

A scenic landscape photograph of a mountain valley. In the foreground, a calm river reflects the surrounding green forest and the sky. The middle ground shows a lush green valley with a small clearing. In the background, majestic mountains rise, some with patches of snow or light-colored rock. The sky is overcast with soft, grey clouds. The overall mood is serene and natural.

Geospatial Revolution in times of urgency for Climate Change

Rebecca Moore, Director, Google Earth, Earth Engine & Outreach
Google

AmazonTEK2023

Nov 15, 2023



Mato Grosso, Brazil

We are hitting planetary tipping points

In 2021

For the first time in history, the Amazon rainforest emitted more carbon than it removed





Source: NASA

COPERNICUS AND ITS SENTINELS

European Earth Observation Programme Copernicus: observing our planet for a safer world

- 

Known as **GMES** until 2012 - Global Monitoring for Environment and Security
- 

30 Public and Private missions are also contributing data
- 

16 years of development and testing
- 

Sentinel-Missions at the heart of the space component
- 

Civil Security. Allowing early warning and crisis prevention in conflict and disaster areas
- 

Emergency Management. Accurate and timely data for emergency plans and rescue for disaster management
- 

Land Surface Monitoring. Geographical information on land cover, related variables and urban development
- 

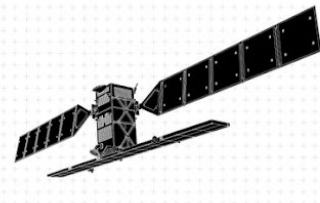
Marine Environmental Monitoring. Observations and forecasts on the state of the physical oceans and regional seas
- 

Climate Change Monitoring. Helps to understand the reason for climate change, rising sea levels and melting ice caps
- 

Earth Atmosphere Monitoring. Daily information on the global atmospheric composition and when Sentinel-4 is in service this will be hourly

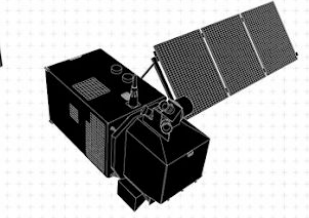
SENTINEL-1

- **All-weather, day-and-night radar imaging satellite for land and ocean services**
- Able to "see" through clouds and rain
- Data delivery within 1 hour of acquisition
- Airbus Defence and Space developed C-band radar instrument



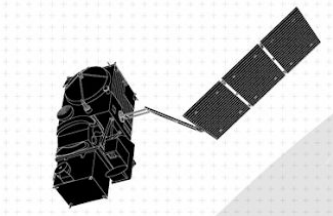
SENTINEL-2

- **Medium Res Multispectral optical satellite for observation of land, vegetation and water**
- 13 spectral bands with 10, 20 or 60 m resolution and 290 km swath width
- Global coverage of the Earth's land surface every 5 days
- Airbus Defence and Space prime contractor for satellites and instruments



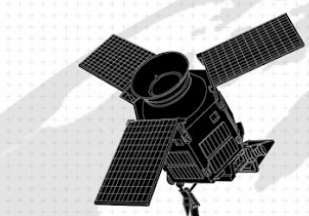
SENTINEL-3

- **Measures sea-surface topography with a resolution of 300 m, sea and land surface temperature and colour with a resolution of 1 km**
- Measures water vapour, cloud water content and thermal radiation emitted by the Earth
- Determines global sea surface temperatures with an accuracy greater than 0.3 K
- Airbus Defence and Space supplies Microwave Radiometer



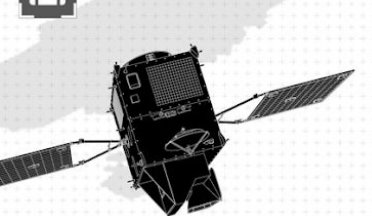
SENTINEL-5P

- **Global observation of key atmospheric constituents, including ozone, nitrogen dioxide, sulphur dioxide and other environmental pollutants**
- Improves climate models and weather forecasts
- Provides data continuously during five-year gap between the retirement of Envisat and the launch of Sentinel-5
- Airbus Defence and Space prime contractor for satellite and TROPOMI instrument



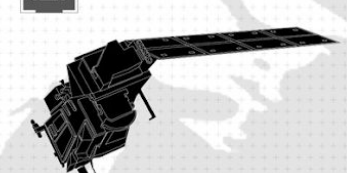
SENTINEL-4

- **Provides hourly updates on air quality with data on atmospheric aerosol and traces gas concentrations**
- Spatial sampling is 8 km and spectral resolution between 0.12 nm and 0.5 nm
- Airbus Defence and Space prime contractor for spectrometer
- Carried aboard EUMETSAT's Meteosat Third Generation (MTG) satellites



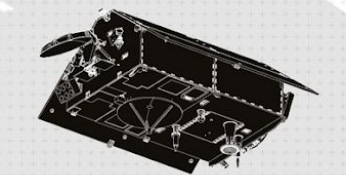
SENTINEL-5

- **Measures air quality and solar radiation, monitors stratospheric ozone and the climate**
- Global coverage of Earth's atmosphere with an unprecedented spatial resolution
- Airbus Defence and Space prime contractor for instrument
- Carried aboard EUMETSAT's MetOp Second Generation satellites



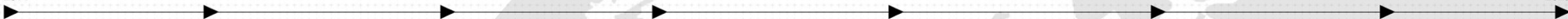
SENTINEL-6

- **Observes changes in sea surface height with an accuracy of a few centimeters**
- Global mapping of the sea surface topography every 10 days
- Enables precise observation of ocean currents and ocean heat storage; vital for predicting rises in sea levels
- Airbus Defence and Space prime contractor for satellite



2014

2020





Earth Observation Data Archives

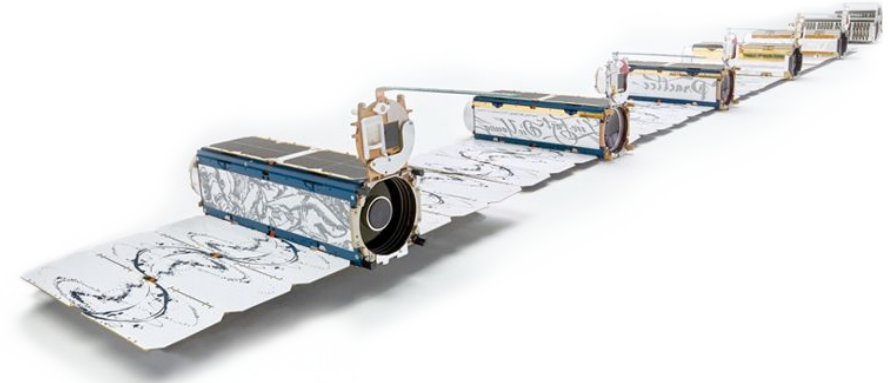


Revolution begins: Explosion of Earth Observation “Big Data”

Big commercial & government satellites



Constellations of small sats



Drones & aerial reconnaissance



Mobile & in-situ sensor networks



**But researchers and practitioners are not software engineers!
How can they access and process all this data?**

An aerial photograph of a coastline. On the left, there is a road with several cars parked along the side. To the right of the road is a dense line of green trees. Further right is a sandy beach with a few people. The water is a vibrant turquoise color, transitioning to a deeper blue further out. The overall scene is bright and clear.

Earth Engine Mission

Build the leading geospatial analysis platform to advance planetary sustainability and resilience to climate change

A planetary-scale platform for Earth science data & analysis

Powered by Google's cloud infrastructure

[▶ Watch Video](#)

Meet Earth Engine



Data Catalog

The world's largest archive of open Earth data at your fingertips.



Computation Platform

A powerful tool to analyze and visualize Earth data at scale.



Collaborative Ecosystem

100,000+ monthly-active users (and growing).

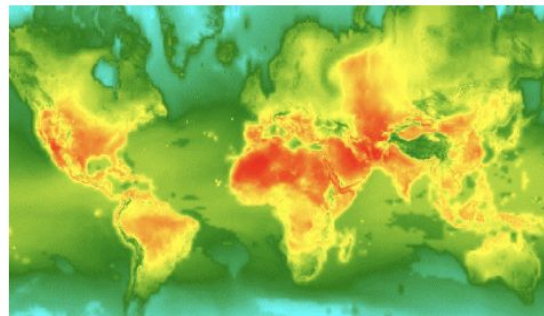
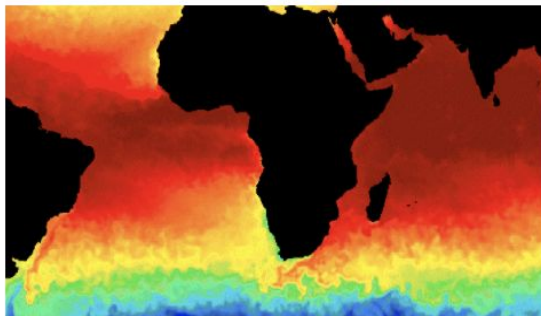
Earth Engine Data Catalog

[HOME](#)

[VIEW ALL DATASETS](#)

[BROWSE BY TAGS](#)

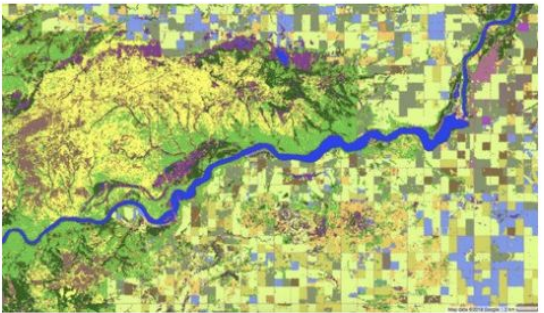
Climate and Weather



Imagery



Geophysical

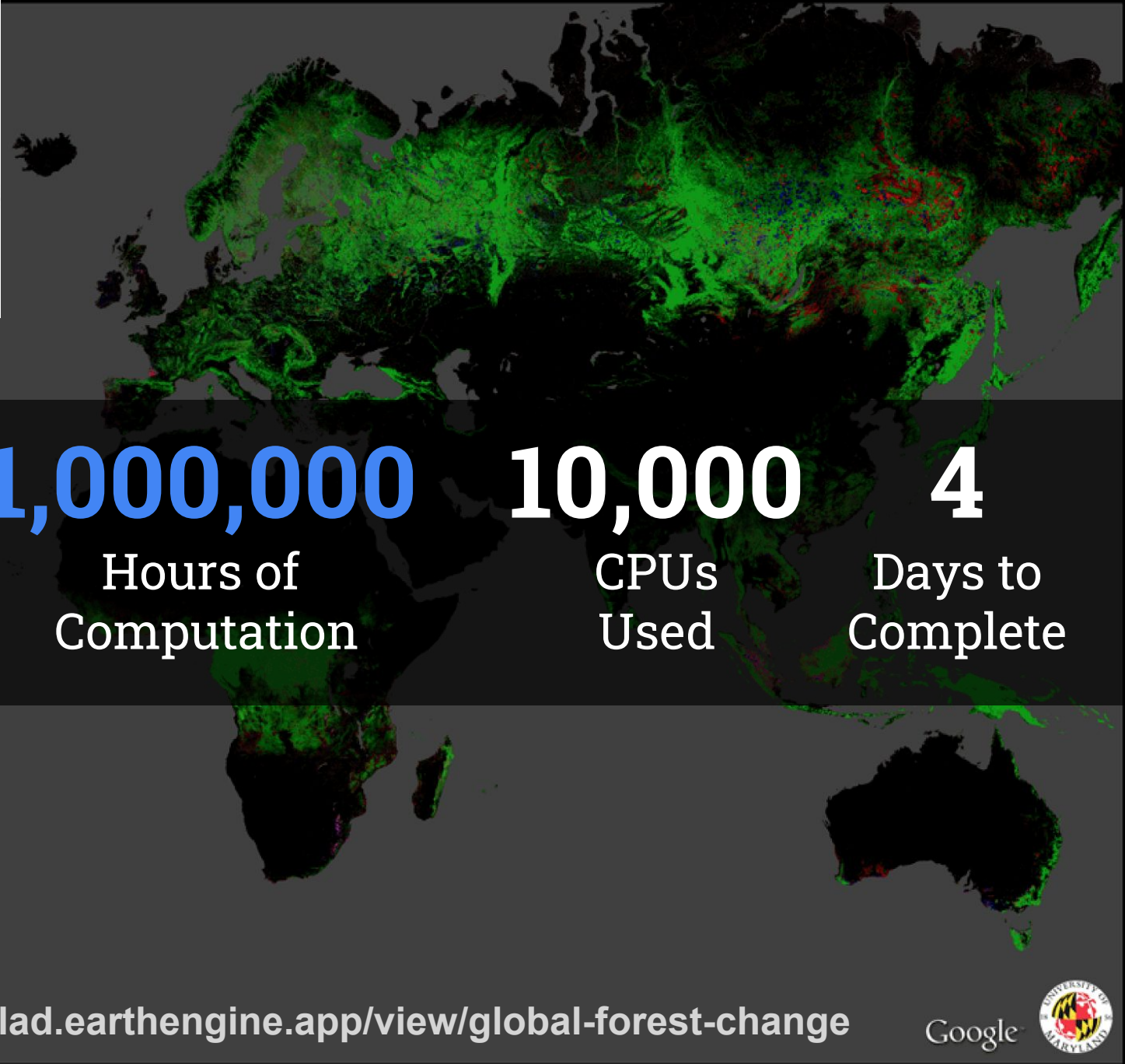


Google Data Center

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. Townshend¹

15 NOVEMBER 2013 VOL 342 SCIENCE www.sciencemag.org



654,178

Landsat
Scenes

700

Terapixels
of Data

1,000,000

Hours of
Computation

10,000

CPUs
Used

4

Days to
Complete

- Forest Extent 2000
- Forest Loss 2000-2012
- Forest Gain 2000-2012
- Both Loss and Gain

glad.earthengine.app/view/global-forest-change



GLOBAL FOREST WATCH

Monitoring matters!

38 Indigenous territories in Peru saw a **51% reduction** in deforestation

161 Mha of Congo Basin forests saw a **18% reduction** in deforestation

GLOBAL
FOREST
WATCH



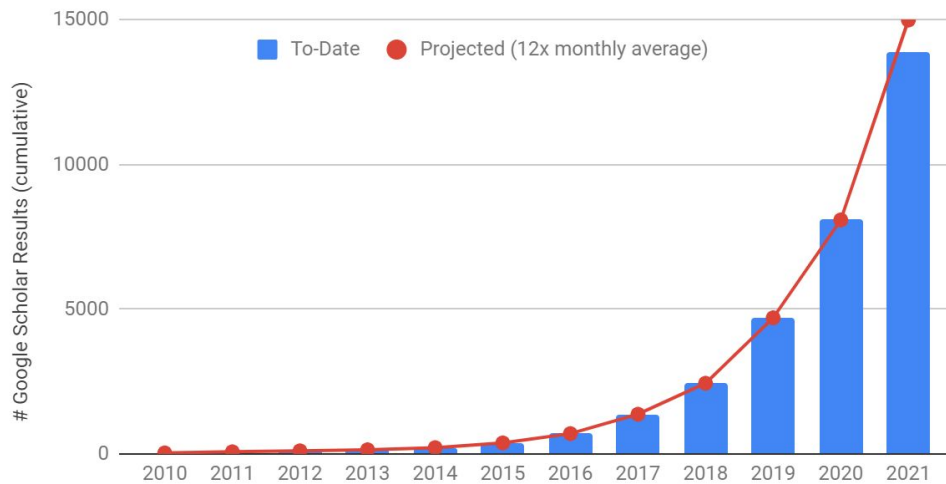
500k+

Scientists around the world

20,000+

Scientific papers ([link](#))

Google Scholar results referencing "google earth engine" - Cumulative



Remote Sensing of Environment

Volume 202, 1 December 2017, Pages 18-27

Google Earth Engine: Planetary-scale geospatial analysis for everyone

Science

Home News Journals Topics Careers

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

M. C. Hansen^{1,*}, P. V. Potapov¹, R. Moore², M. Hancher², S. A. Turubanova¹, A. Tyukavina¹, D. Thau², S. V. Stehman³, S. J. ...

nature

International journal of science

High-resolution mapping of global surface water and its long-term changes

Jean-François Pekel[✉], Andrew Cottam, Noel Gorelick & Alan S. Belward

Science

Home News Journals Topics Careers

Tracking the global footprint of fisheries

David A. Kroodsma^{1,*}, Juan Mayorga^{2,3}, Timothy Hochberg¹, Nathan A. Miller⁴, Kristina Boerder⁵, Francesco Ferretti⁶, Alex ...

RESTORATION ECOLOGY

The global tree restoration potential

Jean-Francois Bastin^{1*}, Yelena Finegold², Claude Garcia^{3,4}, Danilo Mollicone², Marcelo Rezende², Devin Routh¹, Constantin M. Zohner¹, Thomas W. Crowther¹

The restoration of trees remains among the most effective strategies for climate change mitigation. We mapped the global potential tree coverage to show that 4.4 billion hectares of canopy cover could exist under the current climate. Excluding existing trees and agricultural and urban areas, we found that there is room for an extra 0.9 billion hectares of canopy cover, which could store 205 gigatonnes of carbon in areas that would naturally support woodlands and forests. This highlights global tree restoration as our most effective climate change solution to date. However, climate change will alter this potential tree coverage. We estimate that if we cannot deviate from the current trajectory, the global potential canopy cover may shrink by ~223 million hectares by 2050, with the vast majority of losses occurring in the tropics. Our results highlight the opportunity of climate change mitigation through global tree restoration but also the urgent need for action.

Photosynthetic carbon capture by trees is likely to be among our most effective strategies to limit the rise of CO₂ concentrations across the globe (1–3). Consequently, a number of international initiatives [such as the Bonn Challenge, the related AFR100, and

measurements (data file S1) (8) of tree cover across all protected regions of the world (fig. S1) (9, 10). Using global environmental layers (table S1) (11), we examined how climate, edaphic, and topographic variables drive the variation in natural tree cover across the globe. The focus on

mental conditions, with minimal human activity (Fig. 2A). This work is directly underpinned by our systematic dataset of direct tree cover measurements (entirely independent of climate and modeled remote sensing estimates) (13) across the globe (fig. S1) (10).

Across the world's protected areas (fig. S2), tree cover ranged between peaks of 0% in dry desert and 100% in dense equatorial forest, with fewer values falling between these two extremes (figs. S2 and S3). We paired these tree cover measurements with 10 global layers of soil and climate data (table S1) (11). Our resulting random forest model had high predictive power [coefficient of determination (R^2) = 0.86; intercept = -2.05% tree cover; slope = 1.06] (Fig. 1); rigorous k -fold cross-validation (fig. S4A) (11) revealed that our model could explain ~71% of the variation in tree cover without bias (R^2 = 0.71; intercept = 0.34% tree cover; slope = 0.99) (fig. S3, B and C). Our k -fold cross-validation approach also allows us to generate a spatially explicit understanding of model uncertainty (figs. S5 and S6) (11). Across all pixels, the mean standard deviation around the modeled estimate is ~9% in tree cover (28% of the mean tree cover) (figs. S5 and S6) (11). As such, these models accurately reflected the dis-

CARBON

This shows an estimate of how much organic carbon currently exists in the soil of this area and how much could exist if the soil is restored

Current organic carbon in soil

Show on map

578 tonnes

Potential organic carbon in soil

Show on map

613 tonnes

This shows the rate at which carbon is accumulating as biomass in live plants

Net Primary Productivity



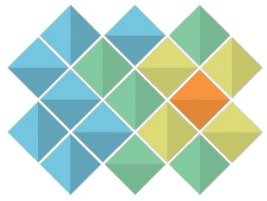
DATA LAYERS

RECENT SATELLITE IMAGERY

View satellite time series

Restor.eco

Google



MAPBIOMAS
[BRASIL]

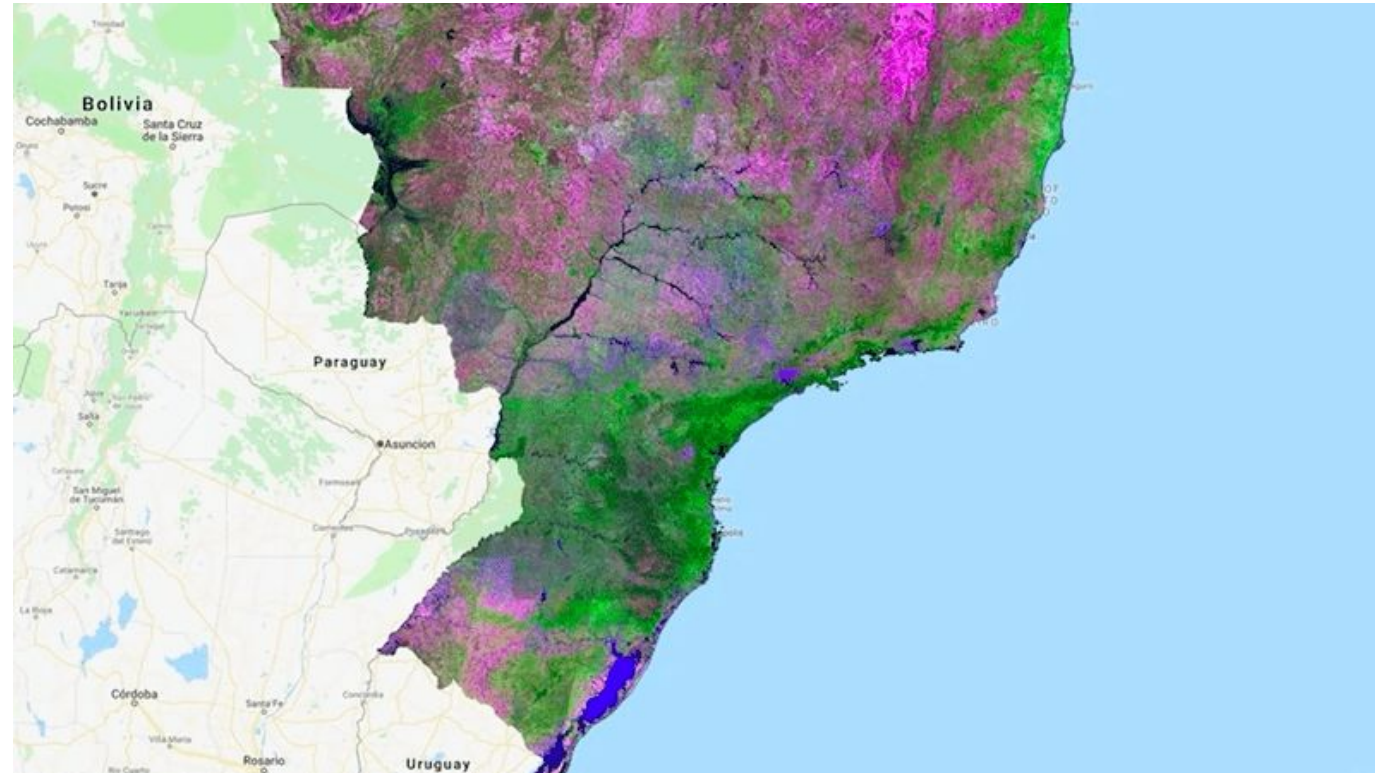
ALERTS

280 million
deforestation alerts

190 million
in the Amazon biome

3 million
hectares of validated
deforestation

1,000+
Property loans stopped
for detected violations



Imagery: Landsat (30m), Planet (3m)



MAPBIOMAS
[INDONESIA]

Expanding MapBiomass to Indonesia

Success story - scaling MapBiomass land cover detection and alerting tools regionally in South - South collaboration

MapBiomass Indonesia consists of ten Indonesian civil society organizations (CSO's) which are coordinated by Auriga Nusantara and integrated into the MapBiomass Global Network.

How Google Earth Engine supports impact

“Google Earth Engine (GEE) ...is a key tool in the MapBiomass process.”

Tutupan lahan

MAPBIOMAS
[INDONESIA]

Wilayah Transisi Bobot

Wilayah
Negara

Sub-Wilayah
Indonesia

Pilih Beberapa Wilayah ⓘ

Legenda
Klik [Di sini](#) dan lihat deskripsi semua kelas.
Tampilkan Berdasarkan

Kelas Alami and Antropogenik

Level 1 Level 2 Level 3

- 1. Hutan
- 2. Tumbuhan Non Hutan
- 3. Pertanian
- 4. Non Vegetasi
- 5. Tubuh Air
- 6. Citra Tertutup Awan

STATISTIK





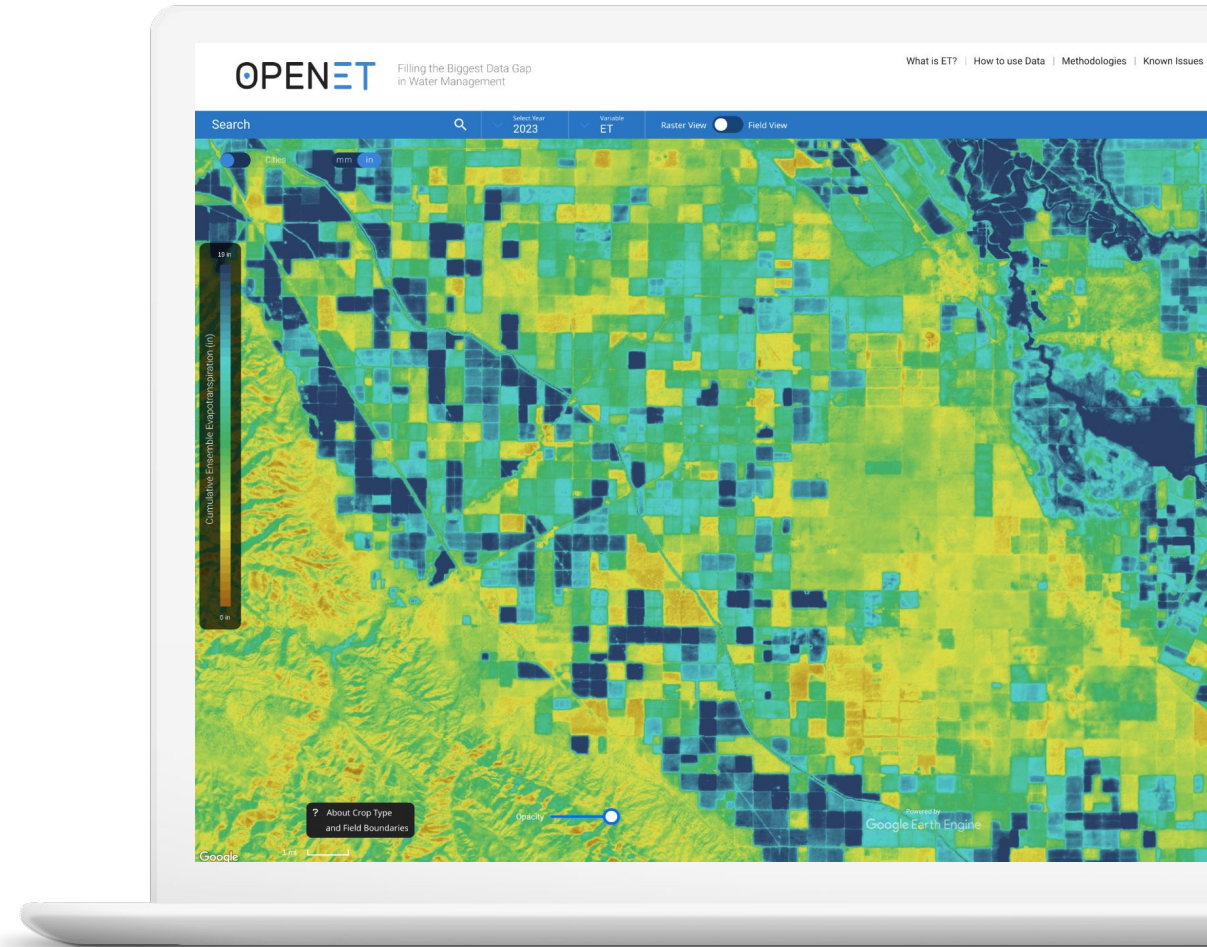
Accessible satellite-based evapotranspiration (ET) data for improved water management

Success story - fostering novel solutions that help decision making

Local communities and water agencies across the west are taking up and using historical and near real-time data from OpenET.

How Google Earth Engine supports impact

“Not only does Earth Engine enable OpenET to produce high resolution ET data at scale and make it readily available to anyone who needs it; it also makes it possible for the scientific community to easily compare approaches and standardize inputs, leading to important advances in the science that serve to continually improve the data over time.”





MOL
MAP OF LIFE

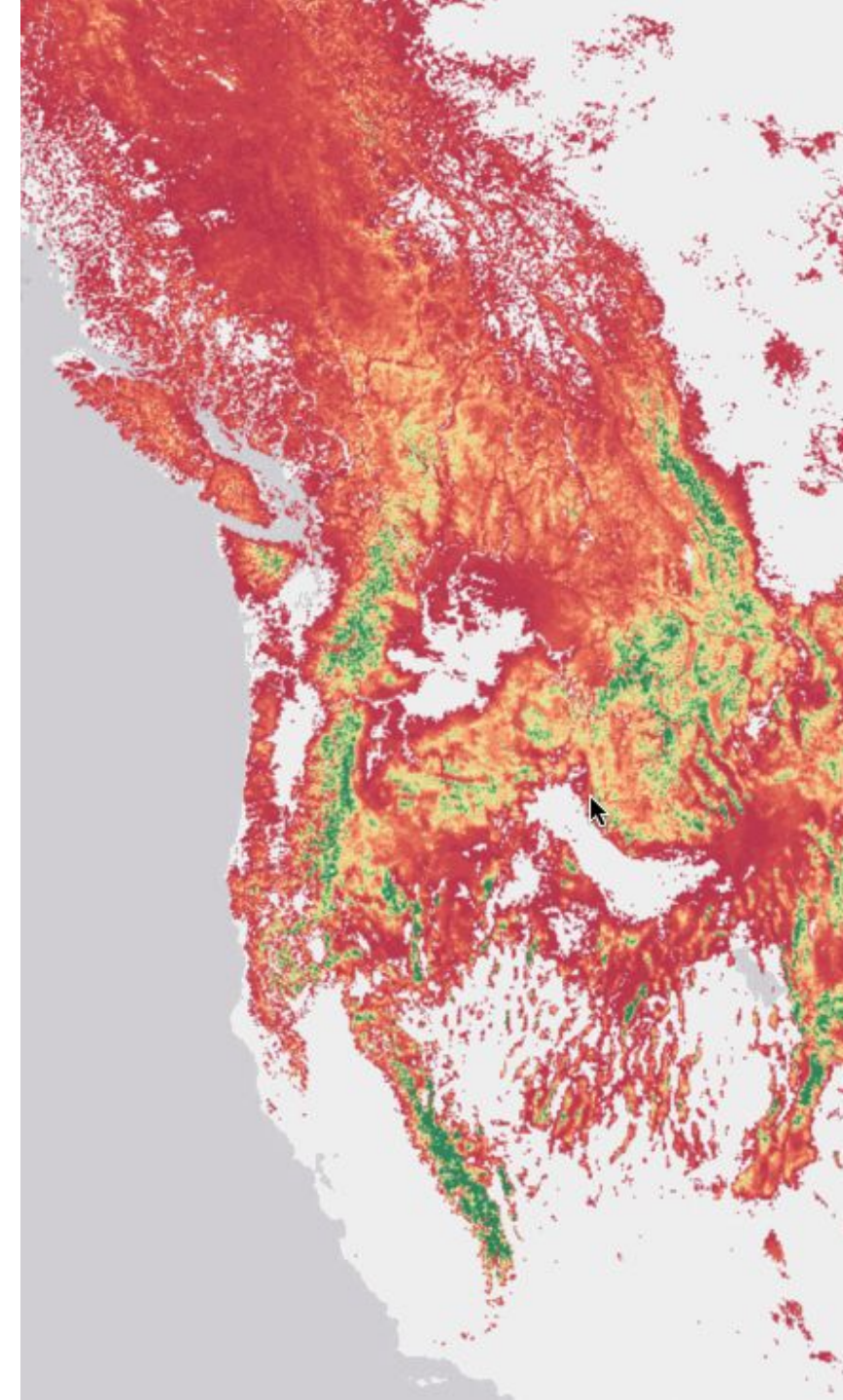
Indicators to identify and protect sufficient habitat to safeguard global biodiversity

Success story - Indicators adopted in UN Global Biodiversity Framework

Species Habitat Index (SHI), Species Protection Index (SPI) and Species Information Index (SII) all adopted as complementary indicators in UN Convention on Biological Diversity - Global Biodiversity Framework.

How Google Earth Engine supports impact

"This is the power of the indicators: they simultaneously provide national metrics for tracking progress and provide locally specific, actionable information." Using EE & Cloud to generate Species Protection Index (SPI) for mapping 40,000 species





Google and FAO partner to make remote sensing data more efficient and accessible

Partnership enhances ability to assess changing forest and to estimate greenhouse gas emissions



Forest researchers in Viet Nam use laser technologies to measure tree height and thickness.



FAO's José Graziano da Silva and Google's Rebecca Moore celebrate the partnership formalization at COP21 in Paris.

Related link

[FAO support to Forest monitoring and assessment](#)



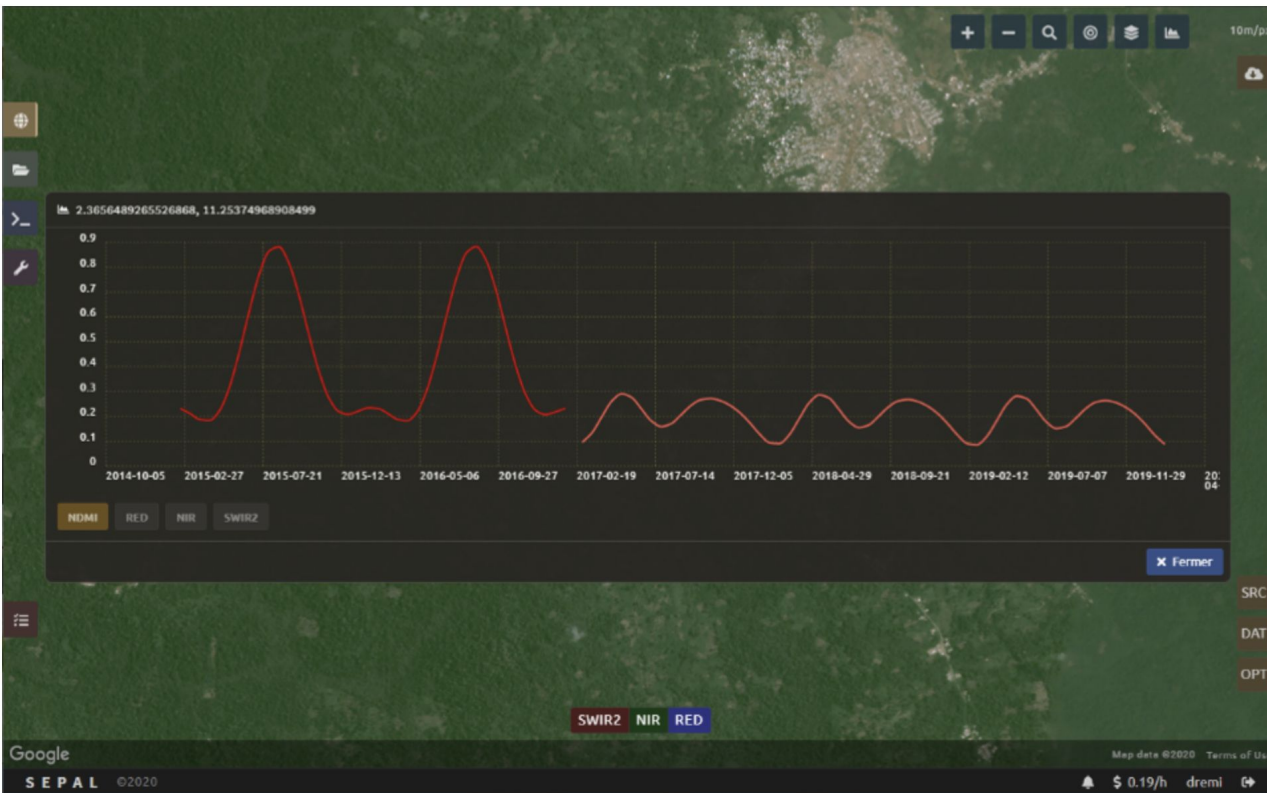
Ranchers in Azerbaijan compare a satellite map with the situation on the ground.

Cool tools

- [FAO's Open Foris](#)
- [Google Earth Engine](#)
- [Collect Earth](#)

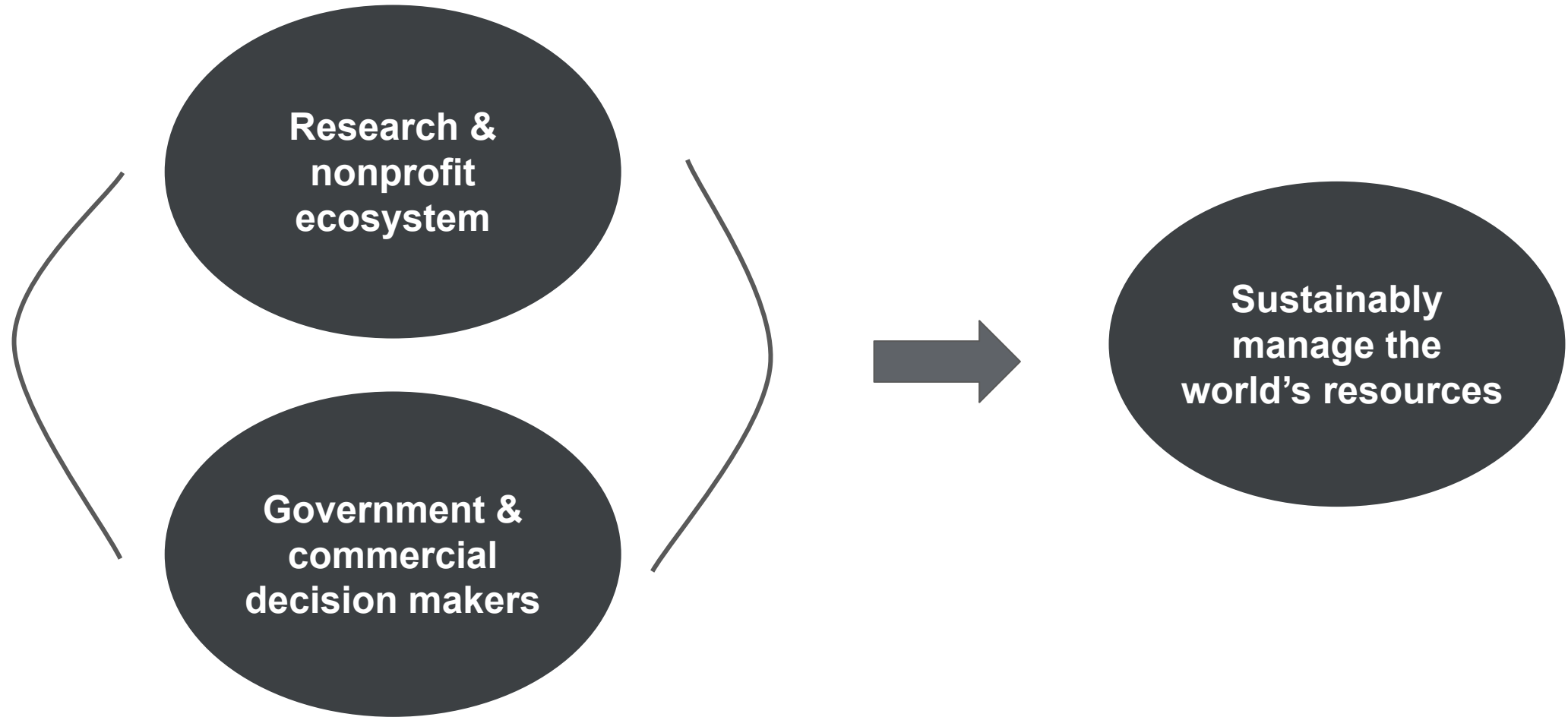


SEPAL



A temporal profile of a satellite pixel of deforestation (left) and degradation (right) in the Congo Basin

Cycle of impact



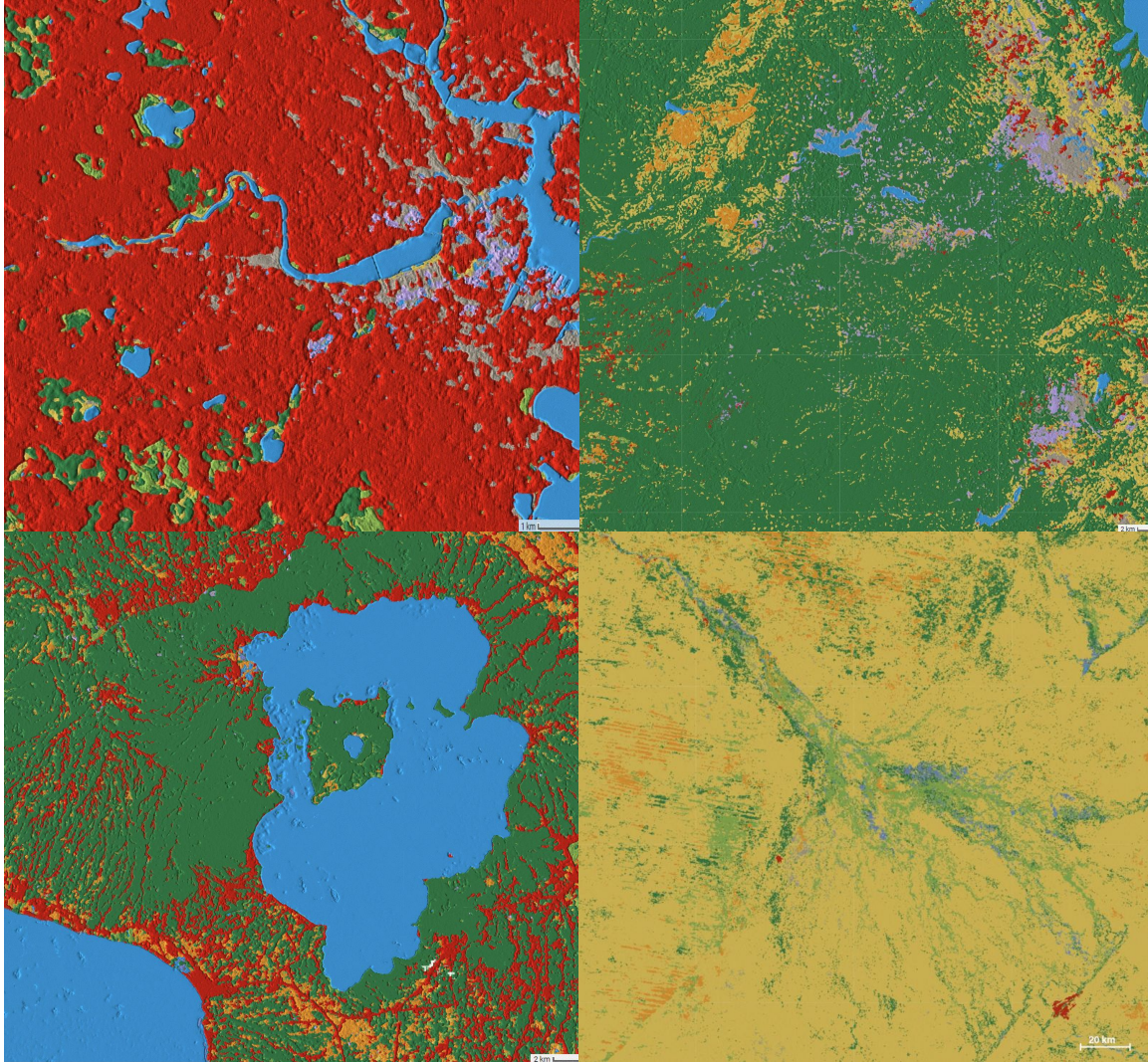
Sustainable sourcing with
satellite-derived insights:
Modeling palm oil
sourcing factors

Detecting Roads in the Amazon with GEE + AI

Source: Carlos Souza, Imazon



Dynamic World: Near Real Time land cover data



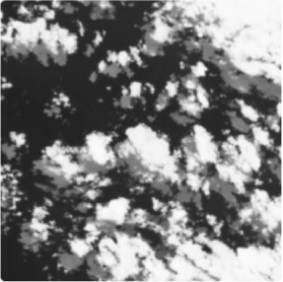
Dataset and AI Model

- 01** Global Land Cover Dataset
- 02** 10m resolution based on ESA Sentinel-2
- 03** Near Real Time: 2-5 day globally for seasonal and recent events
- 04** Per-pixel probabilities across 9 classes
- 05** Free, Open License model & dataset

Announcing new GeoAI-powered EE Dataset Earth Engine > Cloud Score+

Comprehensive Sentinel-2 pixel quality assessment,
supporting flexible generation of clear S2 composites worldwide

Cloud Score+ S2_HARMONIZED V1



DESCRIPTION BANDS IMAGE PROPERTIES TERMS OF USE CITATIONS

Cloud Score+ is a quality assessment (QA) processor for medium-to-high resolution optical satellite imagery. Cloud Score+ outputs do not explicitly provide labels, e.g., "cloud" and "cloud shadow". Instead, QA artifacts are defined on a continuous scale based on ground occlusion with respect to solar radiation or the imaging sensor: if a ray incident to or reflected from a ground pixel is absorbed or reflected by the atmosphere, the QA score is lower. Functionally, Cloud Score+ provides a holistic per-pixel "usability" score that can be thresholded to mask or even weight observations used for downstream tasks such as time series analysis or classification.

The Cloud Score+ S2_HARMONIZED dataset is being operationally produced in parallel with the [harmonized Sentinel-2 L1C collection](#). This dataset includes two QA bands that grade the usability of individual pixels with respect to surface visibility on a scale of [0, 1] where 0 represents "not clear" (occluded) while 1 represents "clear" (unoccluded) observations. The `cs` band scores QA based on a spectral distance between the observed pixel and a (theoretical) clear reference observation, while the `cs_cdf` band represents the likelihood an observed pixel is clear based on an estimated cumulative distribution of scores for a given location through time.

Images in the Cloud Score+ S2_HARMONIZED collection have the same id and system:index properties as the individual Sentinel-2 L1C assets from which they were produced such that Cloud Score+ bands can be linked to source images based on their shared system:index.

Dataset Availability
2022-01-01T00:00:00 -

Dataset Provider
[Google Earth Engine](#)

Collection Snippet

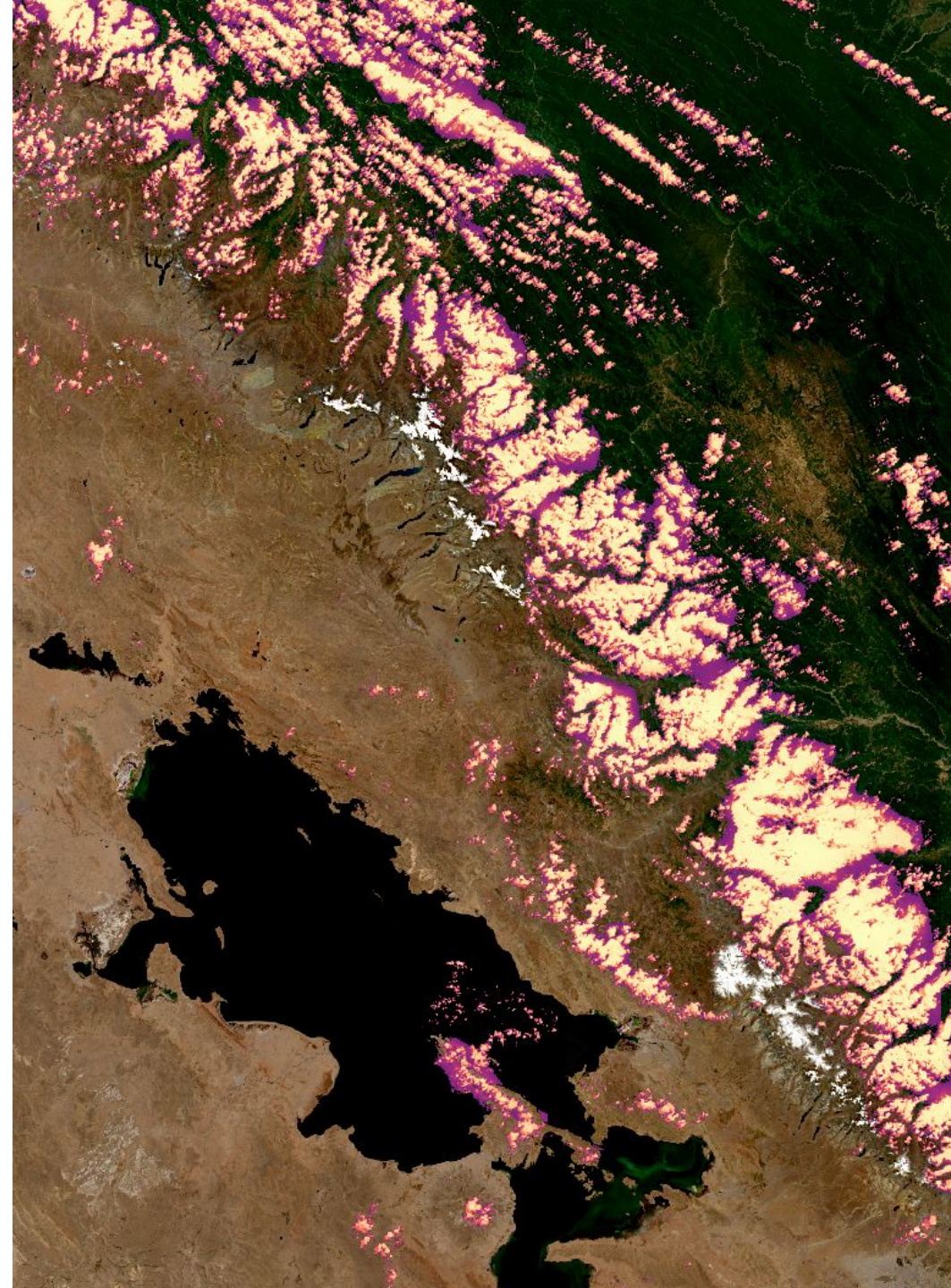
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ee.ImageCollection("GOOGLE/CLOUD_SCORE_PLUS/V1/S2_HARMONIZED")
```

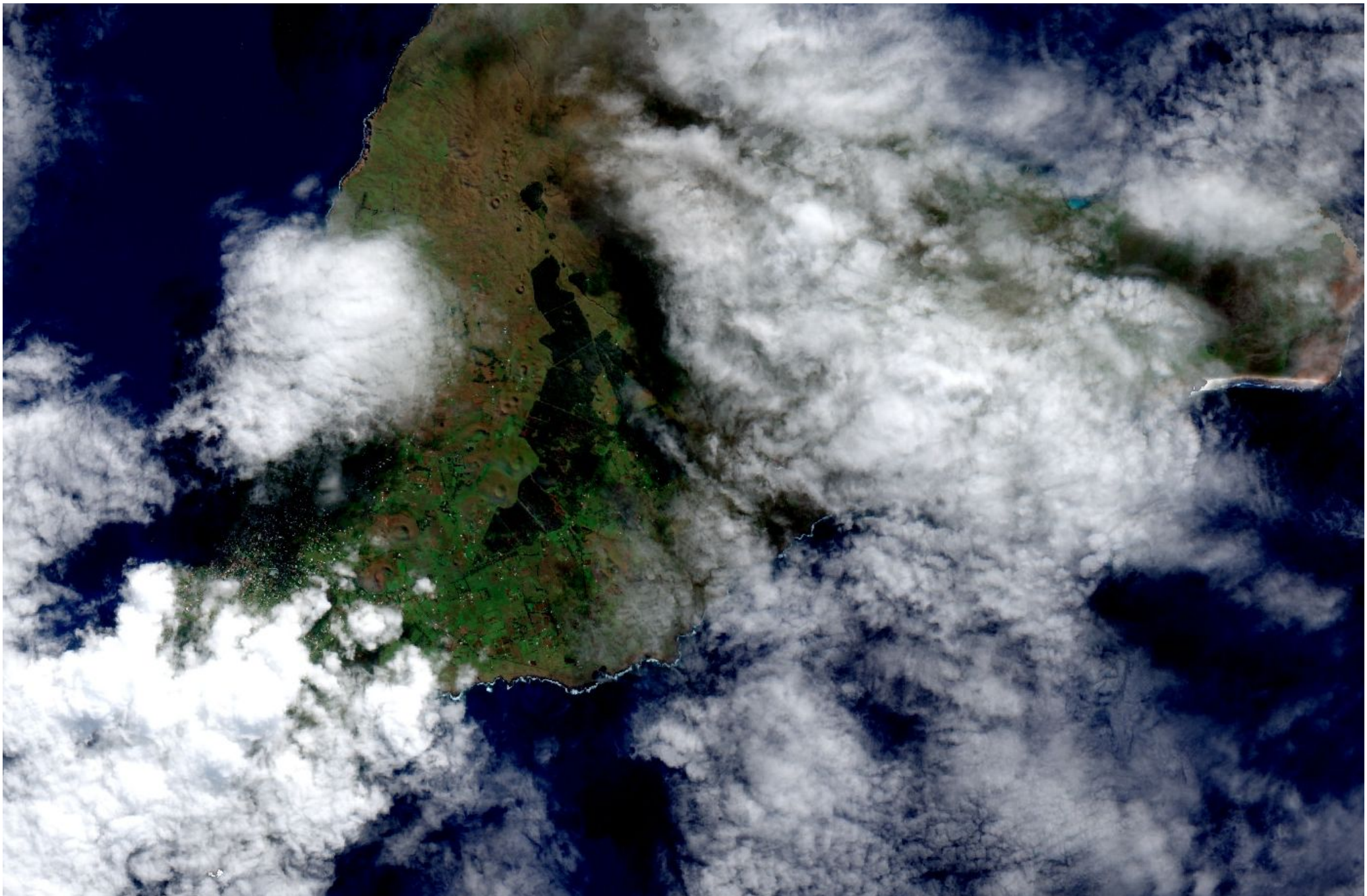
[See example](#)

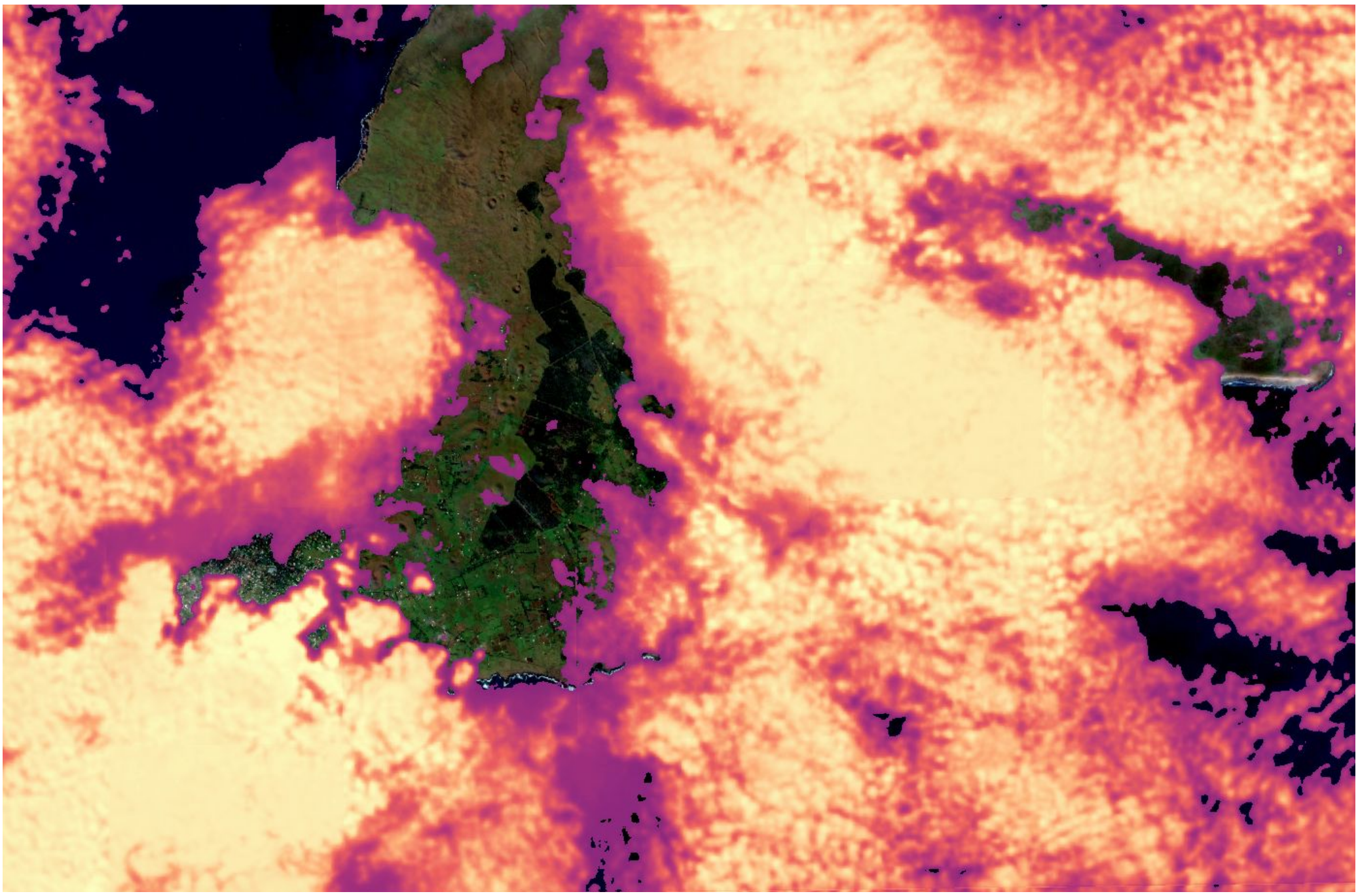
Tags

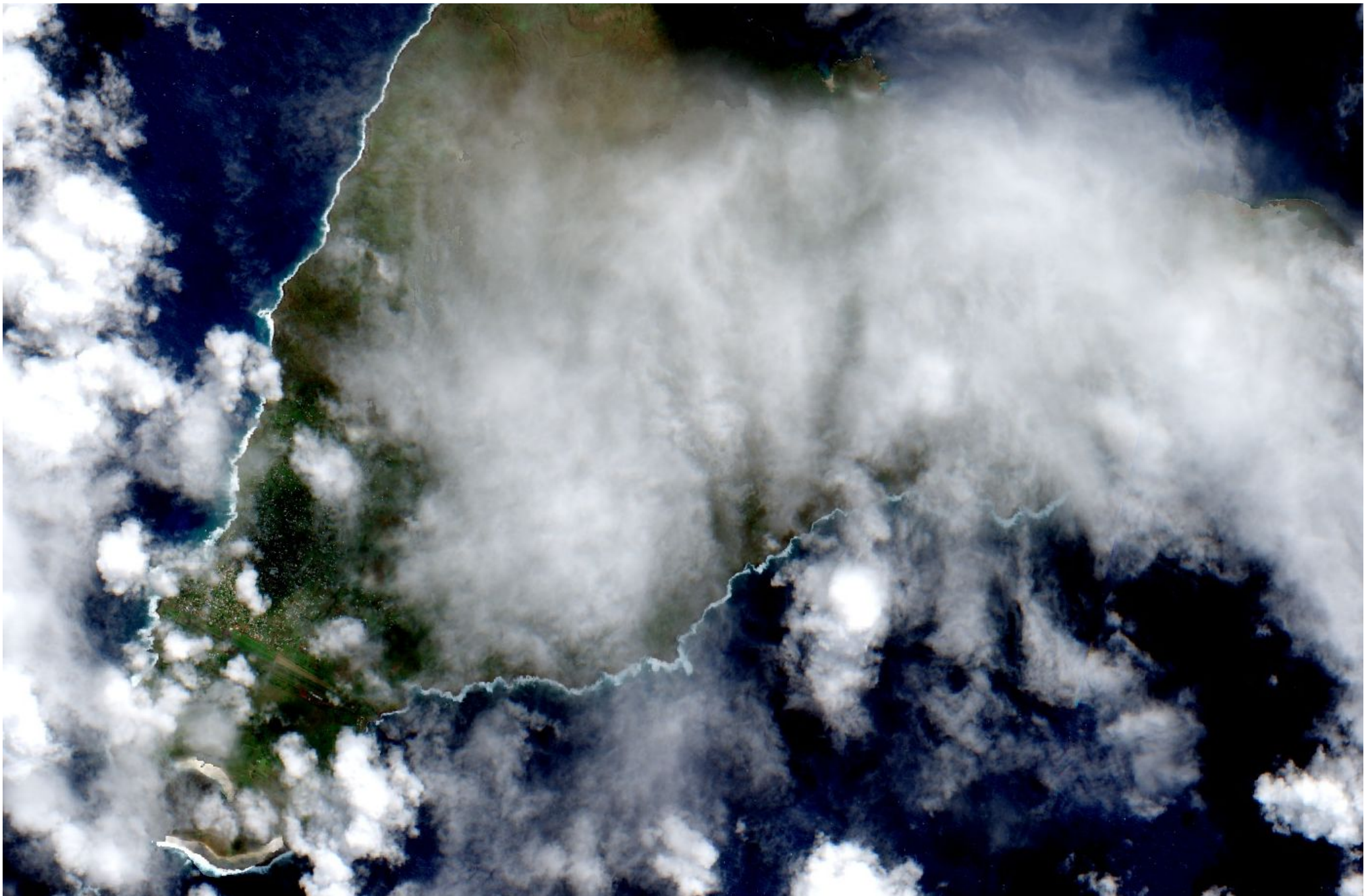
cloud google sentinel2-derived

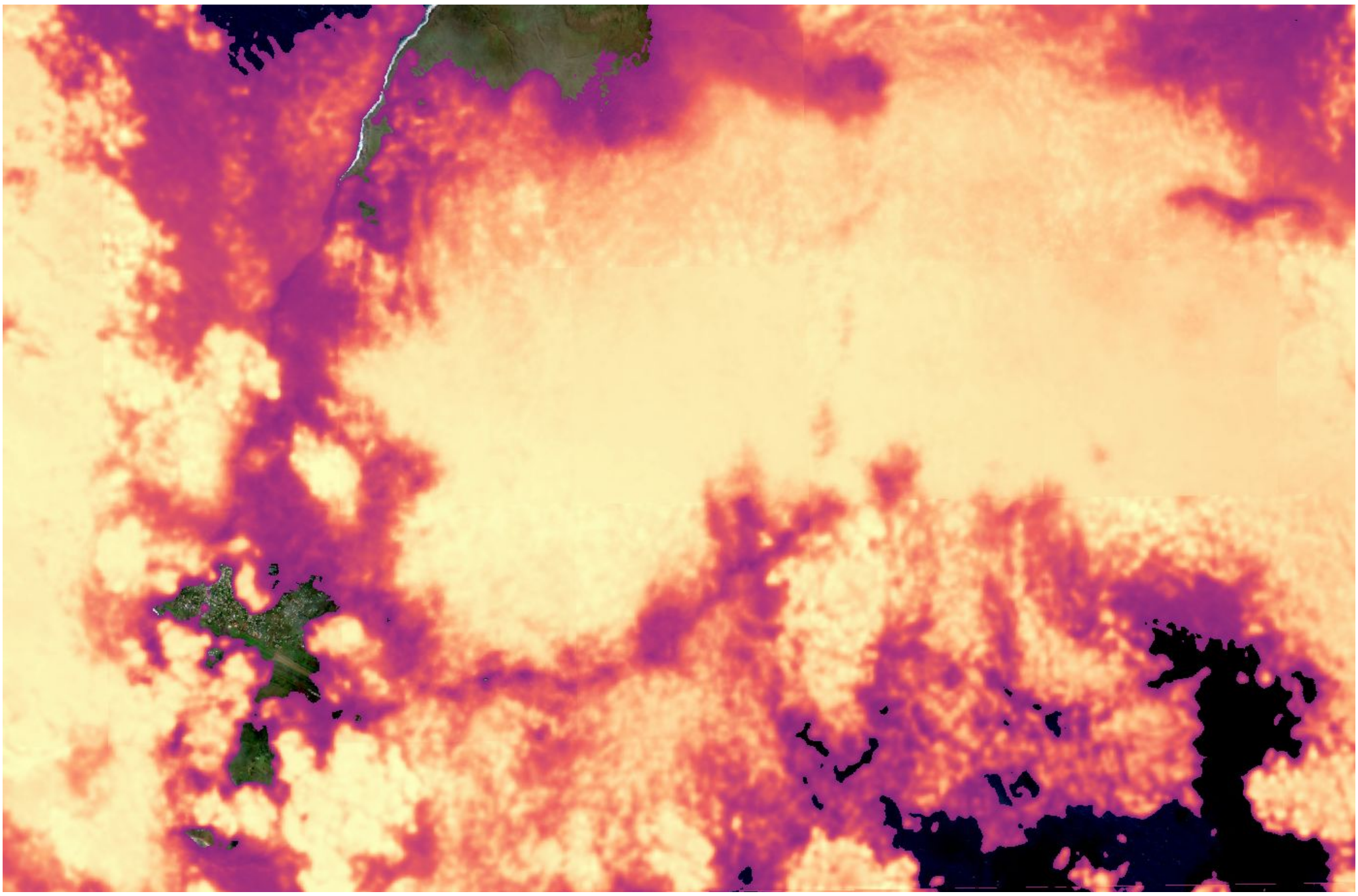
[CLOSE](#) [IMPORT](#)



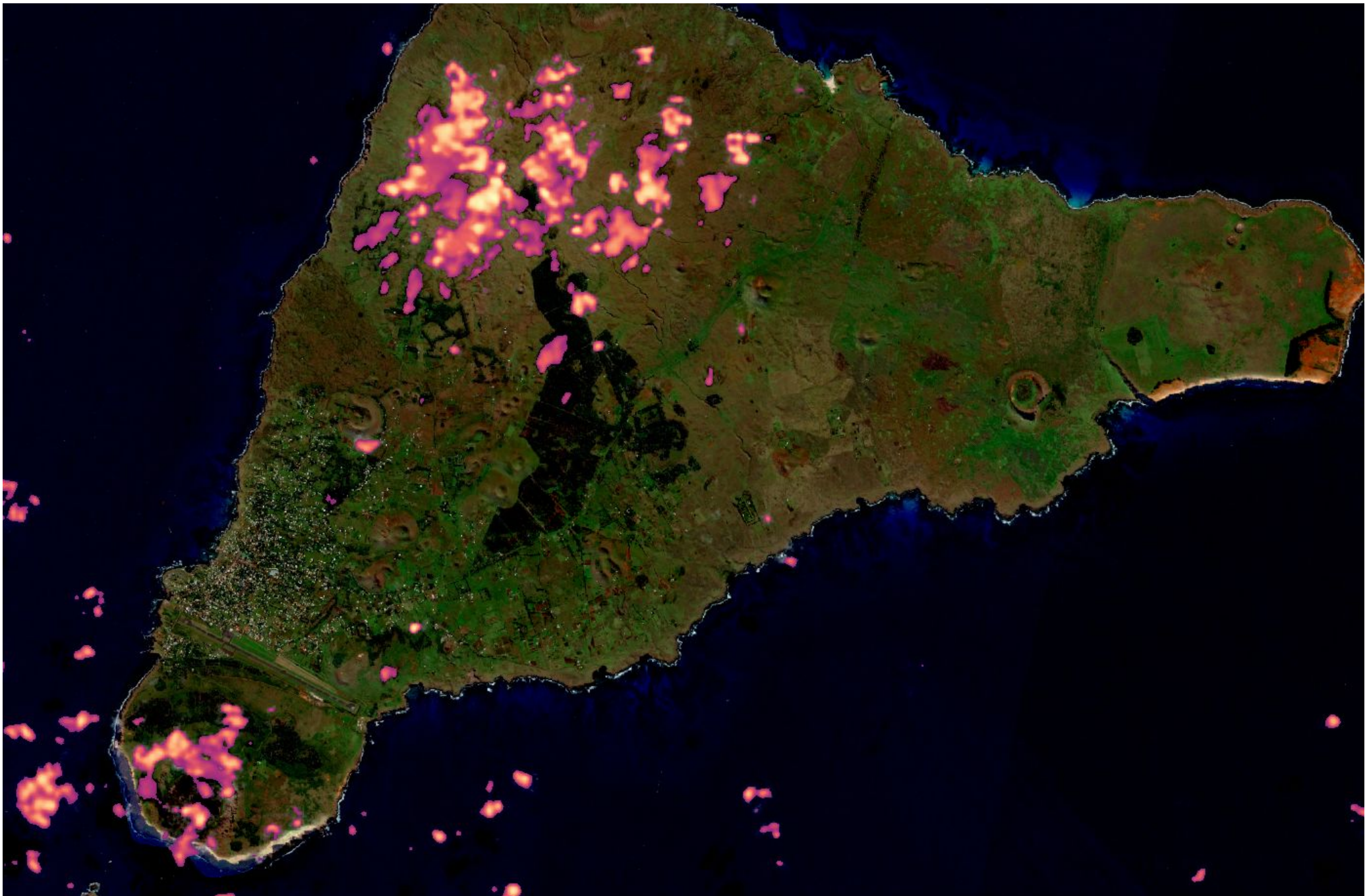


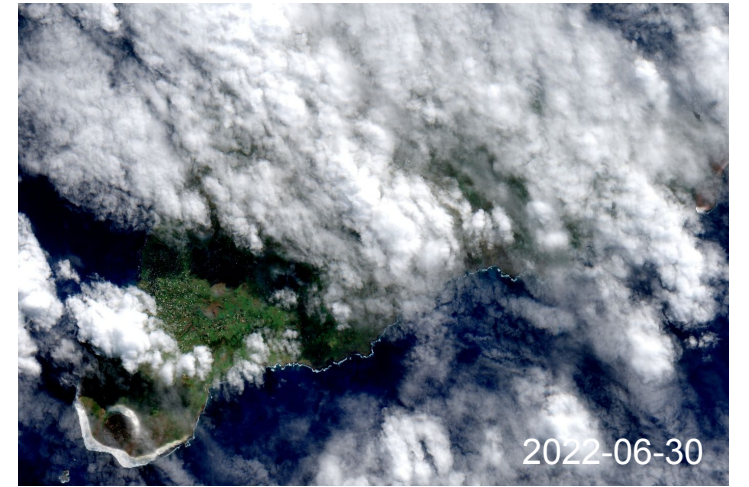
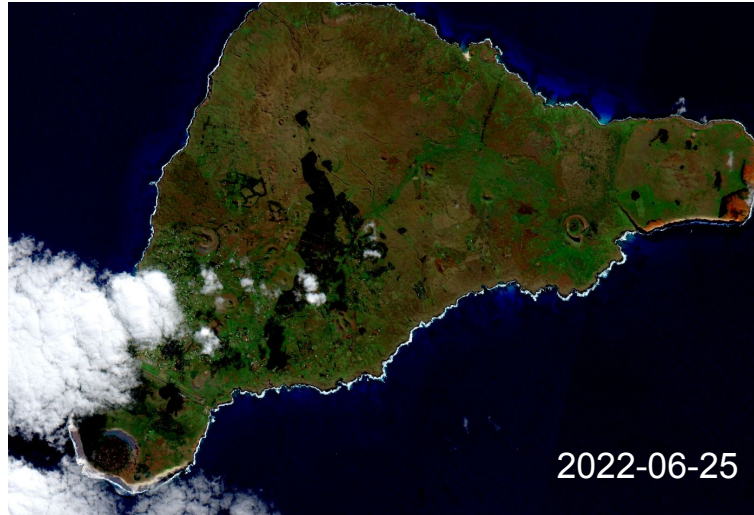
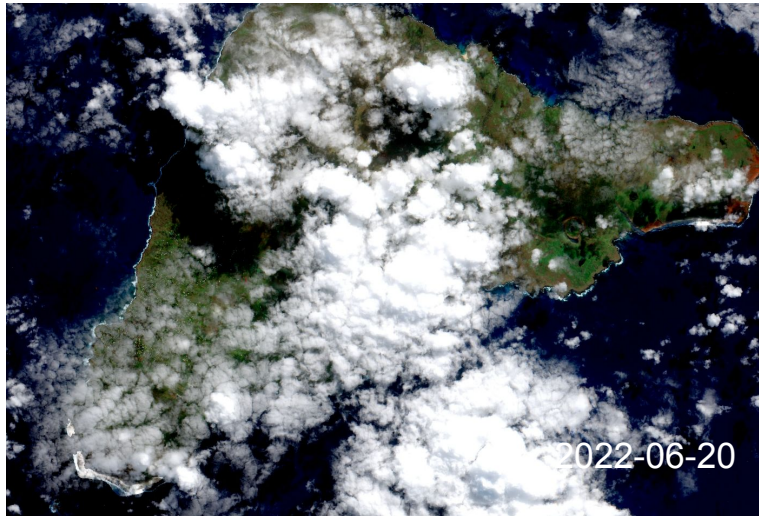
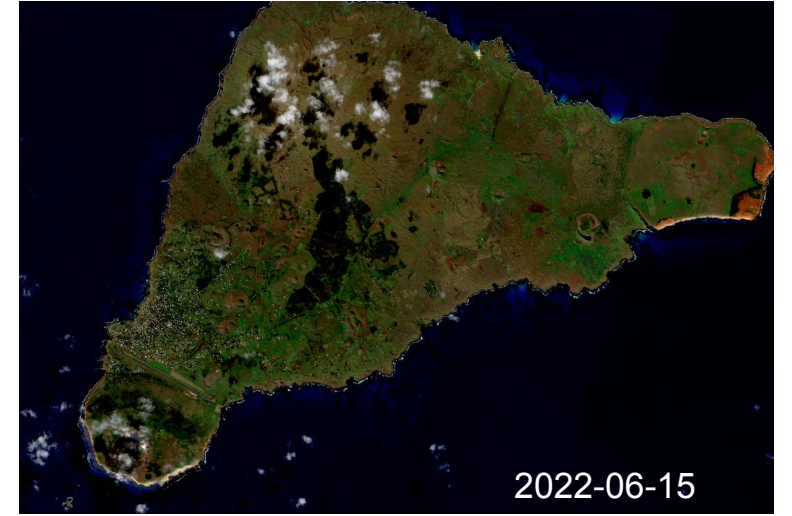
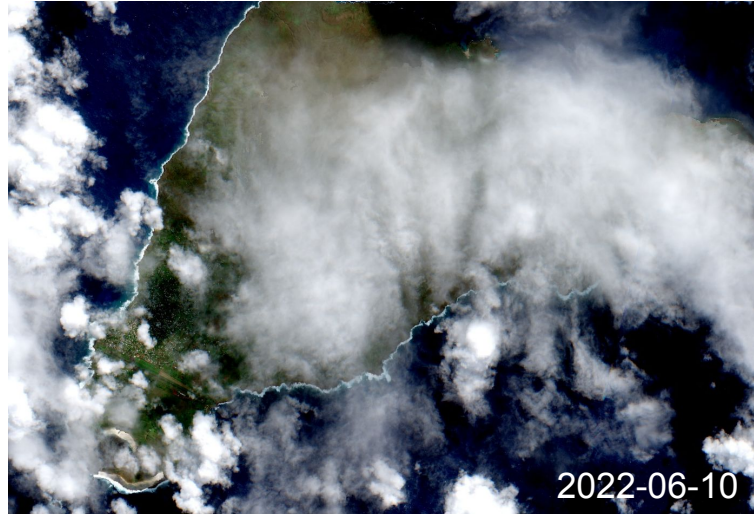
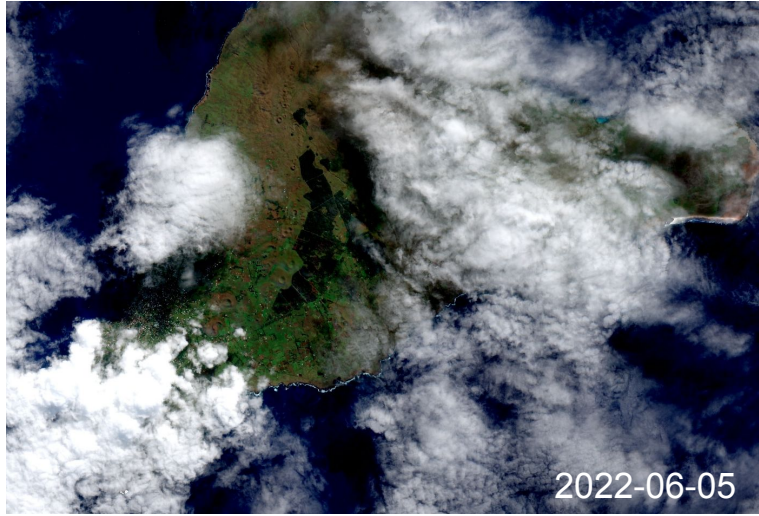


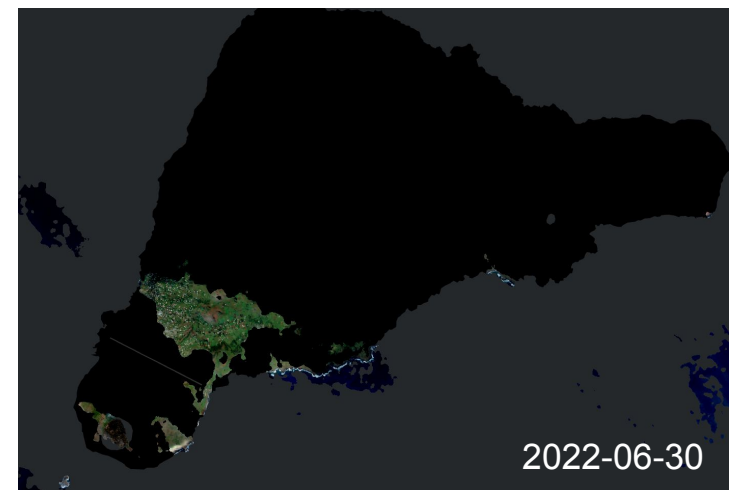
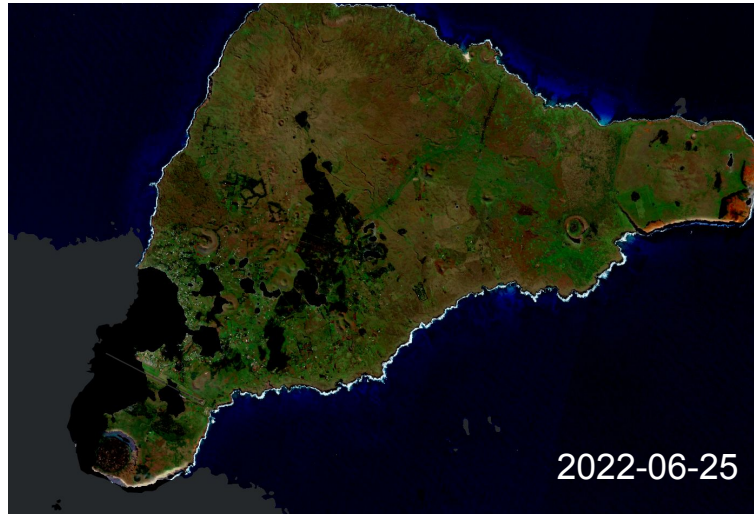
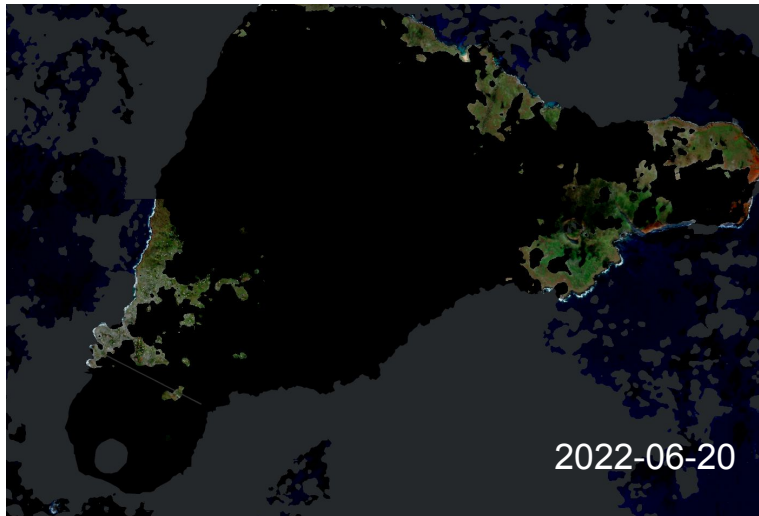
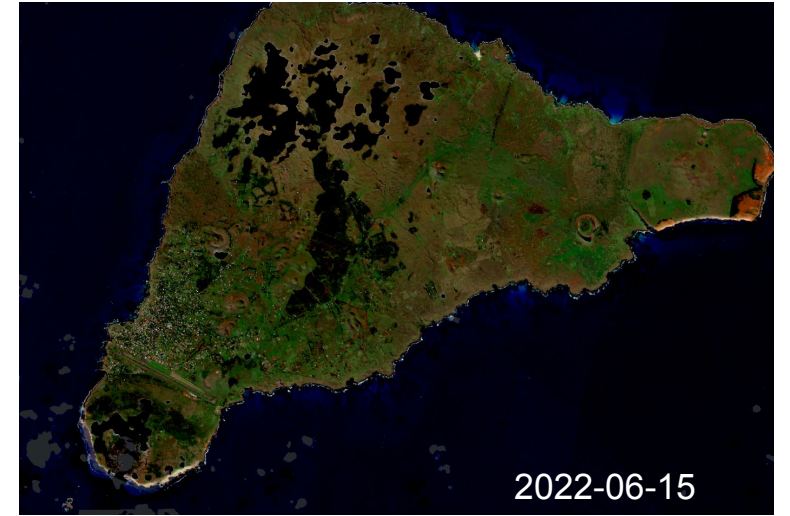
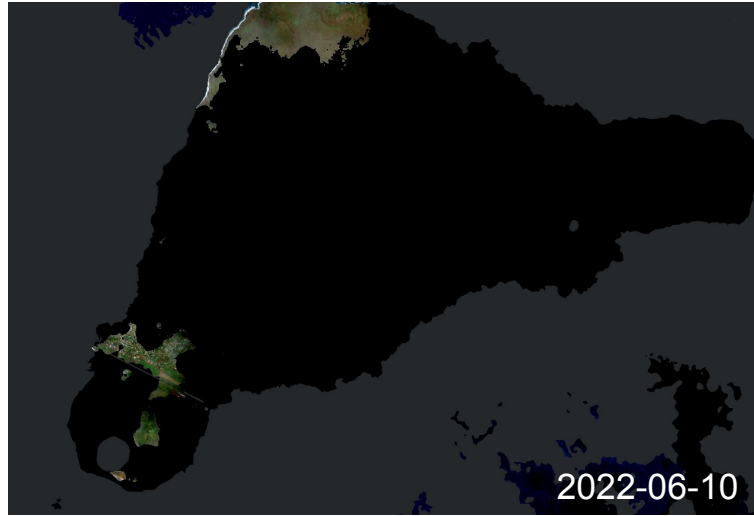
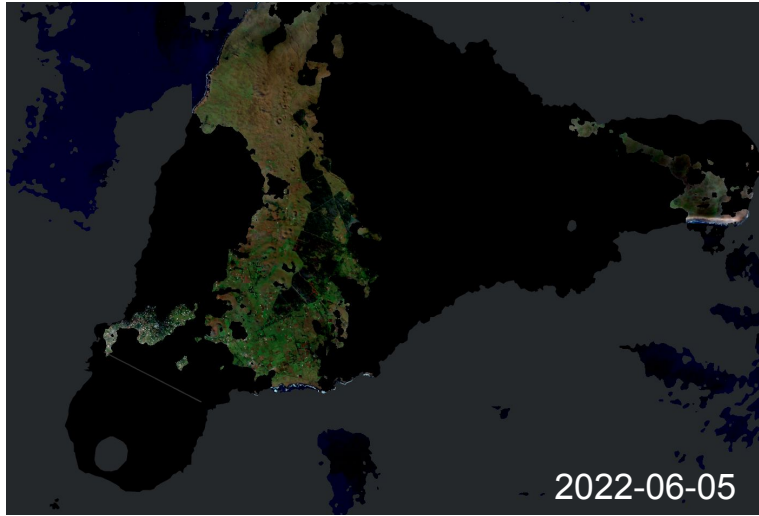






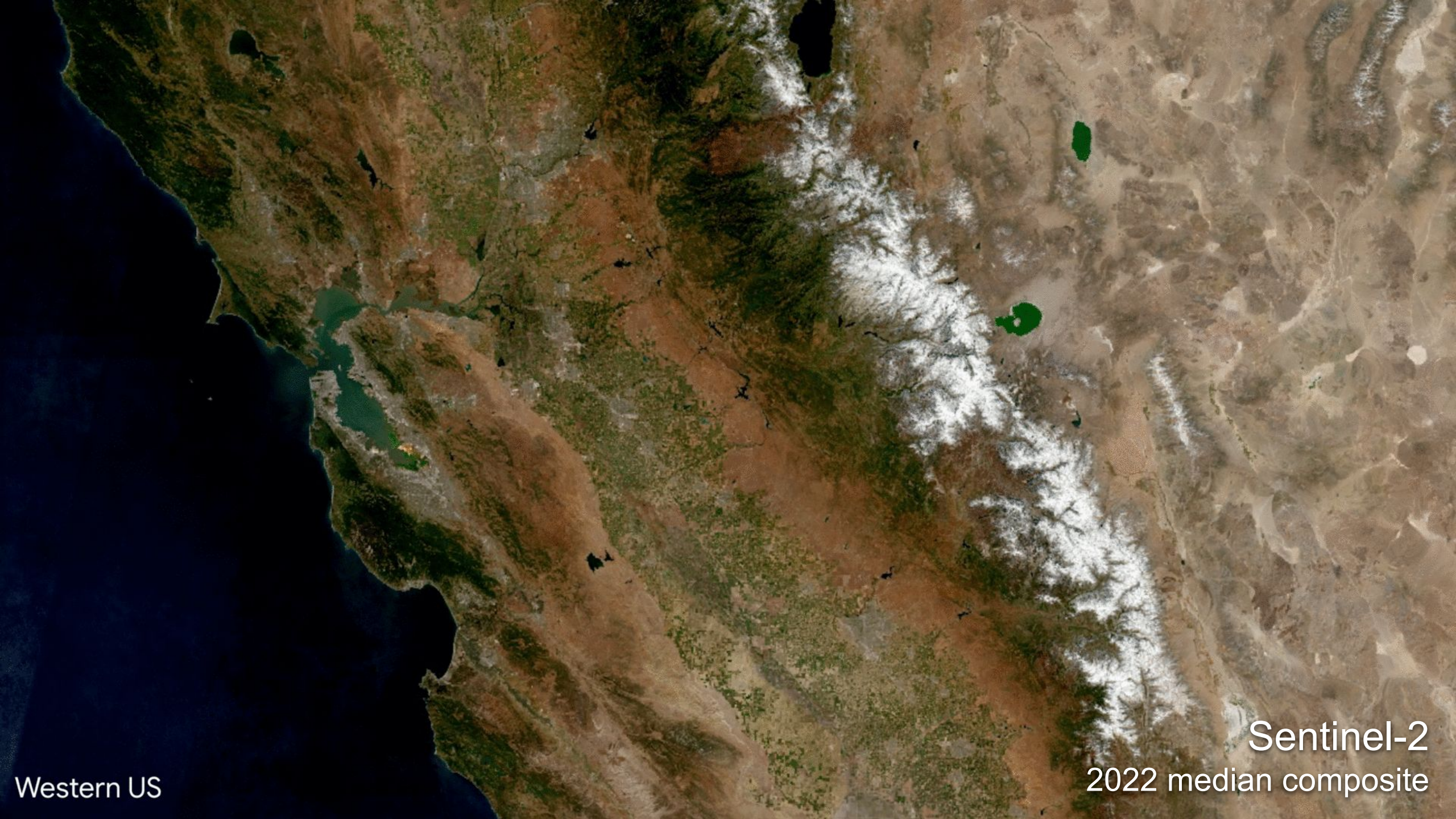








30-day median
composite
June 2022



Western US

Sentinel-2
2022 median composite



Google

#GeoForGood19



Earth Engine Google Developer Experts



Aaron Zuspan



Abena Boatemaa Asare-Ansah



Africa Flores



Alvaro Moreno



Andréa Puzzi Nicolau



Biplov Bhandari



Craig Dsouza



Daniel Wiell



David Montero Loaiza



Eliana Lima de Fonseca



Emil Cherrington



Emma Izquierdo-Verdiguier



Eric Jensen



Erin Trochim



Flávia De Souza Mendes



Guillaume Attard



Guneet Mutreja



Julia Wagemann



Karis Tenneson



Keiko Nomura



Kyle Woodward



Liza Goldberg



Luiz Cortinhas



Maria Luize Pinheiro



Mathieu Gravey



Mirza Waleed



Modou Mbaye



Nathaniel Robinson



Olga Danylo



Qiusheng Wu



Sabrina Szeto



Samapriya Roy



Shengbiao Wu



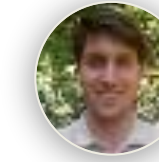
Tim Mayer



TC Chakraborty



Vivian Ribeiro



Zander Venter



Ziyu Lin

Preview: Publisher and Community Data Catalogs

Google Earth Engine > Data Catalog

Search [] [] English [] []

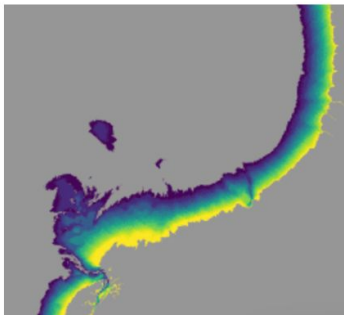
Home View all datasets Browse by tags Landsat MODIS Sentinel Publisher Community API Docs

Geoscience Australia

Geoscience Australia provides Earth observation services. Program objectives are to ensure continuity of access to data, promote use and value of satellite imagery with sensing science through extracting value and use of EOS access to data, and provide national imagery coordination. Looking for another dataset not in Earth Engine yet? Let

Filter list of datasets

National Intertidal Digital Elevation Model 25m 1.0.0



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Awesome GEE Community Catalog

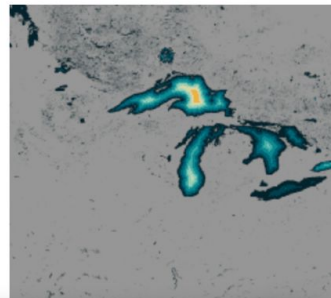
Awesome GEE Community Catalog consists of community-sourced geospatial datasets made available for use by the larger Google Earth Engine community and shared publicly as Earth Engine assets. The project was started with the idea that a lot of research datasets are often unavailable for direct use and require preprocessing before use. This catalog lives and serves alongside the Google Earth Engine data catalog and also houses datasets that are often requested by the community and under a variety of open licenses.

Looking for another dataset not in Earth Engine yet? Let us know by [suggesting a dataset](#).

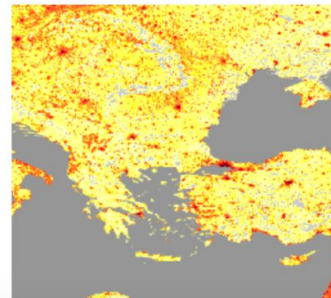


Filter list of datasets

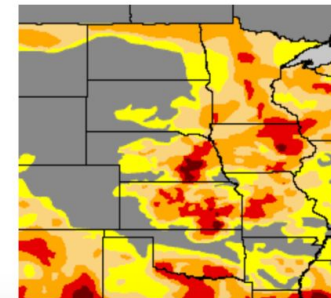
GLOBathy Global lakes bathymetry dataset



LandScan Population Data Global 1km



United States Drought Monitor



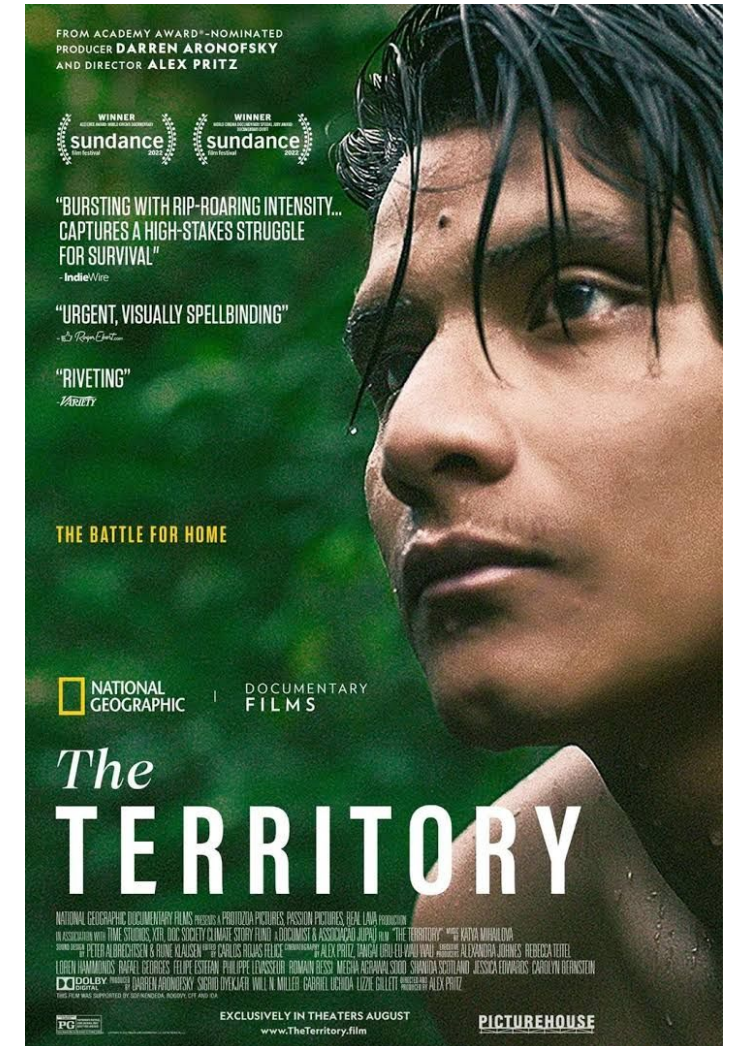
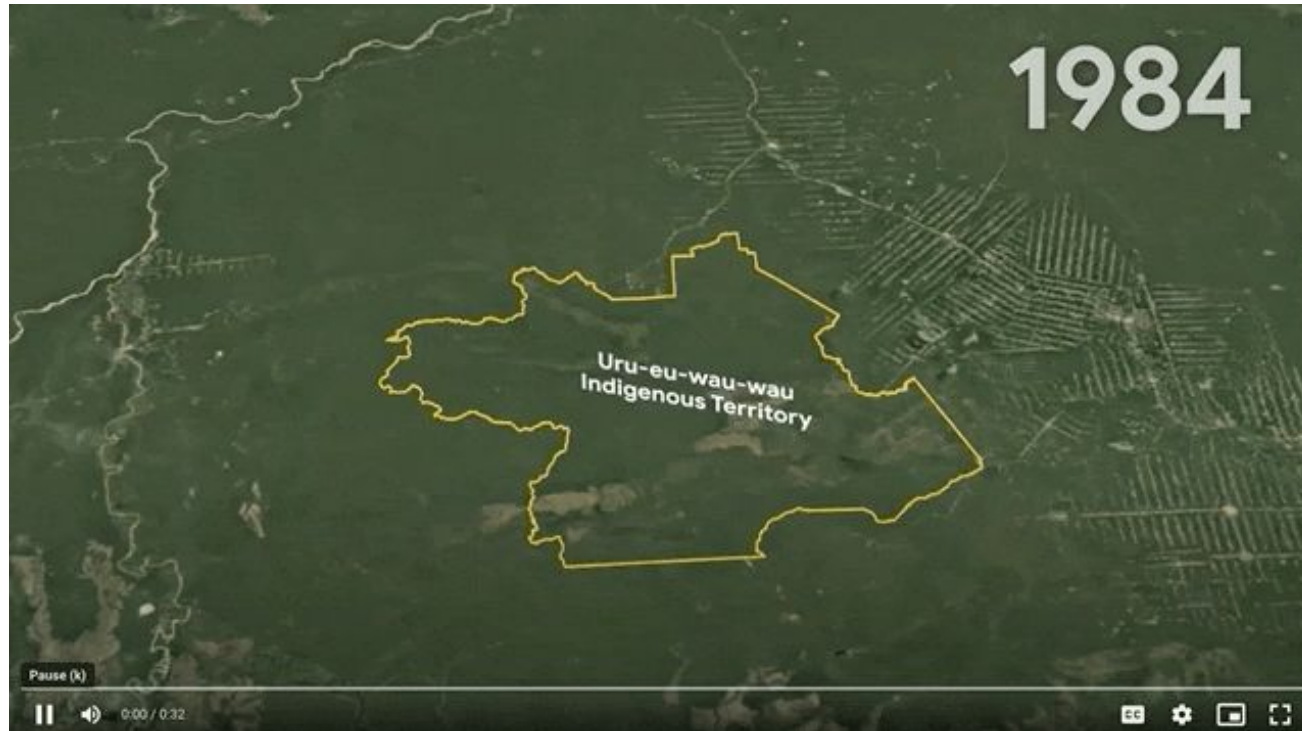
Learning Resources

The image displays the book cover and associated digital resources. The book cover, on the left, features a green and blue background with a satellite-style map. The authors listed are Jeffrey A. Cardille, Morgan A. Crowley, David Saah, and Nicholas E. Clinton, with 'Editors' in italics. The title is 'Cloud-Based Remote Sensing with Google Earth Engine' and the subtitle is 'Fundamentals and Applications'. It is an 'OPEN ACCESS' publication from Springer.

Overlaid on the right are two browser windows. The top window shows the YouTube channel for 'EEFA Book' (@eefabook3667), which has 950 subscribers and 88 videos. The channel's 'PLAYLISTS' tab is active, showing several video thumbnails with titles such as 'Chapter A1.8: Heat Islands', 'Chapter F5.2: Zonal Statistics', 'Chapter F5.1: Raster/Vector Conversions', and 'Chapter F5.3: Advanced Vector Operations'. The bottom window shows the website 'eefabook.org', which has a navigation menu with 'HOME', 'ABOUT', 'GO TO THE BOOK', 'TABLE OF CONTENTS', and 'MORE...'. The main content area features a large satellite map image and a 'Welcome to Cloud-Based Remote Sensing with Google Earth Engine: Fundamentals and Applications' message. Below the map, there is introductory text about the book's origin and a 'LEARN MORE' button.

<http://eefa-book.org>

The Indigenous **Uru-eu-wau-wau** people use Google Earth as a tool to defend their territory from illegal invasion



Thank you!

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earthengine.google.com

The Beatles - Revolution



♪ You say you want a revolution ♪ We'd all love to change the world ♪