Introduction to Remote Sensing

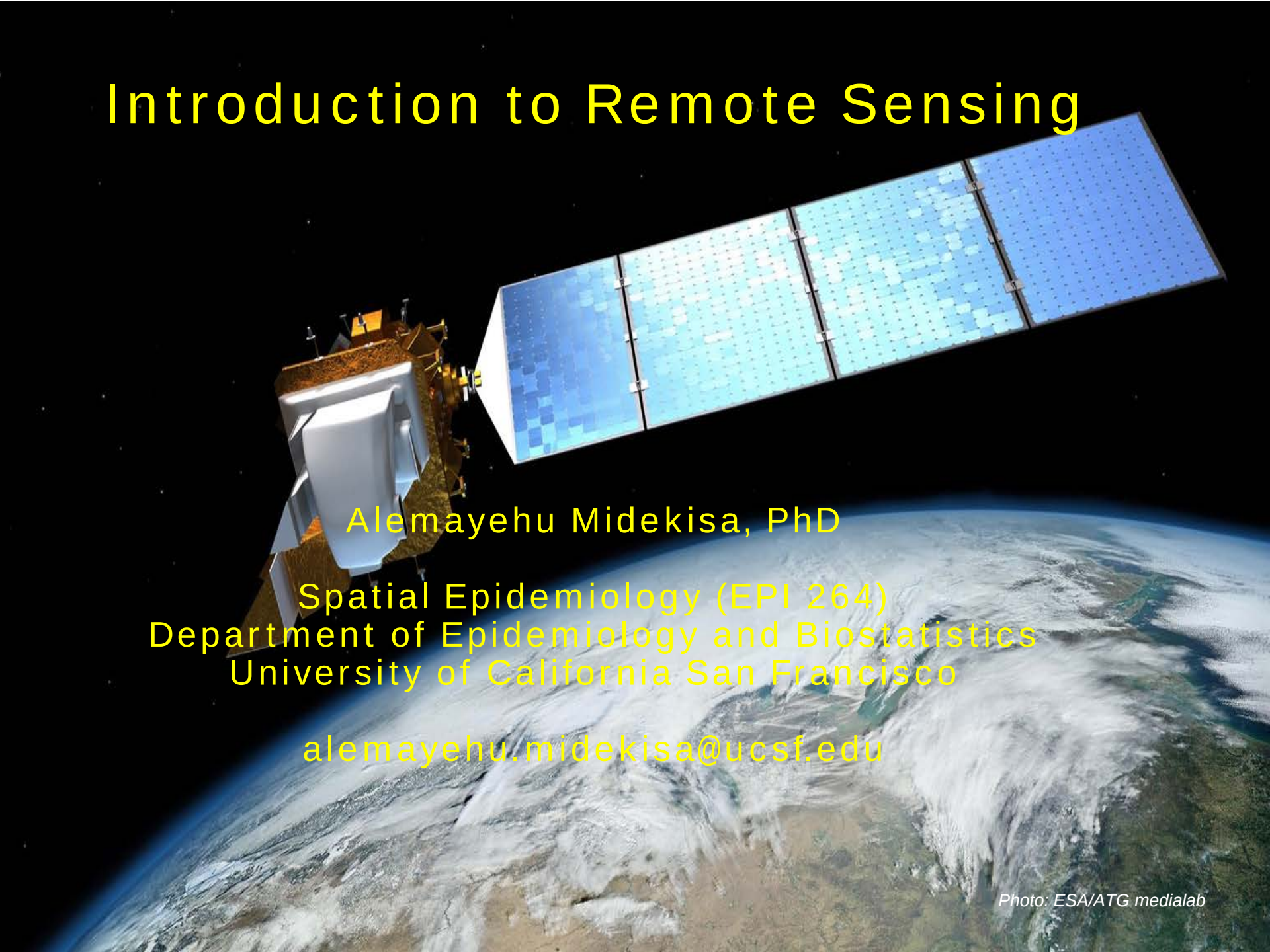

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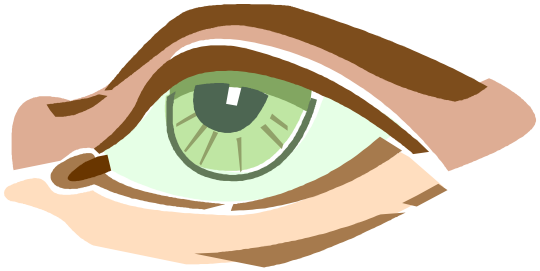
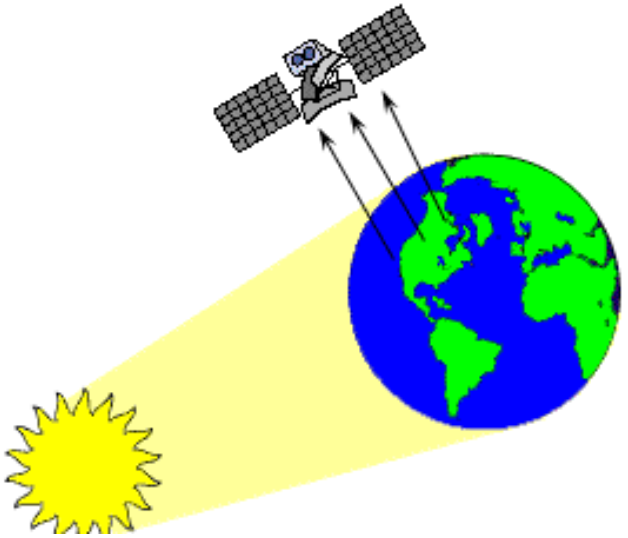
Photo: ESA/ATG medialab

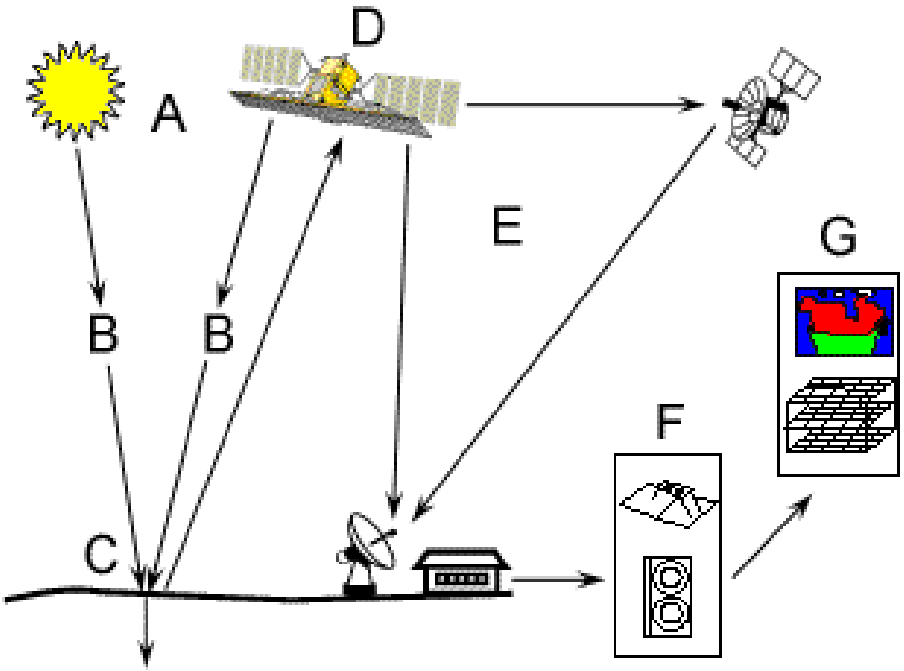
Background to Remote Sensing





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

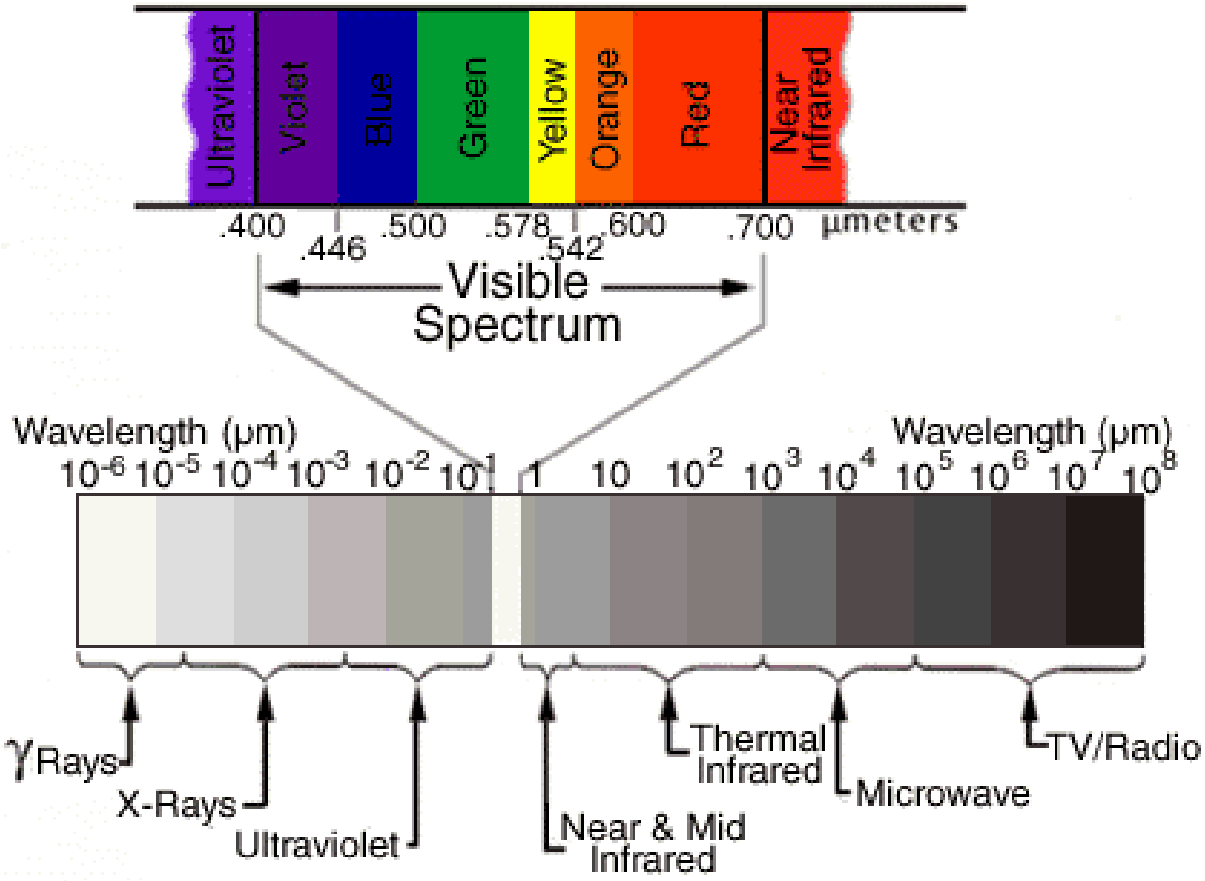
(D) Recording of Energy by the Sensor

(E) Transmission, Reception, and Processing

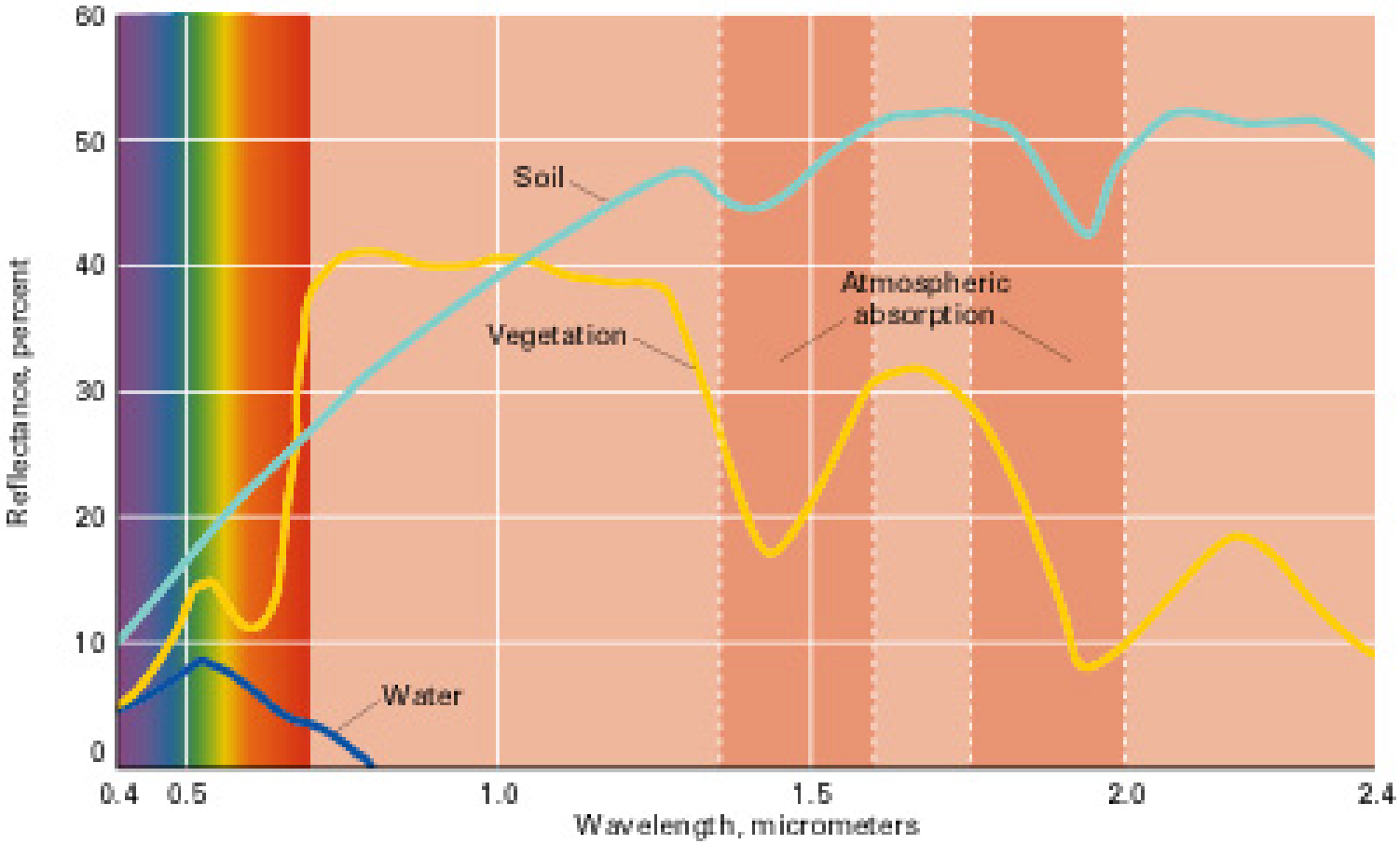
(F) Interpretation and Analysis

(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

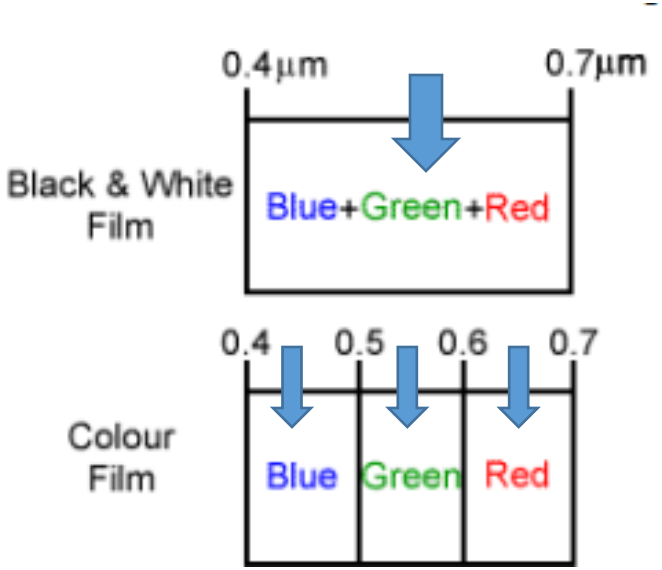
Temporal Resolution

- 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/

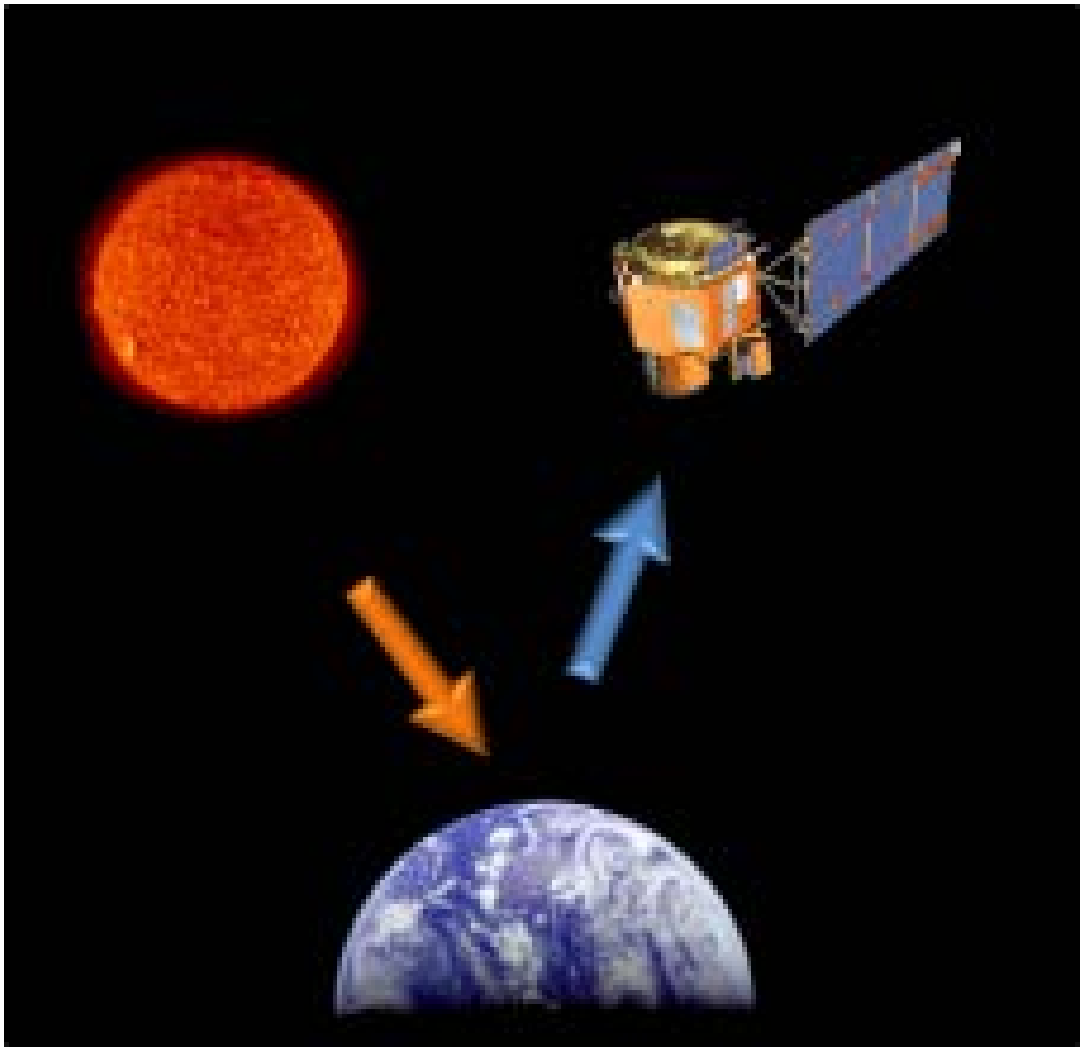
Radiometric Resolution

- 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

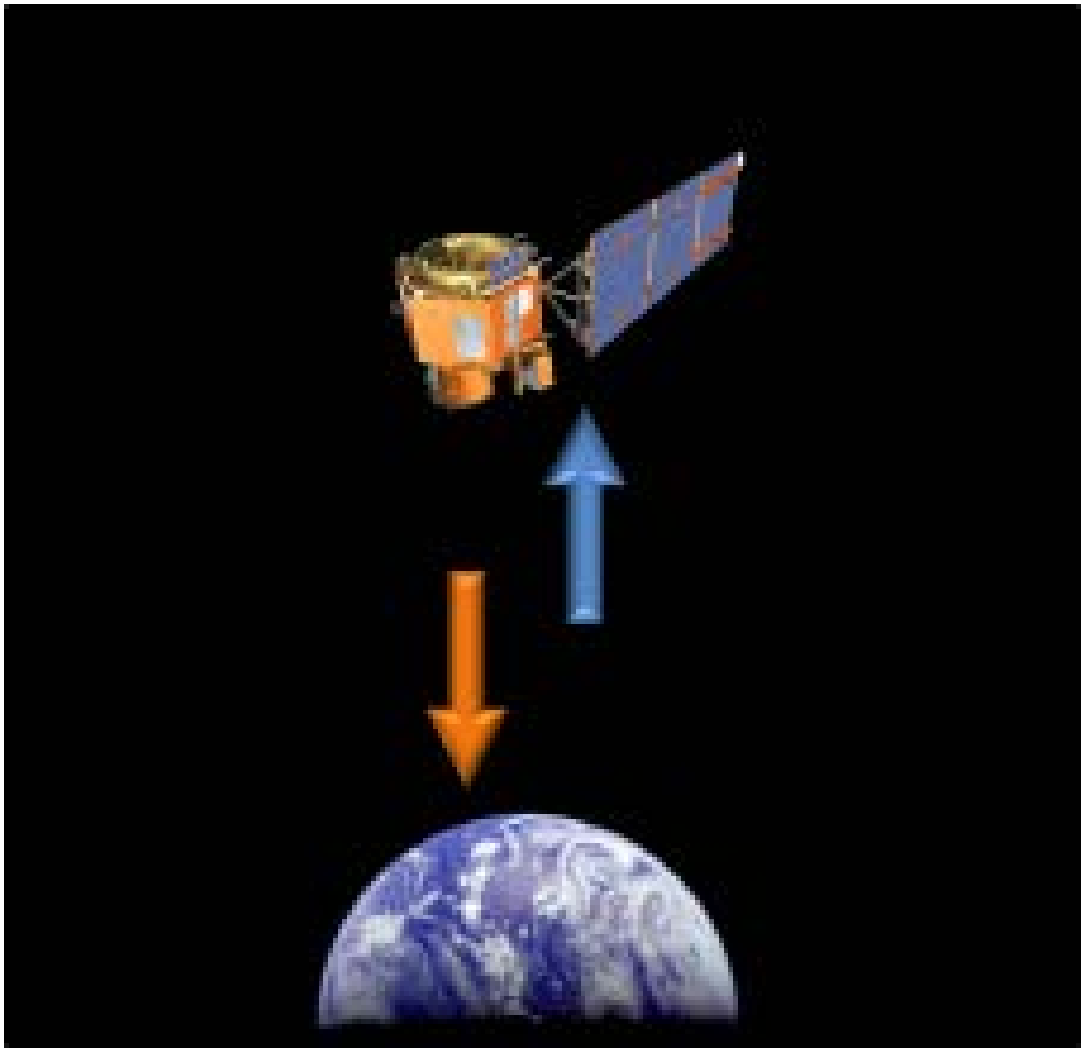


http://www.nasa.gov/

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.

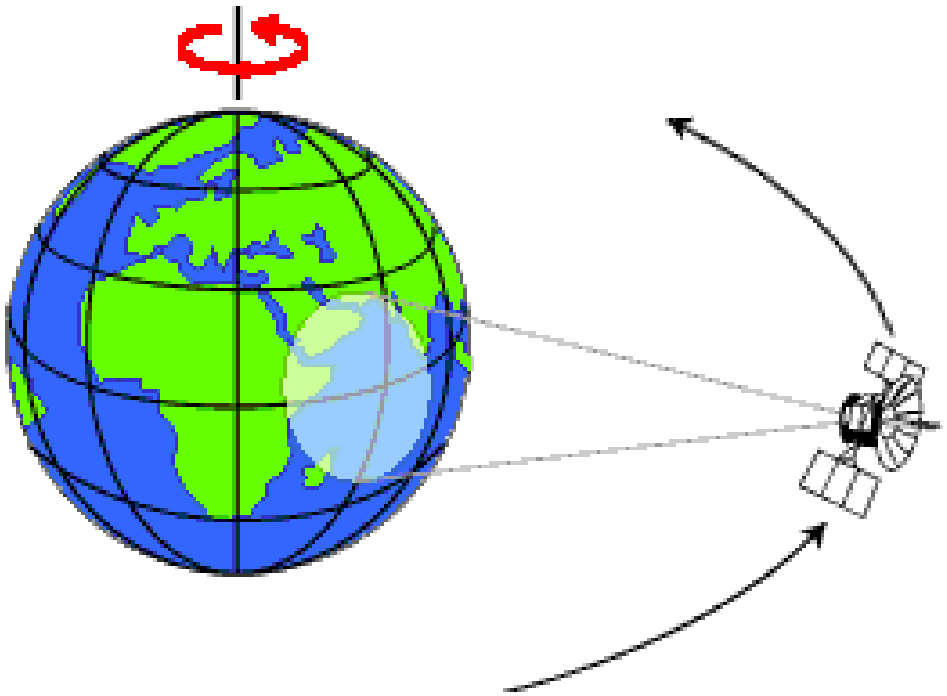
Active sensor



http://www.nasa.gov/

Geostationary orbits

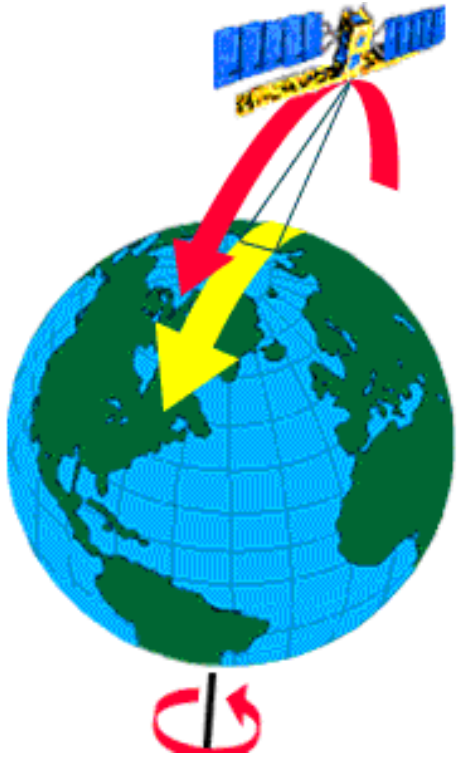
- Satellites at very high altitudes (~36,000km), which view the same portion of the Earth's surface at all times have **geostationary orbits**.
- They revolve at speeds which match the rotation of the Earth so they seem stationary, relative to the Earth's surface.
- E.g. Geostationary Operational Environmental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

NASA Earth Observation Satellites

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

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Shuttle Radar Topography Mission
The Mission to Map the World

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Public Data Distribution

Video Multimedia

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

Data Users Forum

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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.

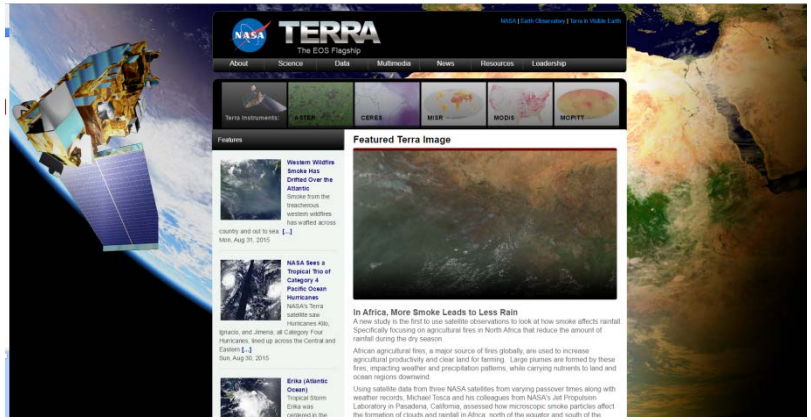
These additional fly around videos further illustrate SRTM elevation data:

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.

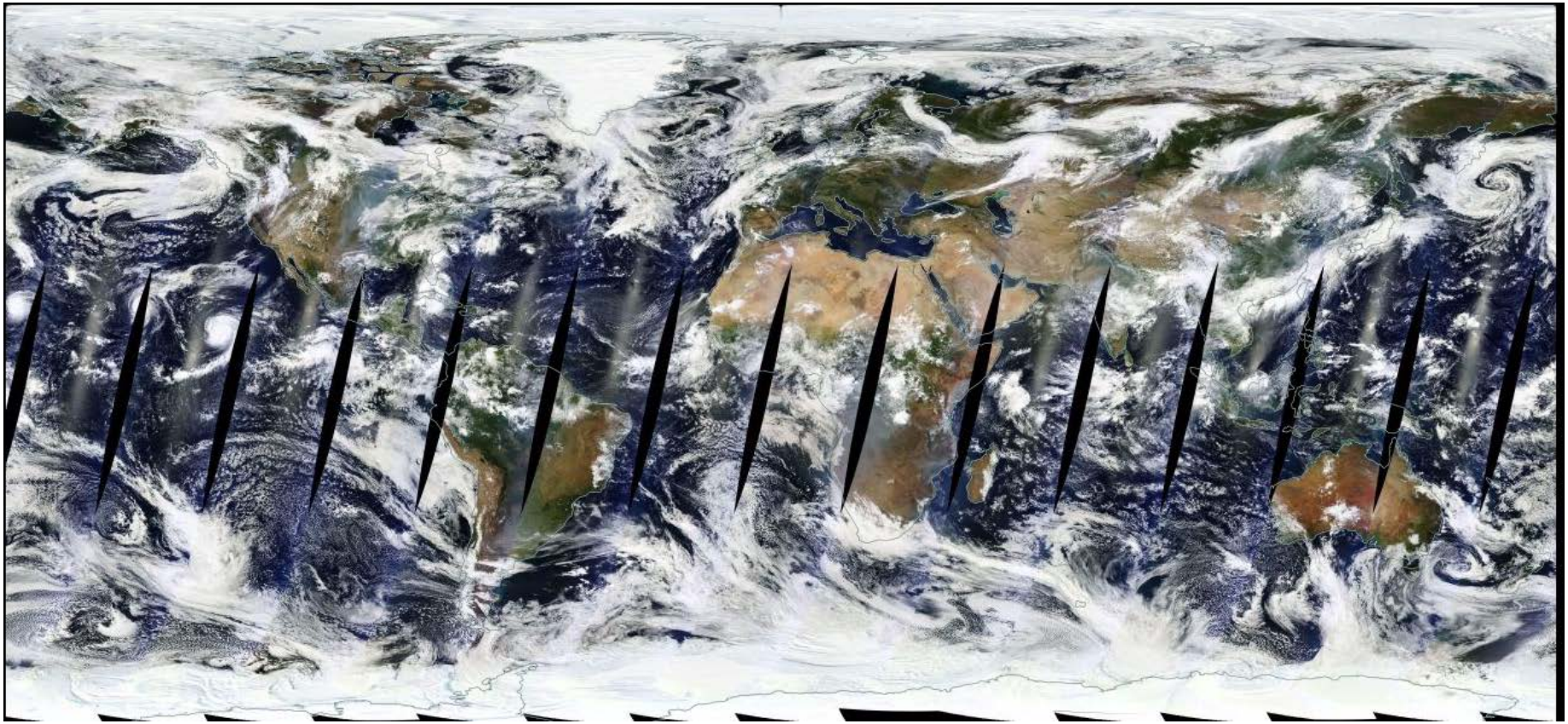
- The Shuttle Radar Topography Mission (SRTM) is an international research effort that obtained digital elevation model on a near-global scale from 56° S to 60° N.
- SRTM flew on board during the 11 day mission in February 2000.
- The resolution of the raw data is 30 meter for the US territory and 90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

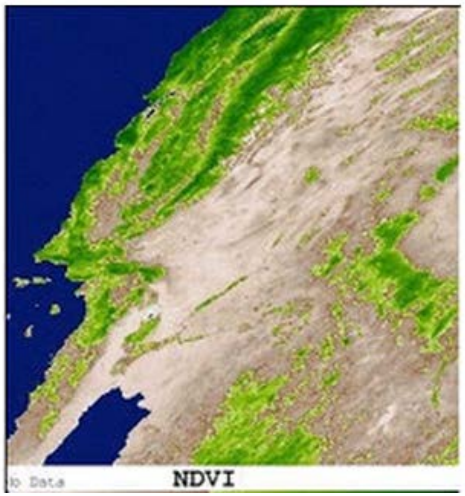
MODIS (Terra Satellite)



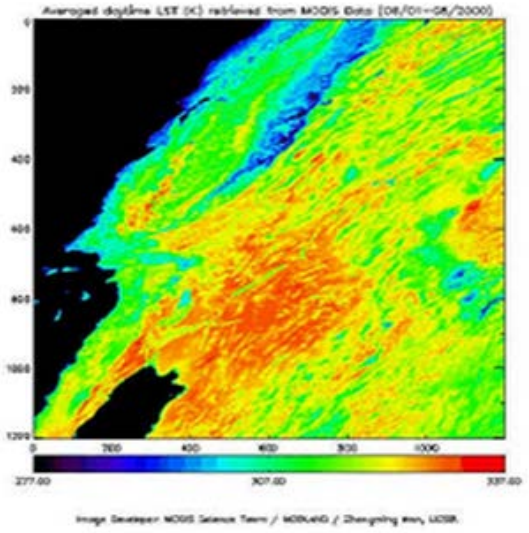
https://earthdata.nasa.gov/labs/worldview/

Satellite Derived Indices

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

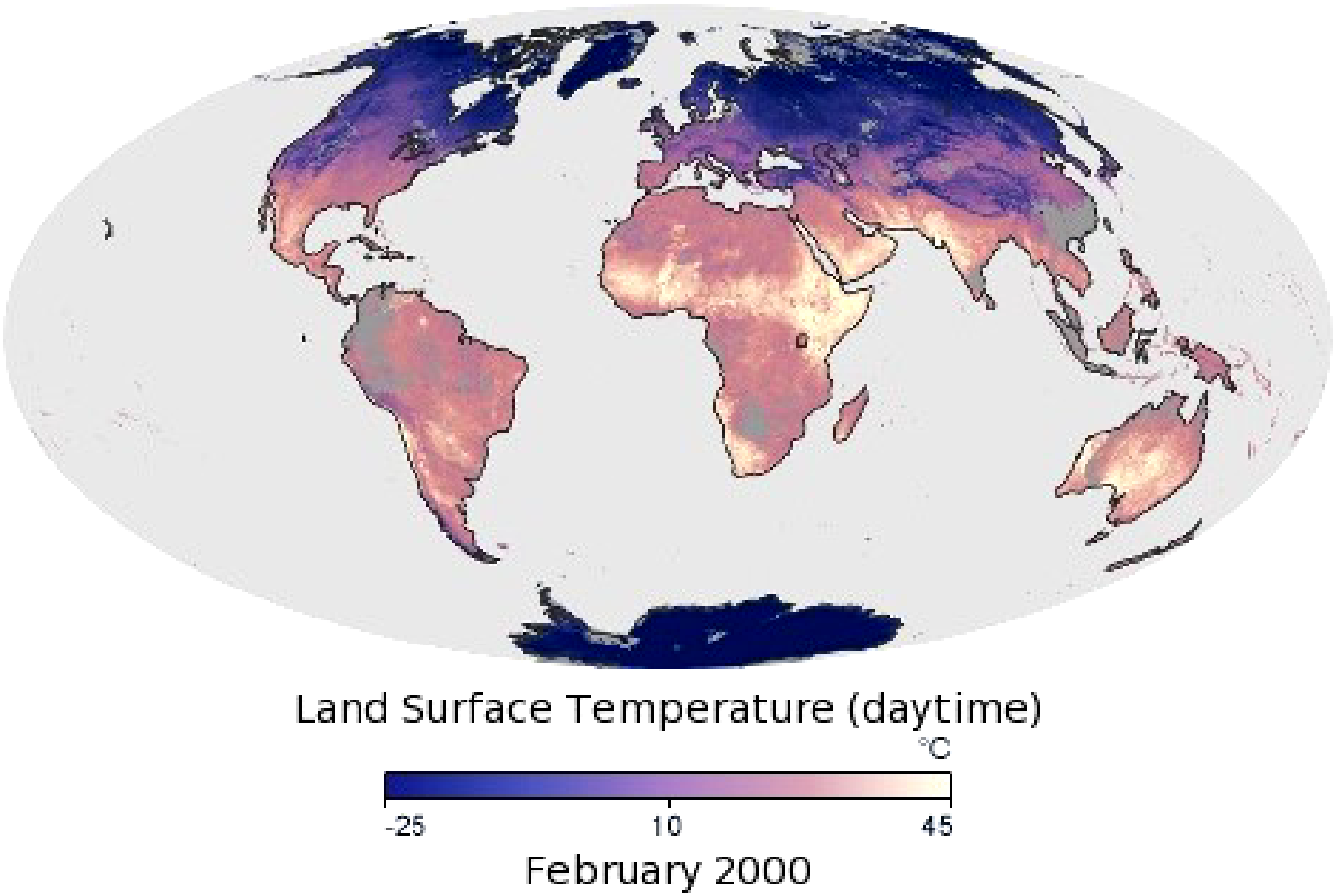


- **Moisture indices:**
  - Normalized difference water index (NDWI)
  - Evapotranspiration (ET)
- **Temperature:**
  - Land surface temperature (LST)



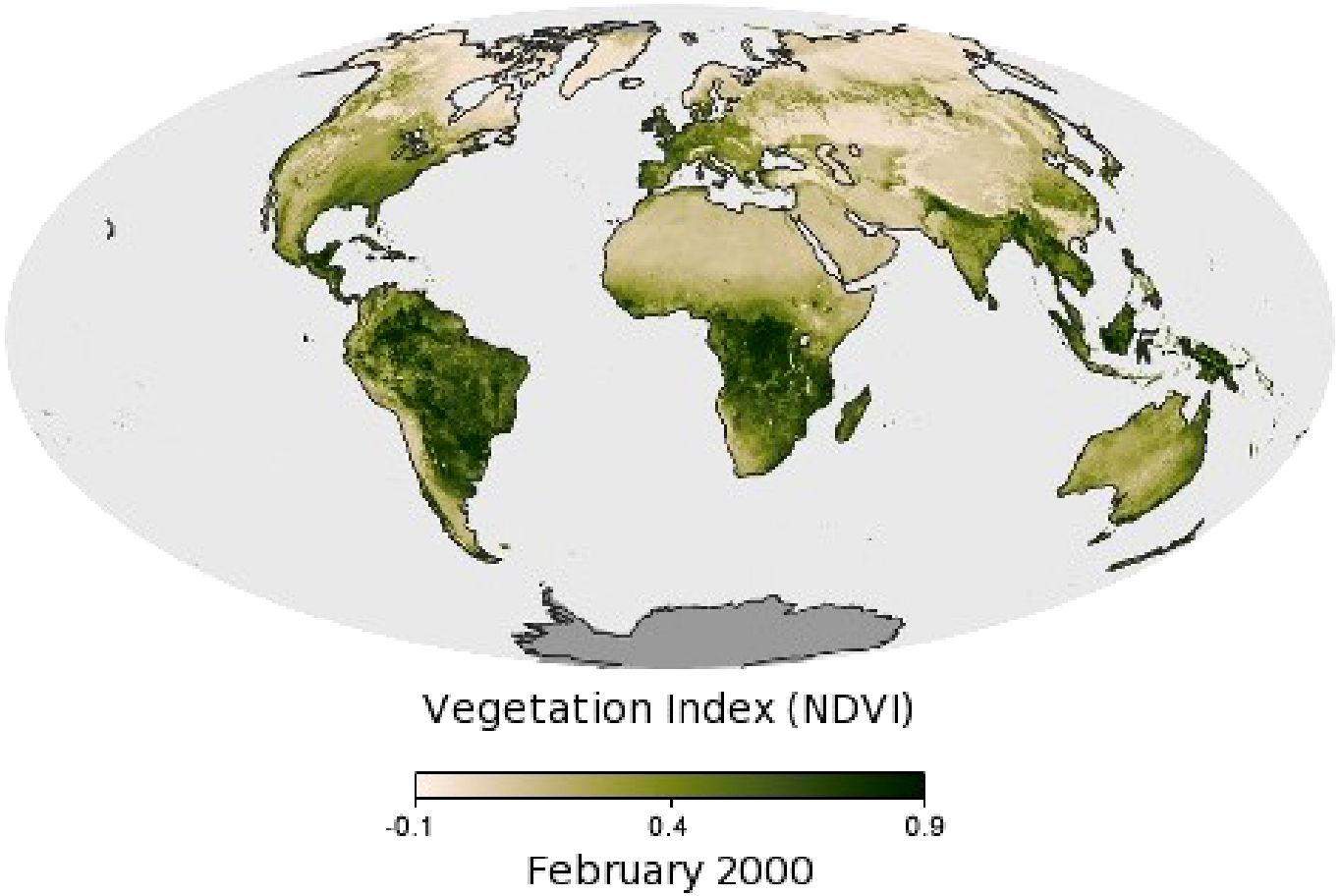
Source: http://modis-land.gsfc.nasa.gov/

Land Surface Temperature(MODIS)



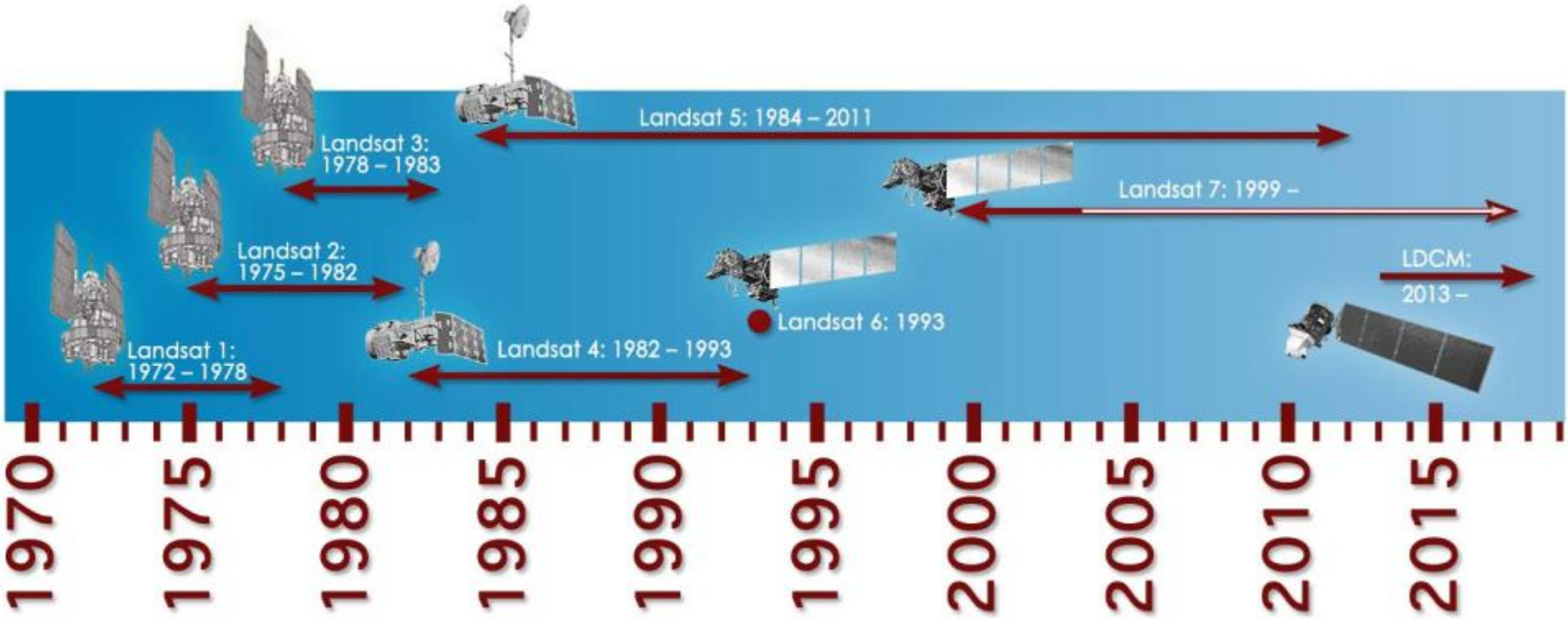
www.earthobservatory.nasa.gov

Vegetation Index (MODIS)



www.earthobservatory.nasa.gov

LANDSAT



http://landsat.usgs.gov

Four decades of monitoring the Earth!

Landsat

Sensors: 1, 2, 3, 4, 5, 7, 8

Date Range: 1972 to present

Landsat 8, launched in 2013, is the newest sensor in the program, capturing between 550–750 new images every day.

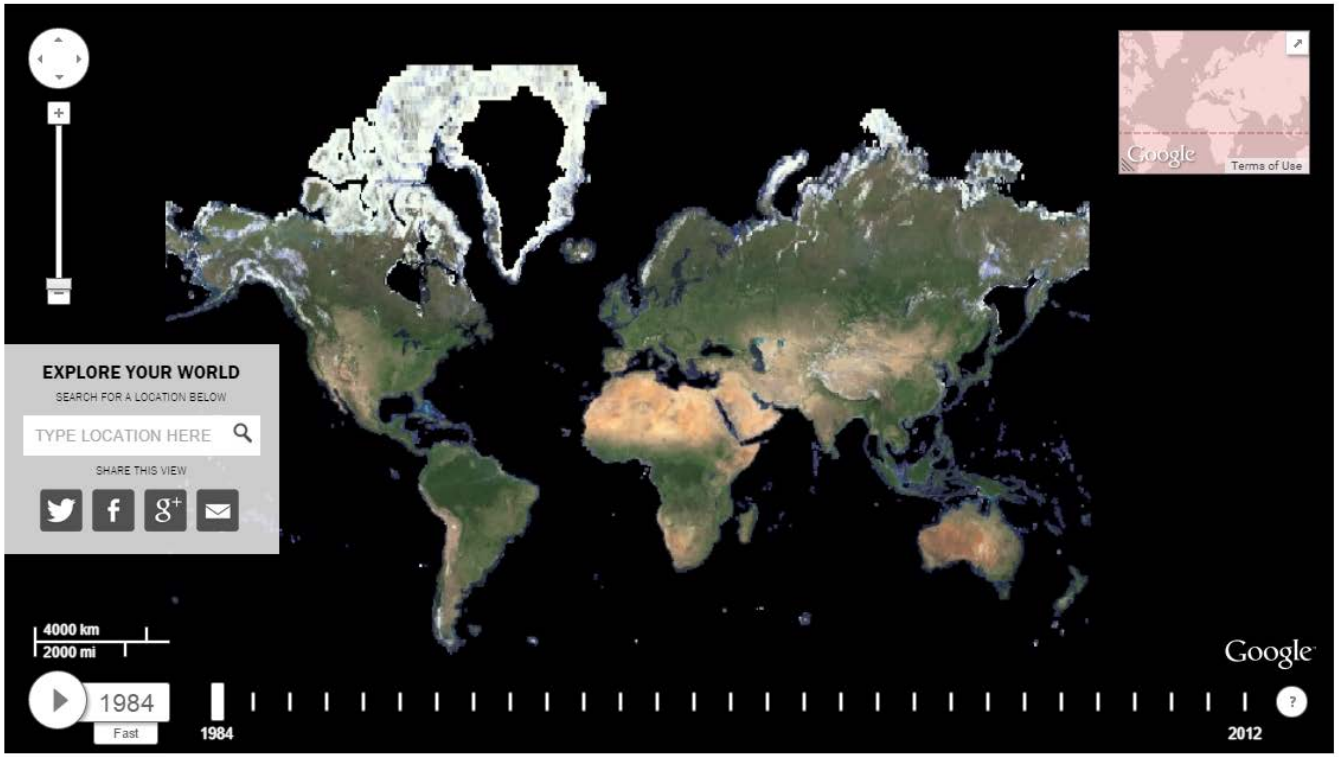
Revisit: 16 days

30/15m per pixel

Image: NASA/Goddard Space Flight Center Conceptual Image Lab

Timelapse

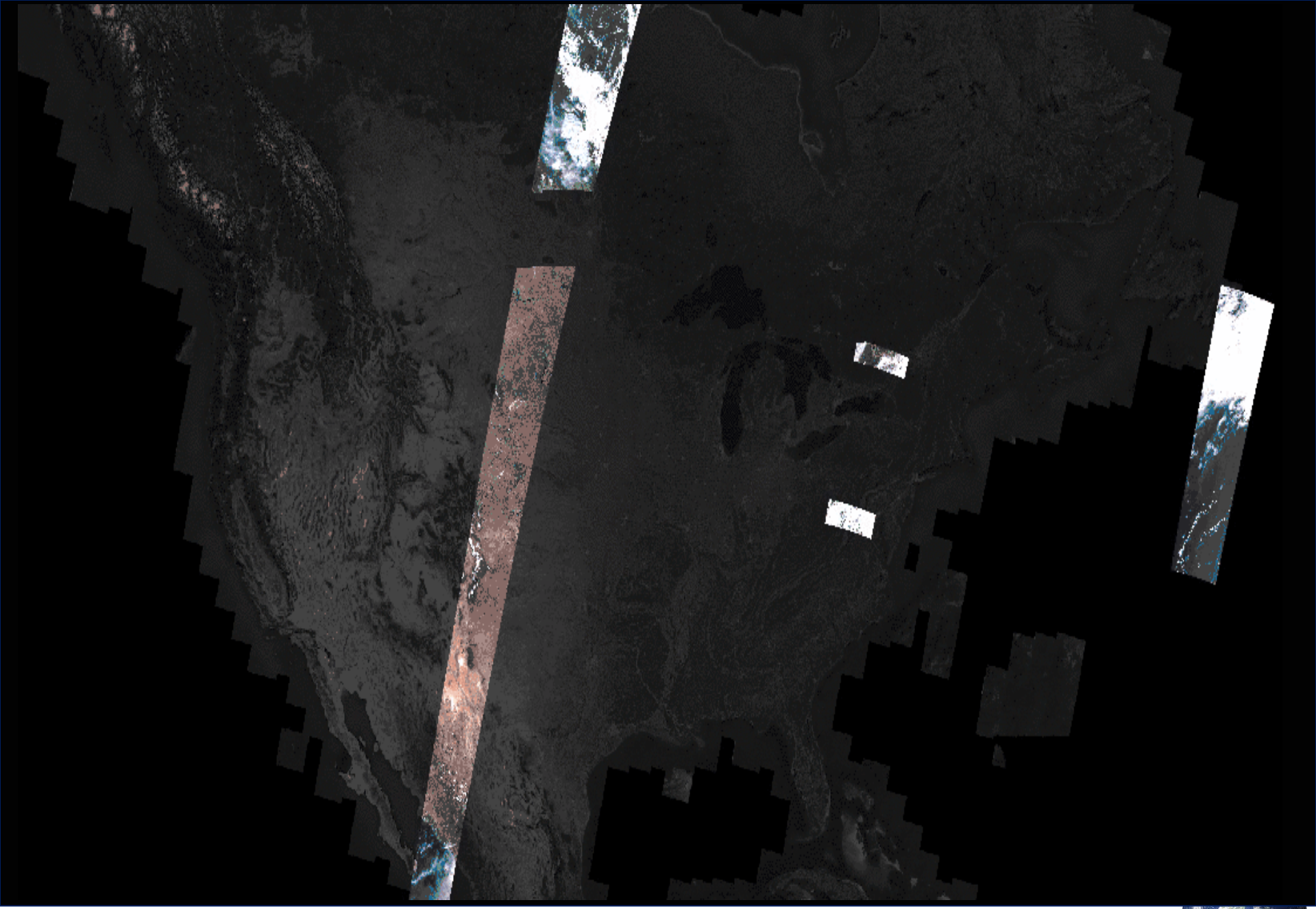
- Timelapse is powered by Google.
- It uses global scale historical archives of Landsat satellite imagery from 1984-2012 to monitor change on the planet.



Sentinel 2

- Part of The European Space Agency's Copernicus Program
- First satellite in orbit since 6/2015
- Second (expected) launch: 4/2017
- **Revisit (at equator)**: 5 days*
- 10m per pixel

Photo: ESA/ATG medialab



Sentinel 1

- Part of The European Space Agency's Copernicus Program
- Uses radar to image the Earth in all weather conditions, even at night.
- The satellites capture C-band synthetic aperture radar (SAR) image data at 30- to 120-meter resolution in several polarization modes.

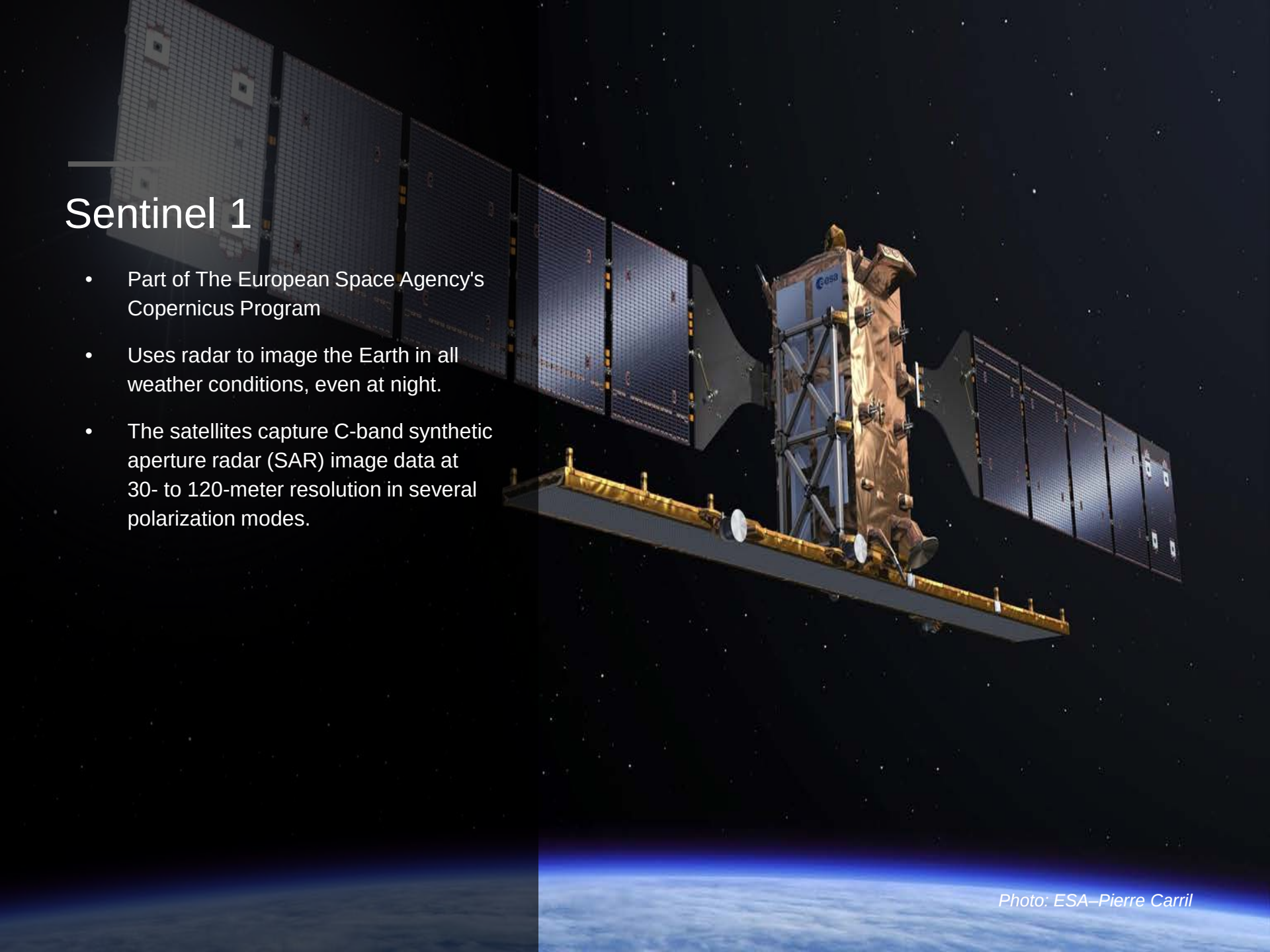
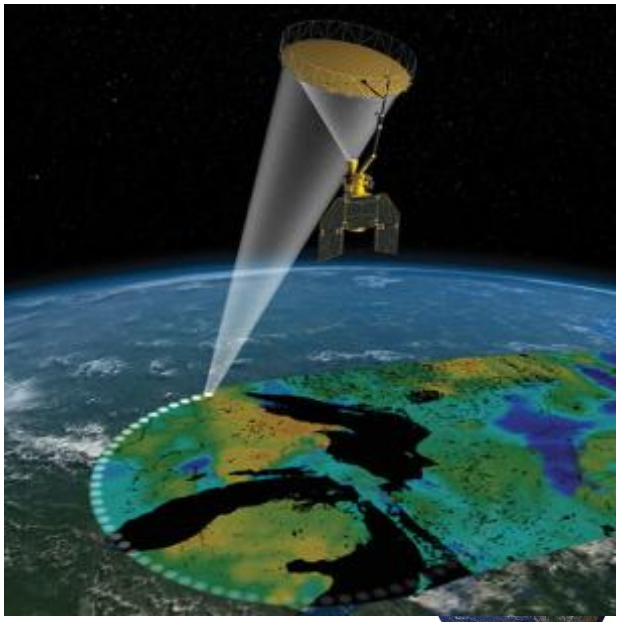


Photo: ESA–Pierre Carril

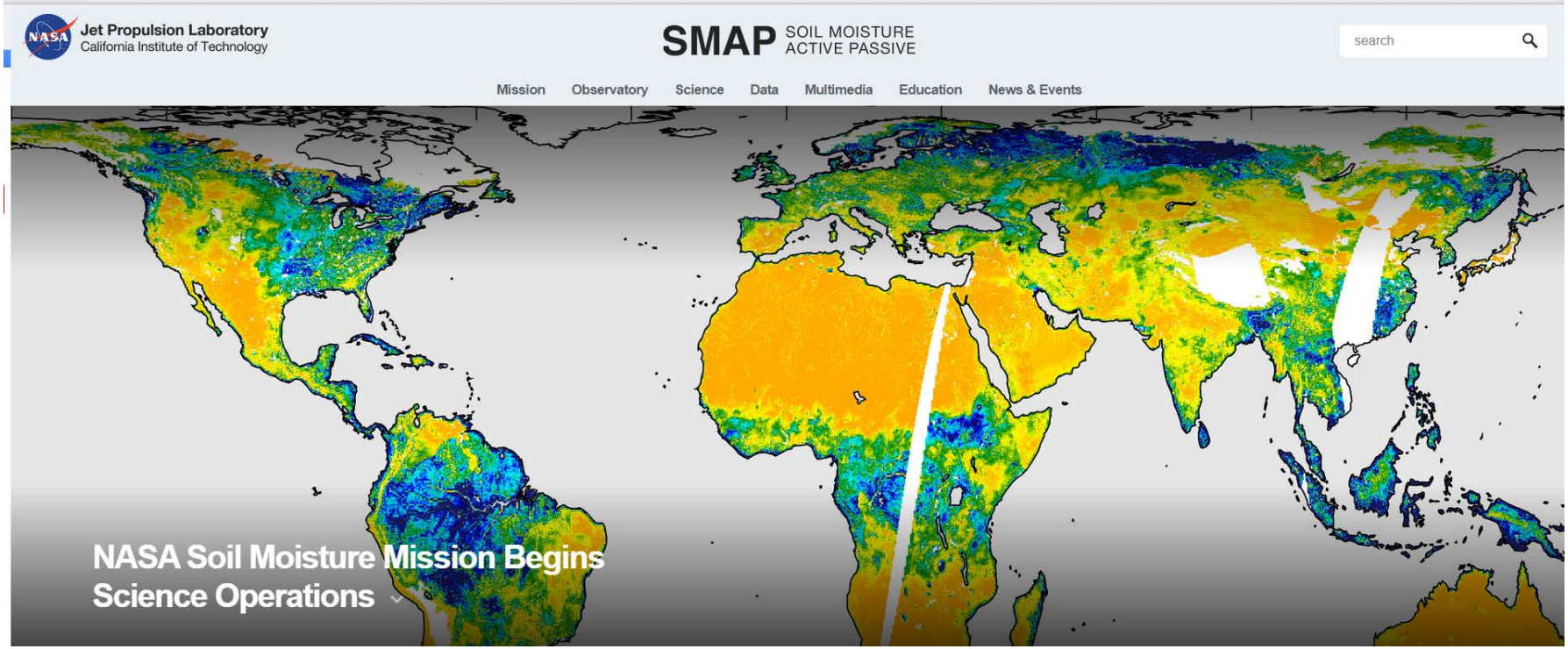
SMAP
(Soil Moisture Active Passive)

- 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**

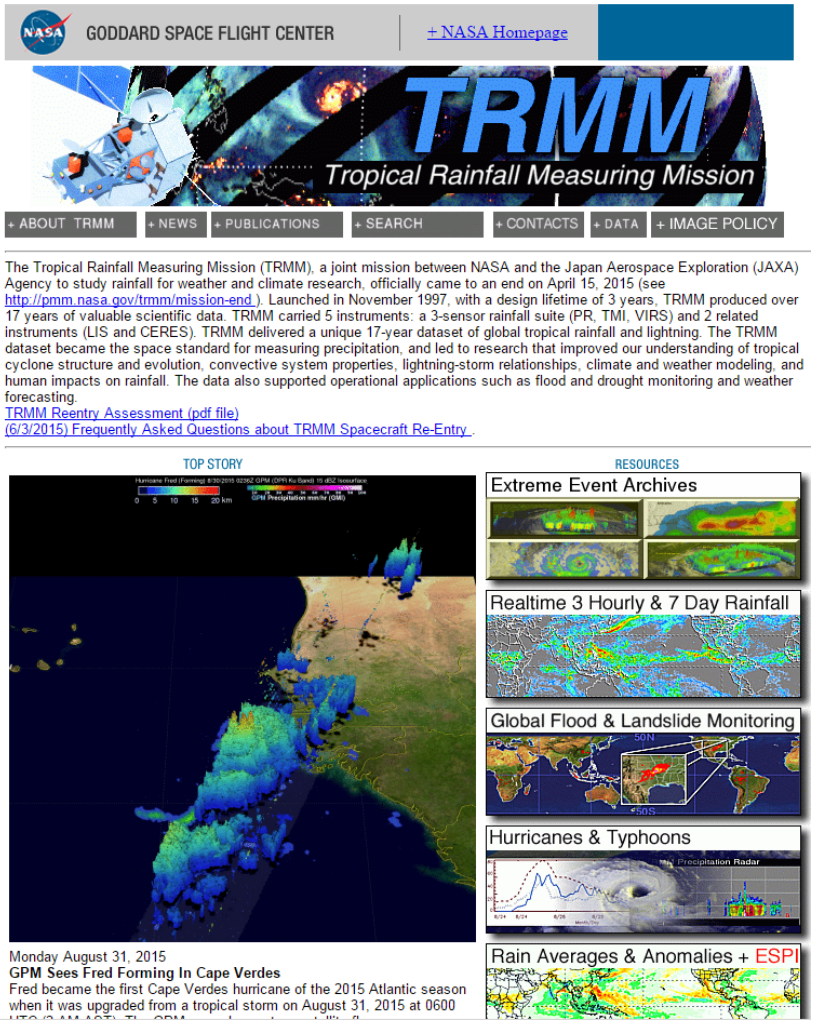


https://smap.jpl.nasa.gov

SMAP

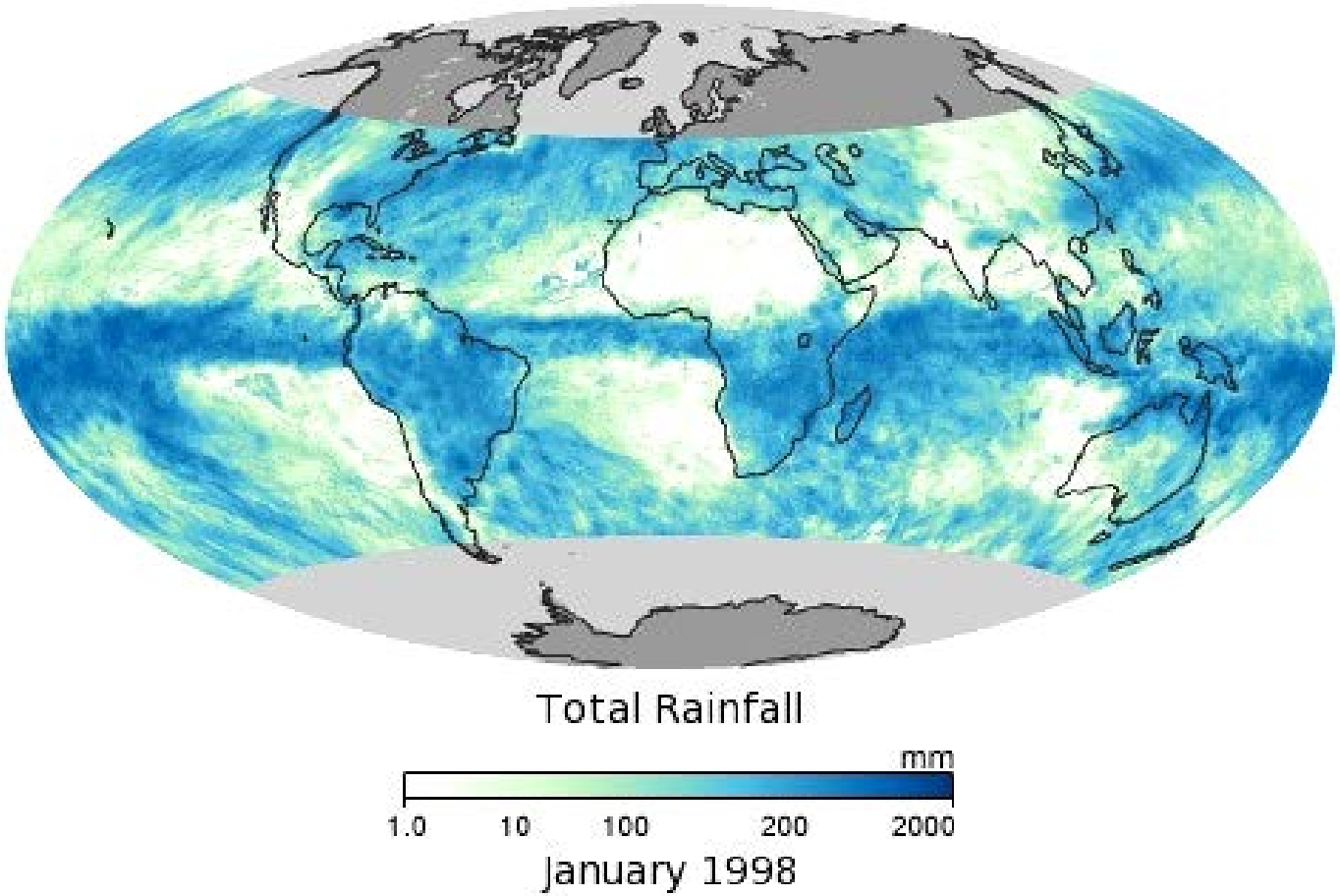

Jet Propulsion Laboratory
California Institute of Technology
SMAP SOIL MOISTURE ACTIVE PASSIVE
search
Mission
Observatory
Science
Data
Multimedia
Education
News & Events
NASA Soil Moisture Mission Begins Science Operations

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

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.

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/

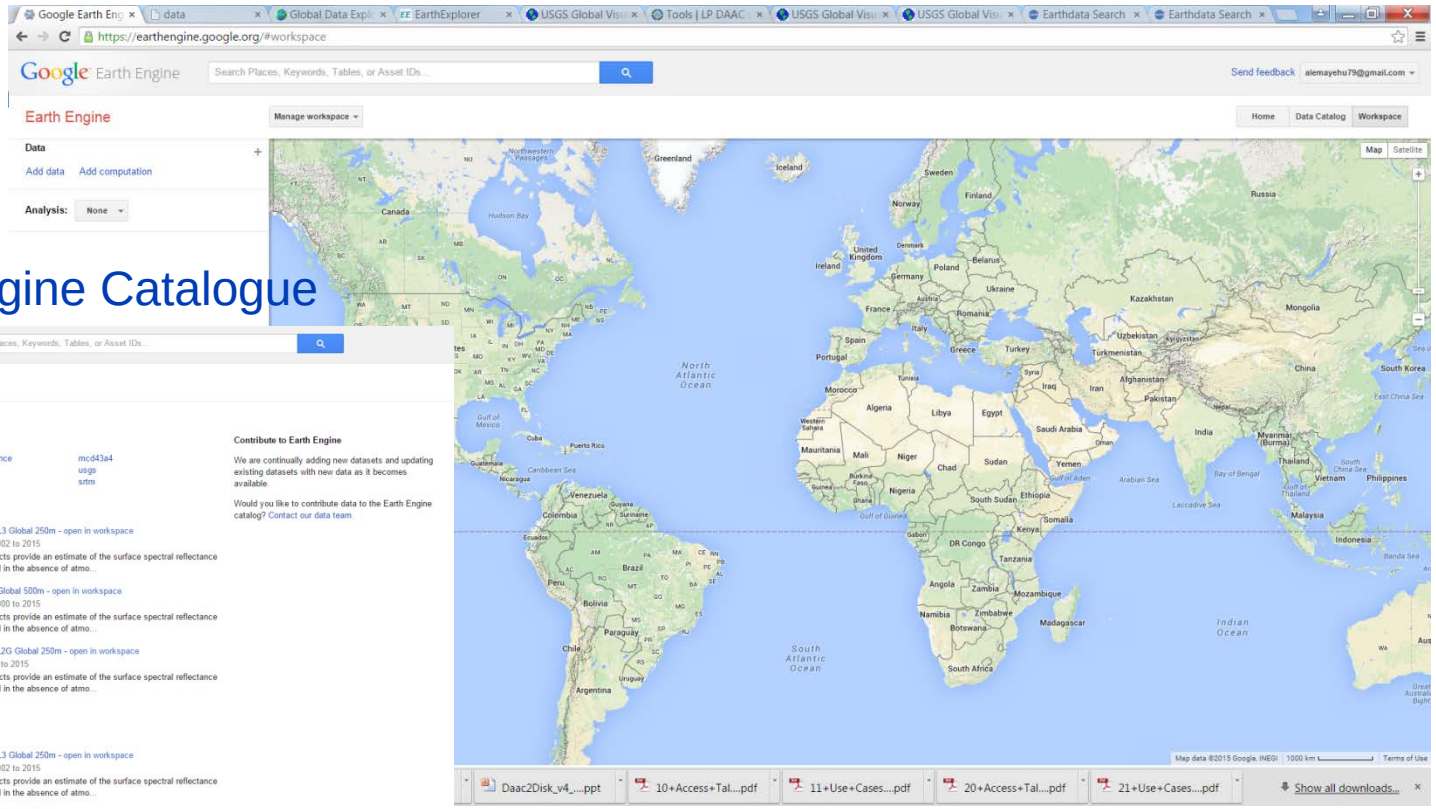
Google Earth Engine

FAQ TIMELAPSE DATASETS CASE STUDIES PLATFORM SIGN UP

Meet Earth Engine

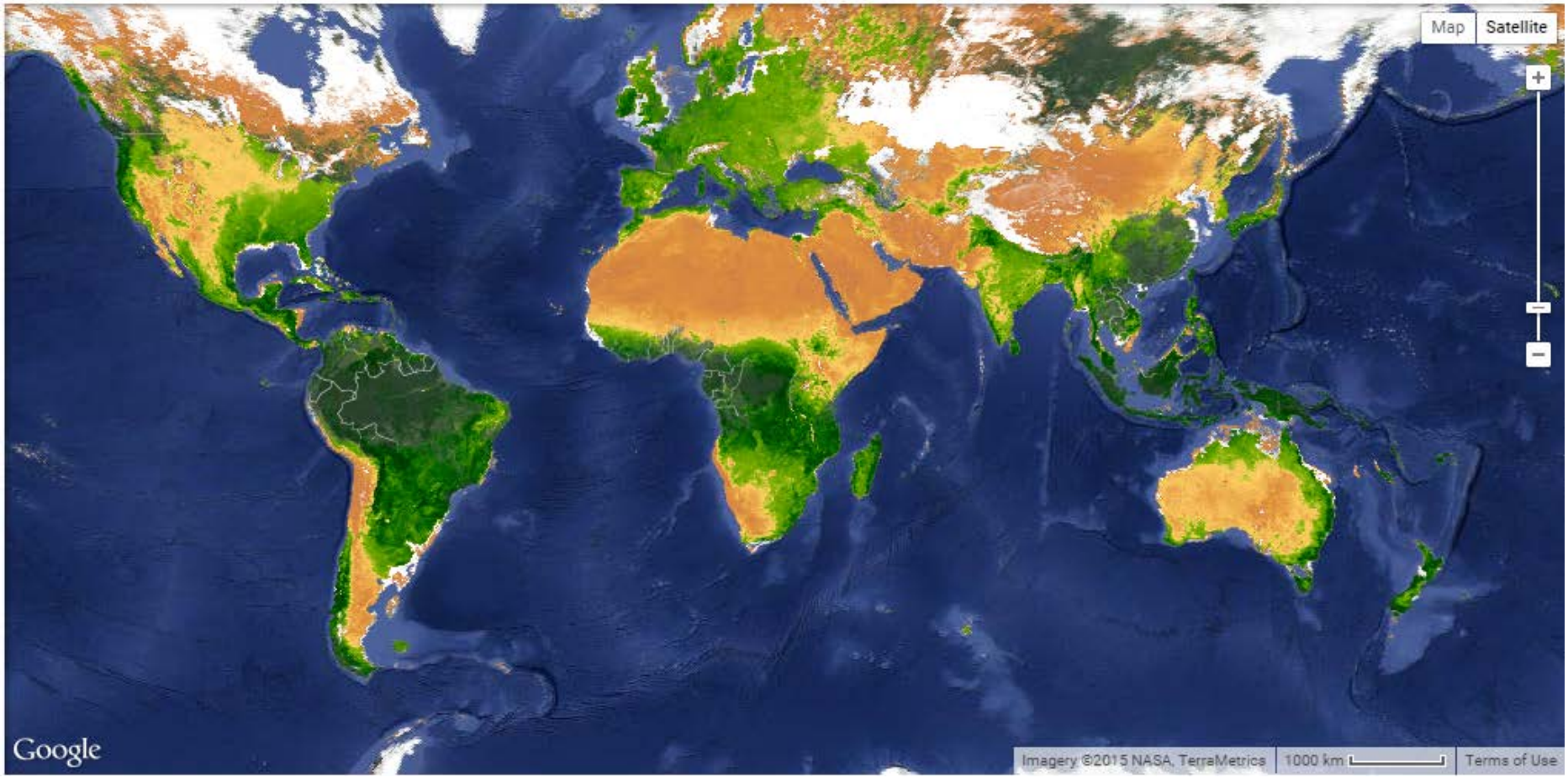
Google Earth Engine combines a multi-petabyte catalog of satellite imagery and geospatial datasets with planetary-scale analysis capabilities and makes it available for scientists, researchers, and developers to detect changes, map trends, and quantify differences on the Earth's surface.

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



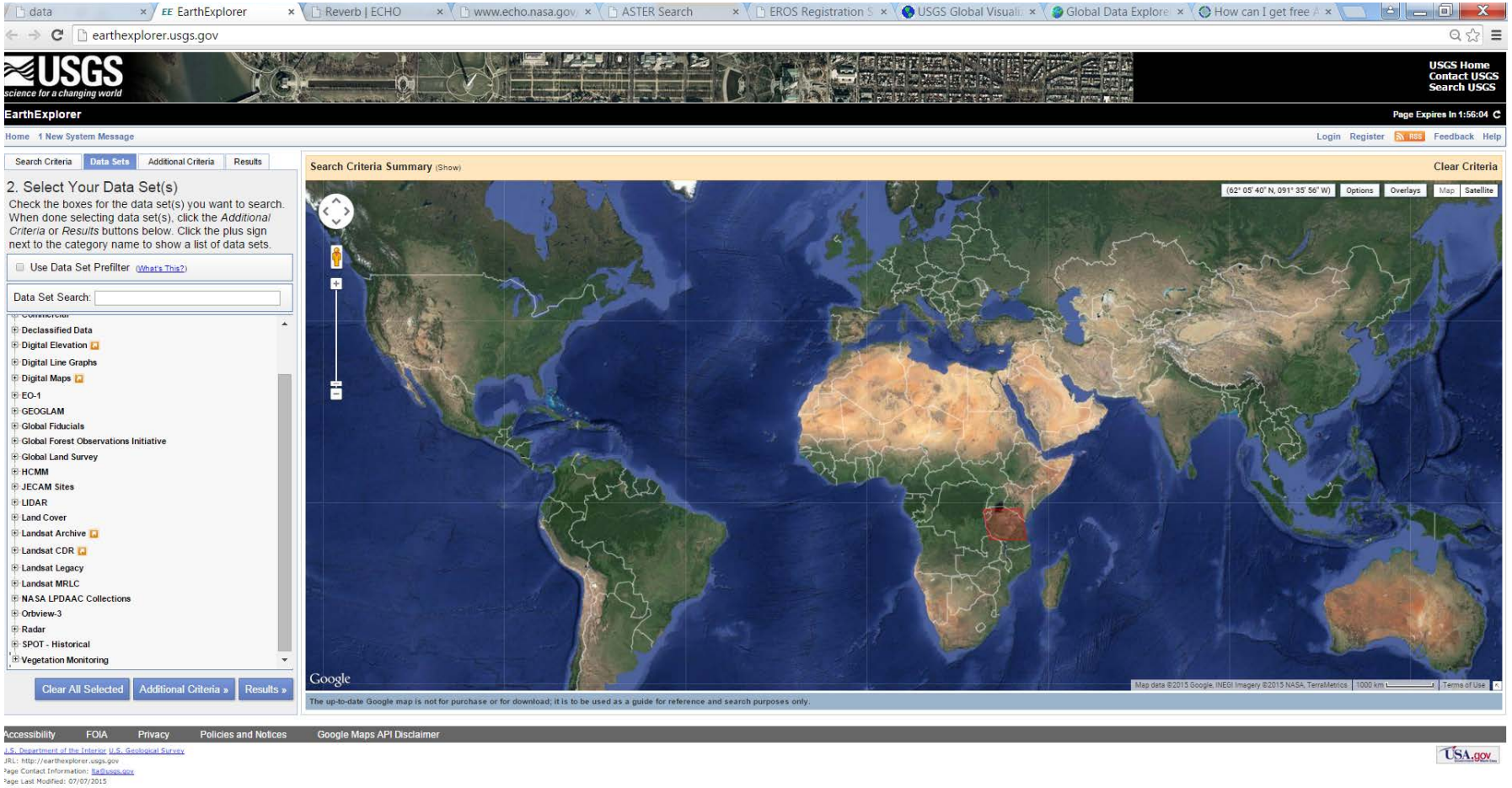
Earth Engine Catalogue

Google Earth Engine

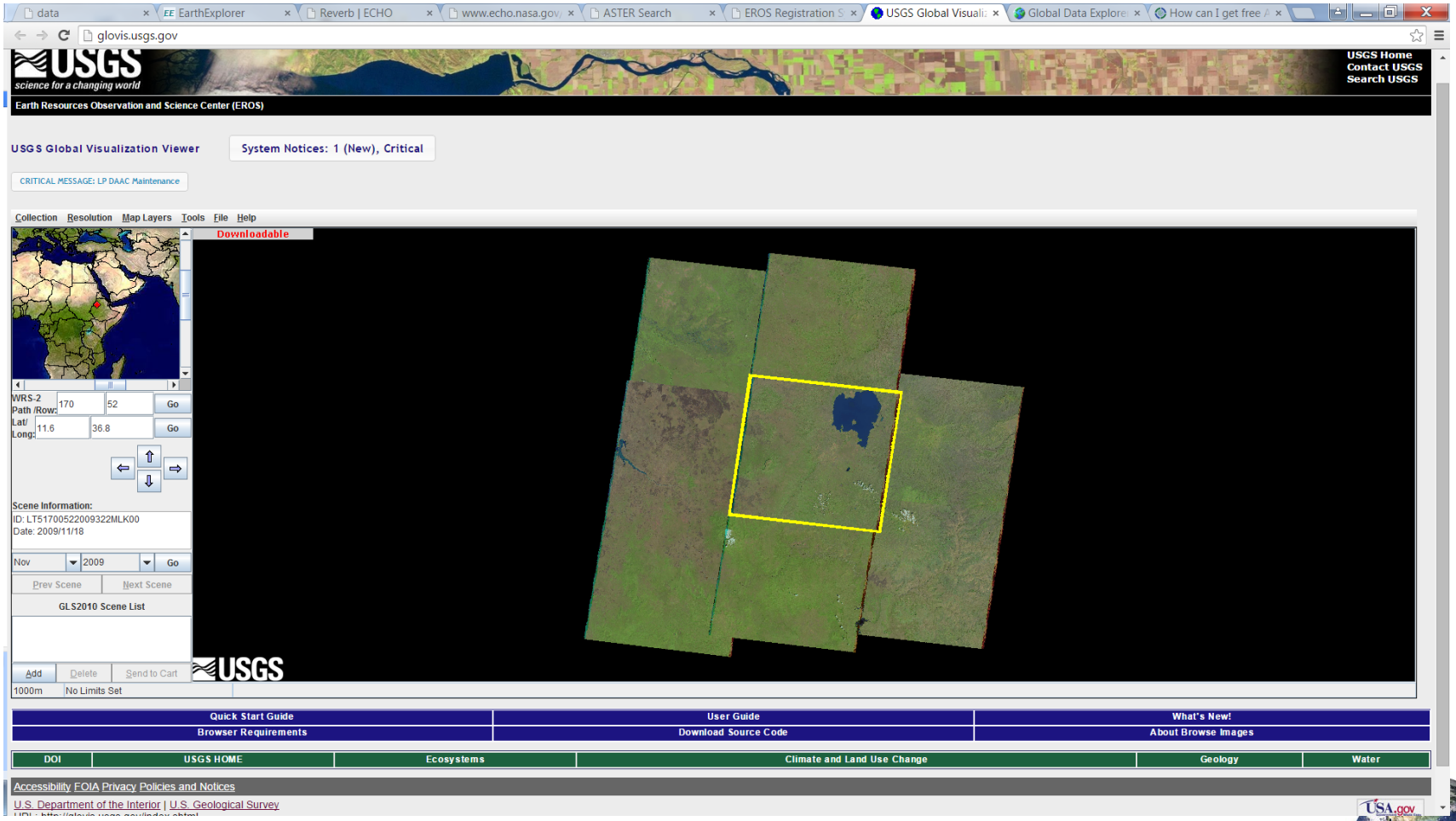


MODIS Normalized Difference Vegetation Index (March 2015)

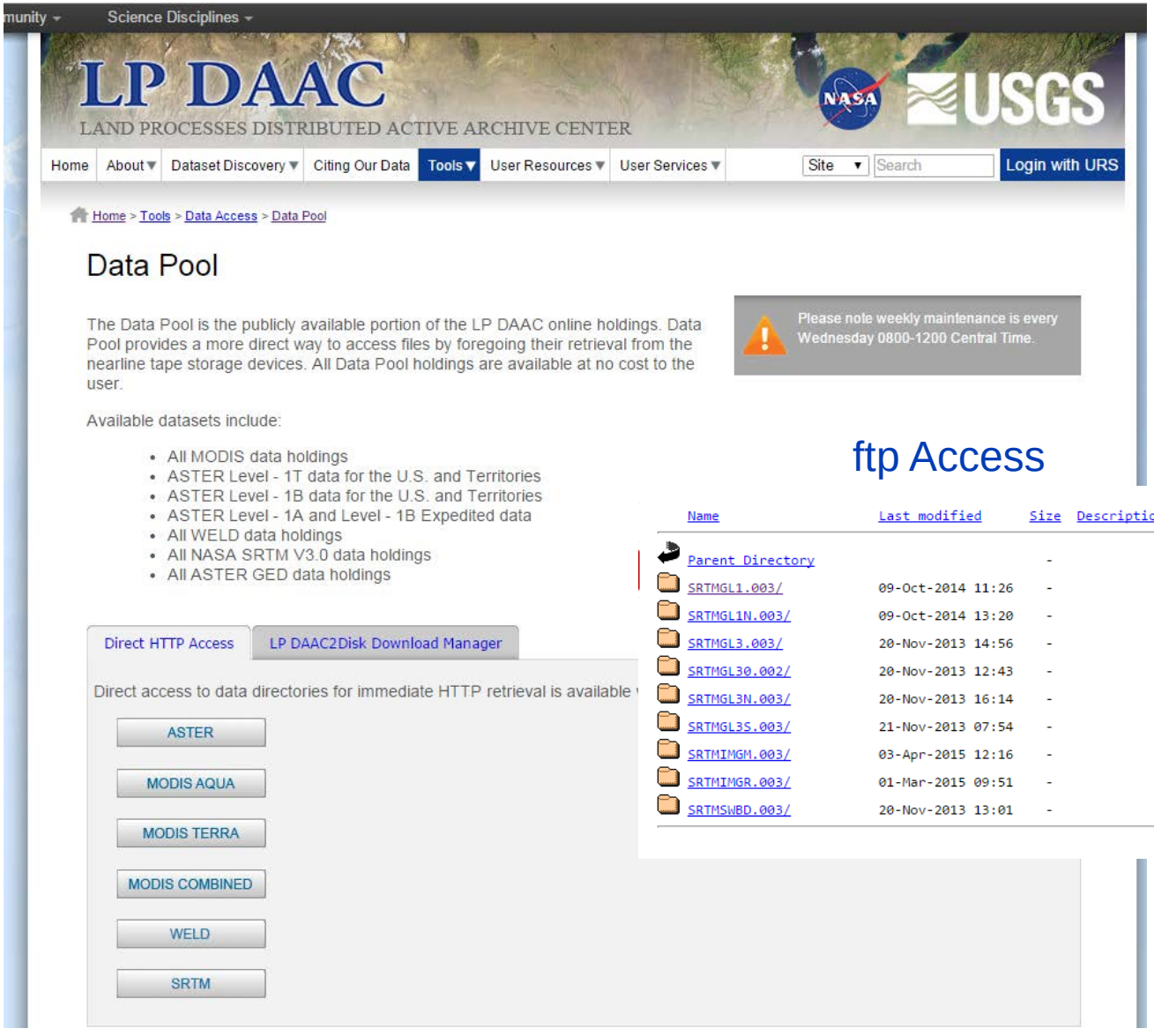
Earthexplorer
http://earthexplorer.usgs.gov/



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

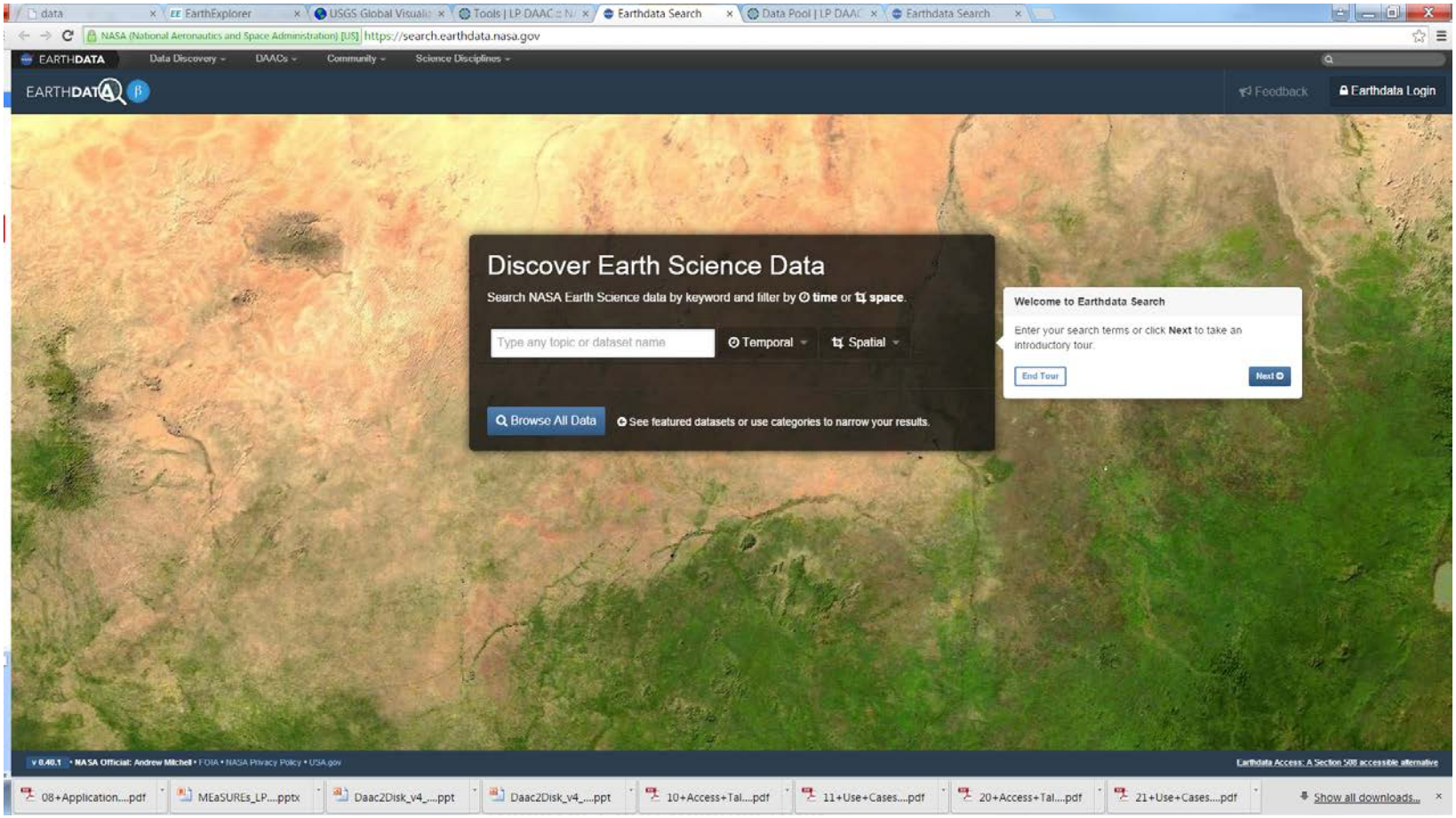


LPDAAC
(Land Processes Distributed Archive Data Center)
https://lpdaac.usgs.gov/data_access/data_pool



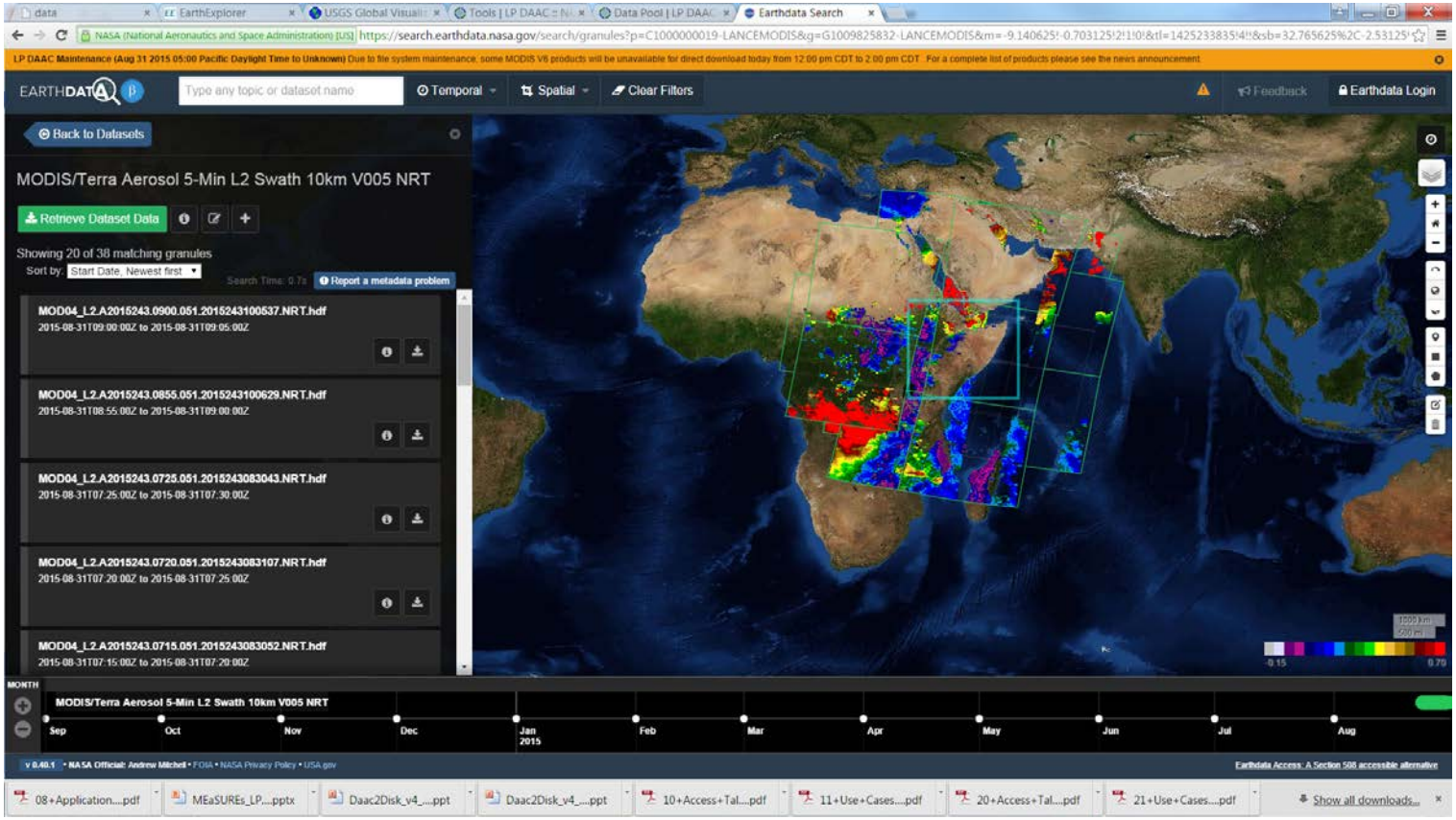
ftp Access

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

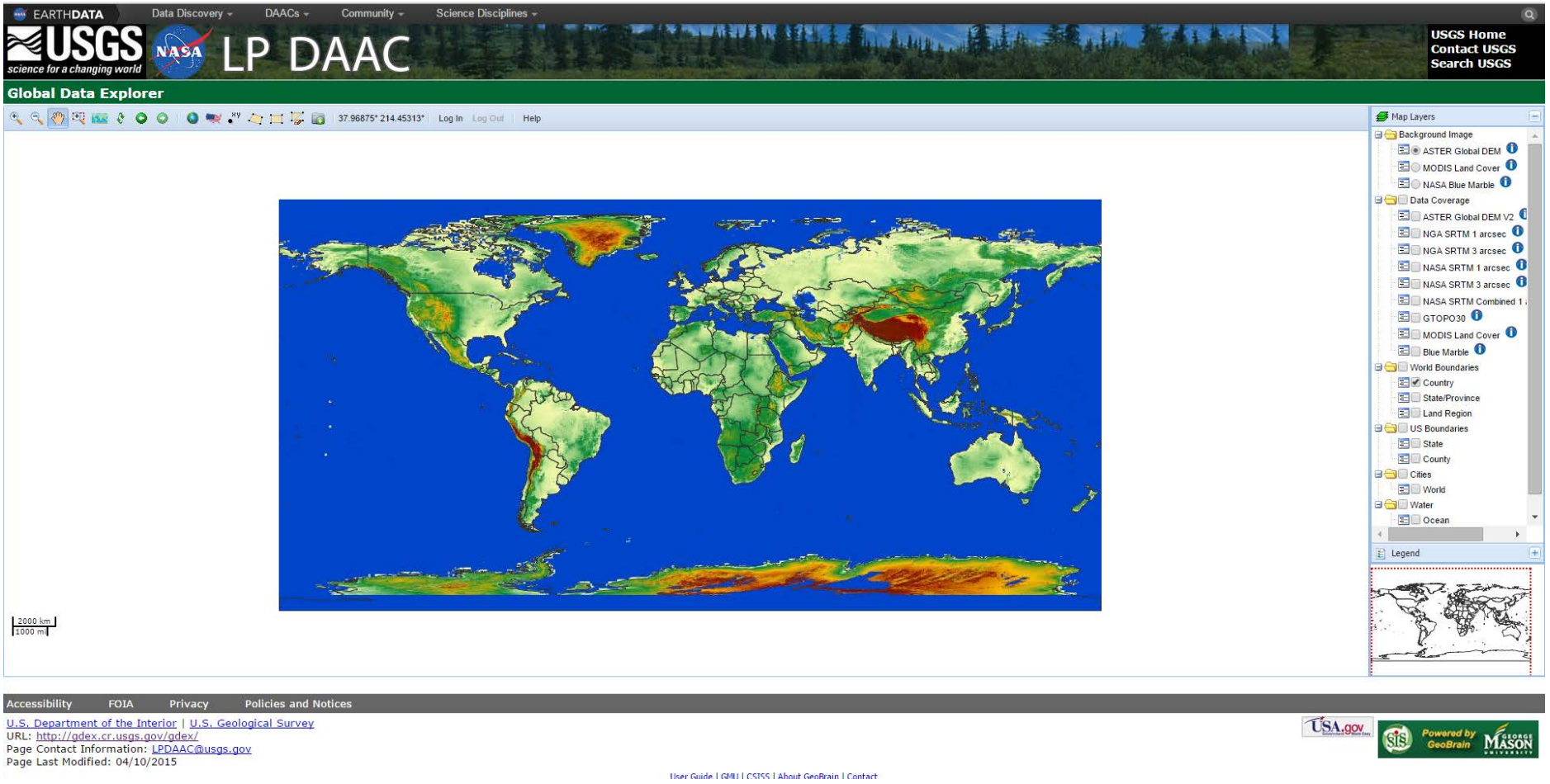


Earthdata offers discovering, searching, visualizing, and retrieving remote sensing.

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

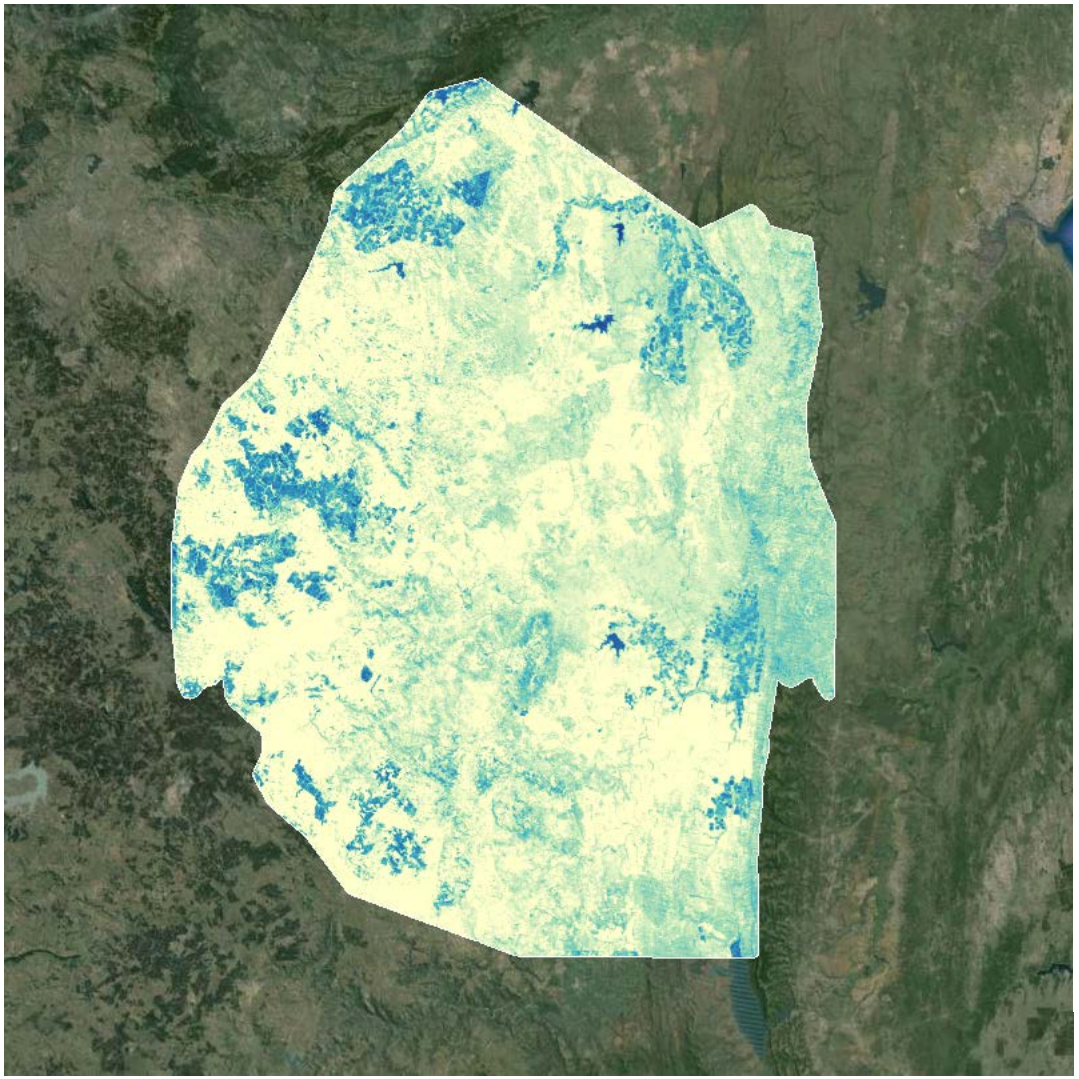


GDEx
http://gdex.cr.usgs.gov/gdex/



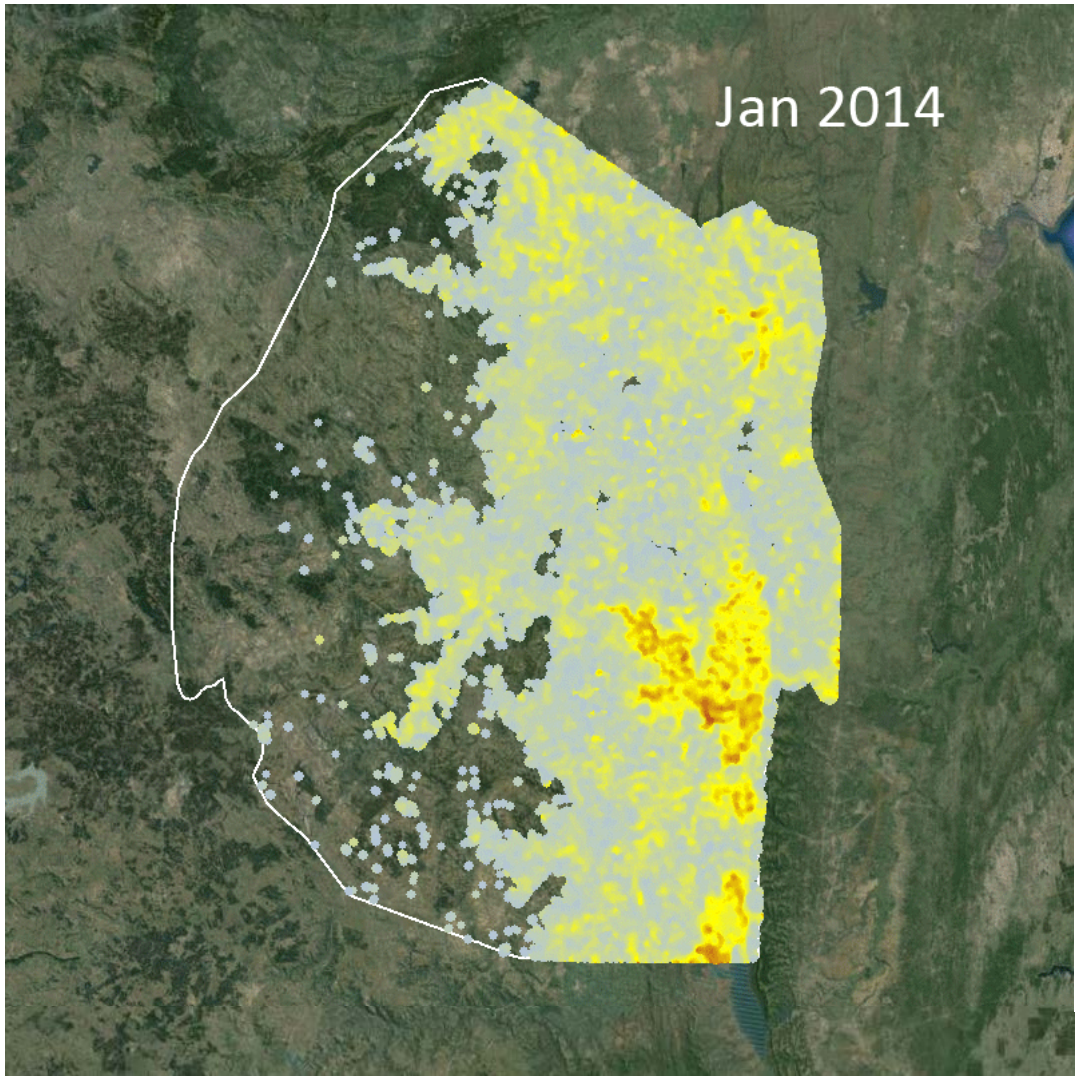
Digital elevation model data for all users.
User-friendly geographic interface.

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

COMMENTARY:

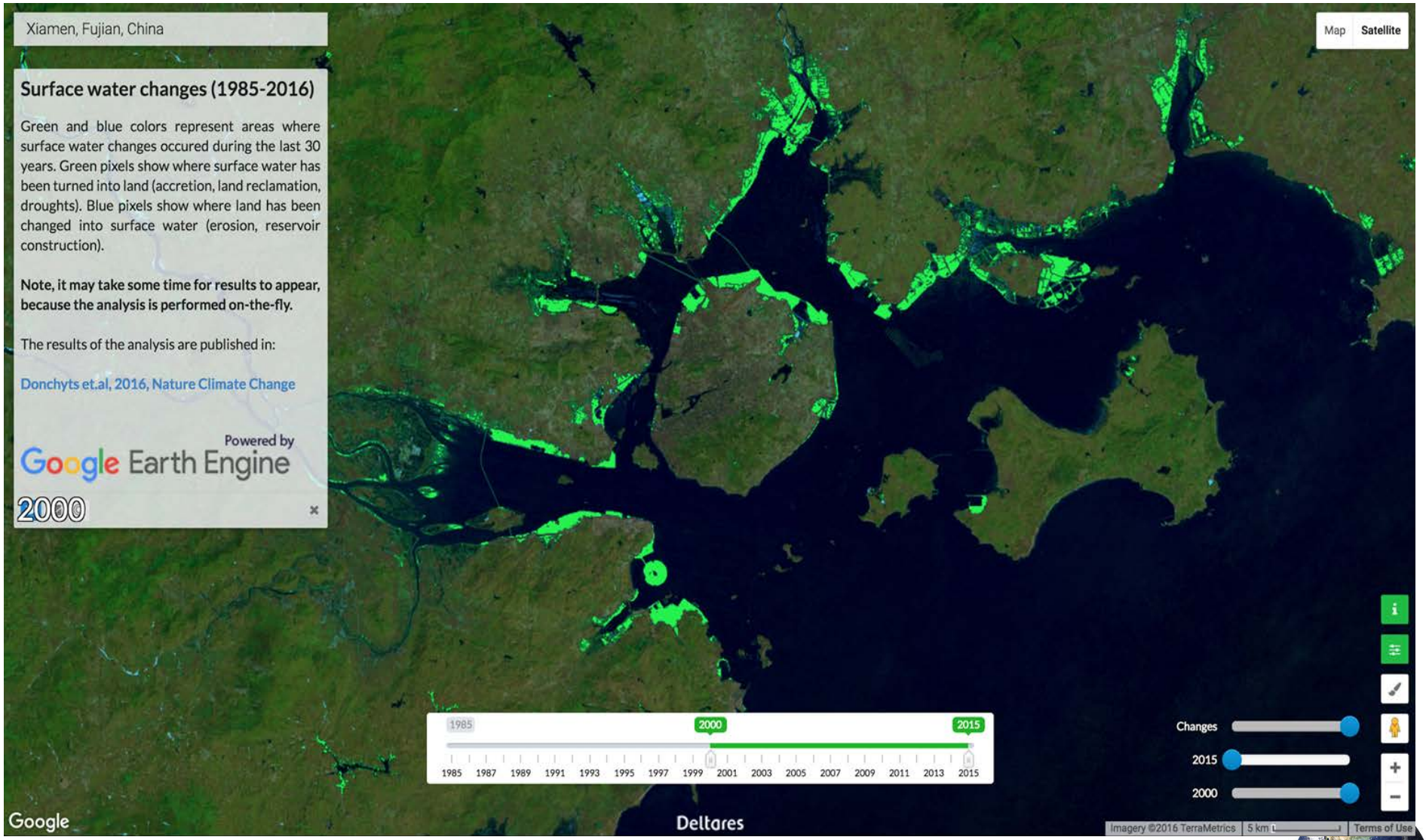
Earth's surface water change over the past 30 years

Gennadii Donchyts, Fedor Baart, Hessel Winsemius, Noel Gorelick, Jaap Kwadijk and Nick van de Giesen

Earth's surface gained 115,000 km^2 of water and 173,000 km^2 of land over the past 30 years, including 20,135 km^2 of water and 33,700 km^2 of land in coastal areas. Here, we analyse the gains and losses through the Deltares Aqua Monitor — an open tool that detects land and water changes around the globe.

NATURE CLIMATE CHANGE | VOL 6 | SEPTEMBER 2016 | www.nature.com/natureclimatechange

Application: http://aqua-monitor.appspot.com/


Xiamen, Fujian, China
Surface water changes (1985-2016)
Green and blue colors represent areas where surface water changes occured during the last 30 years. Green pixels show where surface water has been turned into land (accretion, land reclamation, droughts). Blue pixels show where land has been changed into surface water (erosion, reservoir construction).
Note, it may take some time for results to appear, because the analysis is performed on-the-fly.
The results of the analysis are published in:
Donchyts et.al, 2016, Nature Climate Change
Powered by
Google Earth Engine
2000
Map
Satellite
1985
2000
2015
1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Changes
2015
2000
Google
Deltares
Imagery ©2016 TerraMetrics
5 km
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Science 15 November 2013:
Vol. 342 no. 6160 pp. 850-853
DOI: 10.1126/science.1244693

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REPORT

High-Resolution Global Maps of 21st-Century Forest Cover Change

M. C. Hansen[1,*], P. V. Potapov[1], R. Moore[2], M. Hancher[2], S. A. Turubanova[1], A. Tyukavina[1], D. Thau[2], S. V. Stehman[3], S. J. Goetz[4], T. R. Loveland[5], A. Kommareddy[6], A. Egorov[6], L. Chini[1], C. O. Justice[1], J. R. G. Townshend[1]

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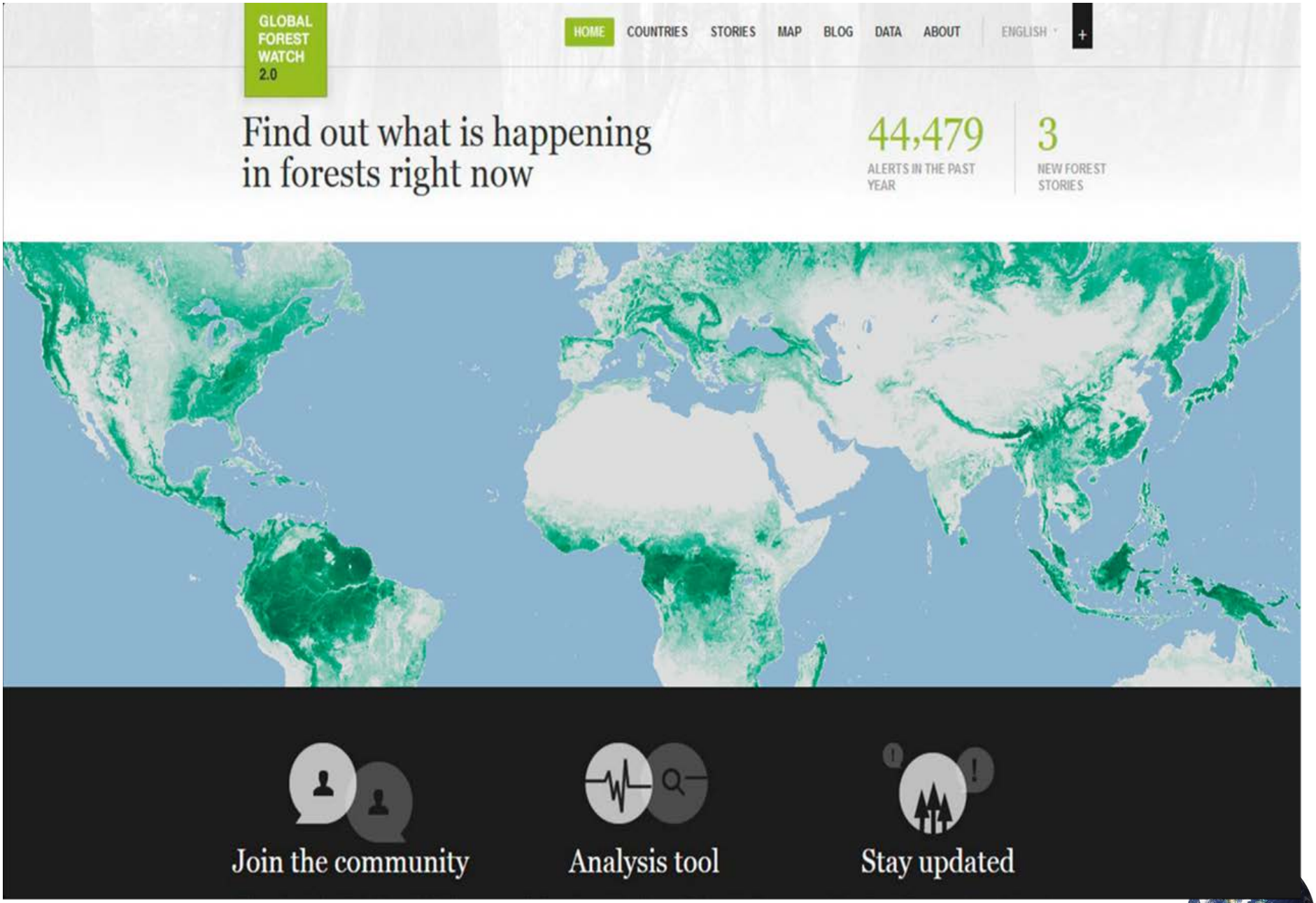
ABSTRACT | EDITOR'S SUMMARY

Quantification of global forest change has been lacking despite the recognized importance of forest ecosystem services. In this study, Earth observation satellite data were used to map global forest loss (2.3 million square kilometers) and gain (0.8 million square kilometers) from 2000 to 2012 at a spatial resolution of 30 meters. The tropics were the only climate domain to exhibit a trend, with forest loss increasing by 2101 square kilometers per year. Brazil's well-documented reduction in deforestation was offset by increasing forest loss in Indonesia, Malaysia, Paraguay, Bolivia, Zambia, Angola, and elsewhere. Intensive forestry practiced within subtropical forests resulted in the highest rates of forest change globally. Boreal forest loss due largely to fire and forestry was second to that in the tropics in absolute and proportional terms. These results depict a globally consistent and locally relevant record of forest change.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NEW FOREST STORIES
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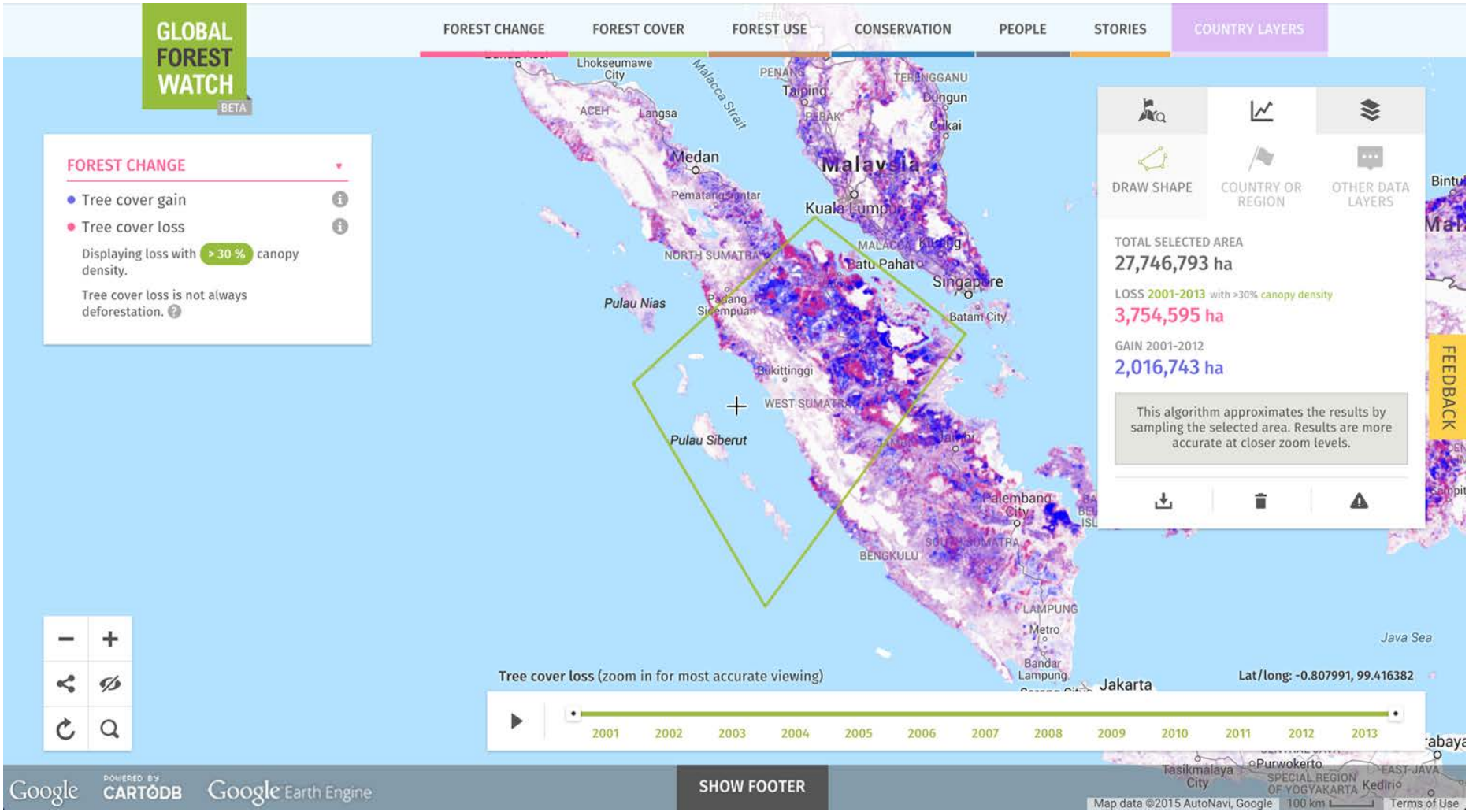
GLOBAL FOREST WATCH
BETA
FOREST CHANGE
FOREST COVER
FOREST USE
CONSERVATION
PEOPLE
STORIES
COUNTRY LAYERS
FOREST CHANGE
Tree cover gain
Tree cover loss
Displaying loss with > 30 % canopy density.
Tree cover loss is not always deforestation.
DRAW SHAPE
COUNTRY OR REGION
OTHER DATA LAYERS
TOTAL SELECTED AREA
27,746,793 ha
LOSS 2001-2013 with >30% canopy density
3,754,595 ha
GAIN 2001-2012
2,016,743 ha
This algorithm approximates the results by sampling the selected area. Results are more accurate at closer zoom levels.
FEEDBACK
Malaysia
Kuala Lumpur
Singapore
Medan
Pulau Nias
Pulau Siberut
Tree cover loss (zoom in for most accurate viewing)
Lat/long: -0.807991, 99.416382
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Java Sea
Jakarta
SHOW FOOTER
Google
CARTODB
Google Earth Engine
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Thank You!

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