Climate Engine Virtual Workshop #3

June 14, 2023

Supporting South Florida Water Management District

Google Cloud

Climate Engine®

Agenda: June 14, 2023

Time (ET)	Section	Section Lead
Introduction (1:00-1:10)	Welcome + Workshop Overview	Caleb White
Session 1A (1:10-1:30)	API Feedback, Questions & Answers	All
Session 1B (1:30-2:00)	Use Cases: Facilitated Discovery Session	Caleb & Ankur
Break (2:00-2:10)	Break (10 min)	
Session 2 (2:10-2:55)	Segment Anything Model Overview (SAM)	Keiko
Break (2:55-3:05)	Break (10 min)	
Session 3 (3:05-3:50)	Working With High Resolution Commercial Satellites	Ankur
Wrap Up (3:50-4:00)	Wrap Up	Caleb White

Section 1A:

API Feedback, Questions & Answers

Open Discussion: API Feedback, Questions & Answers

- How has the experience been so far with the API?
- Are there any blockers in using the API to access requested datasets?
- Have you used the APIs in any experiments or in collaboration with various tasks?
- Are there any ways in which we can support further on the technical onboarding?
- Other Q &A?

Section 1B:

Use Cases: Facilitated Discovery Session

Use Cases: Facilitated Discovery Session

In the fall of 2022, SFWMD IT, Google Cloud and Climate Engine met with various SFWMD scientific stakeholders to identify use cases, workflows and desired capabilities.

In this section, we will review a summary of these workshops to understand how we can help connect these use cases to the new data and technological capabilities that have been enabled and/or identify and gaps or areas of further improvement or functionality.

The following highlights are to be used as a guide, but participants are encouraged to bring forward their own workflows, specific needs and/or questions about how to integrate into your current work.

Use Cases: Facilitated Discovery Session

Everglades Section

- Integration of remote sensing, lidar data, and AI techniques for landscape analysis and environmental monitoring in the Everglades.
- Leveraging data-driven approaches to understand the impact of restored flow, predict algae blooms, and assess the effects of climate change on the Everglades ecosystem.

Coastal Ecosystems

- Estuary health management: Use salinity as a key indicator, conduct aerial and landscape surveys, monitor water quality, and address challenges in identifying triggers for different groups while incorporating QA/QC processes.
- Integrated spatial data utilization: Apply a watershed model for comprehensive analysis, effectively utilize large amounts of spatial data, address temporal and spatial variations, and explore the integration of drone data for monitoring, including the use of NDVI for quantifying blooms.

Land and Water Ecosystems

- Water Quality and Vegetation Mapping:
  - Develop short and long-term water quality forecasts, including bloom identification and characterization, to inform decisions on estuary release.
  - Enhance vegetation mapping through machine learning and open-source resources, combining high-resolution and satellite imagery for more frequent mapping, particularly focusing on wetland vegetation.
- Exotic Species Monitoring and Watershed Analysis:
  - Utilize high-resolution imagery and software tools for the identification and monitoring of exotic and invasive species.
  - Conduct watershed analysis and integrate water depth data with remote sensing products to assess habitat suitability and explore Lidar applications.

Water Quality Treatment

- Develop real-time dashboards and tools for monitoring and reporting on the conditions of Stormwater Treatment Areas (STAs), including water depth assessment and tracking changes in vegetation to evaluate the reduction of phosphorus in the water.
- Implement high-resolution multi-spectral analysis, such as Sentinel with red edge bands, to detect and quantify changes in vegetation types, allowing for event-based analysis and improved decision-making during storm events.

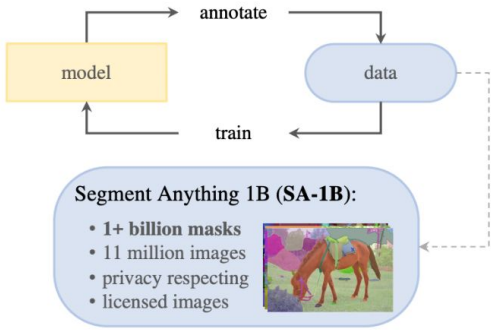
10 minute break

Section 2:

Segment-Geospatial (SAM) Overview

What is Segment Anything Model (SAM)?

- Meta's Segment Anything Model (SAM) is a new AI model released in April 2023 that can **"cut out" any object, in any image, with a single click or a text prompt**
- SAM can segment **unfamiliar** objects and images **without additional training**, making it a powerful tool for computer vision applications
- SAM was trained via a data collection loop to create the largest segmentation dataset to date
    - 1+ billion masks
    - 11 million images
- Type of prompts are supported
    - Foreground/background points
    - Bounding box
    - Mask
    - Text
- The goal is to facilitate further advancements in segmentation and image and video understanding by sharing their research and dataset
- Some limitations due to design for generality and broad usage

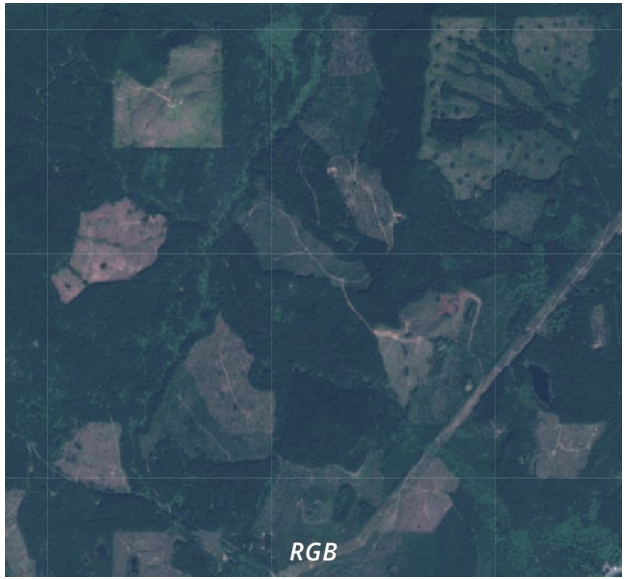


Data: data engine (top) & dataset (bottom)

Paper: Kirillov, A., Mintun, E., Ravi, N., Mao, H., Rolland, C., Gustafson, L., Xiao, T., Whitehead, S., Berg, A., Lo, W.Y., Dollar, P., & Girshick, R. (2023). Segment Anything. *arXiv:2304.02643*.

Segmentation in Remote Sensing

- Image segmentation in remote sensing, also known as “object-based classification” or “object-based image analysis” (**OBIA**), is typically used as **pre-processing step** to group neighbouring pixels into segments or objects (e.g. tree crowns, rooftops)
- This is particularly useful when using **high resolution imagery** for classification in order to avoid the **salt-and-pepper effects of pixel-based classification**
- In practice, the approach consists of two steps: first, the image is segmented using a segmentation algorithm; second, the objects are classified using either supervised or unsupervised classification methods



Common Segmentation Methods:

Clustering-based: Clustering groups of similar pixels or regions together based on their proximity in the data space (e.g. K means)

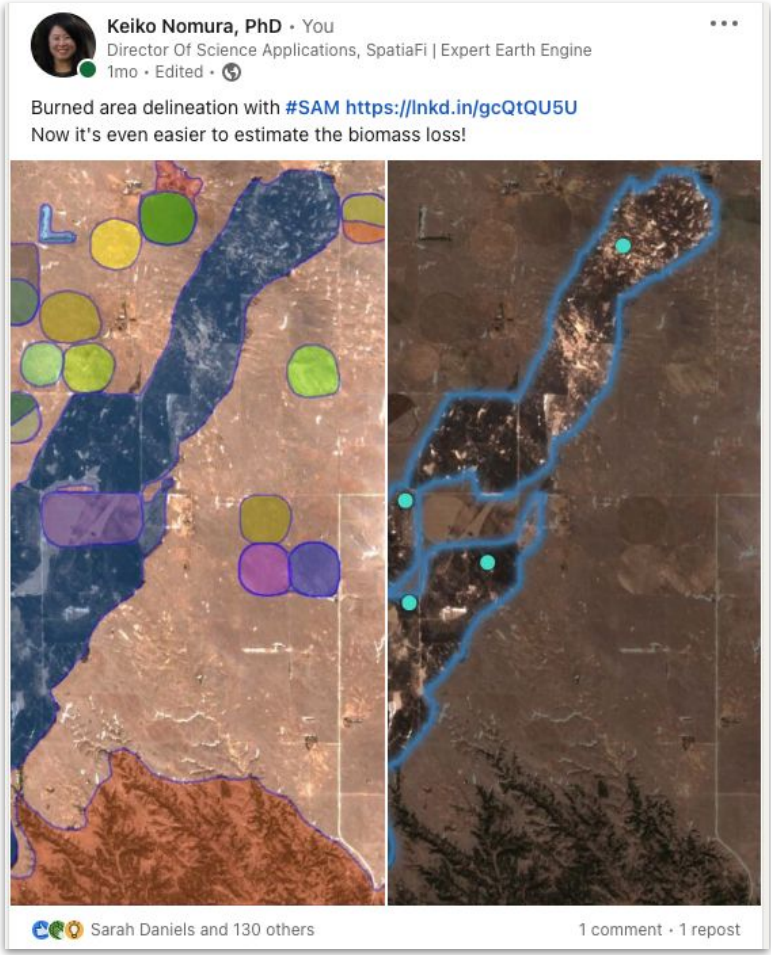
Region-based: Dividing an image into regions by merging pixels with similar properties (eg. Mean-Shift)

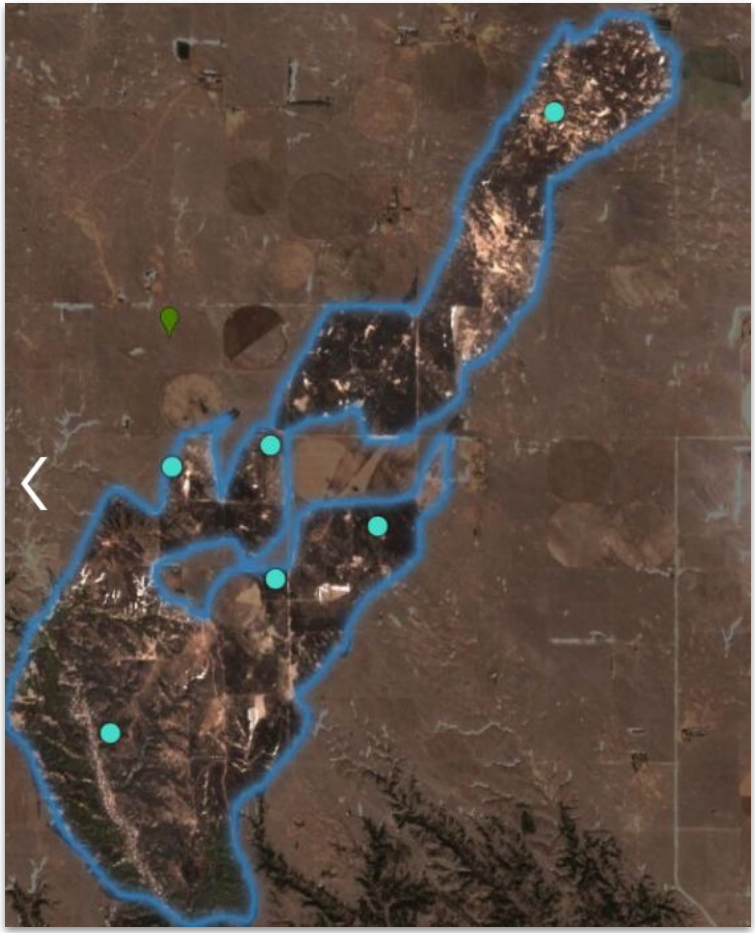
Texture-based: Analyzing patterns of pixels to segment different areas based on their textural characteristics (eg. Co-occurrence Matrix)

Deep learning models: learn and extract features from data to perform accurate segmentation tasks (e.g. U-net, transformers, FCNN)

Application of SAM in remote sensing

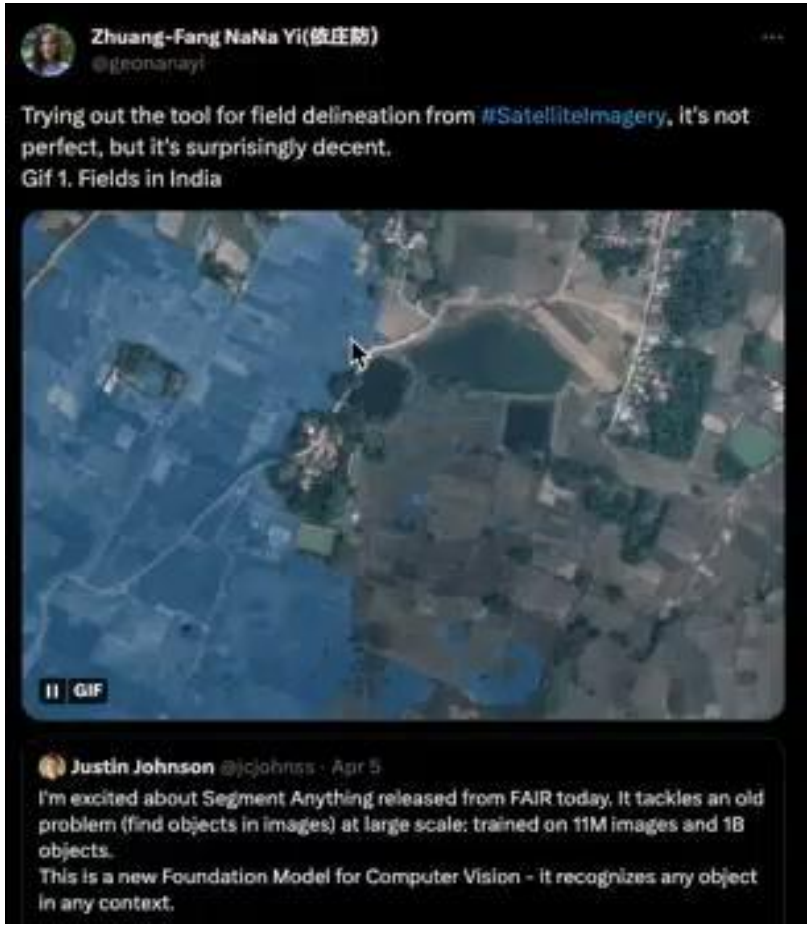
Burned area delineation

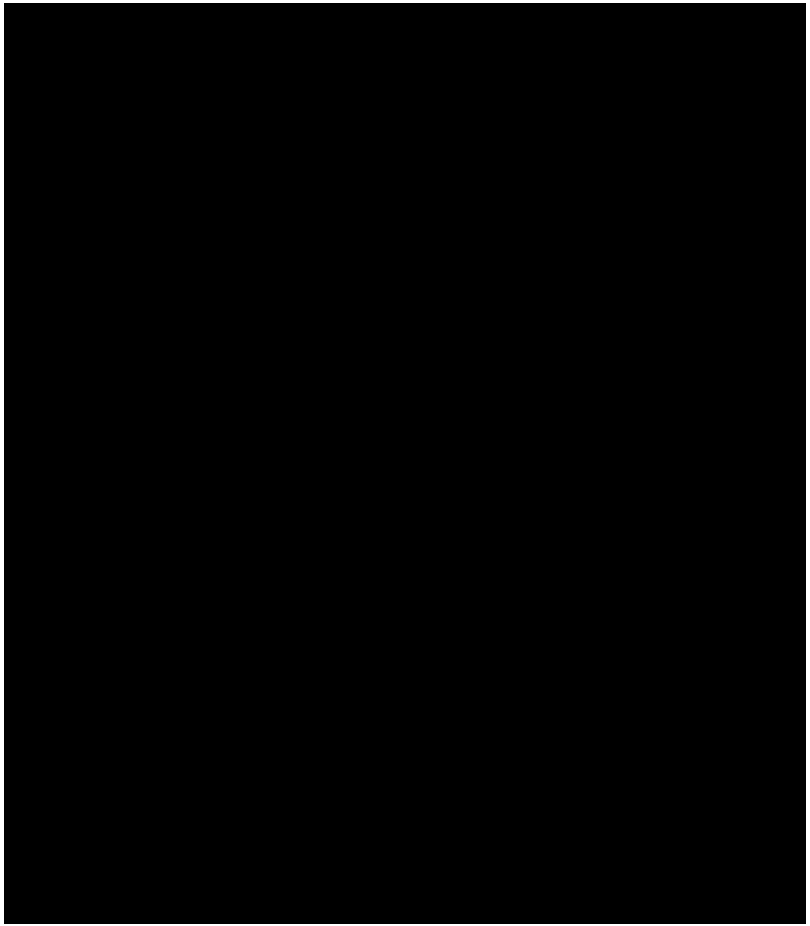




Application of SAM in remote sensing

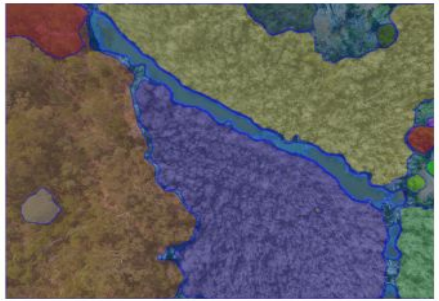
Crop field delineation by RegrowAg



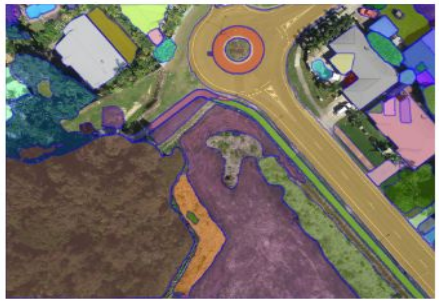


Application of SAM in remote sensing

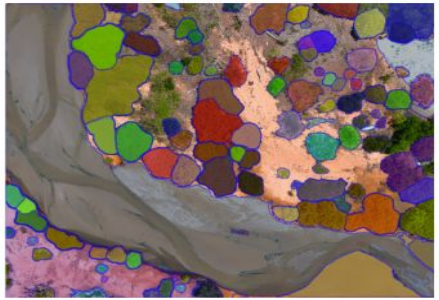
Drone imagery by GeoNADIR



Segment Anything for drone imagery over mangrove ecosystems works well in this example! It has clearly detected the difference between the dead mangrove patches and their surrounds. This is amazing for environmental monitoring!



The high contrast in urban environments is perfect for Segment Anything. We can see individual houses, roads, swimming pools with clarity. At this scale it doesn't detect cars or other smaller objects.



The algorithm works beautifully to detect th edges between patches of trees and the sand dunes. The creek bed is a single segment, which could be seen positively or negatively. If you're interested in the finer features of the creek, then this segmentatio is too coarse. But as general segments, it has performed beautifully!

https://geonadir.com/segment-anything-for-drone-imagery/

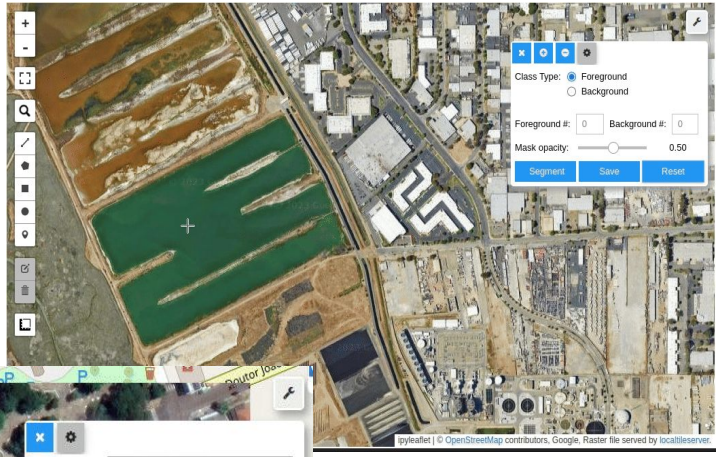
Application of SAM in remote sensing

segment-geospatial

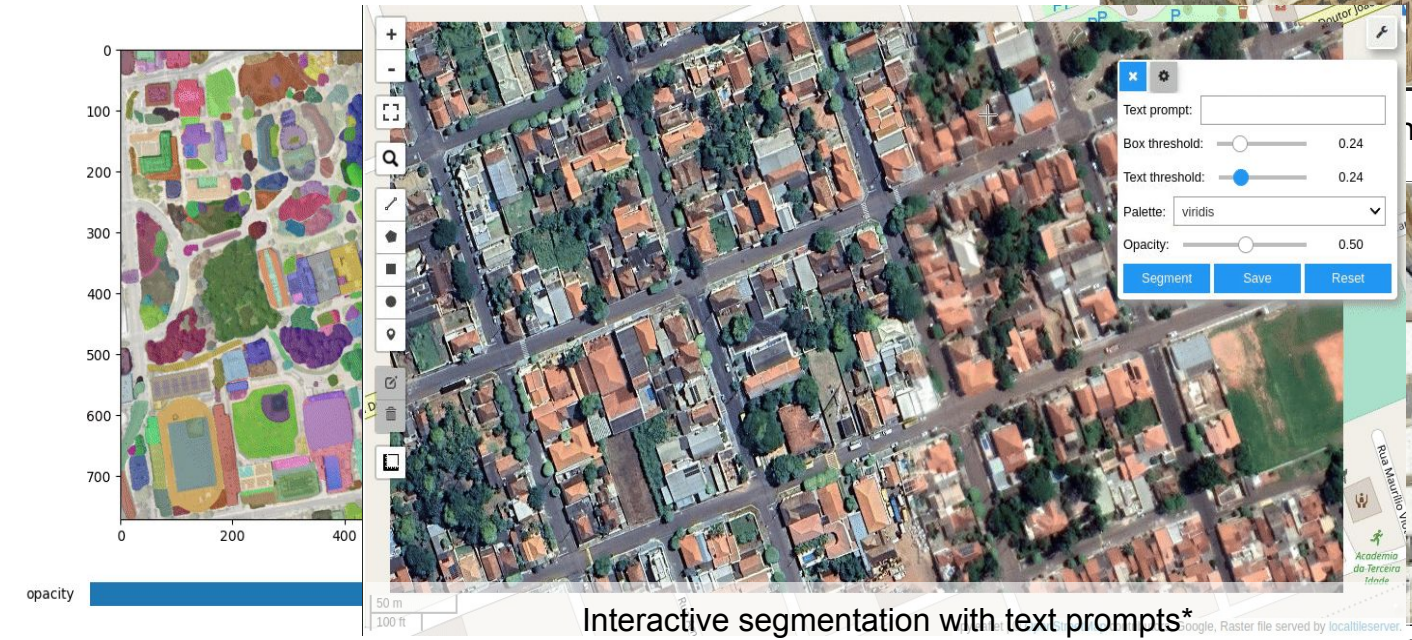
Open Studio Lab | Open Planetary Computer | Open in Colab | pypi v0.8.1 | conda-forge v0.8.1 | pulls 96 | downloads 16k | downloads 1k total | DOI 10.5281/zenodo.7966658

A Python package for segmenting geospatial data with the Segment Anything Model (SAM)

Qiusheng Wu, & Lucas Osco. (2023). samgeo: A Python package for segmenting geospatial data with the Segment Anything Model (SAM). Zenodo. https://doi.org/10.5281/zenodo.7966658

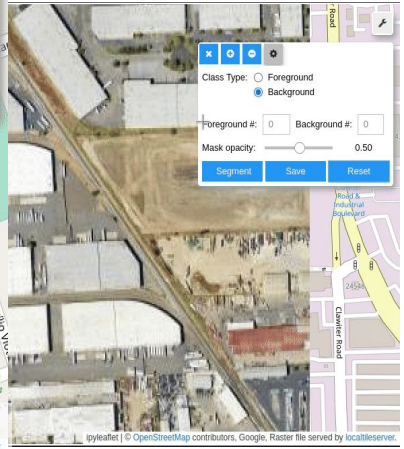


ntation with input prompts

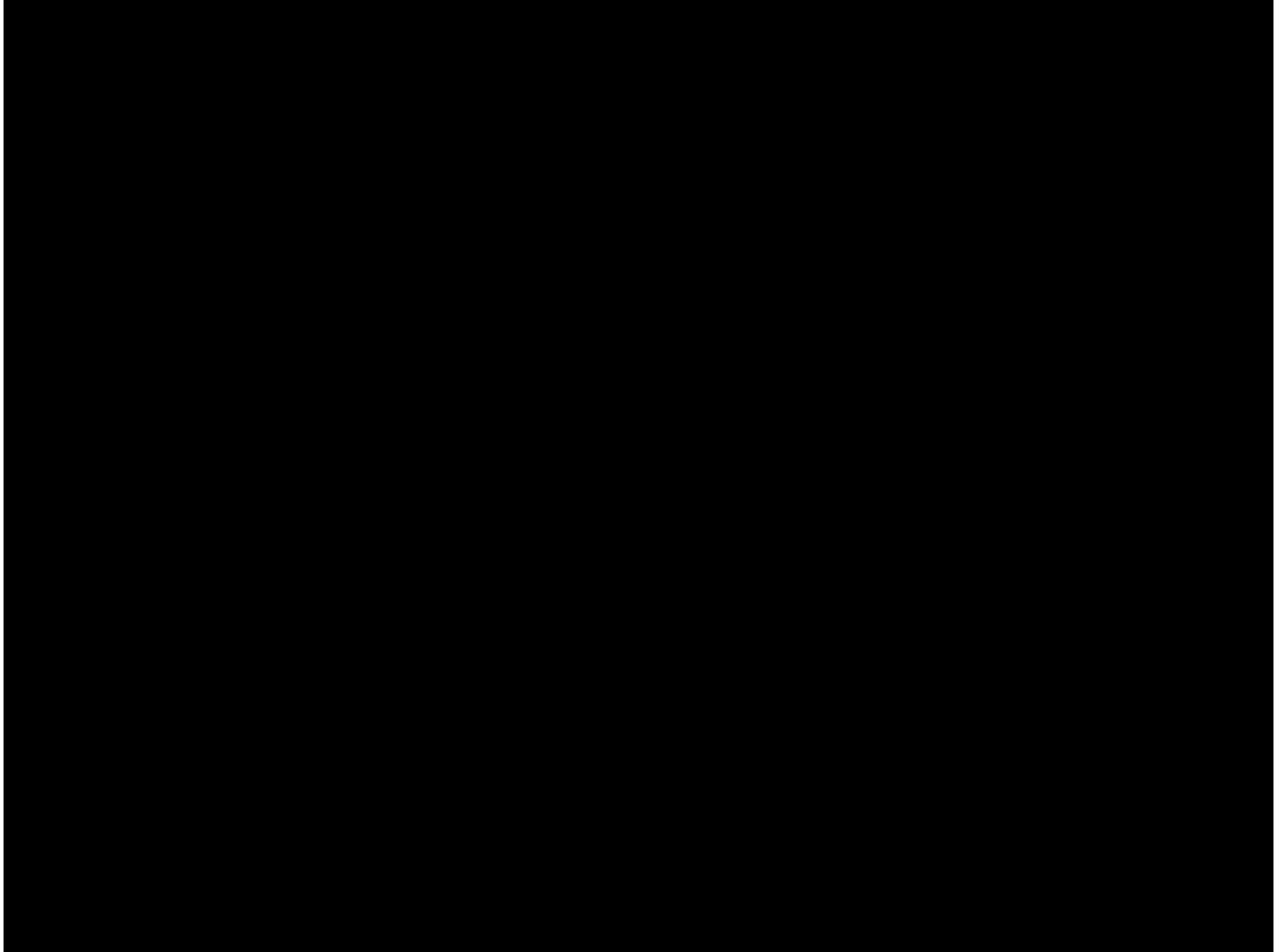


Automatic mask generation

Interactive segmentation with text prompts*



Input prompts from existing files



Application of SAM in remote sensing

Generate RS datasets

- SAM has significant potential to improve the efficiency of annotating RSIs since it delivers promising segmentations on recognized areas
- The study utilize SAM to efficiently construct a large-scale RS segmentation dataset (SAMRS: Segment Anything Model annotated Remote Sensing Segmentation Database)
- Explored the performance of various prompts to determine the optimal settings for SAM
- “SAMRS is a valuable resource when conducting largescale model pre-training research in the field of remote sensing image segmentation”

https://arxiv.org/pdf/2305.02034.pdf

Scaling-up Remote Sensing Segmentation Dataset with Segment Anything Model

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Abstract

The success of the Segment Anything Model (SAM) demonstrates the significance of data-centric machine learning. However, due to the difficulties and high costs associated with annotating Remote Sensing (RS) images, a large amount of valuable RS data remains unlabeled, particularly at the pixel level. In this study, we leverage SAM and existing RS object detection datasets to develop an efficient pipeline for generating a large-scale RS segmentation dataset, dubbed SAMRS. SAMRS surpasses existing high-resolution RS segmentation datasets in size by several orders of magnitude, and provides object category, location, and instance information that can be used for semantic segmentation, instance segmentation, and object detection, either individually or in combination. We also provide a comprehensive analysis of SAMRS from various aspects. We hope it could facilitate research in RS segmentation, particularly in large model pre-training. The code and dataset will be available at SAMRS[1].

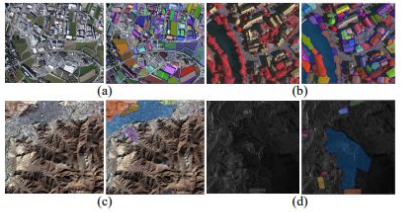


Figure 1. Some examples of SAM segmentation results on RSIs: (a) RGB aerial image obtained from the IsAID dataset [17]. (b) Airborne aerial image composed of near-infrared, red, and green bands. This image is from the ISPRS Vaihingen dataset[2]. (c) RGB satellite image observed by GF-2 sensors. This image is from the GID dataset [12]. (d) Hisea-1 SAR image from the Marine Farms Segmentation track of the 5th Gaofen Challenge[3].

from practitioners. Furthermore, RSI objects are often dis-

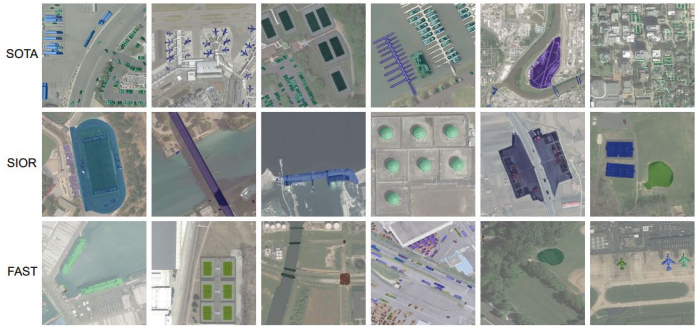


Figure 6. Some visual examples from the three subsets of our SAMRS dataset.

References

Publication

- https://arxiv.org/pdf/2305.02034.pdf
- https://github.com/ViTAE-Transformer/SAMRS
- https://www.researchgate.net/publication/370775417_A_Comprehensive_Survey_on_Segment_Anything_Model_for_Vision_and_Beyond/link/6464985a9533894cac75e856/download

Python packages

- https://github.com/aliaksandr960/segment-anything-eo
- https://samgeo.gishub.org/
- https://zenodo.org/record/7966658
- https://pypi.org/project/segment-anything-py/
- https://github.com/aliaksandr960/segment-anything-eo

Blog

- https://geonadir.com/segment-anything-for-drone-imagery/
- https://developmentseed.org/blog/2023-05-19-segment-anything-potential
- https://medium.com/aimonks/use-segment-anything-model-sam-for-geospatial-data-ef1eea928a6

10 minute break

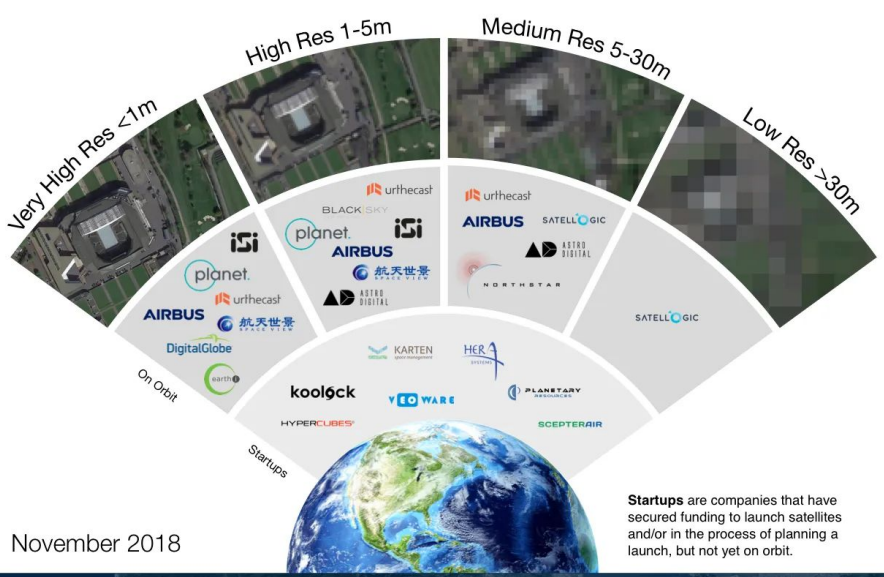
Section 3:

Working With Commercial Imagery

Advent of High Resolution Commercial Imagery

Commercial Visible EO Satellites

The era of commercial EO satellites took off in the US after the passage of the Land Remote Sensing Policy Act in 1992 allowing the private sector to operate space systems.



November 2018

Startups are companies that have secured funding to launch satellites and/or in the process of planning a launch, but not yet on orbit.

Resolution Citation:
Green, Kass, Russell G. Congalton, and Mark Tukman. 2017. Imagery and GIS. Best Practices for Extracting Information from Imagery. ESRI Press, Redlands CA. 437pp.

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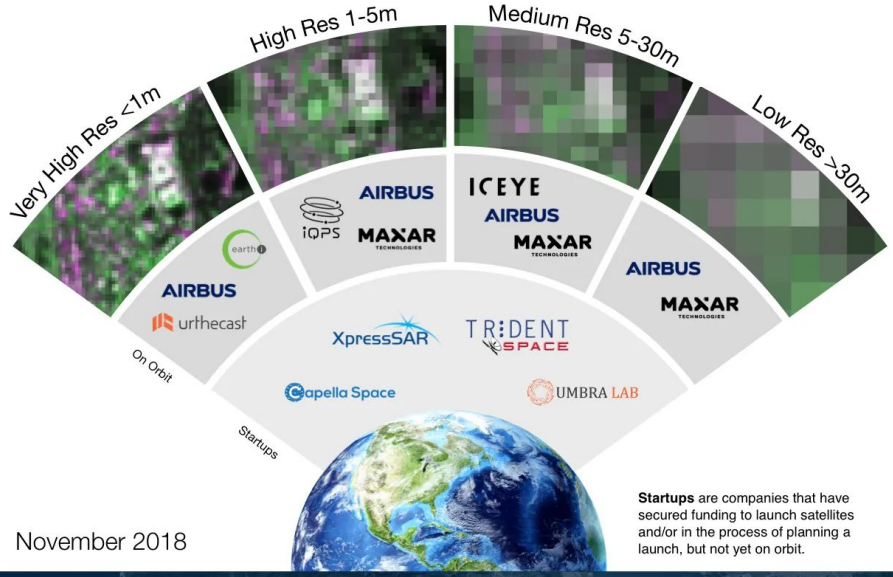
radiant.earth/infographics

Commercial Radar Satellites

Synthetic Aperture Radar (SAR) satellites are active sensors that penetrate through clouds and darkness to monitor Earth surface physical properties.



November 2018

Startups are companies that have secured funding to launch satellites and/or in the process of planning a launch, but not yet on orbit.

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Advantages of High Resolution Commercial Imagery

1. **High-quality Data**: Commercial satellites can capture images with very high resolution. This means the images are detailed enough to distinguish small features on the Earth's surface, which can be crucial for many applications such as mapping, monitoring, and analysis.

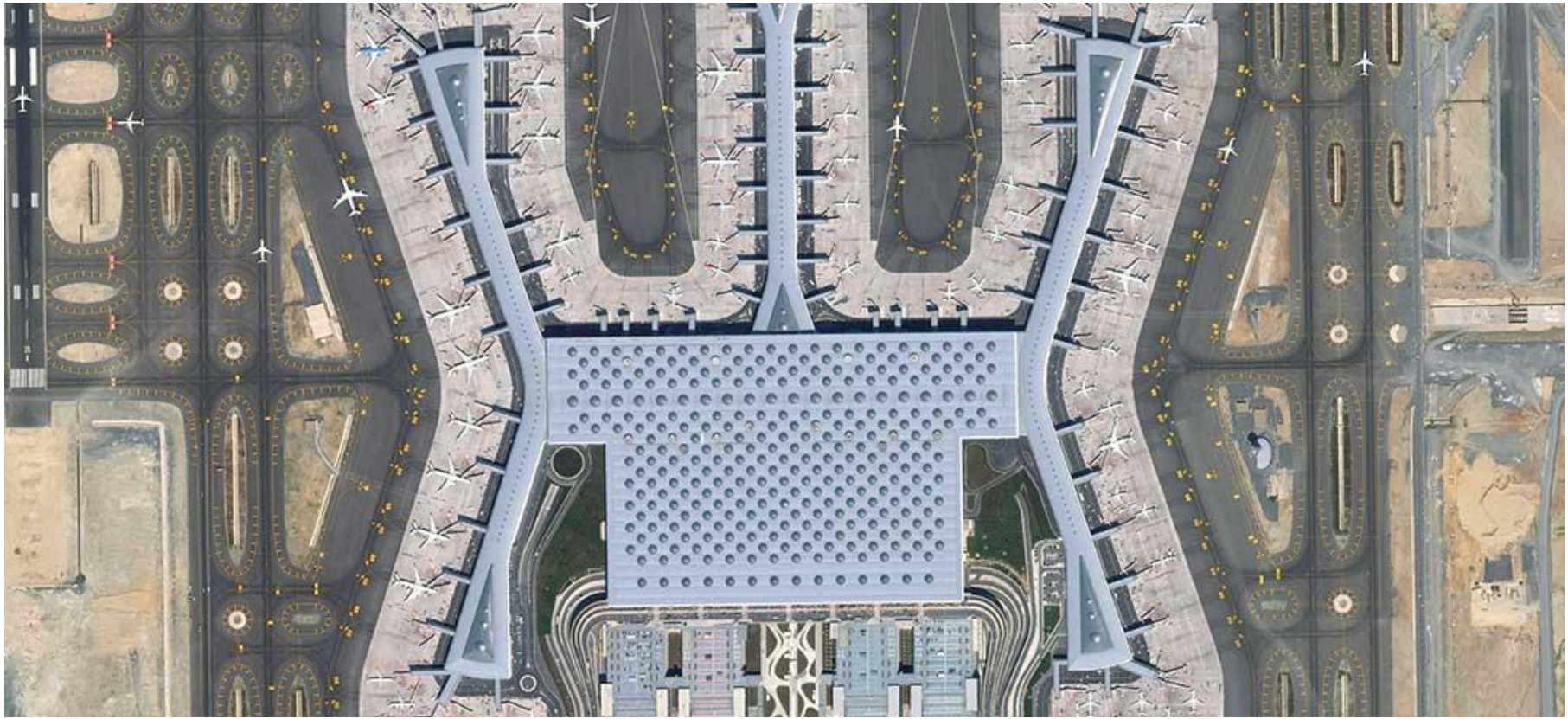
2. **Frequent Revisit Times**: Commercial satellites often have shorter revisit times than public satellites. This means they can capture images of the same area more frequently, which is particularly useful for monitoring changes over time.

3. **On-demand Imaging**: Customers can request images of specific areas at specific times, giving them greater control over the data they receive. One can task satellites.

4. **Rapid Data Availability**: Commercial satellite companies often have the infrastructure to quickly process and deliver images after they are captured. This can be important for time-sensitive applications such as disaster response or real-time monitoring.

5. **Enhanced Security**: Commercial satellite imagery can offer better security and privacy as the data can be exclusively accessed by the client, unlike public satellite data that is available to everyone.

High Resolution Commercial Imagery



Credit: Maxar

Types of Applications

Feature Extraction

Object Detection

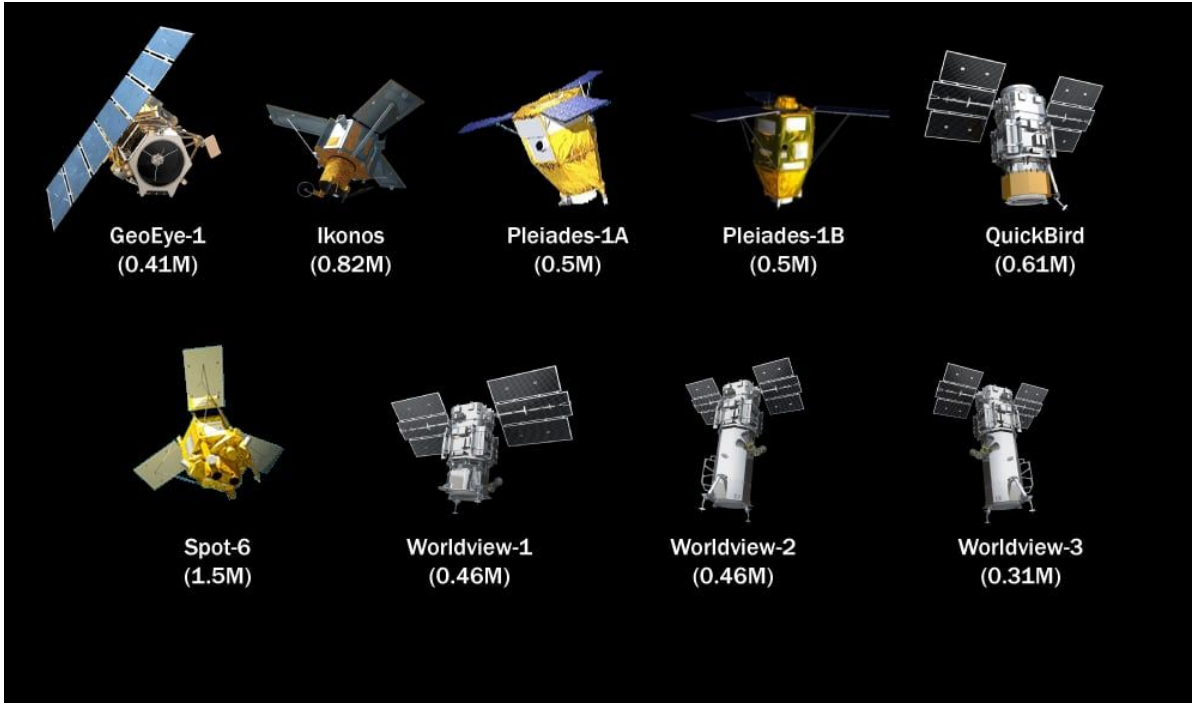
Change Detection

Credit: Maxar

High Resolution Satellite Options

Details:

- WorldView-2
- WorldView-3
- WorldView-4
- GeoEye
- Pleiades
- QuickBird
- IKONOS
- **Planet Satellites**



Credit: MapTiler

High Resolution Satellite Options

Sensor	Ground sample distance at nadir [m]		Coverage [km]	Launch [year]	Provider
	Pan	Multispectral			
Worldview 3 (VNIR)	0.31	1.24 / 3.7	10.5 x 10.5	2014	DigitalGlobe
Worldview 3 (SWIR)		7.5	10.5 x 10.5	2014	DigitalGlobe
Worldview 2	0.46	1.84	16 x 16	2009	DigitalGlobe
GeoEye 1	0.41	1.65	15 x 15	2008	DigitalGlobe
Quickbird*	0.6	2.4	17 x 17	2002	DigitalGlobe
Pléiades	0.7	2.7	20 x 20	2011/12	AstriumGeo
Ikonos*	1	4	11 x 11	1999	DigitalGlobe
Landsat 7 (ETM+)*	15	30	185 x 185	1999	USGS
Landsat 8 (OLI)	15	30	185 x 185	2013	USGS

* since 2015 an acquisition of new images for Antarctica is not possible

Credit: Osama Mustafa et al, 2017

Sensors | Worldview-2

Specifications:

Spatial resolution: 1.84 meters (multispectral)

Temporal resolution: 1.1 days

Period of record: 2009–present

Details:

- Owned by Maxar/DigitalGlobe
- Has a pan-sharpened band with 46 cm resolution
- Covers 1 million sq km per day
- Includes 8 bands - RGB + NIR1 +NIR2 + Red Edge + Coastal + Yellow + Pan sharpened bands

Credit: Maxar

Read more here

Sensors | RapidEye

Specifications:

Spatial resolution: 5 meters

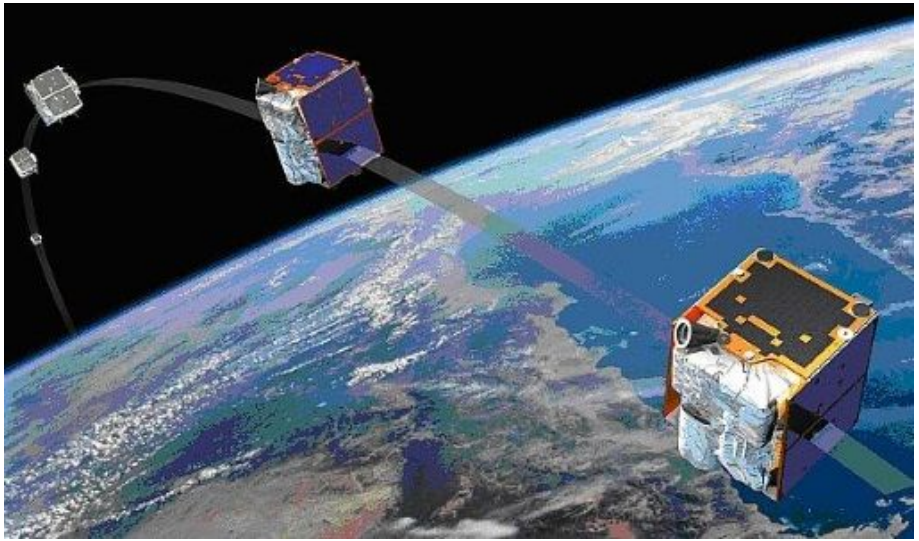
Temporal resolution: 5.5 days

Period of record: 2009–2020

Details:

- Owned by Planet Labs
- Constellation of 5 satellites
- RapidEye Scene products ranged from 75 x 50 square kilometers to 75 x 300 square kilometers
- RapidEye OrthoTile product was a 25 x 25 square kilometers orthorectified and tiled product
- Includes RGB + NIR + Red Edge bands

Read more here



Credit: Planet Labs

Sensors | SkySat

Specifications:

Spatial resolution: 50 cm

Temporal resolution: 10x per day

Period of record: 2016–present

Details:

- Owned by Planet Labs
- Composed of 21 high-resolution satellites.
- The constellation can revisit any location on Earth up to 10 times a day
- Daily collection capacity of 400 thousand km^2/day
- Includes RGB + NIR

Read more here

Credit: Planet Labs

Sensors | Dove Satellites (PlanetScope Products)

Specifications:

Spatial resolution: 3-5 meters

Temporal resolution: 1 day

Period of record: 2014–present

Details:

- Owned by Planet Labs
- Constellation of 130 satellites
- Operate in a relatively low orbit of about 450 km
  - Cloud cover can be a challenge
- Temporal resolution higher when multiple satellites are active
- Daily collection capacity of 200 million km^2/day

Read more here

Type	Dates Available	Bands
Dove Classic	April 2014 - April 2022	RGB + NIR
Dove-R	March 2019 - April 2022	RGB + NIR
SuperDove	March 2020 - present	RGB + NIR + Red Edge, Green 1, Coastal Blue, Yellow

PlanetScope Product Types

Product Name	Description	
PlanetScope Basic Analytic 4B Scene (Level 1B)	Scaled Top of Atmosphere Radiance (at sensor) and sensor corrected 4 band (BGRN) product. Scene based framing and is not projected to a cartographic projection. Radiometric and sensor corrections are applied.	Designed for users with advanced image processing and geometric correction capabilities.
PlanetScope Basic Analytic 8B Scene (Level 1B)	Scaled Top of Atmosphere Radiance (at sensor) and sensor corrected 8-band product. Scene based framing and is not projected to a cartographic projection. Radiometric and sensor corrections are applied.	Designed for users with advanced image processing and geometric correction capabilities.
PlanetScope Ortho Analytic 4B Scene (Level 3B)	Orthorectified, scaled Top of Atmosphere Radiance (at sensor) 4-band image product suitable for analytic applications. Scene based framing and projected to a cartographic projection.	Users who need properly georeferenced data for GIS purposes and mapping
PlanetScope Ortho Analytic 4B SR (Level 3B)	Orthorectified, Surface Reflectance 4-band image product suitable for analytic applications. Scene based framing and projected to a cartographic projection.	Users who need properly georeferenced data for GIS purposes and mapping
PlanetScope Ortho Analytic 8B Scene (Level 3B)	Orthorectified, scaled Top of Atmosphere Radiance (at sensor) 8-band image product suitable for analytic applications. Scene based framing and projected to a cartographic projection.	Users who need properly georeferenced data for GIS purposes and mapping
PlanetScope Ortho Analytic 8B SR (Level 3B)	Orthorectified, Surface Reflectance 8-band image product suitable for analytic applications. Scene based framing and projected to a cartographic projection.	Users who need properly georeferenced data for GIS purposes and mapping

Planet - Sentinel2 Interoperability

Band	Name	Wavelength (fwhm)	Interoperable with Sentinel-2
1	Coastal Blue	443 (20)	Yes - with Sentinel-2 band 1
2	Blue	490 (50)	Yes - with Sentinel-2 band 2
3	Green I	531 (36)	No equivalent with Sentinel-2
4	Green	565 (36)	Yes - with Sentinel-2 band 3
5	Yellow	610 (20)	No equivalent with Sentinel-2
6	Red	665 (31)	Yes - with Sentinel-2 band 4
7	Red Edge	705 (15)	Yes - with Sentinel-2 band 5
8	NIR	865 (40)	Yes - with Sentinel-2 band 8a

Sentinel-2 Bands

Band	Resolution	Central Wavelength	Description
B1	60 m	443 nm	Ultra Blue (Coastal and Aerosol)
B2	10 m	490 nm	Blue
B3	10 m	560 nm	Green
B4	10 m	665 nm	Red
B5	20 m	705 nm	Visible and Near Infrared (VNIR)
B6	20 m	740 nm	Visible and Near Infrared (VNIR)
B7	20 m	783 nm	Visible and Near Infrared (VNIR)
B8	10 m	842 nm	Visible and Near Infrared (VNIR)
B8a	20 m	865 nm	Visible and Near Infrared (VNIR)
B9	60 m	940 nm	Short Wave Infrared (SWIR)
B10	60 m	1375 nm	Short Wave Infrared (SWIR)
B11	20 m	1610 nm	Short Wave Infrared (SWIR)
B12	20 m	2190 nm	Short Wave Infrared (SWIR)

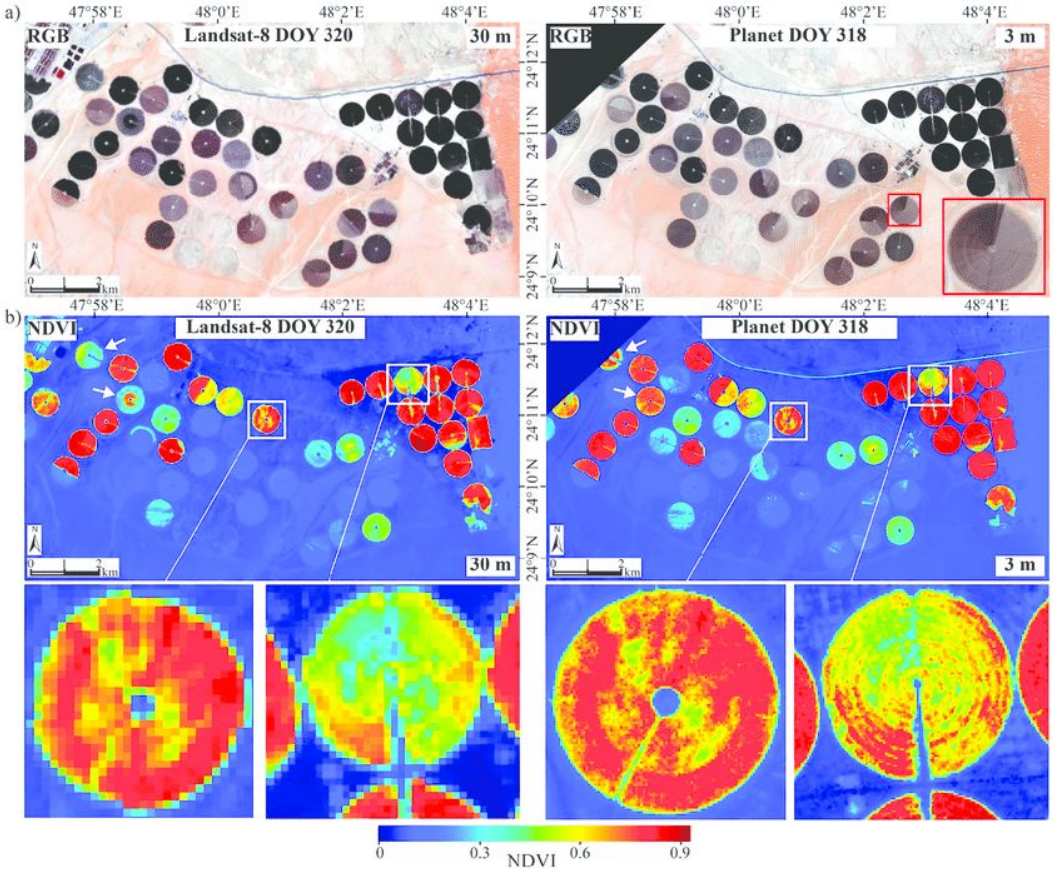
Planet - Sentinel-2 NDVI

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

NDVI (S2) = (B8 - B4) / (B8 + B4)

NDVI (Planet) = (B8 - B6) / (B8 + B6)

Planet - Sentinel-2 NDVI



Citation: Houborg, Rasmus & McCabe, Matthew. (2016). High-Resolution NDVI from Planet's Constellation of Earth Observing Nano-Satellites: A New Data Source for Precision Agriculture. Remote Sensing. 8. 1-19. 10.3390/rs8090768.

Planet - Sentinel-2 NDCI

$$NDCI = \frac{Red\ Edge - Red}{Red\ Edge + Red}$$

NDCI (S2) = (B5 - B4) / (B5 + B4)

NDCI (Planet) = (B7 - B6) / (B7 + B6)

Limitations of High Resolution Commercial Imagery

1. **Spectral Resolution**: Many commercial satellite imagery systems may not have the necessary spectral resolution to effectively monitor specific features such as algal blooms.

2. **Cloud Cover:** Like other satellite-based observations, the presence of clouds can obstruct the view of the water surface, thereby limiting the ability to monitor algal blooms.

3. **Cost**: High-resolution imagery often comes with a high cost, which can be prohibitive for long-term or large-scale monitoring efforts.

4. **Data Volume**: High-resolution images result in large data files, which can present challenges in terms of storage and data processing.

5. **Surface Glare**: Satellite images can sometimes be affected by sun glint or surface glare – the reflection of sunlight off the water surface – which can obscure the signal from the water column and make it difficult to detect algal blooms.

Planet Earthquake Monitoring Case Study

- The July 2019 Ridgecrest earthquakes consist of three main shocks of magnitudes 6.4, 5.4, and 7.1, each followed by a flurry of aftershocks of substantially lower magnitude.

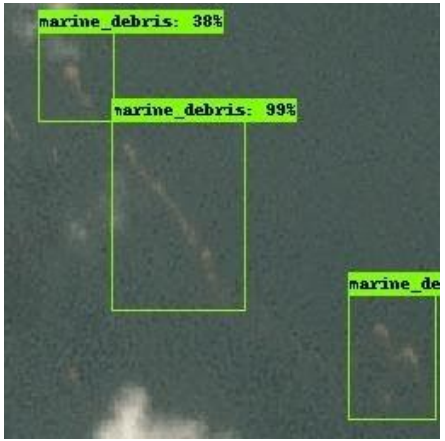
- A group at the California Institute of Technology acquired Planet imagery before and after the quake. By using Planet imagery with GPS data and geophysical modelling, they were able to determine the actual plate motion responsible for the quake.

Credit: Planet Labs

Planet Marine Debris Monitoring Case Study

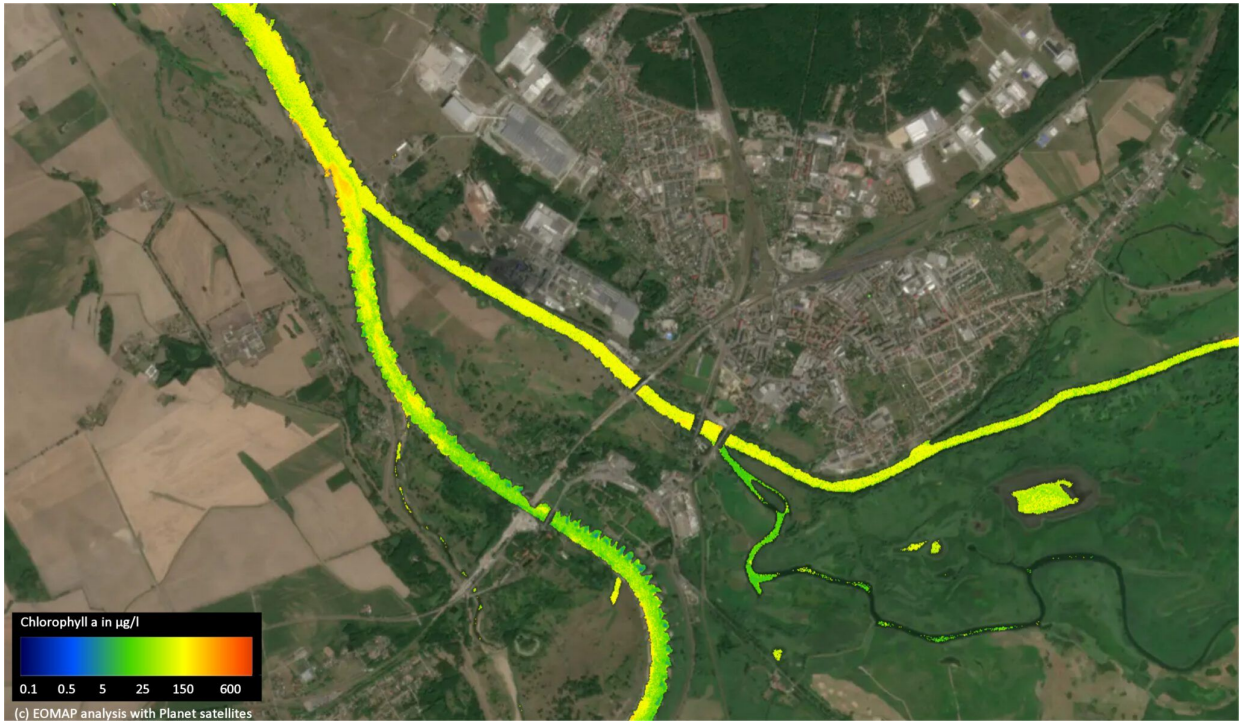
- Using Planetscope 3-meter resolution data, marine debris was labeled on several images.
- This dataset consists of 1370 bounding boxes of marine debris which were validated using peer-reviewed studies.
- An object detection deep learning model (CNN) was trained on the curated dataset and results on Planetscope's optical imagery were obtained.
- Marine debris in this dataset comprises multiple object classes which include floating vegetation such as seaweed and algae, woody materials, timber, sea foam, pumice, and plastics.

Read more and download the dataset here



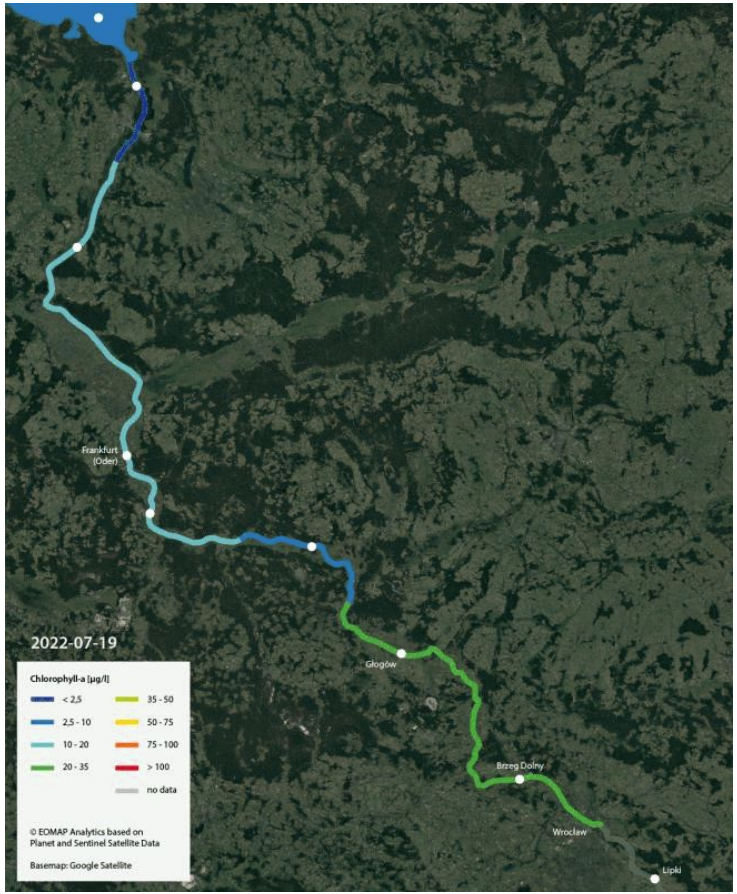
Planet Algal Bloom Monitoring Case Study

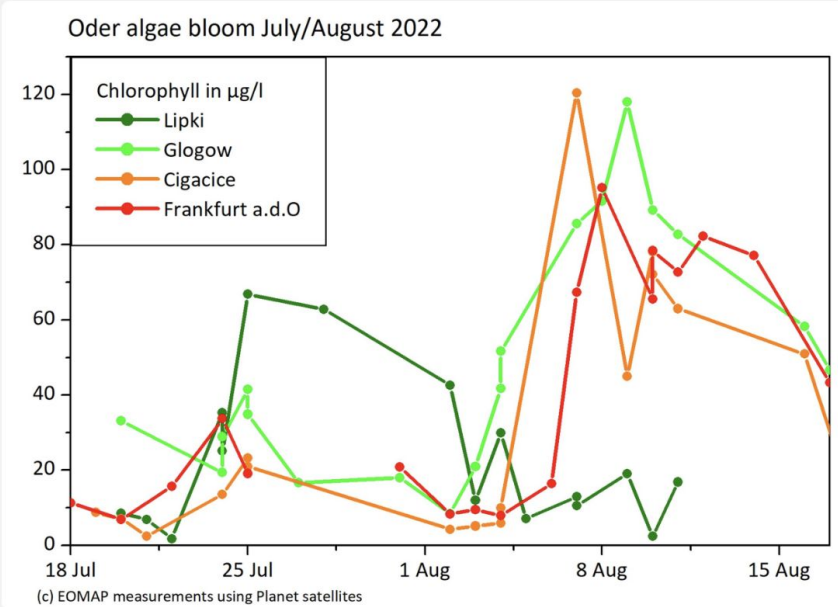
- Combined with European Sentinel data, the EOMAP team in Germany was able to determine the course of the algae bloom in the Oder river using 8-band Dove imagery.
- The algae bloom was traced from Lipki to the mouth of the Oder River.
- The team analyzed eight river sections between Lipki (Poland) and the Szczecin Lagoon.



Credit: EOMAP

Planet Algal Bloom Monitoring Case Study





Spatio-temporal dynamics of the algae bloom along the Oder River between Lipki and Frankfurt/Oder. It clearly visualizes an early bloom near Lipki and its subsequent increase at Glogow as per August 3rd and further flow downstream until Frankfurt. c/ EOMAP / Planet

Credit: EOMAP

Planet Algal Bloom Monitoring Case Study

“The new, high-resolution observation data not only enable us to fill the gaps of in-situ measurements, they also allow us to ***reconstruct the whole catastrophe*** *although all water has already been gone into the sea and cannot be sampled anymore. A general advance from the high-resolution is the observation of small water bodies like tributaries or tailing ponds, which is key for tracing the causes“*

- Dr. Karsten Rinke, Head of the Department of Lake Research at UFZ.

Sensors | Satellite Vu

Climate Engine has partnered with Satellite Vu and part of their early adopter program to bring thermal intelligence and analytics in the Climate Engine Platform.

Specifications:

Spatial resolution: 3.5 m

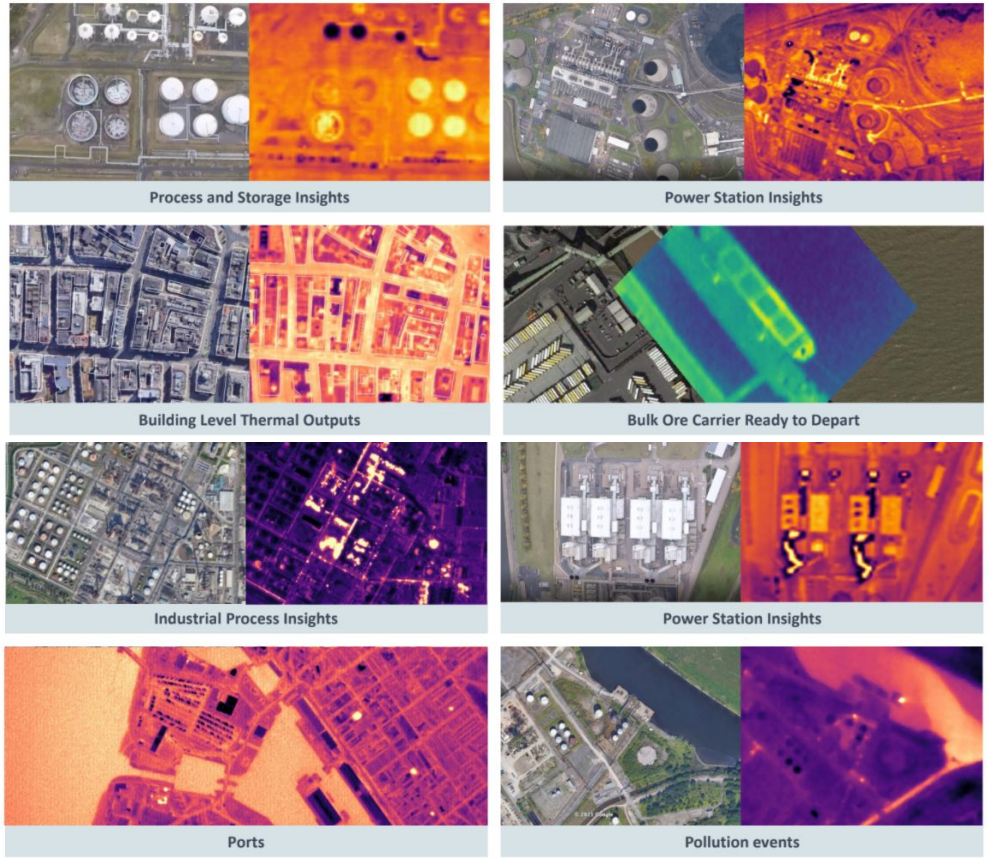
Temporal resolution: up to 20x per day

Period of record: 2023–present

Details:

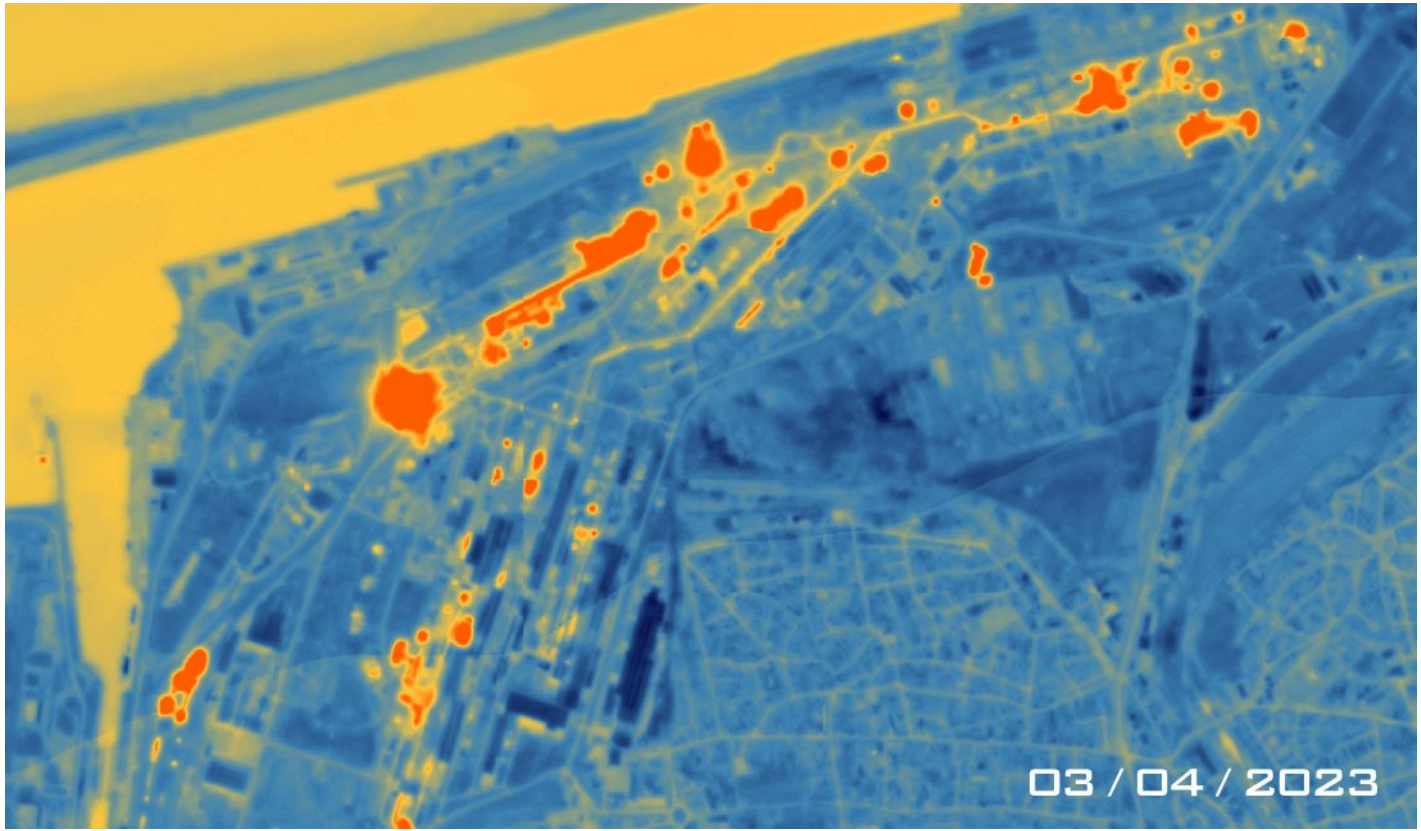
- Owned by Satellite Vu
- Gathers infrared data in the 3.5-5 micron range
- Used for thermal monitoring
  - Industrial activity
  - Thermal pollution of water bodies

Read more here



Credit: Satellite Vu

Satellite Vu Steel Plants Demo



Credit: SatelliteVu

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Thank you!

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