

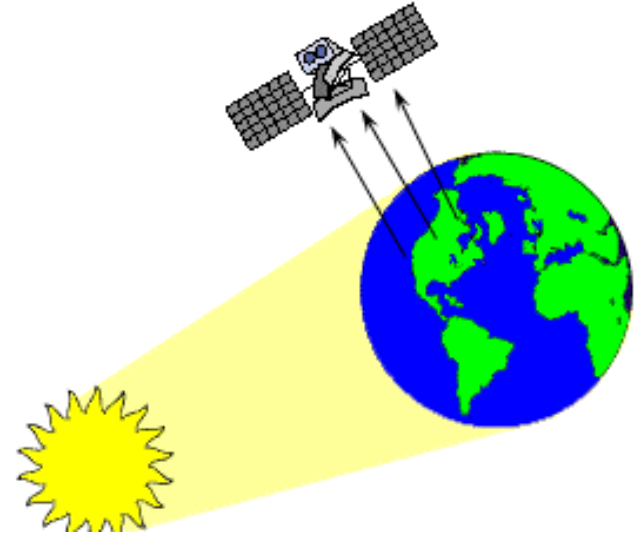
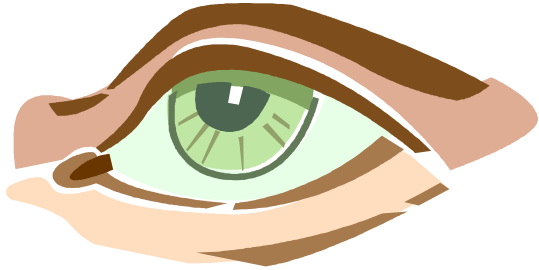
Introduction to Remote Sensing

Alemayehu Midekisa, PhD

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



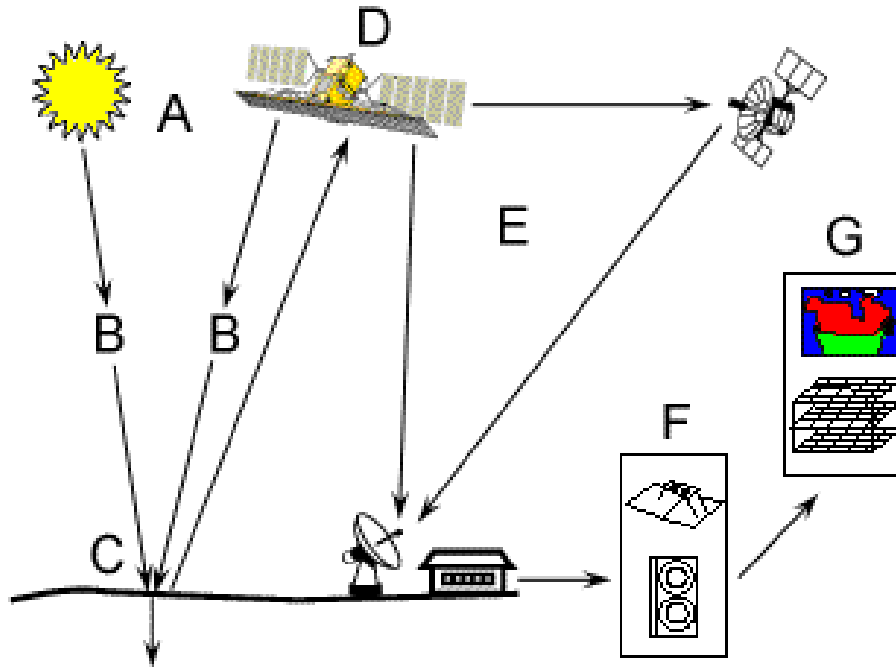
Background to Remote Sensing



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



(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

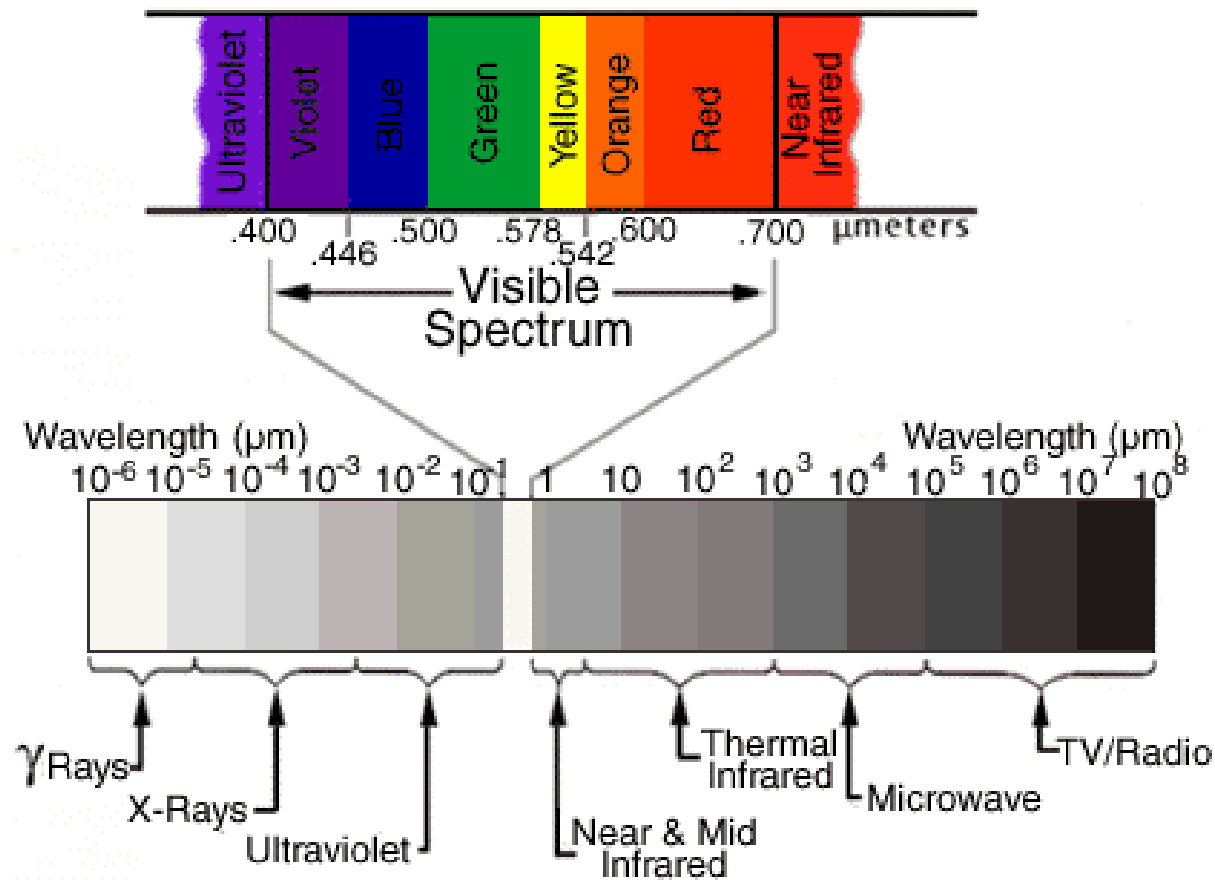
(F) Interpretation and Analysis

(G) Application

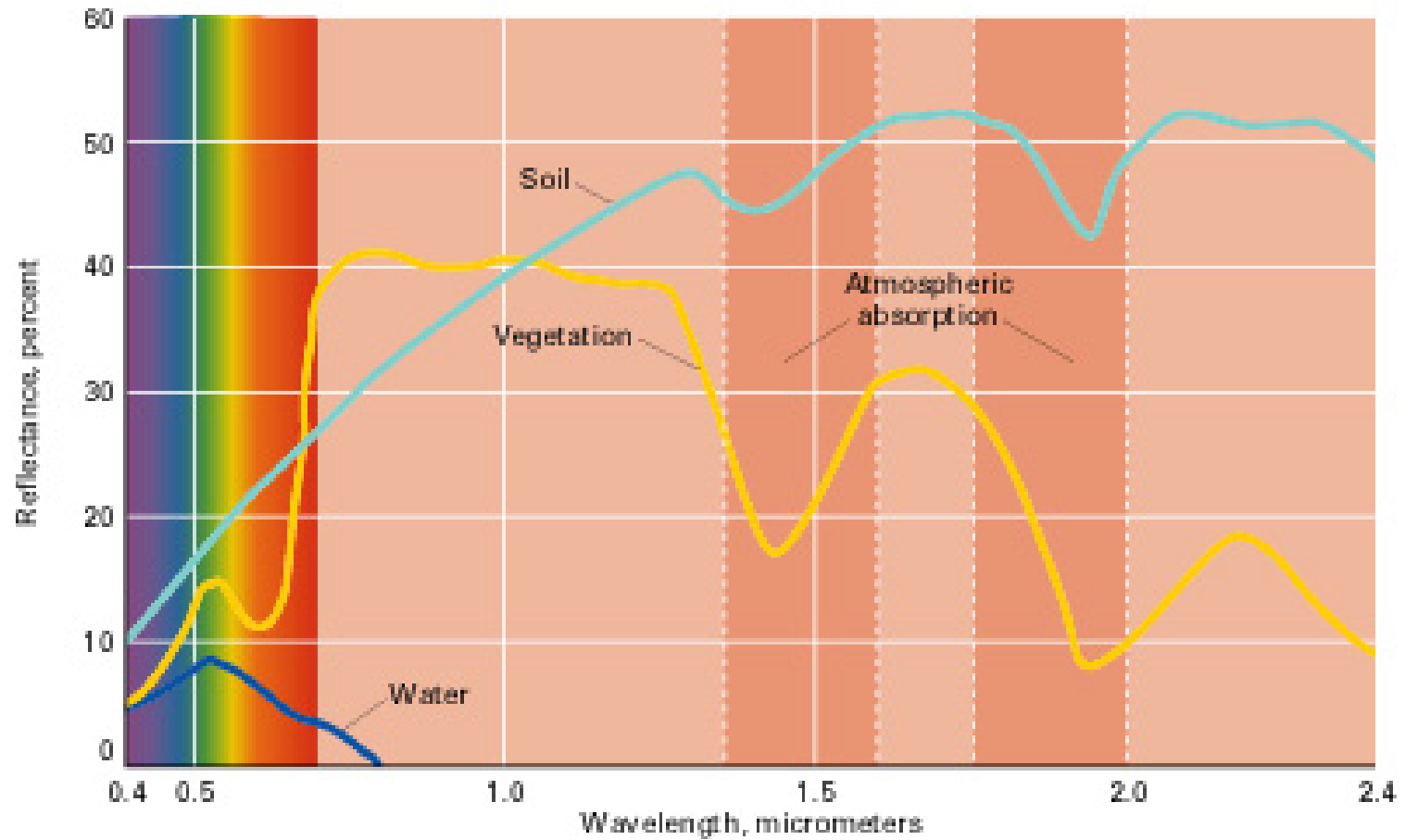
Source: Canadian Centre for Remote Sensing
<http://www.nrcan.gc.ca/>



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**



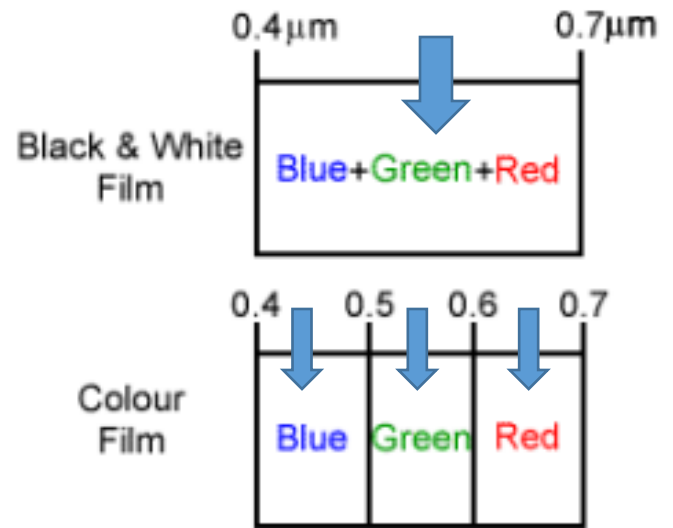
Temporal Resolution

- **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 = $2^{12} = 4096 = (0-4095)$

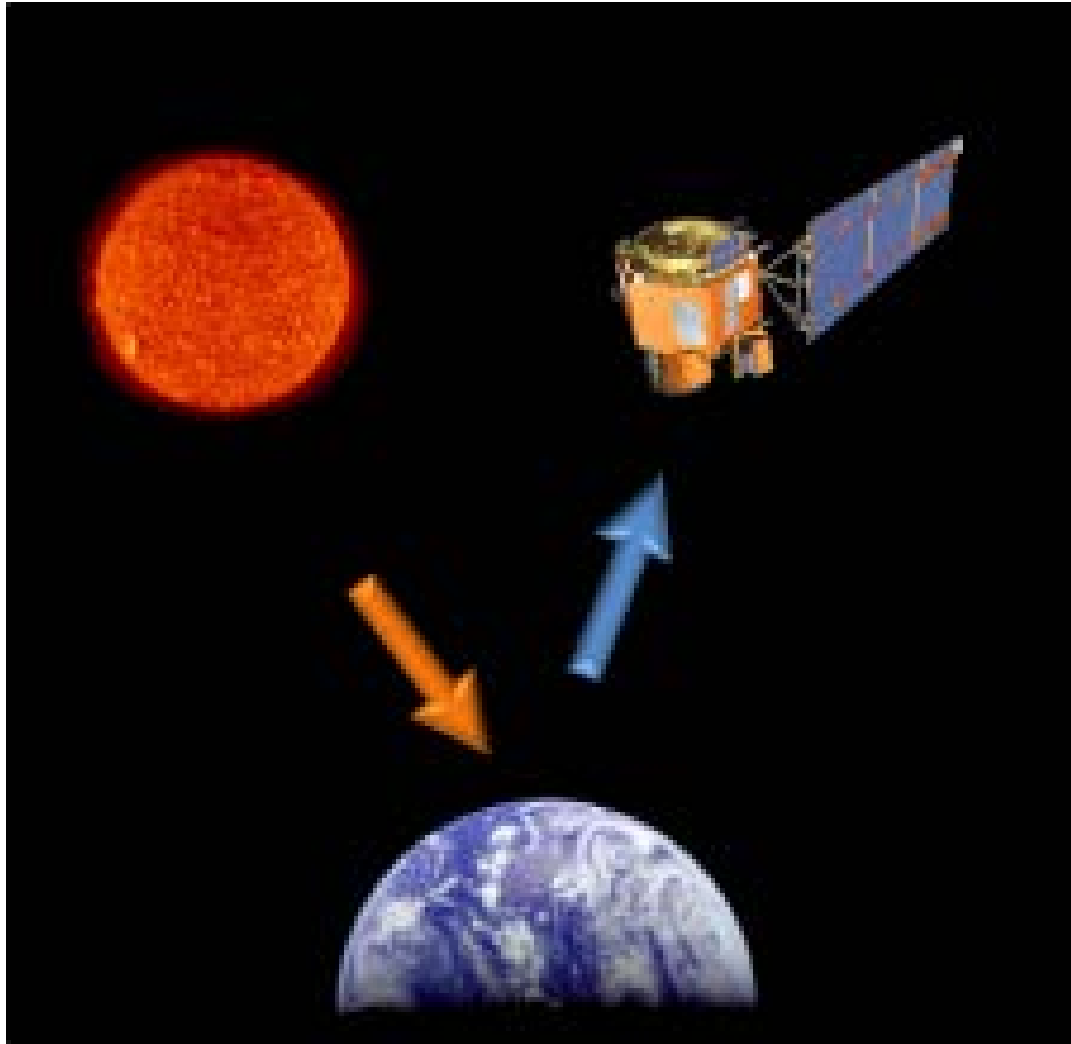


Passive and Active Sensors

- **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/>

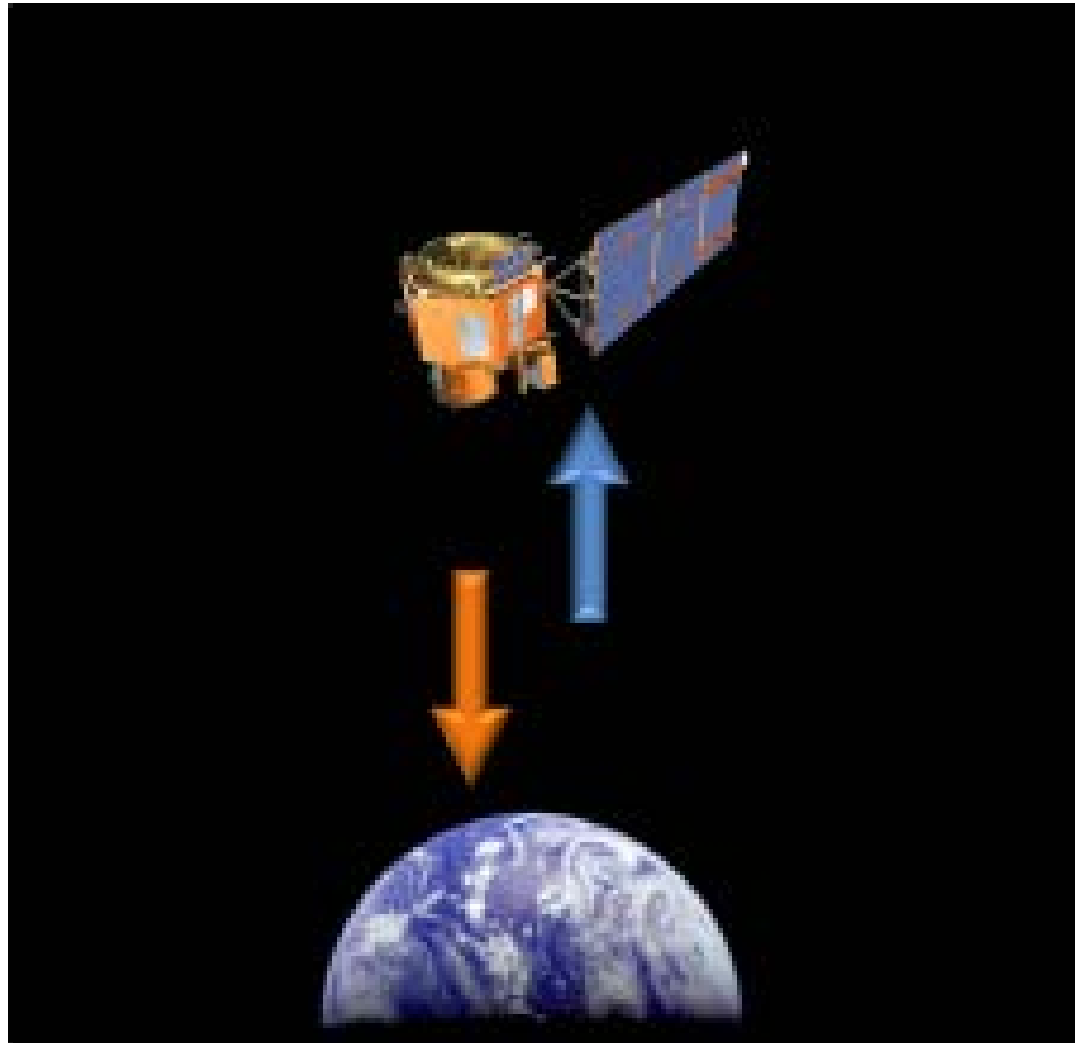


Active sensors

- **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

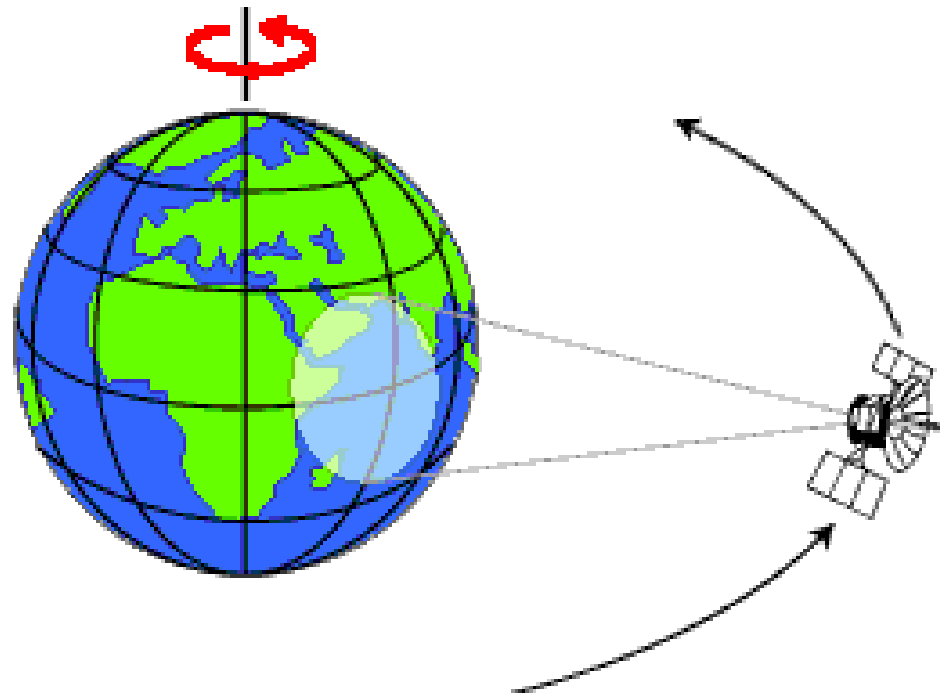


<http://www.nasa.gov/>



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)

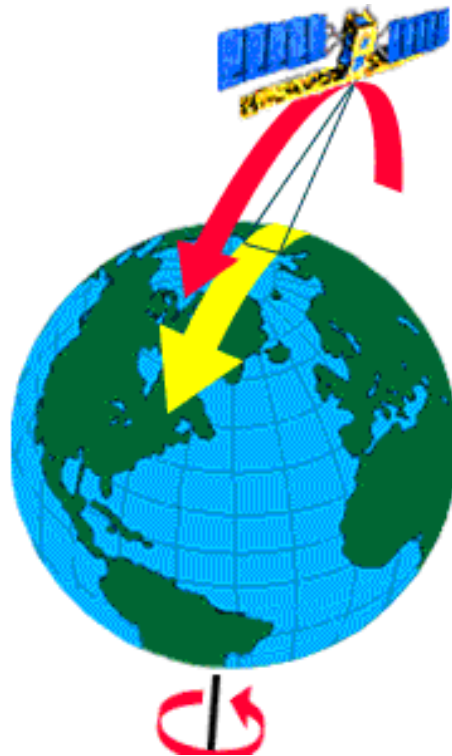


Source: Canadian Centre for Remote Sensing
<http://www.nrcan.gc.ca/>



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



Satellite Derived Indices

- **Vegetation Indices:**

- Normalized difference vegetation index (NDVI)
- Enhanced vegetation index (EVI)

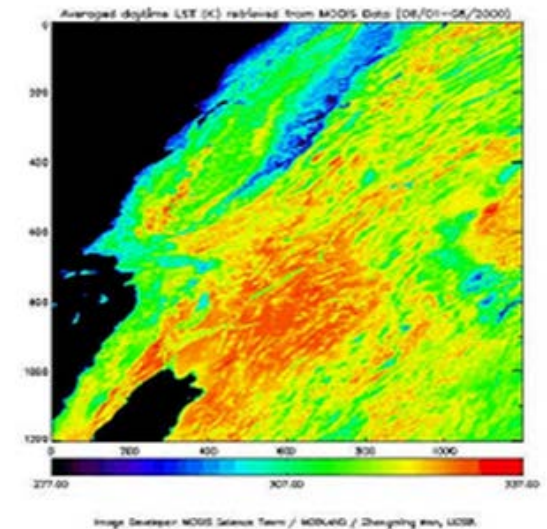


- **Moisture indices:**

- Normalized difference water index (NDWI)
- Evapotranspiration (ET)

- **Temperature:**

- Land surface temperature (LST)



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



NASA Earth Observation Satellites



ASTER



Jet Propulsion Laboratory
California Institute of Technology

[+ View the NASA Portal](#)

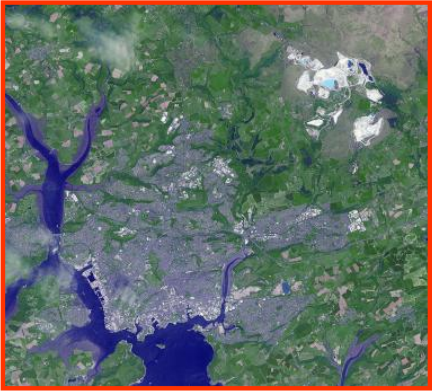
[JPL HOME](#)
[EARTH](#)
[SOLAR SYSTEM](#)
[STARS & GALAXIES](#)
[TECHNOLOGY](#)



ASTER
Advanced Spaceborne Thermal Emission and Reflection Radiometer

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[DATA](#)
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LATEST FEATURED IMAGE FROM ASTER:



[Drakelands Mine, England](#)

The Drakelands Mine (previously known as the Hemerdon Mine) is a historic tungsten and tin mine located northeast of Plymouth, England. Tin and tungsten deposits were discovered in 1867, and the mine operated until 1944. [Read More](#). Updated on 8/21/2015

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) is an imaging instrument onboard Terra, the flagship satellite of NASA's Earth Observing System (EOS) launched in December 1999. ASTER is a cooperative effort between NASA, Japan's Ministry of Economy, Trade and Industry (METI), and Japan Space Systems (J-spacesystems). ASTER data is used to create detailed maps of land surface temperature, reflectance, and elevation. The coordinated system of EOS satellites, including Terra, is a major component of NASA's Science Mission Directorate and the [Earth Science Division](#). The goal of NASA Earth Science is to develop a scientific understanding of the Earth as an integrated system, its response to change, and to better predict variability and trends in climate, weather, and natural hazards.

ASTER Data Archive

[GET DATA](#)

[Request an Acquisition](#)

[Acquisition Calendar](#)

[ASTER Global DEM](#)

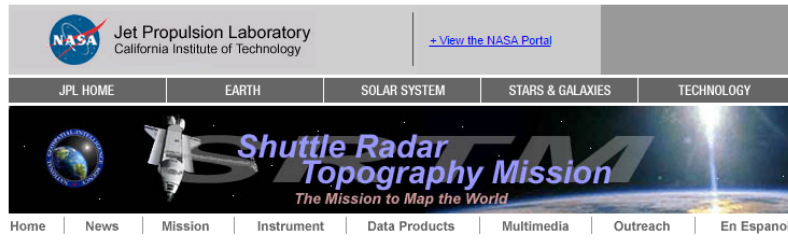
[TerraLook](#)

[ASTER Volcano Archive](#)

- **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



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
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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](#).



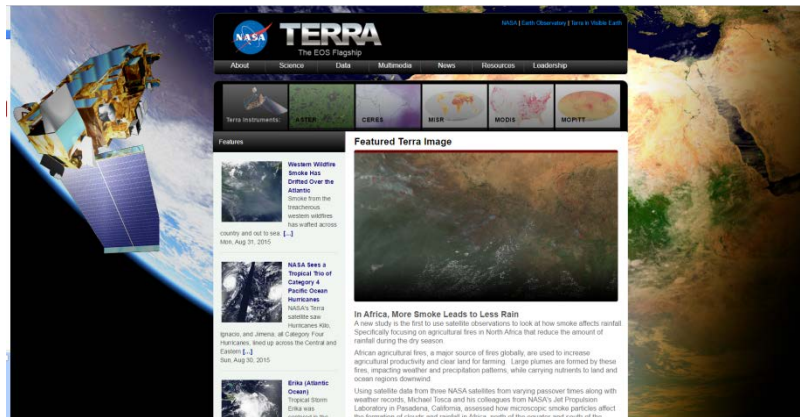
- The Shuttle Radar Topography Mission (SRTM) is an international research effort that obtained digital elevation model on a near-global scale from 56° S to 60° N.
- SRTM flew on board during the 11 day mission in February 2000.
- The resolution of the raw data is 30 meter for the US territory and 90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



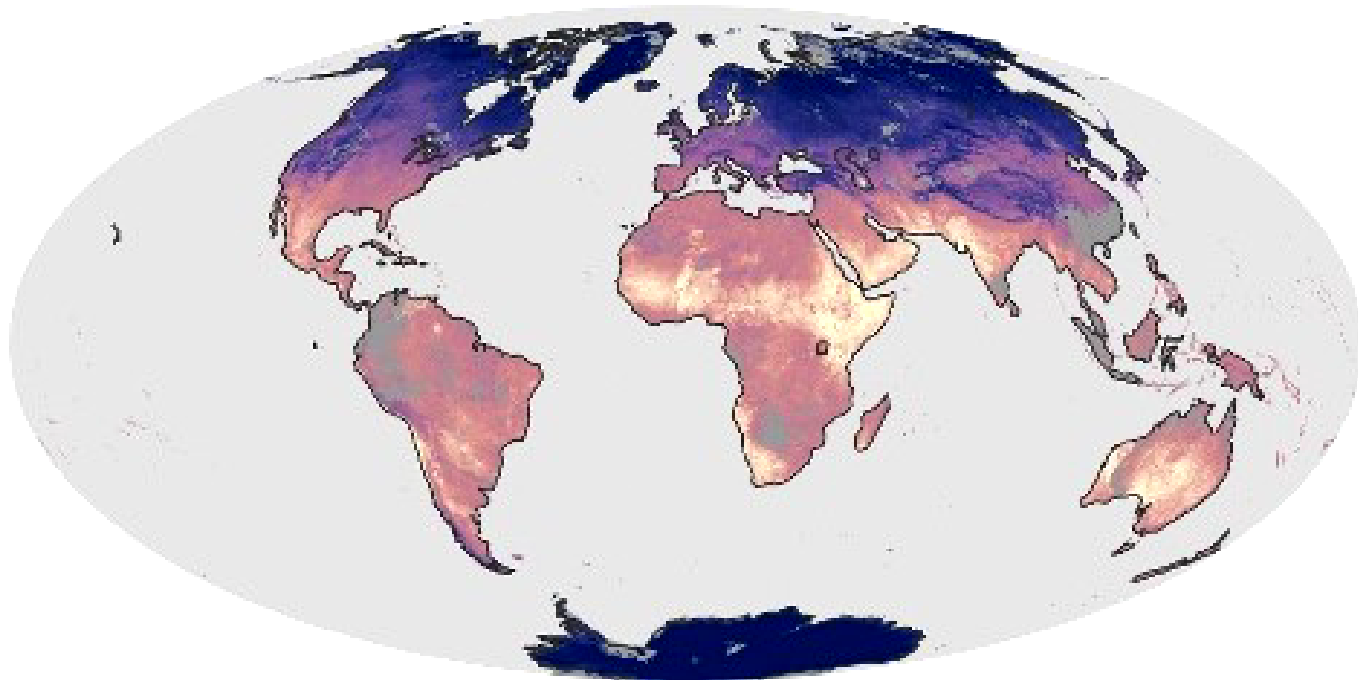
MODIS



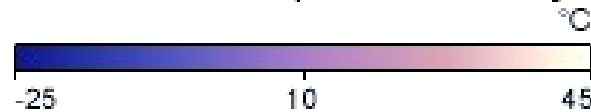
- Moderate Resolution Imaging Spectroradiometer (MODIS)
- Two satellites onboard: Terra and Aqua (10:30 am and 1:30 pm equator overpass).
- Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days.
- MODIS instrument provides data in 36 spectral bands
- Spatial resolution of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



Land Surface Temperature(MODIS)



Land Surface Temperature (daytime)

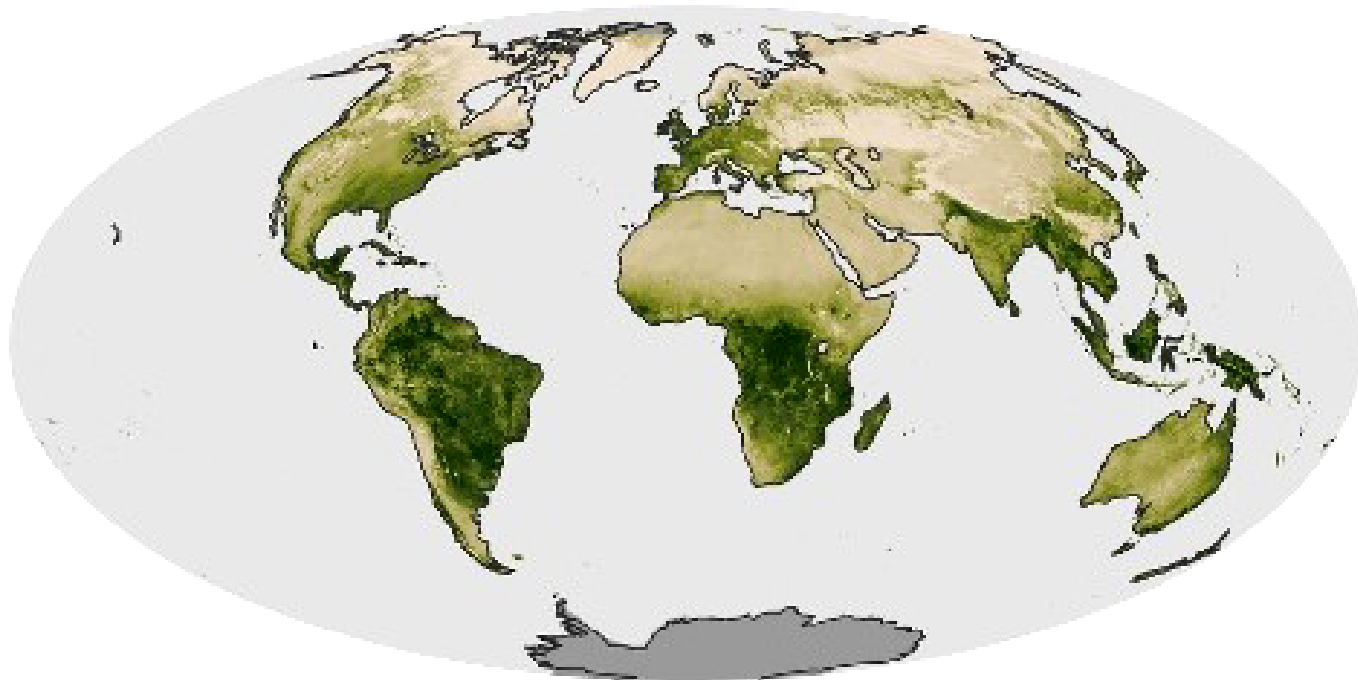


February 2000

www.earthobservatory.nasa.gov



Vegetation Index (MODIS)



Vegetation Index (NDVI)

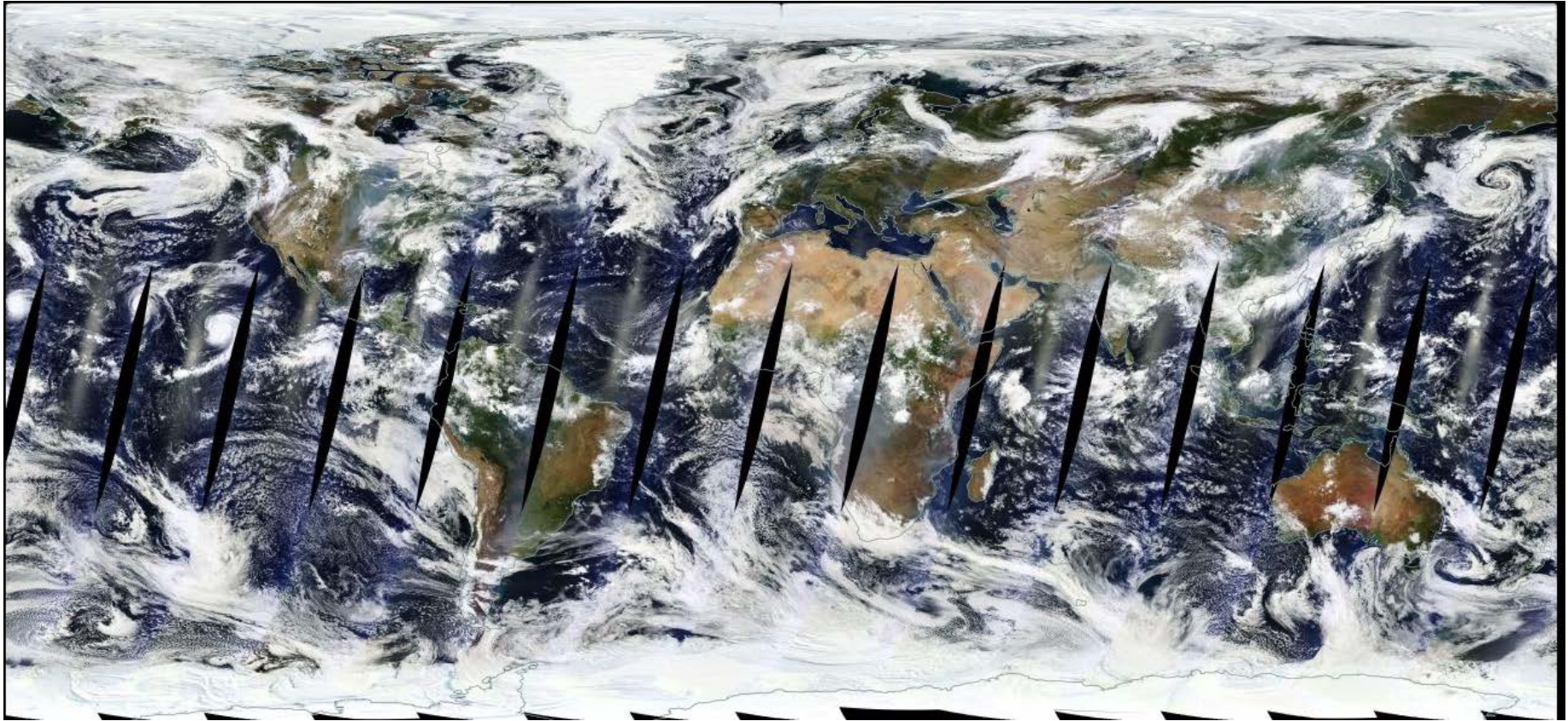


February 2000

www.earthobservatory.nasa.gov



MODIS (Terra Satellite) Aug 30, 2015



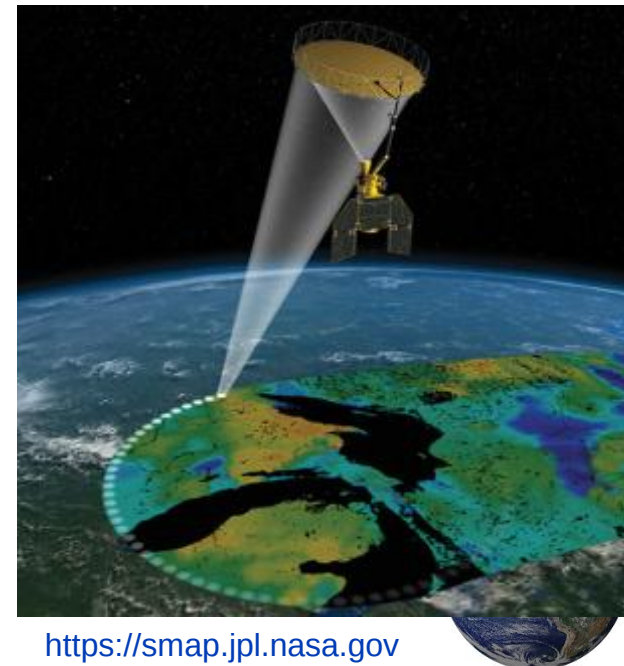
<https://earthdata.nasa.gov/labs/worldview/>



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**



SMAP

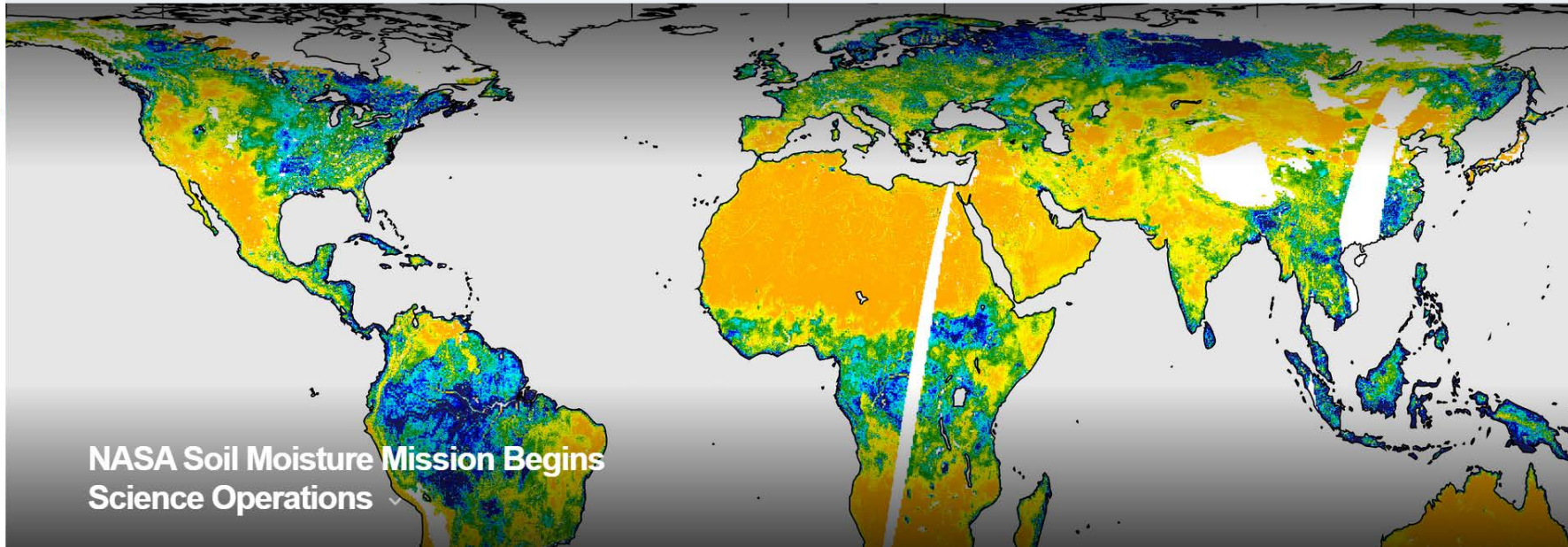


Jet Propulsion Laboratory
California Institute of Technology

SMAP SOIL MOISTURE
ACTIVE PASSIVE



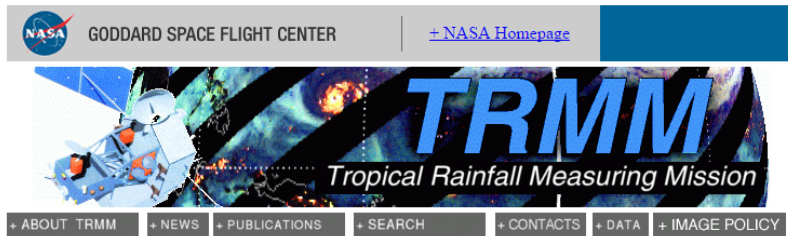
[Mission](#) [Observatory](#) [Science](#) [Data](#) [Multimedia](#) [Education](#) [News & Events](#)



NASA Soil Moisture Mission Begins
Science Operations

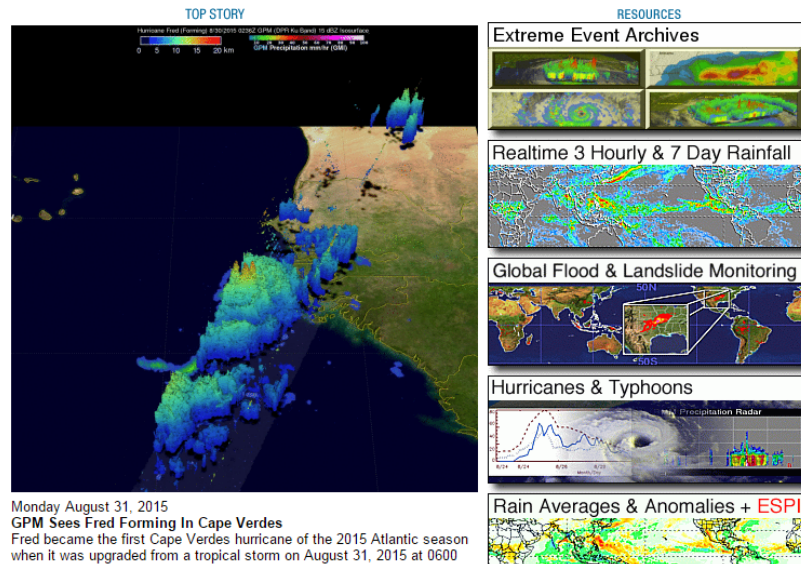


TRMM



The Tropical Rainfall Measuring Mission (TRMM), a joint mission between NASA and the Japan Aerospace Exploration Agency (JAXA) to study rainfall for weather and climate research, officially came to an end on April 15, 2015 (see <http://pmm.nasa.gov/trmm/mission-end>). Launched in November 1997, with a design lifetime of 3 years, TRMM produced over 17 years of valuable scientific data. TRMM carried 5 instruments: a 3-sensor rainfall suite (PR, TMI, VIRS) and 2 related instruments (LIS and CERES). TRMM delivered a unique 17-year dataset of global tropical rainfall and lightning. The TRMM dataset became the space standard for measuring precipitation, and led to research that improved our understanding of tropical cyclone structure and evolution, convective system properties, lightning-storm relationships, climate and weather modeling, and human impacts on rainfall. The data also supported operational applications such as flood and drought monitoring and weather forecasting.

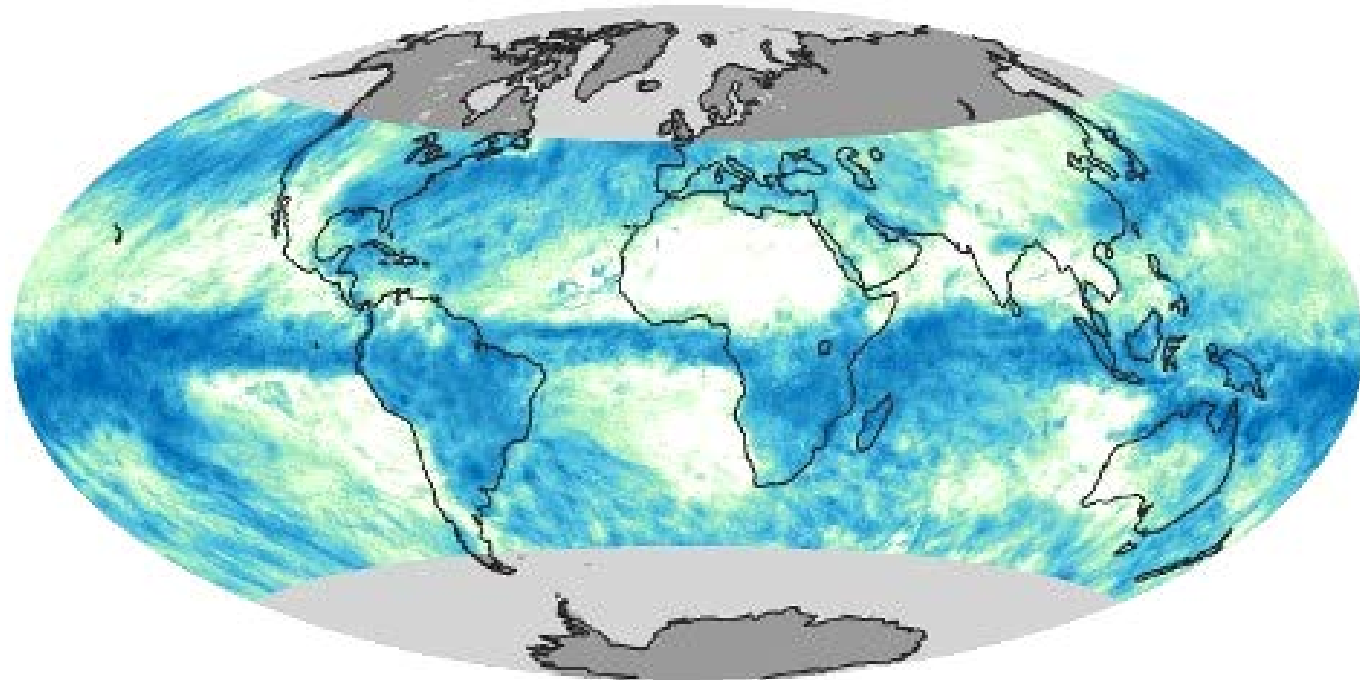
[TRMM Reentry Assessment \(pdf file\)](#)
[\(6/3/2015\) Frequently Asked Questions about TRMM Spacecraft Re-Entry](#)



- 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)



Total Rainfall

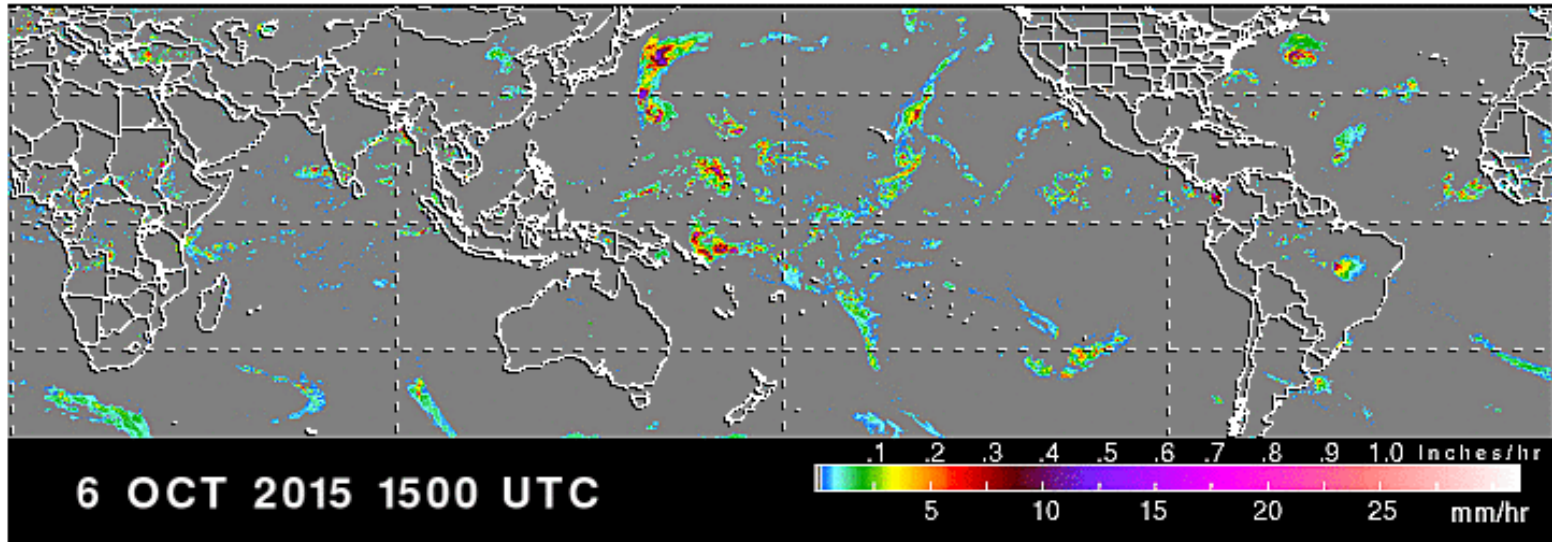


January 1998

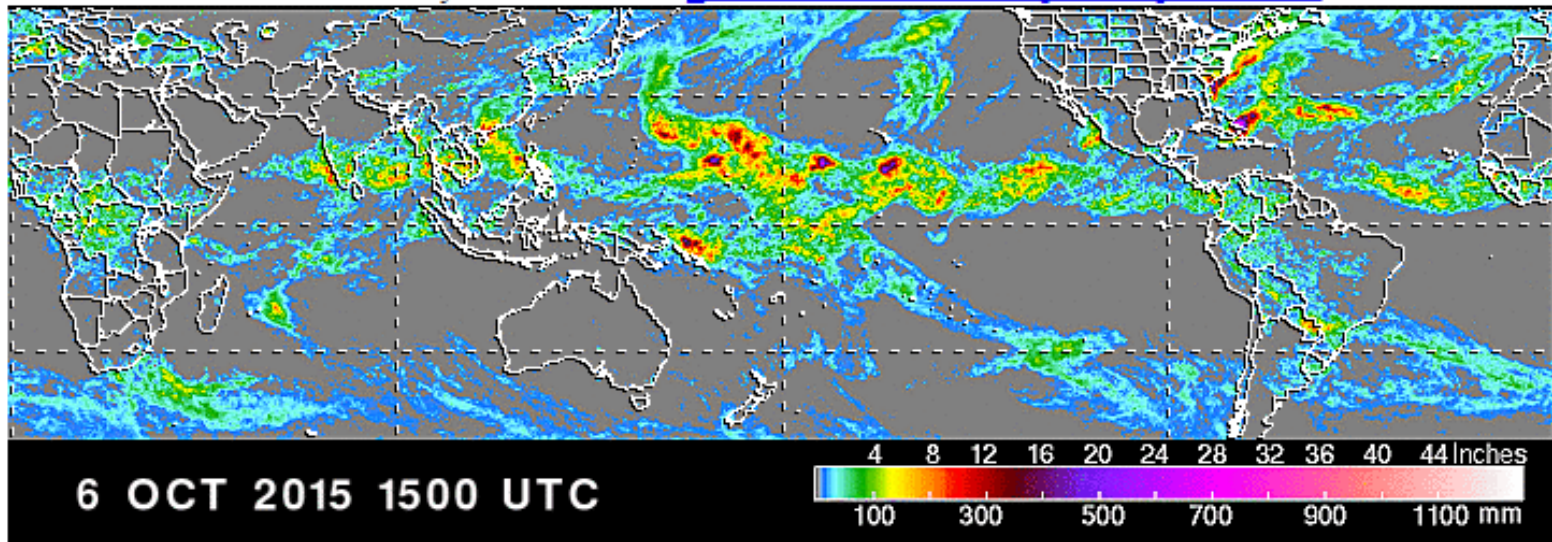
www.earthobservatory.nasa.gov



Global Rainfall Oct 6, 2015



Latest 3 Hourly Global Rainfall [Click to See a Medium \[1.7 MB\] Animation](#)

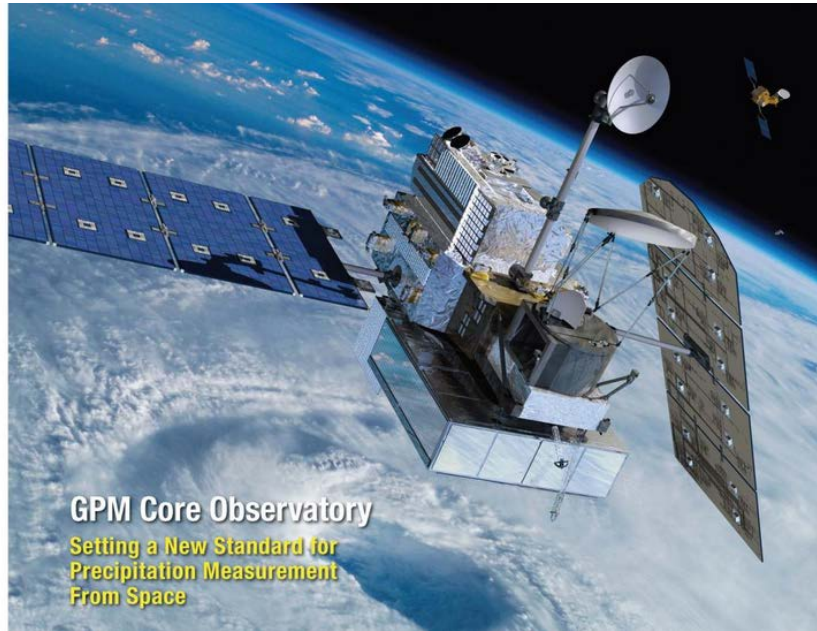


Latest Week of Global Rainfall Accumulation [Click to See a Medium \[1.7 MB\] Animation](#)

<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

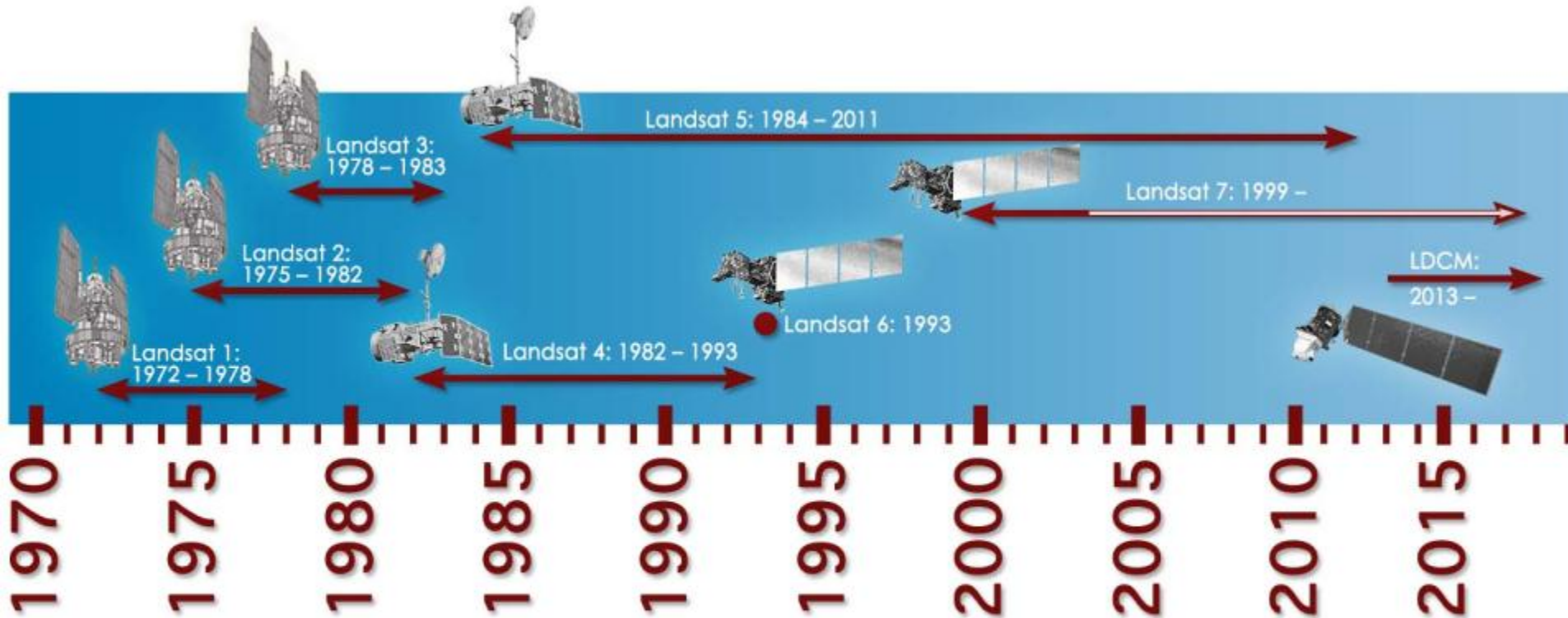


GPM Advancement of TRMM

- 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



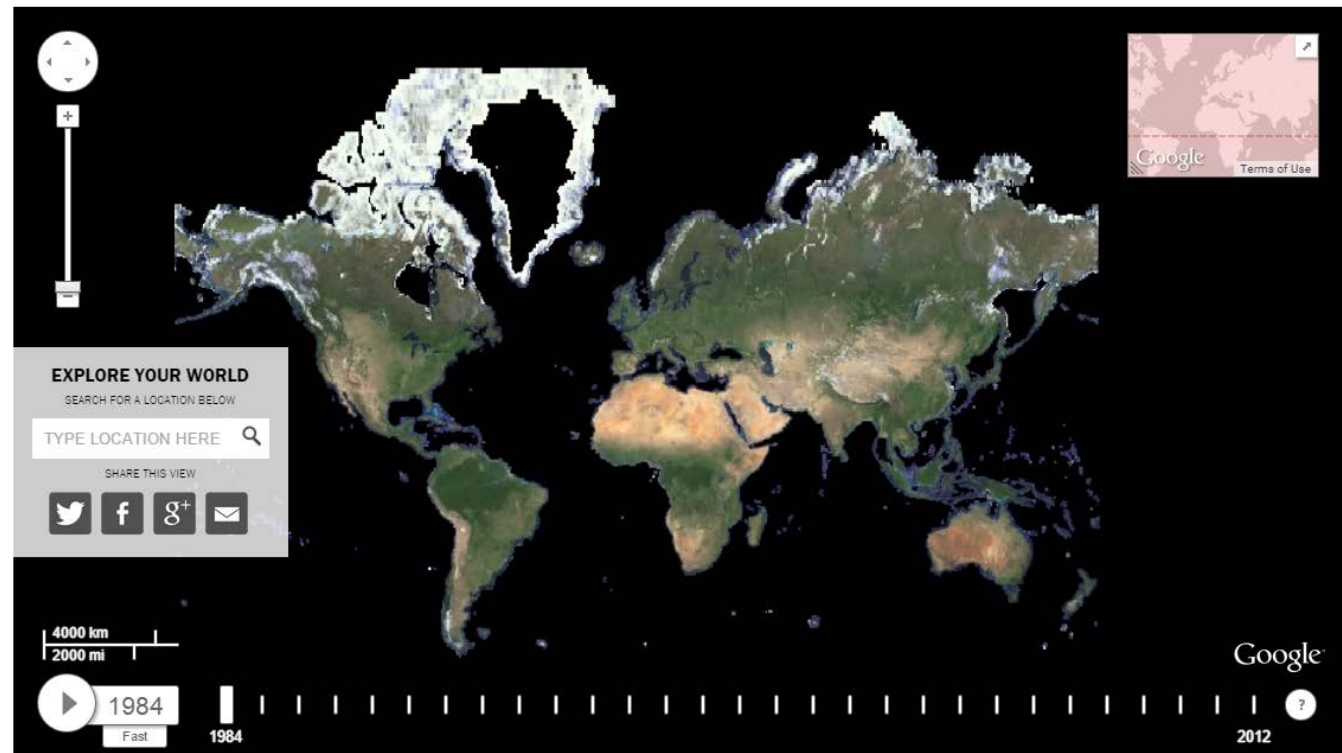
<http://landsat.usgs.gov>

Four decades of monitoring the Earth!

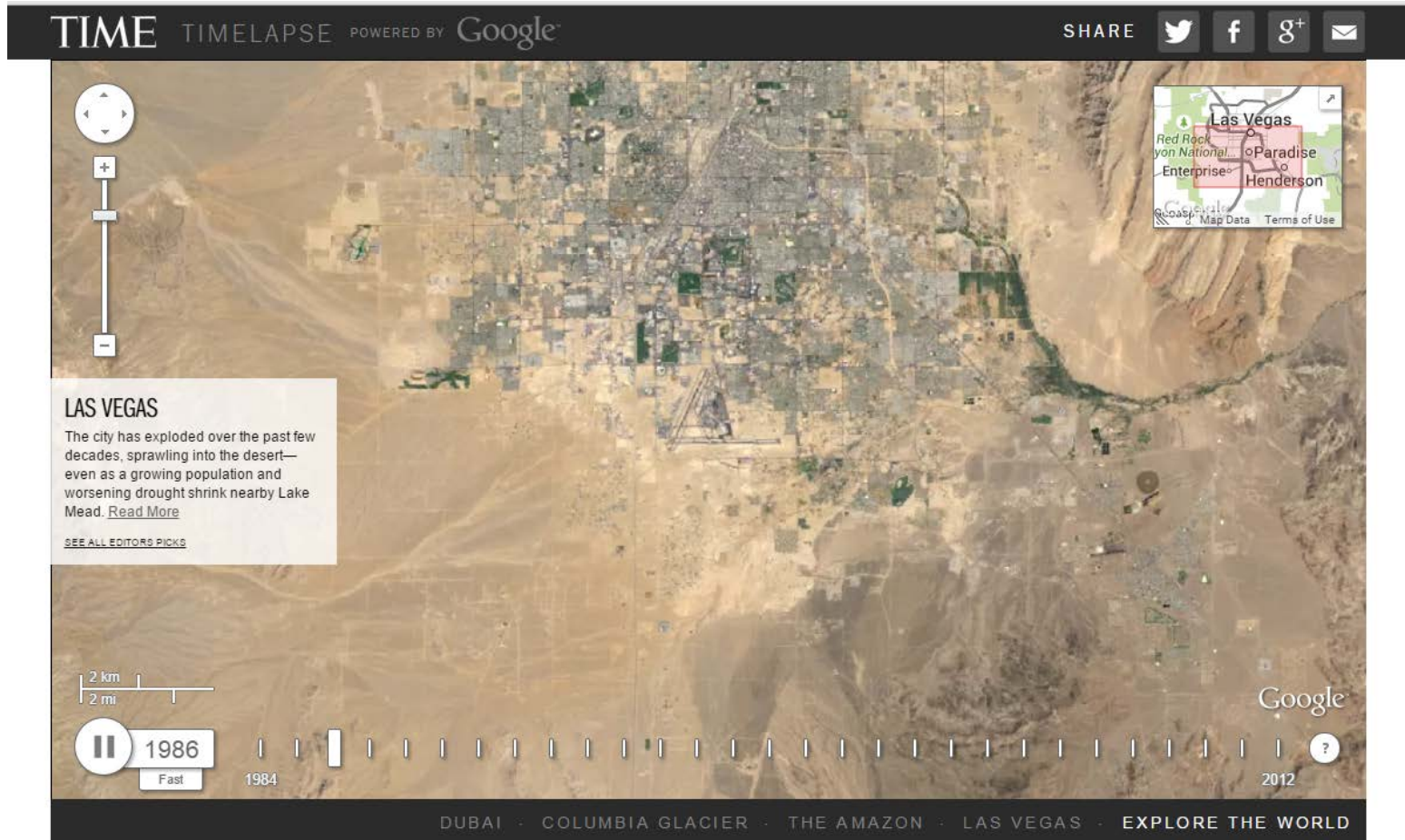


Timelapse

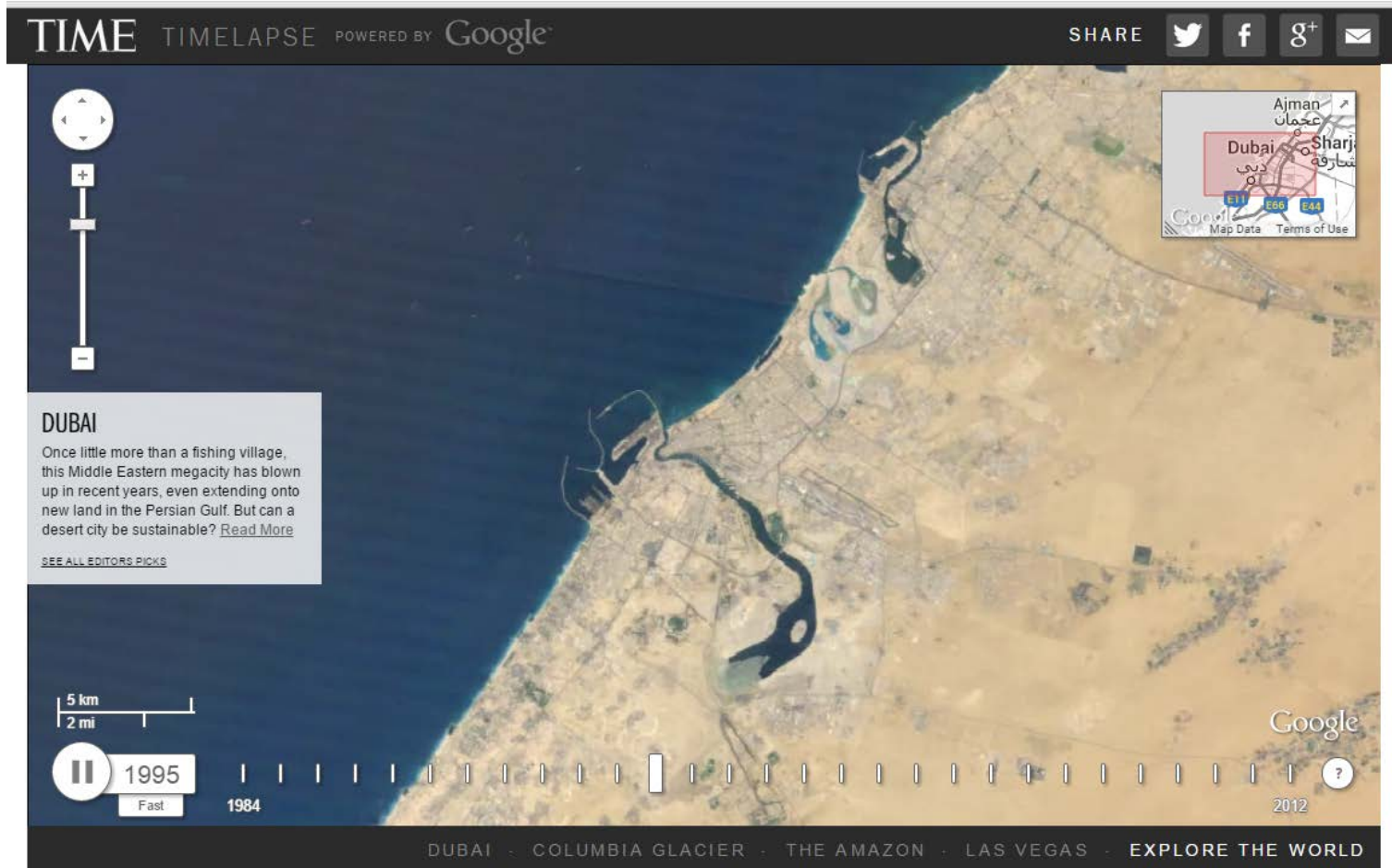
- Timelapse is powered by Google.
- It uses global scale historical archives of Landsat satellite imagery from 1984-2012 to monitor change on the planet.



Las Vegas



Dubai



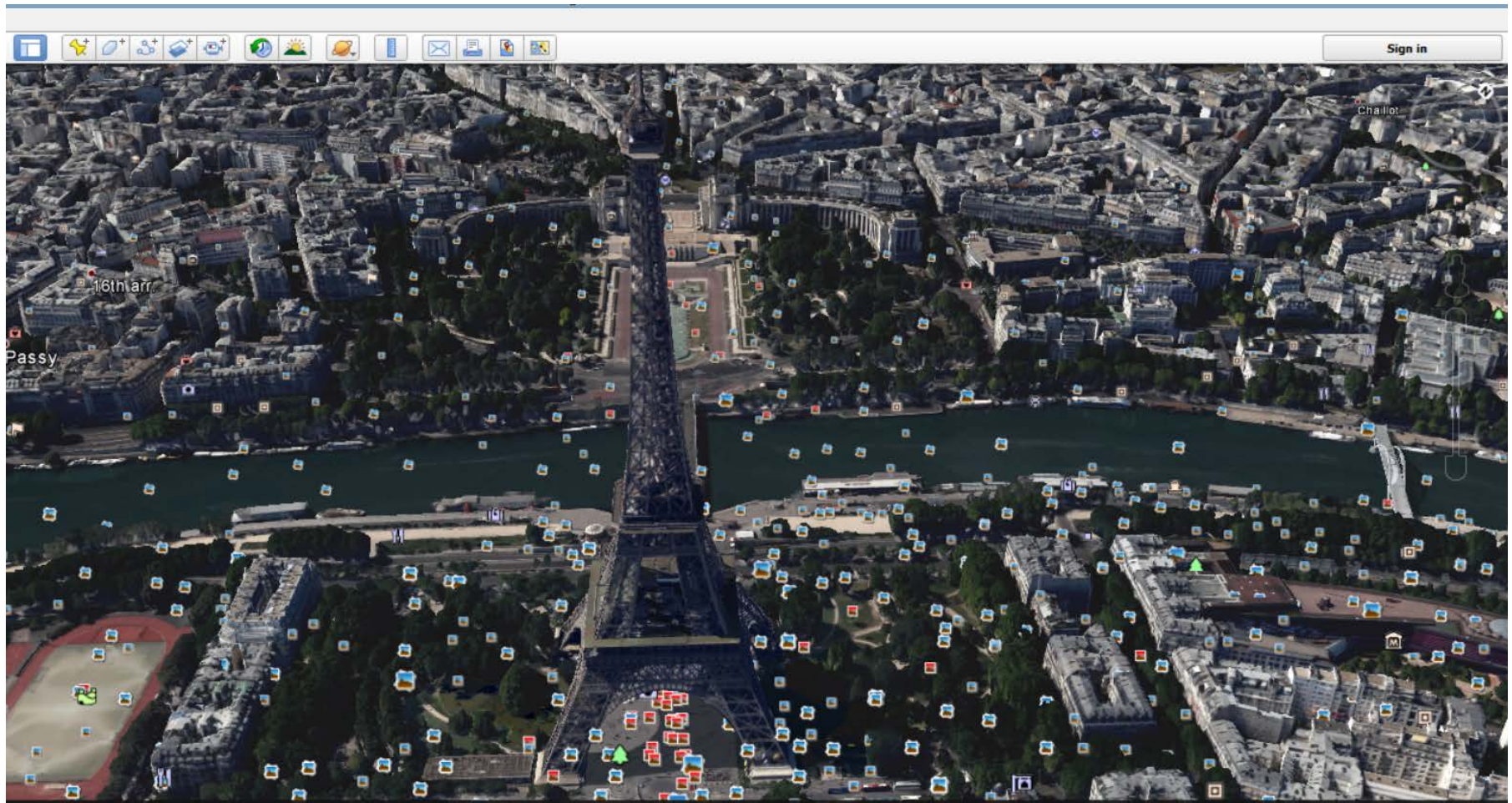
SkyBox SkySat 1 and 2 Satellites



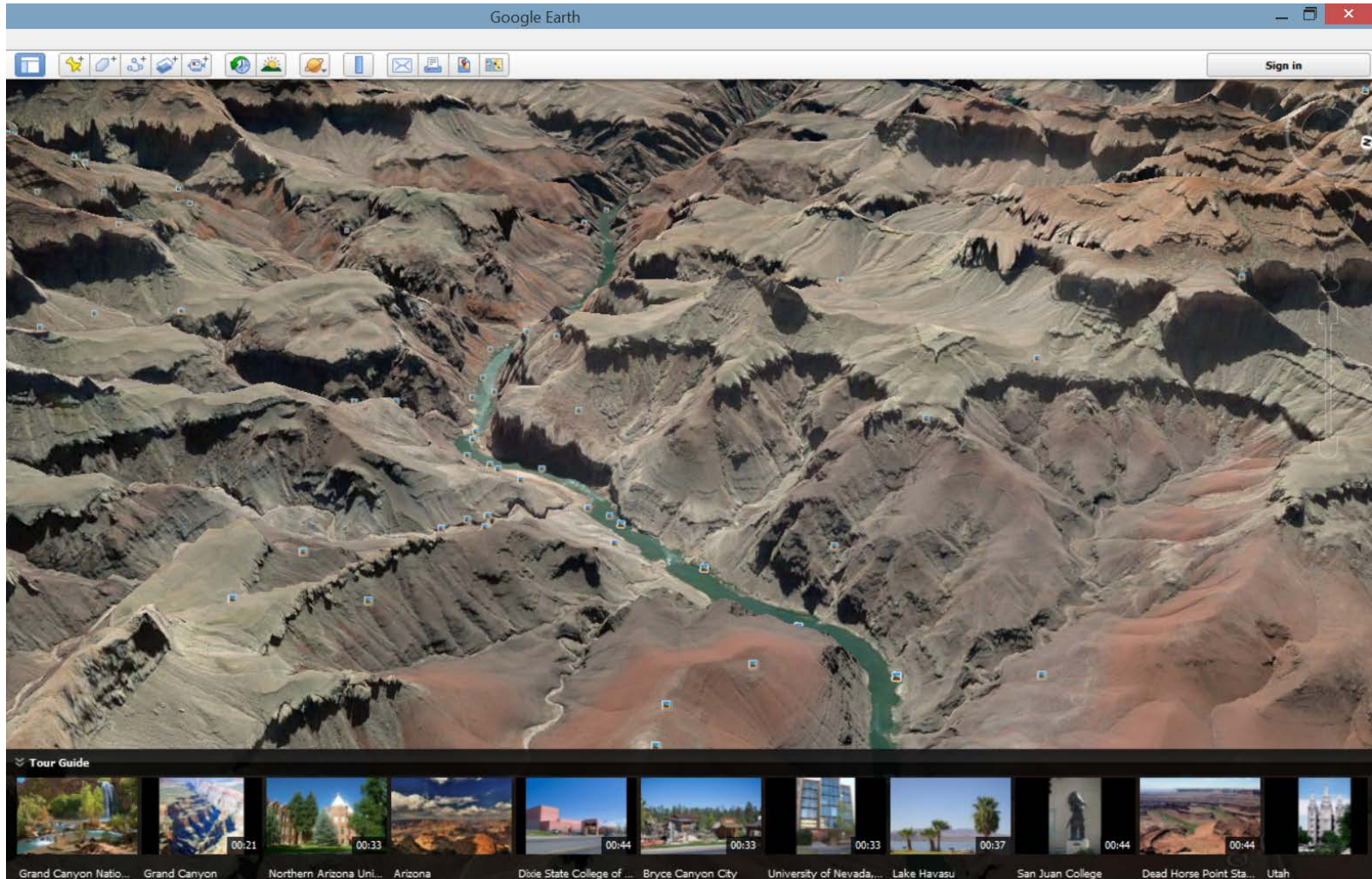
- Panchromatic GSD 90 cm at nadir
- Multispectral GSD 2 m at nadir
- Swath Width 8 km at nadir



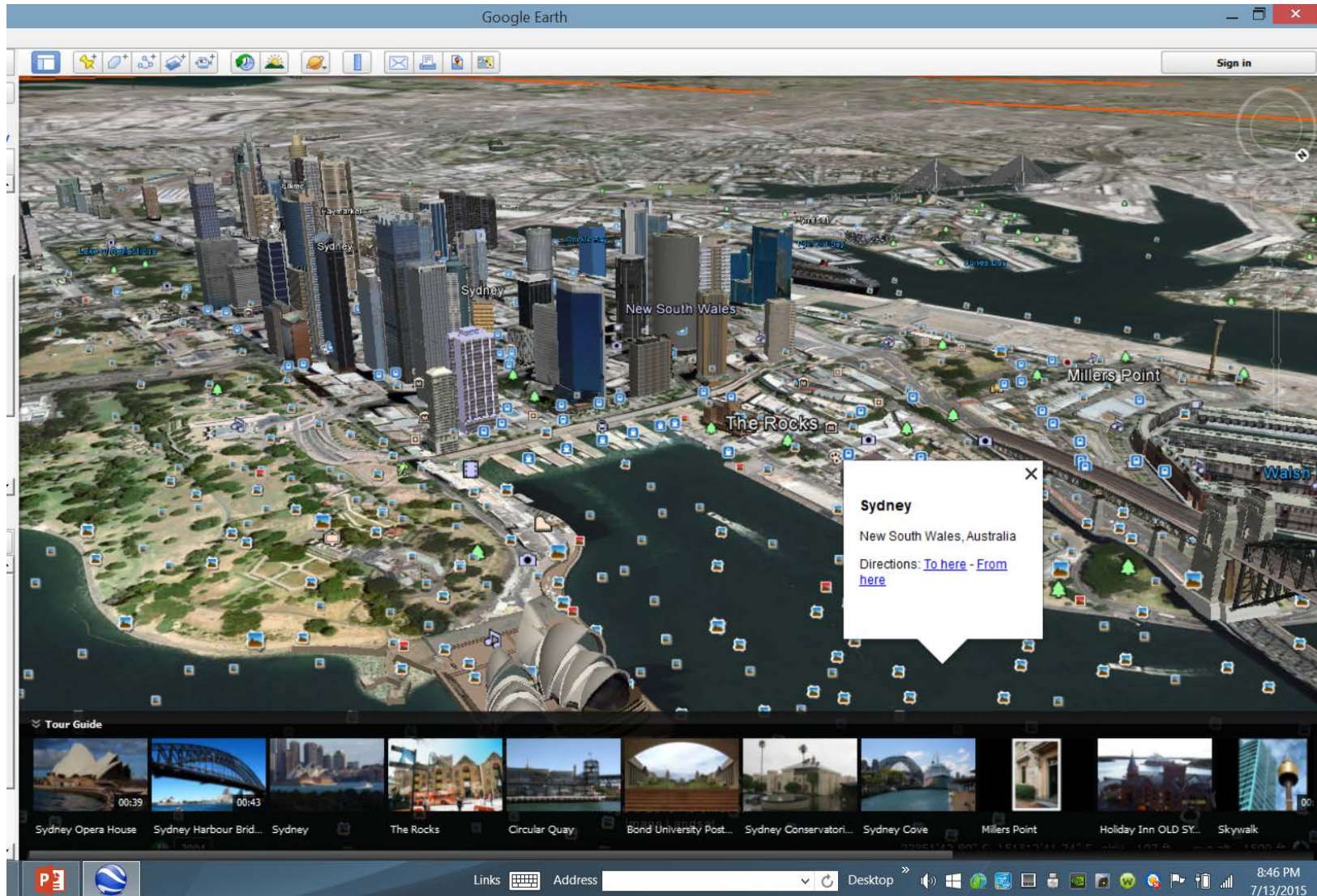
Google Earth: Paris



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>

The screenshot displays the Google Earth Engine workspace. The top navigation bar includes the Google Earth Engine logo, a search bar, and links for 'Send feedback' and 'alenaychu79@gmail.com'. The main area shows a world map with a focus on North America. The left sidebar contains the 'Earth Engine' logo, a search bar, and a 'Data' section with 'Add data' and 'Add computation' buttons. Below this is an 'Analysis' dropdown menu set to 'None'. The 'Data Catalog' section lists various datasets under 'Popular Tags' and 'Surface reflectance'. The '8-day mosaics' section lists datasets like 'MYD09Q1 Surface Reflectance 8-Day L3 Global 250m' and 'Landsat 8 8-Day Raw Composite'. The bottom of the interface shows a task list with items like 'Daac2Disk_v4...ppt', '10+Access+Tal...pdf', '11+Use+Cases...pdf', '20+Access+Tal...pdf', and '21+Use+Cases...pdf', along with a 'Show all downloads...' link.

Google Earth Engine

Search Places, Keywords, Tables, or Asset IDs...

Earth Engine

Manage workspace

Data

Add data Add computation

Analysis: None

Home Data Catalog Workspace

Map Satellite

Popular Tags

daily 8-day 32-day

surface_reflectance radiance toa

mc04394 usgs srtm

Contribute to Earth Engine

We are continually adding new datasets and updating existing datasets with new data as it becomes available.

Would you like to contribute data to the Earth Engine catalog? Contact our data team.

Surface reflectance

MYD09Q1 Surface Reflectance 8-Day L3 Global 250m - open in workspace

USGS LPDAAC - Every 8 days from 2002 to 2015

The MODIS Surface Reflectance products provide an estimate of the surface spectral reflectance as it would be measured at ground level in the absence of atmosphere.

MOD09A1 Surface Reflectance 8-Day Global 500m - open in workspace

USGS LPDAAC - Every 8 days from 2000 to 2015

The MODIS Surface Reflectance products provide an estimate of the surface spectral reflectance as it would be measured at ground level in the absence of atmosphere.

MOD09Q1 Surface Reflectance Daily L2G Global 250m - open in workspace

USGS LPDAAC - Every day from 2000 to 2015

The MODIS Surface Reflectance products provide an estimate of the surface spectral reflectance as it would be measured at ground level in the absence of atmosphere.

More surface reflectance data

8-day mosaics

MYD09Q1 Surface Reflectance 8-Day L3 Global 250m - open in workspace

USGS LPDAAC - Every 8 days from 2002 to 2015

The MODIS Surface Reflectance products provide an estimate of the surface spectral reflectance as it would be measured at ground level in the absence of atmosphere.

Landsat 8 8-Day Raw Composite - open in workspace

USGS - Every 8 days from 2013 to 2015

These Landsat 8 composites are made from Level 1T1 orthorectified scenes, using the DN values, representing scaled, calibrated at-sensor radiance. These are...

MOD09Q1 Surface Reflectance 8-Day Global 250m - open in workspace

USGS LPDAAC - Every 8 days from 2000 to 2015

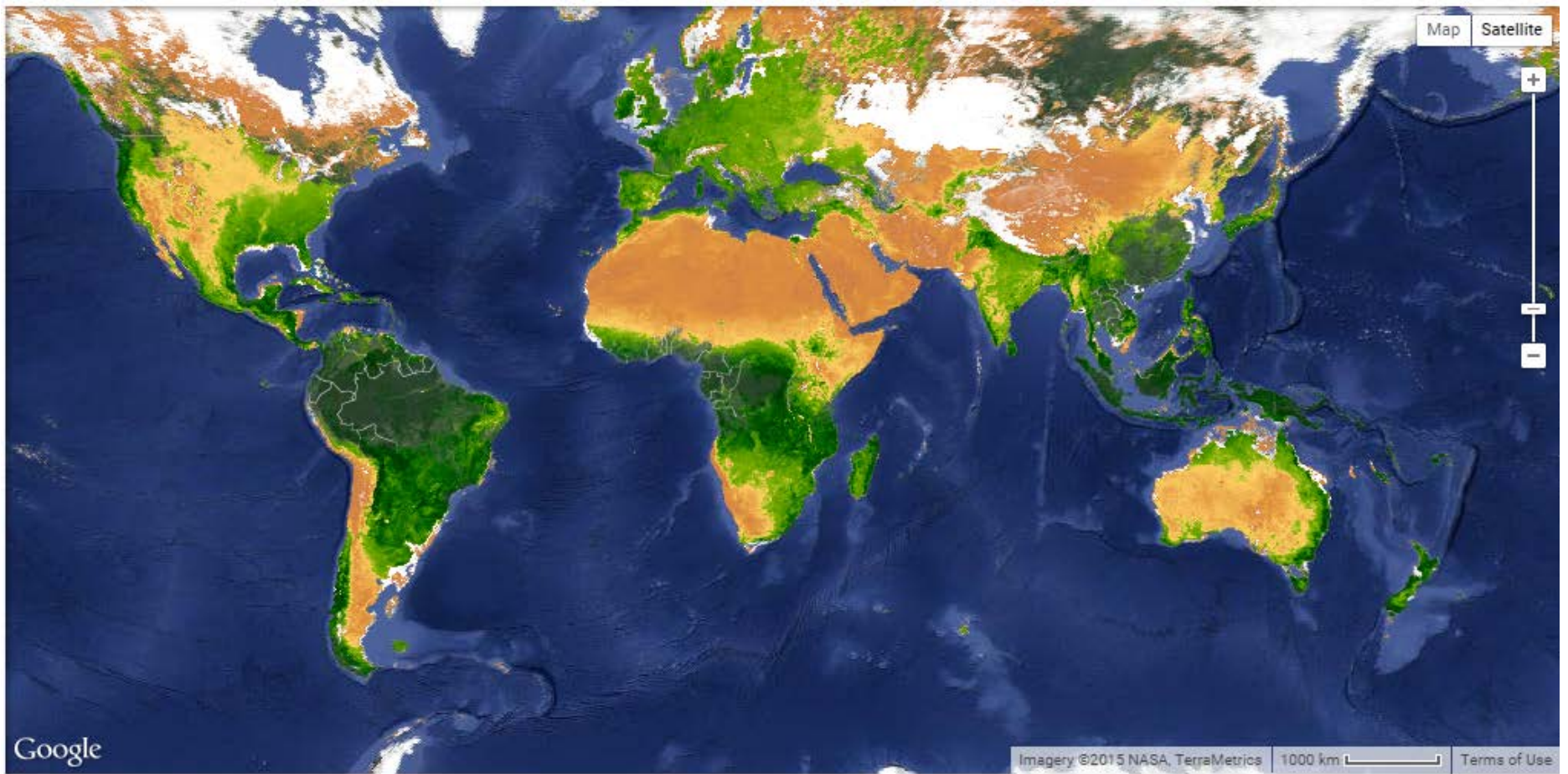
The MODIS Surface Reflectance products provide an estimate of the surface spectral reflectance as it would be measured at ground level in the absence of atmosphere.

More 8-day mosaics

Map data ©2015 Google, INEGI 1000 km Terms of Use

Daac2Disk_v4...ppt 10+Access+Tal...pdf 11+Use+Cases...pdf 20+Access+Tal...pdf 21+Use+Cases...pdf Show all downloads...





MODIS Normalized Difference Vegetation Index (March 2015)



Earthexplorer

<http://earthexplorer.usgs.gov/>

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earthexplorer.usgs.gov

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EarthExplorer

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Page Expires In 1:56:04 C

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Search Criteria Data Sets Additional Criteria Results

2. Select Your Data Set(s)
Check the boxes for the data set(s) you want to search. When done selecting data set(s), click the *Additional Criteria* or *Results* buttons below. Click the plus sign next to the category name to show a list of data sets.

☐ Use Data Set Prefilter (What's This?)

Data Set Search:

- Declassified Data
- Digital Elevation
- Digital Line Graphs
- Digital Maps
- EO-1
- GEOGLAM
- Global Fiducials
- Global Forest Observations Initiative
- Global Land Survey
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Clear Criteria

62° 05' 40" N, 091° 35' 50" W Options Overlays Map Satellite

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The USGS Global Visualization Viewer (GloVis)

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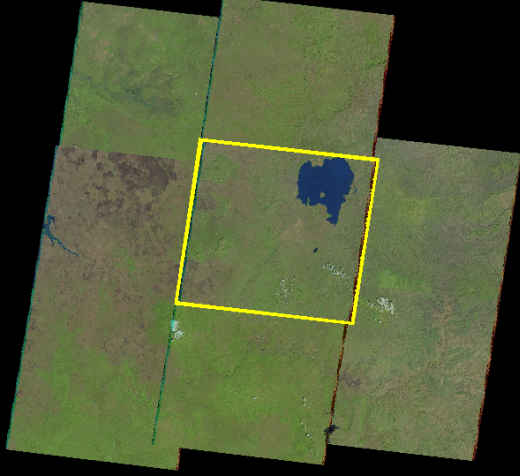
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LP DAAC

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Data Pool

Data Pool

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Available datasets include:

- All MODIS data holdings
- ASTER Level - 1T data for the U.S. and Territories
- ASTER Level - 1B data for the U.S. and Territories
- ASTER Level - 1A and Level - 1B Expedited data
- All WELD data holdings
- All NASA SRTM V3.0 data holdings
- All ASTER GED data holdings

Direct HTTP Access

LP DAAC2Disk Download Manager

Direct access to data directories for immediate HTTP retrieval is available

ASTER

MODIS AQUA

MODIS TERRA

MODIS COMBINED

WELD

SRTM

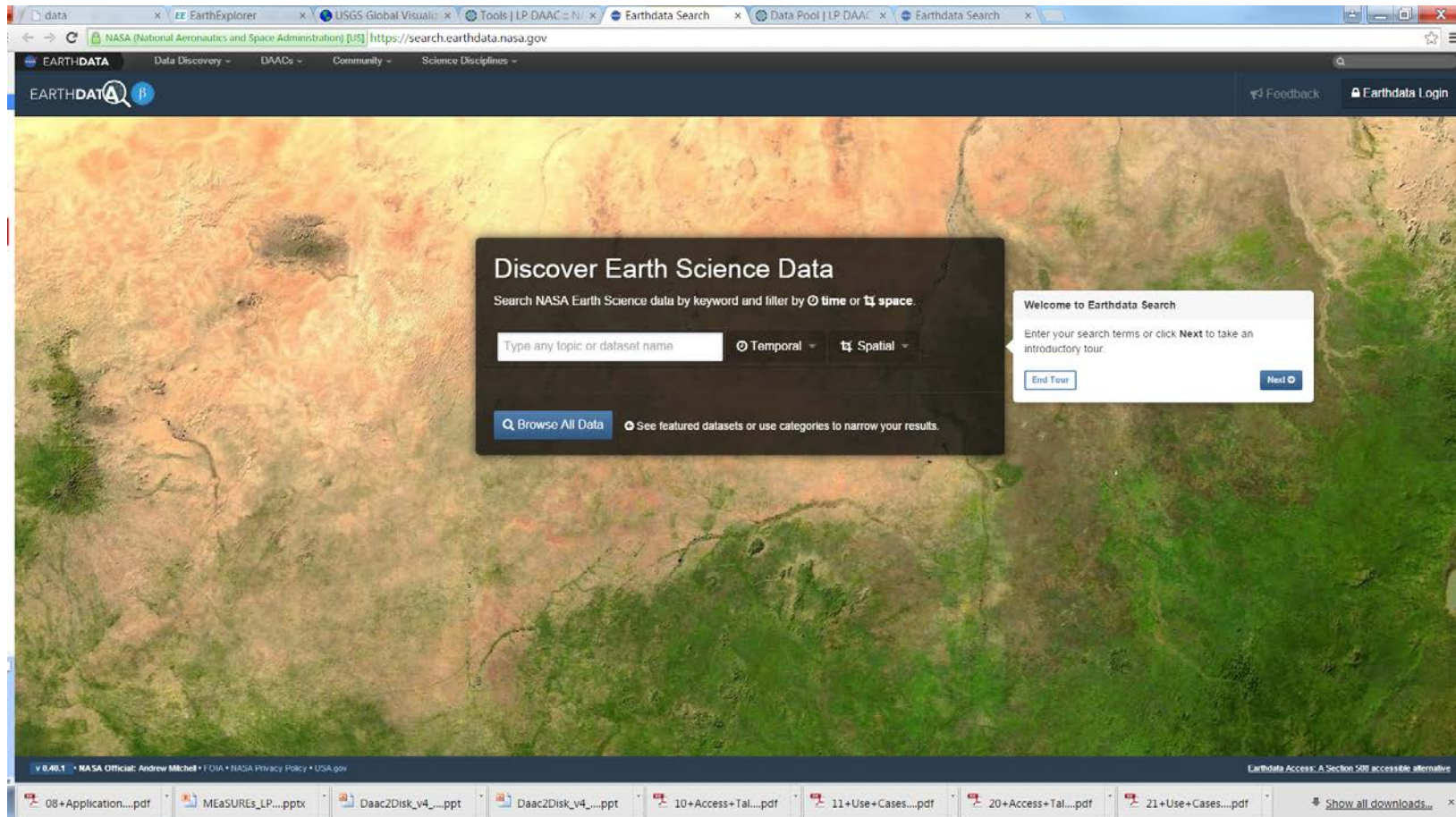
Please note weekly maintenance is every Wednesday 0800-1200 Central Time.

ftp Access

Name	Last modified	Size	Description
 Parent Directory		-	
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 SRTMGL1N.003/	09-Oct-2014 13:20	-	
 SRTMGL3.003/	20-Nov-2013 14:56	-	
 SRTMGL30.002/	20-Nov-2013 12:43	-	
 SRTMGL3N.003/	20-Nov-2013 16:14	-	
 SRTMGL3S.003/	21-Nov-2013 07:54	-	
 SRTMIMGH.003/	03-Apr-2015 12:16	-	
 SRTMIMGR.003/	01-Mar-2015 09:51	-	
 SRTMSWBD.003/	20-Nov-2013 13:01	-	

Earthdata

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

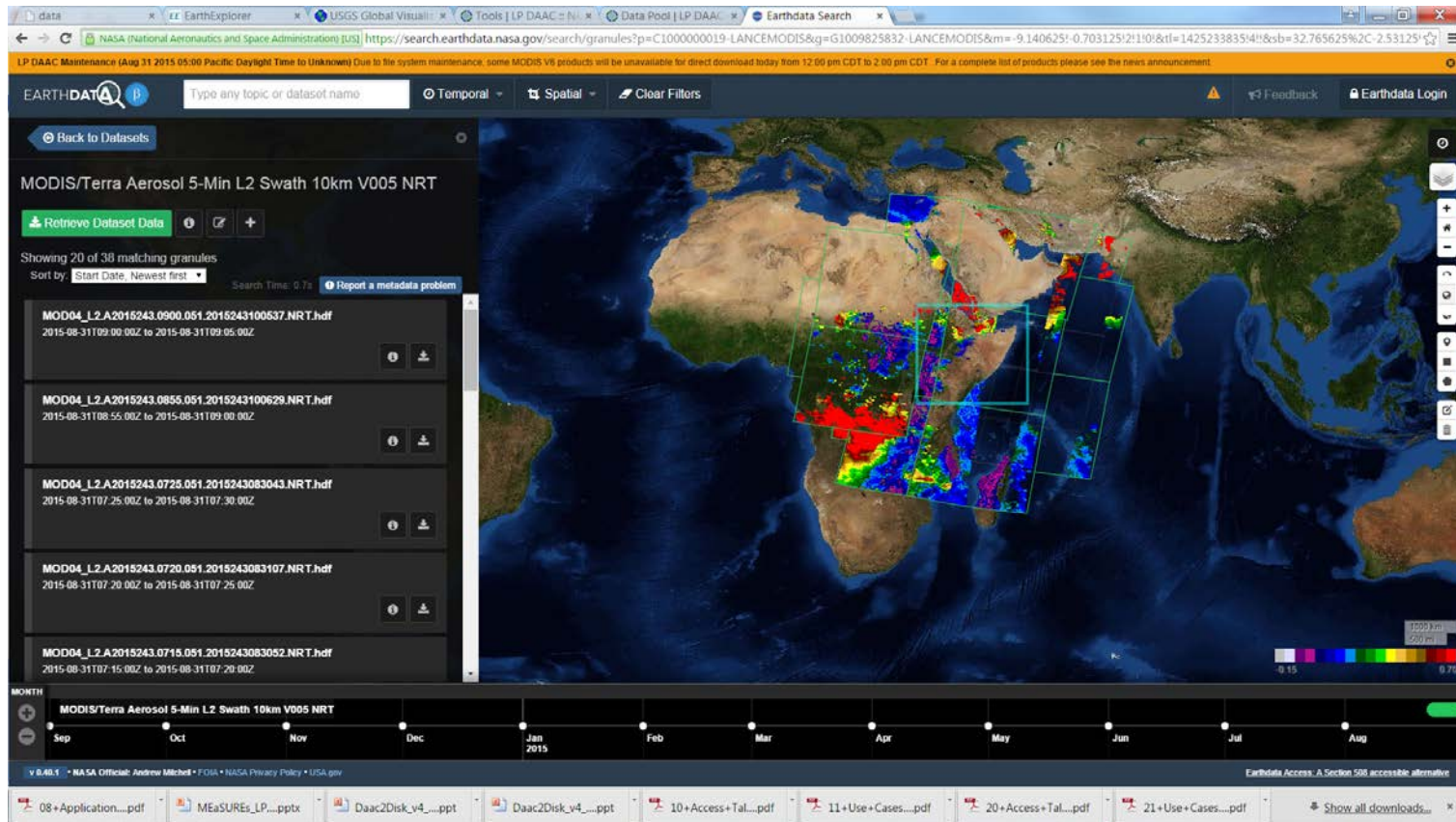


Earthdata offers discovering, searching, visualizing, and retrieving remote sensing.



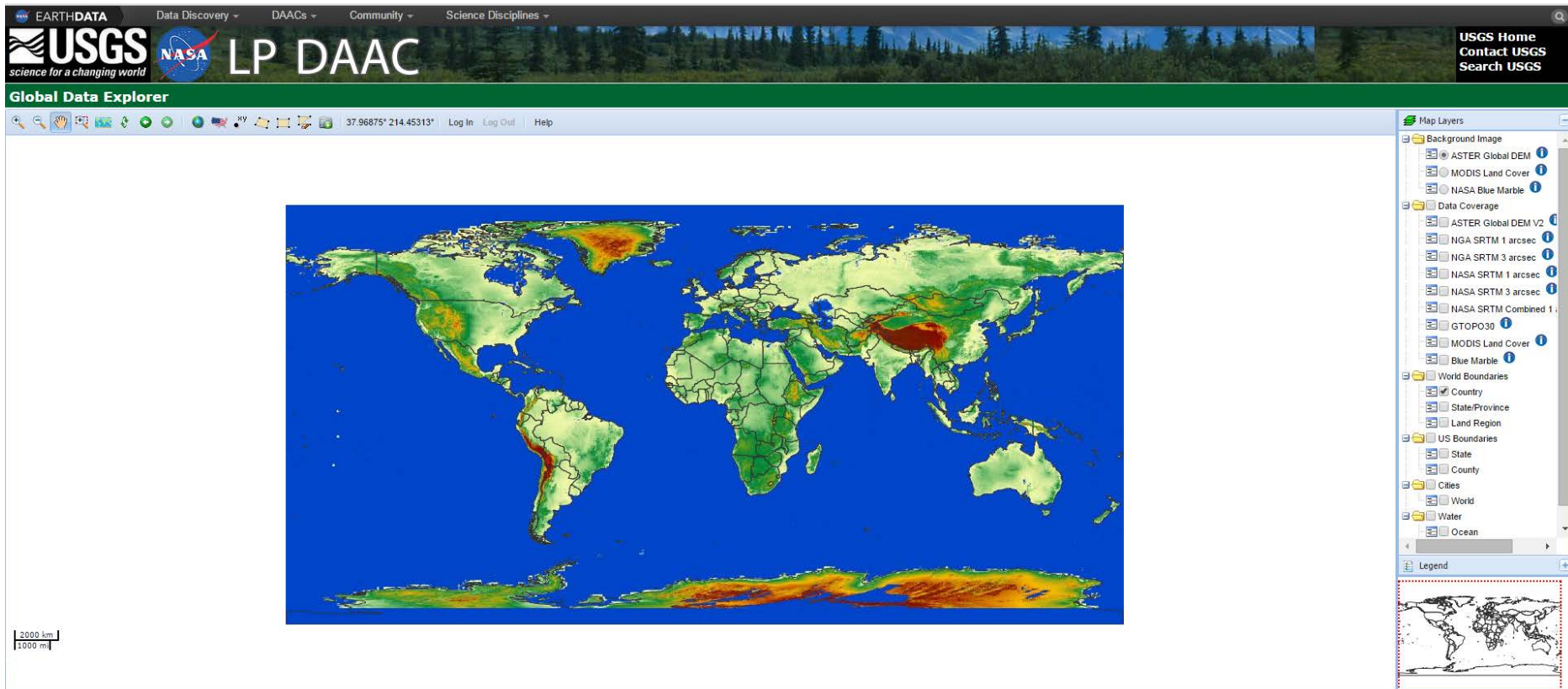
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GDEx

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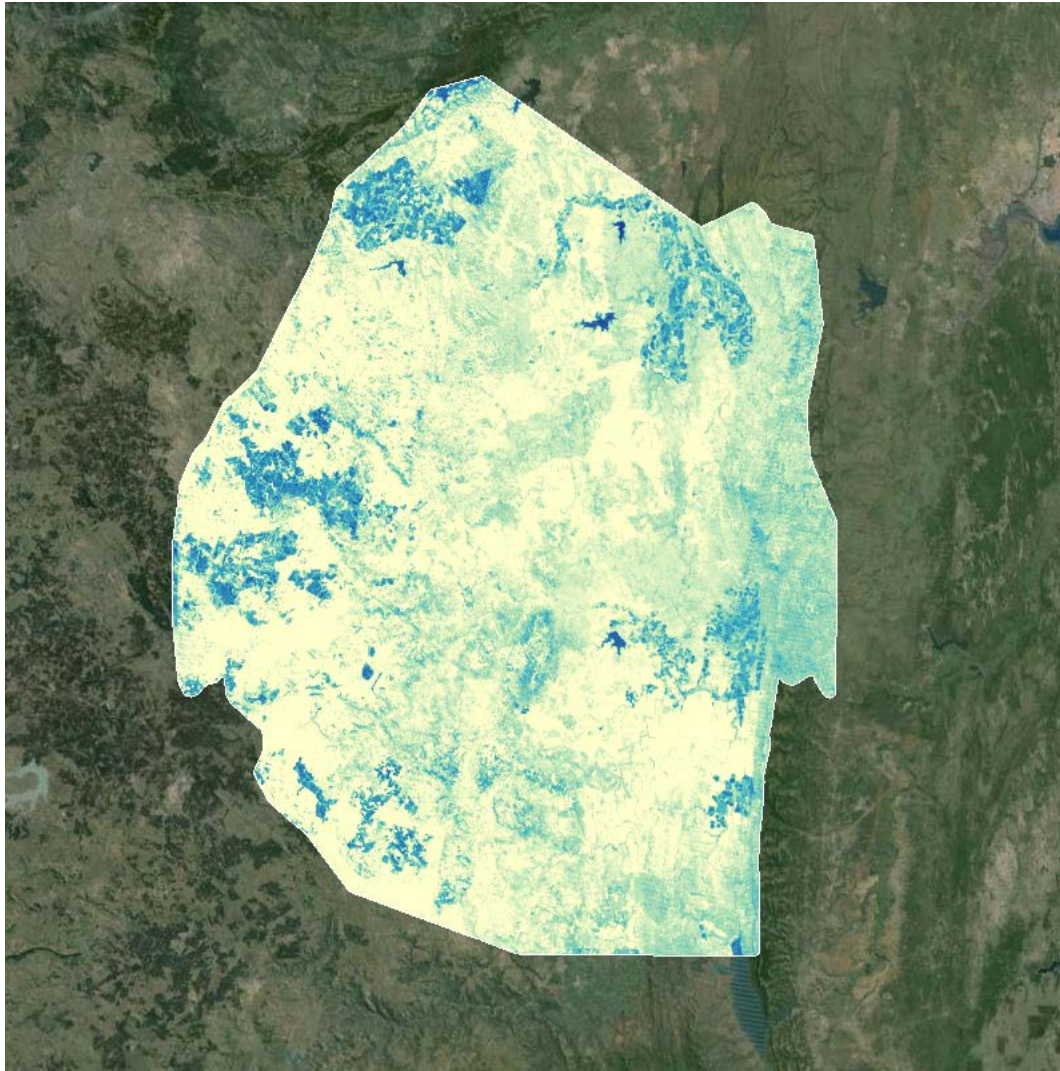


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Digital elevation model data for all users.
User-friendly geographic interface.



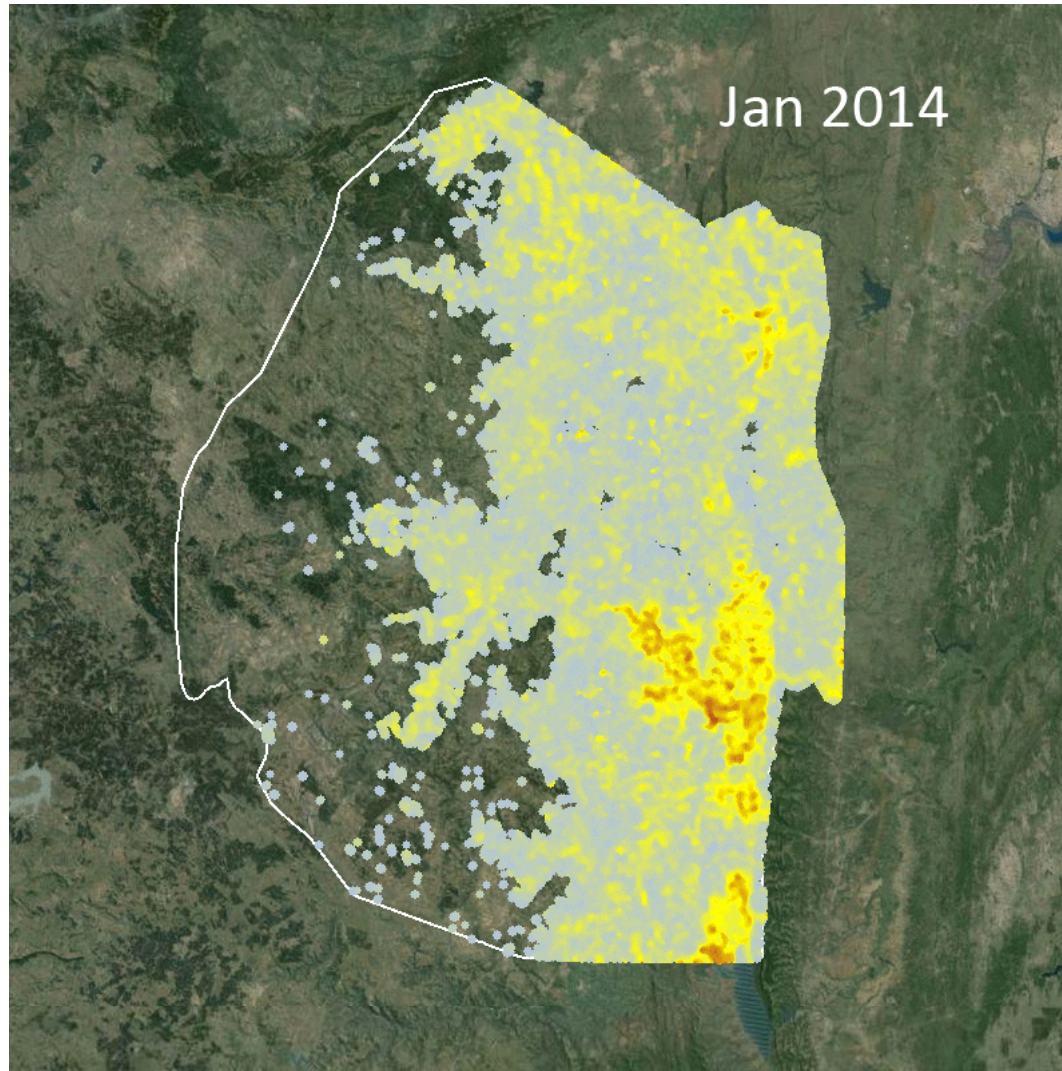
Remote Sensing Application in Public Health



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

A. Dry season

Parasite carriage in humans (low to high)



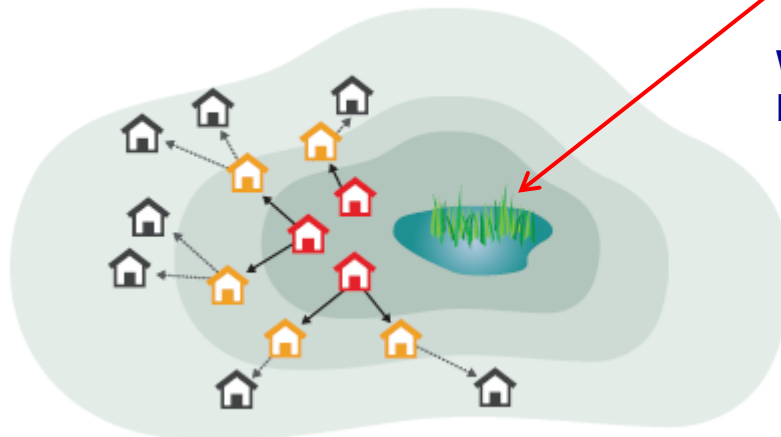
Mosquito exposure (low to high)



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

Wetlands

B. Wet season



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



Research Article

Multisensor earth observations to characterize wetlands and malaria epidemiology in Ethiopia

Alemayehu Midekisa¹, Gabriel Senay²
and Michael C Wimberly^{1,*}

DOI: 10.1002/2014WR015634

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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.)



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Abstract

Supporting Information

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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/FTM+ imagery respectively. The model that integrated data from both sensors yielded more accurate land cover

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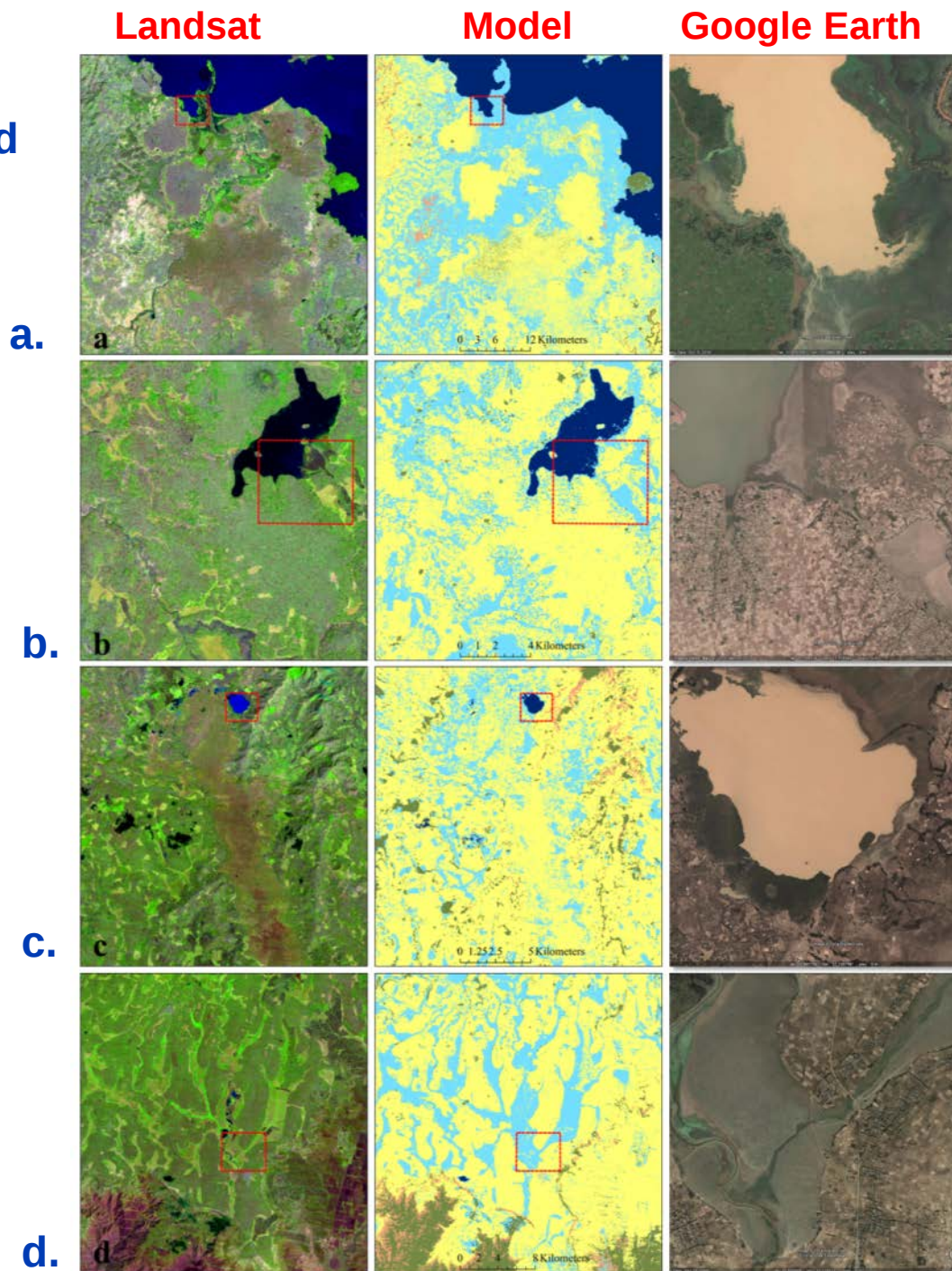
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Comparison of wetland classification with Landsat and Google Earth



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