

Introduction to ARSET and Aerosols Observations from Satellites

Pawan Gupta

Week 1 – October 1, 2015

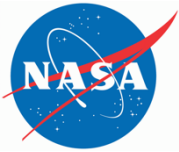
Satellite Remote Sensing of Particulate Matter Air Quality: Data, Tools,
Methods and Applications (Aka AOD-PM)

ARSET - AQ

Applied Remote Sensing Education and Training – Air Quality

A project of NASA Applied Sciences





NASA Applied Remote Sensing Training (ARSET)

Dr. Ana I. Prados
(Program Manager)

University of Maryland Baltimore County, Joint Center for Earth Systems
Technology
and NASA/GSFC



Applied Remote Sensing Training (ARSET)

<http://arset.gsfc.nasa.gov>

GOAL: Increase utilization of NASA observational and model data for decision-support through training activities for environmental professionals.

Online training (free): Live and recorded, 4-6 weeks in length. Include demos on data access, GIS and NASA webtools

In person training: In a computer lab, 2- 4 days, partnering with 1 or more stakeholders.

Train the Trainers: Learn how to design and conduct your own remote sensing training course

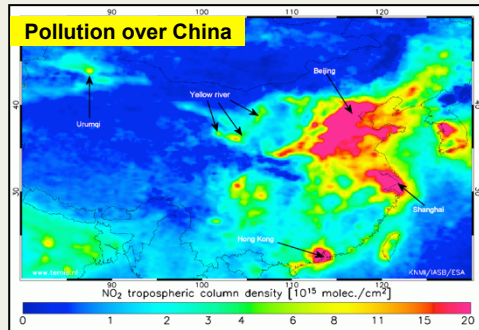


Accomplishments (2008 – 2015)

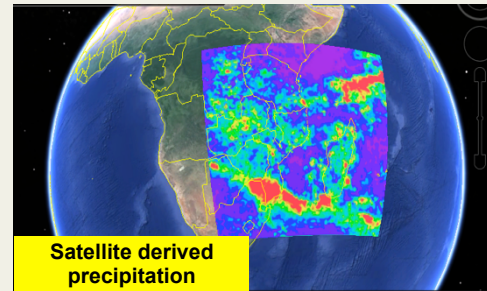
- 52 trainings completed
- 4000+ participants worldwide
- 1480+ organizations
- 132 countries

Applied Remote Sensing Training (ARSET)

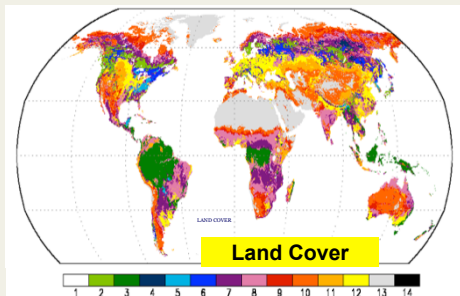
Air Quality



Water Resources and Flood Monitoring



Land Management and Wildfires





Gradual Learning Approach

Basic Training

Webinars

Hands-on

Assume no prior knowledge of RS



Advanced Training

Hands-on

Webinar course generally required
Focused on a specific application/
problem/Data: for example **dust** or
**smoke monitoring in a specific
country or region**

Online Training

The screenshot shows a web browser window with a chat interface on the left and a video player on the right. The chat window displays a message from Rich Kleidman: "If you will not be attending the in person course and want more information about any of these tools - aerosol or data synergy tool - please send Rich and e-mail and I will direct you to exercises you can use to practice using the tools." The video player shows a slide titled "Radiance -to- Aerosol Products" with a large red arrow pointing to the right. Below the slide is a video player showing satellite imagery of ODIS-Terra, May 2, 2007, with a color-coded map of aerosol concentrations. The map shows a high concentration of aerosols over the Indian subcontinent, labeled "High", and a low concentration over the surrounding oceans, labeled "Low".

In-Person Training



ARSET Website

<http://arset.gsfc.nasa.gov/>

The screenshot shows the ARSET website interface. At the top, there is a header with the NASA logo and the text "ARSET Applied Remote Sensing Training". Navigation links include "Earth Science Division", "Applied Sciences", and "ASP Water Resources". A search bar is located on the right. Below the header, there are four main categories: "DISASTERS", "ECO FORECASTING", "HEALTH & AIR QUALITY", and "WATER RESOURCES". A red box highlights a sub-menu for "ARSET" which contains links for "Webinars", "Workshops", "Apply for Training", "Personnel", "Links", and "Upcoming Webinar". A red arrow points from this menu to a larger, zoomed-in view of the same menu on the left side of the image.

ARSET
Webinars
Workshops
Apply for Training
Personnel
Links
Upcoming Webinar

Applied Remote Sensing Training

The goal of the NASA Applied Remote SEnSing Training (ARSET) is to increase the utility of NASA earth science and model data for policy makers, regulatory agencies, and other applied science professionals in the areas of Health and Air Quality, Water Resources, Eco Forecasting, and Disaster Management.

The two primary activities of this project are webinars and in-person courses.

Webinars (Free)

Webinars are offered throughout the year in all four application areas, generally 4-5 weeks in duration, 1 hour per week. They are intended for those new to remote sensing. For more information and to register please go to the webinars section of the website.

In-Person Courses

ARSET in-person courses are a combination of lectures and computer hands-on activities that teach professionals how to access, interpret, and apply NASA data at regional and global scales with an emphasis on case studies. ARSET works with organizations who will host the training for groups within their geographical region, tailoring the curriculum to the needs of the projected participants. NASA does not charge an attendance fee, but attendees must make their own arrangements to travel to the course meeting location.

Skills Taught:

- Search, access, and download of NASA data products and imagery
- Appropriate use and interpretation of satellite imagery.
- Visualization and analysis of NASA imagery using NASA, EPA, and NOAA webtools and other resources such as GIS, Google Earth, Panoply, RSIG, and HDFLook

ARSET is sponsored by the Applied Sciences Program within NASA's Earth Sciences Division. We would like to thank Nancy Searby, Applied Sciences' Capacity Building Program Manager for her support of this project.

Last updated: August 18, 2014
NASA Official: Kenneth Pickering
Webmaster: Susannah Pearce
Curator: Ane Pradco

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ARSET

[Webinars](#)

[Workshops](#)

[Apply for Training](#)

[Personnel](#)

[Links](#)

[Upcoming Webinar](#)

Request a Training

<http://arset.gsfc.nasa.gov>

The screenshot shows the ARSET website interface. At the top, there are navigation tabs for 'Earth Science Division', 'Applied Sciences', and 'ASP Water Resources'. Below this is a search bar and a main navigation menu with categories like 'DISASTERS', 'ECO FORECASTING', 'HEALTH & AIR QUALITY', and 'WATER RESOURCES'. On the left, a sidebar lists 'ARSET' options: 'Webinars', 'Workshops', 'Apply for Training', 'Personnel', 'Links', and 'Upcoming Webinar'. The main content area is titled 'Applied Remote Sensing Training' and contains introductory text about the program's goals and activities. A red arrow points from the 'Apply for Training' link in the sidebar to the main content area.

Apply for Training

The NASA Applied Remote Sensing Training Program provides webinars and in-person courses. The goal of these training activities is to build the capability and skills to utilize NASA earth science observations and model data for environmental management and decision-support. Courses are primarily intended for applied science professionals and decision makers from local, state, federal agencies, NGOS, and the private sector. ARSET also offers a Train the Trainers program, which is recommended for establishing or growing your organizations' capacity in applied remote sensing.

ARSET trainings are NOT designed for research but for operational and application driven organizations.

To apply for a training email Ana Prados at Ana.I.Prados@nasa.gov

The program offers four types of courses. For in-person courses, applicants must provide a computer laboratory or similar facility.

1. Overview webinar course: held over a period of 4-5 weeks, 1 hour per week
2. Basic hands-on: In person applied remote sensing course for those new to remote sensing. Generally 2-3 days in length held. It is highly recommended that attendees first take the webinar course.
3. Advanced hands-on: In person applied remote sensing course that builds the skills to use NASA data for a specific environmental management problem. Intended for those who have already taken the basic course or have previous experience using NASA data and resources. Generally 1-2 days in length.
4. Train the Trainers: In person applied remote sensing course intended for existing remote sensing/geospatial trainers within the organization/institution/agency.

ARSET

Webinars

Workshops

Apply for Training

Personnel

Links

Upcoming Webinar

ARSET ListServ

For information on upcoming trainings and program updates sign up to the listserv

<https://lists.nasa.gov/mailman/listinfo/arset>

This Webinar Series

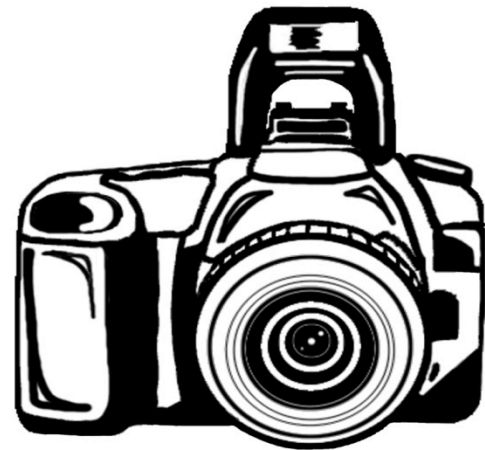
- **Week 1 – Introduction to Aerosol Products**
- **Week 2 – AOD – PM Methods, Tools**
- **Week 3 – Statistical Modeling of AOD-PM**
- **Week 4 – Combining satellite and model outputs**
- **Mini Project – [Read the document](#) - more next week**

Quiz # 1

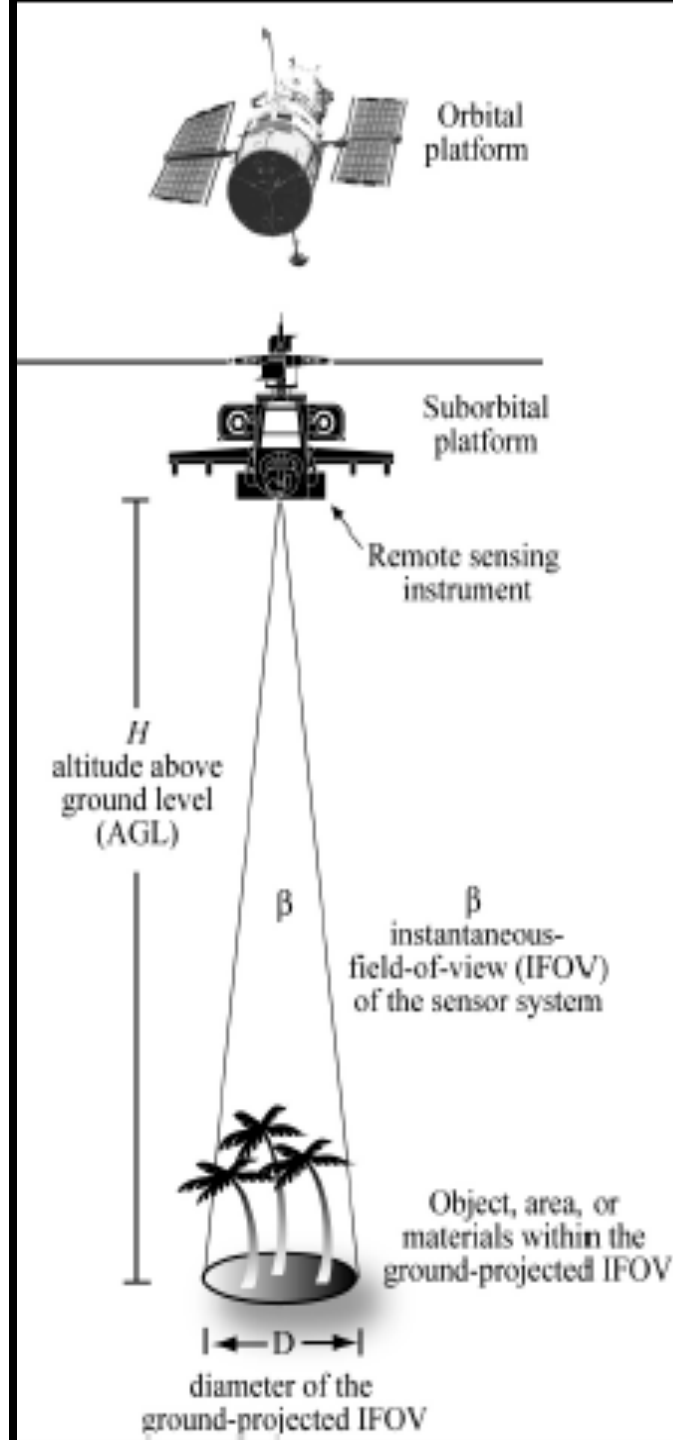
Remote Sensing

Remote Sensing

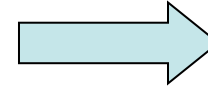
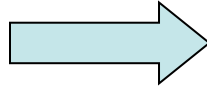
Collecting information about an object without being in direct physical contact with it.



Remote Sensing ...



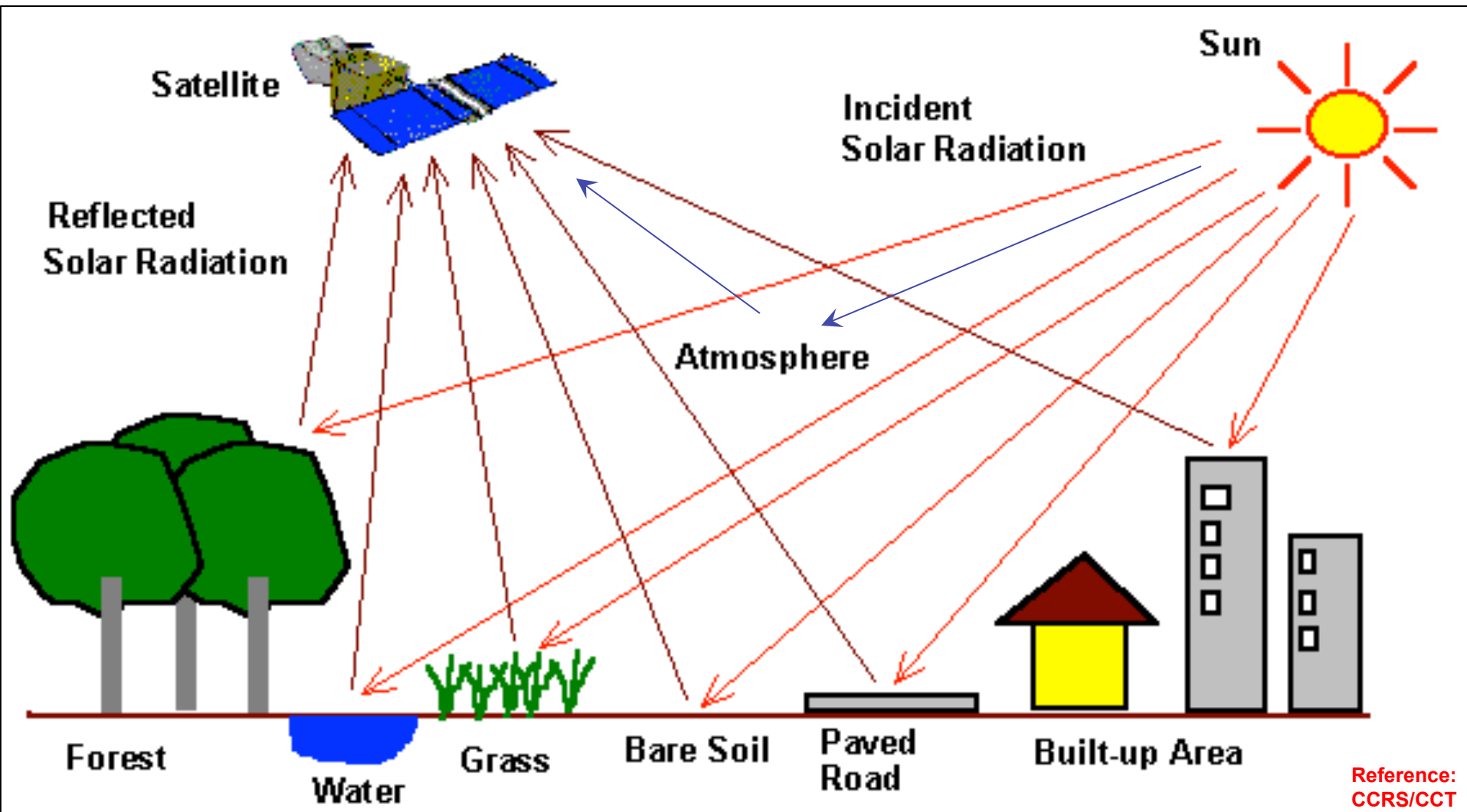
Remote Sensing: Platforms



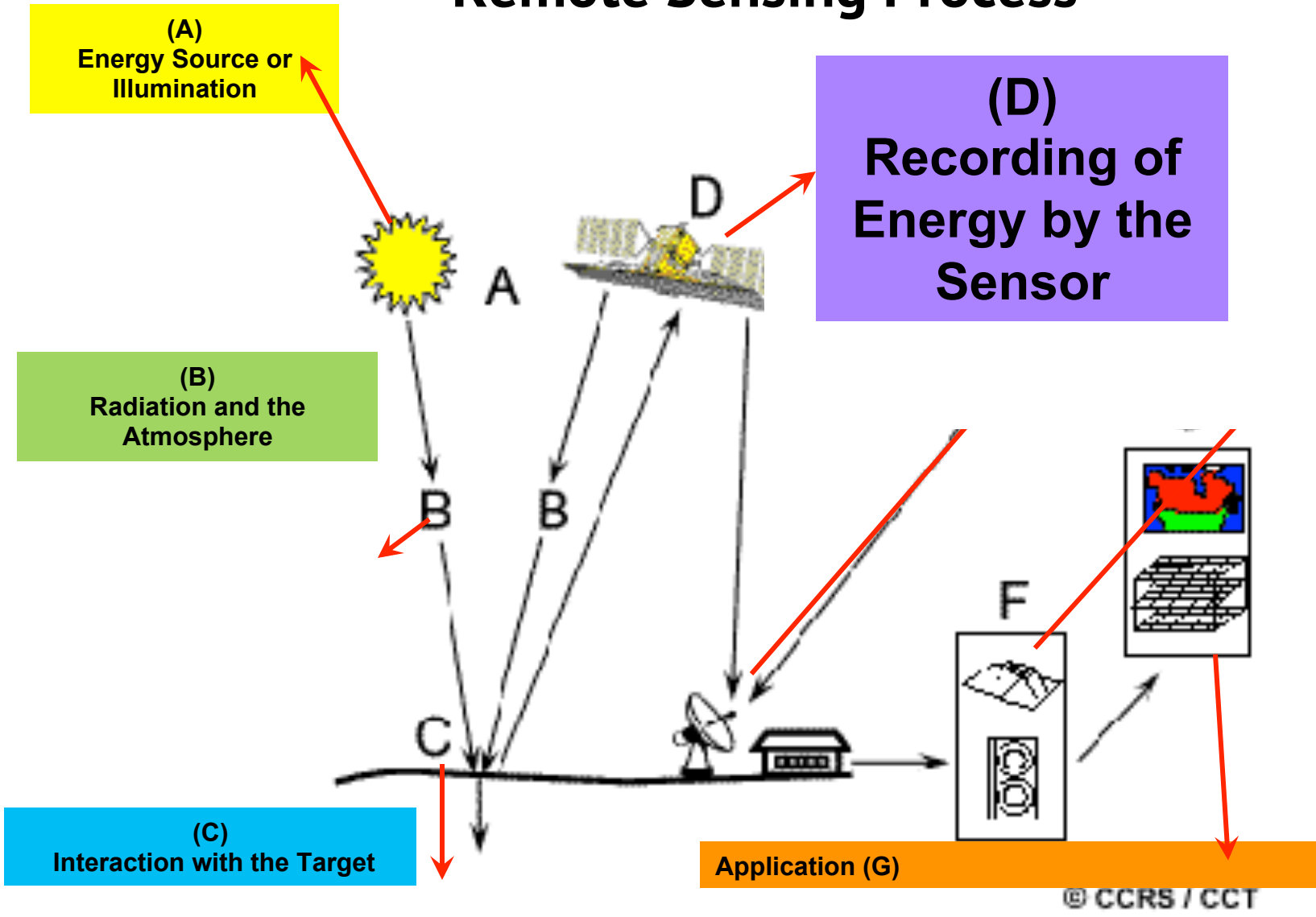
• **Platform depends on the application**

- **What information do we want?**
- **How much detail?**
- **What type of detail?**
- **How frequent?**

What does a satellite measure?



Remote Sensing Process



Suggested Tasks

- **Fundamentals of Remote Sensing**

http://arset.gsfc.nasa.gov/sites/default/files/airquality/webinars/Fundamentals/Fundamentals%20of%20Remote%20Sensing%20-%20Session%201_final.pdf

- Watch basic webinar recordings

<http://arset/airquality/webinars/introduction-remote-sensing-air-quality-applications-indian-sub-continent-and>

- Install Python 3 with pyhdf package

<http://arset.gsfc.nasa.gov/airquality/python-scripts-aerosol-data-sets-merra-modis-and-omi>

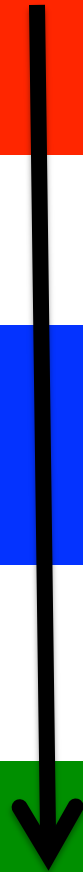
- Read the following article

- [Hoff & Christopher, 2009](#)

Particle Pollution

Particulate Matter

Atmospheric Aerosols



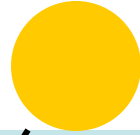
Aerosol Optical Depth

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

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

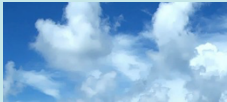
Optical Depth

Sun



Atmosphere

I_0



I

Surface



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

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

$$m = \sec \theta_0$$

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

AERONET

AEROSOL ROBOTIC NETWORK



Home

Aerosol Optical Depth

AEROSOL/FLUX NETWORKS

CAMPAIGNS

COLLABORATORS

DATA

LOGISTICS

NASA PROJECTS

OPERATIONS

PUBLICATIONS

SITE INFORMATION

STAFF

SYSTEM DESCRIPTION

AERONET DATA ACCESS

DATA SYNERGY TOOL

+ Data Display

AEROSOL OPTICAL DEPTH

+ Data Display

+ Download Tool

+ Download All Sites

+ Climatology Tables

AERONET Data Display Interface **Version 2 Direct Sun Algorithm**

Level 2.0. Quality Assured Data.

The following AERONET data are pre and post field calibrated, automatically cloud cleared and manually inspected.

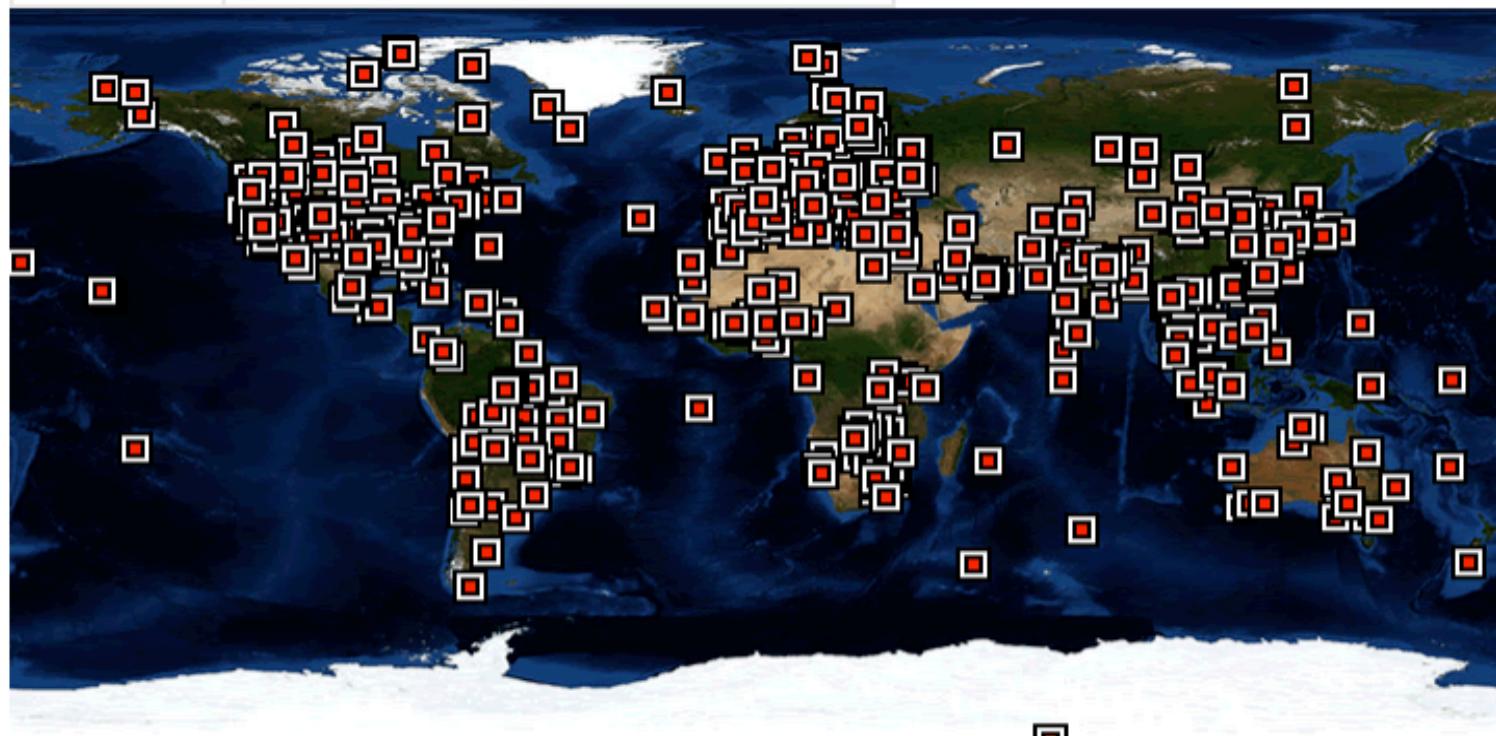
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015

To zoom the map click on it.

[Back to World Map](#)

Total Data (Years): All >0.5 >1 >2 >3 >5 >7 >10 >15

AOT Level Level 1.0 Level 1.5 Level 2.0



Abisko (68N,18E)

Abracos_Hill (10S,62W)

Abu_Dhabi (24N,54E)

Adelaide_Site_7 (34S,138E)



Cancel



Capture

Visibility and Aerosols



Moderate AOD ~ 0.40
Near Mt. Abu, India

Photo courtesy of Brent Holben

Visibility and PM_{2.5}



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

Both AOD and PM_{2.5} represent the presence of aerosols and its impact on visibility or haziness of the atmosphere.

Aerosols from Satellites

Aerosol Retrieval

**Start with aerosol
detection ...**

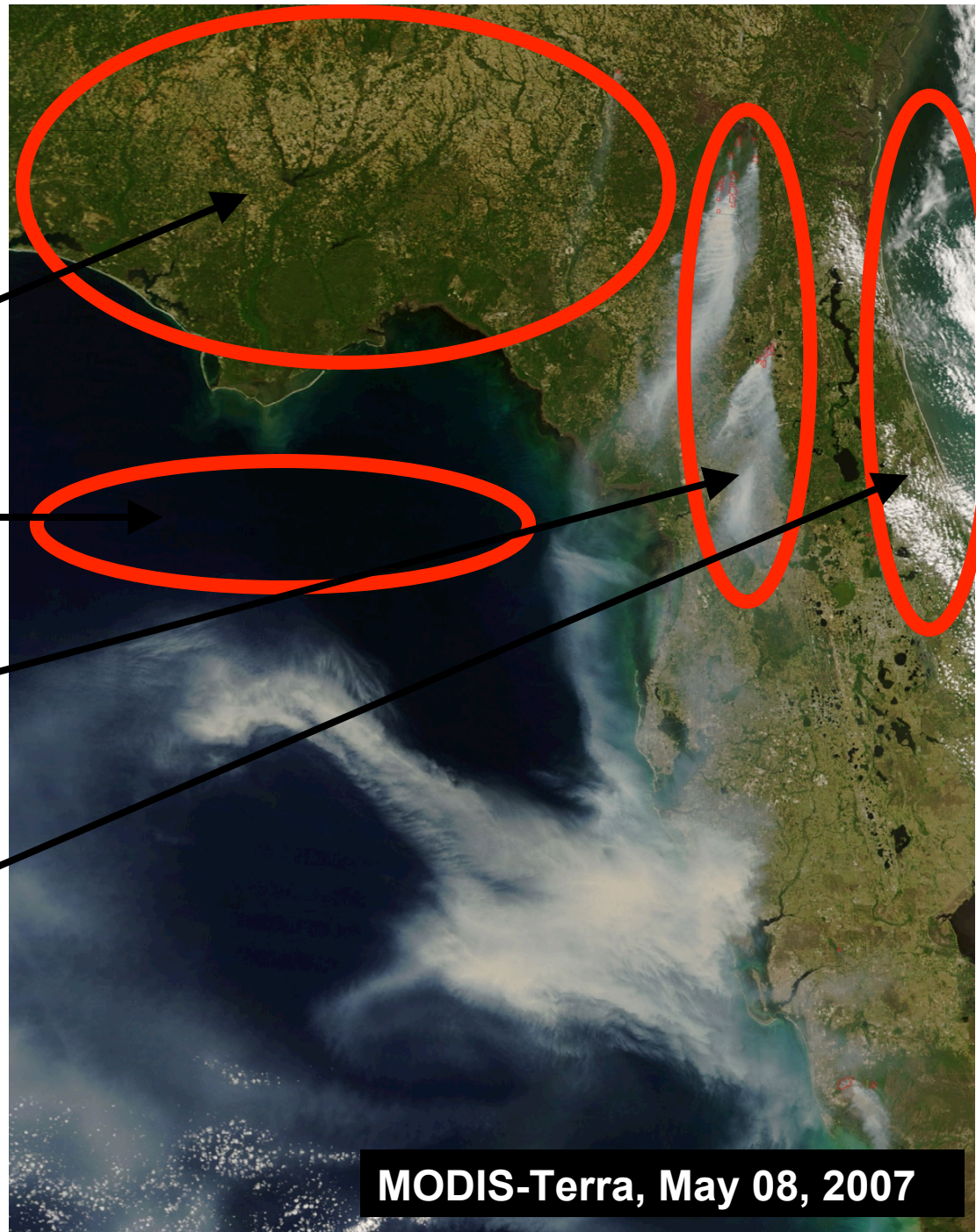
Satellite Observations & Pollution

Land

Water

Smoke

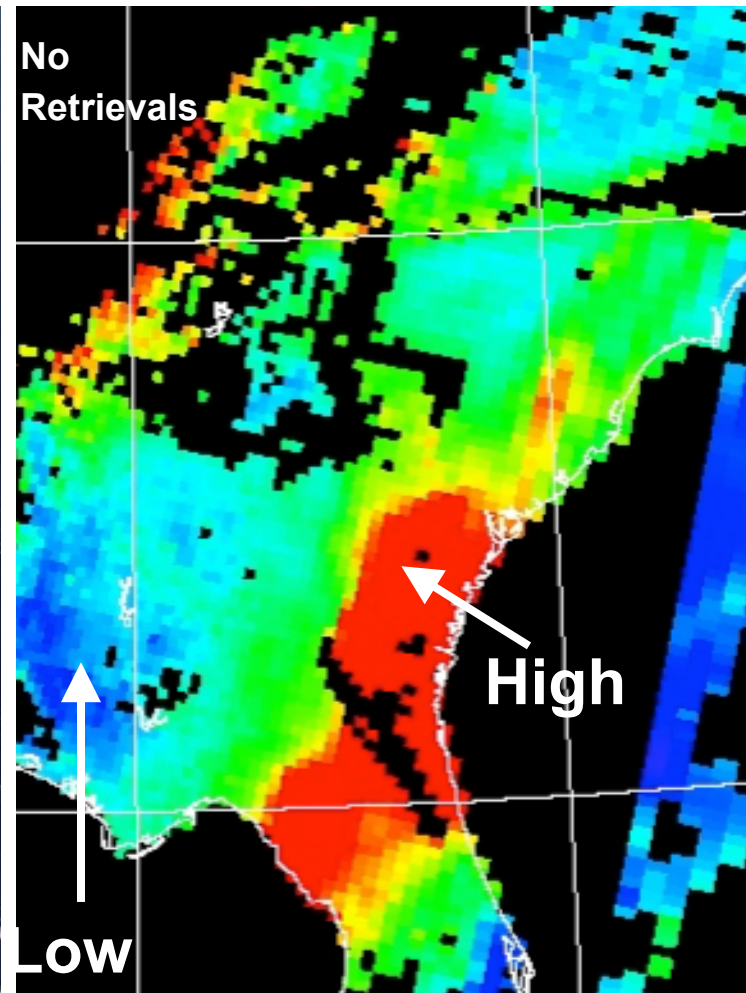
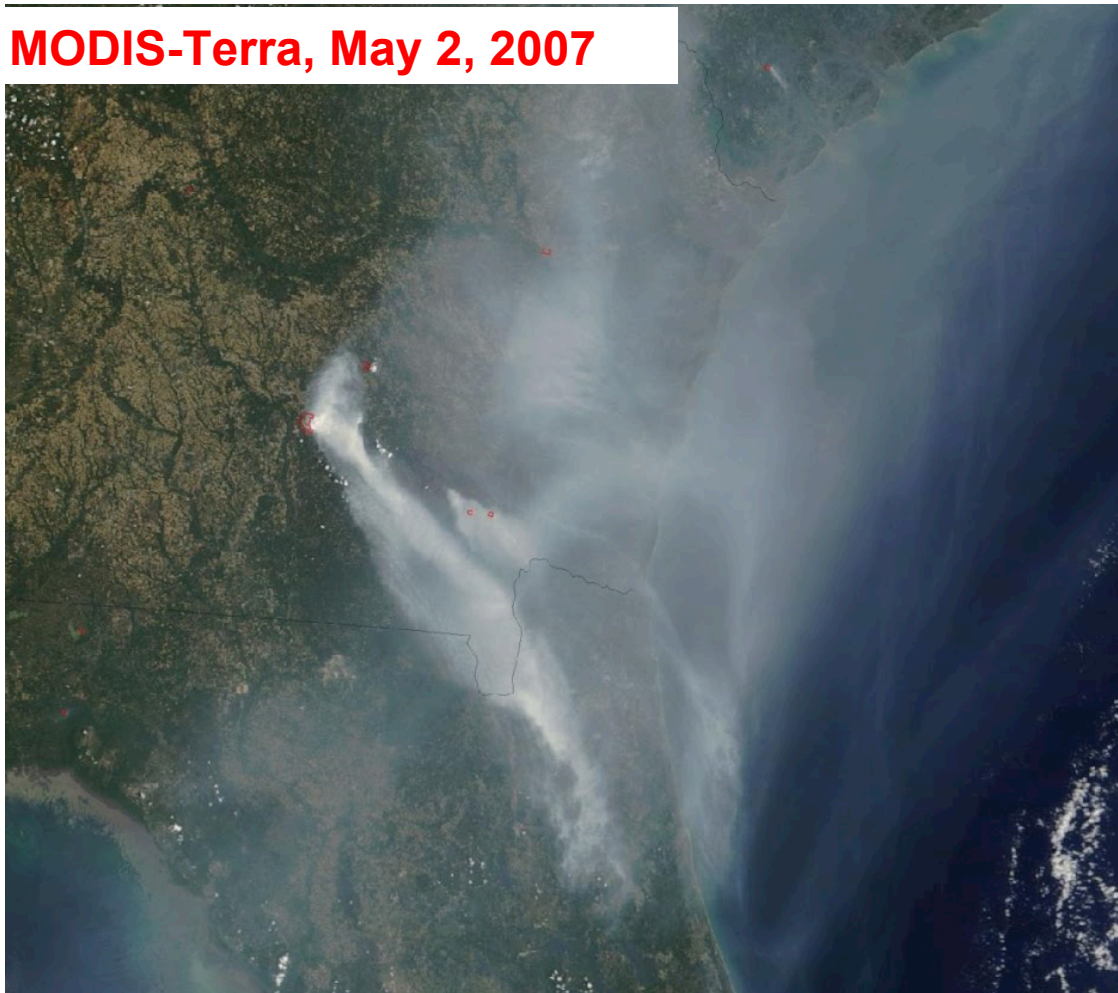
Clouds



MODIS-Terra, May 08, 2007

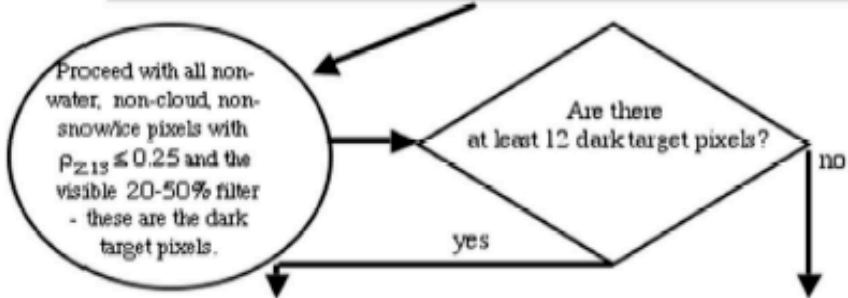
Radiance -to- Aerosol Products

MODIS-Terra, May 2, 2007

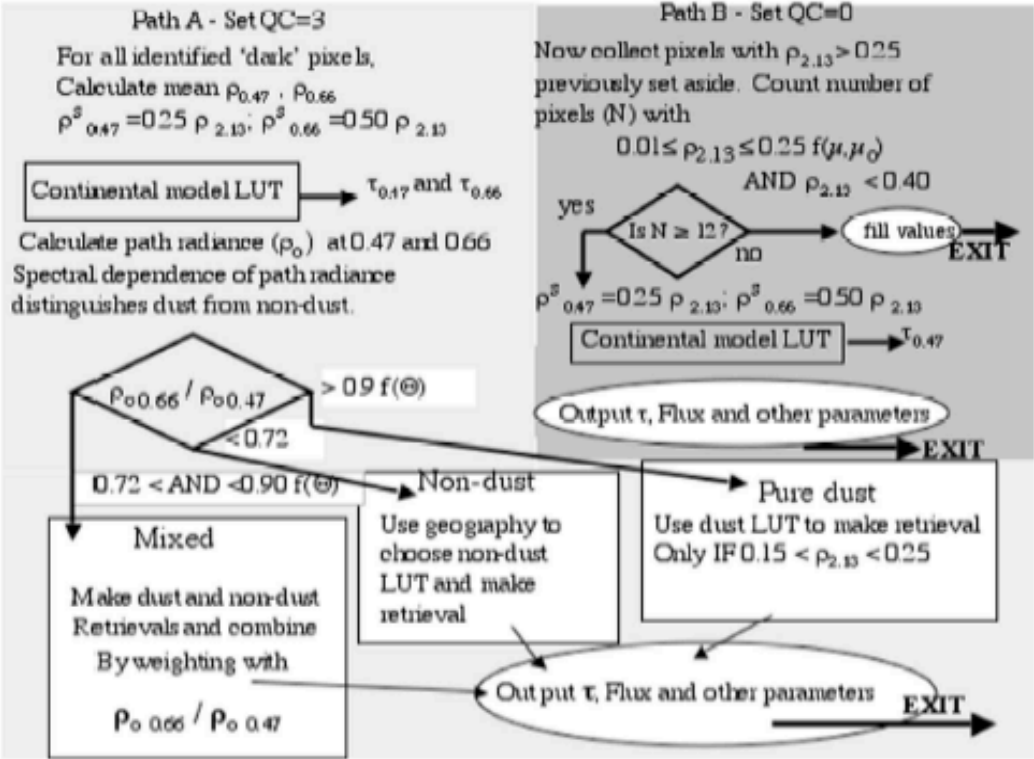


MODIS Over Land Algorithm
 All procedures applied to individual boxes of 20 x 20 pixels at 500 m resolution (10 km at nadir)

Identify and mask all water, cloudy and snow/ice pixels.
 Separate all pixels that are outside of $0.01 < \rho_{2,13} \leq 0.25$
 Discard brightest 50% and darkest 20% of pixels defined with $\rho_{0,66}$



Proceed with all non-water, non-cloud, non-snow/ice pixels with $\rho_{2,13} \leq 0.25$ and the visible 20-50% filter - these are the dark target pixels.

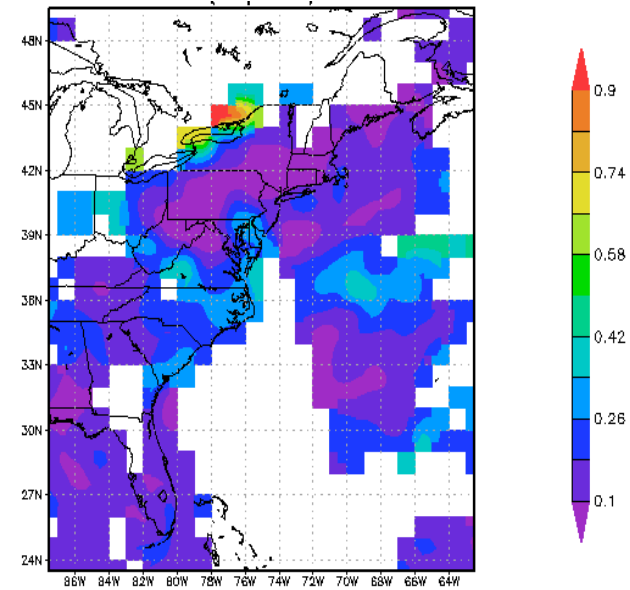
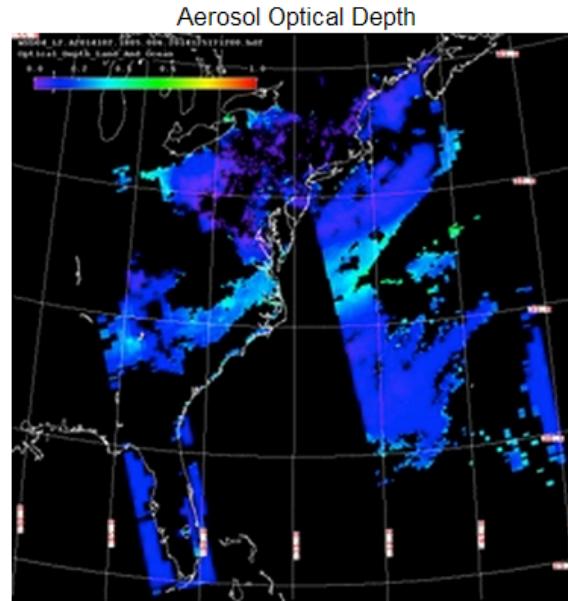
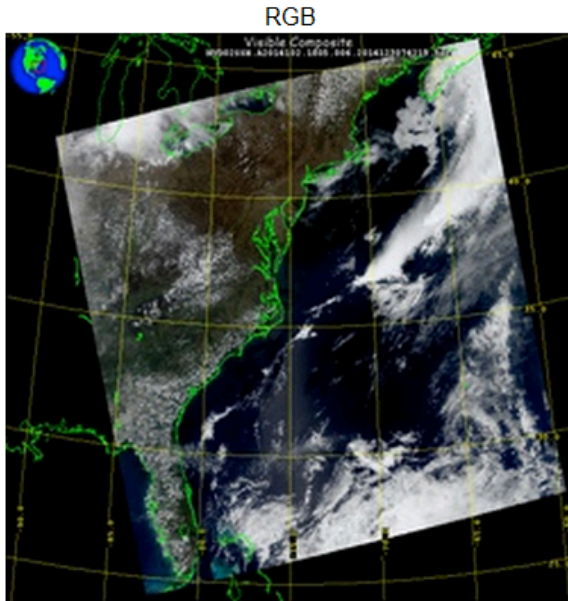


An Aerosol retrieval algorithm is a complex inversion scheme where assumptions are made in simulating satellite observations with advance radiative transfer calculations to retrieve atmospheric aerosol properties

Data Levels

Levels of Data

April 12, 2014



Level 1B

**Calibration to
Radiance**

Level 2

**Aerosol
Retrieval
Algorithm**

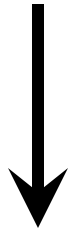
Level 3

**Spatial &
Temporal
Averaging**

Data Product Hierarchy

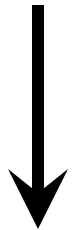
Level 1 Products - Raw data with and without applied calibration.

- **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

MISR- 275m- 1.1 KM

OMI – 13 x 24 KM

VIIRS – 750 m

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 of
405 nm (blue) to
14.385 μm (infrared)

MODIS Products

(MOD for Terra/MYD for Aqua)

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

A few more things to know about MODIS DATA

MOD - Terra product
MYD - Aqua product

- All MODIS products come in **HDF** format
- Each HDF file contains both data and metadata
- **SDS** - Each parameter within a HDF file is referred to as an SDS (Scientific Data Set)

Things that change with each instrument

And you therefore need to learn!

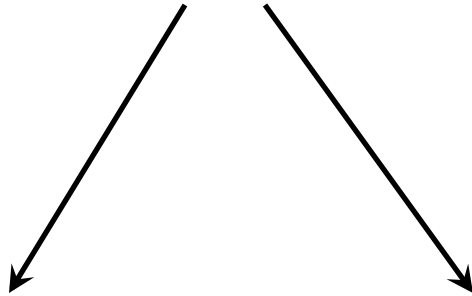
- **Calibration accuracy.**
- **Quality Assurance – quality of the data.**
- **Data formats.**
- **Product Resolutions.**
- **How level 3 products are created from level 2 products
(temporally and spatially averaging).**
- **Current release of the data and data history.**

MODIS Aerosol Products

Three Separate Algorithms

Land

Ocean



Dark Target

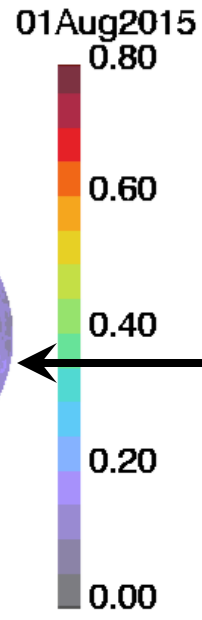
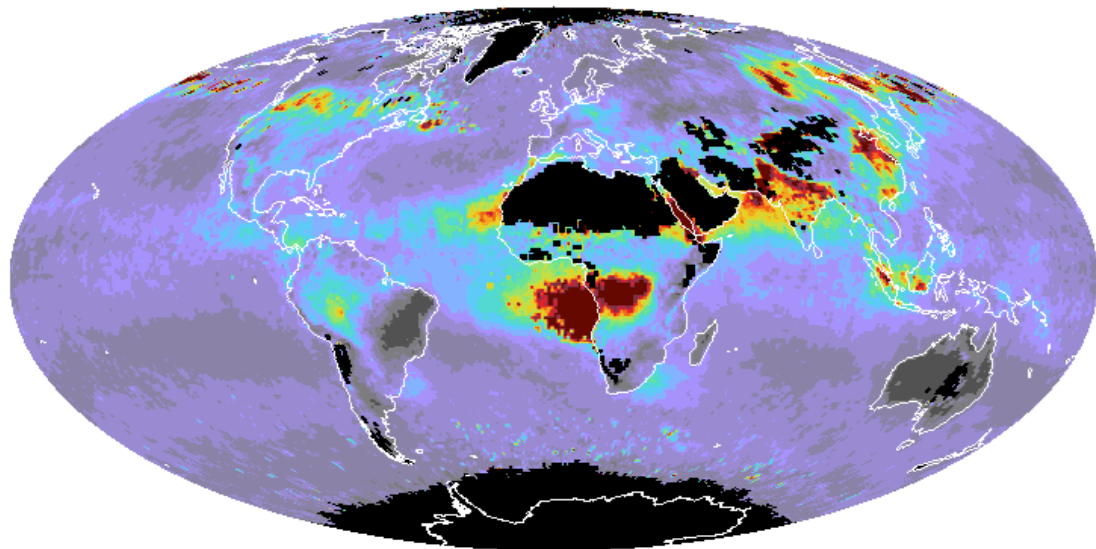
Deep Blue – Used over bright land surfaces

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 is a joint product that uses an automated procedure to select the appropriate product.

Aerosol_Optical_Depth_Land_Ocean_Mean_Mean



August 2015, MODIS-AQUA

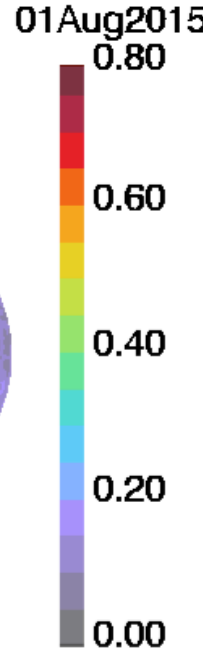
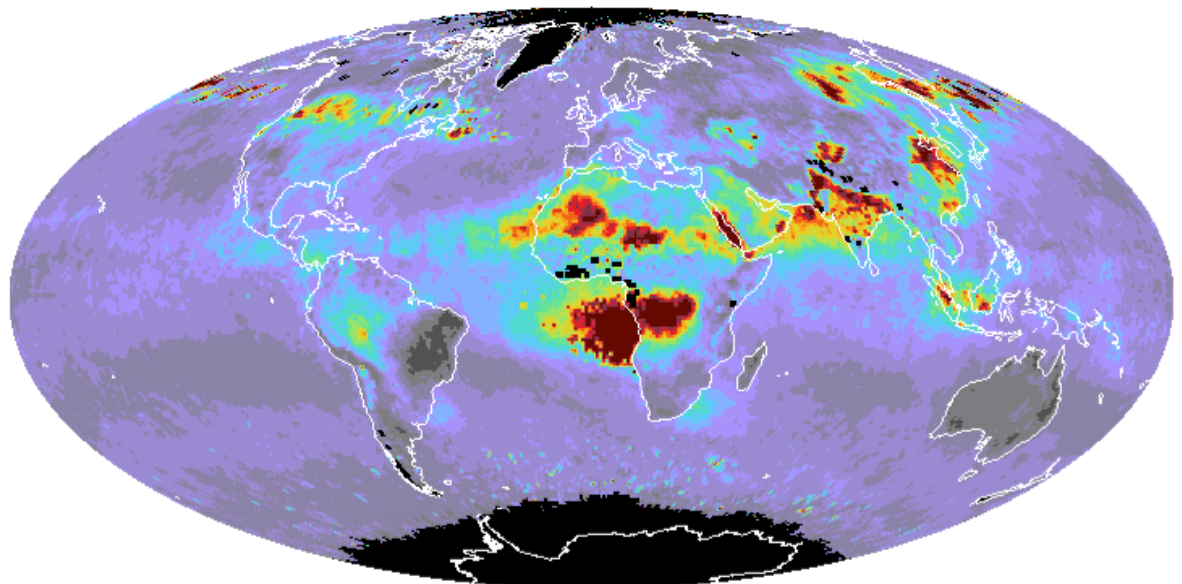
Dark Target

MODIS/Aqua MYD08_M3.A2015213.006.2015244230210.hdf

none

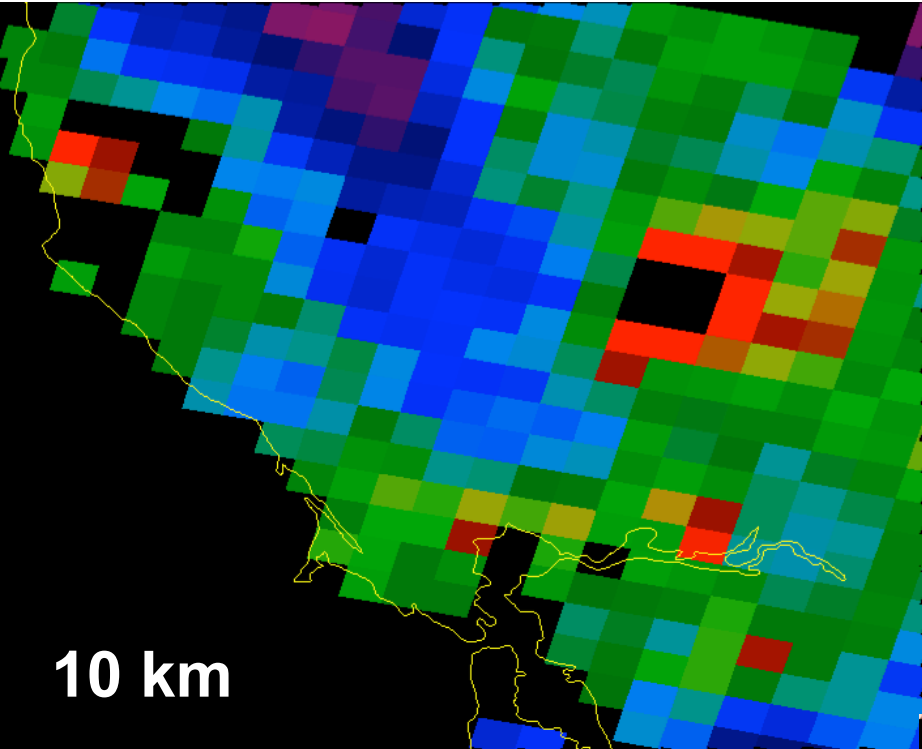
AOD_550_Dark_Target_Deep_Blue_Combined_Mean_Mean

Deep_Dark_Combined



MODIS/Aqua MYD08_M3.A2015213.006.2015244230210.hdf

none



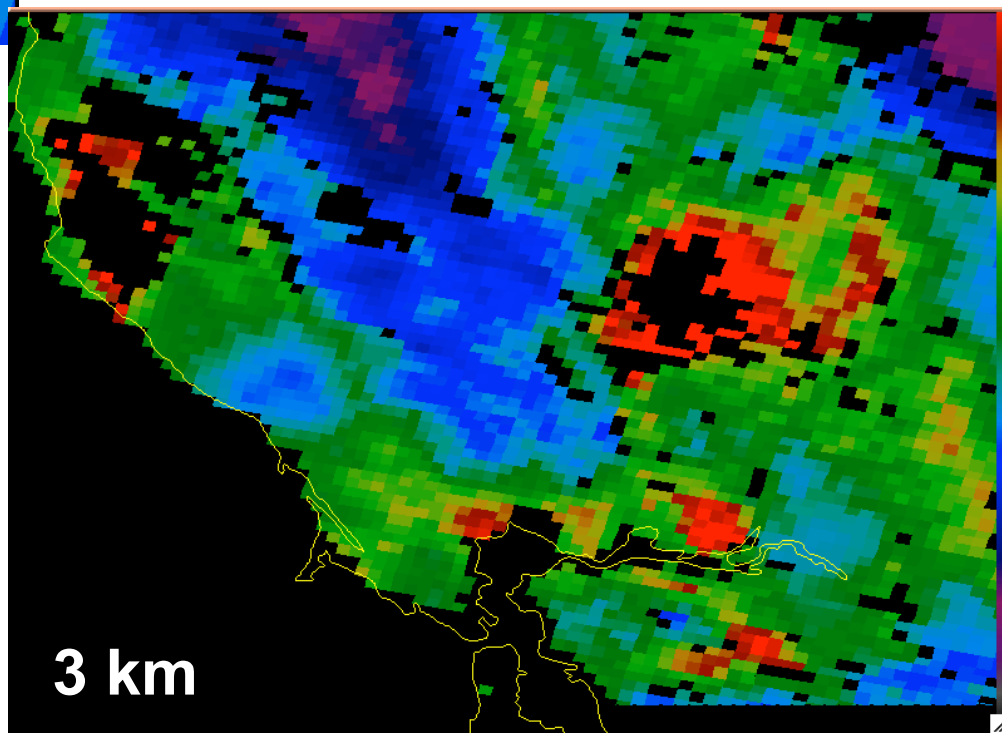
MODIS 10 KM

VS

3 KM Products

(3 km product is only available from dark target algorithm)

3 km AOD product is available in Collection 6 Data Release



3 km

Quality Assurance (QA) 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

Time **Collection**

MOD04_L2.A2001079.0255.006.2006289012028.hdf

Product Name Date - **year**, **Julian** day File processing information

The diagram illustrates the structure of a MODIS file name. The file name is 'MOD04_L2.A2001079.0255.006.2006289012028.hdf'. It is broken down into three main parts: 'MOD04_L2.A' (Product Name), '2001079' (Date - year, Julian day), and '0255.006.2006289012028' (File processing information). The labels 'Time' and 'Collection' are positioned above the date and product name respectively, with lines pointing to their corresponding parts in the file name.

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)

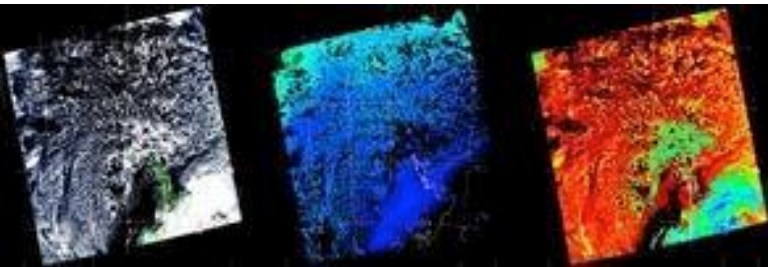
Reference:

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

Satellite Aerosol Products

In/InI	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

Live Demo of MODIS Level 2 Aerosol Data Download



LAADS Web

Level 1 and Atmosphere Archive and Distribution System

<https://ladsweb.nascom.nasa.gov/>

Week 1 Homework

(Due on October 07, 2015)

Objective: *This exercise aims to provide hands-on experience with downloading MODIS Level 2 aerosols data sets.*

<http://goo.gl/forms/EEuLOKjsb3>