National Aeronautics and Space Administration

NASA Earth Science Division Applied Sciences Program

DEVELOP National Program



Overview of NASA Satellite Data Products Used in Assessing Potential Air Quality Impacts from the *Deepwater Horizon* Oil Spill

Josh Stodghill and Jason Jones – May 13, 2011

Presentation Outline

- About NASA's DEVELOP Program
- Overview of NASA's Atmospheric Remote Sensing Instruments: Uses and Limitations
- DEVELOP Oil Spill Air Quality Research
- Acquiring Data and Tutorials

About DEVELOP

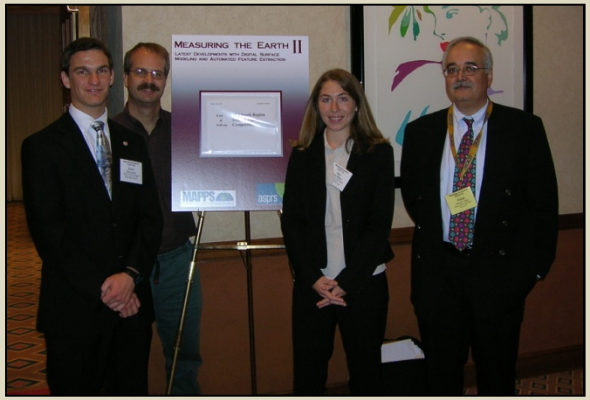
Who We Are



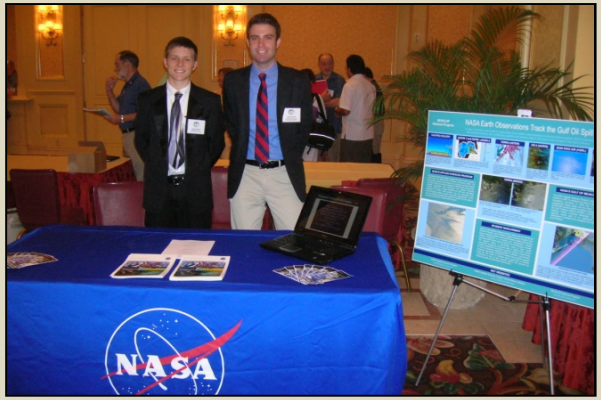
**NASA's Applied Sciences'
DEVELOP National Program**



DEVELOP empowers students and young professionals to extend the benefits of NASA Earth Science to their local communities.



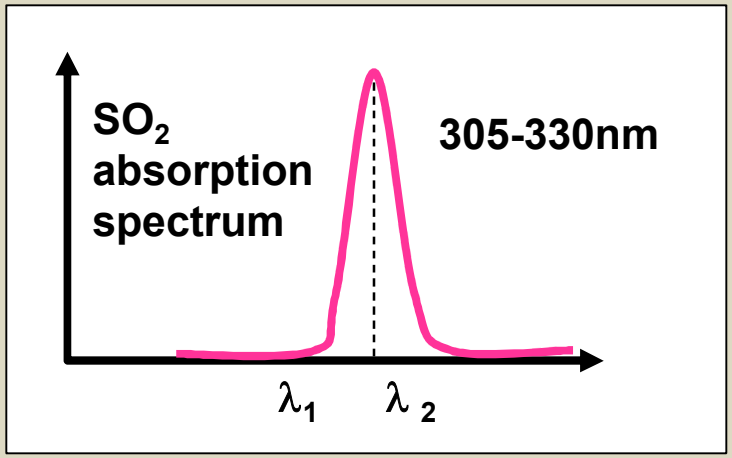


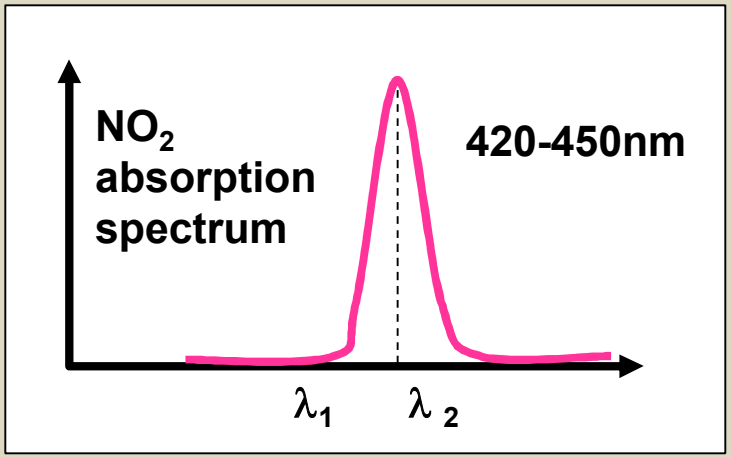


Atmospheric Remote Sensing Instruments

Key Remote Sensing Principles

- Incoming solar radiation can be scattered (reflected), absorbed, or transmitted.
- Various substances and gases possess differing optical properties.
- Sensors/algorithms capitalize on these differences.



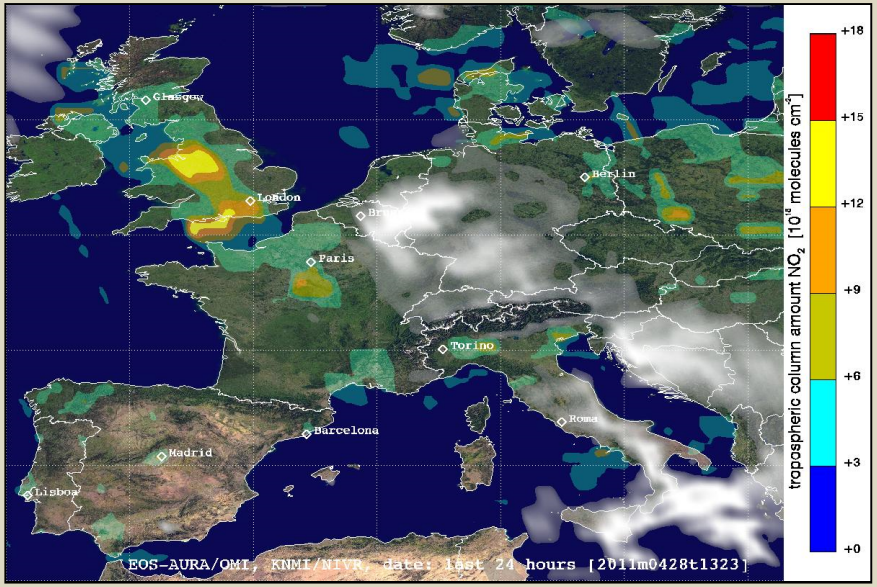


Example Trace Gas Absorption Spectra from a Presentation by Jun Wang, University of Nebraska – Lincoln

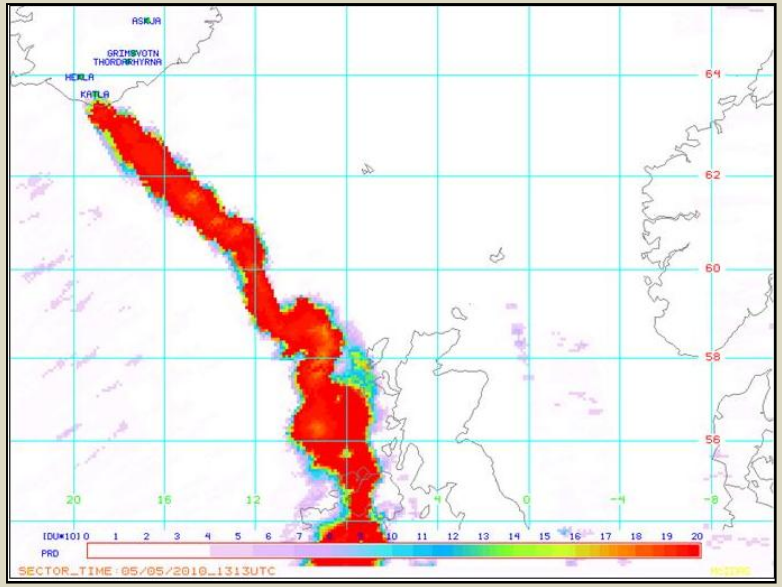
http://arset.gsfc.nasa.gov/materials/index_new.php

OMI

- Ozone Monitoring Instrument
- Dutch/Finish sensor onboard NASA's *Aura* satellite
- Estimates ozone, cloud, aerosol, trace gas, and surface irradiance from UV/Visible backscatter



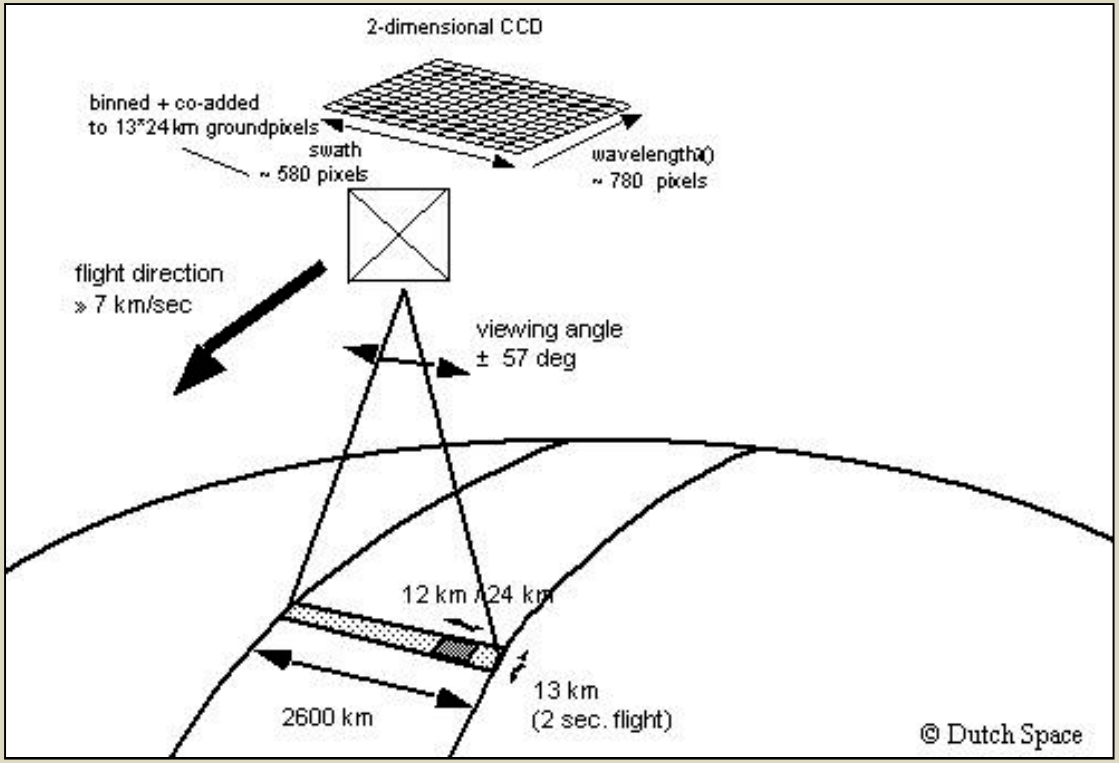
24-Hour NO_2 Composite over Europe, April 28, 2011
Image Credit: KNMI/NIVR



Eyjafjallajökull Volcanic SO_2 Plume, May 5, 2010
Image Credit: NASA

OMI Characteristics

- Measures backscatter in UV/visible λs (264 – 504 nm)
- 2,600 km swath, 14 orbits/day (global coverage)
- 13 x 24 km^2 pixels at nadir, 28 x 150 km^2 at edges



OMI Measurement Design Illustration Adapted from OMI Data User's Guide

OMI Data Products

- Generated by the OMI Science Investigator-led Processing System (SIPS)
- Archived by the NASA Goddard Earth Sciences Data and Information Services Center (GES DISC)
- Different processing levels (levels 0 – 3)
- Swath, gridded, and time composite products
- O_3, NO_2, SO_2, BrO, HCHO, OClO, and aerosols

http://disc.sci.gsfc.nasa.gov/Aura/additional/documentation/README.OMI_DUG.pdf

OMI Data User's Guide

http://mirador.gsfc.nasa.gov

Mirador: Portal for Data Access and Documentation

OMI Ozone Products

- Three Level 2 ozone products / algorithms
- Two “column” products and one “profile” product
- Difficult to measure tropospheric ozone precisely

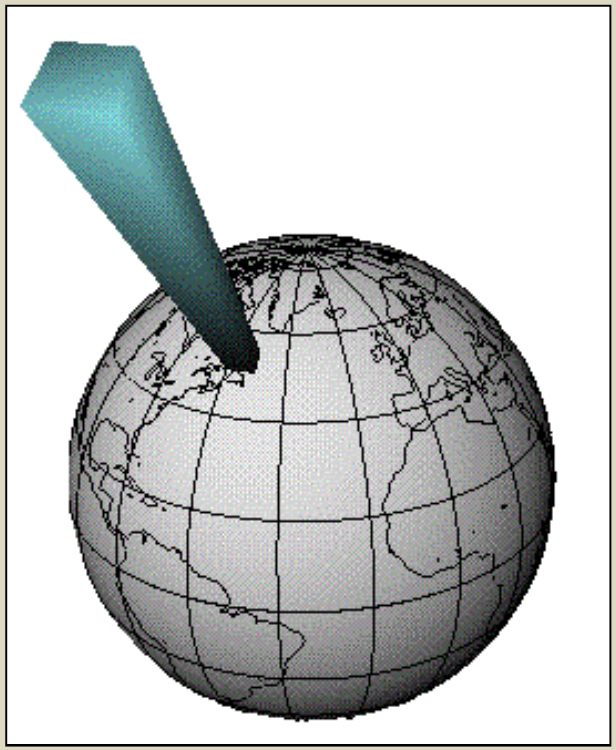
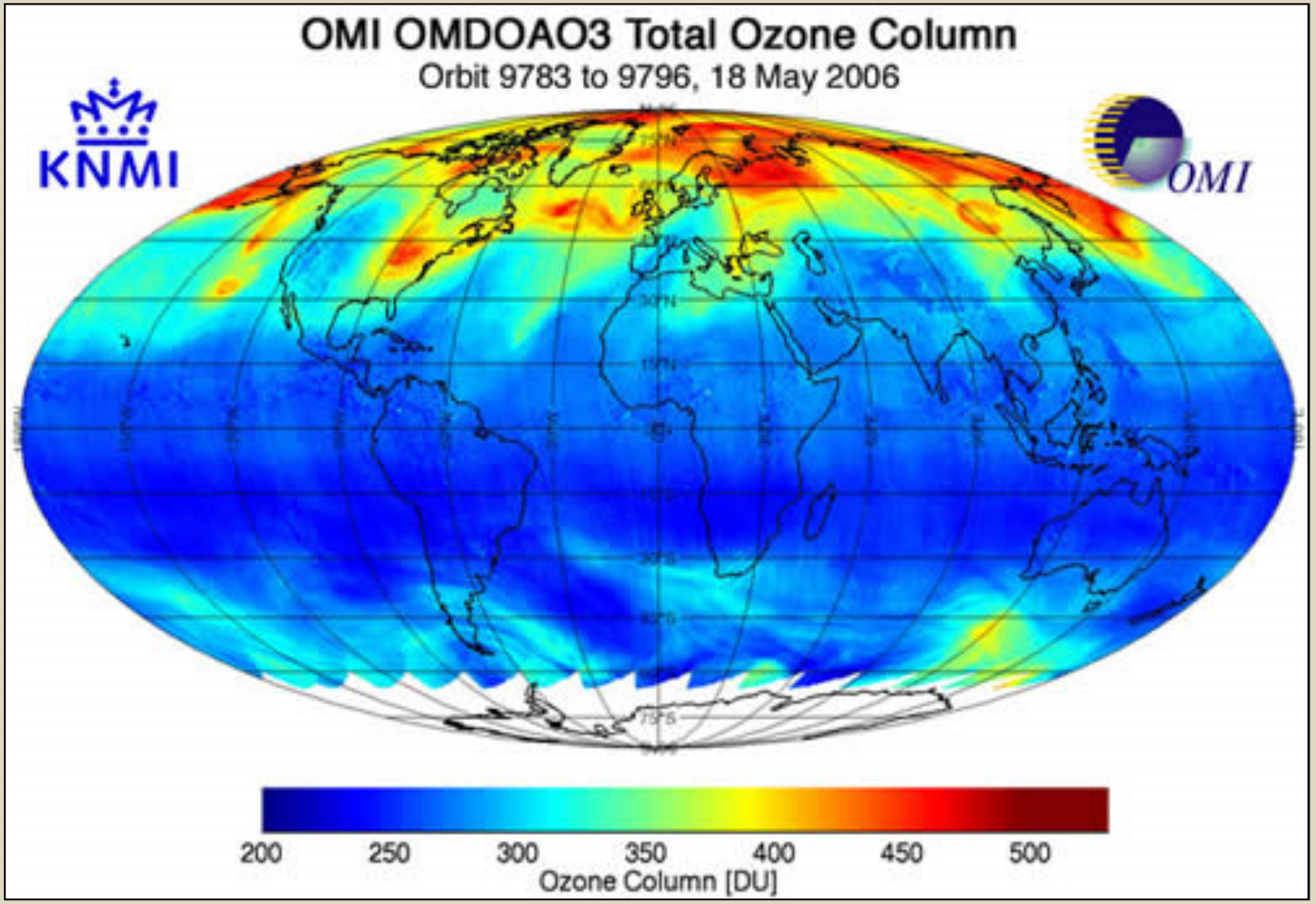


Illustration of an Ozone Column Measurement
Graphic Credit: NASA GSFC / Cambridge University

OMI Ozone Product Example



Global Map of Total Ozone Columns (May 18, 2006) Produced from OMI DOAS Algorithm
Image Source: NASA Mirador

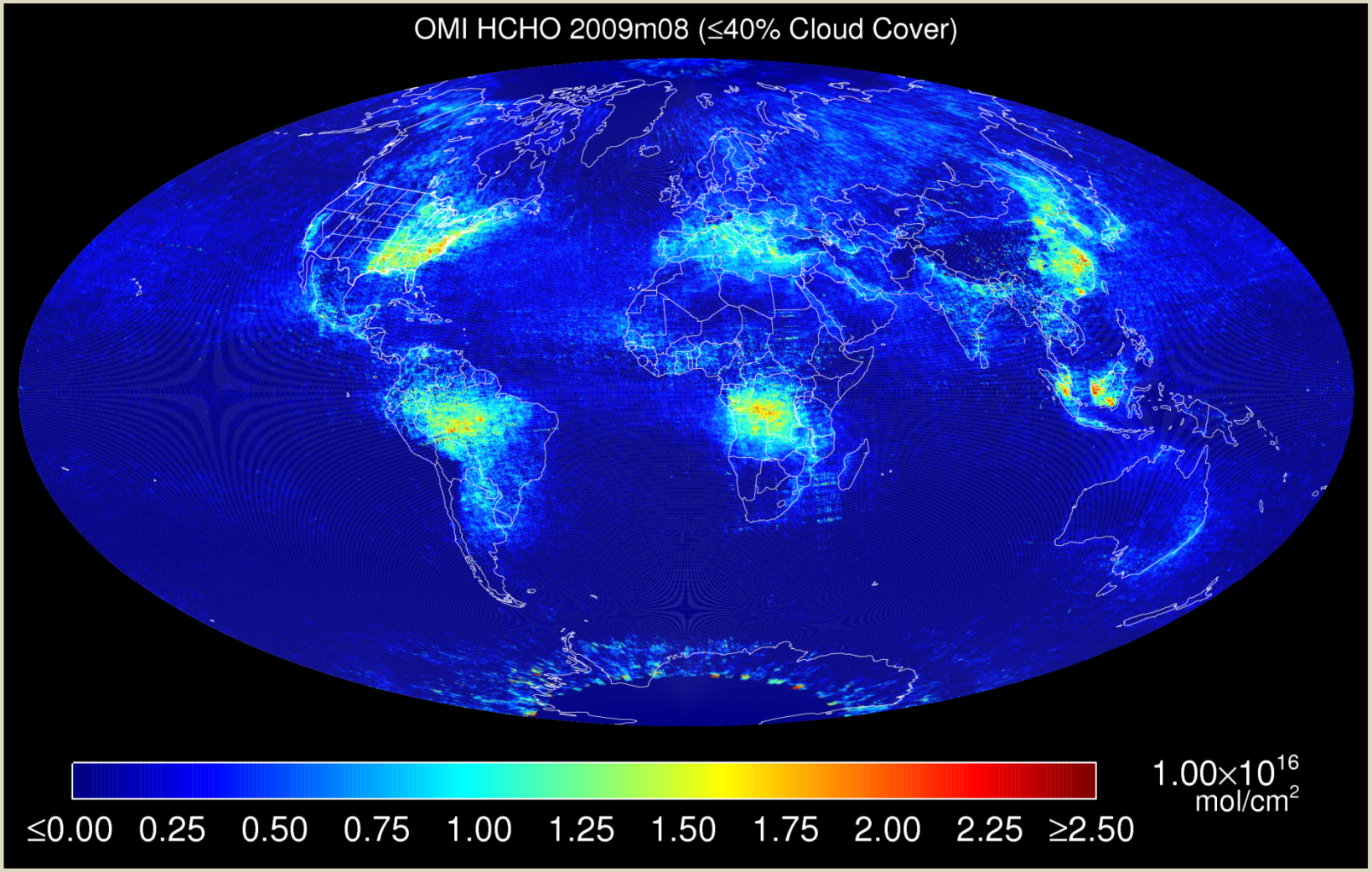
OMI Formaldehyde (HCHO) Product

- Product name: OMHCHO
- Total column estimate of formaldehyde per pixel
- Units in molecules / cm^2
- HCHO is a small absorber (difficult to measure)
- Estimated by non-linear least-squares fitting algorithm
- Best guess through numeric iteration
- 50% to 105% uncertainty!

http://mirador.gsfc.nasa.gov

Mirador Portal for Data Access and Documentation

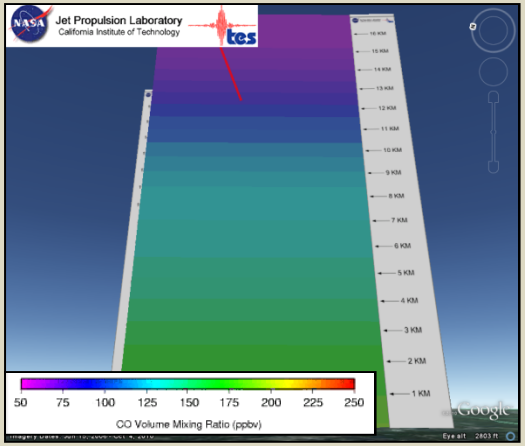
OMI HCHO Product Example



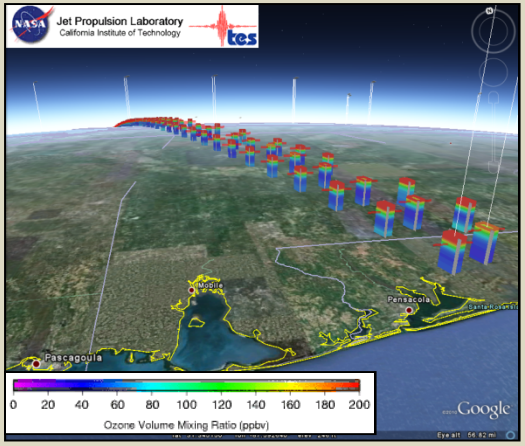
August 2009 Global Average HCHO Column Amounts. Image Credit: Dr. Thomas Kurosu

TES

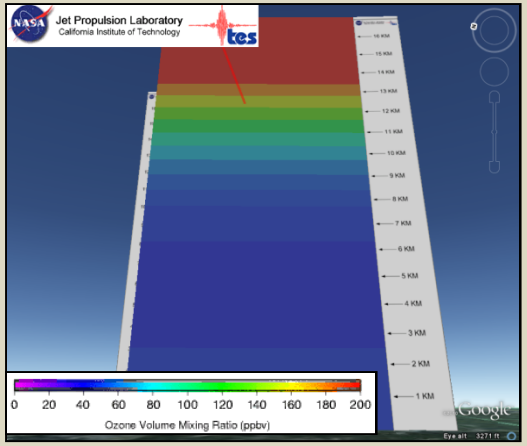
- Tropospheric Emission Spectrometer
- 16-day revisit time (*Aura* satellite)
- Measures O_3, CO, H_2O, HDO, CH_4, HNO_3 profiles
- 5.3 x 8.3 km swath with 0.53 x 5.3 km pixels
- Launched on July 15, 2004



TES CO March 25, 2010
South of Tuscaloosa, AL
Image Credit: NASA

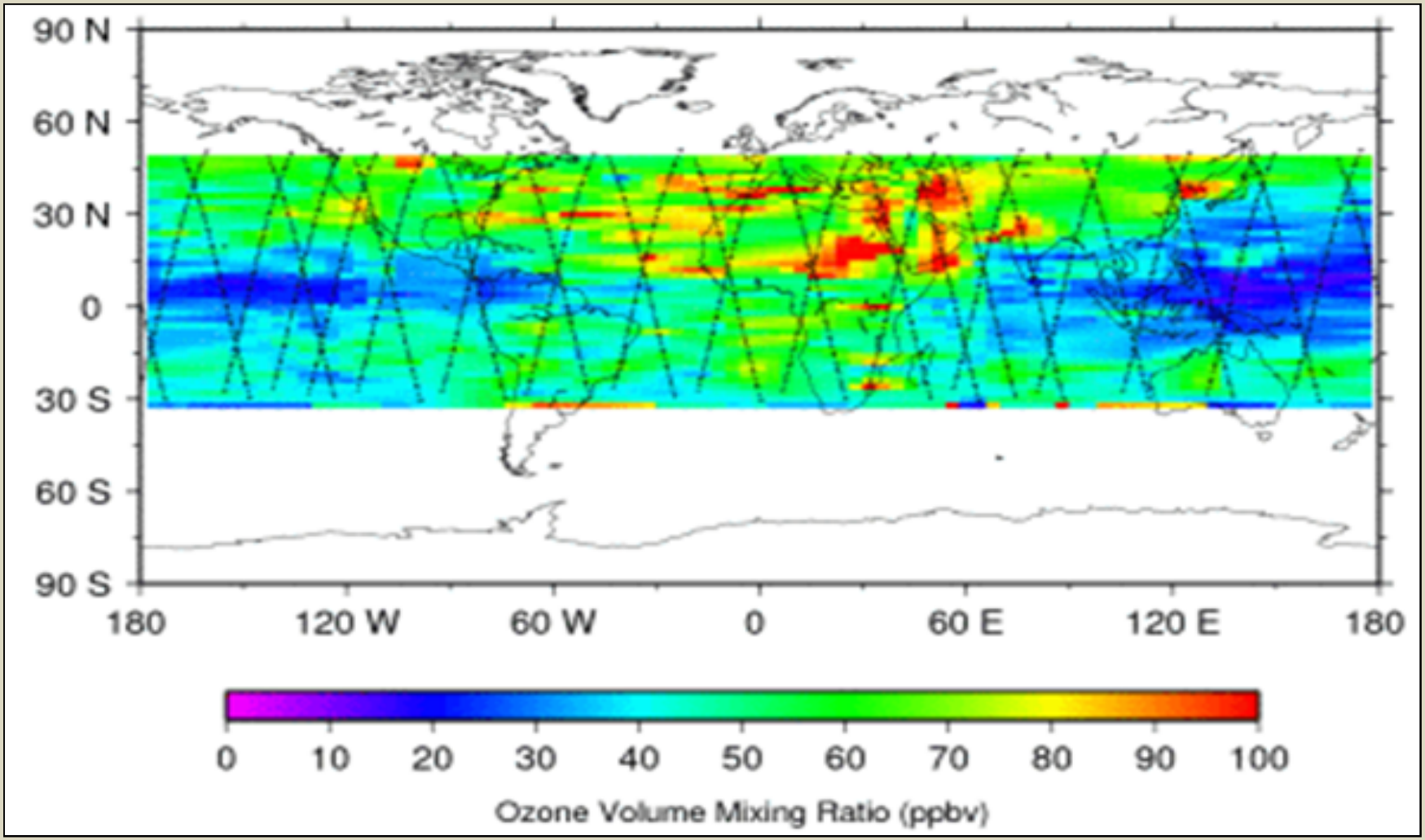


TES O_3 April/March 2010
Across Alabama
Image Credit: NASA



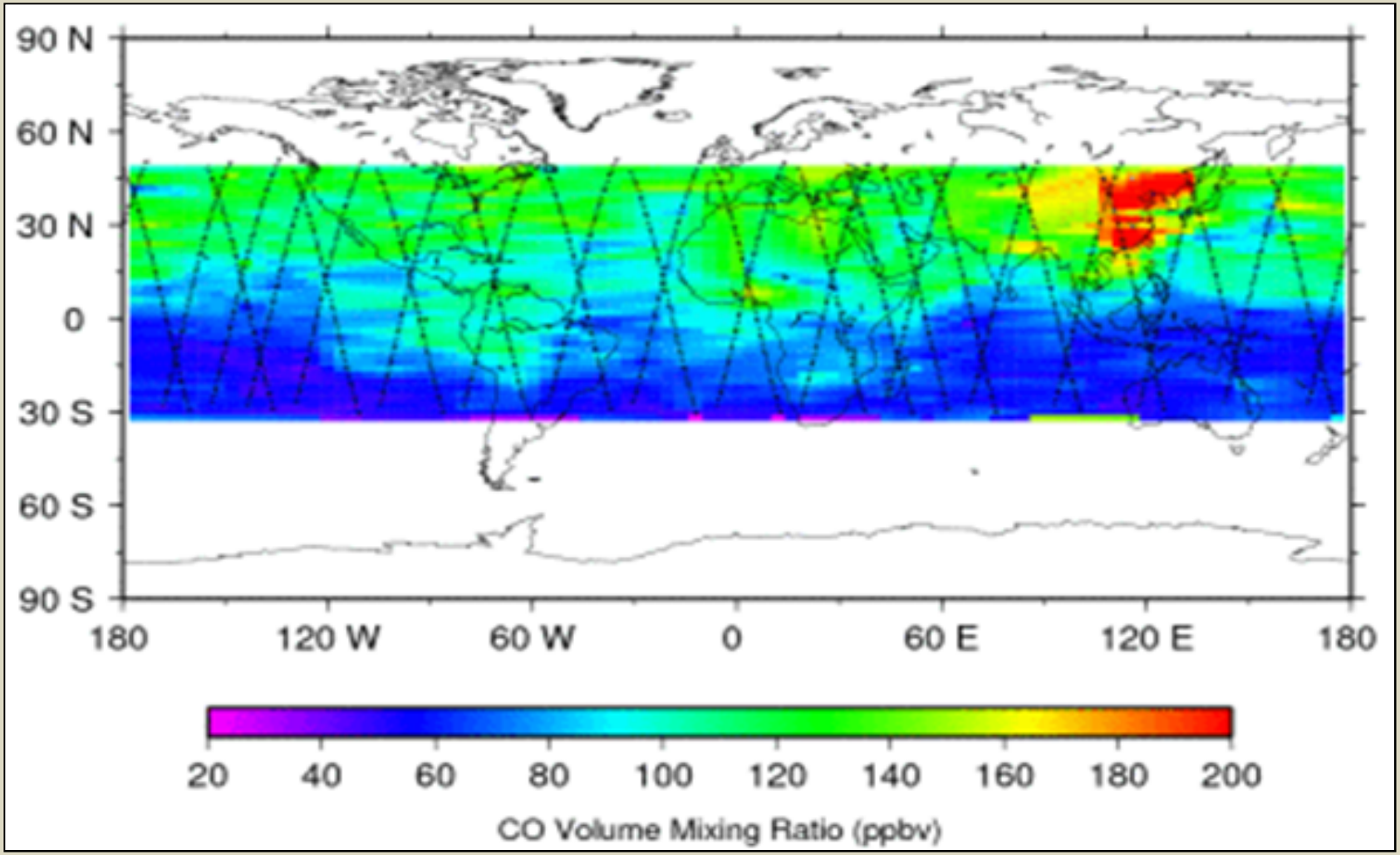
TES O_3 March 25, 2010
South of Tuscaloosa, AL
Image Credit: NASA

TES



TES L3 Ozone Daily Product – June 26-27, 2010. Image Credit: NASA

TES



TES L3 CO Daily Product – May 1-2, 2010. Image Credit: NASA

TES Data Sources

http://eosweb.larc.nasa.gov/PRODOCS/tes/table_tes.html

TES Data and Information

https://wist.echo.nasa.gov/api/

Data – WIST

http://gdata1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=tes_l3daily

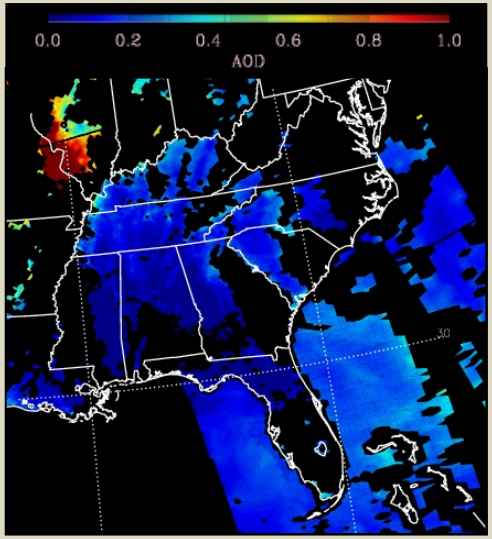
Data Viewer – Giovanni

http://tes.jpl.nasa.gov/visualization/l3plots/

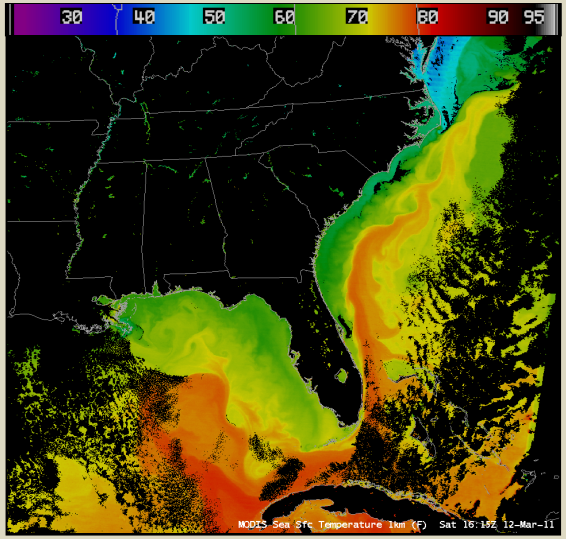
Level 2 & 3 Data Product Viewer

MODIS

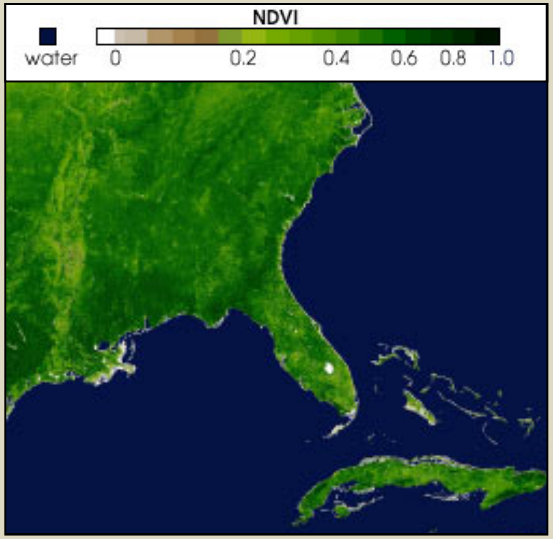
- Moderate Resolution Imaging Spectroradiometer
- Flies over twice daily (*Aqua* and *Terra* satellites)
- 36 spectral bands, 250 m – 10 km products
- Atmospheric, oceanic, and terrestrial applications



Aqua MODIS AOD
April 10, 2011
NOAA NESDIS STAR



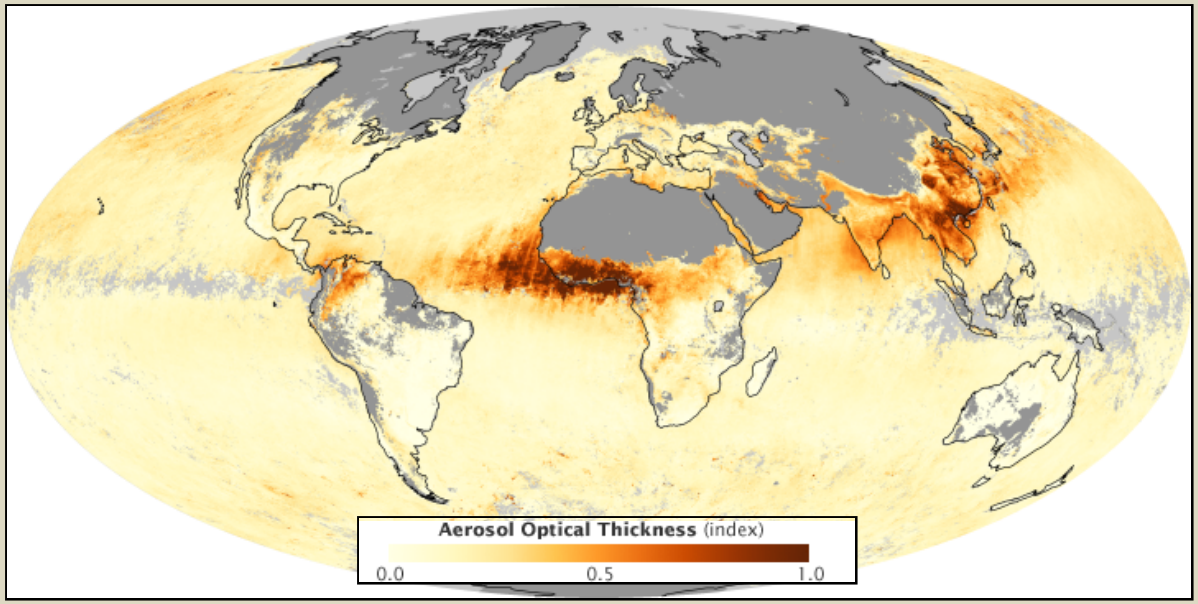
MODIS SST °F
March 12, 2011
NWS/Univ. of Wisconsin-Madison



Subset of MODIS NDVI Composite
March 5 – 20, 2000
NASA/University of Arizona

MODIS Aerosol Product

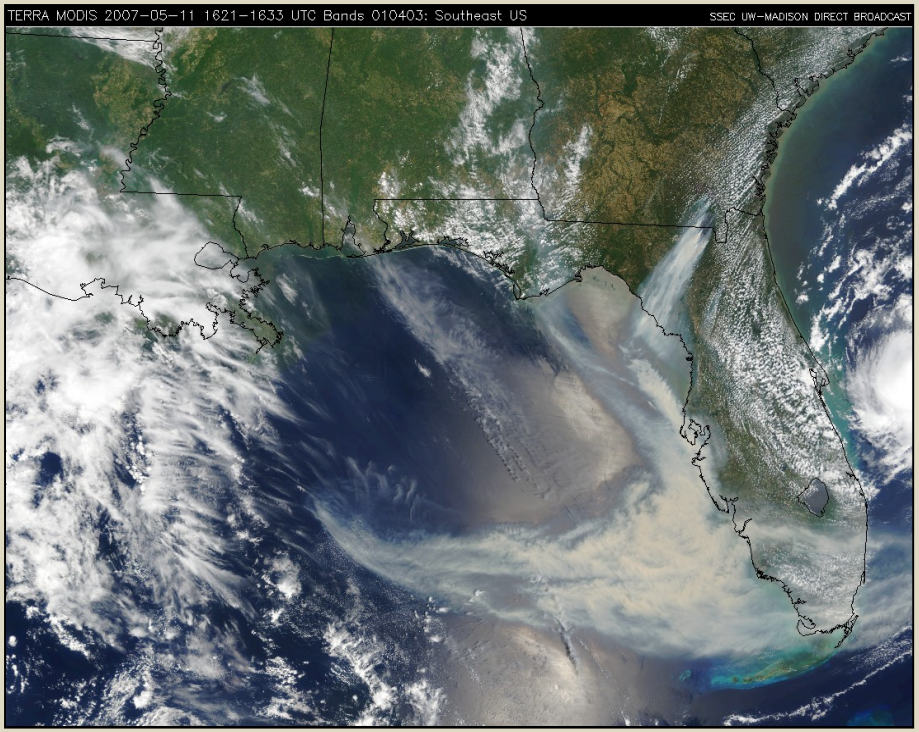
- Aerosols include dust, sea salt, smoke, ash, etc.
- MODIS makes column measurements of aerosol optical thickness (AOT), a measure of opacity.
- AOT is also called “Aerosol Optical Depth” (AOD).



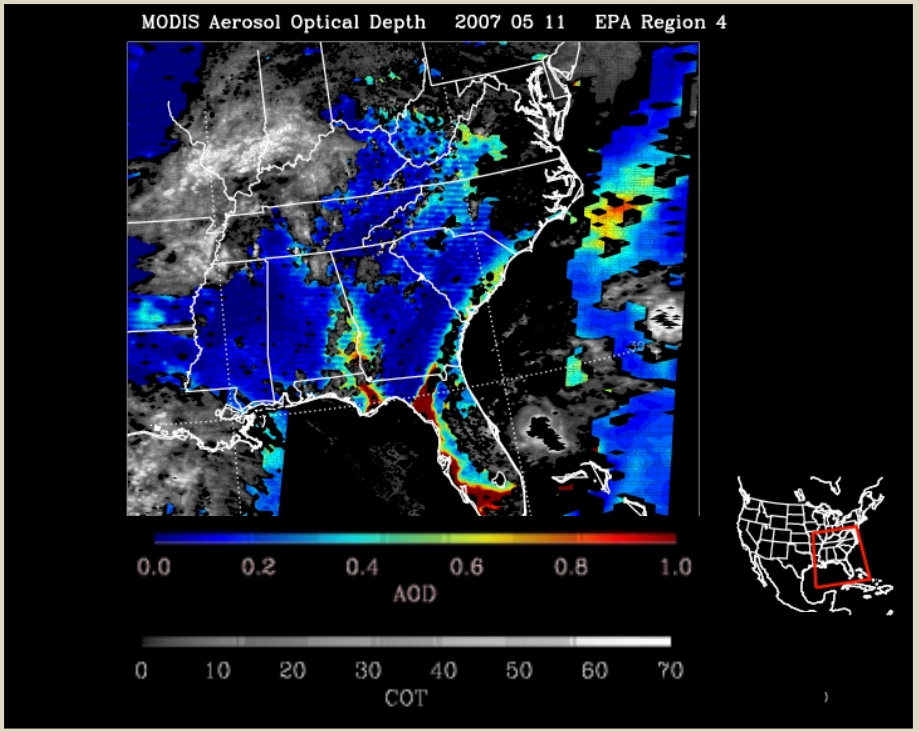
Terra MODIS Measurement of Global Aerosols – March 2010
Image Credit: NASA

Example MODIS AOD Product

True Color Image



AOD Image

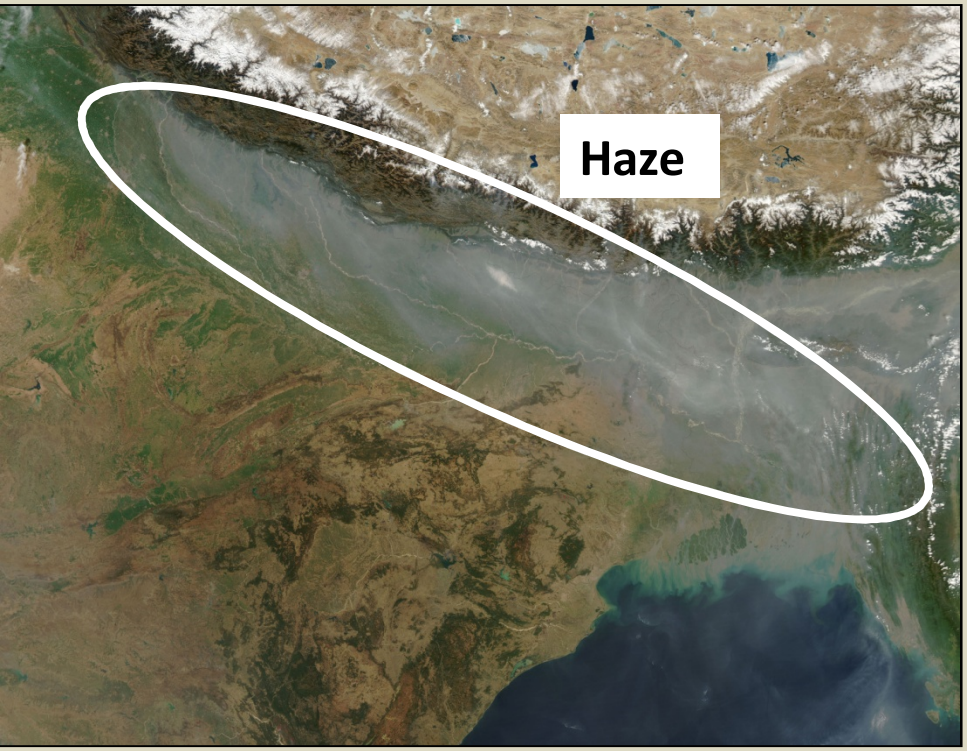


Terra MODIS true color and AOD images of wildfires in Florida on May 11, 2007.

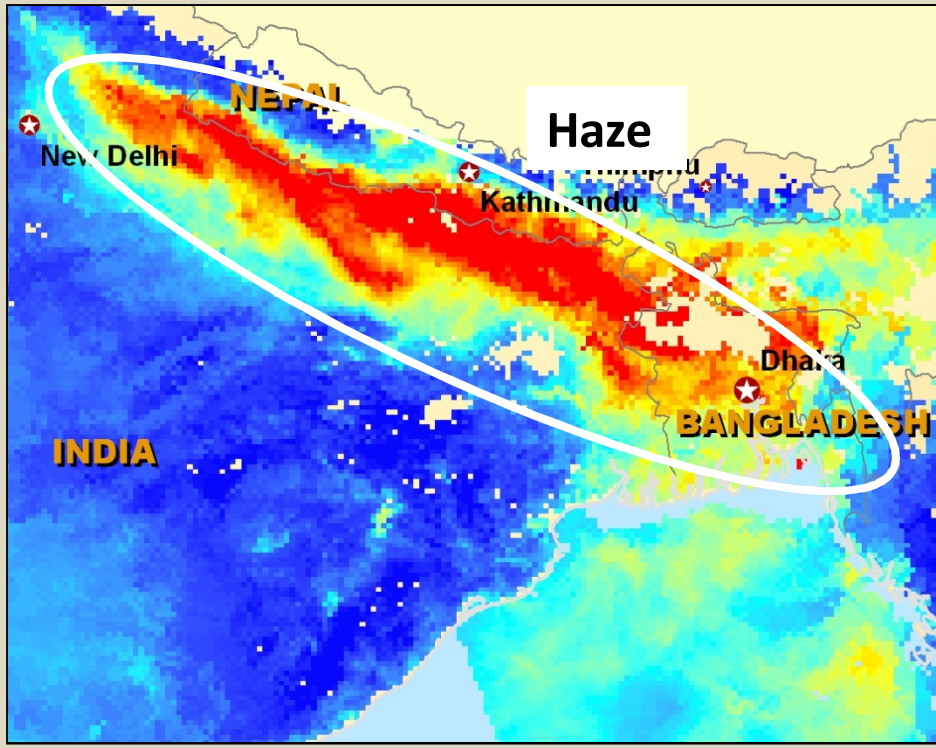
Graphics adapted from a presentation by Dr. Ana Prados, Joint Center for Earth Systems Technology, University of Maryland Baltimore County.
http://arset.gsfc.nasa.gov/materials/index_new.php

Example MODIS AOD Product

True Color Image



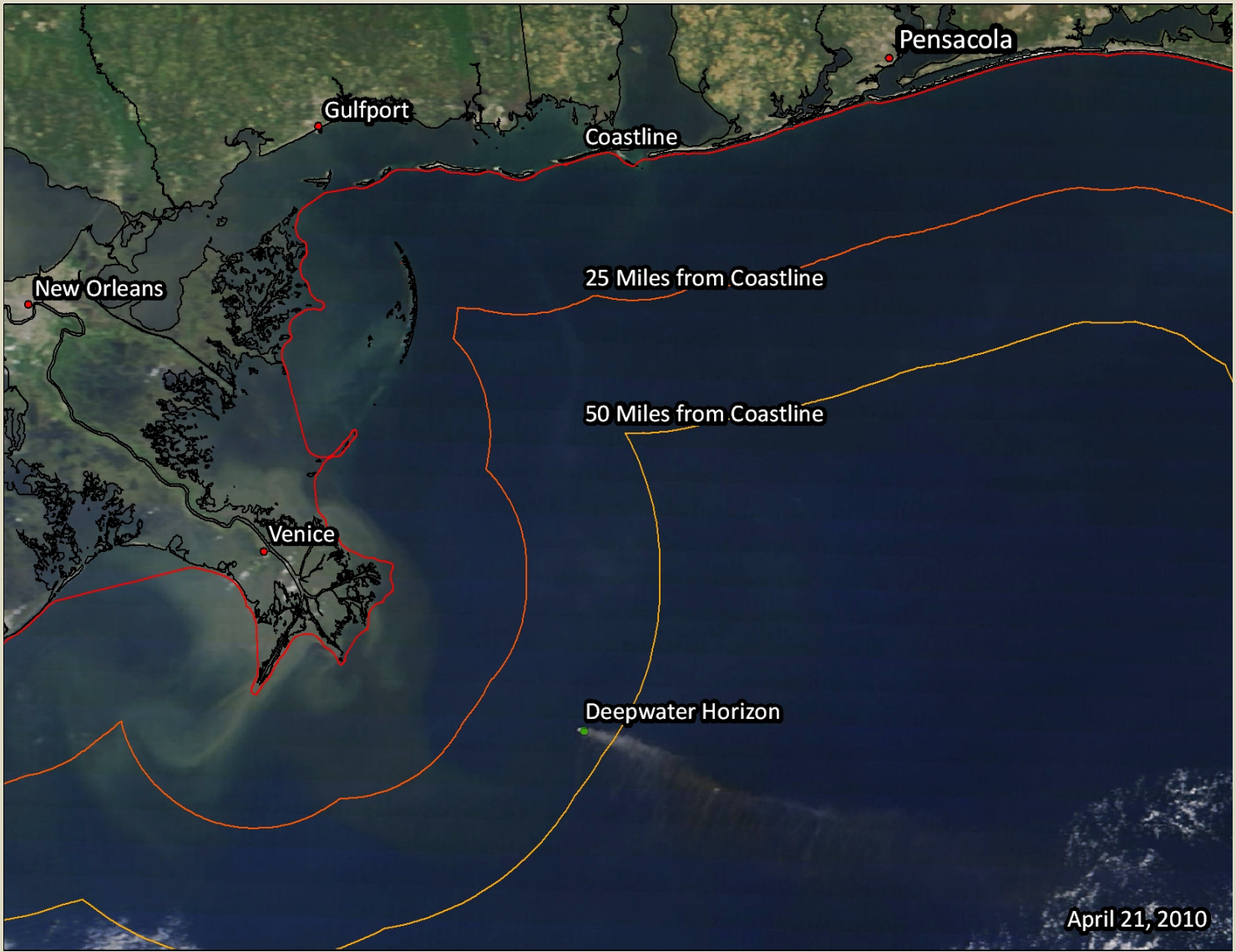
AOD Image



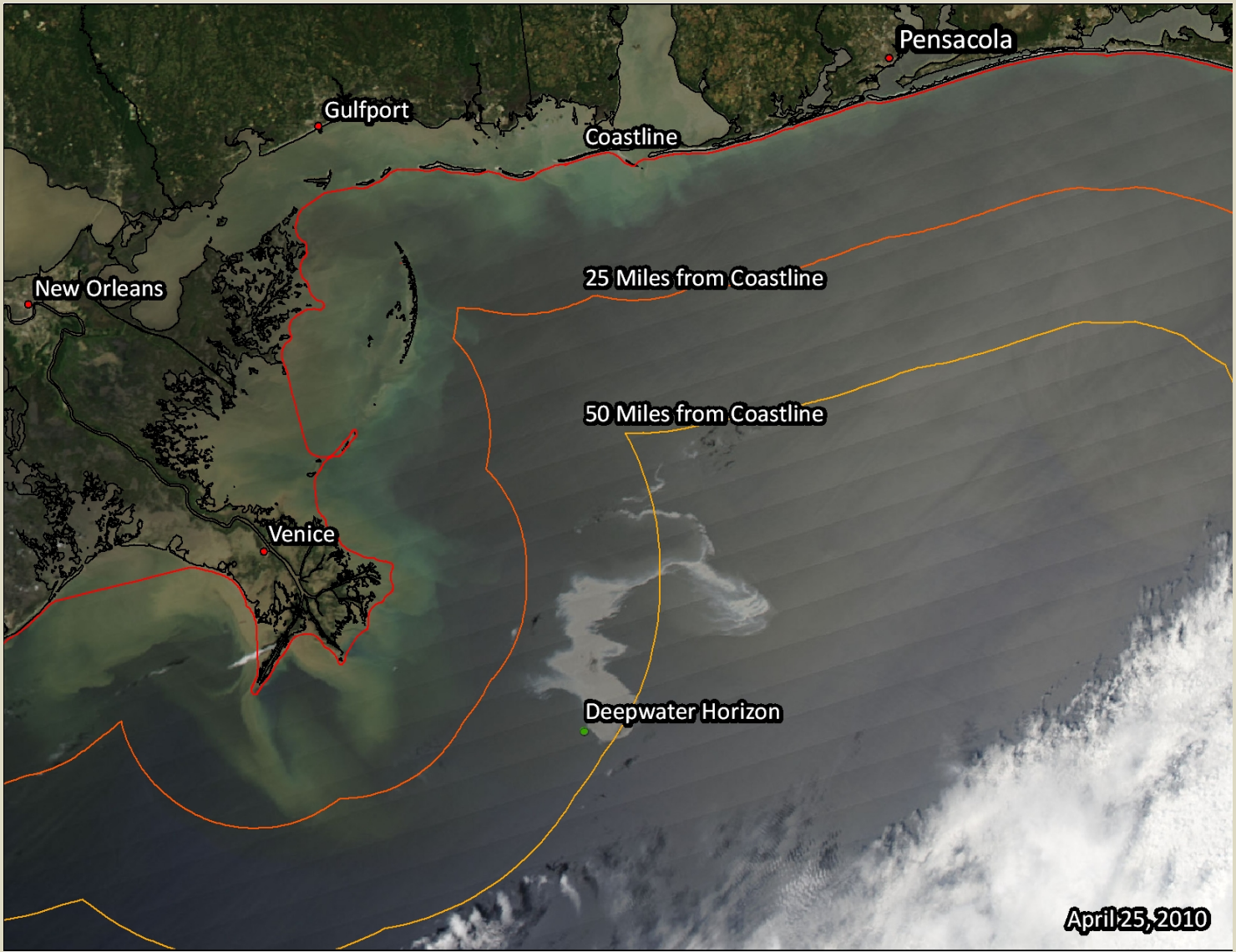
Terra MODIS true color and AOD images of northern India, Nepal, and Bangladesh from February 5, 2006.

Graphic adapted from a presentation by Dr. Ana Prados, Joint Center for Earth Systems Technology, University of Maryland Baltimore County.

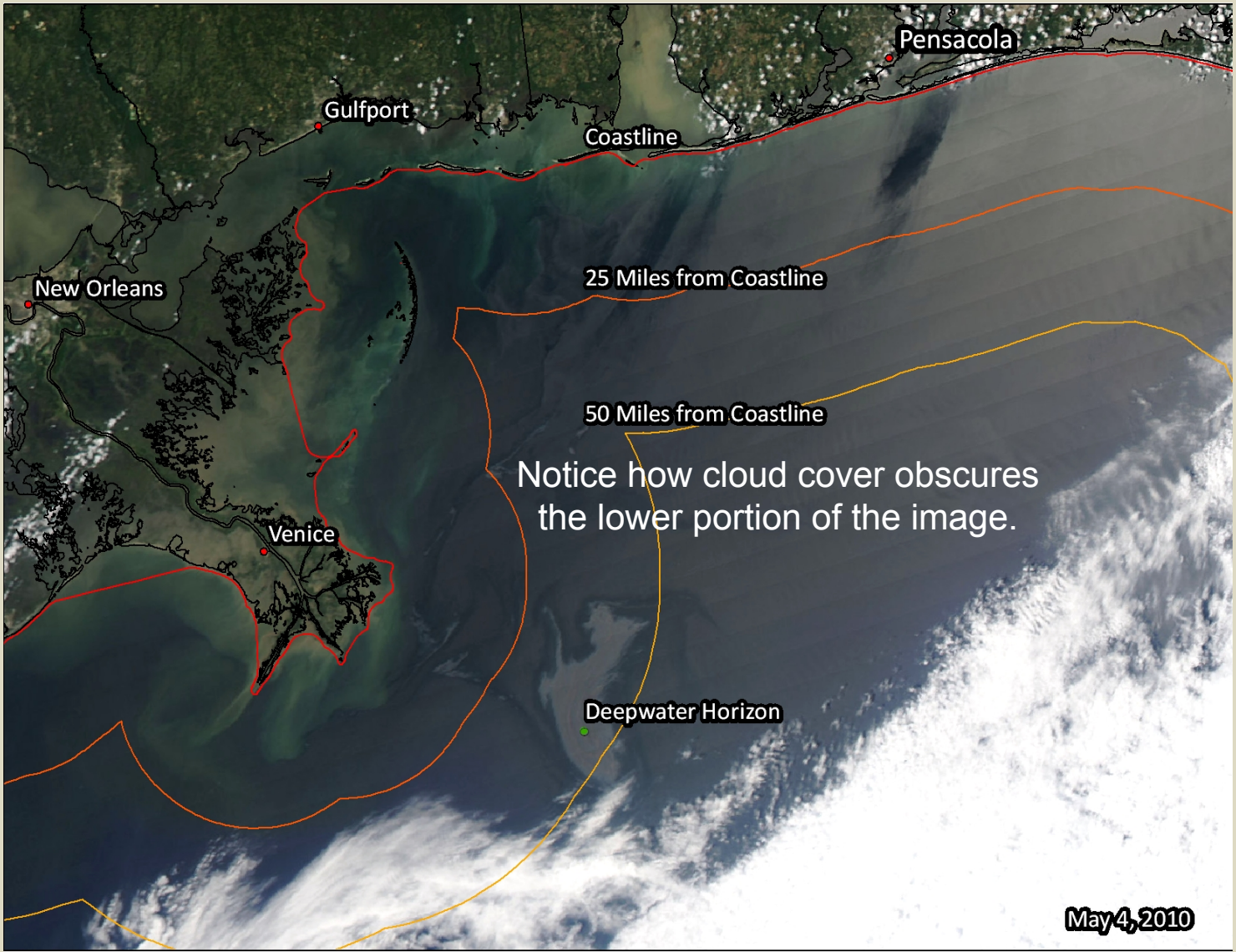
Other Application: Oil Tracking



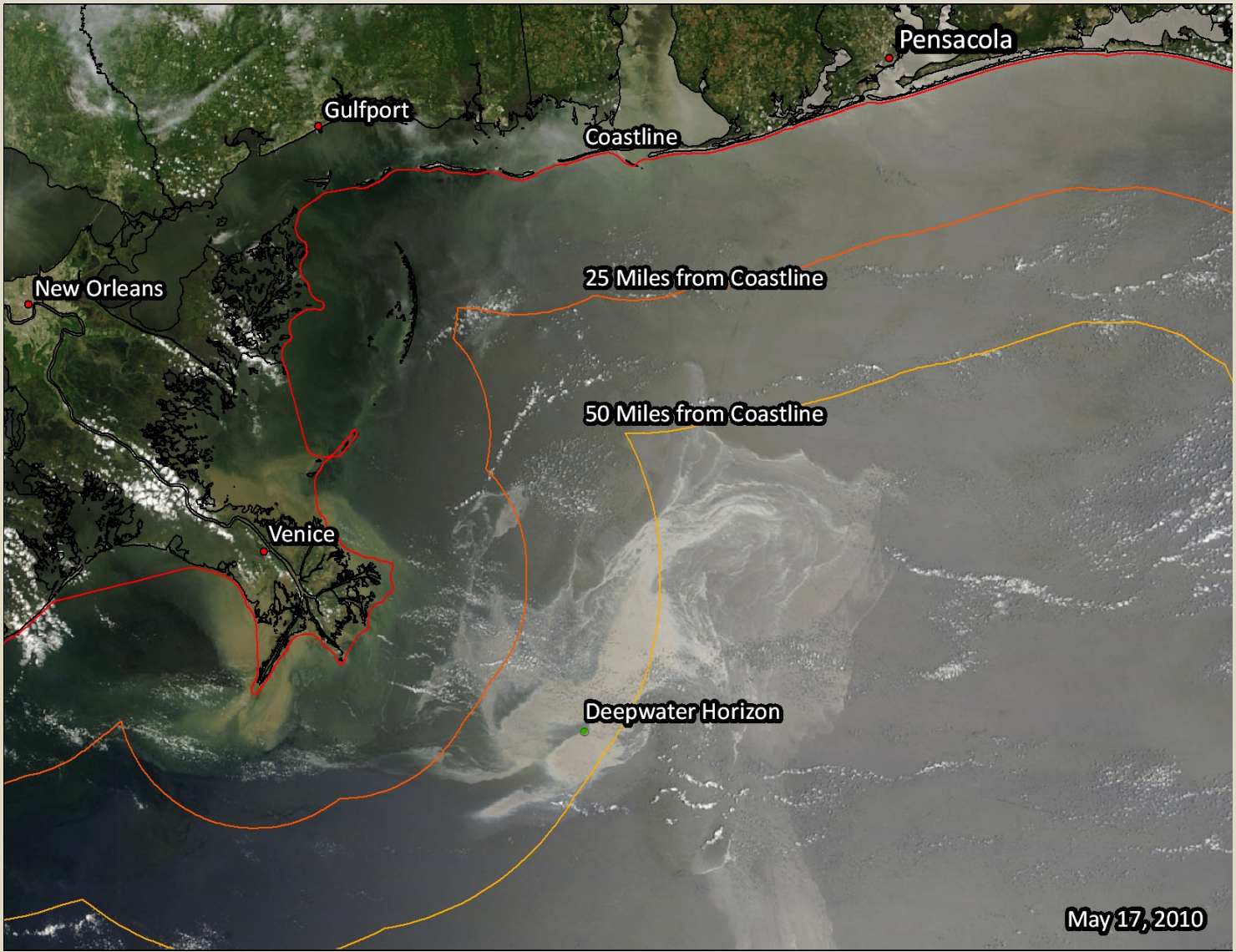
MODIS – April 25, 2010



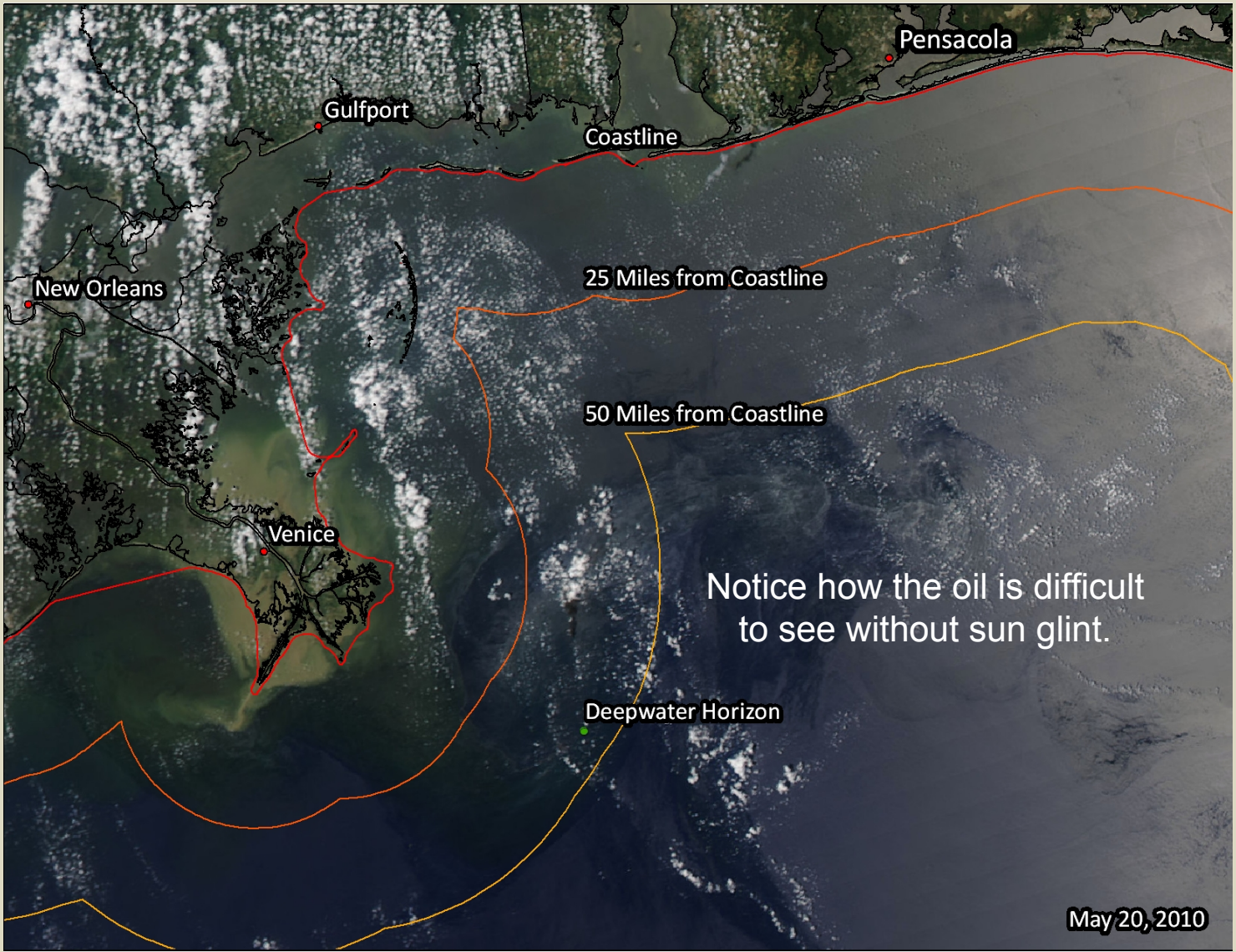
MODIS – May 4, 2010



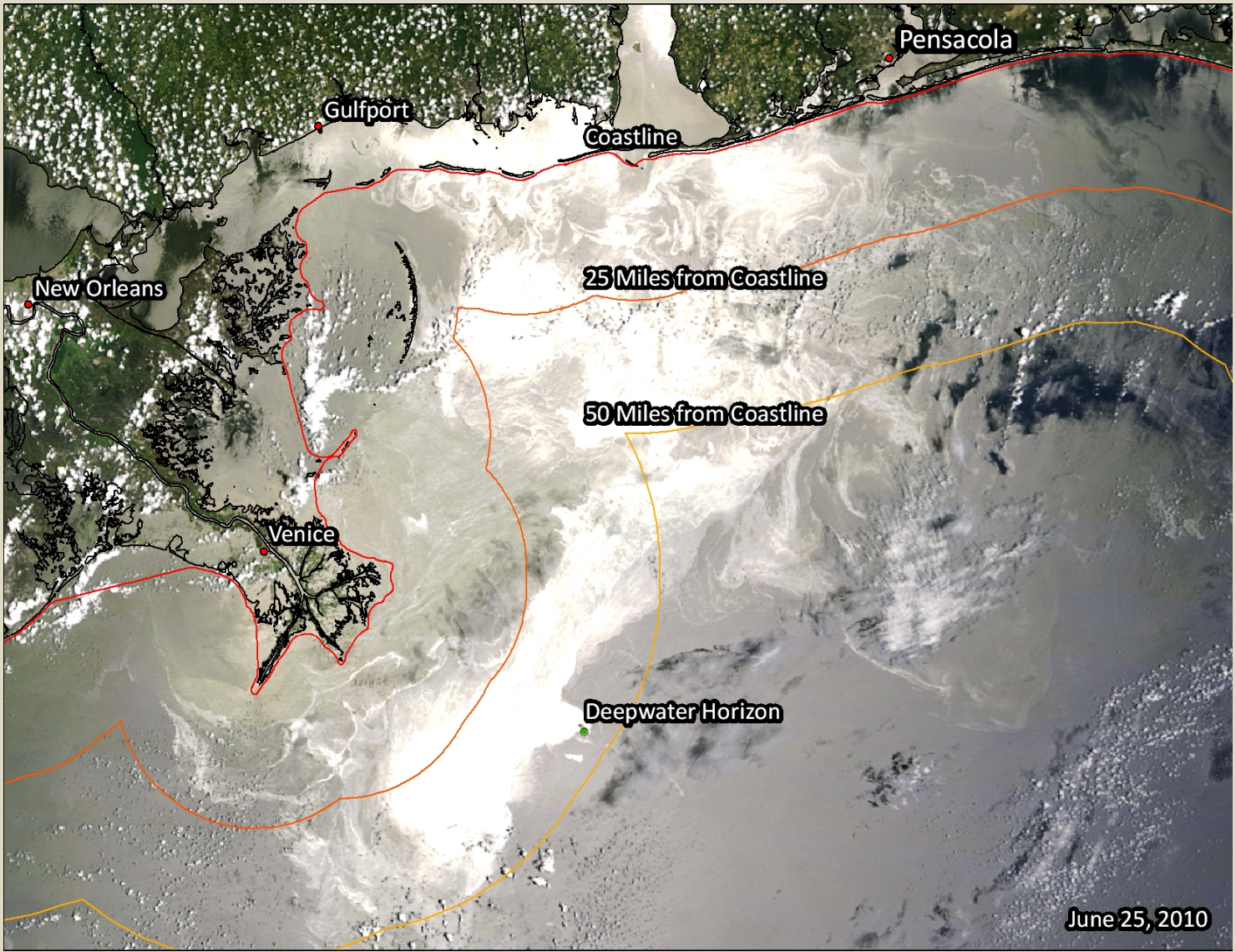
MODIS – May 17, 2010



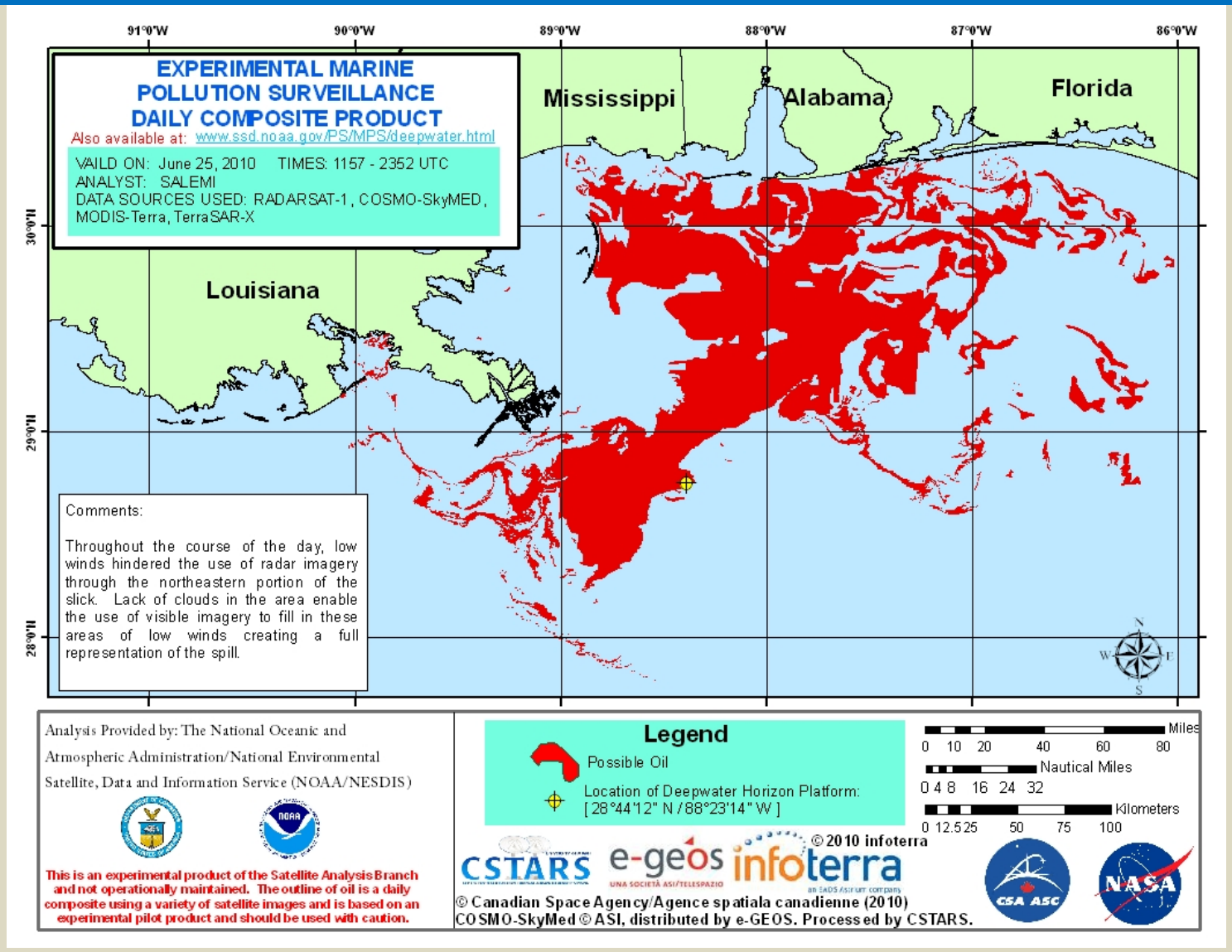
MODIS – May 20, 2010



MODIS – June 25, 2010



MODIS-derived Oil Mapping Product



MODIS Data Sources

http://ladsweb.nascom.nasa.gov/

Level 1 and Atmosphere Archive and Distribution System

(Source of Atmospheric Aerosol Data)

http://rapidfire.sci.gsfc.nasa.gov/

Rapid Fire MODIS System

(Source of Rapidly Processed Near Real Time Imagery)

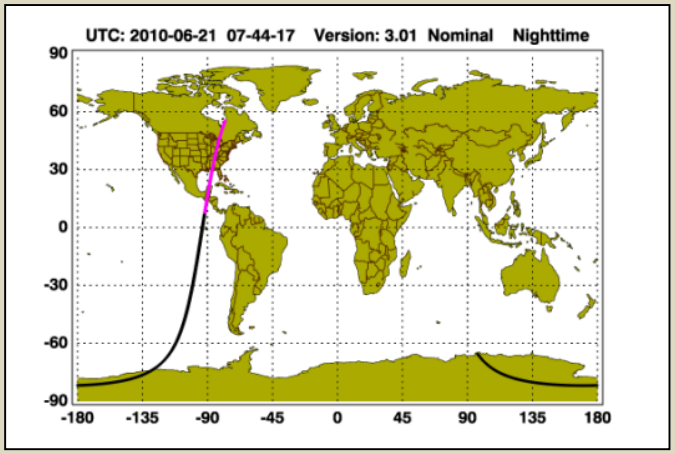
https://lpdaac.usgs.gov/

Land Processes Distributed Active Archive Center

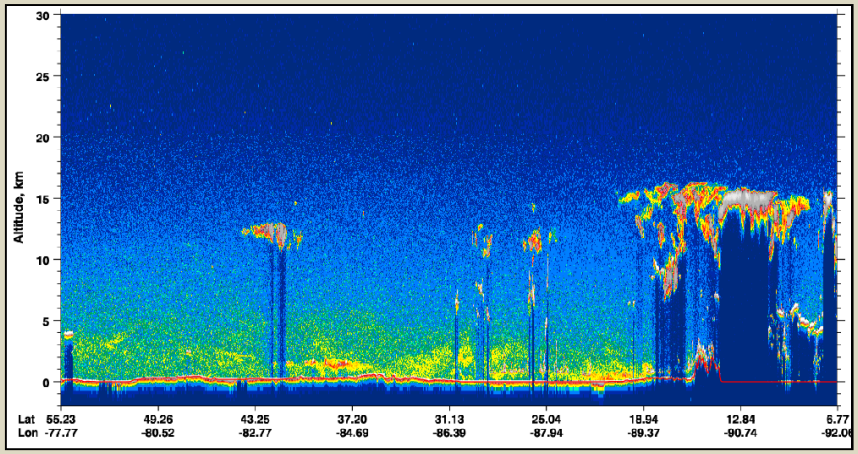
(Source of Archived Land Imagery)

CALIOP

- Cloud-Aerosol LiDAR with Orthogonal Polarization
- Two spectral bands (532 nm polarization-sensitive and 1064 nm)
- Onboard the *CALIPSO* satellite
- Measures clouds and aerosols



Map of *CALIPSO* Orbit Path
June 21, 2010
Image Credit: NASA



CALIOP 532 nm Total Attenuated Backscatter
June 21, 2010
Image Credit: NASA

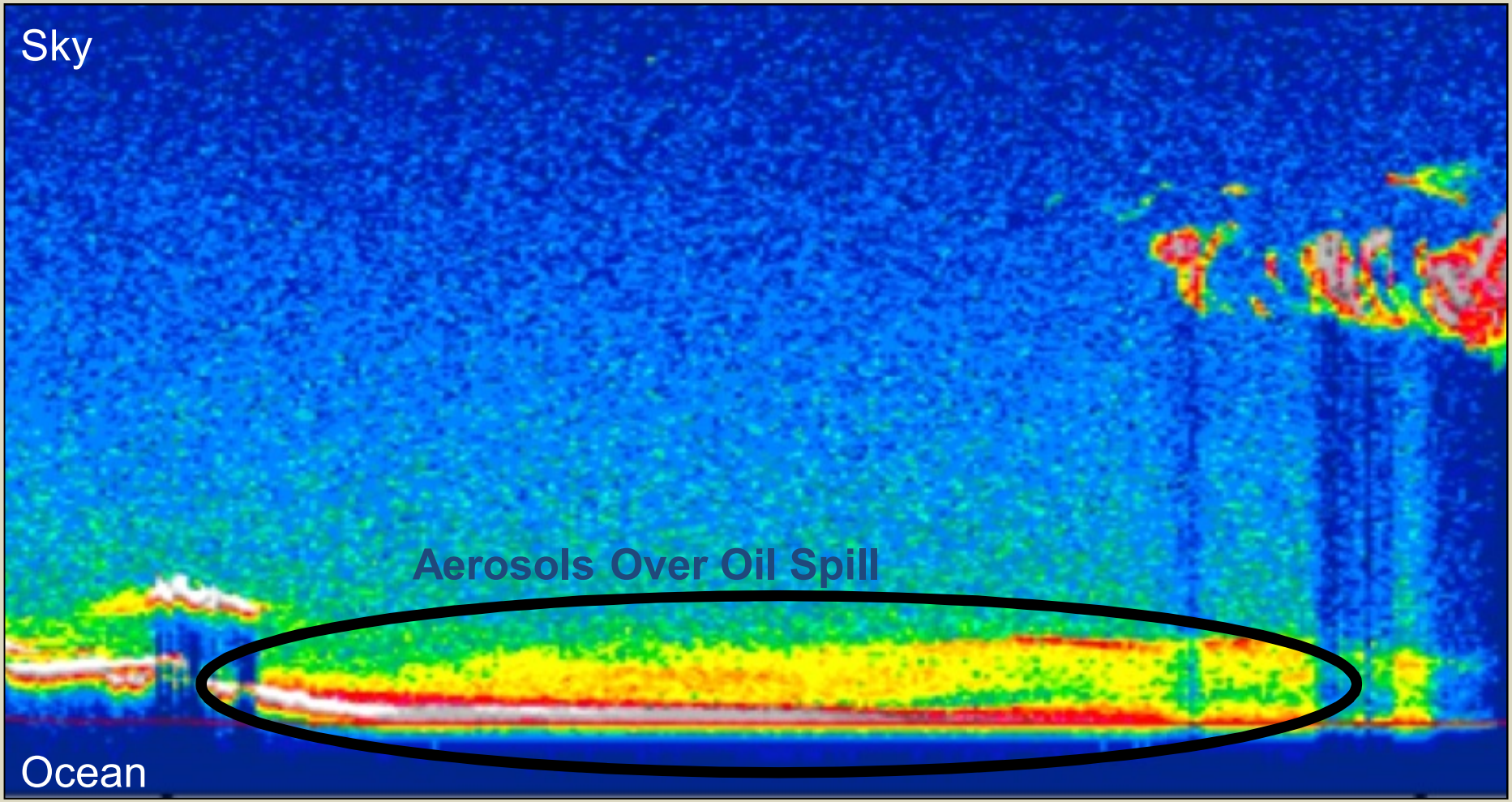
CALIOP

- Level 2 aerosol product
- Horizontal resolution – 5 km
- Temporal resolution – 16 days

Table 1 Profile Vertical Resolution LiDAR Level 2 Aerosol Profile Data Product DP 2.1B.
Source: CALIPSO User Guide, page 34.

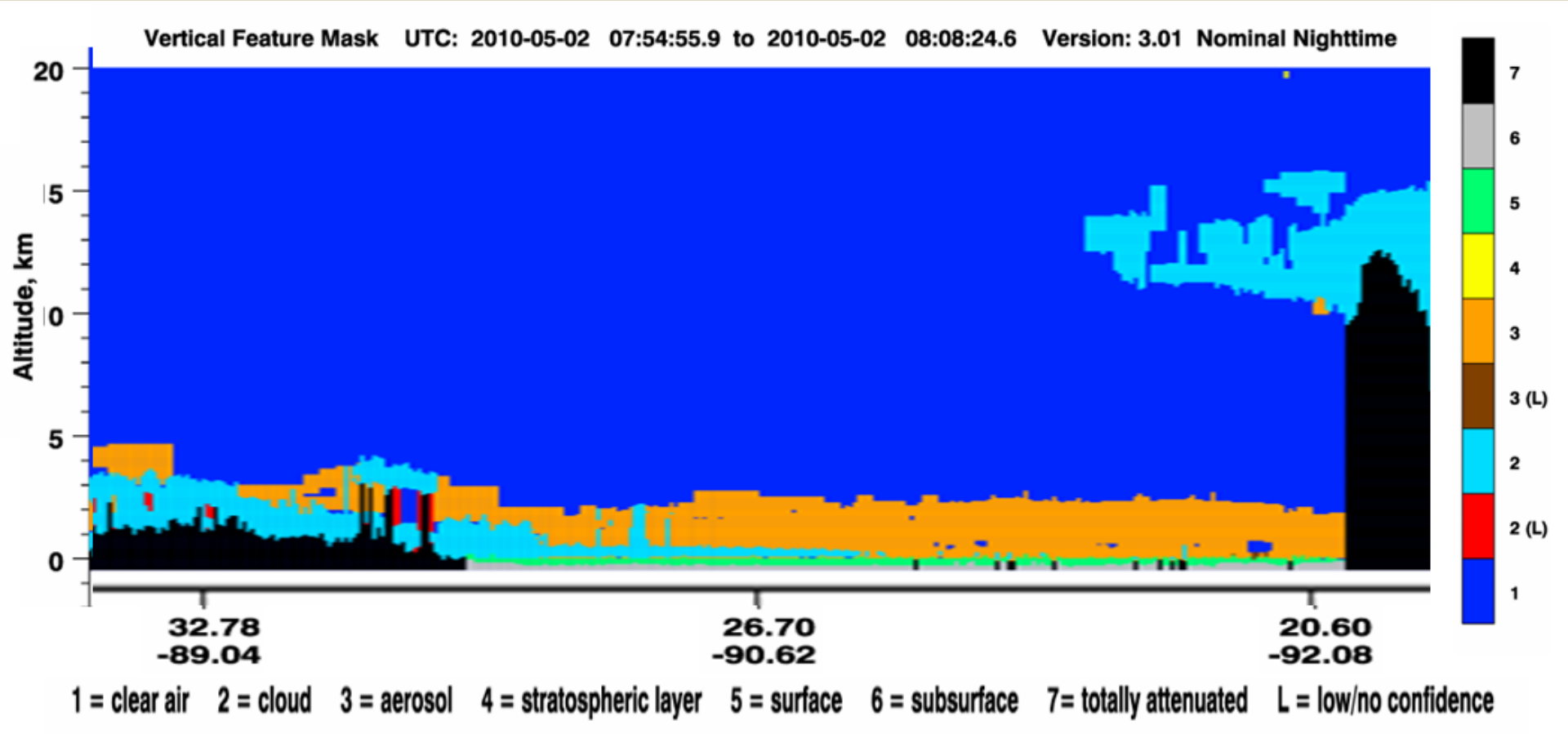
Altitude Region		**Vertical Resolution, meters**	**Sample per Profile**
Base, km	**Top, km**		
-0.5	8.2	120	72
8.2	20.2	120	100
20.2	30.1	360	27
Total			**199**

CALIOP



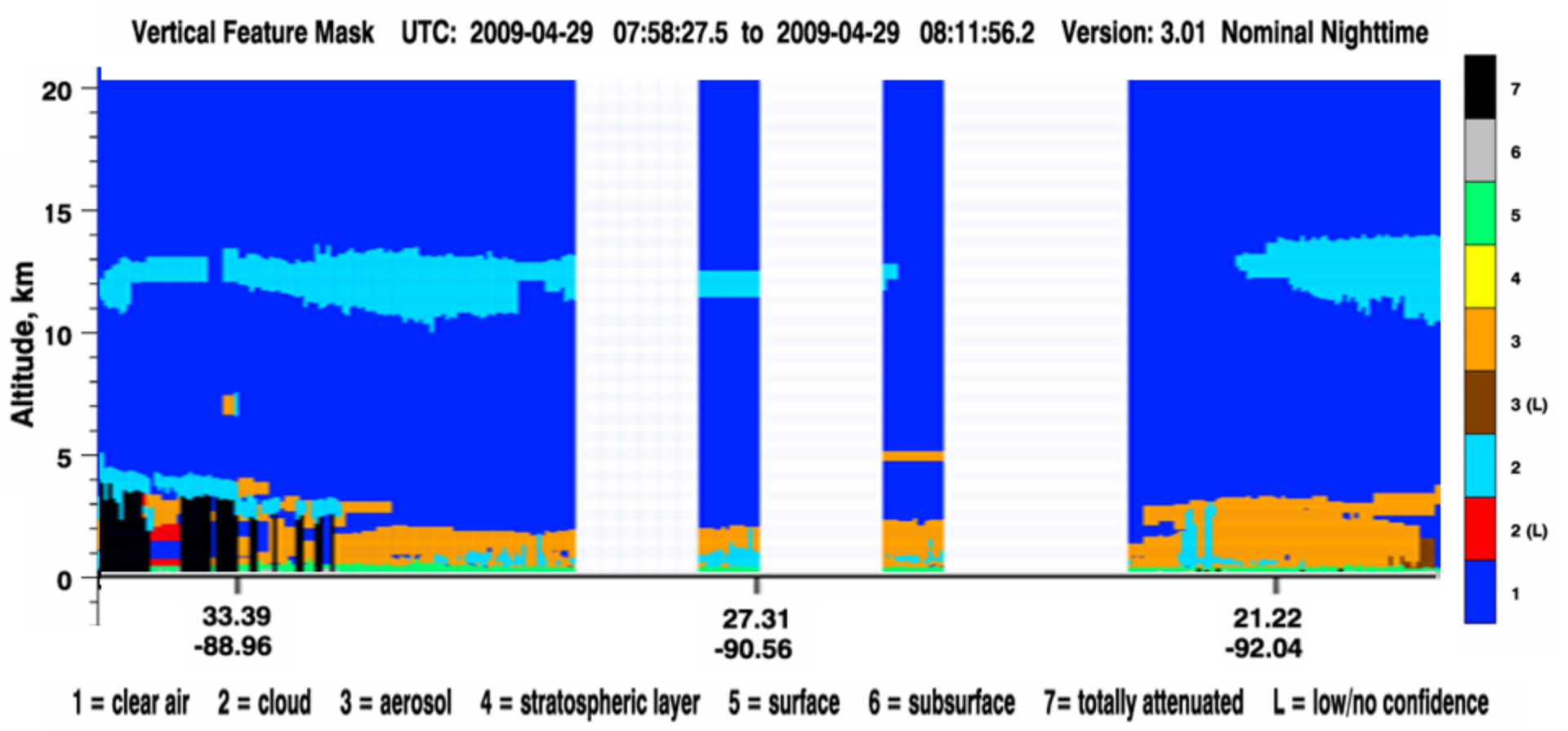
Cross-Section View of CALIOP Data – May 2, 2010. Image Credit: NASA

CALIOP



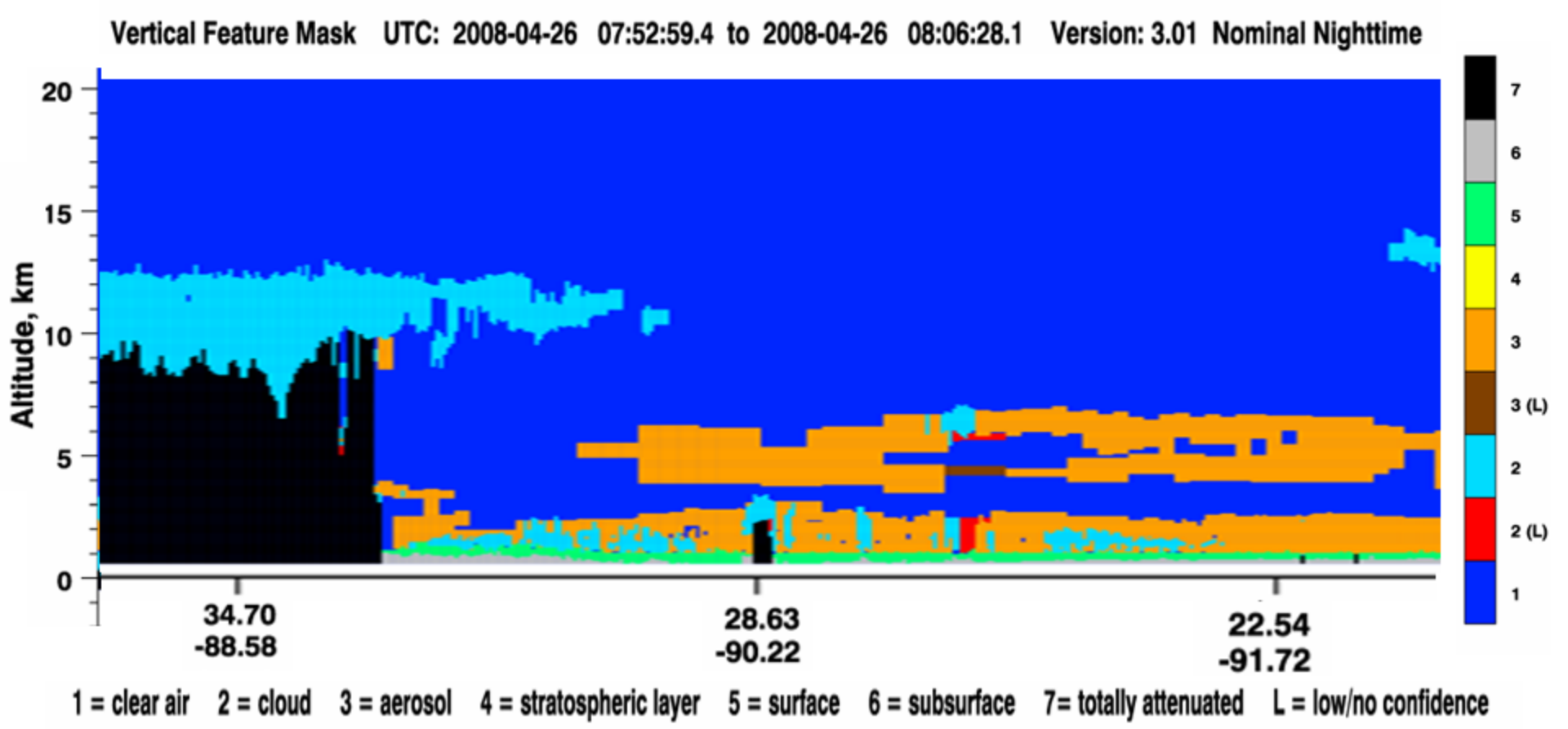
Cross-Section View of CALIOP Vertical Feature Mask – May 2, 2010. Image Credit: NASA

CALIOP



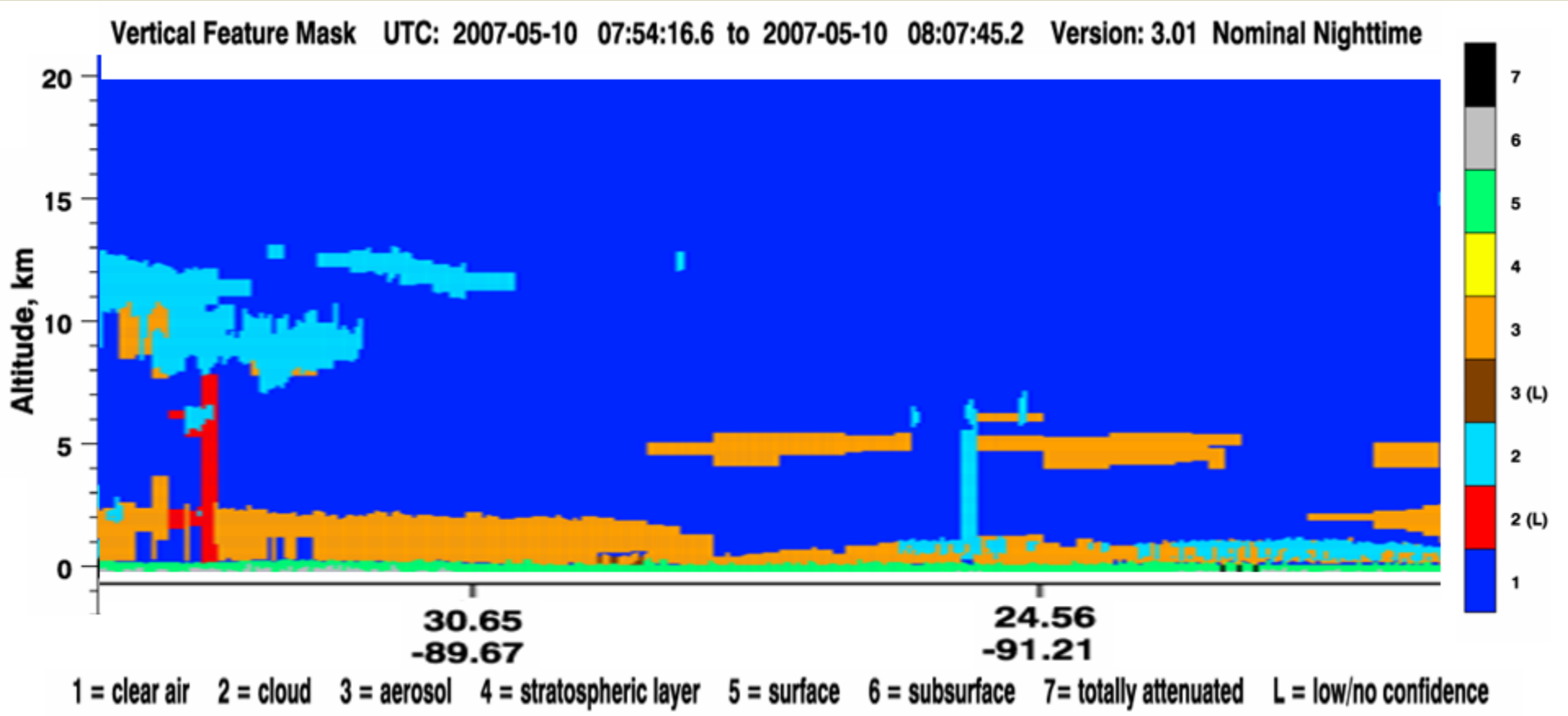
Cross-Section View of CALIOP Vertical Feature Mask – April 29, 2009. Image Credit: NASA

CALIOP



Cross-Section View of CALIOP Vertical Feature Mask – April 26, 2008. Image Credit: NASA

CALIOP



Cross-Section View of CALIOP Vertical Feature Mask – May 10, 2007. Image Credit: NASA

CALIOP Data Source

http://www-calipso.larc.nasa.gov/products/lidar/browse_images

View CALIOP Data

http://eosweb.larc.nasa.gov/PRODOCS/calipso/table_calipso.html

CALIOP Data and Information

http://www-calipso.larc.nasa.gov/resources/calipso_users_guide/

CALIPSO Data User's Guide

http://www-calipso.larc.nasa.gov/resources/pdfs/PC-SCI-202.Part1_v2-Overview.pdf

CALIOP Instrument and Algorithm Overview

DEVELOP Oil Spill Air Quality Research

Project Methodology

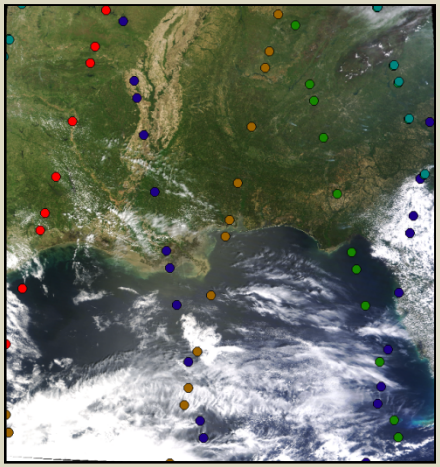
- Timeframe: March – September
- OMI HCHO global swath data (2009 and 2010)
- TES ozone profile data (2010 only)
- MODIS AOD data (2010 only)

***Aura* OMI**



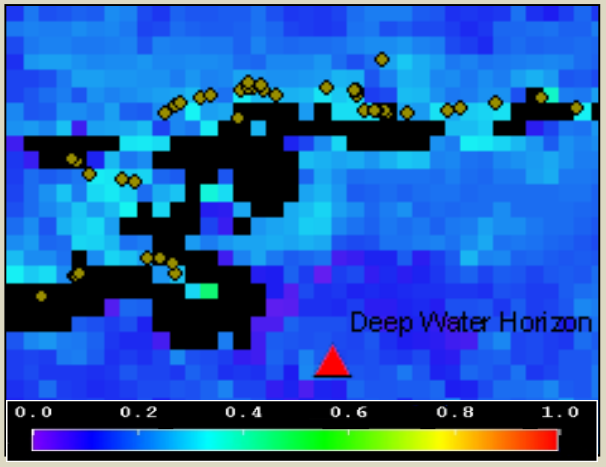
Example OMI Swath over Gulf Coast. Pixel Centers in Green. Pixel Sizes: 14x24 km (nadir) and 28x150 km (edge).

***Aura* TES**



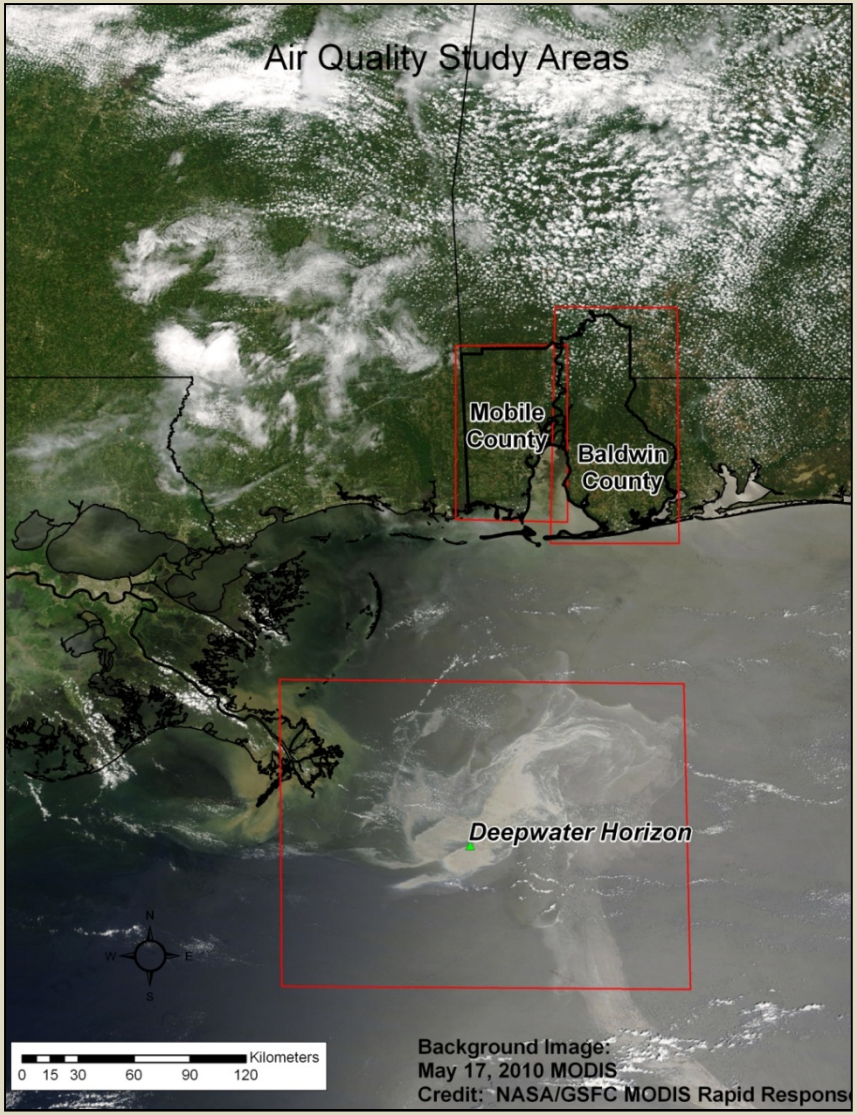
May – Sept. 2010 TES Data. Colors Denote Different Dates. Pixel Size: 0.53x5.3 km.

***Terra* and *Aqua* MODIS AOD**



May – June 2010 Monthly Mean AOD Coastline in Black, EPA Monitoring Points in Green. Pixel Size: 10x10 km.

Project Methodology



Study Areas

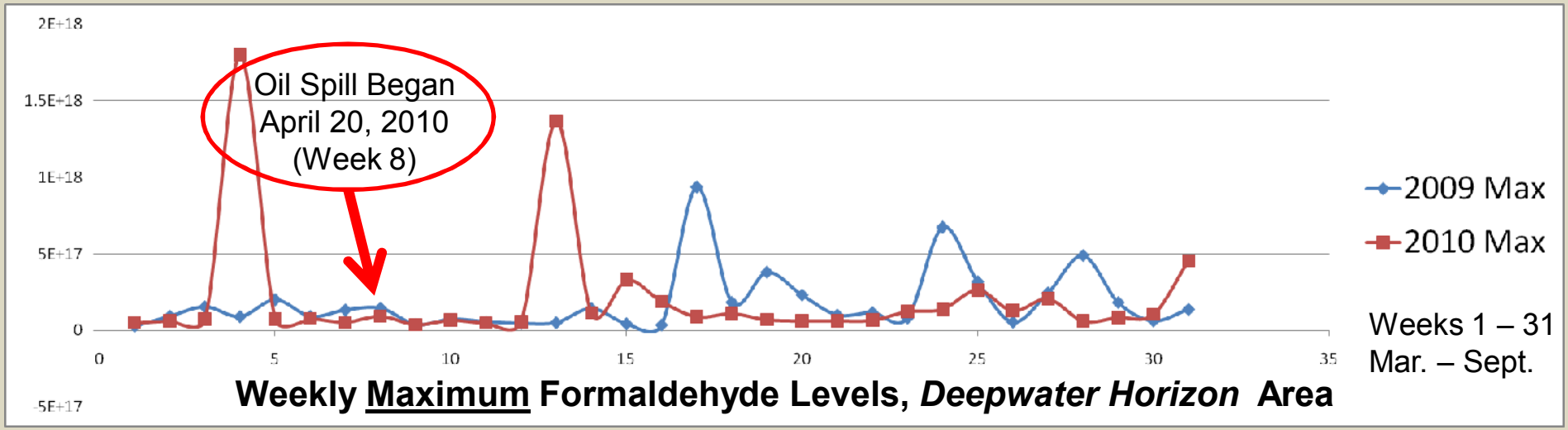
- A 165 km x 190 km box around the *Deepwater Horizon* rig location
- Bounding boxes around Mobile and Baldwin Counties, Alabama

OMI Methodology

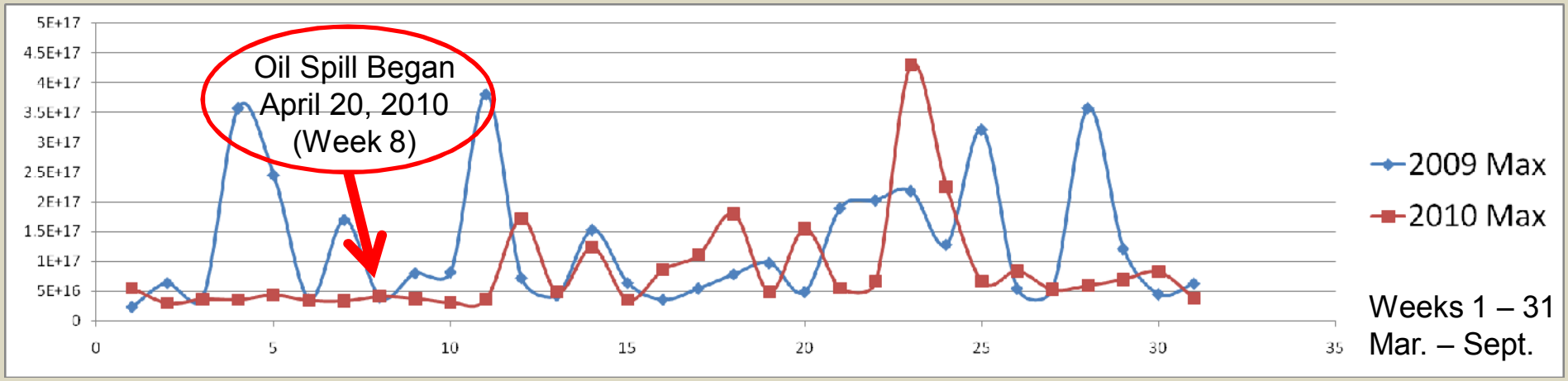
- Downloaded the Level 2, OMCHO product for all 14 orbit swaths per day for March – September 2009 and for March – September 2010.

- Created a C program that used HDF libraries and functions to accomplish the following tasks:
  - Removed pixels flagged as “bad” and/or that fell outside the study area
  - Stored HCHO column amount values in RAM
  - Output weekly maximum HCHO values to CSV files

OMI Results



Weekly <u>Maximum</u> Formaldehyde Levels, *Deepwater Horizon* Area

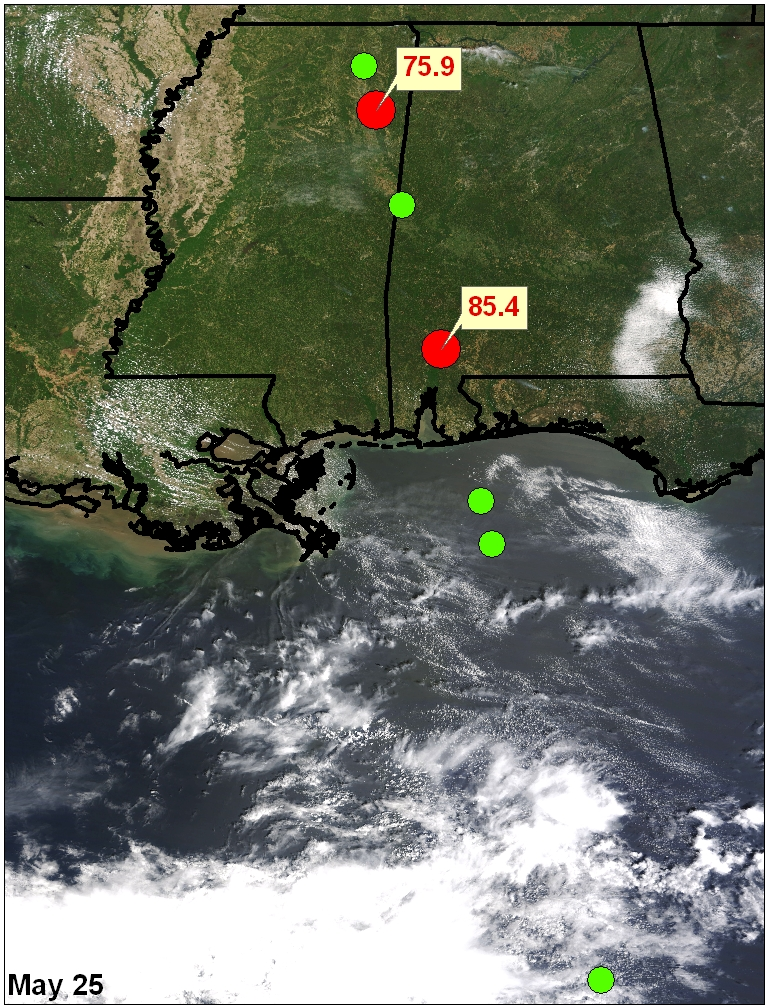


Weekly <u>Maximum</u> Formaldehyde Levels, Mobile County, AL

OMI Conclusions

- OMI formaldehyde weekly maximums showed no indications that the oil spill caused elevated levels of atmospheric VOCs.
- If higher than normal pollution was there, we did not detect it.
- Limitations
  - Necessity of measuring VOCs using formaldehyde
  - Naturally-occurring formaldehyde levels from biogenic isoprene emissions
  - OMI data anomalies in recent years

TES Methodology / Results



- Manually converted HDF data values into delimited text using HDFView. Loaded delimited text files into ArcGIS.
- Converted O_3 values to ppb using (O_3 value) * 10^9
- Removed “bad” / “no-data” points
- Defined two categories per EPA National Ambient Air Quality Standards:
  - High >= 75 ppb (red point)
  - Low < 75 ppb (green point)

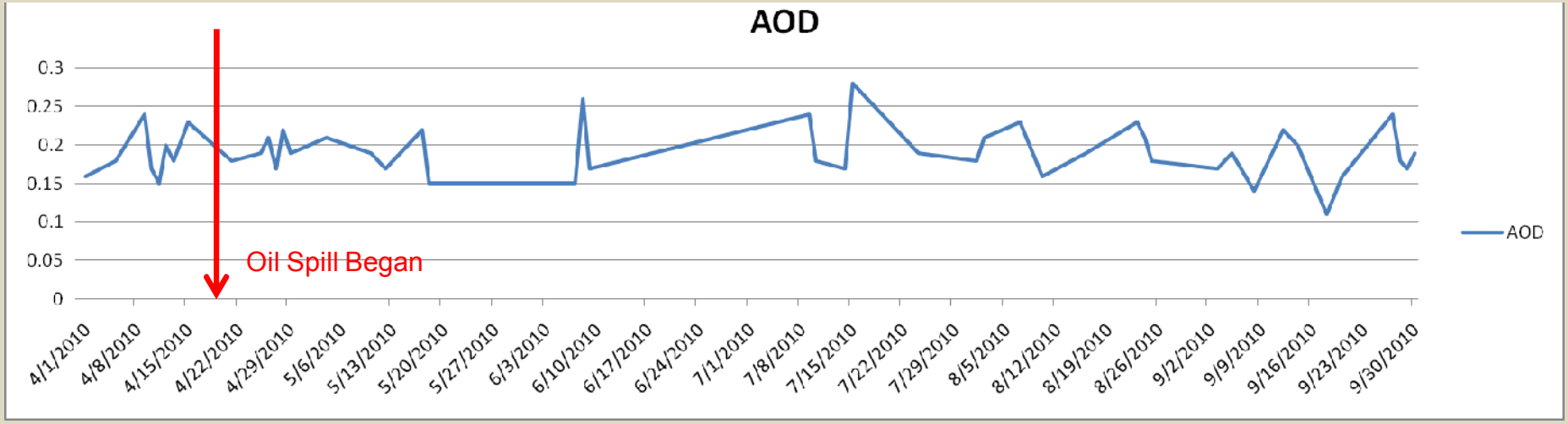
TES Discussion

- Conclusions
  - No apparent relationship between high ozone levels and the oil spill was observed.
- Limitations
  - 2010 TES data not compared to 2009 TES data due to time constraints
  - Poor data availability and minimal coverage
  - Possible ozone pollution from other sources

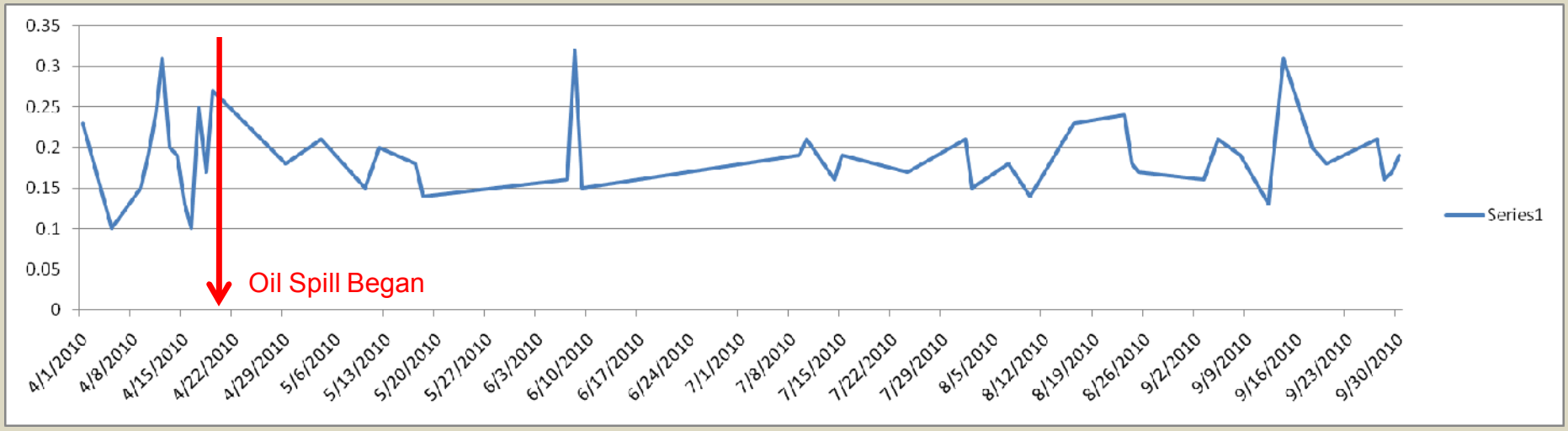
MODIS Methodology

- Converted and projected the MODIS AOD files into GeoTIFF file format using the *HDF to GEOTIFF Conversion Tool* (HEG)
- Subset images to Gulf of Mexico region and rescaled values to 0 – 1 with ERDAS Imagine
- Layer-stacked daily images together using Envi
- Calculated mean AOD values for the area surrounding the *Deepwater Horizon* rig and also for Mobile County, AL.

MODIS Results



Daily Mean MODIS AOD Values, *Deepwater Horizon* Area



Daily Mean MODIS AOD Values, Mobile County, AL

MODIS Conclusions

- AOD levels fluctuated throughout the study period.
- No conclusive indications of elevated AOD levels resulting from the oil spill could be detected.
- Spike in June could be from controlled oil burning or from elevated temperatures increasing evaporation rates.
- Limitations
  - 2010 MODIS data not compared to 2009 MODIS data due to time constraints

Gulf of Mexico Air Quality

Data Acquisition

- CALIOP Level 2 Version 3.01 aerosol profile products from the Langley ASDC website.
- Ancillary air quality data from the EPA website.
- Smoke plume trajectories were created using the HYSPLIT model from NOAA.

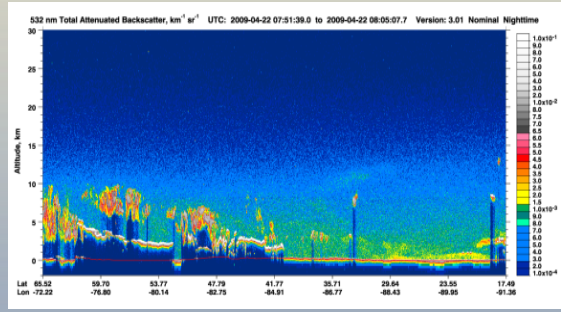
Satellites / Sensors

- CALIPSO – CALIOP L2 Version 3.01

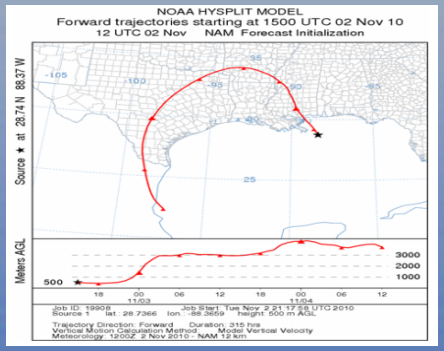


Data Processing & Analysis

- CALIOP – Level 2 products are already processed. The Search and Subset tool was used to analyze the swaths and profiles
- HYSPLIT model – NOAA HYSPLIT model was used to create forward trajectories
- Microsoft Excel was used to average and graph values for Particulate matter from the ancillary data set



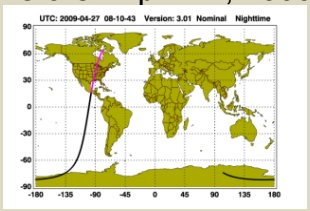
CALIOP aerosol profile



NOAA HYSPLIT Trajectory

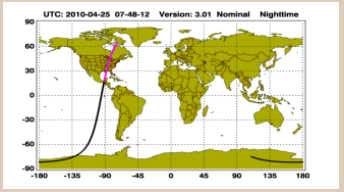
Gulf of Mexico Air Quality

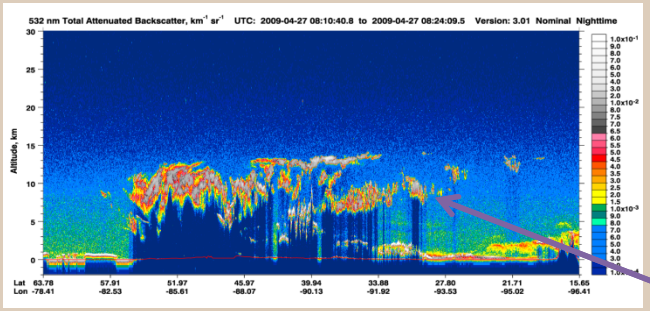
Before: April 27, 2009

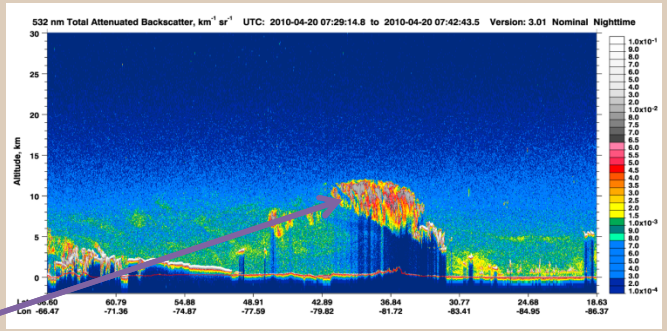


CALIOP aerosol profiles one year previous (left) and immediately after (right) the *Deepwater Horizon* oil spill

After: April 25, 2010



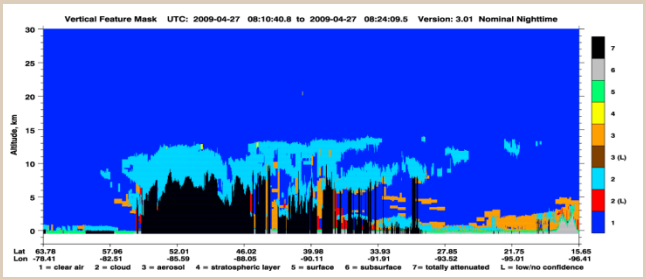


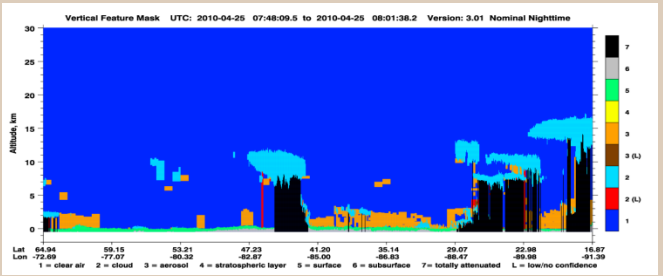


Right image shows more aerosol activity than left image.

Activity at top is potentially due to Yucatan burning.

Some uncertainty distinguishing aerosols from clouds

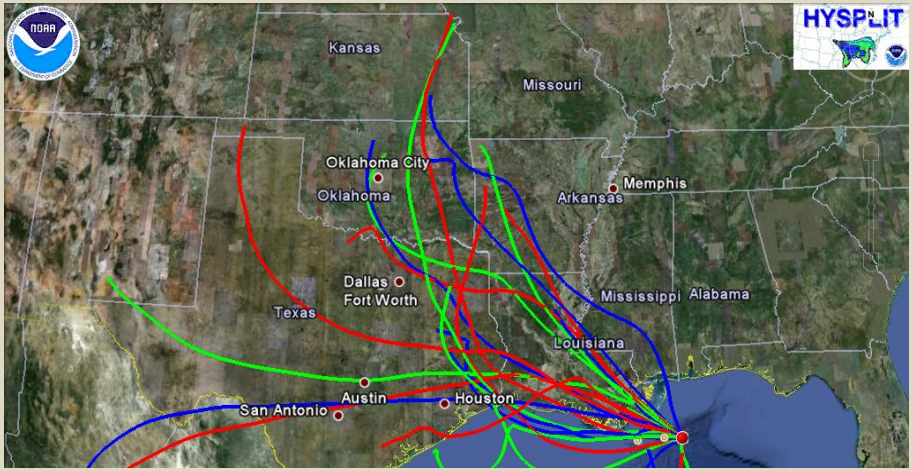




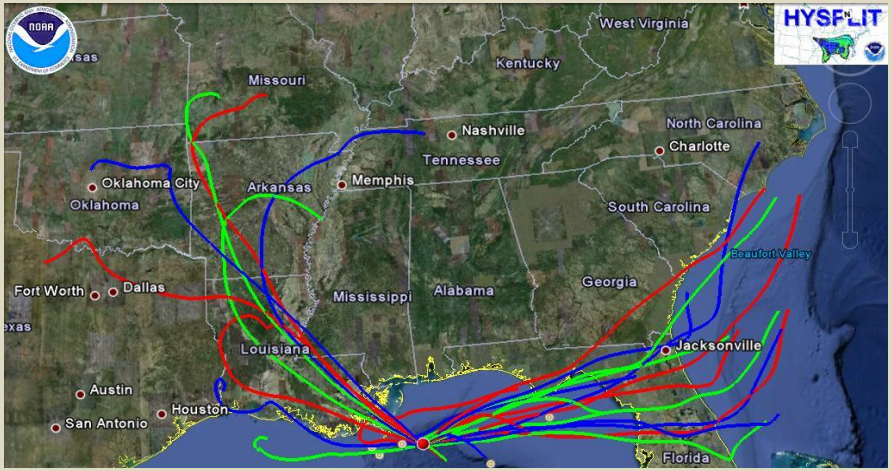
Comparison between these CALIOP profiles shows an apparent difference in aerosol levels in the 0-2 km boundary layer approximately one year before and a few days after the occurrence of the Deepwater Horizon oil spill.

Gulf of Mexico Air Quality

Examples of HYSPLIT Smoke Plume Trajectories



June 30, 2010
Image Credit: DEVELOP LaRC Student Team



July 6, 2010
Image Credit: DEVELOP LaRC Student Team

Acquiring Data

Data Acquisition

http://www.restorethegulf.gov

Official Federal Portal for Oil Spill Response/Recovery

http://www.geoplatform.gov/gulfresponse/

Online Oil Spill Mapping Tool

www.nasa.gov/topics/earth/features/oilspill/index.html

NASA Oil Spill Imagery and Articles

http://hdds.usgs.gov/hdds/

USGS Repository of Imagery and Data

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

NOAA NESDIS

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- Stennis Space Center
- Langley Research Center

Contributors

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- Dr. Thomas Kuroso - Harvard-Smithsonian Center for Astrophysics
- Dr. Peter Leonard - ADNET Systems, Inc
- TES Science Team
- NASA's Applied Science Program
- Mobile County Health Department

Questions / Comments

Questions?

Comments?

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http://develop.larc.nasa.gov

Potential Related Future Work

- Include EPA ground station and vehicle air sampling / monitoring data
- Analyze other pollutants
- Utilize other atmospheric data products (e.g. NO_x, SO_2, etc…)
- Use EPA ASPECT aircraft data to aid pollution detection assessments
- Use NOAA aircraft data as well

Potential Related Future Work

- Calculate different statistics to improve such assessments
- Try different time frames and spatial scales for study areas
- Incorporating wind speed and direction data