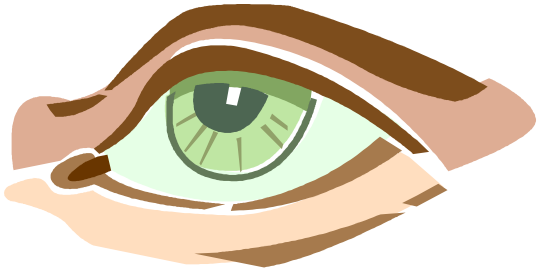
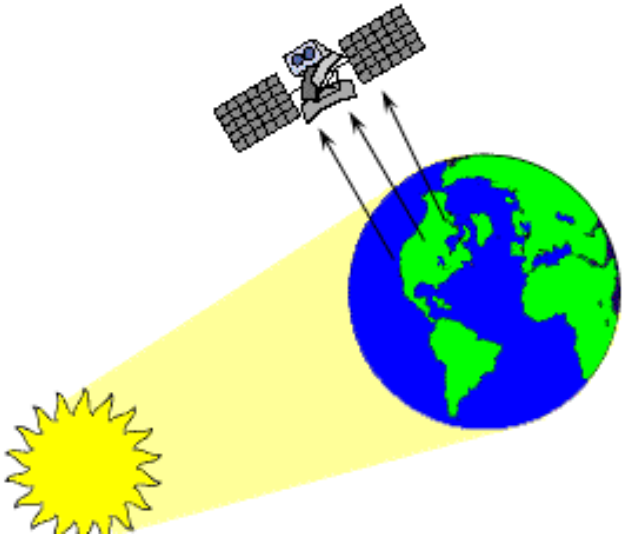
Introduction to Remote Sensing

Alemayehu Midekisa, PhD

Spatial Epidemiology (EPI 264)
Department of Epidemiology and Biostatistics
University of California San Francisco

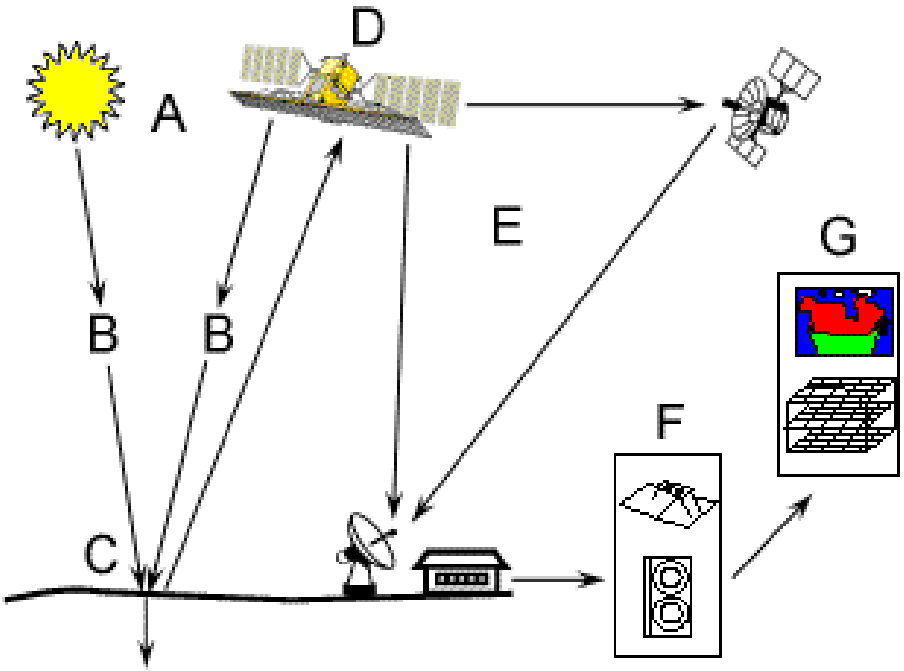
Background to Remote Sensing





Remote sensing is a method of obtaining information about the properties of an object without coming into physical contact with it.

Remote Sensing Process Components



Source: Canadian Centre for Remote Sensing
http://www.nrcan.gc.ca/

(A) Energy Source or Illumination

(B) Radiation and the Atmosphere

(C) Interaction with the Target

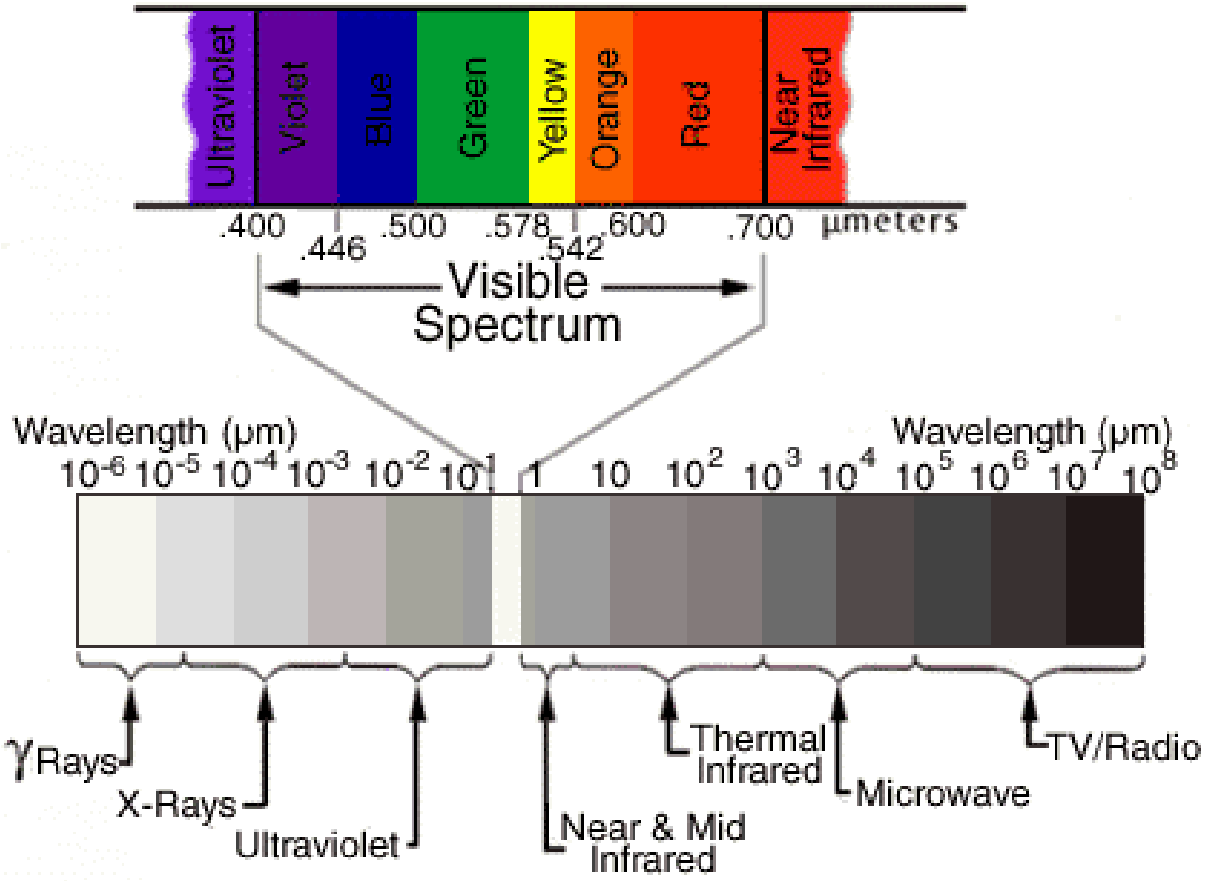
(D) Recording of Energy by the Sensor

(E) Transmission, Reception, and Processing

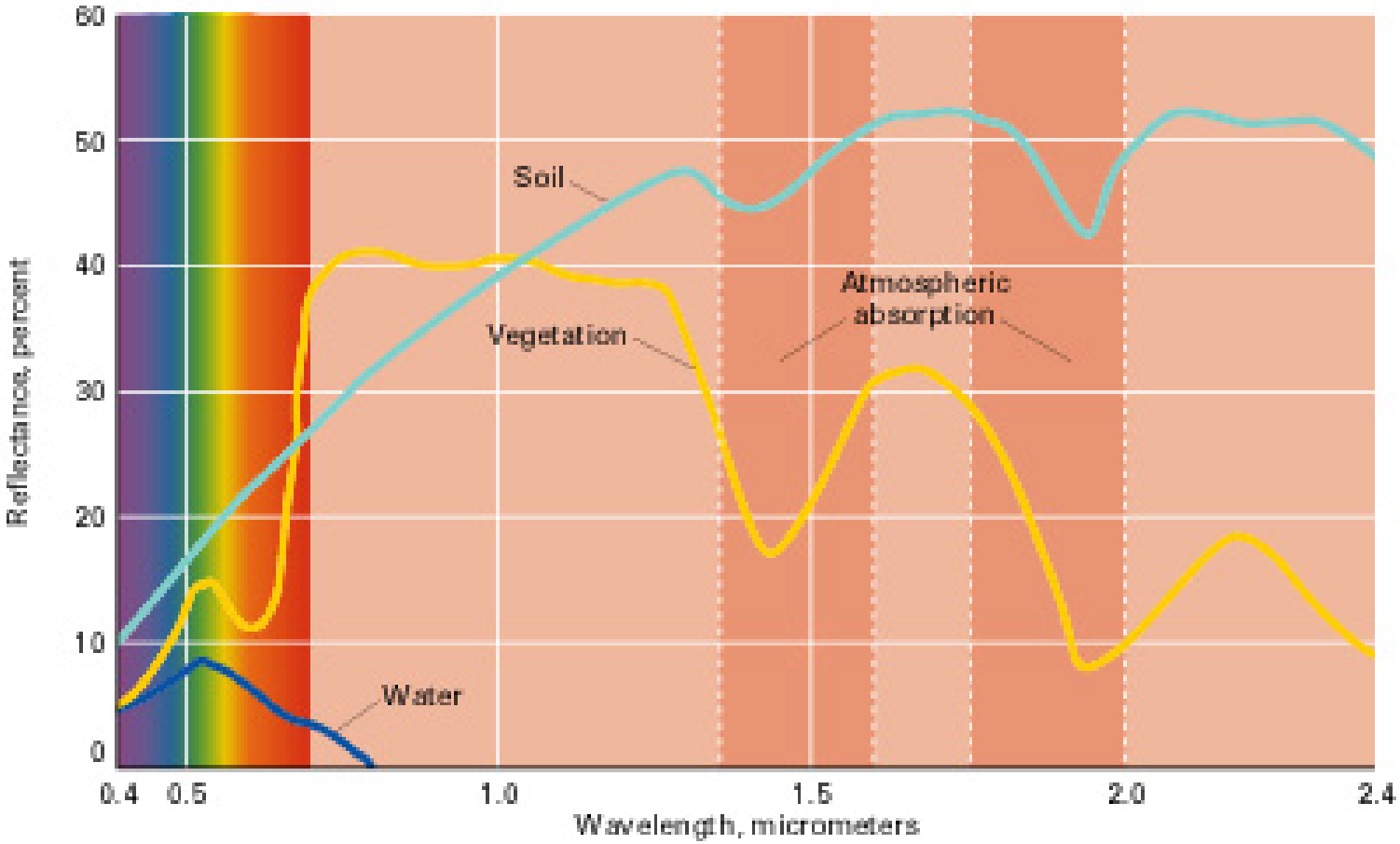
(F) Interpretation and Analysis

(G) Application

Electromagnetic Spectrum



Signature Spectra



Resolution

- **There are four types of resolution in remote sensing:**
  - Spatial Resolution
  - Temporal resolution
  - Radiometric resolution
  - Spectral resolution

Spatial Resolution

- **Spatial resolution** is the smallest area on Earth that a satellite can observe.

- Spatial resolution depends on the type of instrument.

- In **low or coarse spatial resolution** images only large features such as cities, forests, and lakes are visible.
  - E.g. 10 kilometer

- In **high or fine spatial resolution** images small objects such as buildings, roads, and trees can be detected.
  - E.g. 10 meter

Landsat:
30 meters

Digital Globe:
< 10 meters

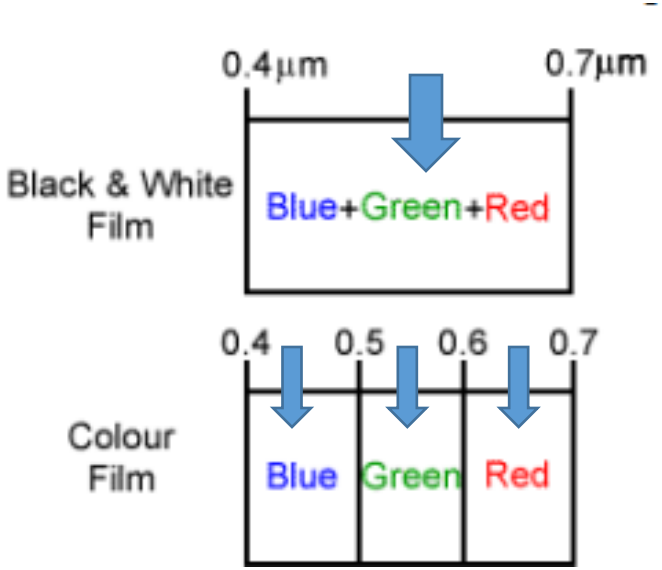
Temporal Resolution

- Temporal resolution is how frequently a satellite observes the same area on Earth.
- The revisit period of a satellite sensor.
- High temporal resolution:
  - E.g. 3 hours (every 3 hours)
- Low temporal resolution:
  - E.g. 16 day (only one observation per 16 days)

Spectral Resolution

- **Spectral resolution** is the ability of a sensor to define fine wavelength intervals.
- The finer the spectral resolution, the narrower the wavelength range for a particular channel or band.

- **Low spectral resolution:**
  - **Black and white film** records wavelengths extending over much of the visible portion of the electromagnetic spectrum.
- **High spectral resolution:**
  - **Color film** has higher spectral resolution and it is sensitive to the blue, green, and red wavelengths.



Source: Canadian Centre for Remote Sensing
http://www.nrcan.gc.ca/

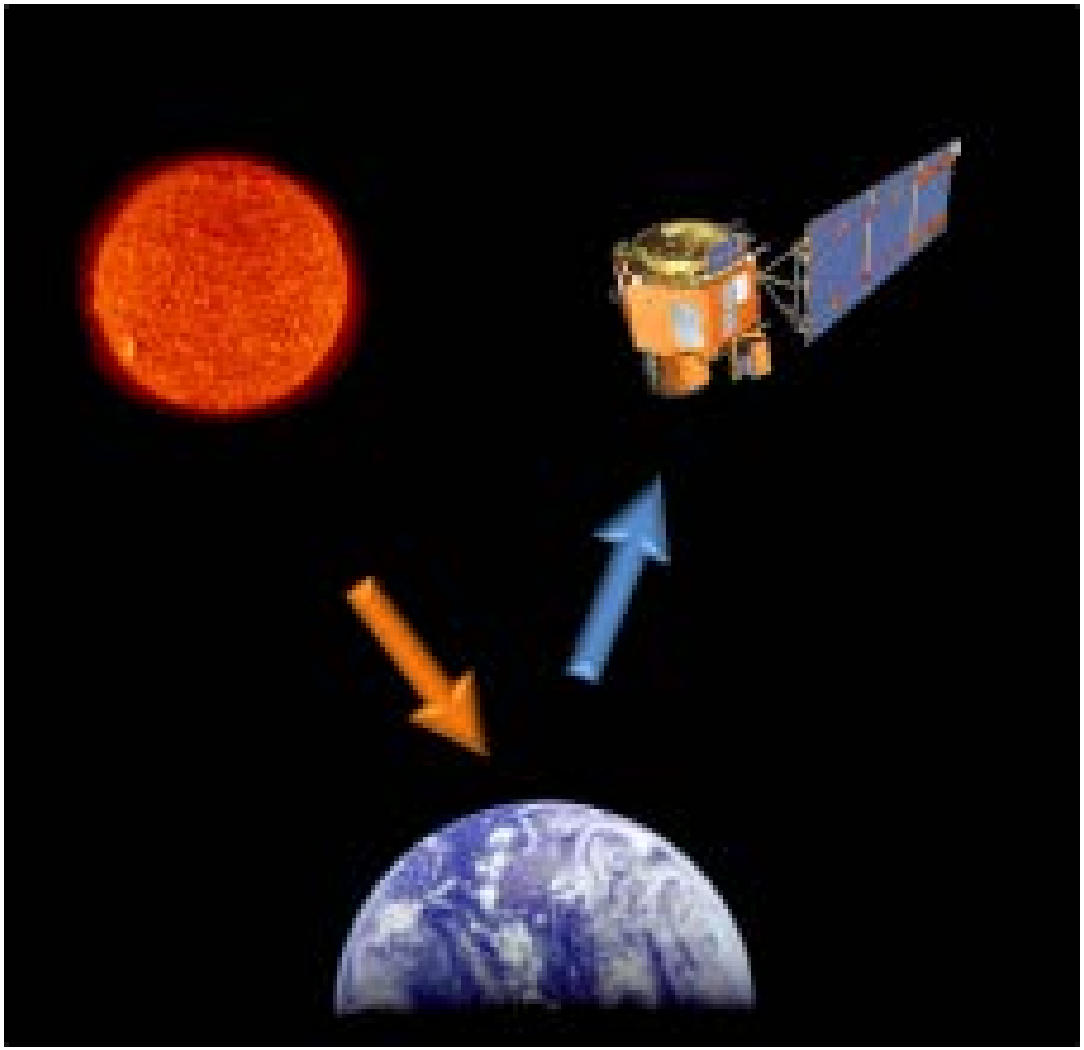
Radiometric Resolution

- The radiometric resolution of an imaging system describes its ability to discriminate very slight differences in energy.
- The finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in reflected or emitted energy.
- Examples:
  - 8 bit = 2^8 = 256= (0-255)
  - 12 bit = 2^{12} = 4096 = (0-4095)

Passive and Active Sensors

- **Passive sensors:**
  - Remote sensing systems that measure energy that is naturally available.
  - They can only be used to detect energy when the naturally occurring energy is available.
  - For all reflected energy, this takes place during the day time.
  - There is no reflected energy available from the sun at night.

Passive sensors

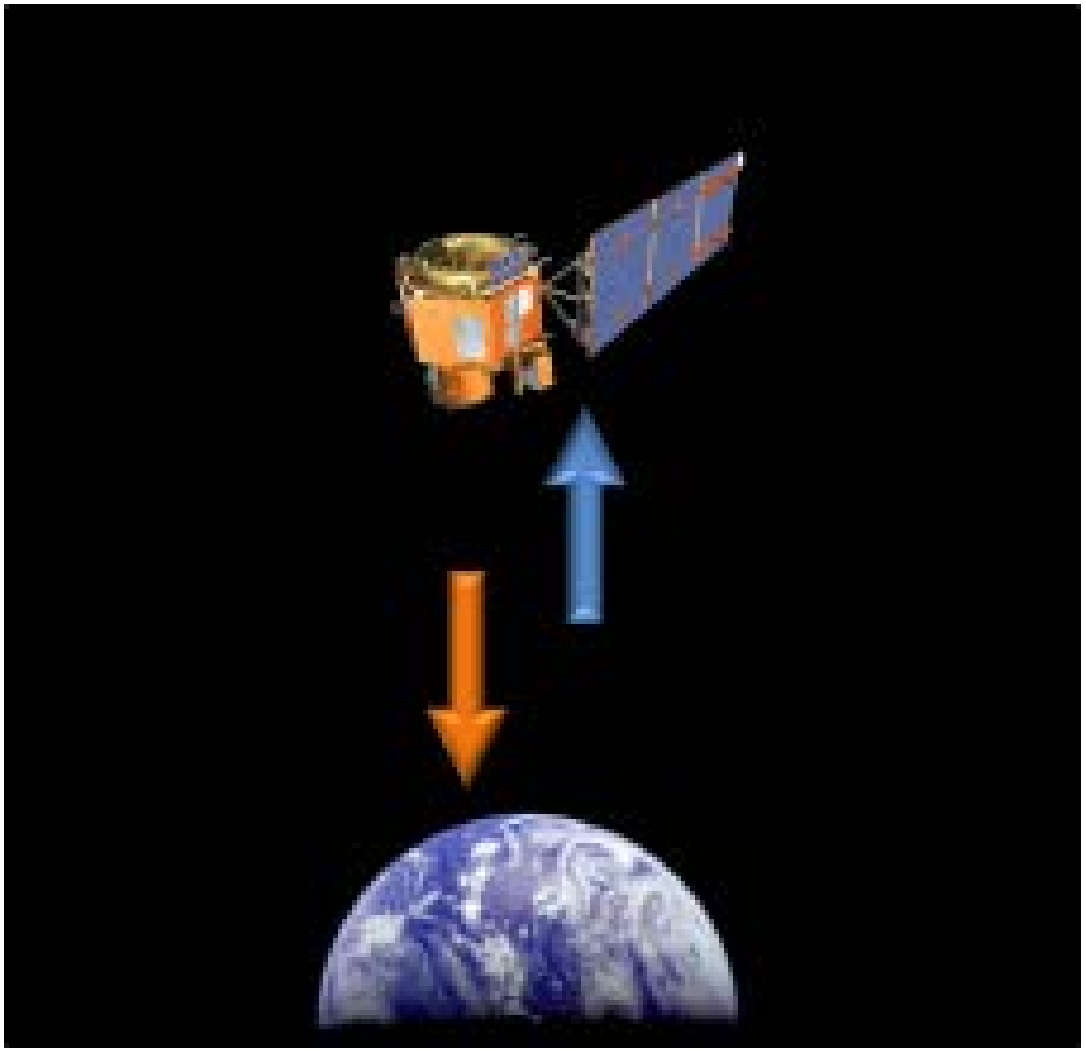


http://www.nasa.gov/

Active sensors

- **An active sensor** provide their own energy source for illumination.
- The sensor emits radiation which is directed toward the target to be investigated.
- The radiation reflected from that target is detected and measured by the sensor.
- Active sensors can obtain measurements anytime, regardless of the time of day or season.

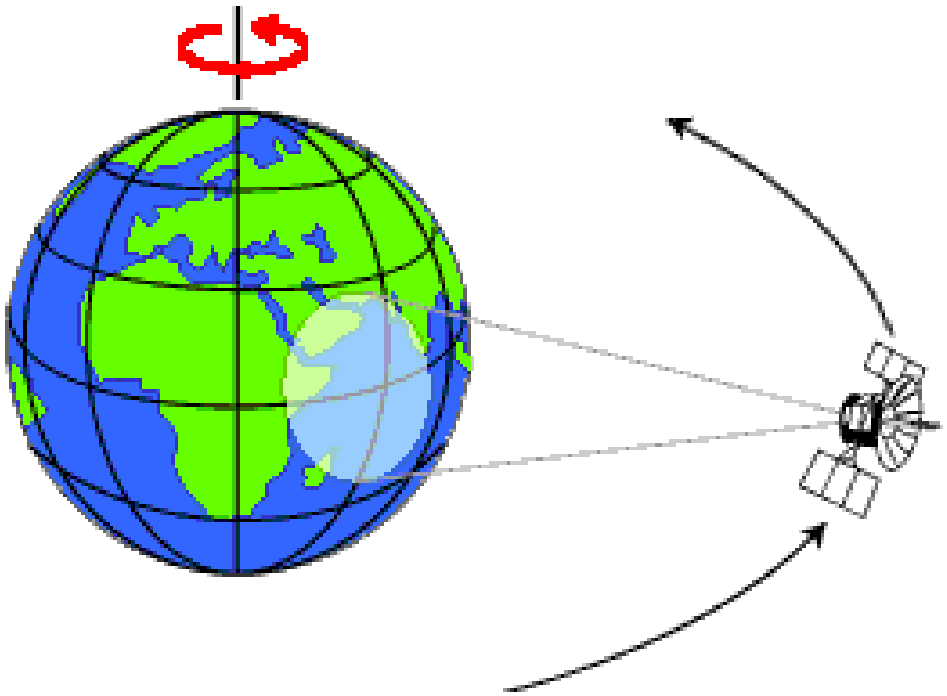
Active sensor



http://www.nasa.gov/

Geostationary orbits

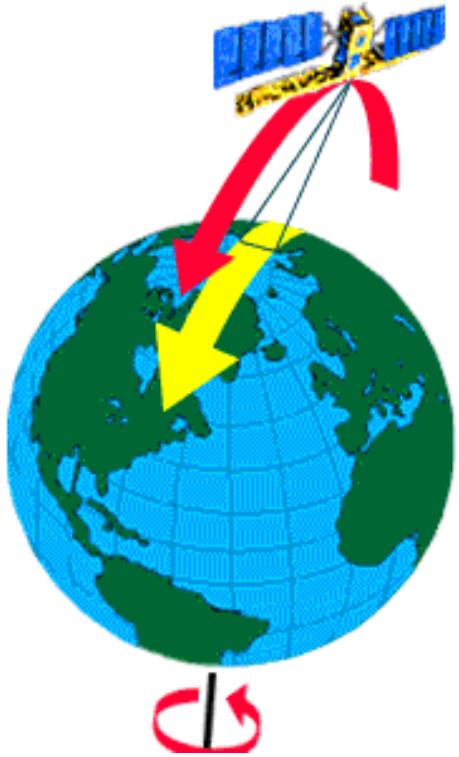
- Satellites at very high altitudes (~36,000km), which view the same portion of the Earth's surface at all times have **geostationary orbits**.
- They revolve at speeds which match the rotation of the Earth so they seem stationary, relative to the Earth's surface.
- E.g. Geostationary Operational Environmental Satellites (GOES)



Source: Canadian Centre for Remote Sensing
http://www.nrcan.gc.ca/

Sun-synchronous

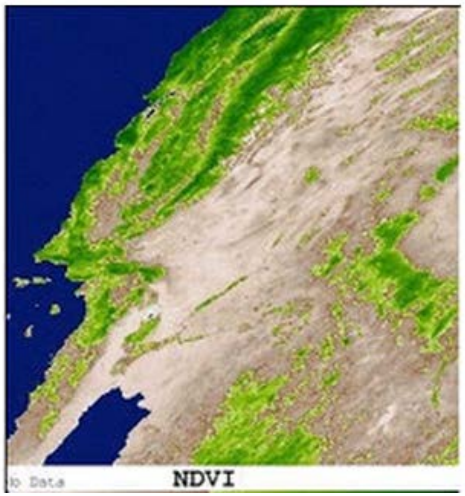
- **Sun-synchronous satellites** pass over the same part of the Earth at roughly the same local time each day.
- This will allow them to cover most of the Earth's surface over a certain period of time.
- They cover each area of the world at a constant local time of day called **local sun time**.
  - E.g. Landsat, MODIS



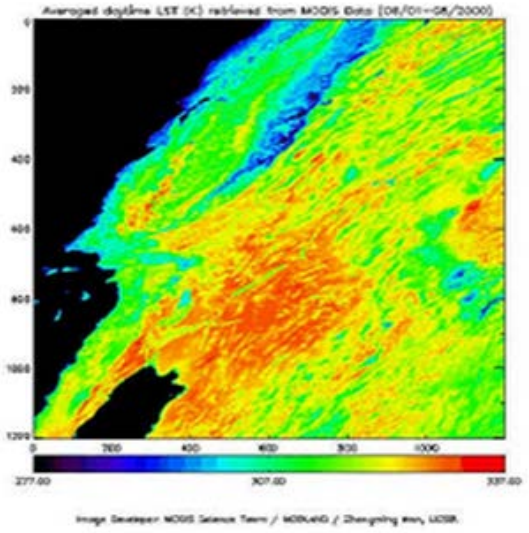
Source: Canadian Centre for Remote Sensing
http://www.nrcan.gc.ca/

Satellite Derived Indices

- **Vegetation Indices:**
  - Normalized difference vegetation index (NDVI)
  - Enhanced vegetation index (EVI)

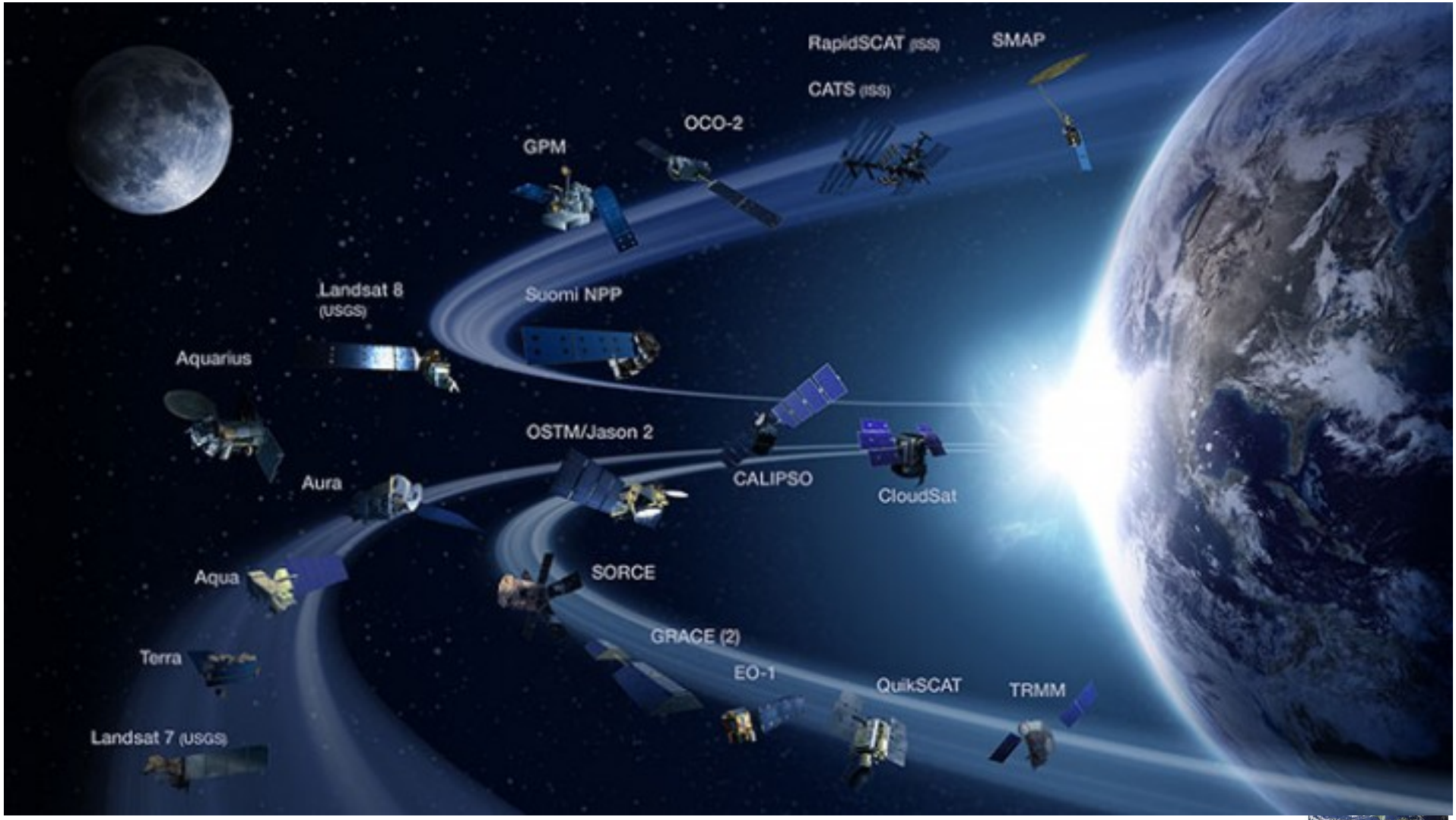


- **Moisture indices:**
  - Normalized difference water index (NDWI)
  - Evapotranspiration (ET)
- **Temperature:**
  - Land surface temperature (LST)



Source: http://modis-land.gsfc.nasa.gov/

NASA Earth Observation Satellites



www.earthobservatory.nasa.gov

ASTER

- ASTER provides high-resolution images of the planet in bands ranging from visible to the thermal infrared.
  - Bands 1-4 (VNIR: visible near infrared) 15 meter
  - Bands 5-10 (SWIR: Shortwave infrared) 30 meter
  - Bands 11-15 (TIR: Thermal Infrared) 90 meter
- ASTER data are used to create detailed maps of land surface temperature, reflectance, and elevation.
- ASTER Global Digital Elevation Model(GDEM) covers the planet from 83 degrees North to 83 degrees South at 30 meter resolution.
- ASTER GDEM version 1 was released in 2009 and version 2 in 2011.

SRTM

Jet Propulsion Laboratory
California Institute of Technology

+ View the NASA Portal

JPL HOME | EARTH | SOLAR SYSTEM | STARS & GALAXIES | TECHNOLOGY

Shuttle Radar Topography Mission
The Mission to Map the World

Home | News | Mission | Instrument | Data Products | Multimedia | Outreach | En Espanol

Gallery of Images
- Image Policy

Public Data Distribution

Video Multimedia

Project Status
Photojournal Search
SRTM Related
- NASA
- German Aerospace Ctr
- Italian Space Agency

Data Users Forum

Site Index
Contact Us

U.S. Releases Enhanced Shuttle Land Elevation Data

On September 23, 2014, the White House announced that the highest-resolution topographic data generated from NASA's Shuttle Radar Topography Mission (SRTM) in 2000 will be released globally over the next year. The announcement was made at the United Nations Heads of State Climate Summit in New York. Since then the schedule has been accelerated, and all global SRTM data, except for the Middle East region, has been released.

See the full JPL Release 2014-321.

Previously, SRTM data for regions outside the United States were sampled for public release at 3 arc-seconds, which is 1/1200th of a degree of latitude and longitude, or about 90 meters (295 feet). The new data are being released with a 1 arc-second, or about 30 meters (98 feet), sampling that reveals the full resolution of the original measurements. Data for most of Africa and its surrounding areas were released with the September 2014 announcement. The next release, in November 2014 included all of South America and North America, most of Europe, and islands in the eastern Pacific Ocean. The most recent release, in January 2015 includes most of continental Asia (now including India), the East Indies, Australia, New Zealand, and islands of the western Pacific.

See an index map of the newly available full-resolution data. (SRTM did not produce data for the northernmost latitudes or Antarctica.)

The new data are available for download from the USGS EROS Data Center - see Public Data Distribution for details.

See the Africa image above and its caption at the PIA04965. A fly around video of the Crater Highlands of Tanzania, using SRTM elevation data and Landsat images is available at http://www.jpl.nasa.gov/video/details.php?id=1335_id=1335.

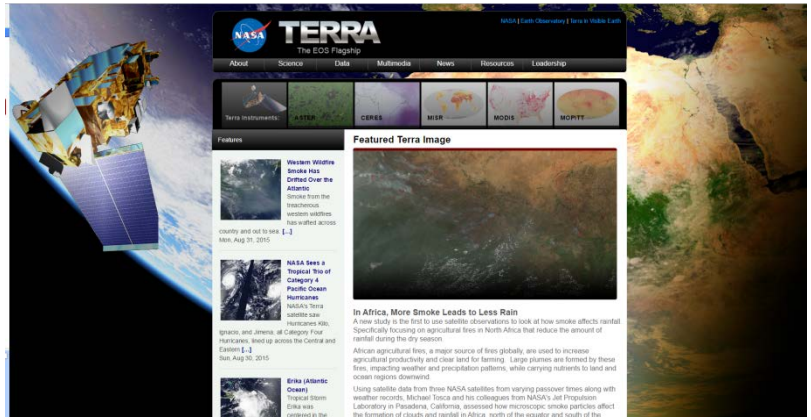
These additional fly around videos further illustrate SRTM elevation data:

India and the Himalaya Mountains, with Landsat satellite images draped over SRTM elevation data. View the full size movie here.
A smaller version can be viewed here.

Indonesia, with many volcanoes, starting at Bali, flying westward over Java, and ending at Krakatoa (Pulau Krakatau). This fly around uses only SRTM data, shaded and with colored height. View the movie here.

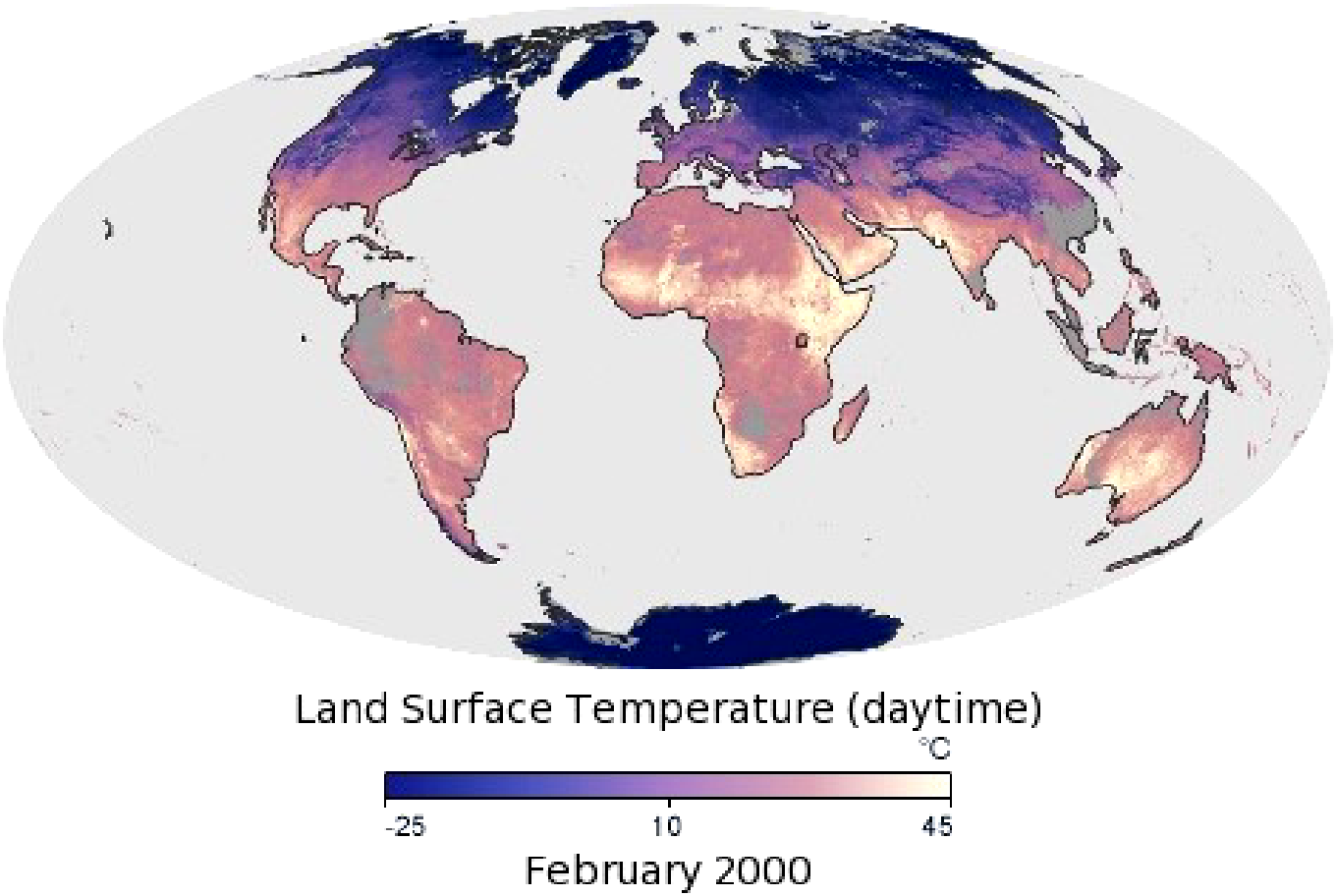
- The Shuttle Radar Topography Mission (SRTM) is an international research effort that obtained digital elevation model on a near-global scale from 56° S to 60° N.
- SRTM flew on board during the 11 day mission in February 2000.
- The resolution of the raw data is 30 meter for the US territory and 90 meter globally.

MODIS



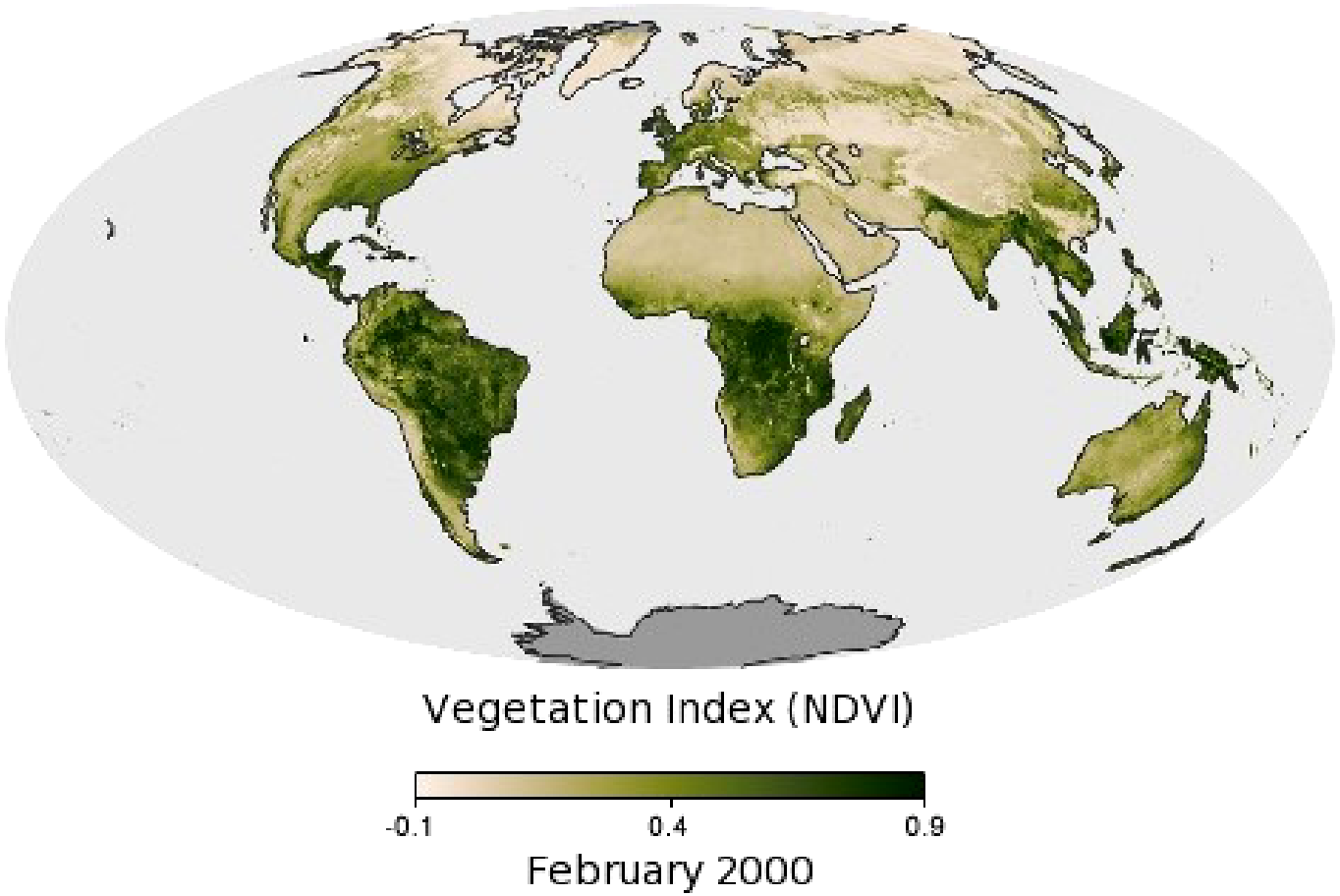
- Moderate Resolution Imaging Spectroradiometer (MODIS)
- Two satellites onboard: Terra and Aqua (10:30 am and 1:30 pm equator overpass).
- Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days.
- MODIS instrument provides data in 36 spectral bands
- Spatial resolution of 250, 500 and 1000 meters

Land Surface Temperature(MODIS)



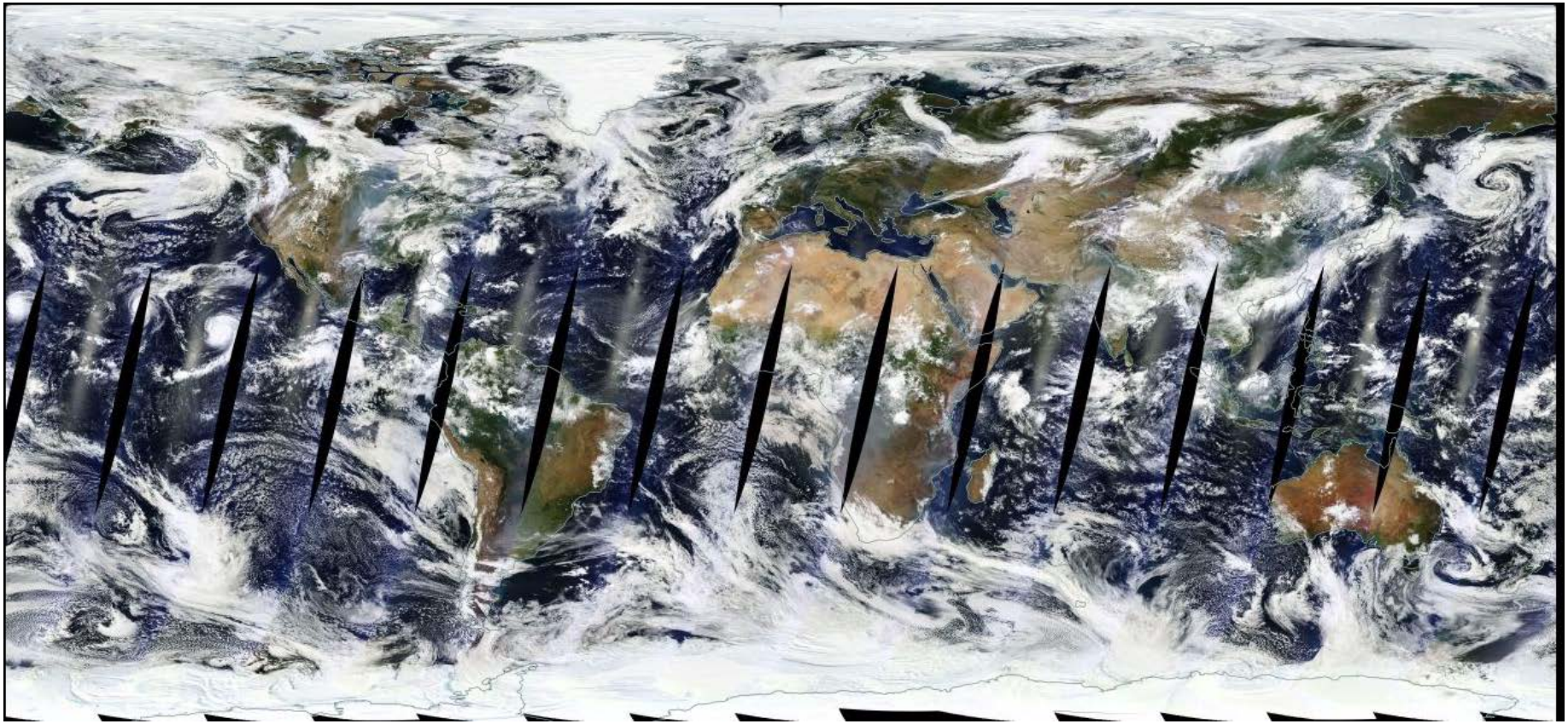
www.earthobservatory.nasa.gov

Vegetation Index (MODIS)



www.earthobservatory.nasa.gov

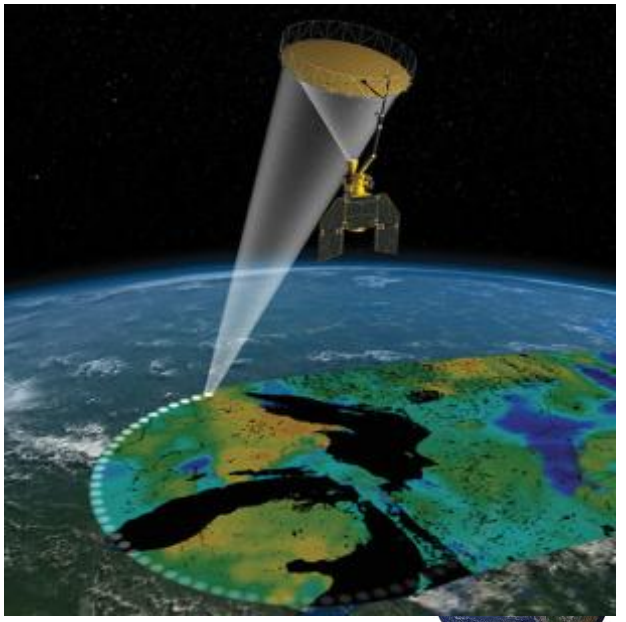
MODIS (Terra Satellite) Aug 30, 2015



https://earthdata.nasa.gov/labs/worldview/

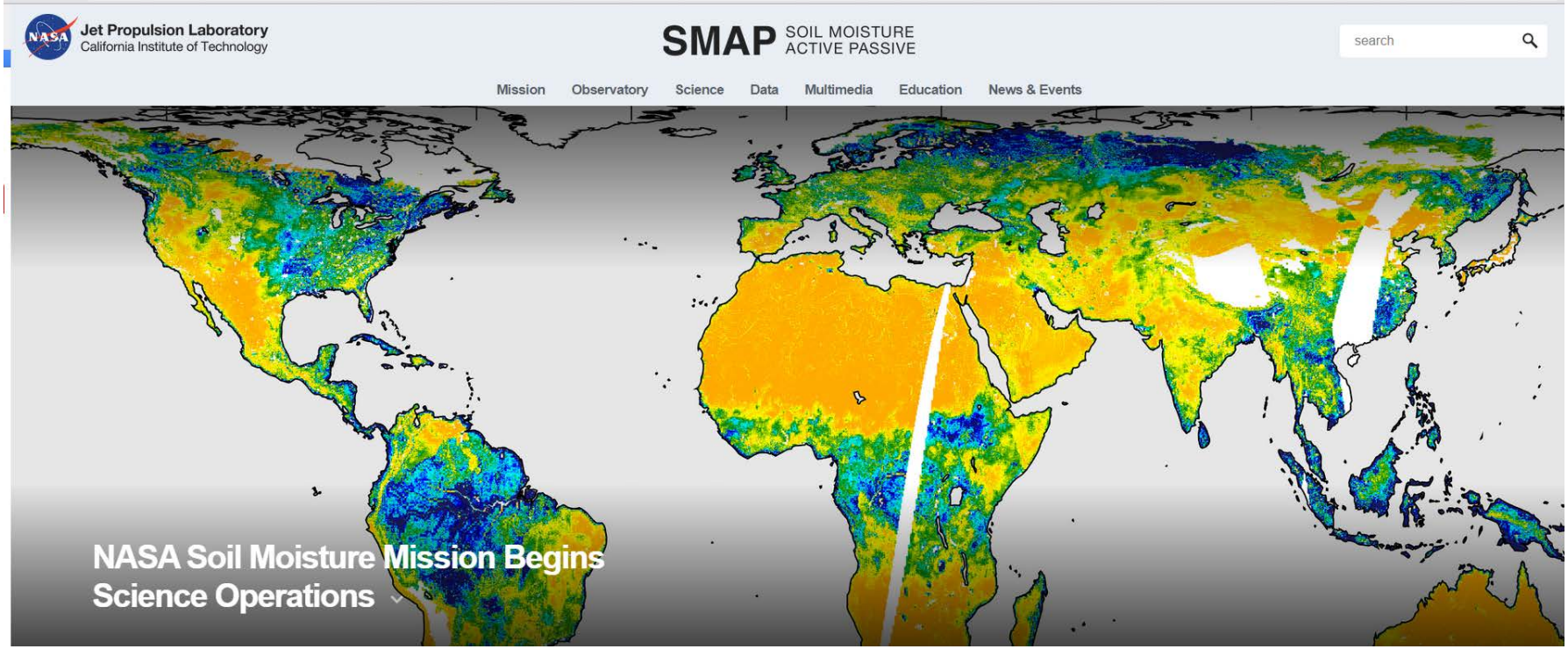
SMAP
(Soil Moisture Active Passive)

- SMAP provides a capability for global mapping of soil moisture with enhanced accuracy and temporal resolution.
- The mission acquires these measurements for at least three years with global coverage.
- 1-47 km spatial resolution
- Providing global coverage:
  - Within 3 days at the equator and
  - 2 days at boreal latitudes (>45 degrees N).
- **Potential application areas:**
  - **Weather Forecasting**
  - **Drought**
  - **Flood and Landslide**
  - **Agricultural Productivity**
  - **Human Health**

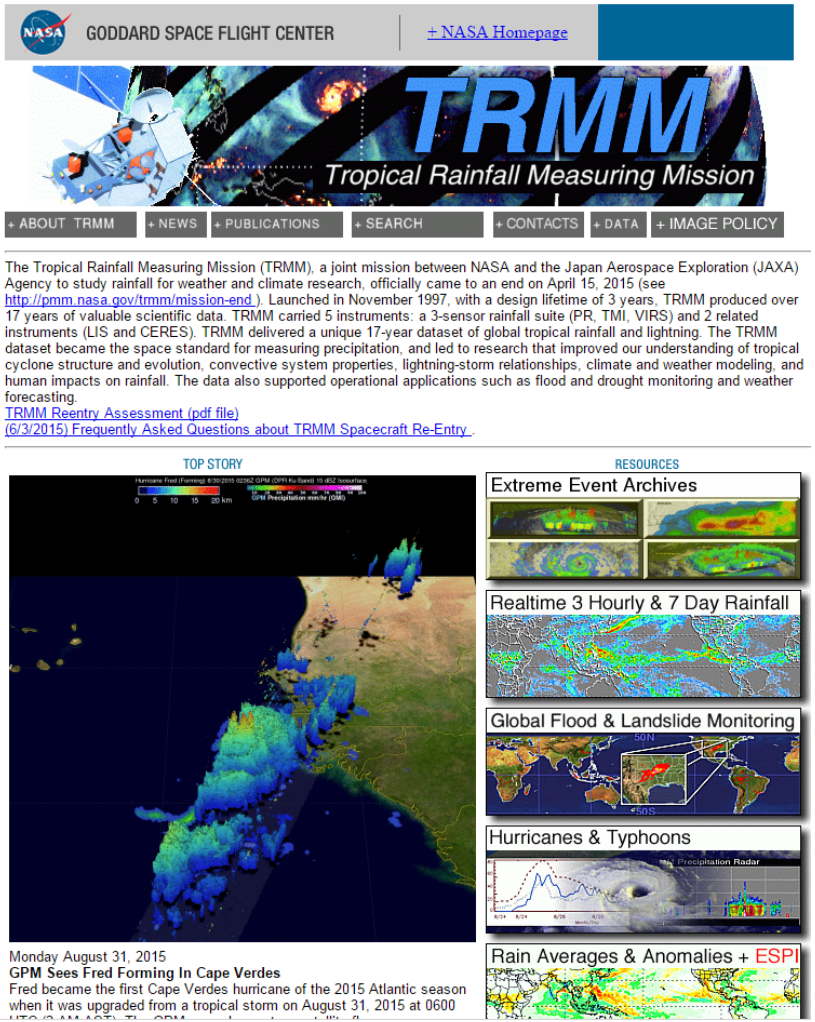


https://smap.jpl.nasa.gov

SMAP

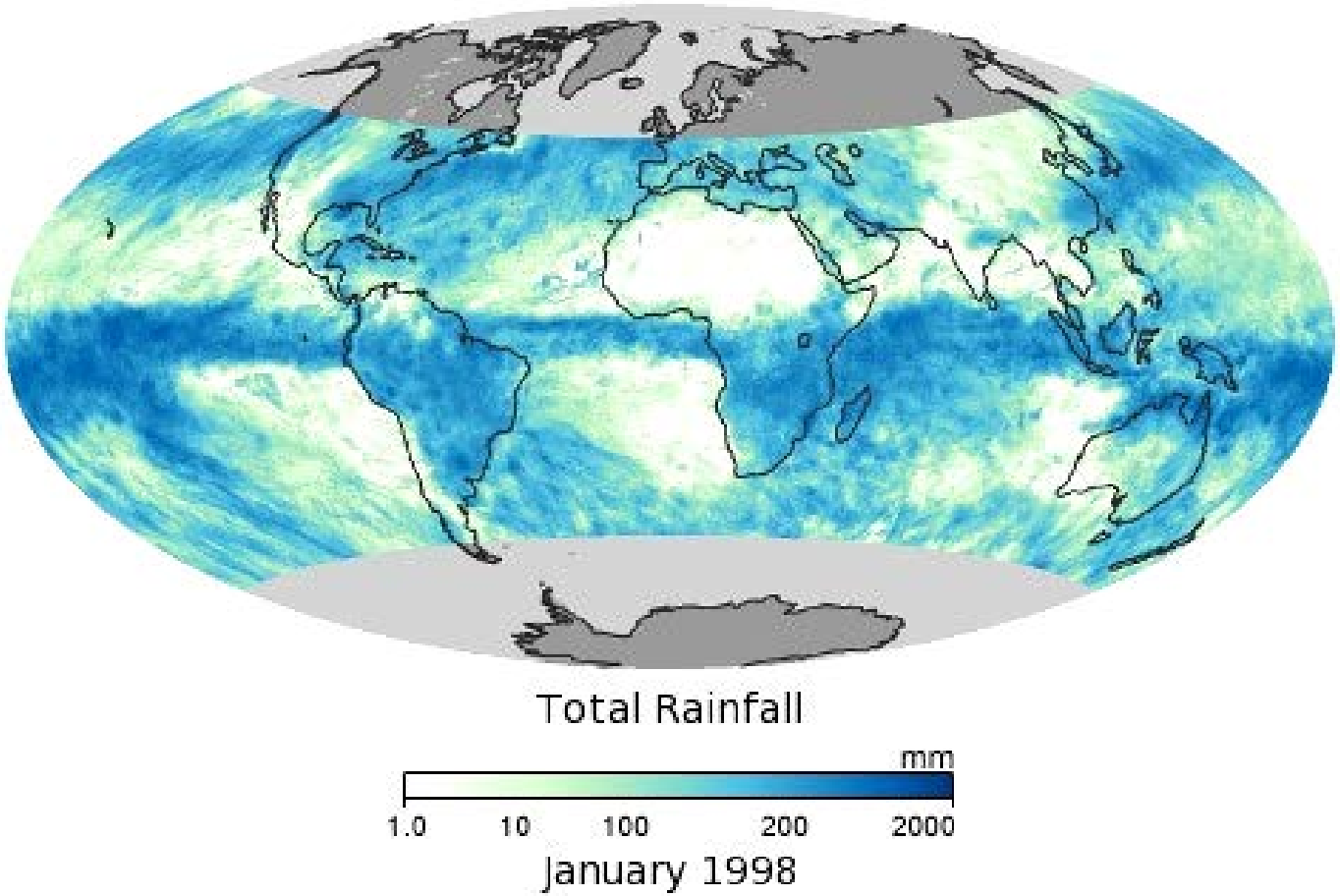

Jet Propulsion Laboratory
California Institute of Technology
SMAP SOIL MOISTURE ACTIVE PASSIVE
search
Mission
Observatory
Science
Data
Multimedia
Education
News & Events
NASA Soil Moisture Mission Begins Science Operations

TRMM



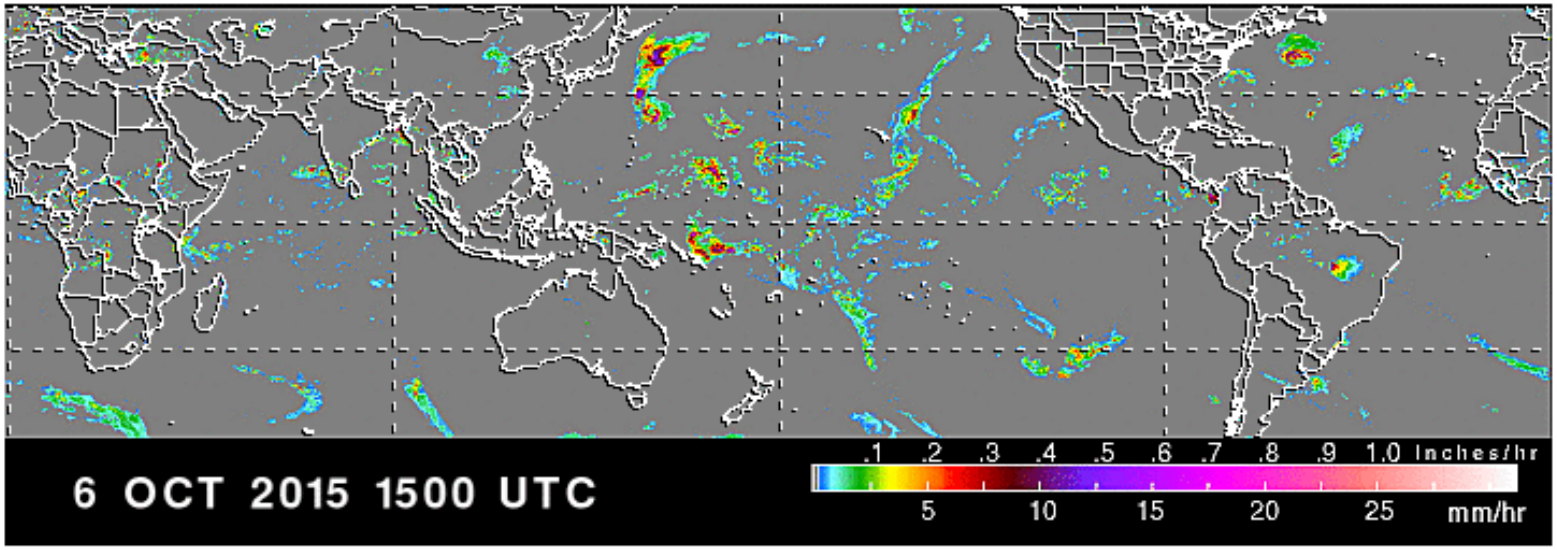
- Tropical Rainfall Measuring Mission
- TRMM is a joint mission between NASA and JAXA since 1997.
- Daily temporal resolution (~3 hourly)
- Spatial coverage extends from 50 degrees south to 50 degree north latitude.
- Spatial resolution of 25km
- Three instruments:
  - TRMM Microwave Imager (TMI)
  - Precipitation Radar (PR)
  - Visible and Infrared Scanner (VIRS)

Precipitation (TRMM)

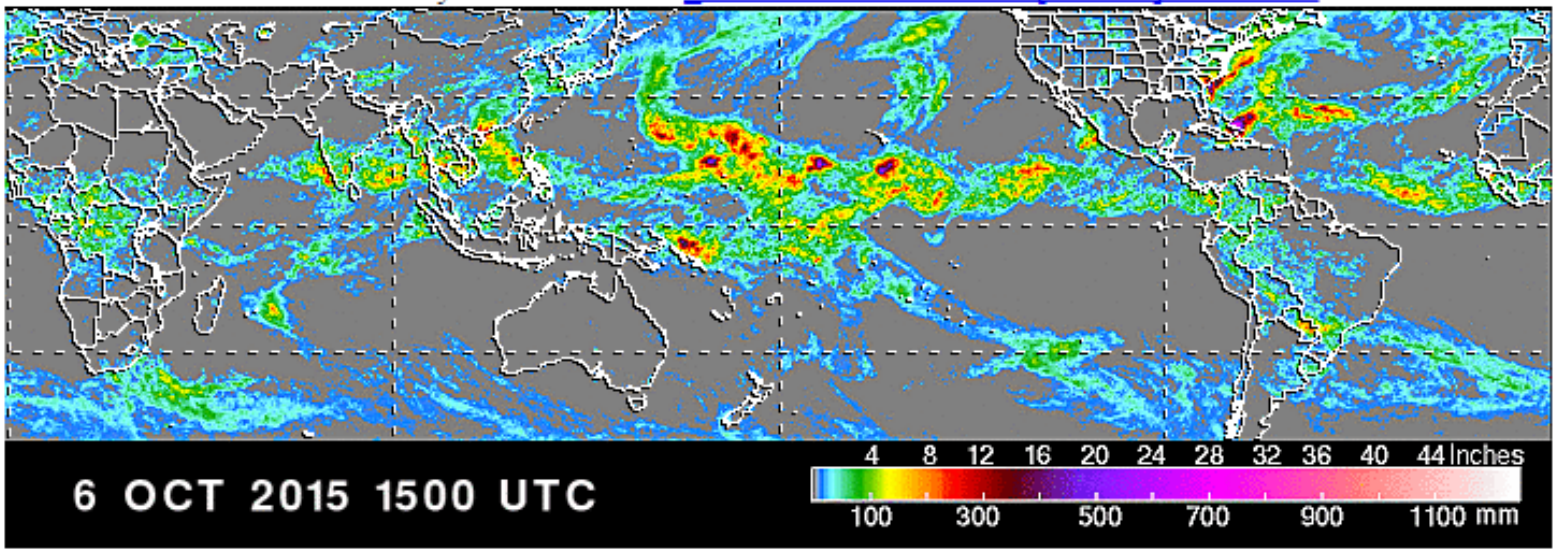


www.earthobservatory.nasa.gov

Global Rainfall Oct 6, 2015



Latest 3 Hourly Global Rainfall _ Click to See a Medium [1.7 MB] Animation



Latest Week of Global Rainfall Accumulation _ Click to See a Medium [1.7 MB] Animation

http://trmm.gsfc.nasa.gov/

GPM

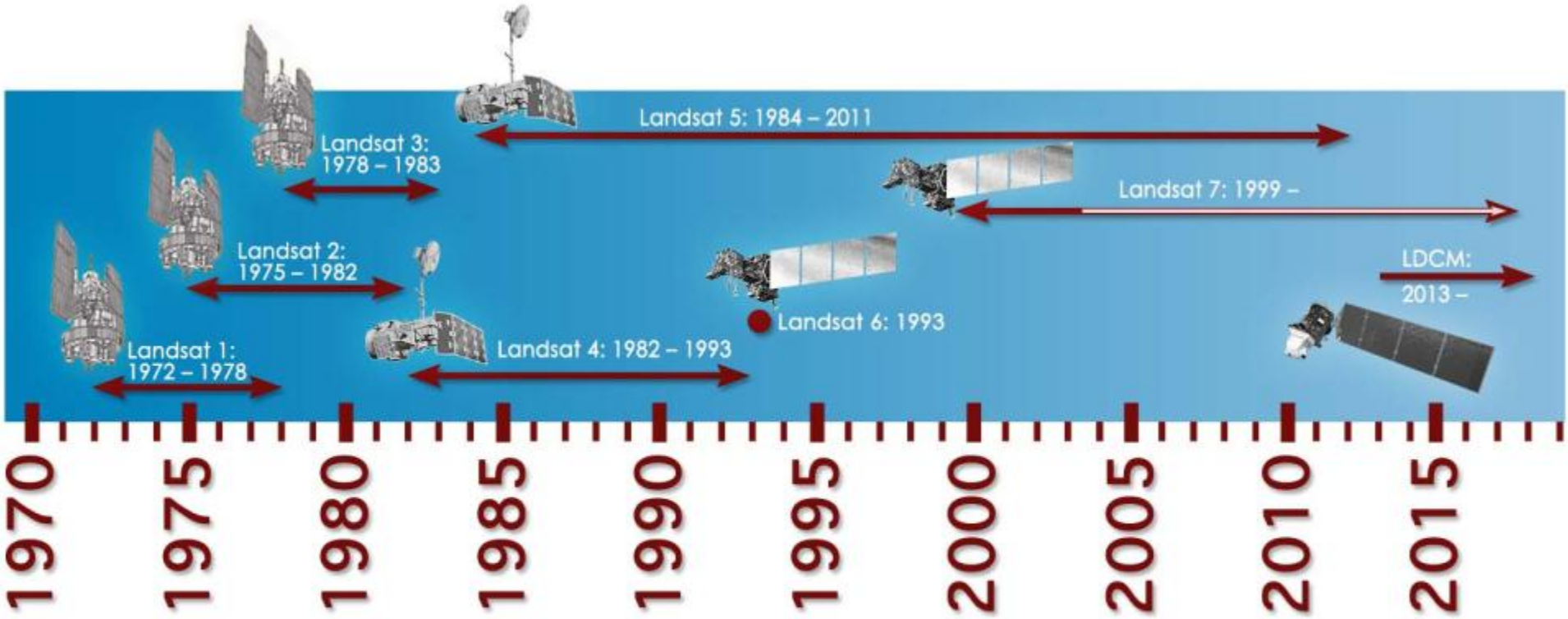
- The GPM Core Observatory is a consortium of GPM partners in the United States, Japan, France, India, and Europe.
- The GPM observes precipitation over the entire globe every 2-3 hours.
- Spatial resolution of 25km
- The Core satellite will measure rain and snow using two science instruments:
  - The GPM Microwave Imager (GMI) and
  - The Dual-frequency Precipitation Radar (DPR).
- GPM covers the Earth from 65°S to 65°N - from about the Antarctic Circle to the Arctic Circle.

http://www.nasa.gov/mission_pages/GPM

GPM Advancement of TRMM

- GPM launched February 27, 2014.
- The design of the GPM is an advancement of TRMM.
- The GPM instruments extend the capabilities of the TRMM sensors to detect falling snow, measure light rain.
- This is significant because light rain and falling snow account for a significant fraction of precipitation occurrence in middle and high latitudes.

LANDSAT

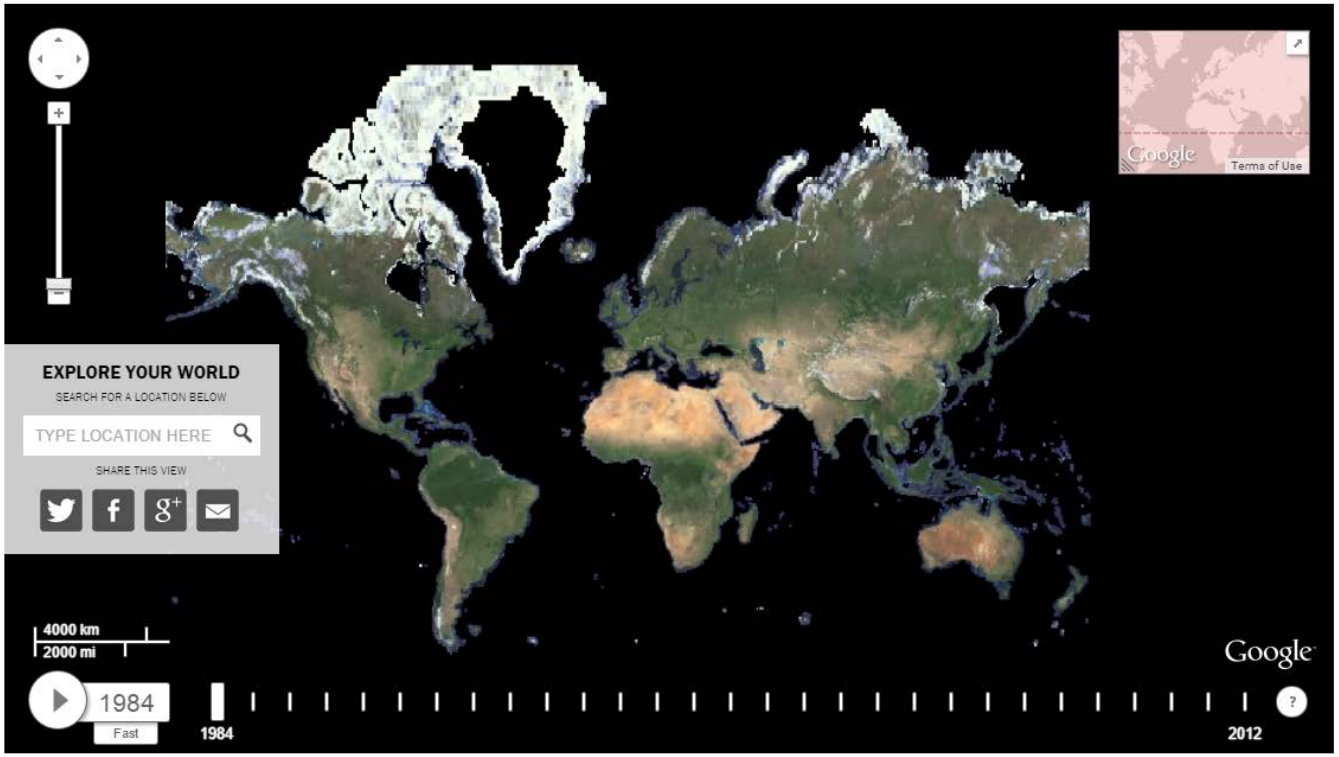


http://landsat.usgs.gov

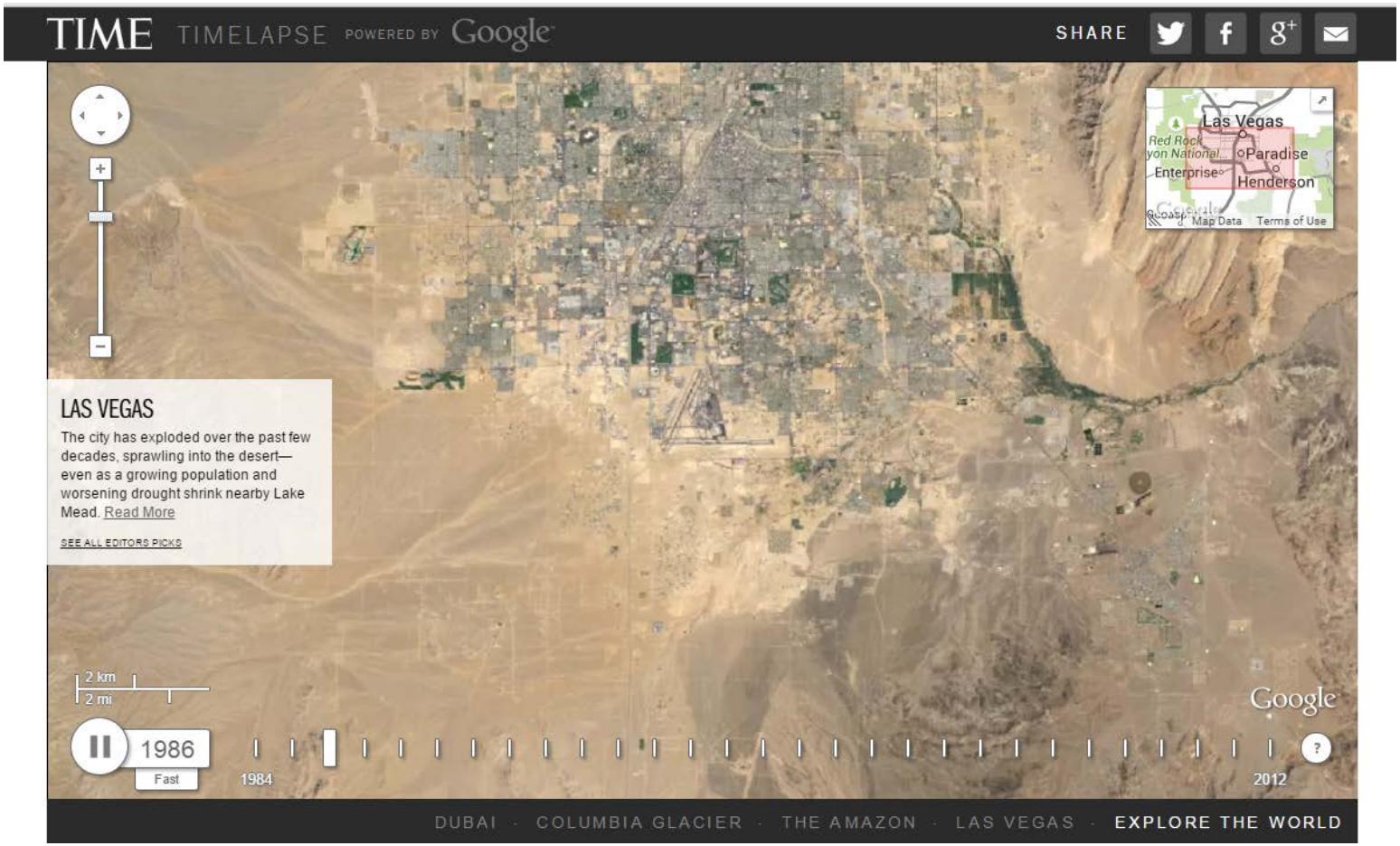
Four decades of monitoring the Earth!

Timelapse

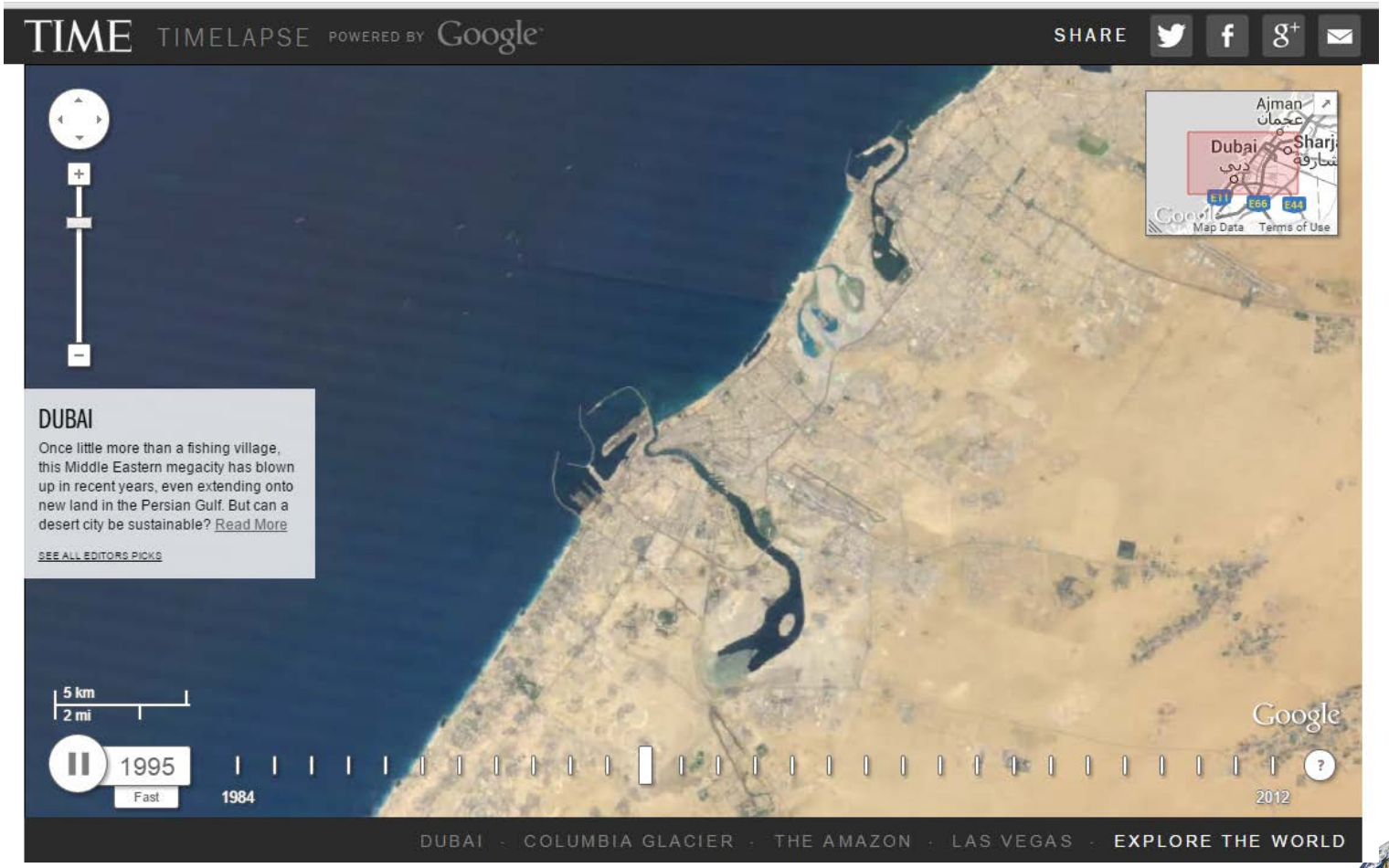
- Timelapse is powered by Google.
- It uses global scale historical archives of Landsat satellite imagery from 1984-2012 to monitor change on the planet.



Lasvegas


TIME TIMELAPSE POWERED BY Google
SHARE
Las Vegas
Paradise
Henderson
Enterprise
Map Data
Terms of Use
LAS VEGAS
The city has exploded over the past few decades, sprawling into the desert—even as a growing population and worsening drought shrink nearby Lake Mead. Read More
SEE ALL EDITORS PICKS
2 km
2 mi
1986
Fast
1984
2012
Google
DUBAI · COLUMBIA GLACIER · THE AMAZON · LAS VEGAS · EXPLORE THE WORLD

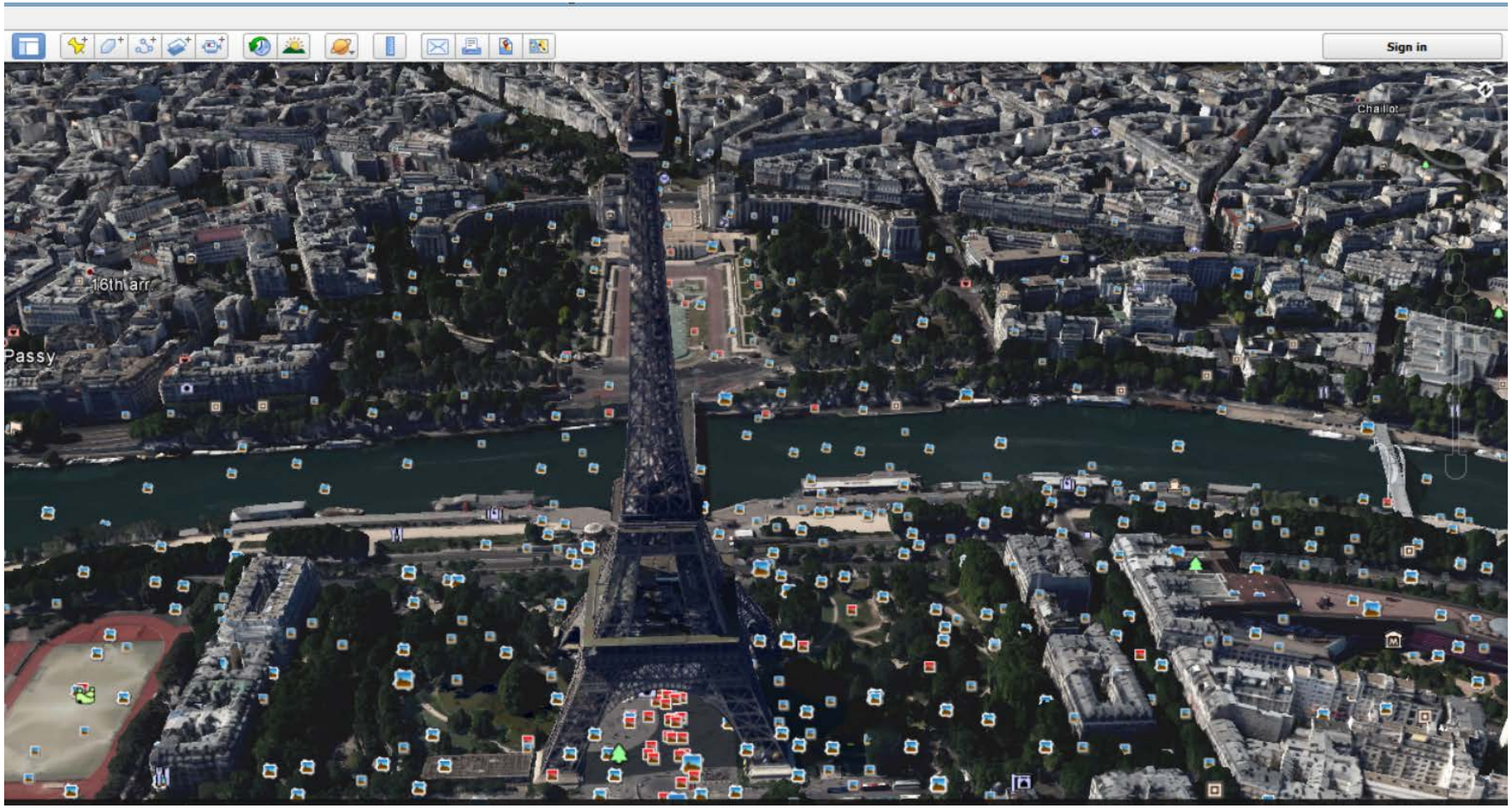
Dubai


TIME TIMELAPSE POWERED BY Google
SHARE
Ajman
عجمان
Dubai
دبي
Sharj
شارقة
E11
E66
E44
Map Data
Terms of Use
DUBAI
Once little more than a fishing village, this Middle Eastern megacity has blown up in recent years, even extending onto new land in the Persian Gulf. But can a desert city be sustainable? Read More
SEE ALL EDITORS PICKS
5 km
2 mi
1995
Fast
1984
2012
Google
DUBAI · COLUMBIA GLACIER · THE AMAZON · LAS VEGAS · EXPLORE THE WORLD

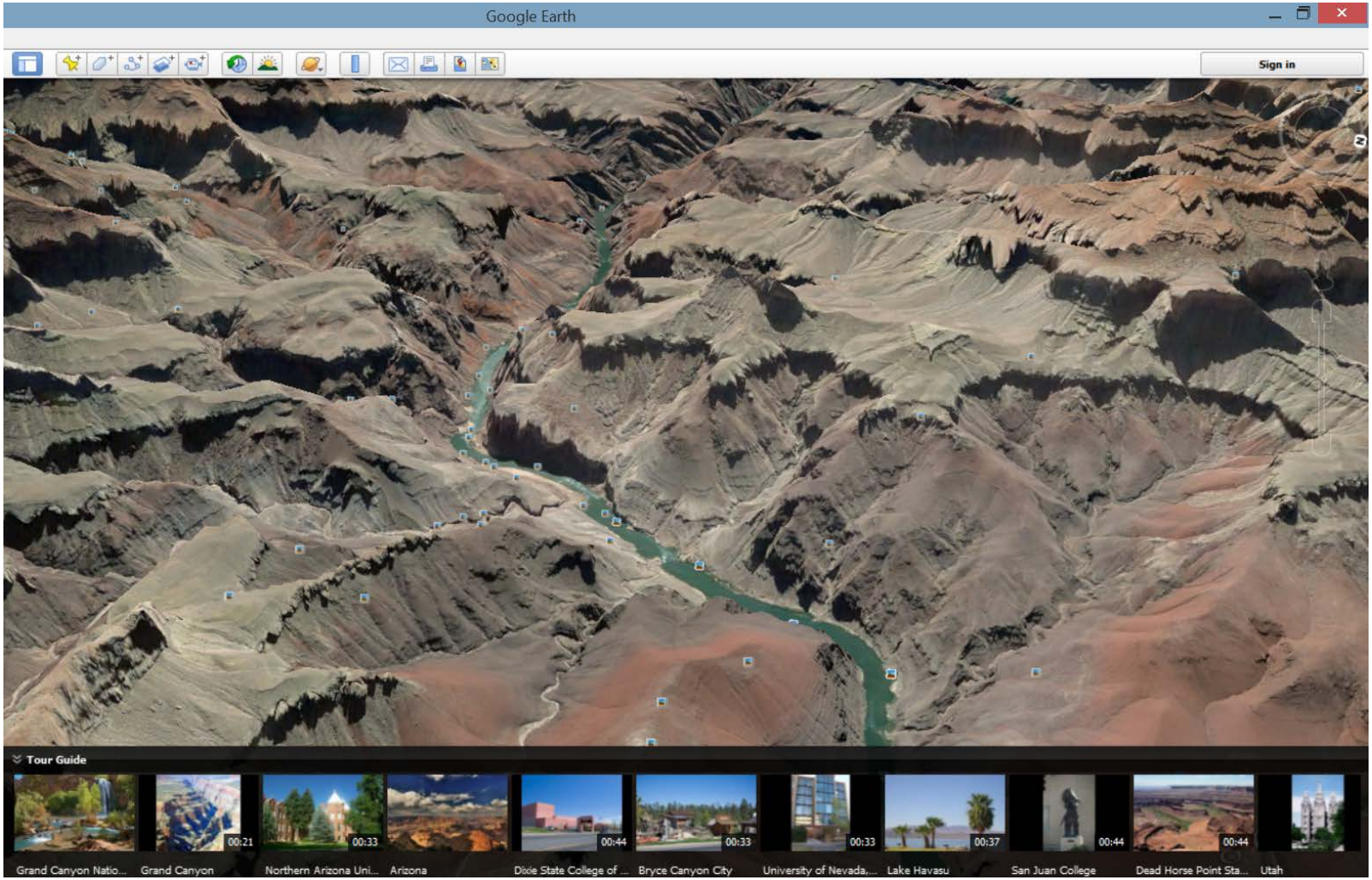
SkyBox
SkySat 1 and 2 Satellites

- Panchromatic GSD 90 cm at nadir
- Multispectral GSD 2 m at nadir
- Swath Width 8 km at nadir

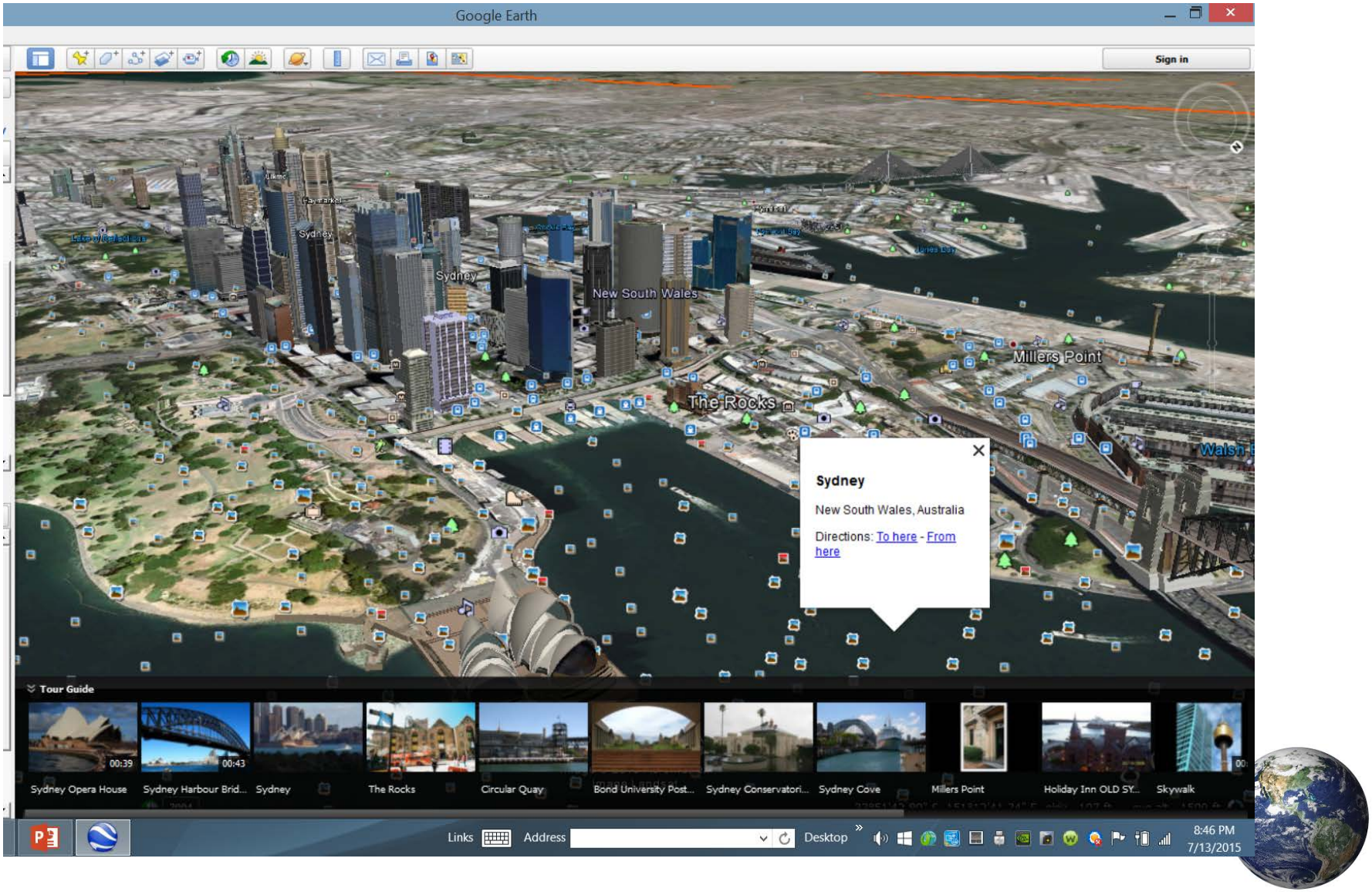
Google Earth: Paris



Google Earth: Grand canyon



Google Earth: Sydney



Remote Sensing Data Access

- **Google Earth Engine**
  https://earthengine.google.org

- **Earthexplorer**
  http://earthexplorer.usgs.gov/

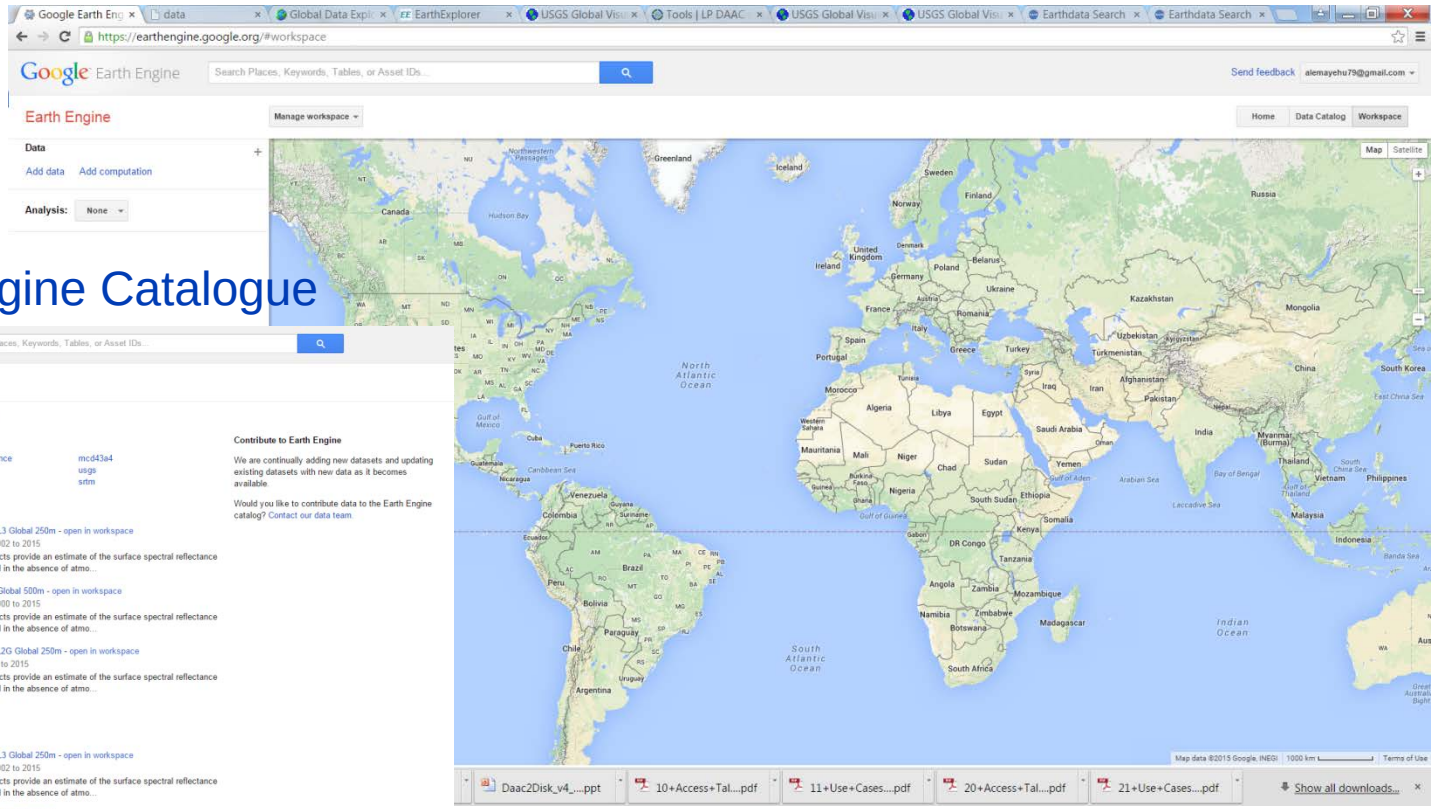
- **The USGS Global Visualization Viewer (GloVis)**
  http://glovis.usgs.gov/

- **LPDAAC**
  (Land Processes Distributed Archive Data Center)
  https://lpdaac.usgs.gov/data_access/data_pool

- **Earthdata**
  https://search.earthdata.nasa.gov/

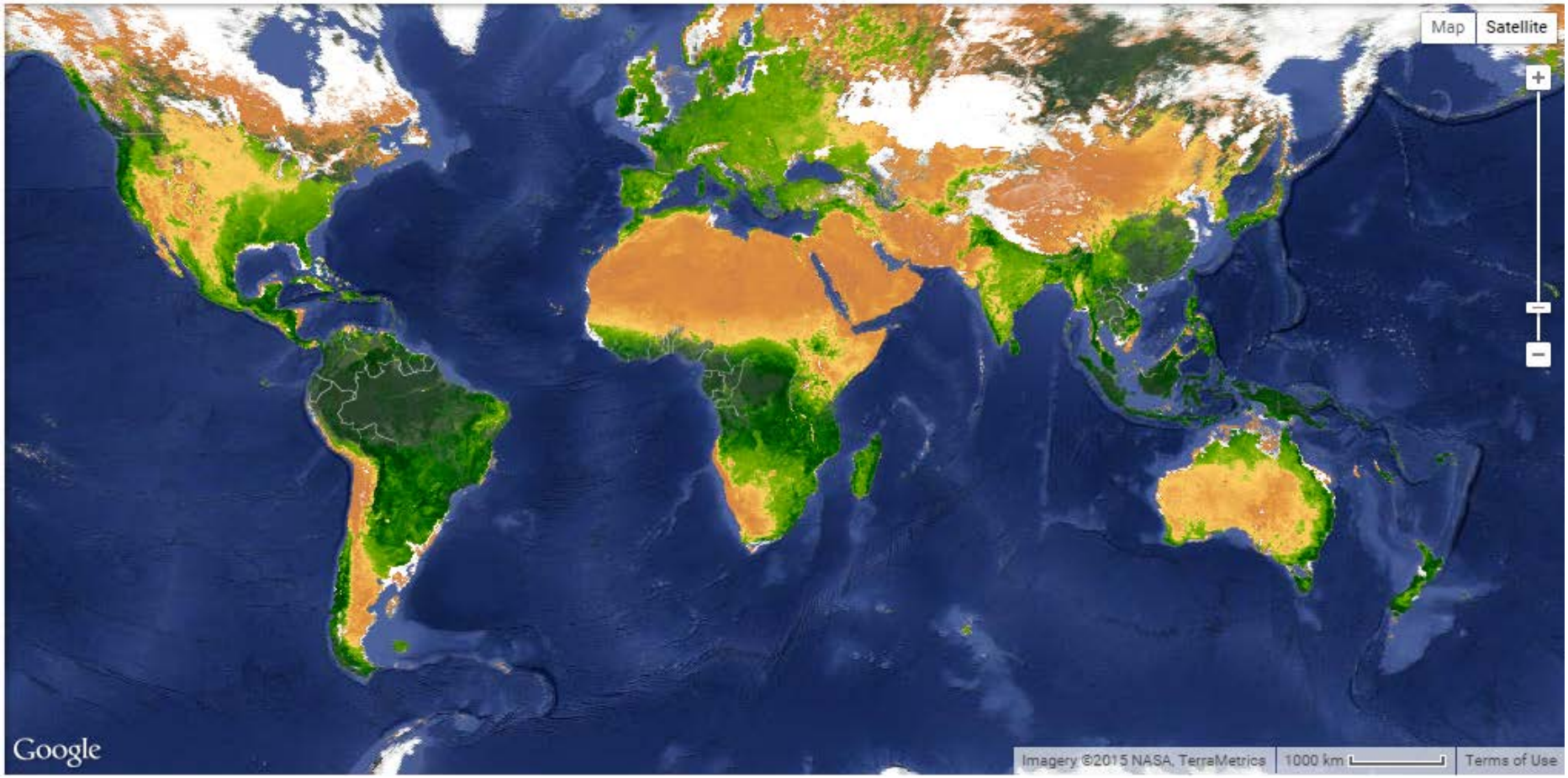
- **GDEx**
  http://gdex.cr.usgs.gov/gdex/

Google Earth Engine https://earthengine.google.org



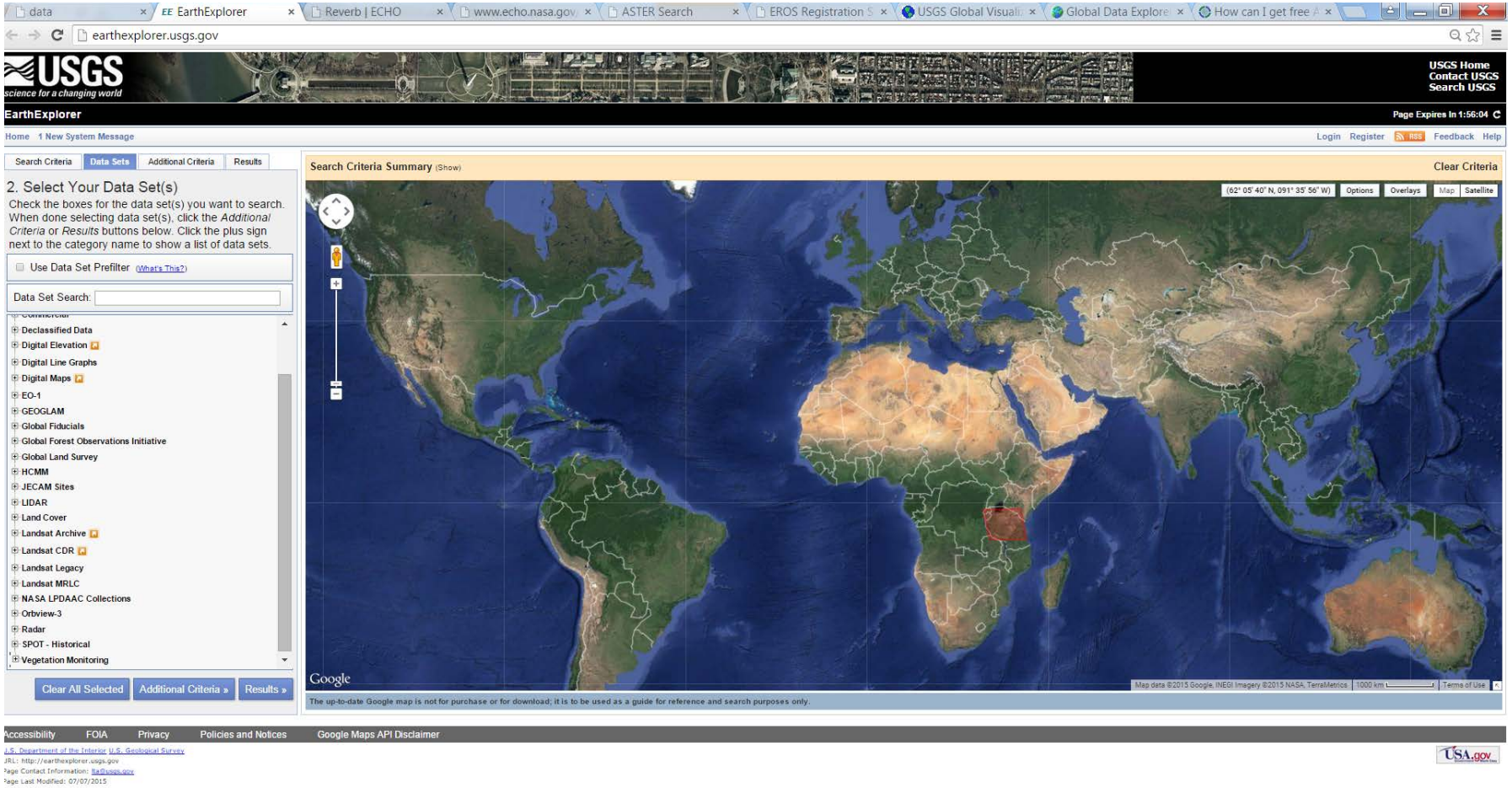
Earth Engine Catalogue

Google Earth Engine

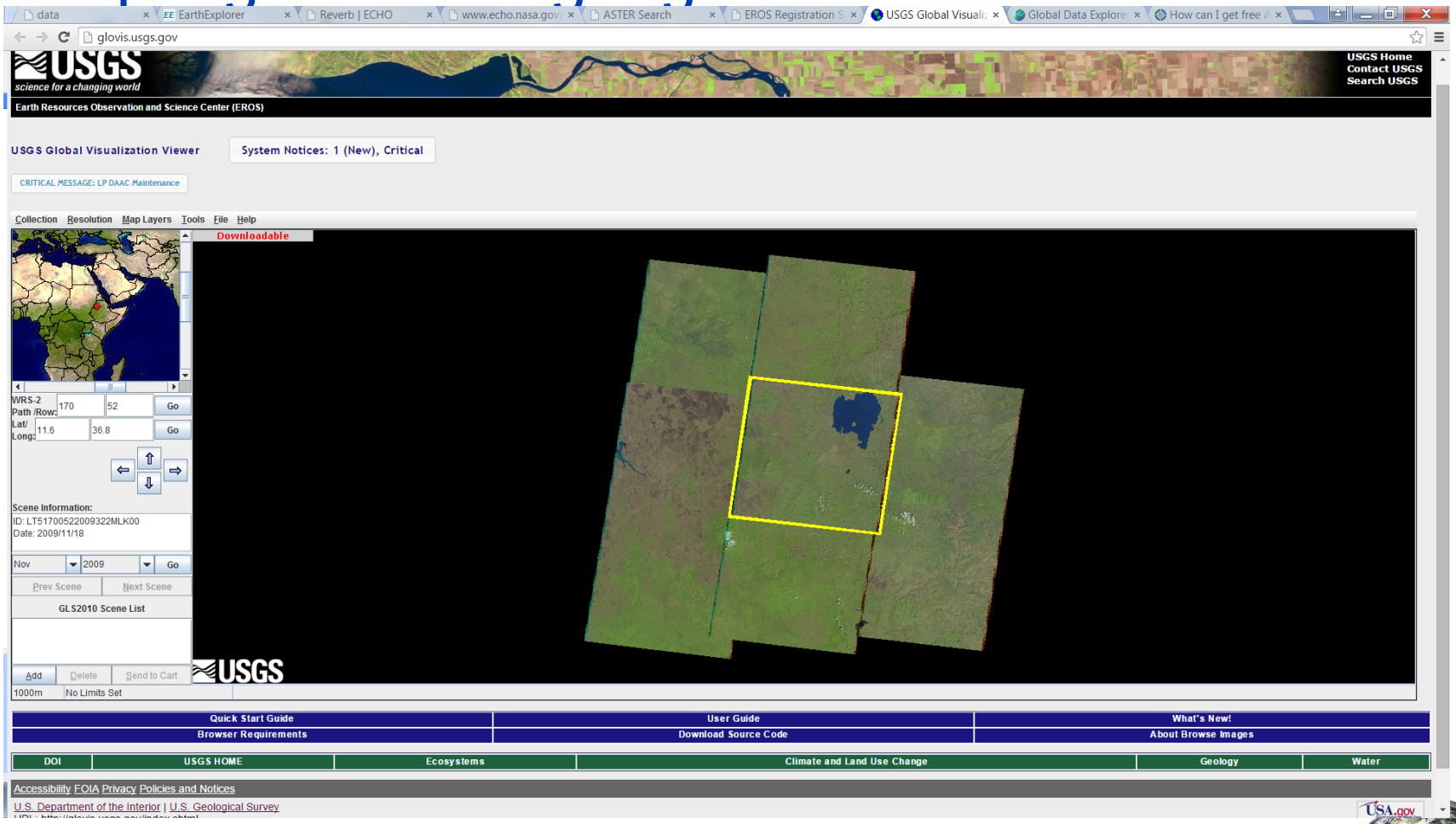


MODIS Normalized Difference Vegetation Index (March 2015)

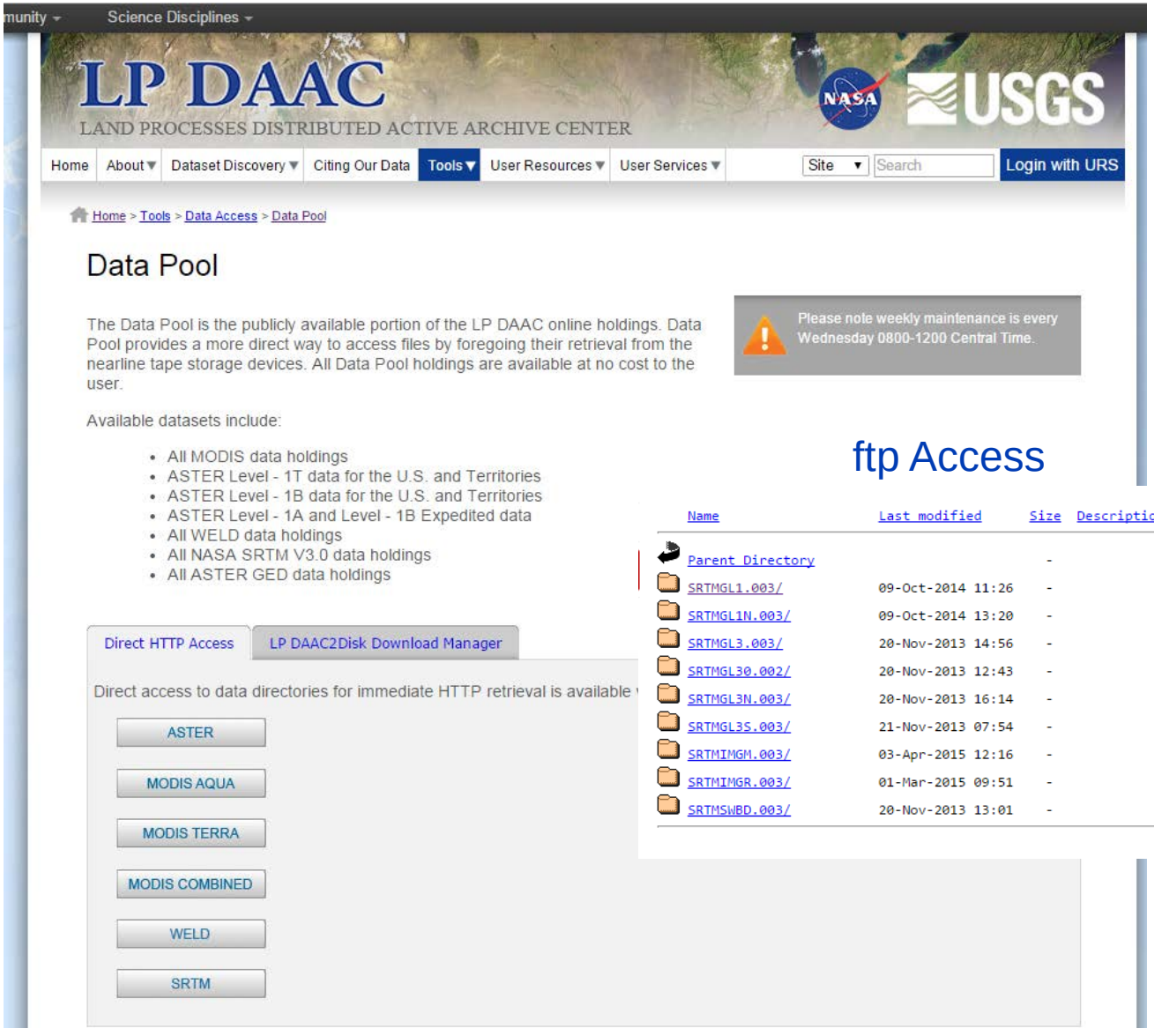
Earthexplorer
http://earthexplorer.usgs.gov/



The USGS Global Visualization Viewer (GloVis) http://glovis.usgs.gov/

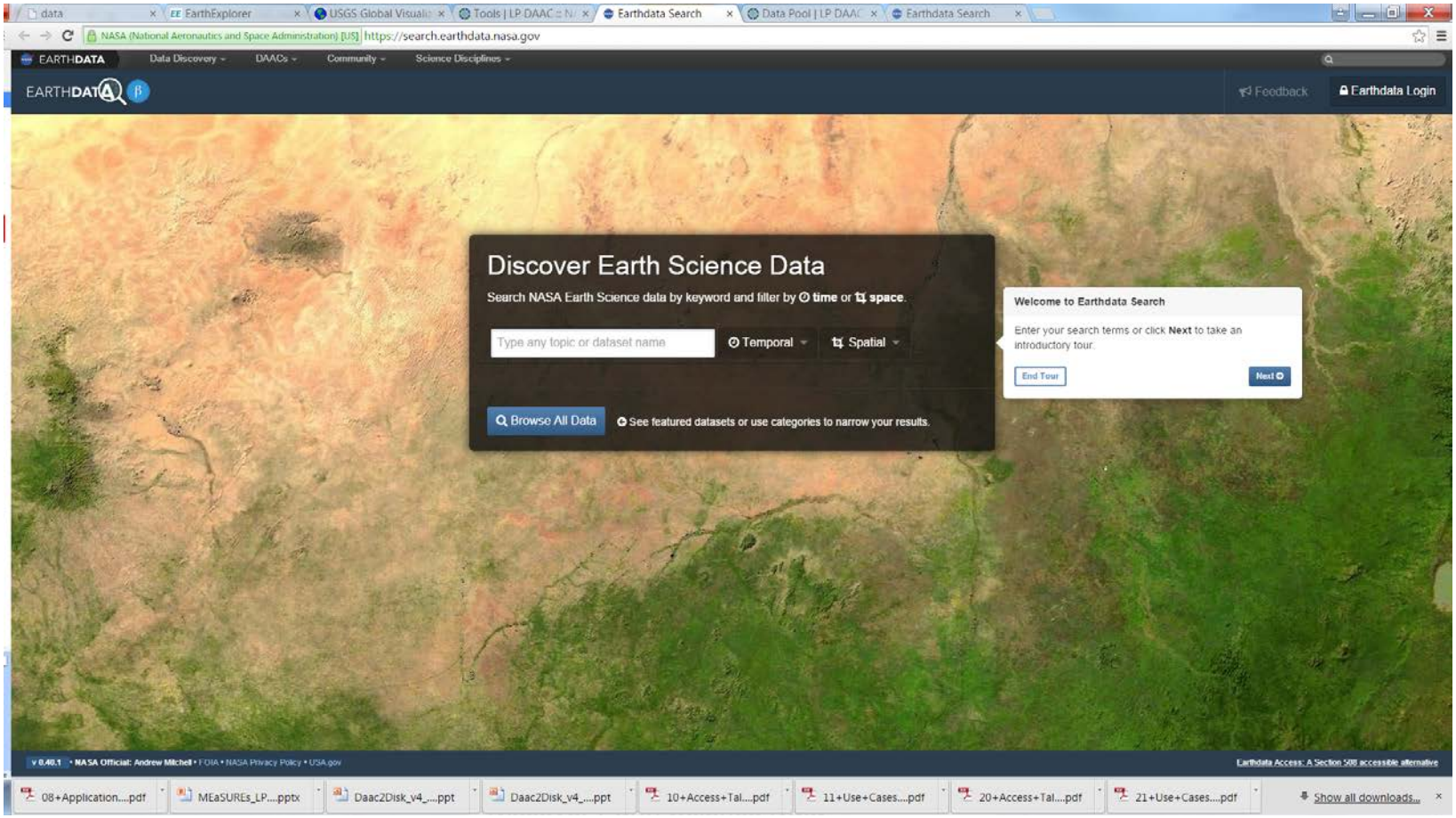


LPDAAC
(Land Processes Distributed Archive Data Center)
https://lpdaac.usgs.gov/data_access/data_pool



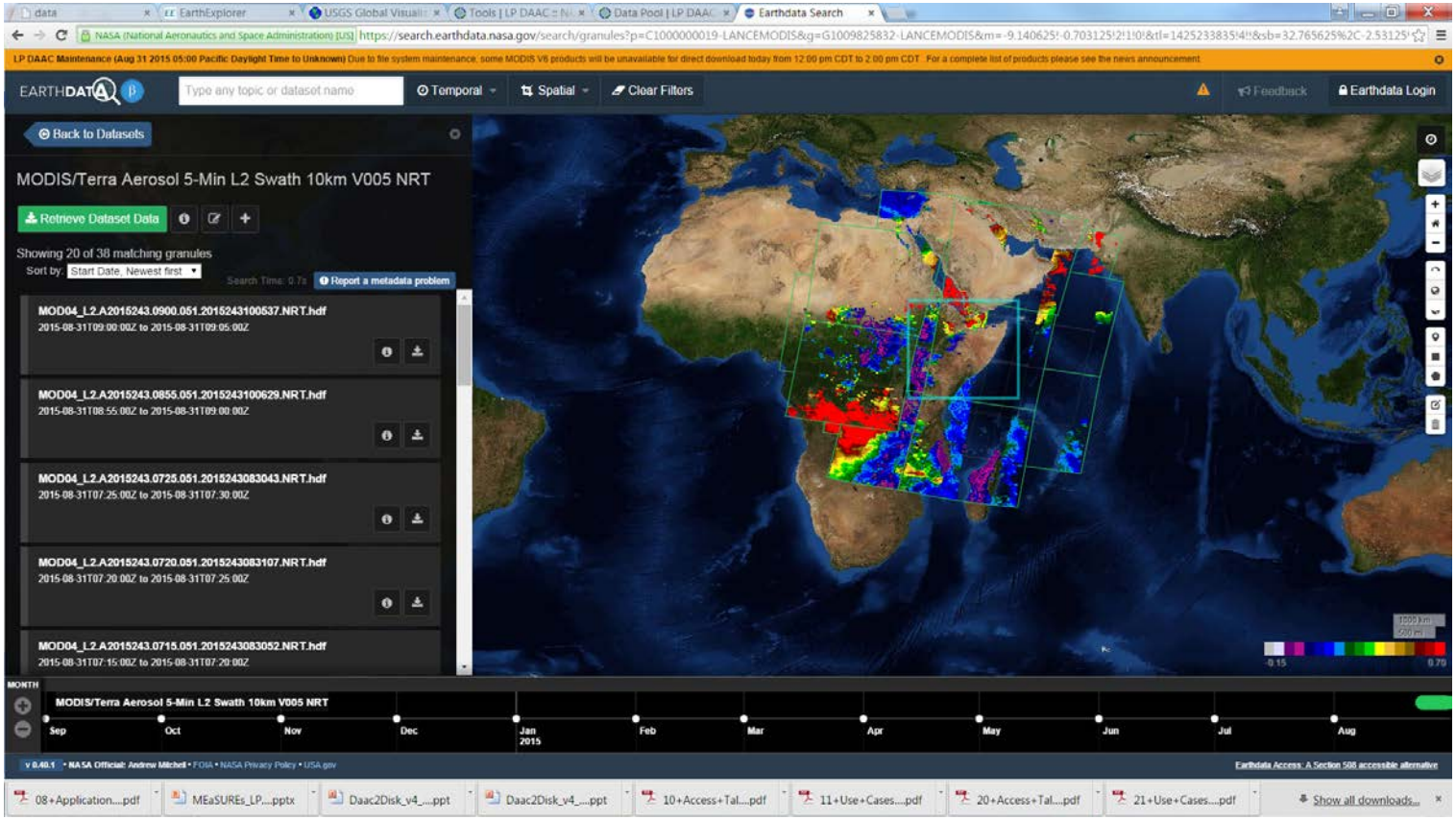
ftp Access

Earthdata
https://search.earthdata.nasa.gov/

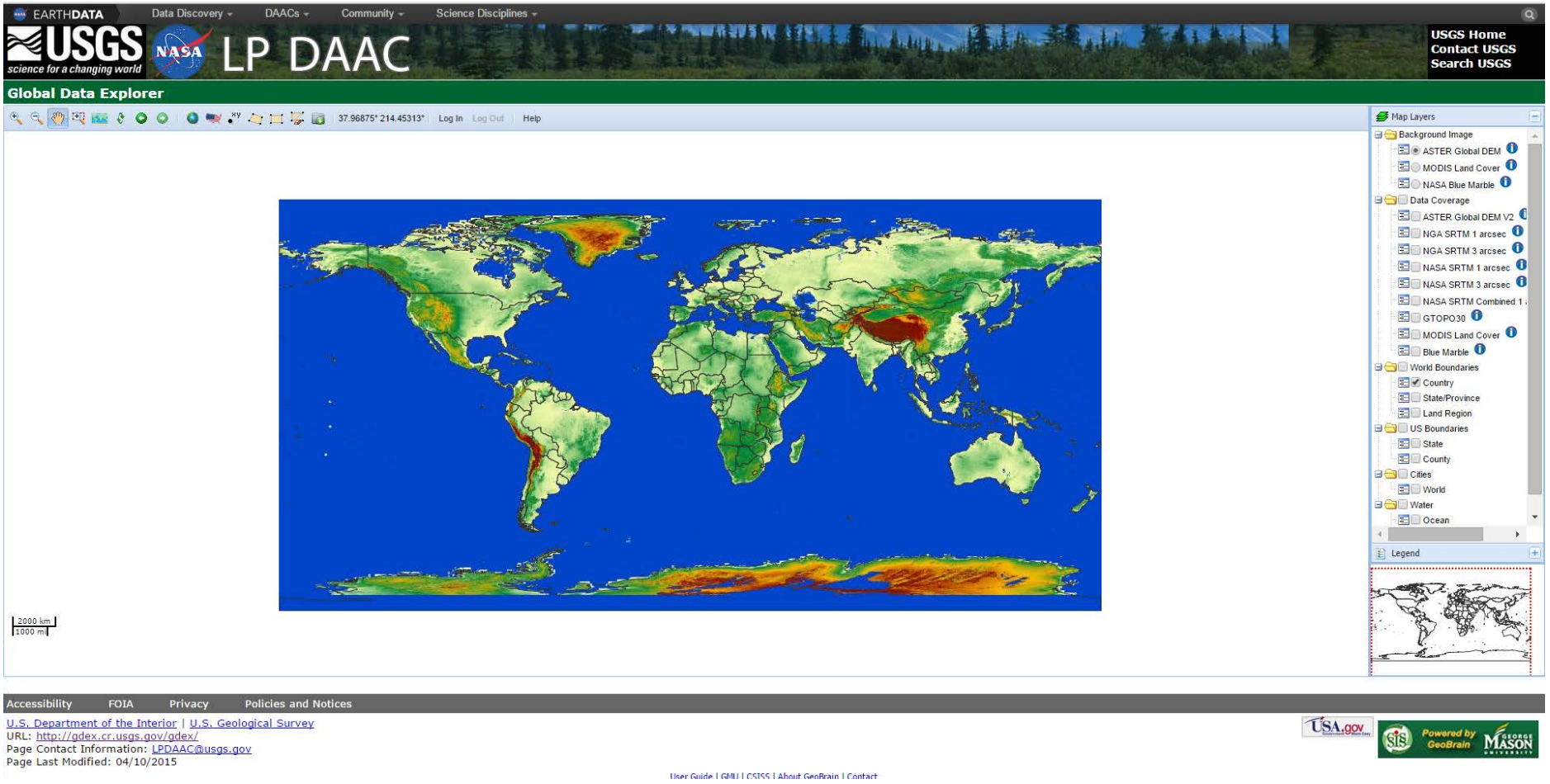


Earthdata offers discovering, searching, visualizing, and retrieving remote sensing.

Earthdata
https://search.earthdata.nasa.gov/

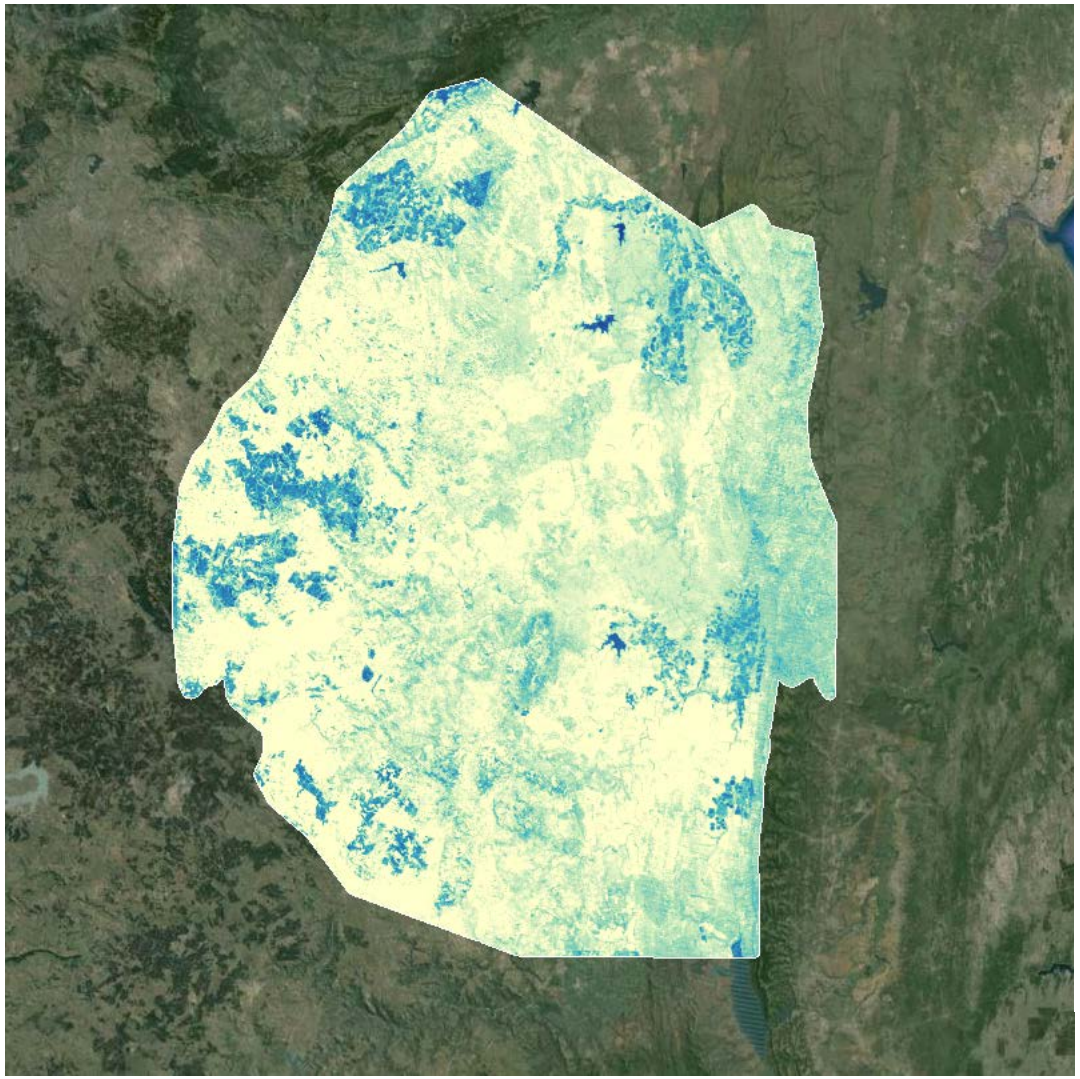


GDEx
http://gdex.cr.usgs.gov/gdex/



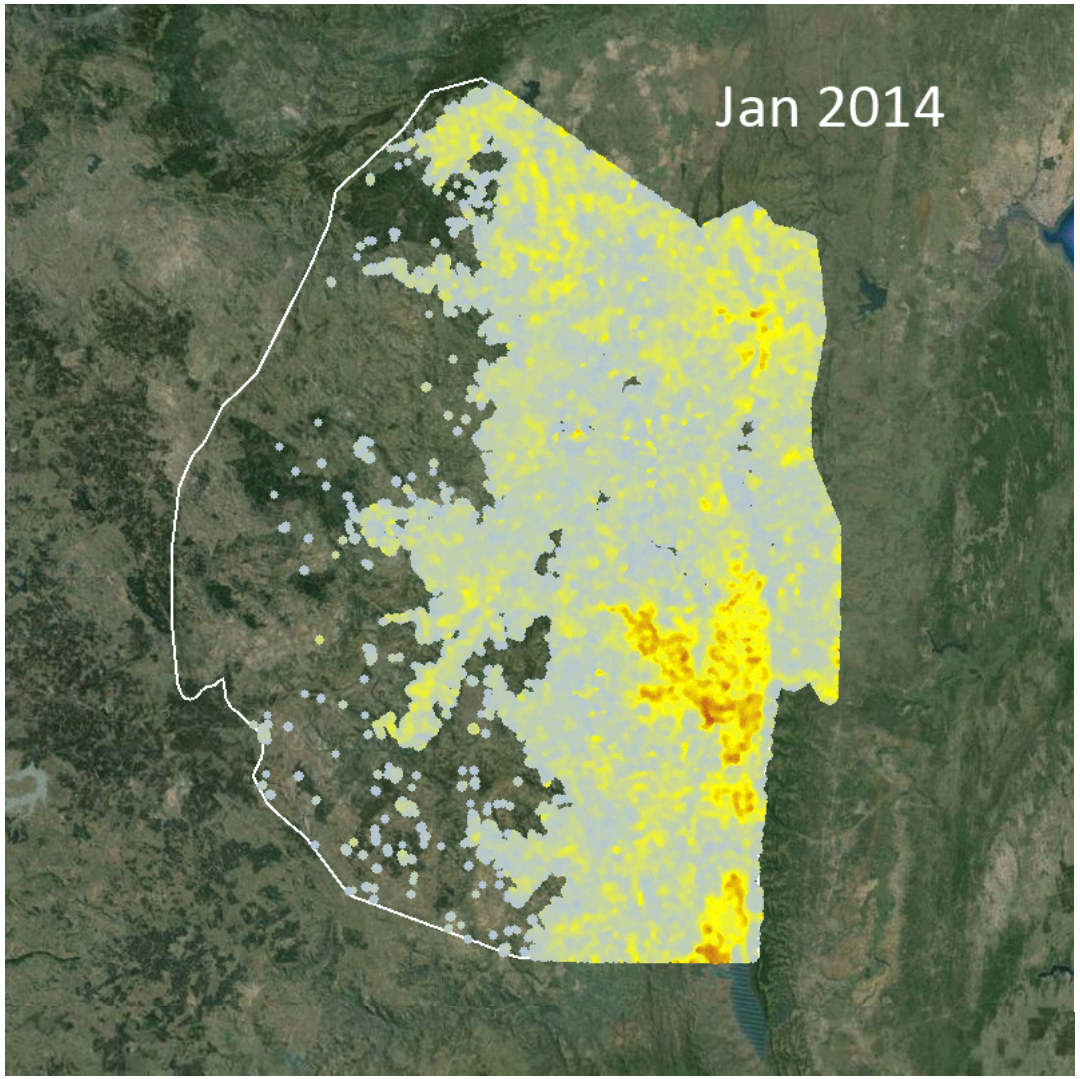
Digital elevation model data for all users.
User-friendly geographic interface.

Remote Sensing Application in Public Health



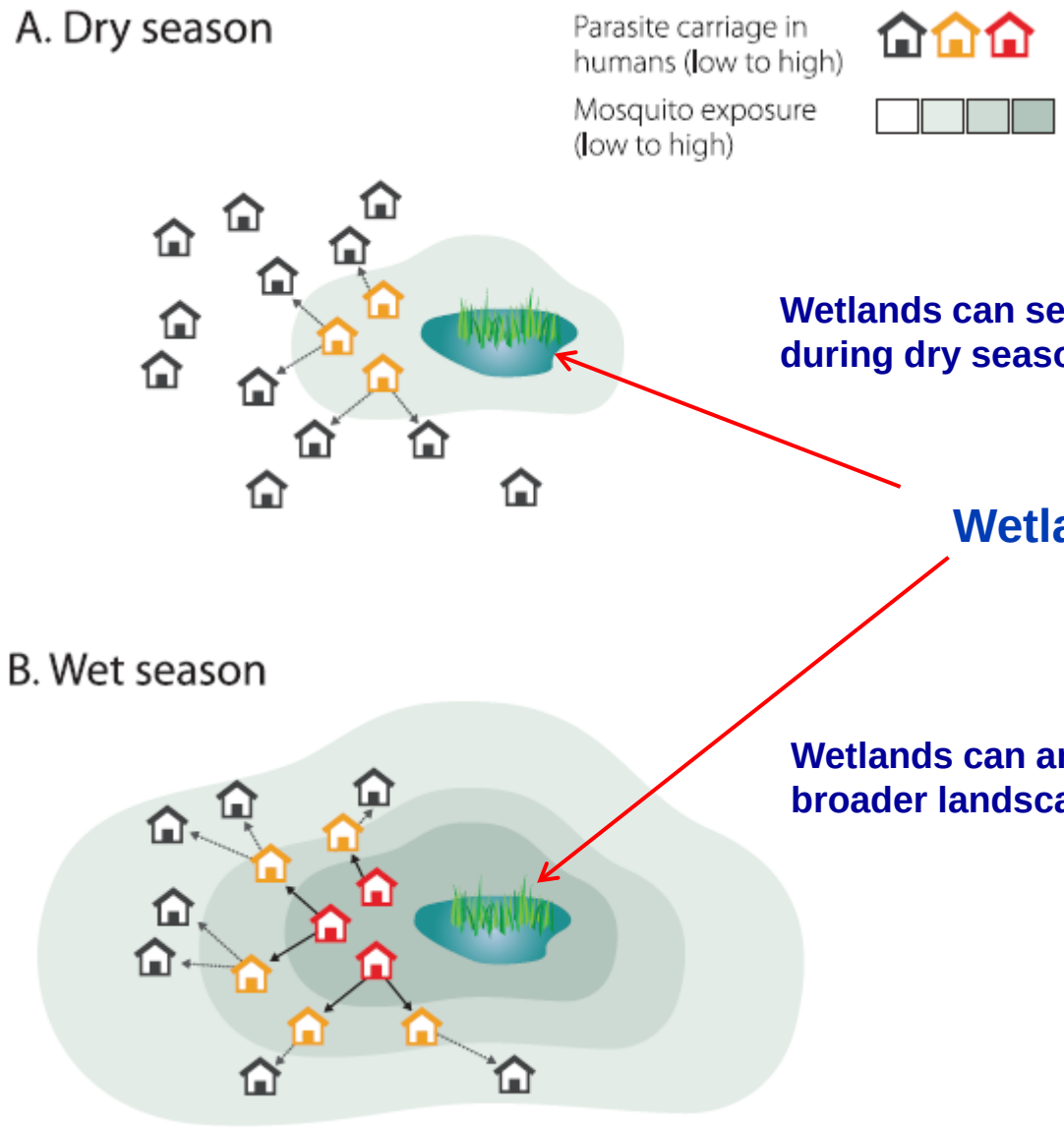
A malaria risk forecasting platform lead by Dr. Hugh Sturrock at UCSF.

Real-Time Risk Forecast



Improve Targeting of Resources

Conceptual Model of Malaria Transmission



Wetlands can serve as foci of malaria transmission during dry season.

Wetlands

Wetlands can amplify malaria transmission to the broader landscape during the wet season.

Bousema, T., J. T. Griffin, R. W. Sauerwein, D. L. Smith, T. S. Churcher, W. Takken, A. Ghani, 483 C. Drakeley, and R. Gosling (2012), Hitting Hotspots: Spatial Targeting of Malaria for Control 484 and Elimination, *Plos Med*, *9*(1).

Water Resources Research
AN AGU JOURNAL

Research Article

Multisensor earth observations to characterize wetlands and malaria epidemiology in Ethiopia

Alemayehu Midekisa[1], Gabriel Senay[2] and Michael C Wimberly[1,*]

DOI: 10.1002/2014WR015634

Issue

Water Resources Research

Accepted Article (Accepted, unedited articles published online and citable. The final edited and typeset version of record will appear in future.)

Am score 1

Additional Information **(Show All)**

Author Information | Publication History | Funding Information

Abstract | Supporting Information | Cited By

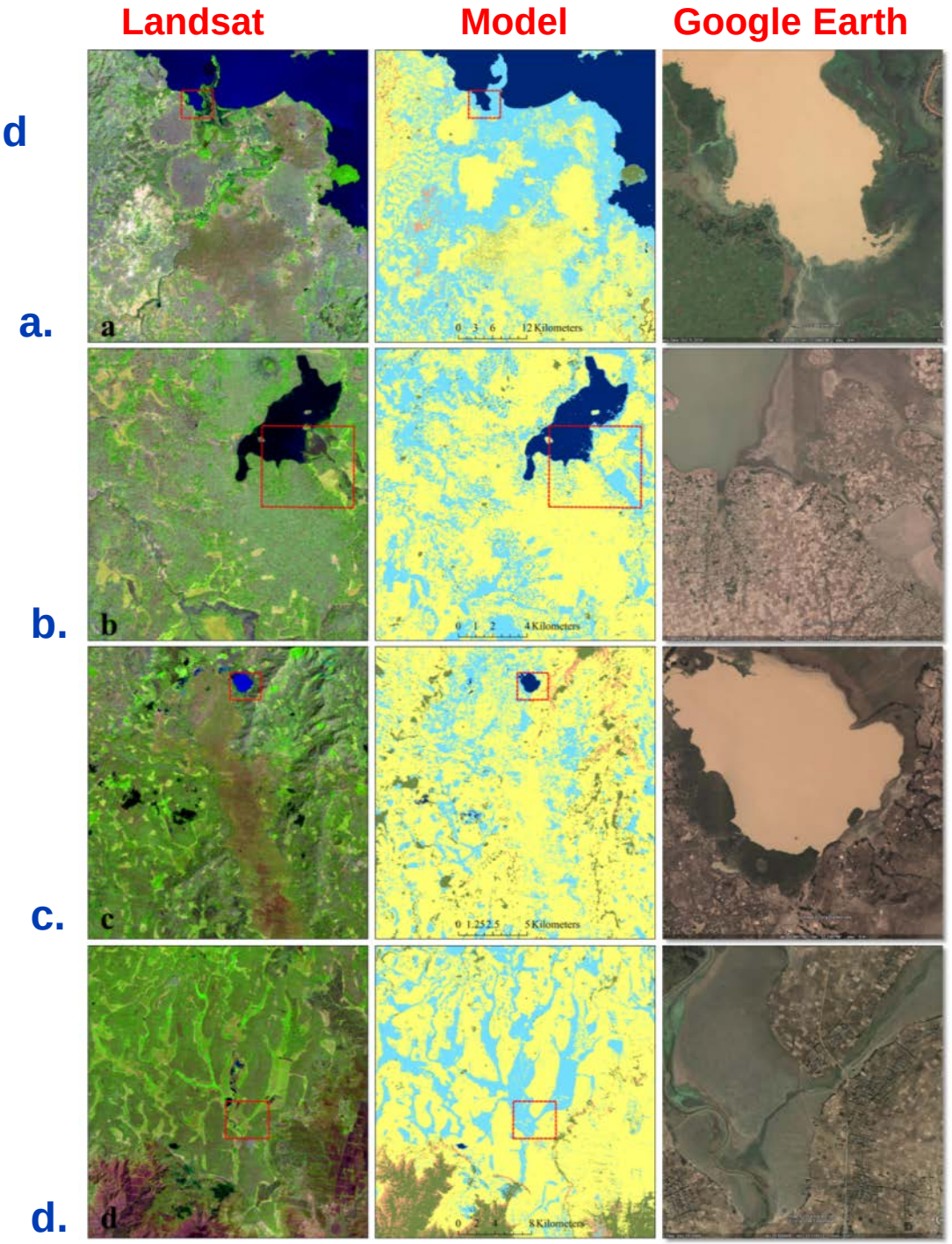
Get PDF (14677K) | Go here for SFX

Keywords:
Malaria; Wetlands; Early Warning; Remote Sensing; Hydrology; Public Health

Abstract

Malaria is a major global public health problem, particularly in sub-Saharan Africa. The spatial heterogeneity of malaria can be affected by factors such as hydrological processes, physiography, and land cover patterns. Tropical wetlands, for example, are important hydrological features that can serve as mosquito breeding habitats. Mapping and monitoring of wetlands using satellite remote sensing can thus help to target interventions aimed at reducing malaria transmission. The objective of this study was to map wetlands and other major land cover types in the Amhara Region of Ethiopia and to analyze district-level associations of malaria and wetlands across the region. We evaluated three random forests classification models using remotely sensed topographic and spectral data based on Shuttle Radar Topographic Mission (SRTM) and Landsat TM/ETM+ imagery respectively. The model that integrated data from both sensors yielded more accurate land cover

Comparison of wetland classification with Landsat and Google Earth



Midekisa (2014)

Resource Links

https://earthengine.google.org

http://earthexplorer.usgs.gov/

http://glovis.usgs.gov/

https://lpdaac.usgs.gov/data_access/data_pool

https://search.earthdata.nasa.gov/

http://gdex.cr.usgs.gov/gdex/

http://fas.org/irp/imint/docs/rst/Front/overview.html

http://www.nrcan.gc.ca/earth-sciences/geomatics/satellite-imagery-air-photos/satellite-imagery-products/educational-resources/9309