NASA Earth Remote Sensing Programs:

An overview with special emphasis on the NASA/JAXA led Global Precipitation Measurement mission

Erich Franz Stocker

Topics to be discussed

- Earth science research within the NASA organization
- Introduction to current NASA Earth science objectives
- Key operating Earth science missions
- Key planned or developing Earth science missions
- Examples of types of data collected by existing missions
- Tropical Rainfall Measuring Mission data
- Overview of Global Precipitation Measurement mission
- Summary

NASA Mission Organization

- **NASA is organized into 4 major organizational directorates which support its responsibilities as a federal agency**
  - Aeronautics research
    - Enable a safer, more secure, efficient, and environmentally friendly air transportation system.
  - Exploration systems
    - Direct the identification, development, and validation of exploration systems and technologies.
  - Science
    - Exploring the Earth-Sun system, our own solar system, and the universe beyond.
  - Space operations
    - Extend the duration and boundaries of human space flight to create new opportunities for exploration and discovery.
- **Earth science research comes under the Science directorate**

Science Directorate Organization

- **Science directorate is organized around 4 broad scientific areas of research**
  - Earth
    - Study the earth from space to advance scientific understanding and meet societal needs
  - Heliophysics
    - Study the Sun and its effects on the Earth and solar systems
  - Planets
    - Advance scientific knowledge of the origin and history of the solar system, the potential of life elsewhere and the hazards and resources present as humans explore space
  - Astrophysics
    - Discover the origin, structure, evolution and destiny of the universe, and search for Earth-like planets
- **Obviously Earth science research comes under the Earth area of research**
  - Goddard Space Flight Center is the lead NASA center for Earth science research and Earth missions

Earth Science Focus Areas

- **Atmospheric Composition**
  - Atmospheric Composition is focused on the composition of Earth's atmosphere in relation to climate prediction, solar effects, ground emissions and time.
- **Weather**
  - Our weather system includes the dynamics of the atmosphere and its interaction with the oceans and land. The improvement of our understanding of weather processes and phenomena is crucial in gaining an understanding of the Earth system.
- **Carbon Cycle and Ecosystems**
  - This Focus Area deals with the cycling of carbon in reservoirs and ecosystems as it changes naturally, is changed by humans, and is affected by climate change.
- **Water and Energy Cycles**
  - Through water and energy cycle research we can improve hurricane prediction, quantify tropical rainfall and eventually begin to balance the water budget at global and regional scales.
- **Climate Variability and Change**
  - NASA's role in climate variability study is centered around providing the global scale observational data sets on oceans and ice, their forcings, and the interactions with the entire Earth system.
- **Earth Surface and Interior**
  - The goal of the Earth Surface and Interior focus area is to assess, mitigate and forecast the natural hazards that affect society, including earthquakes, landslides, coastal and interior erosion, floods and volcanic eruptions.

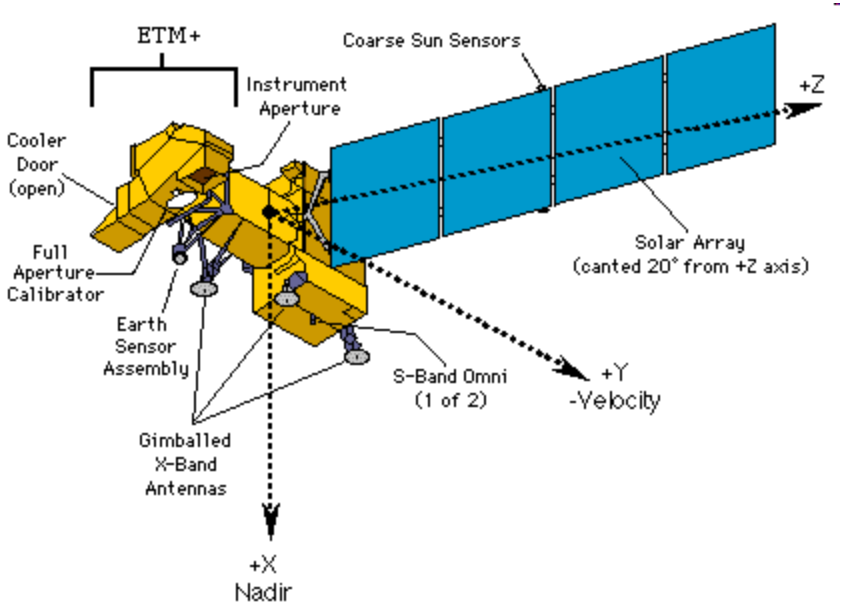
Key NASA Operating Earth Science Missions

Name	Launch Date	Purpose
Aqua	5/4/2002	Collect global data about the earth water cycle
Aura	7/15/2004	Collect data on Atmospheric trace gases
CALIPSO	7/15/2004	Provide information about clouds and aerosols
GOES I-M	4/13/1994	Operational weather monitoring and forecast
GRACE	3/17/2002	Map variations in the Earth gravity field
Landsat 7	4/15/1999	Provide well calibrated, cloud-free Earth continental and coast region images
NOAA-N	5/20/2005	Provide environmental monitoring information
SeaWiFS	8/1/1997	Monitor color of the world's oceans
Tera	12/18/1999	provides global data on the state of the atmosphere, land, and oceans, as well as their interactions with solar radiation and with one another
TRMM	11/27/1997	Study precipitation in the Earth's tropical areas

Key NASA Earth Mission in Study and Development

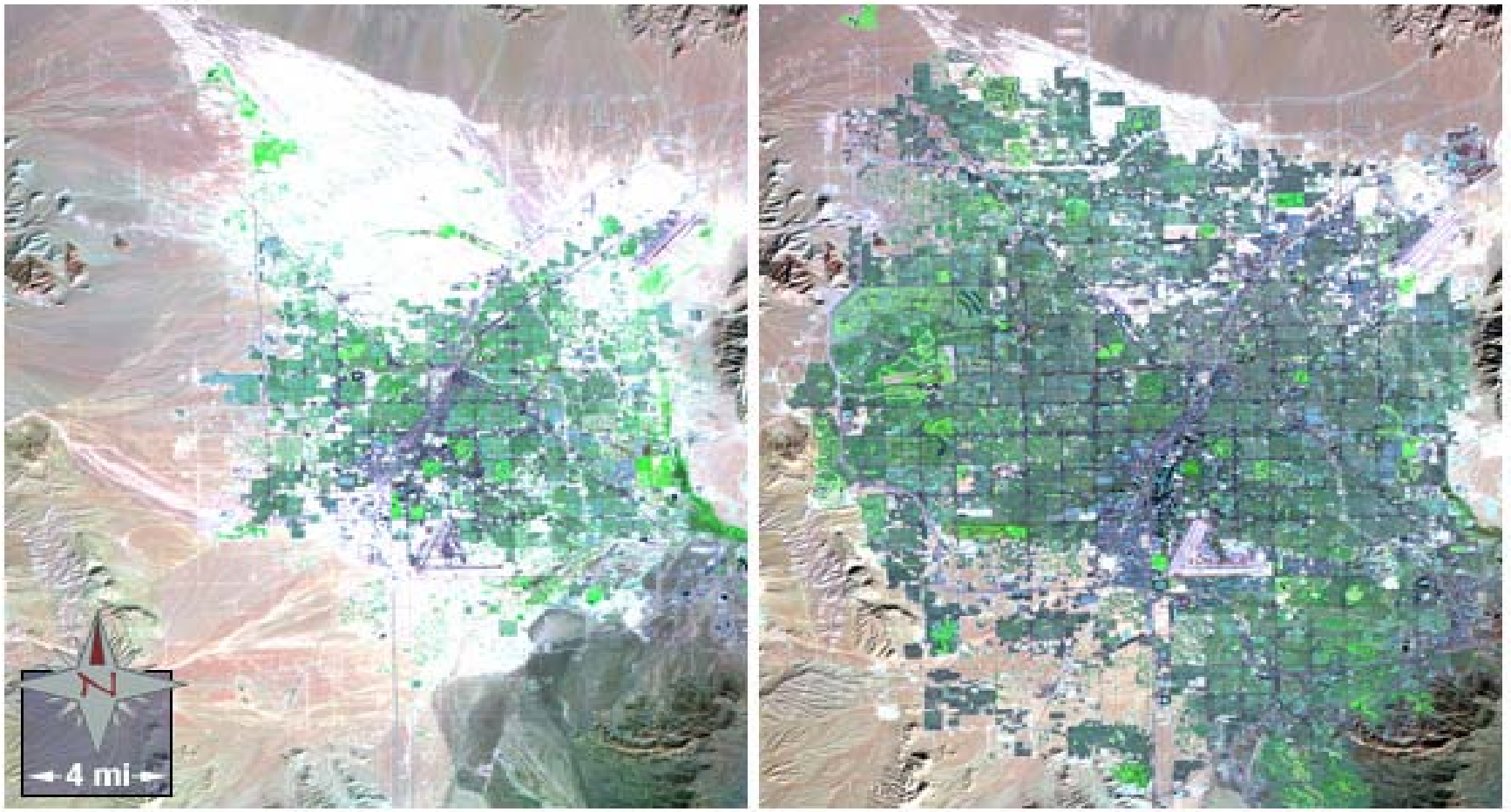
Name	Launch Date	Purpose
Aquarius (develop)	5/22/2010	Global sea-surface salinity measurement
CLARREO (study)	TBD	Climate Absolute Radiance and Refractivity Observatory
DESDynI (study)	TBD	Deformation, Ecosystems Structure and Dynamics of Ice
Glory (develop)	1/23/2010	Measure properties of aerosols and black carbon and solar irradiance
GEOS N-P (develop)	2009	Operational weather monitoring and forecasting
GPM (study)	7/2013	Global Precipitation Measurement mission to study precipitation globally (core and constellations
ICESatII (study)	2015	Ice, cloud and land elevation measurements
LDCM (study)	12/1/2012	Landsat data continuity mission
NPOESS (develop)	3/31/2014	Monitor global environmental conditions in atmosphere, land and oceans
NPP (develop)	1/15/2011	NPOESS Prep-long climate and biological trends
SMAP	1/1/2013	Soil moisture active and passive measurements

Landsat-7



Landsat 7 systematically provides well-calibrated, multispectral, moderate resolution, substantially cloud-free, Sun-lit digital images of the Earth's continental and coastal areas with global coverage on a seasonal basis. It covers the United States every 16 days. Operations were transferred to United States Geological Survey (USGS) in Fall 2000.

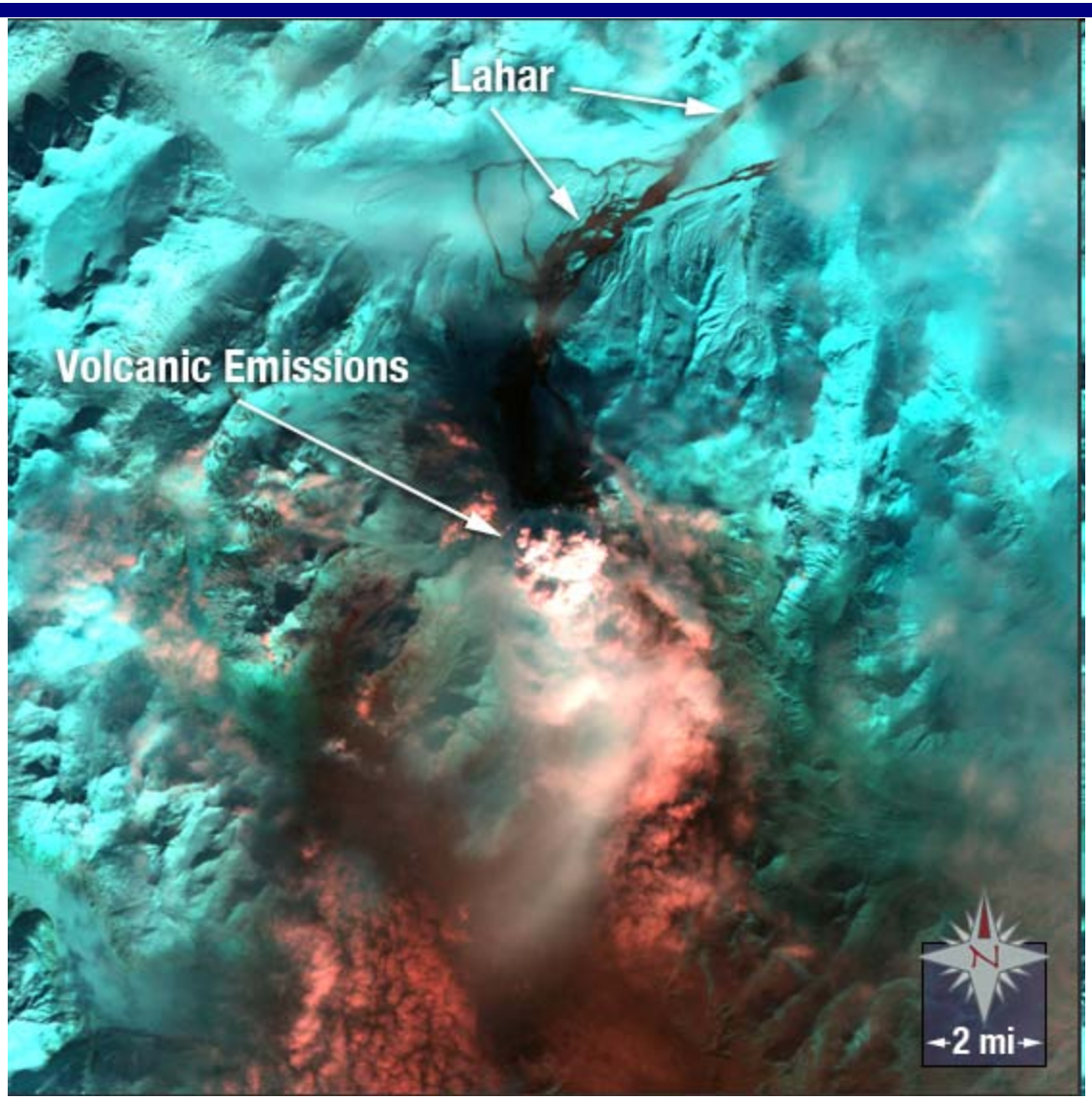
Landsat Images Growth of Las Vegas NV



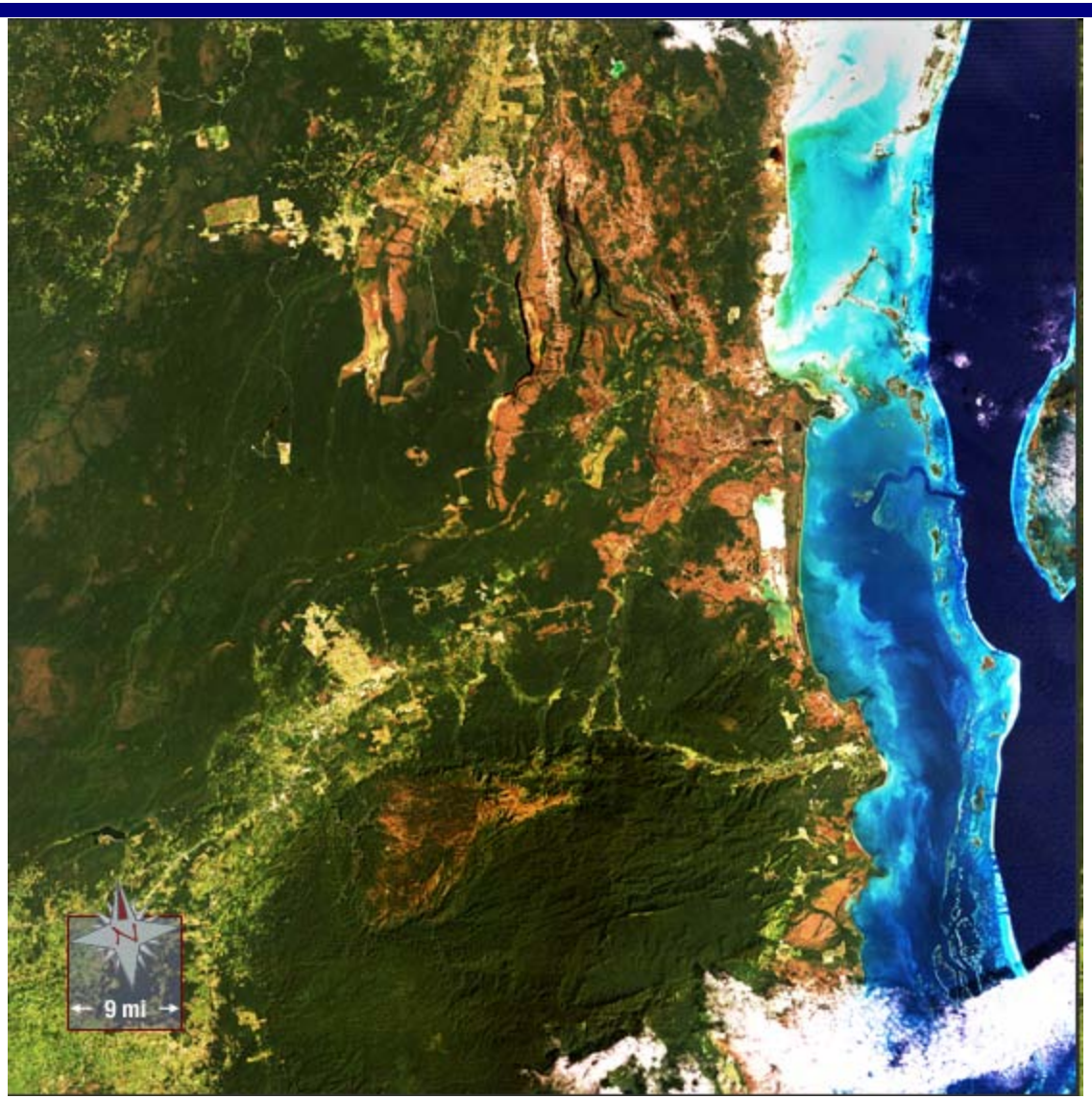
Landsat- 5

Landsat-7

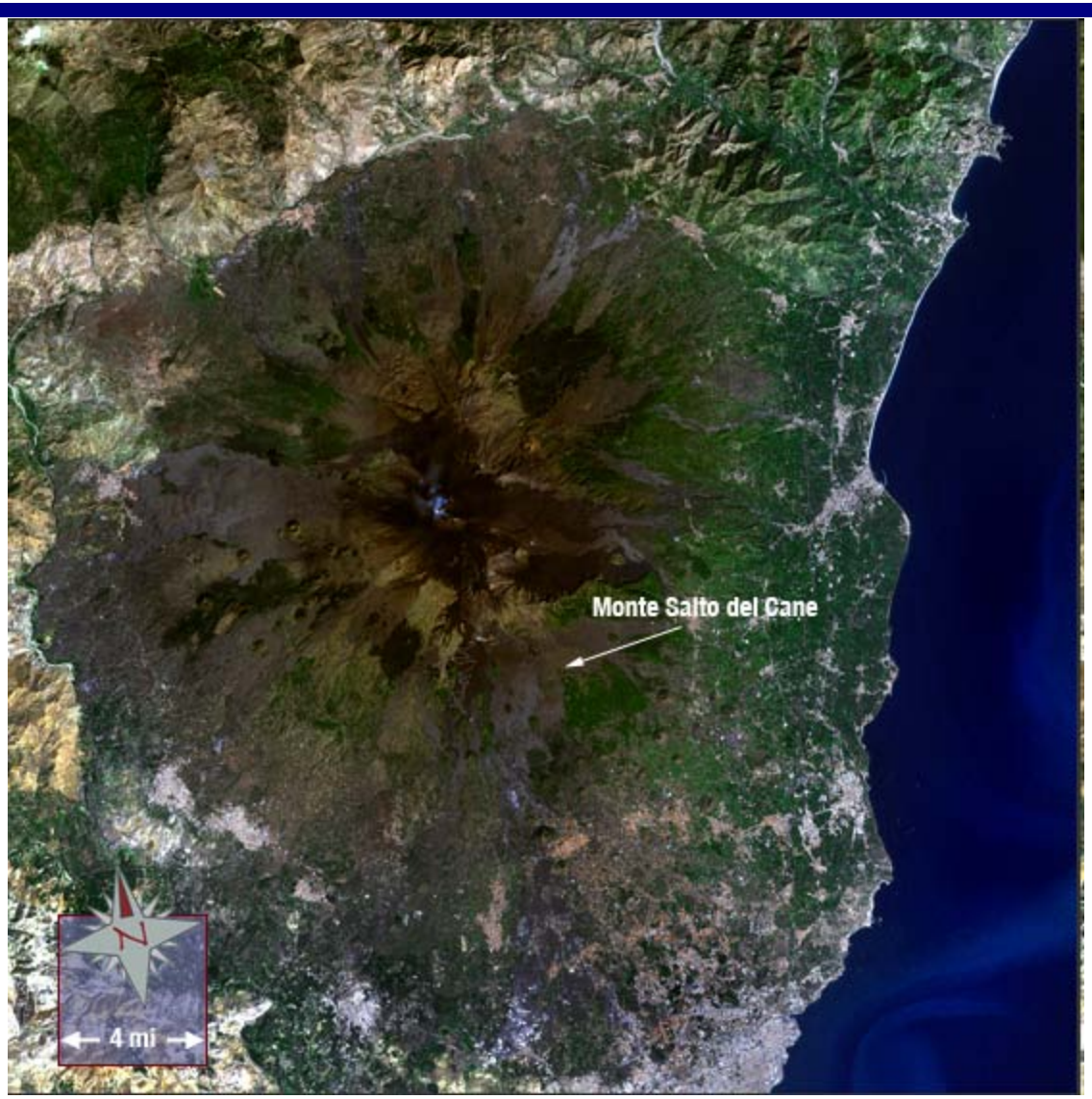
Alaska Mt Redoubt Eruption



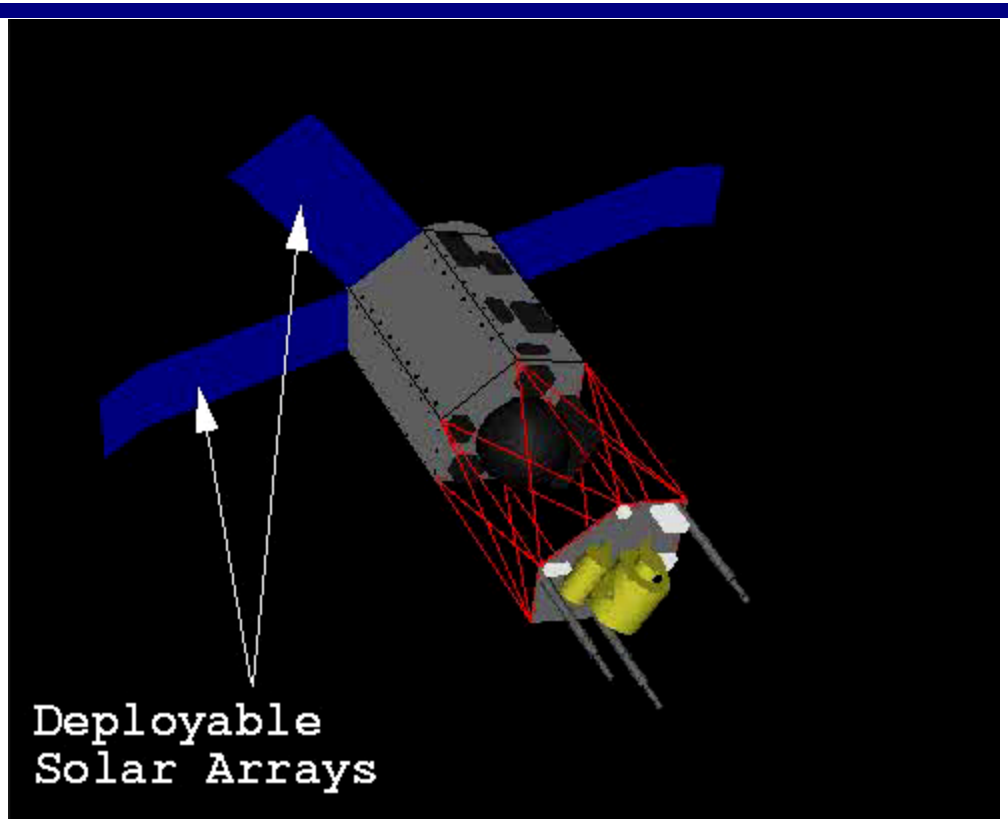
Belize Coastal Image-Barrier Reef



Mt Etna Volcano

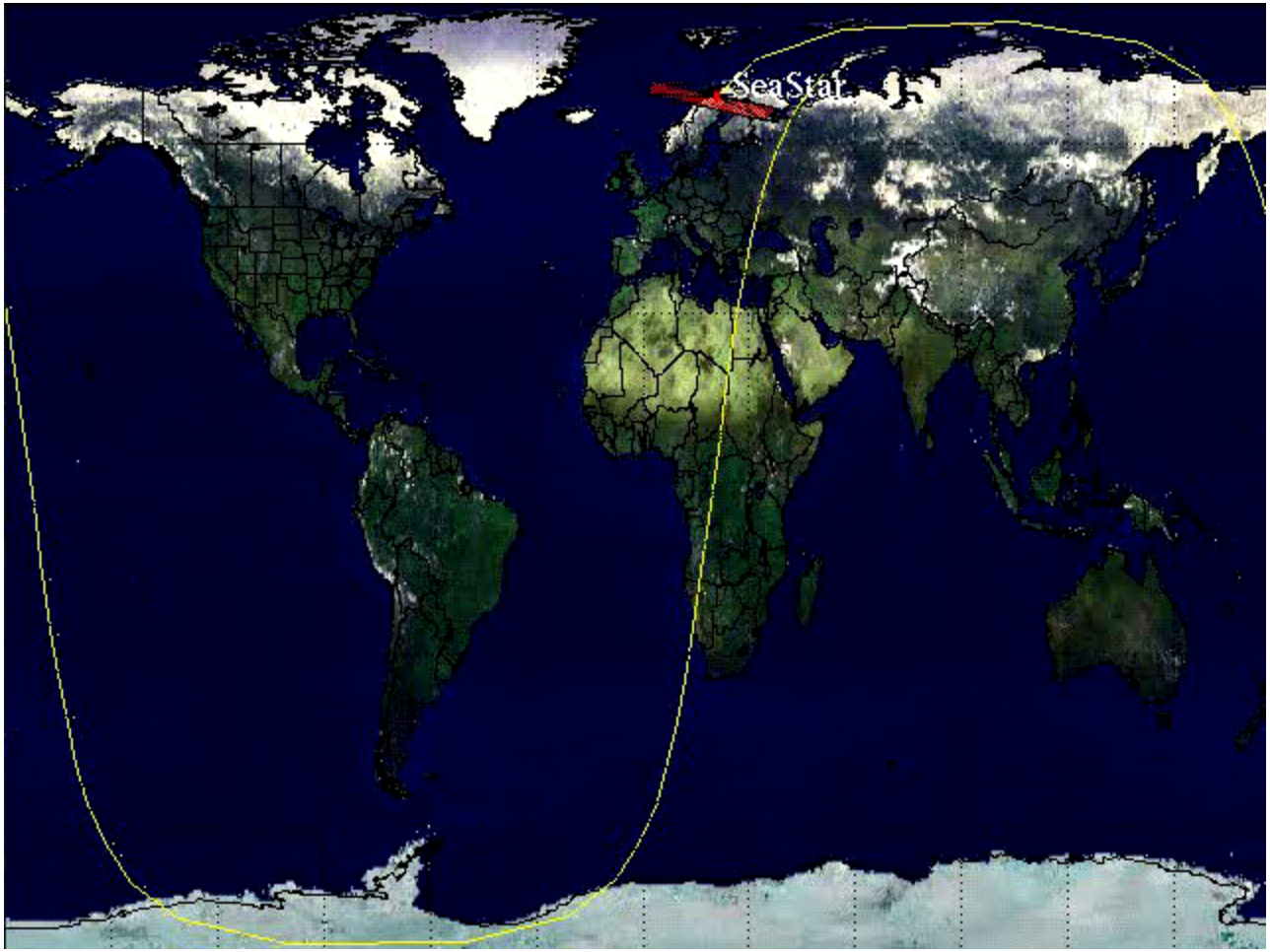


SeaStar Spacecraft – SeaWiFS instrument



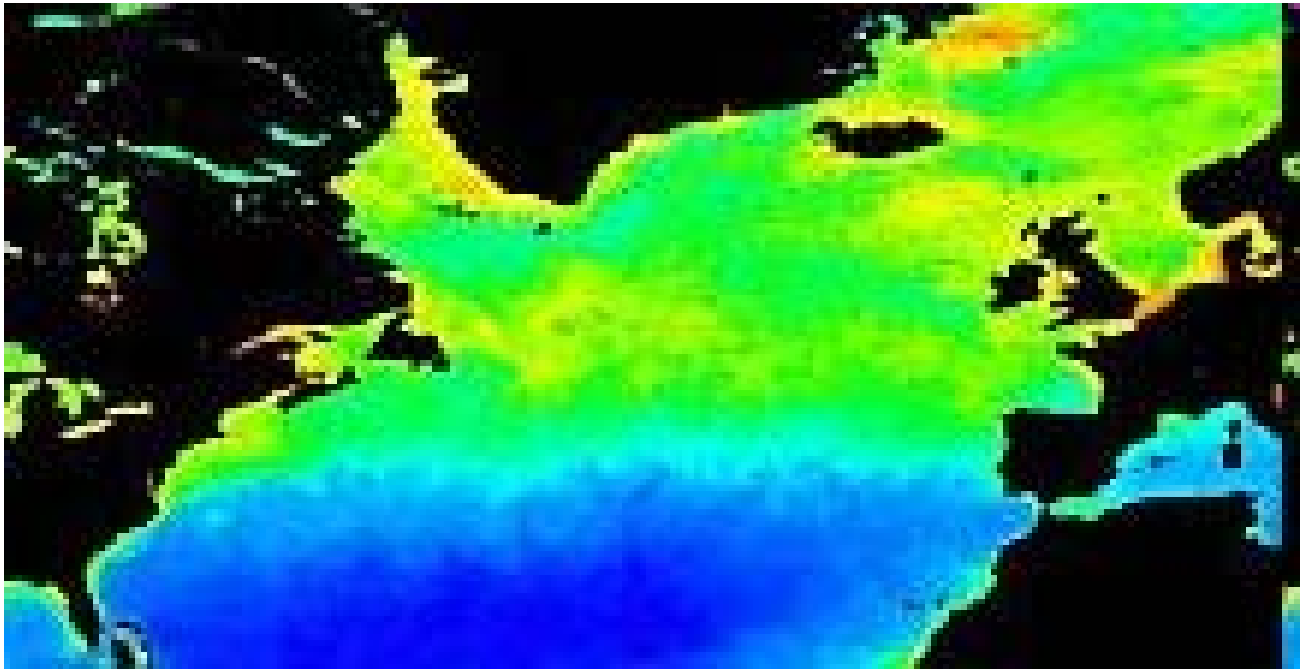
The SeaStar spacecraft, developed by Orbital Sciences Corporation, carries the SeaWiFS instrument and was launched to low Earth orbit on board an extended Pegasus launch vehicle on August 1, 1997. The SeaWiFS instrument will be the only scientific payload on the SeaStar spacecraft. GeoEye has the sole responsibility for the command and control of the satellite. The development of the SeaWiFS instrument was subcontracted to Hughes/SBRC, but GeoEye maintains ultimate responsibility for the instrument.

SeaWiFS Daily Coverage

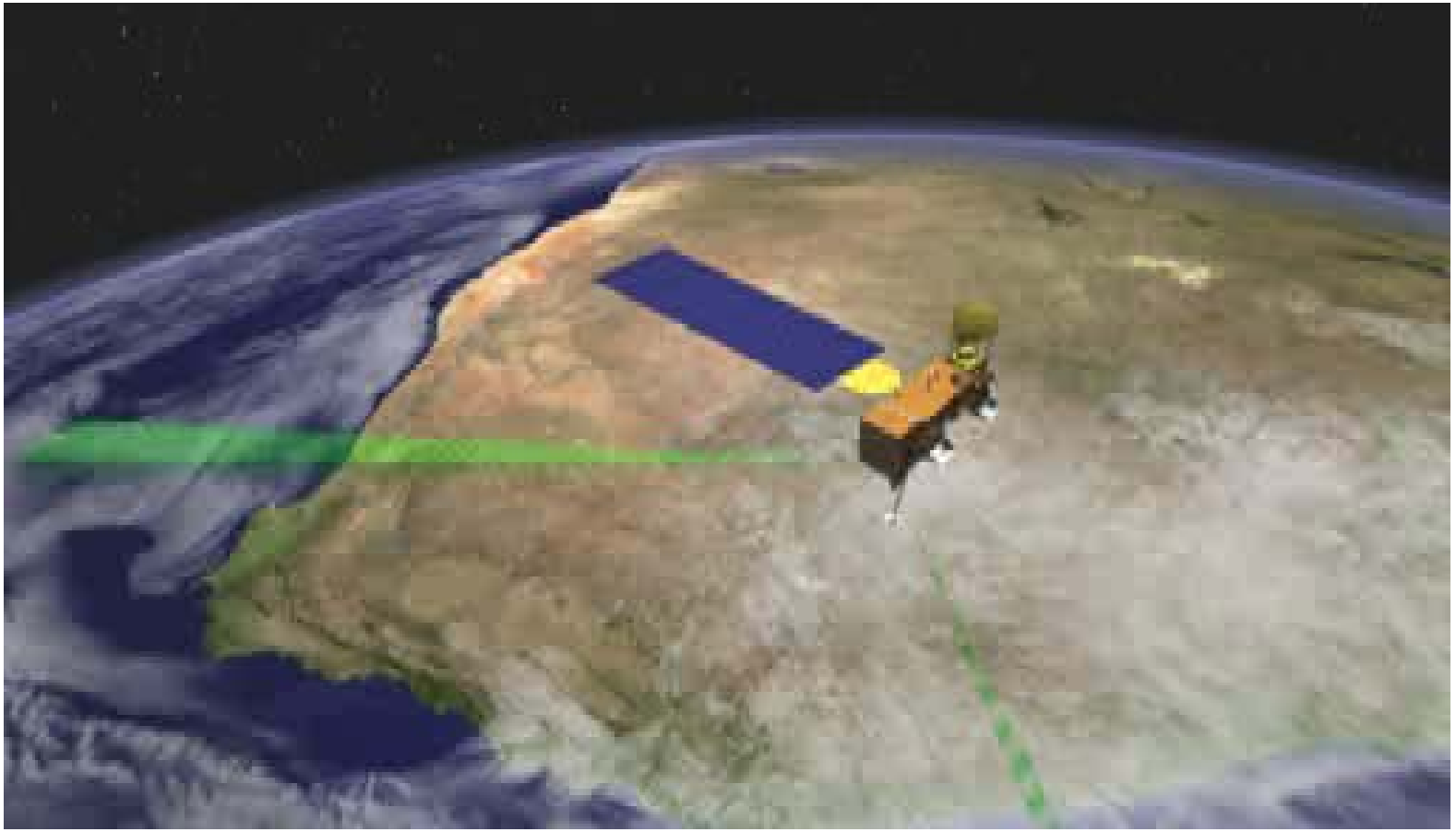


Phytoplankton, coccolithopheres, in Bering Sea

Spring Bloom in North Atlantic

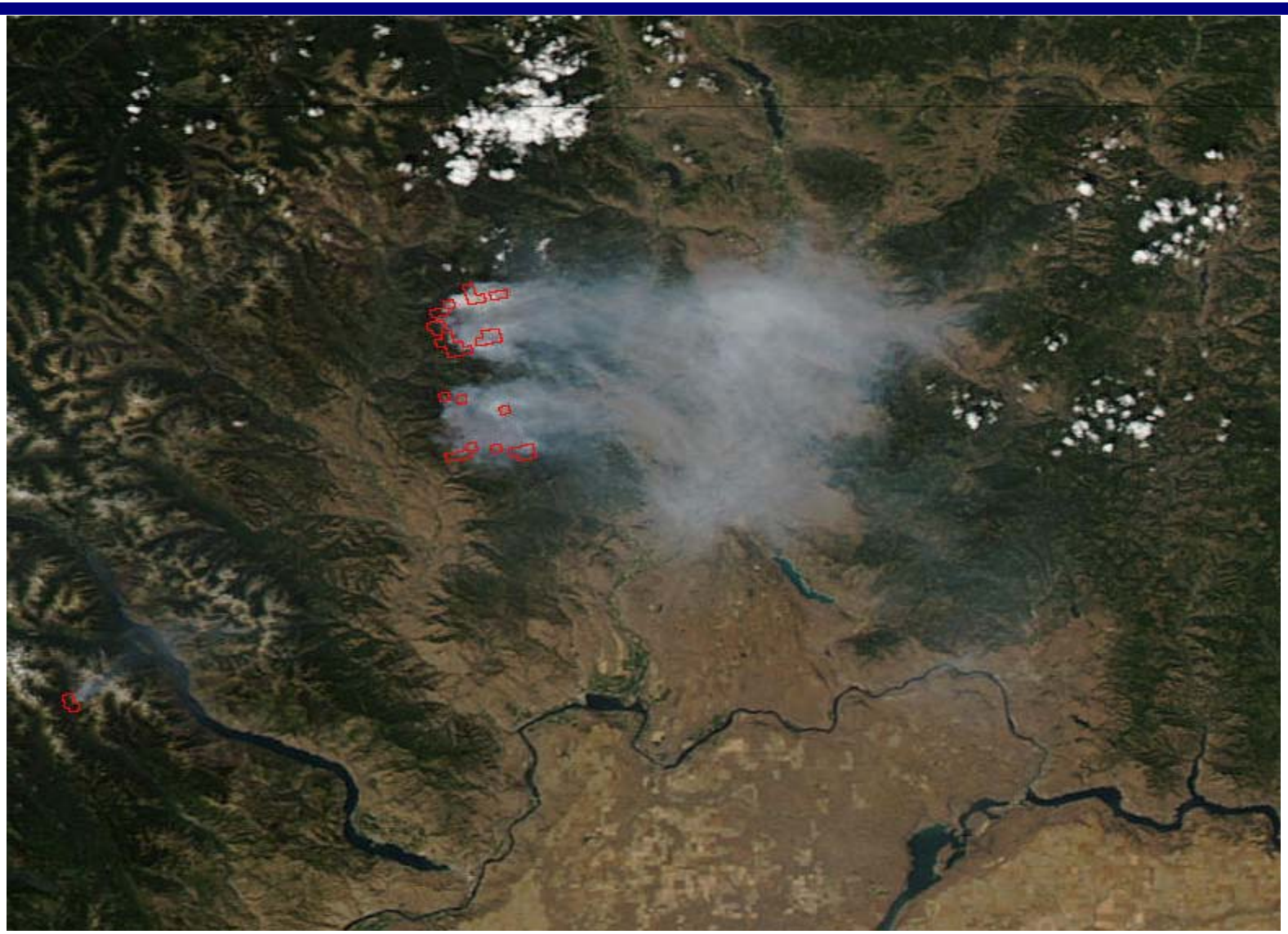


Moderate Resolution Imaging Spectroradiometer MODIS (on Aqua and Terra)

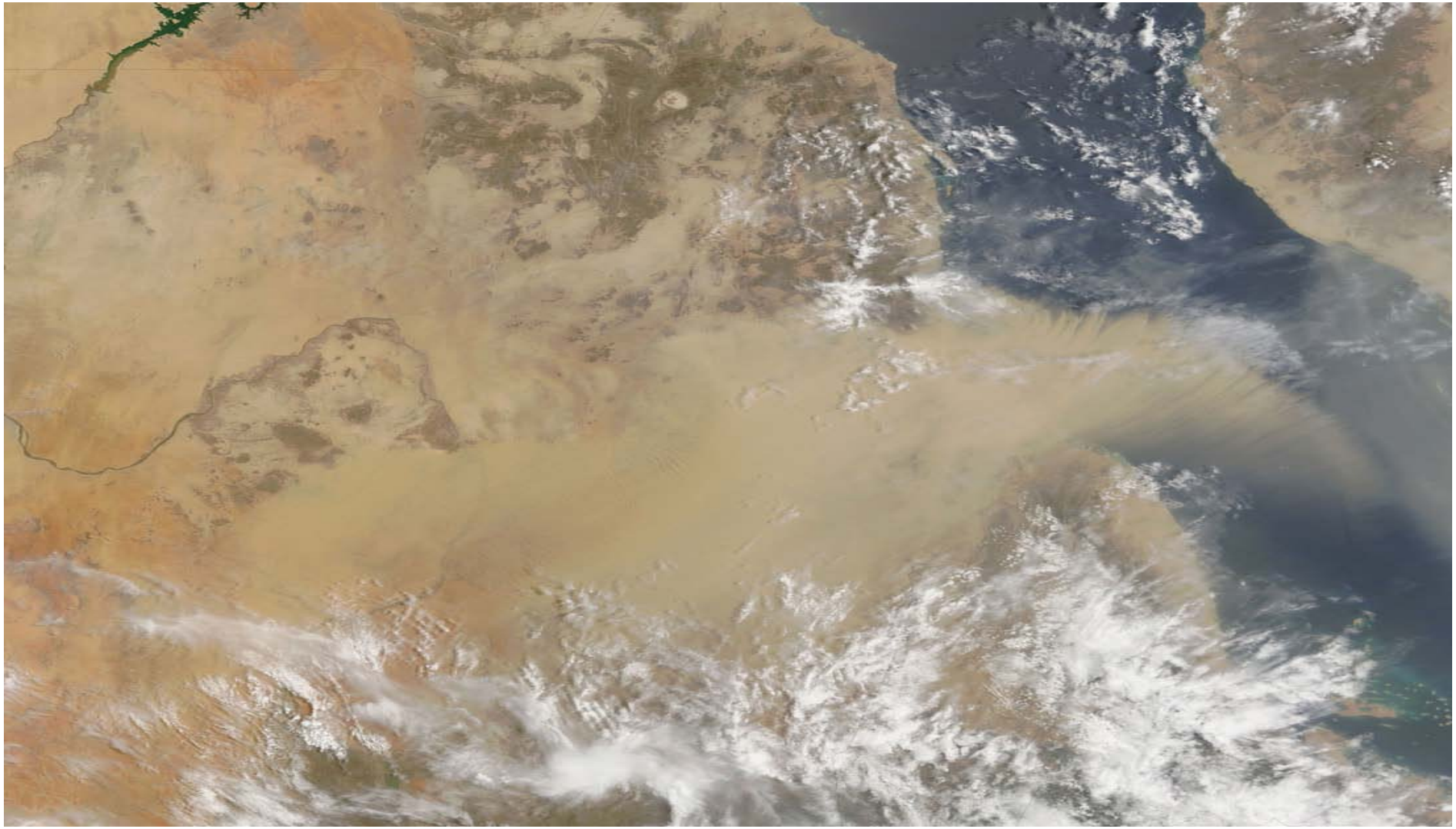


MODIS as part of the Aqua Satellite. Animation shows the coverage of MODIS and other Aqua Instruments. Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands, or groups of wavelengths.

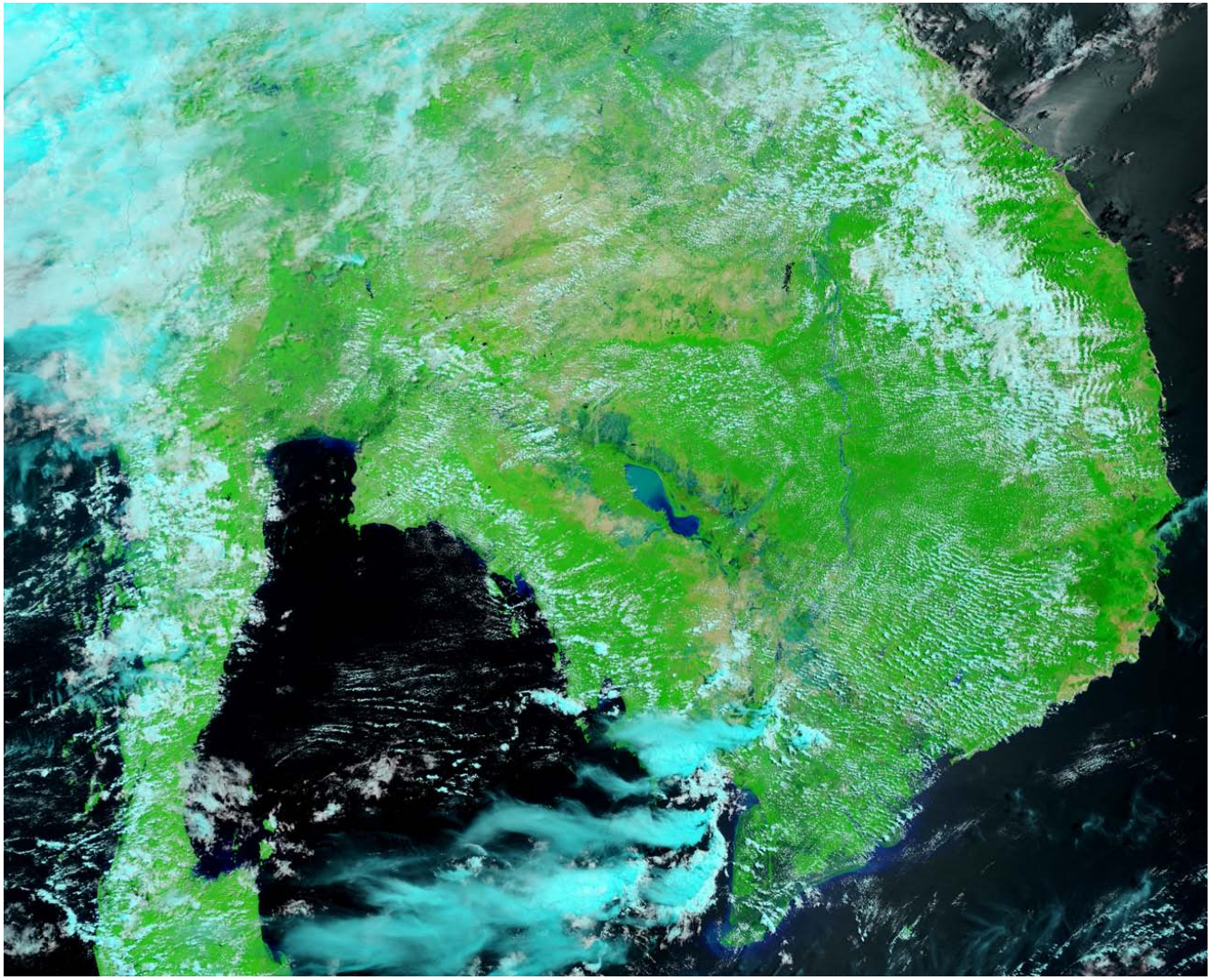
Fires in Northern Washington-500m res



Dust Storm over Red Sea- 1km res

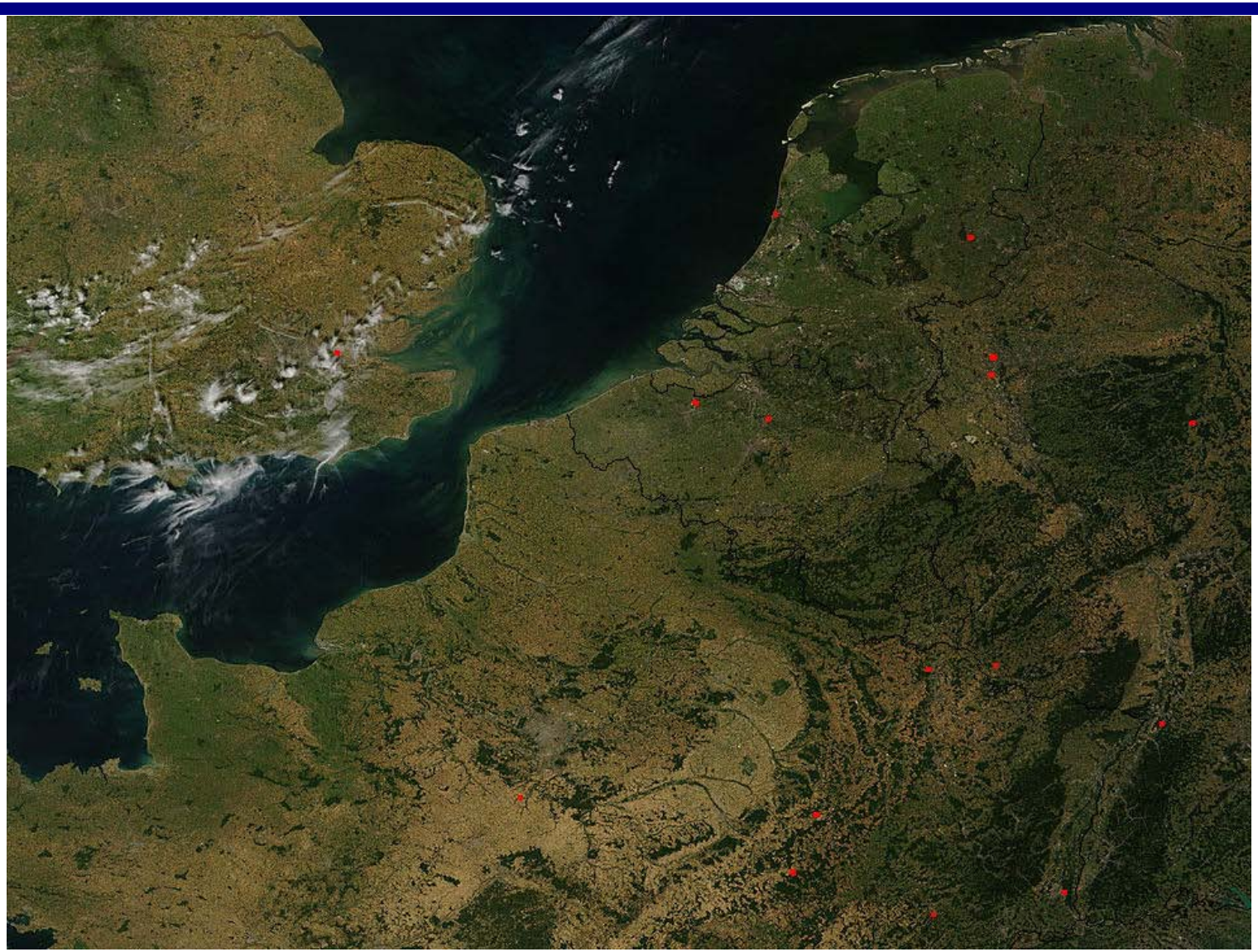


Monsoon Rains Cambodia (1km)-July 2006

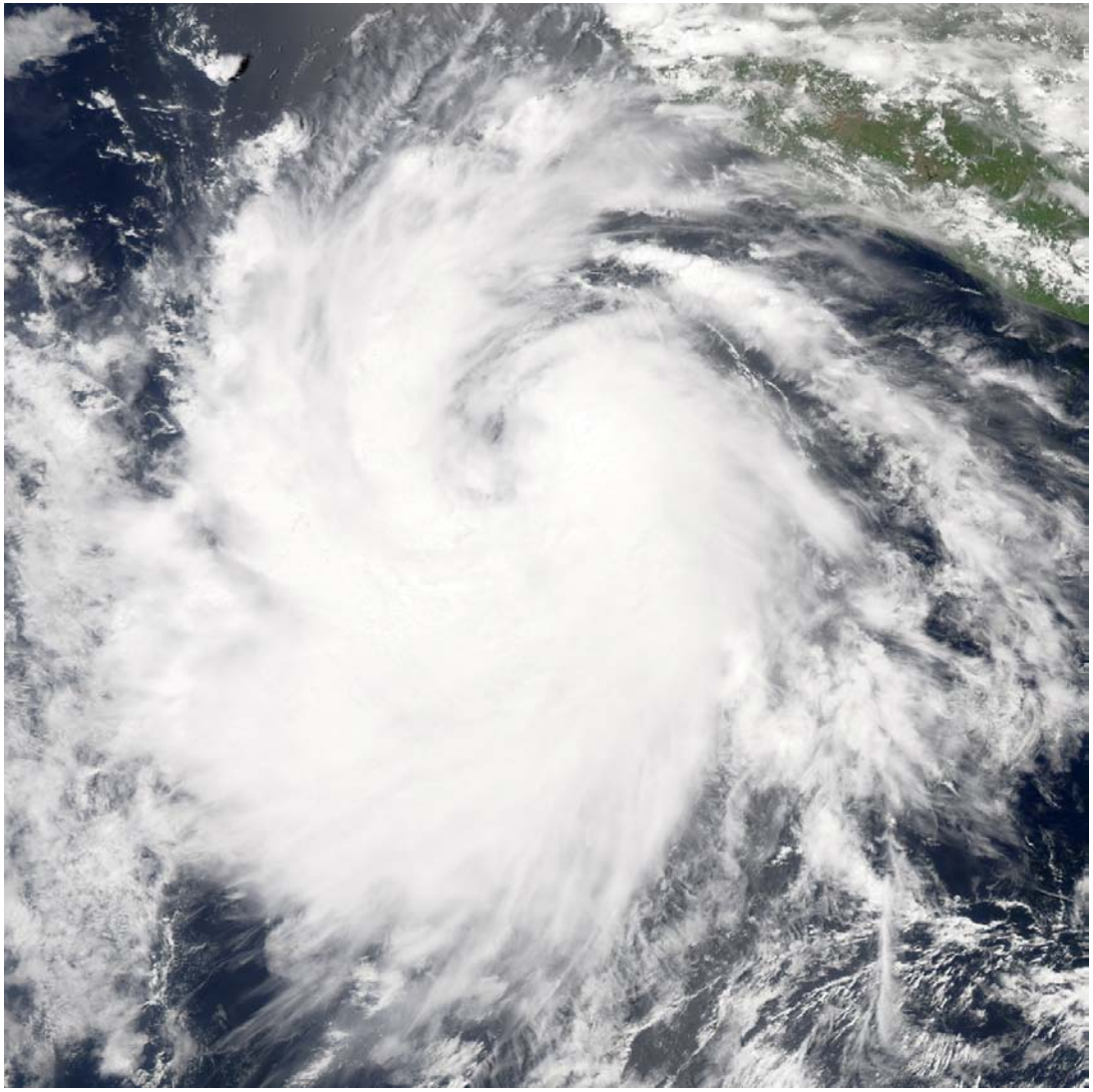


Spain and Algeria

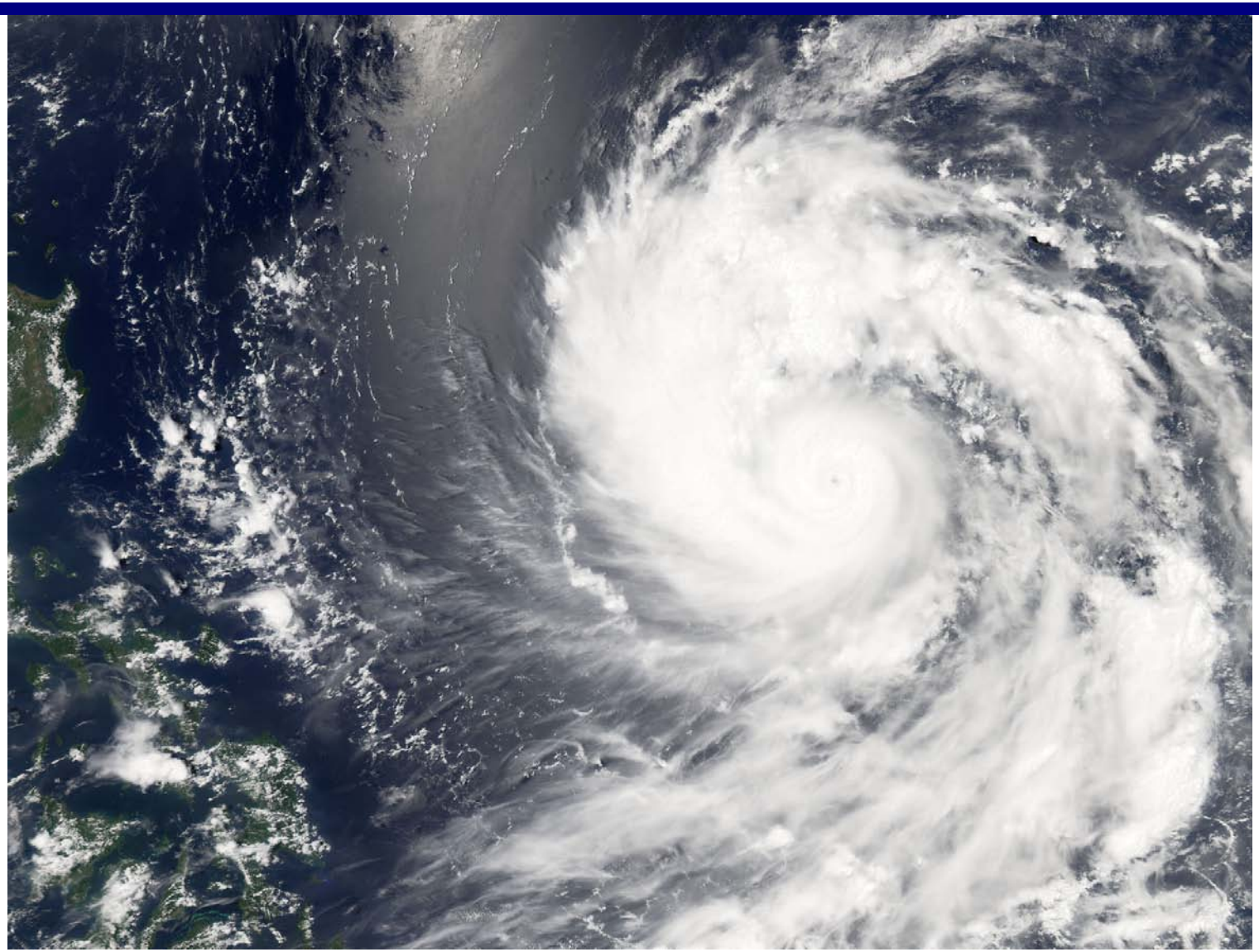
The Netherlands – 1km resolution



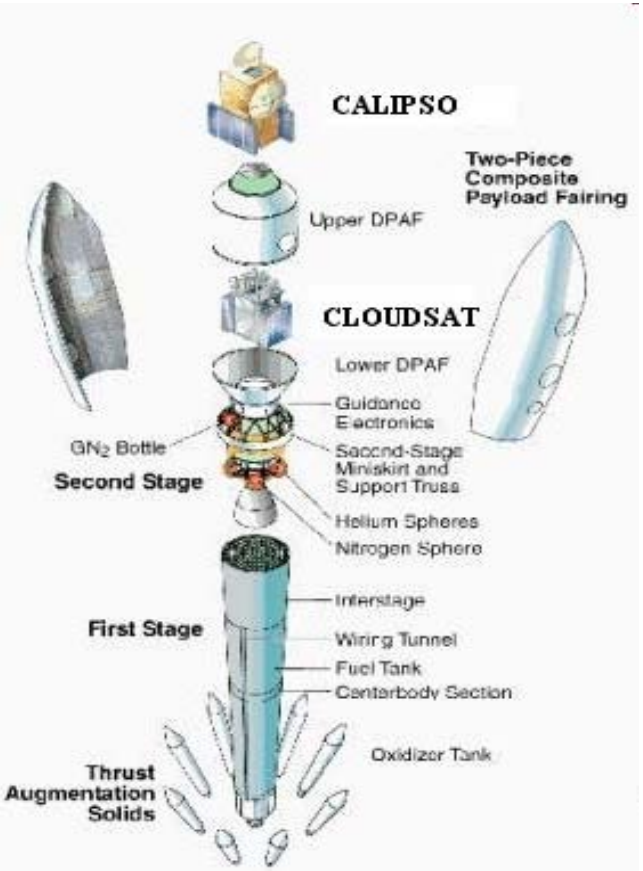
Hurricane Carlotta-Mexico 2006



Typhoon Ewiniar (1km) – Micronesia July 2006

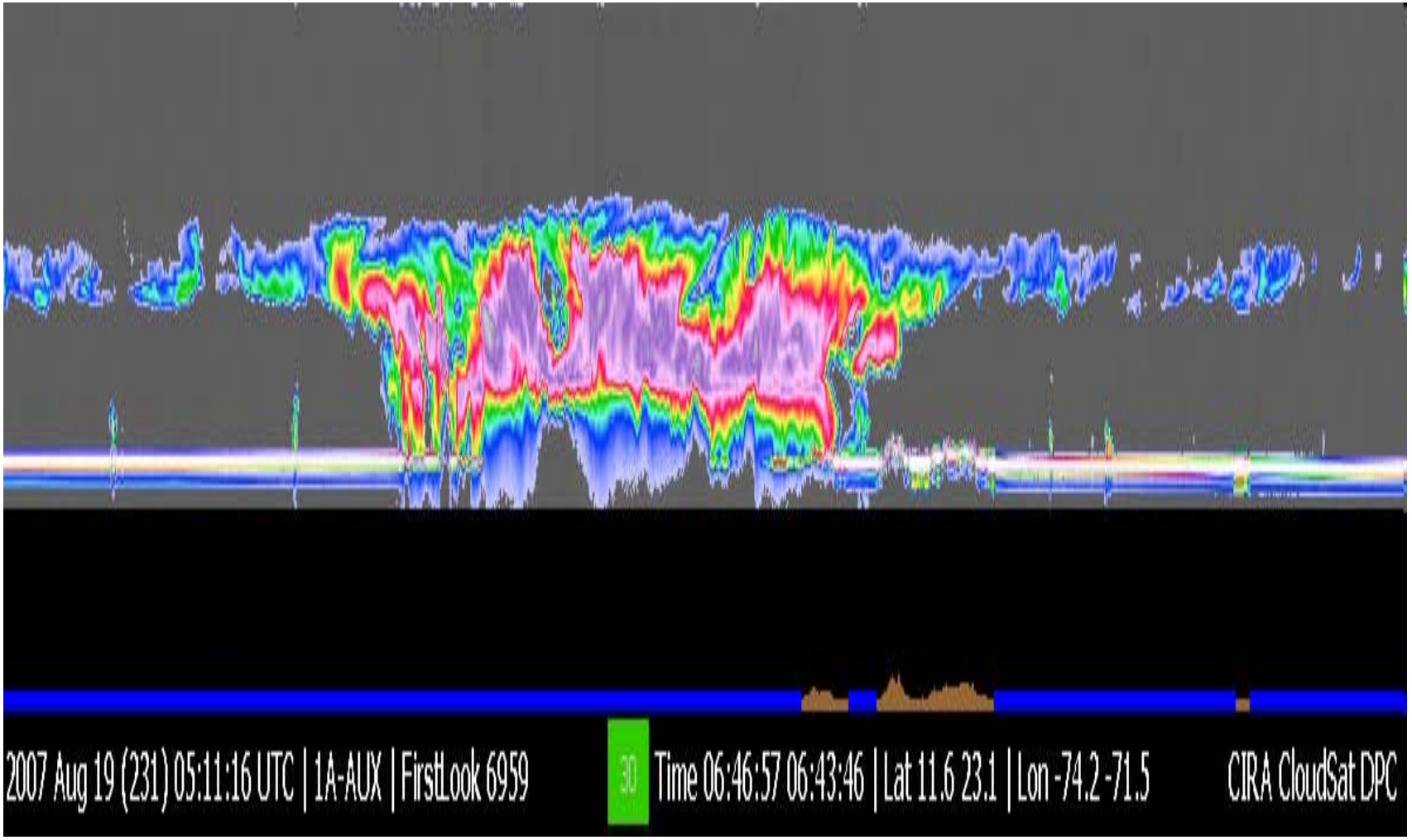


CloudSat

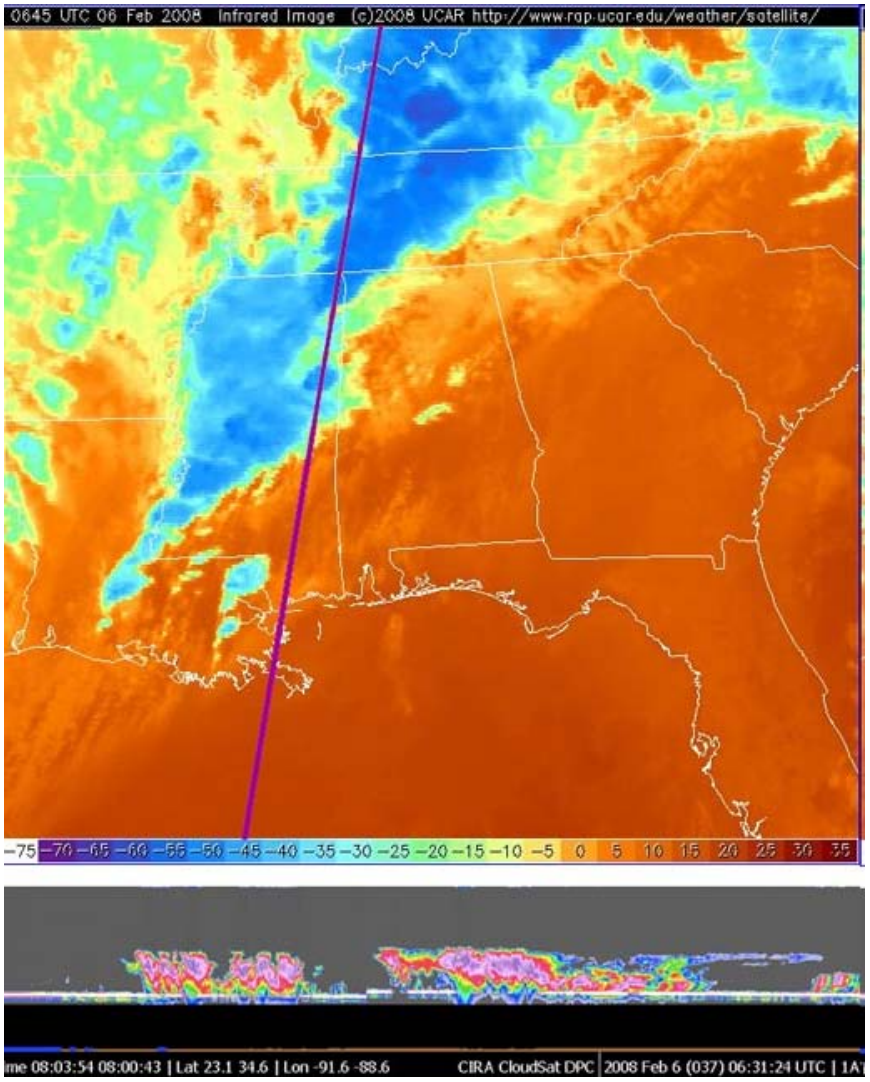


CloudSat's primary mission is scheduled to continue for 22 months after launch in 2006, in order to allow more than one seasonal cycle to be observed, although radar lifetime data indicates that the radar is expected to operate for three years with a 99 percent probability. CloudSat and Calipso launched together

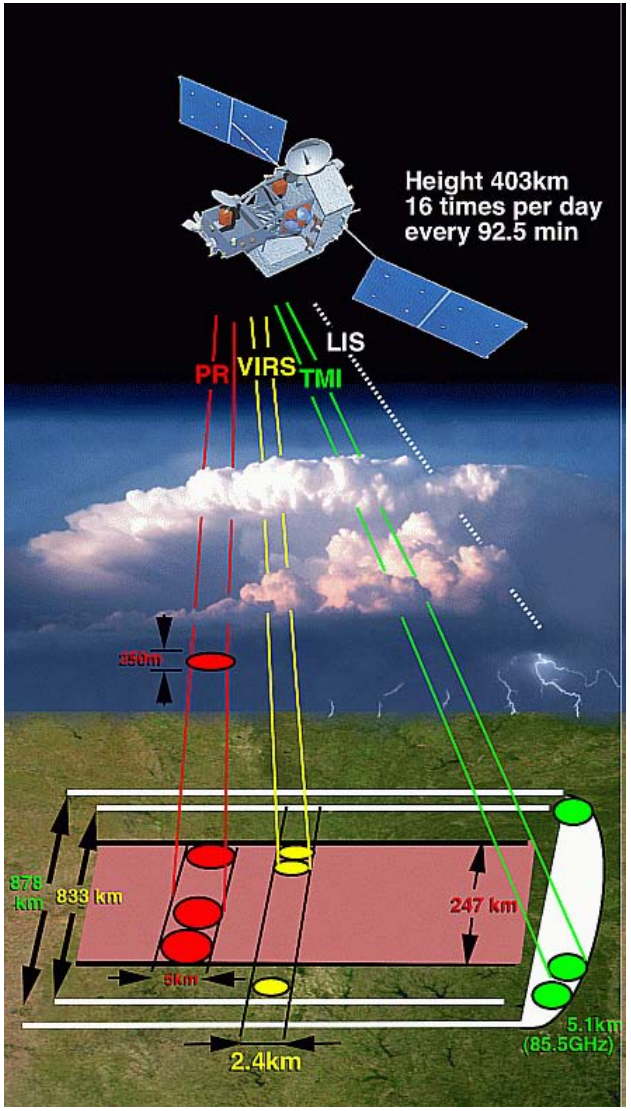
Hurricane Dean 3-D Image - 2007



CloudSat Profiles Tornadic Outbreak Feb 2008 Kentucky, Tennessee, and Mississippi



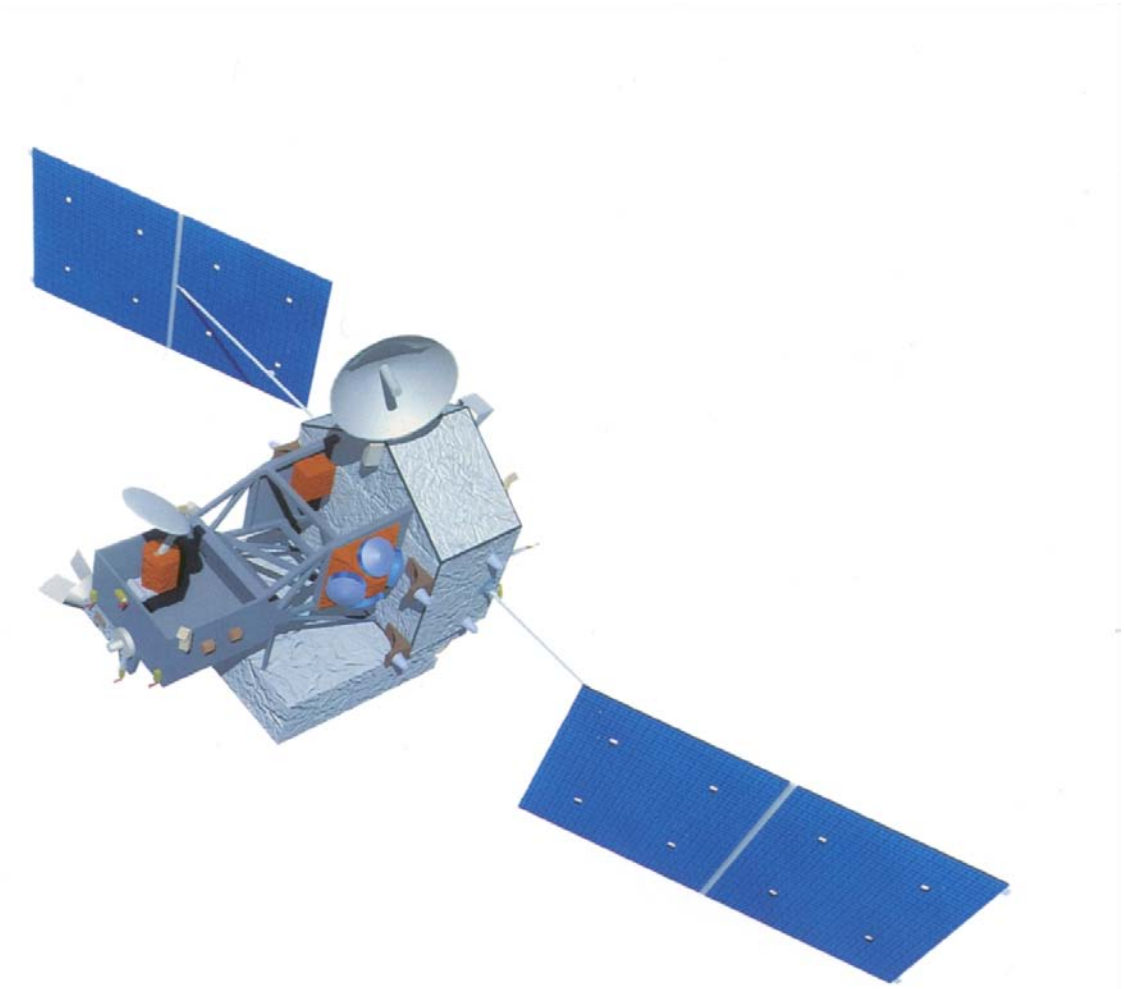
Tropical Rainfall Measuring Mission



The accurate measurement of the spatial and temporal variation of tropical rainfall around the globe remains one of the critical unsolved problems of meteorology. TRMM, during its mission and broad sampling footprint between 35°N and 35°S, is providing some of the first detailed and comprehensive data on the four dimensional distribution of rainfall and latent heating over vastly undersampled oceanic and tropical continental regimes. Combined with concurrent measurement of the atmosphere's radiation budget, estimates of the total diabatic heating are being realized for the first time ever on a global scale.

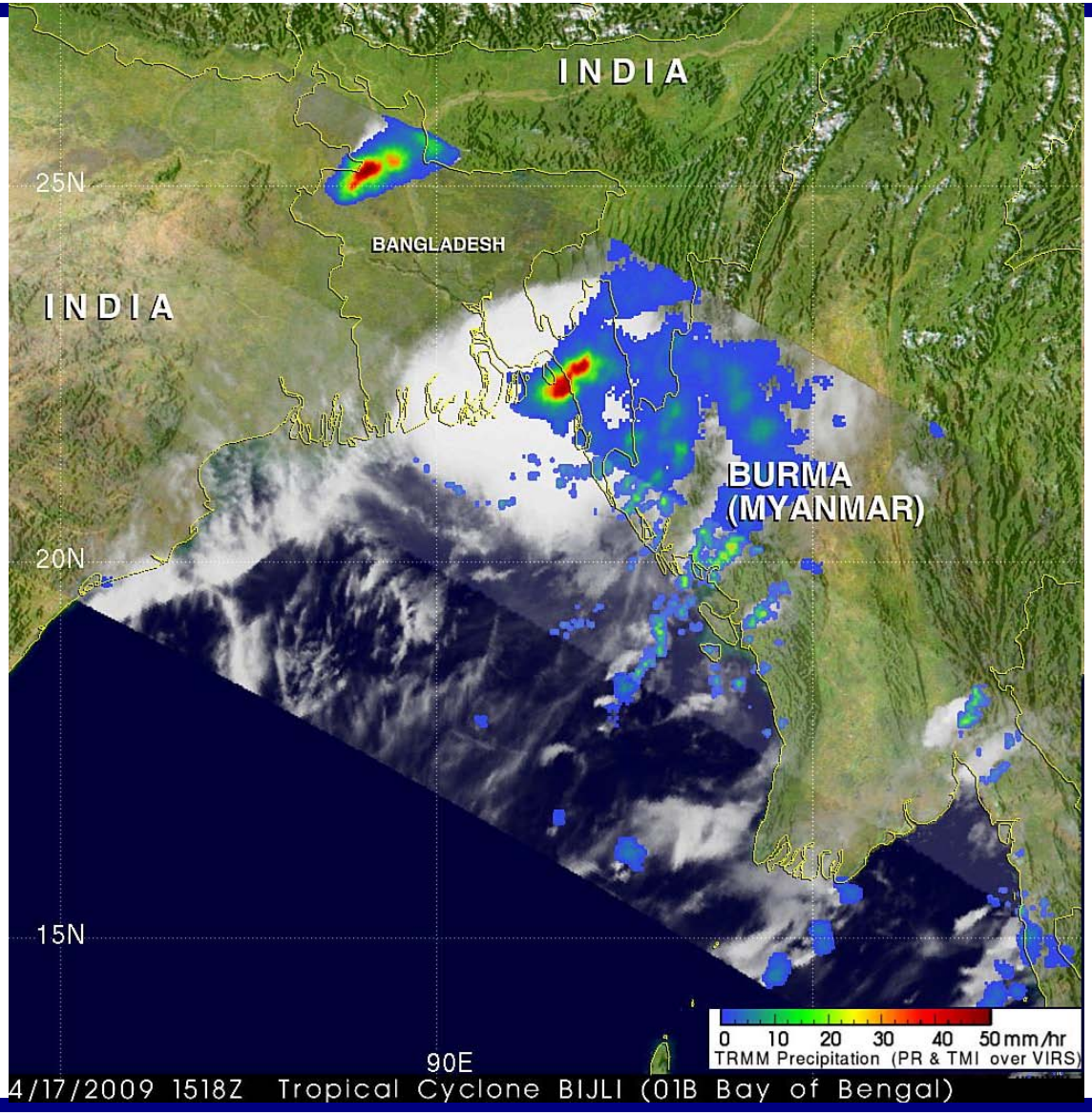
TRMM fills many gaps in our understanding of rainfall properties and their variation.

TRMM Satellite Graphic

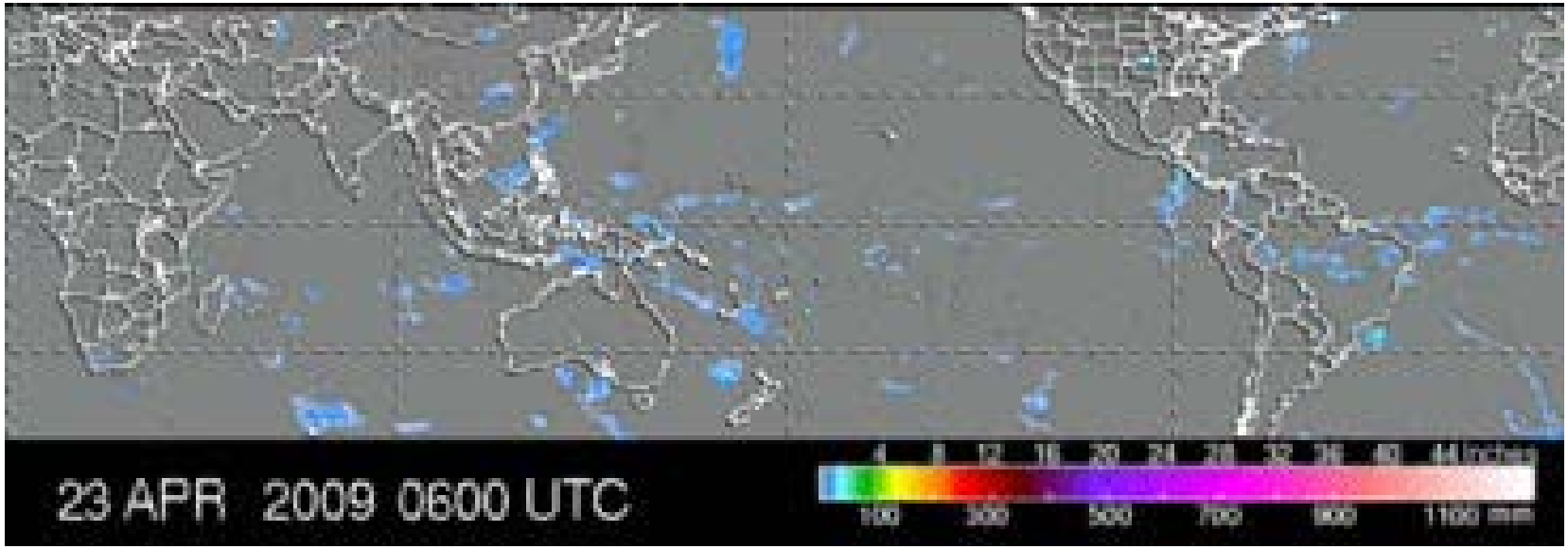


TRMM Assembly at GSFC

TRMM Instrument View over Bay of Bengal

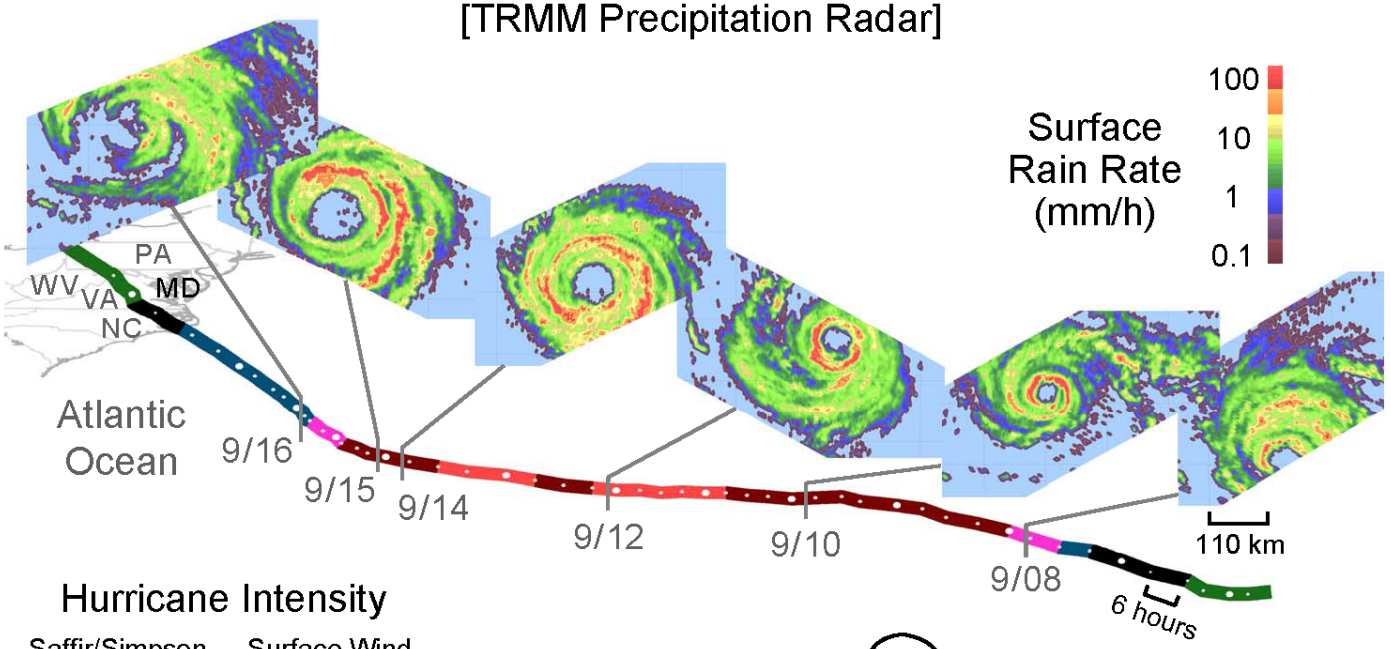


Week of 3hr Merged Realtime Global Rain



Horizontal View of Hurricane Isabel in September, 2003

[TRMM Precipitation Radar]

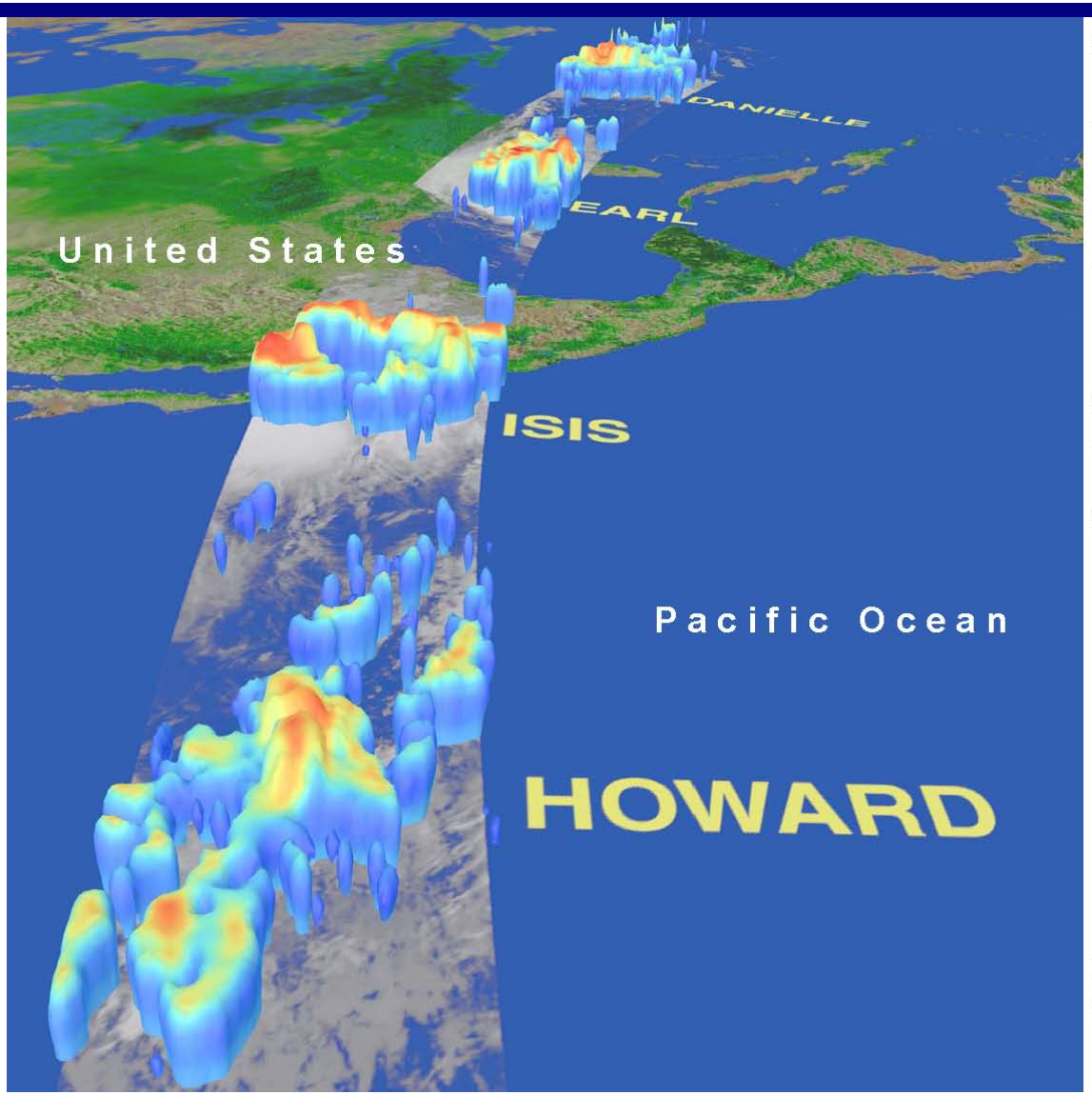


Hurricane Intensity

Saffir/Simpson Category	Surface Wind (km/h)	(mph)
5	≥ 248	≥156
4	209	130
3	180	112
2	151	94
1	118	74
Tropical Storm	61	38

Circular Motion

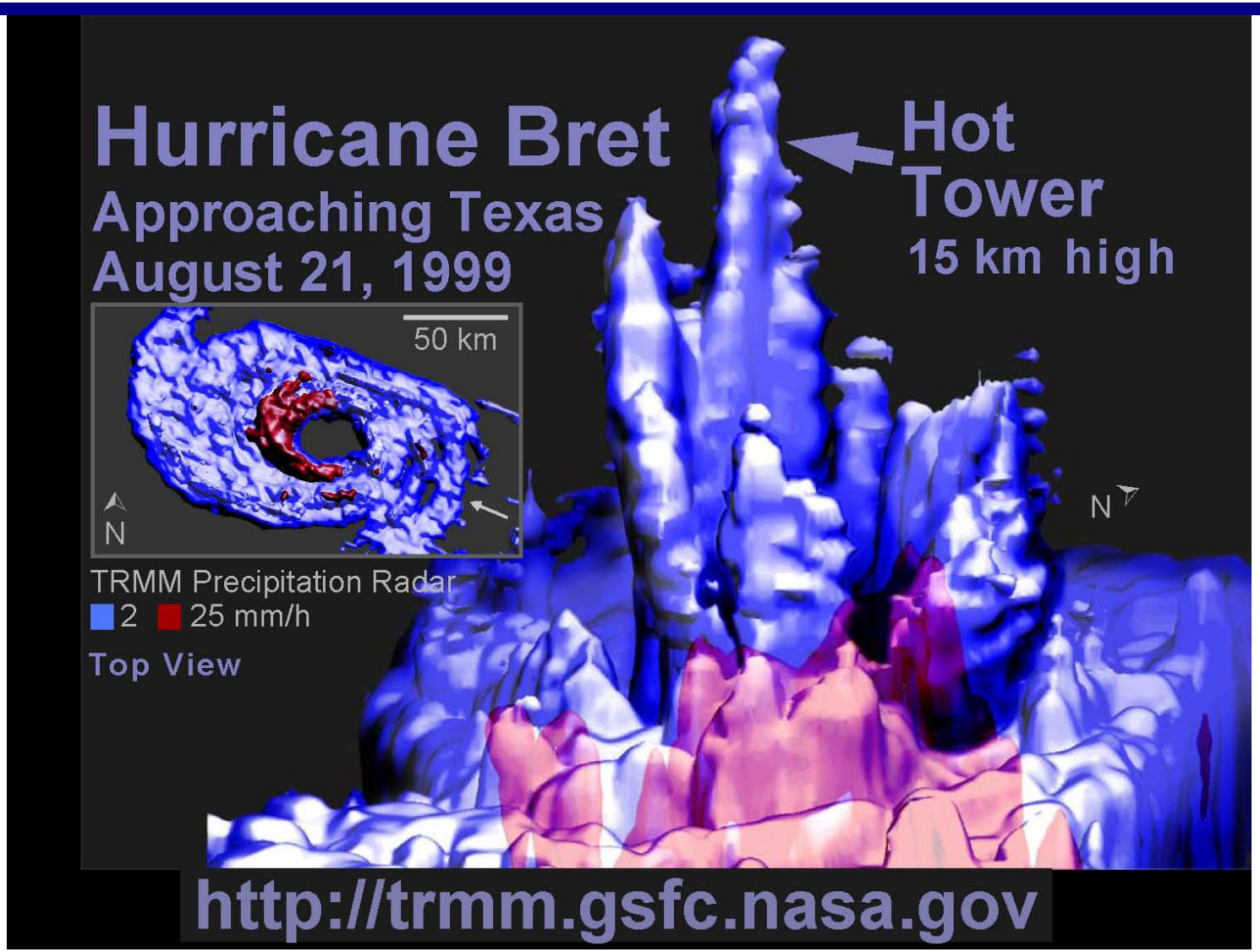
Forward Motion

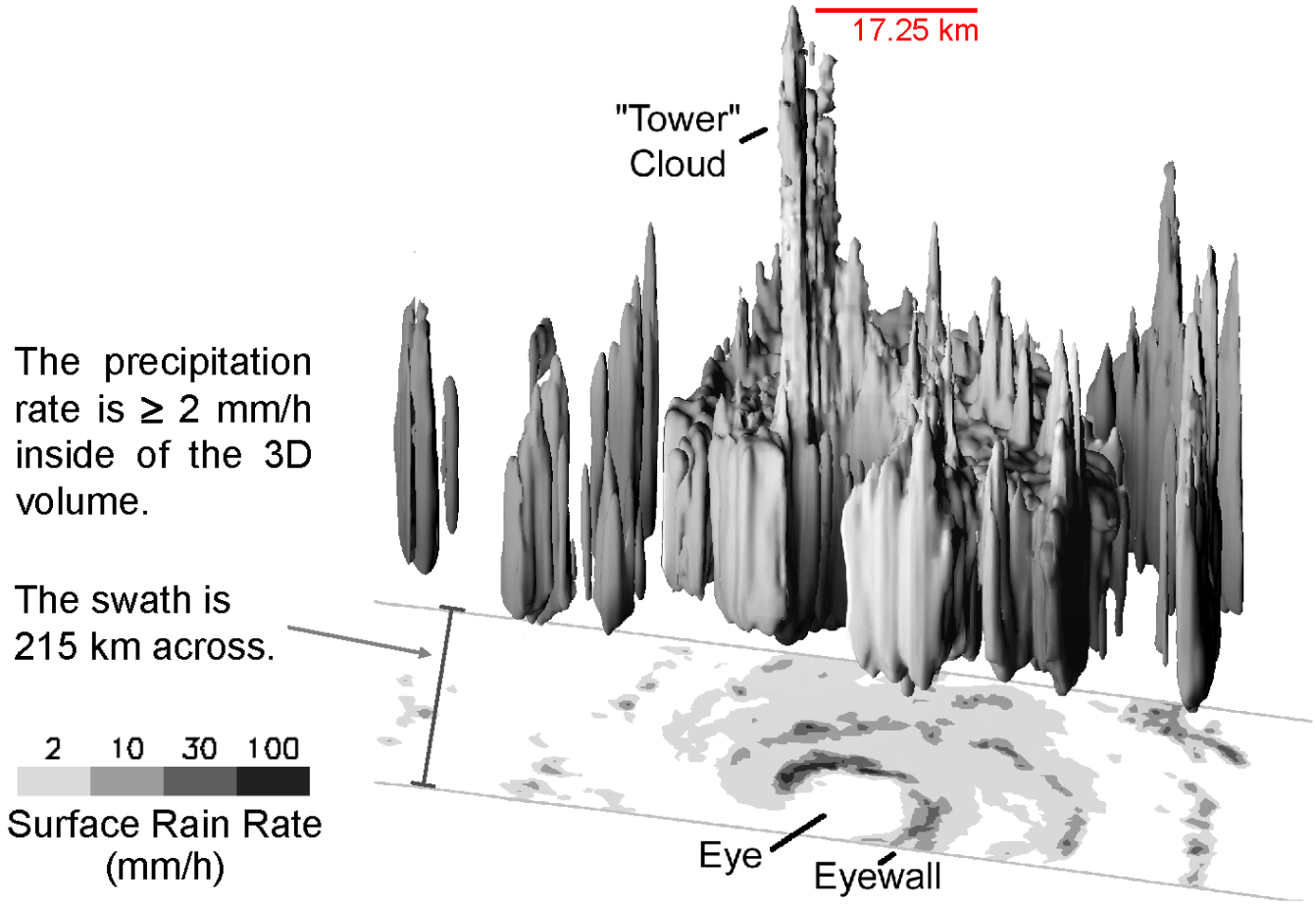


"Hurricane Alley"

TRMM Microwave Imager (TMI) overflights of four hurricanes on 2 Sept. 1998: Hurricanes Howard, Isis, Earl, and Danielle.

Image: NASA Goddard SVS
http://svs.gsfc.nasa.gov/goto?213


Hurricane Bret
Approaching Texas
August 21, 1999
Hot
Tower
15 km high
50 km
N
TRMM Precipitation Radar
2 25 mm/h
Top View
N
http://trmm.gsfc.nasa.gov

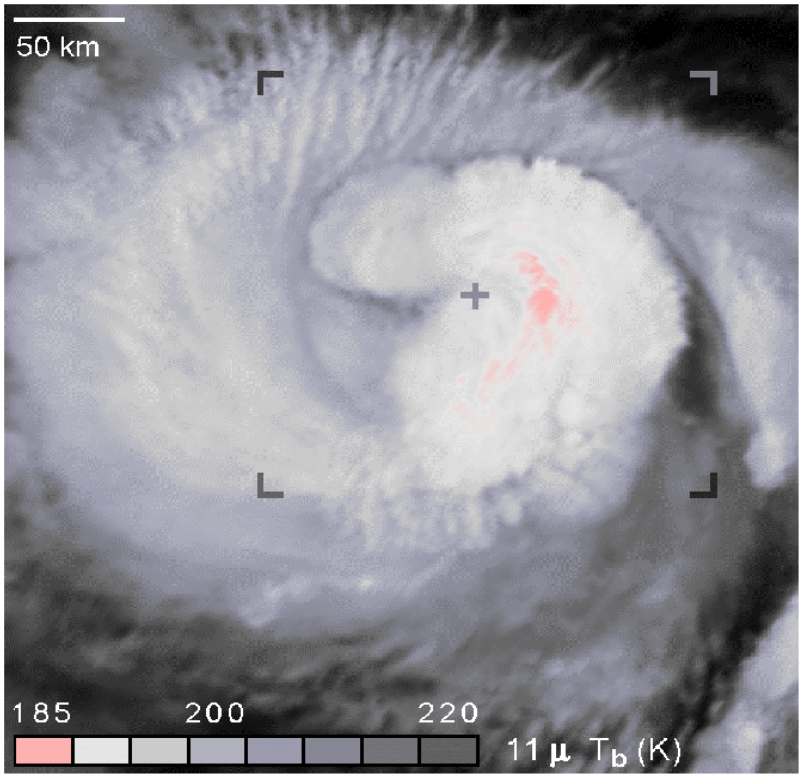


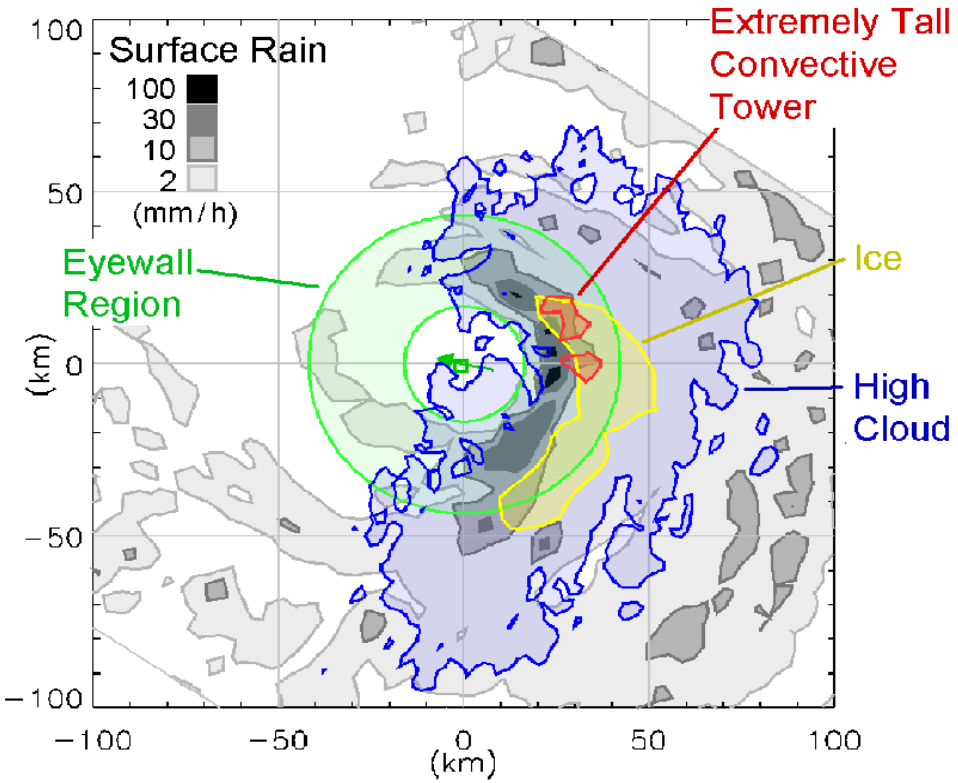
Hurricane Bonnie on August 22, 1998

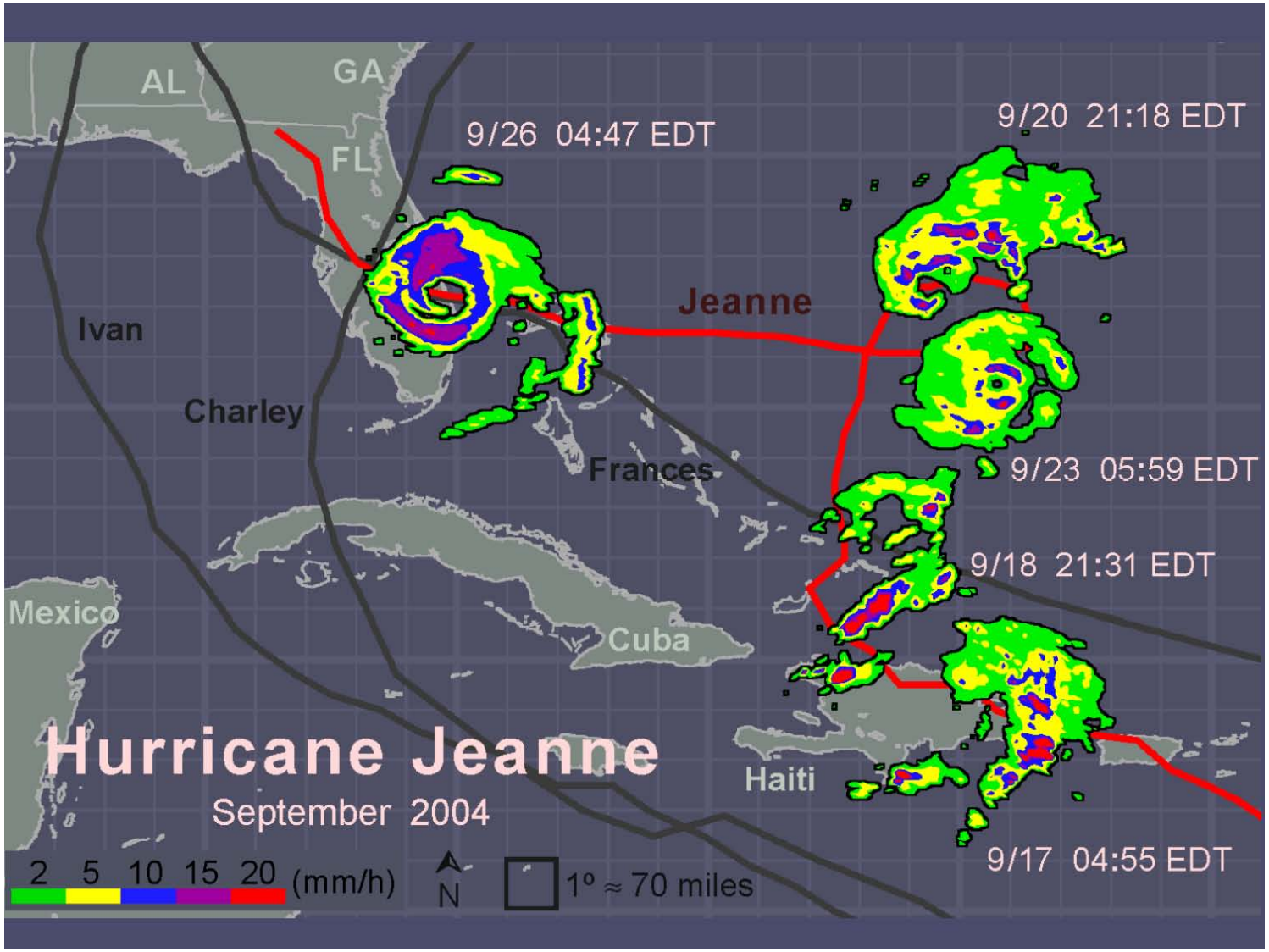
[TRMM Precipitation Radar]

Hurricane Carlotta

06/20/2000, 1055 UT, 14.66 N lat. 101.02 W lon., West of Mexico





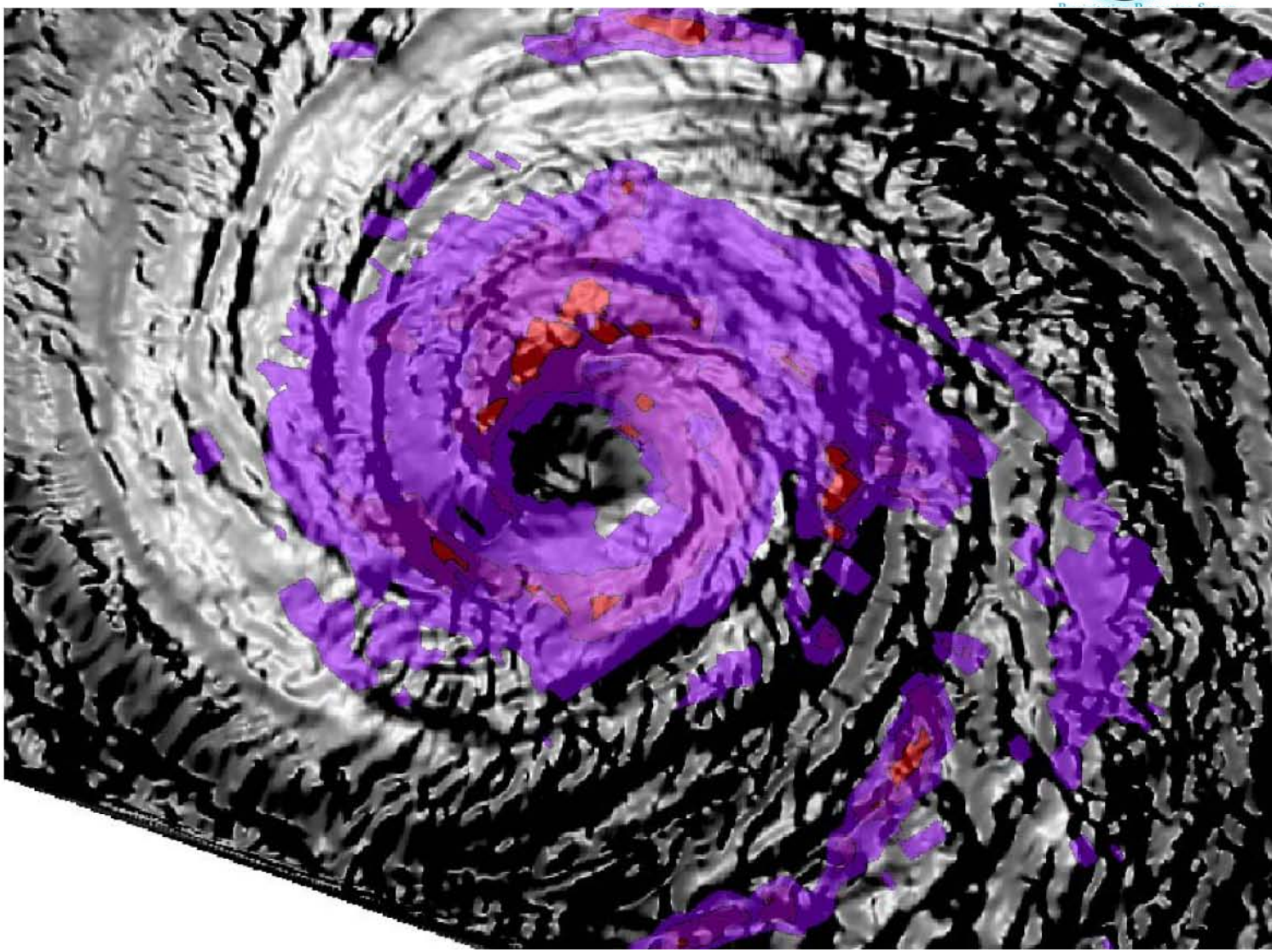

AL
GA
FL
9/26 04:47 EDT
9/20 21:18 EDT
Jeanne
Ivan
Charley
Frances
9/23 05:59 EDT
9/18 21:31 EDT
Mexico
Cuba
Hurricane Jeanne
September 2004
Haiti
9/17 04:55 EDT
2 5 10 15 20 (mm/h)
N
1° ≈ 70 miles

Hurricane Jeanne making landfall in Florida, USA

Sept. 26, 2004

TMI surface rainfall rate (transparent color)

TRMM VIRS cloud top temperature (shaded relief)

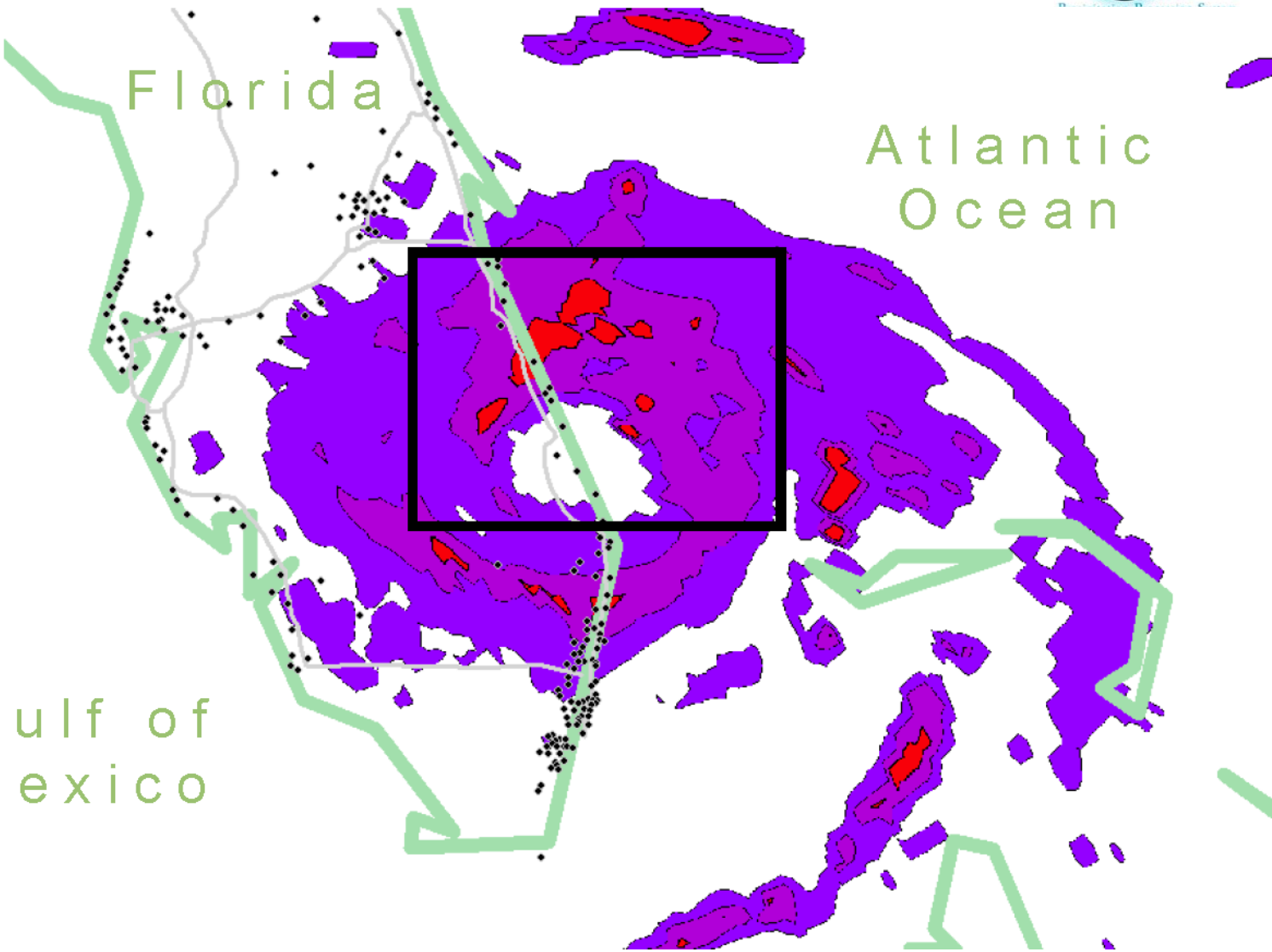


Hurricane Jeanne making landfall in Florida, USA

Sept. 26, 2004

TMI surface rainfall rate (color)

Coastline, Highways, and Cities



Hurricane Jeanne making landfall in Florida, USA

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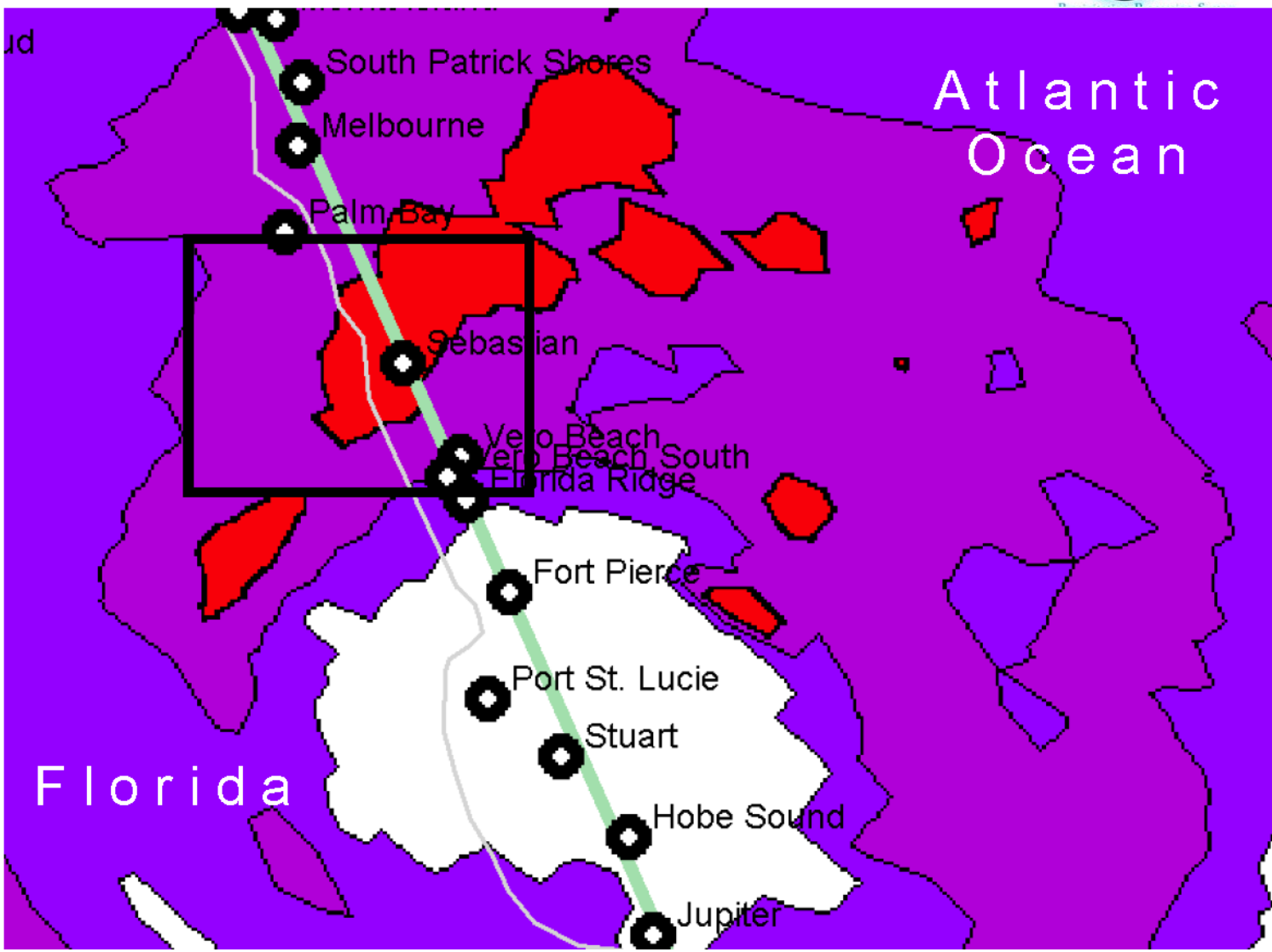
TMI surface rainfall rate (color)

Coastline, Highways, and Cities

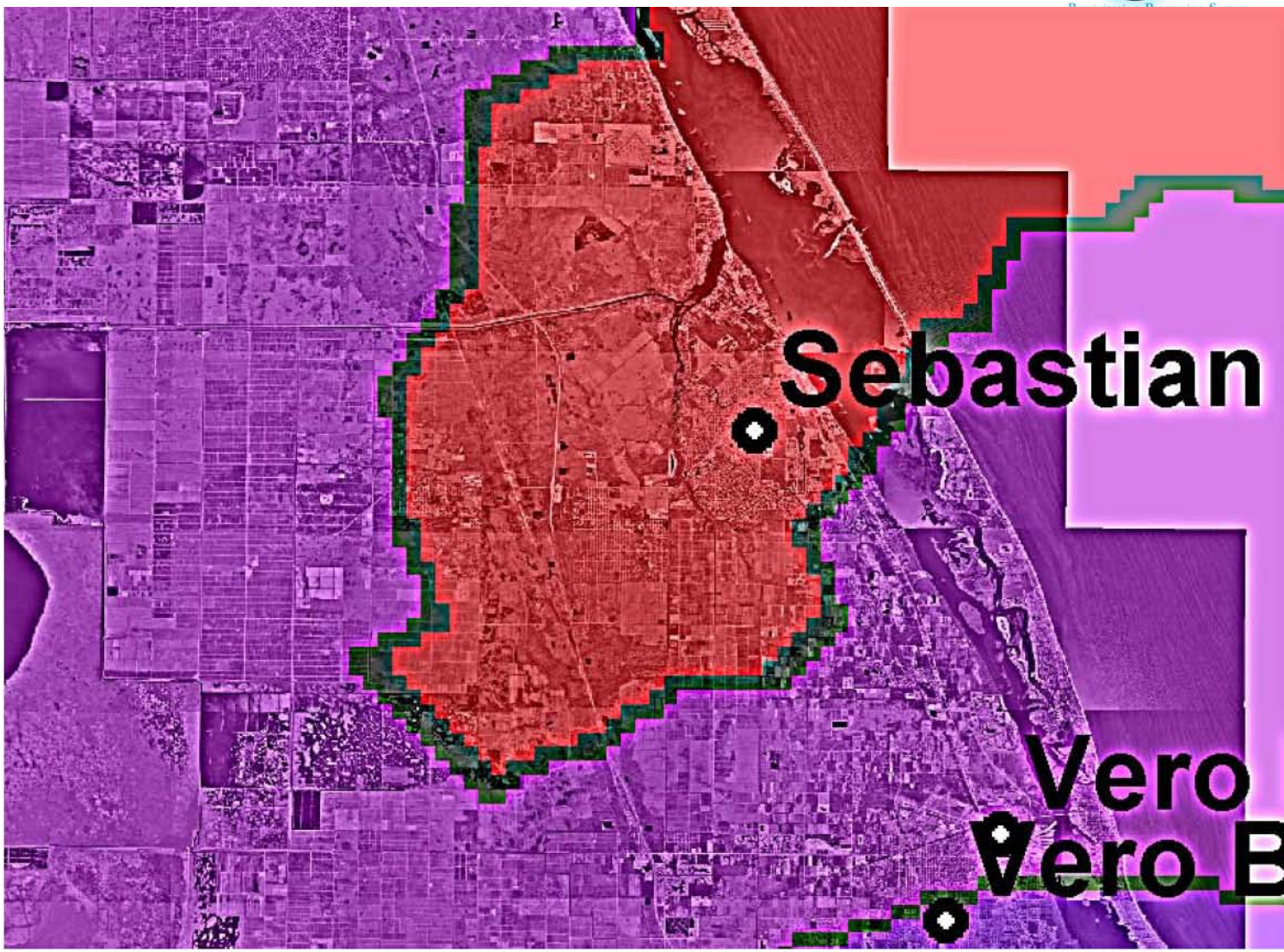


Hurricane Jeanne making landfall in Florida, USA

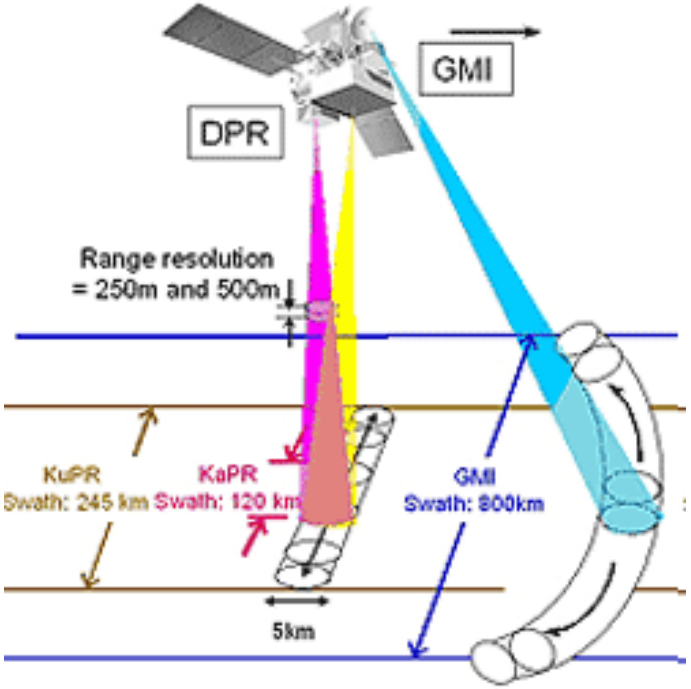
Sept. 26, 2004

TMI surface rainfall rate (transparent color)

GlobalMapper TerraServer (grayscale)



Global Precipitation Measurement mission



GPM will extend TRMM's observations of precipitation to higher latitudes, with more frequent sampling, and with focused research on providing a more complete understanding of the global hydrological cycle. GPM will be capable of measuring rain rates as small as a hundredth of an inch per hour to as large as 4 inches an hour. GPM will be able to estimate the various sizes of precipitation particles, and will also discriminate between snow and rain. GPM will seek to achieve these measurements with a 3-hour average revisit time over 80% of the globe, and the data will be available to users within 3 hours of observation time.

GPM Reference Concept

Specifically designed to unify and advance global precipitation measurements from dedicated and operational satellites for research & applications

GPM Low-Inclination Observatory (40°)
(NASA, LRD: Nov. 2014)
GMI (10-183 GHz)

- Improved "asynoptic" sampling from non-Sun-synchronous orbit for near realtime
- monitoring of hurricanes and midlatitude storms

GPM CORE Observatory (65°)
(NASA-JAXA, LRD: July 2013)
DPR (Ku-Ka band)
GMI (10-183 GHz)

- Precipitation physics observatory
- Reference standard for
- inter-calibration of constellation precipitation measurements

Partner Satellites: GCOM-W, DMSP, Megha-Tropiques, MetOp-B, NOAA-N', NPP, NPOESS

Precipitation Data Processing Systems
(NASA & JAXA)

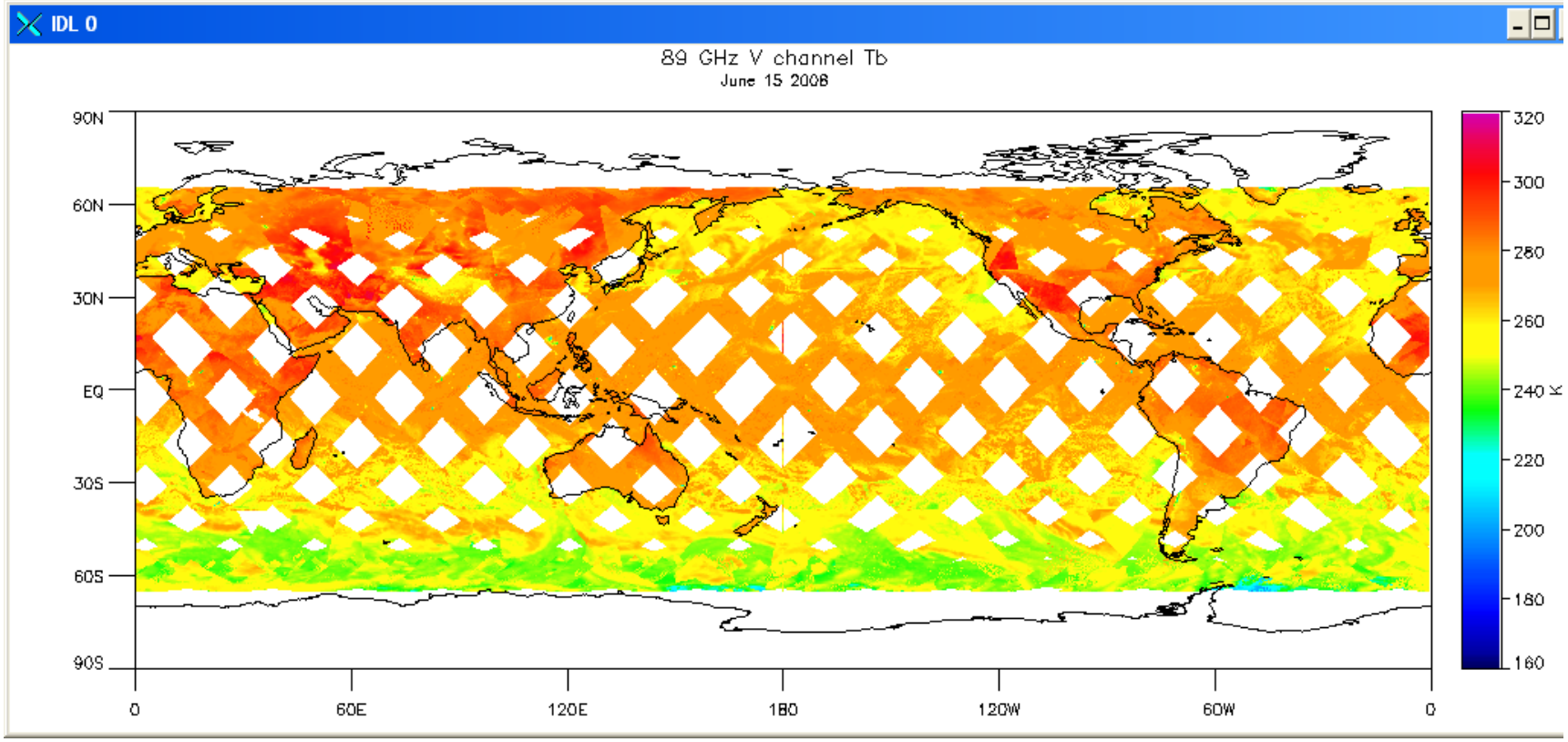
- Next-generation, constellation-based global precipitation products within a unified framework of inter-satellite calibration

Ground Validation

- International cooperative sites for pre-launch algorithm development post-launch product evaluation

Synthetic GMI 89 GHz Vertical

Synthetic GMI Tb of 89 GHz V Channel



Summary

- **NASA has a long history of monitoring the earth from space**
- **NASA currently has a number of highly successful earth observing missions that are being used for research and operations**
  - TRMM, a joint NASA-JAXA, mission is key among these. TRMM was a 3 year mission that is in its 11th year of observation
  - TRMM carries the first precipitation radar designed by Japan's NICT and built by JAXA
  - TRMM observatory built and integrated by NASA and launched by JAXA for Tanegashima Space Center
- **NASA has a suite of exciting earth observation mission under development and study**
- **GPM will extend the highly successful**
  - Tropical rainfall observation to a global precipitation (including snow, etc.) observation
  - Partnership between NASA and JAXA
  - Extend partnership to the international community which will provide both space and ground assets in support of GPM
- **NASA's missions will join other international missions to provide advanced and continuing monitoring of the earth and its ecological system**