# Polar Orbiter Product Environmental Applications: Part 4

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UPR Direct Broadcast Polar Orbiter Workshop

28 April 2016

# Viewing Atmospheric Aerosols From the MODIS Satellite Sensor

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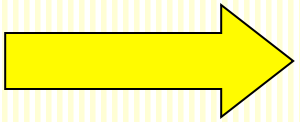
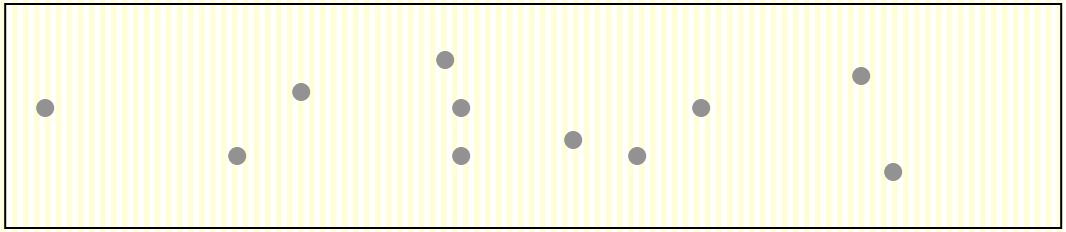
R-R. Li, J.V. Martins, S. Mattoo

# What are aerosols?

Definition: Aerosols are suspended droplets or particles that can scatter or absorb incoming sunlight

# Scattering and Absorption of Light by Aerosols





**$I_o$=Light Source (W/m²)**

**L=Path Length**

**I=Light Detector (W/m²)**

$$\frac{I}{I_0} = e^{-\sigma_{ext} L} = e^{-(\sigma_{sp} + \sigma_{ap}) L}$$

$$\tau = (\sigma_{sp} + \sigma_{ap}) * L \qquad \varpi = \sigma_{sp} / (\sigma_{sp} + \sigma_{ap})$$

The quantity L is called the density weighted path length. $\sigma_{ext(\lambda)}$ L is a measure of the cumulative depletion that the beam of radiation has experienced as a result of its passage through the layer and is often called the optical depth $\tau_\lambda$.

# Wide Spectral Range makes land retrieval possible

- **Mid-IR is used to observe the surface brightness**
- **Then aerosol is derived from estimated surface reflectance in the visible and actual reflectance**

$\tau_{0.66} \sim [\rho^*_{0.66} - 0.5\rho^*_{2.1}]$

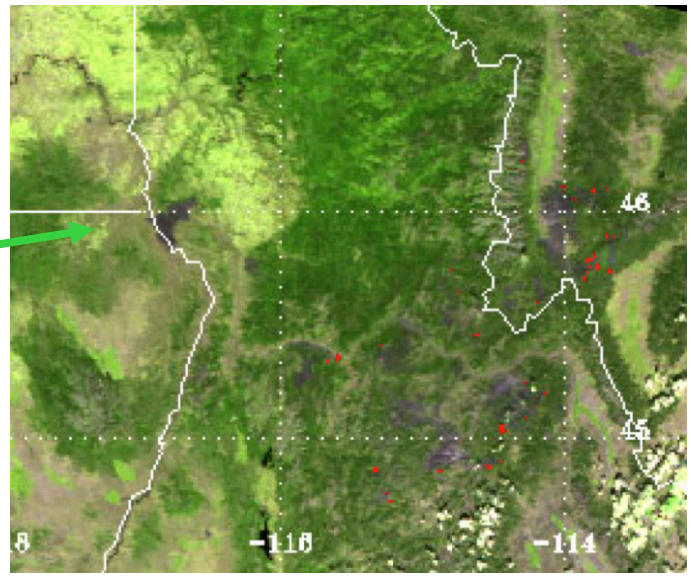
$\tau_{0.47} \sim [\rho^*_{0.47} - 0.25\rho^*_{2.1}]$

$\lambda(\mu m)$

**1.2**

**1.6**

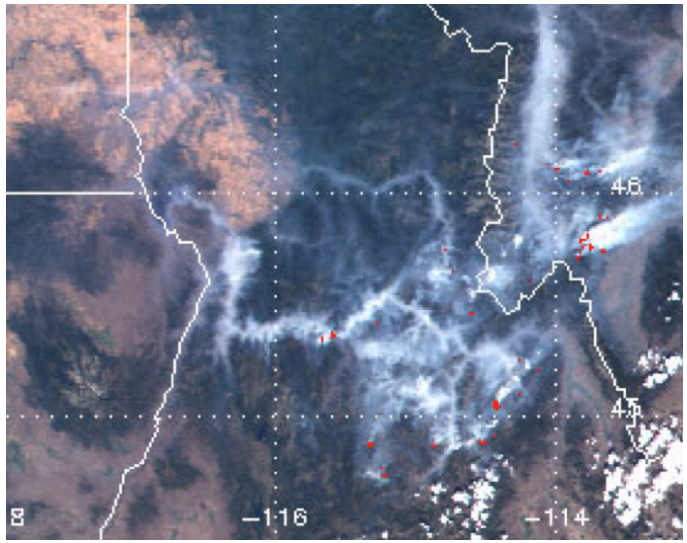
**2.1**




**0.47**

**0.55**

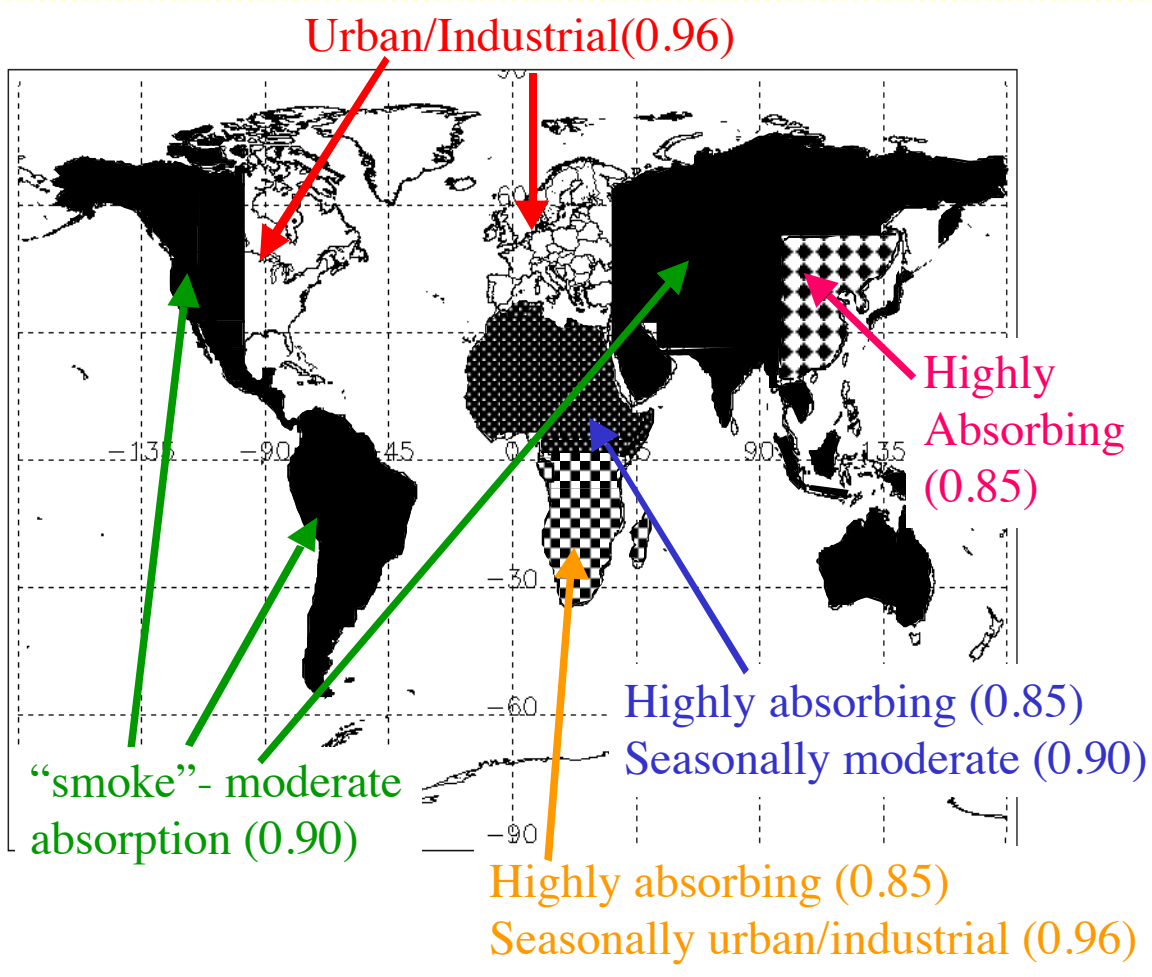
**0.66**



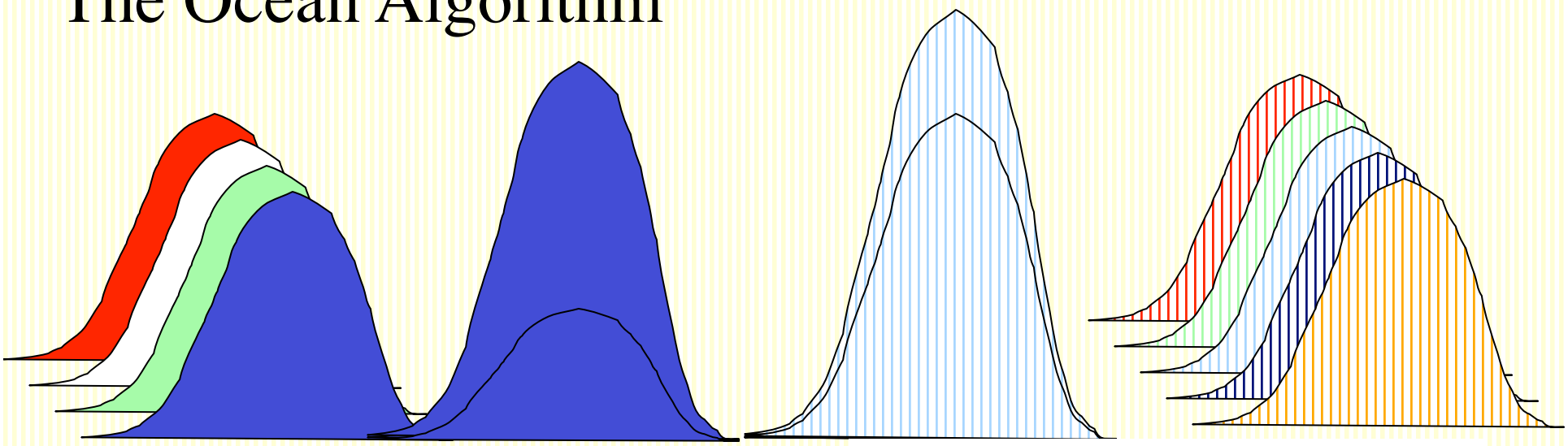

Yoram Kaufman

3 non-dust models
plus dust
Set by geography and
season

Models are dynamic f(τ)

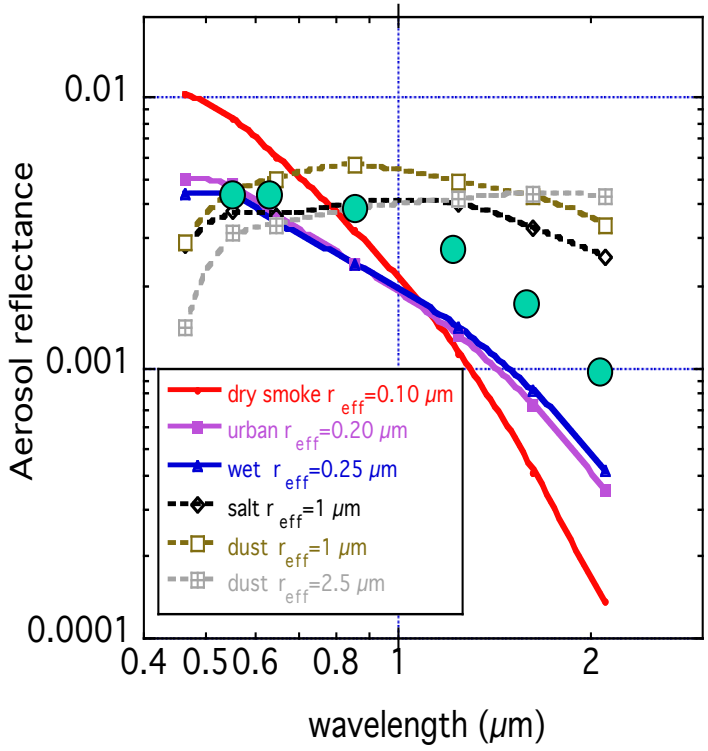


# The Ocean Algorithm



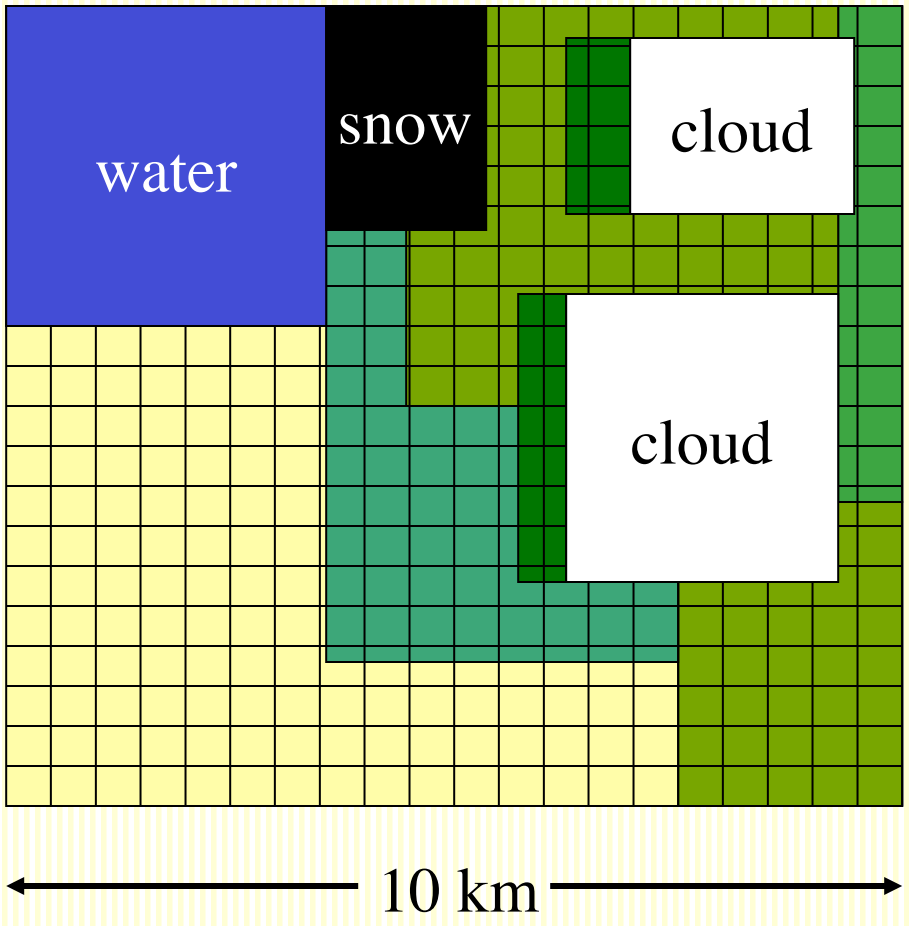
Choice of 4 fine modes
and 5 coarse modes

In order to minimize
$(\rho_{meas} - \rho_{LUT})$ over 6 wavelengths




s

# MODIS Over Land Algorithm
## 20 x 20 pixels at 500 m resolution
## (10 km at nadir)




400 total
- 56 water

344
- 24 snow

320
- 55 cloud

265
-116 “bright”

149 “good”

Discard brightest 50% and darkest 20% of the 149 good pixels.

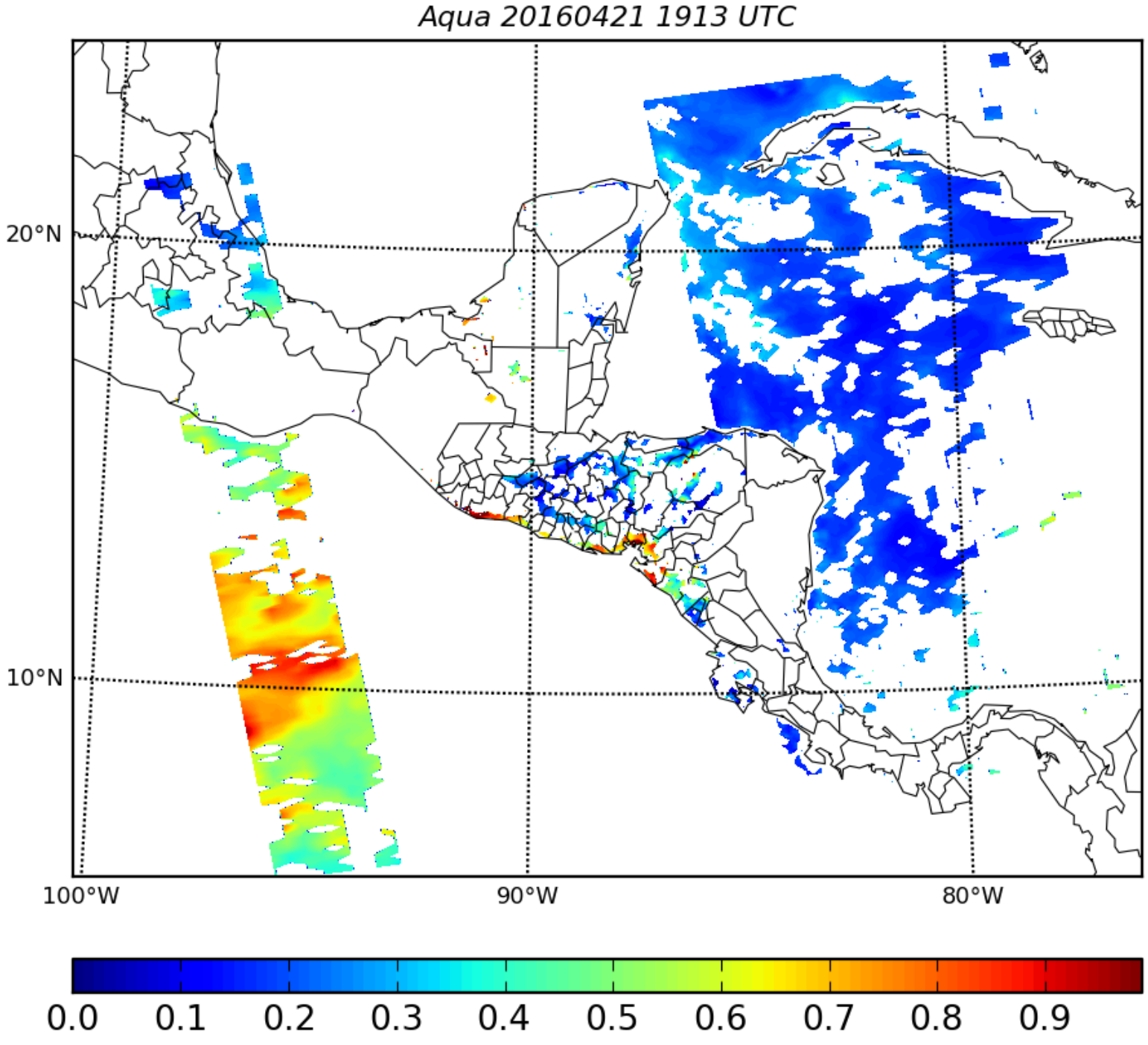
44 pixels

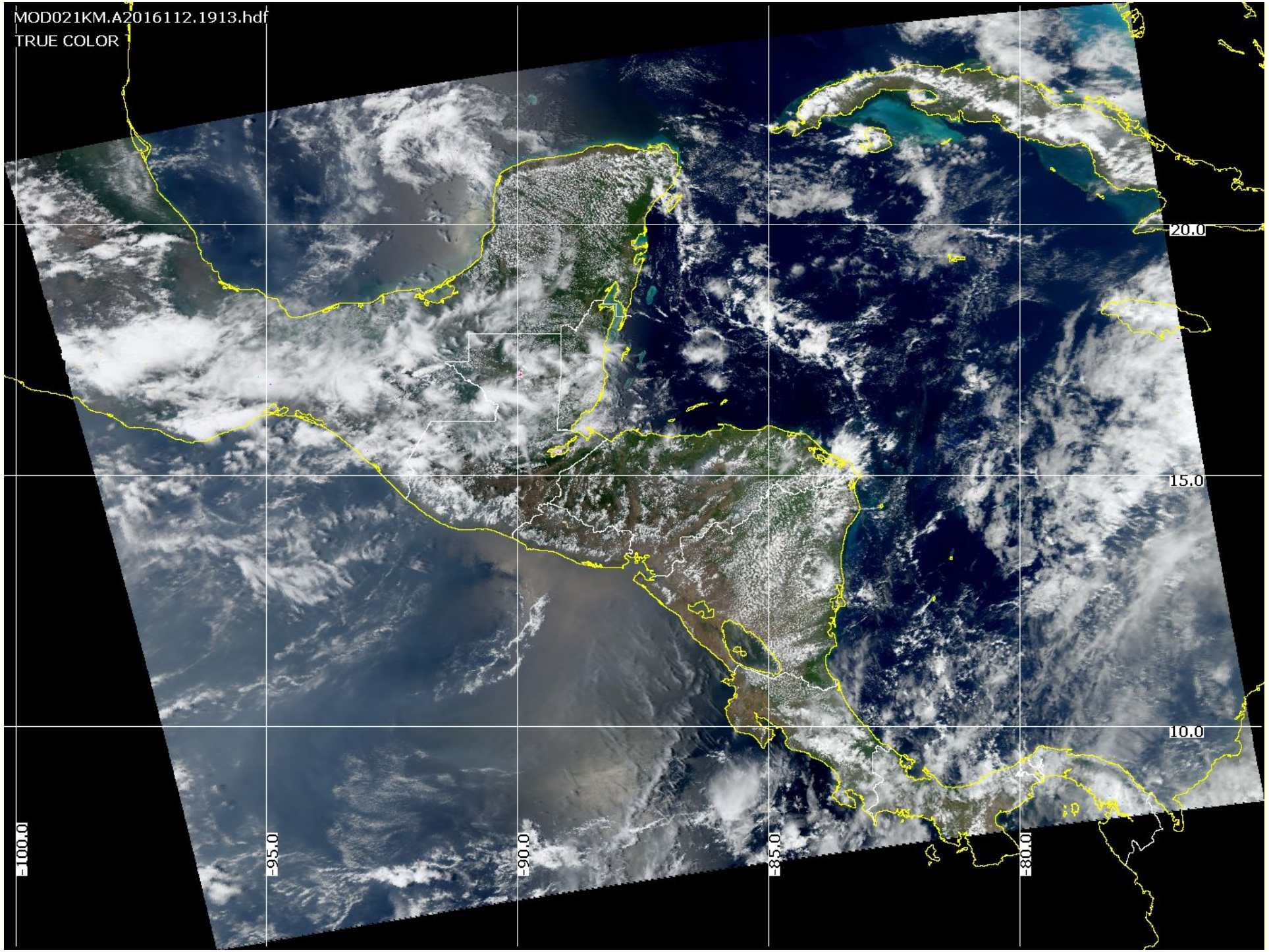
# MOD04 Key Output Parameters

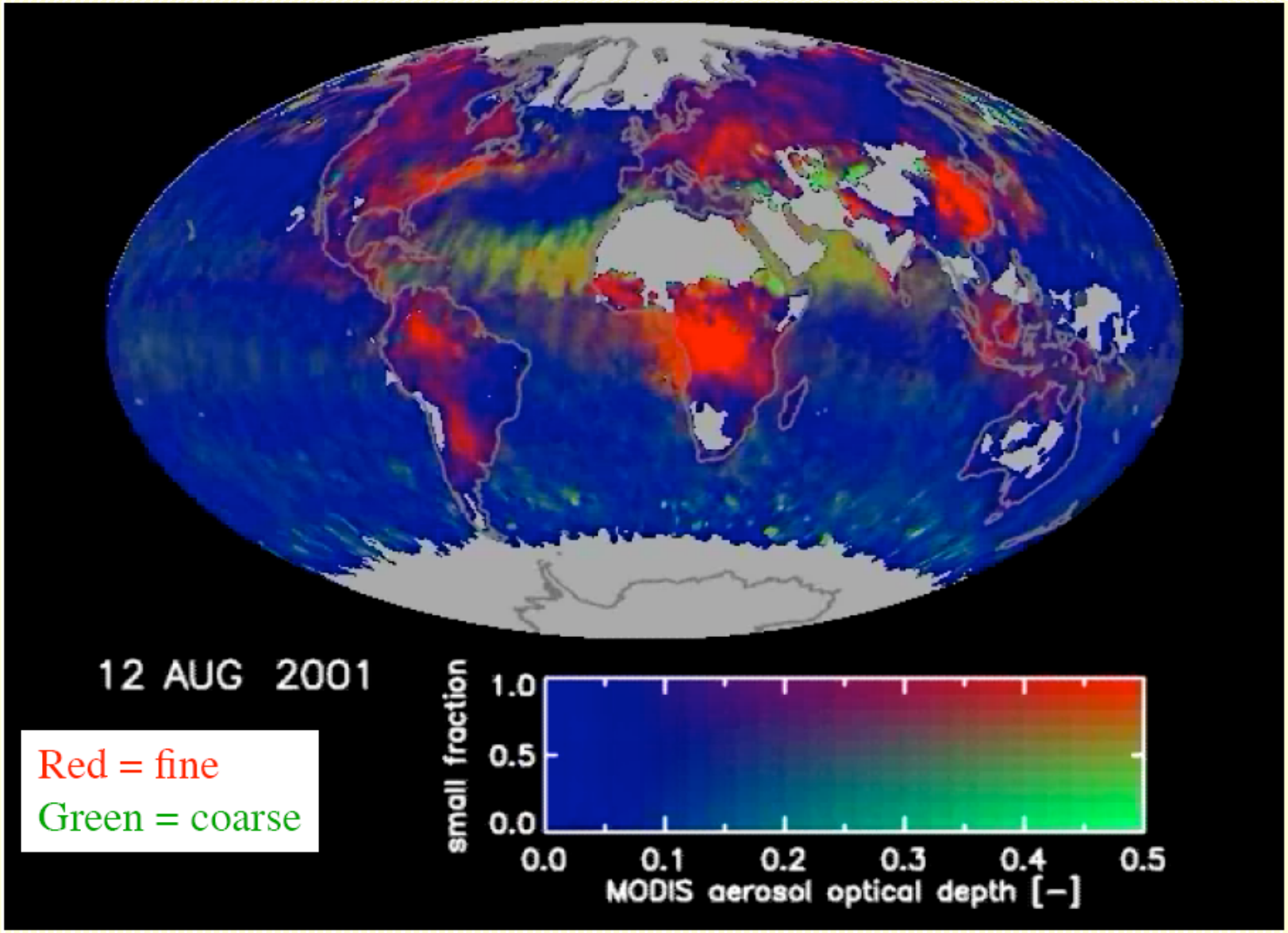
## 10x10 pixel (1km) resolution and 3x3 km resolution

- Optical_Depth_Land_And_Ocean – Aerosol Optical Thickness (AOT) at 0.55 microns for both ocean and land
- Optical_Depth_Ratio_Small_Land_And_Ocean - Ratio of small particle optical depth to total at 0.55 microns

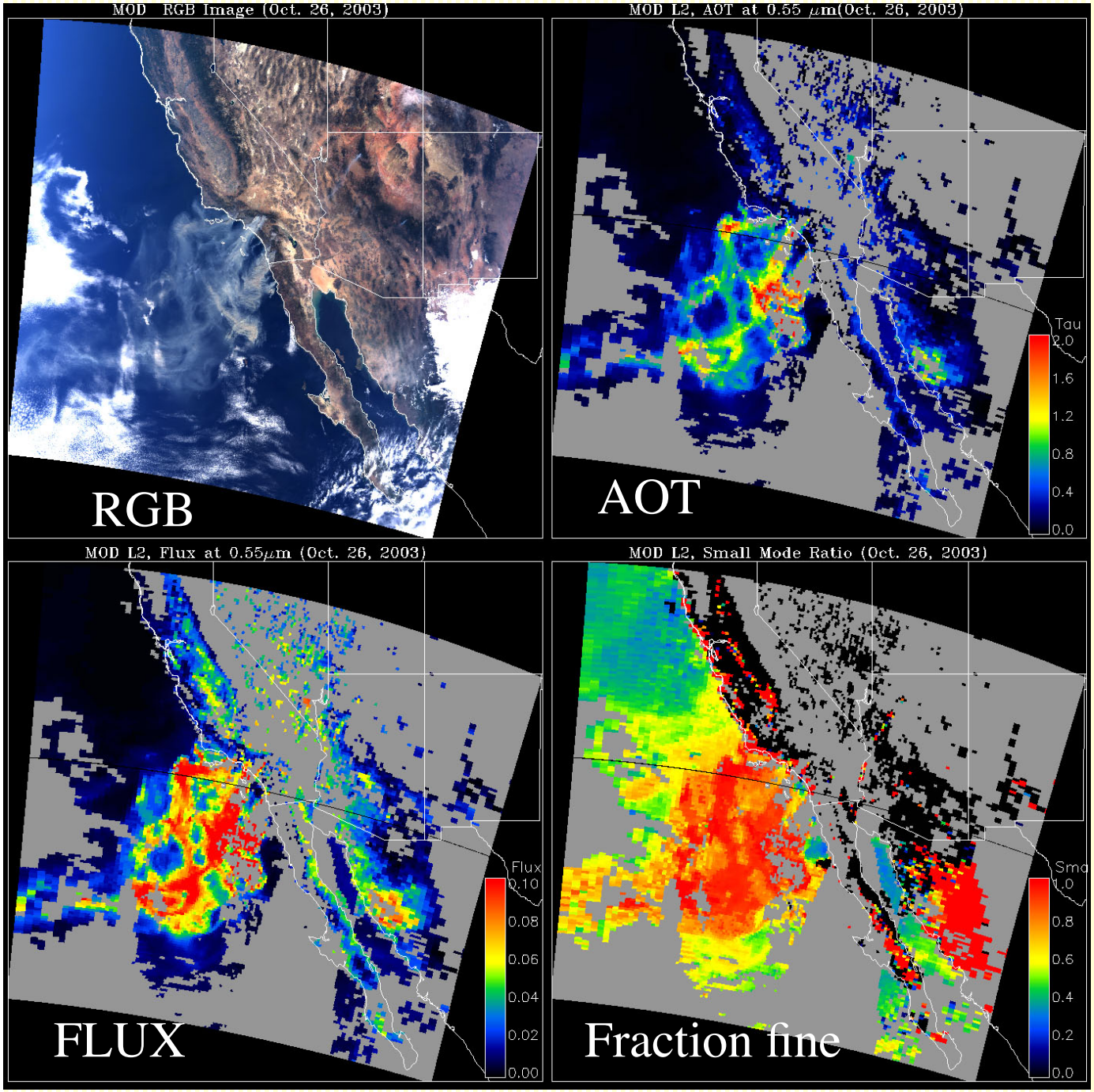
- a1.16105.1726.mod04.hdf – MODIS Aerosol Product file
- a1.16105.1726.mod04_3k.hdf – MODIS Aerosol High Resolution Product file
- VAOOO_npp*.h5 files - VIIRSAerosol Optical Depth EDR


Aqua 20160421 1913 UTC
20°N
10°N
100°W
90°W
80°W
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9


MOD021KM.A2016112.1913.hdf
TRUE COLOR
20.0
15.0
10.0
-100.0
-95.0
-90.0
-85.0
-80.0




Separating fine mode from coarse mode aerosol




California Wildfires Oct. 26, 2003

From Terra-MODIS

Rong-Rong Li

# Infrared Detection Technique

Qualitative Product Developed at EUMETSAT

See http://www.eumetsat.int/website/home/Data/Training/TrainingLibrary/DAT_2042669.html

http://www.eumetsat.int/website/home/Data/Training/TrainingLibrary/DAT_2042669.html

EUMETSAT

MONITORING WEATHER AND CLIMATE FROM SPACE

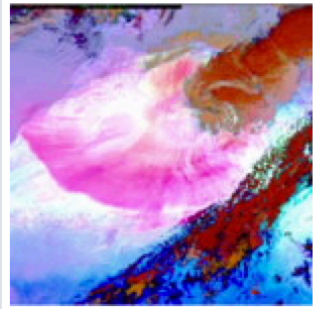
SEARCH

HOME IMAGES ABOUT US SATELLITES DATA NEWS QUICK LINKS

# DUST DETECTION: THE DUST RGB PRODUCT



## In this session the reason why dust detection by satellite is important is going to be explored interactively with the participants.



*Published: 25 October 2011*

The session will focus on the use of RGB products as a tool to retrieve relevant information from certain MSG channels. In particular, the DUST RGB is going to be thoroughly analysed, exploring the benefits of combining three channels in the infra-red region of the electromagnetic spectrum: IR8.7, IR10.8 and IR12.0. The principle of reverse absorption for dust with the IR10.8 and IR12.0 channels, as well as the differences in desert emissivity between IR10.8 and IR8.7, are key topics of the presentation.

Finally, other colours in DUST RGB images are explained to further exploit the product.

At the end of this lecture you should be able to:

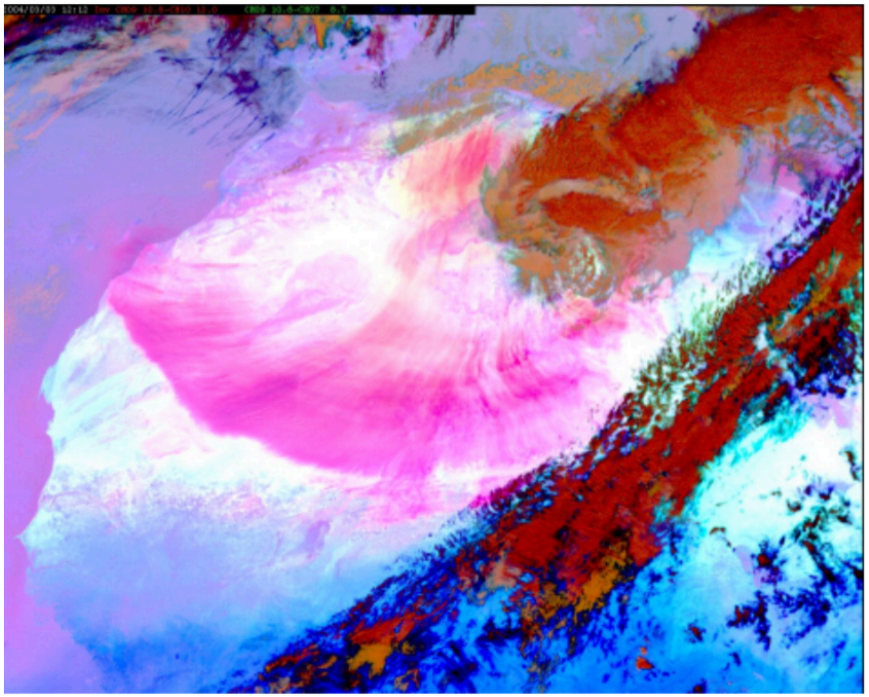
- identify dust clouds in DUST RGB products;
- understand the reason why dust is magenta in the DUST RGB product;
- identify different magenta shades for exploring dust level in the DUST RGB product;
- get acquainted with the principle of reverse absorption with IR10.8 and IR12.0 channels;
- realise the impact of the desert emissivity and temperature in RGB products;
- learn what other colours in the DUST RGB product mean.

Pre-requisites: some knowledge in infra-red and visible satellite imagery and some experience in weather forecasting and/or air quality.

# Why dust detection ?

à frente do nosso tempo

UNCCD United Nations Convention to Combat Desertification



## NEWS RELEASE

### Disastrous Sand and Dust Storms Force Global Partnership

**Buenos Aires, 24 September 2009**. Experts from the United Nations Convention to Combat Desertification (UNCCD) and the World Meteorological Organization (WMO) have called for an immediate global response to the increasing number of sand and dust storms. Talks during the ninth session of the Conference of Parties (COP 9) of the UNCCD in Buenos Aires, Argentina, took account of the 4th Assessment Report of the Inter-government Panel on Climate Change (IPCC) warning that there will be an increased frequency of drought, especially in the dryland regions of the world.

Suspended particles in the atmosphere can affect global warming and have many deadly impacts on society. A high probability that meningitis in Africa and Valley Fever in the Americas is associated with sand and dust weather was reported. Meningitis in the sub-Saharan belt is one of the most feared epidemic diseases in Africa with high fatality rates and brain damage being common.

"Policy makers need to know the source of disease outbreaks, whether they are due to airborne or human transport, and to take actions to minimize risk to health and agriculture," WMO's Robert Stefanski said. "Present capabilities to provide effective climate services fall far short of the needs in developing countries and must be improved." As much as 330,000 tons of sand fell on Beijing in a single night during spring conditions in 2006.

WMO is establishing a Sand and Dust Storm Warning Advisory and Assessment System to help countries receive early warnings on devastating sand and dust storms around the world.

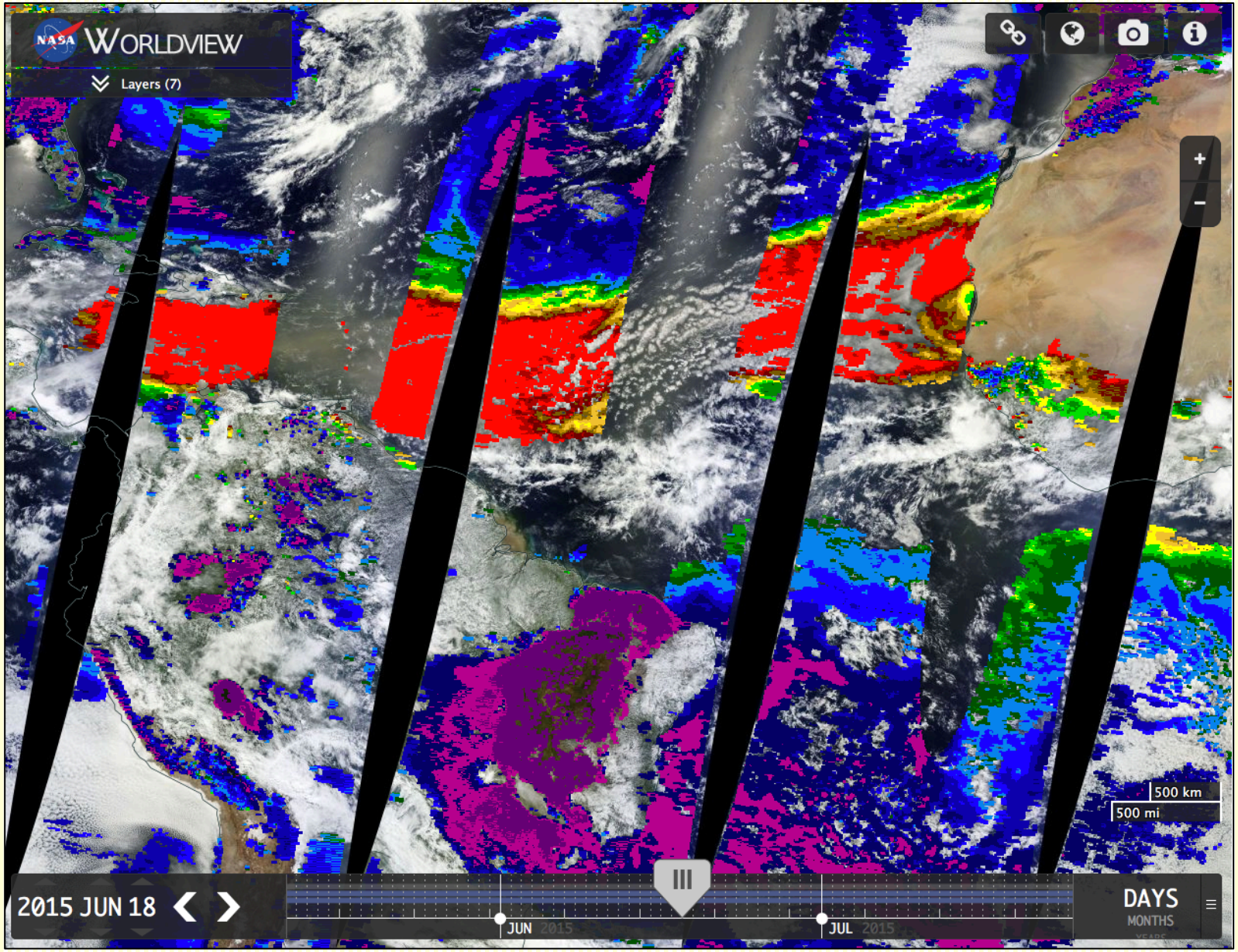
A key expert on sand and dust storms, Yang Youlin of the UNCCD office in Bangkok, called for an enhanced ability of countries to deliver timely and quality forecasts of sand and dust storms. "Land degradation and sand encroachment in China has expanded to 3,436 square kilometers per year during the late 1990s and early 2000s."

In China alone, dust and sand storms originate from a total area of about 1 million sq. km. Rainfall patterns combined with efforts to control land degradation in Northern China, such as the 'Grain for Green Project', have helped to minimise sand and dust events in recent years.

In North America, the annual on-farm cost of wind erosion in the Prairie Provinces of Canada is estimated at USD $250 million. "Long-term drought in Australia and its recent sand and dust storms highlight the risk to the world," said Stefanski.

Scientists meeting in Buenos Aires from 22-24 September during the UNCCD's COP 9 are also discussing over-grazing, over-cultivation and destruction of soil that accelerates wind erosion in dryland regions.

http://www.unccd.int/publicinfo/pressrel/showpressrel.php?pr=press24_09_09a


NASA WORLDVIEW
Layers (7)
500 km
500 mi
2015 JUN 18
JUN 2015
JUL 2015
DAYS
MONTHS

# Dust RGB Product

**Ranges and Enhancements:**

| Beam | Channel | Range | Gamma |
|---|---|---|---|
| Red | IR12.0 - IR10.8 | -4 K … +2 K | 1.0 |
| Green | IR10.8 - IR8.7 | 0 K … +15 K | 2.5 |
| Blue | IR10.8 | 261 K … 289 K | 1.0 |

Dust appears largely due to the influence of the
12 micron minus 11 micron brightness temperature difference

# Other colors in "Dust RGB"

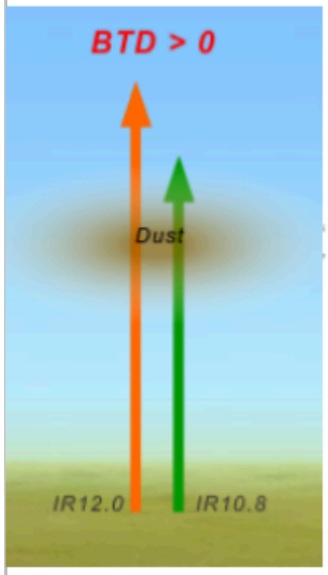
à frente do nosso tempo

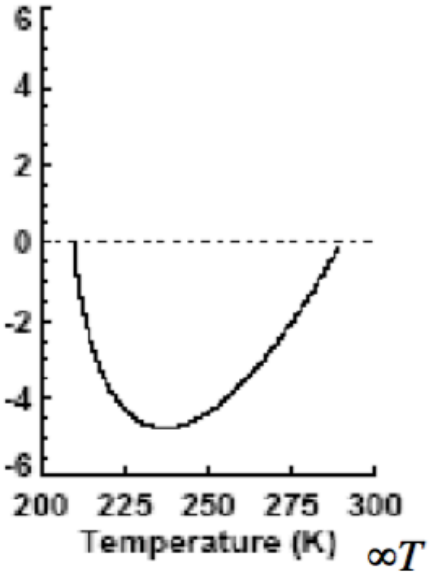
In fact the spectral property of silica-rich particles is called **reverse absorption**

For water and Ice, the absorption is larger for 12.0 micra than for 10.8 micra

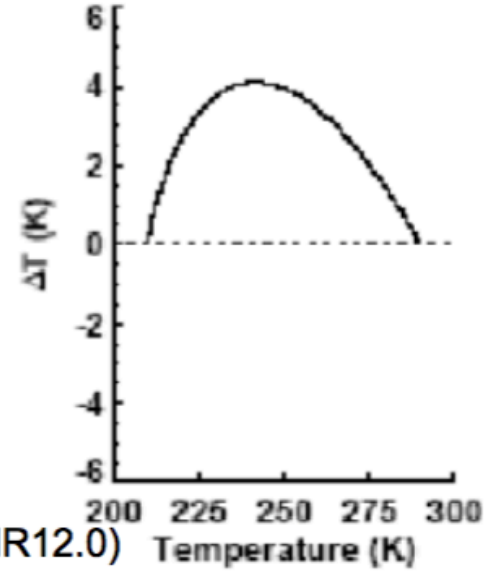
Dust / Ash : BT (10.8) < BT (12.0)

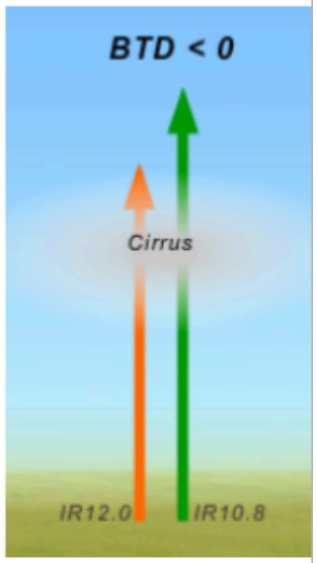
Water / Ice : BT (10.8) > BT (12.0)



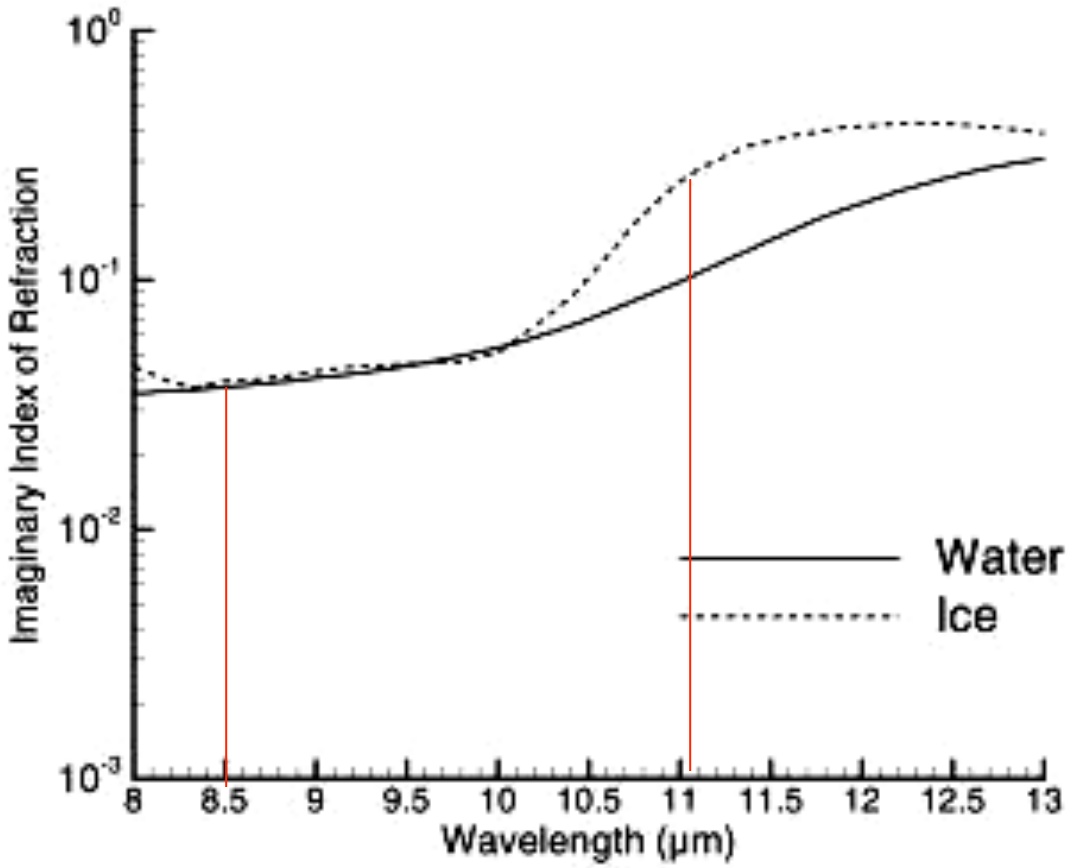




$\propto T$ = BT(IR10.8) – BT(IR12.0)

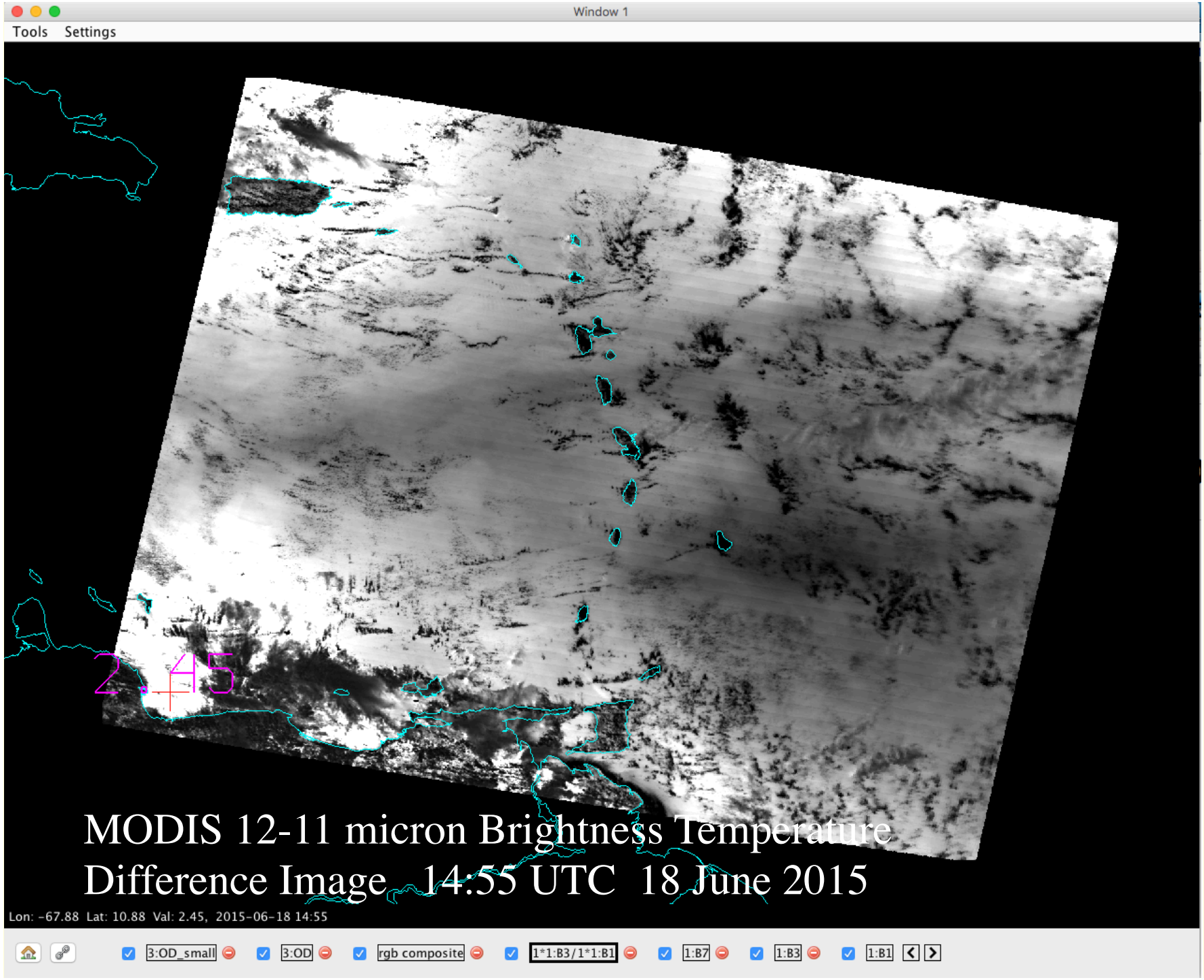


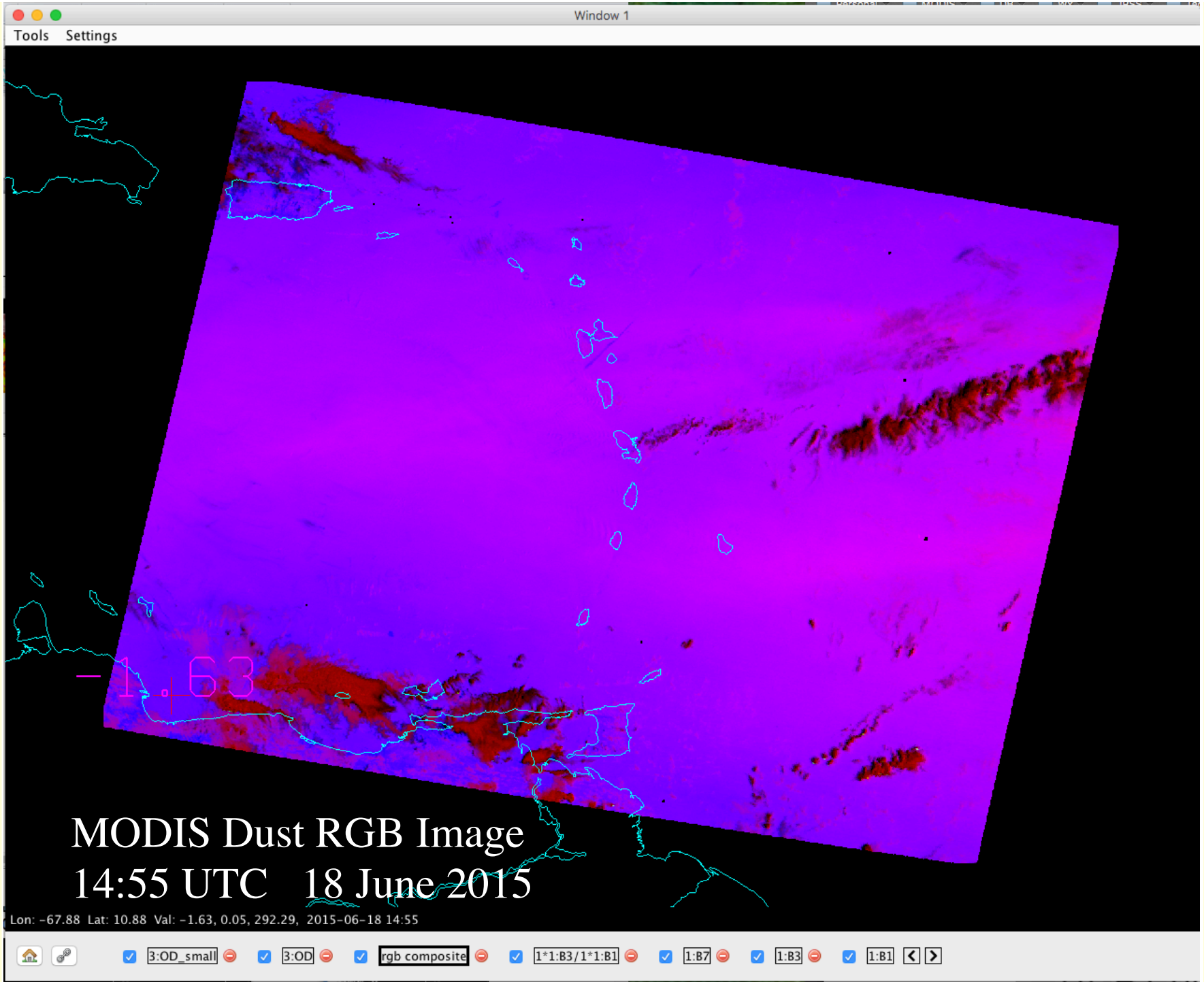




Ministério da Ciência e Educação
**Instituto de Meteorologia, I. P.** Rua C – Aeroporto de Lisboa 1749-077 Lisboa – Portugal Tel.: (351) 21 844 7000 Fax: (351) 21 840 2370 e-mail: informacoes@meteo.pt URL:



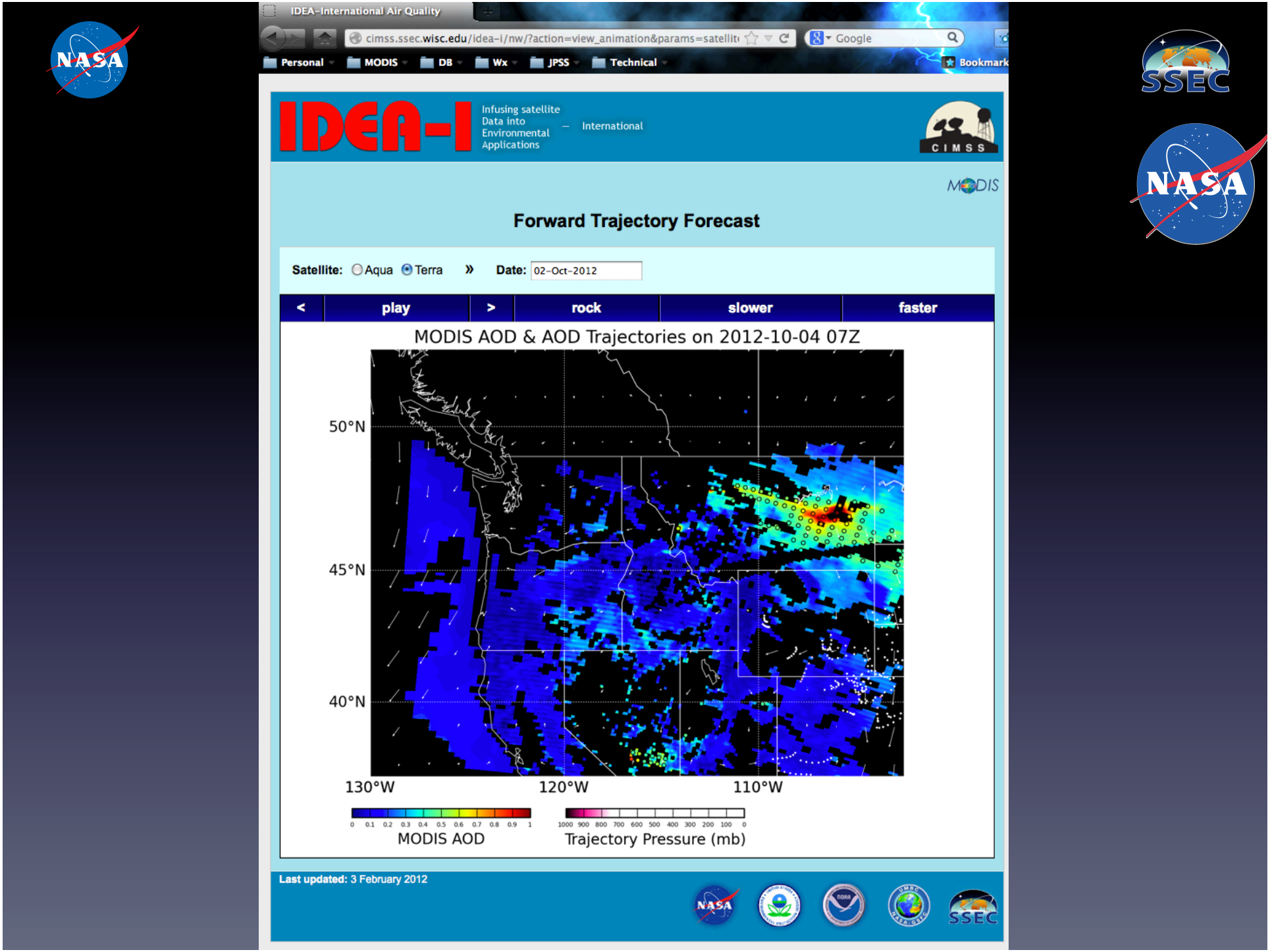

Imaginary Index of Refraction of Ice and Water 8 – 13 microns


Window 1
Tools
Settings
2.45
MODIS 12-11 micron Brightness Temperature
Difference Image 14:55 UTC 18 June 2015
Lon: -67.88 Lat: 10.88 Val: 2.45, 2015-06-18 14:55
3:OD_small
3:OD
rgb composite
1*1:B3/1*1:B1
1:B7
1:B3
1:B1

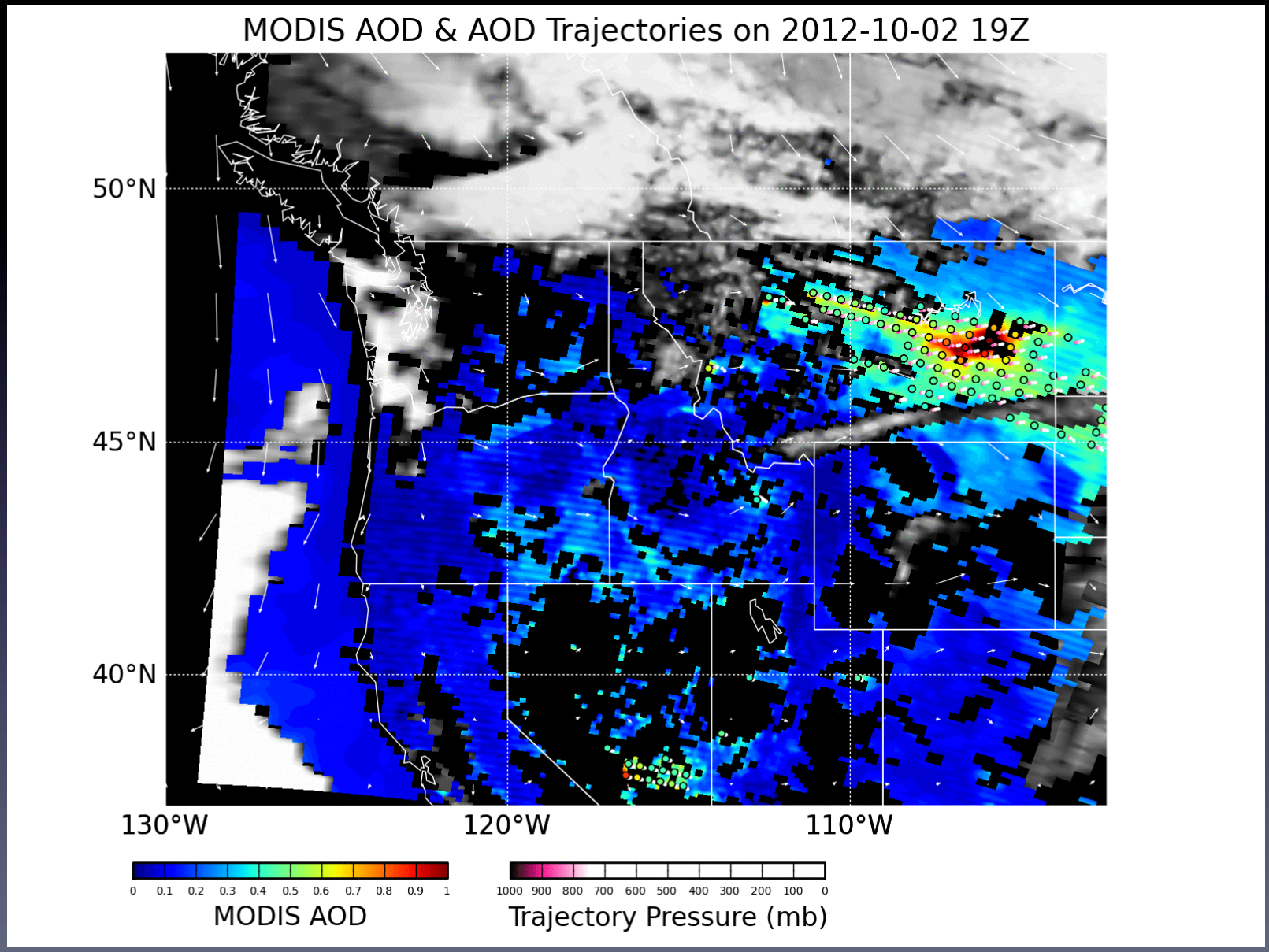

Window 1
Tools
Settings
MODIS Dust RGB Image
14:55 UTC 18 June 2015
Lon: -67.88 Lat: 10.88 Val: -1.63, 0.05, 292.29, 2015-06-18 14:55
3:OD_small
3:OD
rgb composite
1*1:B3/1*1:B1
1:B7
1:B3
1:B1

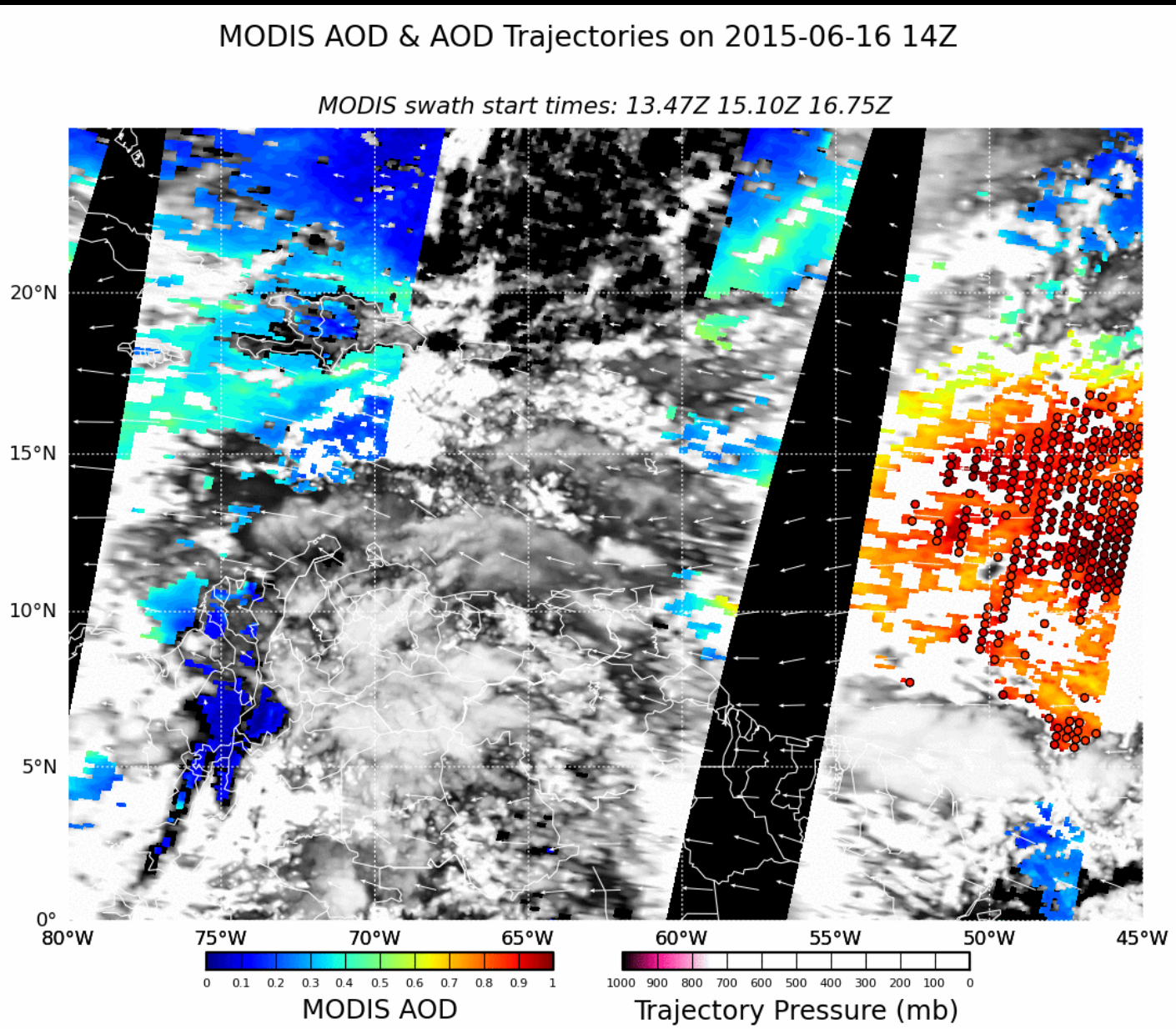
# IDEA-I

- Infusing Satellite Data into Environmental Applications - International
- Globally configurable air quality trajectory forecast
- Identifies areas of high aerosol optical depth (MOD04 product), then runs 48 hour trajectory forecast to identify where the aerosols are moving in 3 dimensions
- Released as part of IMAPP (International MODIS/AIR Processing Package)


IDEA-International Air Quality
cimss.ssec.wisc.edu/idea-i/nw/?action=view_animation&params=satellit
Google
Personal
MODIS
DB
Wx
JPSS
Technical
Bookmark
IDEA-I
Infusing satellite Data into Environmental Applications
International
CIMSS
MODIS
Forward Trajectory Forecast
Satellite: Aqua Terra
Date: 02-Oct-2012
< play > rock slower faster
MODIS AOD & AOD Trajectories on 2012-10-04 07Z
50°N
45°N
40°N
130°W
120°W
110°W
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
MODIS AOD
1000 900 800 700 600 500 400 300 200 100 0
Trajectory Pressure (mb)
Last updated: 3 February 2012
NASA
SSEC

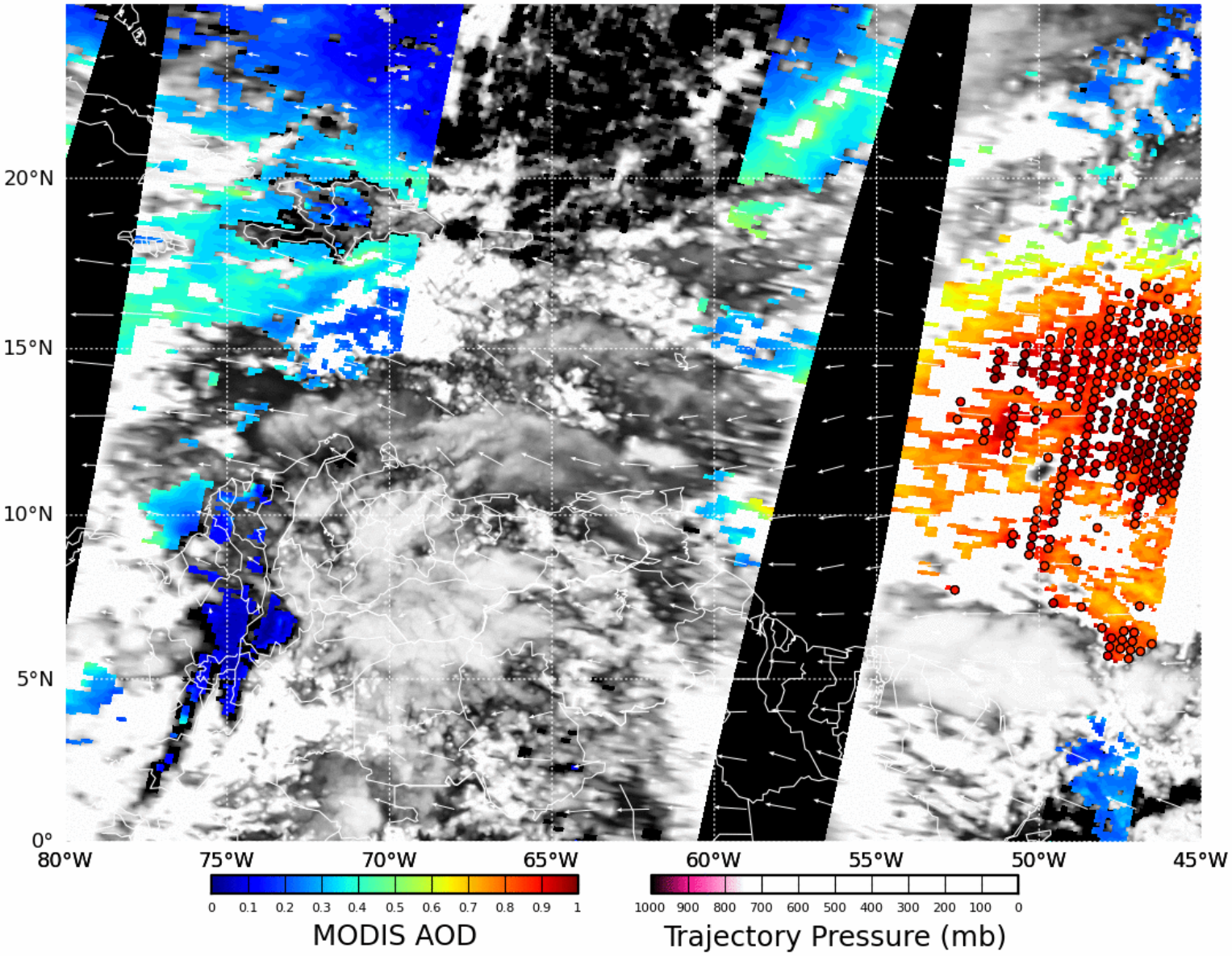
# Northwest US IDEA-I Domain




MODIS AOD & AOD Trajectories on 2015-06-16 14Z
MODIS swath start times: 13.47Z 15.10Z 16.75Z
20°N
15°N
10°N
5°N
0°
80°W
75°W
70°W
65°W
60°W
55°W
50°W
45°W
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
MODIS AOD
1000 900 800 700 600 500 400 300 200 100 0
Trajectory Pressure (mb)

# MODIS AOD & AOD Trajectories on 2015-06-16 14Z

*MODIS swath start times: 13.47Z 15.10Z 16.75Z*



# OCEAN COLOR

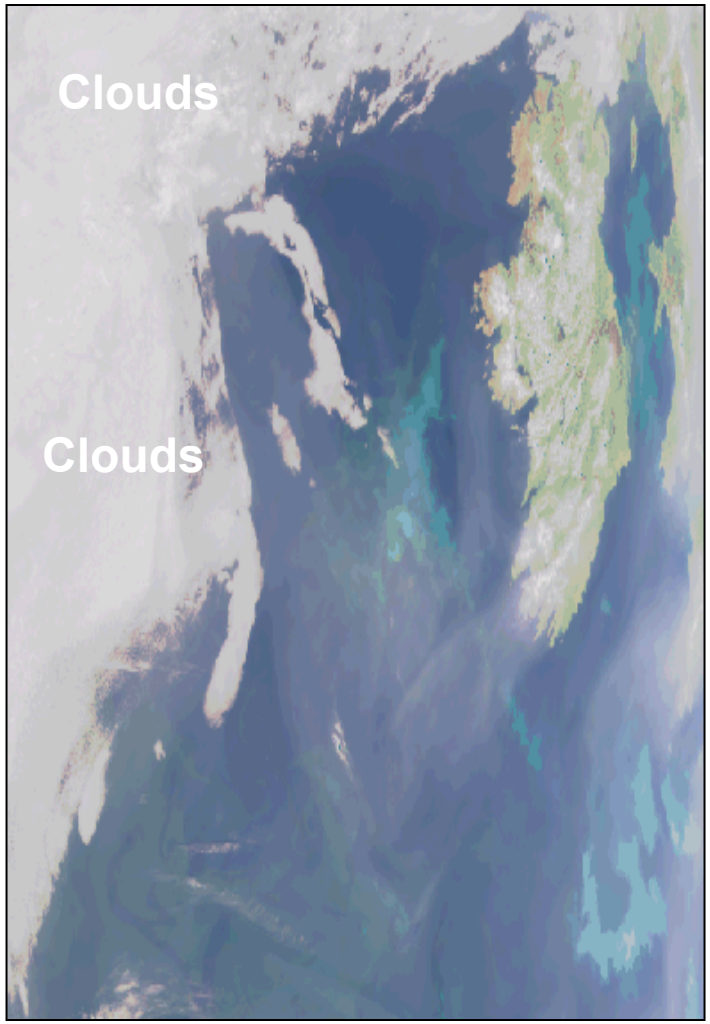
# Ocean Color - SeaDAS

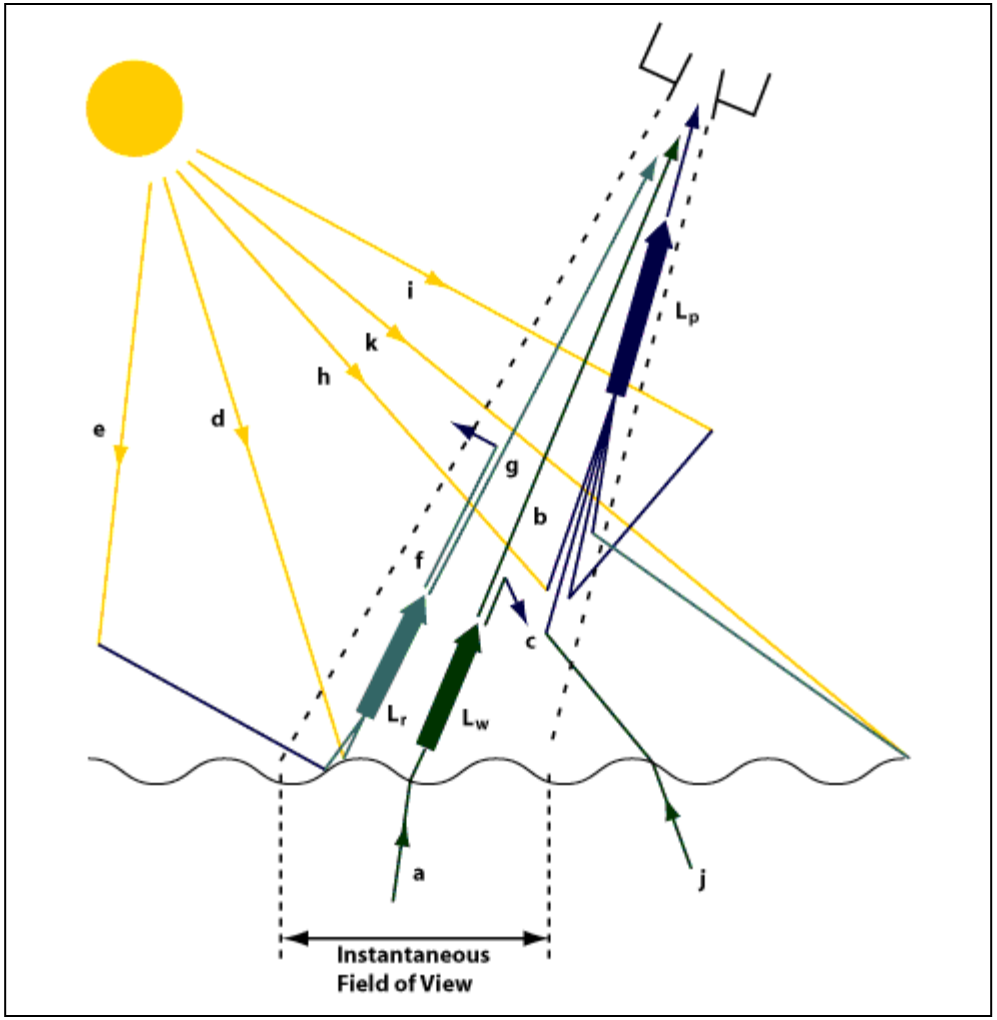
# SeaDAS Key Output Products

Table 1. Summary of Level-2 geophysical parameters and attributes

| **Parameter** | **Storage (bytes)** | **Approximate Range** | **Units** | **Long Name** |
|---|---|---|---|---|
| Rrs_WWW | 2 | -0.015 – 0.115 | $sr^{-1}$ | Remote sensing reflectance at WWW nm |
| chlor_a | 4 | 0 – 100 | mg $m^{-3}$ | Chlorophyll Concentration, OC4 Algorithm |
| sst | 2 | -2 – 45 | degrees C | Sea Surface Temperature |

# Atmospheric correction is critical for ocean color retrievals




- $L_w$ is only 5-10% of signal reaching satellite: rest due to $L_p$
- $L_p$ components: molecular (Rayleigh) & aerosols

# MODIS Atmospheric Correction for Ocean Bands

Statement of the problem:

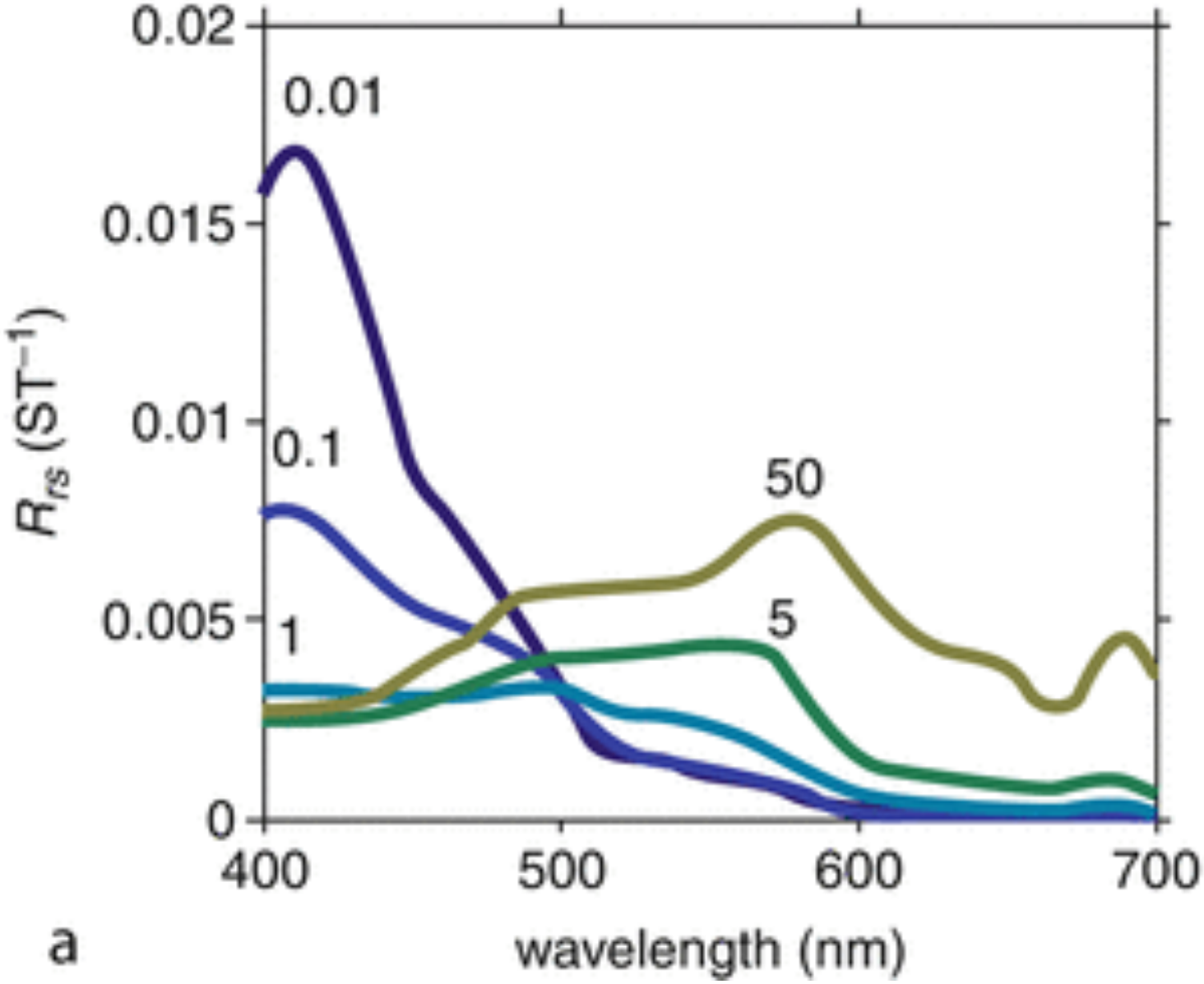
- Total radiance observed by the satellite is composed of 5-10% ocean signal and 90-95% atmosphere signal.
- The atmospheric and ocean surface scattering effects must be accurately modelled and removed.
- Desired parameter is normalized water leaving radiance (remote sensing reflectance) for MODIS bands 8, 9, 10, 11, 12, 13 (0.412, 0.443, 0.488, 0.531, 0.551, 0.667 microns)

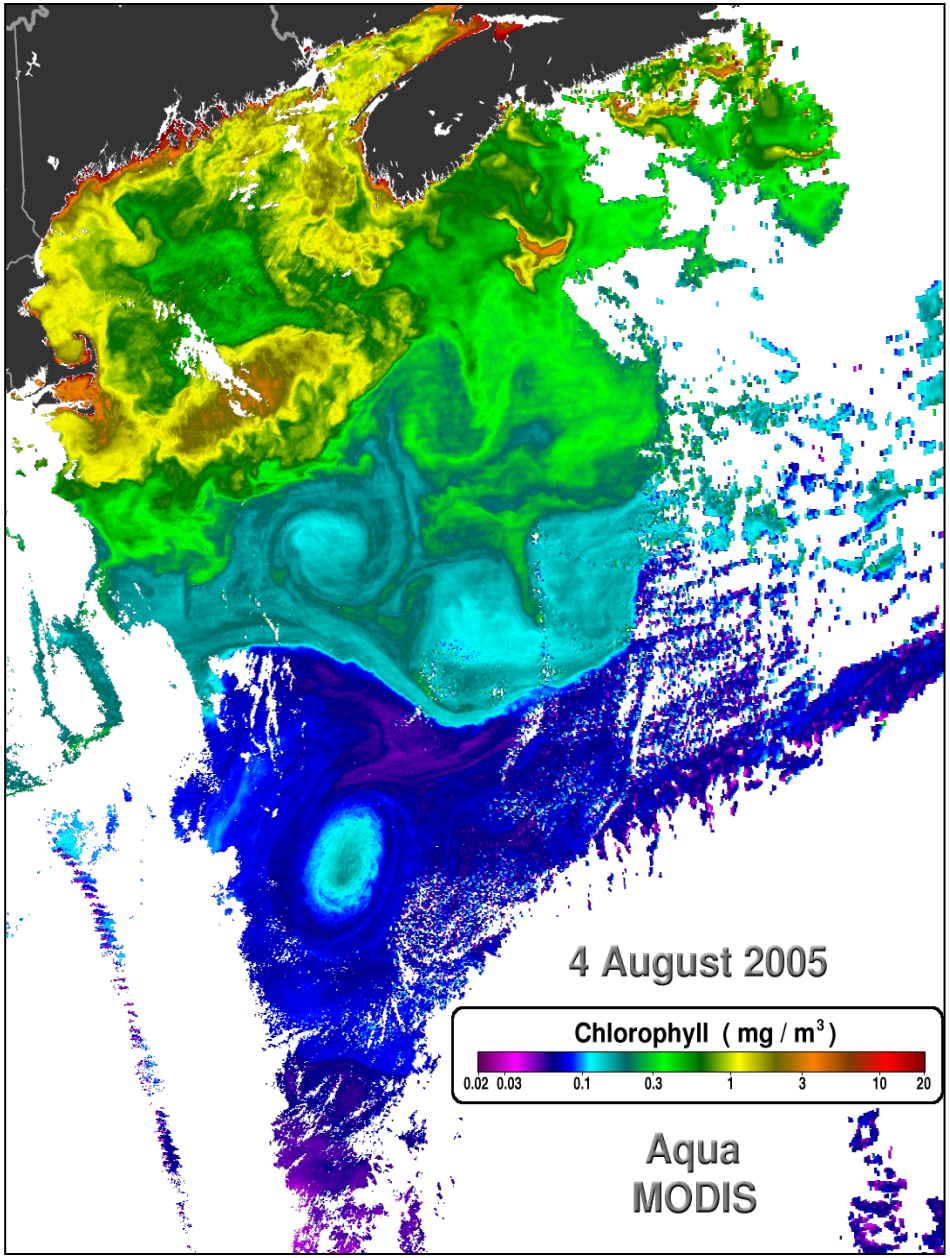
SeaDAS file names:

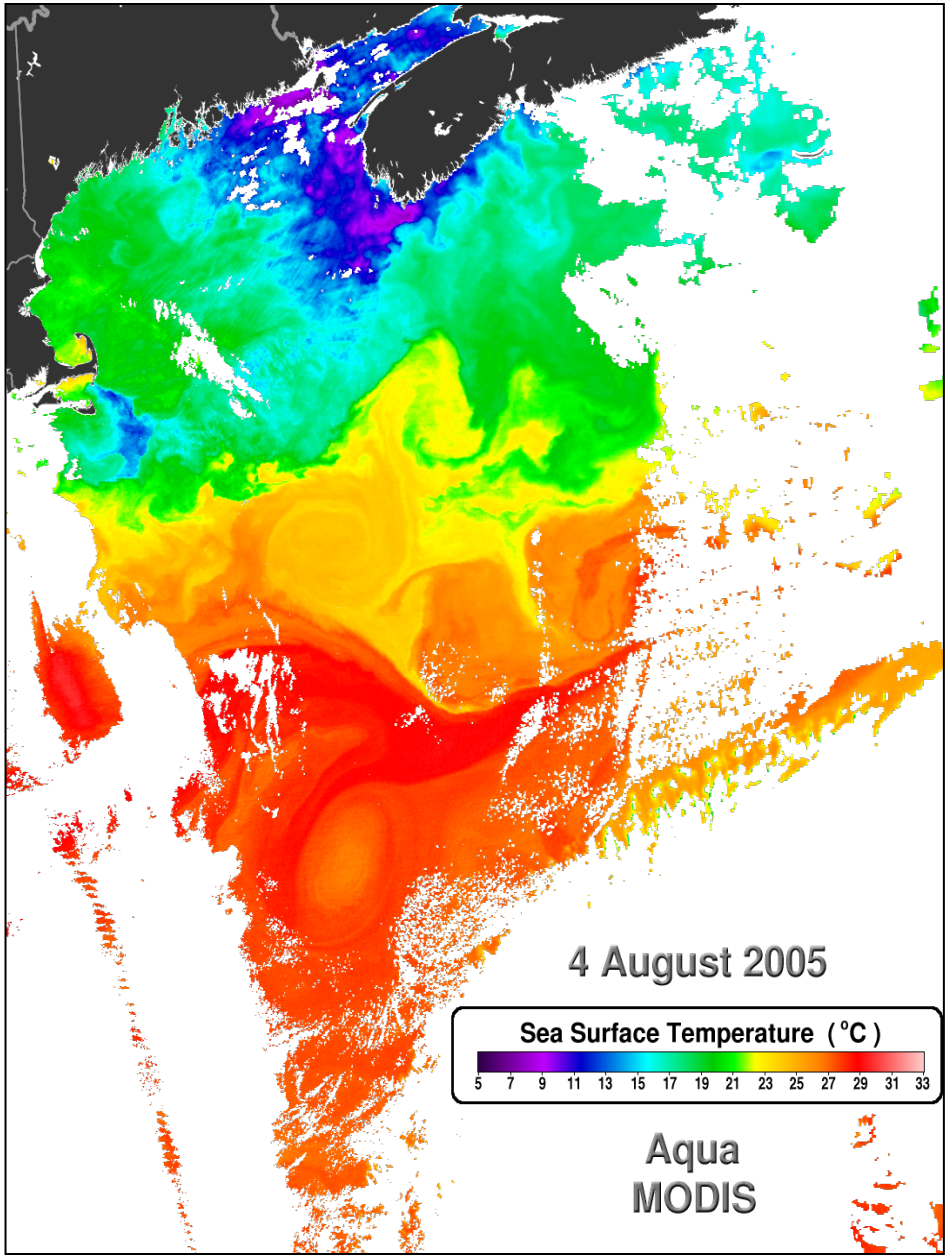
MODIS: a1.16111.0556.seadas.hdf

VIIRS: SEADAS_npp_d20160420_t1914590_e1922052.hdf

Remote sensing Reflectance and Chlorophyll Concentrations




4 August 2005
Chlorophyll ( mg / m3 )
0.02 0.03 0.1 0.3 1 3 10 20
Aqua
MODIS


4 August 2005
Sea Surface Temperature ( °C )
5 7 9 11 13 15 17 19 21 23 25 27 29 31 33
Aqua
MODIS

# examples of ocean color applications

## SeaWiFS depth classification

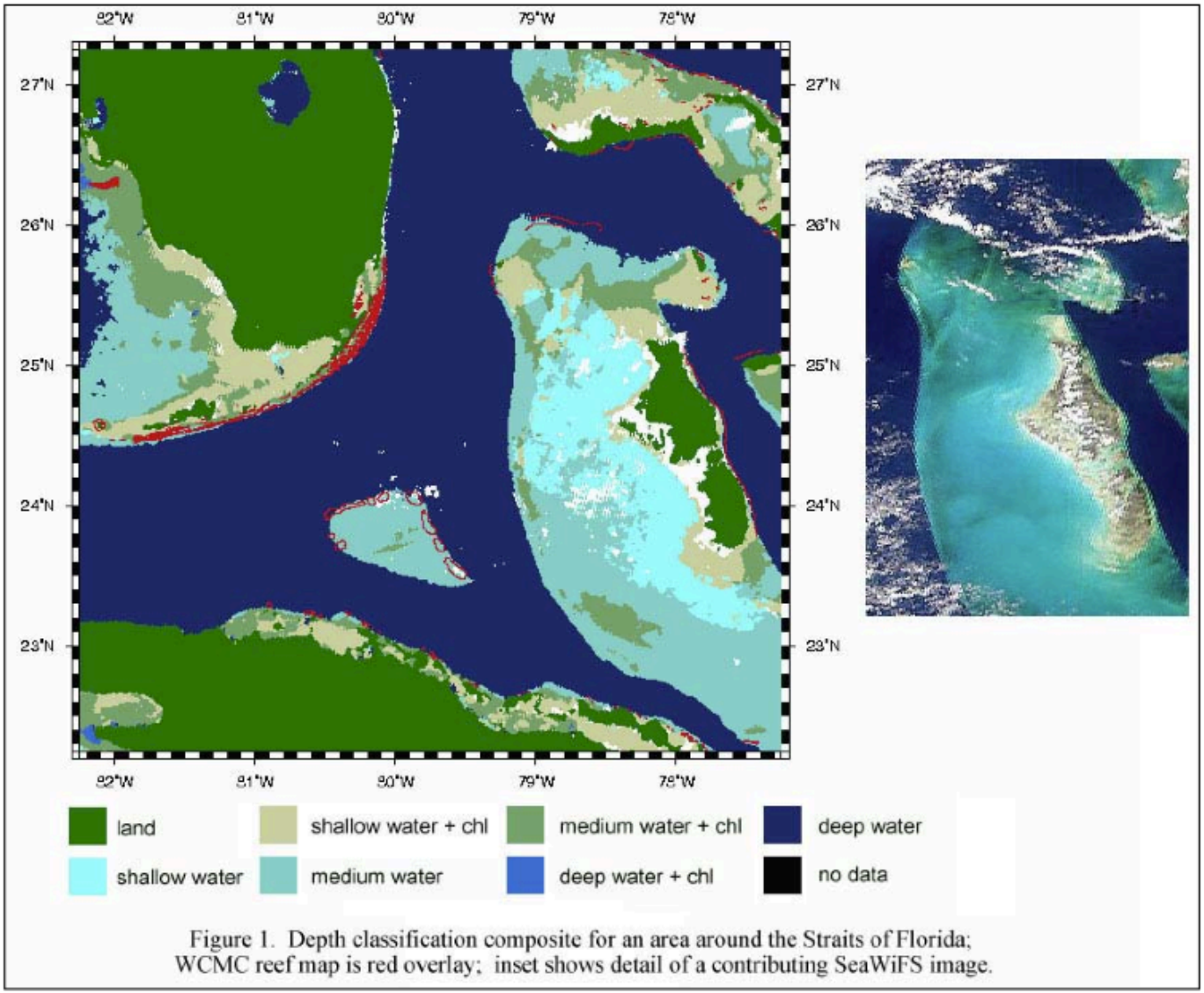



Figure 1. Depth classification composite for an area around the Straits of Florida; WCMC reef map is red overlay; inset shows detail of a contributing SeaWiFS image.

# examples of ocean color applications

## harmful algal blooms

### Gulf of Mexico Harmful Algal Bloom Bulletin

27 October 2005

National Ocean Service

National Environmental Satellite, Data, and Information Service

Last bulletin: October 24, 2005

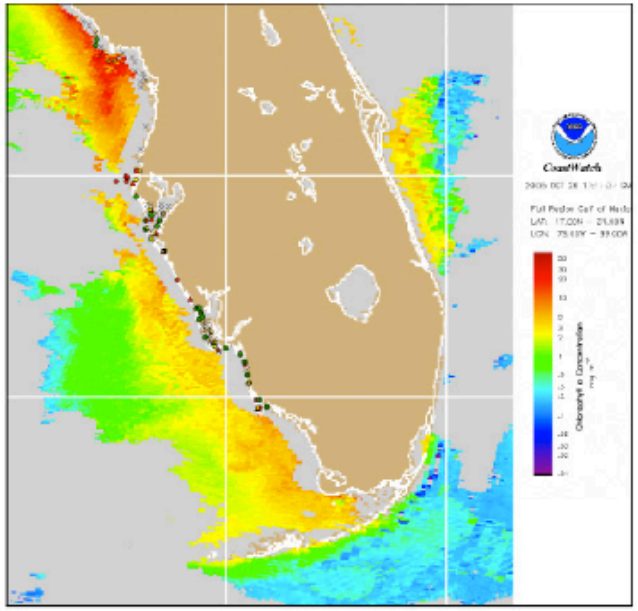
*Conditions:* Harmful algal blooms have been identified in Pinellas County, Dixie to Levy County and in very small patches from Manatee to Collier County in Florida. A secondary bloom has been identified in patches along Alabama and the Florida Panhandle. No impacts are expected along the coast from Pinellas to Collier County or from Dixie to Levy County today through Sunday. Patchy very low to low impacts are possible from Wakulla to Okaloosa County, FL and Baldwin to Mobile County, AL today through Sunday. Dead fish have been reported in Bay and Okaloosa Counties over the past few days. Dead fish smell, while unpleasant, does not produce the same respiratory irritation as red tide.

*Analysis:* The harmful algal bloom continues to dissipate along the SW Florida coastline; however very small remnant populations of *K. brevis* may still be present in patches from Pinellas to Collier County. Low *K. brevis* concentrations remain offshore of Bunces Pass in southern Pinellas County. Previous low *K. brevis* concentrations in Sarasota County have decreased to background levels (FWRI 10/20-26). Chlorophyll levels are elevated all along the Florida coast due to resuspension produced by Hurricane Wilma; thus bloom extent analysis is limited. Results of a wind transport model indicate possible bloom movement 20-30km southward since October 24. No recent samples have been reported from Levy to Dixie Counties. Sampling is recommended. Persistent northeasterlies will minimize coastal impacts through Sunday. Continual dissipation of the bloom is expected. Reports of discolored water are likely.

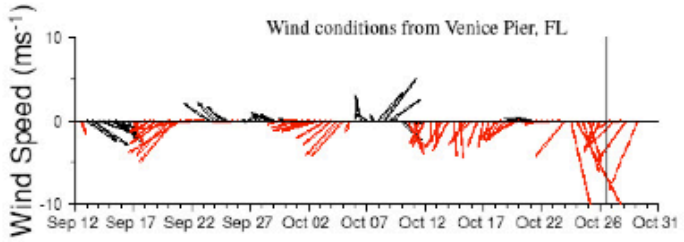
~Fisher, Bronder

Please note the following restrictions on all SeaWiFS imagery derived from CoastWatch.

1. These data are restricted to civil marine applications only; i.e. federal, state, and local government use/distribution is permitted.
2. Distribution for military, or commercial purposes is NOT permitted.
3. There are restrictions on Internet/Web/public posting of these data.
4. Image products may be published in newspapers. Any other publishing arrangements must receive OrbImage approval via the CoastWatch Program.



Chlorophyll concentration from satellite with HAB areas shown by red polygon(s). Cell concentration sampling data from October 19, 2005 shown as red squares (high), red triangles (medium), red diamonds (low b), red circles (low a), orange circles (very low b), yellow circles (very low a), green circles (present), and black "X" (not present).




Wind speed and direction are averaged over 12 hours from measurements made on buoys. Length of line indicates speed; angle indicates direction. Red indicates that the wind direction favors upwelling near the coast. Values to the left of the dotted vertical line are measured values; values to the right are forecasts.

SW Florida: Moderate (10-15kts, 5-8m/s) northeasterly winds today will continue through Sunday; strengthening up to 20kts (10m/s) Saturday and Sunday.

# examples of ocean color applications

impacts of natural disasters

Hurricane Floyd

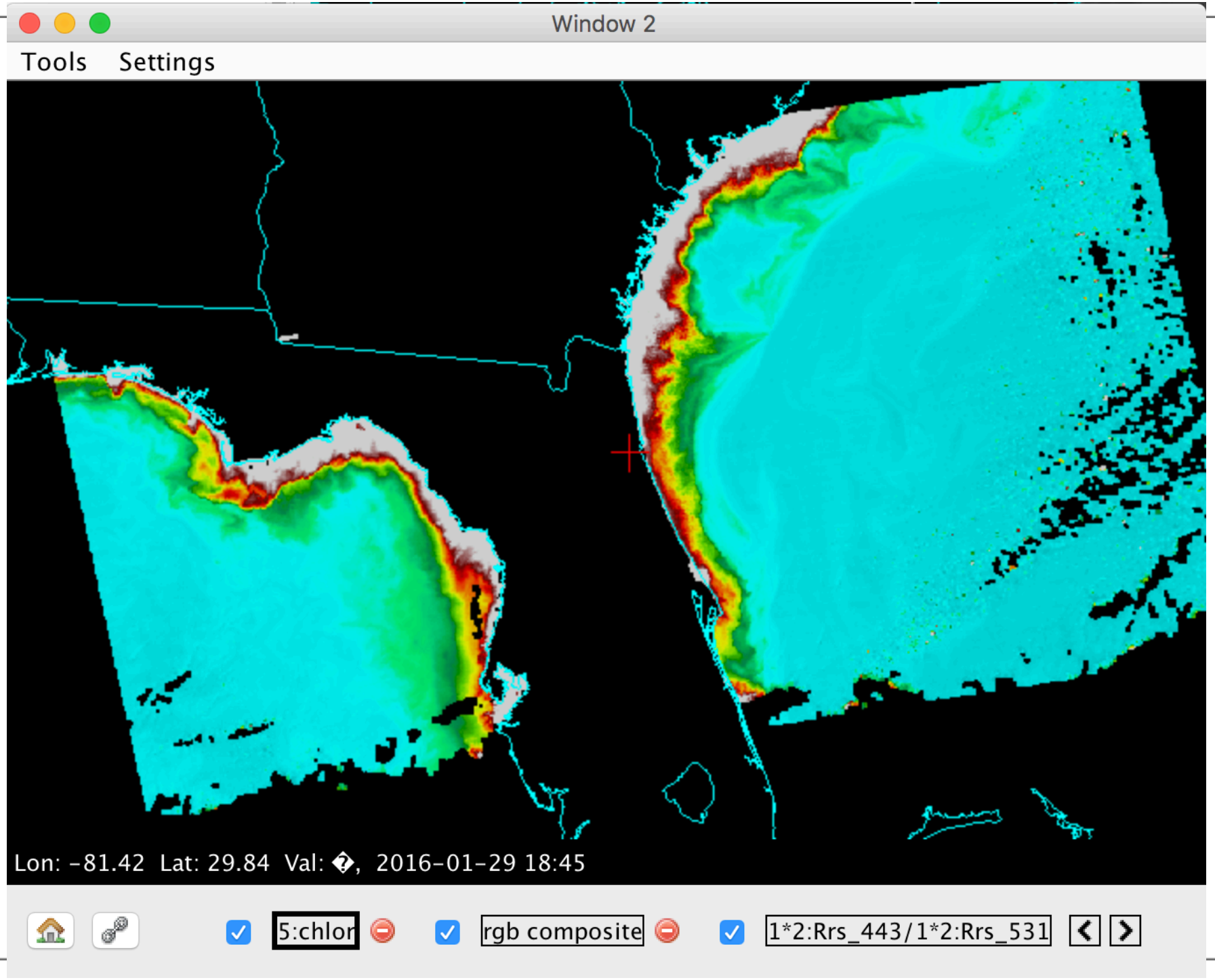
23 September 1999

massive flooding

rivers carried sediment & sewage discharge into coastal areas

resulted in anoxic conditions in bays

Sept. 23, 1999


Window 2
Tools
Settings
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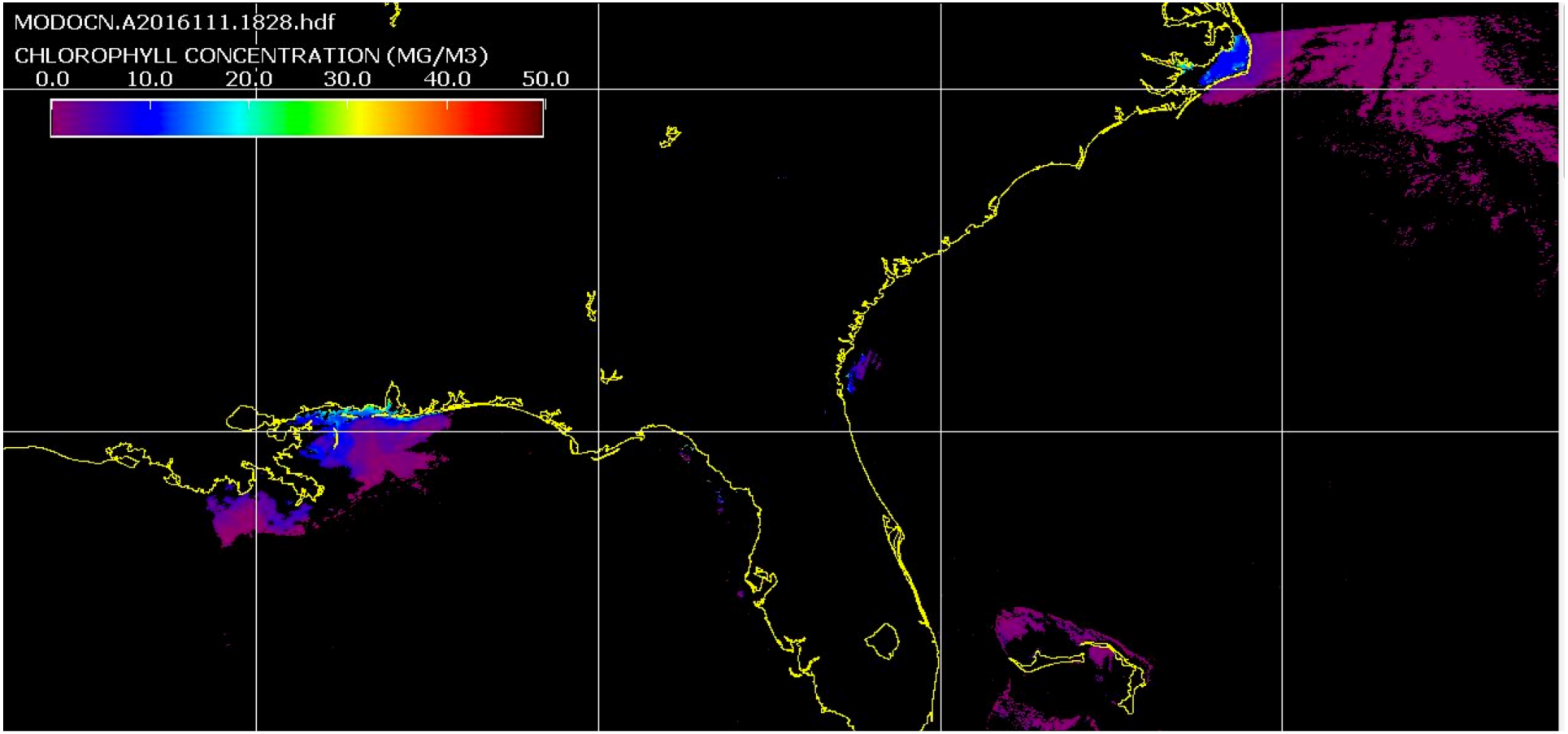
5:chlor
rgb composite
1*2:Rrs_443/1*2:Rrs_531

# MODIS Chlorophyll-a Concentration