handling tutorial

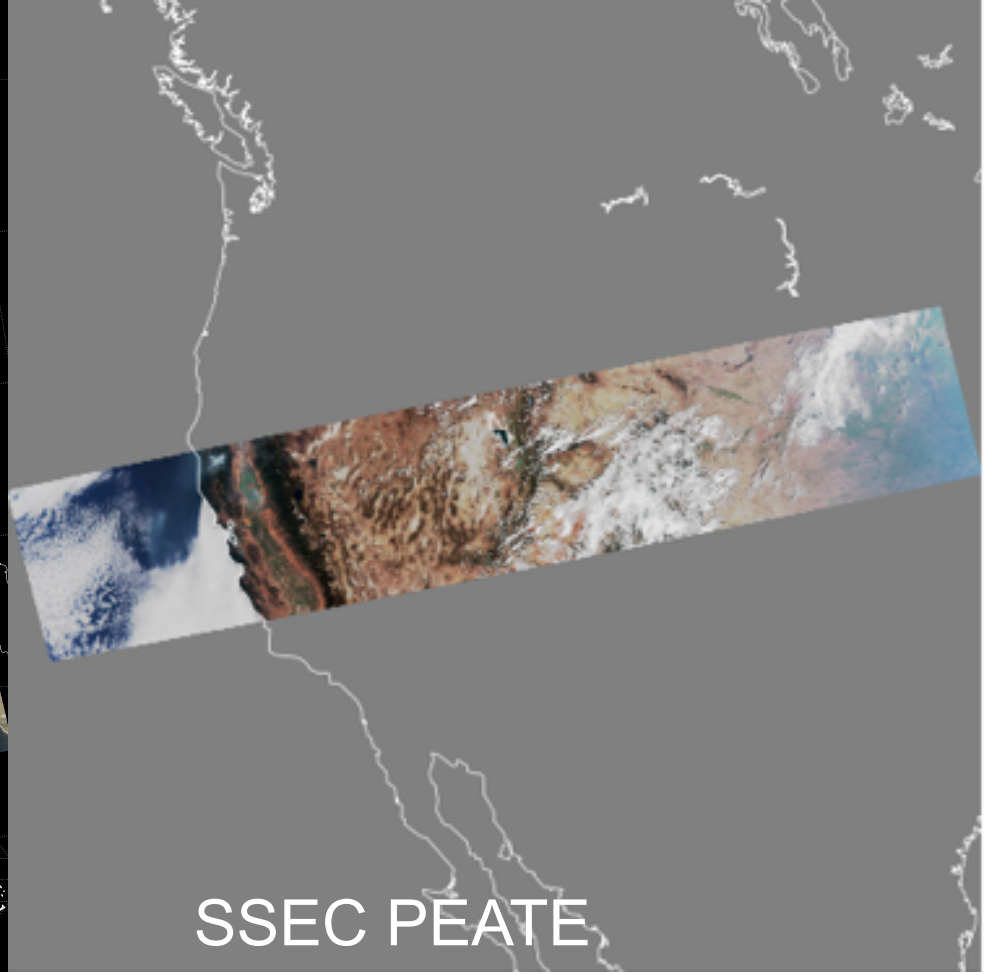
http://eosweb.larc.nasa.gov/PRODOCS/misr/workshop/ppt/2010_lcluc/misr_tutorial.pdf

VIIRS

VIIRS is a multi wavelength imager, like MODIS with similar wavelength bands

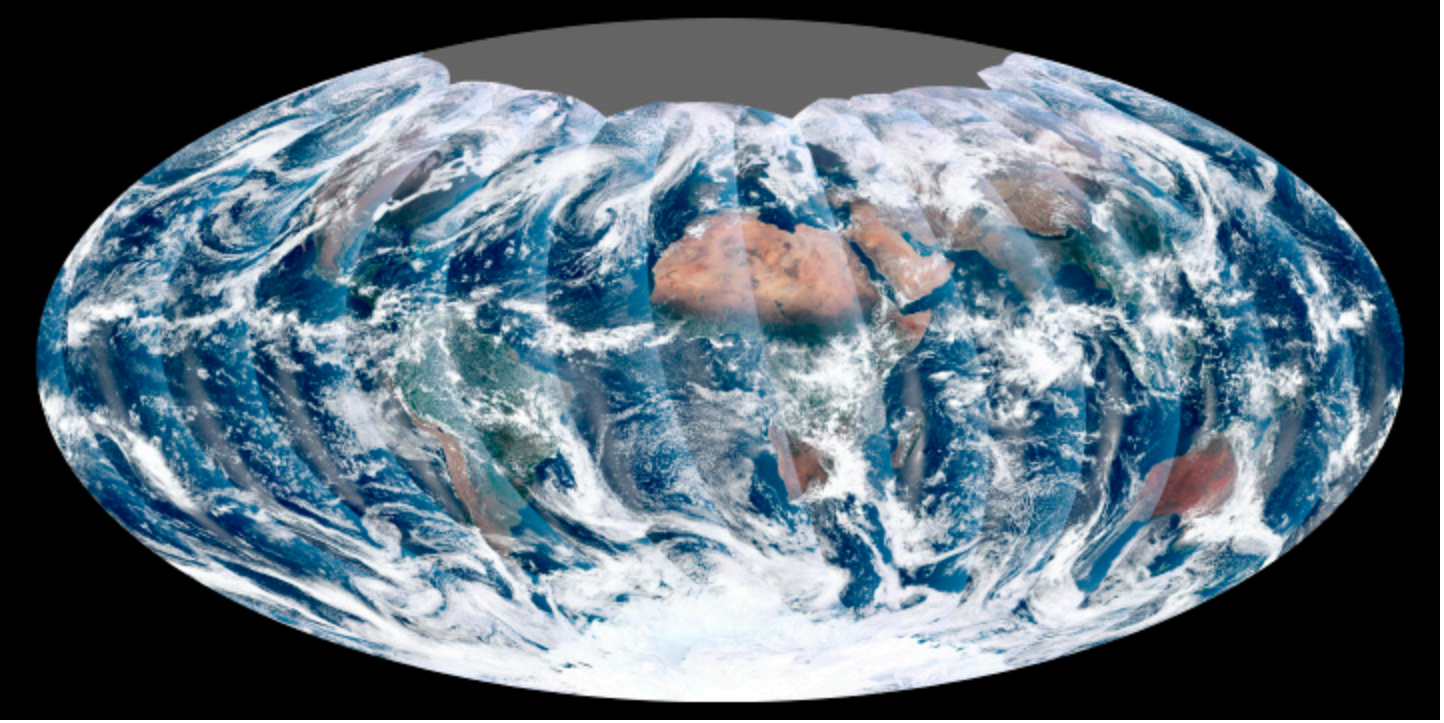
	MODIS	VIIRS
Orbit altitude	690 km	824 km
Equator crossing time	13:30 LT	13:30 LT
Granule size	5 minutes	86 seconds
swath	2330 km	3000 km
Pixel nadir	0.5 km	0.75 km
Pixel edge	2 km	1.5 km





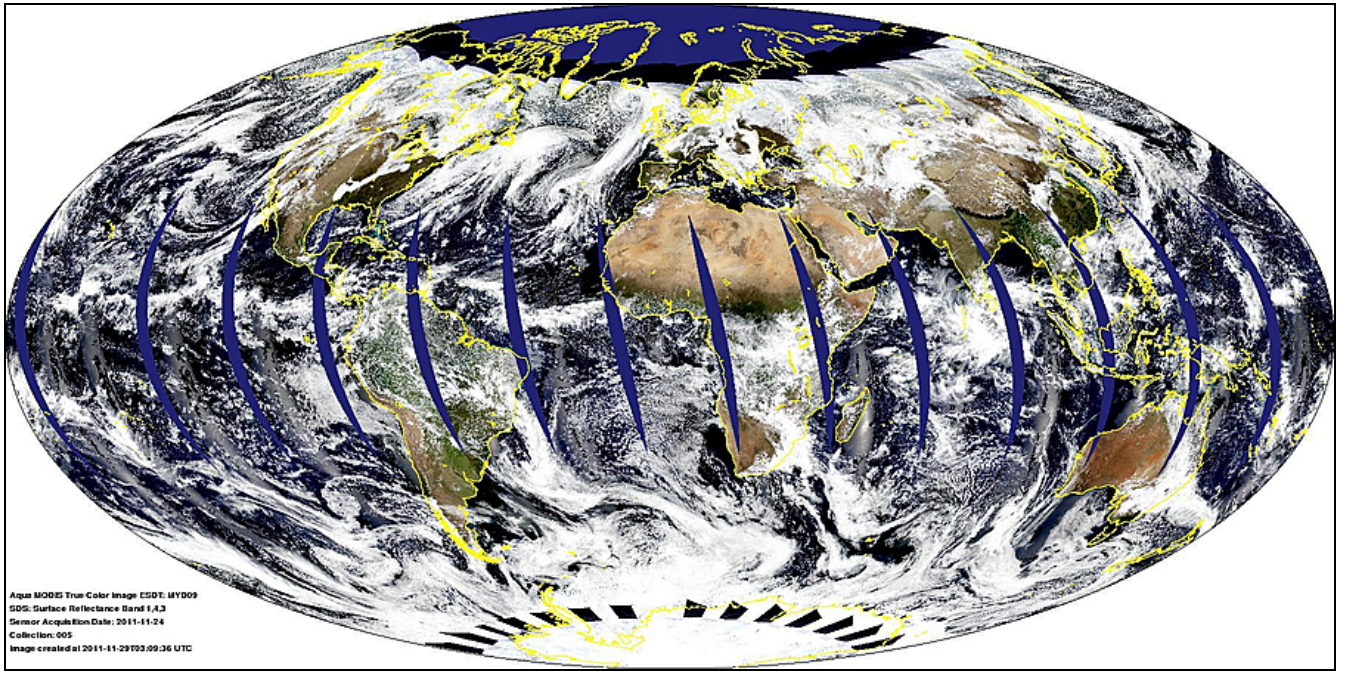
MODIS
0.66 – 0.55 – 0.47 µm
2 Sep 2012
21:40 UTC

VIIRS
0.67 – 0.55 – 0.49 µm
2 Sep 2012
20:24:27.8 UTC



VIIRS
Nov 24, 2011

MODIS - AQUA
Nov 24, 2011



VIIRS Level 2 & 3 Aerosol Data

Level 2, VIIRS Data

http://www.class.ngdc.noaa.gov/saa/products/search?sub_id=0&datatype_family=VIIRS&submit.x=26&submit.y=6

Level 3, Quarter Degree Gridded VIIRS Data

http://www.star.nesdis.noaa.gov/smcd/emb/viirs_aerosol/products_gridded.php

References & links

. ARSET-AQ webpage

http://airquality.gsfc.nasa.gov/index.php?section=11

. MODIS ATMOS

http://modis-atmos.gsfc.nasa.gov/mod04_l2/

. MISR DATA

http://eosweb.larc.nasa.gov/PRODOCS/misr/Quality_Summaries/L2_AS_Products.html

. OMI DATA

http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI

. IDEA

http://www.star.nesdis.noaa.gov/smcd/spb/aq/

. SMOG BLOG

http://alg.umbc.edu/usaq/