

Investigating Time Series of Satellite Imagery

Cindy Schmidt, Amber McCullum

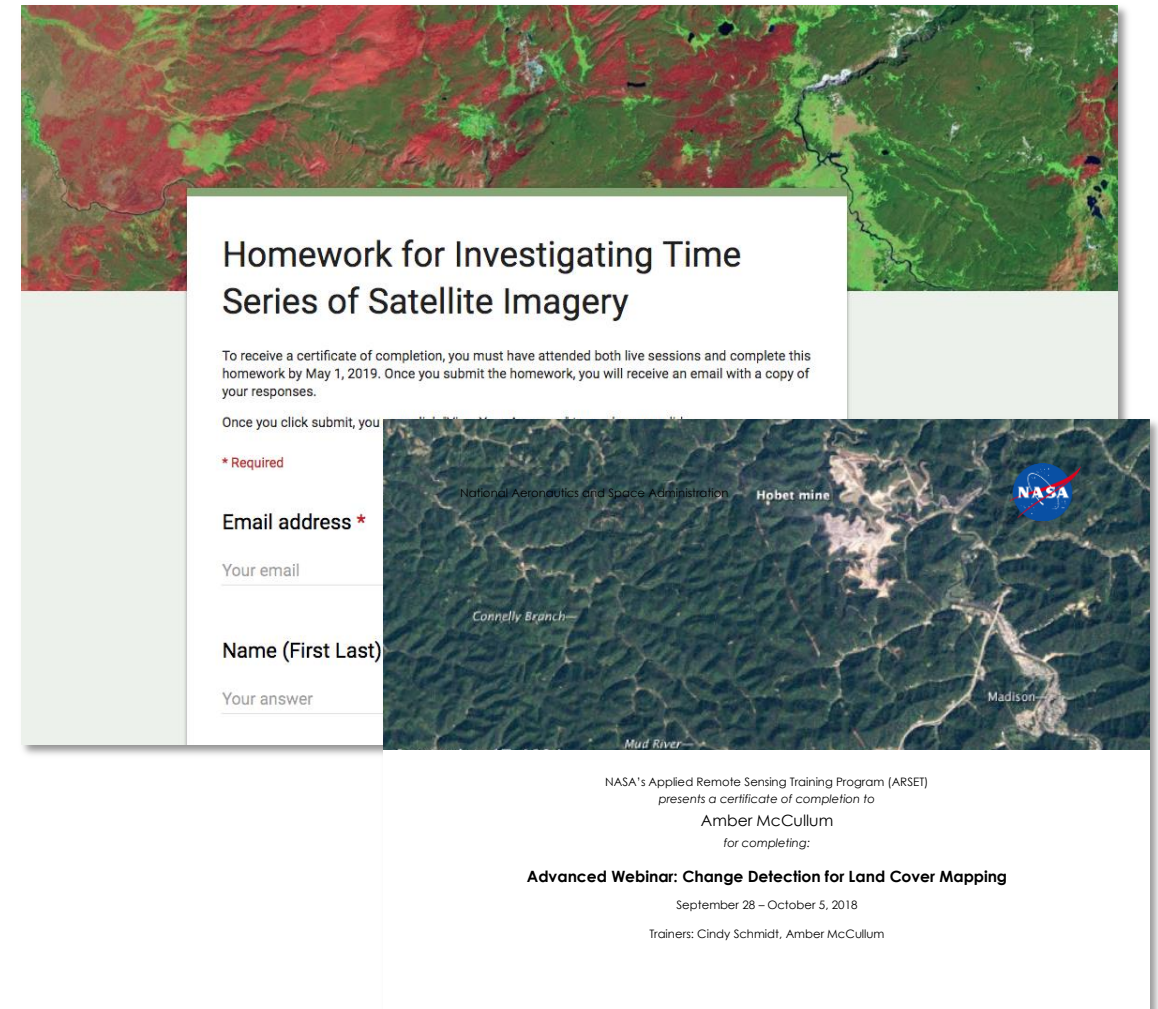
April 15, 2019

Course Structure

- Two, two-hour sessions on April 15 and April 17, 2019
- The same content will be presented at two different times each day:
 - Session A: 10:00-12:00 EST (UTC-4)
 - Session B: 18:00-20:00 EST (UTC-4)
 - **Please only sign up for and attend one session per day**
- Webinar recordings, PowerPoint presentations, and the homework assignment can be found after each session at:
 - <https://arset.gsfc.nasa.gov/land/webinars/time-series-19>
- Q&A: Following each lecture and/or by email
 - cynthia.l.schmidt@nasa.gov, or
 - amberjean.mccullum@nasa.gov

Homework and Certificates

- Homework
 - One homework assignment
 - Answers must be submitted via Google Forms
- Certificate of Completion:
 - Attend both live webinars
 - Complete the homework assignment by the deadline (access from ARSET website)
 - **HW Deadline: Wednesday May 1st**
 - You will receive certificates approximately two months after the completion of the course from:
marines.martins@ssaihq.com



Homework for Investigating Time Series of Satellite Imagery

To receive a certificate of completion, you must have attended both live sessions and complete this homework by May 1, 2019. Once you submit the homework, you will receive an email with a copy of your responses.

Once you click submit, you

*** Required**

Email address *

Your email

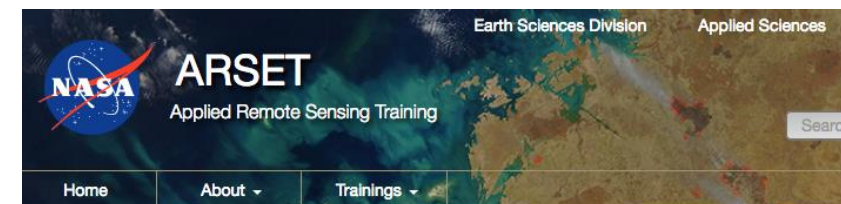
Name (First Last)

Your answer

NASA's Applied Remote Sensing Training Program (ARSET)
presents a certificate of completion to
Amber McCullum
for completing:
Advanced Webinar: Change Detection for Land Cover Mapping
September 28 – October 5, 2018
Trainers: Cindy Schmidt, Amber McCullum

Prerequisites

- ARSET Webinar *Introduction to Remote Sensing* or equivalent knowledge
- Complete the [Advanced Webinar: Change Detection for Land Cover Mapping](#)
- Install Google Chrome: <https://www.google.com/chrome/>
 - For the Google Earth Engine exercise, Chrome should be used to make sure all features work
- Sign up for the Google Earth Engine Code Editor: <https://signup.earthengine.google.com/>



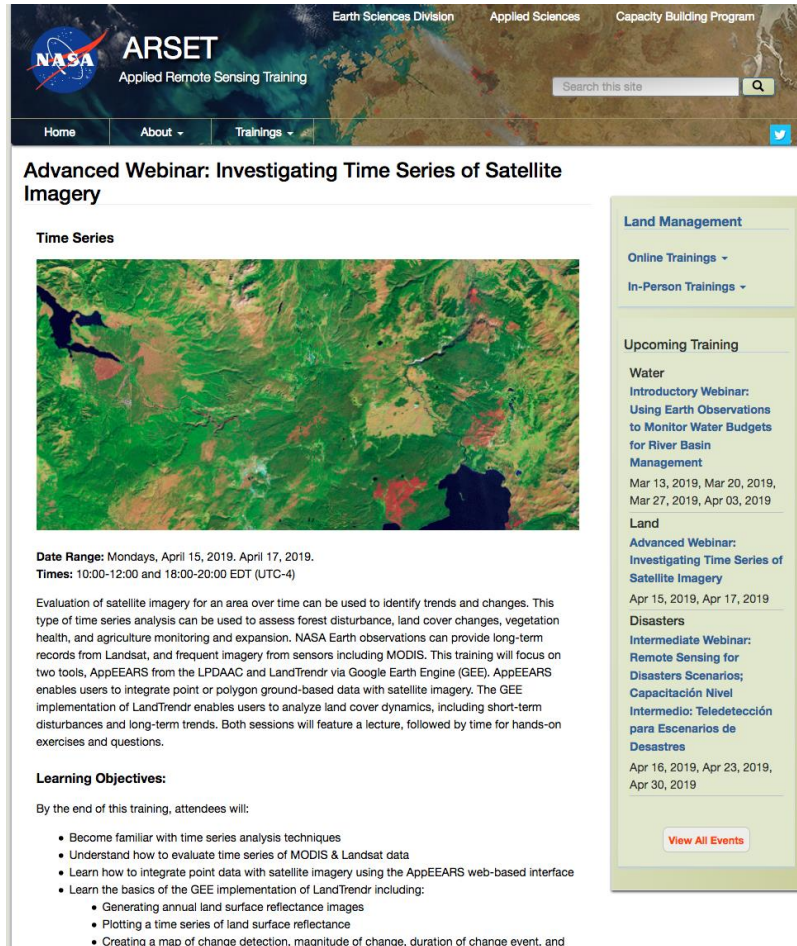
Advanced Webinar: Change Detection for Land Cover Mapping



Google Chrome

Accessing Course Materials

<https://arset.gsfc.nasa.gov/land/webinars/time-series-19>



The screenshot shows the ARSET (Applied Remote Sensing Training) website. The header includes the NASA logo, 'ARSET Applied Remote Sensing Training', and navigation links for 'Home', 'About', and 'Trainings'. The main content area is titled 'Advanced Webinar: Investigating Time Series of Satellite Imagery'. It features a satellite image of a landscape with a river and a lake. Below the image, the text describes the course content, including the date range (Mondays, April 15 and 17, 2019), times (10:00-12:00 and 18:00-20:00 EDT), and a detailed description of the training. The 'Learning Objectives' section lists several goals, such as becoming familiar with time series analysis techniques and learning how to use the AppEEARS interface. A sidebar on the right lists other training topics like 'Land Management', 'Online Trainings', and 'Upcoming Training'.

ARSET
Applied Remote Sensing Training


Earth Sciences Division Applied Sciences Capacity Building Program

Search this site

Home About Trainings

Advanced Webinar: Investigating Time Series of Satellite Imagery

Time Series



Date Range: Mondays, April 15, 2019, April 17, 2019.
Times: 10:00-12:00 and 18:00-20:00 EDT (UTC-4)

Evaluation of satellite imagery for an area over time can be used to identify trends and changes. This type of time series analysis can be used to assess forest disturbance, land cover changes, vegetation health, and agriculture monitoring and expansion. NASA Earth observations can provide long-term records from Landsat, and frequent imagery from sensors including MODIS. This training will focus on two tools, AppEEARS from the LPDAAC and LandTrendr via Google Earth Engine (GEE). AppEEARS enables users to integrate point or polygon ground-based data with satellite imagery. The GEE implementation of LandTrendr enables users to analyze land cover dynamics, including short-term disturbances and long-term trends. Both sessions will feature a lecture, followed by time for hands-on exercises and questions.

Learning Objectives:

By the end of this training, attendees will:

- Become familiar with time series analysis techniques
- Understand how to evaluate time series of MODIS & Landsat data
- Learn how to integrate point data with satellite imagery using the AppEEARS web-based interface
- Learn the basics of the GEE implementation of LandTrendr including:
 - Generating annual land surface reflectance images
 - Plotting a time series of land surface reflectance
 - Creating a map of change detection, magnitude of change, duration of change event, and

Upcoming Training

Water
Introductory Webinar:
Using Earth Observations
to Monitor Water Budgets
for River Basin
Management
Mar 13, 2019, Mar 20, 2019,
Mar 27, 2019, Apr 03, 2019

Land
Advanced Webinar:
Investigating Time Series of
Satellite Imagery
Apr 15, 2019, Apr 17, 2019

Disasters
Intermediate Webinar:
Remote Sensing for
Disasters Scenarios;
Capacitación Nivel
Intermedio: Teledetección
para Escenarios de
Desastres
Apr 16, 2019, Apr 23, 2019,
Apr 30, 2019

[View All Events](#)

Prerequisites:

Attendees that do not complete prerequisites may not be adequately prepared for the pace of the course.

- Complete **Sessions 1 & 2A of Fundamentals of Remote Sensing**, or equivalent experience
- Complete the **Advanced Webinar: Change Detection for Land Cover Mapping**
- Install Google Chrome: <https://www.google.com/chrome/>
 - For the Google Earth Engine exercise, Chrome should be used to make sure all features work
- Sign up for the Google Earth Engine Code Editor: <https://signup.earthengine.google.com/>

Audience:

Advanced users of remote sensing data within local, regional, state, federal, and non-governmental organizations involved in land management and conservation efforts. Professional organizations in the public and private sectors engaged in environmental management and monitoring will be given preference over organizations focused primarily on research.

Registration Information:

There is no cost for the webinar, but you must register to attend the sessions. Because we anticipate a high demand for this training, please only sign up for one session. Sessions will only be broadcast in English - Session A will cover the same content as Session B. Professional organizations in the public and private sectors engaged in water resources management and monitoring will be given preference over organizations focused primarily on research.

- [Register for Session A, 10:00-12:00 EDT \(UTC-4\)](#) »
- [Register for Session B, 18:00-20:00 EDT \(UTC-4\)](#) »

Course Agenda:

[Agenda_41.pdf](#)

April 15, 2019

This session will include a review of MODIS and Landsat, a review of change detection, an overview of time series analysis methods, and an AppEEARS hands-on exercise.

Application Area: Land

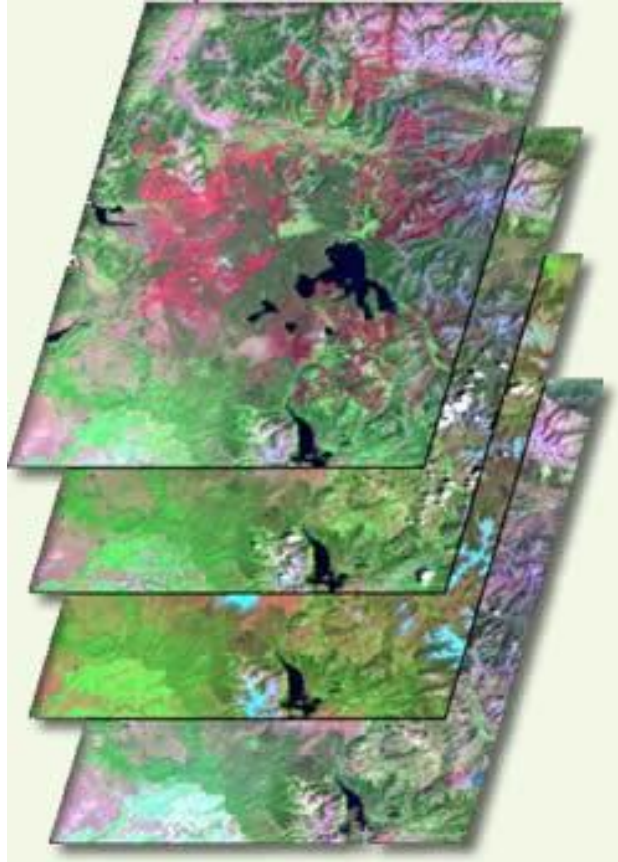
Available Languages: English

Instruments/Missions: Terra, Landsat, MODIS, Aqua

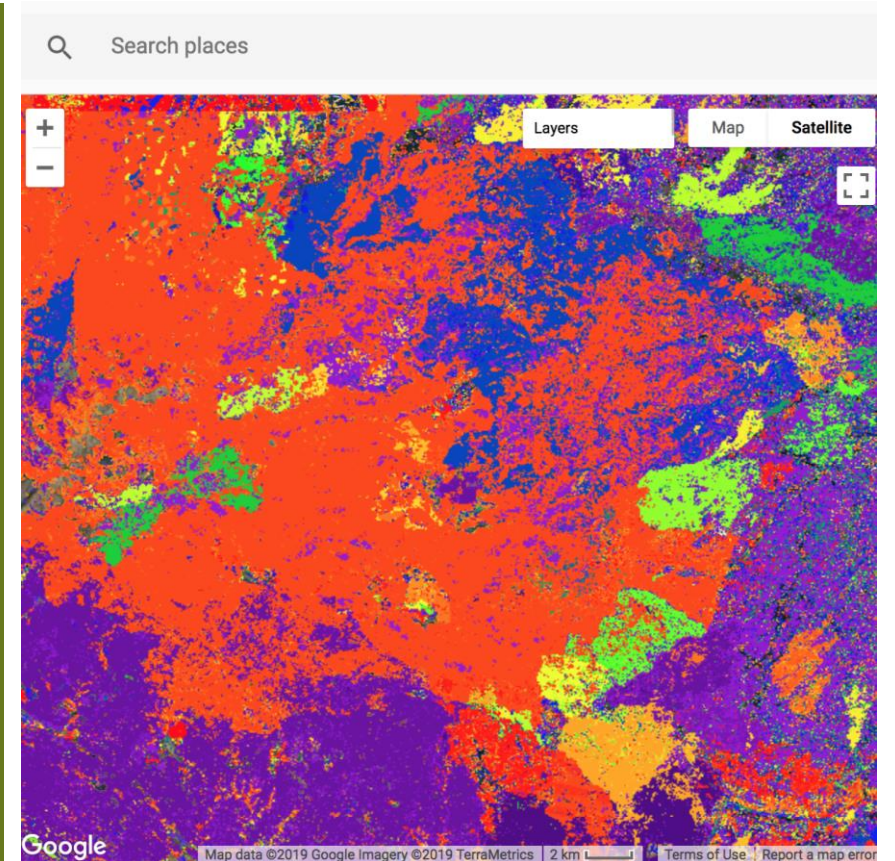
Keywords: Ecosystems, Land-Cover and Land-Use Change (LCLUC), Satellite Imagery, Tools

Course Outline

Session 1:
Intro to Time
Series and
AppEEARS

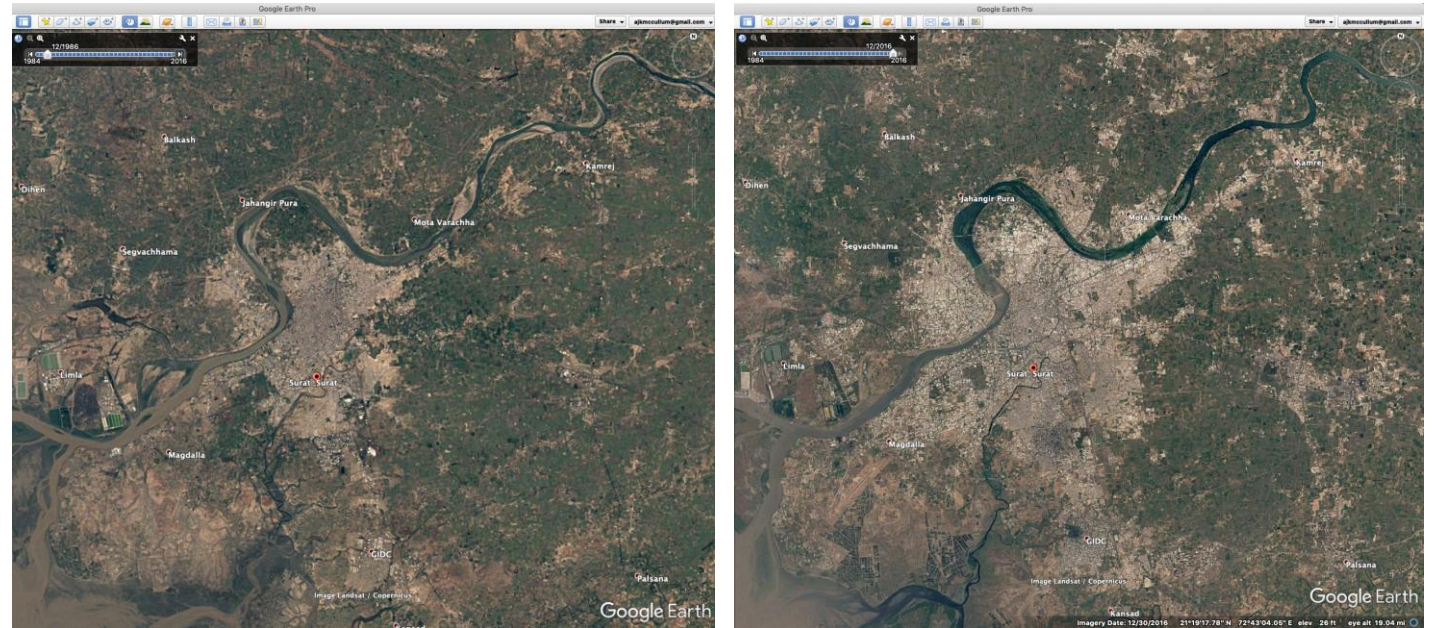


Session 2:
LandTrendr
Overview
and
Applications

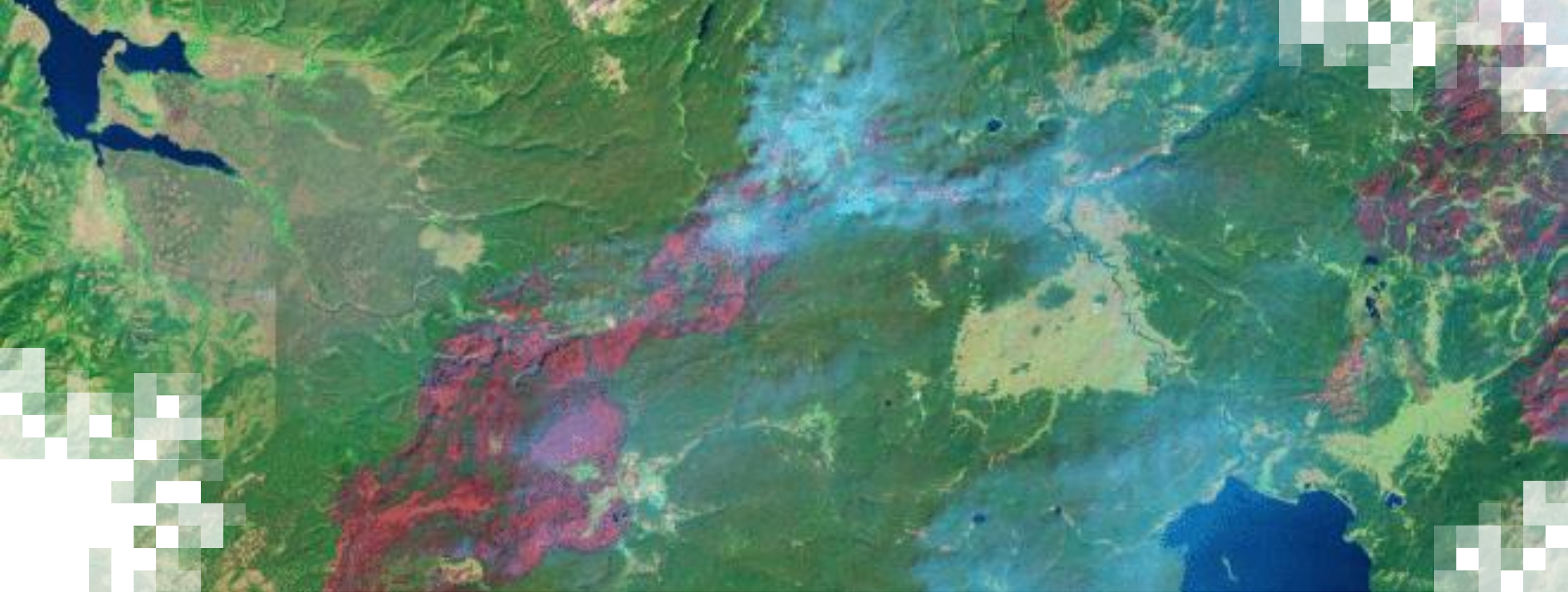


Session 1 Agenda

- Overview of time series satellite imagery
- Types of time series analysis:
 - Annual and Seasonal Trends
 - Anomalies
 - Environmental Descriptors
- Time Series Tools
- Sustainable Development Goals (SDGs)
 - Open Data Cubes
- Overview of AppEEARS



Google Earth Pro (with time slider). Images of Surat, India, one of the fastest growing cities in the world from 1986 (left) and 2016 (right).

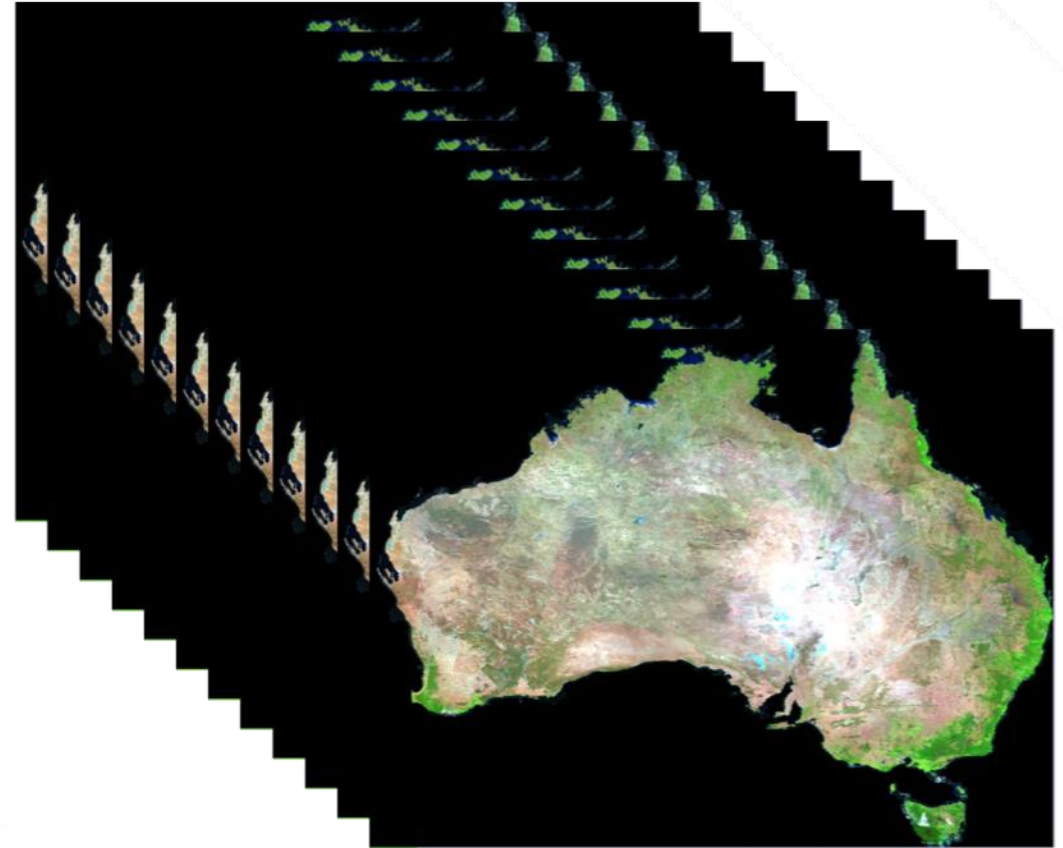


Overview of Time Series Satellite Imagery

Satellite Time Series

Our ability to identify changes over time has changed because:

- The availability of long term satellite data sets
 - Landsat (30+ years)
 - MODIS (18 years)
- Increased computing power and cloud computing
- Improved processing methods

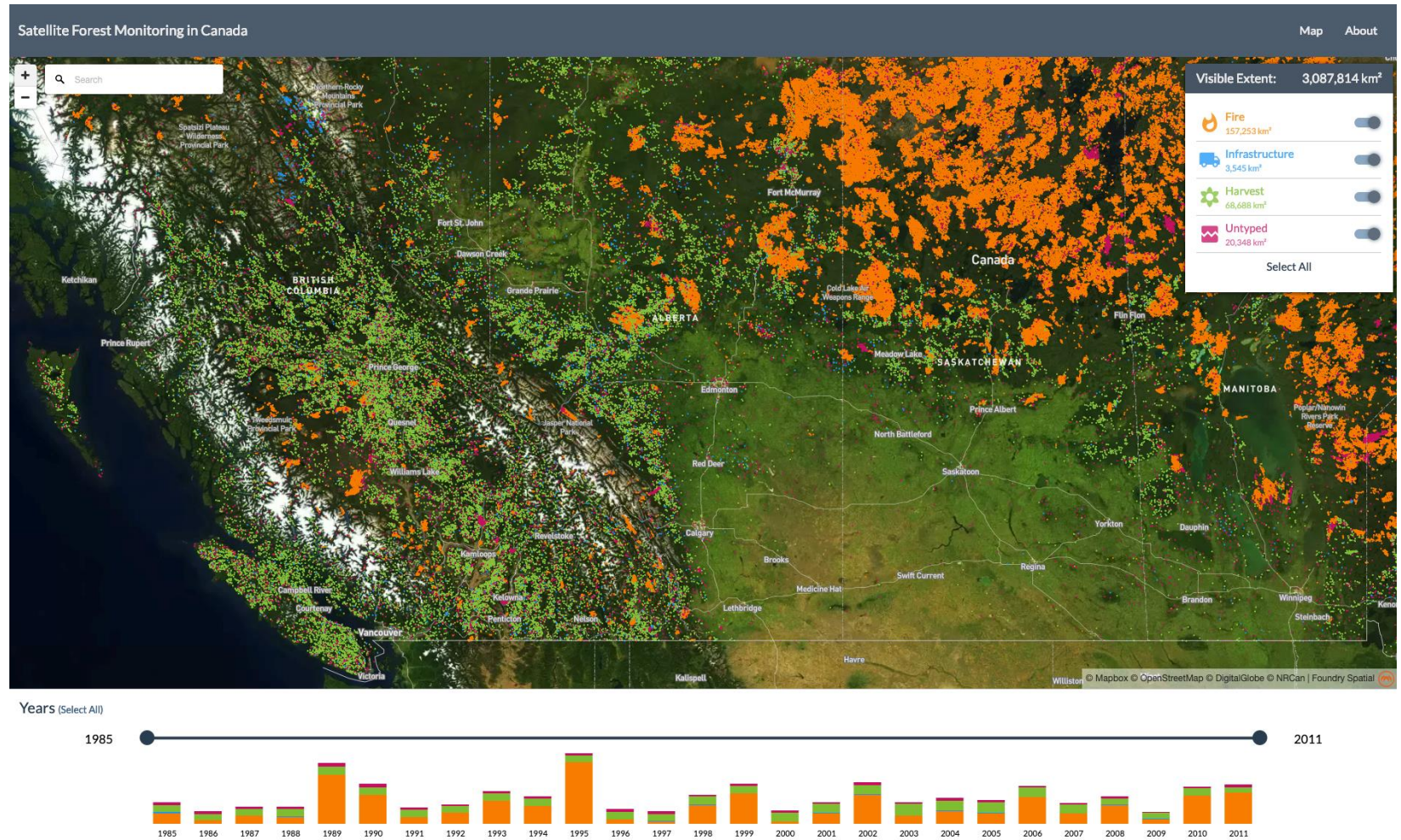


Stack of Landsat images of Australia

Image credit: [Data Cube](#).

Types of Time Series Analysis

- Annual vs. seasonal trends
- Gradual vs. abrupt changes
- Anomalies
- Environmental descriptors



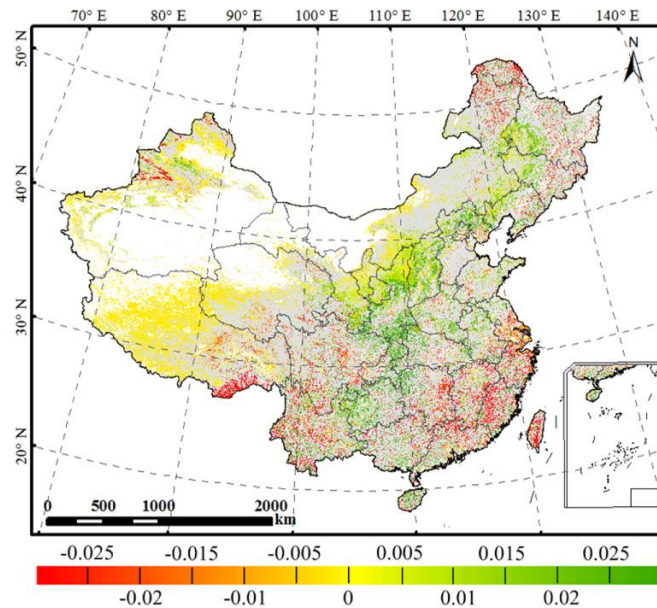
Satellite forest monitoring in Canada. Image credit: [Foundry Spatial](#)

Annual vs. Seasonal Trends

- Annual Trends
 - Annual land cover/land use changes over long time periods
 - Ex: Trends in vegetation greenness in China

Annual mean Leaf Area Index (LAI) during 2000-2014 from MODIS

These data were used to analyze the change in evapotranspiration and water yield



- Seasonal Trends
 - Driven by annual temperature and/or precipitation
 - Ex: Snow cover monitoring in the Himalayas

Seasonal snow cover based on MODIS snow cover time series from Mar 2000 to Feb 2008. (Winter, (top), Spring, Summer Autumn (bottom)

The values show the percentage of time that a pixel was snow-covered during the season within the time period

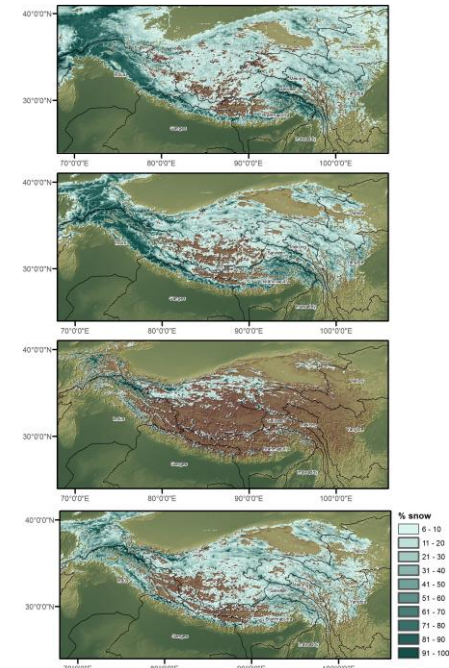
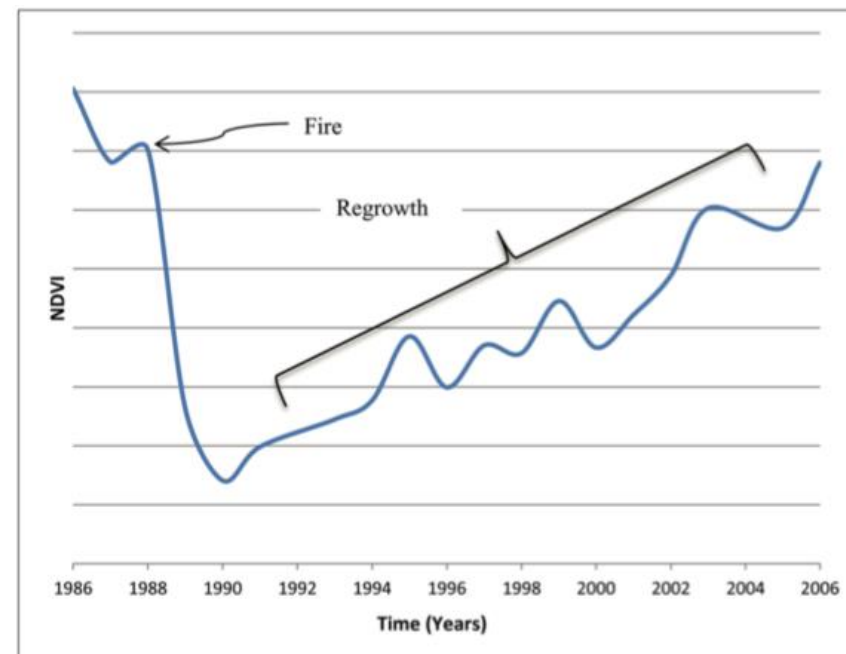


Image Credits: (left) Liu, Y. et al. (2016) Recent trends in vegetation greenness in China significantly altered annual evapotranspiration and water yield, Environmental Research Letters; (right) Immerzeel, W.W. et al. (2009). Large-scale monitoring of snow cover and runoff simulation in Himalayan river basins using remote sensing, Remote Sensing of Environment

Gradual vs. Abrupt Changes

- Gradual changes:
 - Insect infestation in forests
 - Land degradation
 - Forest recovery
- Abrupt changes:
 - Wildfire
 - Deforestation
 - Urban development

- Example: Forest recovery after wildfire in Yellowstone National Park

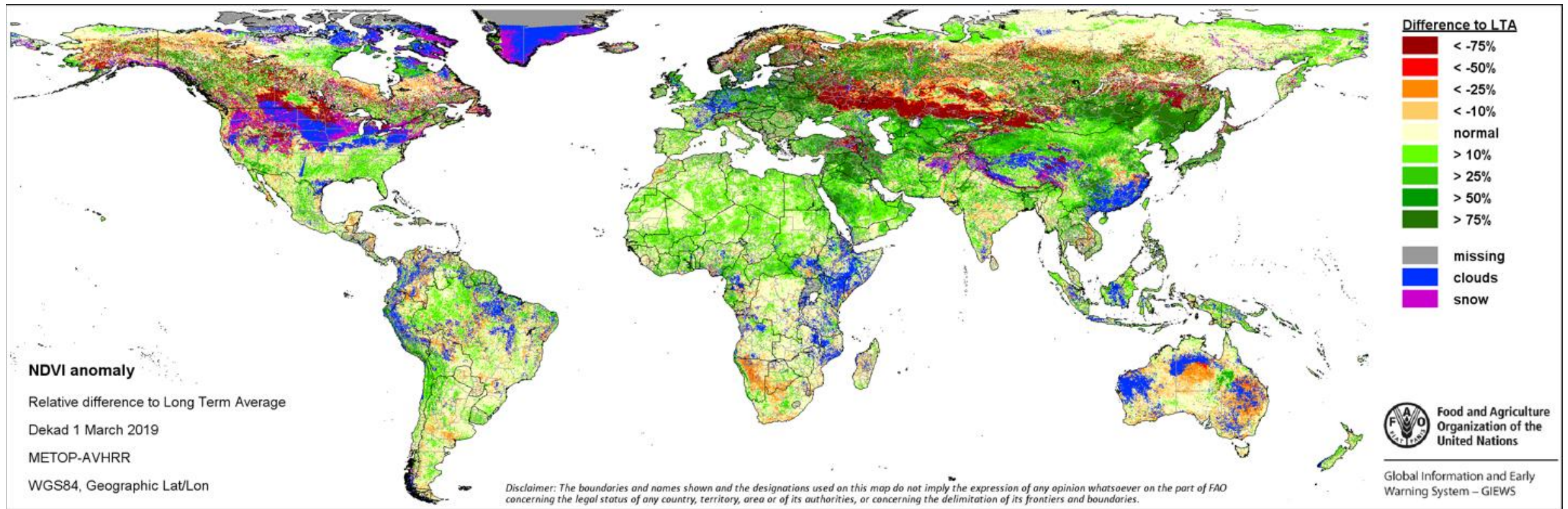


Changes in NDVI values between 1986 and 2006 for one site in Yellowstone National Park

Image Credit: Franks, S. et al. (2013). Monitoring forest regrowth following large scale fire using satellite data- A case study of Yellowstone National Park, USA, European Journal of Remote Sensing

Anomalies

- Relative difference from a long term average
- Example: FAO Global NDVI Anomalies

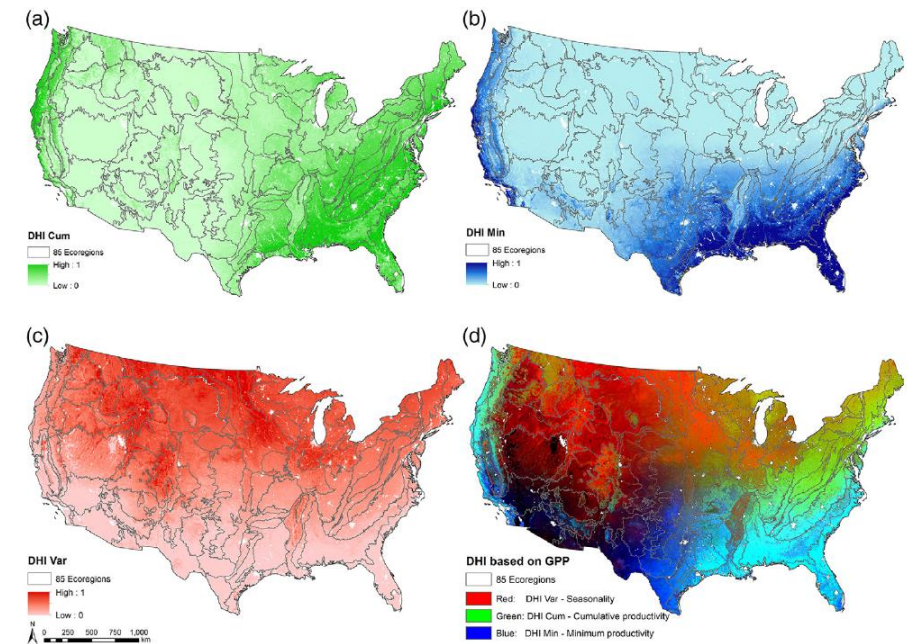


<http://www.fao.org/giews/earthobservation/>

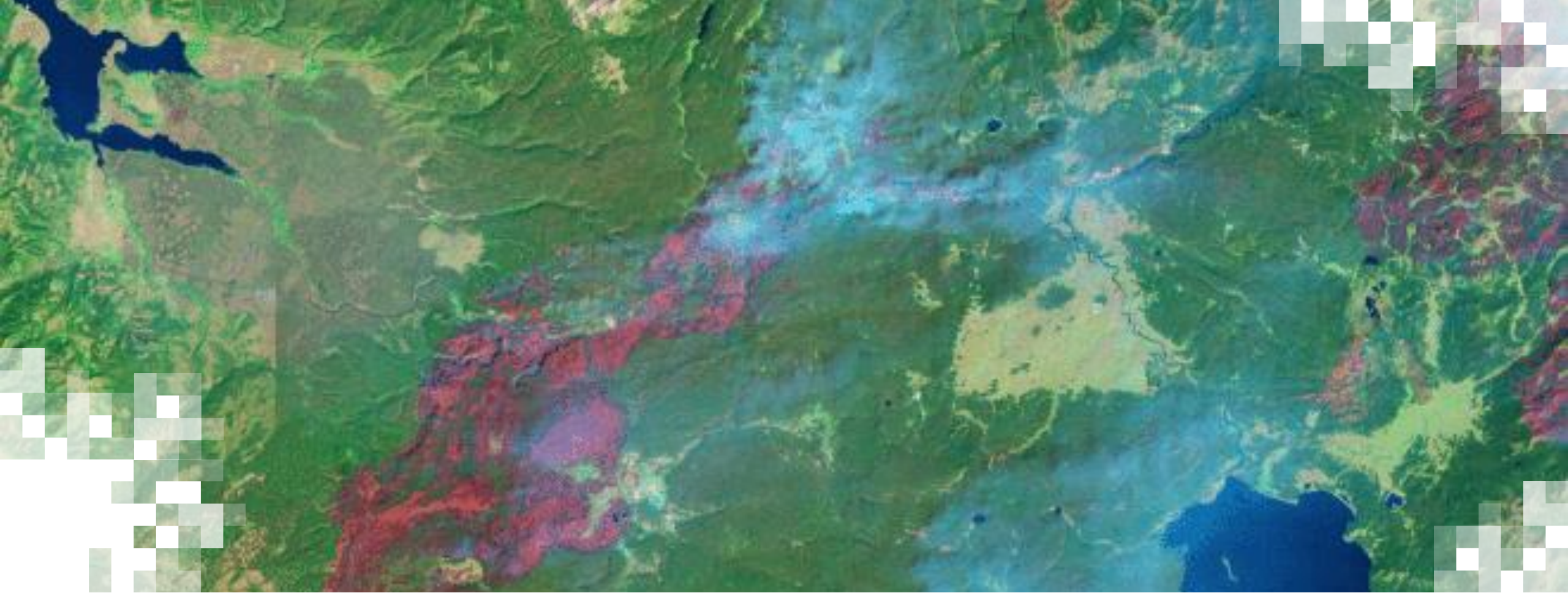
Environmental Descriptors

- Use time series of satellite observations to derive environmental descriptors
- Example: Dynamic Habitat Indices (DHIs) use time series of satellite observations of greenness to describe vegetation dynamics to understand bird species richness
 - DHIs capture seasonal variations in energy that species can utilize in the form of food
 - Vegetation dynamics include: productivity, minimum level of perennial cover, degree of vegetation seasonality

Dynamic Habitat Indices derived from MODIS GPP 2003-2014 data
(a) cumulative DHI; (b) minimum DHI;
(c) variation DHI; (d) combined DHI



Hobi, M.L. et al. (2017). A comparison of Dynamic Habitat Indices derived from different MODIS products as predictors of avian species richness, Remote Sensing of Environment.

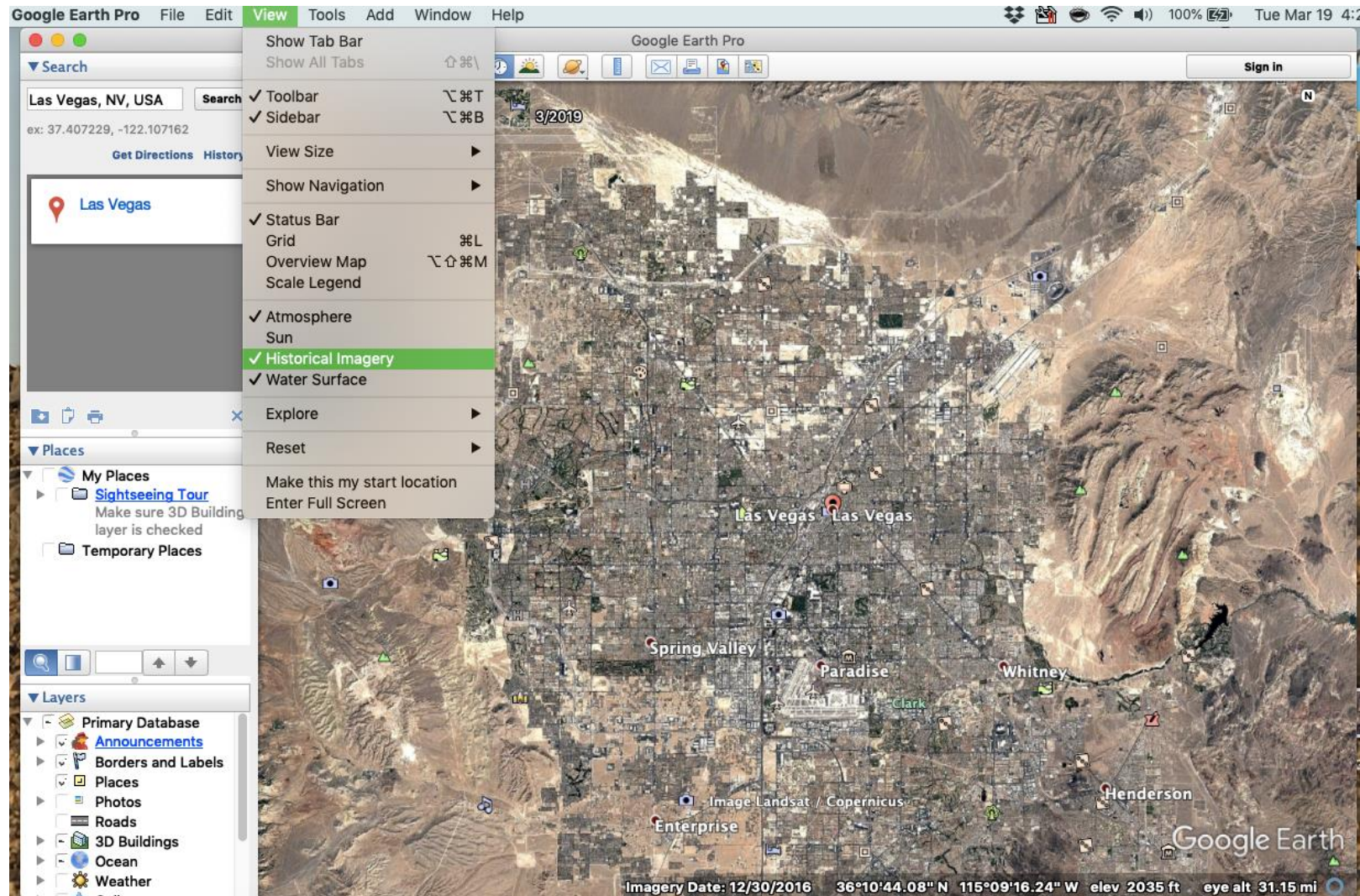


Time Series Tools

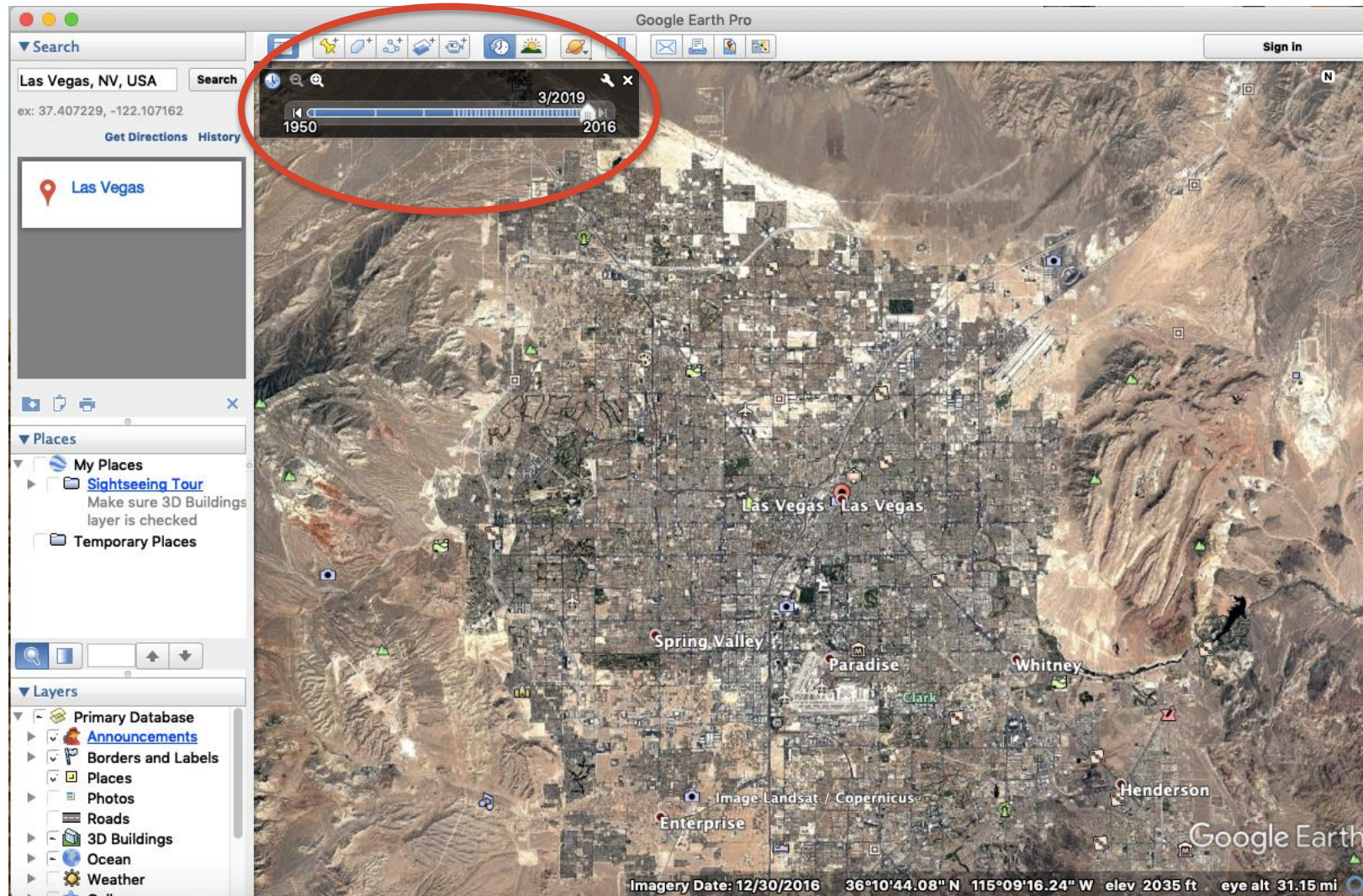
Time Series Tools

- Visualizing time series
 - Google Earth Engine Time Lapse
 - Google Earth
 - Sentinel Hub EO Browser (European Space Agency)
- Analyzing time series
 - Open Data Cube
 - BFAST
 - AppEEARS (Land Processes DAAC)
 - Landtrendr (next week)

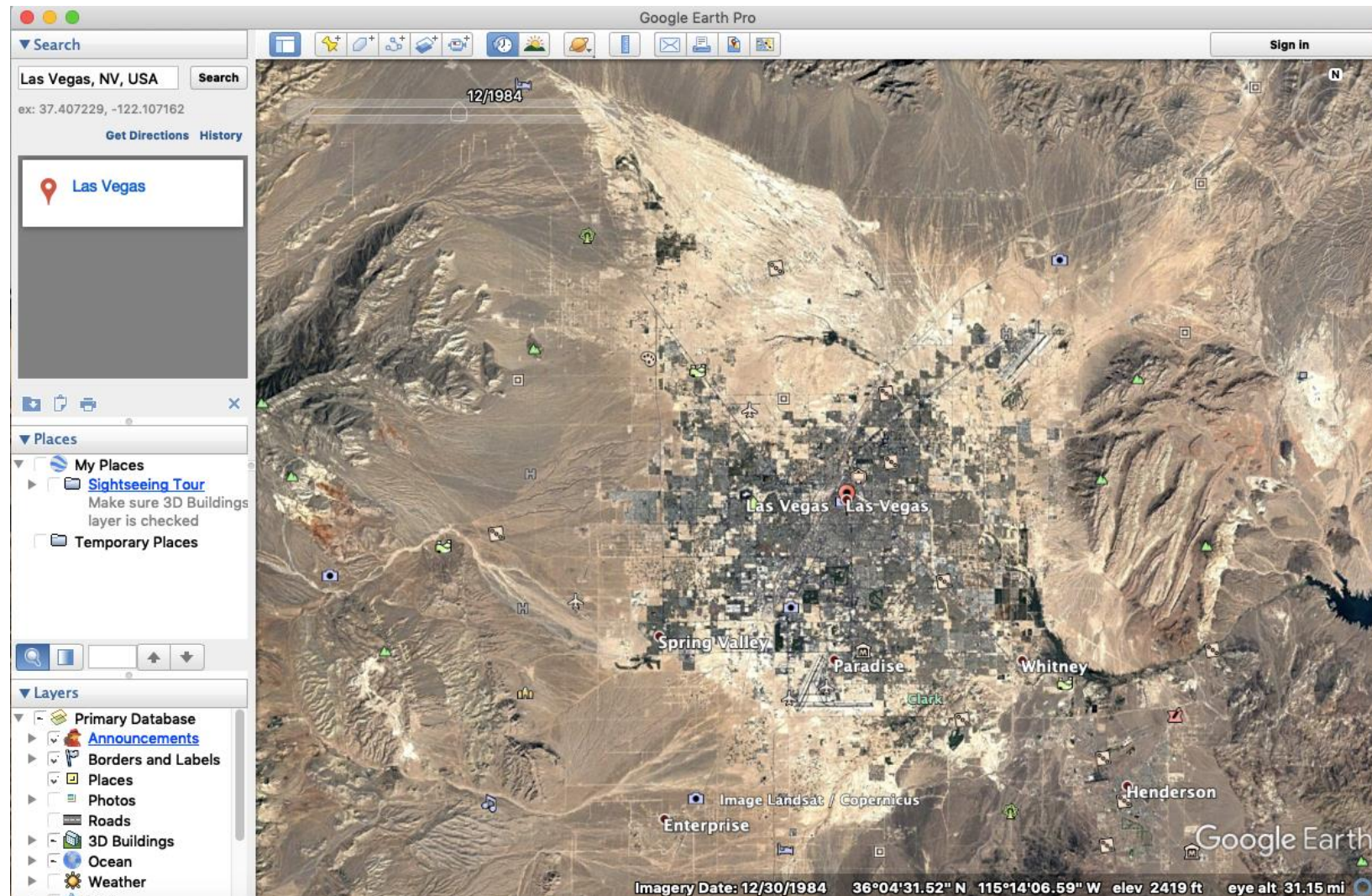
Google Earth: Las Vegas



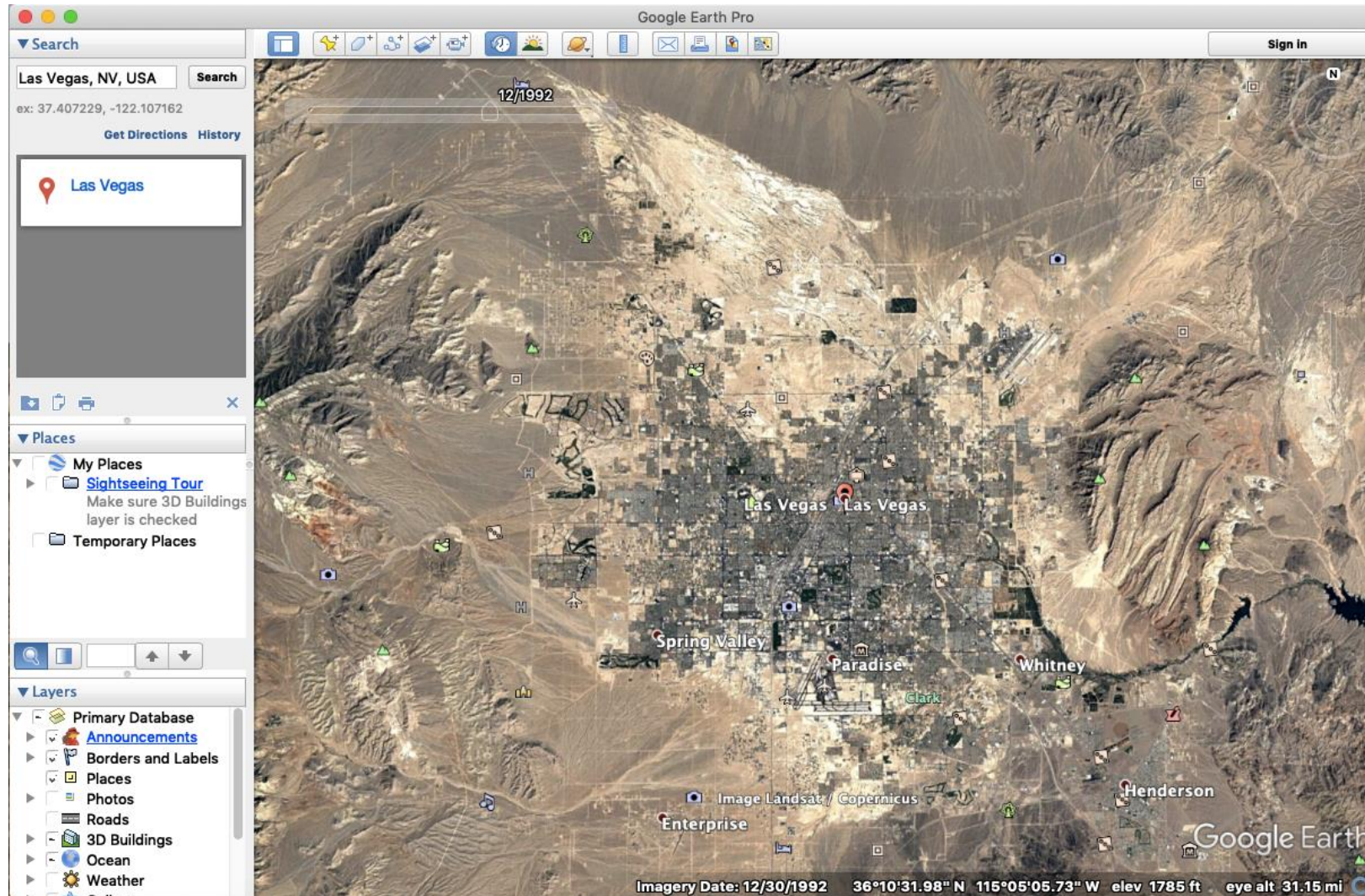
Las Vegas 2016



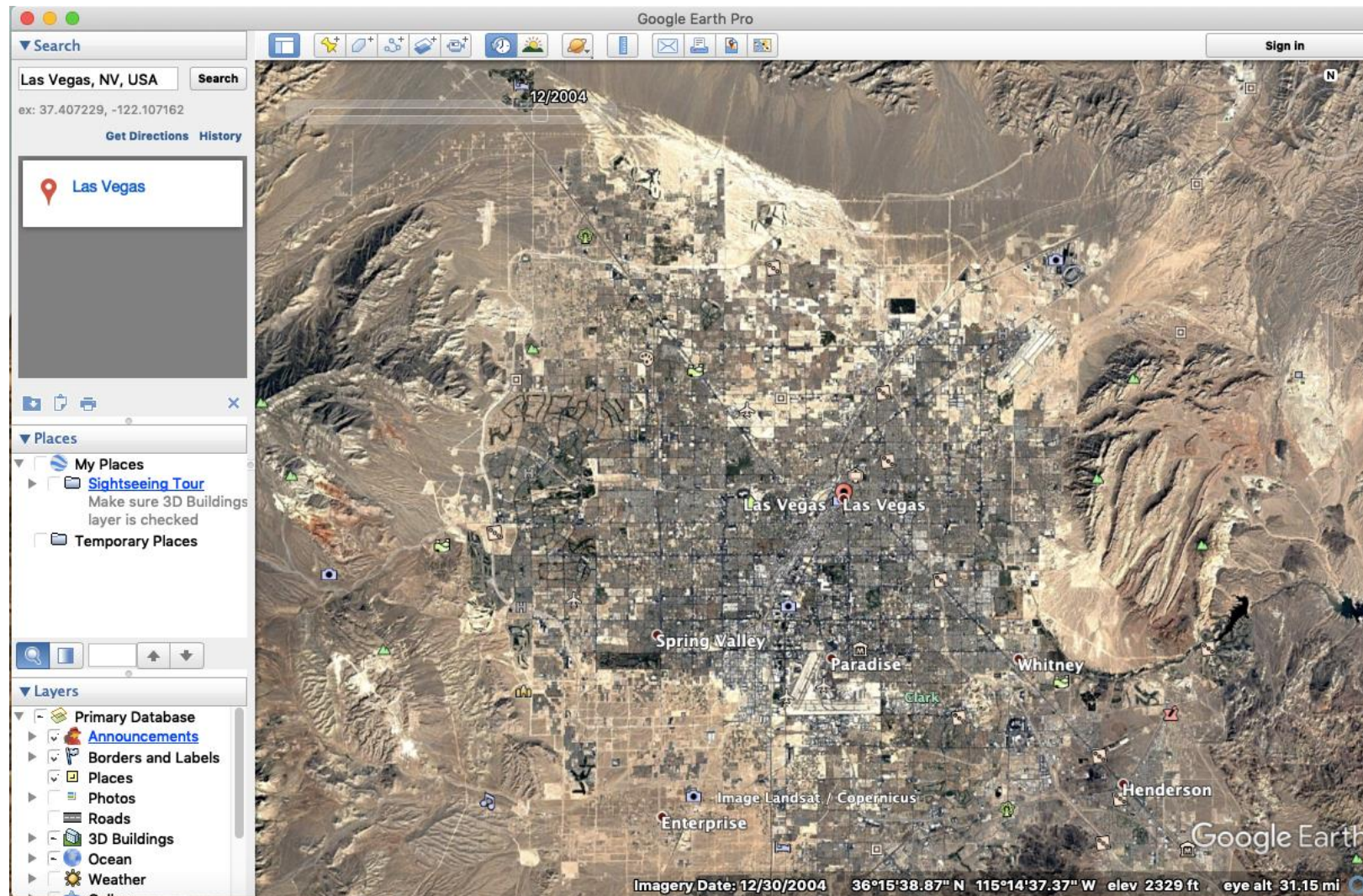
Las Vegas 1984



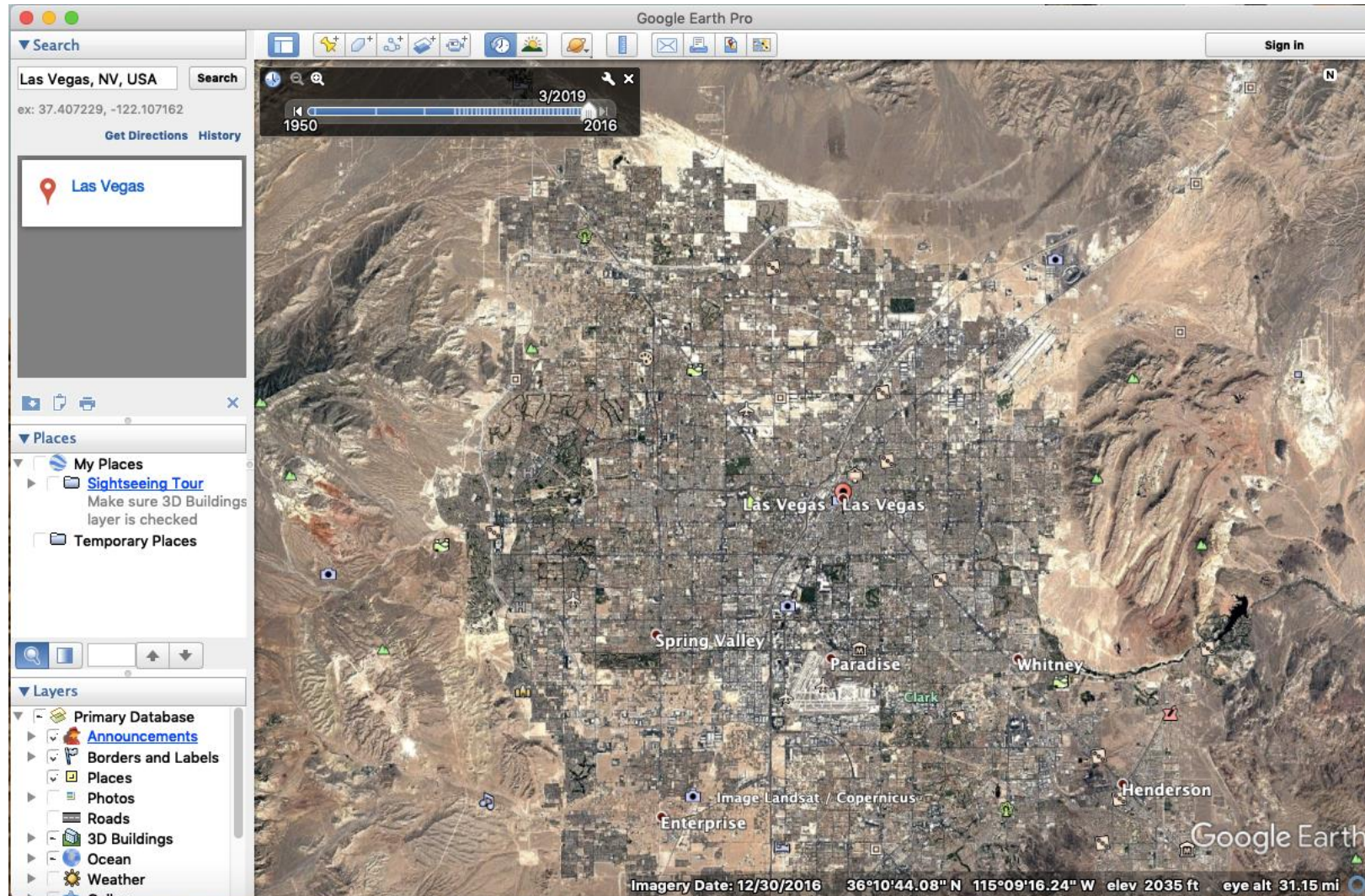
Las Vegas 1992



Las Vegas 2004



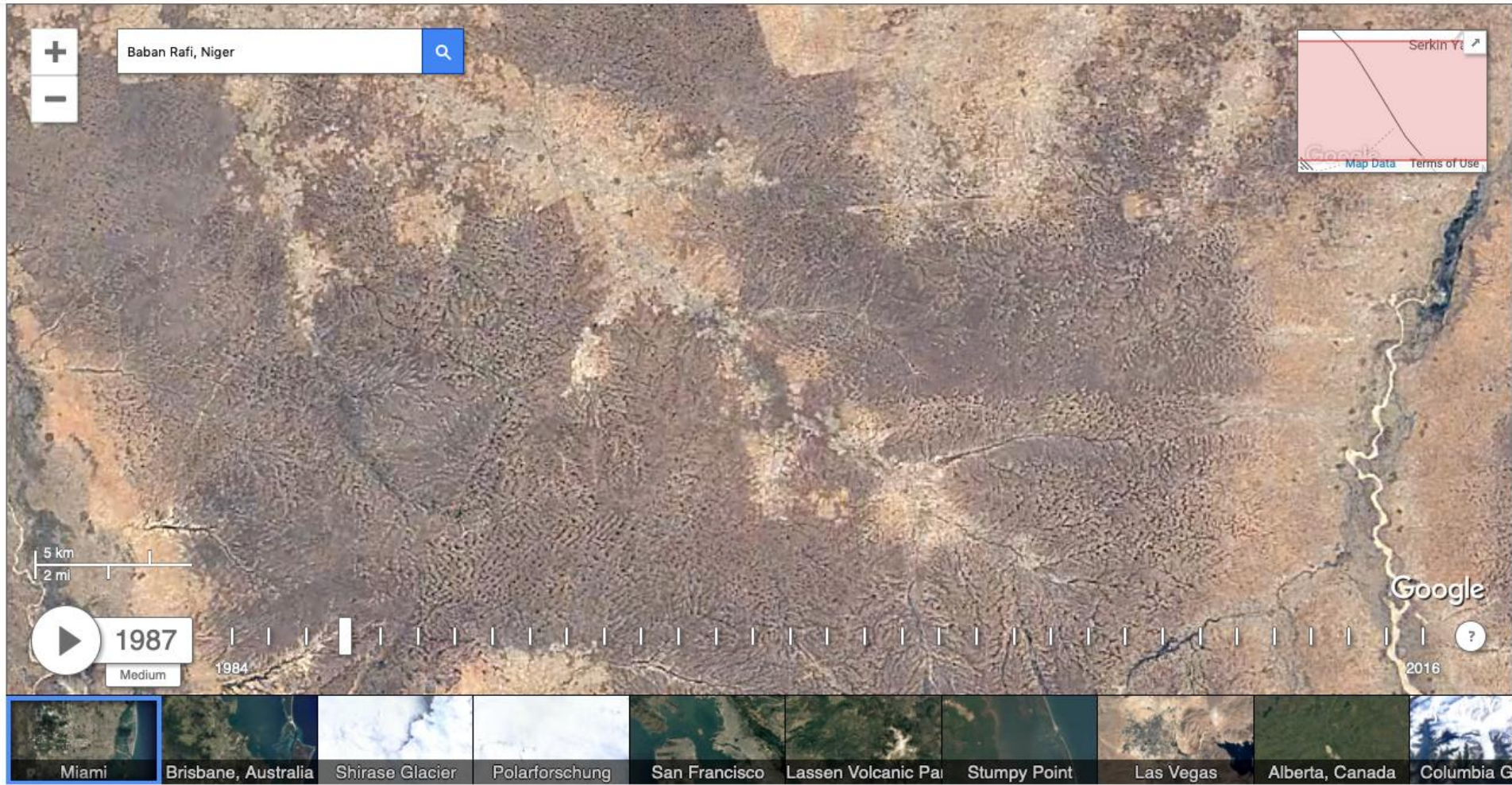
Las Vegas 2016



Google Earth Engine Time Lapse: Baban Rafi Forest, Niger

Google Earth Engine

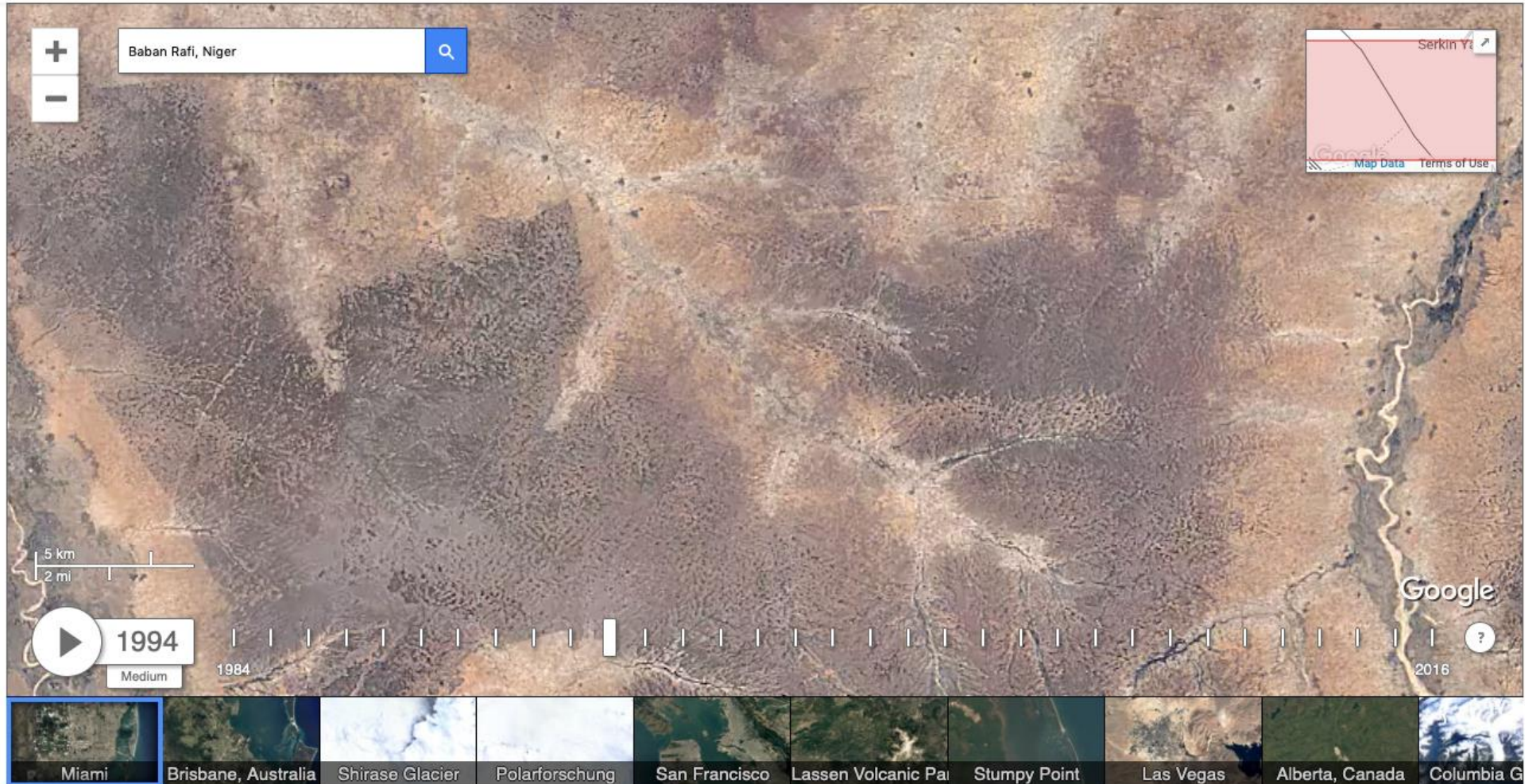
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Google Earth Engine Time Lapse: Baban Rafi Forest, Niger

Google Earth Engine

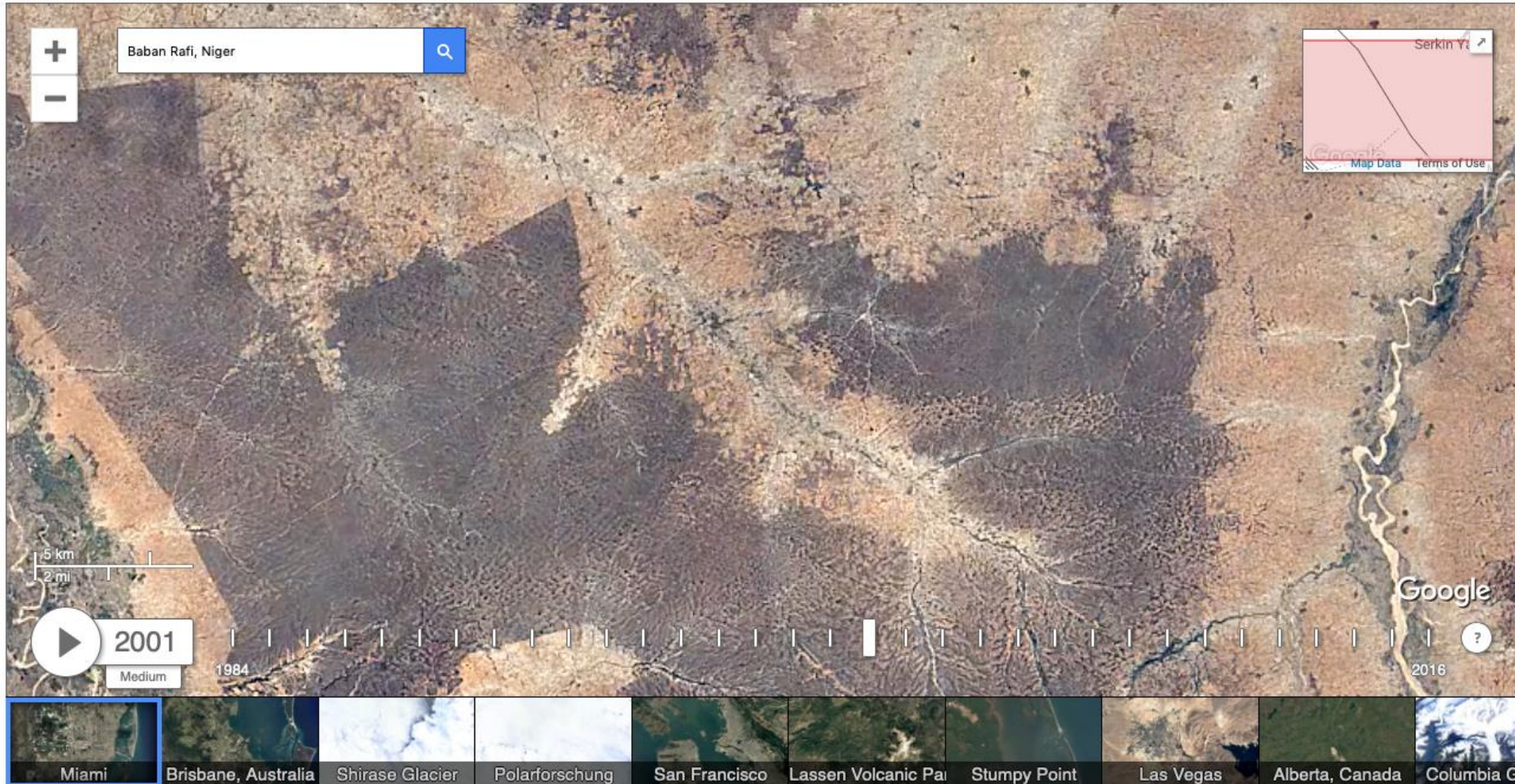
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Google Earth Engine Time Lapse: Baban Rafi Forest, Niger

Google Earth Engine

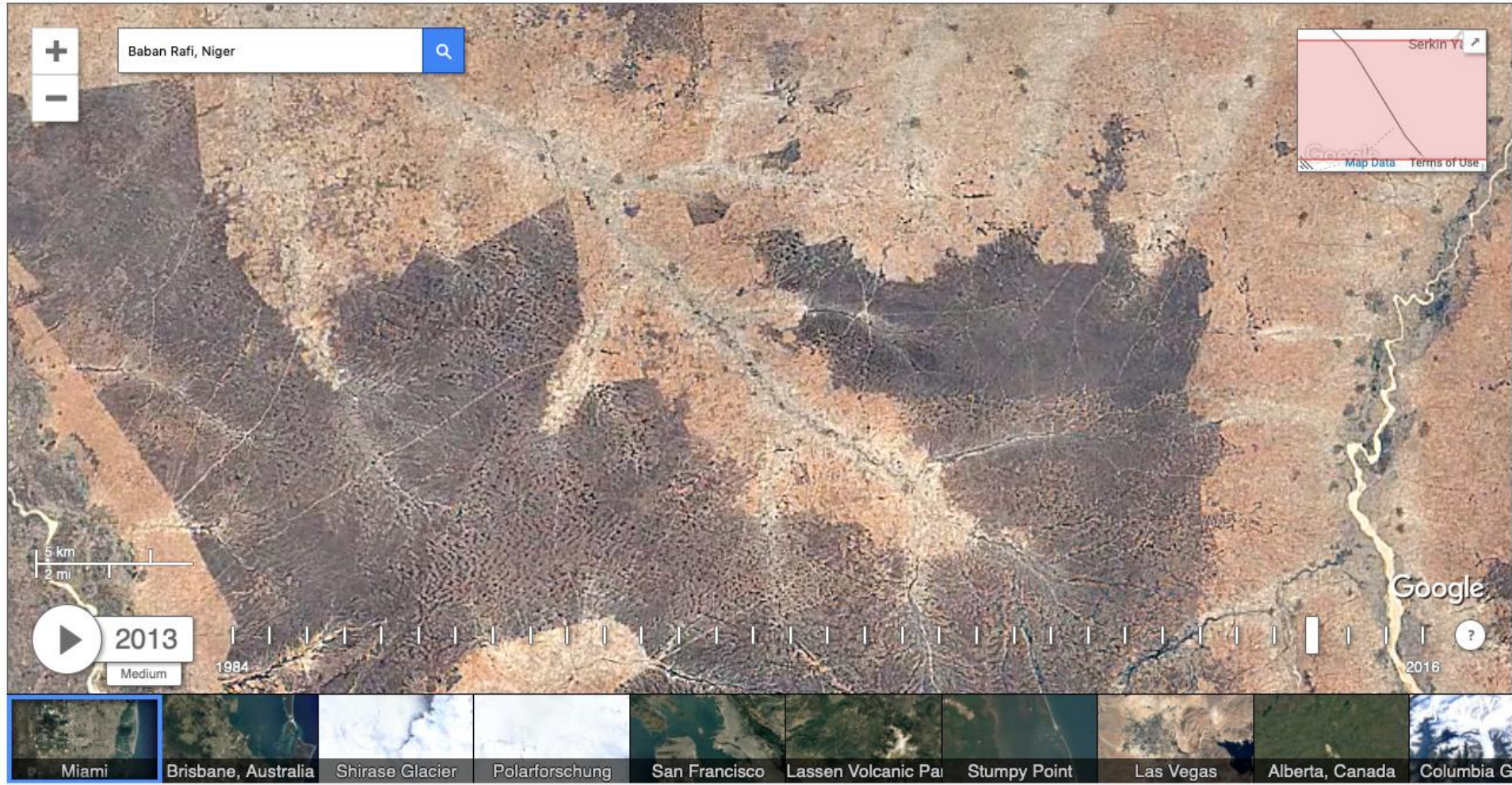
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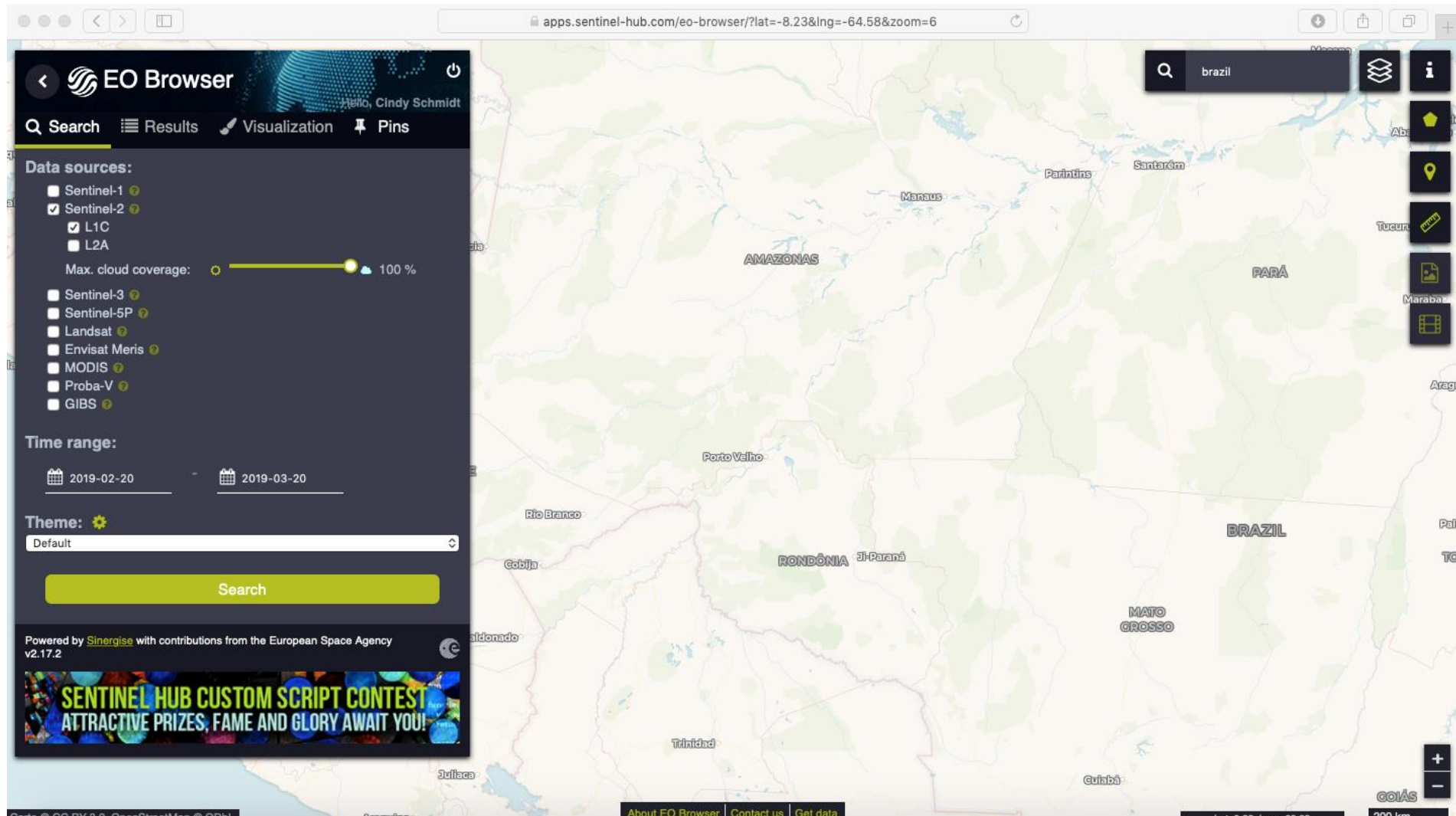
Google Earth Engine Time Lapse: Baban Rafi Forest, Niger

Google Earth Engine

[Datasets](#) [FAQ](#) [Timelapse](#) [Case Studies](#) [Platform](#) [Blog](#) [Sign In](#)



Sentinel Hub EO Browser: Brazil



Sentinel Hub EO Browser: Brazil

The screenshot displays the Sentinel Hub EO Browser interface. The browser address bar shows the URL: `apps.sentinel-hub.com/eo-browser/?lat=-8.23&lng=-64.58&zoom=6`. The interface includes a search bar with the text "brazil", a navigation menu with "Search", "Results", "Visualization", and "Pins", and a "Results" panel on the left. The "Results" panel shows 50 results, with three visible entries for March 19, 2019. Each entry includes a thumbnail, acquisition time, cloud cover percentage, EPSG code, and a "Visualize" button. The map on the right shows a satellite view of Brazil with several blue rectangular search areas overlaid. The map labels include "AMAZONAS", "PARÁ", "RONDÔNIA", "MATO GROSSO", "Rio Branco", "Gobjia", "Trindade", "Guibá", "Porto Velho", "Manaus", "Parintins", "Santarém", "Tucuru", "Marabá", "Araguaína", "Painópolis", and "TOCANTINS". The bottom of the interface features a banner for the "SENTINEL HUB CUSTOM SCRIPT CONTEST" and a footer with "About EO Browser", "Contact us", and "Get data" links.

Results

Showing 50 results. [Clear data](#)

- 2019-03-19
15:24:02 UTC
1.71 %
EPSG:4326
18LVK
[Visualize](#)
- 2019-03-19
14:43:03 UTC
2.54 %
EPSG:4326
20LNL
[Visualize](#)
- 2019-03-19
14:41:27 UTC
0.63 %
EPSG:4326
20LQH
[Visualize](#)

Powered by [Sinergise](#) with contributions from the European Space Agency v2.17.2

SENTINEL HUB CUSTOM SCRIPT CONTEST
ADAPTIVE DDTES GAME AND GLORY AWAIT YOU!

[About EO Browser](#) [Contact us](#) [Get data](#)

Sentinel Hub EO Browser: Brazil

The screenshot displays the Sentinel Hub EO Browser interface. The browser address bar shows the URL: `apps.sentinel-hub.com/eo-browser/?lat=-8.23&lng=-64.58&zoom=6`. The interface includes a search bar with the text "brazil", a navigation menu with "Search", "Results", "Visualization", and "Pins", and a "Results" panel on the left. The "Results" panel shows 50 results, with three visible entries for March 19, 2019, each with a "Visualize" button. The main map area shows a satellite view of Brazil with a blue grid overlay. A red circle highlights the "Create time lapse animation" button in the right-hand toolbar. The text "Create time lapse animation" is overlaid on the map area.

Powered by [Sinergise](#) with contributions from the European Space Agency v2.17.2

SENTINEL HUB CUSTOM SCRIPT CONTEST
ADAPTIVE DDT7C FAME AND GLORY AWAIT YOU!

[About EO Browser](#) [Contact us](#) [Get data](#)

Sentinel Hub EO Browser: Brazil

Timelapse

2014-02-01 - 2019-03-19

20 % Select All

- 2015-09-16
- 2015-10-06
- 2016-01-04
- 2016-02-03
- 2016-02-16
- 2016-03-04
- 2016-03-17
- 2016-04-03
- 2016-04-13

2016-04-03

20 km

OpenGIS SENTINEL Hub

Speed: 1 frames / s 1 / 122: 2016-04-03 Download

Sentinel Hub EO Browser: Brazil

Timelapse

2014-02-01 - 2019-03-19 Select time frame

20 % Select All

- 2015-09-16
- 2015-10-06
- 2016-01-04
- 2016-02-03
- 2016-02-16
- 2016-03-04
- 2016-03-17
- 2016-04-03
- 2016-04-13

2016-04-03

20 km

Openicus SENTINEL Hub

Speed: 1 frames / s 1 / 122: 2016-04-03 Download

Sentinel Hub EO Browser: Brazil

Timelapse

2014-02-01 - 2019-03-19

Select cloud cover

20 %

Select All

- 2015-09-16
- 2015-10-06
- 2016-01-04
- 2016-02-03
- 2016-02-16
- 2016-03-04
- 2016-03-17
- 2016-04-03
- 2016-04-13

2016-04-03

20 km

OpenGIS SENTINEL Hub

Speed: 1 frames / s

1 / 122: 2016-04-03

Download

Sentinel Hub EO Browser: Brazil

Timelapse

2014-02-01 - 2019-03-19

20 % Select All

- 2015-09-16
- 2015-10-06
- 2016-01-04
- 2016-02-03
- 2016-02-16
- 2016-03-04
- 2016-03-17
- 2016-04-03
- 2016-04-13

Select images

2016-04-03

20 km

Openeo SENTINEL Hub

Speed: 1 frames / s 1 / 122: 2016-04-03 Download

Sentinel Hub EO Browser: Brazil

Timelapse

2014-02-01 - 2019-03-19

20 % Select All

- 2015-09-16
- 2015-10-06
- 2016-01-04
- 2016-02-03
- 2016-02-16
- 2016-03-04
- 2016-03-17
- 2016-04-03
- 2016-04-13

2016-04-03

20 km

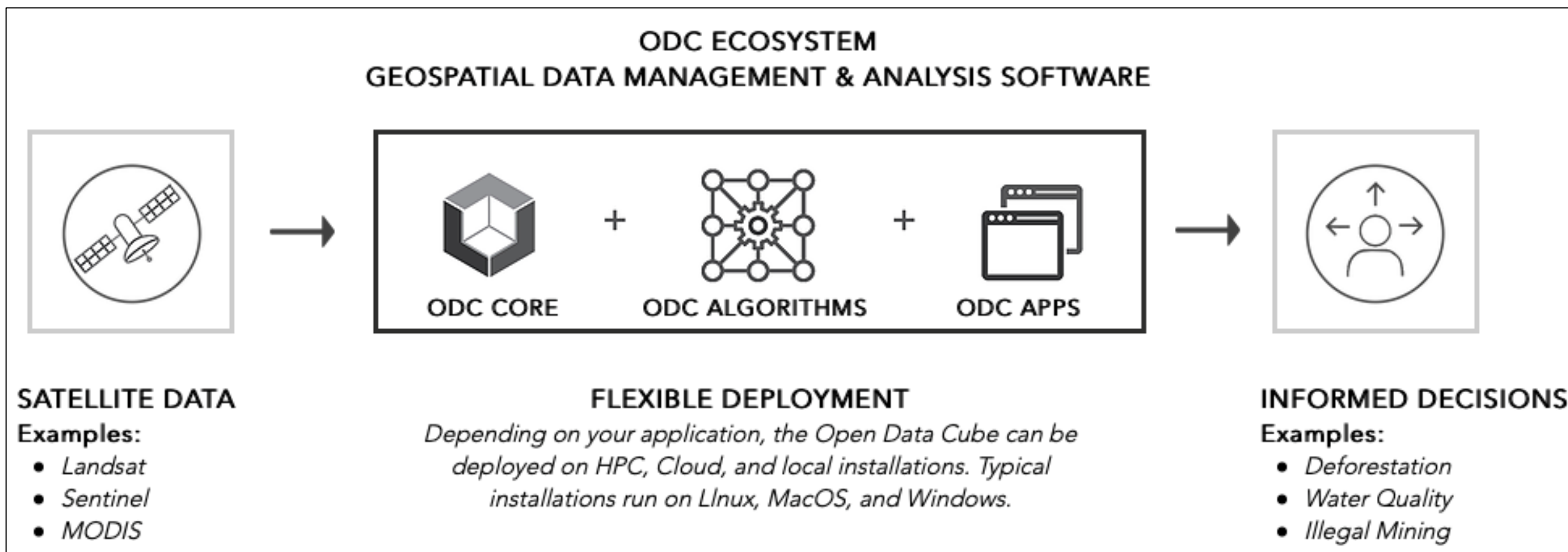
OpenGIS SENTINEL Hub

Play animation

speed: 1 frames / s 1 / 122: 2016-04-03 Download

Open Data Cube

- Open source geospatial data management and analysis software project



<https://www.opendatacube.org>

Africa Regional Data Cube

- Developed to address Sustainable Development Goals (SDGs)
- Developed by the Committee on Earth Observations Satellite (CEOS) in partnership with the Group on Earth Observations (GEO), Amazon Web Services and Strathmore University in Kenya



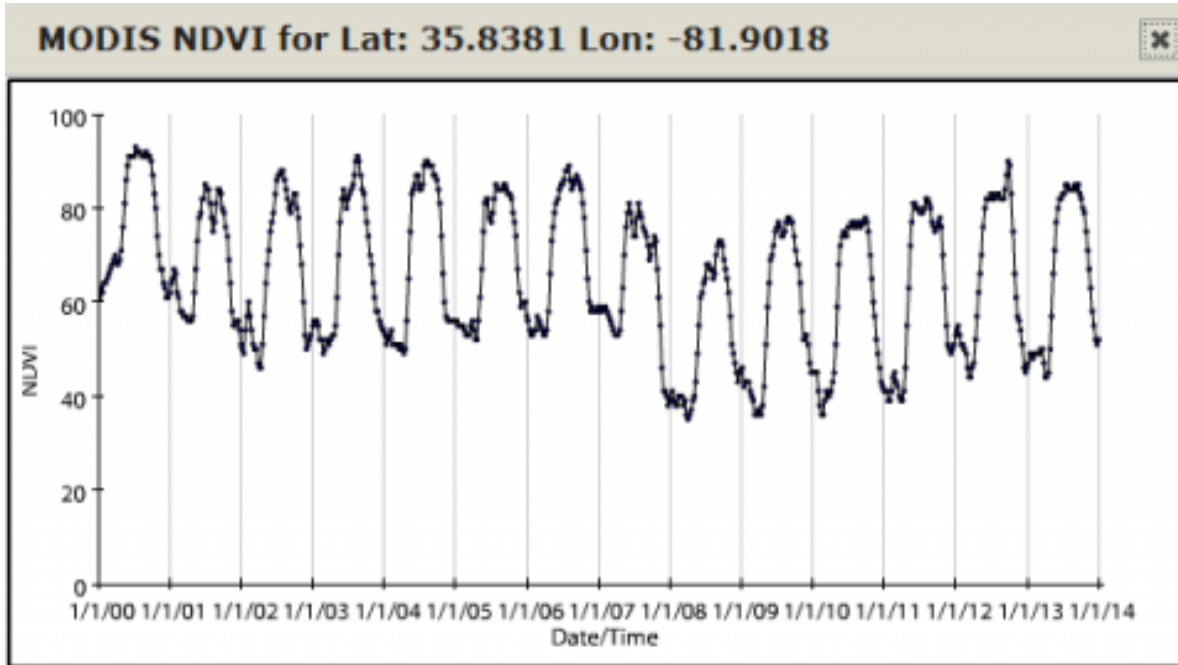
Africa Regional Data Cube

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Times Series Graphing

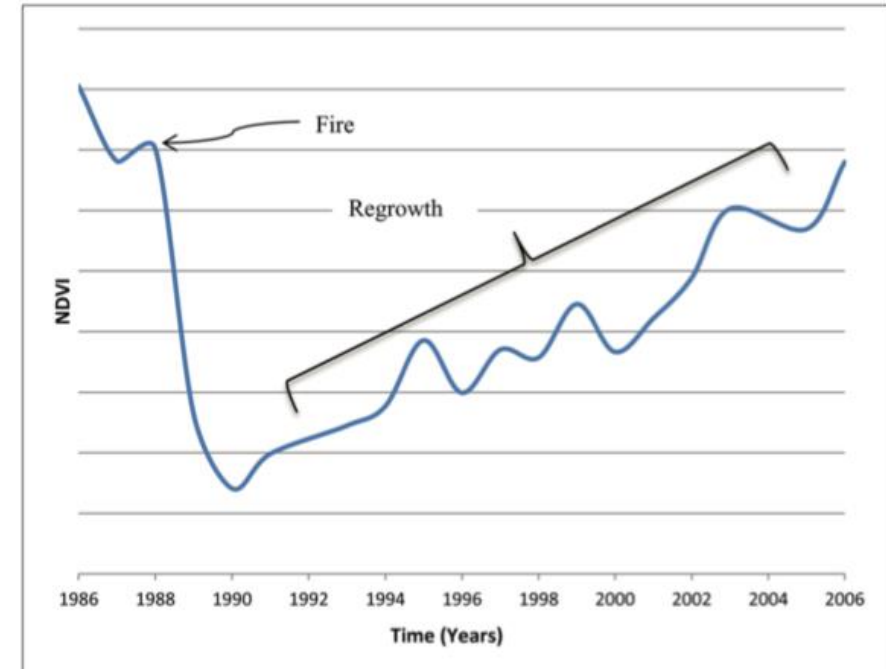
- Phenology: Monthly NDVI



What are the trends?

- Annual max., min., or mean

- Disturbances: Annual trends

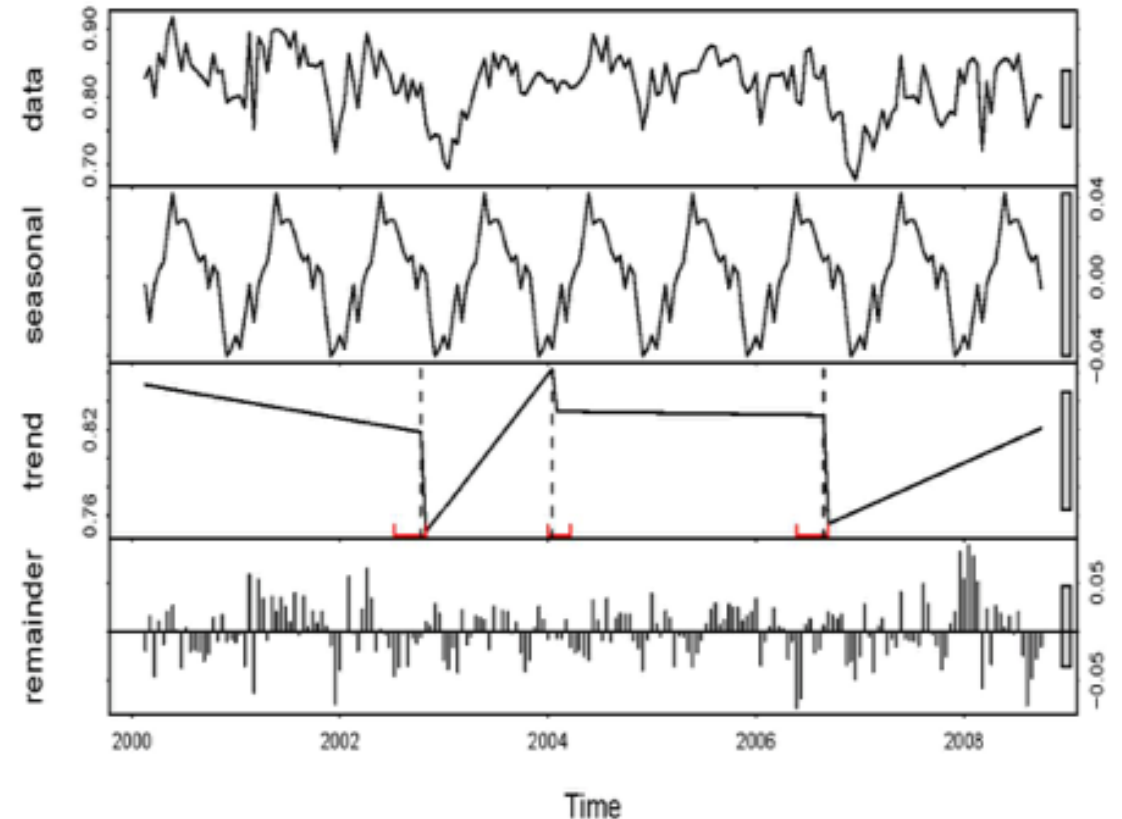


Changes in NDVI values between 1986 and 2006 for one site in Yellowstone National Park

Breaks for Additive Seasonal and Trend Method (BFAST)

- Decomposes time series satellite data into trend, seasonal and remainder components
- Allows you to pinpoint the location and timing of changes
- Available as an R package:
<http://bfast.r-forge.r-project.org>

NDVI time series of a pine plantation



Reference: Verbesselt, J. et al. (2010). Detecting trend and seasonal changes in satellite image time series. Remote Sensing of Environment 114 (1): 106-115

Application for Extracting and Exploring Analysis Ready Samples (AppEEARS)

Land Processes Distributed Active Archive Center (LP DAAC)

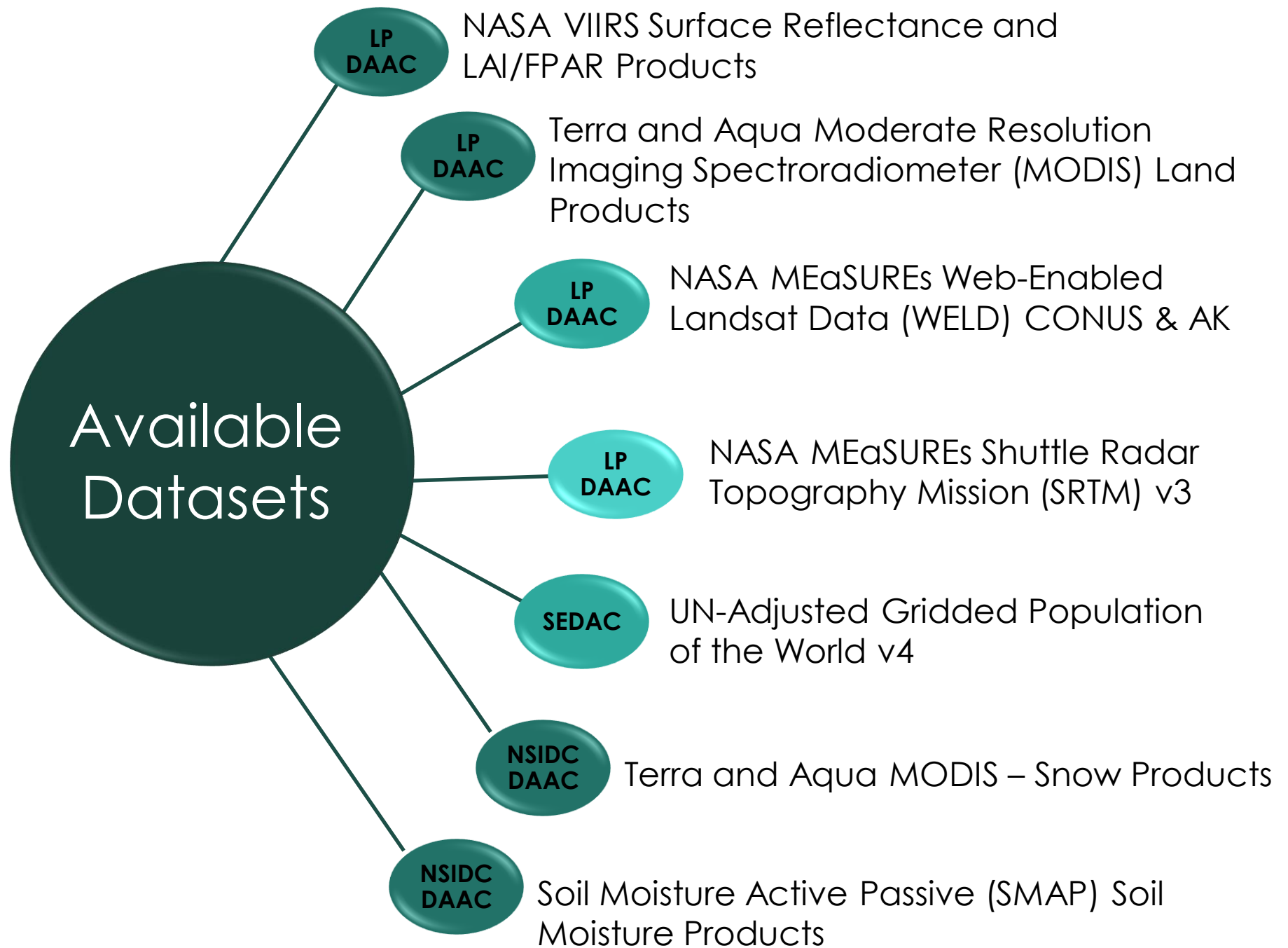
Web interface for accessing, processing, & visualizing geospatial data products

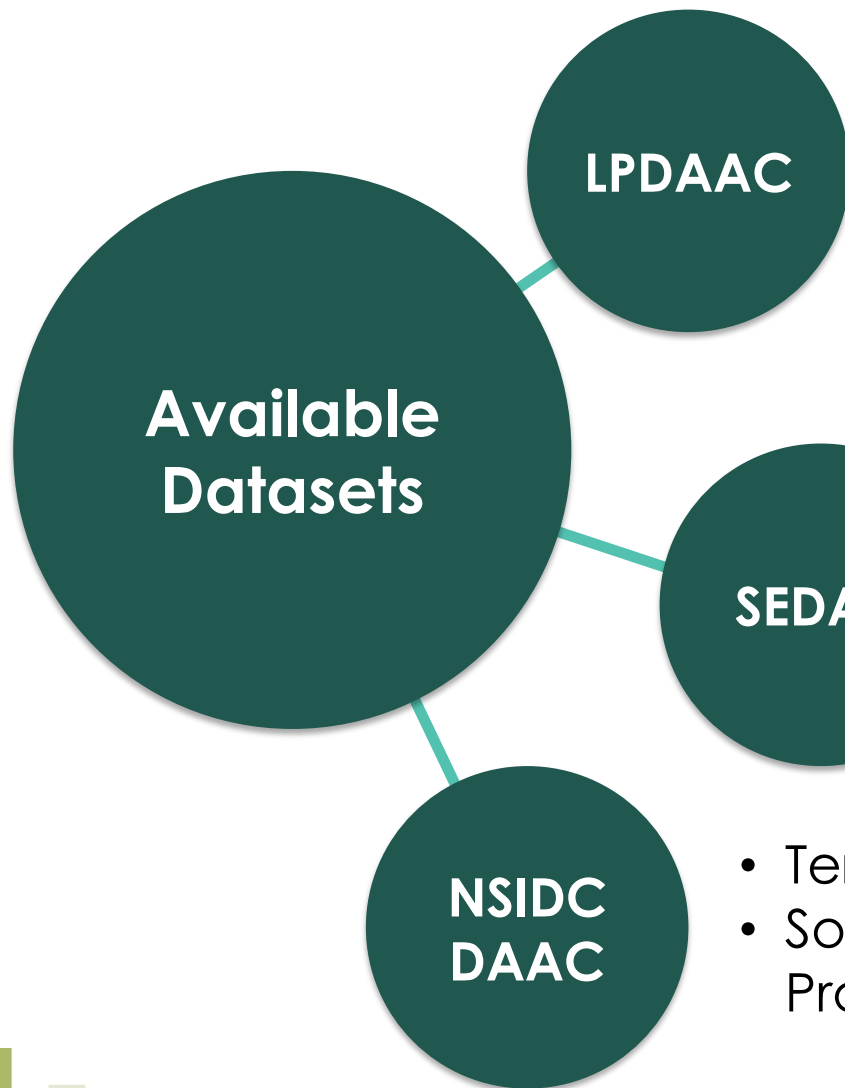
The screenshot displays the AppEEARS web interface with several key components:

- Welcome to AppEEARS!**: A central banner with the application name and a brief description: "Application for Extracting and Exploring Analysis Ready Samples (AppEEARS)".
- Extract Area Sample**: A panel on the left for defining geographic areas, including a map and input fields for coordinates and dates.
- Extract Point Sample**: A panel on the right for defining specific point locations, also featuring a map and coordinate input fields.
- View Area Sample**: A central panel showing a map and a time-series plot of data for the selected area.
- View Point Sample**: A panel showing a time-series plot and a scatter plot for the selected point.
- Quality**: A panel displaying box plots for different data categories.

Overlaid on the interface is a dark grey box with the text: "AppEEARS https://lpdaacsvc.cr.usgs.gov/appeears/"

<https://lpdaacsvc.cr.usgs.gov/appeears/>





- NASA VIIRS Surface Reflectance and LAI/FPAR Products
- Terra and Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) Land Products
- NASA MEaSUREs Web-Enabled Landsat Data (WELD) CONUS & AK
- NASA MEaSUREs Shuttle Radar Topography Mission (SRTM) v3

- UN-Adjusted Gridded Population of the World v4

- Terra and Aqua MODIS – Snow Products
- Soil Moisture Active Passive (SMAP) Soil Moisture Products

Available Datasets

LPDAAC

NASA VIIRS Surface Reflectance and LAI/FPAR Products

LPDAAC

Terra and Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) Land Products

LPDAAC

NASA MEaSUREs Web-Enabled Landsat Data (WELD) CONUS & AK

LPDAAC

NASA MEaSUREs Shuttle Radar Topography Mission (SRTM) v3

SEDAC

UN-Adjusted Gridded Population of the World v4

NSIDC DAAC

Terra and Aqua MODIS – Snow Products

NSIDC DAAC

Soil Moisture Active Passive (SMAP) Soil Moisture Products

Area Sample
Point Sample

Welcome to AppEEARS!

Application for **E**xtracting and **E**xploring **A**nalysis **R**eady **S**amples (**AppEEARS**)

The Application for Extracting and Exploring Analysis Ready Samples (**AppEEARS**) offers a simple and efficient way to access and transform geospatial data from a variety of federal data archives. AppEEARS enables users to subset **geospatial datasets** using spatial, temporal, and band/layer parameters. Two types of sample requests are available: **point samples** for geographic coordinates and **area samples** for spatial areas via vector polygons. Sample requests submitted to AppEEARS provide users not only with data values, but also associated quality data values. Interactive visualizations with summary statistics are provided for each sample within the application, which allow users to preview and interact with their samples before downloading their data. Get started with a sample request using the Extract option above, or visit the [Help page](#) to learn more.



Extract Point Sample



Start a new request



Copy a previous request

- Beetle 3 i

- Beetle 2 i

- Beetle1 i

- point sample july i

- Point Example i



Upload a request file

Drop a JSON file containing the request to copy or [click here](#) to select the file.

JSON request files (*.request.json) are included in the download bundle available from any AppEEARS requests.

Extract Point Sample

Enter a name to identify your sample

Upload coordinates from a file

Drop a CSV file containing the coordinates or [click here](#) to select the file. Coordinates can also be entered manually in the uploaded coordinates box.

The CSV file can contain up to 4 columns separated by commas with each coordinate on a separate line.

1. ID (*optional*) - uniquely identifies the coordinate
2. Category (*optional*) - label to group common coordinates
3. Latitude - latitude in decimal degrees (-90 to 90)
4. Longitude - longitude in decimal degrees (-180 to 180)

Uploaded coordinates (ID, Category, Lat, Long): 0

Upload or enter the coordinates to include in the sample (e.g. US-Ha1, DBF, 42.5378, -72.1715)

Start Date



End Date ⓘ



Is Date Recurring?

Selected coordinates

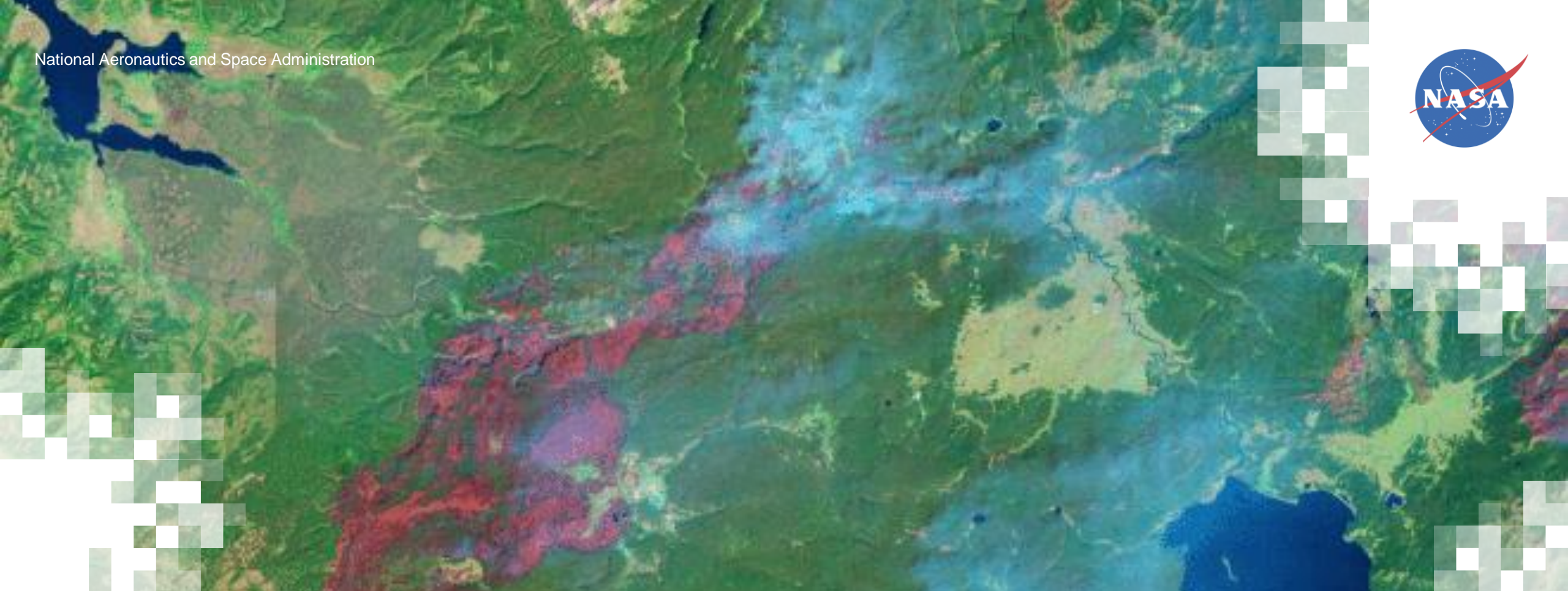


Let's get started!!!



Contacts

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Thank You

Session 2: Thursday April 17th, Time Series Algorithms and LandTrendr

04/15/2019