United Nations / Austria / European Space Agency Symposium on

Space Applications for Sustainable Development to Support
the Plan of Implementation of
the World Summit on Sustainable Development

SPACE TOOLS FOR MONITORING AIR POLLUTION AND ENERGY USE FOR SUSTAINABLE DEVELOPMENT

12-15 September 2006 at
Austrian Academy of Sciences, Institute for Space Research
Schmiedlstraße 6, Graz, Austria

Dissemination of Space Based information relating to air pollution and energy use to rural population: Experiences from India

Dr Vasala Madhava Rao
Head(Geomatics Cell)
National Institute of Rural Development
(Ministry of Rural Development, Government of India)
Hyderabad, India

Overview

- Indian Rural Air pollution and Energy Scenario
- Measures taken for monitoring and control
- Space Science Application in monitoring the Air Pollution and Energy
- Conclusion
- Snapshots

Indian Rural Air pollution and Energy Scenario

- India's cities are among some of the world's most polluted, but environmental analysis found its rural areas are also suffering.

- "Smoke Screen", a Study by SIPCOT Area Community Environmental Monitors, found 45 chemicals, including 13 carcinogens, in 21 air samples it collected in village areas between 2004 and 2006.

- The Study samples collected at 13 locations, the majority of which were small communities, particularly in the southern state of Tamil Nadu.

- **Air pollution monitoring and regulation measuring the toxic and air pollutants, reflect significant increase in levels in rural India.**

- **National data on the state of outdoor air quality in rural areas, collected from various sources viz. Pollution Control Boards, WHO, UNICEF, CES, National and International Agencies including the pollution from stoves fueled by wood, cow dung and other materials kerosene, charcoal etc.**

- **World Bank and Asian Development Bank study in 2004 found at least four Indian cities were among the most polluted in Asia.**

- **New Delhi topped the list of cities with unacceptably high levels of suspended particulate matters, considered the most dangerous pollutant with 350 to 800 micrograms of suspended particulates per cubic meter(World Health Organisation recommends less than 50 micrograms)**

- India as a most populace country, with it's rural energy needs, land use practices, associated climatic and environmental changes made India vulnerable to atmospheric pollution on a wide scale.

- The majority of India's population, (72 percent in 1991 census; 70 percent in 2001), live in rural areas, are predominantly dependent on agricultural and related activities, and fulfill their energy requirement from biomass resources like wood, agricultural residues, dung-cakes etc.

- Industries also use a lot of biomass energy like sugar, agro processing, small and cottage industries, household industries etc.

- In India, the amount of biomass burnt annually is estimated to be about 426 Tg or about 6.3% of the global level of 6800 Tg/yr.

- India also has a very large cattle population and is one of the top milk producers in the world.

- Preliminary estimates taking into account the various factors like feed intake values, type of animal, population of lactating calves etc. have shown that the total methane emissions from Indian ruminant cattle is around 5.8 Tg/yr. (ALGAS, India, 1998).

- **Another source of methane is Livestock manure of methane emissions adding to the inventories of Green House Gases(GHGs).**

- **India is one of the largely dependent on fossil fuel for its energy requirements viz. coal, petroleum, natural gases etc**

- **Coal accounts for about 60% of fossil fuel use in caloric terms followed by liquid petroleum (about 30%) and the rest is natural gas.**

- **The relative emissions from Coal 328.4 Tg/yr (65%)**
  Petroleum 162.7 Tg/yr(32%)
  Natural Gas 17.5 Tg/yr(3%)

- **Electricity generation in India accounts for about 67% from coal-based thermal.**

- **Growth in industry and urbanisation in India has led to associated changes in its environment.**

- **India has witnessed a growth in motorised vehicles during the last decade with an average growth rate of nearly 13% per annum.**

- **The growth of two-wheelers has been very high (16.6%) followed by cars (6.9%) and buses (5.7%).**

- **Motor vehicles are estimated to contribute 8% of the total fossil fuel related CO2 emissions in India against the world average of approximately 15% [India ALGAS Report, 1998].**

- **A variety of industrial processes which transform materials from by physical or chemical processes are responsible for emissions of various GHGs like CO2, CH4, N2O and CO.**

Space Science Application in monitoring the Air Pollution and Energy

- Over the years, significant changes in climatic and weather conditions have taken place over the Indo-Gangetic basin
- INDOEX experiment , observed a relative link between the air pollution, atmospheric brown clouds and the Indian monsoon.
- The Asian brown cloud (ABC) was stated to be due to the influence of greenhouse gases (GHGs) on climate through the solar incident energy, solar reflected energy and earth's emitted energy.
- GHGs have increased significantly after 1950s, leading to significant influence on dimming of the planet, sea surface temperature, and cloud formation and rainfall.
- It is estimated that India is about 6–7% darker now than in 1950 due to the influence of GHGs.

- **The Indian Space Programme has initiated ISRO–GBP (Global Biosphere Programme) programme laid emphasis on aerosol studies over marine and land regions of India.**

- **The ISRO also has climate programme under which studies on aerosol in the last 15–20 years were undertaken.**

- **The nature of radiative forcing over India in different seasons is being studied through the sun photometer network at 22 locations.**

- **The Department of Science and Technology (DST) has also promoted several studies on air pollution and energy namely MONTBLEX (1990), CASPEX (1995–96), BOBMEX (1999) and ARMEX (2002–03).**

- **The radiative forcing due to anthropogenic aerosol in the Asian region because of the rapid growth of population and industrialization and it's impact on climate are highly heterogeneous in chemical and optical characteristics.**

- **The radiative flux could be a major functions of the energy budget, especially over India in terms of growing pollution.**

- **The Nainital laboratory study identified heavy metal content of particulate matter from diesel engines .**

- **There are also pollutions due to bio and radioactive aerosols and nano-particles (1.0 to 100 nm), from furnace and flame reactors, and also from nano-particle technology to pharmaceuticals.**

- **The PM2.5 concentration and composition variation in highway traffic leading to air pollution problems, particularly due to low spatial variations is well established.**

- **Satellite pictures indicate significant impact of growing pollution and dust events which are likely to affect rainfall and cause the decline of total ozone column over the Indo-Gangetic basin.**

- **There are studies on carbon and CO source inventorization of forest fires and biomass burning over entire India using satellite data and vegetation statistics.**

- **Seasonal variation of aerosol parameters from satellite data, and aerosol optical thickness and Ångström exponent from sun/sky photometry show a large variation between pre- and mid-monsoon periods.**

- **The aerosol size distribution and optical characteristics are significantly affected by the climate regime of the region and vary depending on the year.**

- **Many Universities and Engineering Colleges have introduced Environmental and Atmospheric Science and aspects like geophysical, fluid dynamics, mathematical modeling, earth radiation budget, climate studies and modeling like climate change, hydrology and study of atmospheric water cycle and its modeling, atmospheric/environ-mental pollution, and atmospheric technology is steadily taking prominent role in assessing the pollution levels and energy radiations across the country.**

- **Measurements of tropospheric carbon monoxide from space have now been made for over 20 years starting with the Measurements of Air Pollution from Satellites (MAPS) instrument. Pollution is known to alter temperature and precipitation patterns.**

- **Global satellite imageries like that of NOAA's Geostationary Operational Environmental Satellites (GOES), Polar Operational Environmental Satellites (POES) and the Moderate Resolution Imaging Spectroradiometer (MODIS) Terra and Aqua are being extensively used for monitoring the air pollutions and energy uses in rural India.**

- **Fire detection could be conveniently identified by the satellite imageries and the smoke is annotated by a satellite image analyst by infrared resolution.**

- **The ocean color sensors provide information about the ocean and atmospheric parameters. India is surrounded by the Bay of Bengal and the Arabian ocean, the inland water flows through numerous rivers into the ocean.**

- **The chlorophyll and suspended sediment concentrations change significantly over the years.**

- **Due to the strong variability of rainfall the water flux going to the ocean also changes significantly.**

- **Using IRS P4 OCM and MODIS data, ocean parameters and also aerosol optical depth have been retrieved for the period 1999 – 2003 along the eastern and western coasts and also at various locations near the rivers mouth and near the numerous industrial cities.**

- **The ocean parameters and aerosol optical depth show strong annual and inter-annual variability along the two coasts and also near the industrial cities.**

- **The annual variability in view of the upwelling and dynamic meteorological conditions over the eastern and western coasts could be observed.**

- **The data from INSAT/METSAT satellites lead to a satellite-based operational air quality monitoring program for India.**

- **GOES observation on aerosol and smoke help to monitor air quality**

- **The tropical region is characterized by intense photochemical activity, strong upwelling and higher amount of water vapour.**

- **The Indian region also has strong summer monsoon, which not only brings heavy rainfall but also clean marine air from the south-west direction.**

- **During winter season winds from north and north-west direction bring pollutants from long distances.**

- **These natural features and the changing anthropogenic activities make this region important to study chemical transformation of pollutants, their transport and their impact on the regional environment and climate.**

- India has a relatively strong programme to study trace gases, their emissions, chemistry and transport and have been monitoring O3, CO, NOx etc at several sites in India.

- Several field experiments to study emissions of CO, NOx, CH4 etc from biomass burning have also been conducted.

- Detailed measurements to study methane and nitrousoxide emissions from paddy and other crops are being made.

- Several cruises have been conducted over the surrounding marine regions to study transport of pollutants.

- Vertical distributions of important trace gases (CFCs, halons, CH3Br, N2O, CH4 etc) have been made using high altitude balloons.

- Regular measurements of ozone, humidity and temperature are being made from four sites in India using rubber balloons.

- The studies on chemical transformation and transport of pollutants over the central and southern Indian region have been conducted.

- **These programmes are expended to make detailed regional coverage and also making use of satellite and aircraft platforms and expand modeling activities.**

- **By the use of space technology, estimation of GHG emissions from the transport sector are assessed by:**

  - **Estimation of emissions on the basis of gms/km or gms/litre of fuel**
  - **Estimation of total emissions of CO_2, CO, per kilometre driven**
  - **Computation of current estimates and projection for the future.**
  - **Estimation of impact of growth of vehicles on emissions and subsequent deterioration in air quality.**

- **Measure of emissions of various GHGs in different parts of the country, to get the representative emission values specially from burning of biomass fuels, such as charcoal, wood, and animal waste, and hard coal, are being assessed.**

- **Estimation process for discriminating sustainable from non-sustainable biomass supplies and the emission of various GHGs from the burning of different kinds of biomass materials are being studied through the space science.**

- **The methane contents in Indian coal belts has been assessed by the use of satellite imageries.**

- **The estimation of GHG emission from various industrial processes, namely the information regarding the clinker production which is an intermediate product, from which cement is formed and which is associated with the CO2 emission, are being studied**

- **Adipic acid and nitric acid production processes, as a source of N2O emission, and emissions from the construction sector has been tried for development of a reliable database for the preparation of a credible inventory for this sector.**

Ozone Observations (Upper air Instruments)

IMD's National Ozone Centre at New Delhi is designated as Regional Ozone Centre for Regional Association II (Asia) of the World Meteorological Organisation.

The centre maintains and controls a network of ozone monitoring stations including Maitri (Antarctica).
Total ozone and Umkehr observations are recorded regularly during the day at five stations using selective wavelengths in the UV region with the help of Dobson Spectrophotometer.

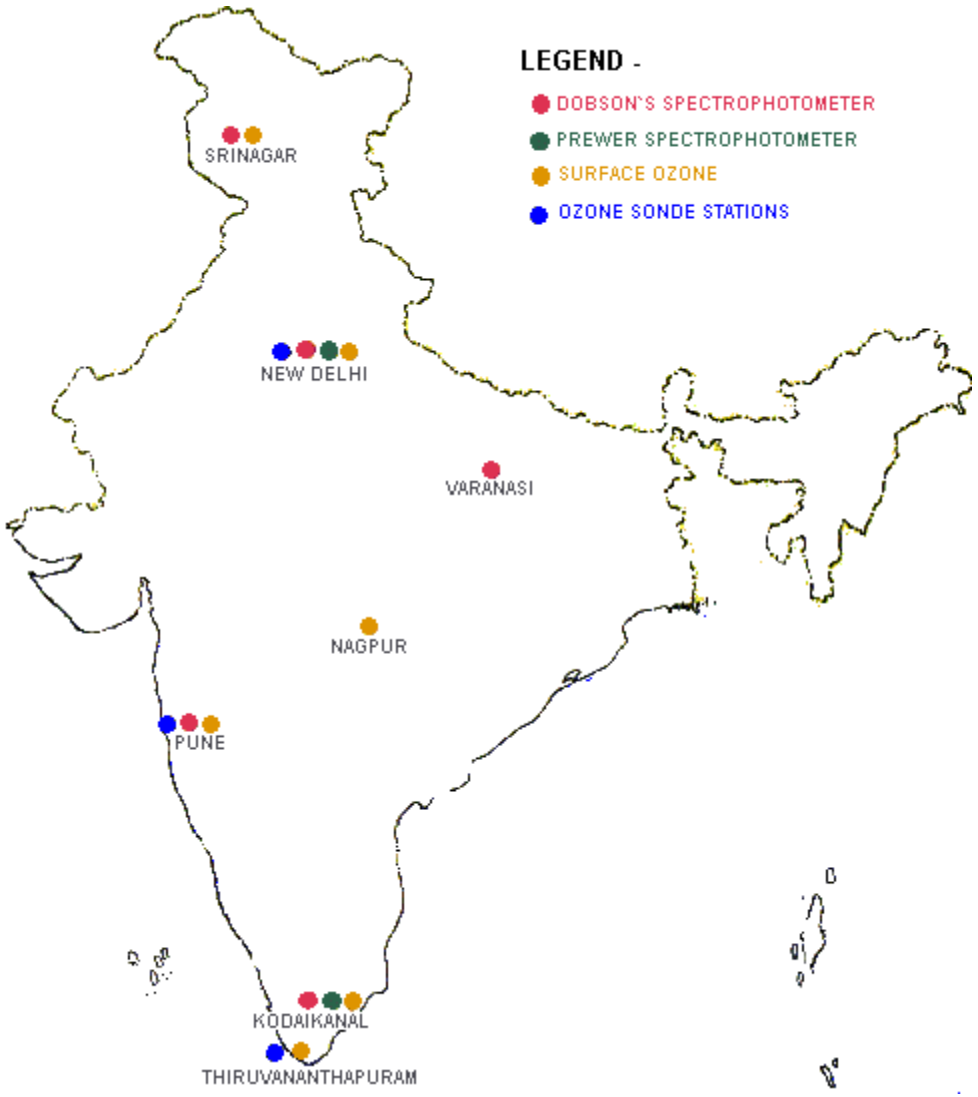
Brewer Spectrophotometers, having capability to monitor UV-B radiation besides concentrations of total Ozone, SO2 and NO2 simultaneously, were also introduced in the existing network at two stations in 1994. One such additional Brewer spectrophotometer was installed at Maitri(Antarctica) in July 1999.

Ozone Monitoring Network

Vertical ozone profiles using indigenous balloon-borne ozone-sondes are observed fortnightly at 4 stations including Maitri. Surface ozone measurements using electrochemical method are recorded continuously at 7 stations including Maitri.

Ozone data is being regularly sent to World Ozone Data Centre, Canada for archival.

IMD is collaborating at both the national and international levels through international intercomparison of instruments, conducting experiments to study tropospheric ozone over the Indian ocean, comparing satellite data with ground truth and studying diurnal and seasonal variations in the ozone layer over Indian and Russian stations.


LEGEND -
DOBSON'S SPECTROPHOTOMETER
PREWER SPECTROPHOTOMETER
SURFACE OZONE
OZONE SONDE STATIONS
SRINAGAR
NEW DELHI
VARANASI
NAGPUR
PUNE
KODAIKANAL
THIRUVANANTHAPURAM

Radiation observations

(i) Surface Observations

There are at present 45 radiation observatories recording various radiation parameters. At all these stations, measurement of global solar radiation is being carried out while at a few selected stations other parameters like diffuse, direct, net, net-terrestrial and reflected radiation and atmospheric turbidity are also measured. Data loggers have been introduced at four stations viz. New Delhi, Patna, Jaipur and Thiruvanathapuram. The primary objective of the observational programme is to have an understanding of basic physical processes involved in the conversion of the Sun's radiant energy into atmospheric motions as also into chemical and biochemical energy. The observations made at national network of radiation stations are useful in the assessment of solar energy potential in different parts of the country.

(ii) Upper Air Observatories

Besides the measurements on the surface, fortnightly airborne soundings are made with radiometersondes to measure directly the vertical distribution of the infrared radiation flux and radiation cooling from surface upto a height of 20 Km or more in the free atmosphere, at New Delhi, Srinagar, Thiruvananthapuram, Pune, Nagpur, Jodhpur, Calcutta and Bhubaneshwar. Radiometersonde ascents are being conducted regularly at Maitri, the Indian Antaractic station also.

Background Air Pollution Monitoring Network (BAPMoN)

With a view to documenting the long term changes in composition of trace species of the atmosphere as a result of changing land use pattern, WMO had commissioned a global programme called Background Air Pollution Monitoring Network (BAPMoN) which is now a part of the Global Atmospheric Watch (GAW) Programme. India had set up 10 such BAPMon stations.

At these stations, rain water samples are collected every month and these are sent to the Central Chemical Laboratory at Pune for complete chemical analysis. Acidity of rain and mineral deposition is determined from these.

Atmospheric turbidity which indicates the columnar aerosol load of the atmosphere, is also measured at these stations using sunphotmeters. These data are important for identifying the current levels of pollution as well as for study of the long term trends in the concentration of trace constituents of the atmosphere which may affect the environment and induce a climate change.

To study the impact of industrialisation, urbanisation and terrain modification on micro-climatological features of urban areas, urban climatological studies are carried out in metropolitan cities.

Conclusion

- **Many ongoing and future international missions are expected to be useful for the specific observational needs over tropics. Indian missions consisting of geostationary platforms carrying optical sensors, imager and sounder operating in thermal region while polar orbiter with microwave imager, sounder and scatterometer are on the anvil, like the INSAT-3 D, Oceansat-2 (Scatterometer) , the Megha-Tropiques and the Climatsat missions.**

- **The accurate parameter retrieval either from imager or from sounder essentially depends upon the extent of radiometric and geometric correction applied, calibration, normalization, navigation and earth location of basic pixel data.**

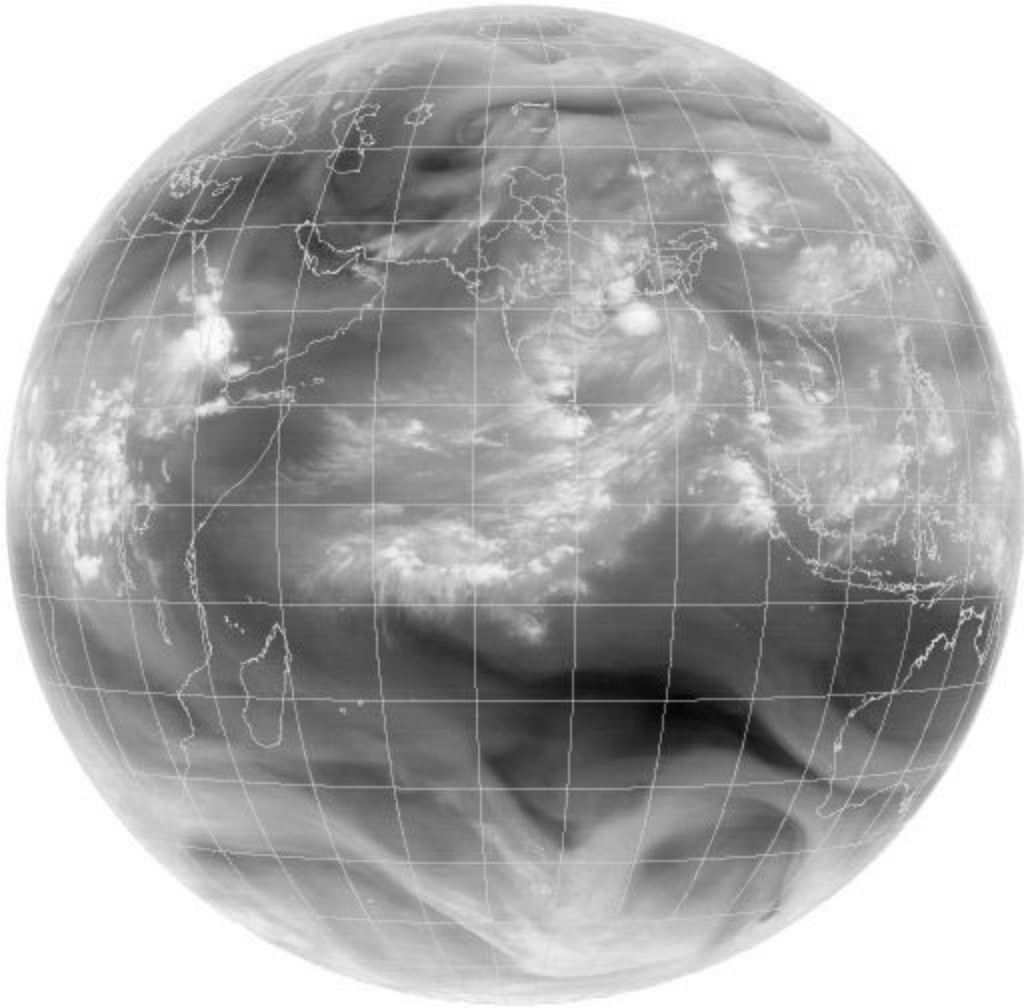
- **On-board INSAT-3D, Image Navigation and Registration (INR) similar to that of GEOS-8, mirror motion compensation (MMC) and Image Motion Compensation (IMC) from INR reduce the navigational errors encountered.**

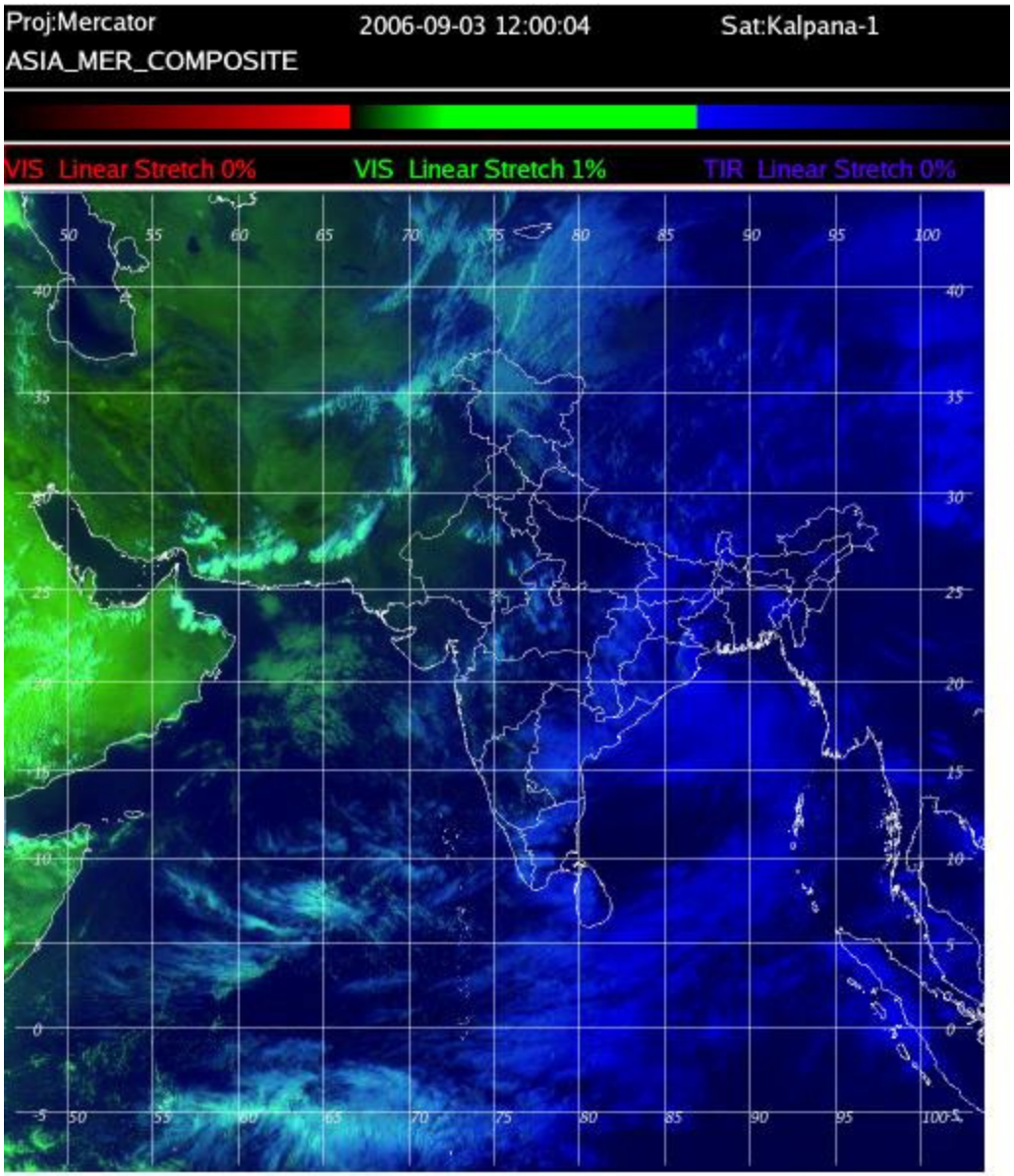
- **With indispensable applications of oceanic winds in meteorology, oceanography and water resources, India has planned to launch OCEANSAT-2 satellite carrying a Ku-band scatterometer similar to Quikscat and an Ocean Colour Monitor (OCM) soon, which will give multidimensional data on atmosphere and environment and help better monitoring of air pollution and energy levels.**

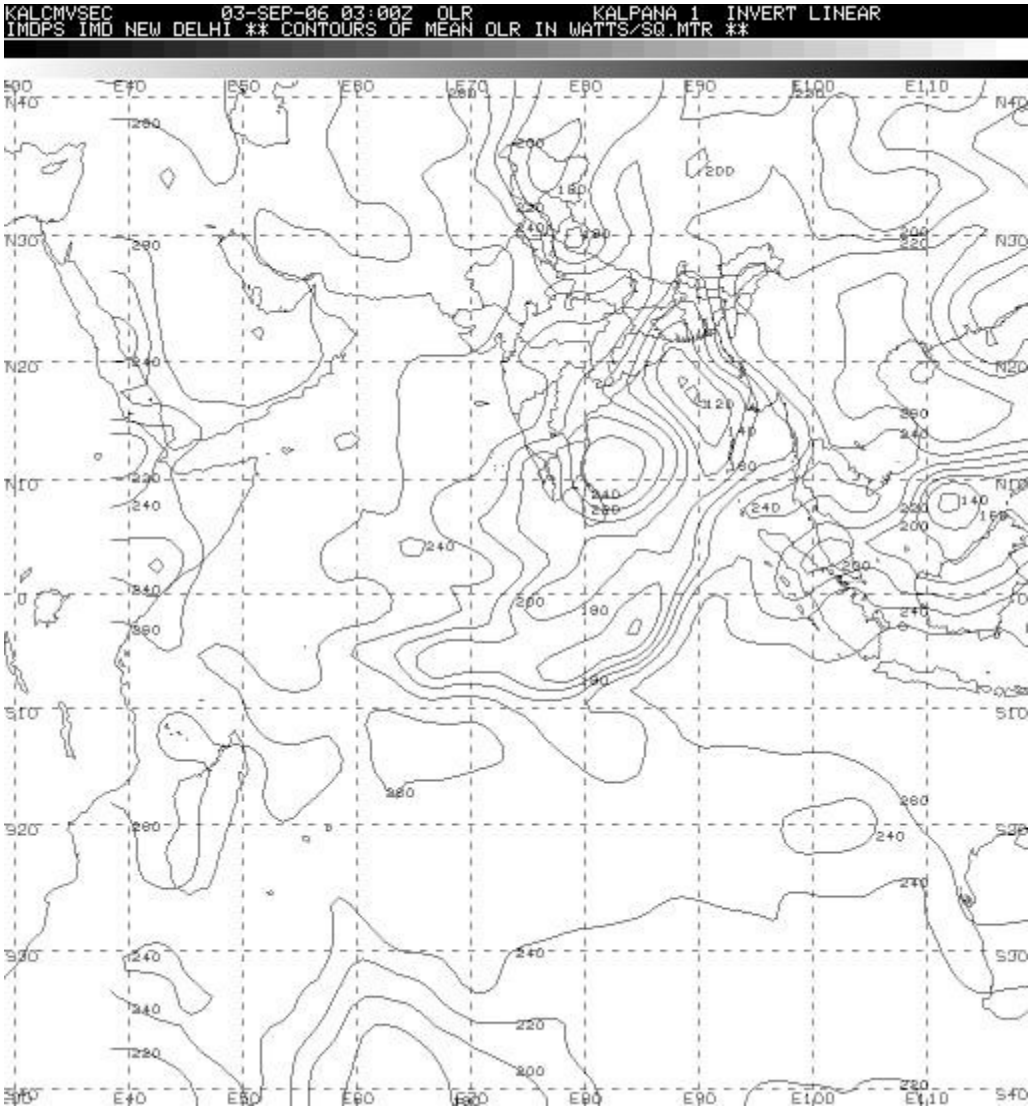
Proj:None 2006-09-03 15:00:04 Sat:Kalpana-1

GLOBE_WV

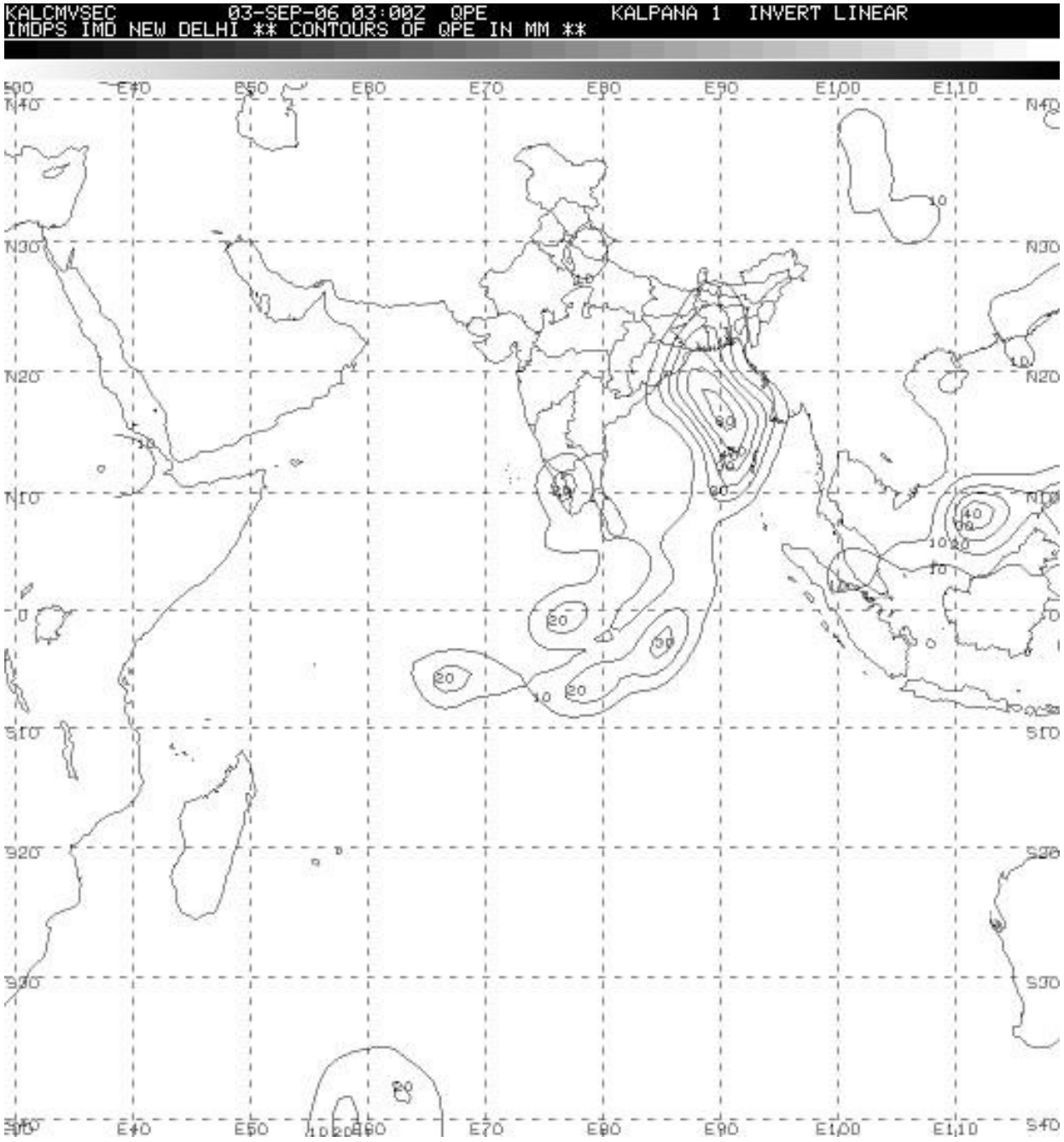
WV No Enhancement



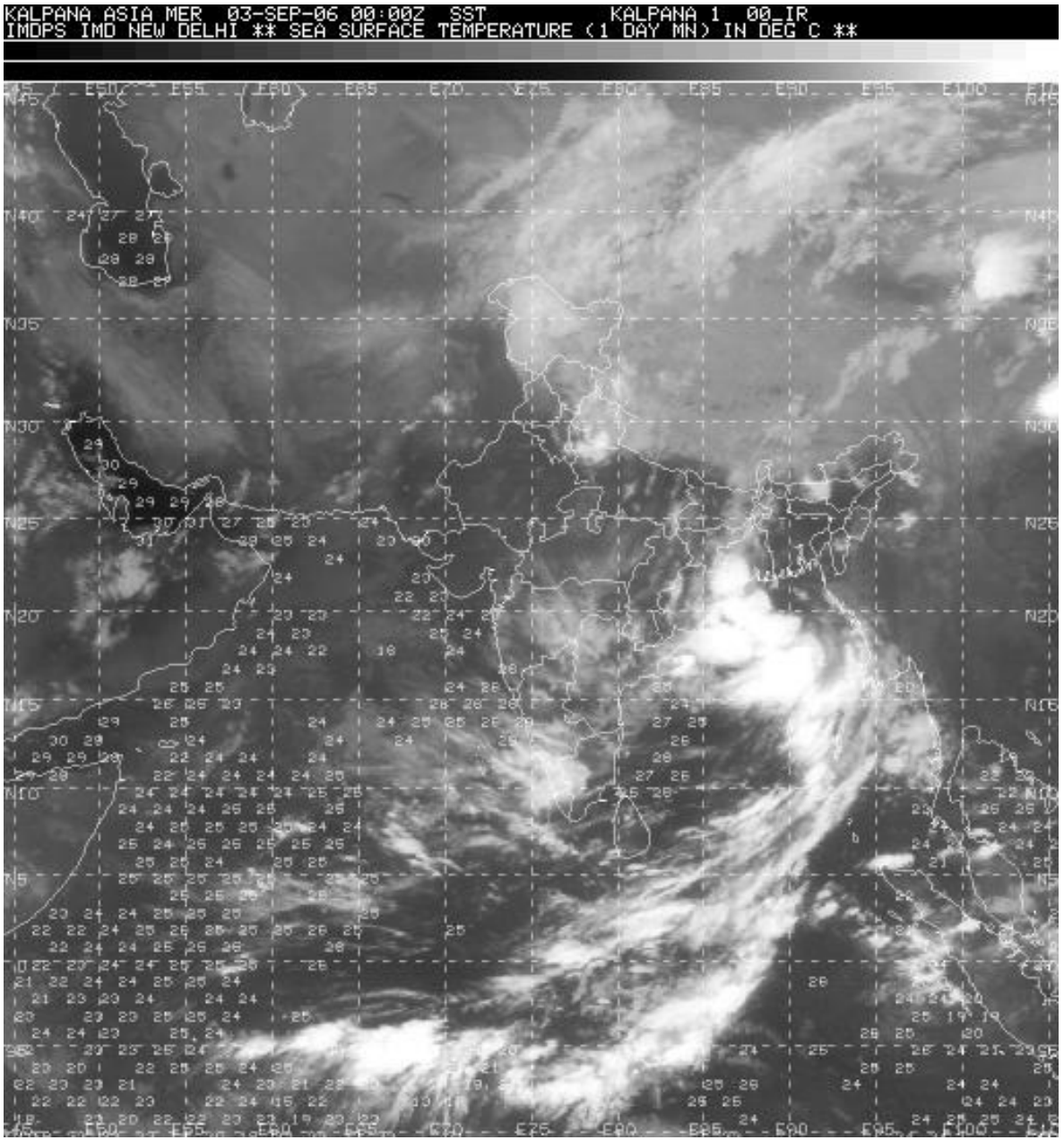

Proj:Mercator
2006-09-03 12:00:04
Sat:Kalpana-1
ASIA_MER_COMPOSITE
VIS Linear Stretch 0%
VIS Linear Stretch 1%
TIR Linear Stretch 0%

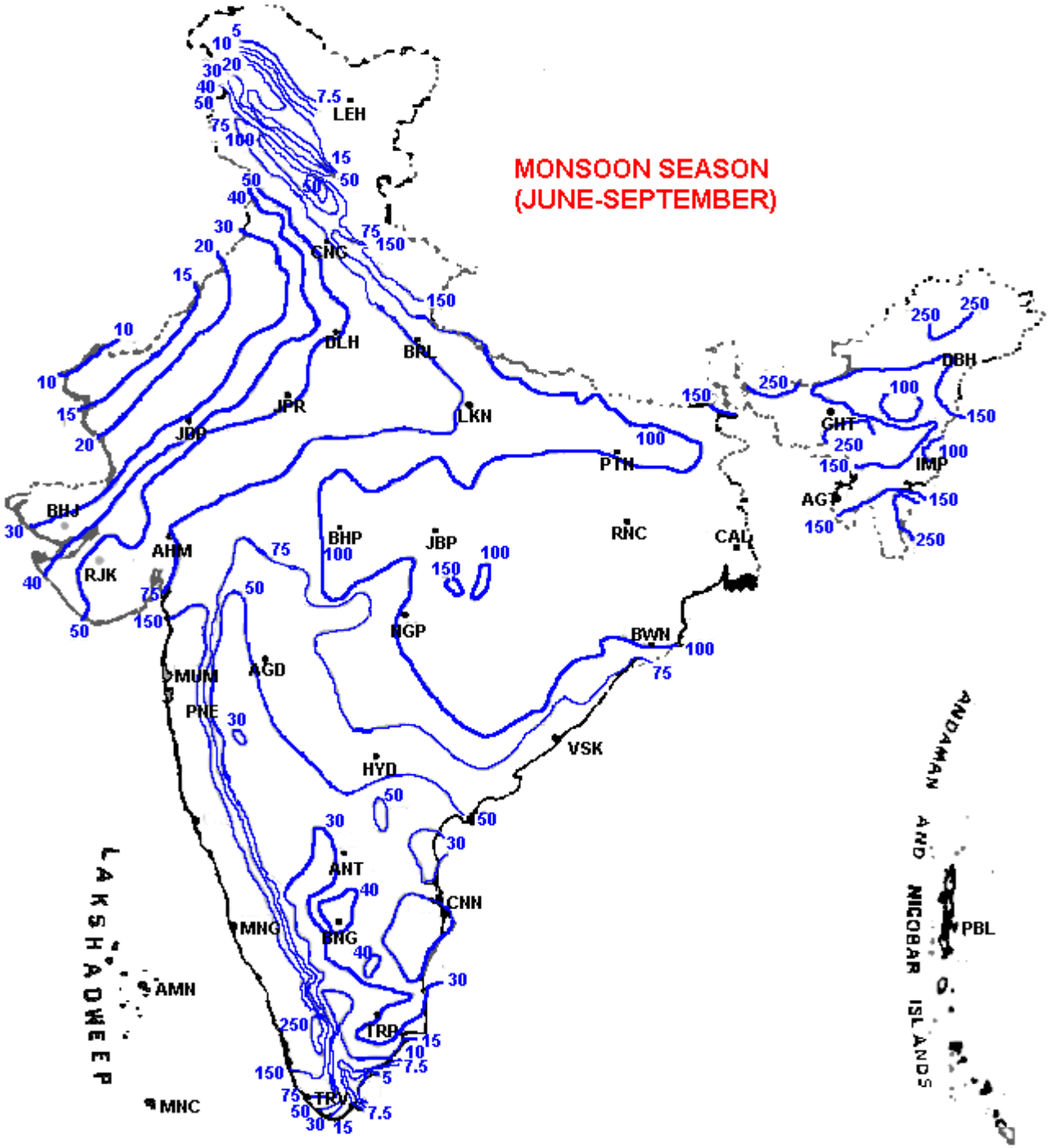

KALCMVSEC 03-SEP-06 03:00Z OLR KALPANA 1 INVERT LINEAR
IMDPS IMD NEW DELHI ** CONTOURS OF MEAN OLR IN WATTS/SQ.MTR **
E50
E60
E70
E80
E90
E100
E110
N40
N30
N20
N10
0
S10
S20
S30
S40

INSAT Quantitative Precipitation Estimate (QPE)

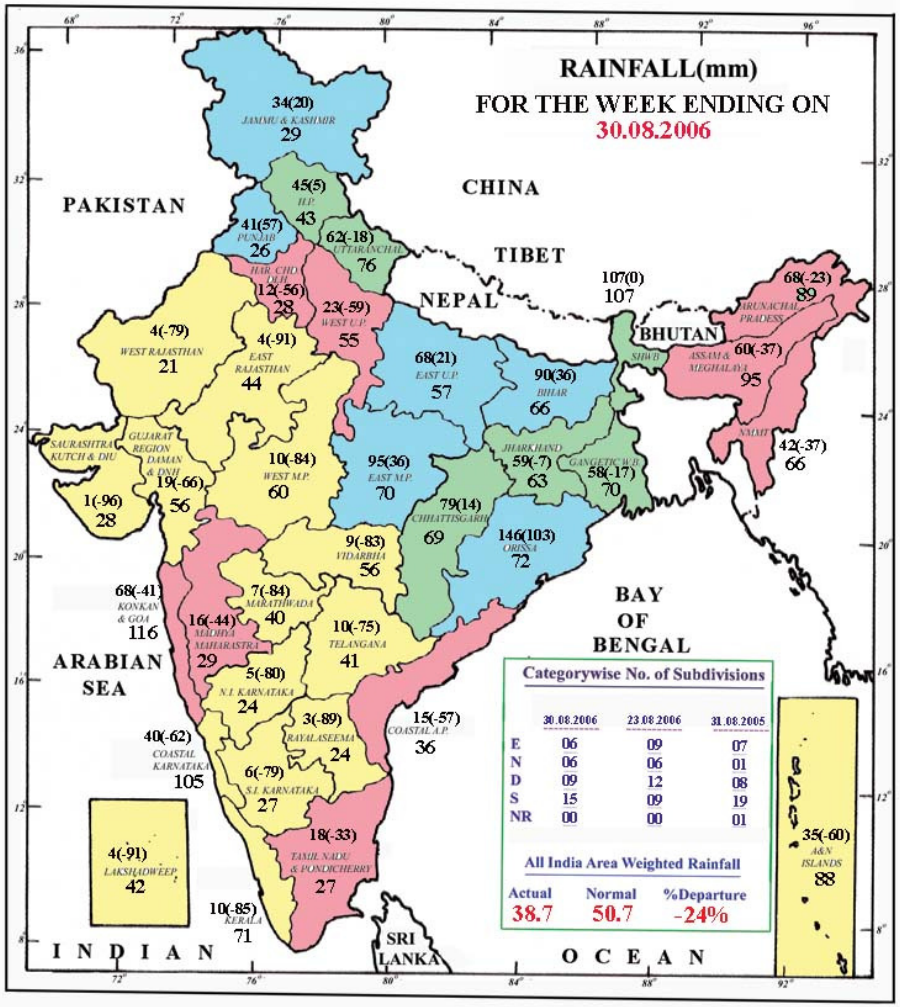


Sea Surface Temperature derived from Satellite Data




MONSOON SEASON
(JUNE-SEPTEMBER)
LEH
CNG
DLH
BRL
JPR
JDP
LKN
PTN
BHJ
AHM
RJK
BHP
JBP
RNC
CAL
NGP
BWN
MUM
AGD
PNE
VSK
HYD
ANT
CNN
MNG
BNG
AMN
TRP
MNC
TRV
DBH
GHT
IMP
AGT
LAKSHADWEEP
ANDAMAN AND NICOBAR ISLANDS
PBL

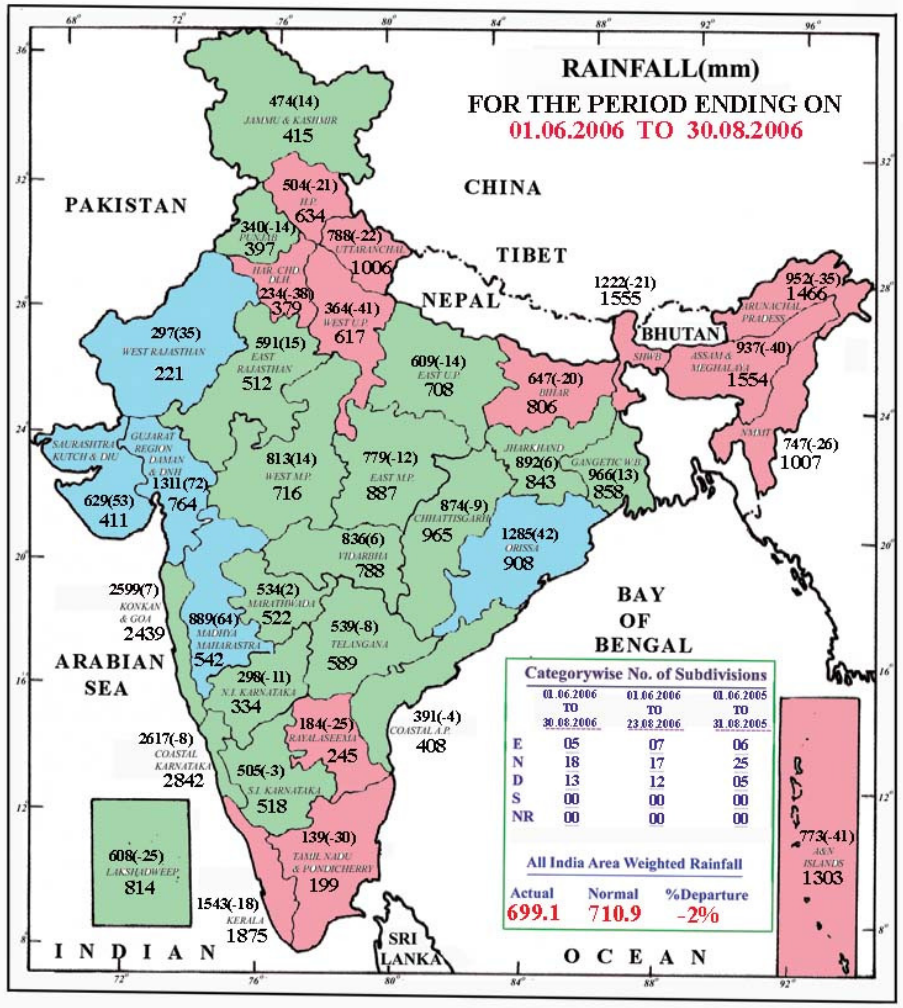
भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT



LEGEND : EXCESS (E) + 20% OR MORE | NORMAL (N) +19% TO -19% | DEFICIENT (D) -20% TO -59% | SCANTY (S) -60% TO -99% | NO RAIN (NR) -100% | NO DATA

NOTES:
(a) Rainfall figures are based on operational data.
(b) Small figures indicate actual rainfall (mm), while bold figures indicate normal rainfall (mm). Percentage departures of rainfall are shown in brackets.

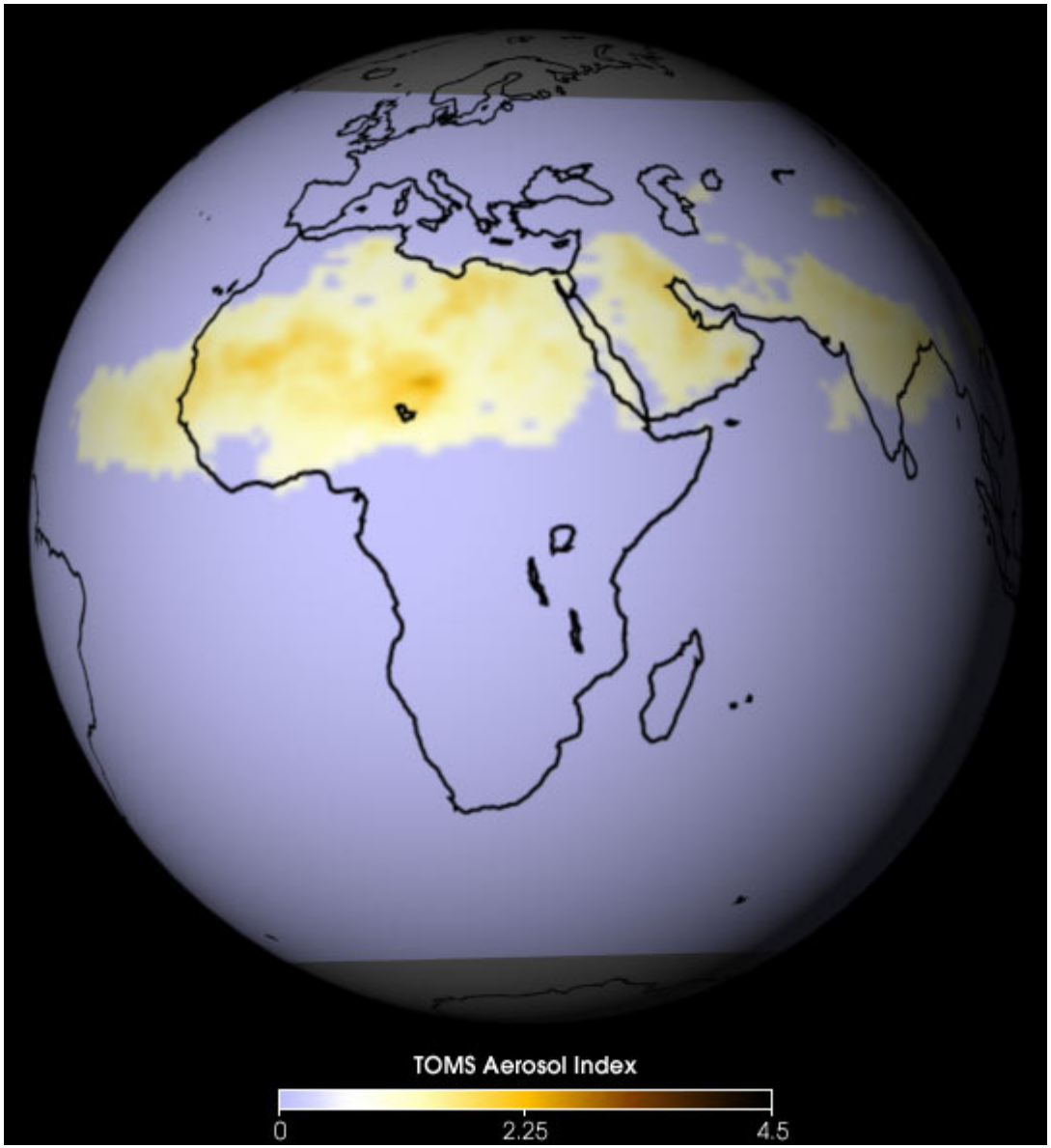
भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT



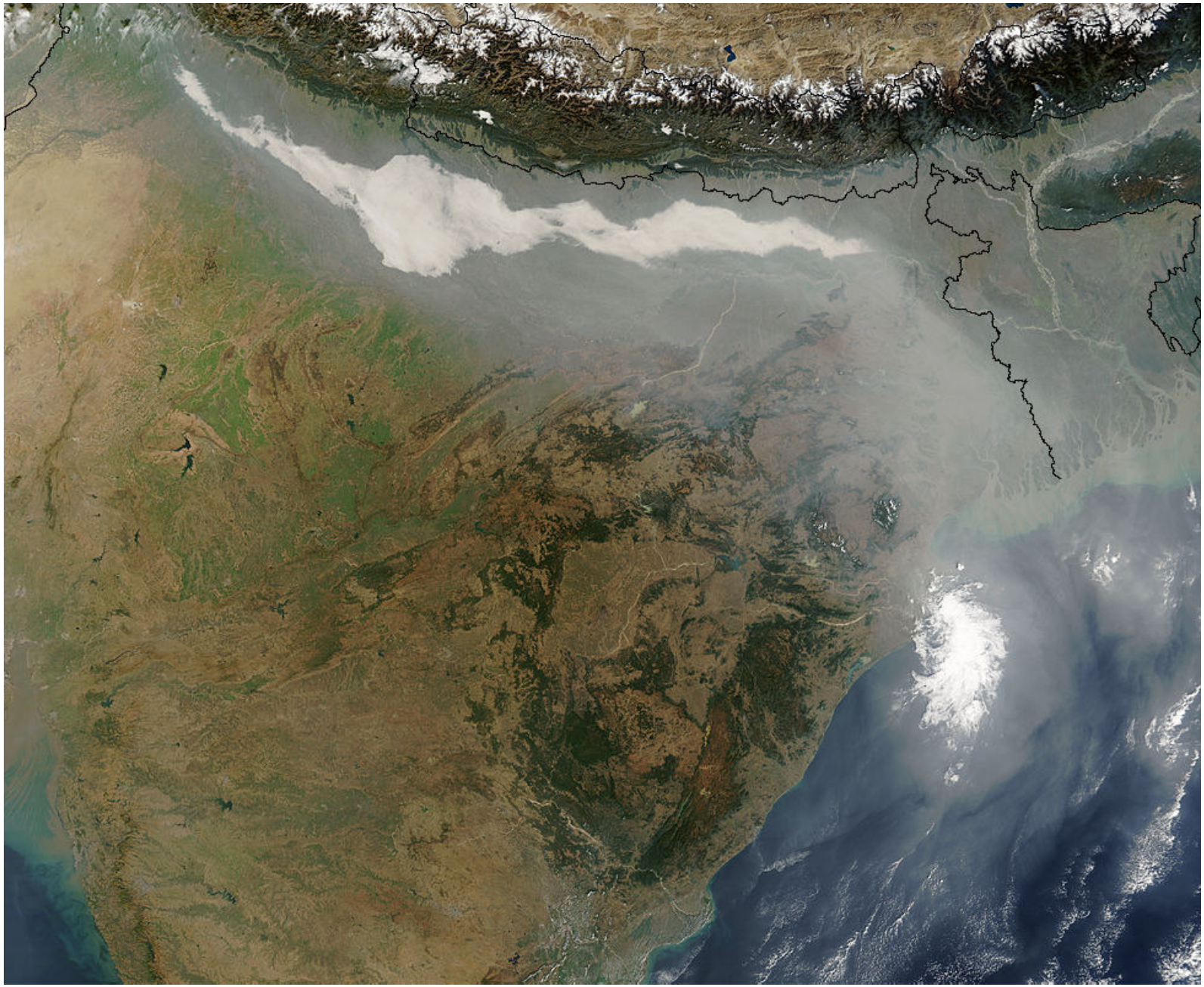
NOTES:

(a) Rainfall figures are based on operational data.

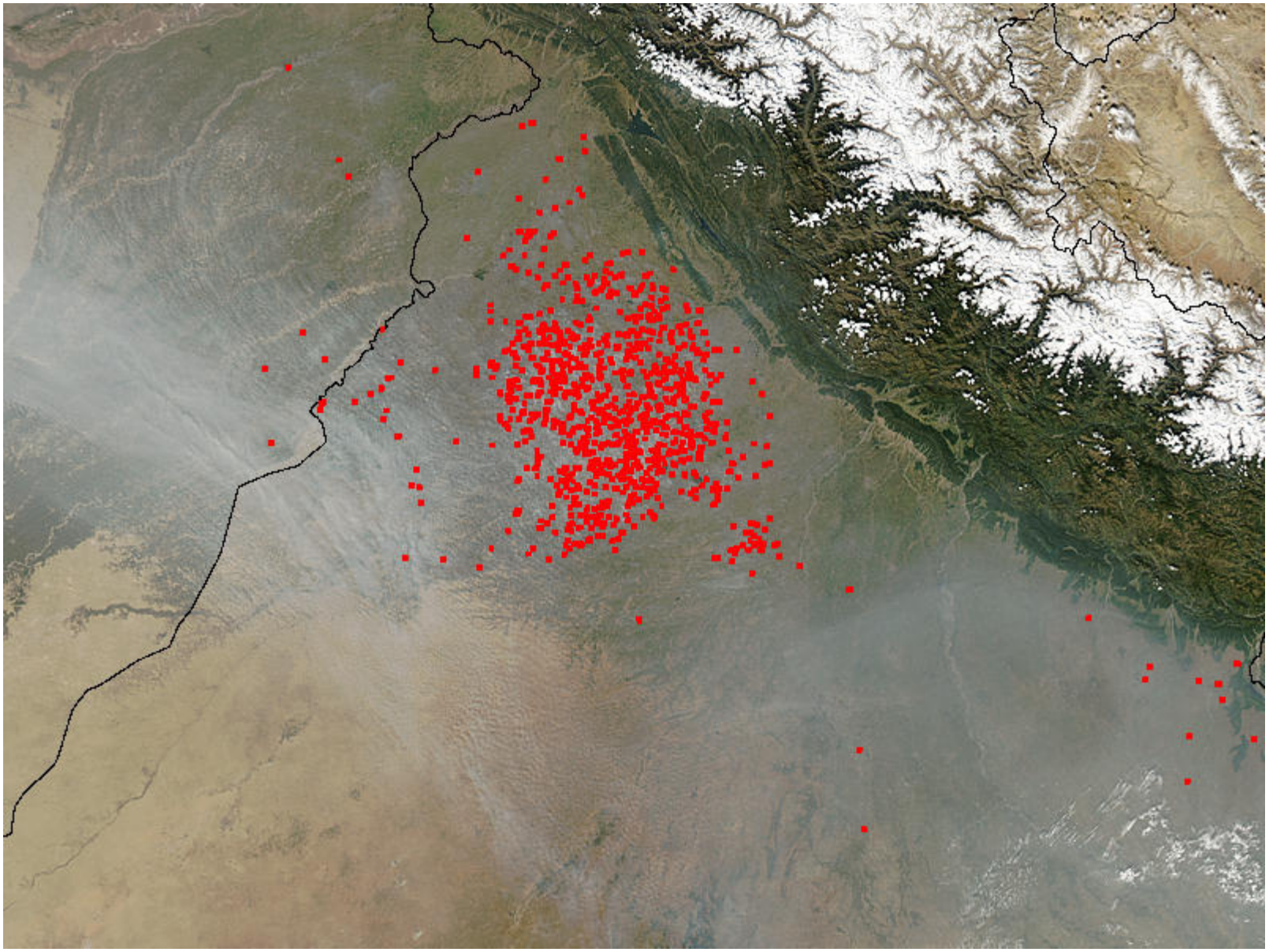
(b) Small figures indicate actual rainfall (mm), while bold figures indicate normal rainfall (mm). Percentage departures of rainfall are shown in brackets.


TOMS Aerosol Index
0
2.25
4.5

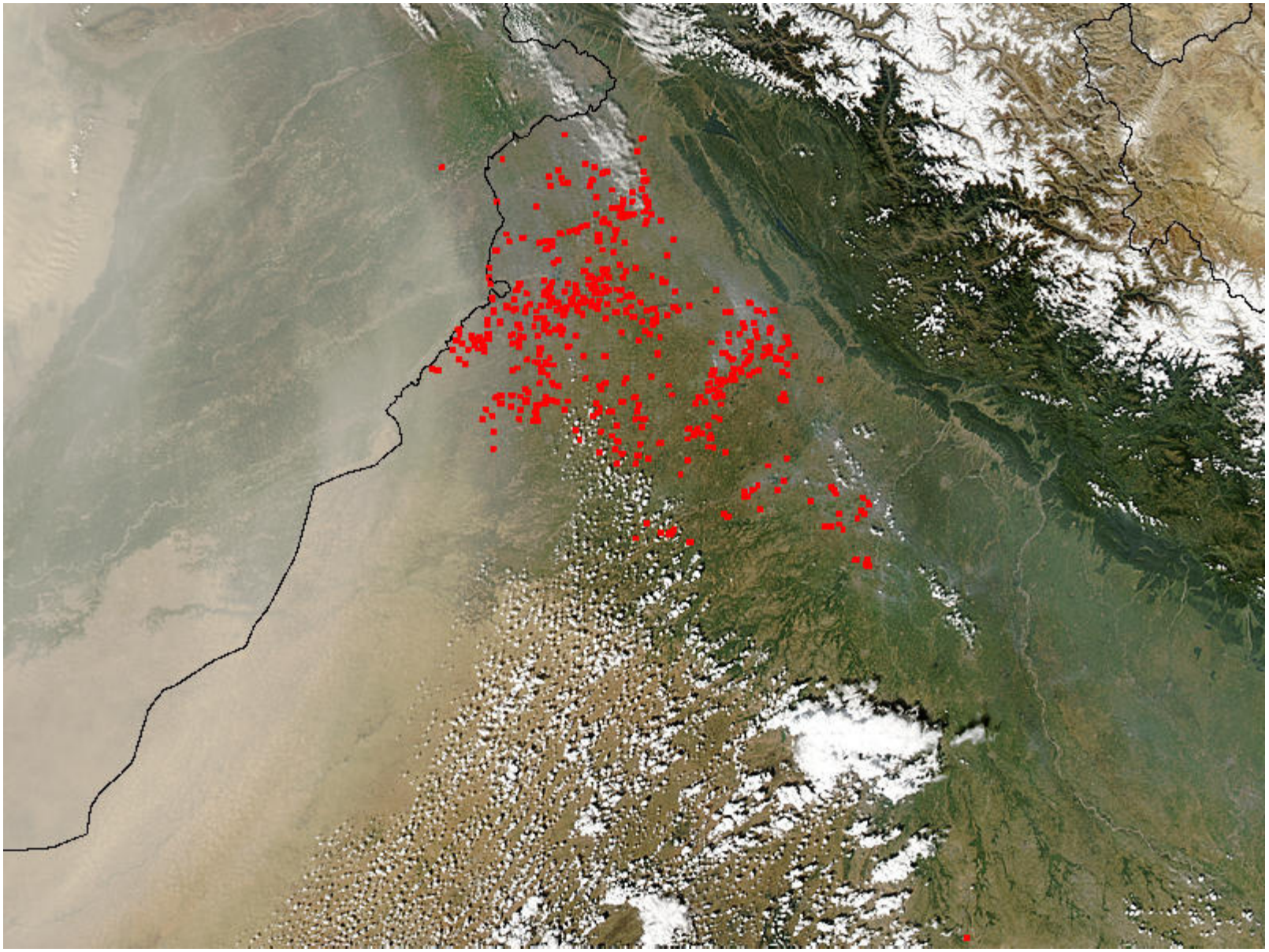
Haze and smog across Northern India



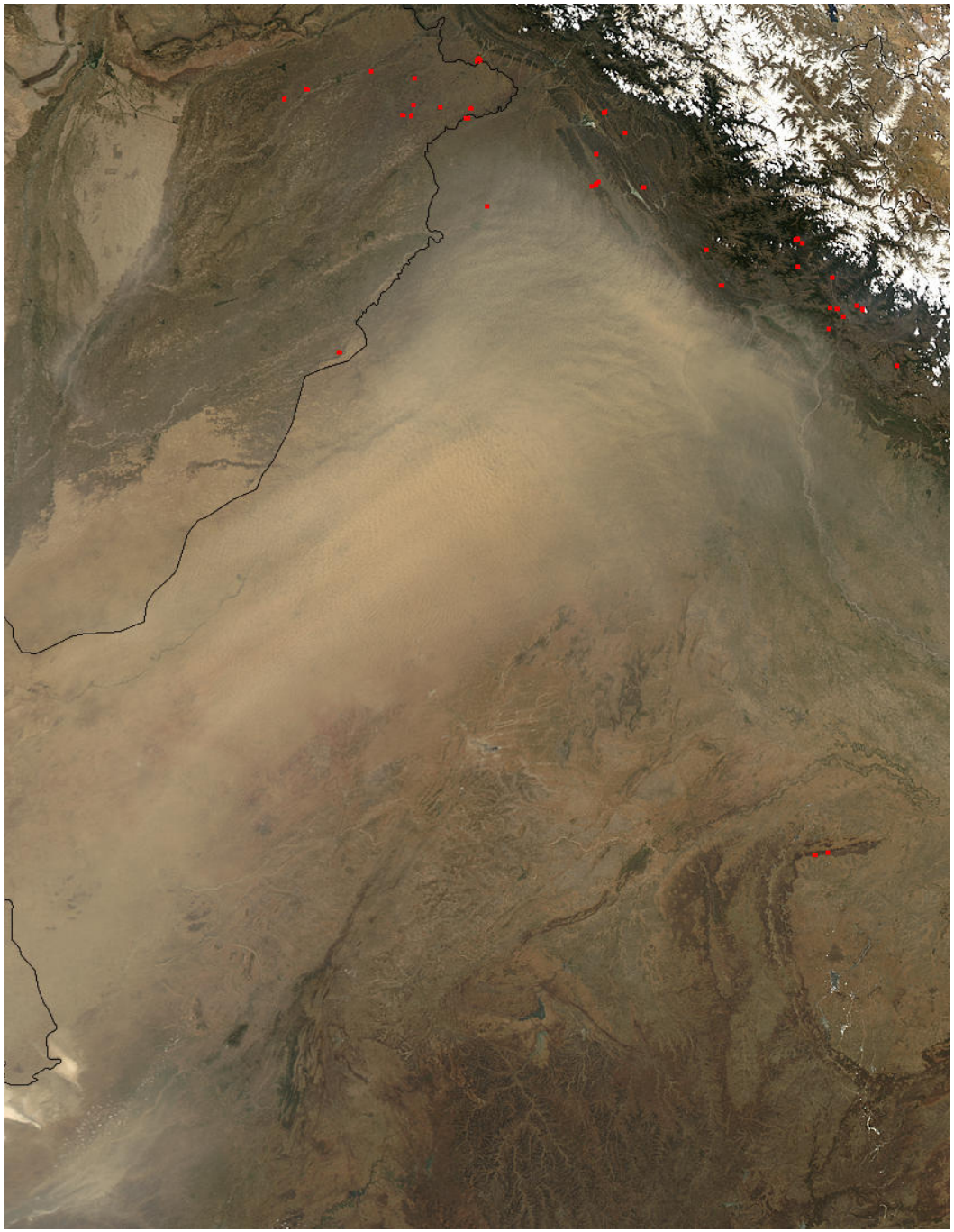
Intense agricultural fires and smoke in Northwest India



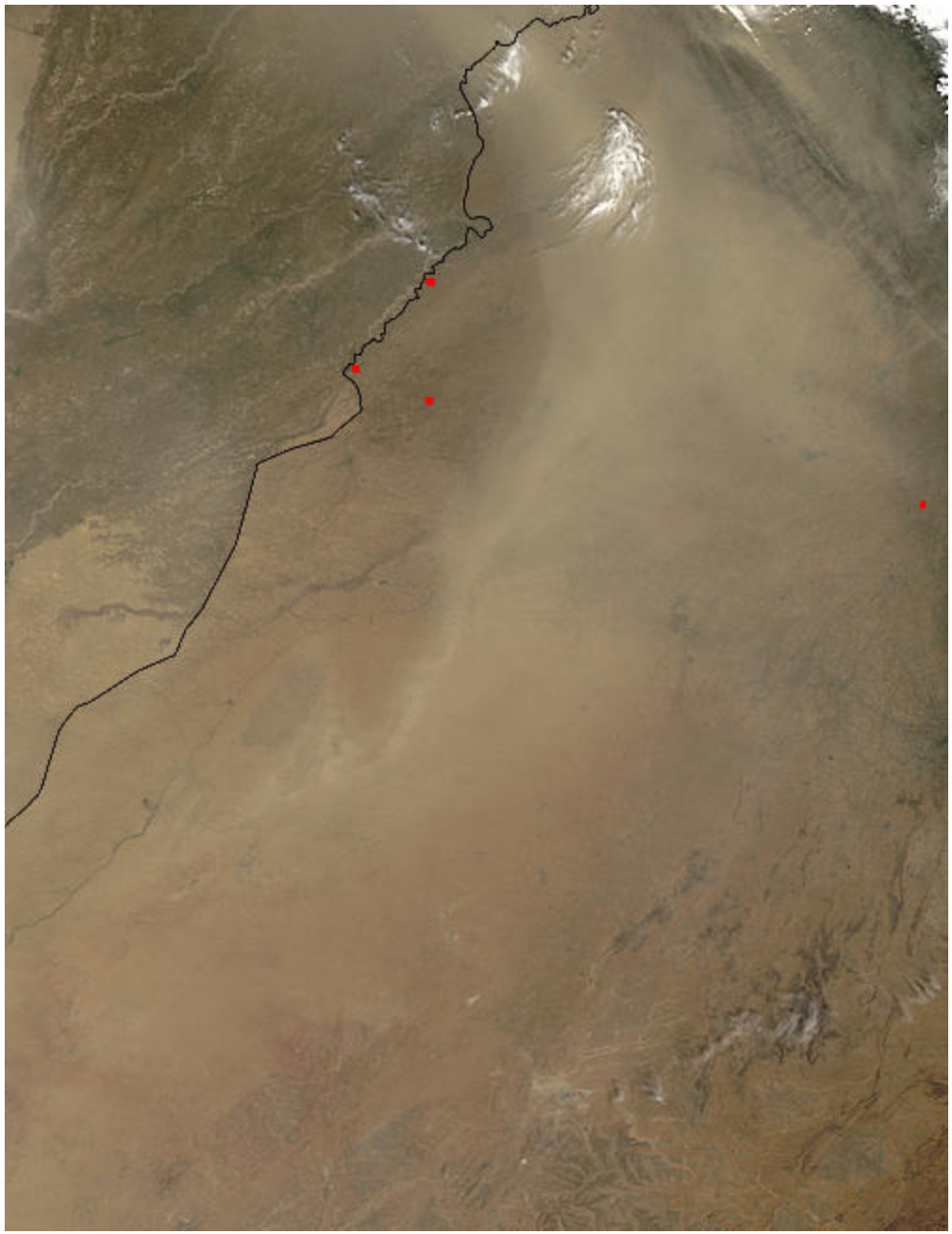
Fires, smoke and dust in Northwest India



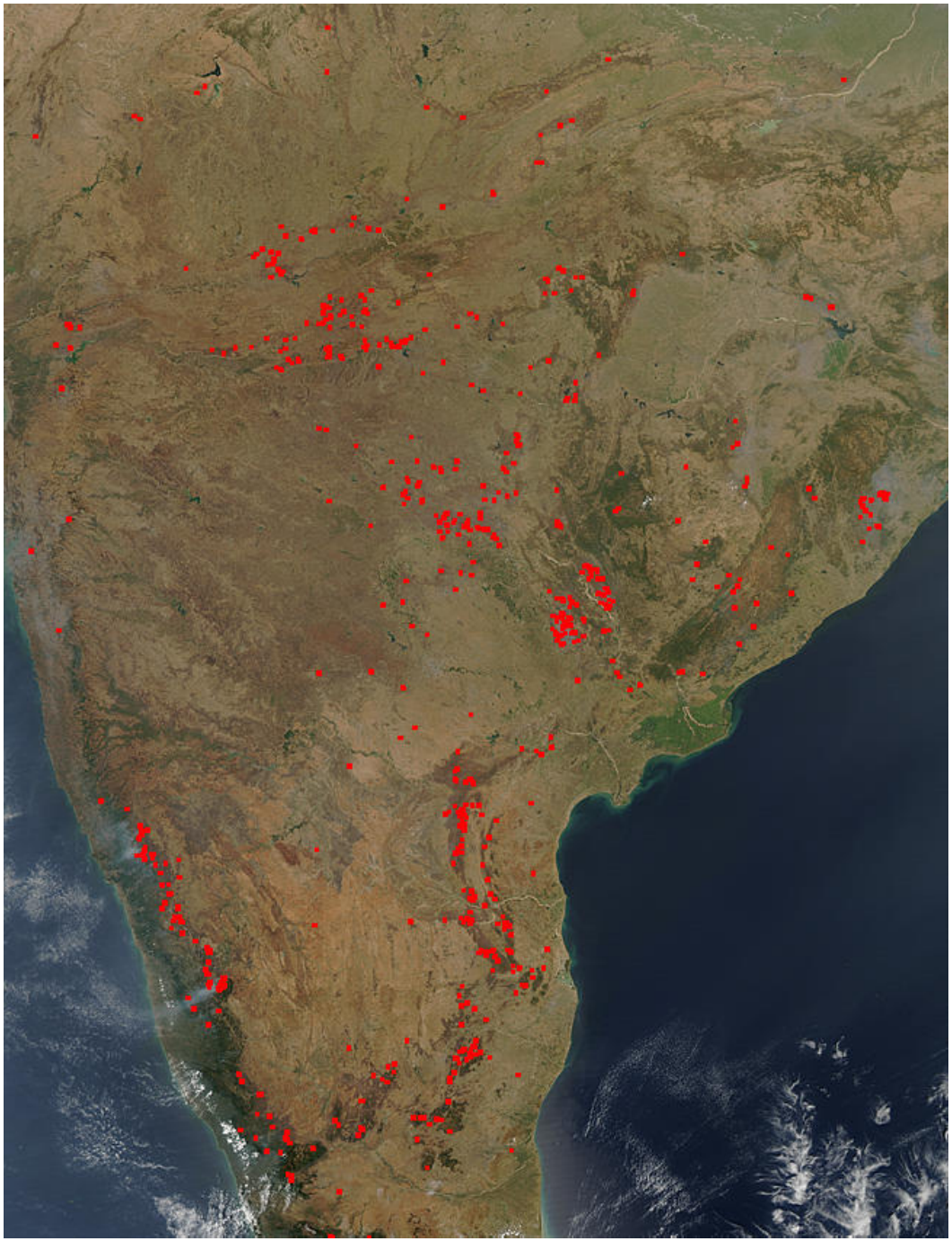
Dust storm in the Great Indian Desert



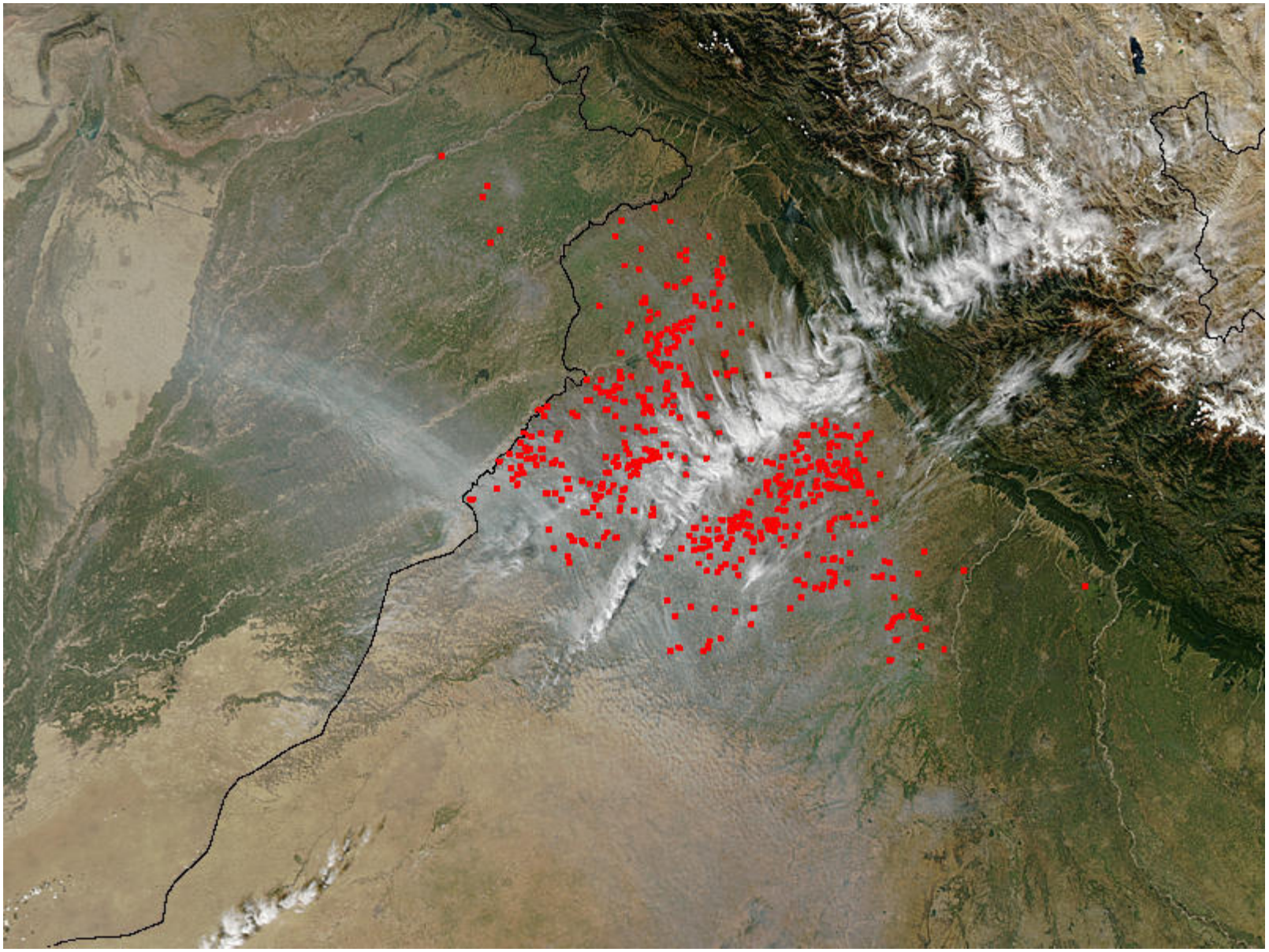
Dust storm in northwest India



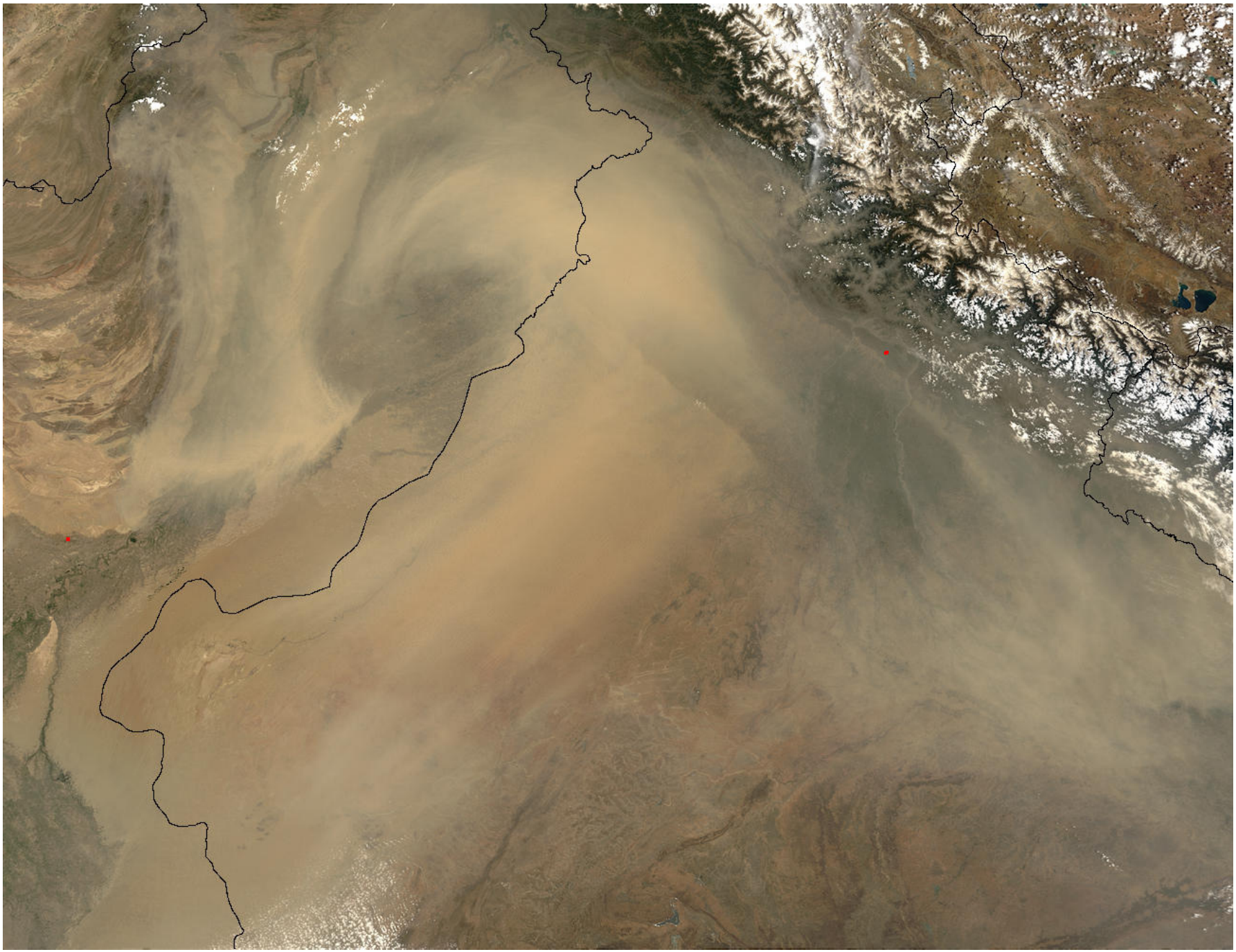
Fires in southern India



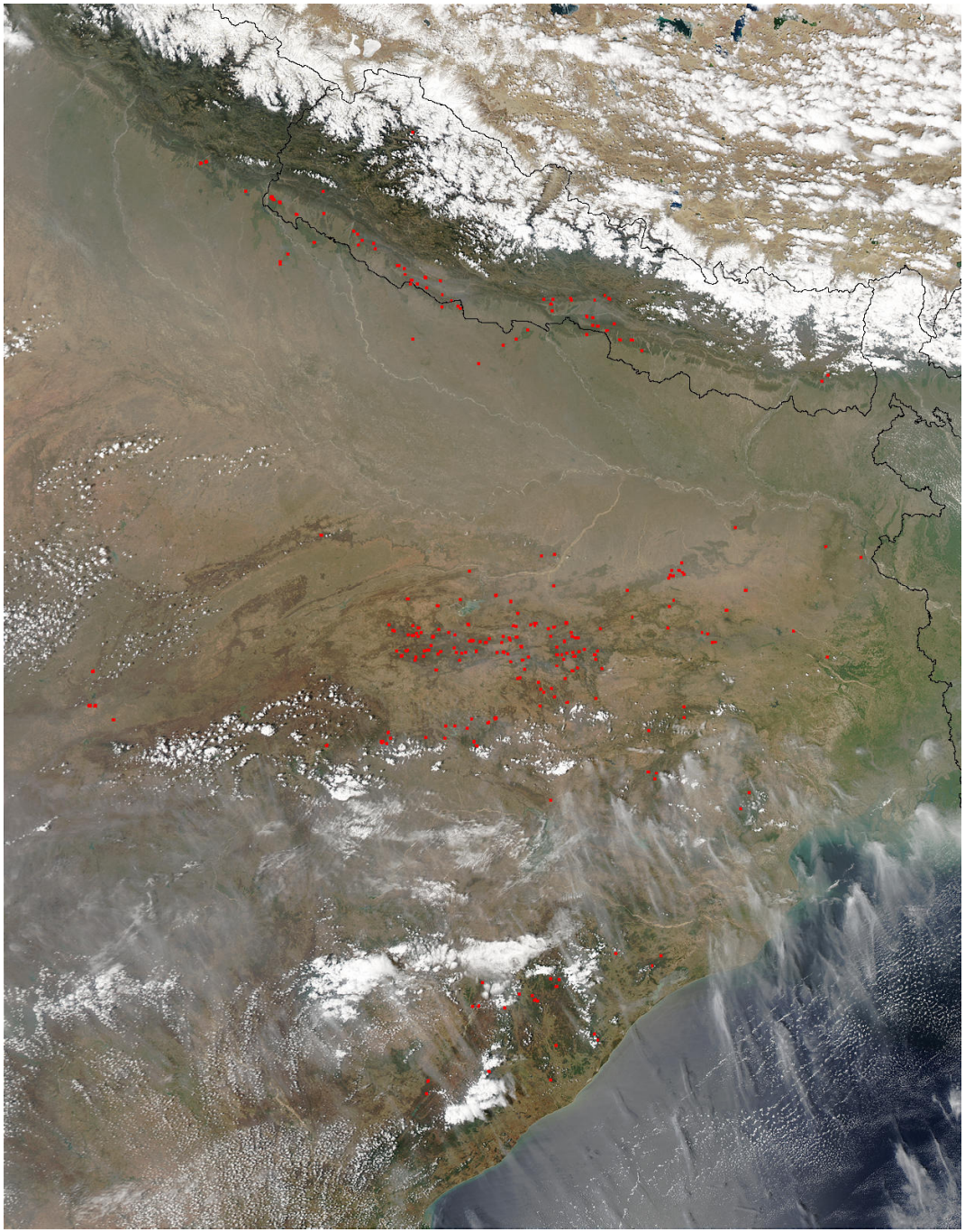
Fires and smoke in Northwest India



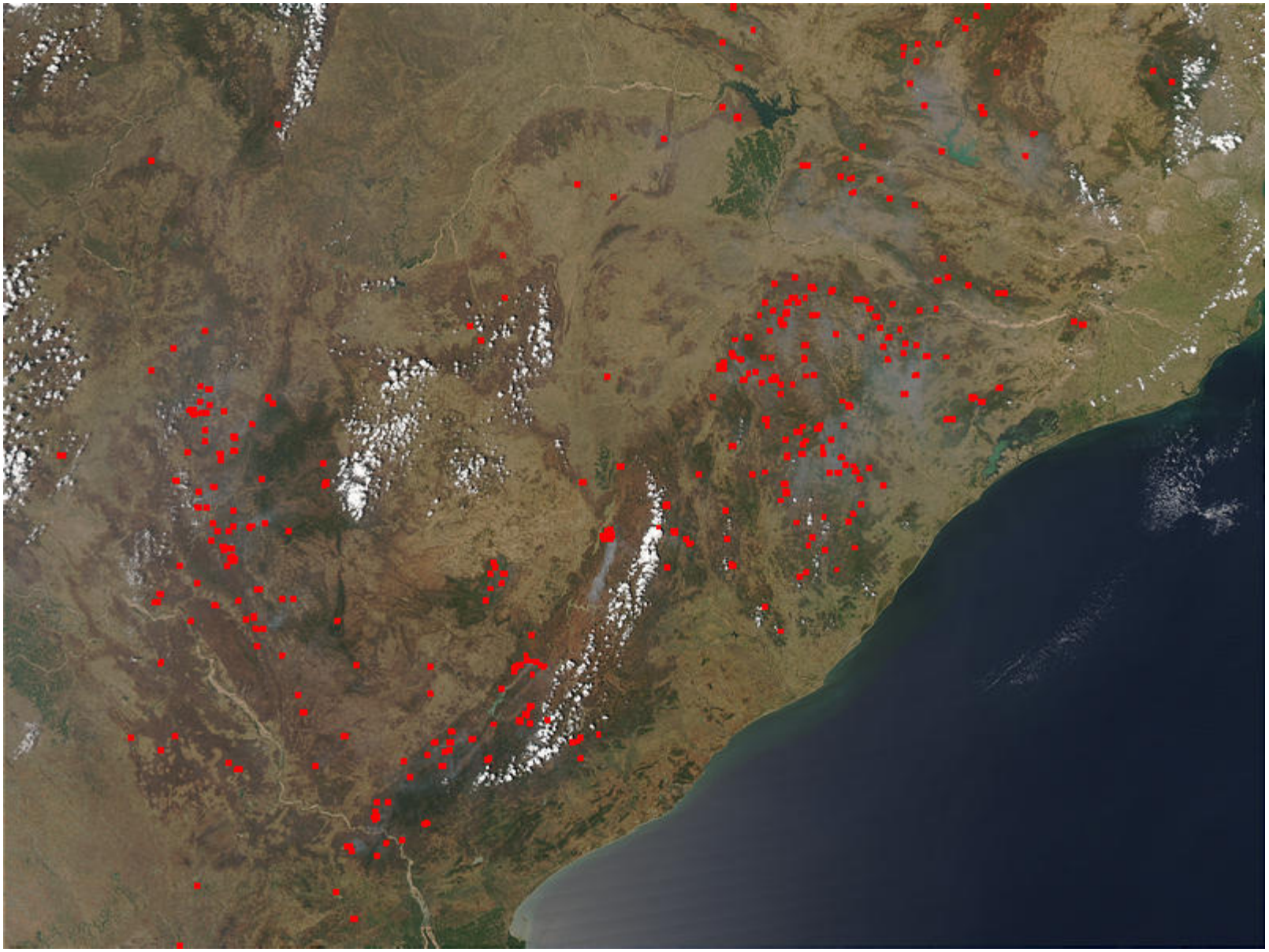
Dust Storms in India and Pakistan



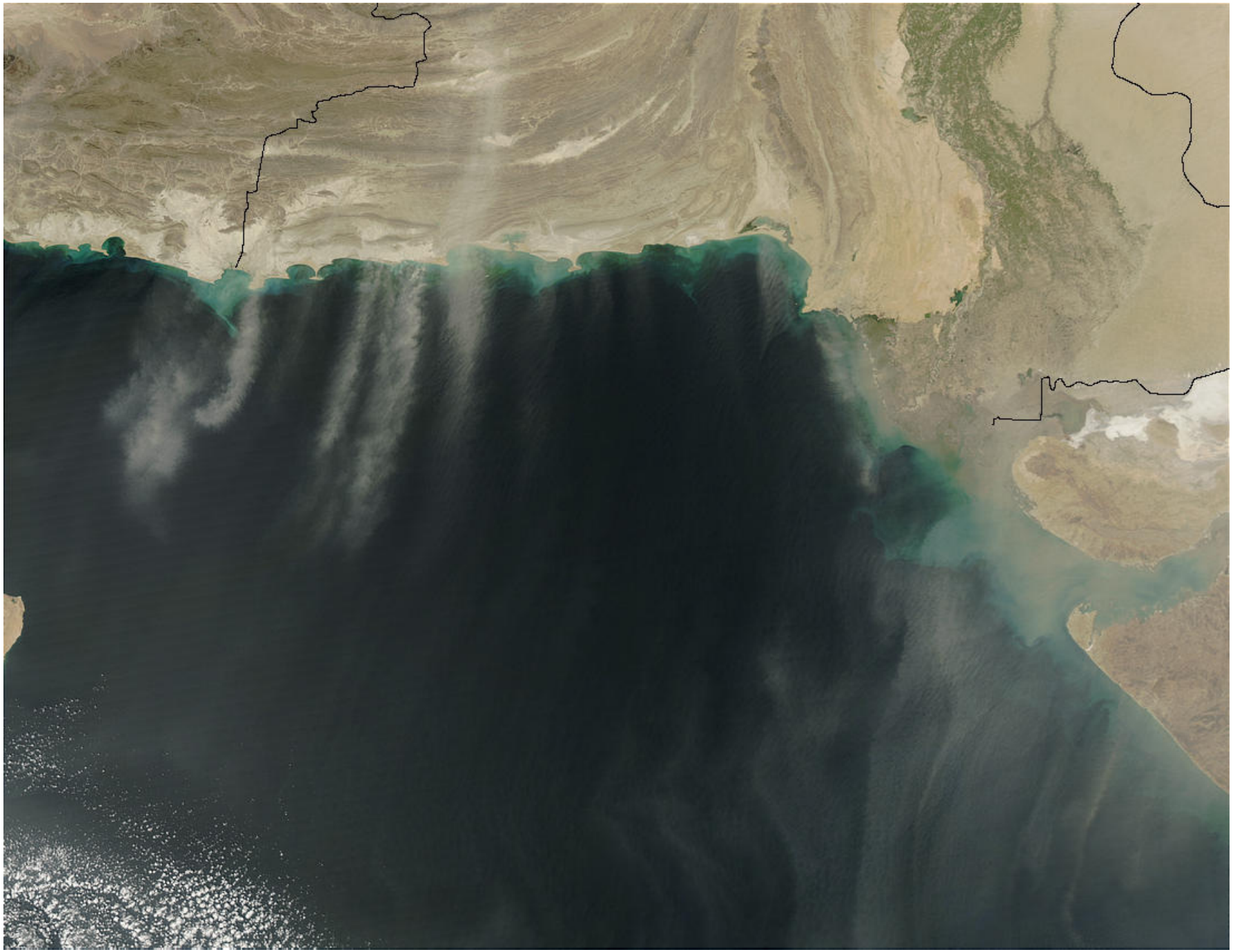
Fires in eastern India



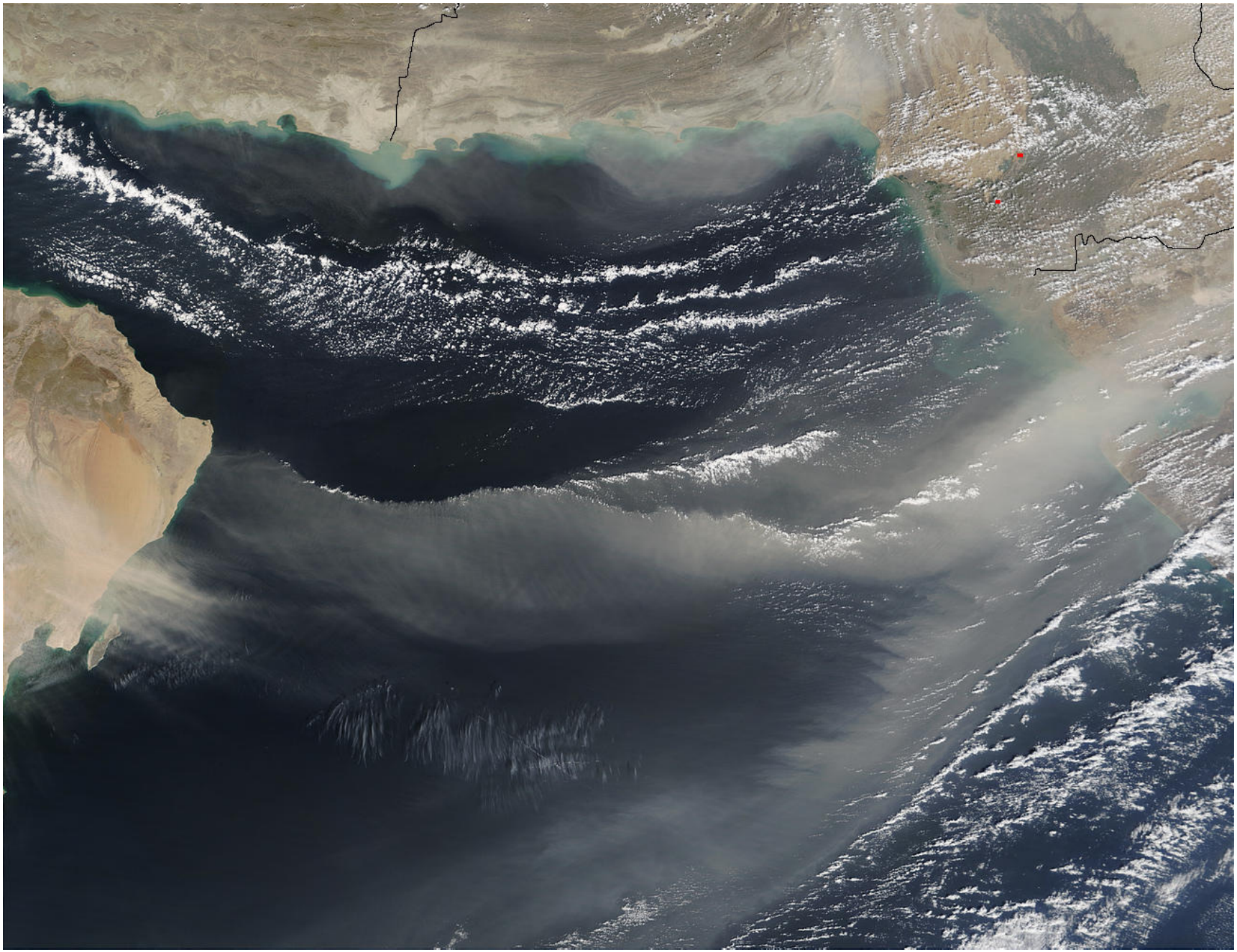
Fires in eastern India



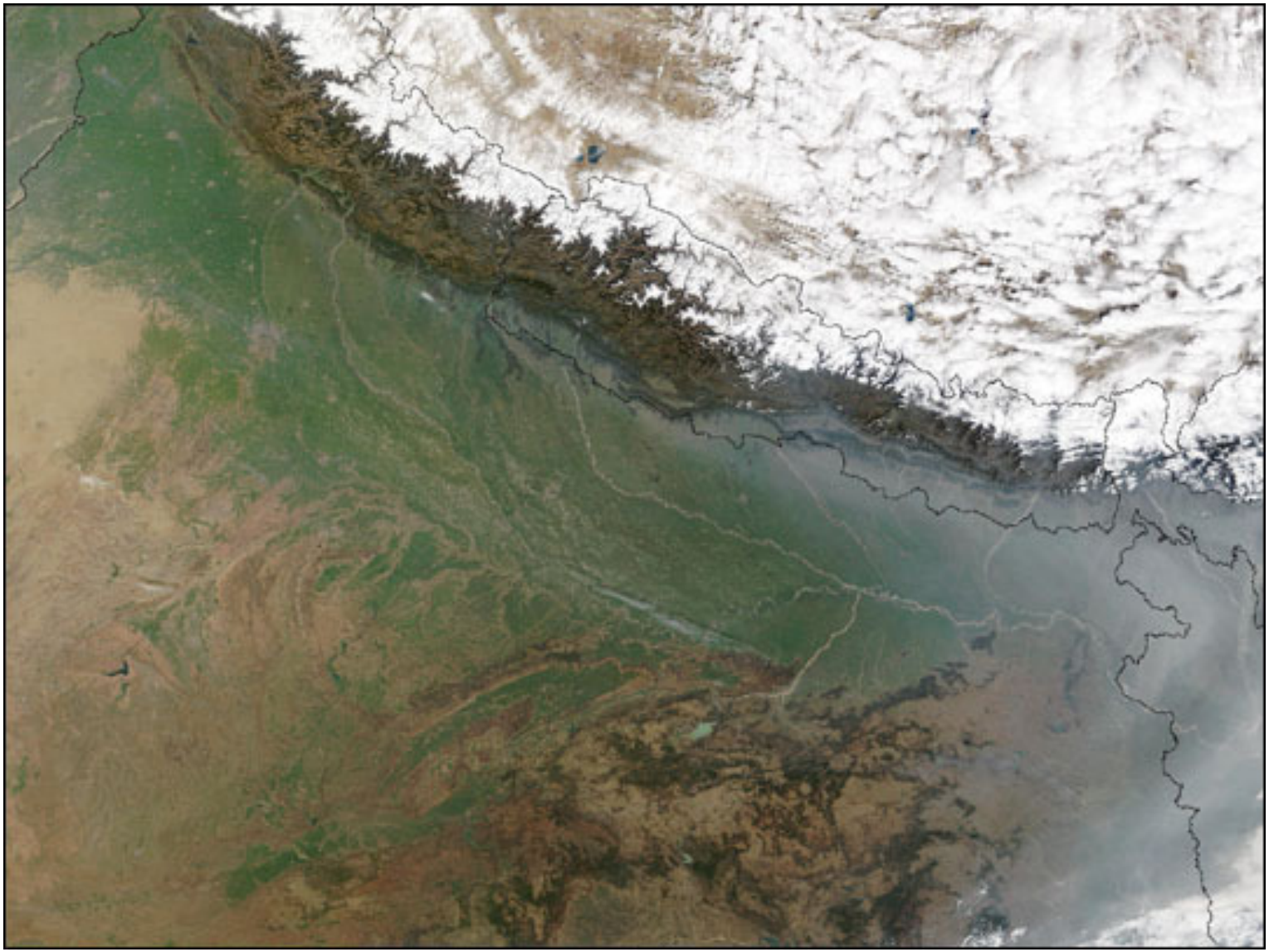
Dust over the Arabian Sea



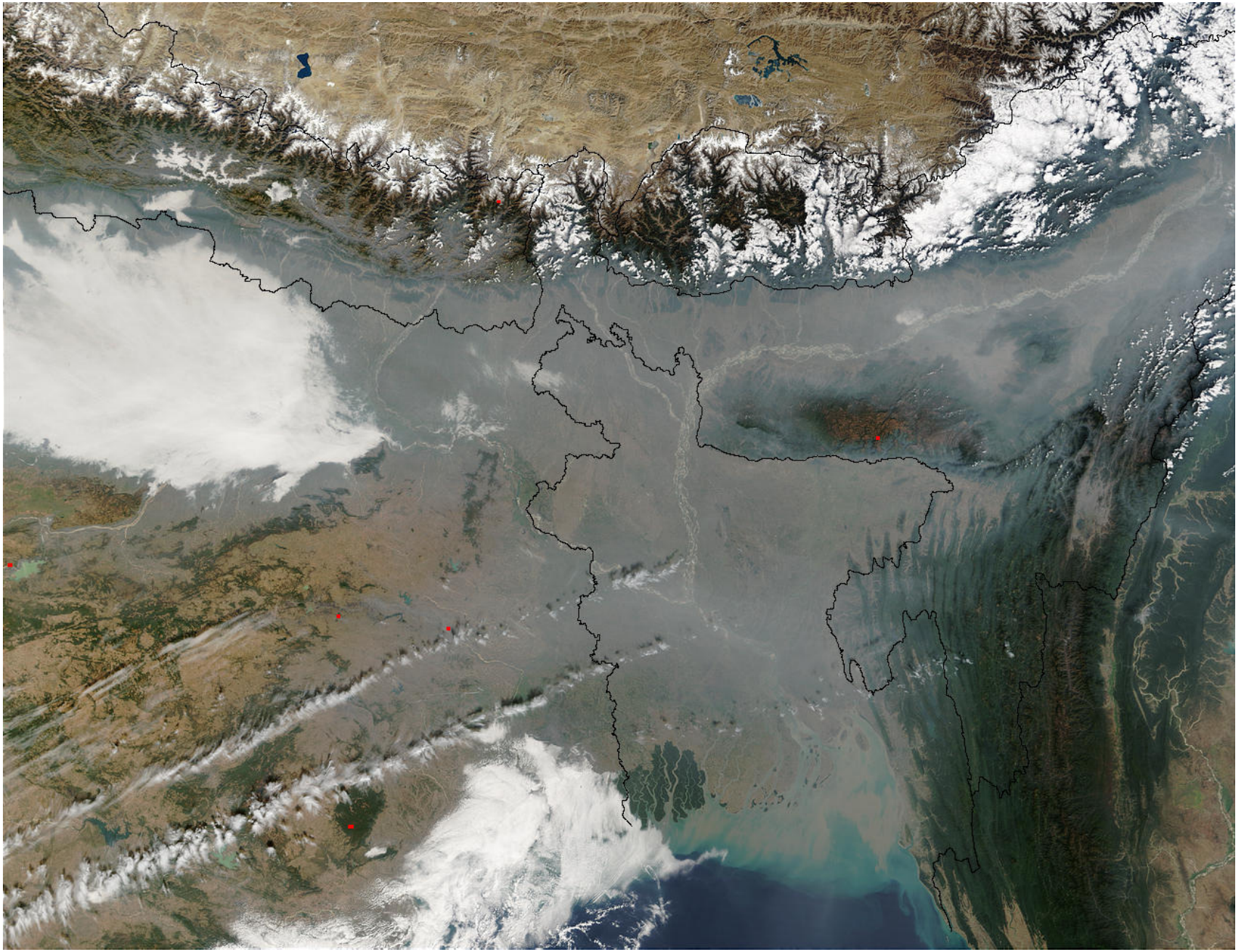
Dust over the Arabian Sea



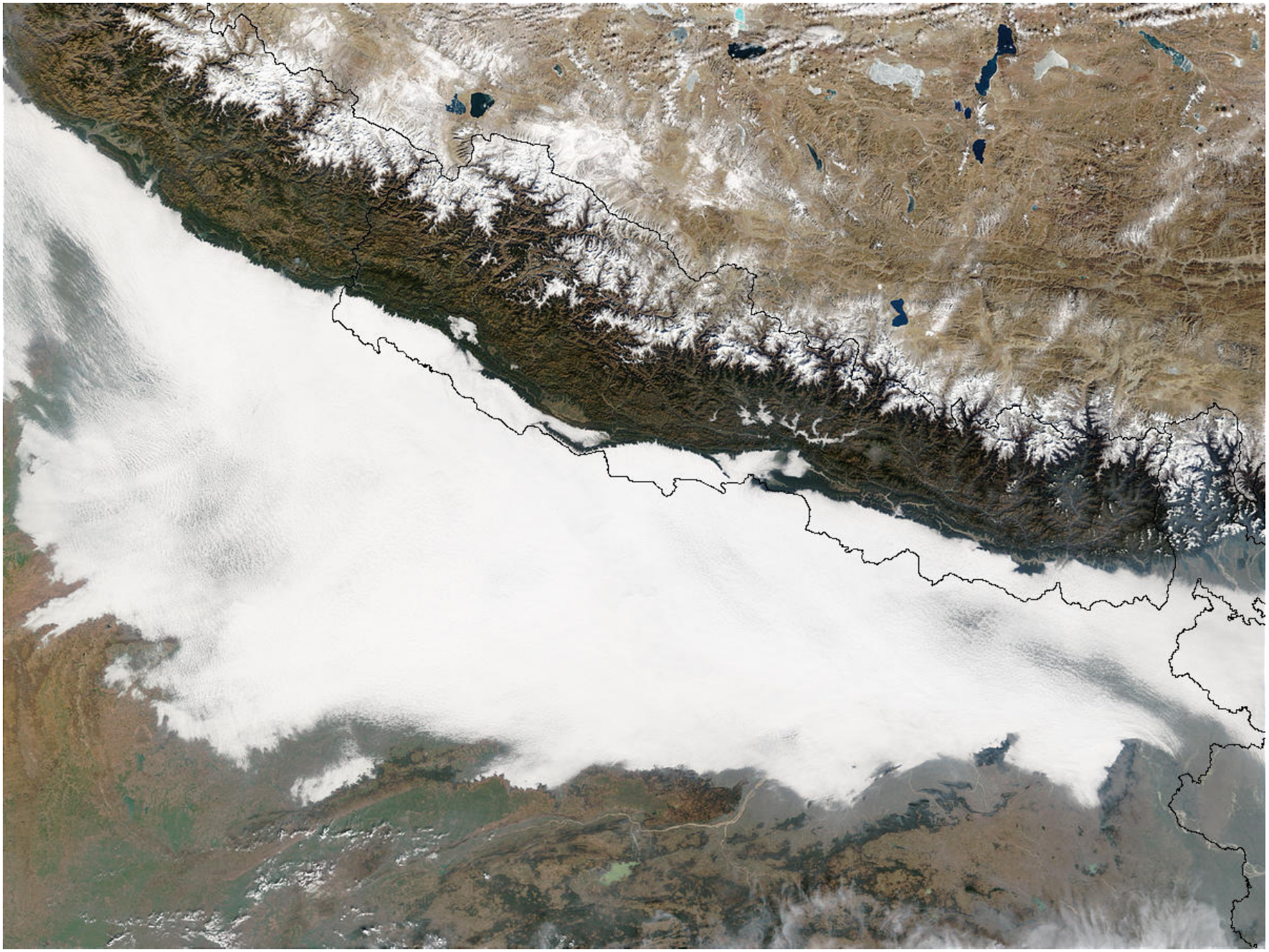
Pollution over Bangladesh and India



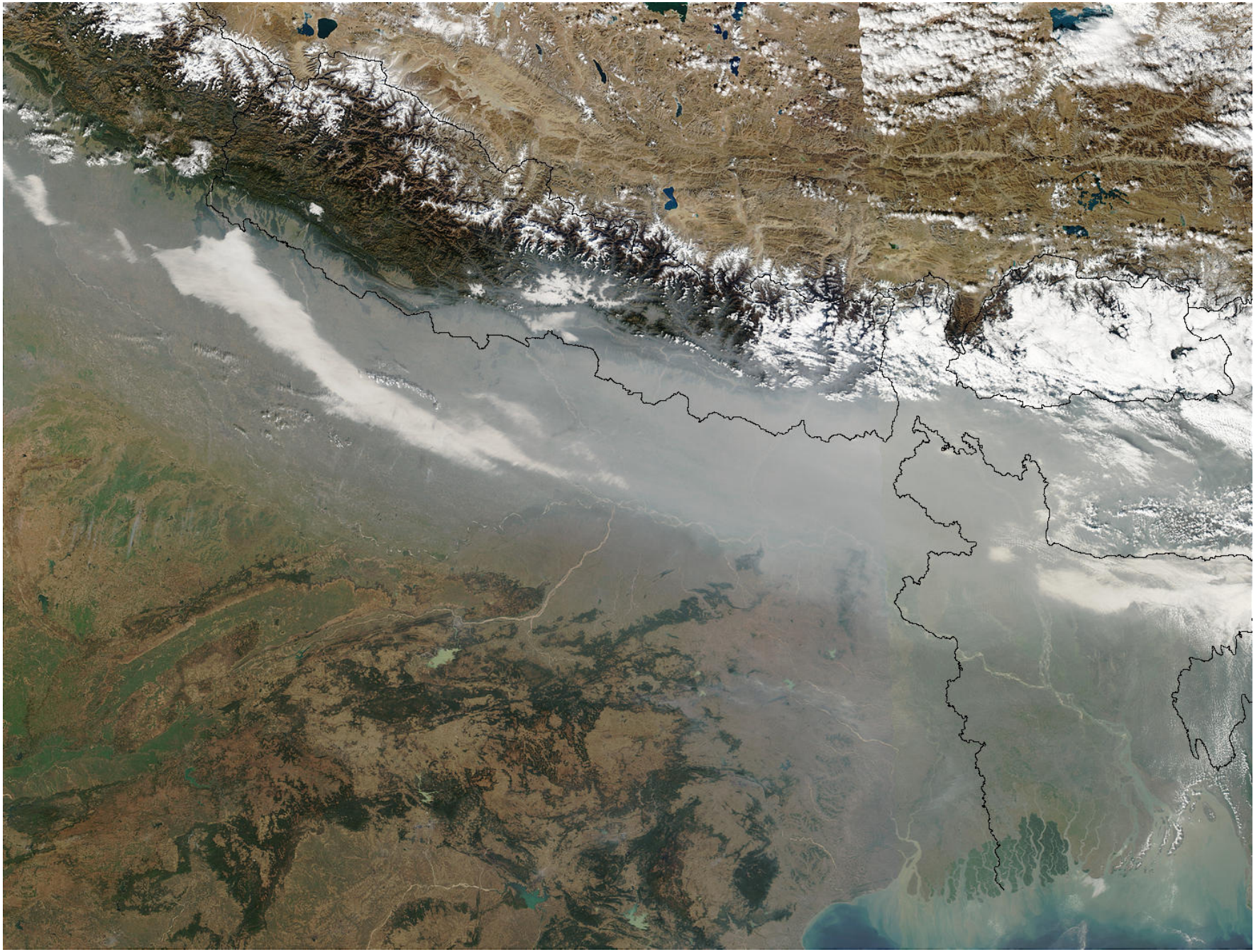
Pollution in Bangladesh and Northern India



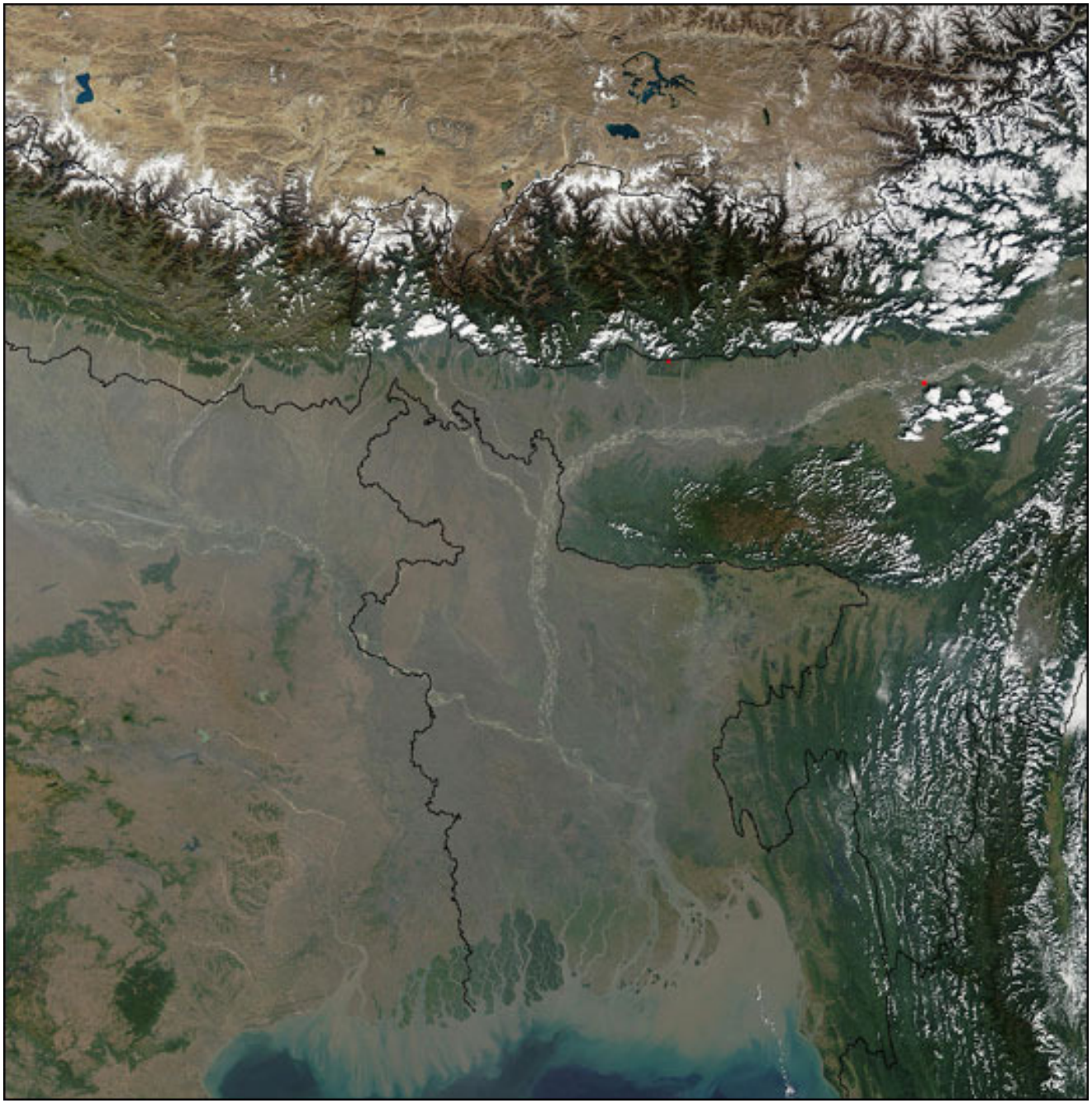
Smog in Northern India



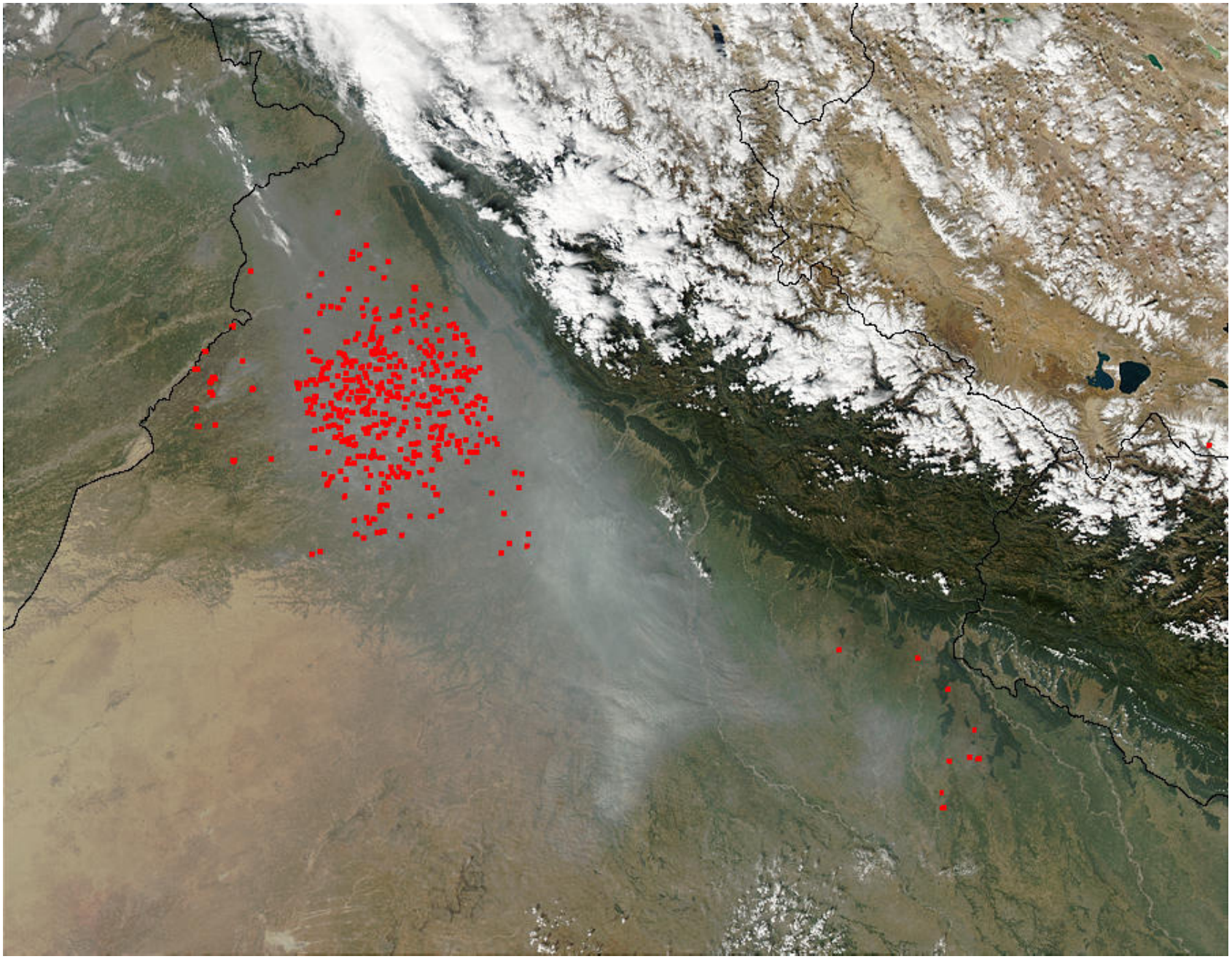
Pollution in Northern India and Bangladesh



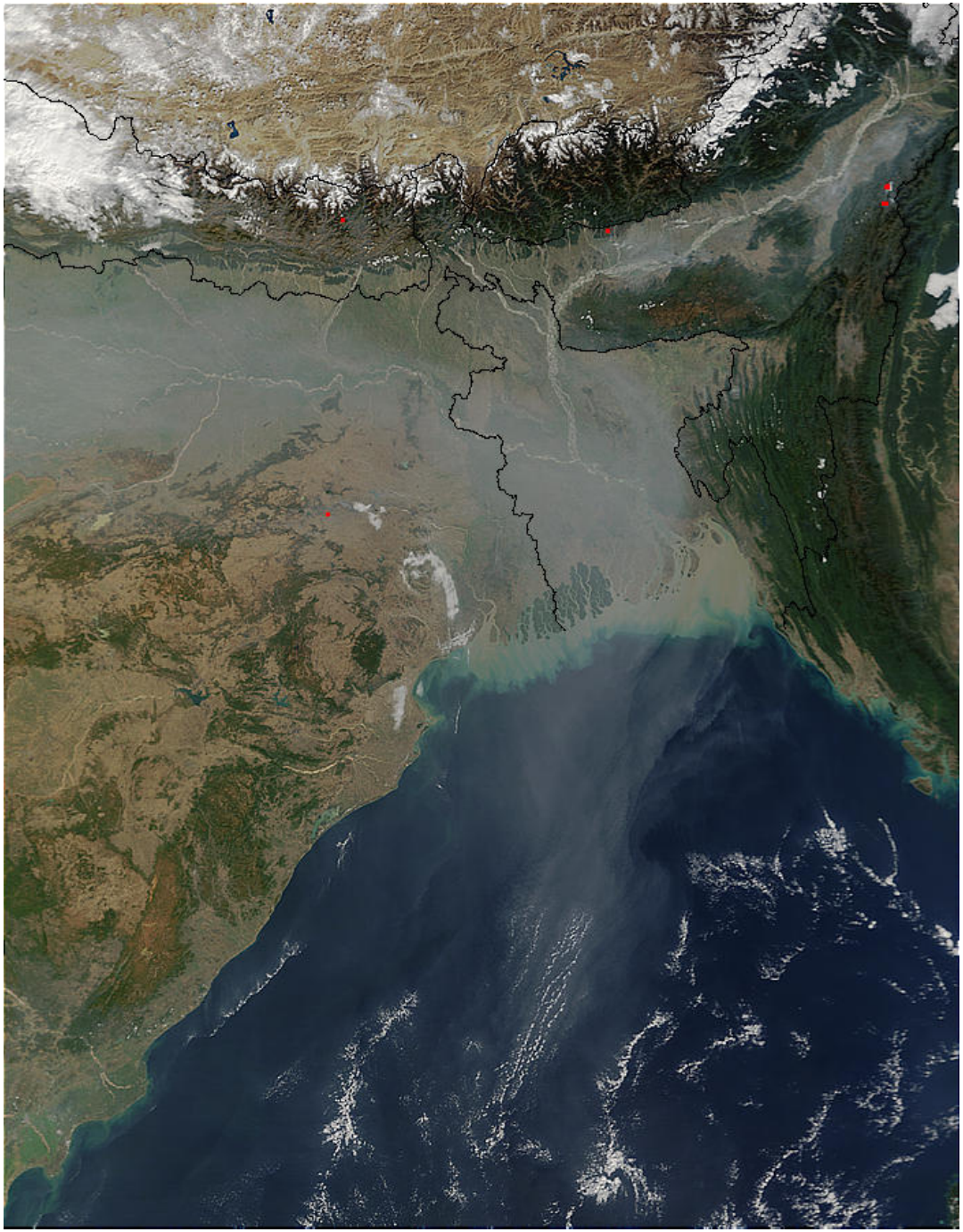
Pollution over Bangladesh and India



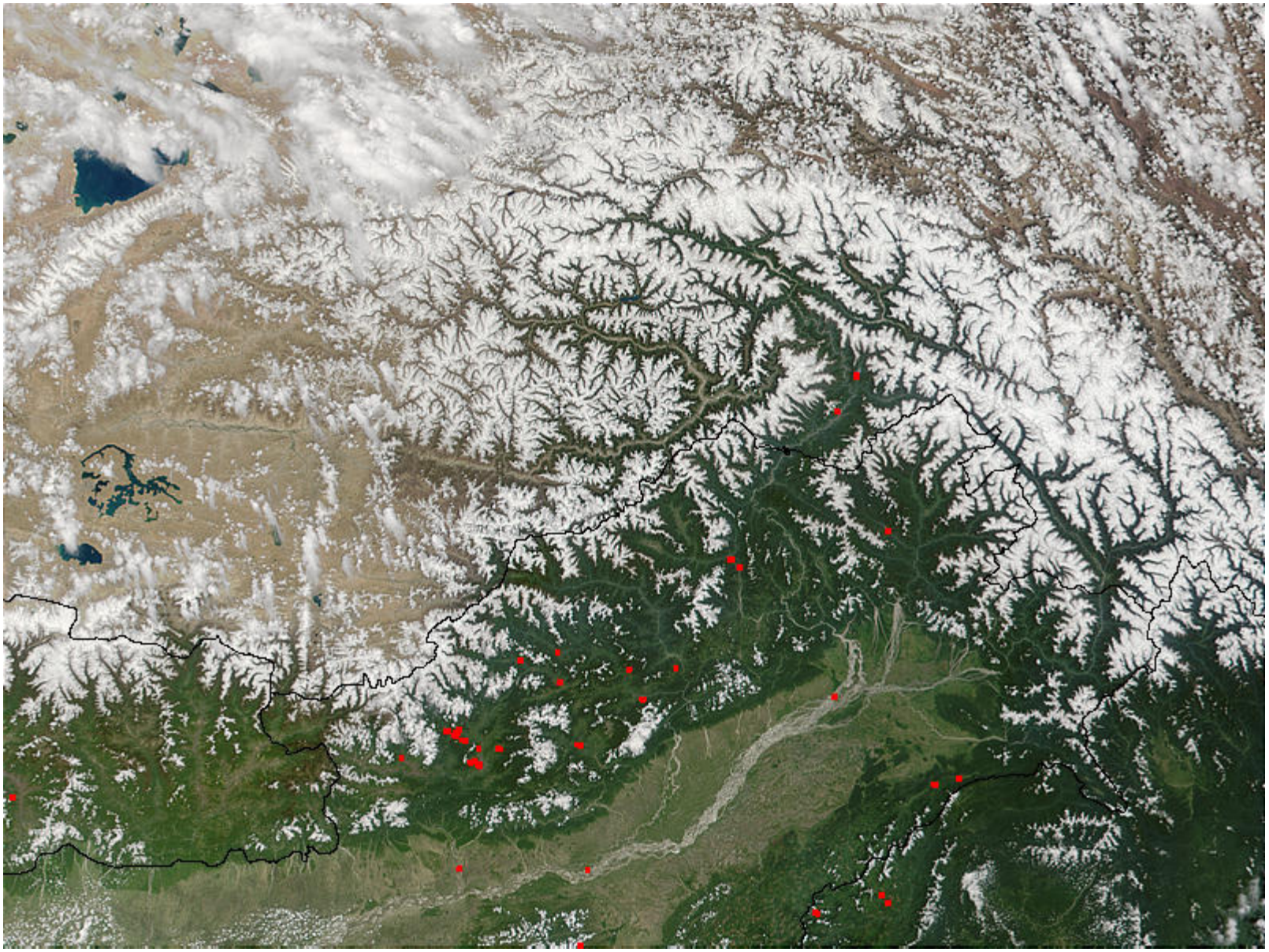
Fires and smoke in Northwest India



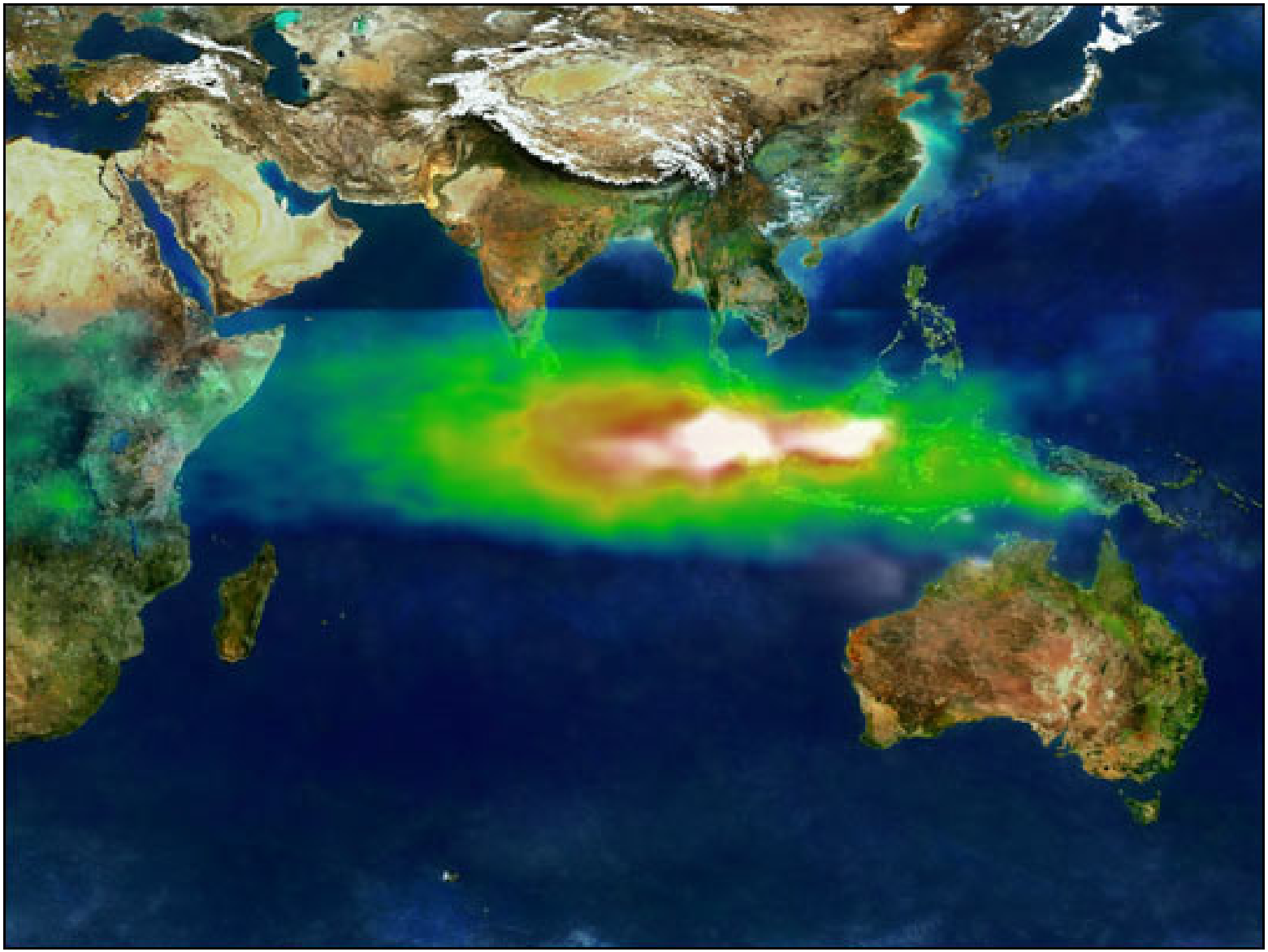
Aerosol pollution over Northern India, Bangladesh, and Bay of Bengal



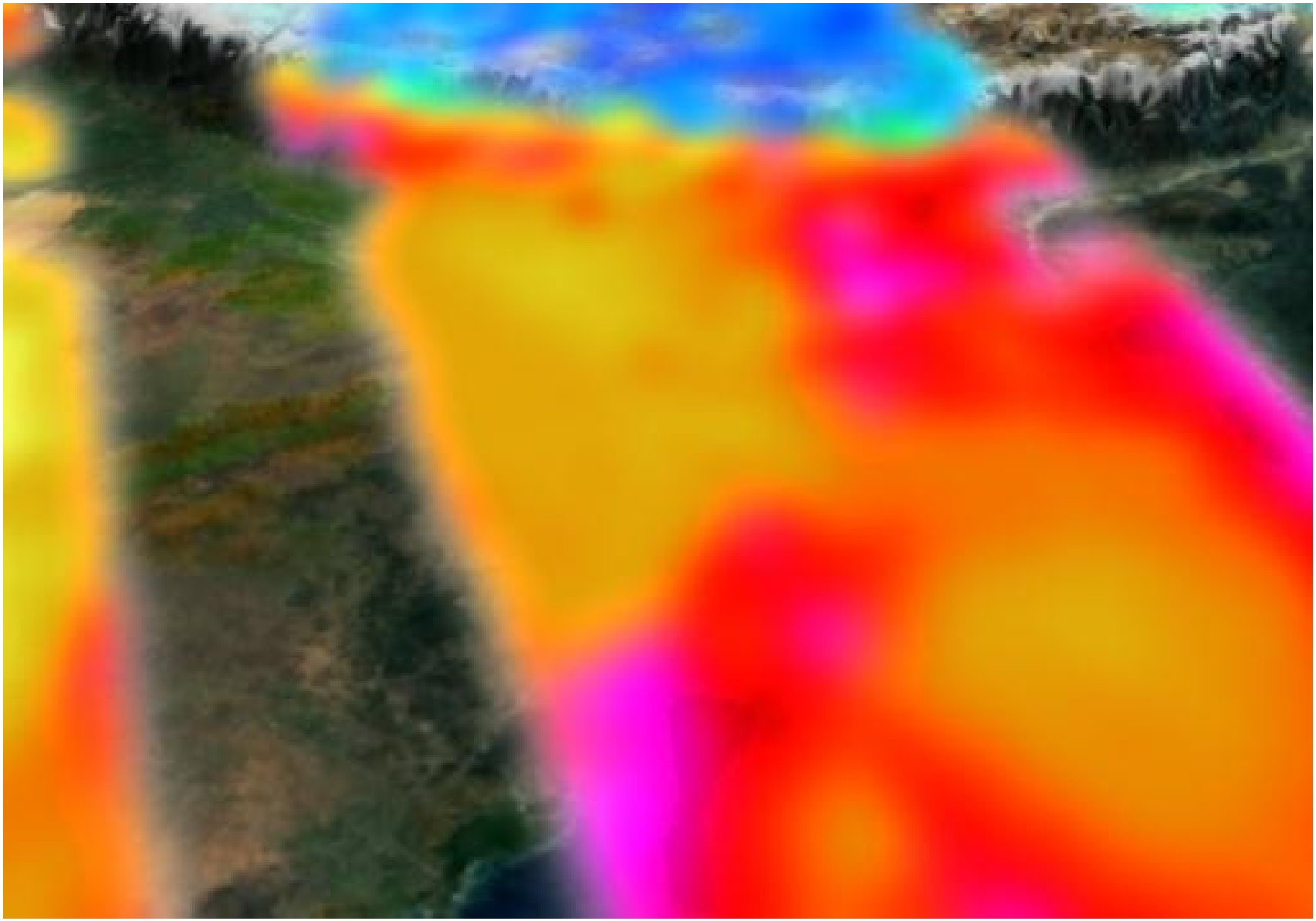
Fires in Northeast India (Assam region)



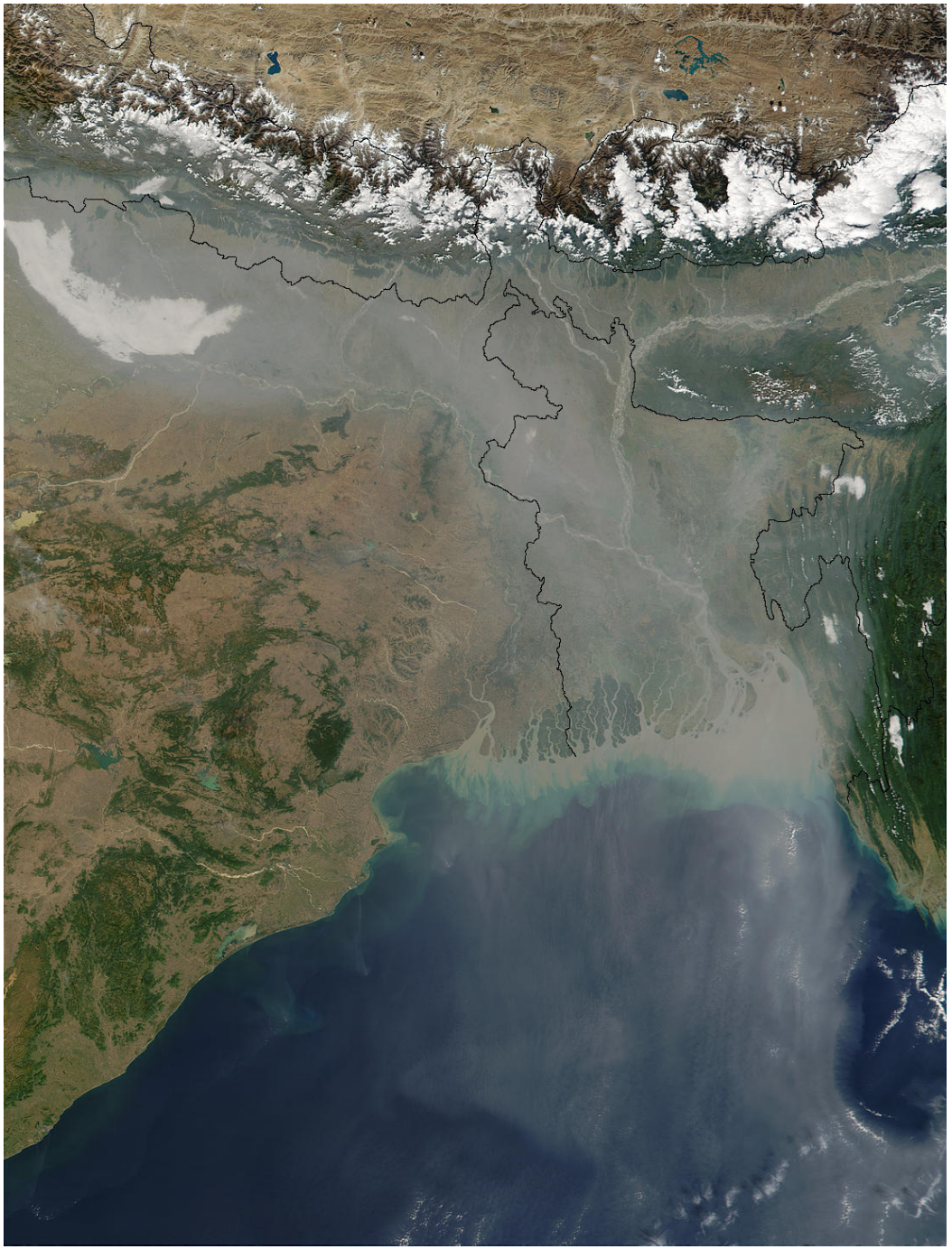
Satellite Tracks Hazardous Smoke and Smog



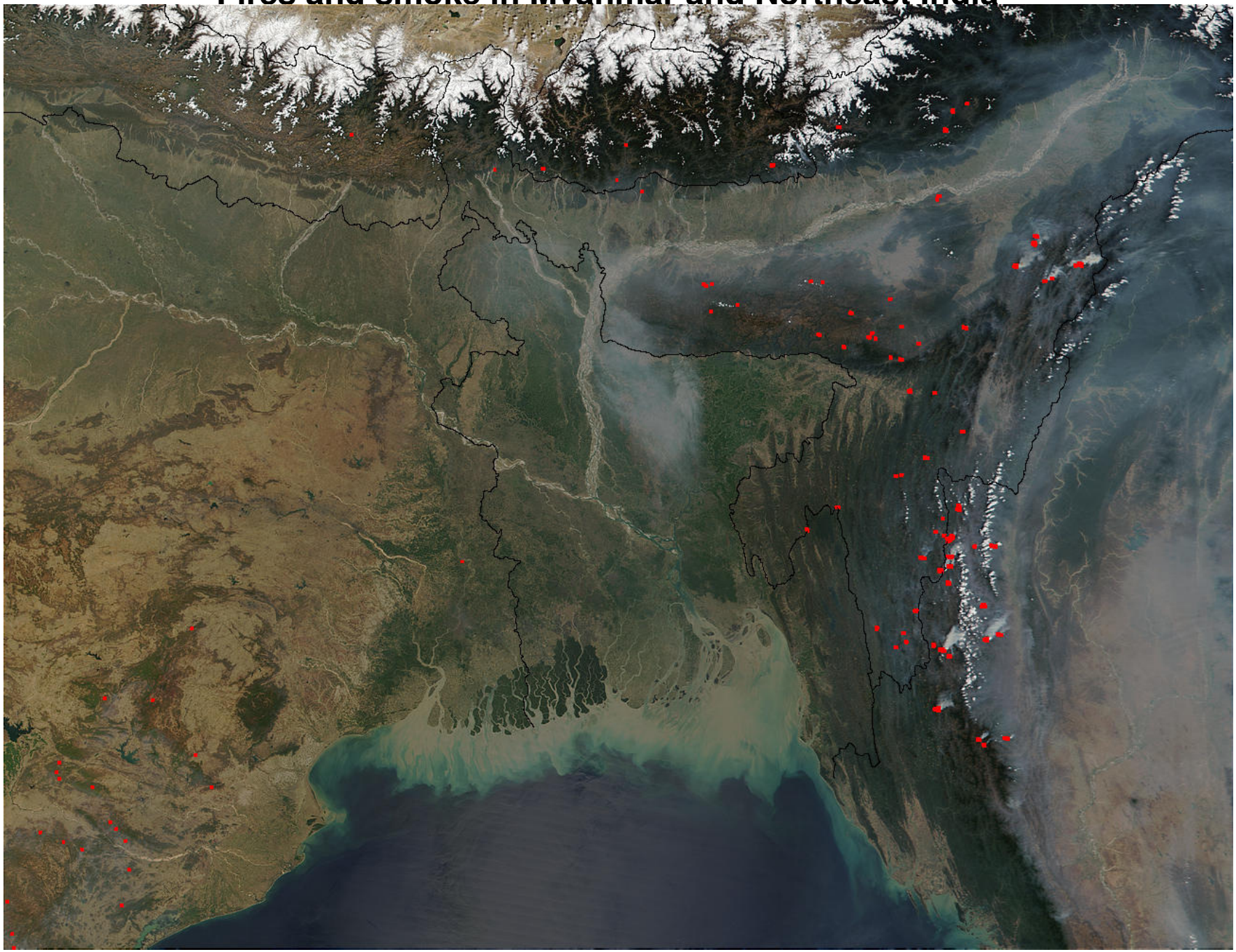
MOPITT Carbon Monoxide Over India



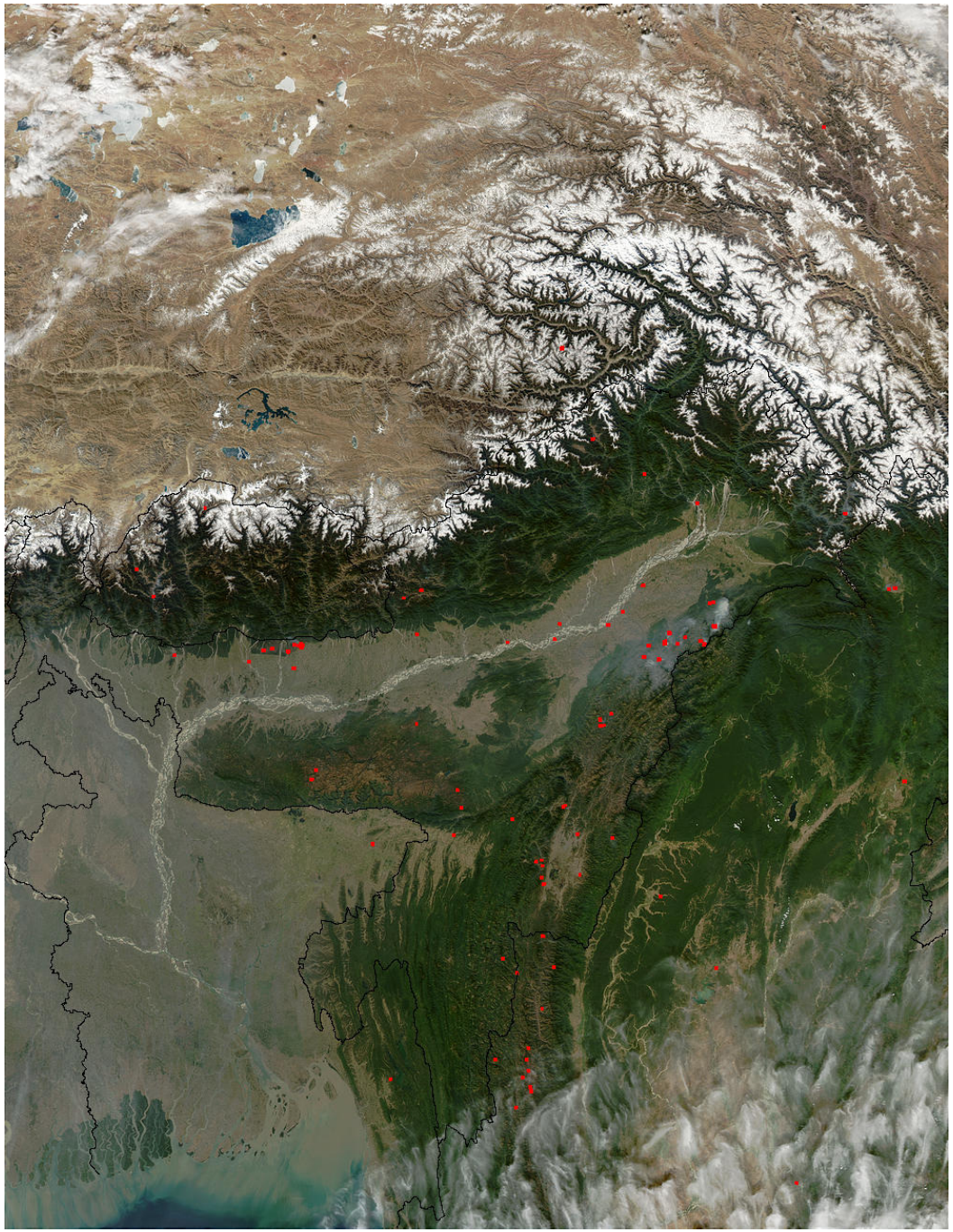
Aerosol pollution over Northern India and Bangladesh



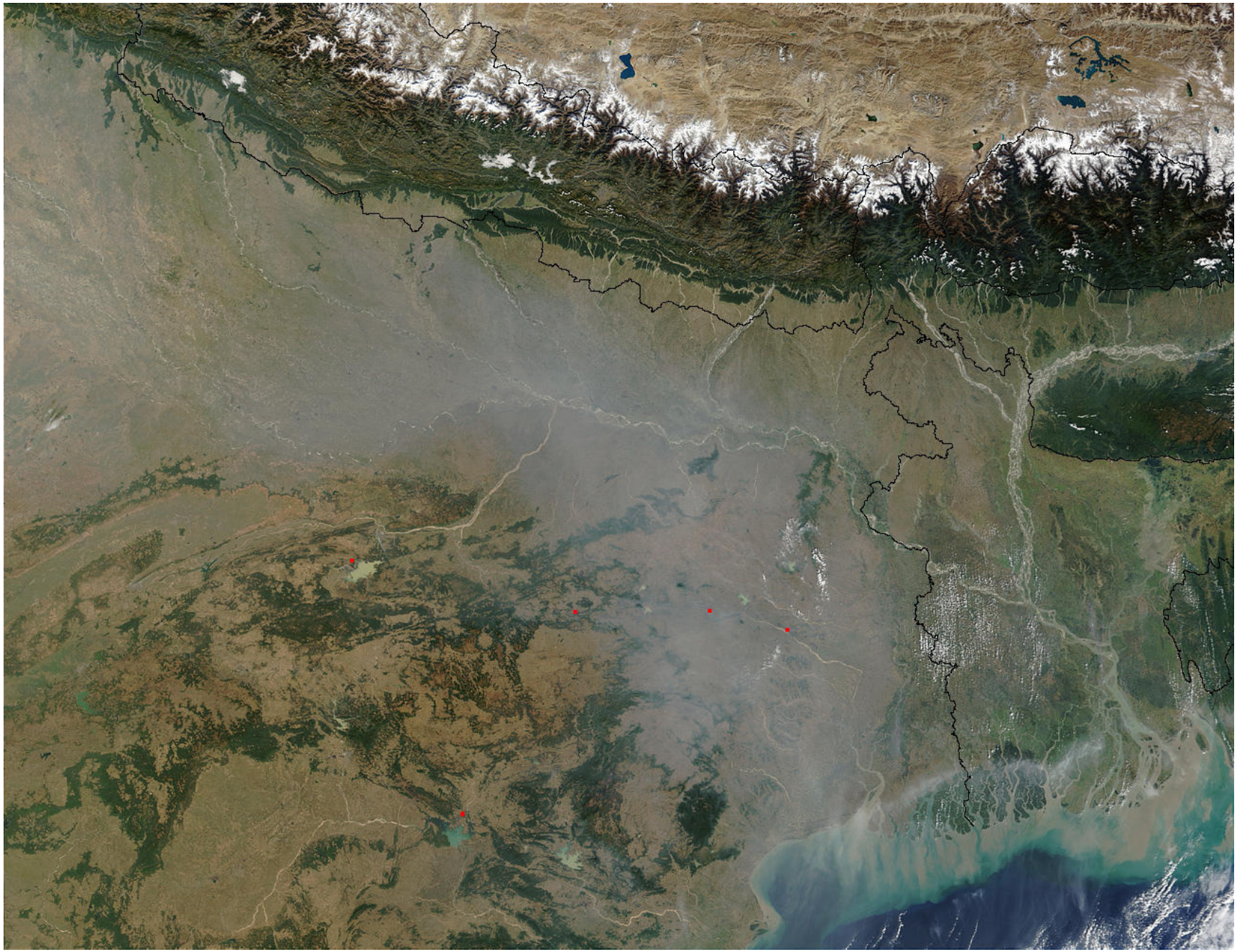
Fires and smoke in Myanmar and Northeast India



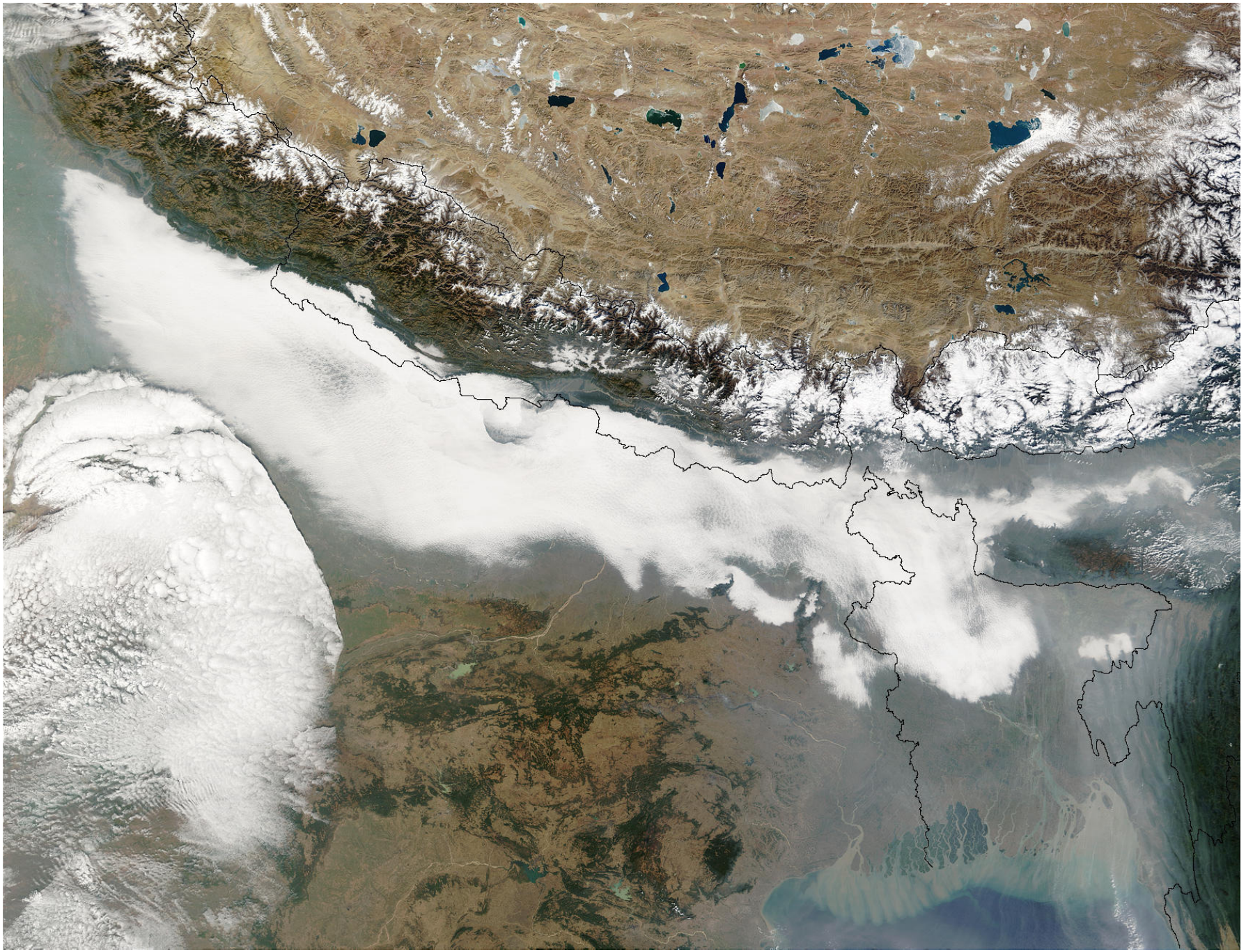
Fires in eastern India



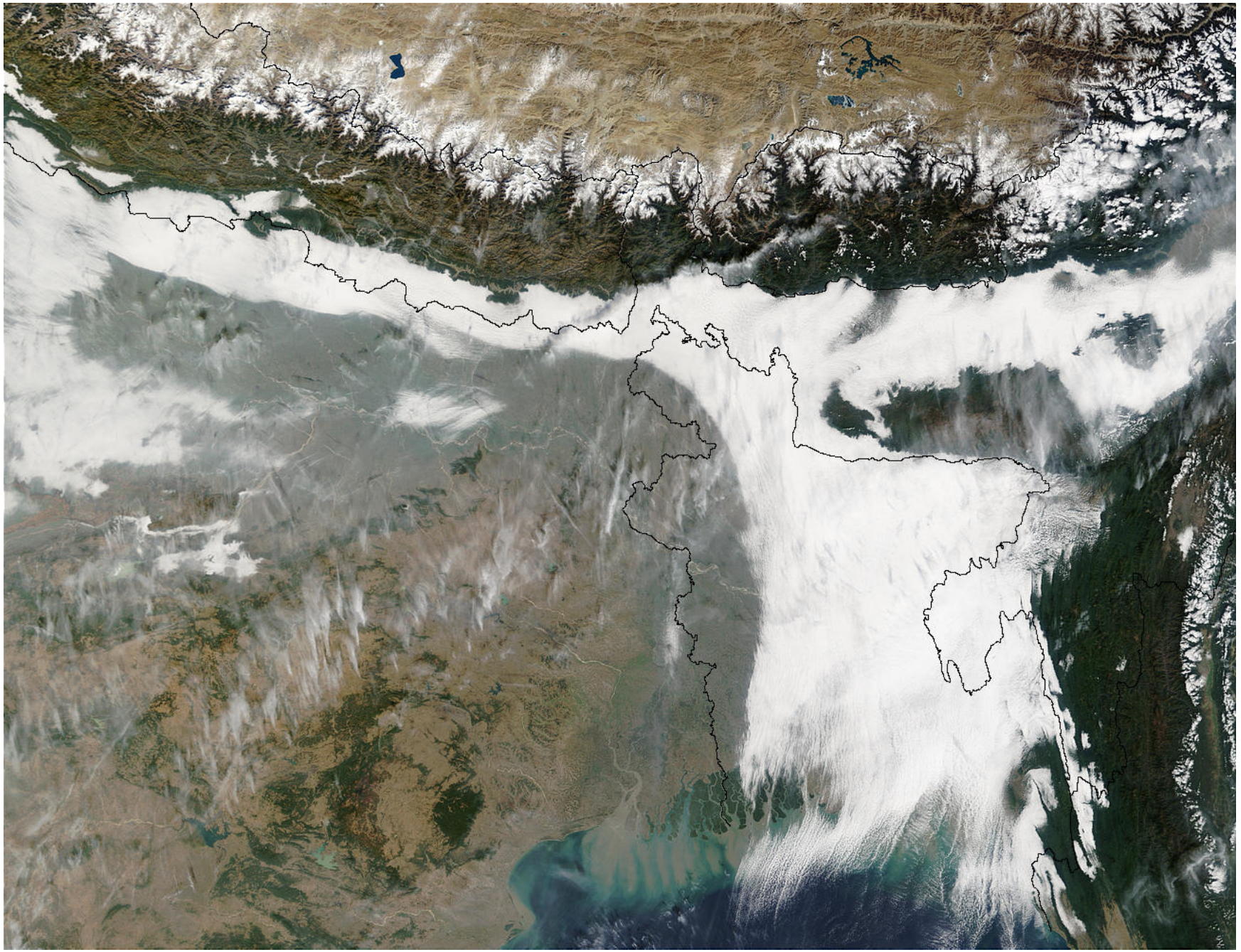
Pollution in Northeast India



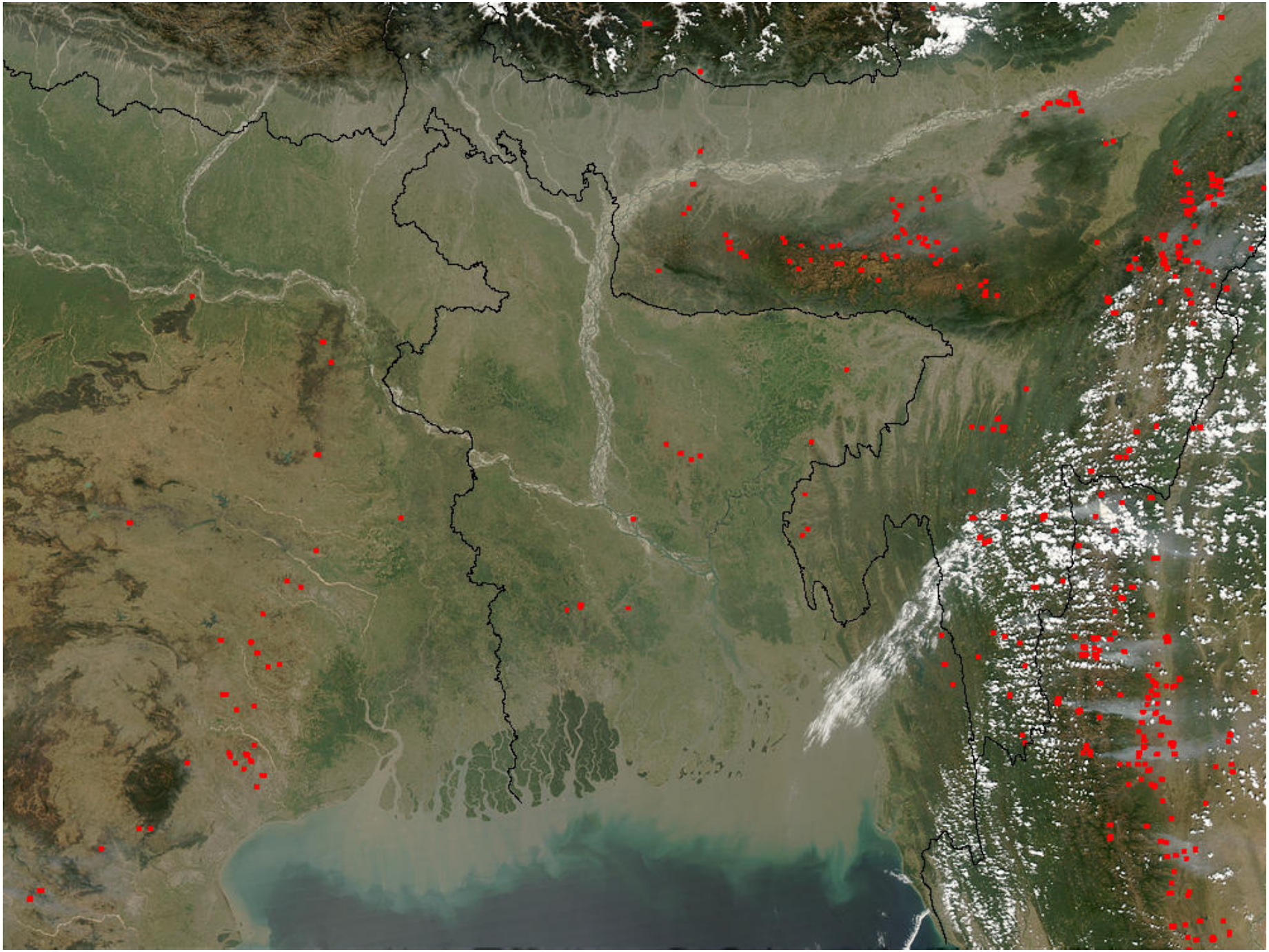
Haze and smog in Northern India and Bangladesh



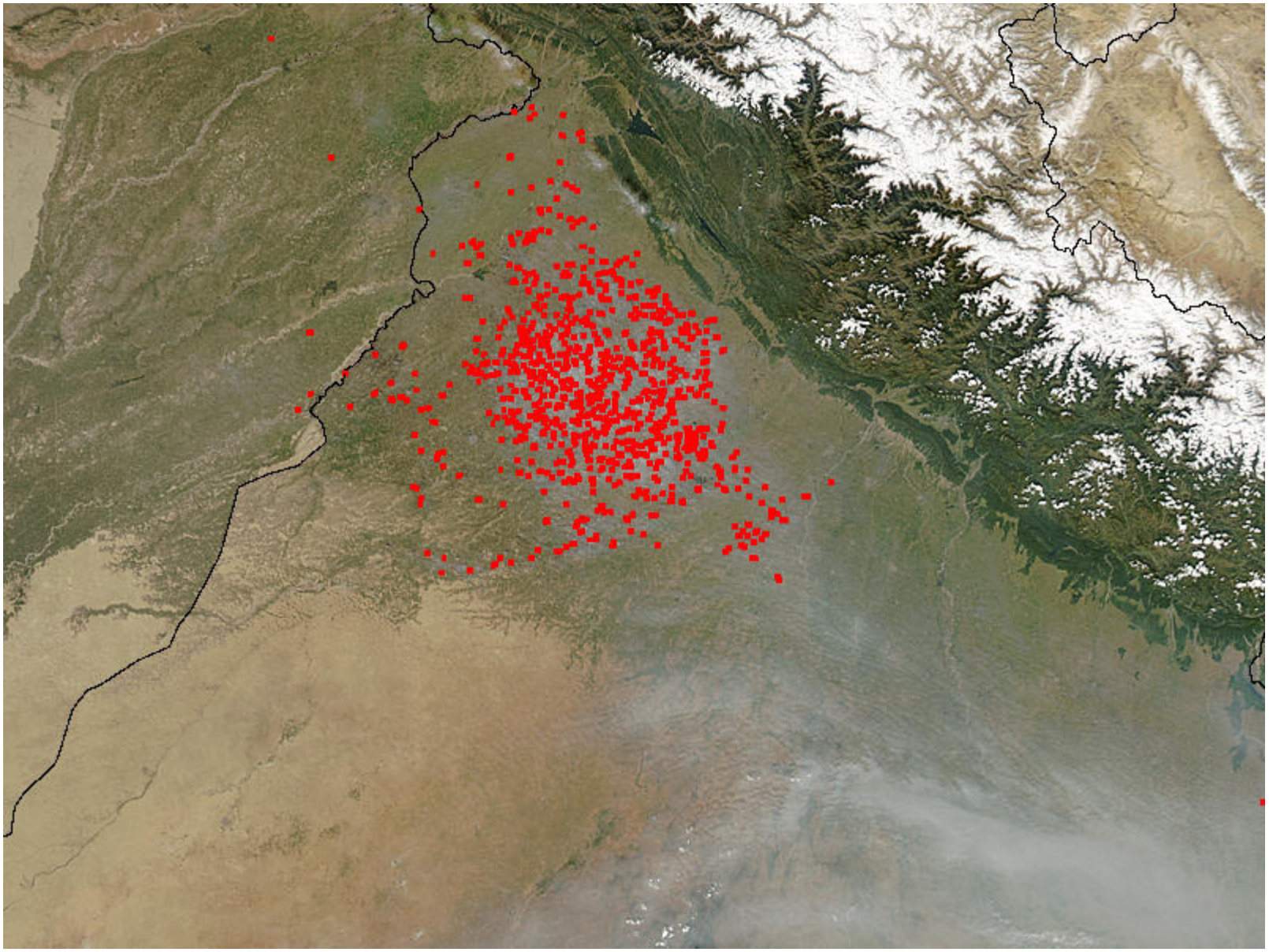
Haze and smog in Northeast India and Bangladesh



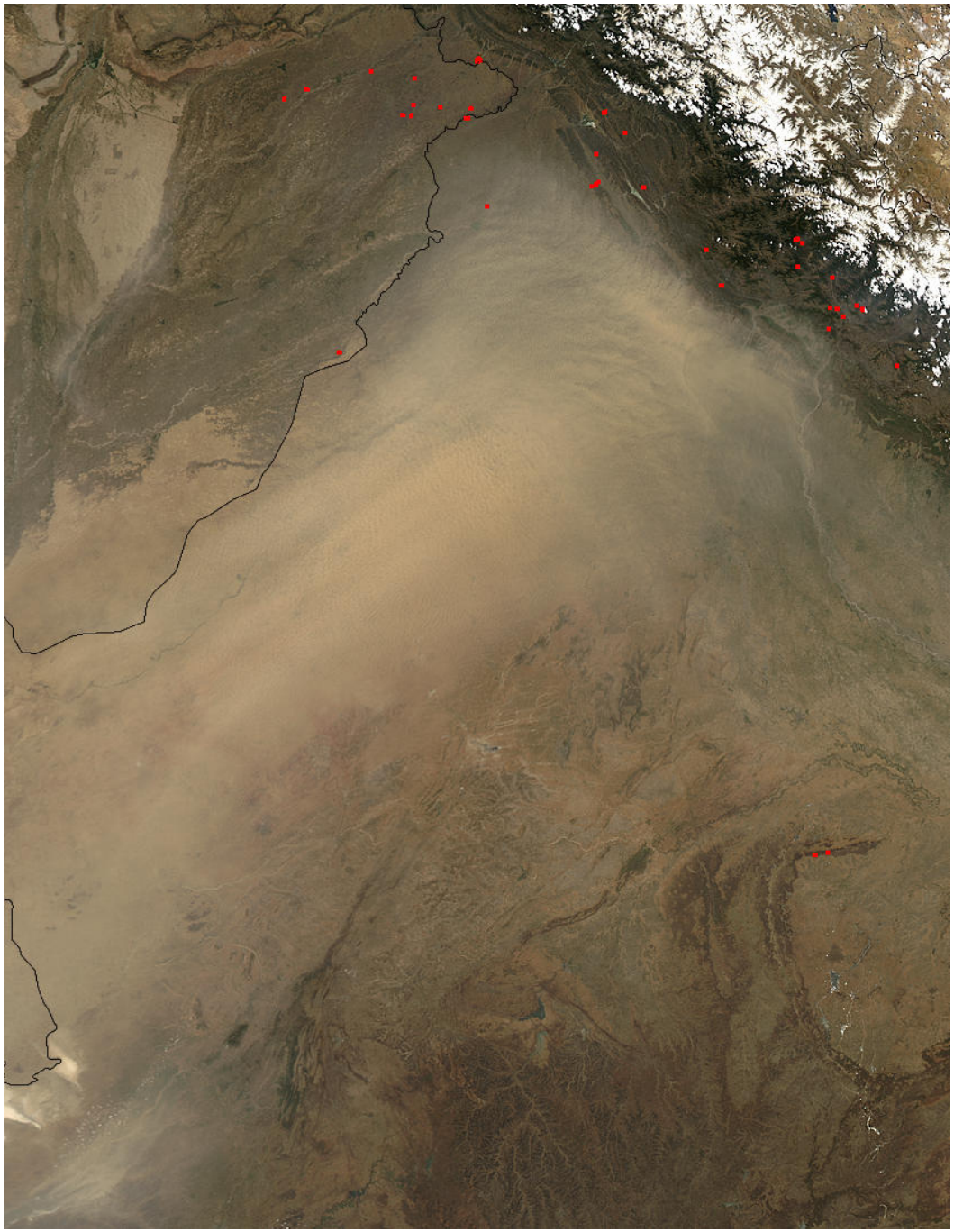
Bangladesh and Northeast India



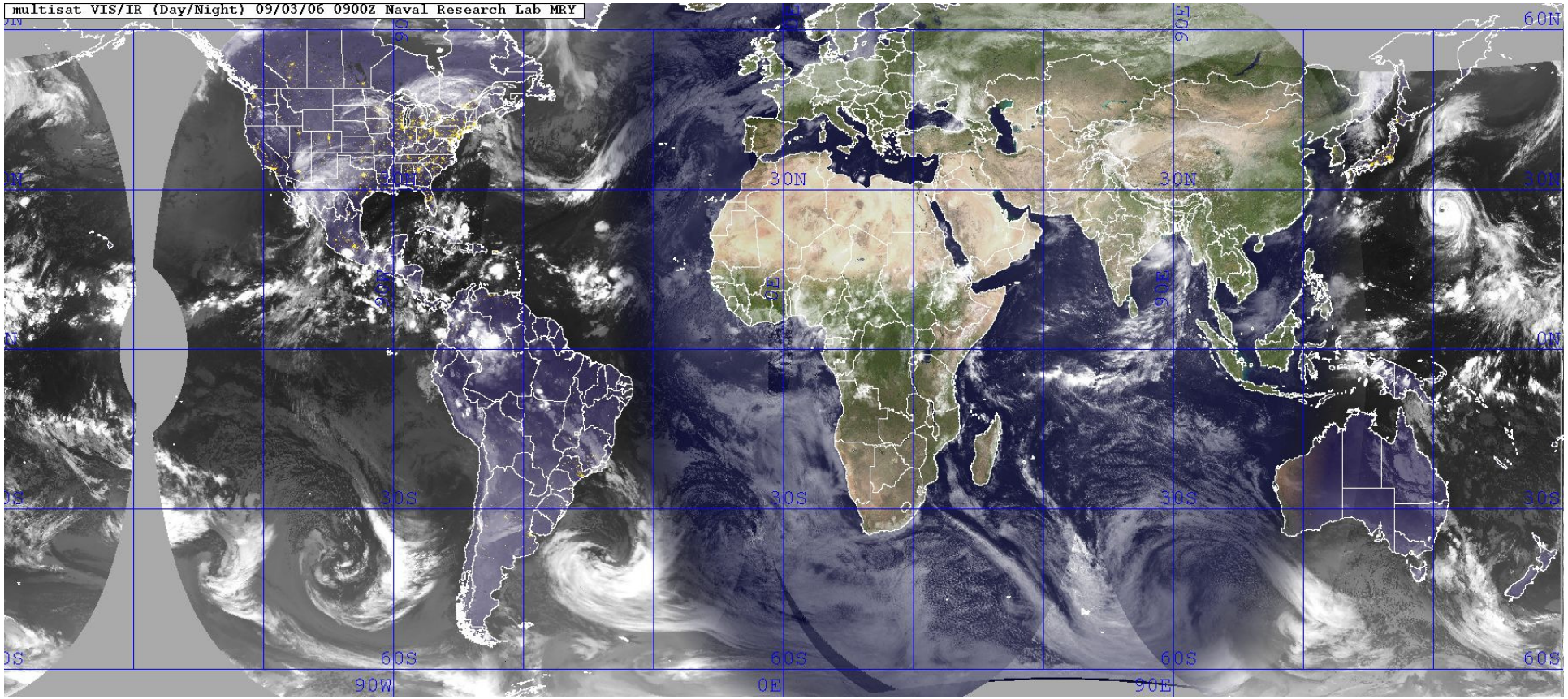
Intense agricultural fires and smoke in Northwest India

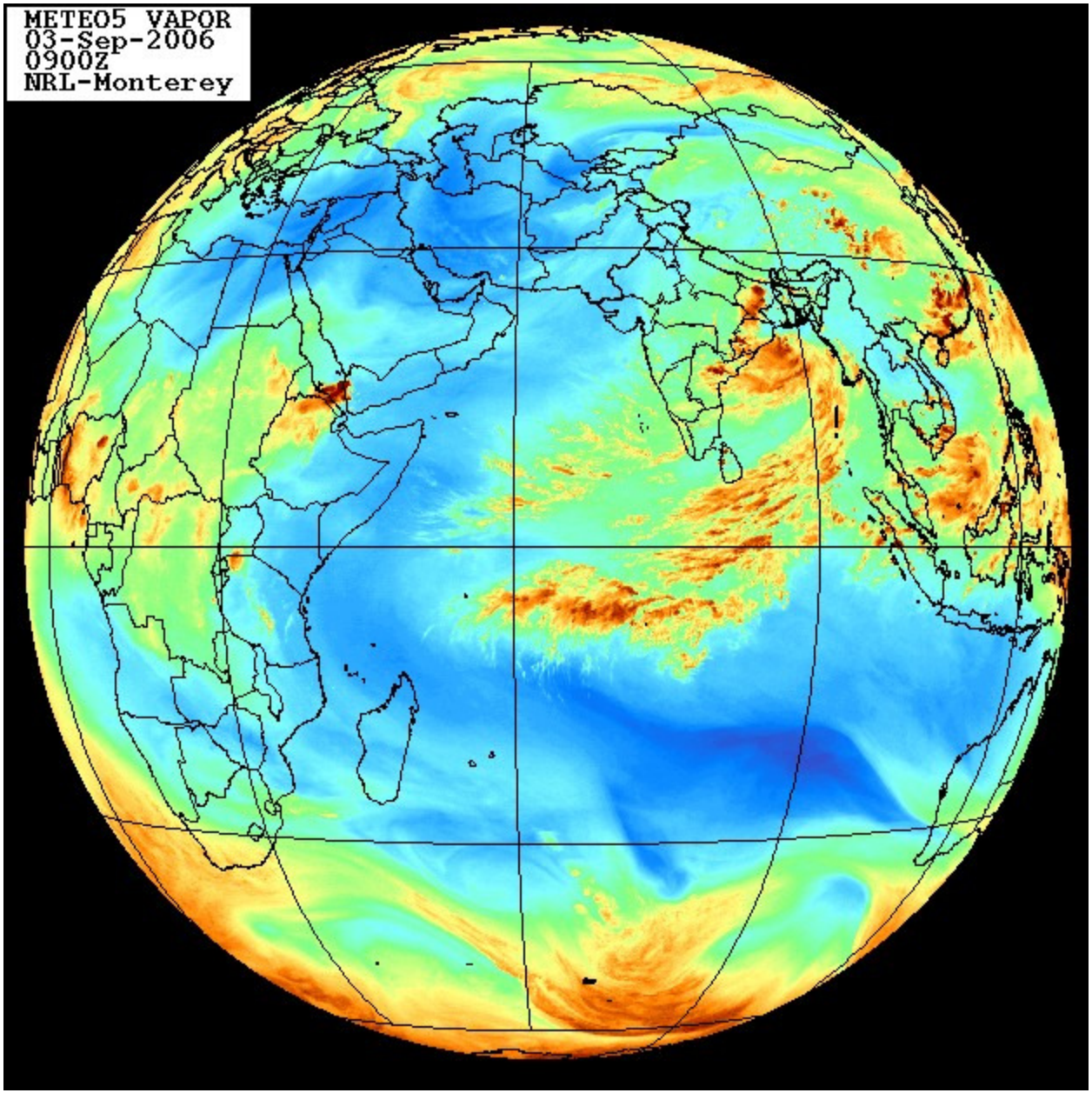


Dust storm in the Great Indian Desert



Stitched Global IR (Vis,Vapor, and GEO_Color)




METEO5 VAPOR
03-Sep-2006
0900Z
NRL-Monterey

October 1984 Global Carbon Monoxide Values

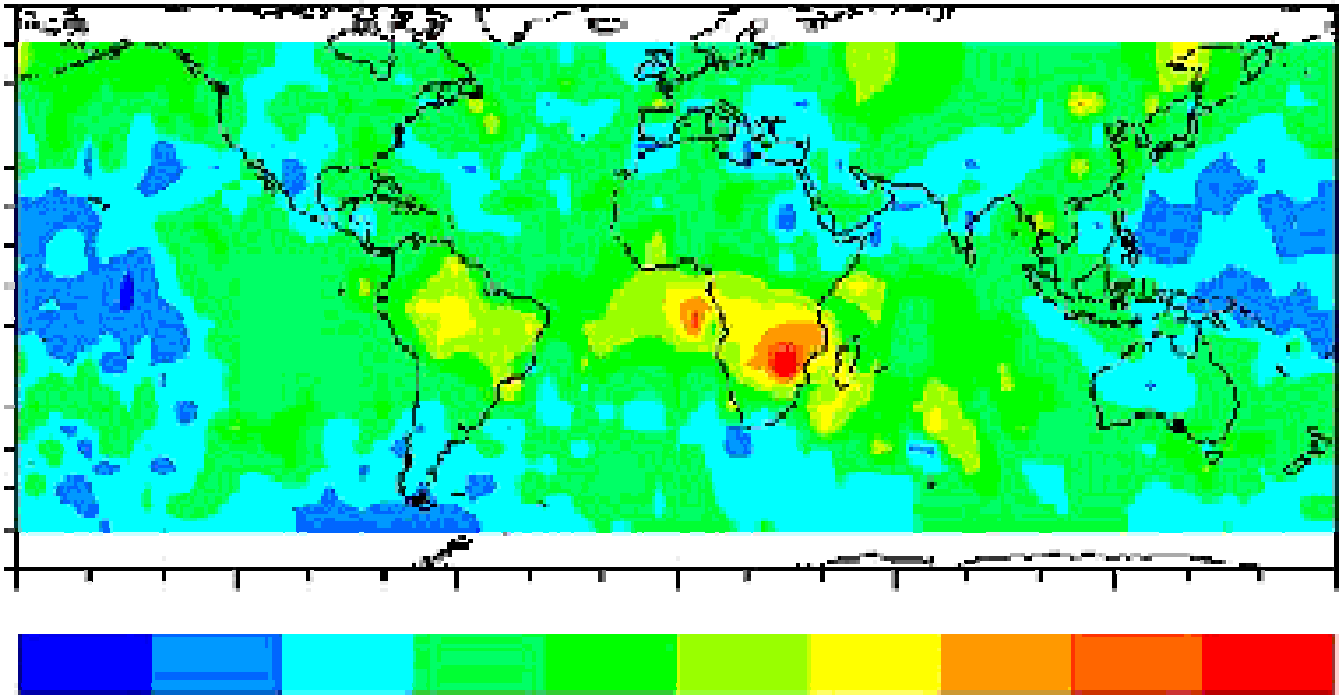


Figure 1

Large concentrations of atmospheric carbon monoxide, caused by biomass burning in South America and southern Africa, can be seen in measurements made by the Measurement of Air Pollution from Satellites (MAPS) instrument. These October 1984 measurements, made from the Space Shuttle Challenger (STS-41G), were the first to show that biomass burning is a very large source of air pollution in the lower atmosphere (3 to 10 kilometers above the surface of the Earth) of the Southern Hemisphere. Carbon monoxide, a colorless and odorless gas, is created by the burning of fossil fuels such gasoline and by the burning of forests and grasslands.

April 1994 Global Carbon Monoxide Values

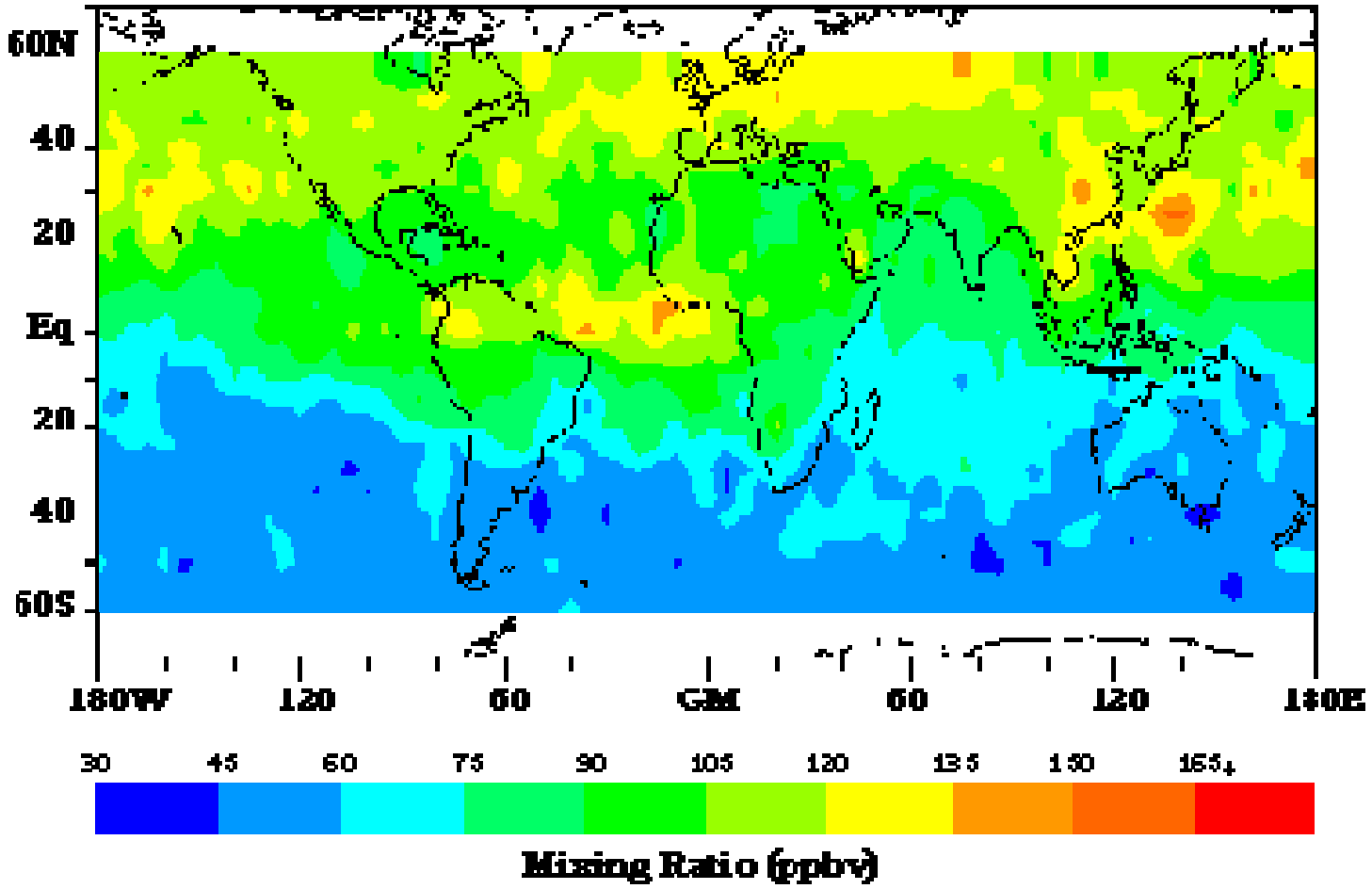


Figure 2

Relatively high concentrations of carbon monoxide over the Northern Hemisphere can be seen in measurements made by the Measurement of Air Pollution from Satellites (MAPS) instrument. These April 1994 measurements, made from the Space Shuttle Endeavour (STS-59), show large sources of air pollution in the lower atmosphere (3 to 10 kilometers above the surface of the Earth) over the industrialized Northern Hemisphere. Carbon monoxide, a colorless and odorless gas, is created by the burning of fossil fuels such as gasoline and by the burning of forests and grasslands. These measurements were made from April 9-19, 1994.

October 1994 Global Carbon Monoxide Values

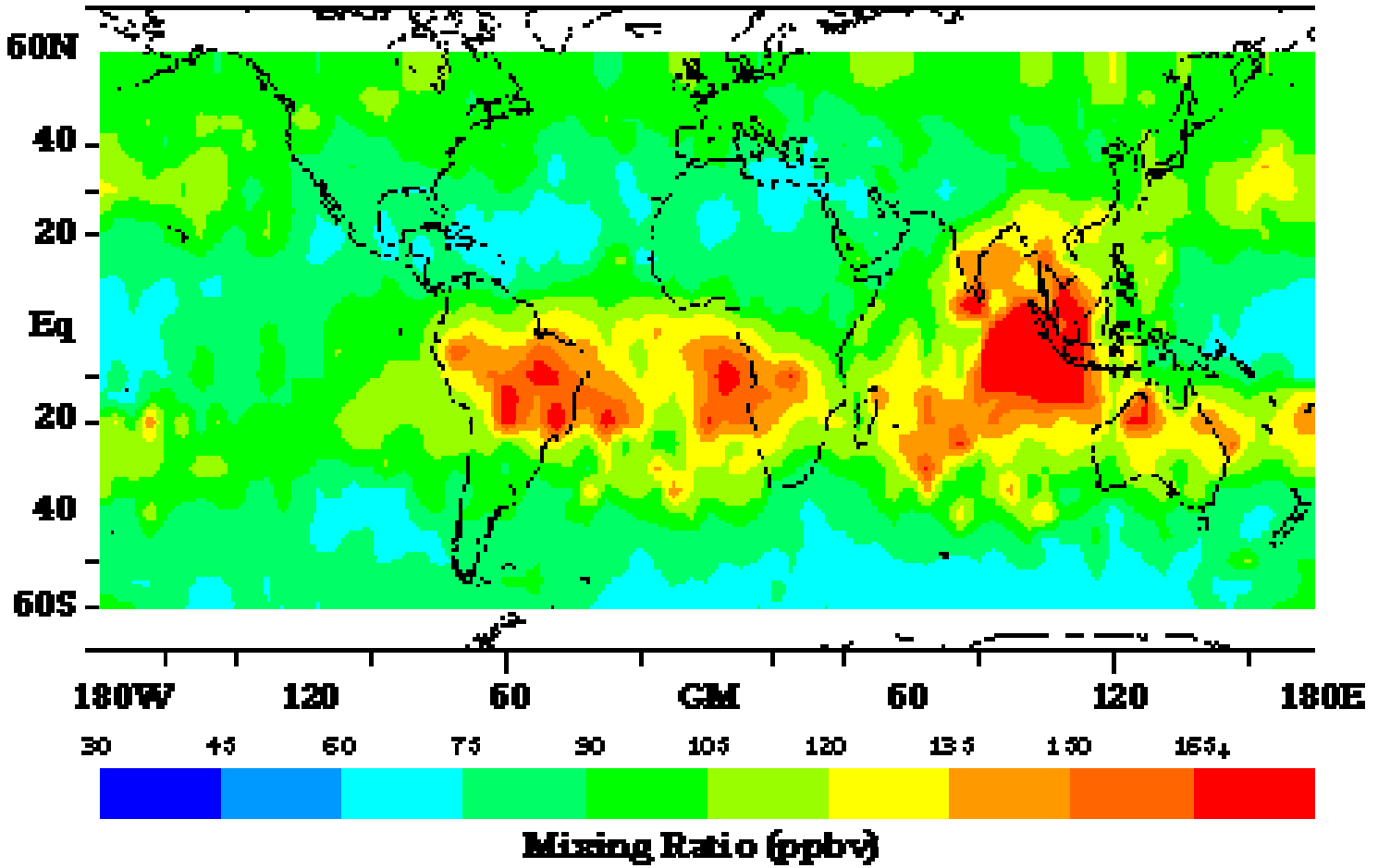
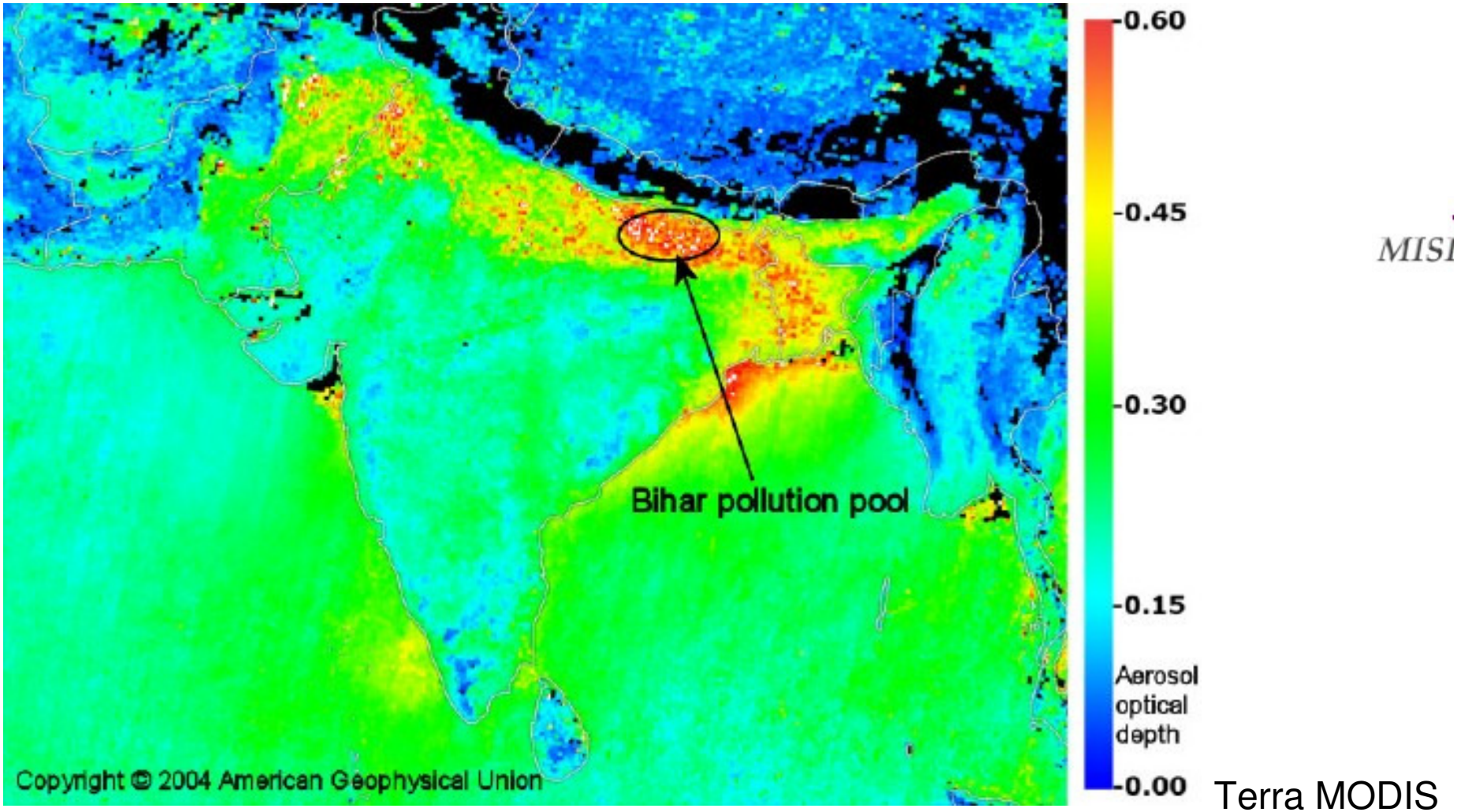


Figure 3

High concentrations of carbon monoxide over the Tropics and Southern Hemisphere can be seen in measurements made by the Measurement of Air Pollution from Satellites (MAPS) instrument. These October 1994 measurements, made from the Space Shuttle Endeavour (STS-68), show large sources of air pollution in the lower atmosphere (3 to 10 kilometers above the surface of the Earth) over the grasslands and savannas in central South America, southern Africa, and over the Indonesian Islands. Carbon monoxide, a colorless and odorless gas, is created by the burning of fossil fuels such as gasoline and by the burning of forests and grasslands. These measurements were made from September 30 - October 11, 1994.

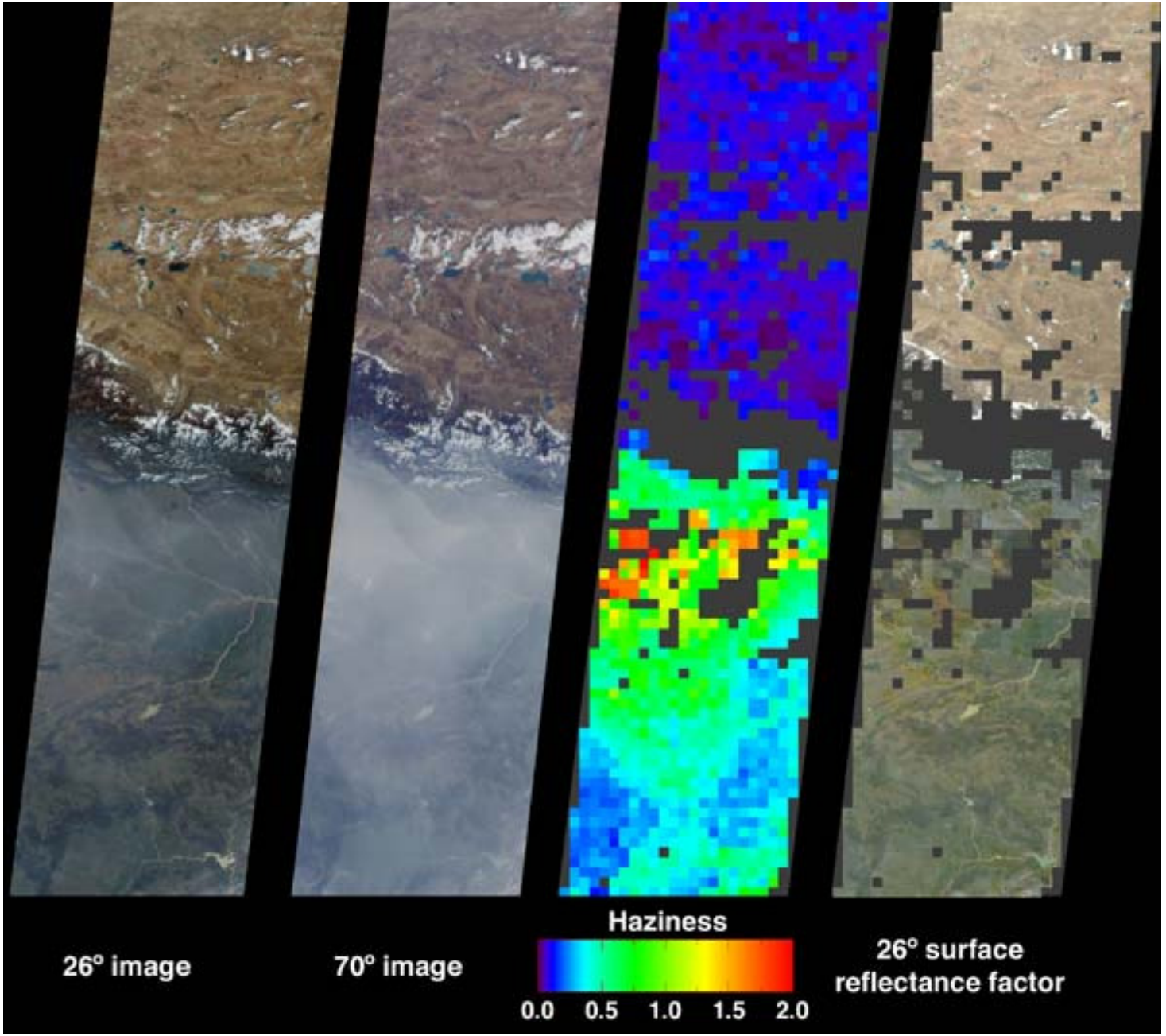
Satellite Data Reveal Immense Pollution Pool Over Bihar, India



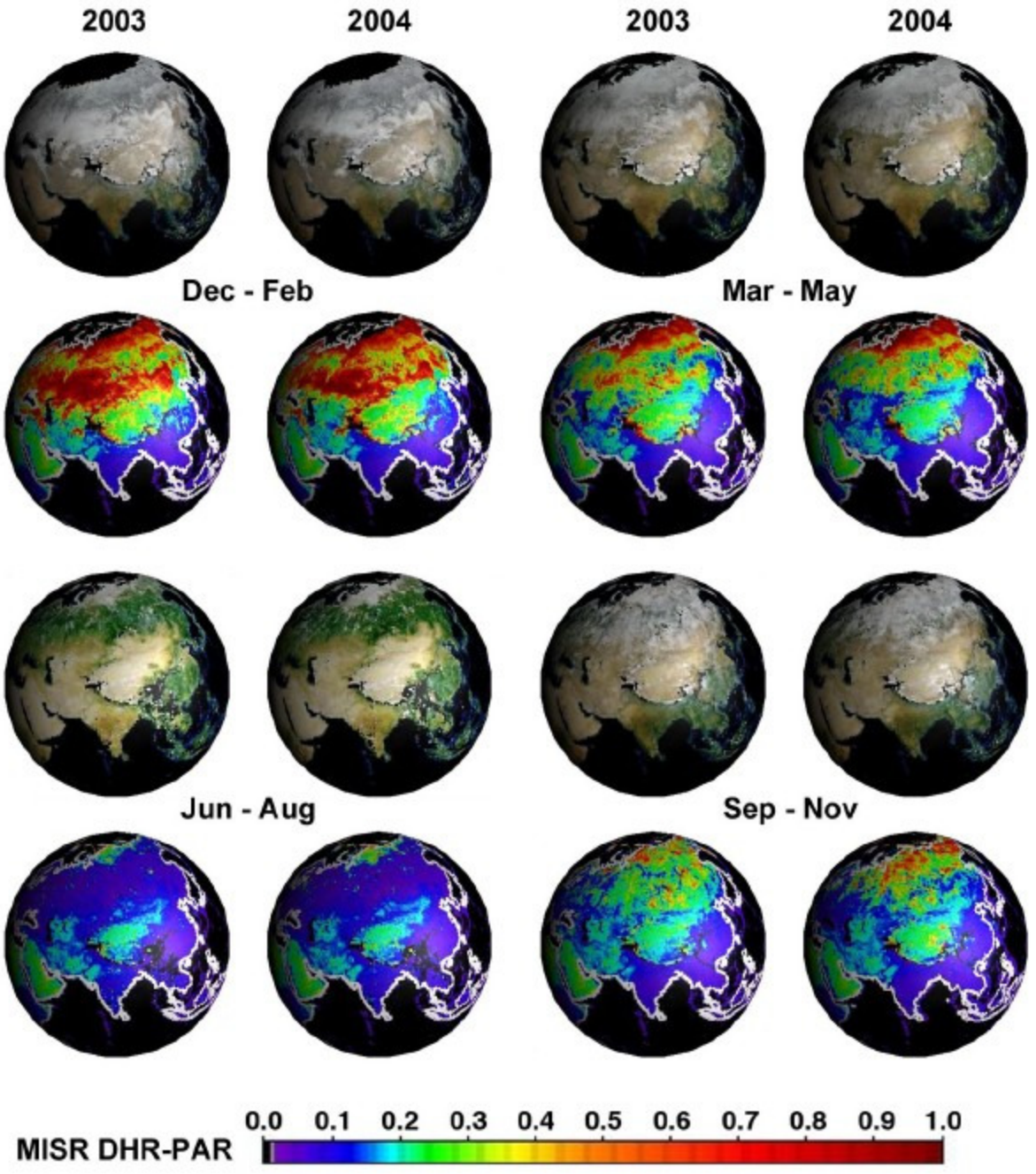
Terra MODIS

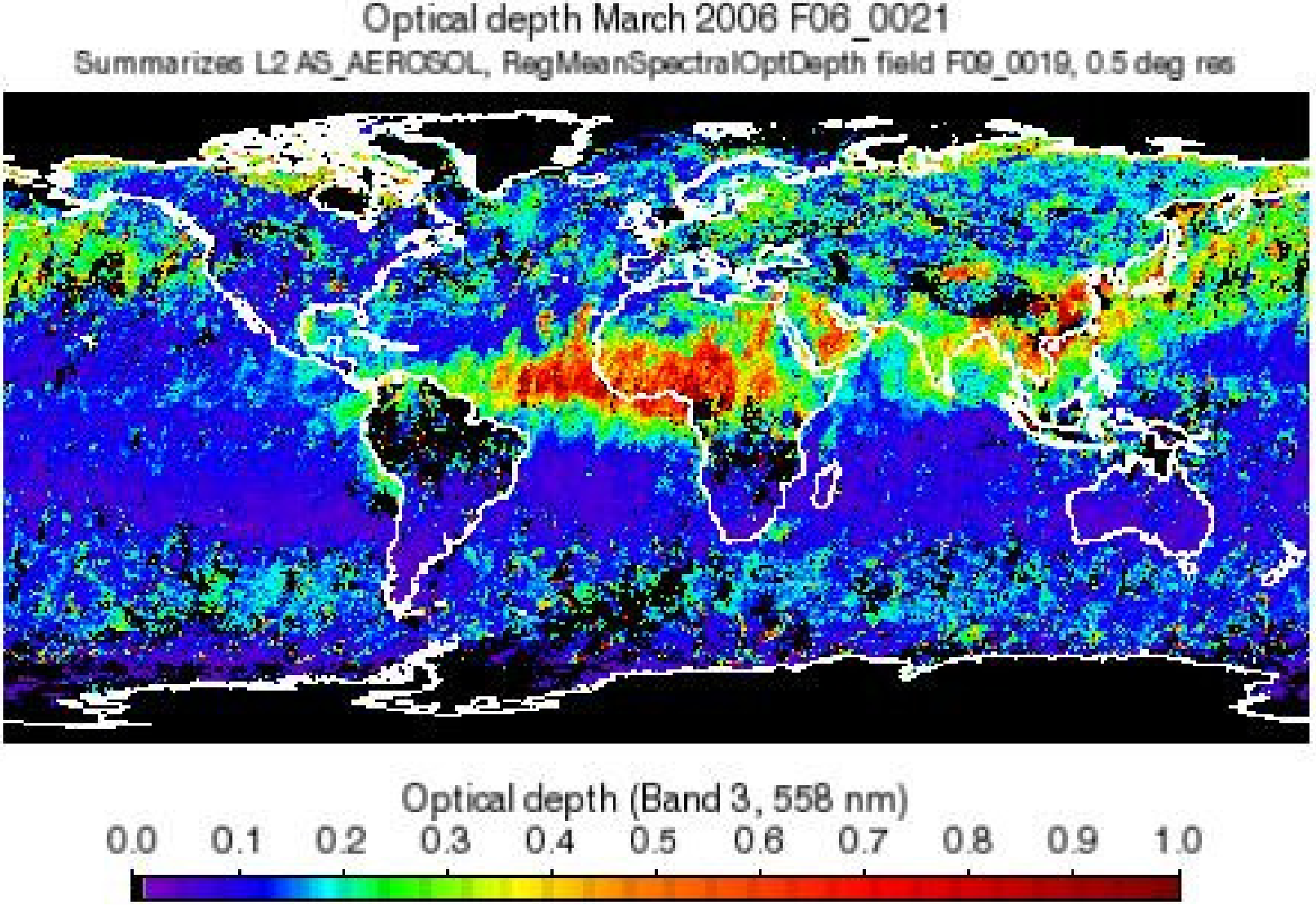
Analyzing four years of data collected by the Multi-angle Imaging Spectro-Radiometer (MISR) onboard the Terra satellite who discovered an immense wintertime pool of pollution over the northern Indian state of Bihar. Immense wintertime pool of over the northern Indian state of Bihar. Blanketing around 100 million people, primarily in the Ganges Valley, the pollution levels are about five times larger than those typically found over Los Angeles.

Aerosols over India Oct 15, 2001.



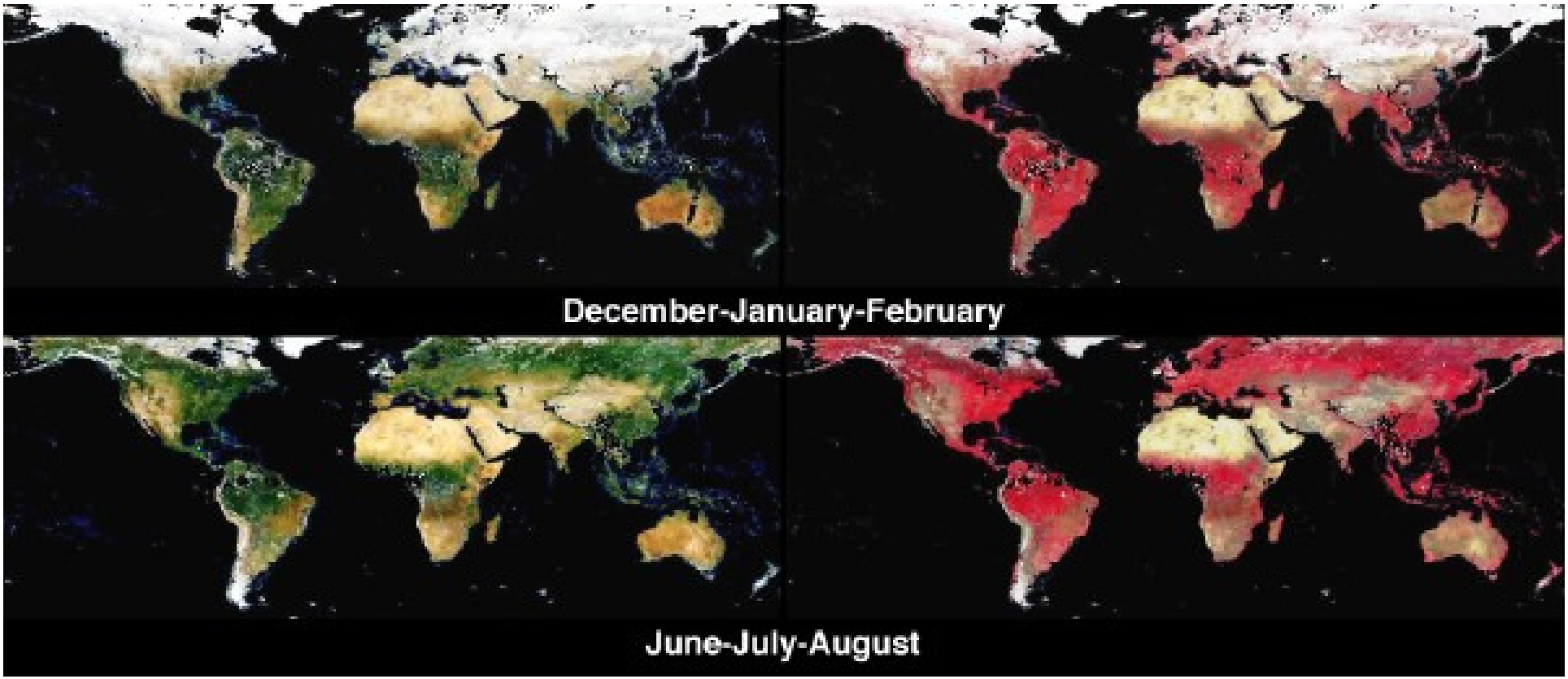
Seasonal Changes in Earth's Surface Albedo




Optical depth March 2006 F06_0021
Summarizes L2 AS_AEROSOL, RegMeanSpectralOptDepth field F09_0019, 0.5 deg res
Optical depth (Band 3, 558 nm)
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

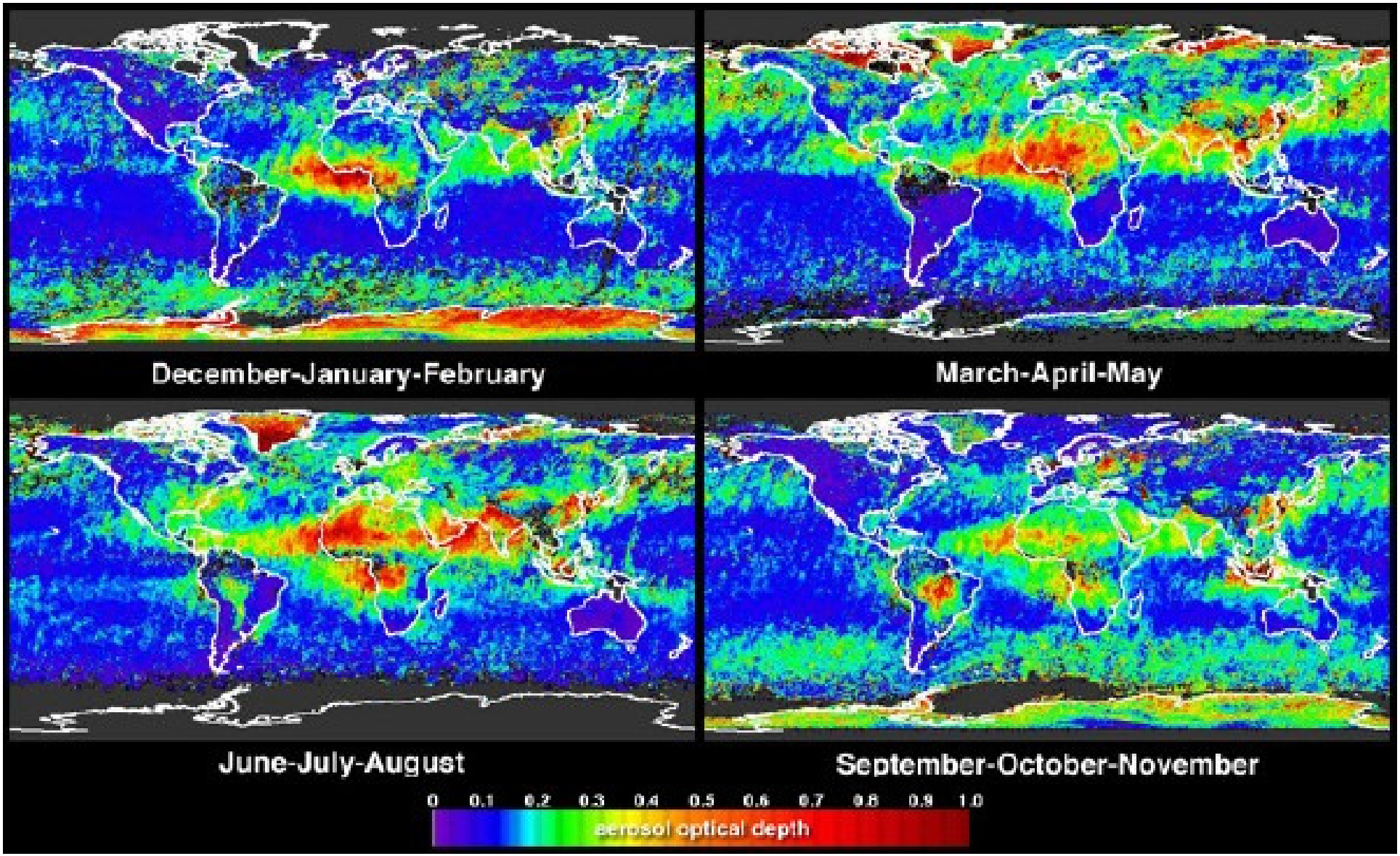
Global and Seasonal Surface Albedos from MISR

Temporal

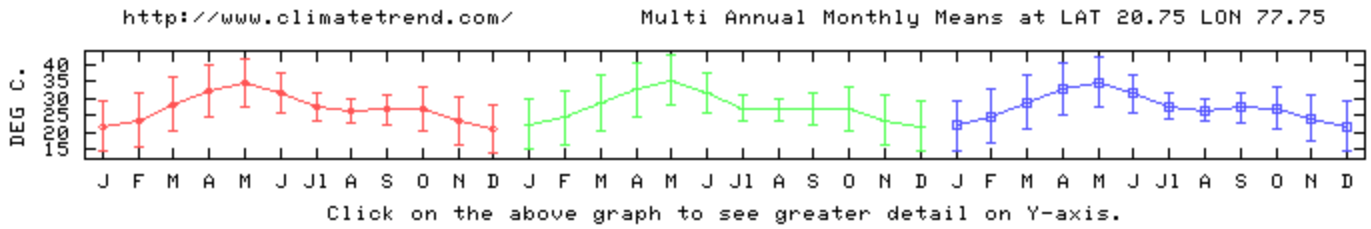


Global and Seasonal Aerosol Distributions from MISR

Temporal



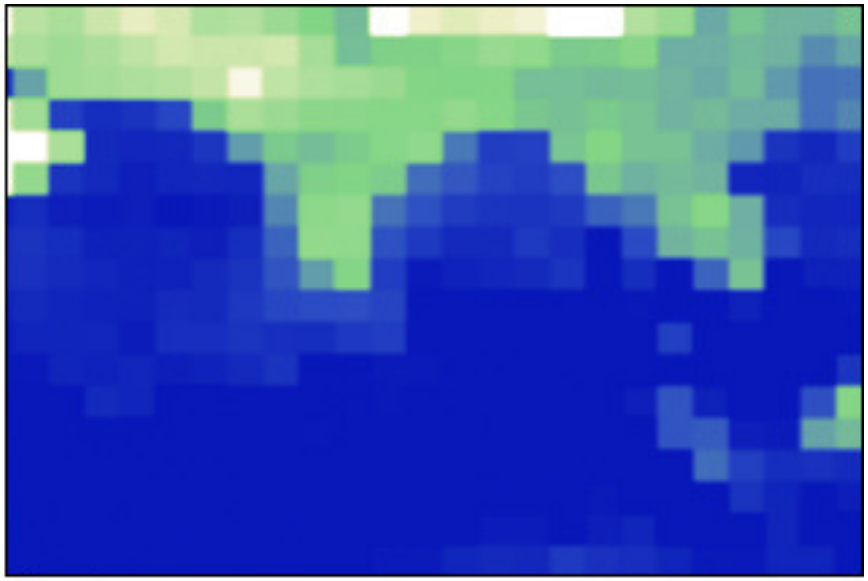
Annual monthly min, max, mean temperature profiles



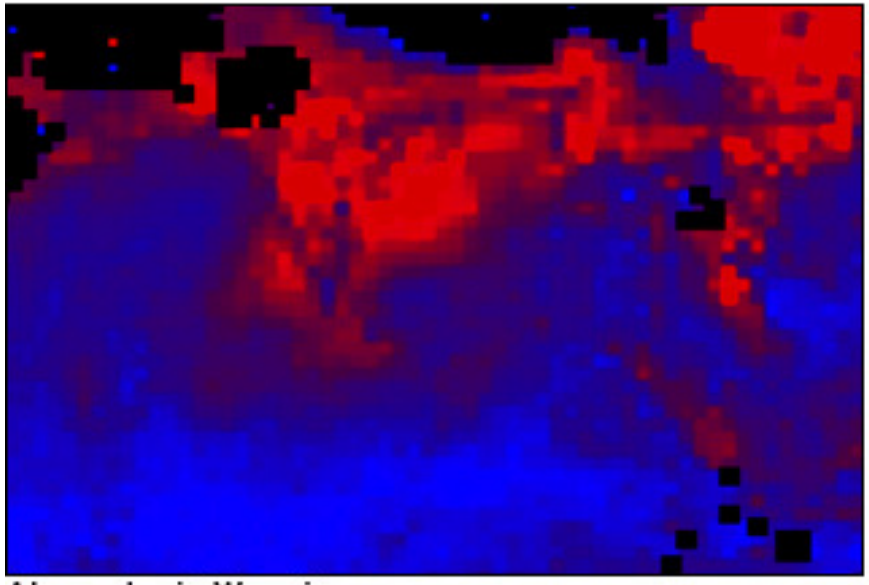
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	29.2	31.6	36.4	40.0	41.9	37.4	31.4	29.9	31.2	33.2	30.5	28.4
1901-1930	21.8	23.7	28.3	32.2	34.6	31.7	27.4	26.4	26.7	26.8	23.5	21.1
	14.4	15.9	20.3	24.4	27.4	26.0	23.5	23.0	22.2	20.5	16.5	13.8
	29.8	32.4	36.9	40.6	42.6	37.5	31.2	30.2	31.4	33.2	31.0	29.3
1931-1960	22.4	24.5	28.8	32.6	35.3	31.7	27.2	26.7	26.8	26.8	23.7	21.8
	15.1	16.6	20.7	24.7	28.0	26.0	23.2	23.3	22.3	20.4	16.4	14.4
	29.5	32.7	37.0	40.6	42.2	37.2	31.7	30.1	31.8	33.6	31.3	29.2
1961-1990	22.1	24.8	28.9	32.8	34.9	31.5	27.7	26.6	27.3	27.2	24.3	21.9
	14.7	17.0	20.9	25.0	27.7	25.8	23.8	23.2	22.8	20.9	17.3	14.6

Temporal

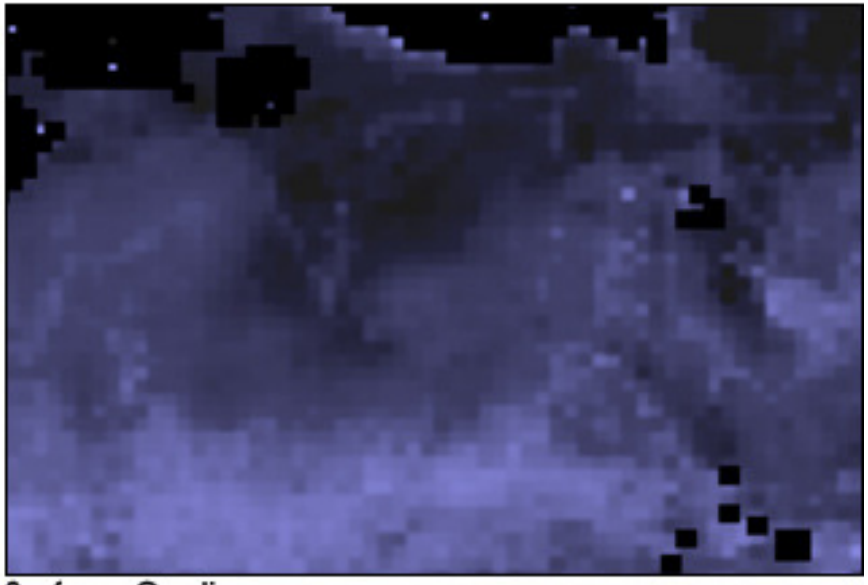
Aerosol



Albedo



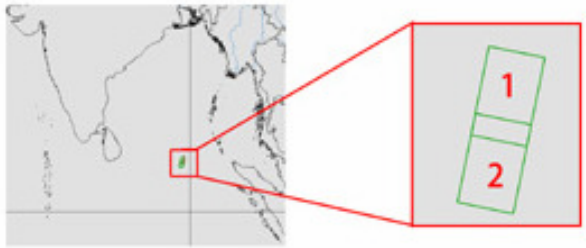
Atmospheric Warming



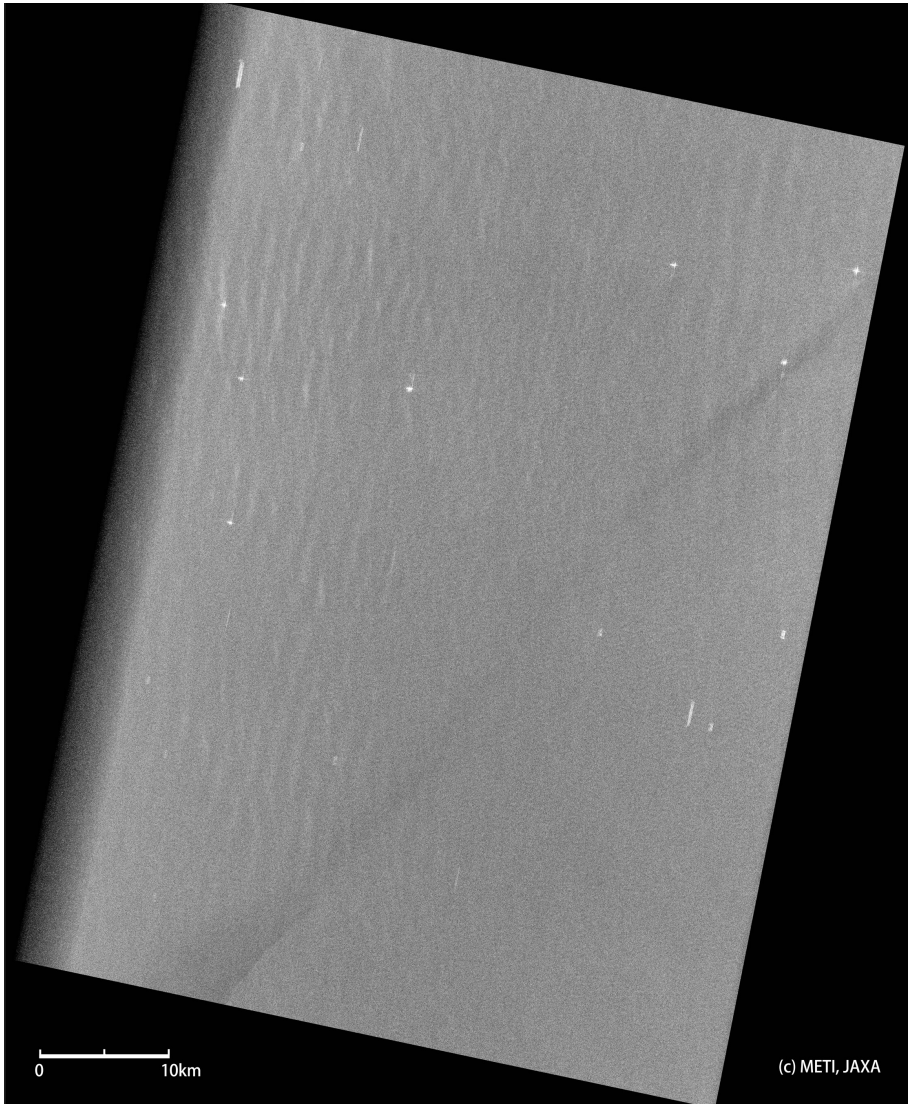
Surface Cooling

March 13–21, 2001

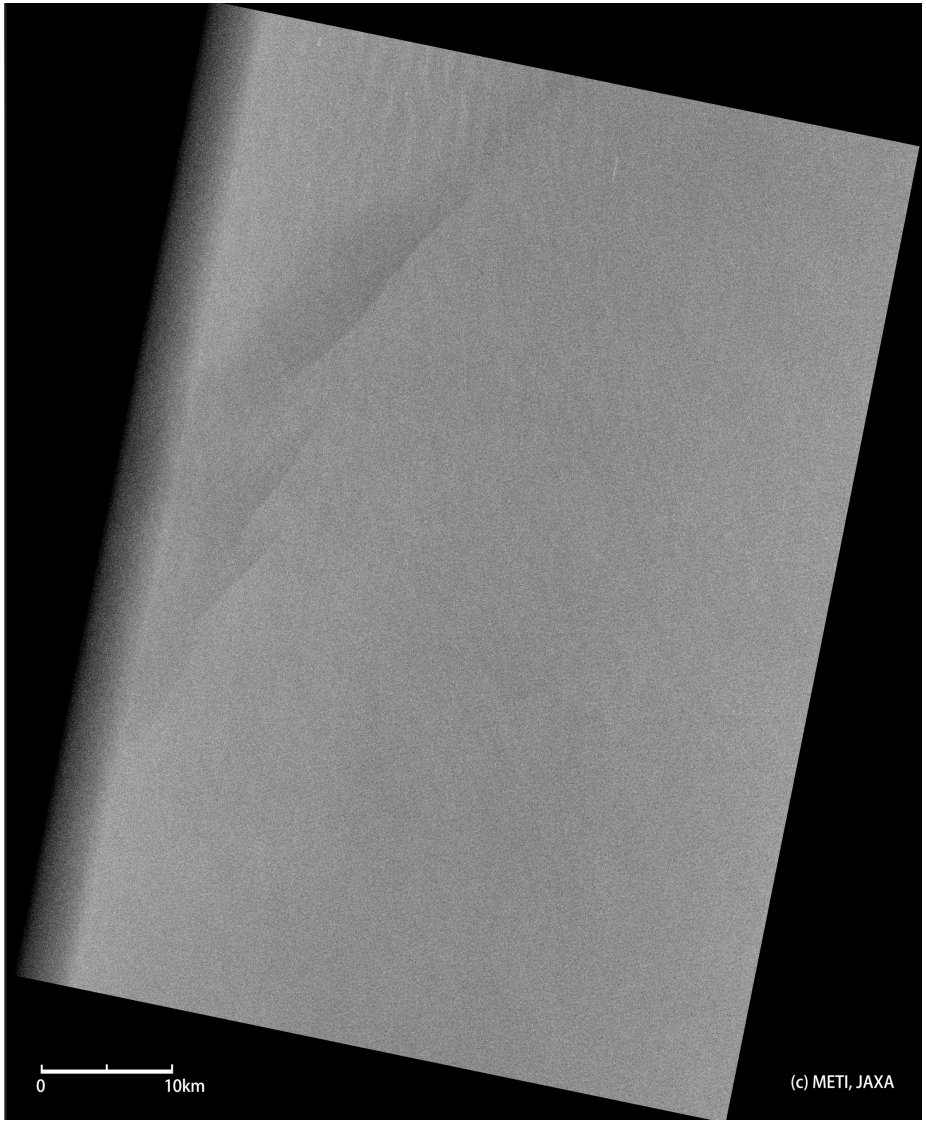
Estimated tanker oil-spill area in the eastern Indian Ocean observed by "Daichi"(ALOS) on August 18, 2006



August 18 04:04 (UTC)
CenterLatitude : 5.945 N
CenterLongitude : 89.089 E



August 18 04:05 (UTC)
CenterLatitude : 5.451 N
CenterLongitude : 88.985 E




Thank You
Namaskar