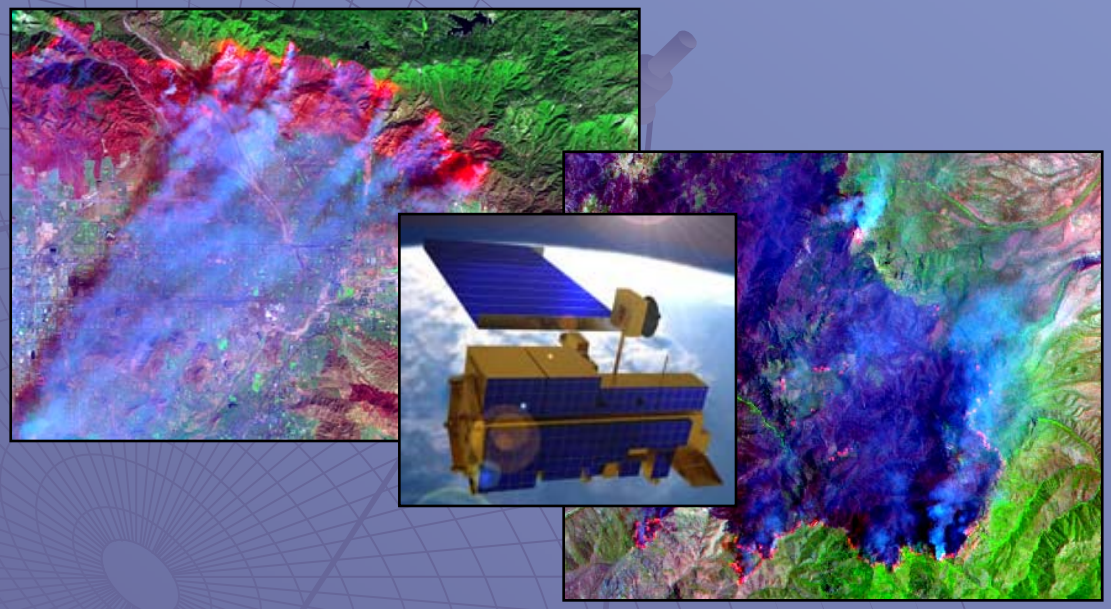
MODIS – ASTER – NPOESS



Training Center

U.S. Geological Survey
Center for Earth Resources
Observation and Science (EROS)
Sioux Falls, South Dakota, USA

Applications of Coarse to High Resolution Satellite Imagery for Land Productivity Assessment & Management

MODIS – ASTER - NPOESS

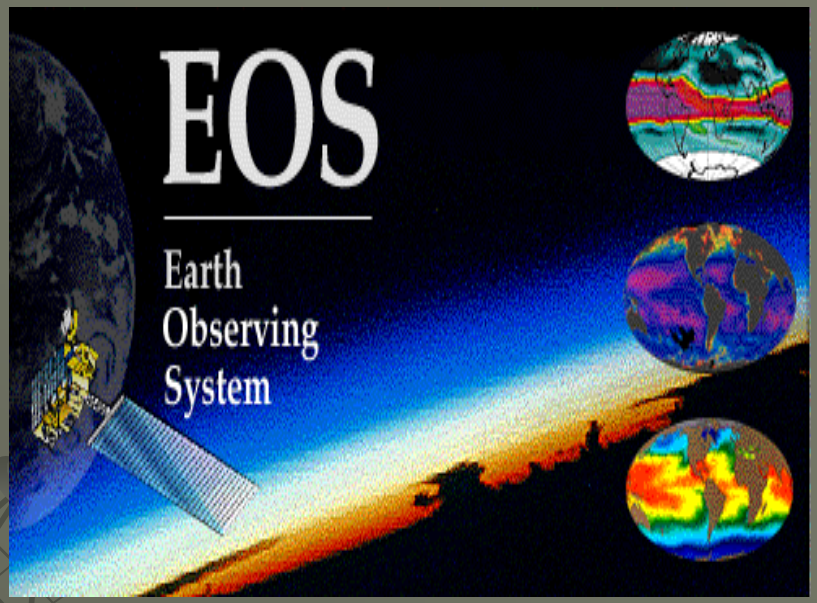
Michael Budde – SAIC / USGS EROS

Bamako , Mali

6 - 17 February, 2006

USGS EROS Data Center

Earth Observing System



EOS MISSION:

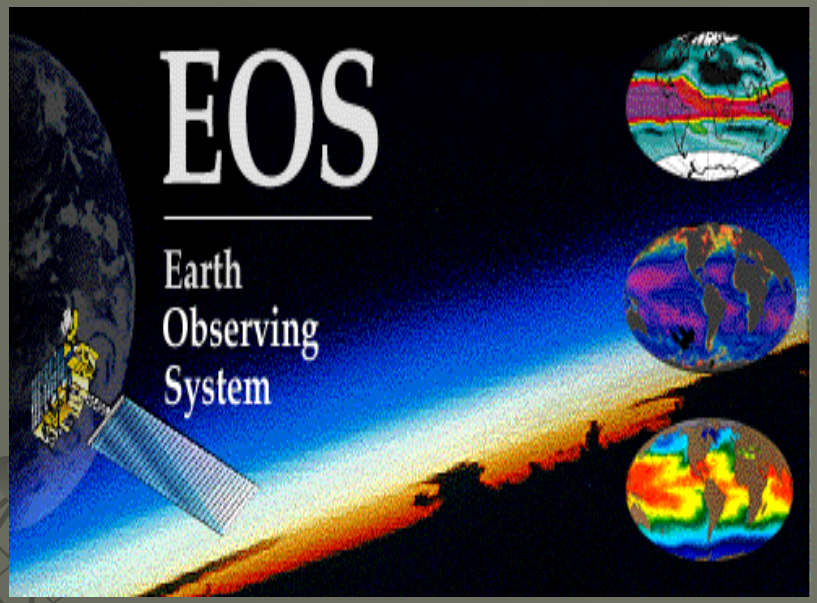
Use spaceborne sensors to study the Earth as an integrated system and to understand the effects of natural and human-induced changes on the global environment.

- Space-based and in situ measurements
- Data & Information System (EOSDIS)
- Scientific research (data synthesis and modeling)

USGS
science for a changing world

EOS: The Big Question

What influences Climate Variability and Climate Change?



- Radiation, Clouds, Water Vapor, Precipitation, and Atmospheric Circulation
- Ocean Circulation, Productivity, and Exchange with the Atmosphere
- Atmospheric Chemistry and Greenhouse Gases
- Land Ecosystems and Hydrology
- Cryospheric Systems
- Ozone and Stratospheric Chemistry
- **Volcanoes** and Climate Effects of Aerosols

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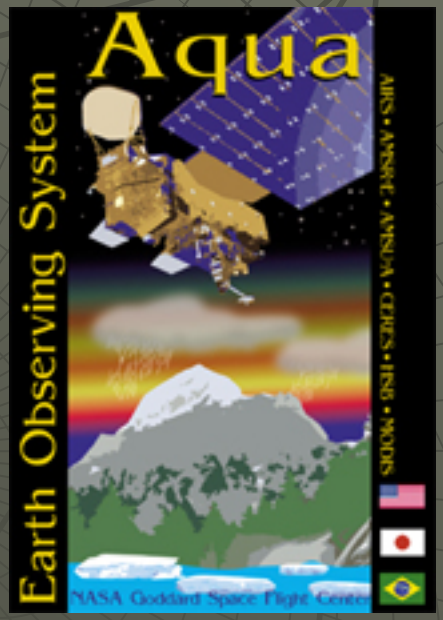
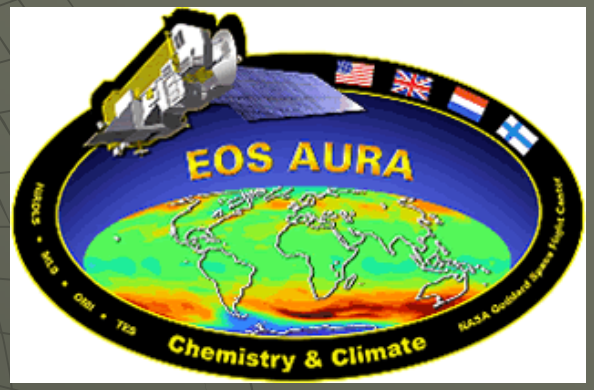
EOS: Data Acquisition

16+ continuous years of satellite measurement

Dec 18 1999



May 4 2002



January 2004

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science for a changing world

Terra

MISSION: to observe and measure how Earth's atmosphere, cryosphere, lands, oceans, and life all interact

LAUNCH: December 18, 1999 - Vandenberg AFB

ORBIT: Sun-synchronous
Near-Polar 705 km (438 mile)

EQUATOR CROSSING:
10:30 am descending

DESIGN LIFE: 6 years (extended)

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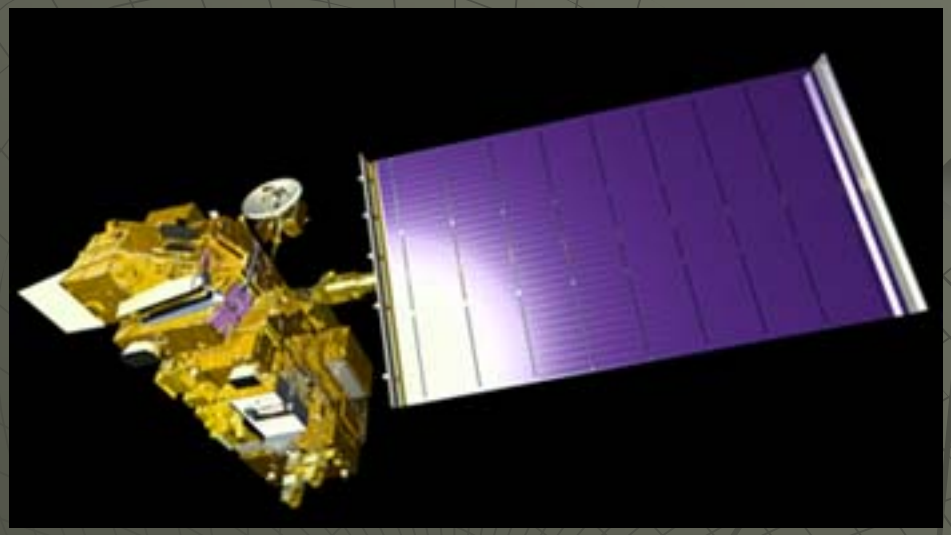
Terra - Payload



ASTER - Advanced Spaceborne Thermal Emission and Reflection Radiometer (MITI/JPL)

MODIS - Moderate Resolution Imaging Spectroradiometer (NASA)

MISR - Multi-Angle Imaging Spectroradiometer (JPL)

MOPITT - Measurements of Pollution in the Troposphere (CSA)

CERES - Clouds & Earth's Radiant Energy System (NASA)

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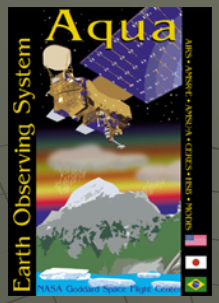

AQUA

MISSION: atmospheric temperature and humidity profiles, clouds, precipitation and radiative balance; terrestrial snow and sea ice; sea surface temperature and ocean productivity; soil moisture; and the improvement of numerical weather prediction

LAUNCH: May 4, 2002 - Vandenberg AFB

ORBIT: Sun-synchronous
Near-Polar
705 km (438 mile)

EQUATOR CROSSING:
1:30 pm ascending

DESIGN LIFE: 6 years

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AQUA - Payload

AIRS - Atmospheric Infrared Sounder (NASA)

AMSR/E - Advanced Microwave Scanning Radiometer-EOS (NASDA)

AMSU - Advanced Microwave Sounding Unit (NASA)

HSB - Humidity Sounder for Brazil (INPE)

CERES - Clouds and the Earth's Radiant Energy System (NASA)

MODIS - Moderate Resolution Imaging Spectroradiometer (NASA)

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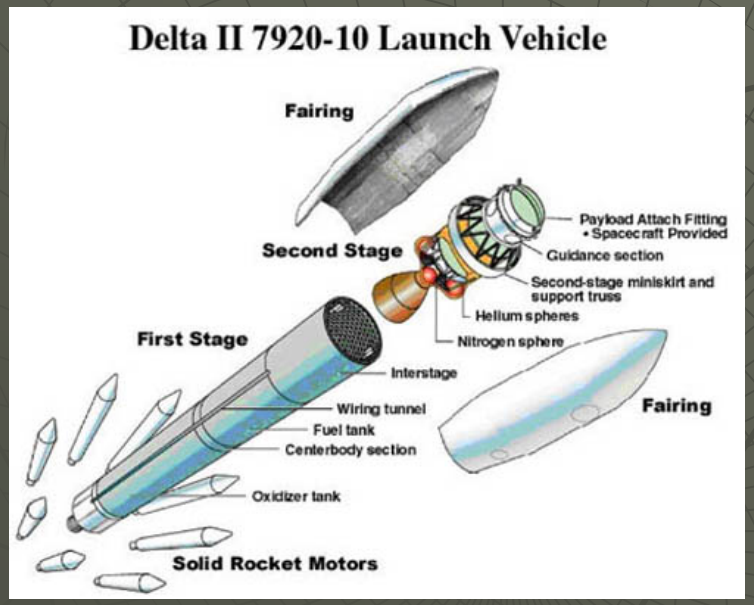
AURA



MISSION: ozone, air quality, climate

LAUNCH: January 2004 Vandenberg AFB

ORBIT: Sun-synchronous
Polar
705 km (438 mile)

EQUATOR CROSSING:
1:45 pm ascending

DESIGN LIFE: 6 years

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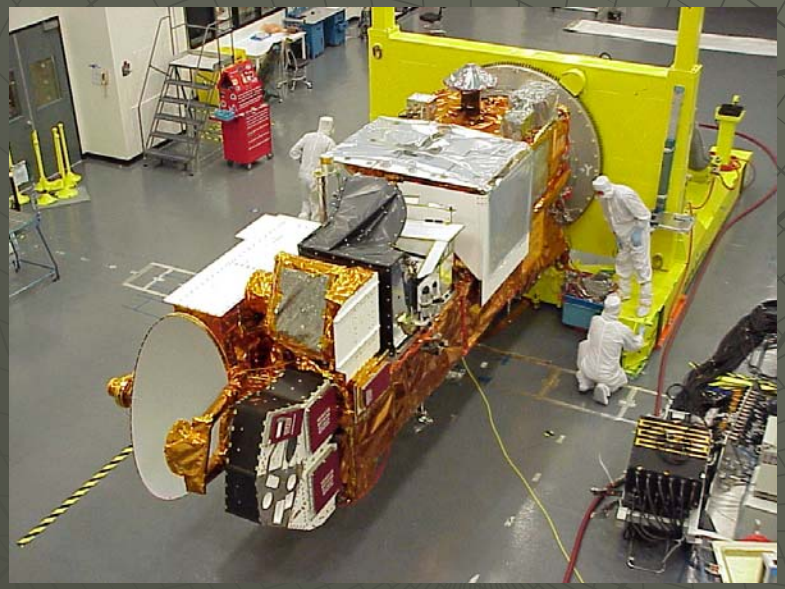
AURA - Payload



HIRDLS – High Resolution Dynamics Limb Sounder (US/UK)

MLS – Microwave Limb Sounder (JPL)

OMI – Ozone Monitoring Instrument (Netherlands)

TES – Tropospheric Emission Spectrometer (JPL)

EOS Data & Information System (EOSDIS)

EOSDIS was developed by NASA's Earth Science and Data Information System (ESDIS) Project to *acquire, archive, manage, and distribute* Earth observation data to a diverse group of users.

- perform mission operations for instrument & spacecraft control.
- capture and process telemetry data.
- generate higher level standard data products.
- archive and distribute data products.

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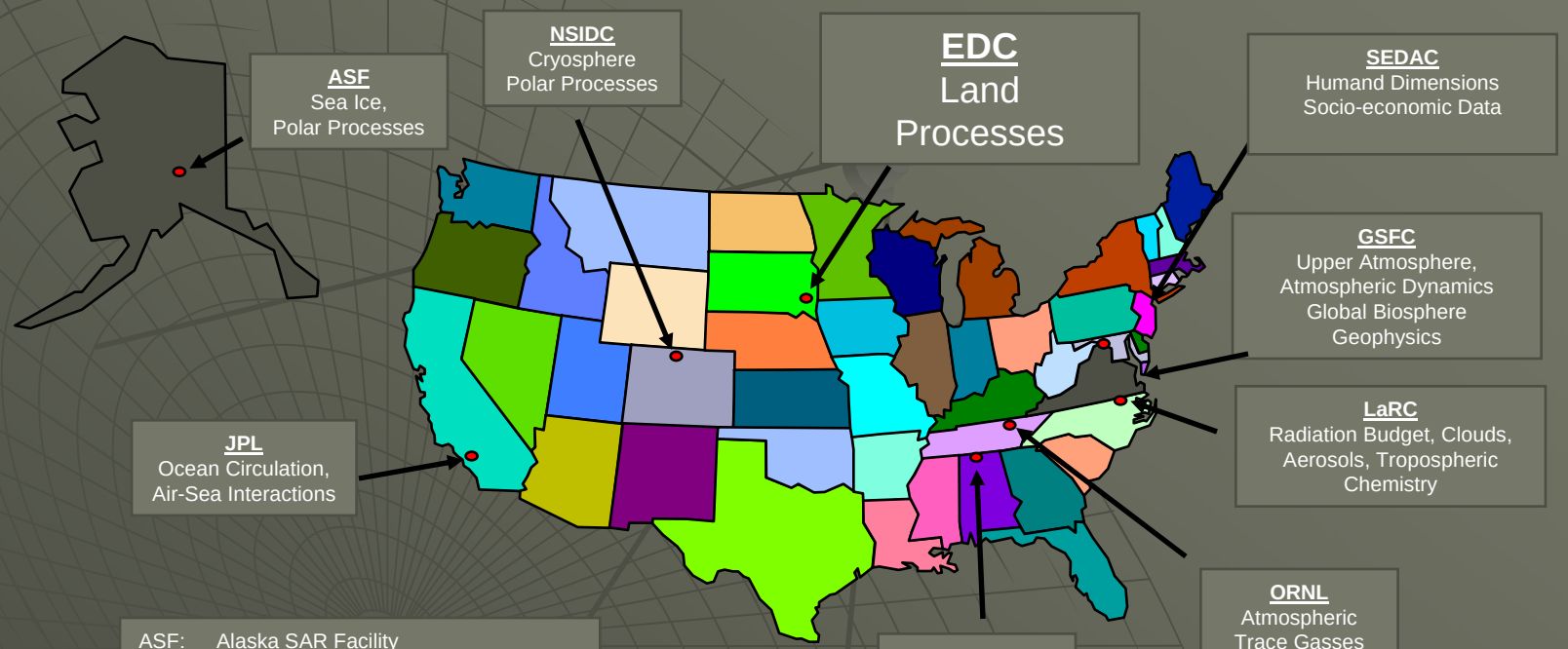
DISTRIBUTED ACTIVE ARCHIVE CENTERS



ASF: Alaska SAR Facility
EDC: EROS Data Center
GSFC: Goddard Space Flight Center
JPL: Jet Propulsion Laboratory
LaRC: Langley Research Center
MSFC: Marshall Space Flight Center
NSIDC: National Snow and Ice Data Center
ORNL: Oakridge National Lab

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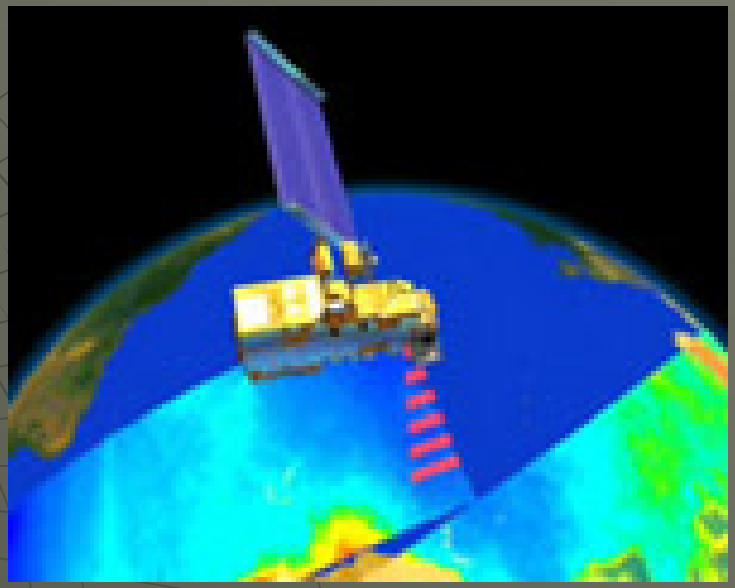
Terra Sensors - MODIS

- Moderate Resolution Imaging Spectroradiometer (MODIS)
  - MODIS will provide comprehensive measurements of ocean life (phytoplankton), land vegetation, cloud cover, and fires
  - Twice daily coverage from *Terra* and *Aqua*



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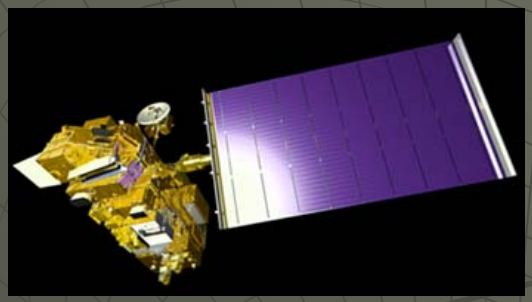
MODIS DATA FLOW



TERRA SATELLITE

TDRSS WHITE SANDS

GES DAAC

MODAPS

EROS DATA CENTER

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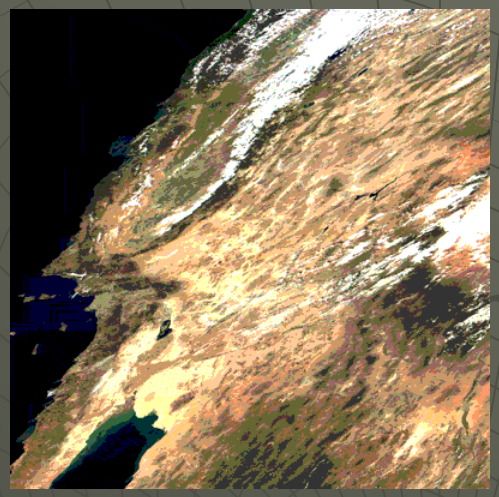
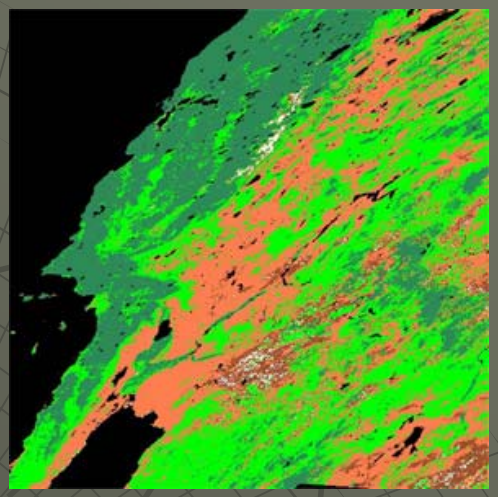
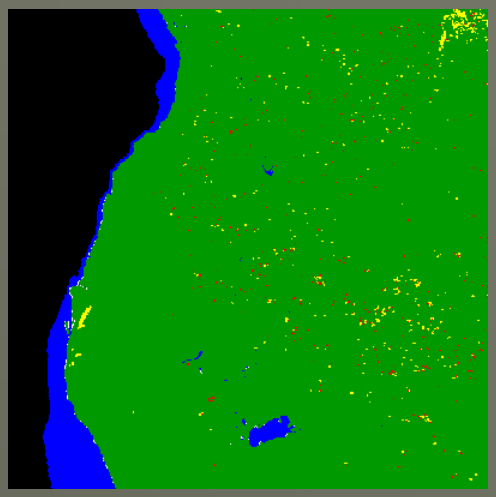
MODIS LAND DATA OVERVIEW







Radiation Budget	Ecosystem	Land Cover
Surface Reflectance	Vegetation Index	Thermal Anomalies/Fire
BRDF/Albedo	LAI/FPAR	Land Cover/Change
Temperature/Emissivity	NPP	Vegetation Continuous Fields

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MODIS LAND DATA at LP DAAC

MOD 09	Surface Reflectance
MOD 43	BRDF / Albedo
MOD 11	Land Surf. Temp. / Emissivity
MOD 14	Thermal Anomalies / Fire
MOD 12	Land Cover / Change
MOD 13	Vegetation Indices
MOD 15	Leaf Area Index / FPAR
MOD 17	Veg.Net Primary Production
MOD 44	Vegetation Continuous Fields

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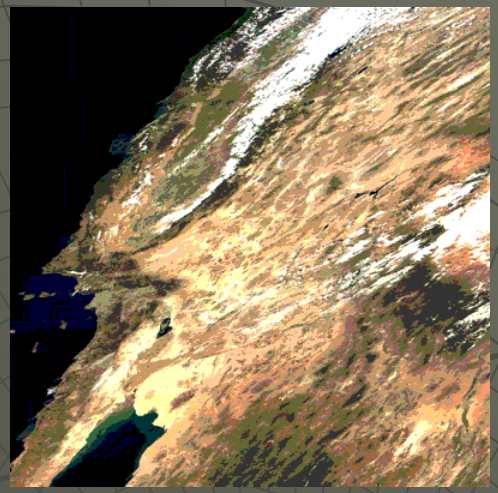
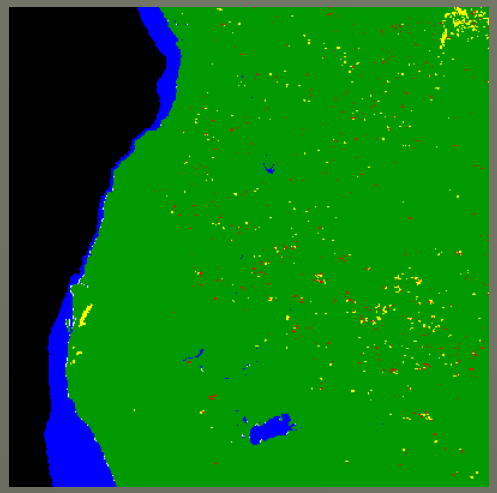
MODIS LAND DATA



Radiation Budget

Ecosystem



Land Cover

Surface Reflectance

BRDF/Albedo

Temperature/Emissivity

Vegetation Index

LAI/FPAR

NPP

Thermal Anomalies/Fire

Land Cover

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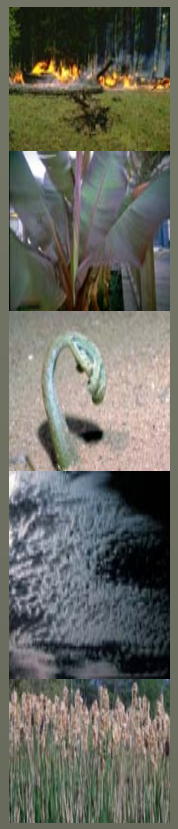
MODIS LAND DATA at LP DAAC

MO/YD 09	Surface Reflectance
MO/CD 43	BRDF / Albedo
MO/YD 11	Land Surf. Temp. / Emissivity
MO/YD 14	Thermal Anomalies / Fire
MO/YD 12	Land Cover / Change
MO/YD 13	Vegetation Indices
MO/YD 15	Leaf Area Index / FPAR
MO/YD 17	Veg. Net Primary Production
MO/YD 44	Vegetation Continuous Fields



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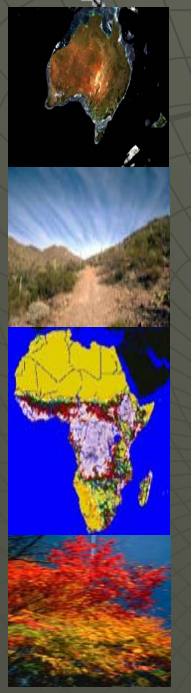
MODIS LAND DATA at LP DAAC: Data Characteristics



Temporal	1-, 8-, 16-, 32-day, monthly, quarterly, yearly
Spatial	250m, 500m, 1km, 0.25deg, 0.05deg
Level 2	Derived geophysical variables at the same resolution and location as Level 1 source data
Level 2G	Level 2 data mapped on uniform space-time grid scales
Level 3	Variables mapped on uniform space-time grid scales in derived spatial and/or temporal resolutions
Level 4	Model output or results from analyses of lower-level data.

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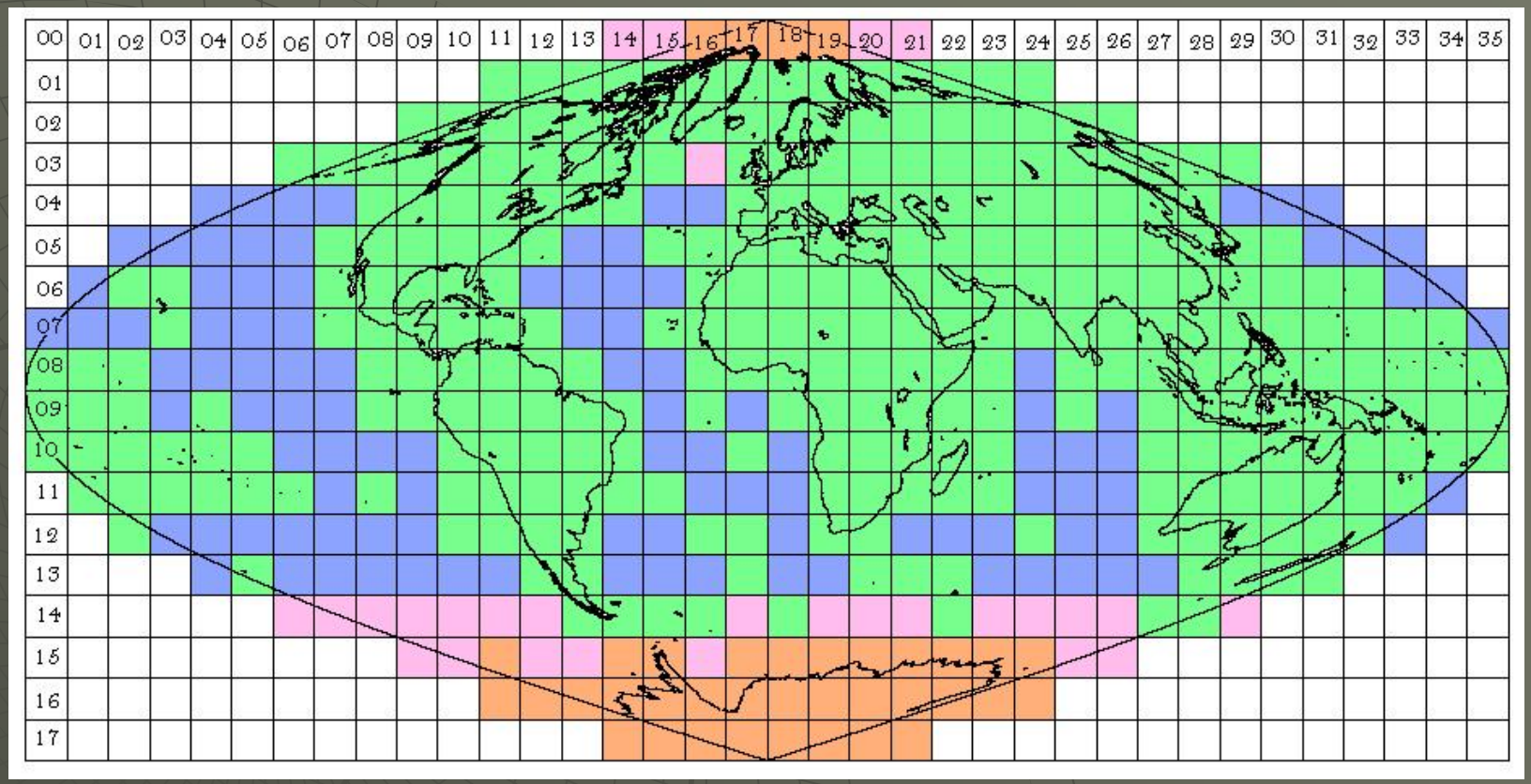
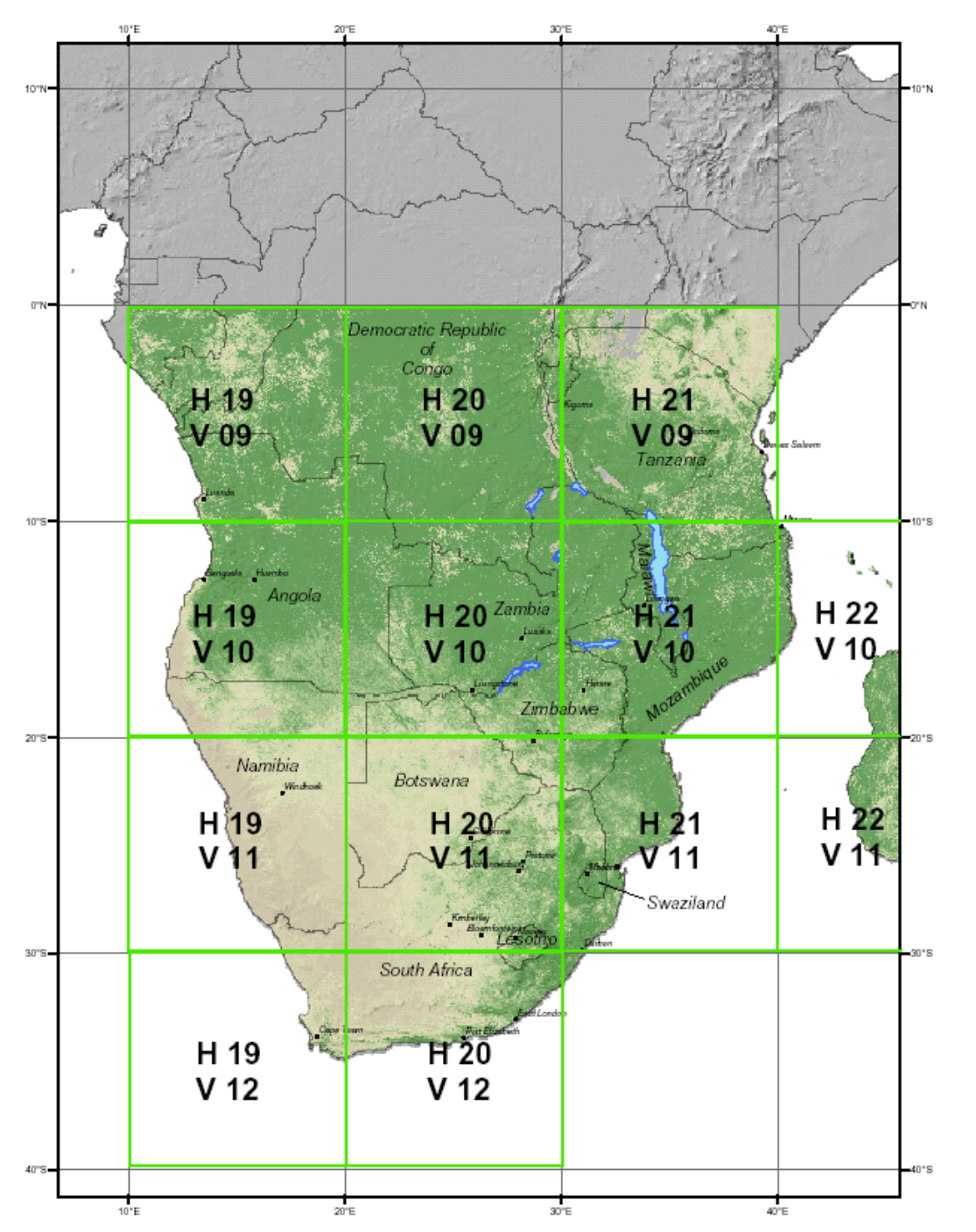
MODIS

Blue = ocean tiles, not produced
Pink = tiles produced for Sea ice products
Green = land products are generated





Approximate Tile Locations for MODIS Coverage of Southern Africa

FEATURES/CHALLENGES

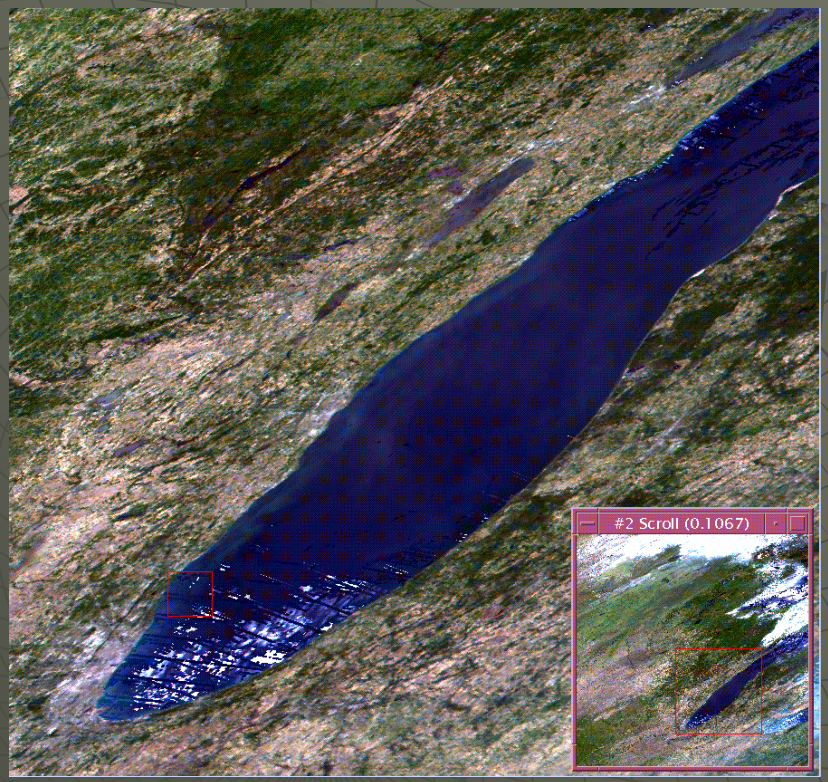
Data format

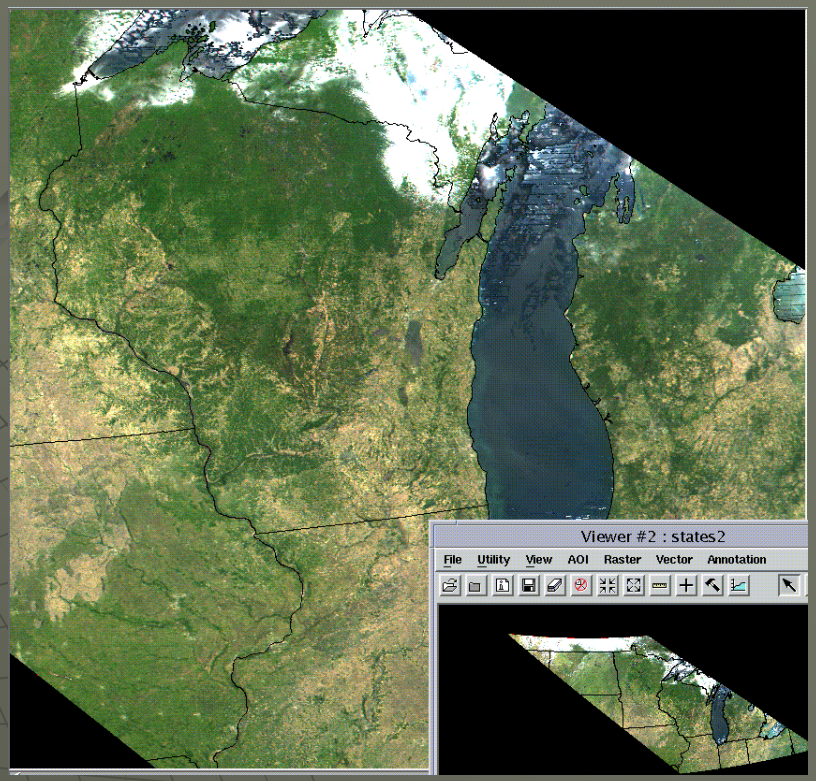
Bit-encoded quality information

Map projection

Timeliness

MAP PROJECTION





ISIN – Integerized Sinusoidal Grid – early products

SIN – Sinusoidal Map Projection – version 4 products

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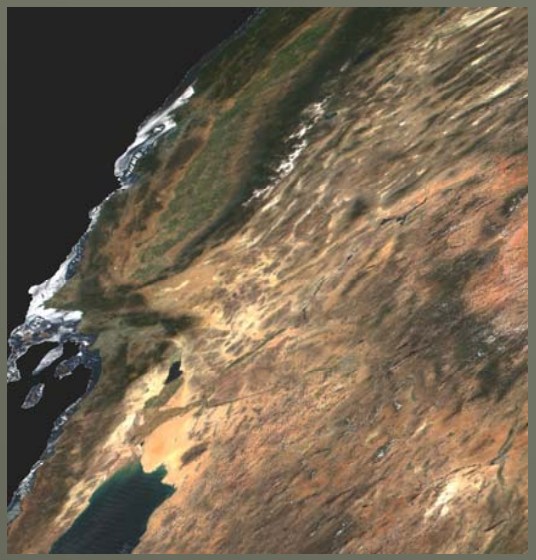
Surface Reflectance

DATATYPE	LEVEL	TEMPORAL	SPATIAL
MOD09GHK	2G	DAILY	500M
MOD09GST	2G	DAILY	1000M
MOD09A1	3	8-DAY	500M
MOD09Q1	3	8-DAY	250M
MOD09CMG	*3*	*DAILY*	*0.05deg*



Surface spectral reflectance for each band as if measured at ground level with no atmospheric scattering or absorption.

Corrections for gases, aerosols, cirrus clouds

Surface Reflectance

Data Set Characteristics	MOD09A1 8Day 500m
Area	~ 10° x 10° lat/long
Image Dimensions	2400 x 2400
File Size	~161 MB
Resolution	500 meters
Projection	V3 ISIN – V4 SIN
Data type	16-bit Integer
Science Data Sets (Bands)	13

Surface Reflectance

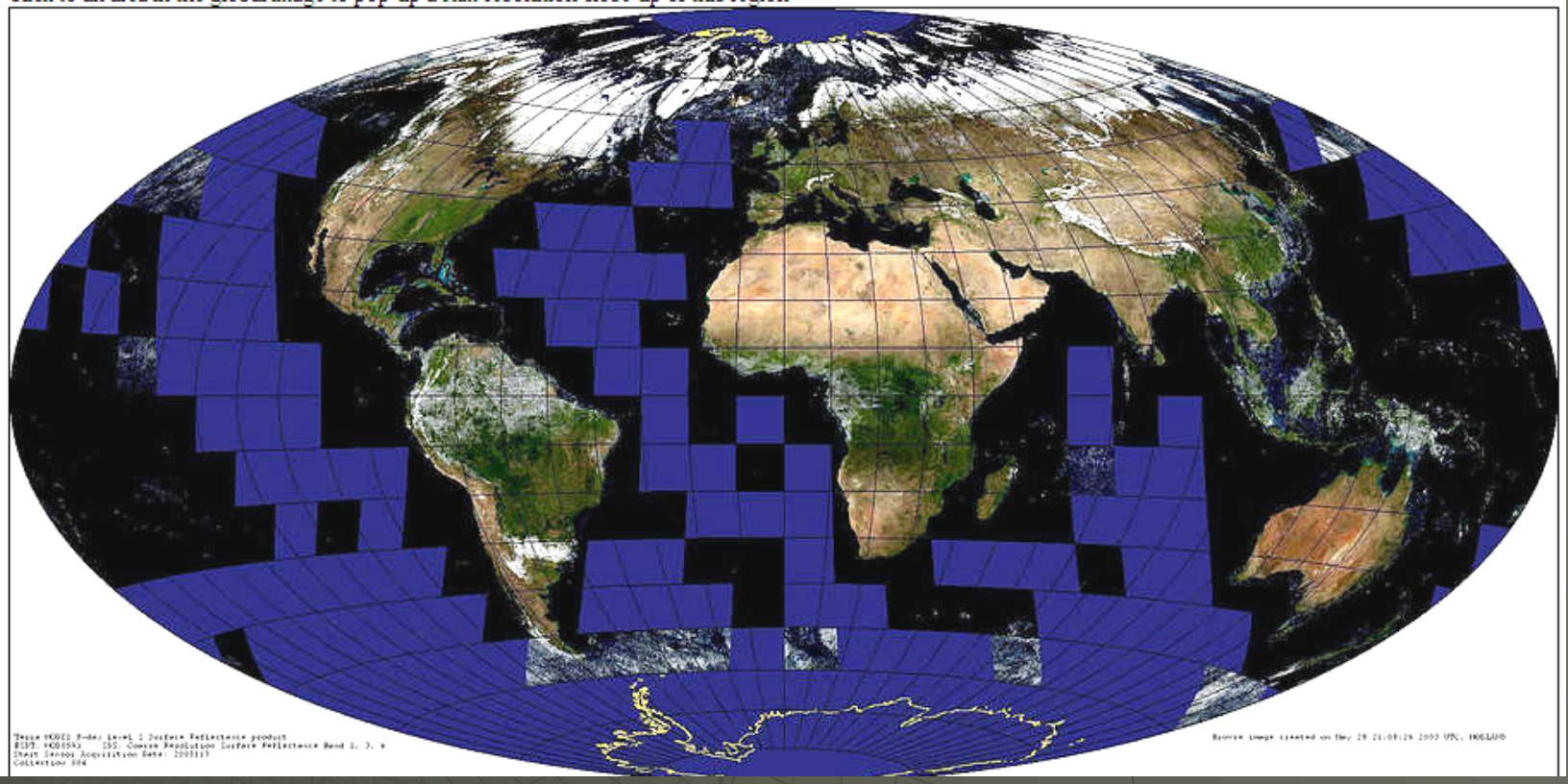
SCIENCE DATA SETS MOD09A1

SDS MOD09A1	UNITS		SDS MOD09A1	UNITS
Band1 620-670 nm	Reflectance		Day of the Year	Julian
Band2 (841-876 nm)	Reflectance		500m state flags	Bit Field
Band3 (459-479 nm)	Reflectance		Solar zenith	Degree
Band4 (545-565 nm)	Reflectance		View Zenith	Degree
Band5 (1230-1250 nm)	Reflectance		Relative Azimuth	Degree
Band6 (1628-1652 nm)	Reflectance		QC Flags	Bit Field
Band7 (2105-2155 nm)	Reflectance			

Surface Reflectance

TERRA, MOD09A1, day 2003113, Collection 4

Click to an area in the global image to pop-up a 5km-resolution close-up of this region



http://landqa2.nascom.nasa.gov/cgi-bin/browse/browse.cgi

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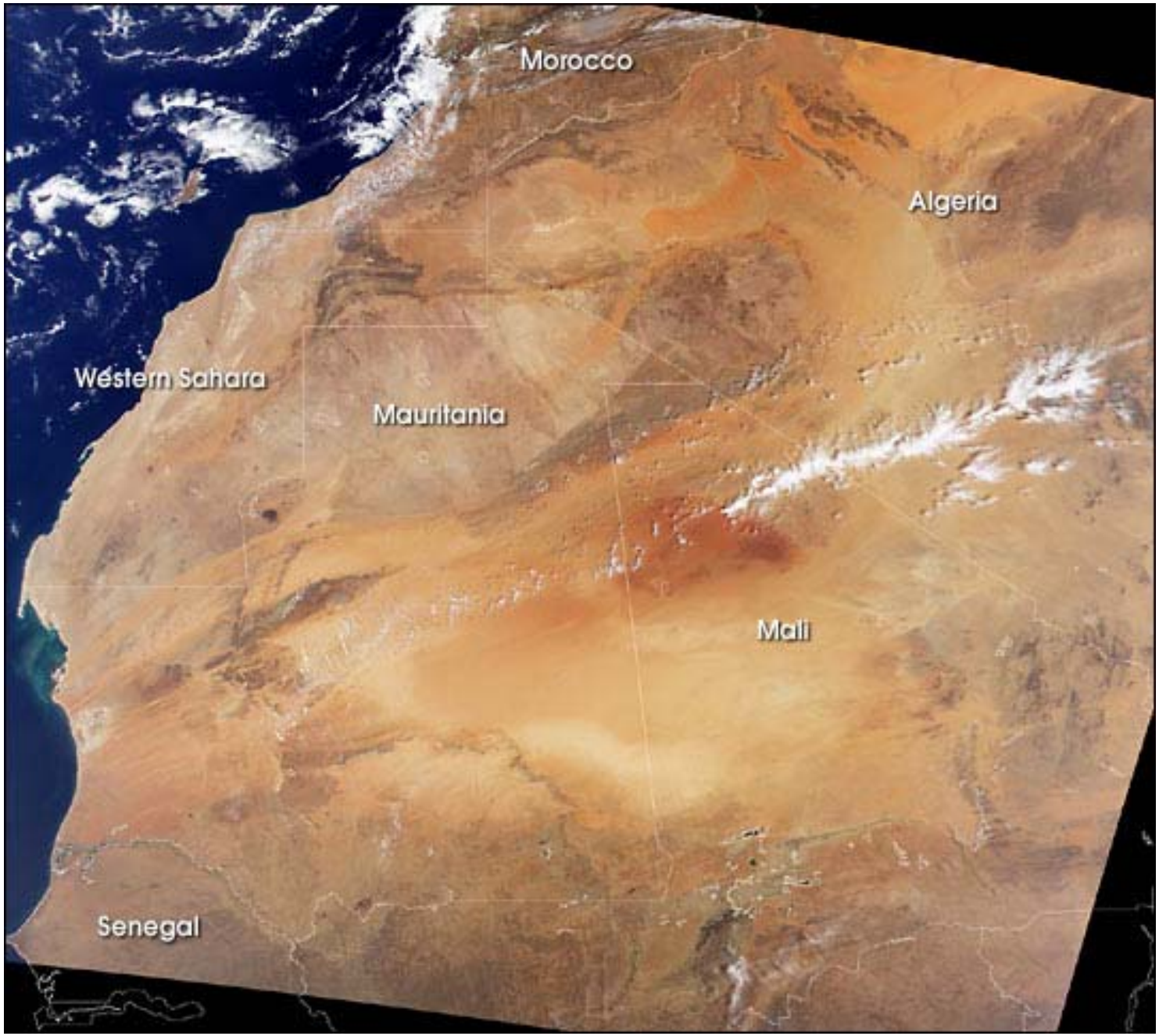

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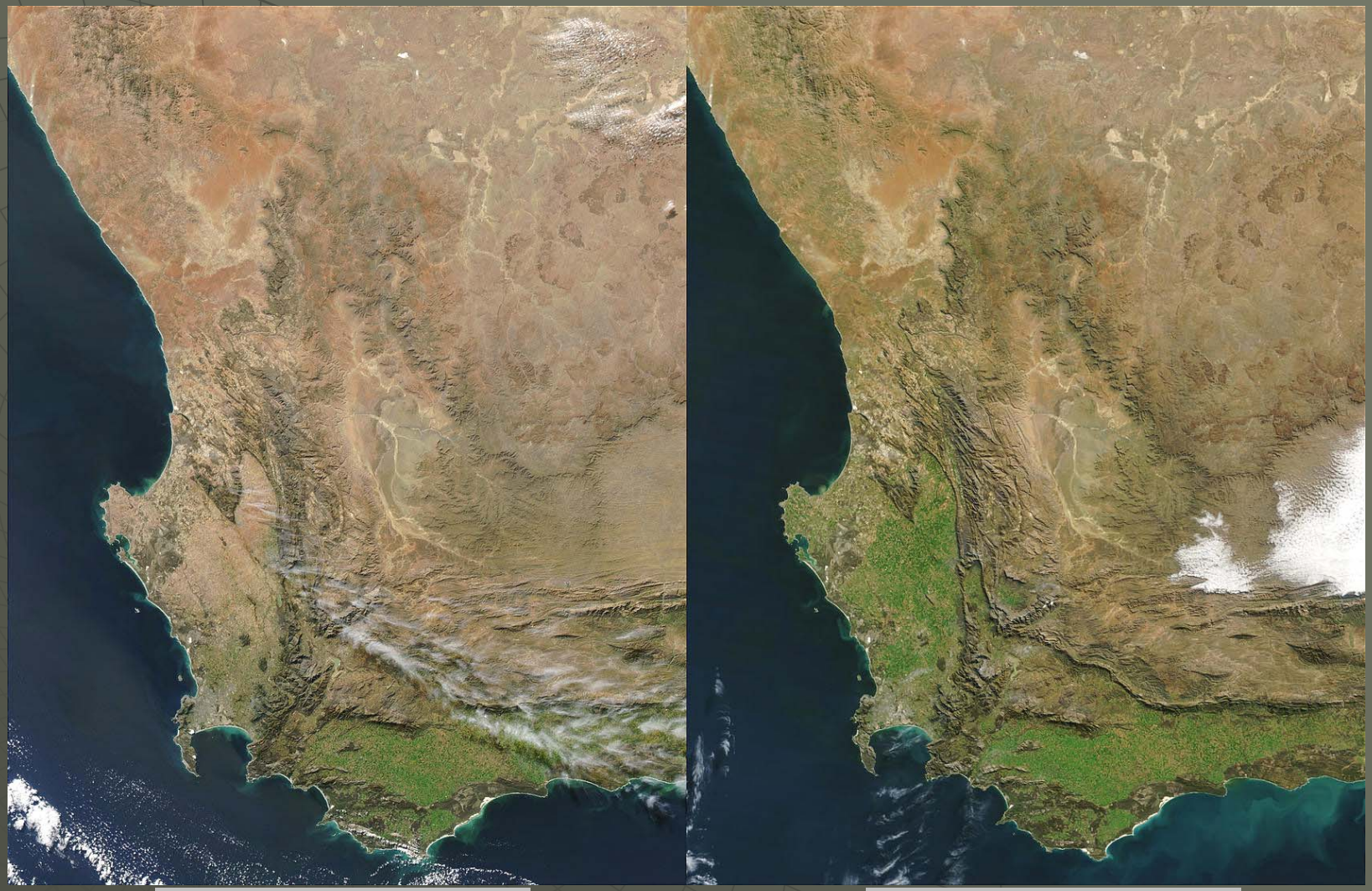
Drought in Western Cape, South Africa 2003

MODIS 500m Daily Surface Reflectance



July 21, 2003

July 21, 2002

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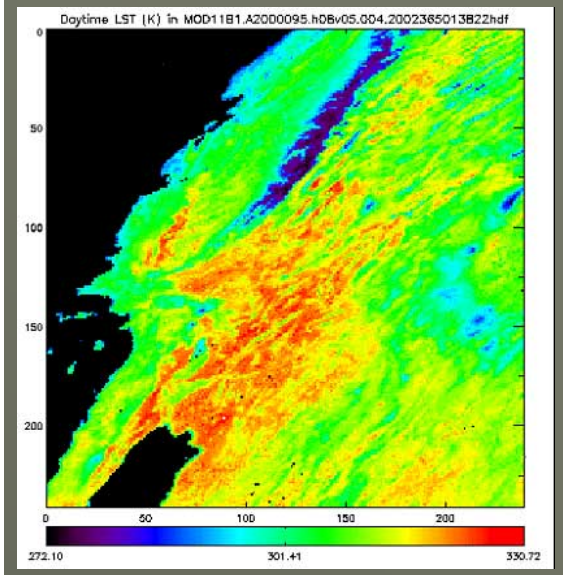
Land Surface Temperature / Emissivity

DATATYPE	LEVEL	TEMPORAL	SPATIAL
MOD11_L2	2	1-DAY	1000M
MOD11A1	3	1-DAY	1000M
MOD11B1	3	1-DAY	5000M
MOD11C1	3	1-DAY	1000M
MOD11A2	3	8-DAY	1000M
MOD11C2	3	8-DAY	0.05DEG
MOD11C3	3	MONTHLY	0.05DEG



1 K accuracy

MODIS Land Surface Temperature and Emissivity (LST/E) products provide per-pixel temperature and emissivity values. Temperatures are extracted in Kelvin with a view-angle dependent algorithm applied to direct observations.

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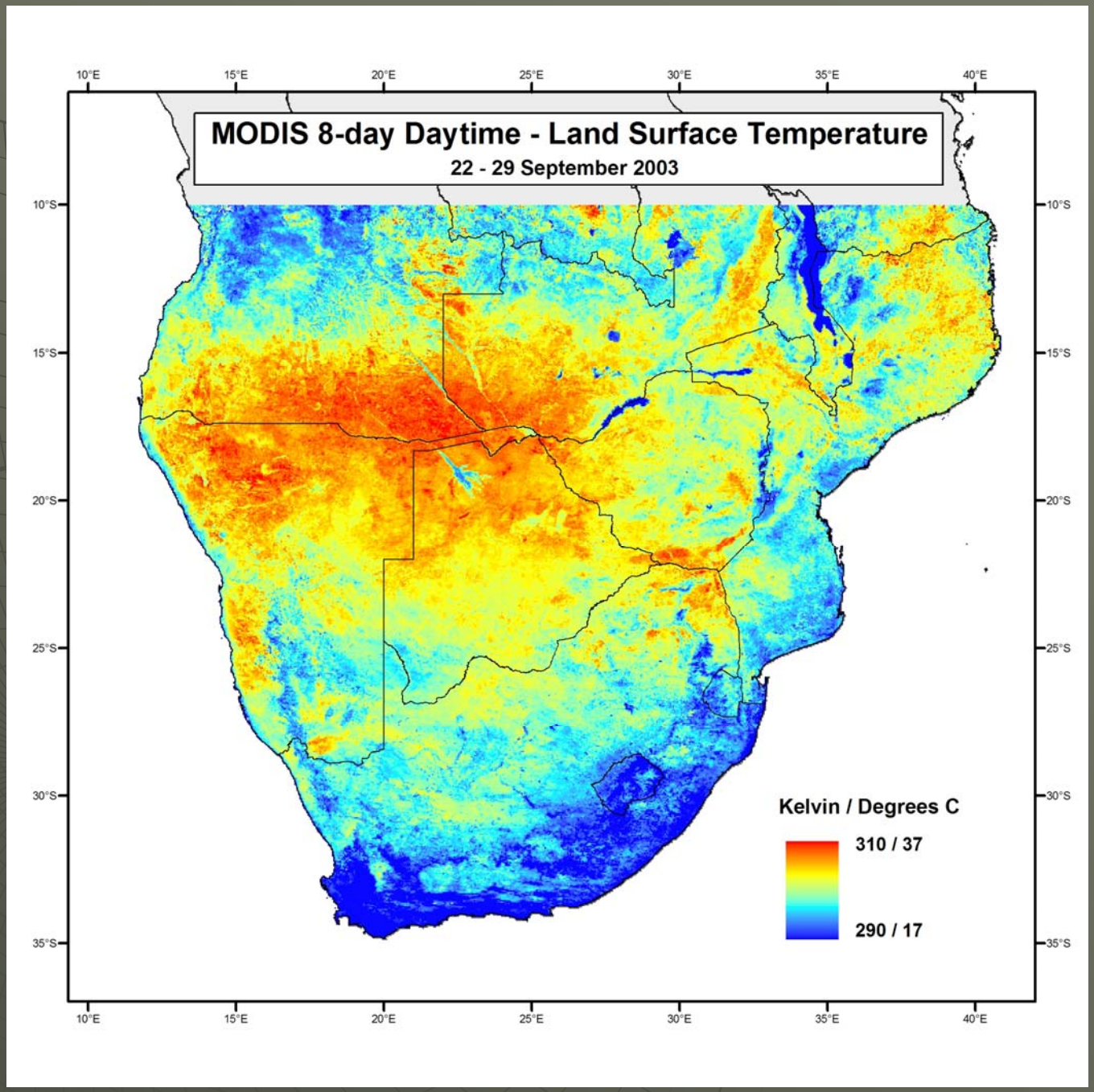

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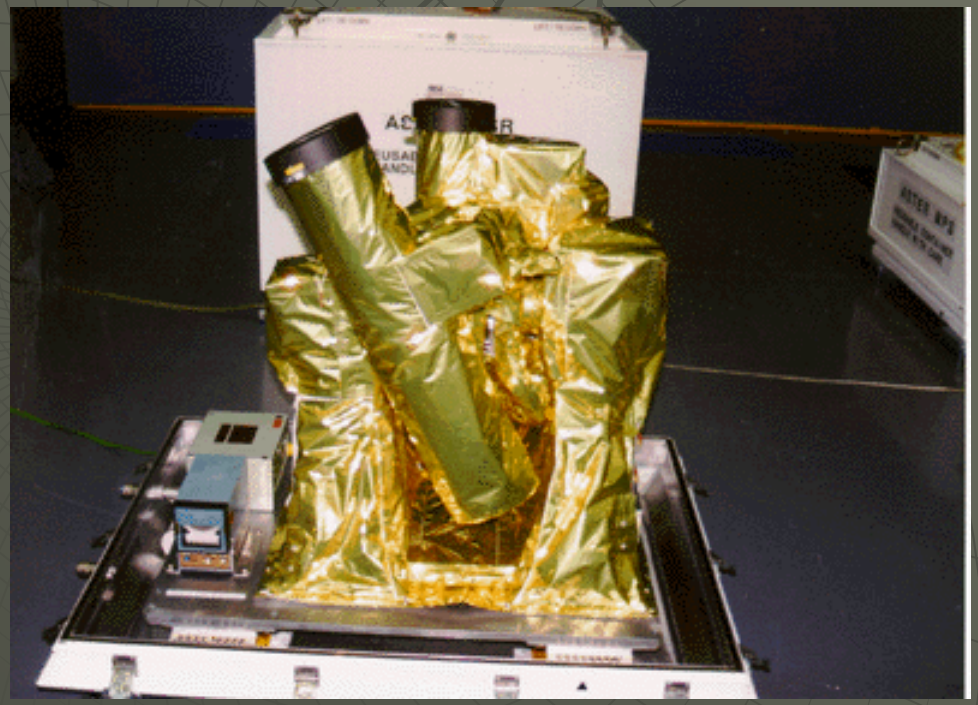
Terra Sensors - ASTER

- Advanced Spaceborne Thermal Emission and Reflection Radiometer



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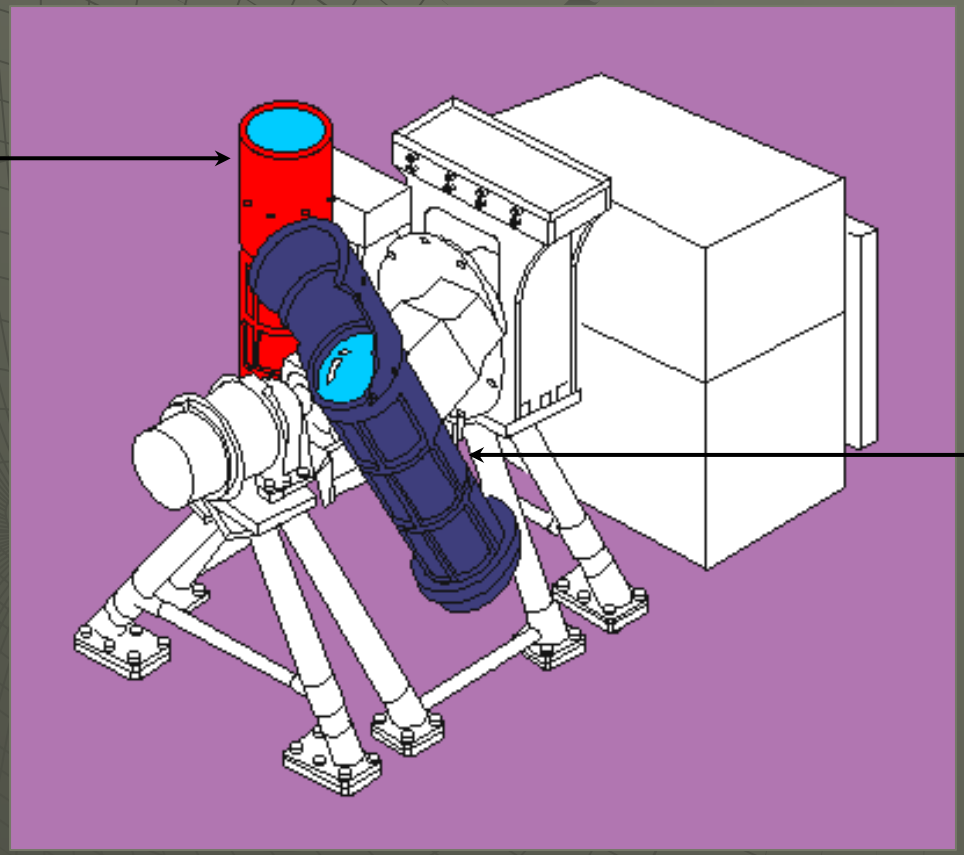
ASTER Instrument & Sensor Systems: VNIR Subsystem Design

VNIR Nadir Telescope:

The nadir & backward-looking telescope pair are used for same orbit stereo imaging, & can be rotated as a unit +/- 24° to provide extensive cross-track pointing capability



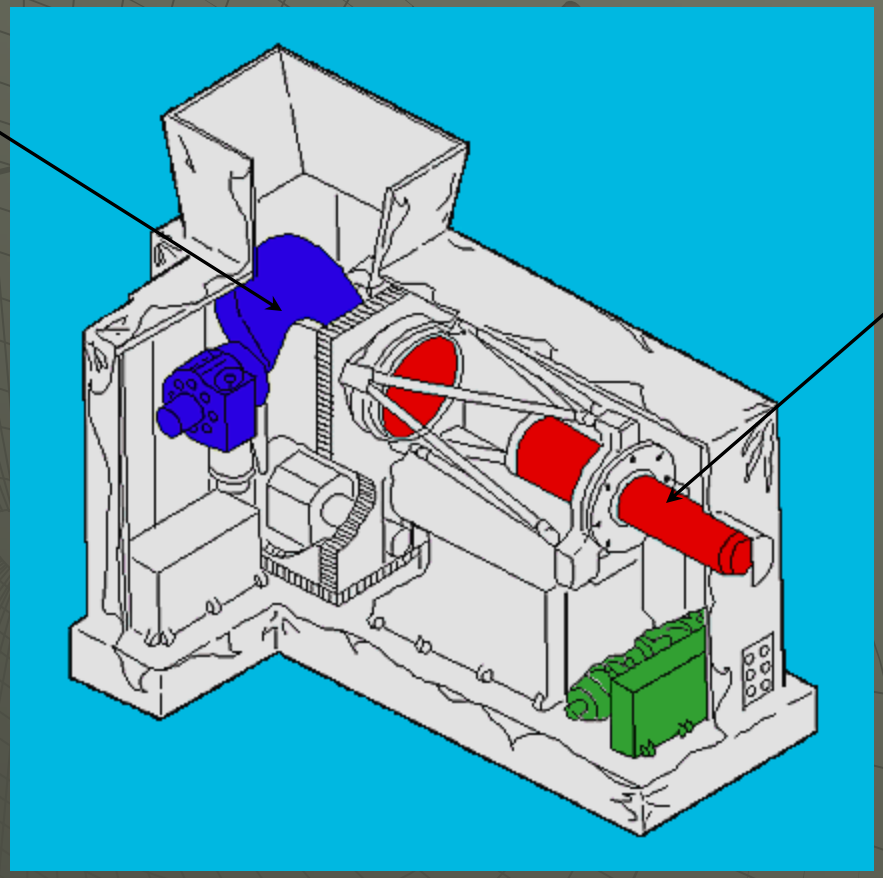
VNIR Backward-Looking Telescope:

ASTER Instrument & Sensor Systems: SWIR Subsystem Design

Pointing Module:

The pointing mirror can point +/- 8.54° from the nadir direction to allow coverage of any point over the spacecraft's 16 day mapping cycle.

This mirror is also periodically used to direct light from either of 2 calibration lamps into the system's telescopes



SWIR Subsystem's single fixed refracting telescope

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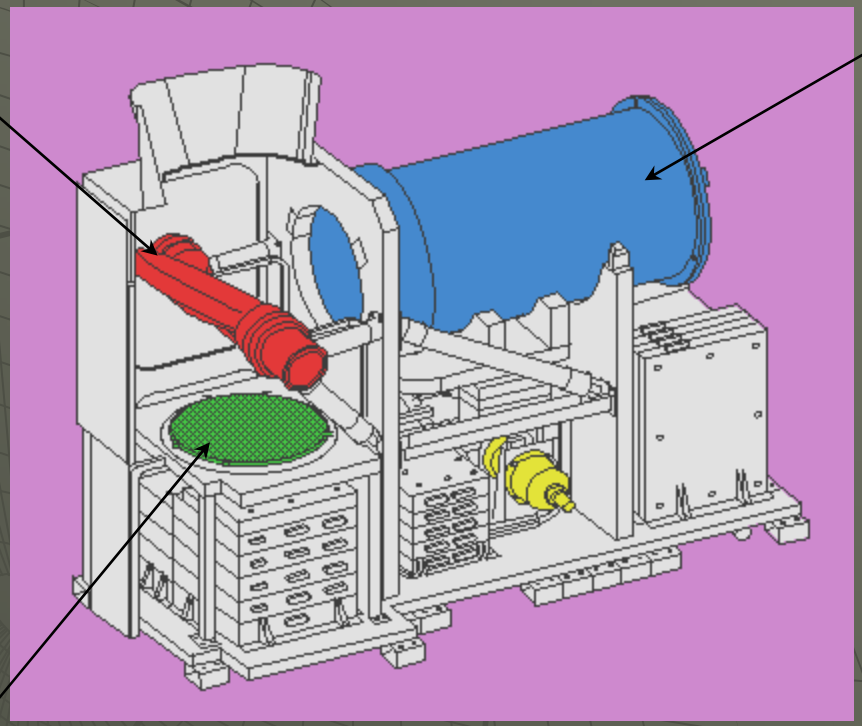
ASTER Instrument & Sensor Systems: TIR Subsystem Design

Scan Mirror:

The scan mirror is used for both scanning & pointing .

The mirror can point +/- 8.54° from the nadir direction to allow coverage of any point on the Earth over the spacecraft's 16 day mapping cycle



Telescope

Reference Plate (Blackbody):

A high emissivity reference plate is used as the on-board calibration reference for the TIR Subsystem. This plate is viewed before & after each observation to provide an estimate of instrument drift, and instrument gain and offset

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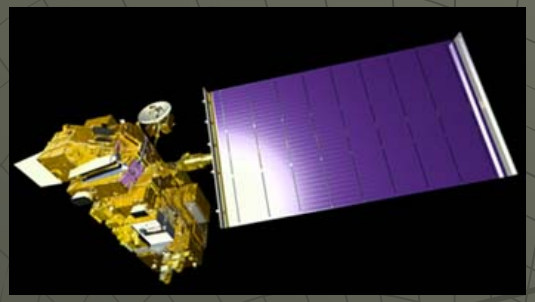
ASTER DATA FLOW



TERRA SATELLITE

TDRSS WHITE SANDS

GES DAAC
EDOS

ASTER GDS - Japan

EROS Data Center Land Processes DAAC

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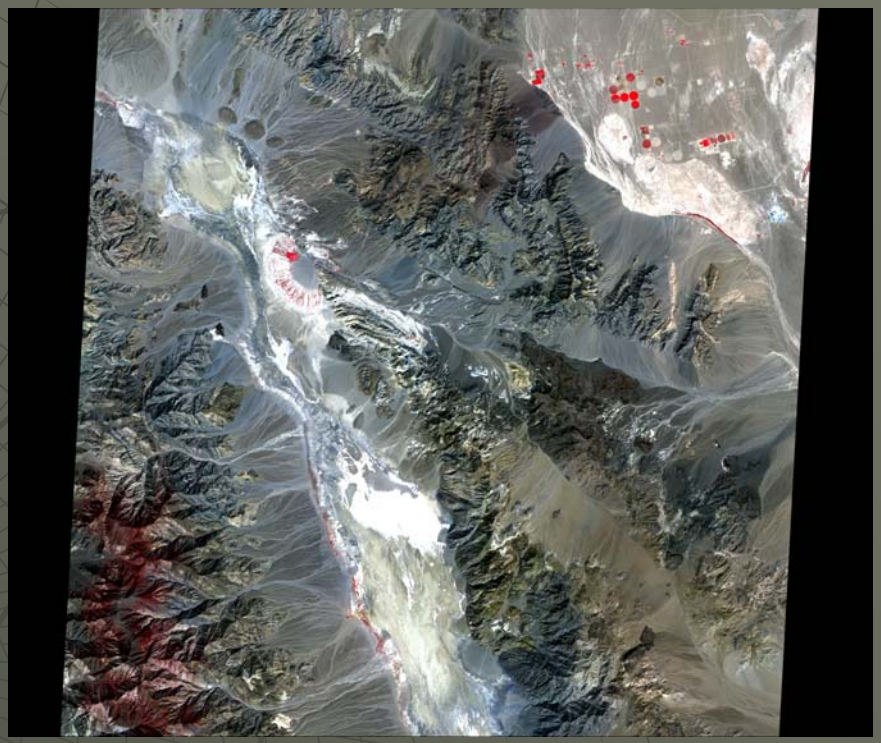
ASTER Data Products:
Surface Reflectance (VNIR & SWIR)

Level: 2
Units: %
Resolution: 15, 30 m
Size: 238 Mb
Mode: On demand



Description: Surface reflectance data, recorded as percent reflectance, derived by applying atmospheric corrections to observed radiance. Uses a Gauss-Seidel iteration of the Radiative Transfer Code.

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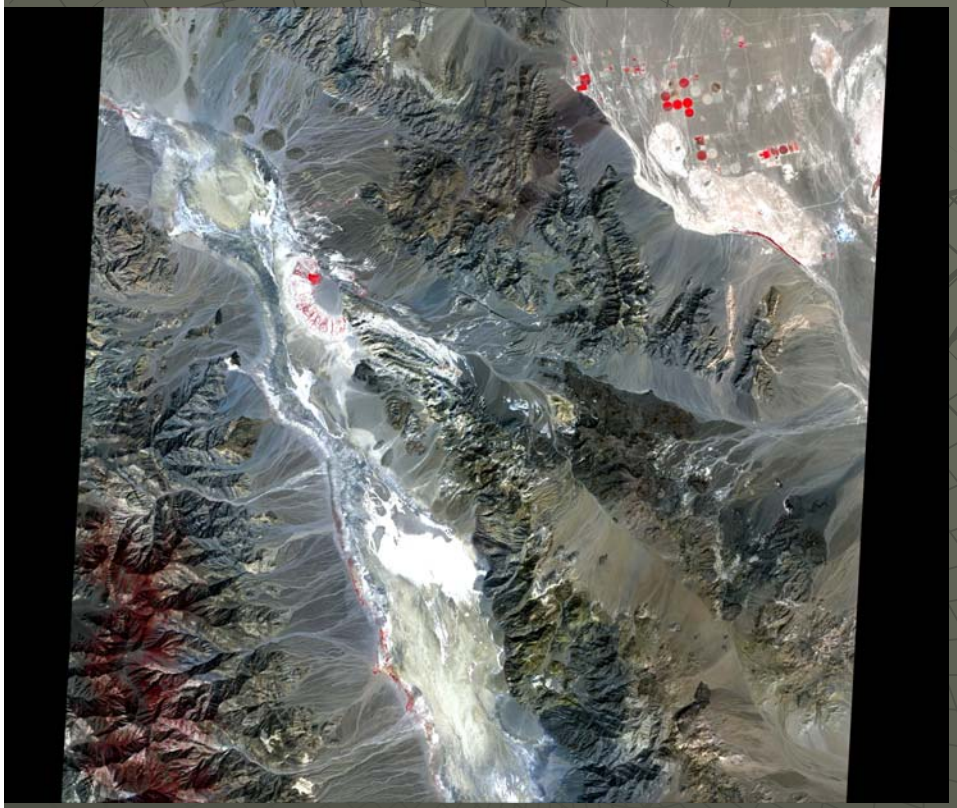
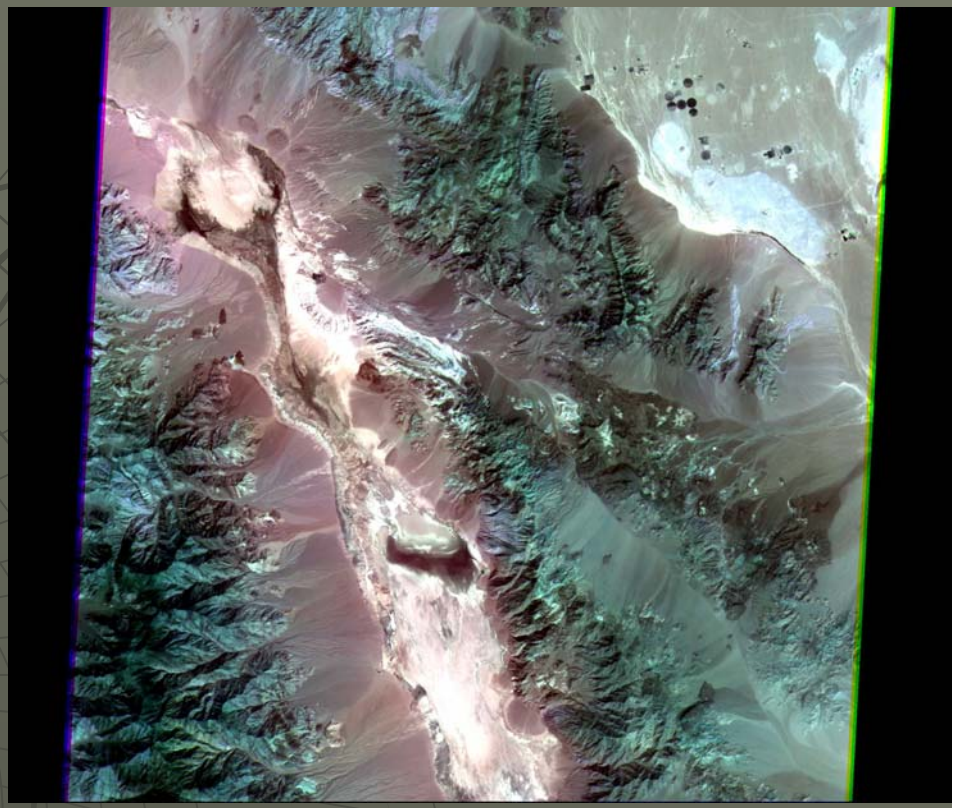
Surface Reflectance



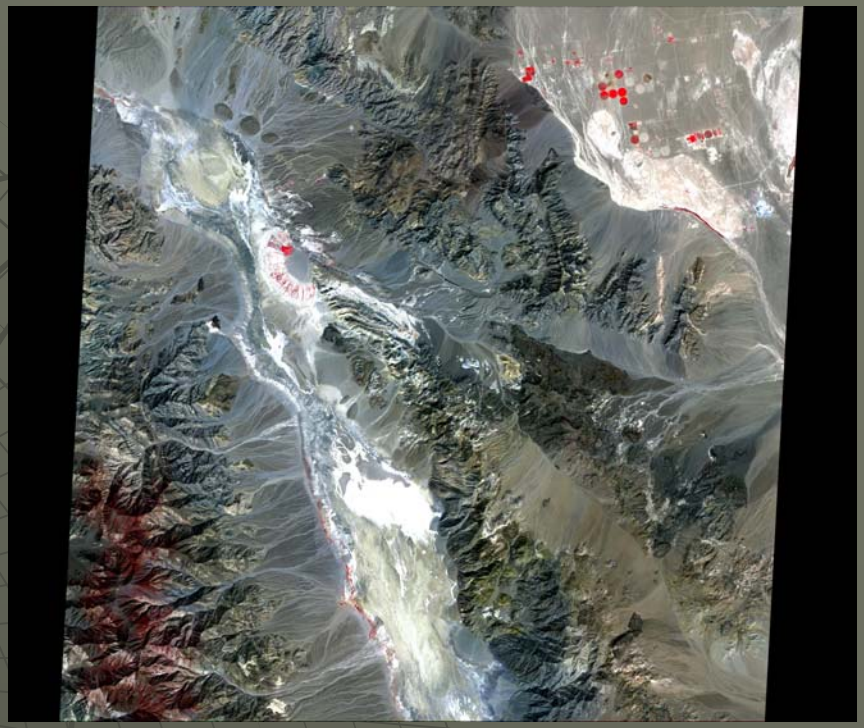
VNIR



SWIR

ASTER Data Products:
Surface Radiance (VNIR, SWIR, & TIR)

Level: 2
Units: W/m2/sr
Resolution: 15, 30, 90 m
Size: 238 (VNIR, SWIR), 6 (TIR) Mb
Mode: On demand



Description: Atmospherically corrected surface radiance calculated for clear sky scenes. Includes surface-reflected and surface-emitted components for TIR.

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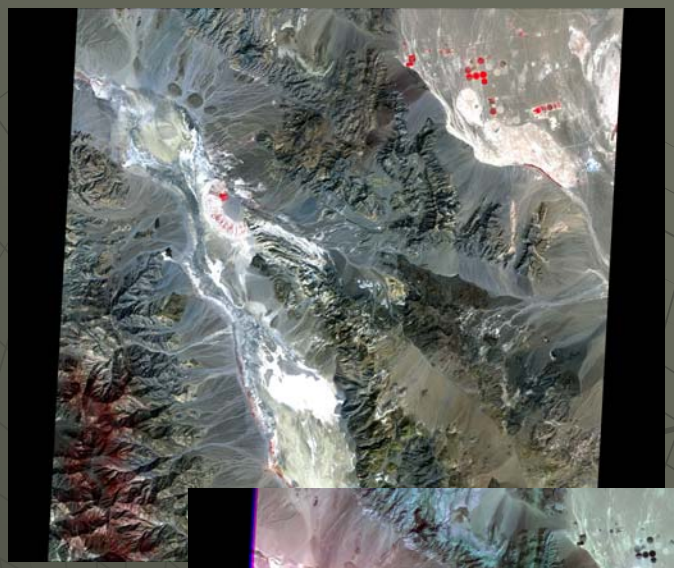
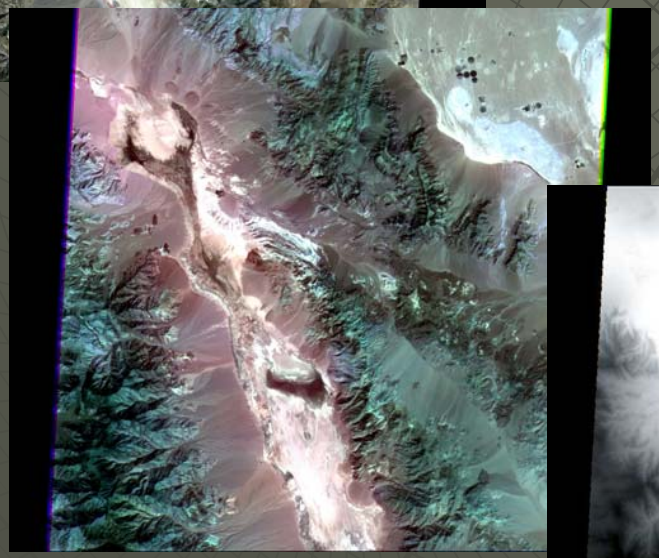
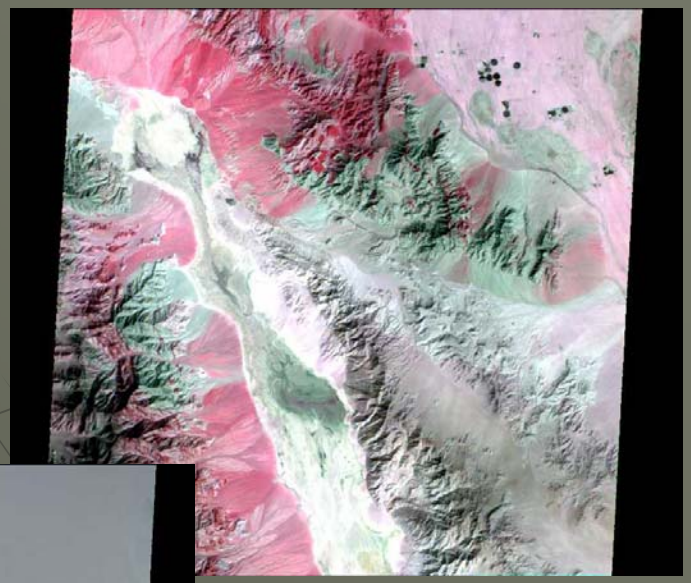
VNIR



SWIR



TIR surface emitted



TIR surface reflected

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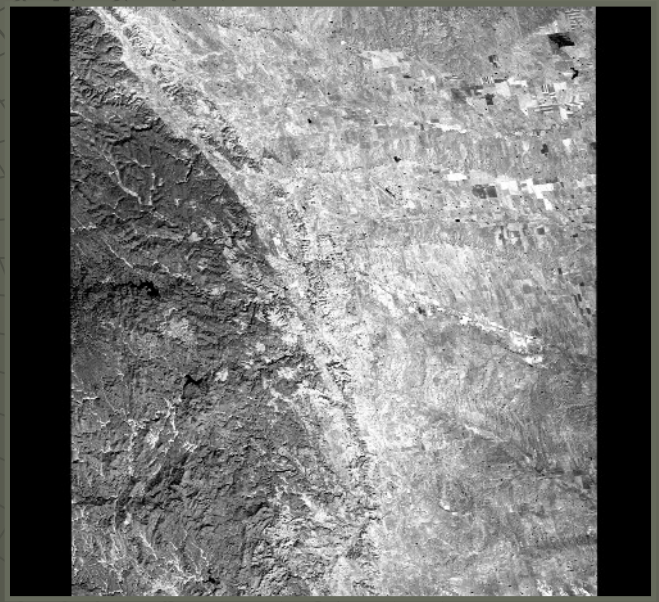
Terra Sensors - ASTER

- Visible and Near Infrared (VNIR)
  - Stereo capabilities!

3N (4100 X 4200)

3B (5000 X 4600)



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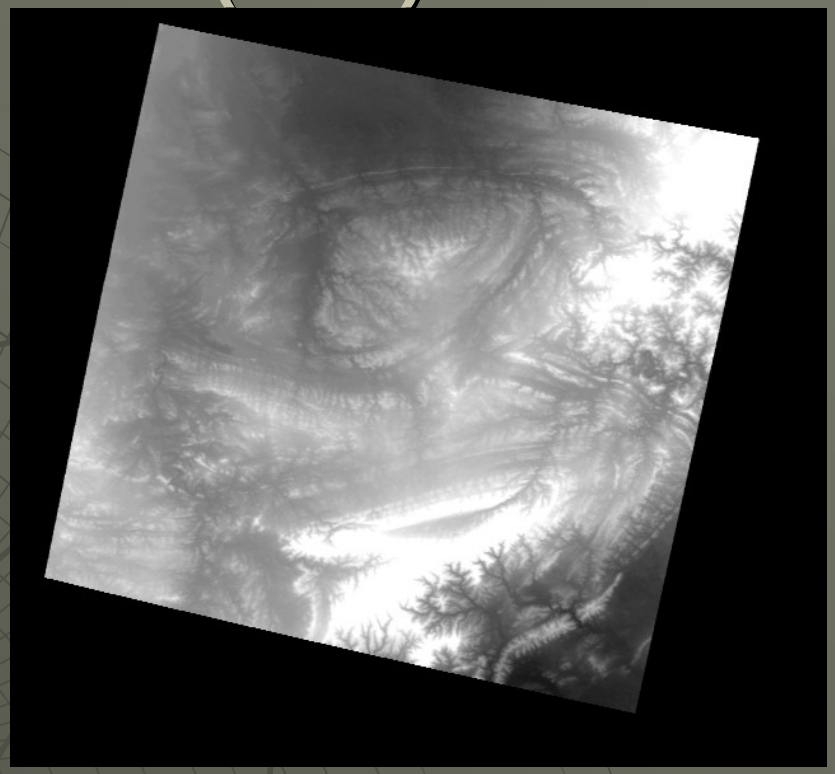
ASTER Data Products: Digital Elevation Model (DEM)



Level: 4
Units: m
Resolution: 15 m
Size: 35 Mb
Mode: On demand

Description: Topographic data set generated by photogrammetric methods using nadir & aft stereo images. Both absolute (with user-supplied GCPs) and relative DEMs are produced. Absolute horizontal & vertical accuracy with ground control: >= 7 m and relative accuracy without ground control: 10 m.

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ASTER Image draped on DEM

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ASTER Data Applications

The primary science objective of the ASTER mission is to improve [our] understanding of the local and regional-scale processes occurring on or near the Earth's surface and lower atmosphere, including surface-atmosphere interactions (Yamaguchi *et al*., 1998).

Areas of ASTER science investigation include:

- Land surface climatology
- Monitoring volcanoes
- Hazards monitoring
- Carbon cycle in the marine ecosystem
- Geology and soils
- Aerosols and clouds
- Hydrology

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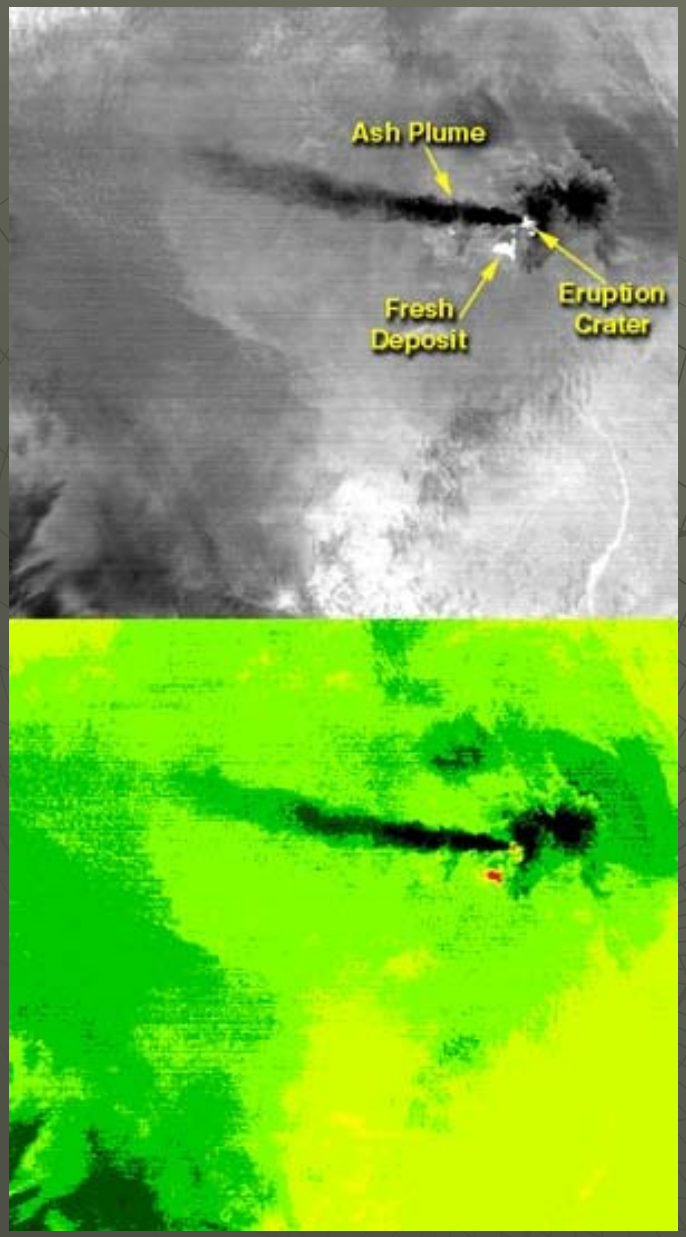

June 4, 2001 thermal image of Shiveluch volcano on Kamchatka Peninsula.

A lava dome is the hot spot visible on the summit of the volcano. The second hot area is either a debris avalanche or hot ash deposit.

An ash plume is seen as a cold "cloud" streaming from the summit.

NASA/GSFC/MITI/ERSDAC/JAROS
U.S./Japan ASTER Science Team

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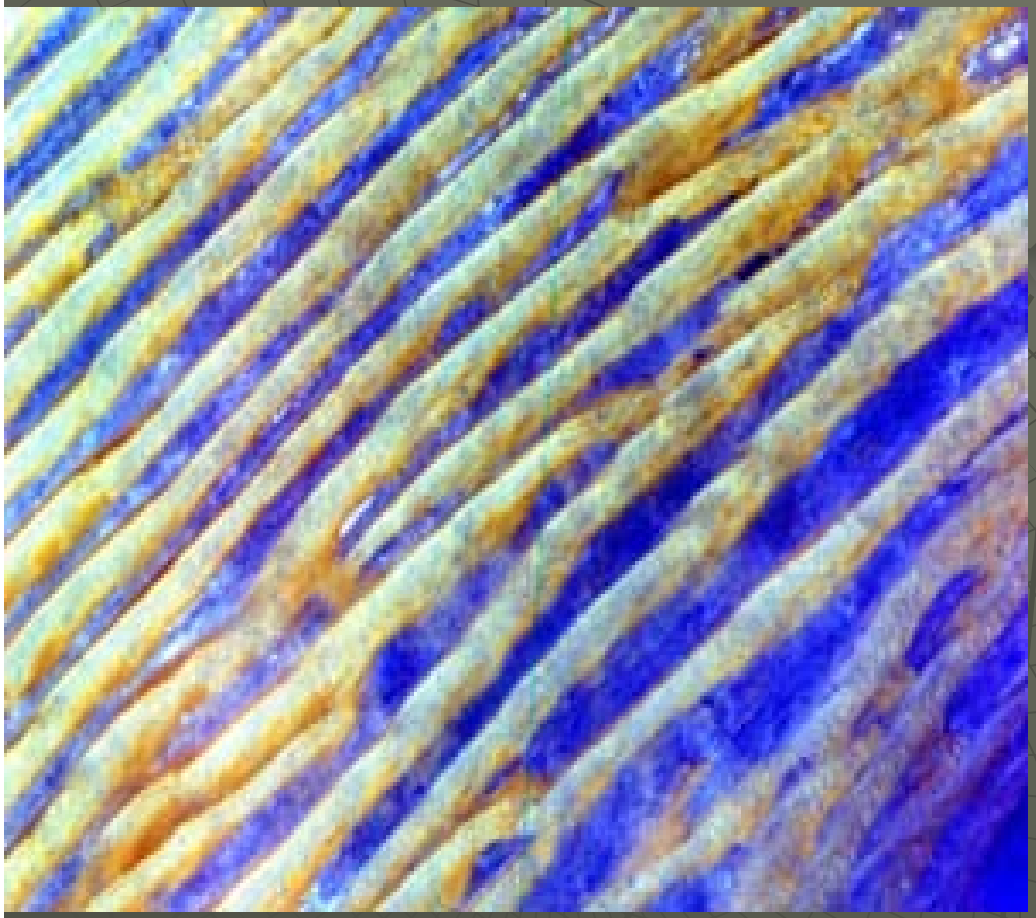
Saudi Arabia sand dunes June 25, 2000



Depicts linear dunes in Rub' Al Khali or Empty Quarter in Saudi Arabia.

Dunes are yellow due to iron oxide minerals; inter-dune areas are made up of clays and silt and appears blue due to high reflectance in Band 1

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Lake Garda, Italy - June 29, 2000

Lake Garda lies in the provinces of Verona, Brescia, and Trento. It is 51 km long and 3 to 18 km wide.

The image on the right was contrast stretched to display variations in sediment load

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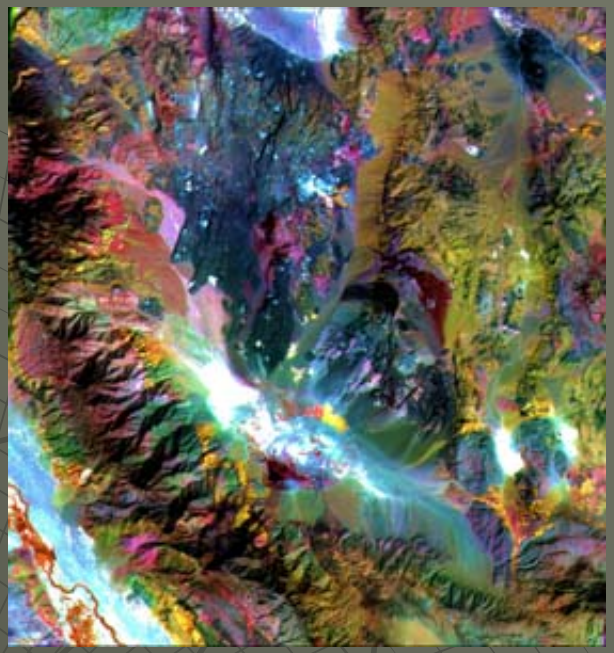
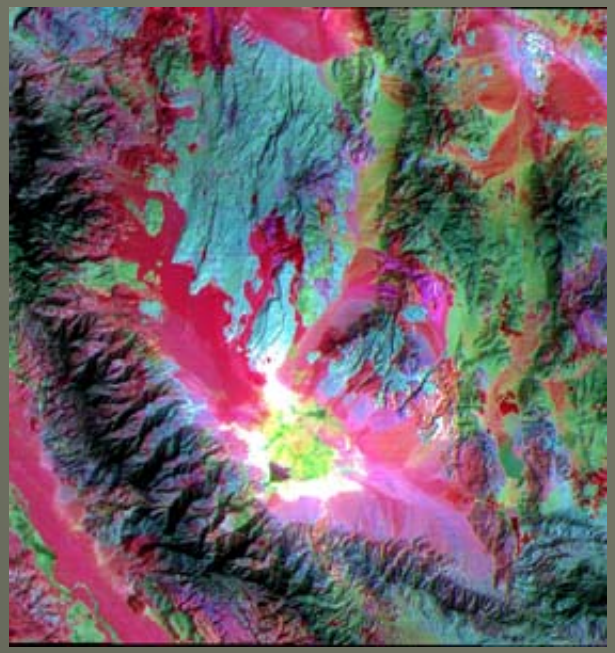
Saline Valley, California – March 30, 2000

VNIR



SWIR



TIR

VNIR (3,2,1) – vegetation appears red, snow and dry salt lakes are white, exposed rocks are brown, gray, yellow, and blue

SWIR (4,6,8) – clay, carbonate, and sulfate minerals result in distinctive colors; limestones are yellow-green and kaolinite rich areas are purple

TIR (13,12,10) – variations in quartz content are shades of red; carbonates are green and mafic volcanic rocks are purple

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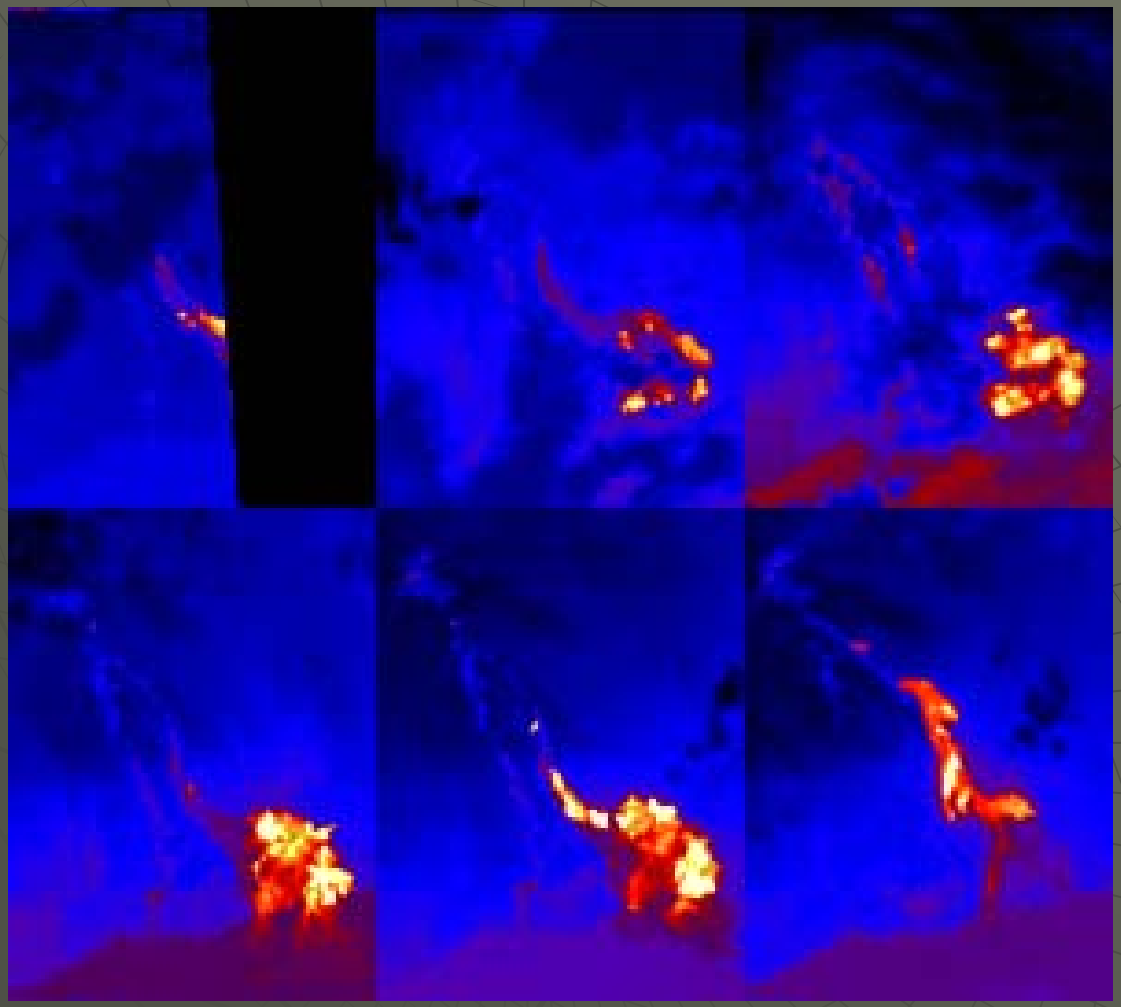
Pu'u O'o, Hawaii

May 13, '00 May 22, '00 June 30, '00



June 30, '00 Aug. 1, '00 Jan. 1, '00

TIR – Band 14 is color coded from black (coldest) through blue, red, yellow, and white (hottest).

The first 5 images show a time sequence of a single eruptive phase; the last image shows flows from a later phase

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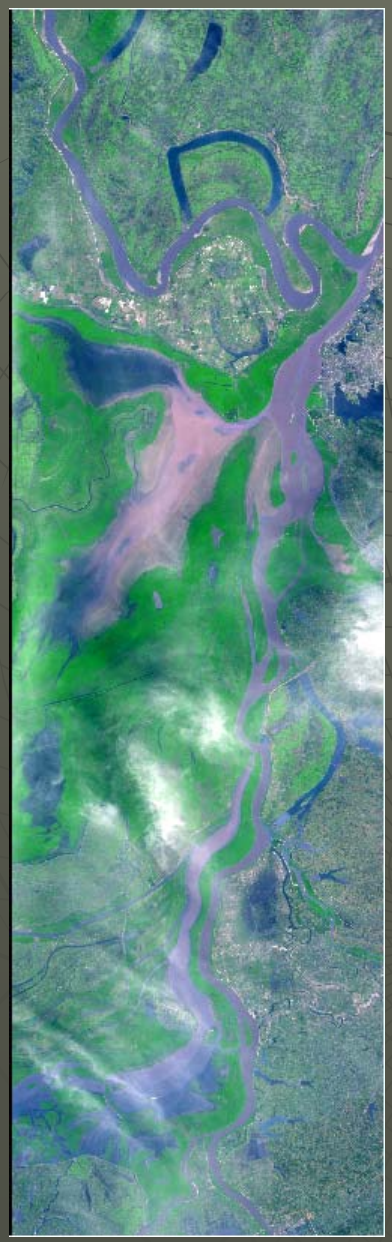

Data Applications Flood monitoring

These images show dramatic change in the water at Dongting Lake in Hunan province, China. A flood crest surged down the Yangtze River in late August of year 2002, but the embankments made by residents there held.

The left image was obtained March 19, 2002 before the flooding began. The right image was acquired on September 2, 2002 and shows the extent of the lake. The images cover an area of 39 x 119 km.

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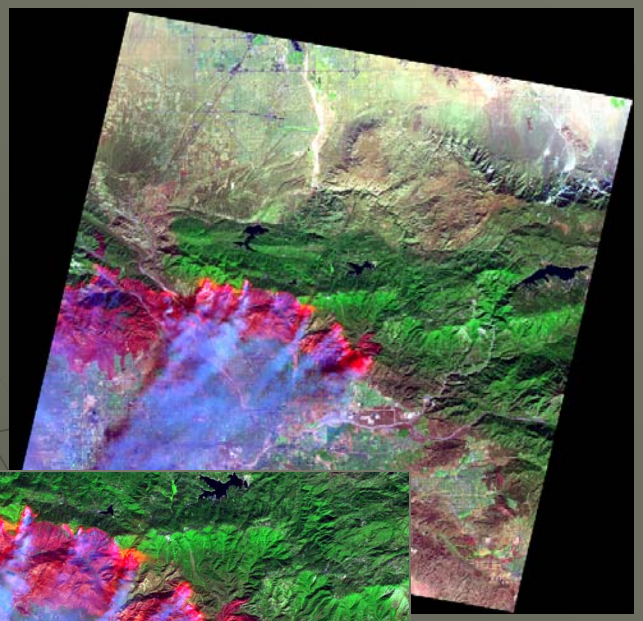
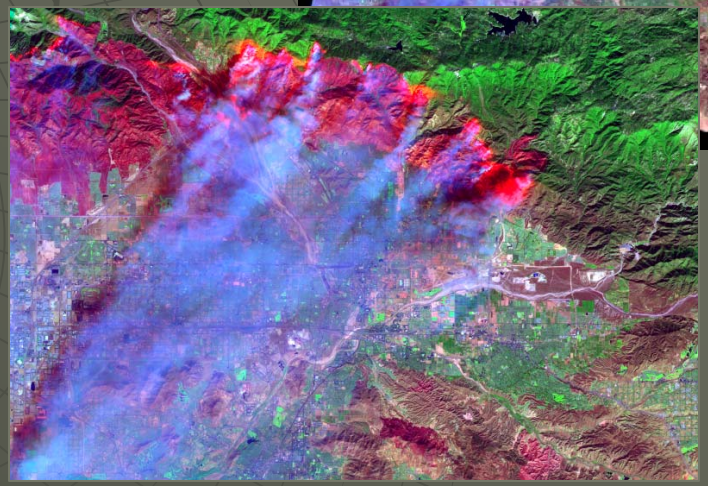
ASTER Data Applications

- Wild fire monitoring
- This ASTER image shows the Old Fire/Grand Prix fire burning on both sides of Interstate 15 near Cajon Pass in the San Bernardino Mountains 80 km east of Los Angeles
- The image combines visible, near-infrared, and shortwave-infrared bands





GranuleID: SC:AST_L1B.003:2018230740
Acquisition date & time: 10/26/2003 18:39:41
Granule Center Lat/Lon: 34.21°N, 117.24°W

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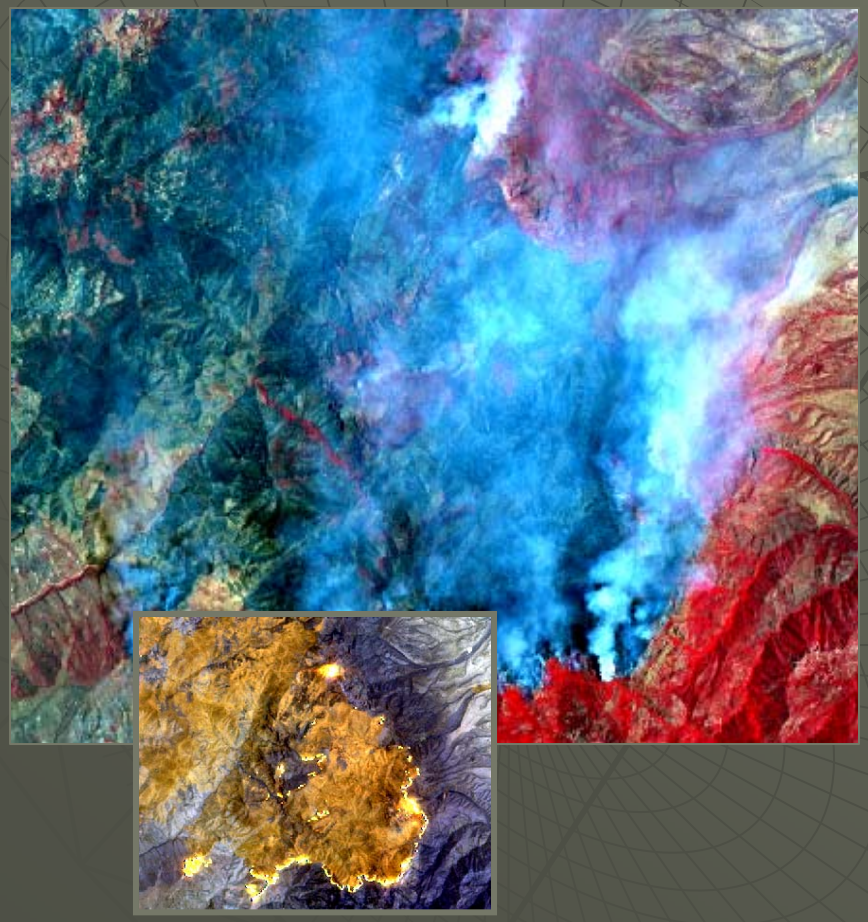
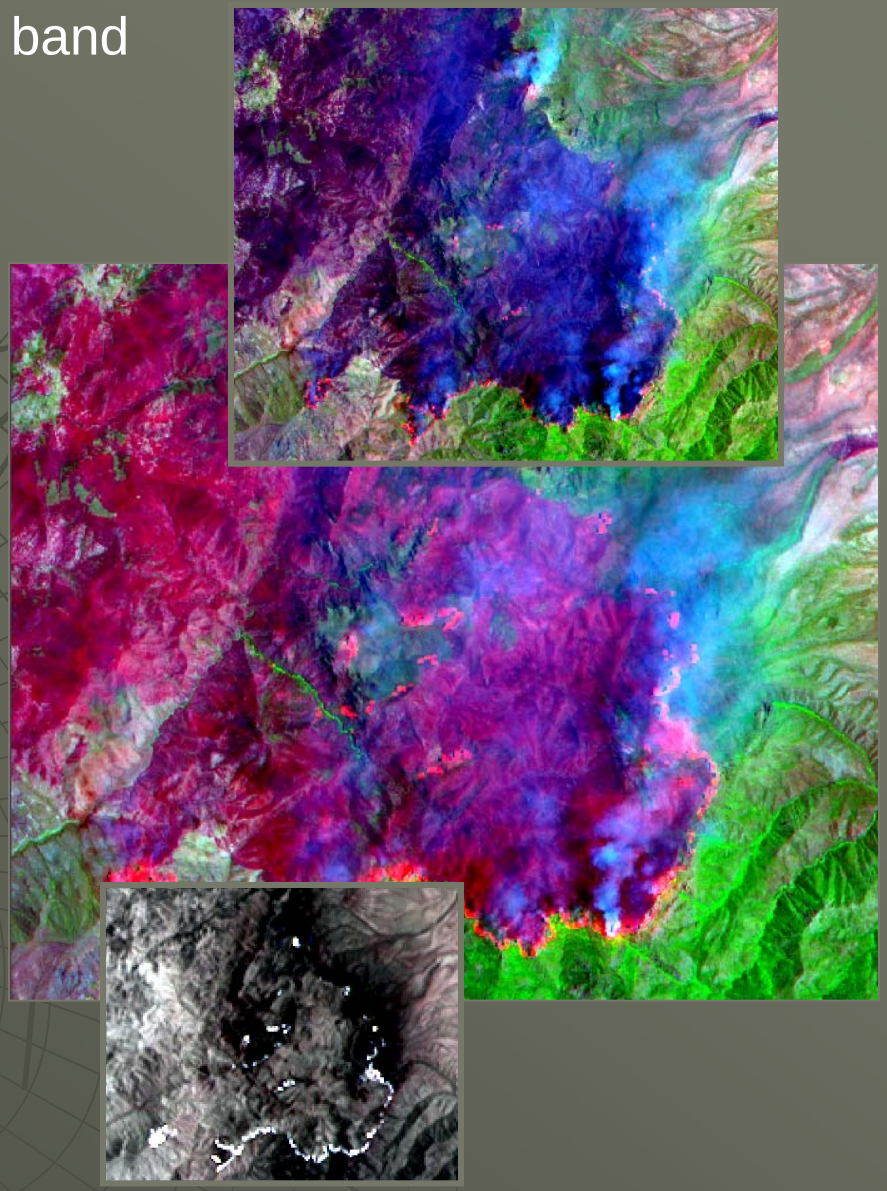
- Wild fire monitoring (cont.)
  - Fire activities in different band combinations





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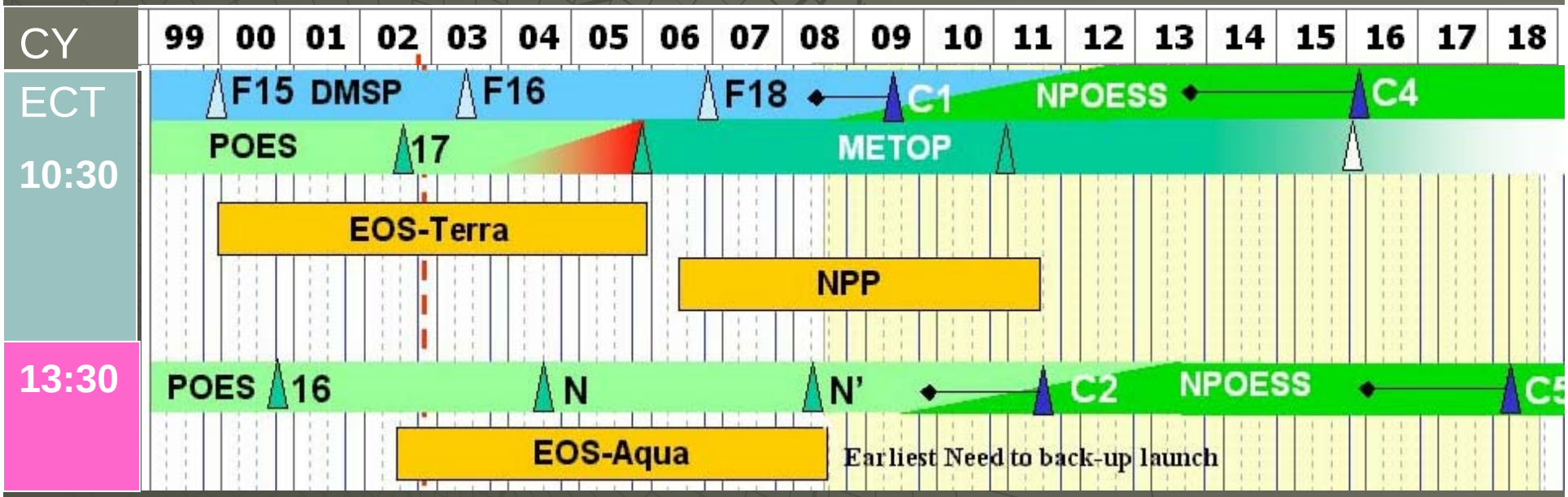
Transition to new generation sensors

AVHRR → MODIS → NPP → NPOESS



Lei Ji; CSU
Kevin Gallo; NOAA

VIIRS at a Glance

- **VIIRS: Visible Infrared Imager Radiometer Suite**
- **VIIRS will continue the observational program of:**
  - OLS: Optical Line Scanner
  - AVHRR: Advanced Very High Resolution Radiometer
  - SeaWiFS: Sea viewing Wide Field-of-view Sensor
  - MODIS: Moderate Resolution Imaging Spectroradiometer
- **VIIRS will provide operational and research users with:**
  - Spectral coverage from 412 nm to 12 microns in 22 bands
    - Imagery at 371 m nadir resolution in 5 bands
  - Complete global daily coverage with a single sensor
  - **Routine data products of:**
  - Cloud cover, cloud layers
  - Cloud and aerosol physical properties
  - Land & ocean biosphere properties, snow & ice
  - Sea Surface Temperature, Land & Ice Temperatures

VIIRS Design is Evolutionary from MODIS

- **Spatial resolution & MTF improved**
  - 341m & 742 m at nadir, reduced pixel growth
- **Improved stray light control with Rotating telescope**
- **Added "day-night" band for cross-terminator imaging**
- **Higher orbit yields full global coverage in one day**
- **Comparable radiometric & spectral quality**
  - 12 bit data
  - Equivalent on-board calibrators
  - Characterization equivalent to Aqua MODIS
  - Bandpasses widened with no loss of specificity
- **Bandset reduced from 36 to 22**
  - MODIS supported research products not yet proven for operational purposes
    - Ocean Fluorescence, CO_2 "slicing bands", Ozone

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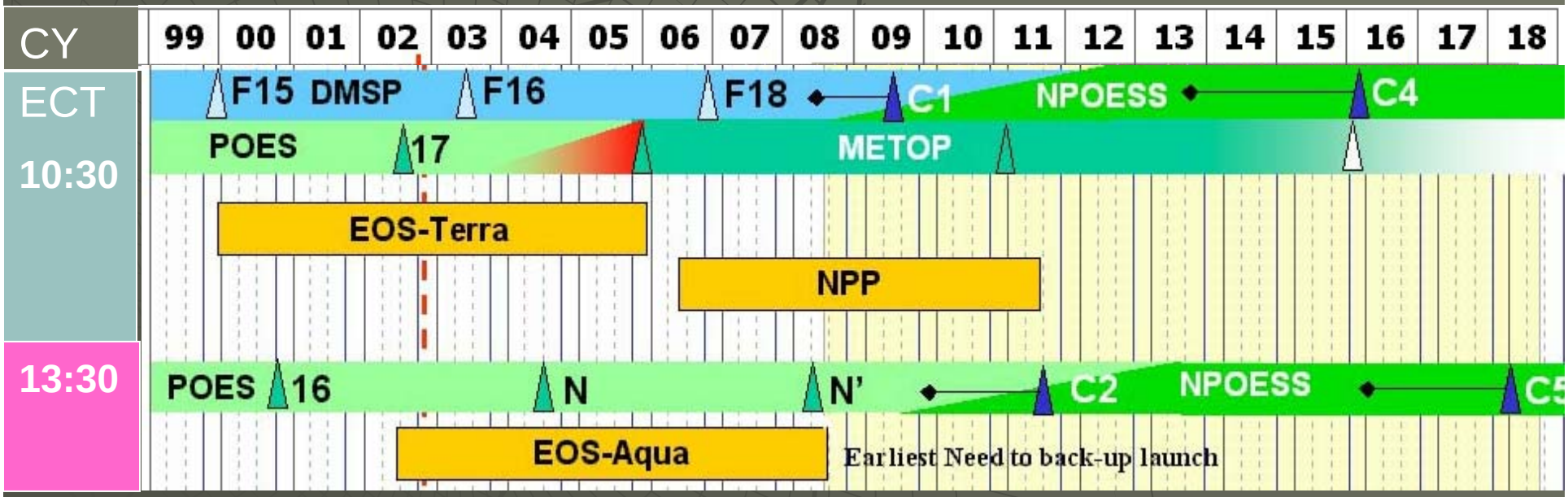
Transition to new generation sensors

AVHRR ⟶ MODIS ⟶ NPP ⟶ NPOESS



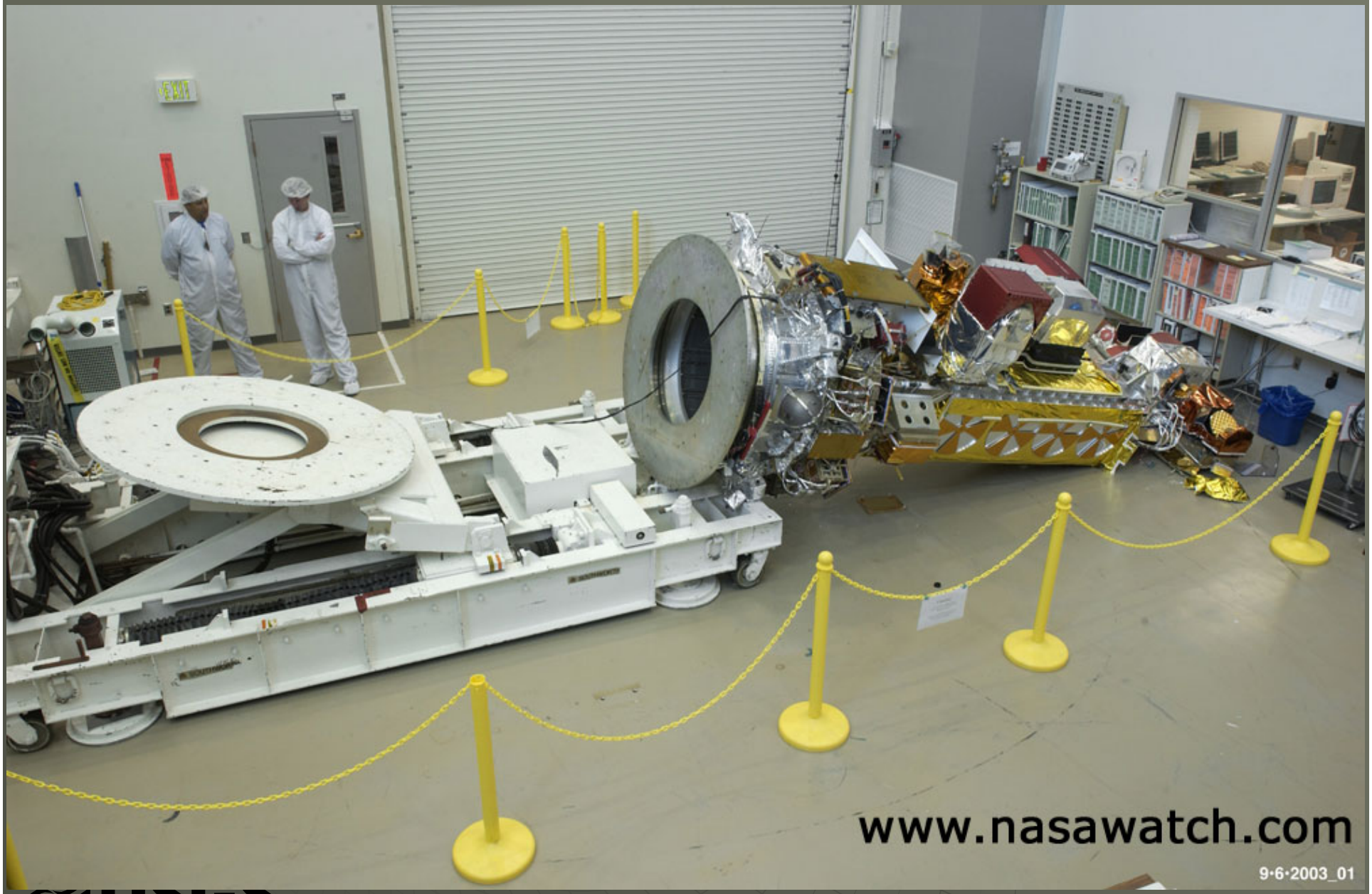
Lei Ji; CSU
Kevin Gallo; NOAA

EARTH SCIENCE MISSIONS ANOMALY REPORT
DATE: September 6, 2003
PROGRAM/PROJECT: GOES/POES Program/POES Project
DATE OF ANOMALY: September 6, 2003
LOCATION OF ANOMALY: Lockheed Martin, Sunnyvale CA
DESCRIPTION OF EVENT:

As the NOAA-N Prime spacecraft was being repositioned from vertical to horizontal on the "turn over cart" at approximately 7:15 PDT today, it slipped off the fixture, causing severe damage. (See attached photo).

The mishap was caused because 24 bolts were missing from a fixture in the “turn over cart”. Two errors occurred. First, technicians from another satellite program that uses the same type of “turn over cart” removed the 24 bolts from the NOAA cart on September 4 without proper documentation. Second, the NOAA team working today failed to follow the procedure to verify the configuration of the NOAA “turn over cart” since they had used it a few days earlier.
IMPACT ON PROGRAM/PROJECT AND SCHEDULE:
The shock and vibration of the fall undoubtedly caused tremendous damage. Significant rework and retest will be required. NOAA-N Prime is planned for launch in 2008.

www.nasawatch.com
9·6·2003_05


EXIT
www.nasawatch.com
9·6·2003_01