A global look at satellite data and monitoring

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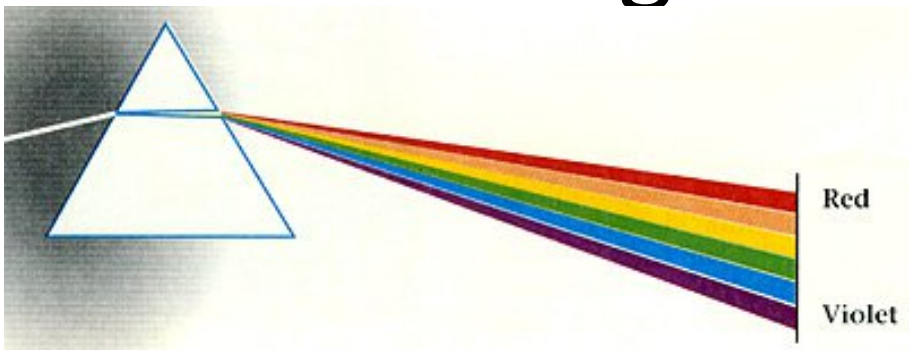
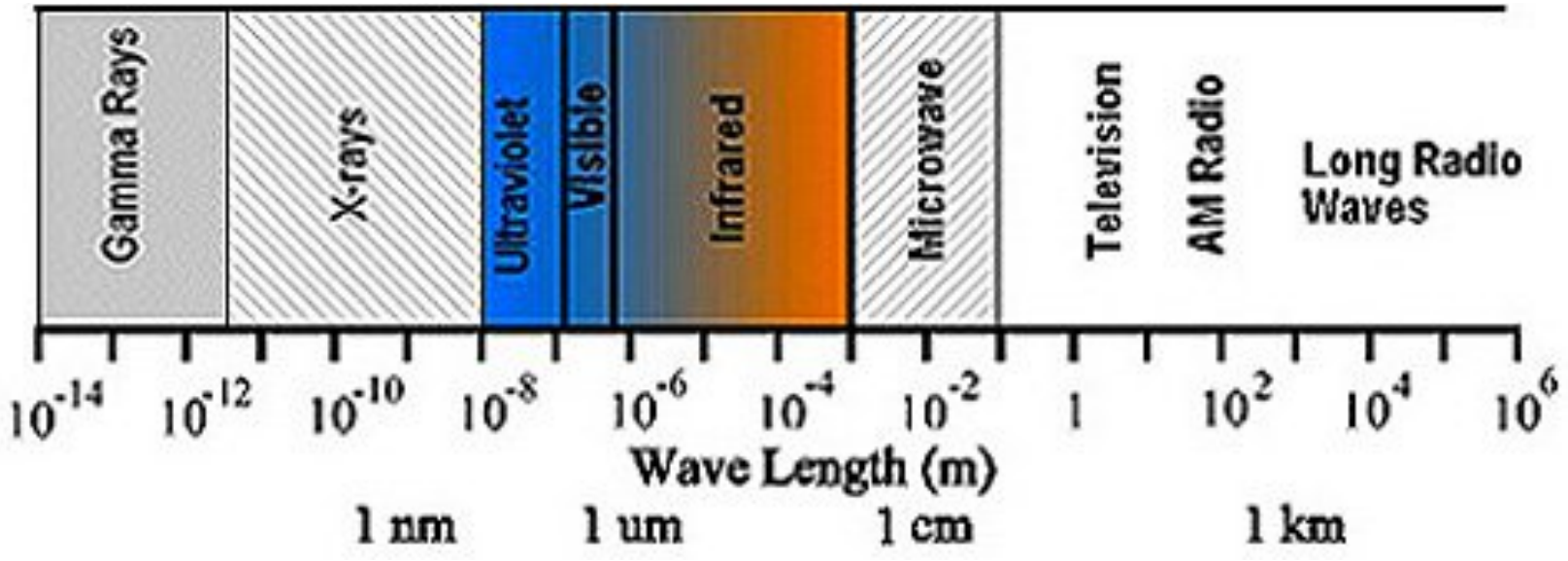
Electromagnetic Radiation (Light)

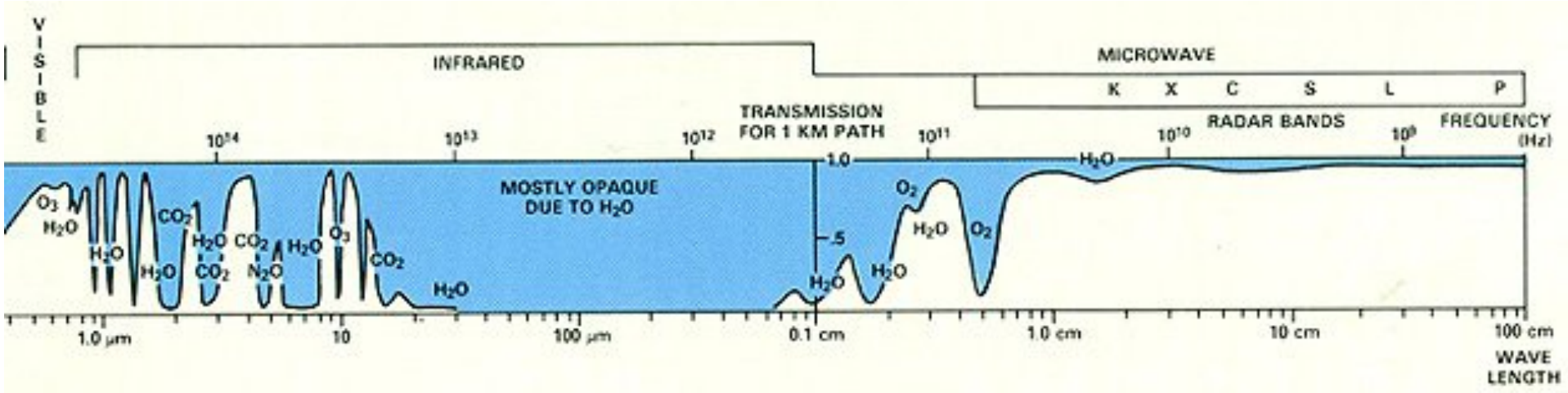


Human vision covers wavelengths 0.4 to 0.7 micrometers

Remote sensing spans the UV to microwave



Atmospheric Windows



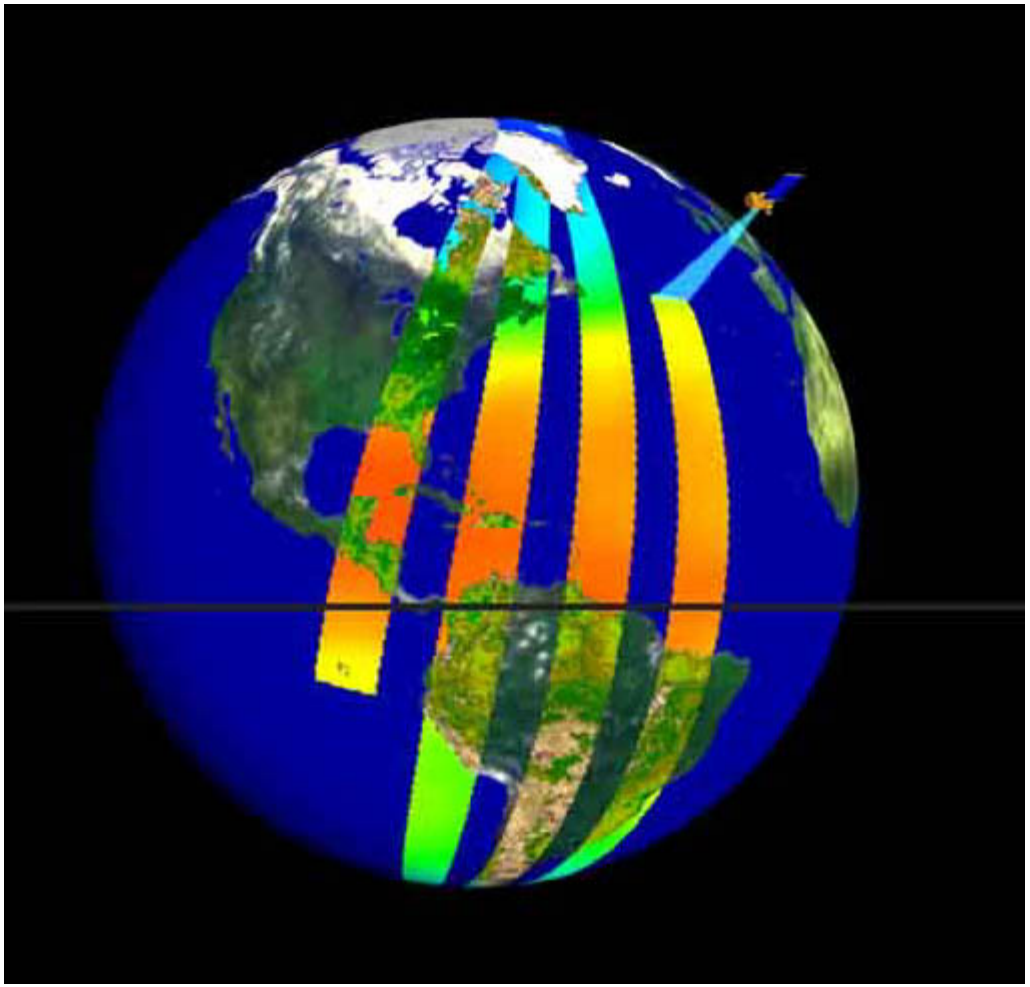
Observation of the earth surface in clear atmospheric windows. The individual windows are the locations of "see to the ground spectral bands". Spectral ranges outside the atmospheric windows can be used to measure atmospheric water, greenhouse gases, temperature and pressure profiles.

Active versus passive remote sensing

- Most remote sensing systems are passive, relying on sunlight or emissions from the objects themselves.
- In visible, near infrared, short-wave infrared sunlight can be used as the illumination source – passive remote sensing. Earth surface features only detectable during daylight hours and are blocked by clouds.
- In long-wave infrared and microwave the objects emit based on their temperature and composition suitable for day and night passive remote sensing. LWIR view of the earth surface is blocked by clouds. Some MW channels see through clouds, but spatial resolution is coarse.
- Active remote sensing: synthetic aperture radars, LIDARs. These are typically fee based services. SAR systems can see through clouds.

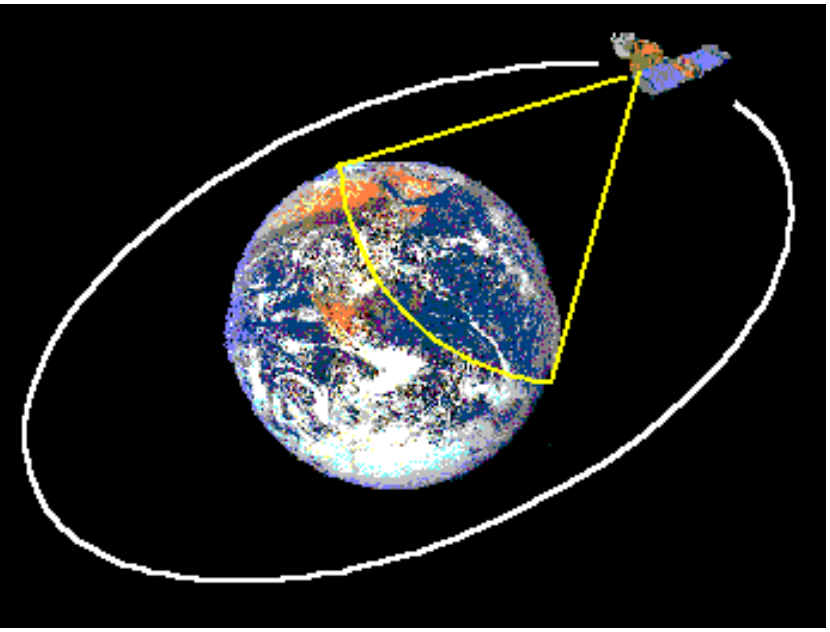
Spatial and Temporal Resolution

- High spatial resolution data is typically a fee based commercial service.
- 30 meter Landsat 8 data are freely available, but have a 16 day repeat cycle.
- ~1 km data from NASA and NOAA satellites each collect twice per day (day and night). Open access data and environmental products.



Polar Orbits

In polar orbits, satellite fly over the north and south poles at elevations ranging from 400 to 1000 km altitude. Easier to obtain higher spatial resolution, but limits the number of daily observations. Examples: Landsat, MODIS, VIIRS.

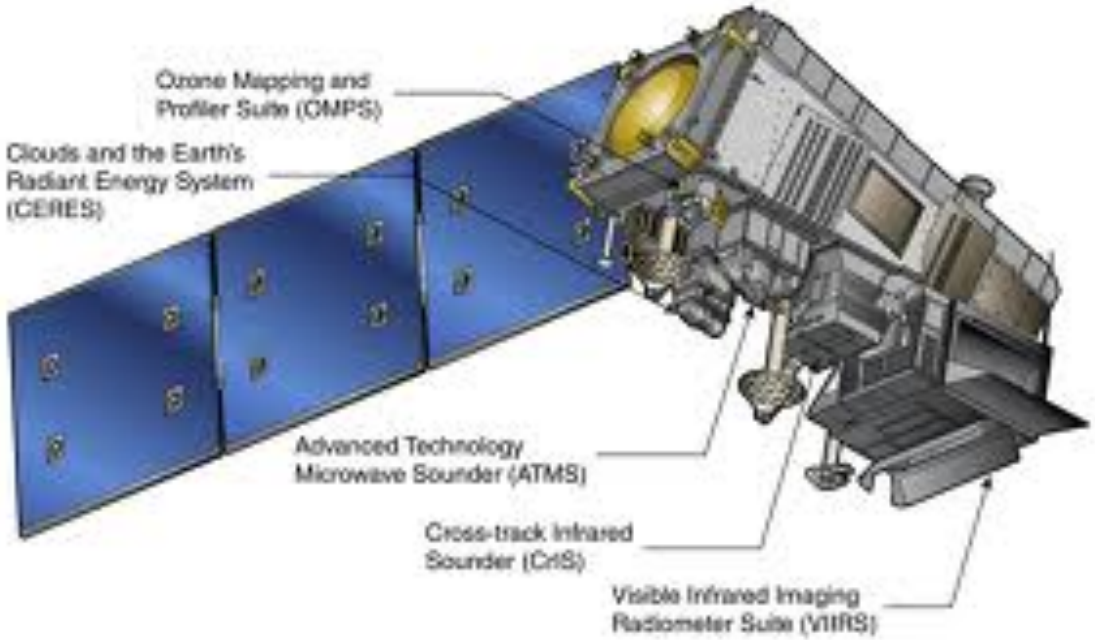


Geostationary Orbits

Geostationary systems stay in a fixed position 36,000 km above a single position above the equator. This orbit is favored by meteorological satellites. MTSAT collects data of the Mekong Region.

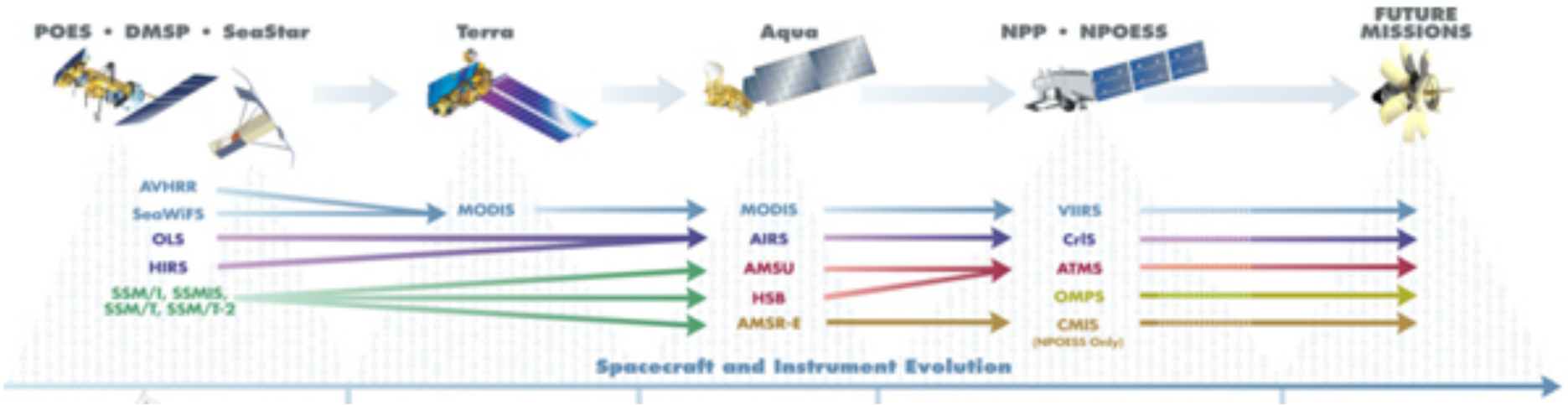
Local versus global data collection

- NASA, NOAA, USGS collect global data from on-board recorders from high latitude ground stations. Data distribution delayed by ~12 hours.
- NASA and NOAA satellites broadcast the sensor data in-flight. It is possible to collect the data with a local ground station to reduce the temporal latency and bypass intercontinental data transfer.
- Landsat ground stations licensed by USGS.

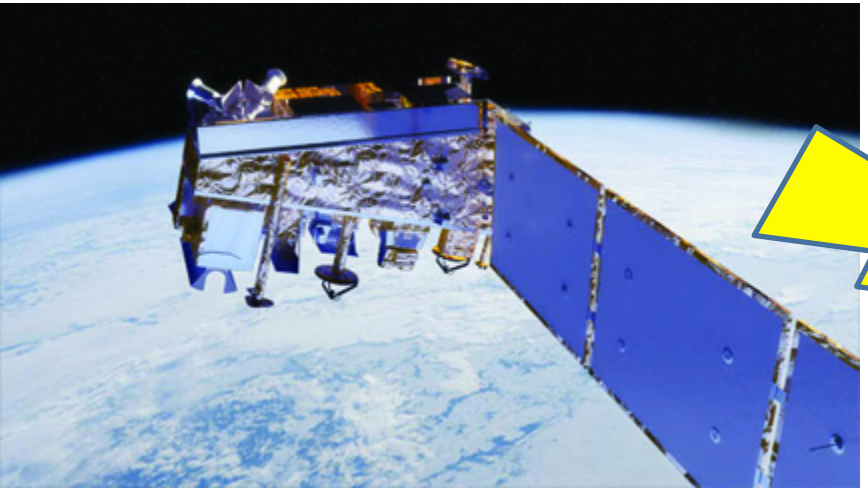


NASA/NOAA Suomi National Polar Partnership (SNPP) satellite was launched October 28, 2011.

SNPP is the USG's 3rd Generation Polar Orbiting Environmental Satellite



The NASA/NOAA Suomi National Polar Partnership (SNPP) satellite was launched October 28, 2011. NGDC serves as one of two archives for SNPP data. The full stream of image data and products are received at NGDC 8-10 hours from collection.



Svalbard Ground Station

SNPP Data Flow

National Geophysical Data Center

Other Users

National Weather Service

VIIRS Spectral Bands

VIIRS bands and bandwidths

VIIRS Band	Central Wavelength (µm)	Bandwidth (µm)	Wavelength Range (µm)	Band Explanation	Spatial Resolution (m) @ nadir
M1	0.412	0.02	0.402 - 0.422	Visible	750 m @ nadir
M2	0.445	0.018	0.436 - 0.454		
M3 (blue)	0.488	0.02	0.478 - 0.488		
M4 (green)	0.555	0.02	0.545 - 0.565		
M5 (red)	0.672	0.02	0.662 - 0.682		
M6	0.746	0.015	0.739 - 0.754	Near IR	
M7	0.865	0.039	0.846 - 0.885		
M8	1.240	0.020	1.23 - 1.25	Shortwave IR	
M9	1.378	0.015	1.371 - 1.386		
M10	1.61	0.06	1.58 - 1.64		
M11	2.25	0.05	2.23 - 2.28		
M12	3.7	0.18	3.61 - 3.79	Medium-wave IR	
M13	4.05	0.155	3.97 - 4.13		
M14	8.55	0.3	8.4 - 8.7	Longwave IR	
M15	10.763	1.0	10.26 - 11.26		
M16	12.013	0.95	11.54 - 12.49		
DNB	0.7	0.4	0.5 - 0.9	Visible	750 m across full scan
I1	0.64	0.08	0.6 - 0.68	Visible	375 m @ nadir
I2	0.865	0.039	0.85 - 0.88	Near IR	
I3	1.61	0.06	1.58 - 1.64	Shortwave IR	
I4	3.74	0.38	3.55 - 3.93	Medium-wave IR	
I5	11.45	1.9	10.5 - 12.4	Longwave IR	

M = Moderate-resolution bands
I = Imagery-resolution bands
DNB = Day-Night Band (or Near Contrast Band)

VIIRS

Albedo (Surface)
Cloud Base Height
Cloud Cover/Layers
Cloud Effective Part Size
Cloud Optical Thickness
Cloud Top Height
Cloud Top Pressure
Cloud Top Temperature
Land Surface Temp
Surface Type
Ocean Color/Chlorophyll
Suspended Matter
Vegetation Index
Aerosol Optical Thickness
Aerosol Particle Size
Ice Surface Temperature
Imagery
Sea Ice Characterization
Snow Cover/Depth
Sea Surface Temperature

CrIS/ATMS

ATM Vert Moist Profile
ATM Vert Temp Profile
Pressure (Surface/Profile)

OMPS

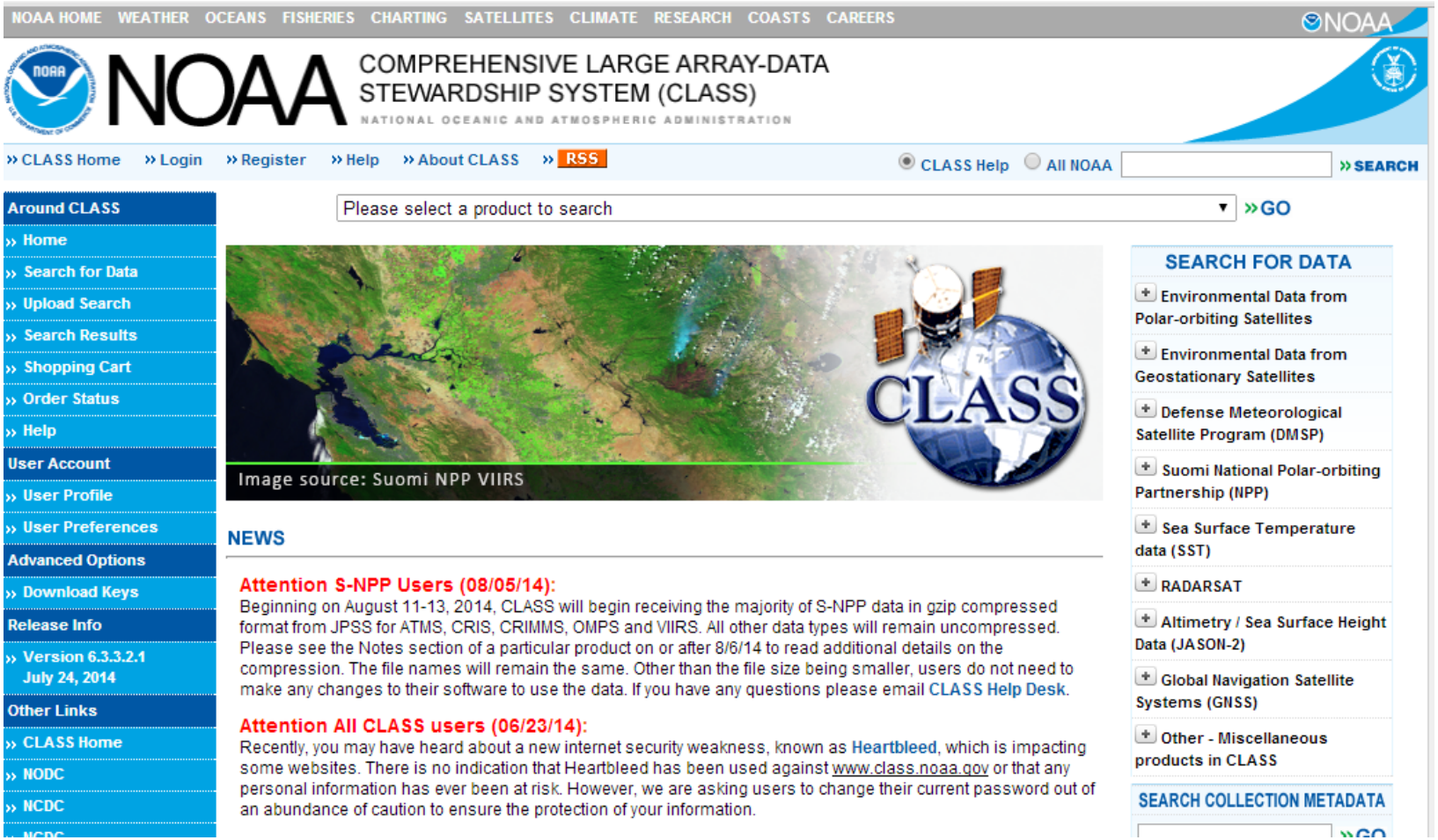
O_3 Total Column (also CrIS)
O_3 Profile

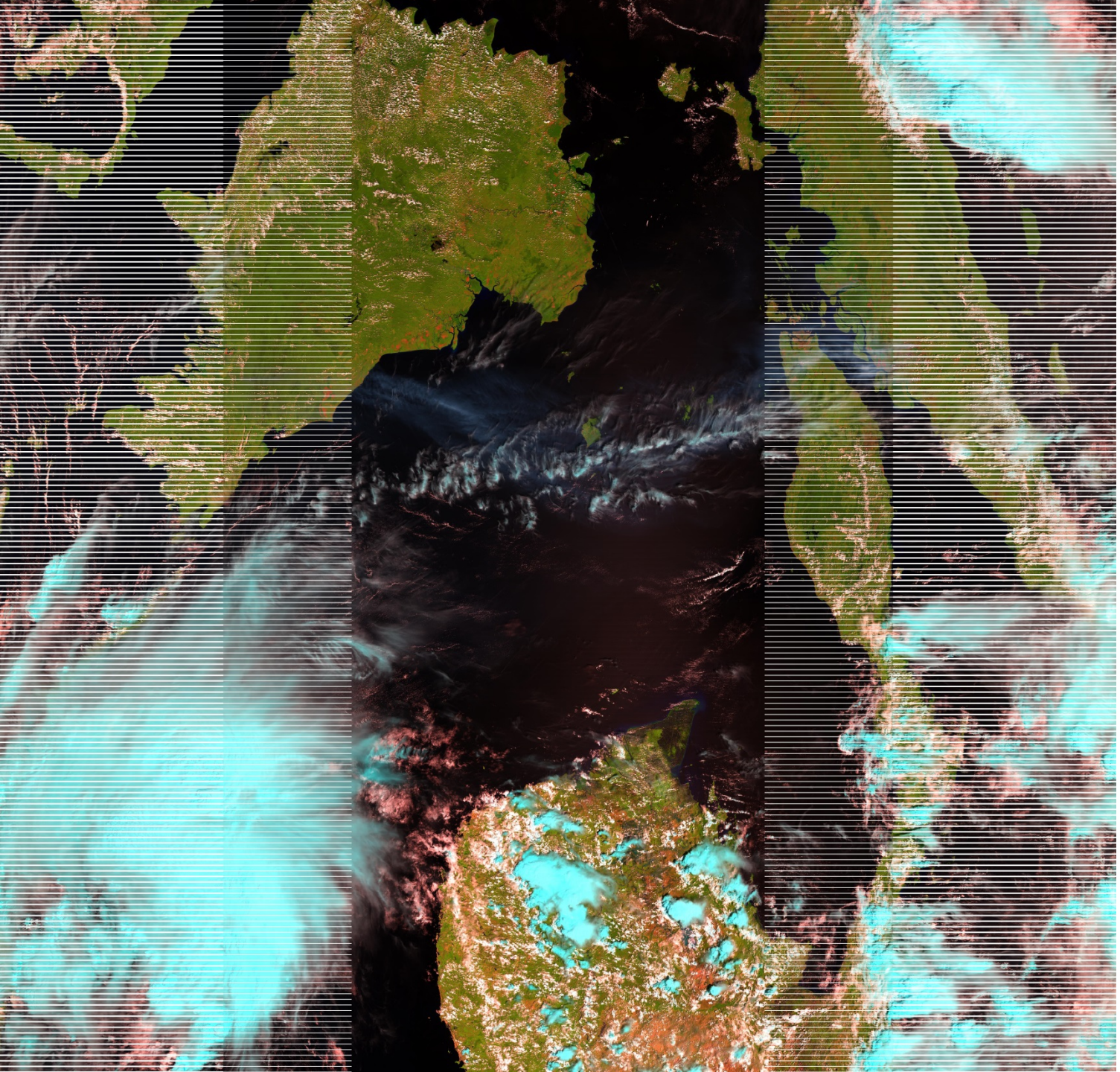
CERES

Down LW Radiance (Sfc)
Down SW Radiance (Sfc)
Net Solar Radiation (TOA)
Outgoing LW Rad (TOA)

SNPP Environmental Products

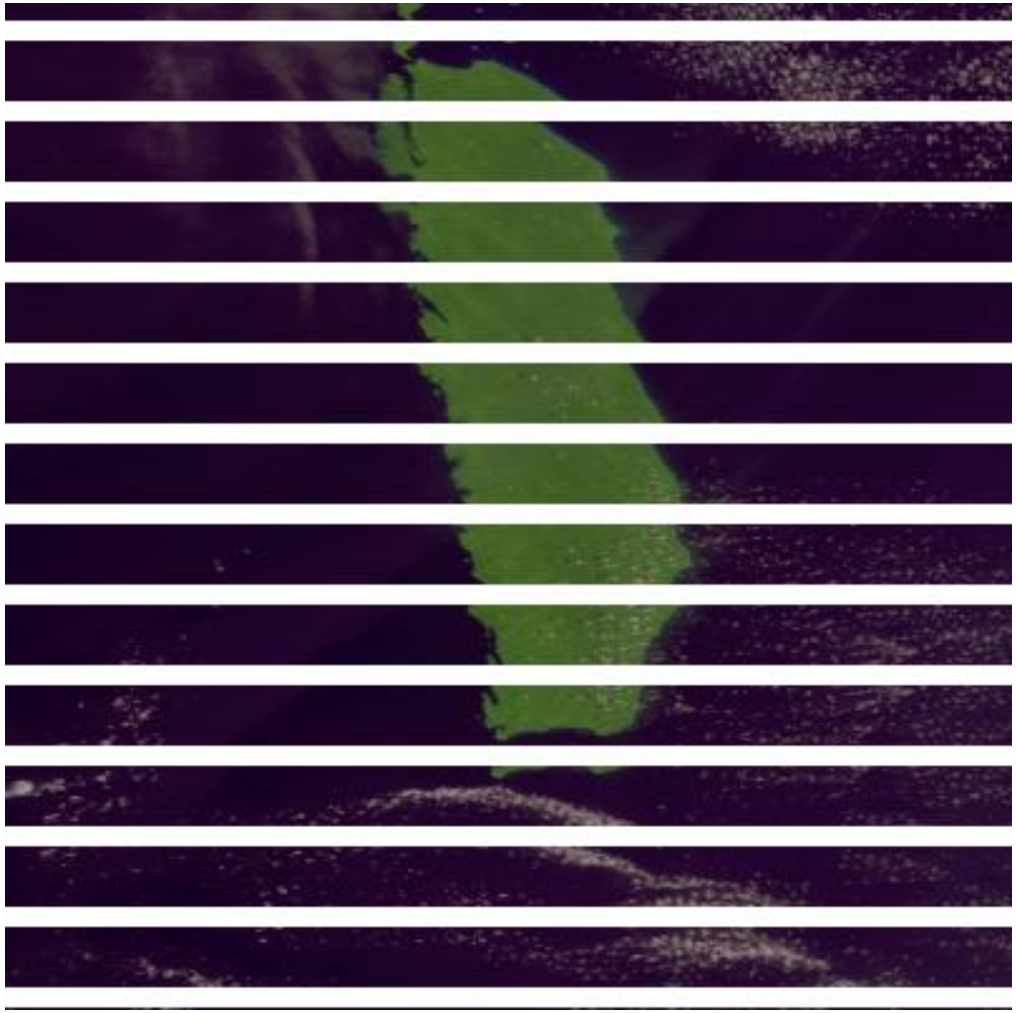
VIIRS data are freely available from NOAA in HDF5 format





VIIRS Data Aggregate June 19, 2013

Panoramic Bowtie Effect



Nias Island, Sumatra

Note the repetition of shoreline features

Why SNPP Data Are Difficult to Use

- Few systems able to open HDF5 format.
- Stacking of metadata balloons file sizes.
- VIIRS data
  - Daytime data are “upside down”.
  - have latitude / longitude locations separate from image data (geolocation has not been performed).
  - VIIRS data and products have line deletions and redundant Earth features at edge of scan. The exception if the day/ night band which has constant 742 meter pixels across full scan.
  - Regional study areas will be covered by multiple 5 minute aggregates and orbits.

What Array Data Are Inside the HDF5?

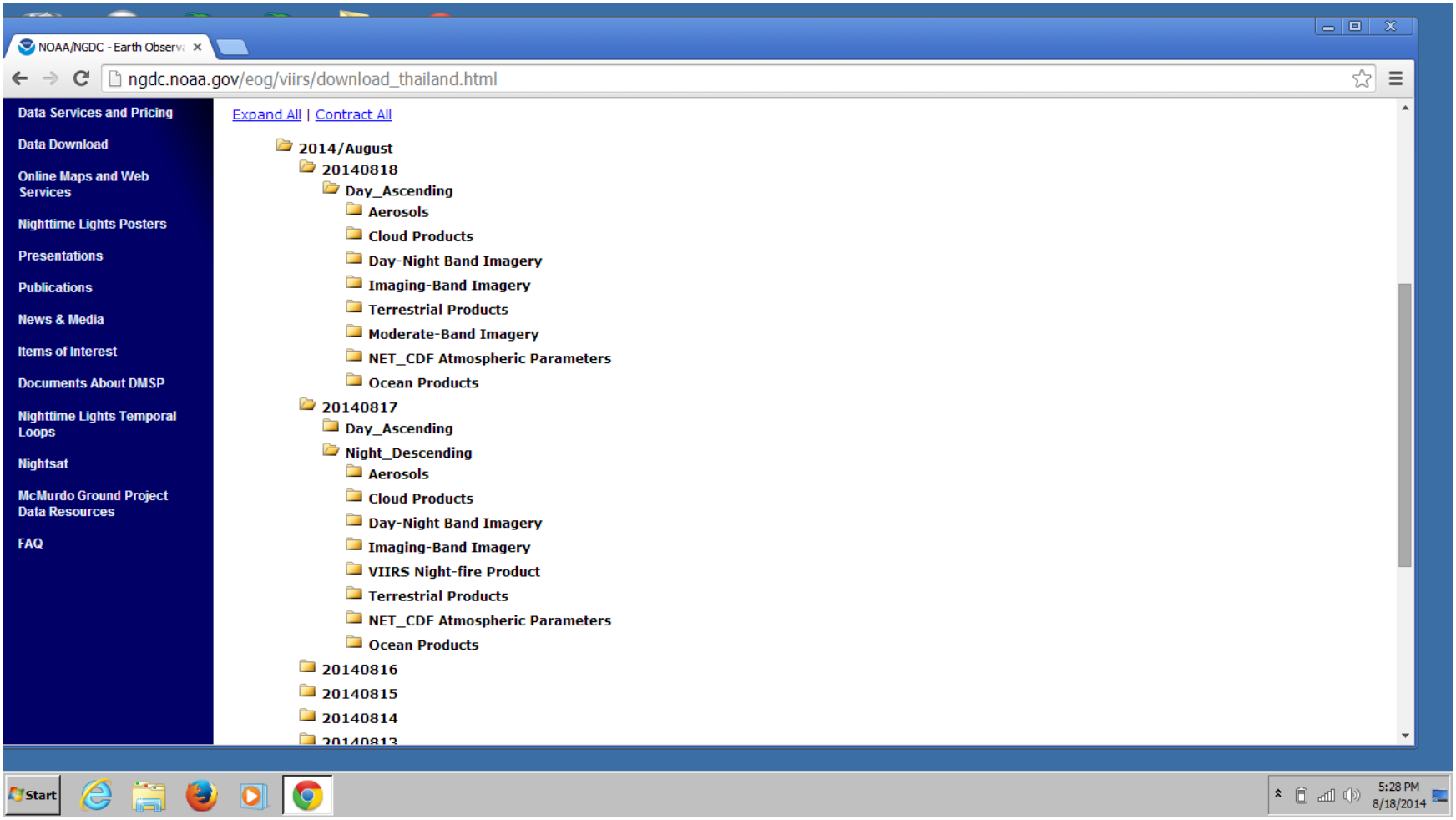
- Radiances or data values. These are often unsigned integers that must be multiplied by a coefficient to obtain the radiance or environmental data value (e.g. degrees K).
- Solar zenith angle
- Solar azimuth angle
- Satellite zenith angle
- Satellite azimuth angle
- Satellite range (distance from pixel on ground to satellite)
- Quality flag
- Terrain corrected longitude
- Terrain corrected latitude

Solution

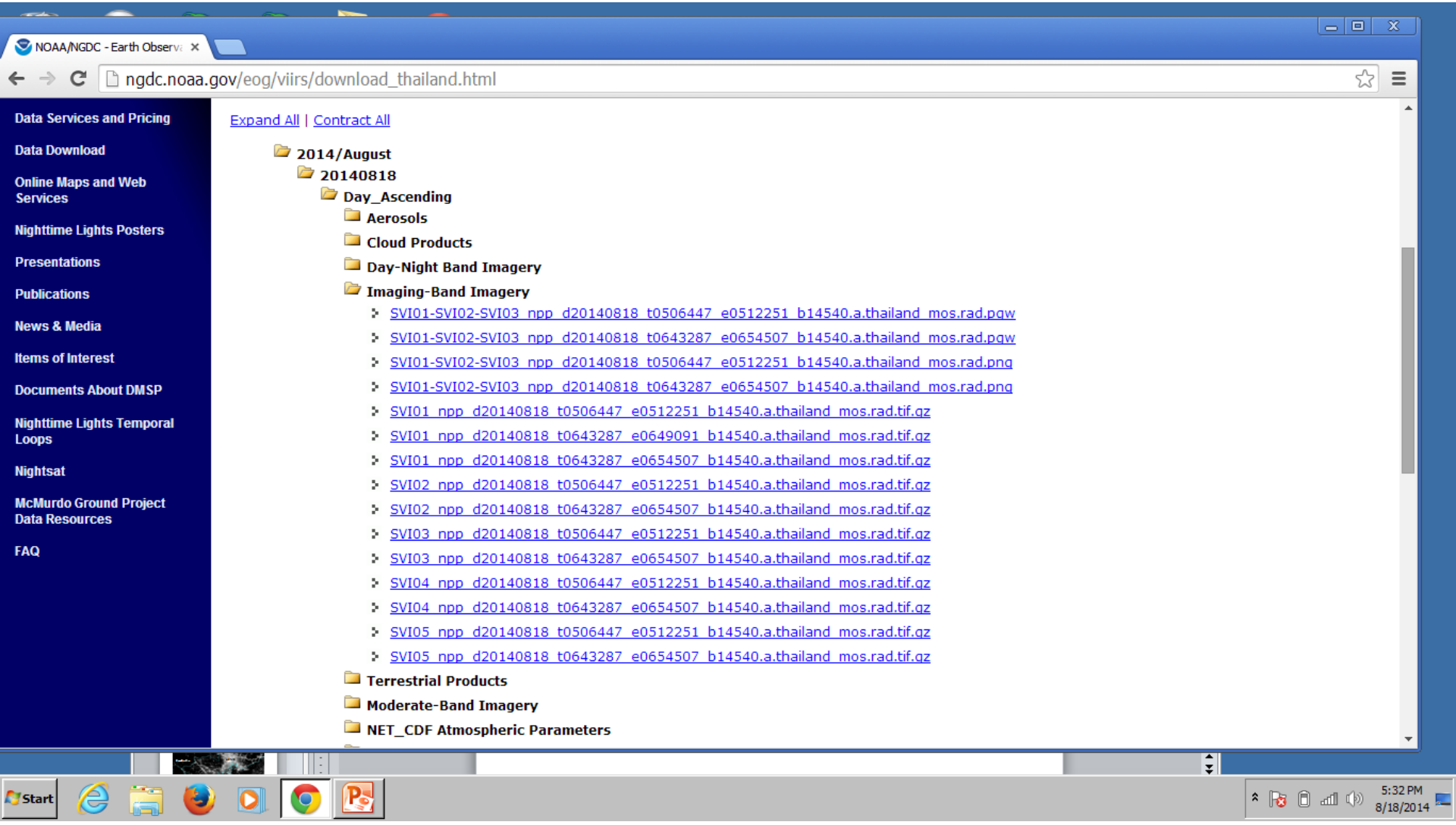
- NGDC identifies the data covering East Asia as they arrive for archiving
- Coefficients are applied to obtain physical data values.
- VIIRS data are projected into 15 arc second grids: north is up, line deletions are screened out, bowtie duplicates removed.
- Output as geotiff.
- Post for download.

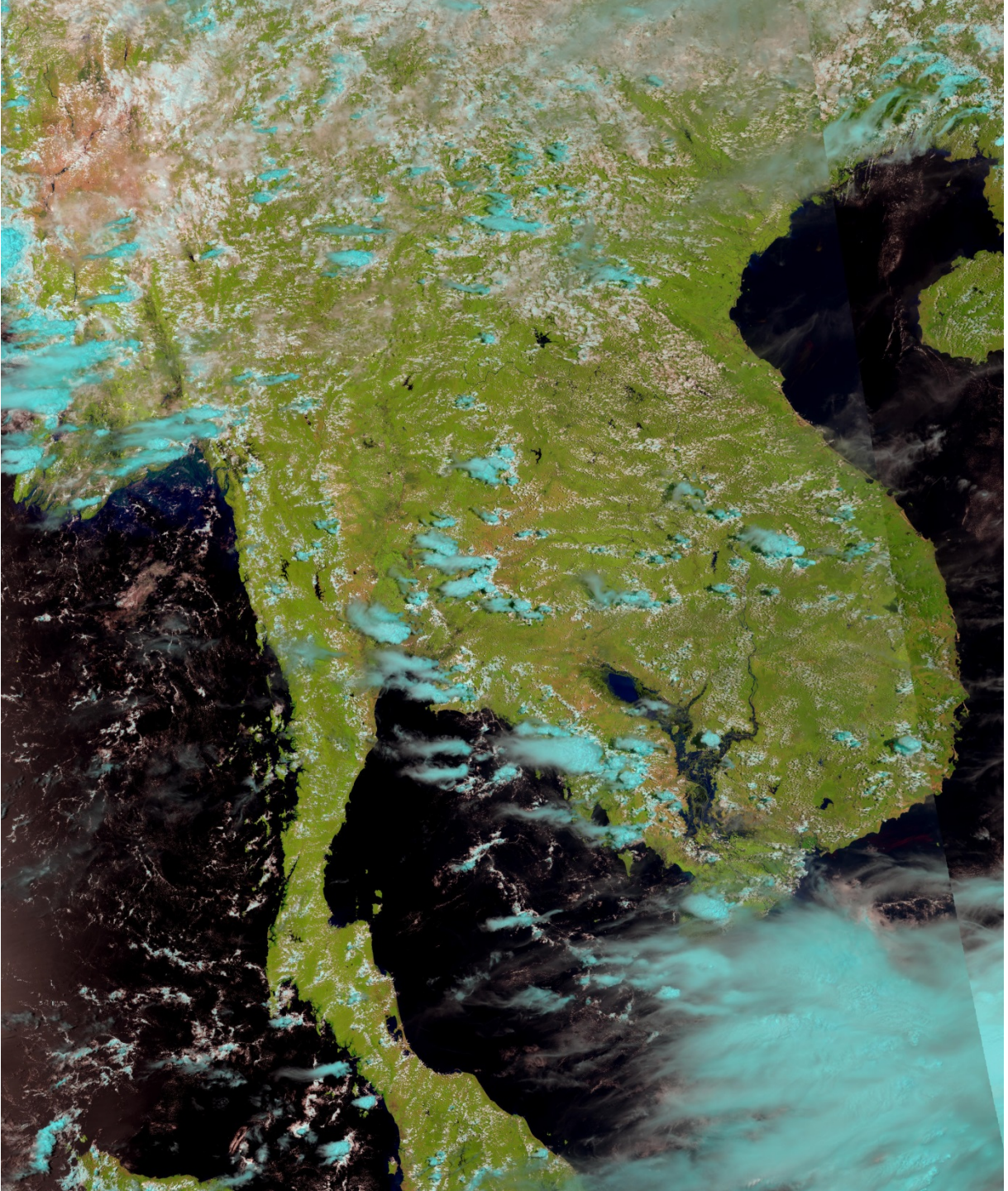
Data Access Page Has Been Established

Product Type Directory Tree



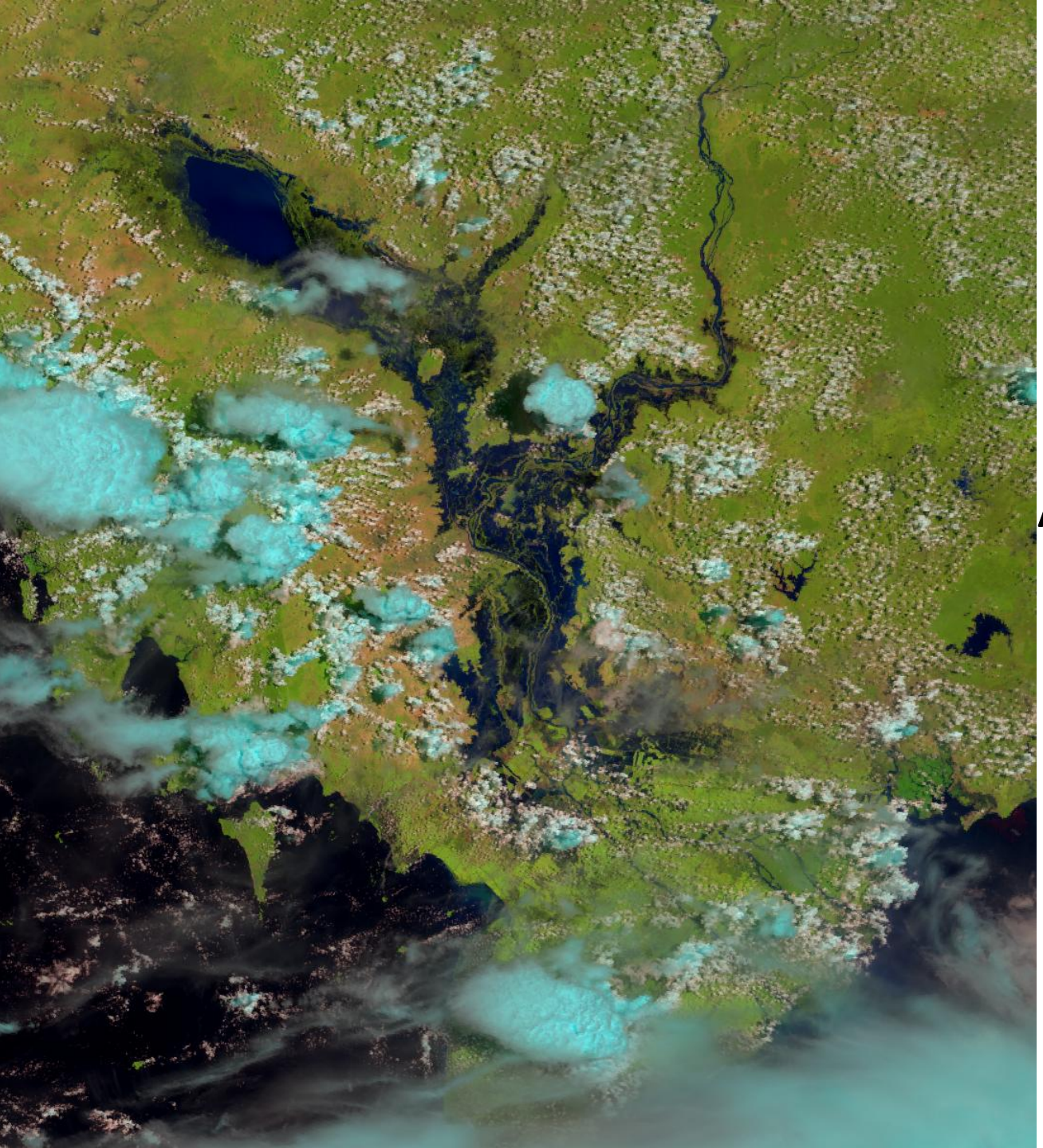
File Listing



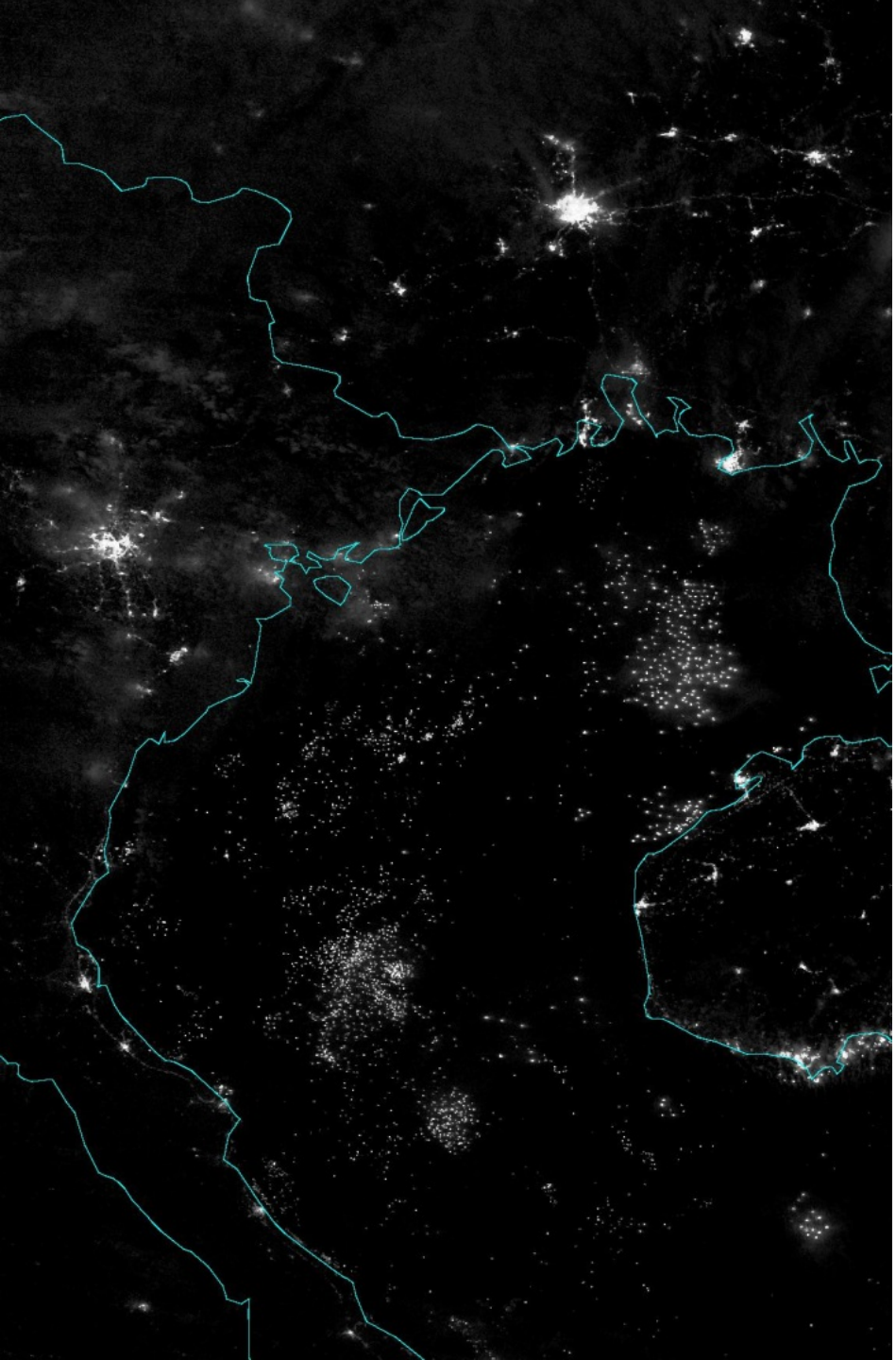


VIIRS imaging band data from August 17, 2014

Raw imaging band data for four HDF5 aggregates = 9 GB. From NGDC service as geotiff = 450 MB. A 95% data volume reduction.

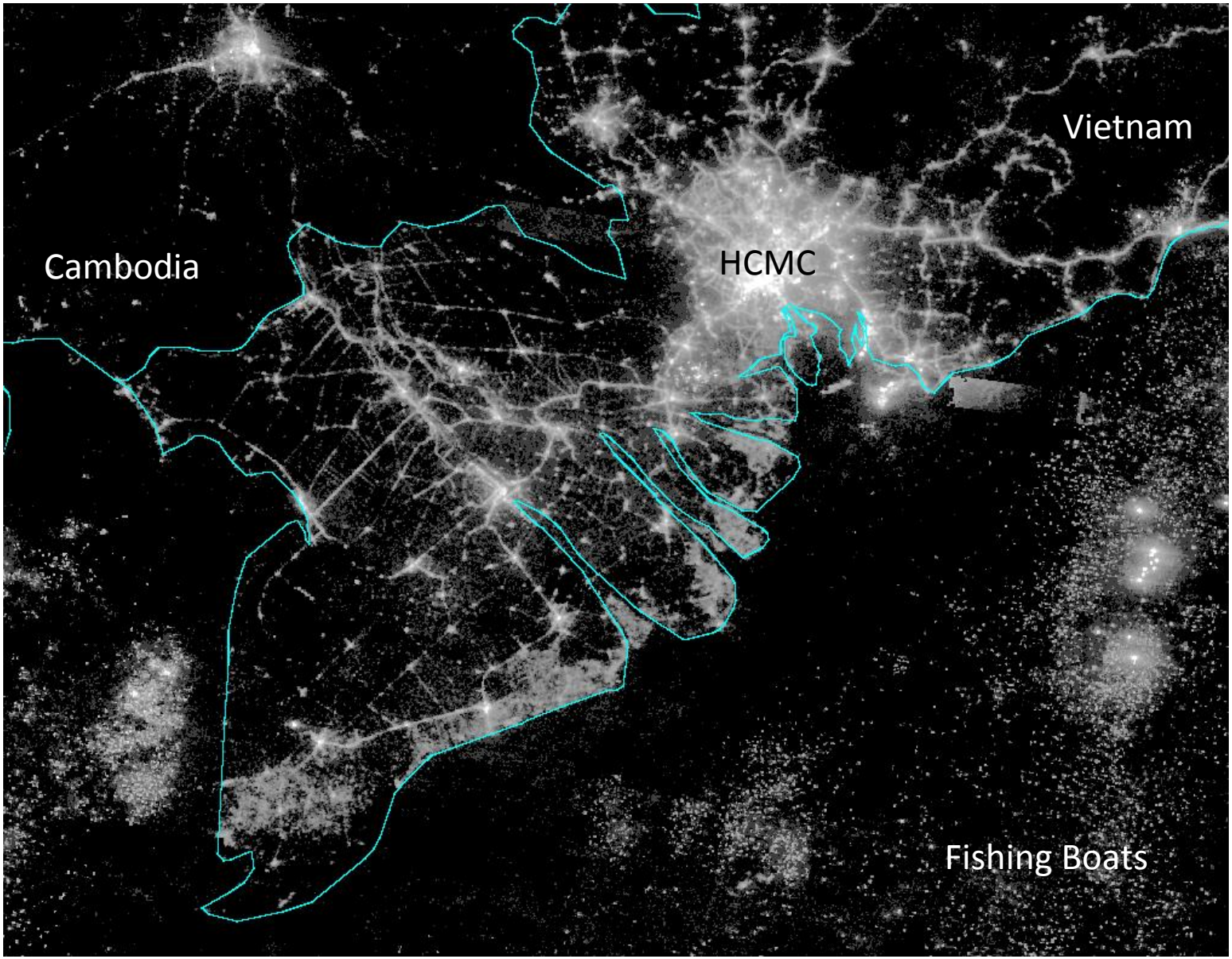


Flooding in Cambodia and Vietnam
August 17, 2014
VIIRS imaging bands 3,2,1 as red, green, blue

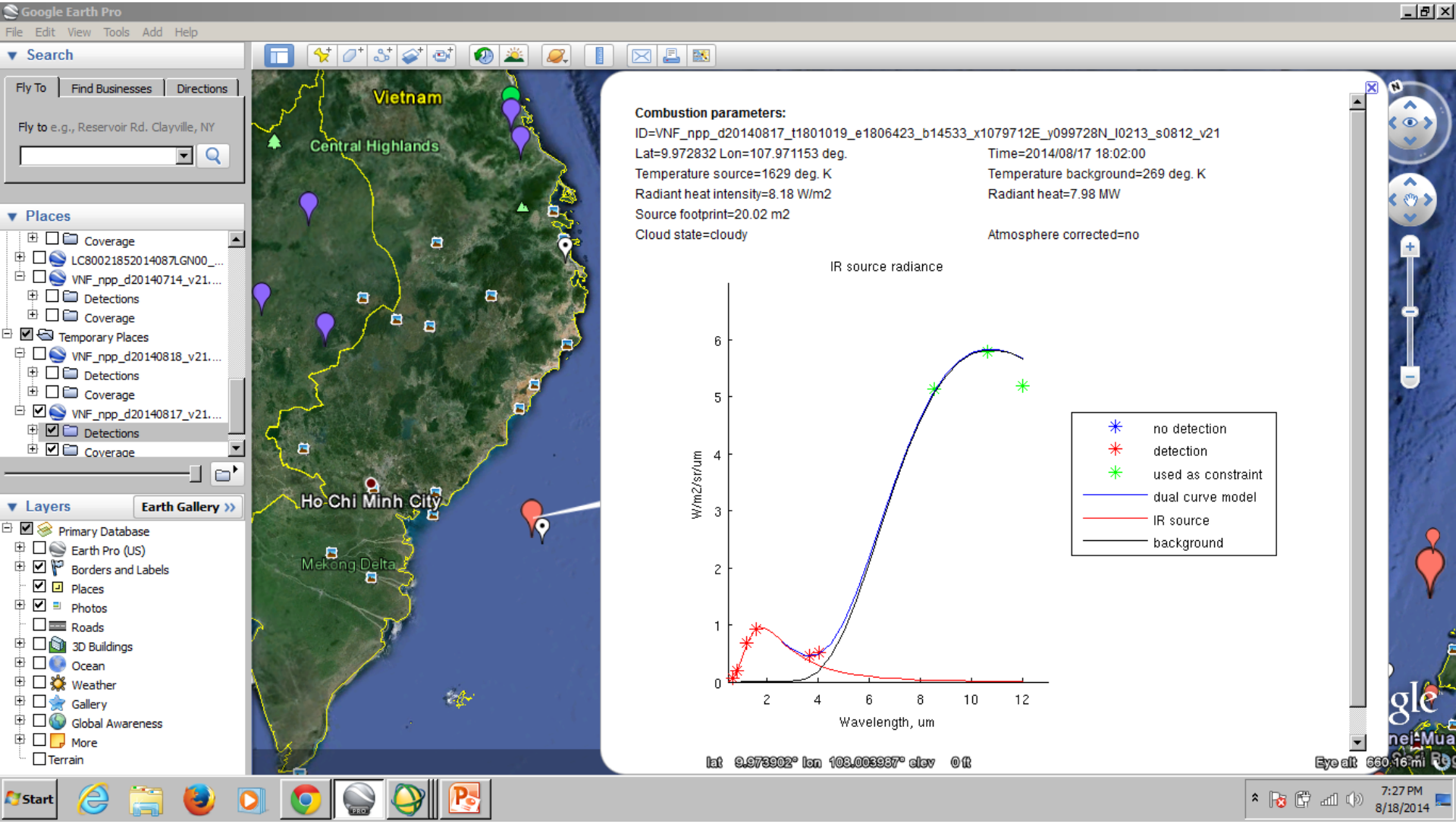


VIIRS DNB boat detections – August 17, 2014

NGDC's VIIRS DNB Composite – May, 2014



VIIRS Nightfire



Water Disasters

- Flooding (inundation)
  - Heavy precipitation with insufficient drainage
  - Coastal storm surge
  - Coastal tsunami
  - Dam and levee failures
- Drought
  - Insufficient precipitation

Basic remote sensing observables related to flooding and drought

- Inundation mapping with optical and radar sensors
- Typhoon movement, wind speed, temperature
- Rain rates from thermal and microwave sensors
- Response of land surface to drought
- Damage assessment with high spatial resolution imagery

Water Disaster Management Phases Using Remote Sensing Data

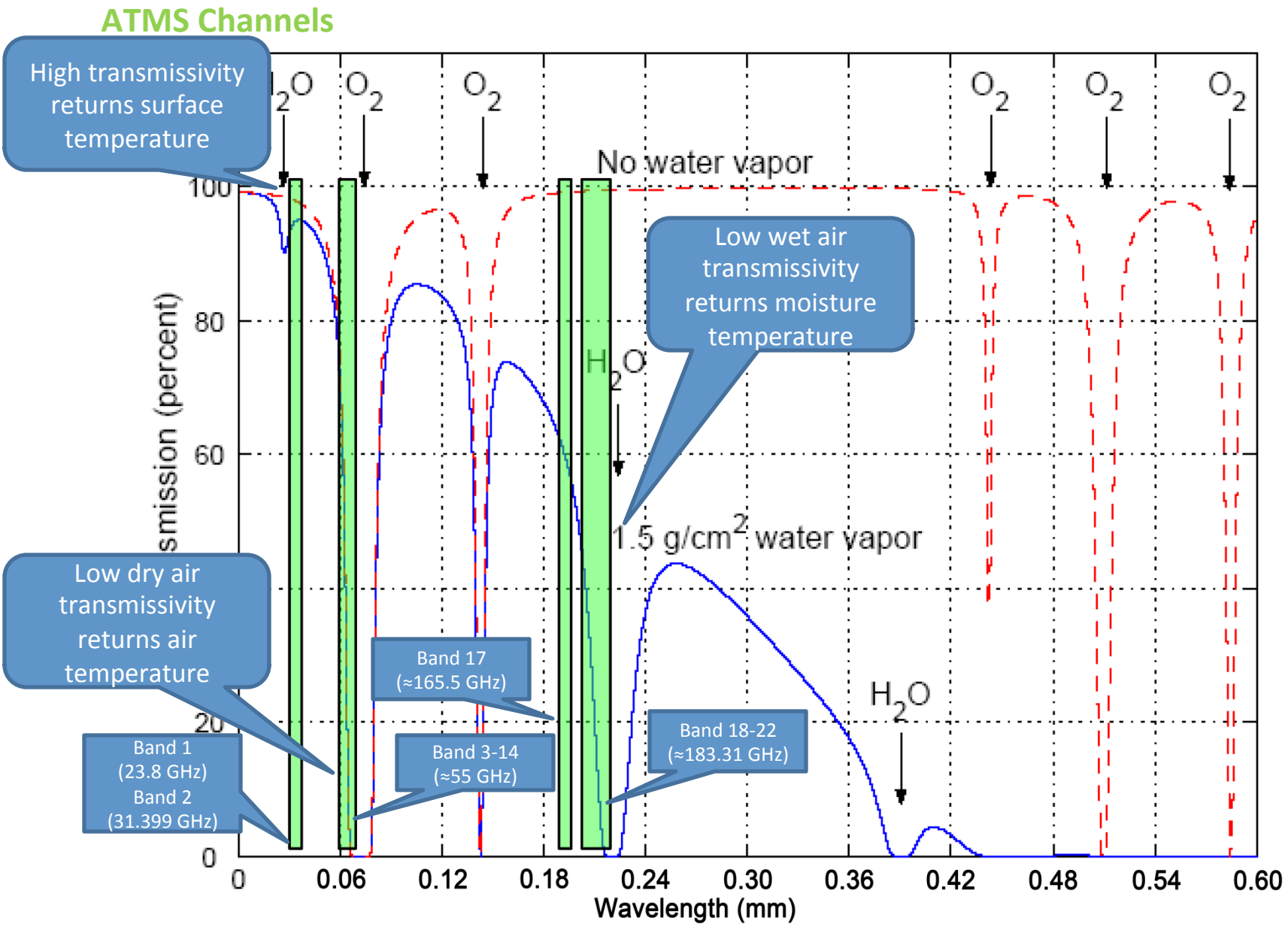
- Prediction and warning
  - Rain rates
  - Storm track and storm surge prediction
  - Generation of digital topographic data
  - Maps of constructed surface densities
- Observation of the severity of disaster events
  - Extent and depth of flooding
  - Extent of drought
  - Affected population
- Damage assessment / Recovery
  - Damage to infrastructure (buildings and roads)
  - Interruption of electric power service
  - Damage to crops

Microwave Rain Rates

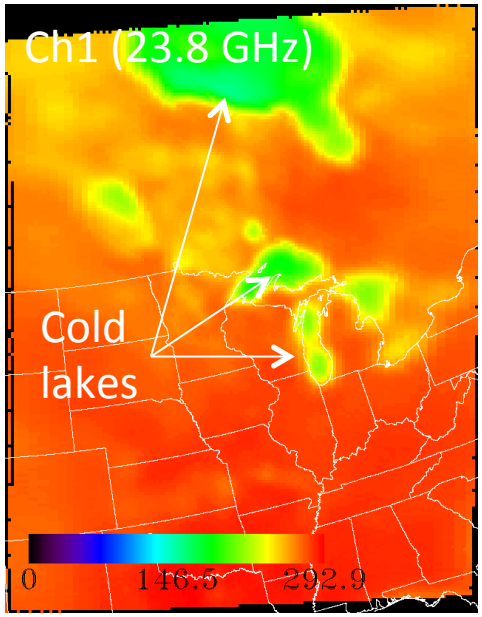
- The earth surface radiates microwave energy.
- Rain rates are estimated by measuring the absorption of certain microwave frequencies. See-to-the-ground frequencies are used as reference.
- Current satellites do not provide continuous global monitoring of rain rates by microwave sensing, but provide a sampling, with multiple observations of most areas each day.

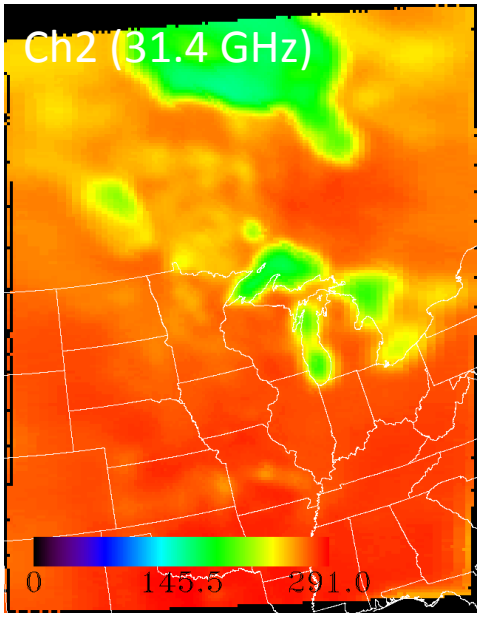
Atmospheric Transmission at Microwave Wavelengths

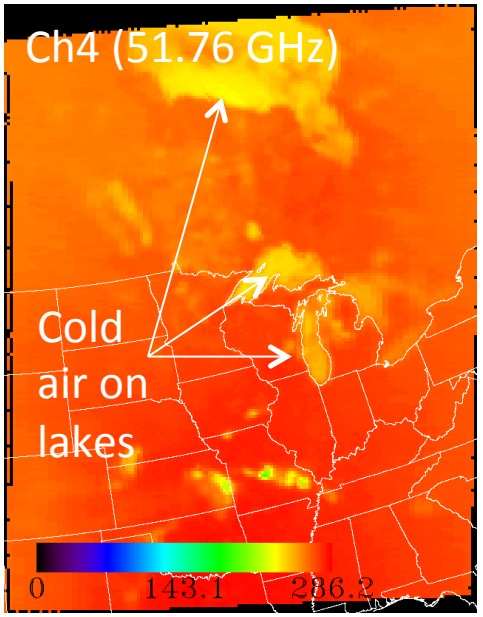
Dry air versus air with water vapor (missing liquid water spectrum)

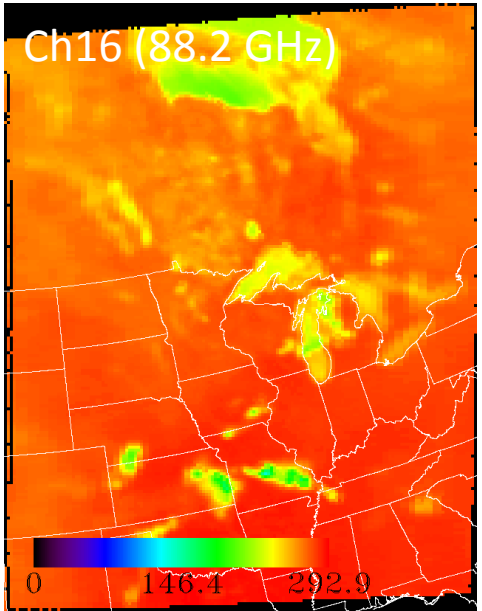


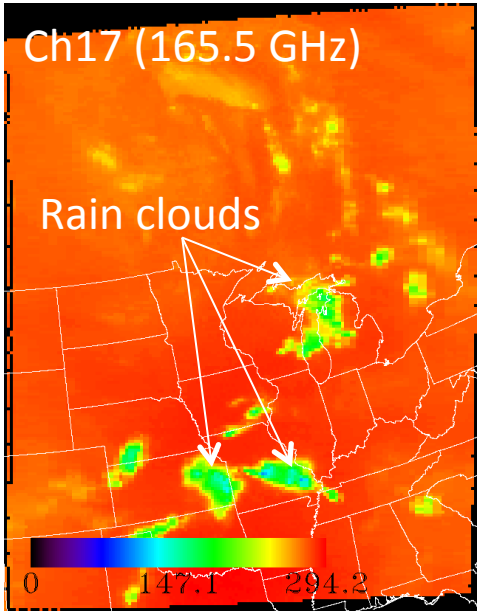
SNPP ATMS Inter-channel Comparison

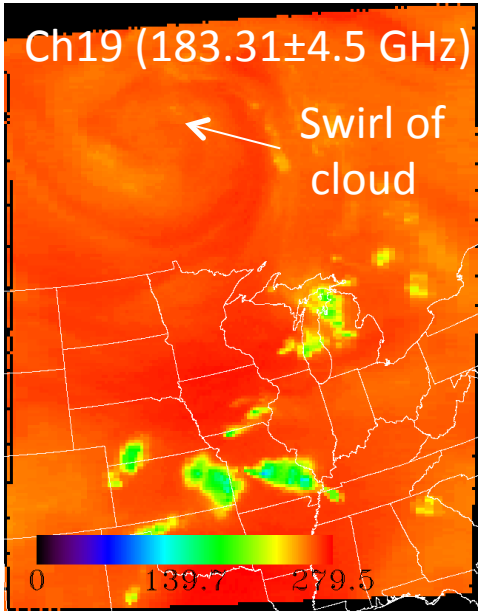




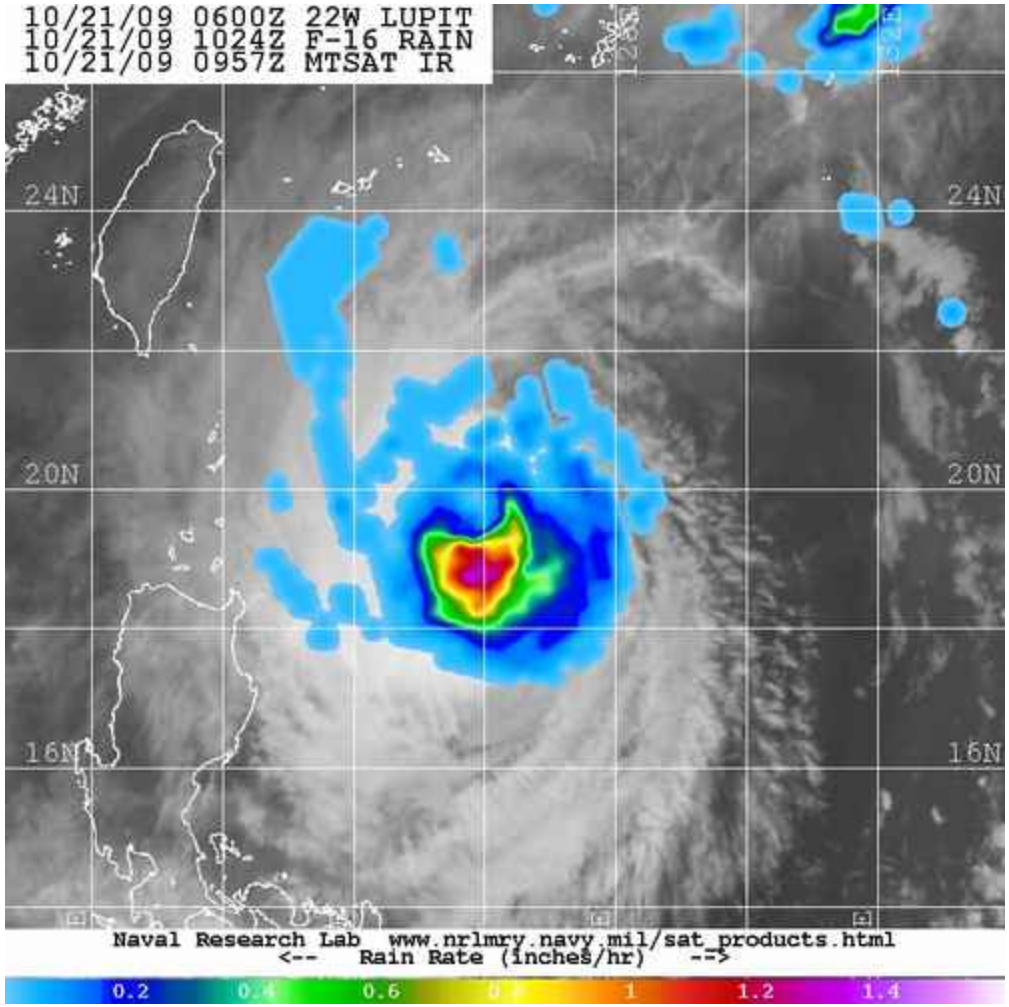






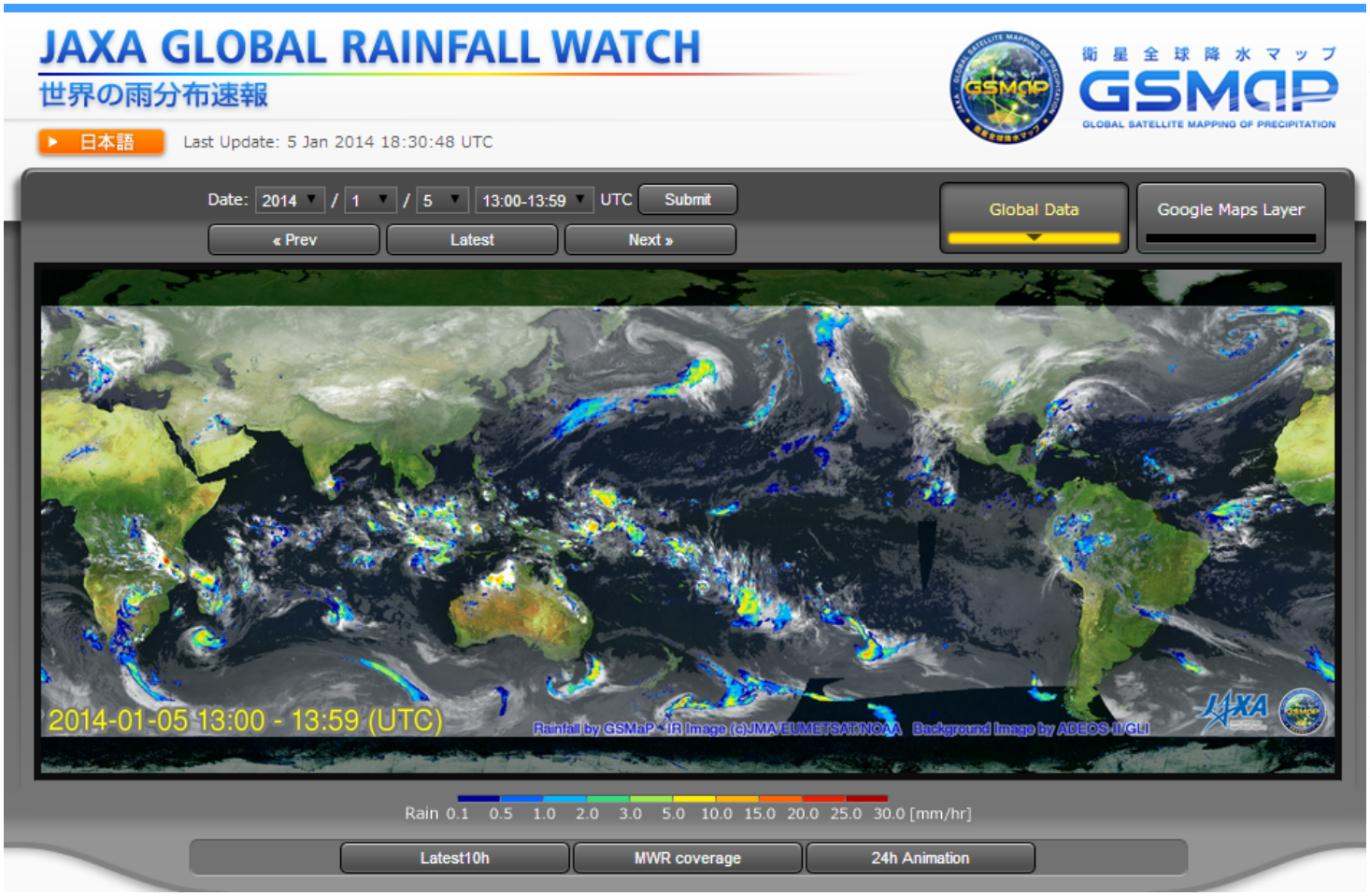


Thermal Infrared Rain Rates



There is a general relationship between cloud top temperature and rain rate.

Best source for satellite rain rates

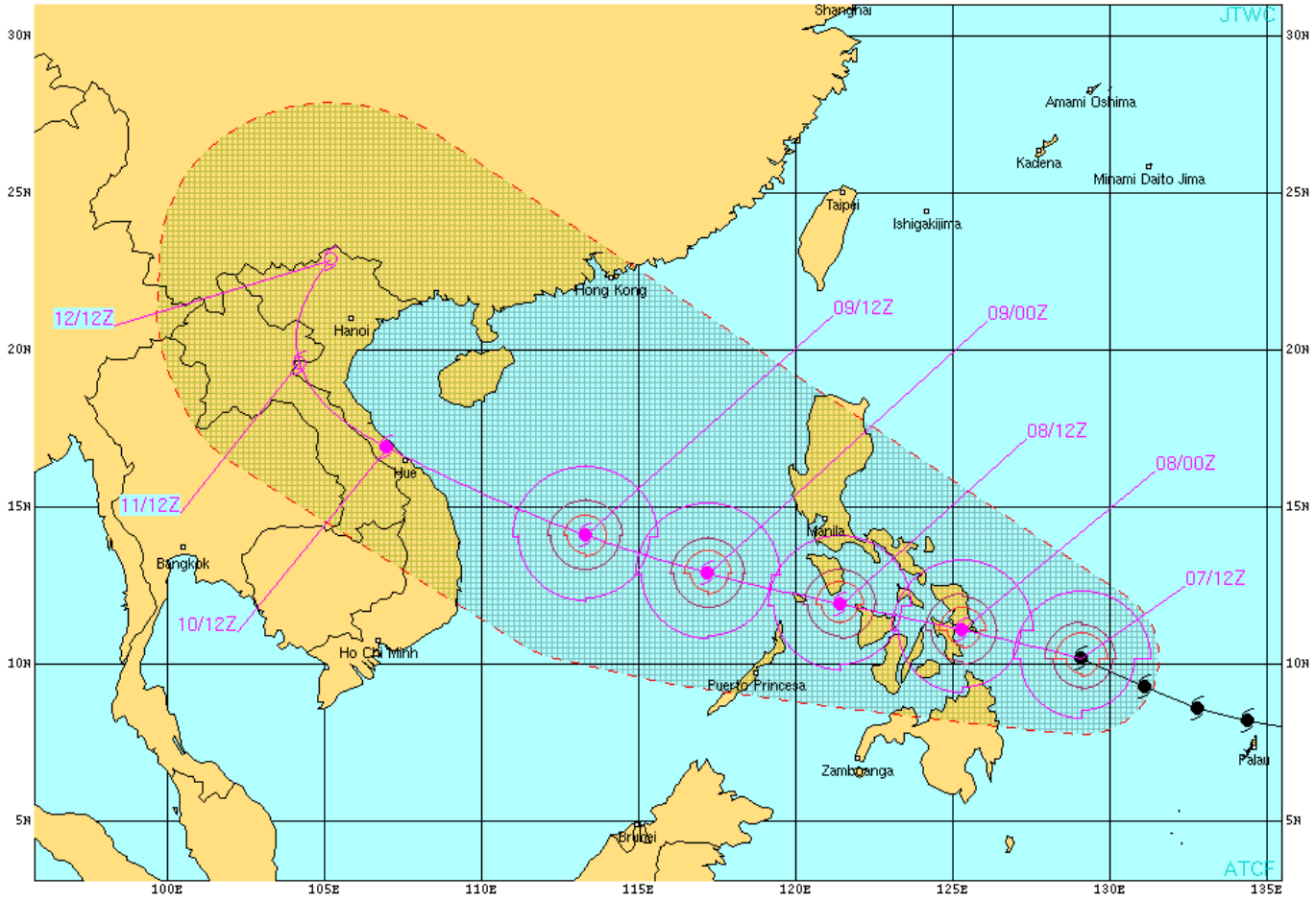


Access to hourly global rainfall maps in near real time (about four hours after observation) using the combined MW-IR algorithm with TRMM TMI, Aqua AMSR-E, GCOM-W1 AMSR2, DMSP SSM/I and SSMIS, NOAA-19 AMSU, MetOp-A AMSU and GEO IR data.

Input into prediction and warning models

- Observation of storms
  - Prediction of storm tracks
  - Rain rates
  - Wind speeds, wind directions
  - Storm surge predictions
- Geostationary weather satellites provide many observations in a day. Repeat cycles range from hours to minutes. MTSAT covers this region. High orbits limit spatial resolution. Poor coverage of polar regions.
- Polar orbiting weather satellites provide data twice daily.
- To reduce temporal latency collect data with local ground station.

Typhoon Haiyan Track Prediction

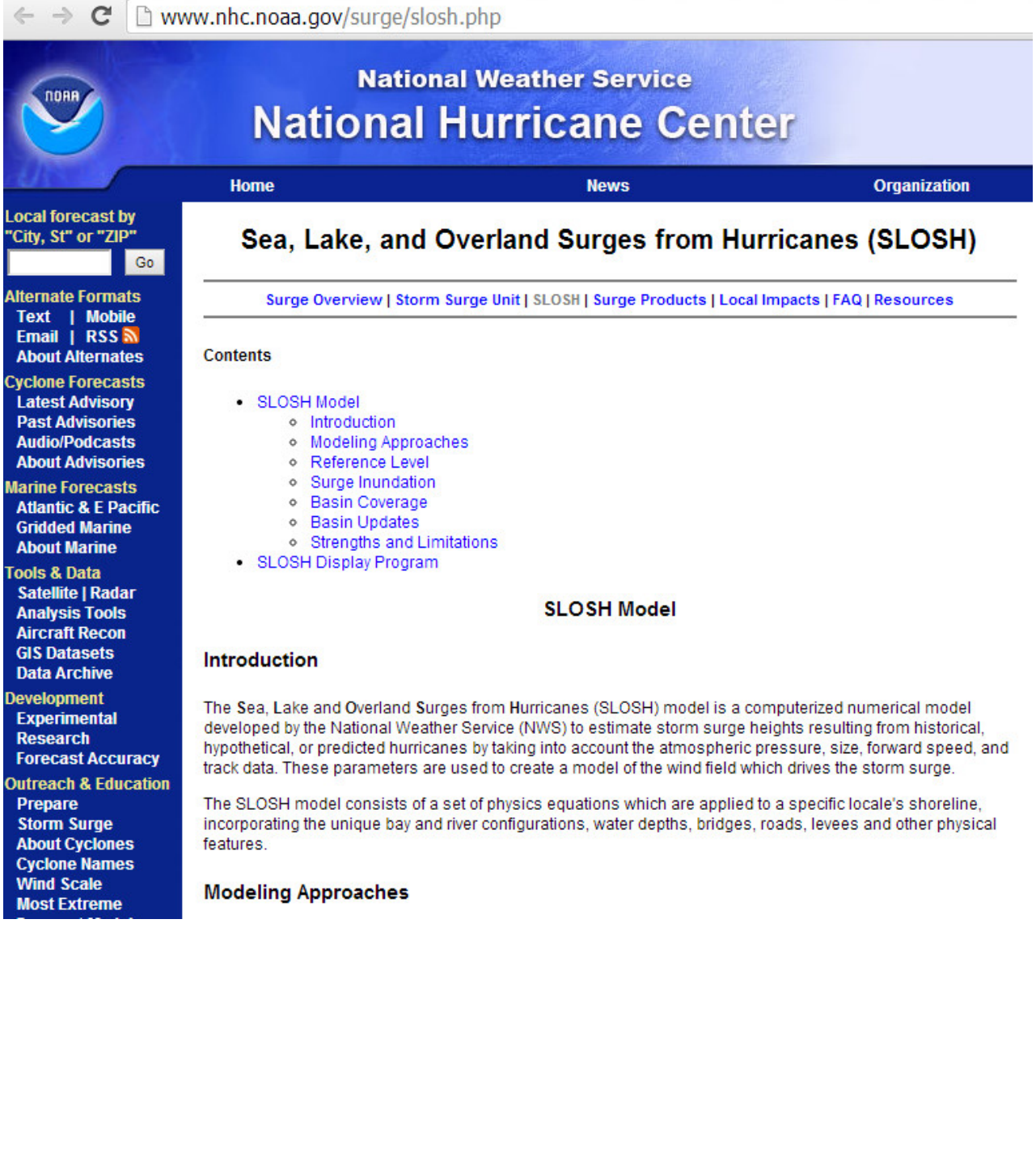


SUPER TYPHOON 31W (HAIYAN) WARNING #18
WTPN33 PGTW 071500
071200Z POSIT: NEAR 10.2N 129.1E
MOVING 295 DEGREES TRUE AT 22 KNOTS
MAXIMUM SIGNIFICANT WAVE HEIGHT: 50 FEET
07/12Z, WINDS 165 KTS, GUSTS TO 200 KTS
08/00Z, WINDS 150 KTS, GUSTS TO 180 KTS
08/12Z, WINDS 130 KTS, GUSTS TO 160 KTS
09/00Z, WINDS 125 KTS, GUSTS TO 150 KTS
09/12Z, WINDS 115 KTS, GUSTS TO 140 KTS
10/12Z, WINDS 090 KTS, GUSTS TO 110 KTS
11/12Z, WINDS 060 KTS, GUSTS TO 075 KTS
12/12Z, WINDS 045 KTS, GUSTS TO 055 KTS

CPA TO:	NM	DTG
ZAMBOANGA	285	08/07Z
MANILA	152	08/15Z
SUBIC_BAY	153	08/17Z
PUERTO_PRINCESA	164	08/18Z
HO_CHI_MINH_CITY	333	10/03Z
DA_NANG	12	10/06Z
HANOI	92	12/03Z

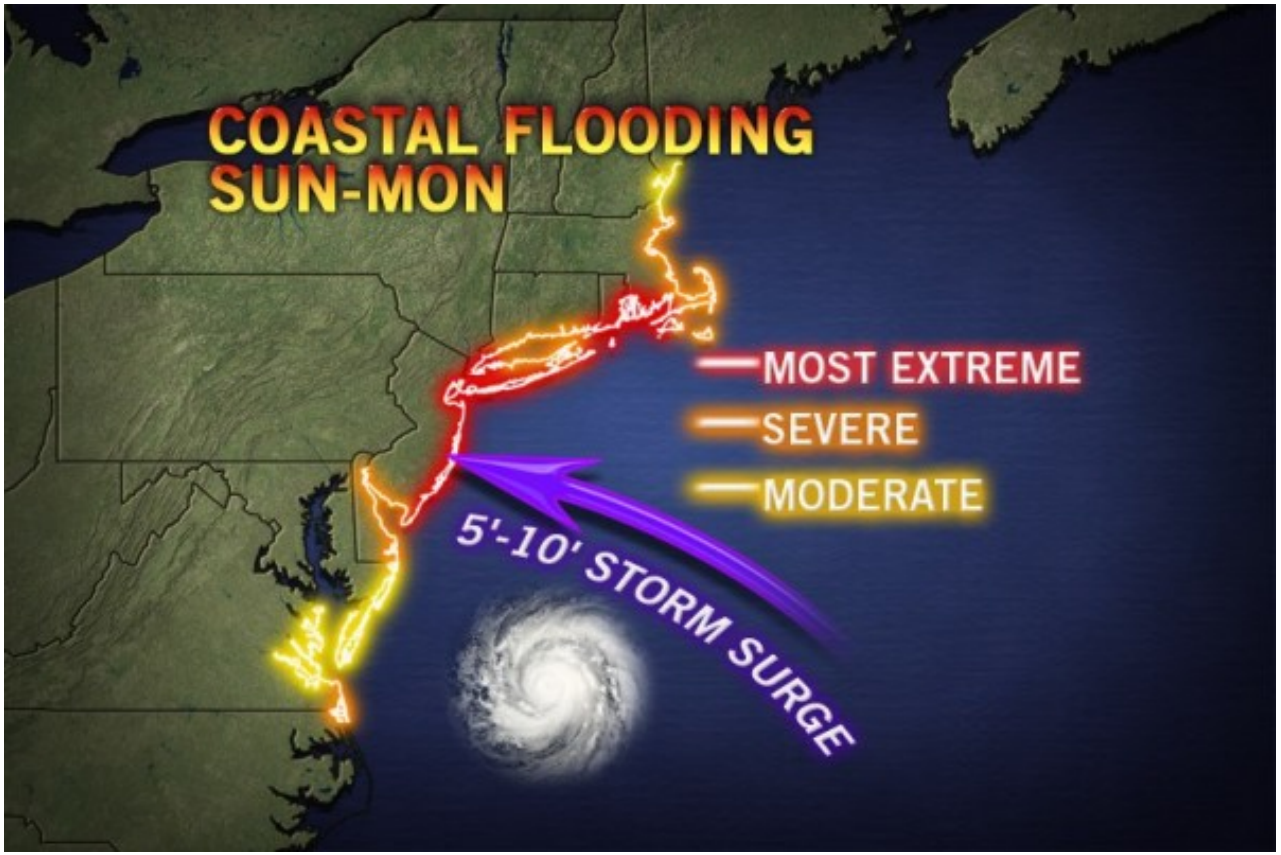
BEARING AND DISTANCE	DIR	DIST (NM)	TAU (HRS)
MANILA	172	164	24
SUBIC_BAY	158	188	24
PUERTO_PRINCESA	050	207	24
ZAMBOANGA	352	303	24

◇ LESS THAN 34 KNOTS
◯ 34-63 KNOTS
● MORE THAN 63 KNOTS
PAST 6 HOURLY CYCLONE POSITS IN BLACK
FORECAST CYCLONE POSITS IN COLOR



Storm Surge Prediction Model

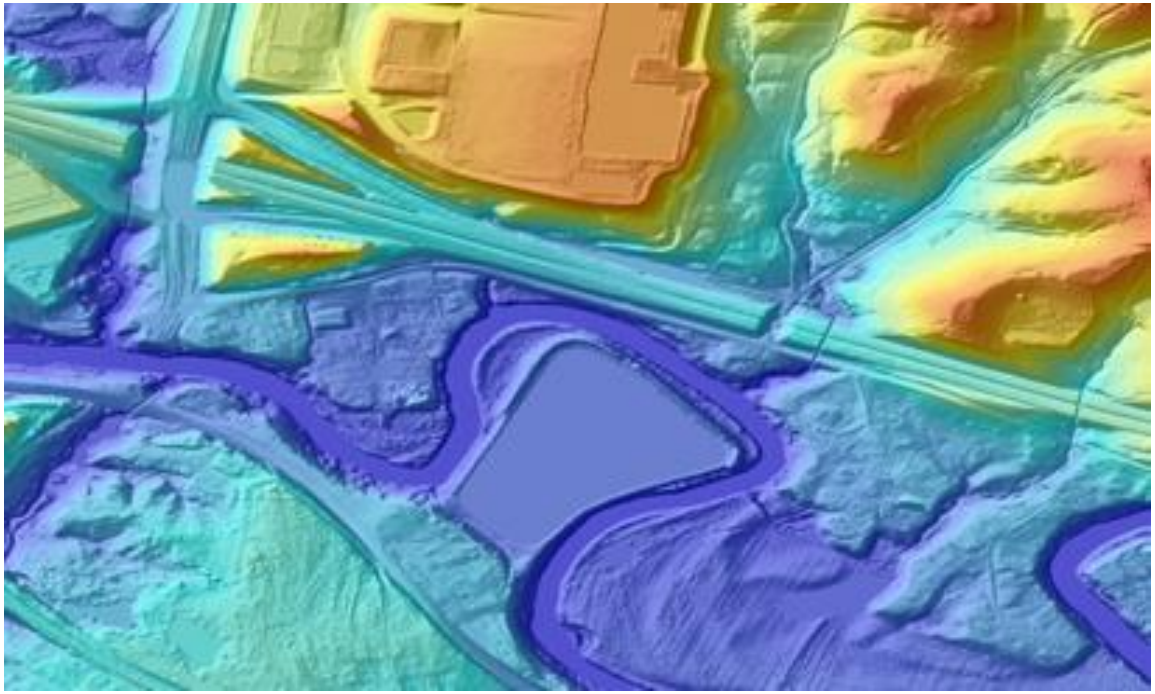
Storm Surge Prediction



In the northern hemisphere storm rotate counterclockwise. Wind drives a bulge in the sea surface. Surge is worst in the right-forward quadrant of the storm.

Input into prediction and warning models

Topographic Data Are Essential For Flood Prediction



LIDAR (light detection and ranging) systems are producing the best topographic data.

Input into prediction and warning models

Constructed Surface Density Grids Are Essential For Flood Prediction in Urban Areas

Impervious Surface areas (pixel value 1)

Non-Impervious Surface areas (pixel value 0) are represented by the white background.

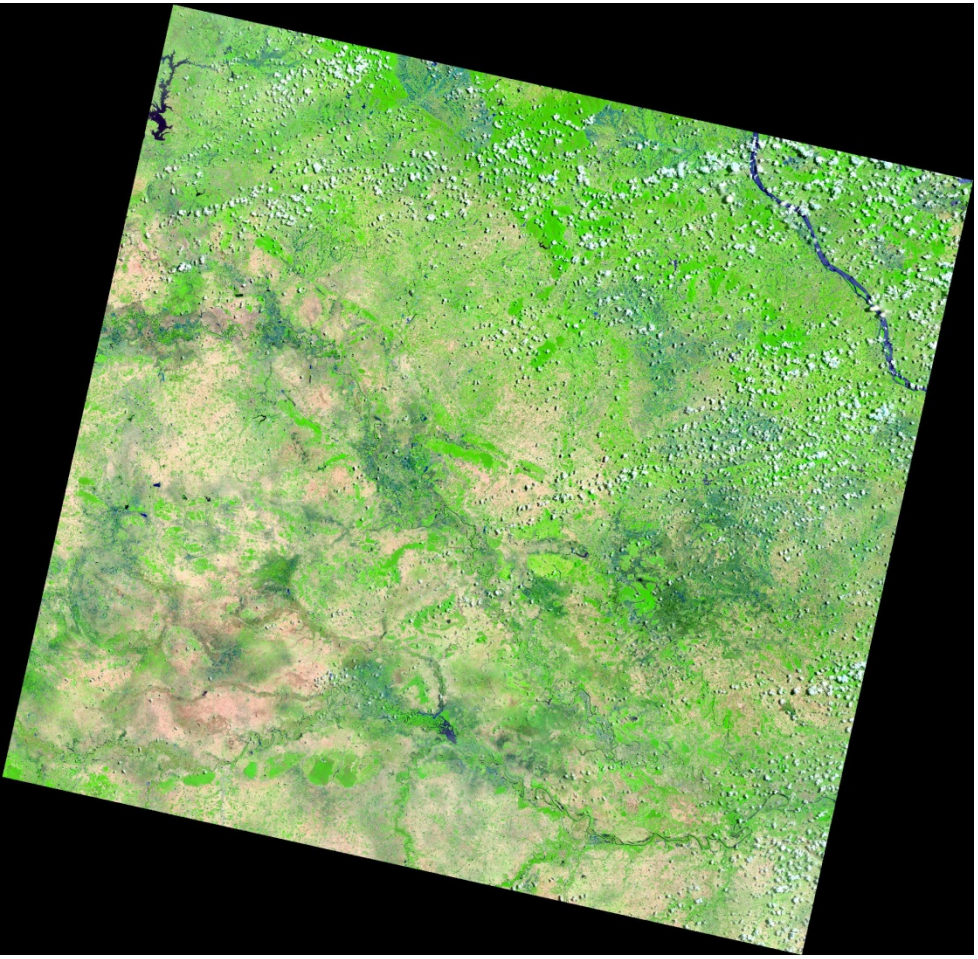
Various techniques are used.

Observation of the severity of disaster events
Observation of Inundation

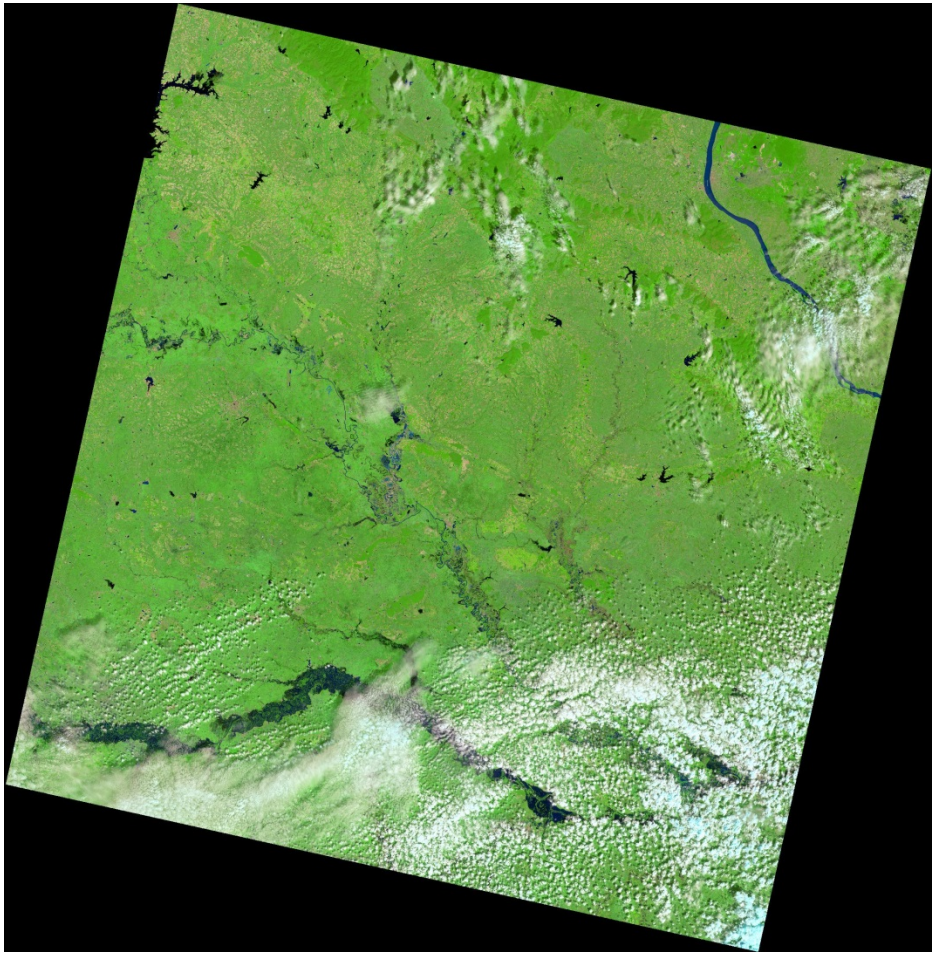
- Low reflectivity of water in optical imagery
  - Even muddy water has low (near zero) reflectivity in near-infrared and short-wave infrared
  - Wide range of sources with varying spatial resolutions. Inverse relationship between spatial resolution and repeat cycle, cost
  - Only works in day
  - Low tolerance to cloud cover

Landsat 8 detection of inundation in Cambodia

June 9, 2013



October 31, 2013



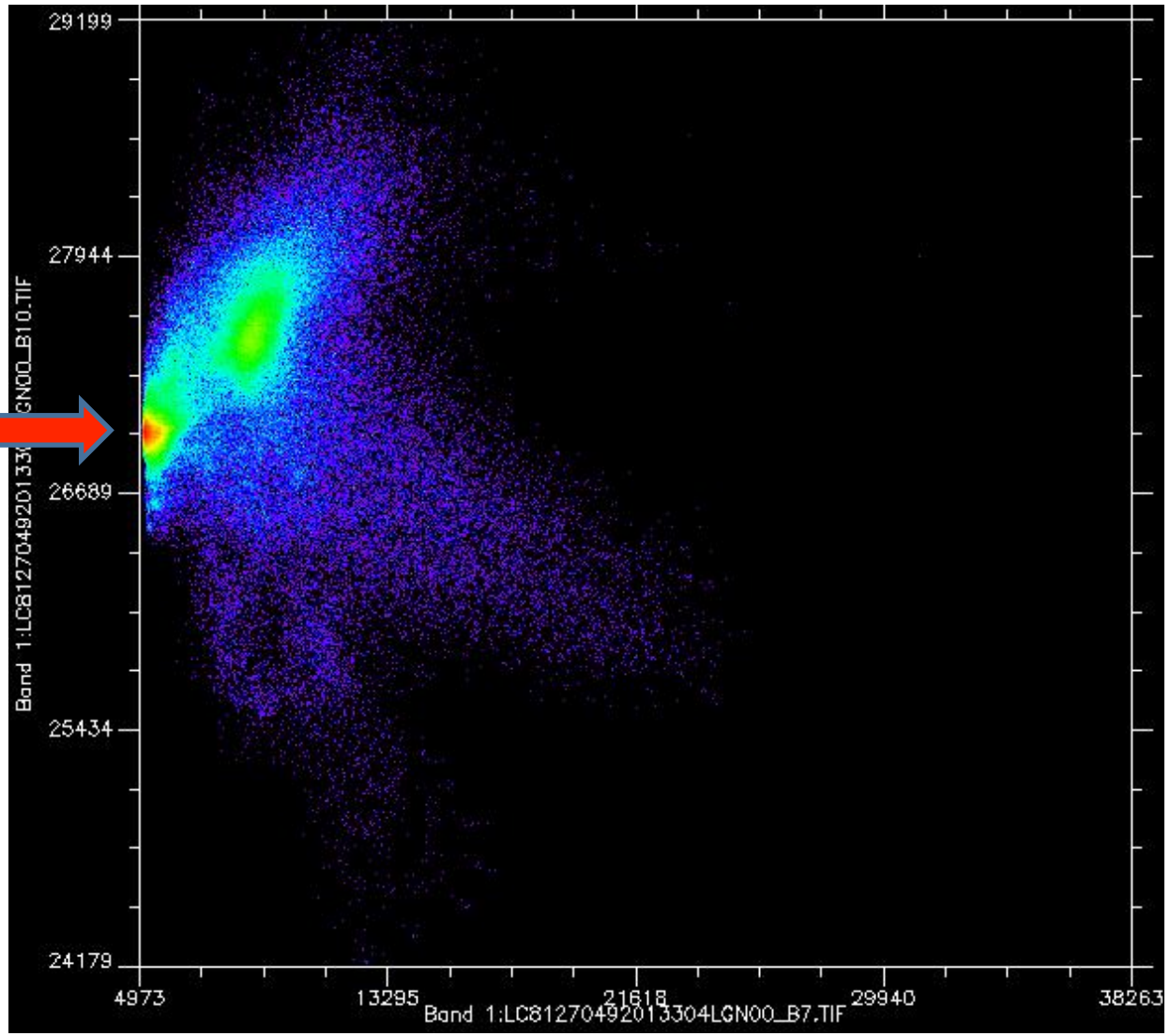
Landsat 8 detection of inundation in Cambodia

June 9, 2013

October 31, 2013

Scattergram B7 vs B10

Open water



Landsat 8 detection of inundation in Cambodia

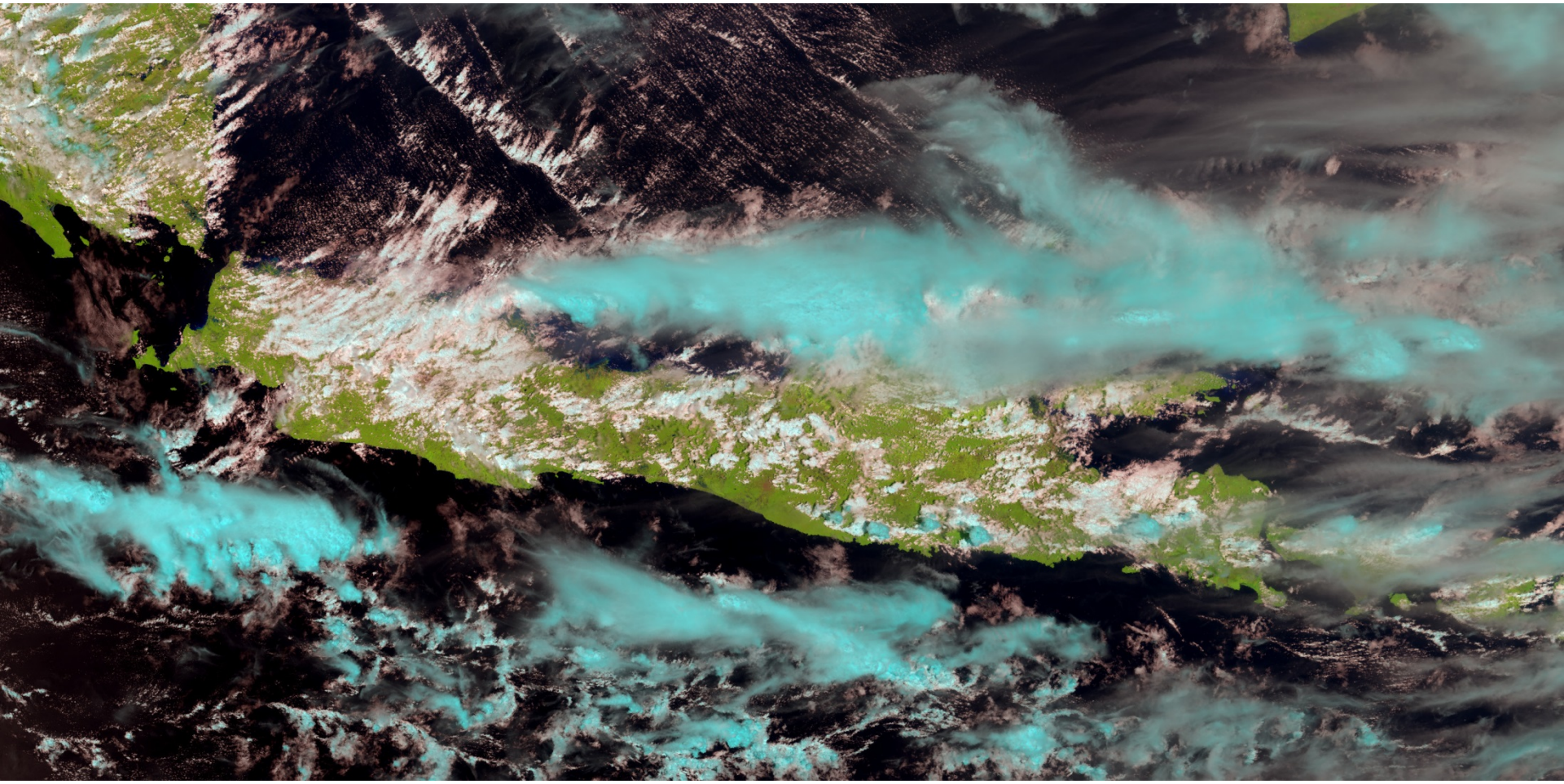
October 31, 2013

Flooded areas identified from
SWIR versus TIR scattergram

Flooded areas and cloud shadows are dark in SWIR
Thermal is used to distinguish flooded areas from cloud shadows

Java image from VIIRS Jan. 22, 2014

http://ngdc.noaa.gov/eog/viirs/download_indonesia.html

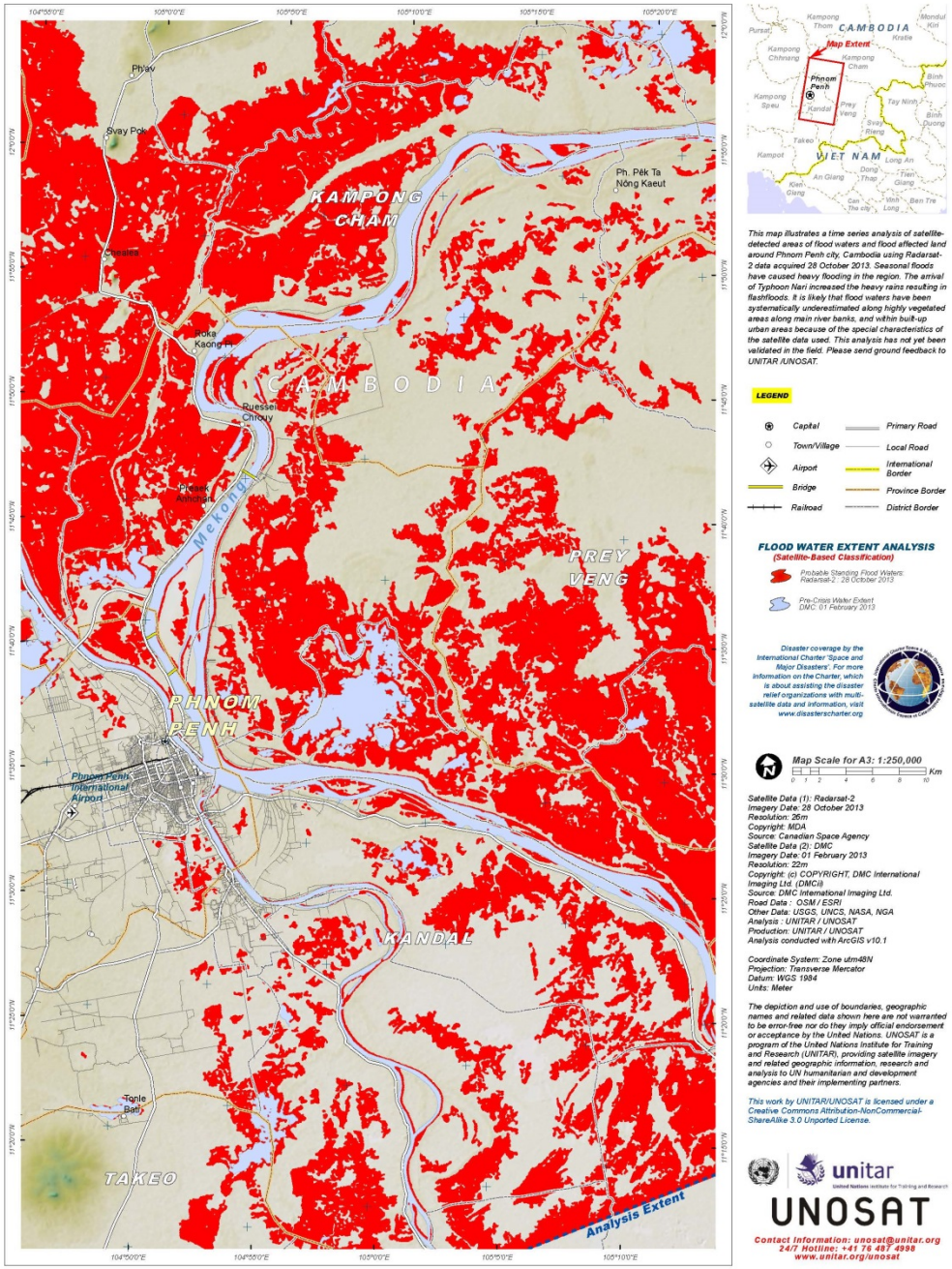


Imaging spectral bands provide 400 meter resolution data

RADAR detection of flooding

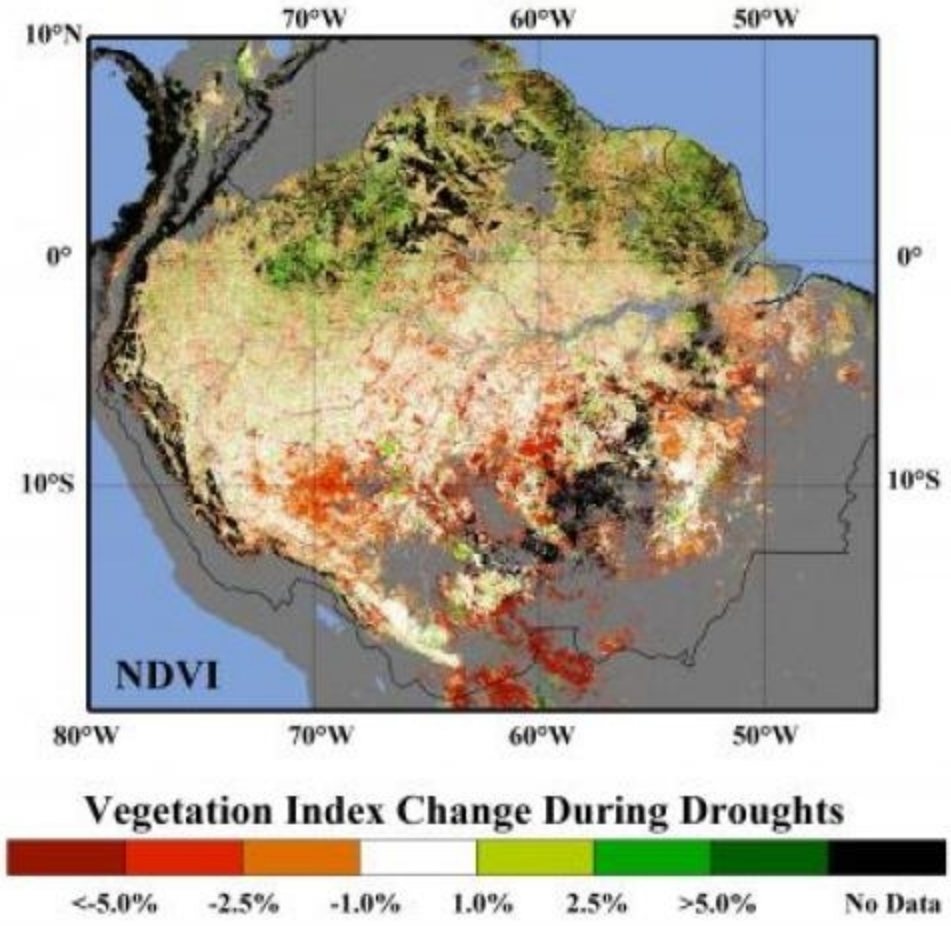
RADARSAT-2 June 22, 2013 13:56 UTC, Wide 1

- Low backscatter of water in radar imagery
  - Water covered areas are dark
  - Primarily from commercial sources
  - Radar works day or night in all weather conditions



Radarsat map of Cambodia flooding

Observation of the severity of disaster events
Drought

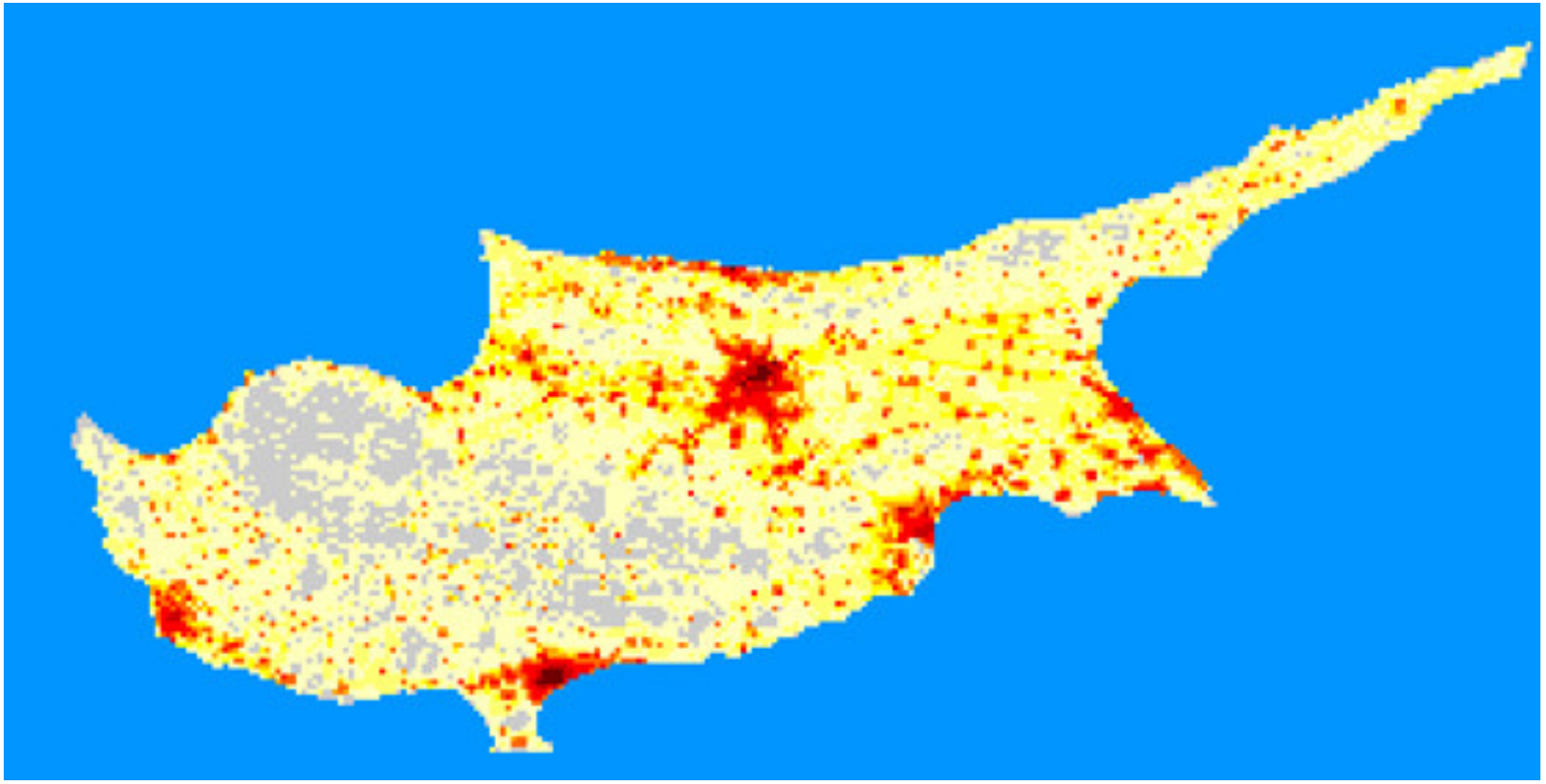


- Prediction based on rain rates and surface temperature patterns
- Severity measured with NIR/red vegetation index declines

Observation of the severity of disaster events

Affected Population

- Overlay affected area with population grid

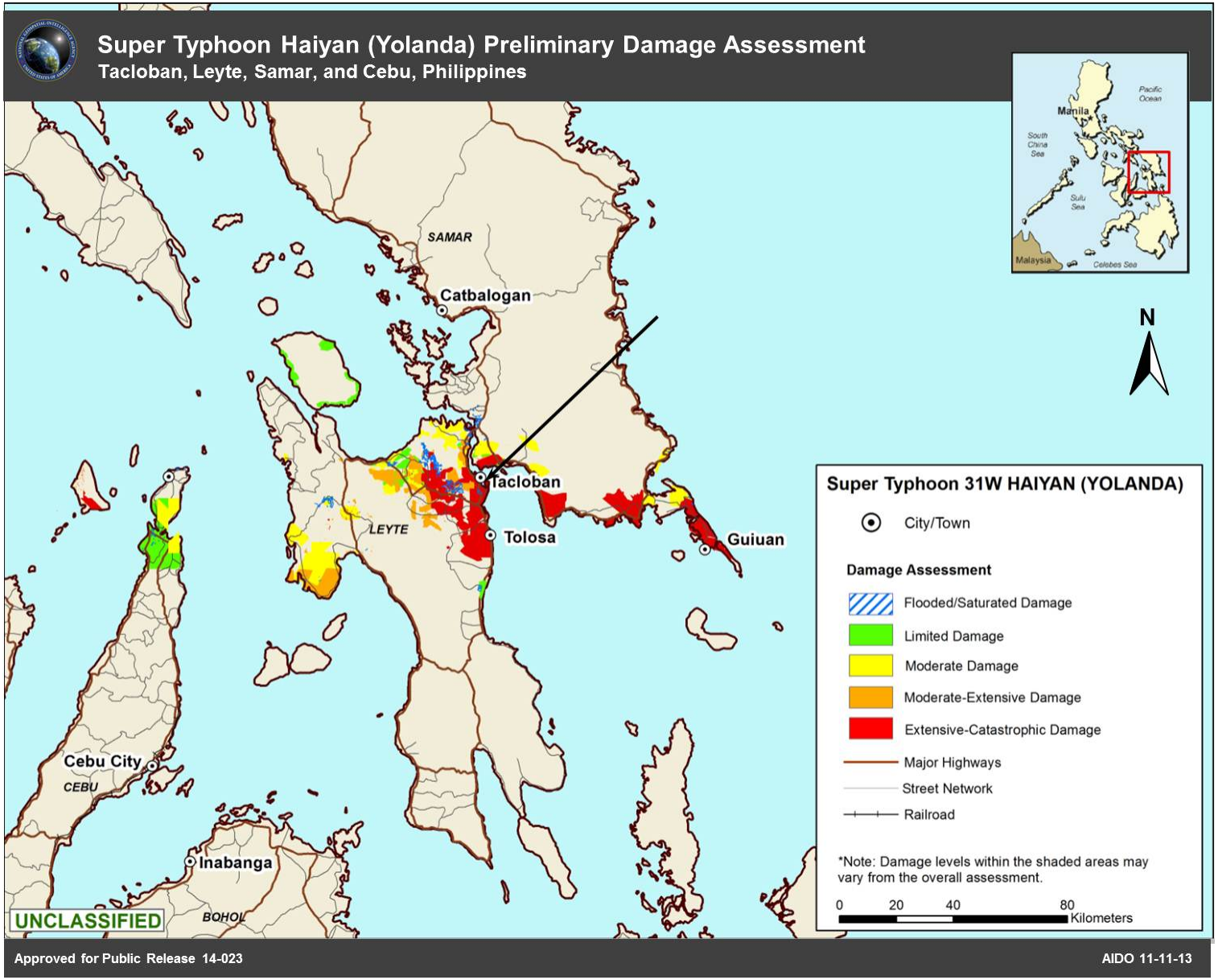


U.S. Department of Energy Landscan population count grid

Damage assessment

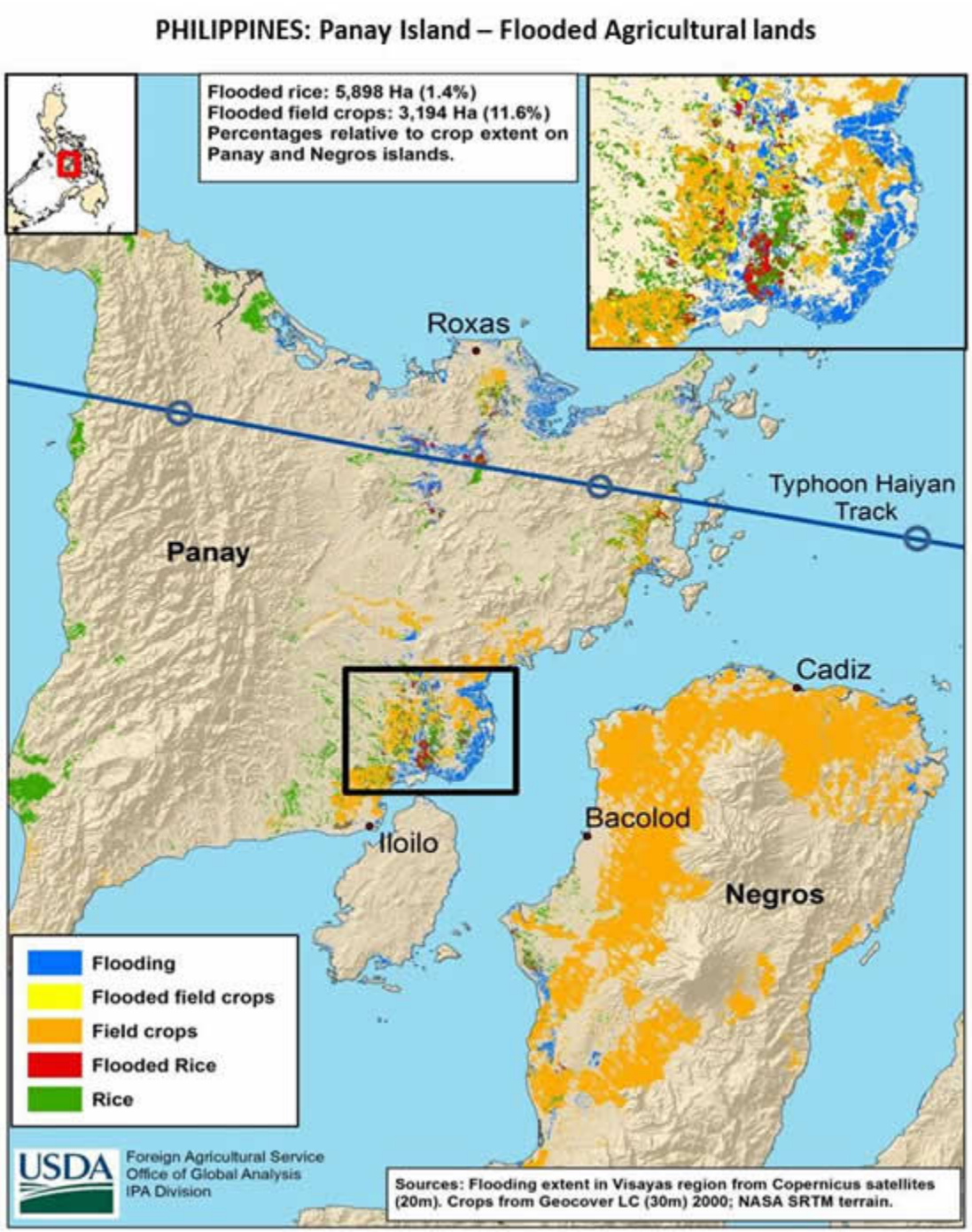
Visual assessment using high spatial resolution imagery from commercial providers. Problems with cloud obscuration and small image coverage areas.

Damage assessment

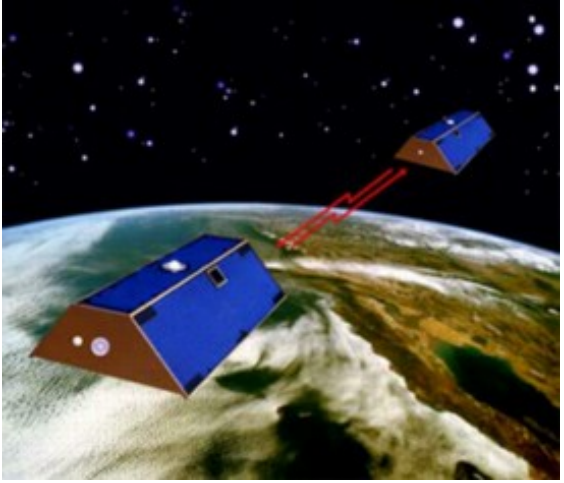


Crop damage assessment

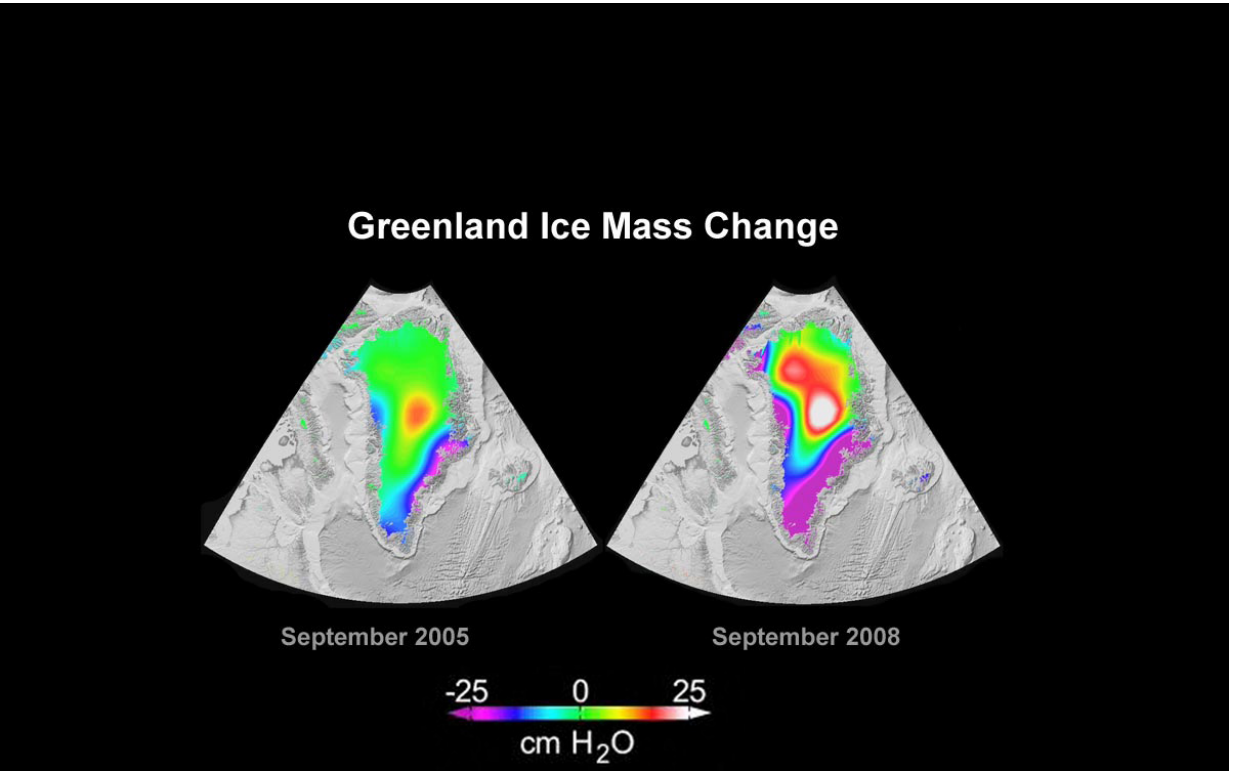
The satellite images is displayed in a manner (false color infrared) which portrays vegetation as a range of red colors. Humans can distinguish more variations of the color red than any other, and thus falsecolor infrared imagery is especially useful to agricultural analysts by highlighting subtle differences in crop conditions. The sample images provided here (above and below) were annotated to show examples a few of the discernable characteristics which are widely evident in various areas throughout the images (H=harvested; E=emerging; M=maturing; C=cultivated; D=damaged; N=non-crop vegetation).



Crop damage assessment

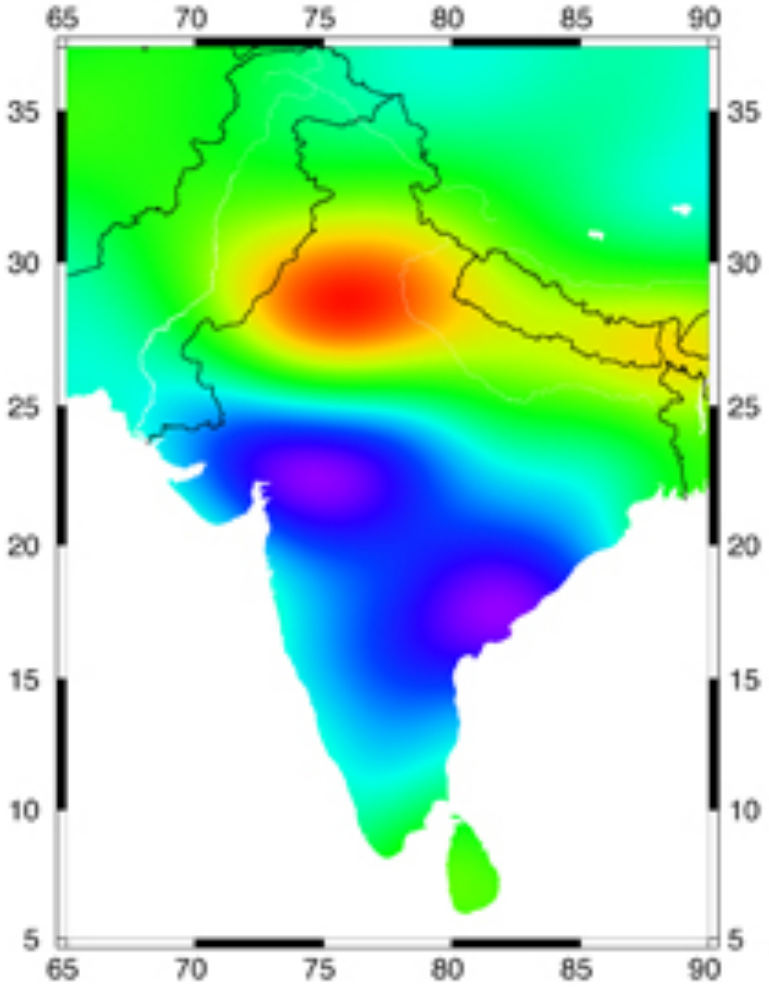


Gravity Recovery and Climate Experiment (GRACE) NASA/JPL and the German Aerospace Center

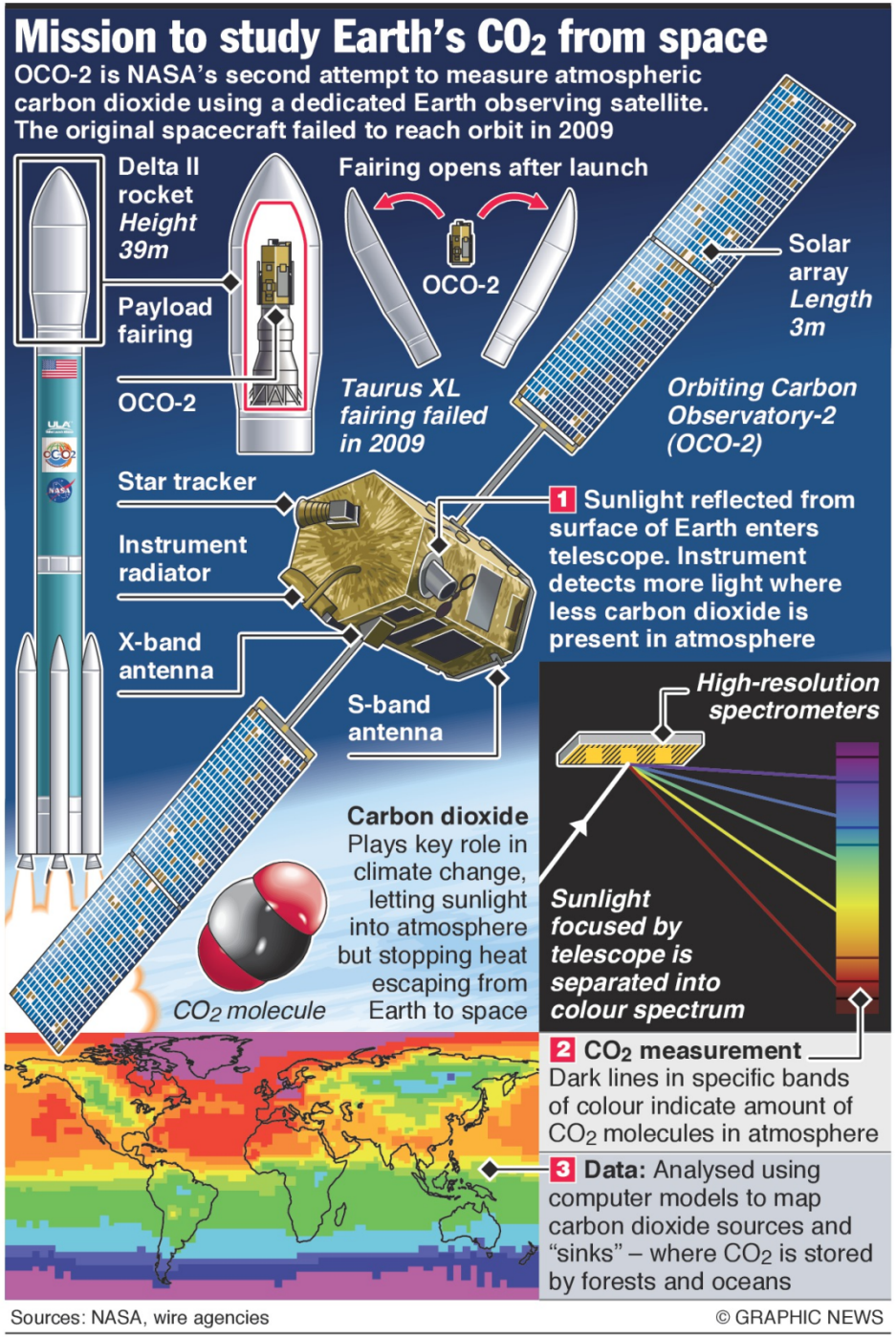


GRACE, twin satellites launched in March 2002, are making detailed measurements of Earth's gravity field which will lead to discoveries about gravity and Earth's natural systems. These discoveries could have far-reaching benefits to society and the world's population.

GRACE Observation of groundwater



The map shows groundwater changes in India during 2002-08, with losses in red and gains in blue, based on GRACE satellite observations. The estimated rate of depletion of groundwater in northwestern India is 4.0 centimeters of water per year, equivalent to a water table decline of 33 centimeters per year. Increases in groundwater in southern India are due to recent above-average rainfall, whereas rain in northwestern India was close to normal during the study period. **Credit:** I. Velicogna/UC Irvine



NASA/JPL Orbital Carbon Observatory (OCO-2) is designed to provide global data on atmospheric carbon dioxide levels at spatial resolutions suitable for regional source / sink analyses.

Summary

- A wide range of remote sensing systems collect data over the Lower Mekong region.
- Meteorological satellite data – geostationary and polar
  - Rain rates, storm track predictions, surge predictions, drought predictions
  - Flooding (limited to daytime / cloud free observations)
  - Drought losses in green vegetation
- Moderate resolution satellite data (e.g. Landsat 8)
  - Flooding
  - Damage assessment of crops
  - Density of constructed surfaces
- High spatial resolution remote sensing data
  - Damage assessment for infrastructure and crops
  - Generation of topographic data
  - Density of constructed surfaces
- Specialized sensors provide unique data: GRACE, OCO-2, VIIRS DNB.