EOS-Terra remote sensing of atmospheric pollutants

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- **Examples of the New Science from Terra: The Indian and African stories – how Terra can distinguish natural from human induced processes (**with John Gille – NCAR, Jim Drummond – U. Toronto and Bruce Barkstrom – NASA/LaRC)

- **Remote sensing of aerosol from MODIS – first validation (**with Didier Tanré and Lorriane Remer)

Ignition!!

Vandenberg, AFB

Dec. 18, 1999

Up to space

and new era in Earth Science begins

The Terra Observatory:

MODIS – **global, daily** views with 36 spectral channels, 250m-1km (PI - V. Salomonson – GSFC)

MISR – 9 **angle views** (PI – D. Diner – JPL)

ASTER – **stereo zoom** view: visible – IR (PIs Yasushi/Kahle MITI/JPL)

MOPITT – first **carbon monoxide** and methane (PIs Drummond/Gille U. Toronto/NCAR)

CERES – **measurements of the impact** of the Earth processes on its ability to reflect and emit energy to space (PI B. Barkstrom LaRC)

Overall Objective of EOS-Terra – reflection on aerosol science

- **Provide the first global and seasonal measurements of the Earth System:** a thorough "check-up" of planet Earth – distribution of aerosol optical thickness, mass, size and radiative forcing (coming up – single scattering albedo)

- **Distinguish natural variability from human impact**, → "fingerprint" of human activity. Natural/anthropogenic aerosol

- **Start long-term monitoring** of global climate change and changes in our environment.

- **Develop technologies for disaster prediction,** wildfires, volcanoes, floods, and droughts – effect of aerosol on health, pollution control, aircraft safety?

Terra observations MODIS-MOPITT-CERES distinguish human-induced vs. natural impact on air quality and radiative forcing of climate:

Pollution in Indian sub-continent -
Dust over the Atlantic off Africa

- A erosol over the **Bay of Bengal → small aerosol particles and elevated CO** levels → human-induced pollution source.

- A erosol **off the coast of Africa →** large aerosol particles, low CO concentrations →natural dust air mass

The **Himalayan mountains**, **and the heavily populated and polluted parts of** the Indian sub-continent.

Topography + meteorology →

High moisture (MODIS) under the Himalayas, precipitation→

Dense vegetation (MODIS) →

Atracts people - half a billion people (red)**→**

dense haze (aerosol - MODIS, CO gas -MOPITT)→

alters reflection of **sunlight** to space **(CERES)**

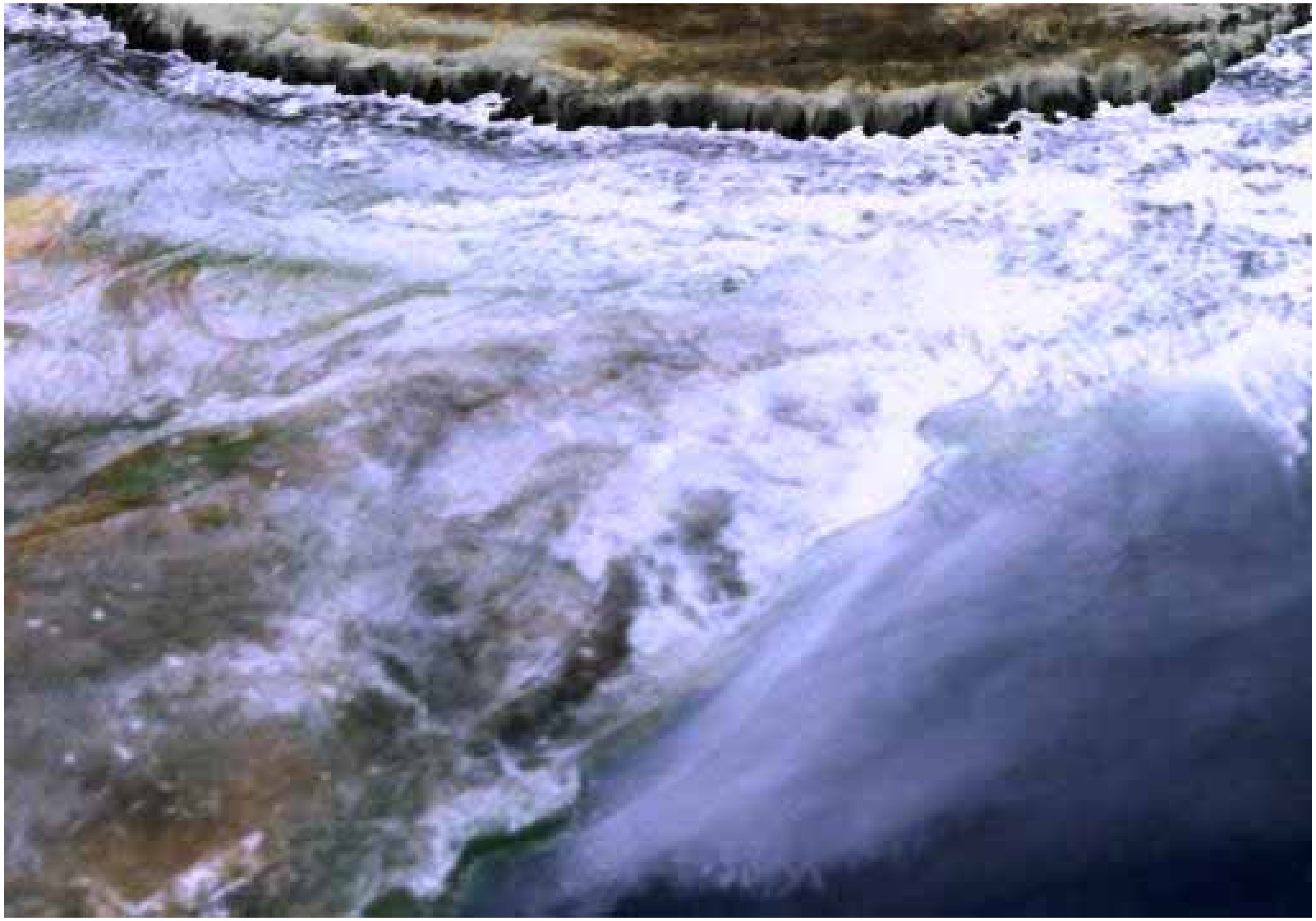
Astronaut photo of the Himalayan mountains and the Indian sub-continent shrouded in haze

The Earth needs a thorough "check-up" -> EOS-Terra is ready to provide

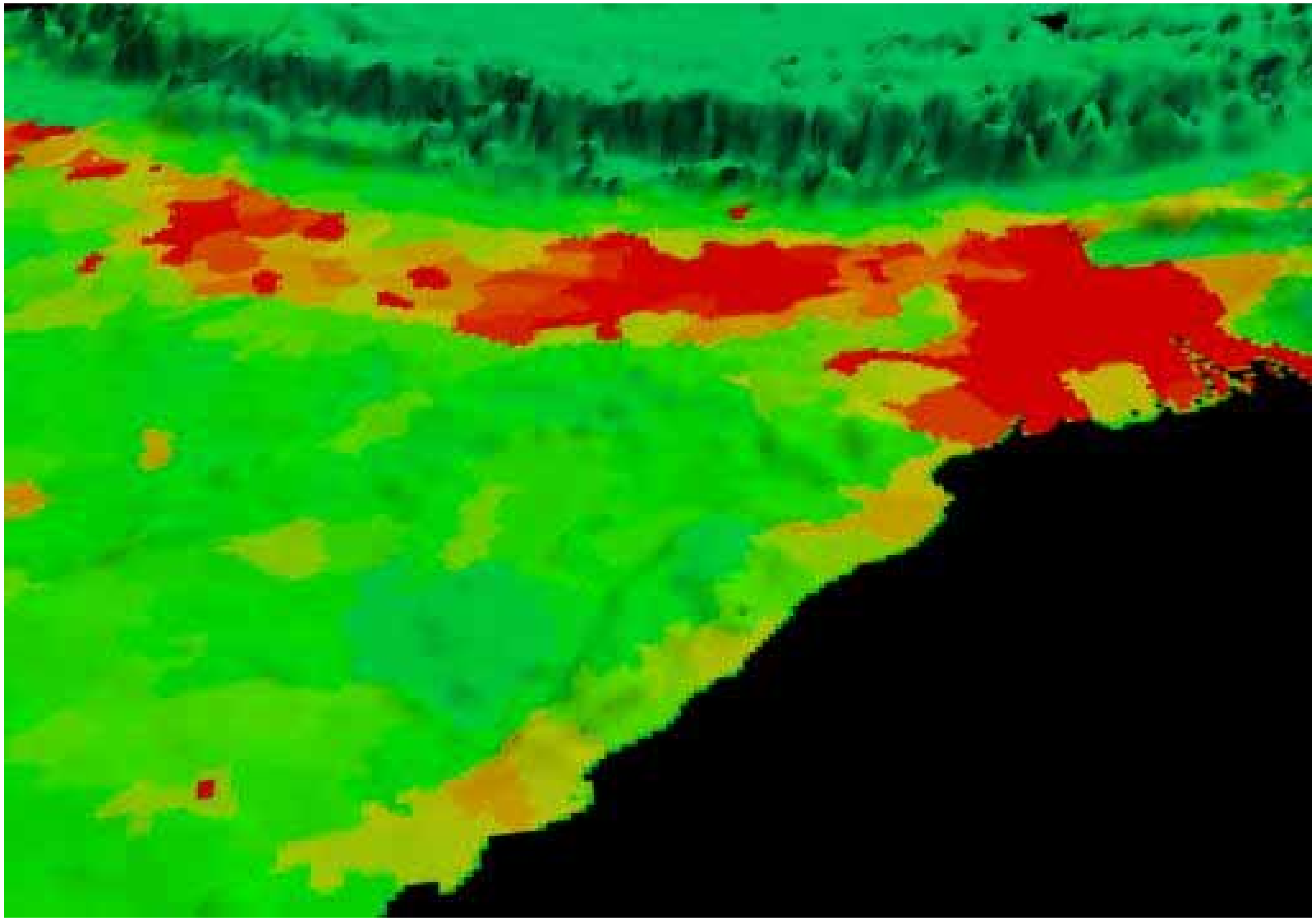
Topography of the Himalayan region and the Indian sub-continent

(MODIS data + DEM) - Dense vegetation under the Himalayas

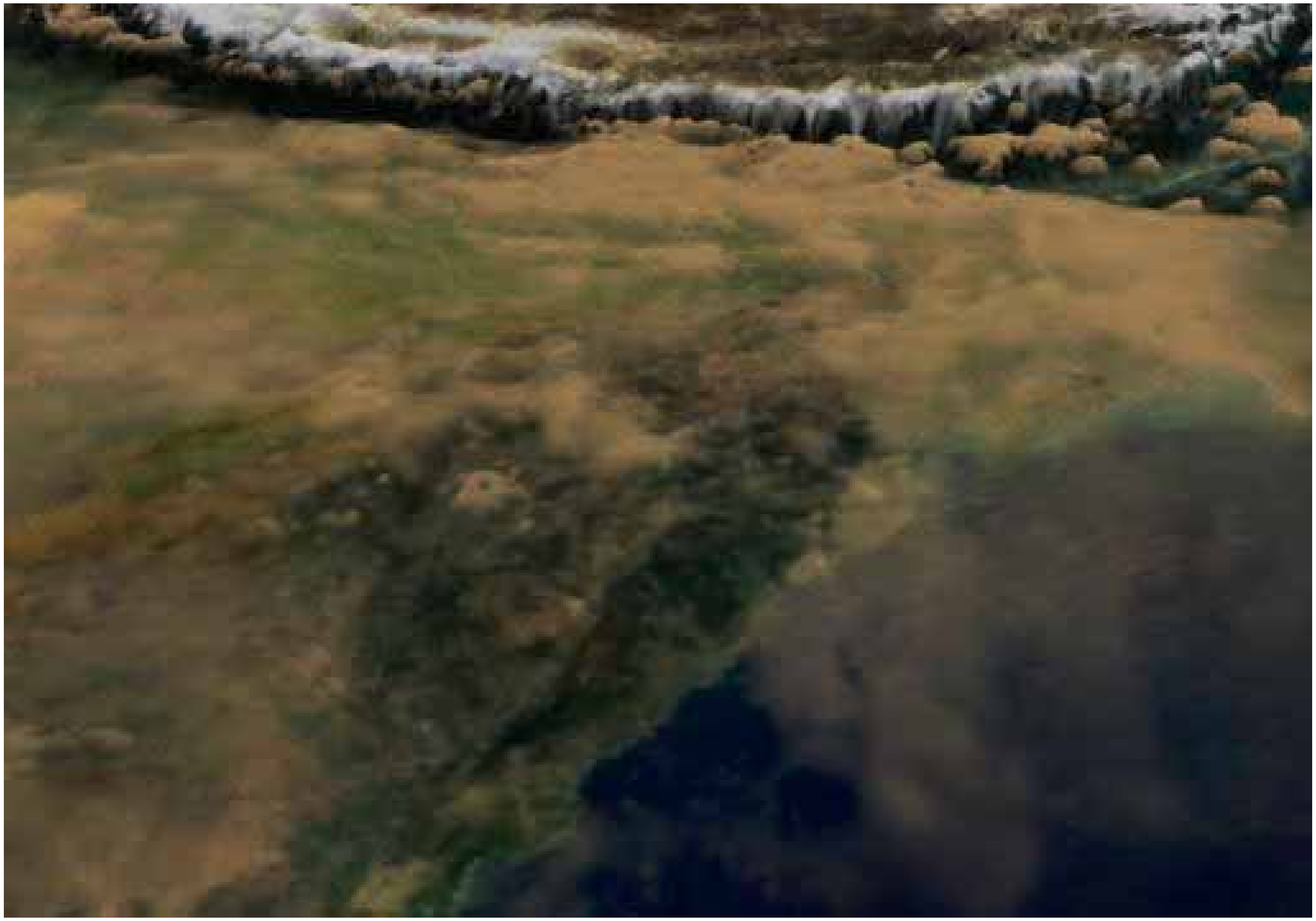
Topography --> concentration of Water Vapor (MODIS)



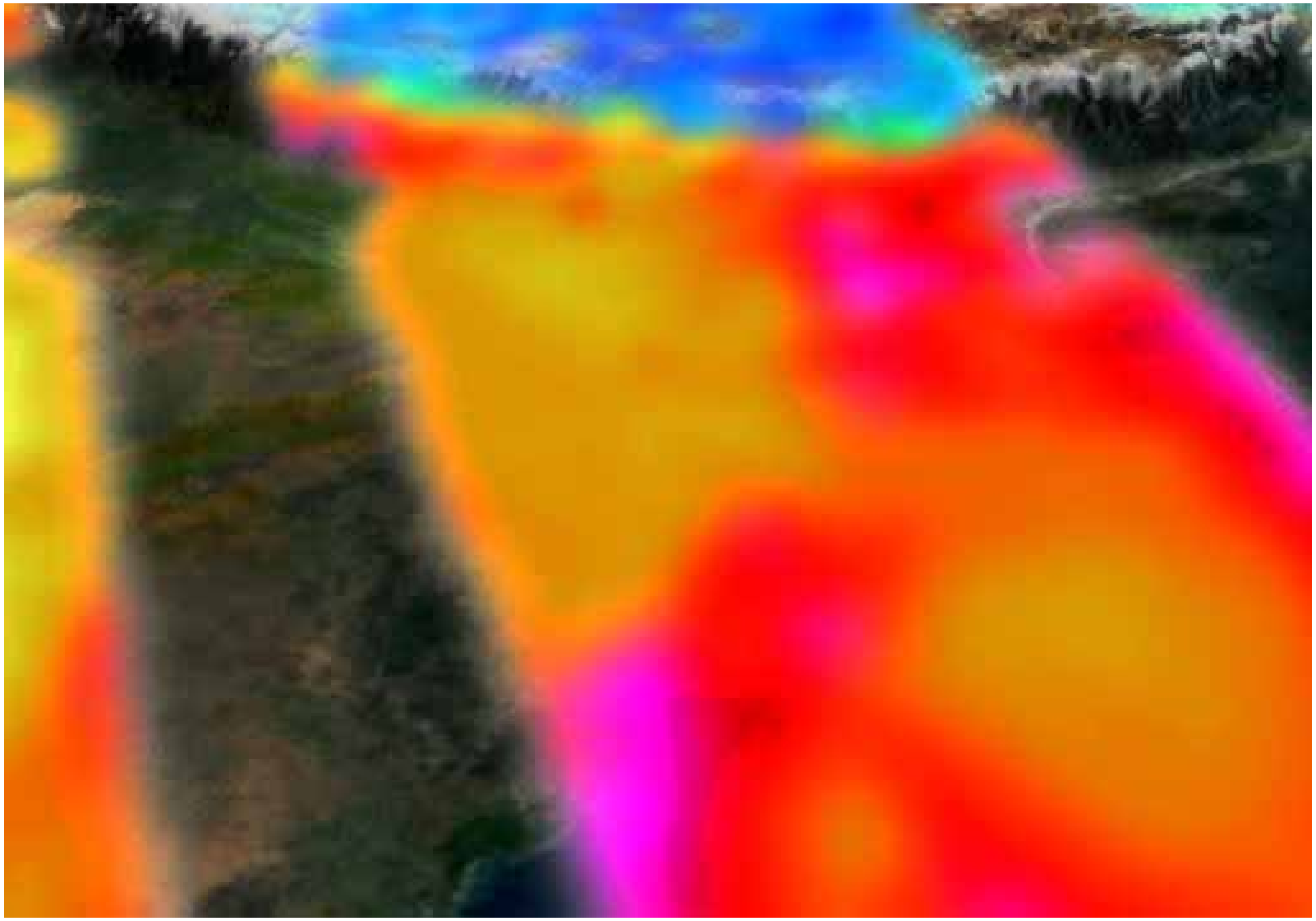
Dense Vegetation --> Dense population



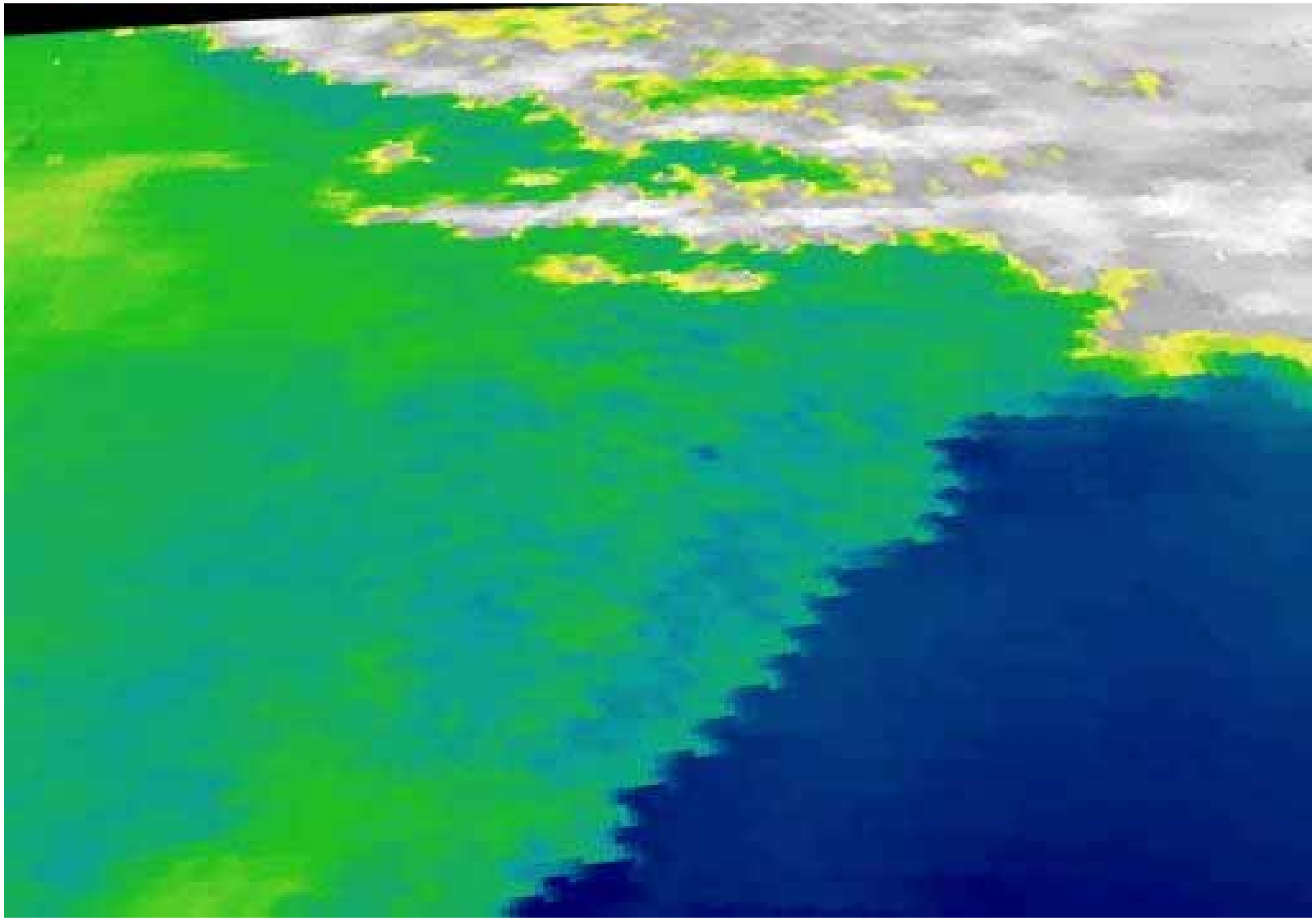
Dense population --> dense aerosol haze (MODIS)



Dense population --> high CO concentrations (MOPITT);
John Gille - NCAR; Jim Drummond- U. Toronto



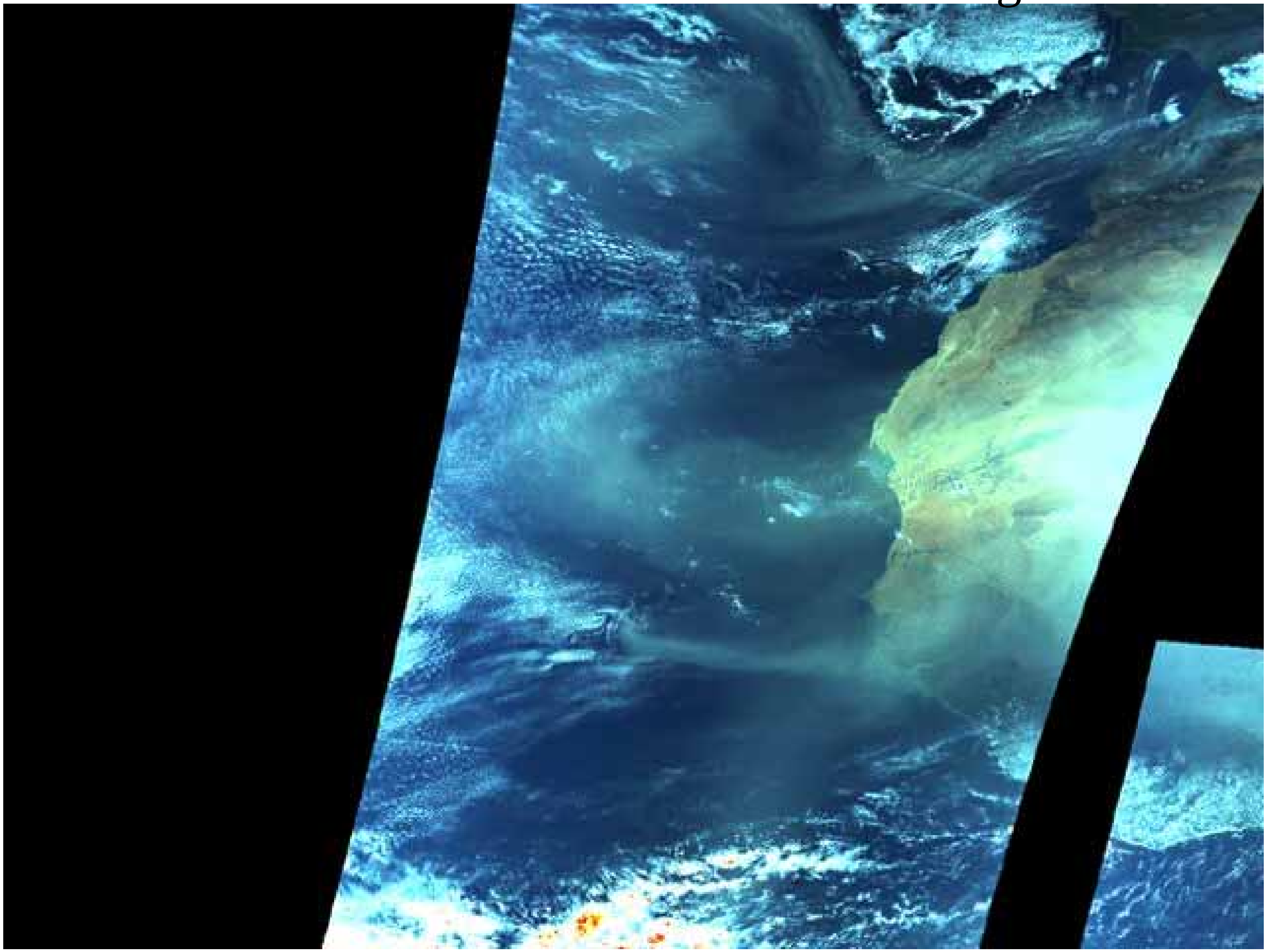
Dense haze ==> reflection of sunlight to space (CERES)



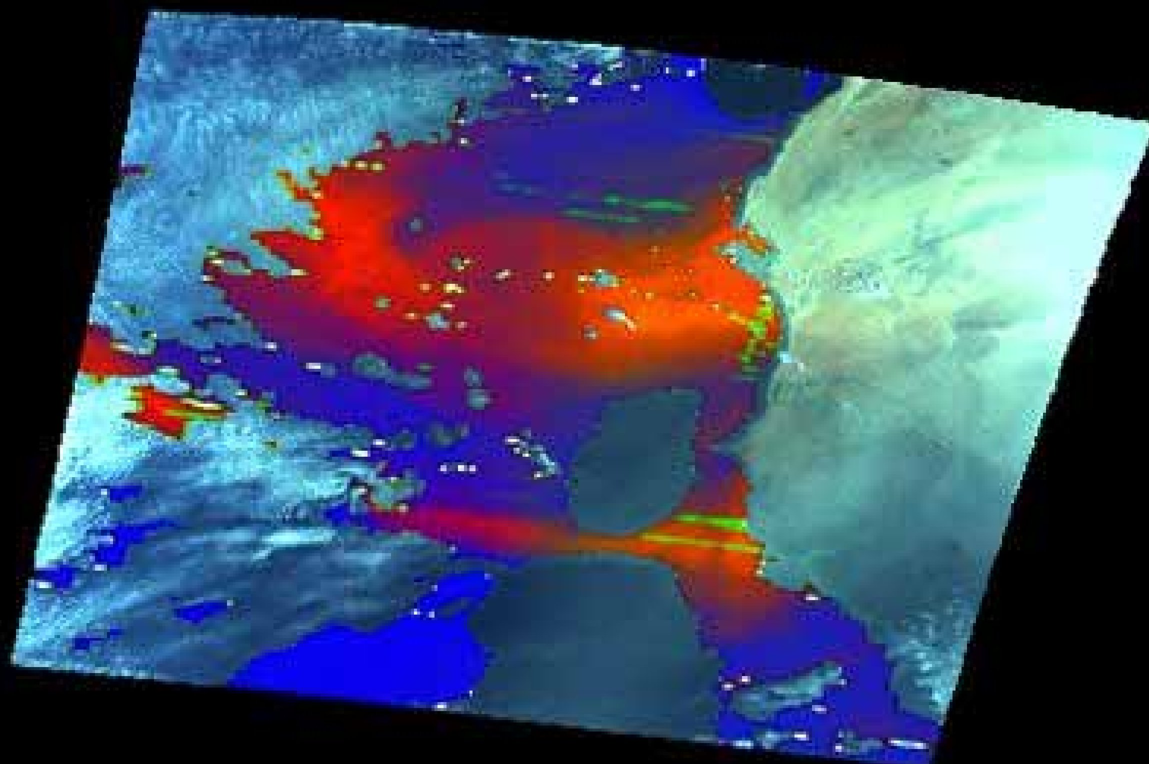
Dust over the Atlantic

- MODIS true color image
- MODIS dust detection (large particles –red)
- CERES reflected energy

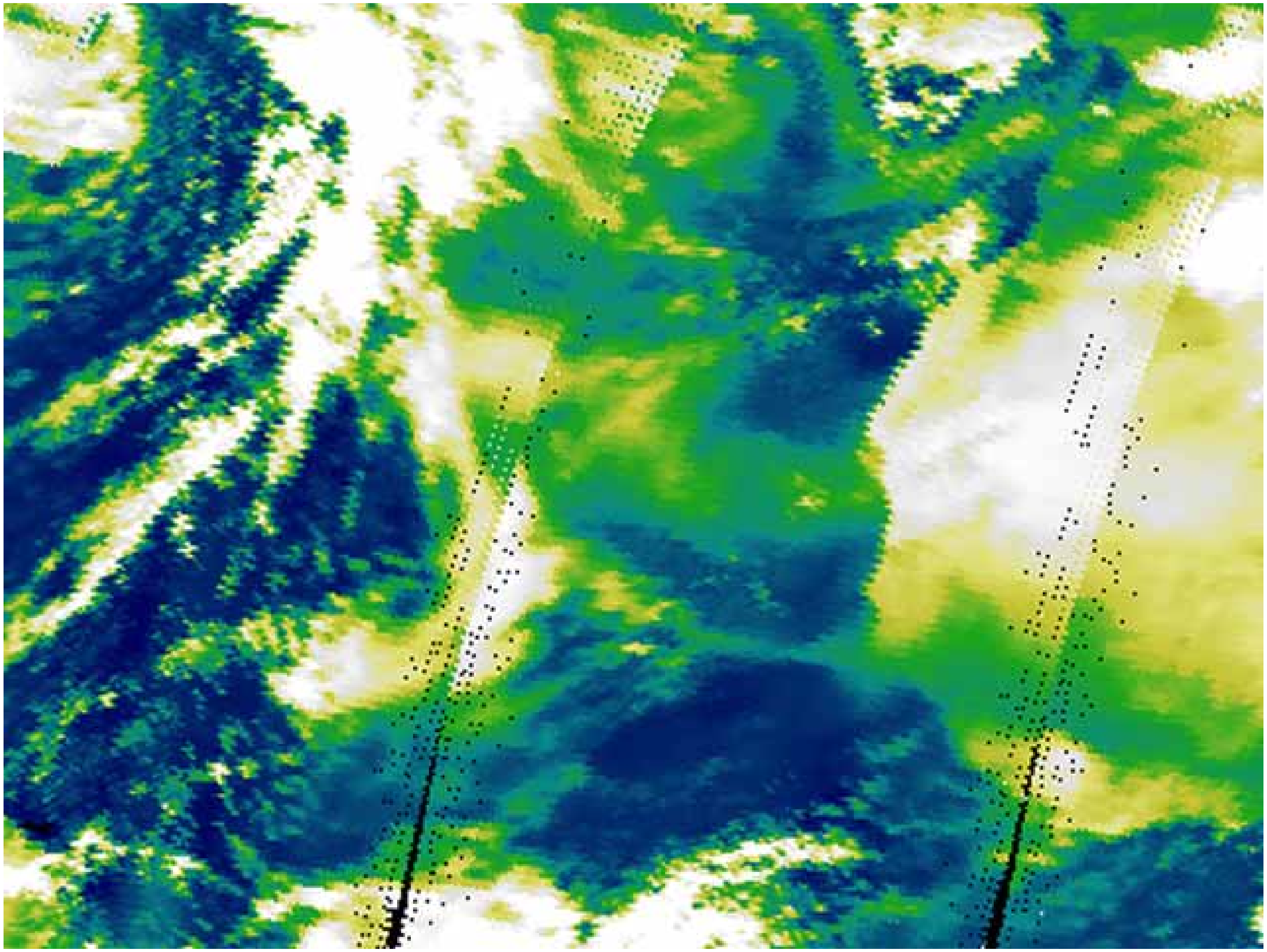
2/29/2000 MODIS true color dust image



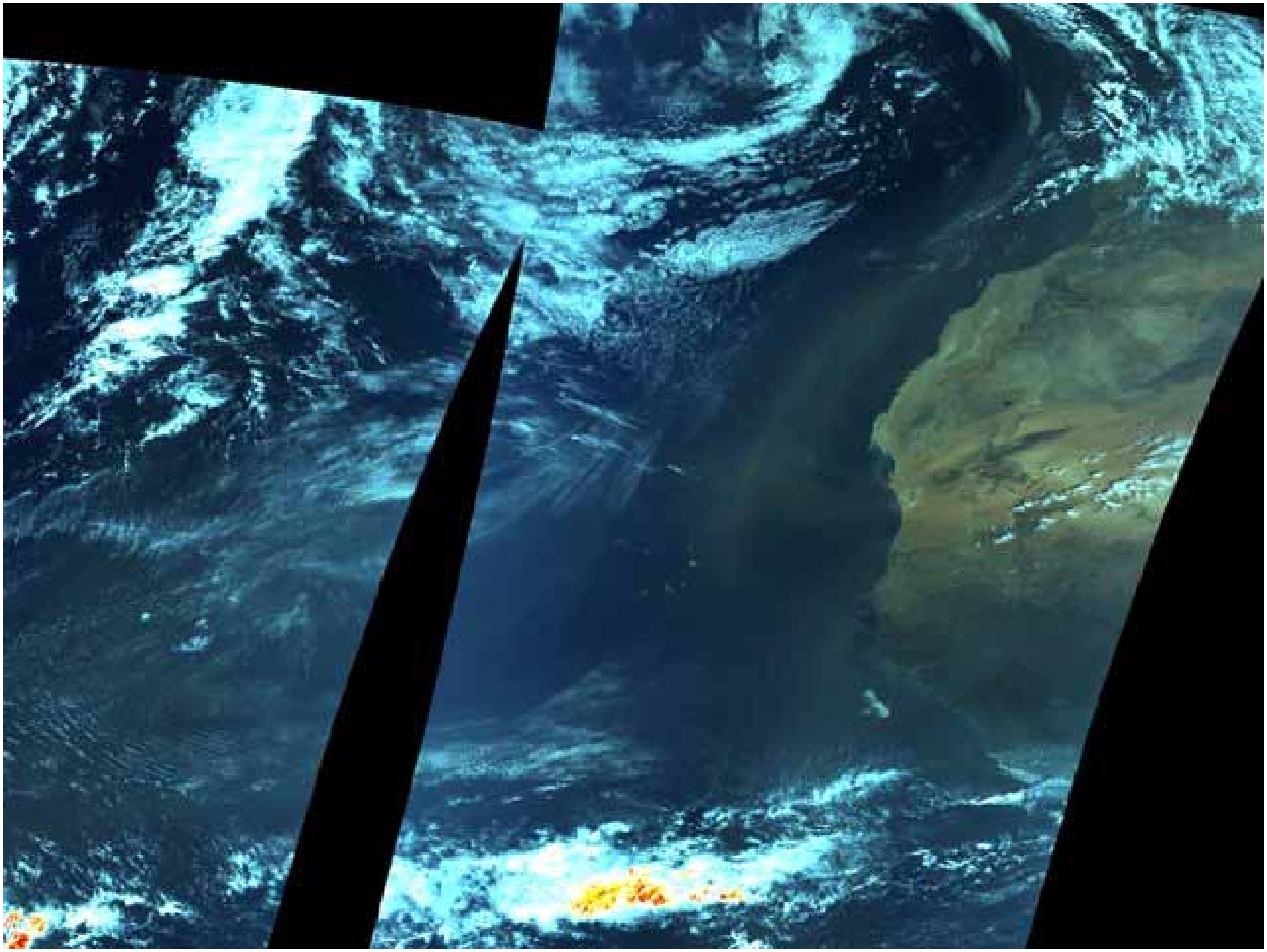
2/29/2000 MODIS analysis of dust (red - Tanre et al)



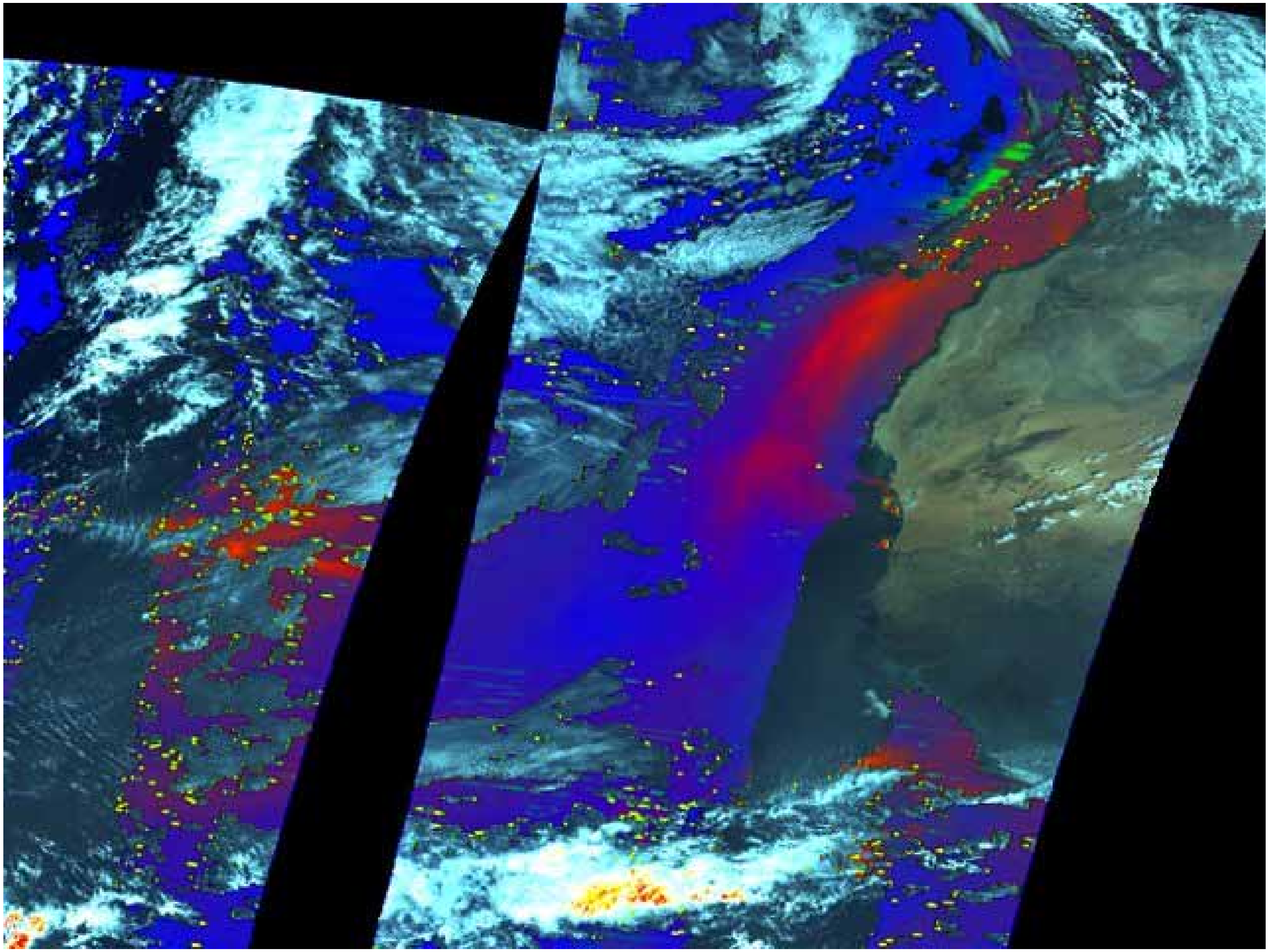
2/29/2000 CERES reflected sunlight (Barkstrom et al)



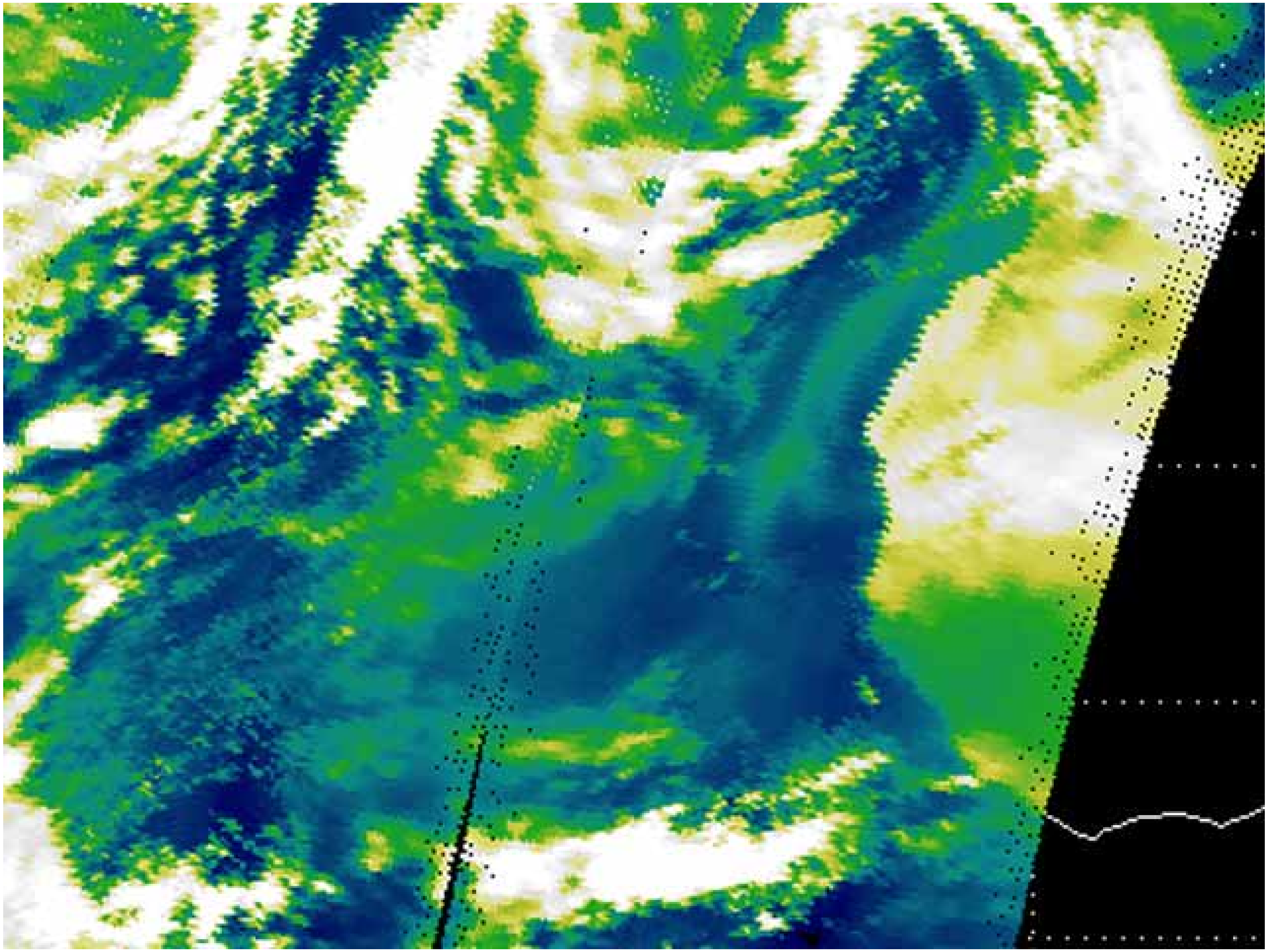
3/9/2000 MODIS true color of dust



3/9/2000 MODIS analysis of dust (red)

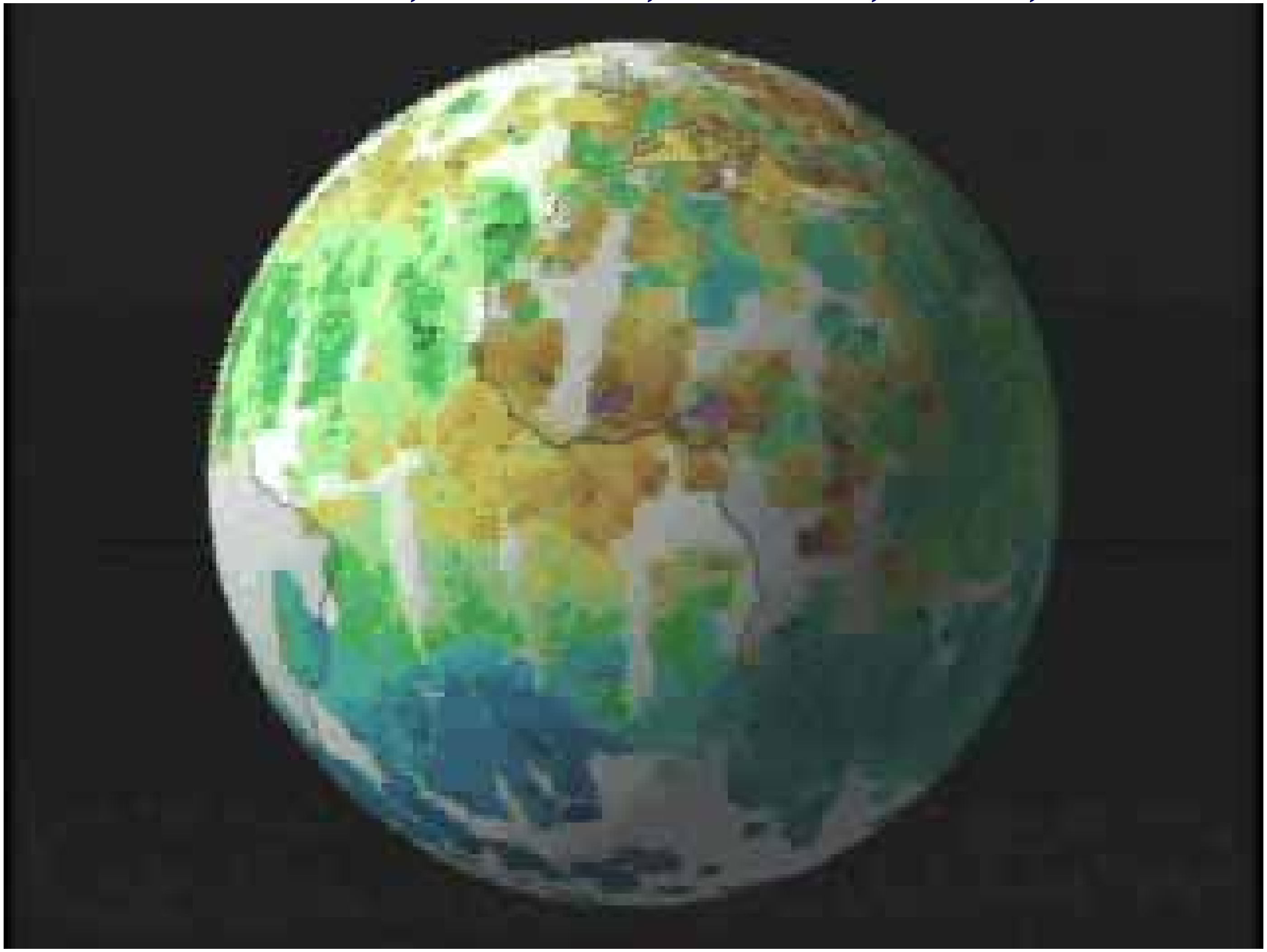


2/29/2000 CERES reflected sunlight

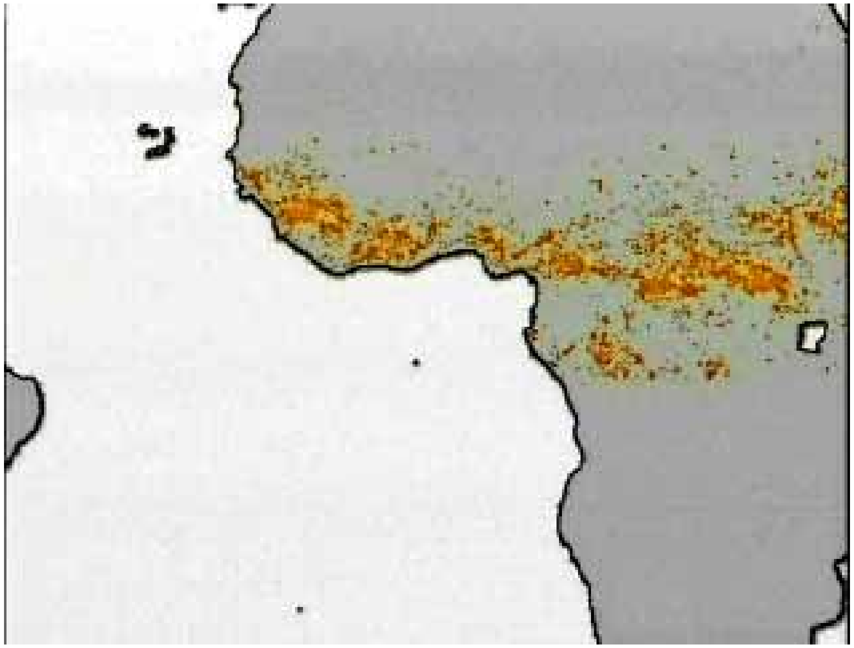


MOPITT view of carbon monoxide (blue-low, red-high)

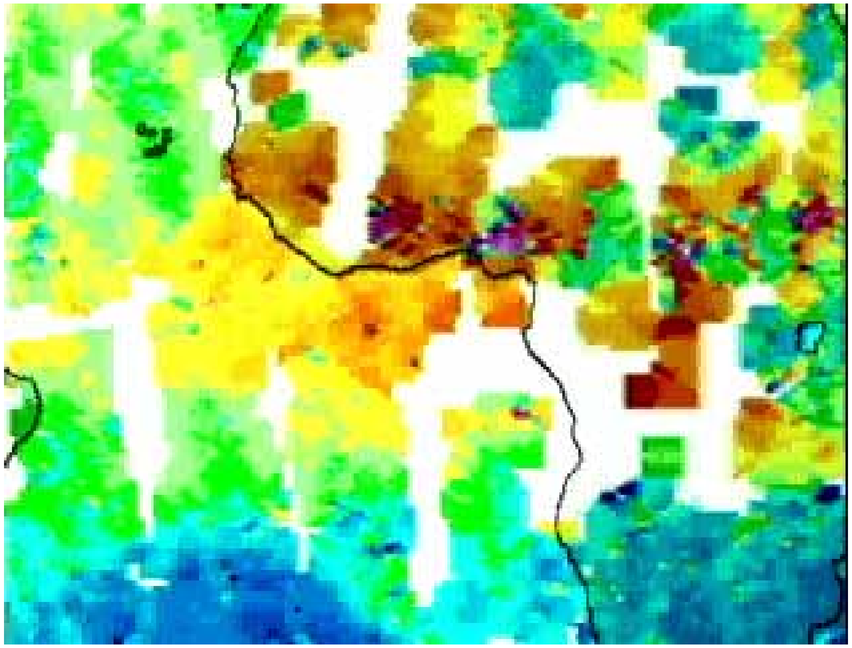
Jim Drummond, U. Toronto, John Gille, NCAR, MOPITT PIs



Fire count from ATSR



MOPITT view of carbon monoxide (blue-low, red-high)



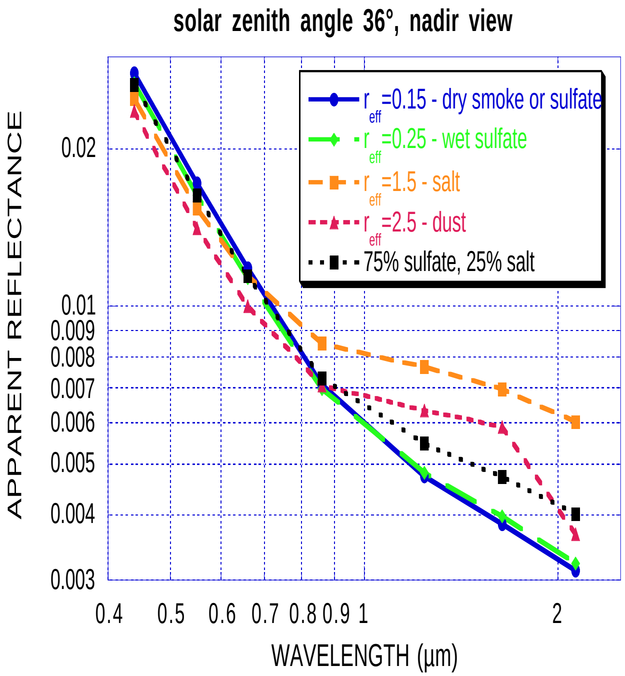
REMOTE SENSING OF AEROSOL FROM MODIS

Ocean:

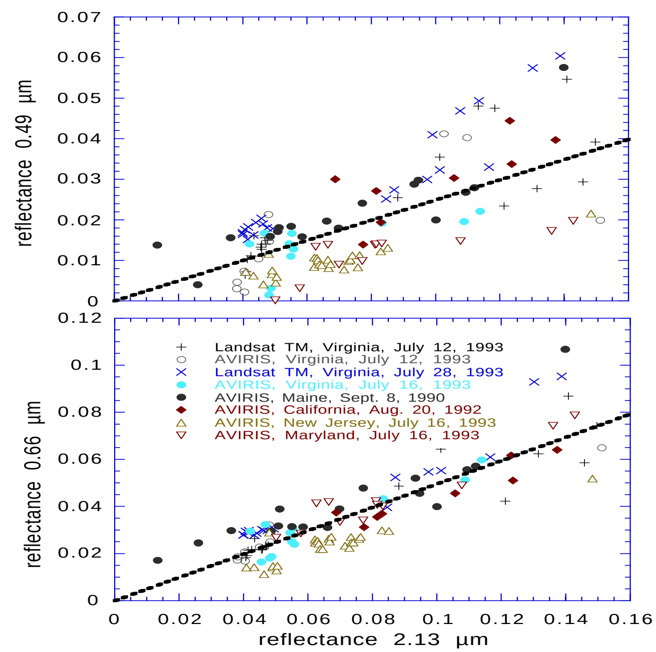
- 6 λs 0.55-2.1 μm ➔ $\tau(\lambda)$
- small & large modes τ_{small}, τ_{large}
- effective radius

Land:

- $\rho_{2.1} \rightarrow \rho_{0.66}$, $\rho_{0.47}$
- $\Delta\rho_{0.66}$, $\Delta\rho_{0.47}$ ➔
- $\tau_{0.66}$,$\tau_{0.47}$



$\Delta\tau = \pm 0.03 \pm 0.05\tau$



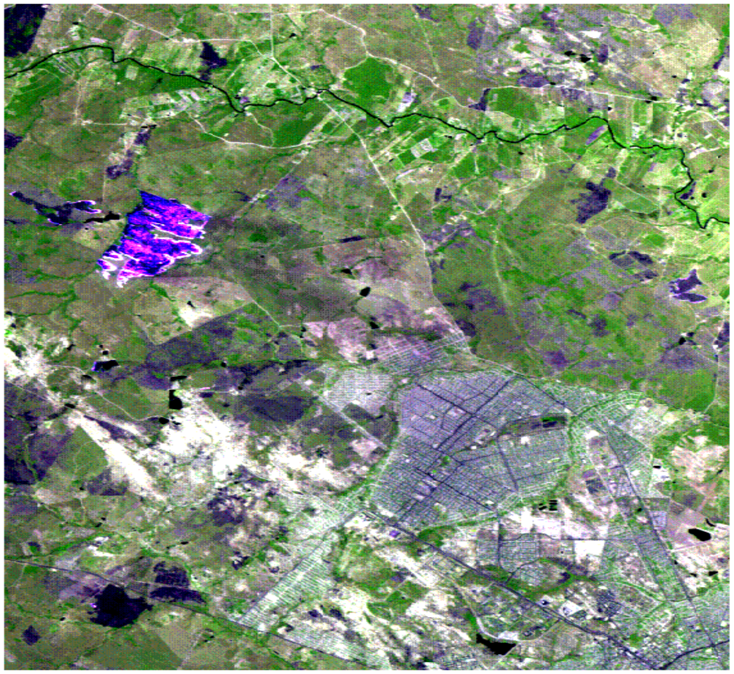
$\Delta\tau = \pm 0.05 \pm 0.15\tau$

Using the spectral information to sense aerosol

ER-2, AVIRIS spectral image from SCAR-B of smoke over Cuiaba on Aug. 25, 1995

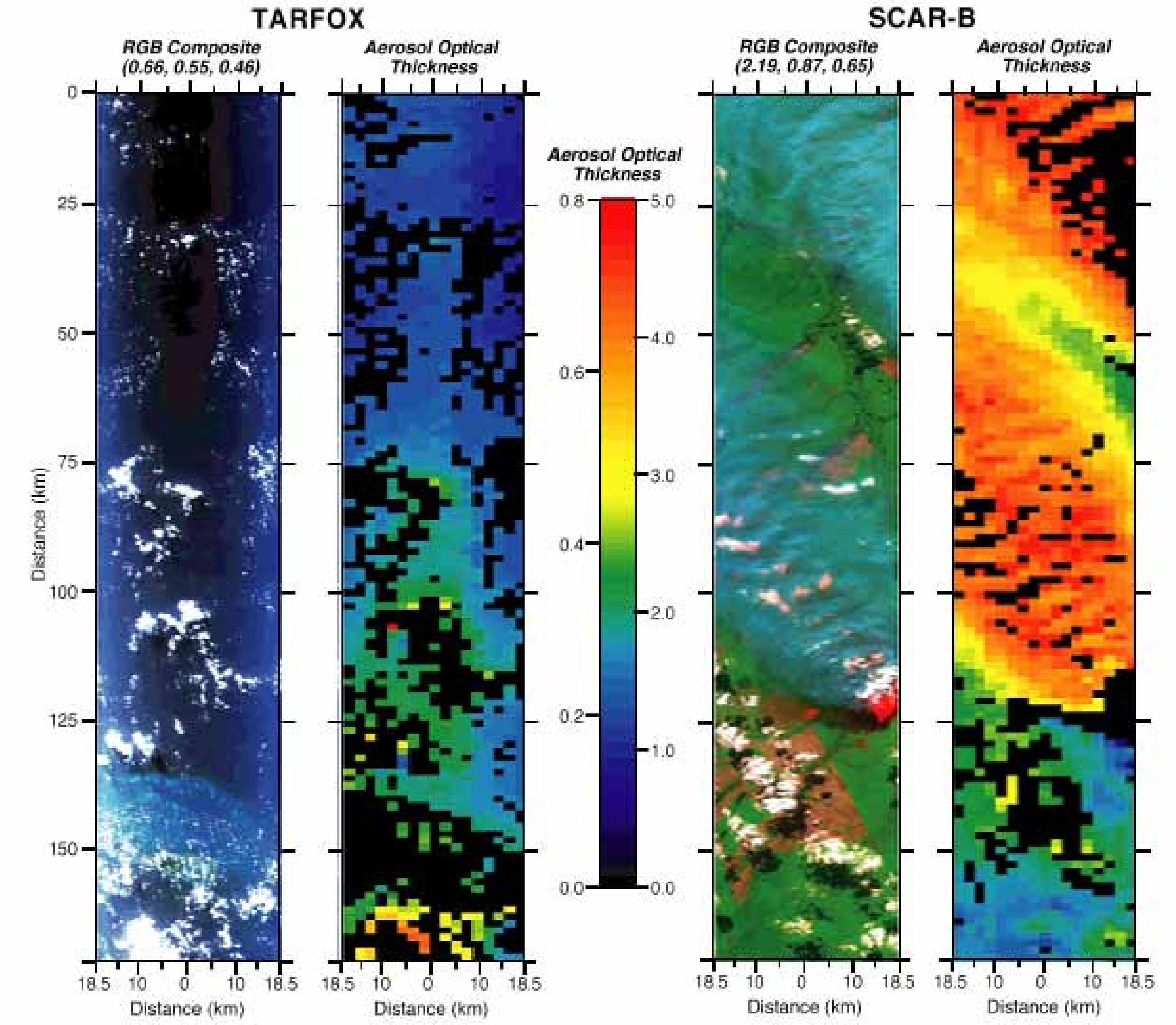
RGB: 0.47 μm, 0.55 μm, 0.66 μm

Heavy smoke. The image resembles human vision.

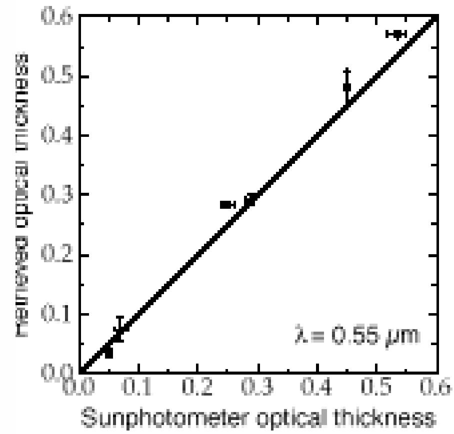


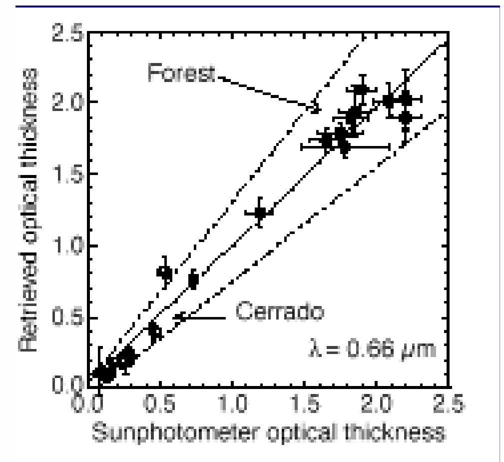
Near-IR RGB: 2.1 μm, 1.2 μm, 1.65 μm

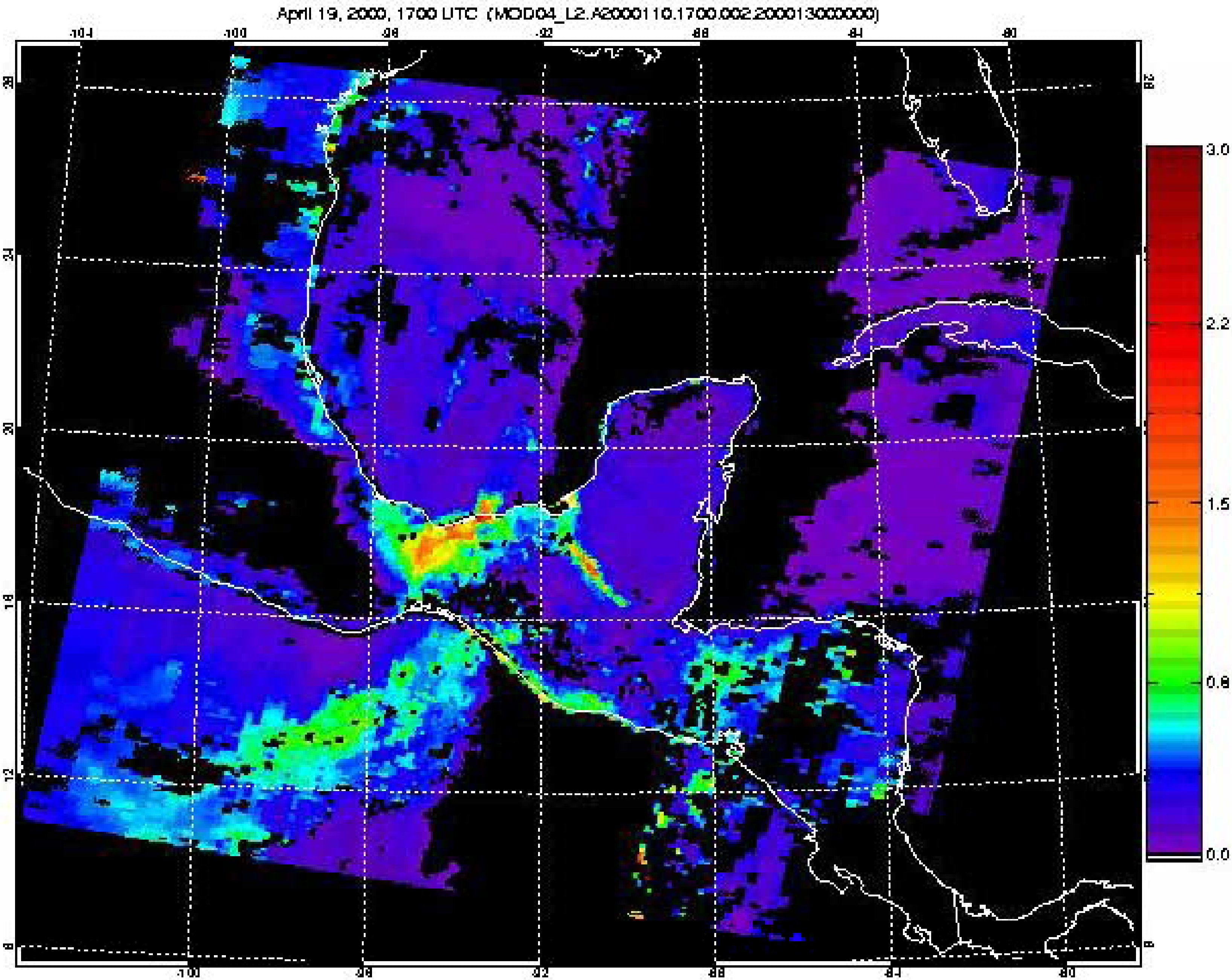
The smoke is almost transparent in the mid-IR, surface features are visible.



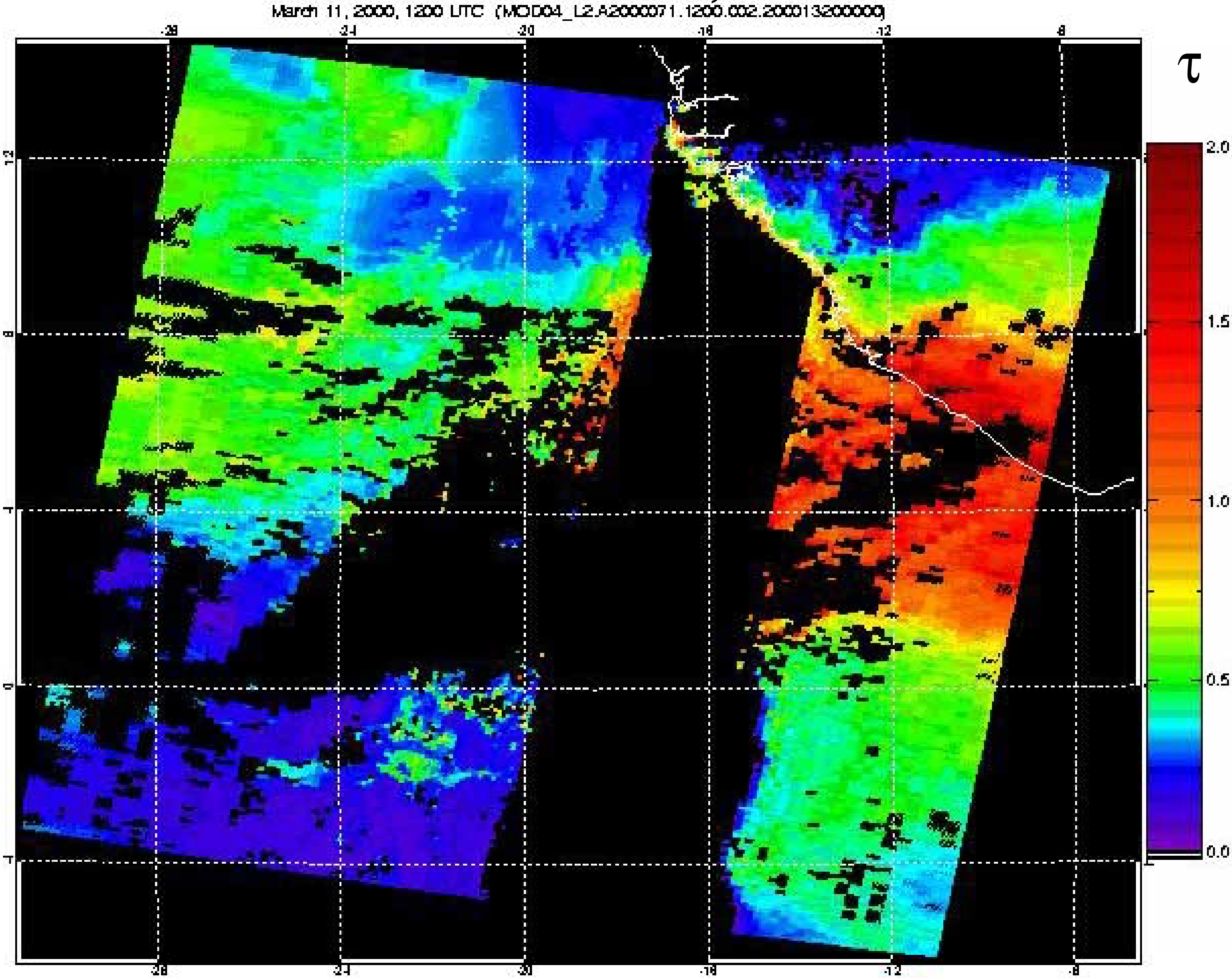
King, Kaufman, Tanre and Nakajima, BAMS, 1999

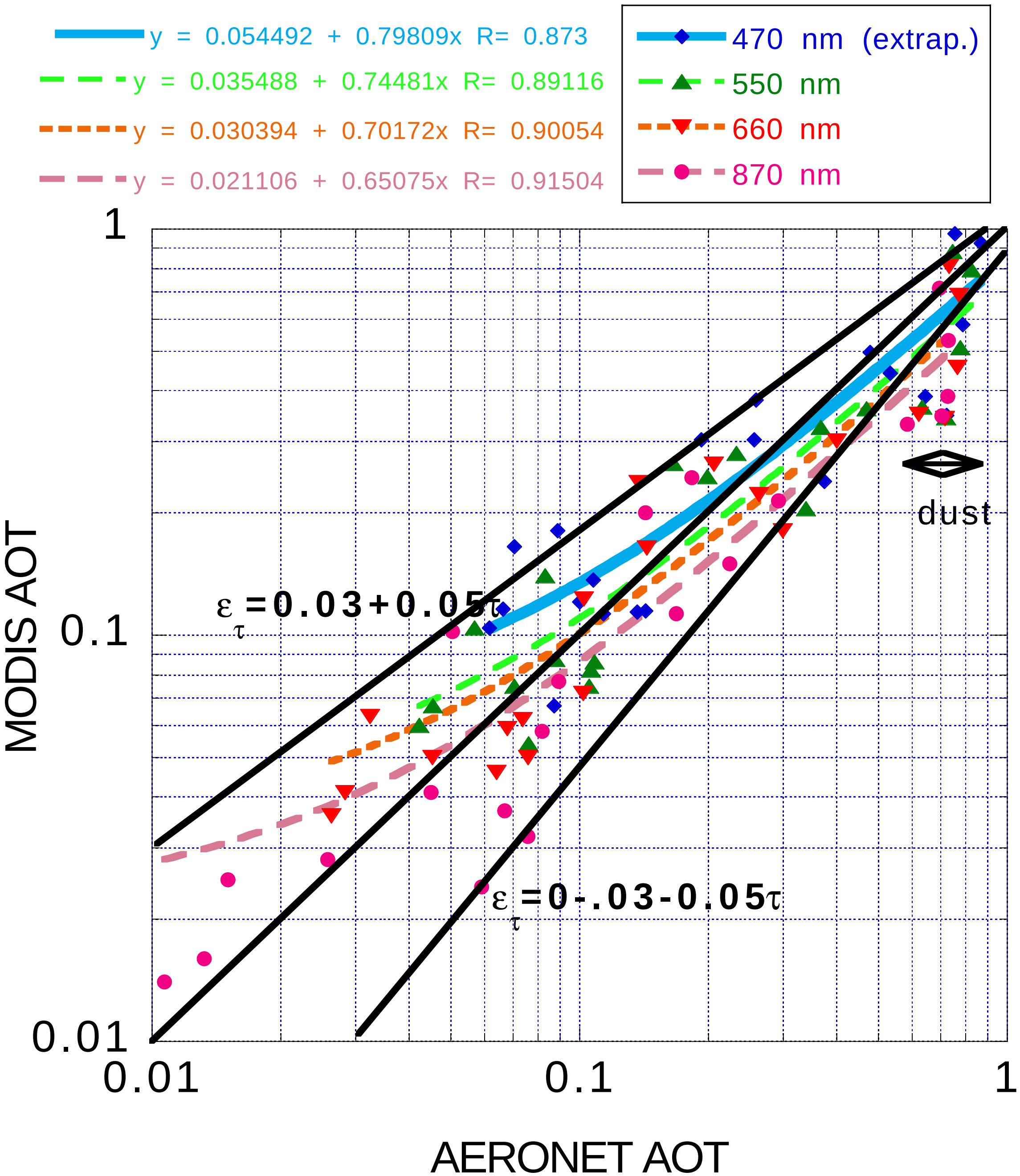




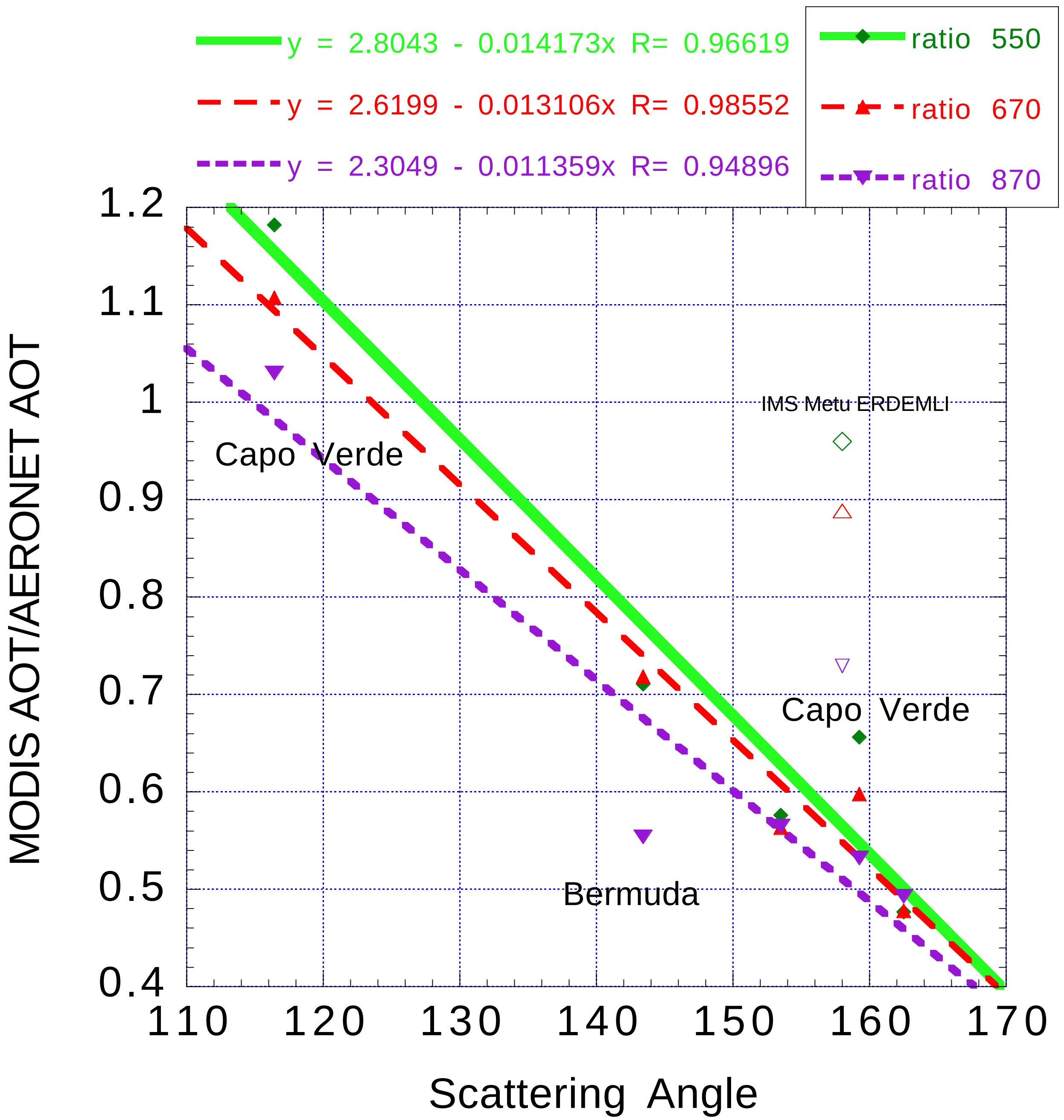

April 19, 2000, 1700 UTC (MOD04_L2.A2000110.1700.002.200013000000)
-104
-100
-96
-92
-88
-84
-80
28
24
20
16
12
8
3.0
2.2
1.5
0.8
0.0

Dust from Africa March 11, 2000

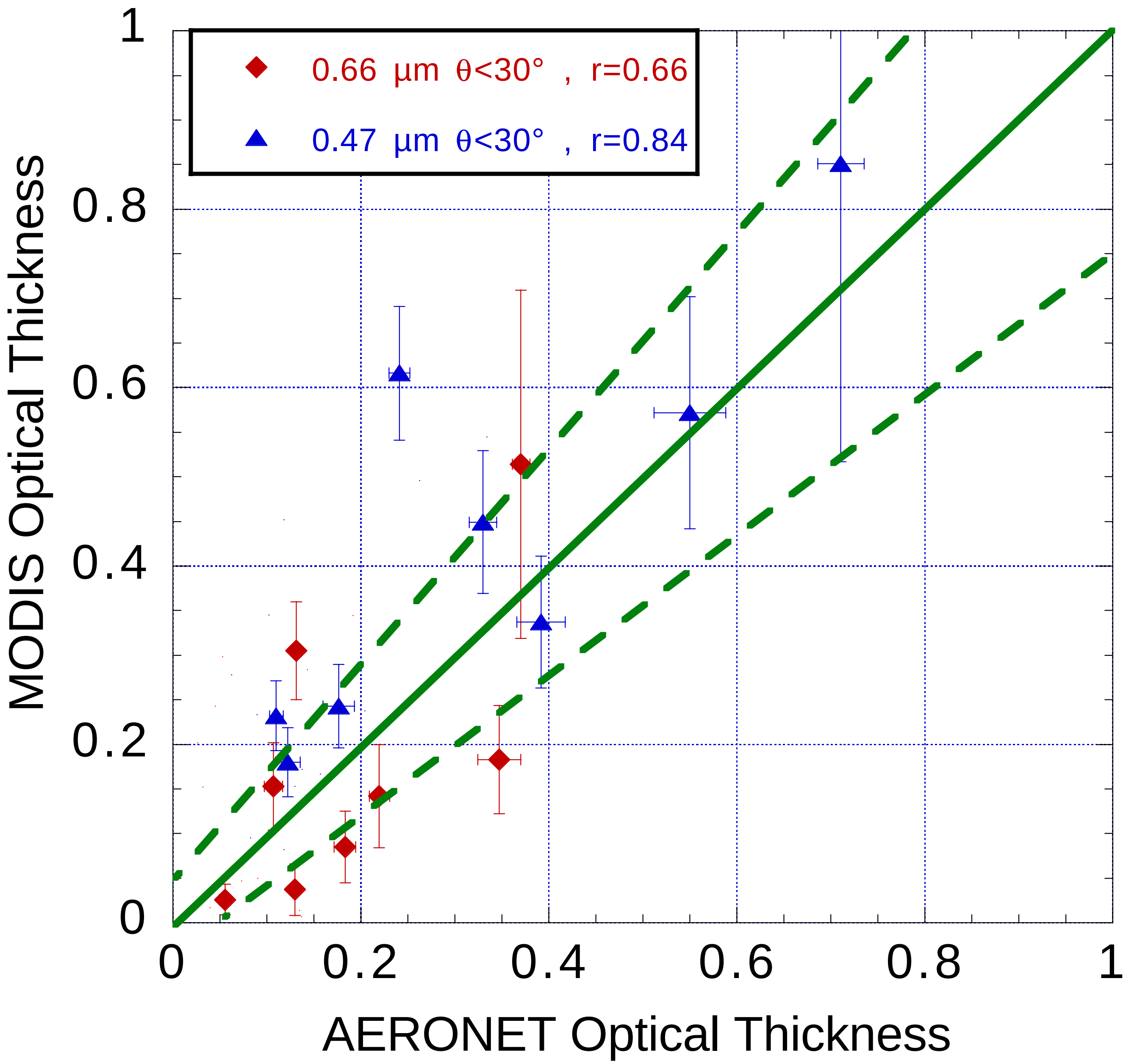


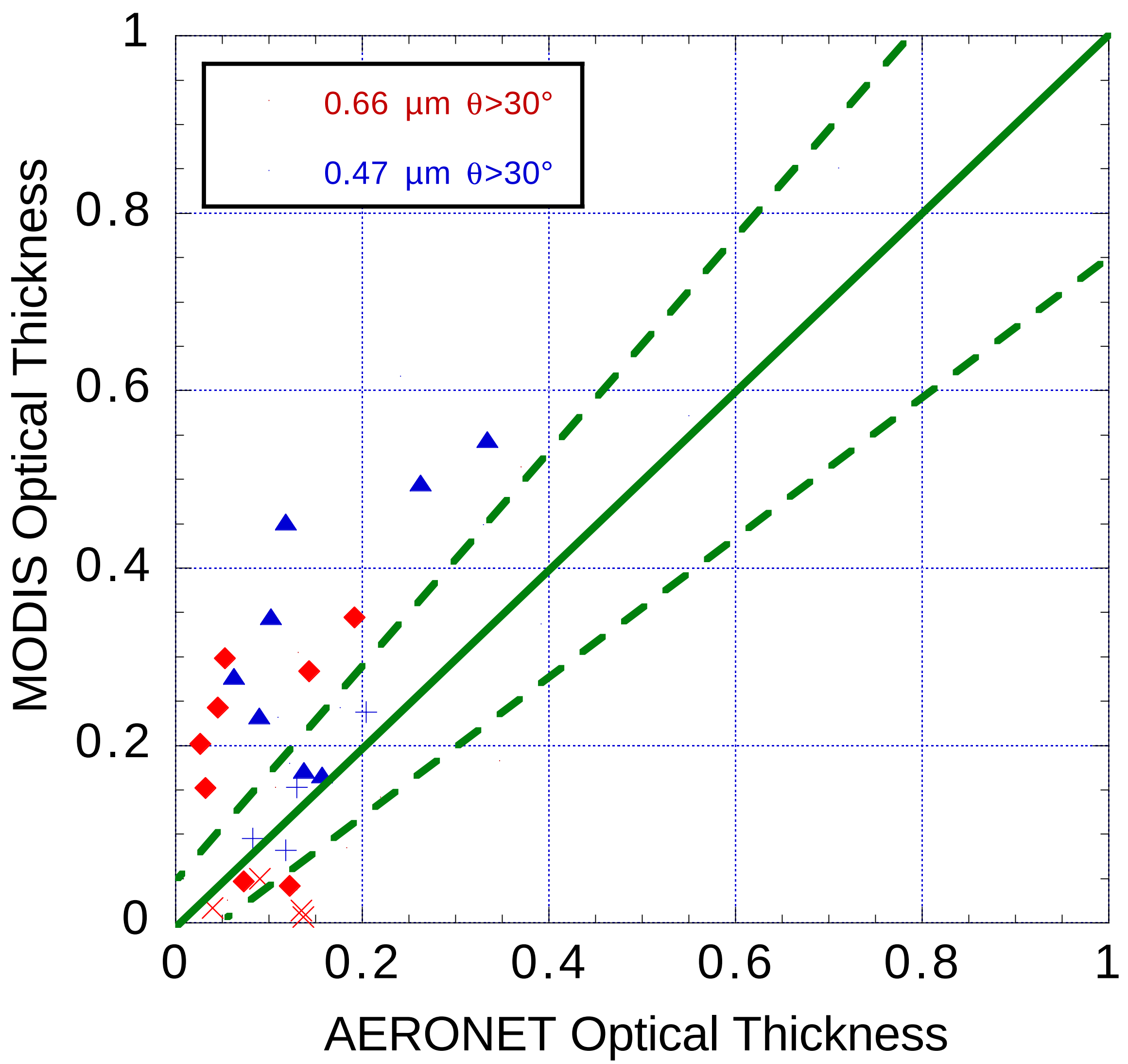


y = 0.054492 + 0.79809x R= 0.873
y = 0.035488 + 0.74481x R= 0.89116
y = 0.030394 + 0.70172x R= 0.90054
y = 0.021106 + 0.65075x R= 0.91504
470 nm (extrap.)
550 nm
660 nm
870 nm
MODIS AOT
AERONET AOT
1
0.1
0.01
0.01
0.1
1
ε τ =0.03+0.05τ
ε τ =0-.03-0.05τ
dust



y = 2.8043 - 0.014173x R= 0.96619
y = 2.6199 - 0.013106x R= 0.98552
y = 2.3049 - 0.011359x R= 0.94896
ratio 550
ratio 670
ratio 870
MODIS AOT/AERONET AOT
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
110
120
130
140
150
160
170
Scattering Angle
Capo Verde
IMS Metu ERDEMLI
Capo Verde
Bermuda


0.66 µm θ<30° , r=0.66
0.47 µm θ<30° , r=0.84
MODIS Optical Thickness
AERONET Optical Thickness
0
0.2
0.4
0.6
0.8
1


0.66 µm θ>30°
0.47 µm θ>30°
MODIS Optical Thickness
AERONET Optical Thickness
0
0.2
0.4
0.6
0.8
1

CONCLUSIONS

- **MODIS before final calibration can detect aerosol with errors slightly larger than predicted**
- **Land: τ for 0.47 and 0.66 µm**
- **Ocean: $\tau(\lambda)$ for 0.55 to 2.1 µm, τ_{small}, τ_{large}, R_{eff}**
- **Land and ocean algorithm generate similar results over sea shore**
- **Combination of aerosol small and large mode over ocean and CO from MOPITT may be used to fingerprint the human influence**