AI as a Resilience Technology

TRILLIUM APPLIED

trillium.tech/applied
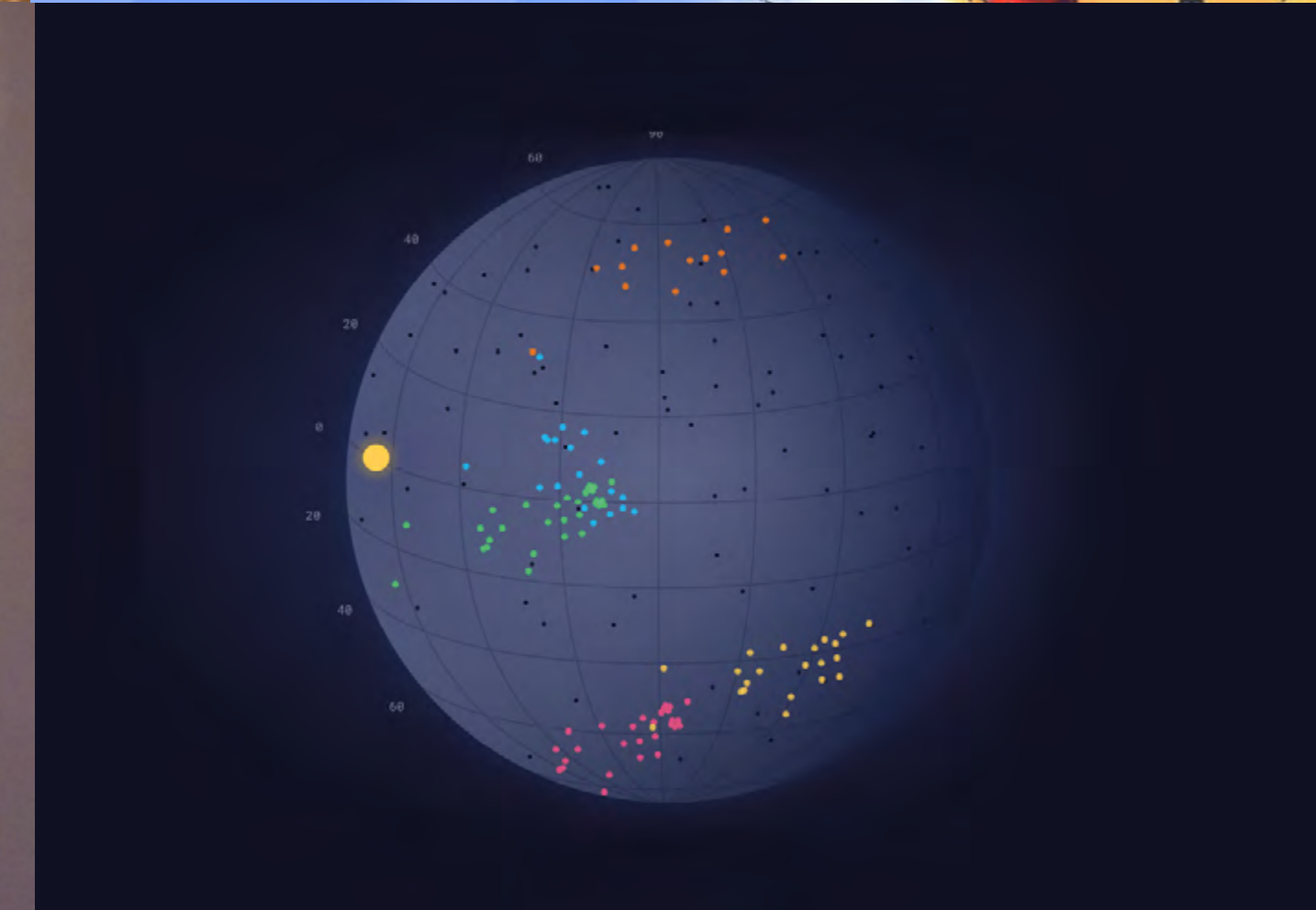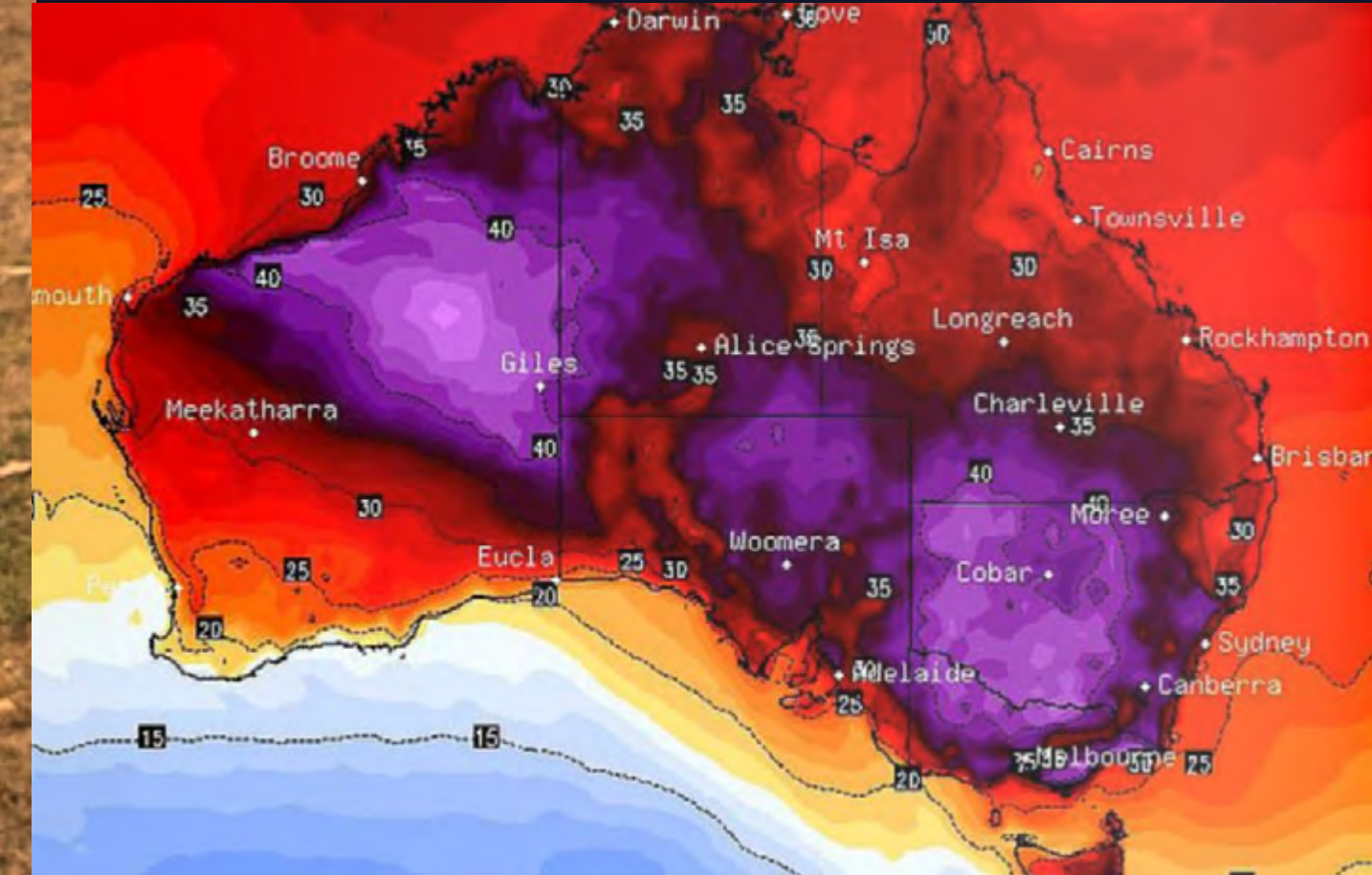
AI and EO for Resilience and Civic Security

We are seeing that AI paired with Earth Observation capabilities are becoming a powerful toolbox for adapting to a changing situational context. Surrogate models are leap-frogging traditional prediction methods, while AI onboard spacecraft , drones and robots are allowing action to be taken in real-time.
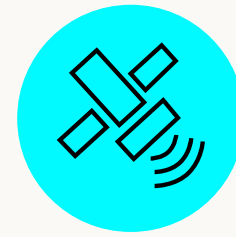
This revolution in speed, cost and prediction accuracy is creating a new category of capabilities we are calling 'resilience technologies'.

We share examples of this growing category here.
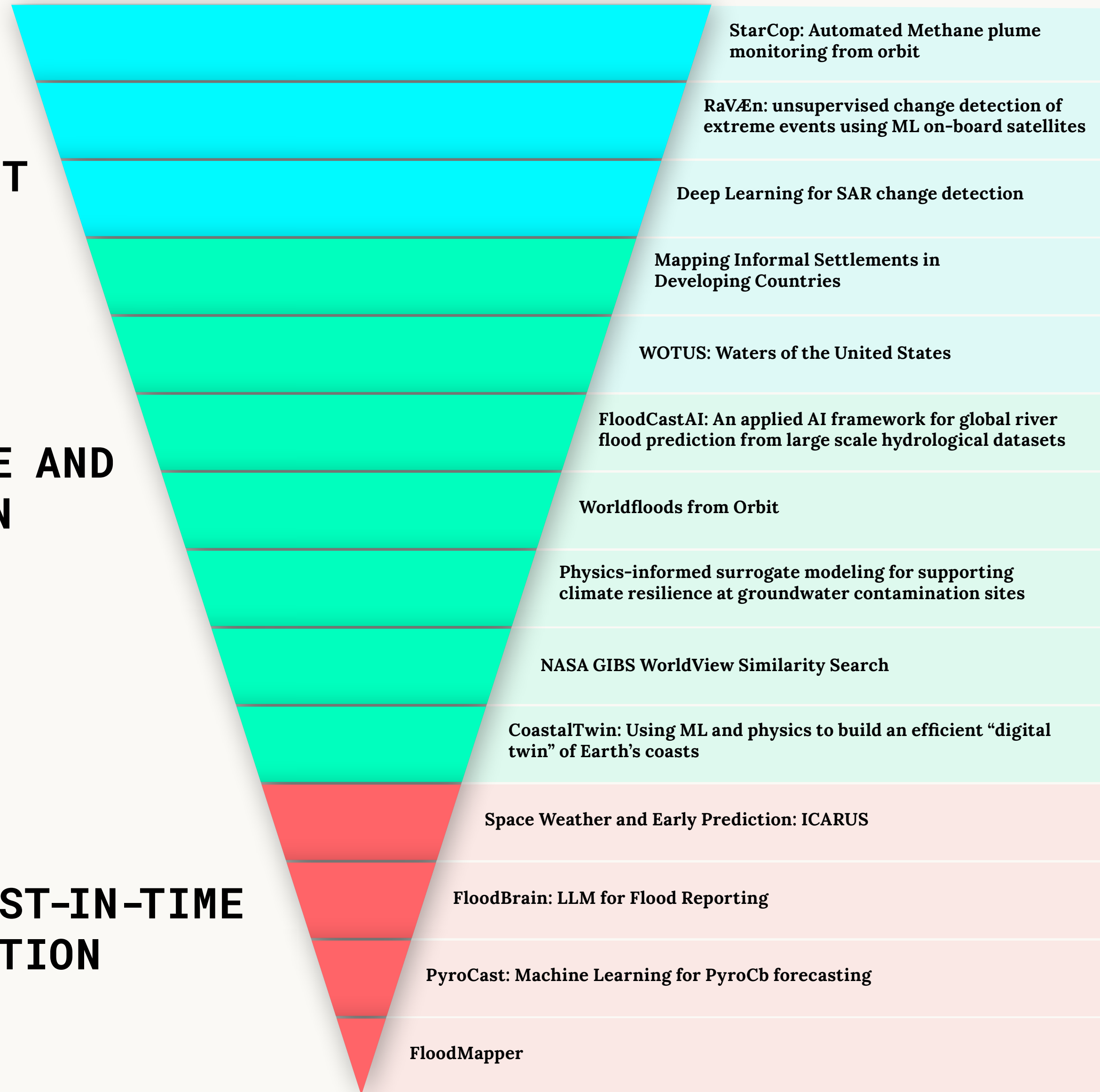
FROM DAYS

Data

INSIGHT
FROM ORBIT

RESILIENCE AND
MITIGATION

JUST-IN-TIME
ACTION

Decision

TO MILLISECONDS

StarCop: Automated Methane plume monitoring from orbit

RaVÆn: unsupervised change detection of extreme events using ML on-board satellites

Deep Learning for SAR change detection

Mapping Informal Settlements in Developing Countries

WOTUS: Waters of the United States

FloodCastAI: An applied AI framework for global river flood prediction from large scale hydrological datasets

Worldfloods from Orbit

Physics-informed surrogate modeling for supporting climate resilience at groundwater contamination sites

NASA GIBS WorldView Similarity Search

CoastalTwin: Using ML and physics to build an efficient "digital twin" of Earth's coasts

Space Weather and Early Prediction: ICARUS

FloodBrain: LLM for Flood Reporting

PyroCast: Machine Learning for PyroCb forecasting

FloodMapper

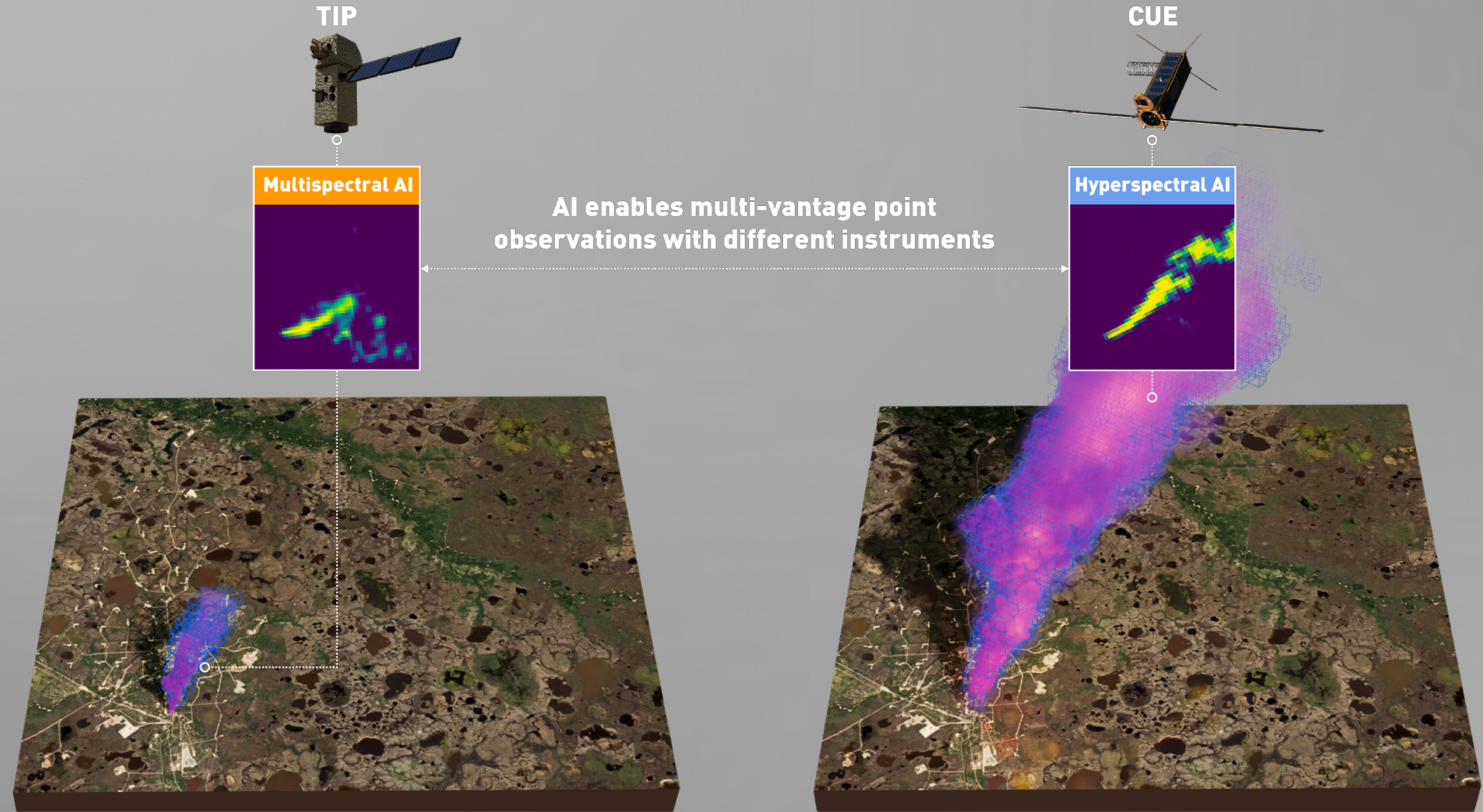# StarCop: Automated Methane plume monitoring from orbit

Reducing anthropogenic methane emissions is arguably the most urgent lever we have in preventing future catastrophic climate change (UNEP methane assessment report). Among methane emissions, episodic oil and gas super-emissions contribute disproportionately to the concentration of methane in the atmosphere (Lavaux et al 2021). These emissions are caused by equipment failures on oil rigs, pipelines or well pads and are manageable if detected in time.

STARCOP is Trillium's initiative to pair AI methane detection using multiple satellites with diverse detection capabilities to quickly detect methane leaks onboard and provide notifications in near-real-time.

STARCOP is an accurate and lightweight AI and can be run on edge devices.

Further reading
http://nio.space

TIP

CUE

Multispectral AI

Hyperspectral AI

AI enables multi-vantage point observations with different instruments

NIO.SPACE

Z AXIS DATA IS SIMULATED FOR ILLUSTRATIVE PURPOSES

TRILLIUM APPLIED
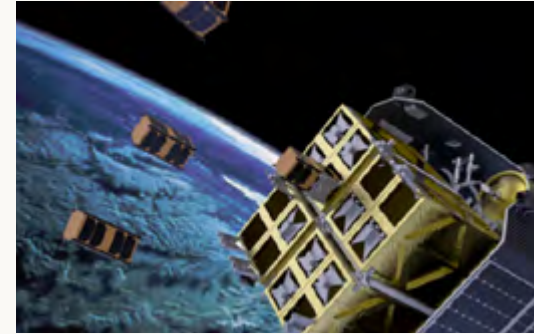
RaVÆn: unsupervised change detection of extreme events using ML on-board satellites

Applications such as disaster management enormously benefit from rapid availability of satellite observations. Traditionally, data analysis is performed on the ground after being transferred—downlinked—to a ground station. Constraints on the downlink capabilities, both in terms of data volume and timing, therefore heavily affect the response delay of any downstream application.

Networked Intelligence in Orbit - part of a unifying vision to build a world-class capability in ML-enhanced hybrid observations and decision intelligence in space.

RaVÆn, a lightweight, unsupervised approach for change detection in satellite data based on Variational Auto-Encoders (VAEs), with the specific purpose of on-board deployment. RaVÆn pre-processes the sampled data directly on the satellite and flags changed areas to prioritise for downlink, shortening the response time.

nature.com/articles/s41598-022-19437-5

Further reading
http://nio.space/

RaVÆn: A new fully-unsupervised novelty-detection model that avoids the limitations inherent in supervised classifiers and is suitable for deployment on remote sensing platforms.

BEFORE HURRICANE

AFTER HURRICANE

CHANGE DETECTION

Locations used for training (left) and validation (right) images.

Hurricanes
Fires
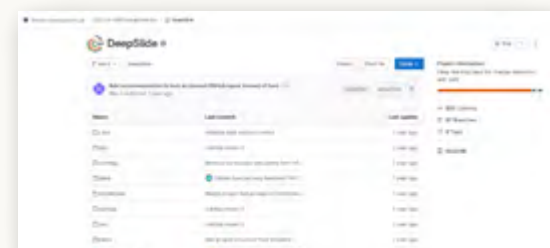Landslides
Floods

TRILLIUM APPLIED

Deep Learning for SAR change detection

SAR is all-weather capable, but complex to use. Radar signals are sensitive to the structure of teh terrain, and able to detect centimeter-level changes over time. Howeverm, SAR data is not trivial to use, as it involbes complex numbers and over 19 processing steps.

To streamline the flow of information from SAR data products to actionable results for natural hazard responses (e.g. for landslides, floods, wildfires, etc), we present DeepSlide, a machine learning pipeline designed end-to-end to leverage the true potential of SAR.

Landslide label dataset over a sample region in Puerto Rico. Yellow circles represent the landslide head (highest elevation point of a landslide). Background is optical satellite imagery.
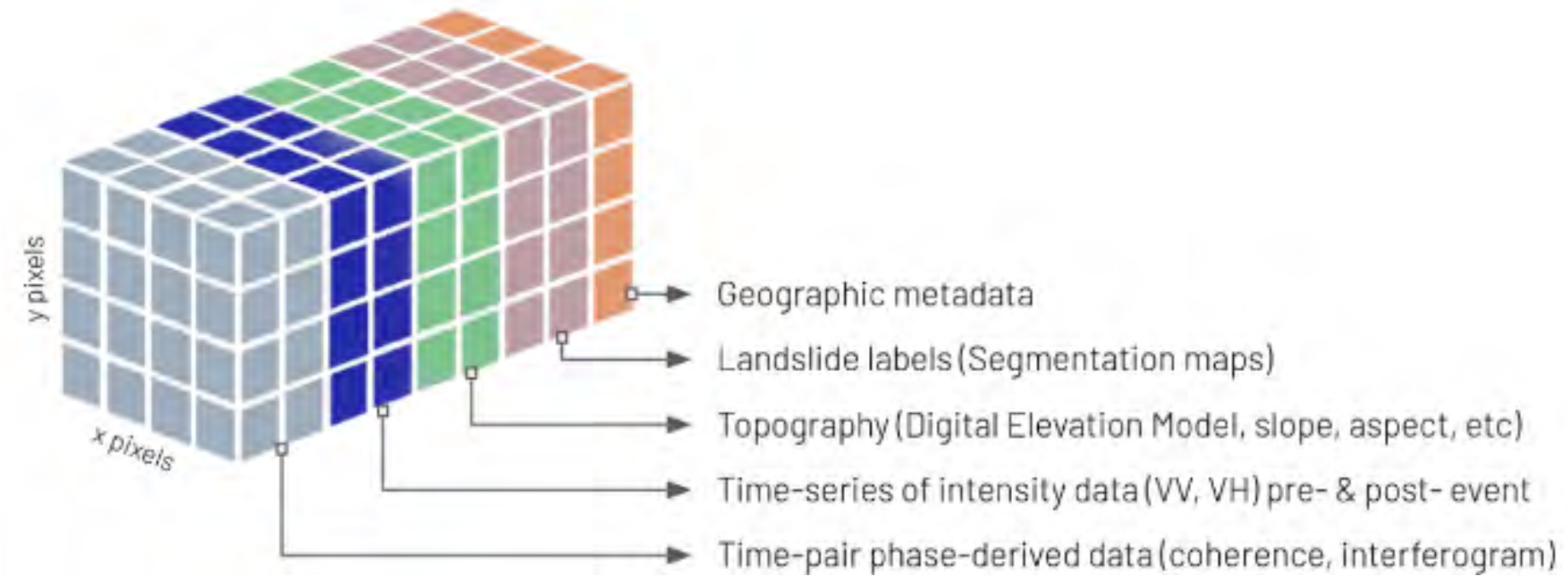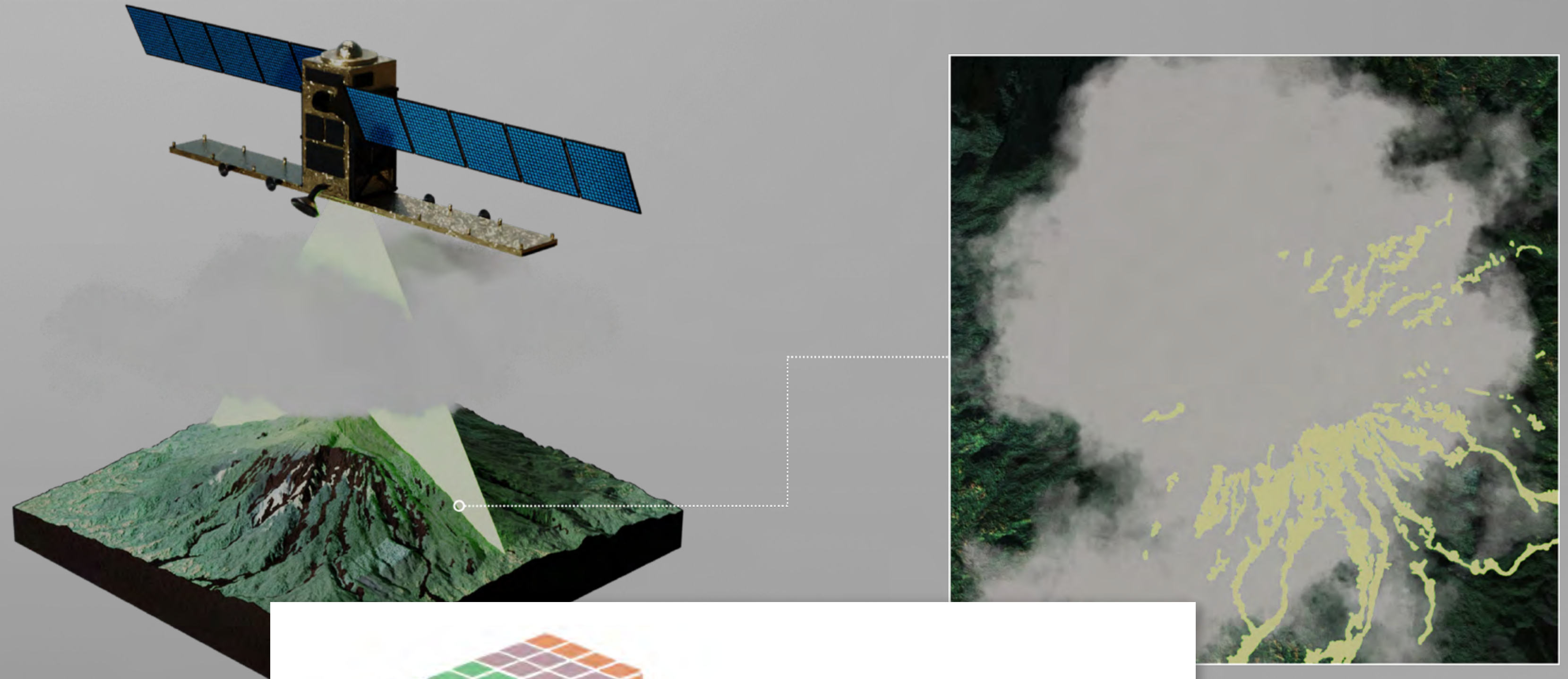

https://gitlab.com/
frontierdevelopmentlab/2022-
us-sarchangedetection/
deepslide

Further reading

frontierdevelopmentlab.org/fdl-2022

https://agu.confex.com/agu/fm22/
meetingapp.cgi/Paper/1162298

Towards automated landslide detection for disaster assessment after Hurricanse or Earthquakes.

Geographic metadata

Landslide labels (Segmentation maps)

Topography (Digital Elevation Model, slope, aspect, etc)

Time-series of intensity data (VV, VH) pre- & post- event

Time-pair phase-derived data (coherence, interferogram)

y pixels

x pixels

Datacubes for Landslide Detection : A Synthetic Aperture Radar (SAR) datacube with multiple data layers stacked together.

TRILLIUM APPLIED

Mapping Informal Settlements in Developing Countries

Detecting and mapping informal settlements encompasses several of the United Nations sustainable development goals. This is because informal settlements are home to the most socially and economically vulnerable people on the planet.

However, data regarding informal and formal settlements is primarily unavailable and if available is often incomplete. This is due to the cost and complexity in gathering it on a large scale. Moreover, the definition of informal settlements is also very broad, which makes it a non-trivial task to collect data and thus teach a machine what to look for.

People live in densely populated, unplanned and unstructured settlements.

Generating Material Maps to Map Informal Settlements **NeurIPS 2018 Machine Learning for the Developing World Workshop**

Further reading

https://frontierdevelopmentlab.github.io/informal-settlements/

https://arxiv.org/abs/1812.00786

Mapping Informal Settlements: The work provide two datasets with both high and mid resolution imagery from a variety of locations, with the accompanying annotations, as well as an effective end-to-end framework that detects and maps the locations of informal settlements using only mid-resolution, freely available, Sentinel-2 satellite imagery with noisy annotations.
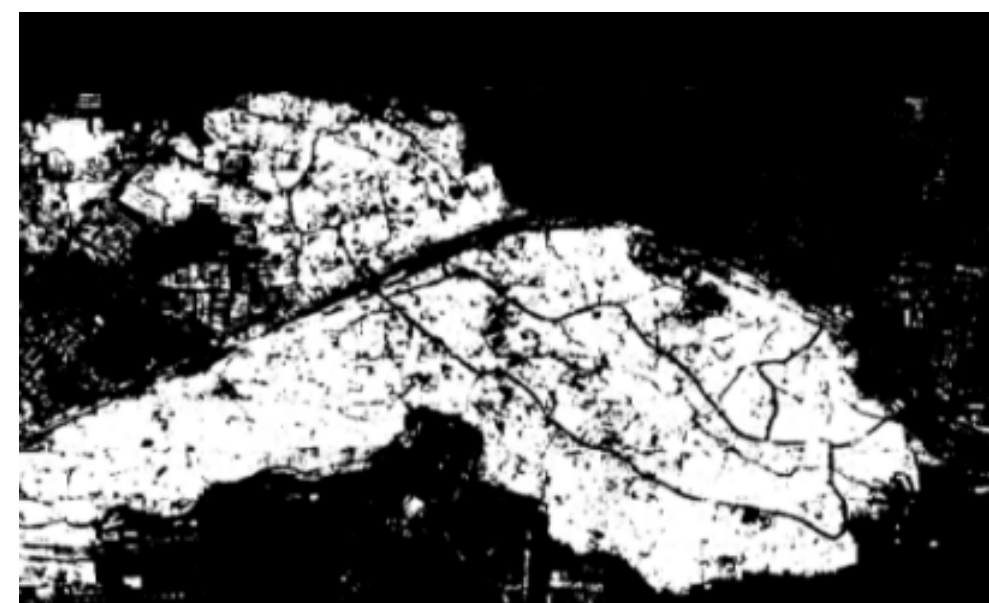

Mapping Informal Settlements

Prediction on medium-resolution Sentinel-2

Mapping Informal Settlements

Prediction on VHR imagery

Ground Truth

Ground truth mask

WOTUS: Waters of the United States

Water stress is becoming one of the most critical challenges as our planet warms. The health of hydrology networks informs flood models, fire susceptibility and drought. Yet, 48% of total surface water in the stream network exists at the dendritic tips (the irregular pattern in which streams branch in all directions and angles) and isn't monitored.

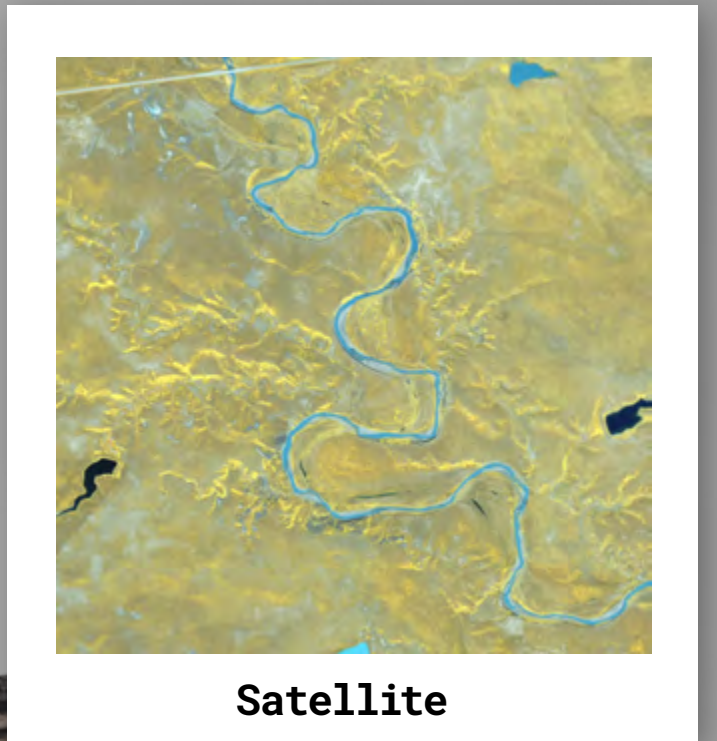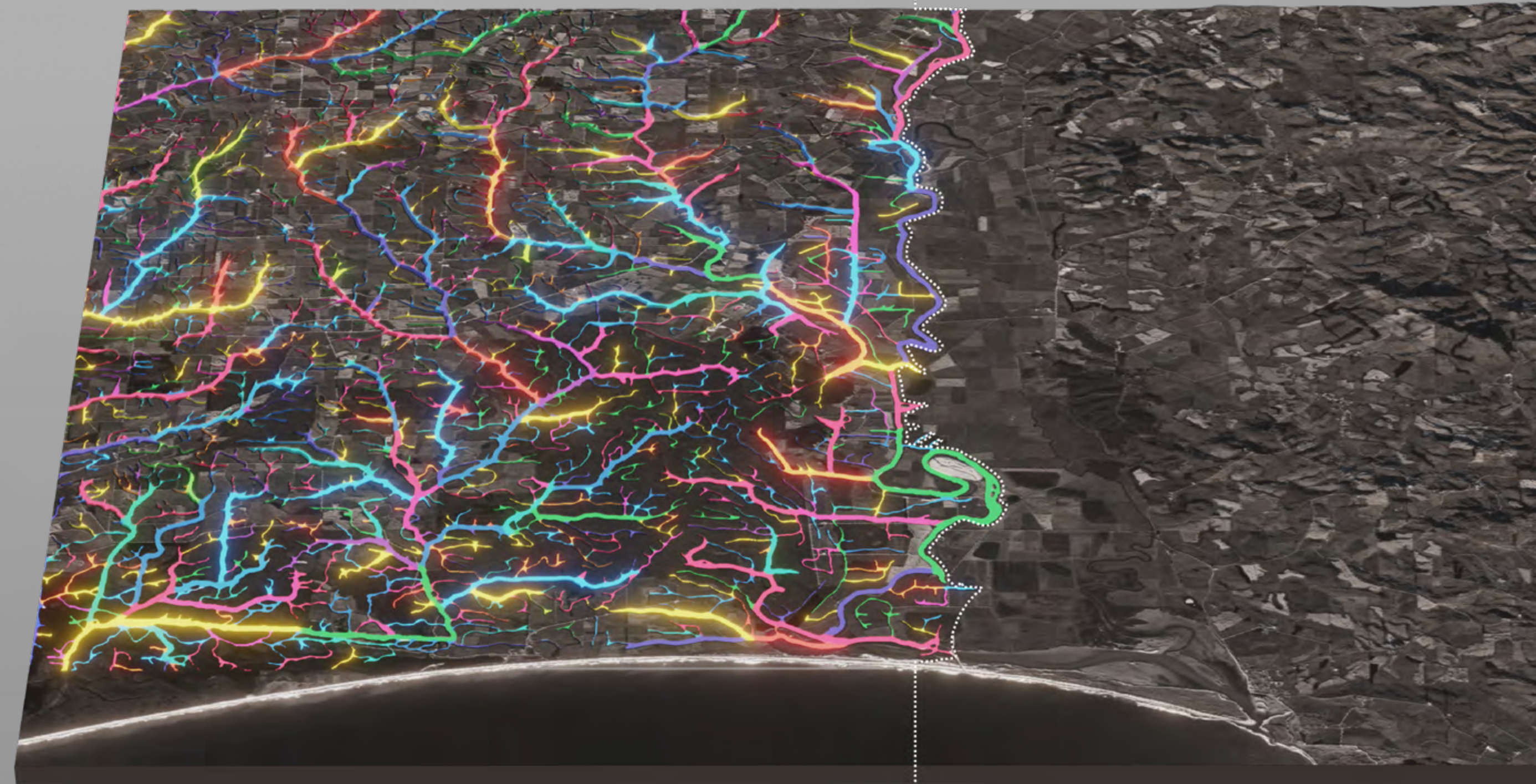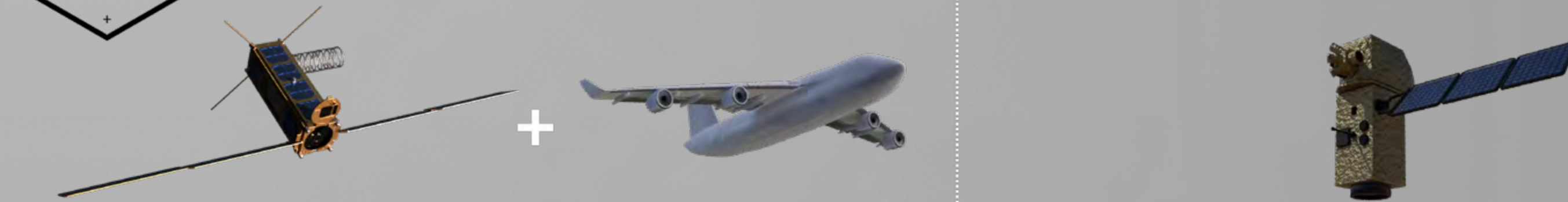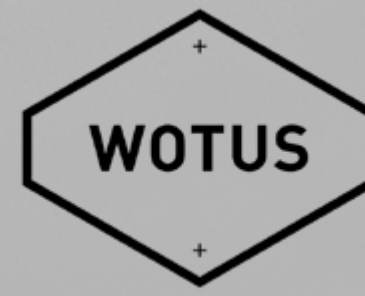*Audits of the US waterways are done by foot every 20 years.*

The WOTUS high temporal imagery from space and AI models change the game for hydrology network monitoring, allowing us to now observe how these low-flow streams are changing in real time.
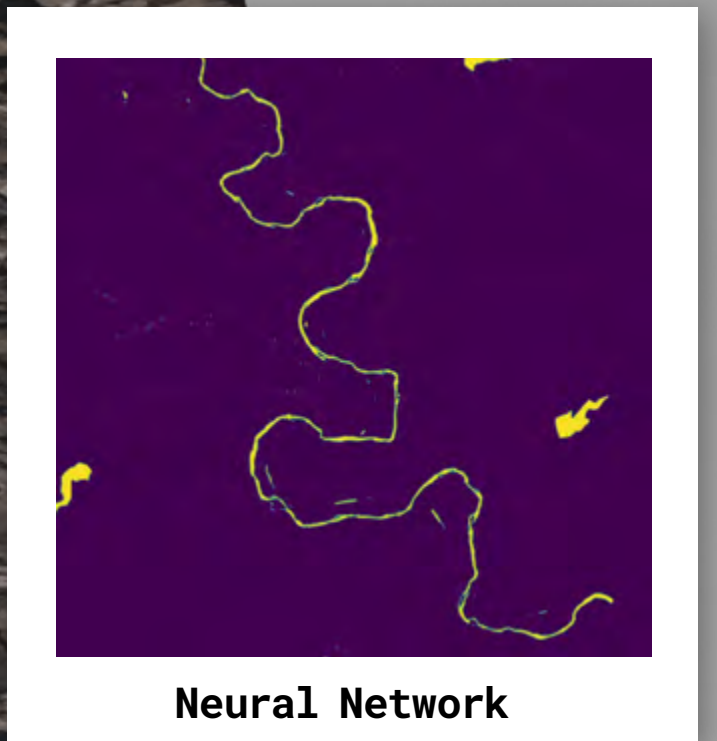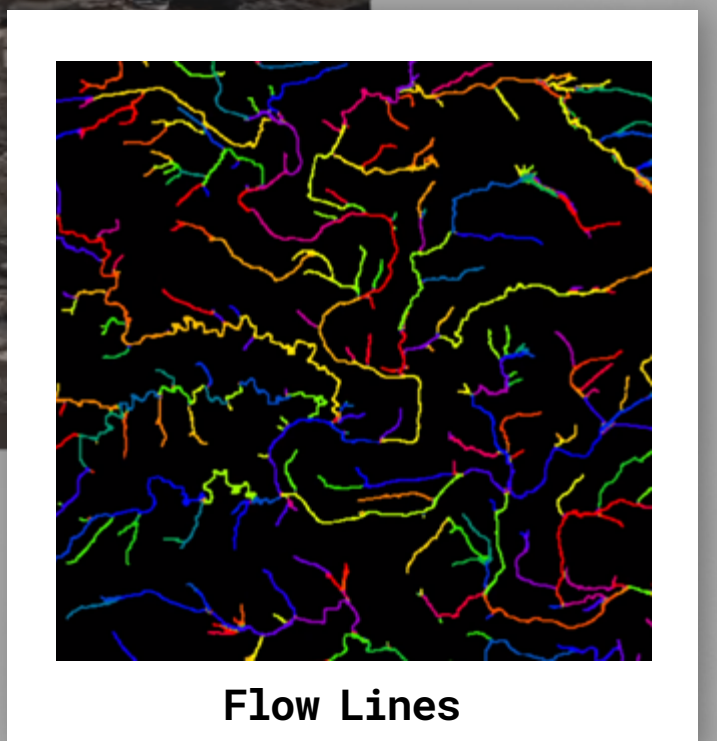
Further reading

https://trillium.tech/wotus

https://frontierdevelopmentlab.org/fdl-2020

WOTUS

Satellite

Neural Network

Flow Lines

WOTUS: Otterworks is a toolbox for assessing the water volume of a river system by auditing the low-flow extended networks of a river basin.

TRILLIUM APPLIED

FloodCastAI: An applied AI framework for global river flood prediction from large scale hydrological datasets

Floods are the most destructive extreme event that exists, causing several casualties and significant economic damage every time occur. In the last decade over 2.2 billion people have been affected by floods, and the amount of people exposed to floods is increasing due the climate change. This fact is particularly true for low to middle income countries, home of 90% people affected by floods. Therefore, mapping the areas at risk of flooding and developing fast and efficient emergency response is crucial to mitigate the damages caused by floods.
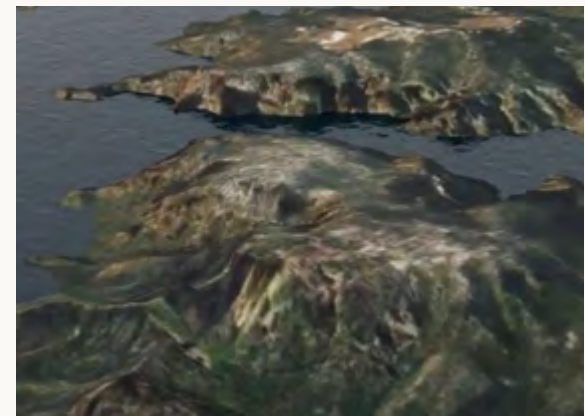
The vast majority of populations vulnerable to flooding do not have access to reliable, actionable flood warnings.
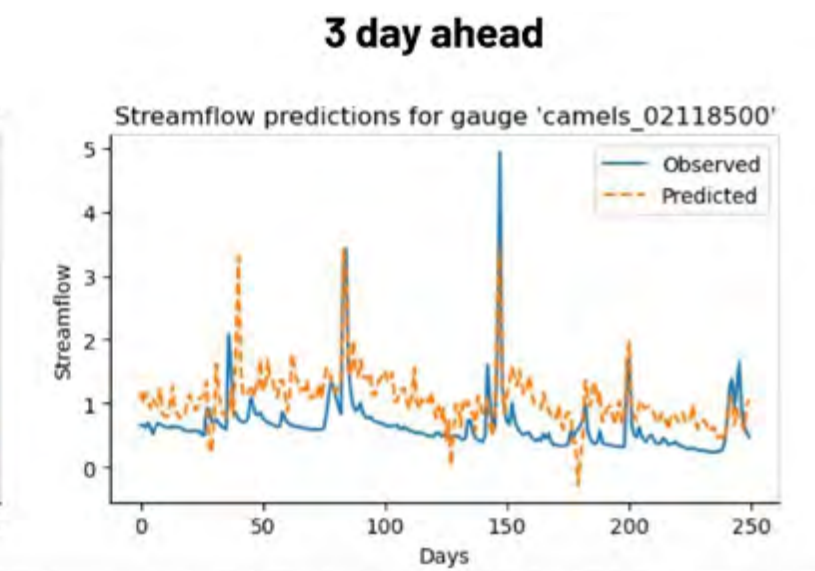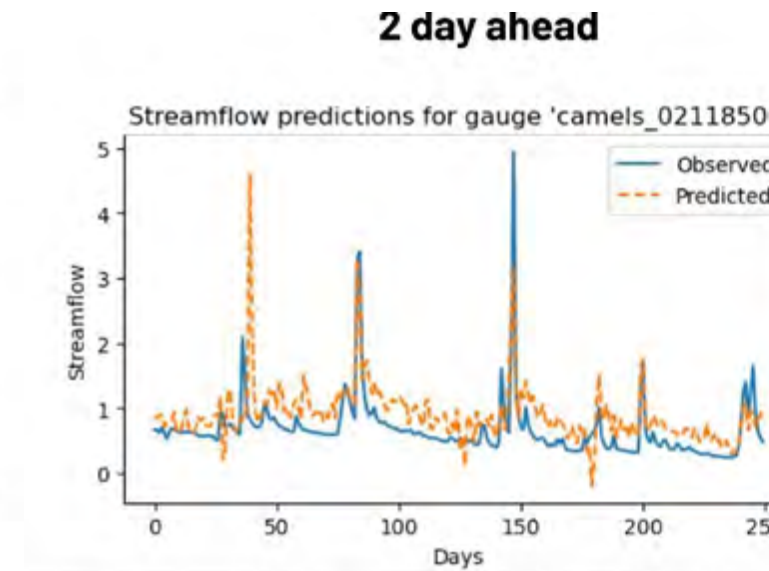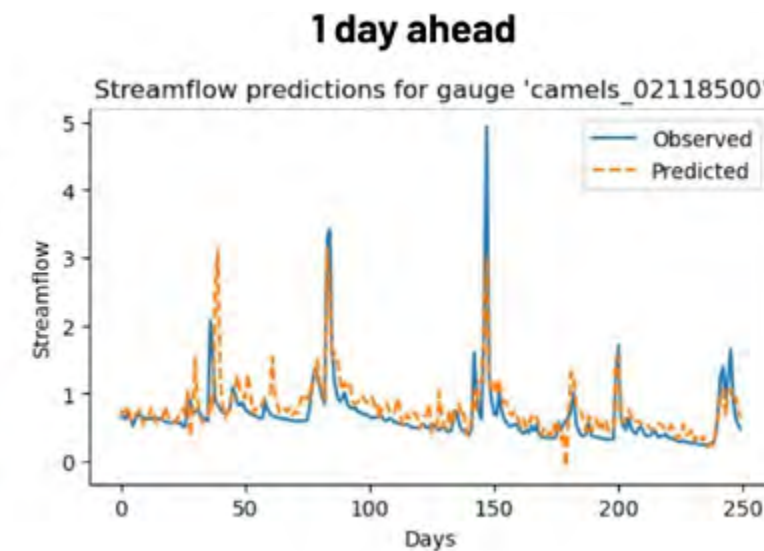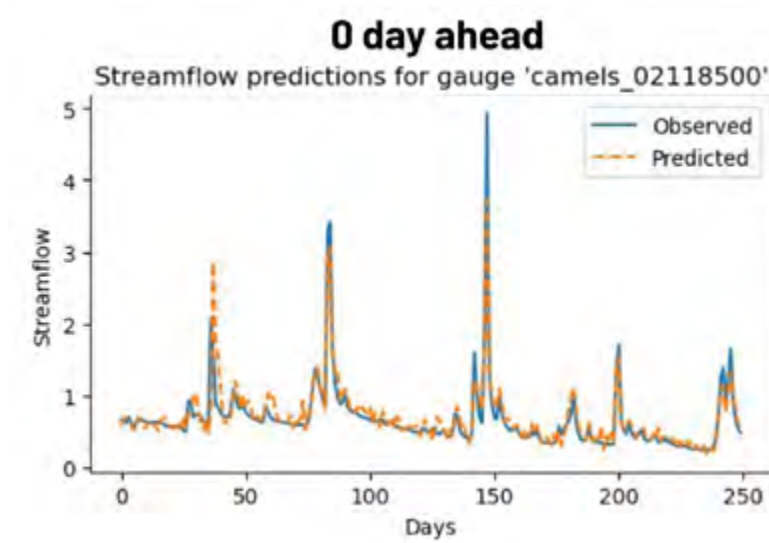

Further reading
https://fdleurope.org/fdl-europe-2022

floodcastAI

First benchmark pipeline for global river flood predictions

0 day ahead
Streamflow predictions for gauge 'camels_02118500'

1 day ahead
Streamflow predictions for gauge 'camels_02118500'

2 day ahead
Streamflow predictions for gauge 'camels_02118500'

3 day ahead
Streamflow predictions for gauge 'camels_02118500'
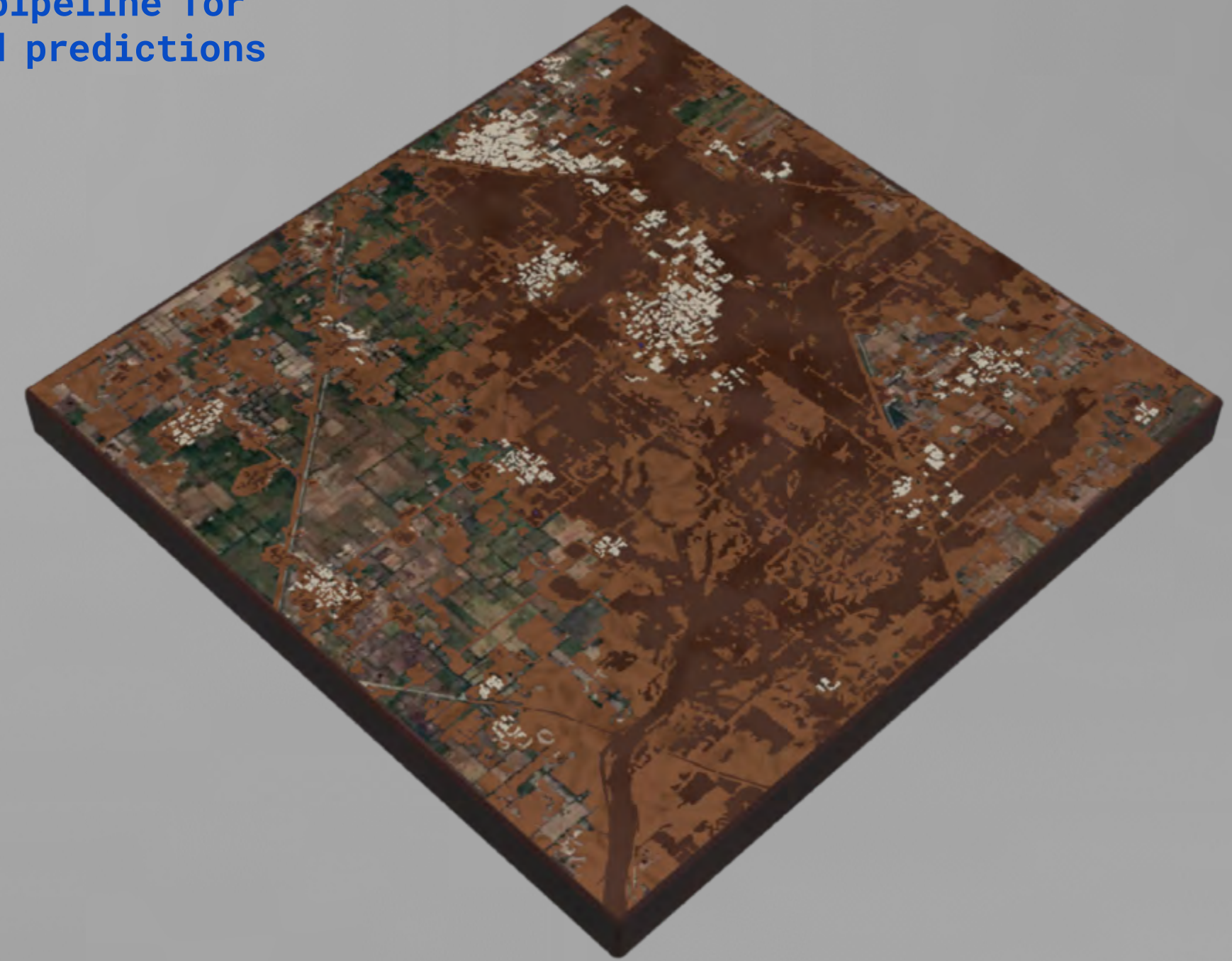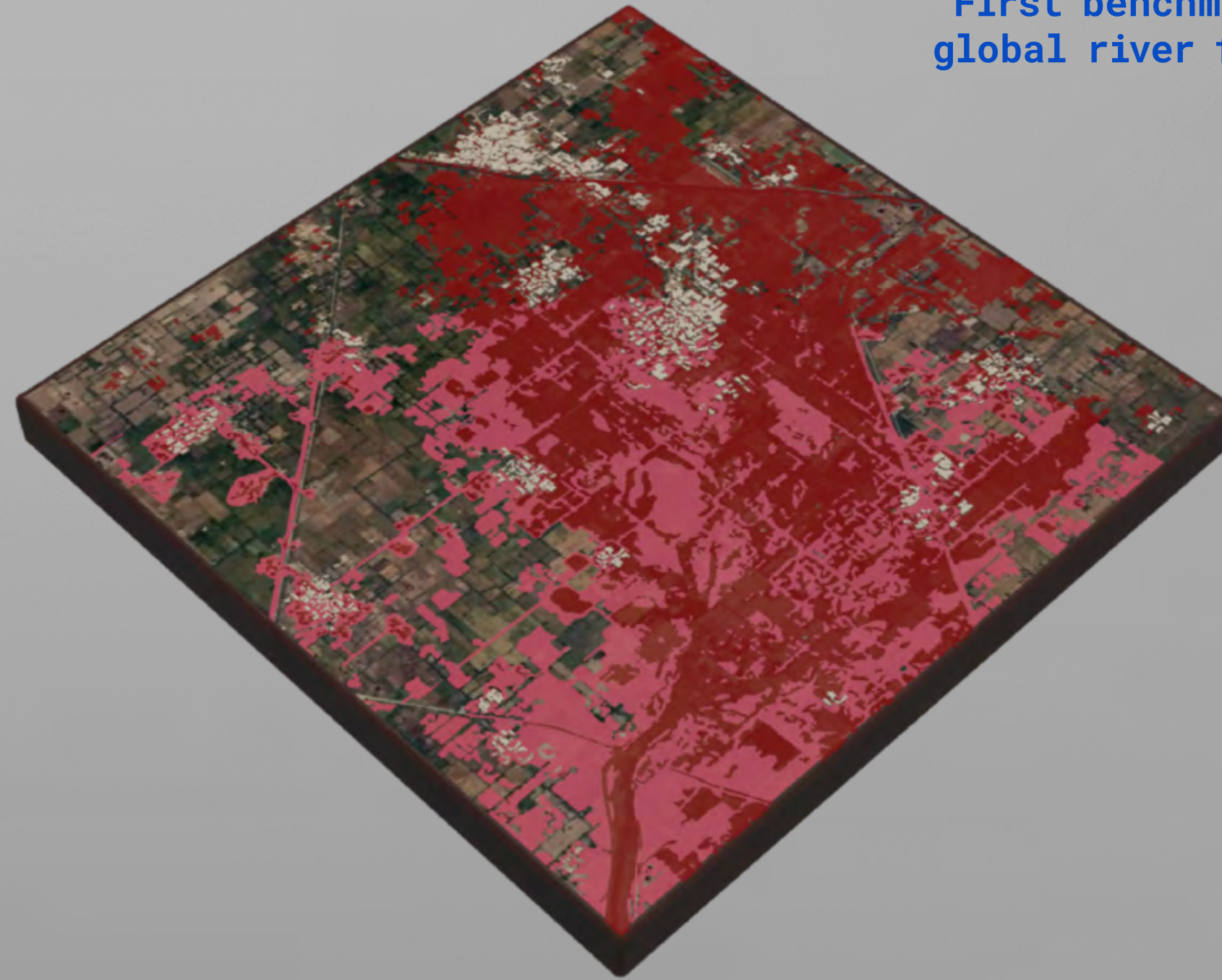
Streamflow prediction 3 days ahead

TRILLIUM APPLIED

Worldfloods from Orbit

The WorldFloods contains 509 pairs of Sentinel-2 images and flood segmentation masks. It requires approximately 300GB of hard-disk storage.

Spaceborne Earth observation is a key technology for flood response.

A flood extent map is a vector layer (shapefile) derived from a satellite image with polygons indicating which part of that image has water (in some cases it distinguishes between flood water and permanent water and in other cases it does not); we assigned a date to each flood extent map which corresponds with the date of acquisition of the original satellite image that was used to derive it. Each flood extent map belongs to a flood event hence a flood event could have several flood maps which may cover different areas of interest or different days of the same area in the same flood event; in total the dataset covers 119 floods events that occurred between November 2015 and March 2019.

Further reading

http://ml4floods.com

nature.com/articles/s41598-021-86650-z

WorldFloods: Global flood extent segmentation in optical satellite images
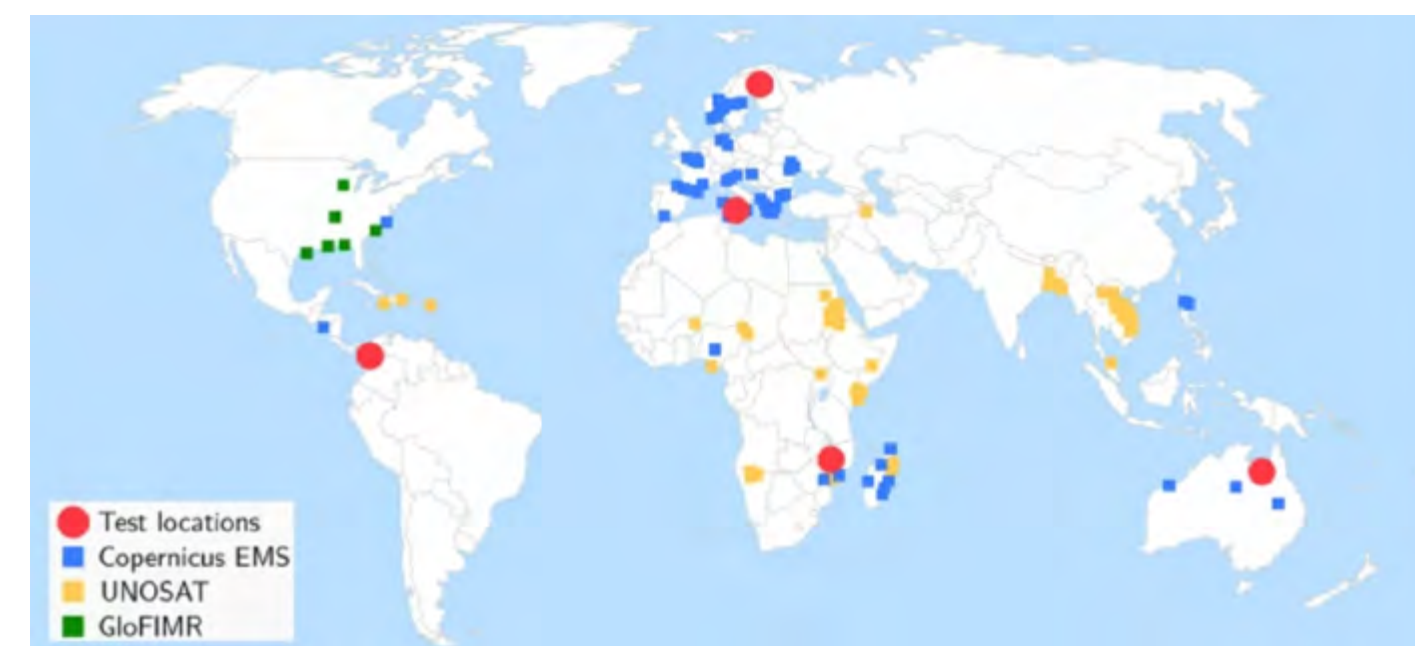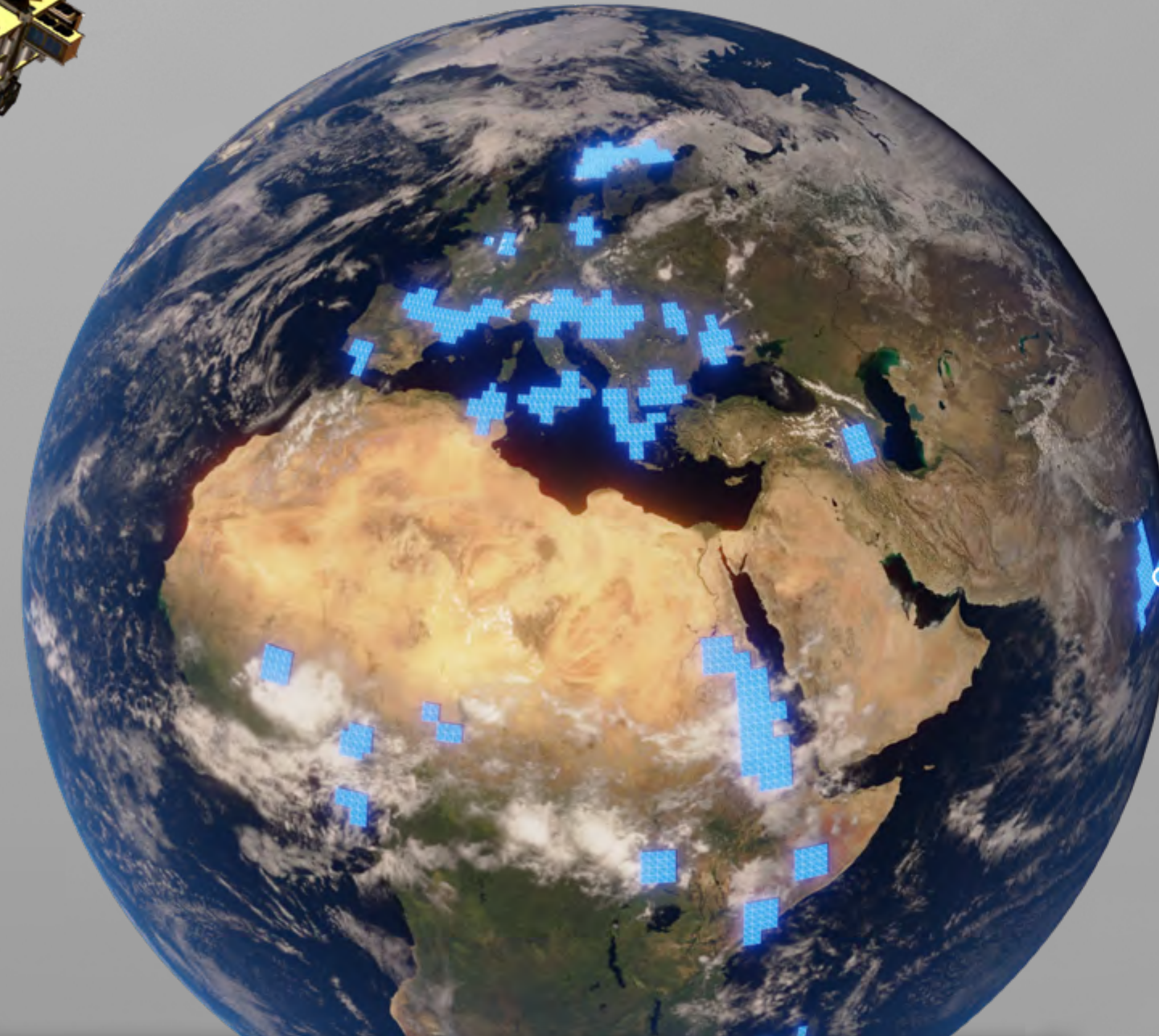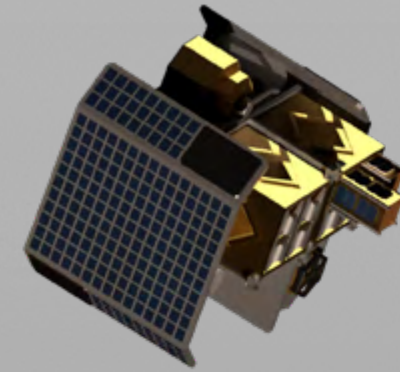
Locations of flood events contained in WorldFloods.

TRILLIUM APPLIED

Physics-informed surrogate modeling for supporting climate resilience at groundwater contamination sites

With climate change, there is an increasing concern as to if toxic chemicals can reach nearby ground or surface waters. Contaminants can contaminate the drinking water supply and can have many negative impacts on human health, wildlife and ecological systems.

Our solution creates a surrogate model which will potentially help address the climate resilience on groundwater flow and contamination transport on DOE's Savannah River Site F-Area.

The project analyzes future climate scenarios and cluster climate data across the US in order to downscale the climate data and apply to local-scale.

Contaminated sites often require decades to remediate or to monitor natural attenuation.

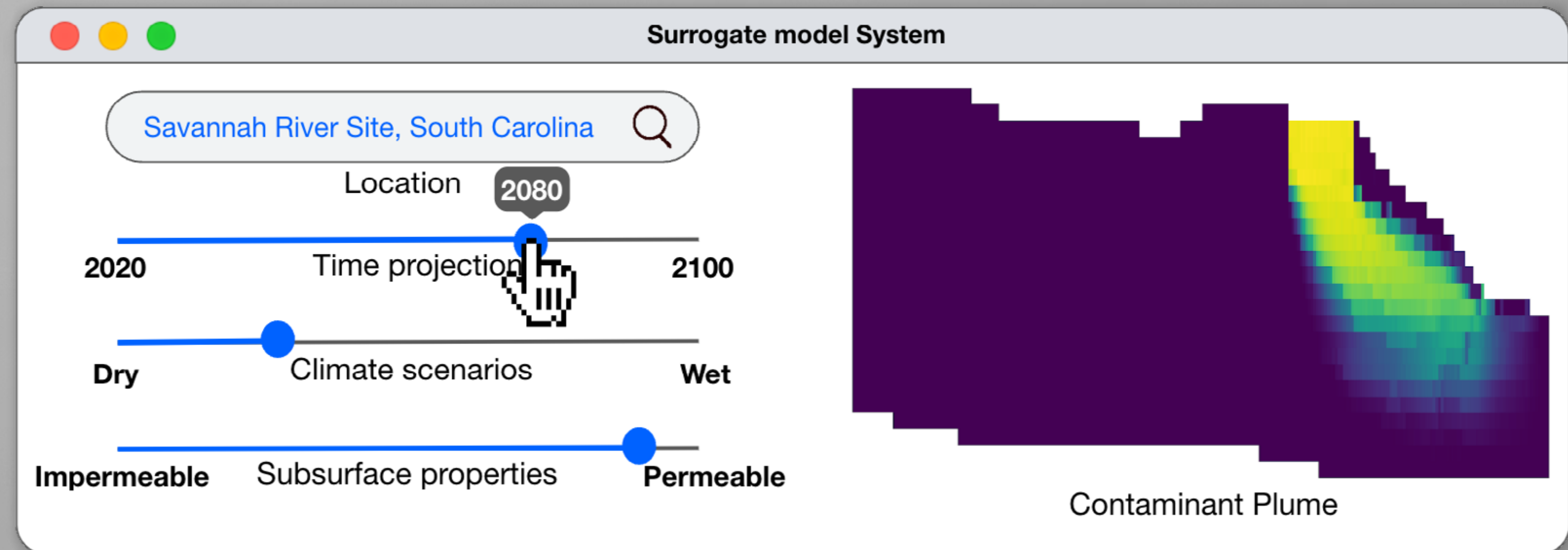*Machine Learning and the Physical Sciences workshop, NeurIPS 2022.*

Further reading

frontierdevelopmentlab.org/fdl-2022

https://ml4physicalsciences.github.io/2022/files/NeurIPS_ML4PS_2022_118.pdf

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We have accurate predictions on unseen testing cases. Our surrogate model gives us the correct overall trend of contaminant flow and transport.


TRILLIUM△PPLIED
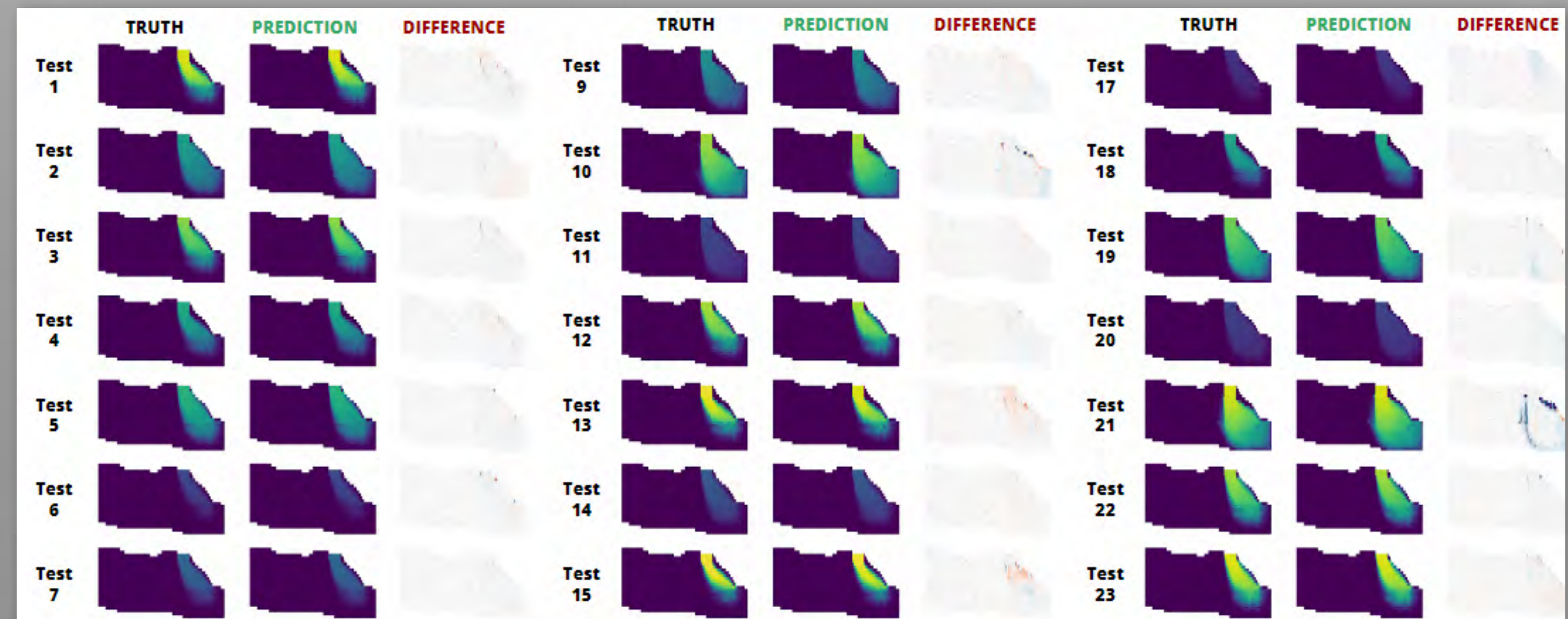
NASA GIBS WorldView Similarity Search

This project aims to empower scientists to search through vast amounts of satellite imagery given a single image, returning conceptually similar images, and then with a human-in-the-loop active labelling system, build a curated dataset.

The project solved the challenge by utilizing advances in self-supervised learning (SimSiam, SimCLR) to train AI models to represent the data, and then Approximate Nearest Neighbors methods deployable on cloud to search at scale

Additional innovations like pixel generation for missing parts and fast cloud identification were employed as pre-processing to put attention on specific parts of the image (e.g. on temporal items like clouds or on static objects like land and ocean)
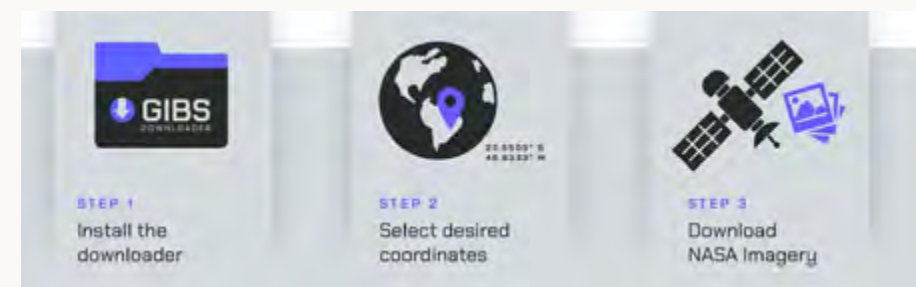
GIBS Downloader is a command-line tool which facilitates the downloading of NASA satellite imagery in order to prepare the images for training in a machine learning pipeline.

SpaceML: Rise of the Machine (Learning)
earthdata.nasa.gov/learn/articles/spaceml

Further reading

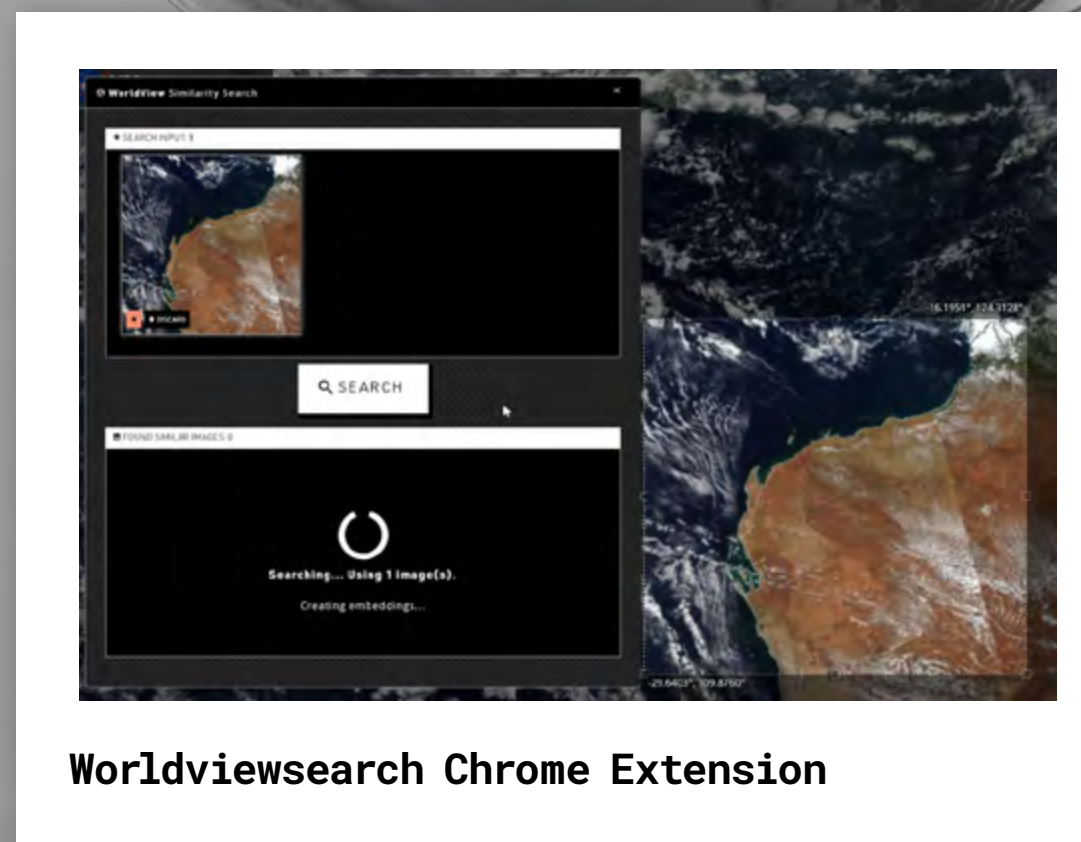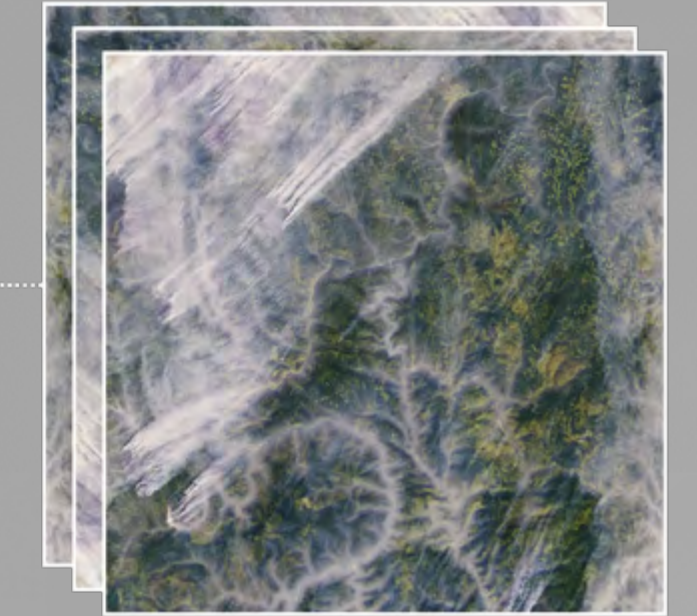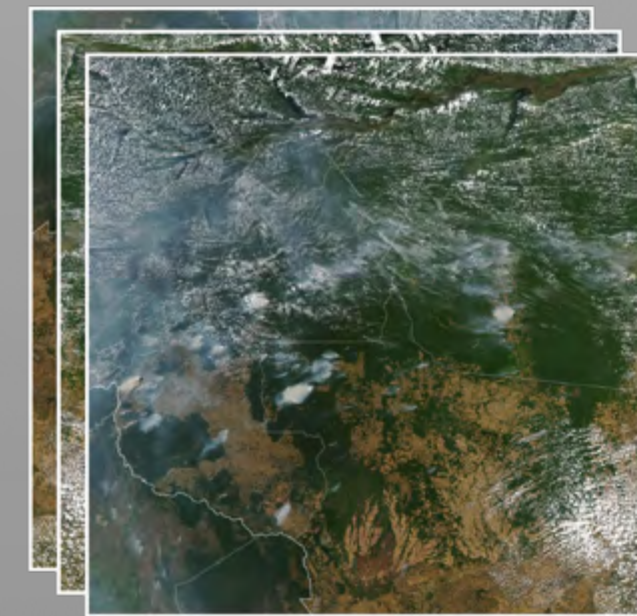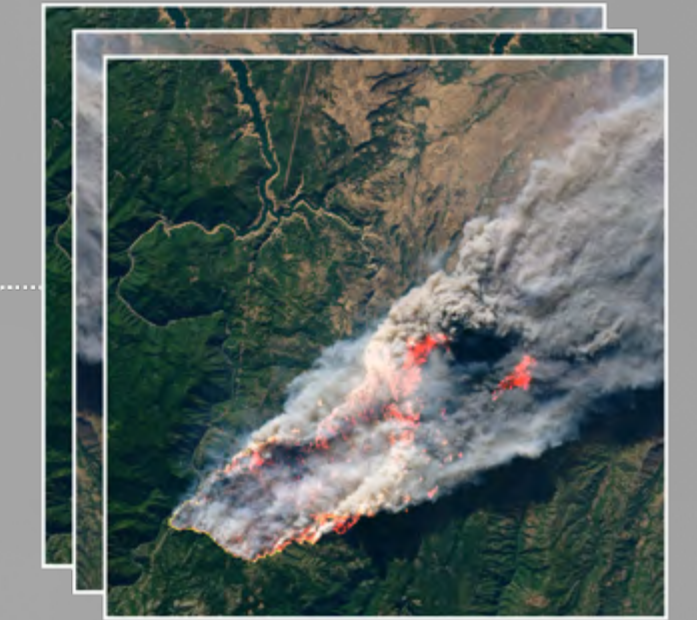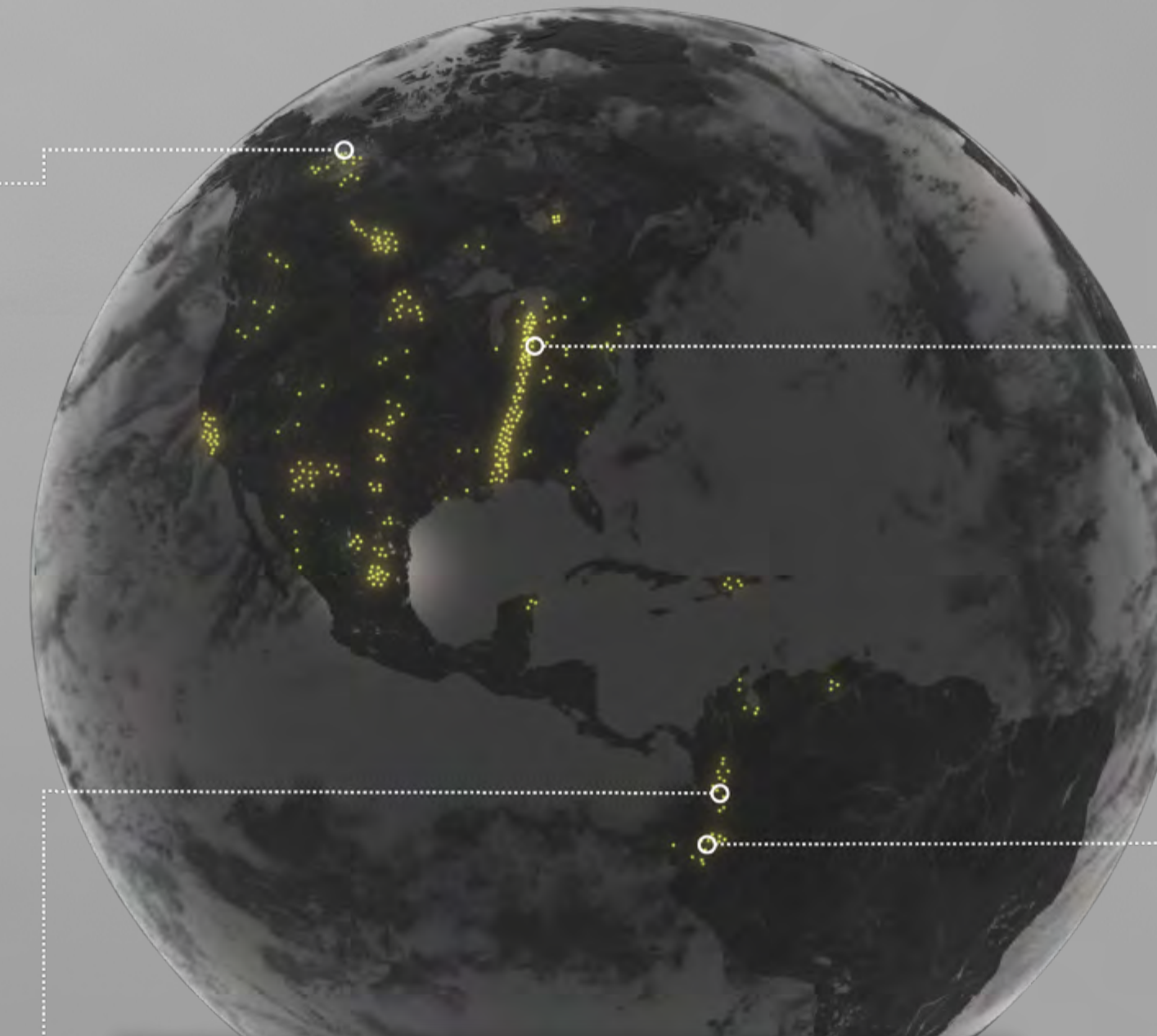https://github.com/spaceml-org

/SPACE**ML**
OPEN SCIENCE

A No-Code, Self-Supervised Learning and Active Labeling Toolset to enable searching Petabyte-Scale Imagery

SEARCH IMAGERY

🔍 **WILDFIRES**

Worldviewsearch Chrome Extension

TRILLIUM APPLIED

CoastalTwin: Using ML and physics to build an efficient "digital twin" of Earth's coasts

Coastal flooding is considered one of the most significant impacts of rising sea levels, potentially threatening lives and damaging infrastructure. Today's coastal flooding prediction is performed using physics-based numerical models, driven by wind speed and sea level pressure to simulate the dynamics of water velocity and sea surface height. Running these physics-based simulators can be extremely computationally expensive

Coastal Twins pipeline predicts the sea surface height either at the current time or 30 or 60 minutes into the future using as input the bathymetry and the forcings (wind speed and sea level pressure) at the current time and up to 15 minutes in the past (in 5 minute intervals).
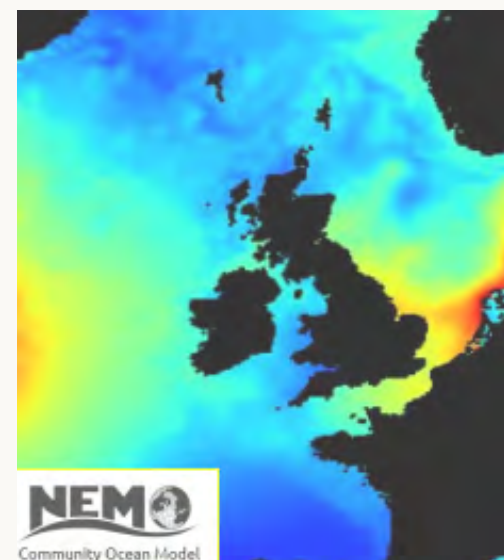
Traditional physics-based simulators: Map of the sea surface height simulated by the Nucleus for European Modelling of the Ocean (NEMO Ocean Model)

Further reading

frontierdevelopmentlab.org/fdl-2021

https://arxiv.org/abs/2110.07100

CoastalTwin: The first coastal "digital twin" with state-of-art physics-informed machine learning techniques.

SUPER COMPUTER

GPU
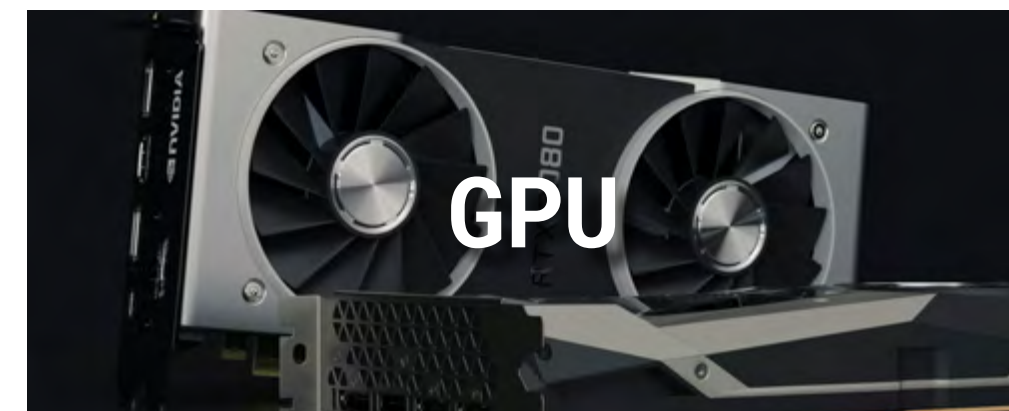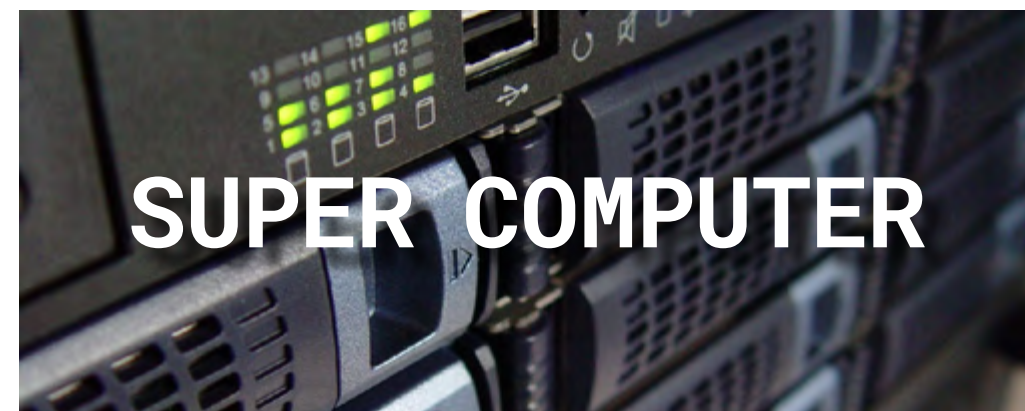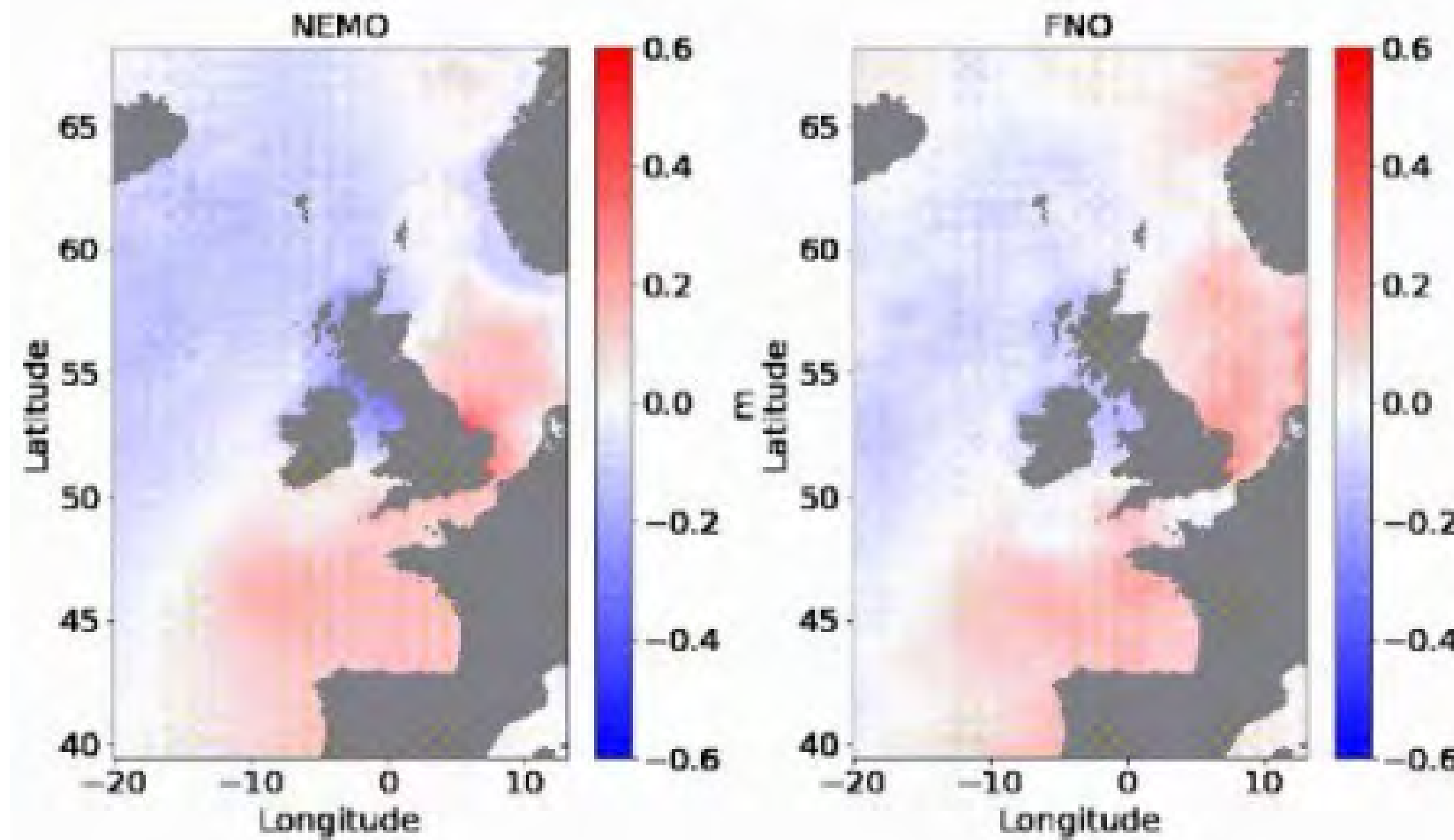
Fourier Neural Operator (FNO), a neural network that can approximate solutions to partial differential equations (PDEs) 1-3 orders of magnitude faster than traditional PDE solvers.

coastal twin.ai

Space Weather and Early Prediction: ICARUS

Reliable space weather warnings through AI onboard and physics-informed ML.

The ICARUS system makes detection and characterisation of coronal mass ejections on the Sun more efficient, accurate and reliable. Firstly, it implements a CME detection system and task-based compression algorithm onboard the spacecraft, maximising the throughput of useful data to the Earth. The received data is used by an innovative physics-informed ML system to quickly build a 4D (space and time) model of the CME, providing well-characterised estimates of physical parameters.

With this high-quality insight, space weather experts can provide confident warnings to satellite operators, electricity suppliers and others potentially affected by these damaging events.

A huge coronal mass ejection that was spotted in 2012 by the ESA/NASA Solar Heliospheric Observatory.

Further reading
fdleurope.org/fdl-europe-2023

CME-aware compression performed onboard; downlinked observations used for 3D reconstruction and CME parameter estimation using Physics-informed Neural Radiance Field (PINNeRF) on ground.
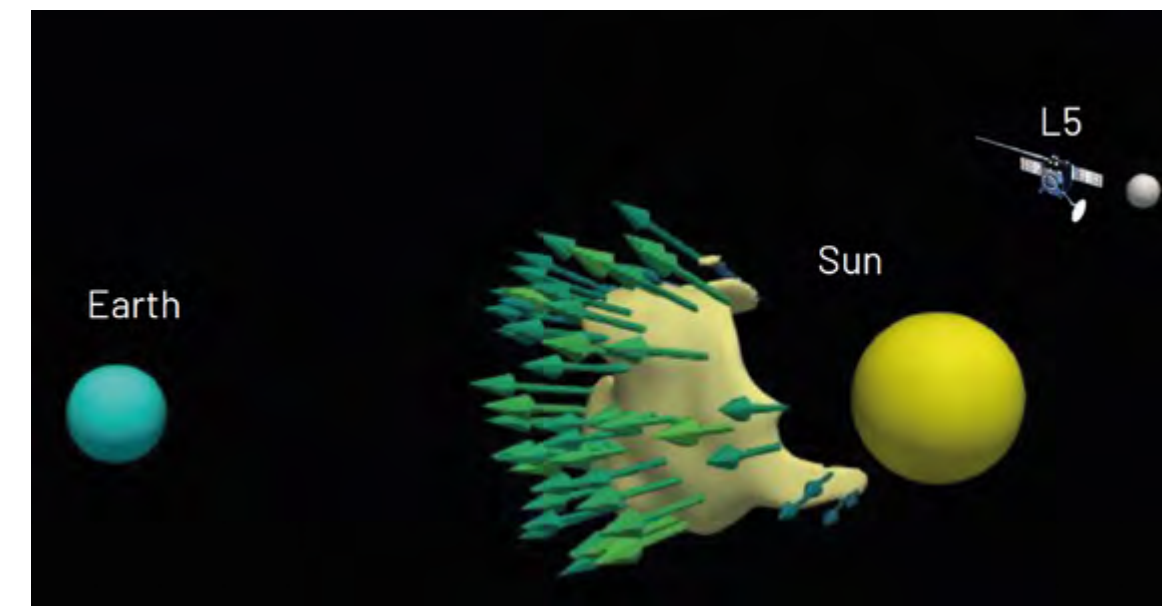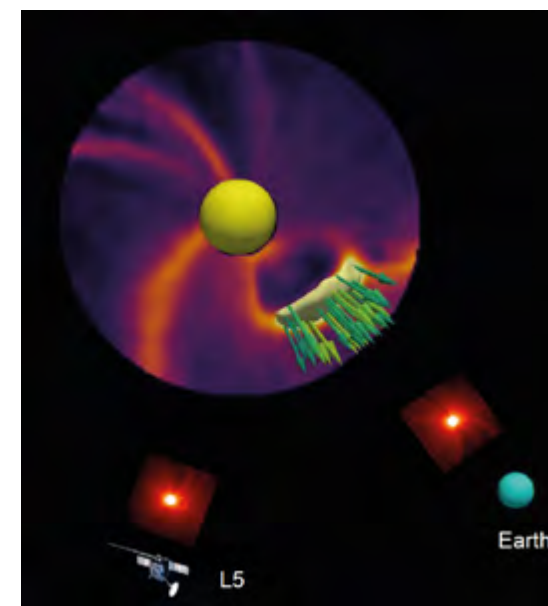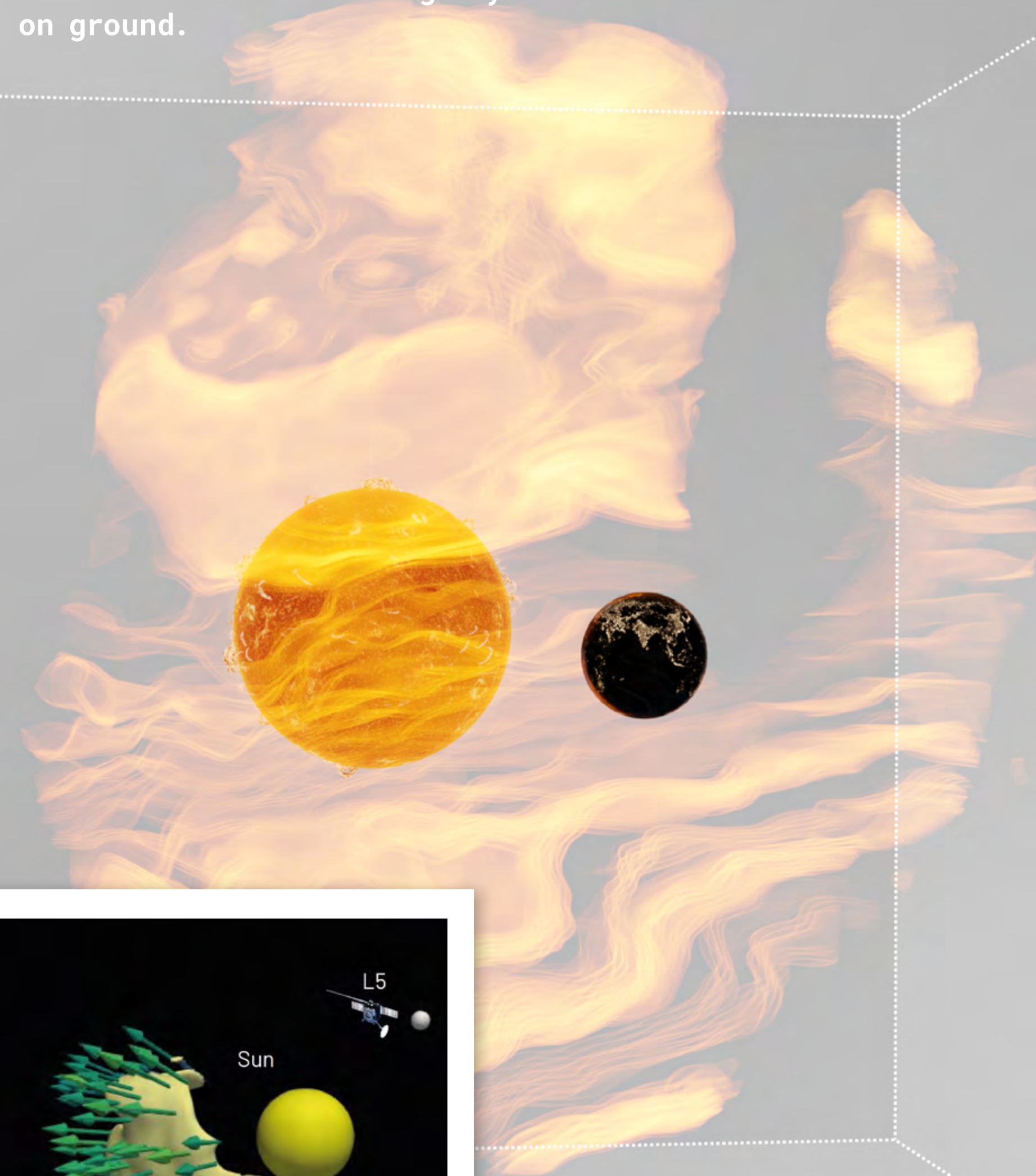
Velocity and density field snapshot of a simulated CME (reconstructed from observations from L5 and the Earth)

FloodBrain: LLM for Flood Reporting

Climate change is already changing the world with more frequent extreme weather events. Floods are the some of the most damaging & violent natural disasters. To better make flood relief decisions and resilience plans, disaster reports are made to give a summary overview of the event.

FloodBrain provides LLM-driven flood Reports:

- Robust pipeline that searches the web to deliver concise summaries on specific flood events.

- References enable to double-check sources. Interactive Flood Map

- Showcases essential visual data: flood extent, critical landmarks, and population density regions.

- Custom Chat Interface

- Retrieve detailed insights for specific floods.

Artificial Intelligence for Humanitarian Assistance and Disaster Response Workshop @ Neurips2023

https://arxiv.org/abs/2311.02597

Further reading
floodbrain.com

floodbrain.com
preview password:
floodbrain

FloodBrain
LLM Assisted Flood Reporting

Flood Extent & Impact Mapping
Event Summary & Source Inspection
Event Aware Chatbot

FloodBrain v0-alpha-b   Help us by providing feedback

report maker   evaluate   about

Making a disaster report...

Requested a summary...

Composing report...

Report summary done

Making map

Flood map made

Creating population impact map

Message here

send message

FloodBrain Report: EMSR664   Edit   Share   About   Update style

Italy floods: At least 14 dead, thousands evacuated

Overview | Inspect

Overview

Affected region or location
The flooding affected the Emilia-Romagna region of Italy. The region is located in the north of the country and is bordered by the Adriatic Sea to the east. The region is home to a population of over 4.4 million people and is one of the most industrialized regions in Italy.

Impact
The flooding has caused widespread damage to infrastructure and homes. At least 14 people have died and thousands more have been evacuated from their homes. The estimated cost of the flood is in the region of EUR 500 million or more and could reach as high as EUR 1 billion.

Context

🔗 Sources
- https://emergency.copernicus.eu/EMS...
- https://time.com/6280579/italy-floo...
- https://www.efas.eu/en/news/flood-e...
- https://floodlist.com/europe/italy-...
- https://www.dw.com/en/italy-severe-...
- https://www.washingtonpost.com/worl...

Flood Extent
AoI
Population
Residential
Roads

Leaflet | © OpenStreetMap contributors

floodbrain-llm@trs4PmH: Loading saved report...

TRILLIUM APPLIED

PyroCast: Machine Learning for PyroCb forecasting

Extreme wildfires create smoke plumes that ascend into the atmosphere where they form storm clouds known as Pyrocumulonimbus (PyroCb).

PyroCb clouds further exacerbate and change the course of the wildfire in very adverse and unpredictable ways, either by generating lightning that ignite further fires, or by creating turbulent winds that change the direction of the fire spreads. Being able to predict in advance whether a wildfire is likely to produce a PyroCb will aid in allocating limited resources in preventing the wildfire from generating a PyroCb in the first place, as well as allowing for an extension of an evacuation zone in case the PyroCb changes the direction of the wildfire.

PyroCast consists of: PyroCb Database, PyroCb Forecasting Model and PyroCb Discovery Framework.

2022 NeurIPS Workshop on Causal Machine Learning for Real-World Impact

https://arxiv.org/abs/2211.08883

Further reading
fdleurope.org/fdl-europe-2022

Pyrocast

PyroCB Casual Drivers

Veg.
Hum.
Hei.
Win.

Deep convection
Deep convection + high opacity
PyroCb

Humidity

Wind

Height

Vegetation

PyroCast Discovery Framework:
Causal Invariance Results lead to important causal interactions.
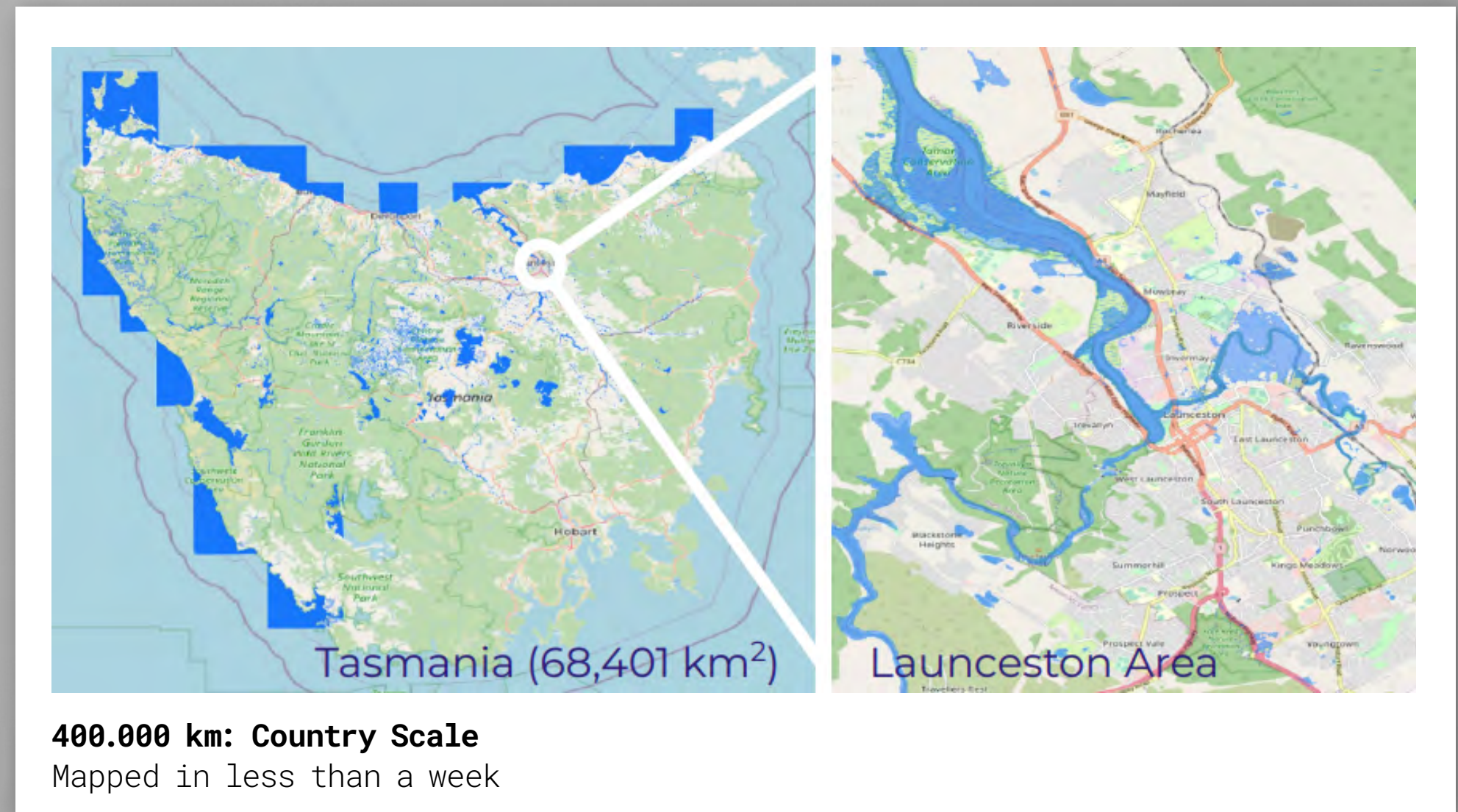
TRILLIUM APPLIED

FloodMapper

Floods are the most common natural disaster worldwide, affecting millions of people every year. We need better tools to predict flooding in advance and to support communities through recovery.

During early 2022 almost 2,000 kilometers of Australia's eastern seaboard was flooded due to prolonged heavy rainfall. The sheer scale of this disaster made mapping the extent highly challenging - even with modern satellite technology. Existing flood-mapping tools struggle to analyse the large volumes of data and simply can't deliver timely and accurate water extent maps.
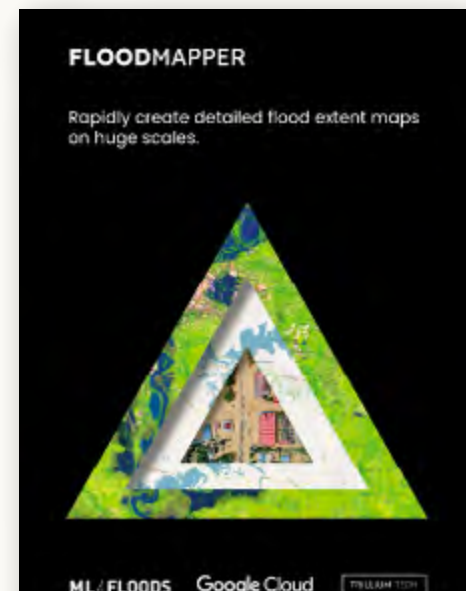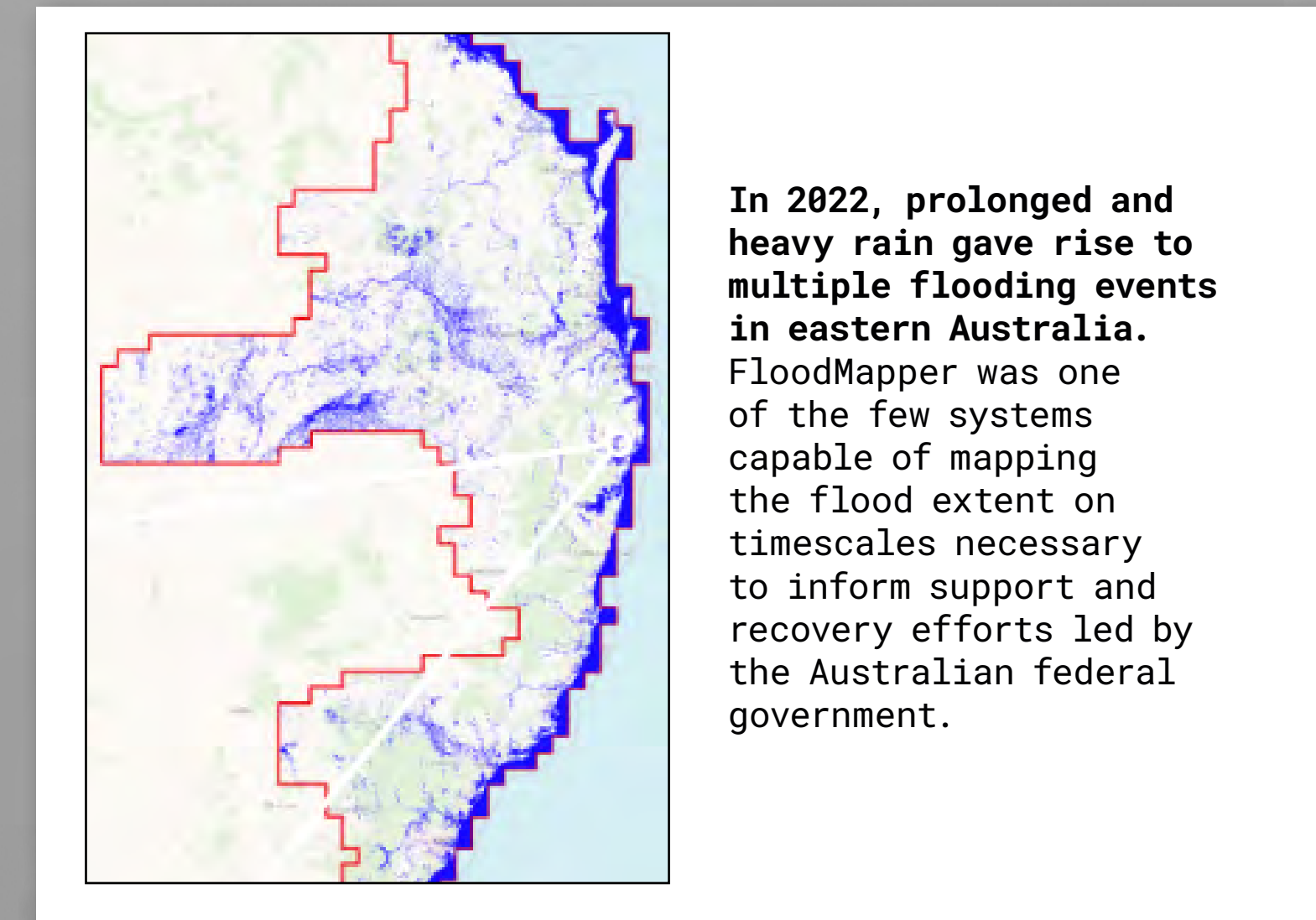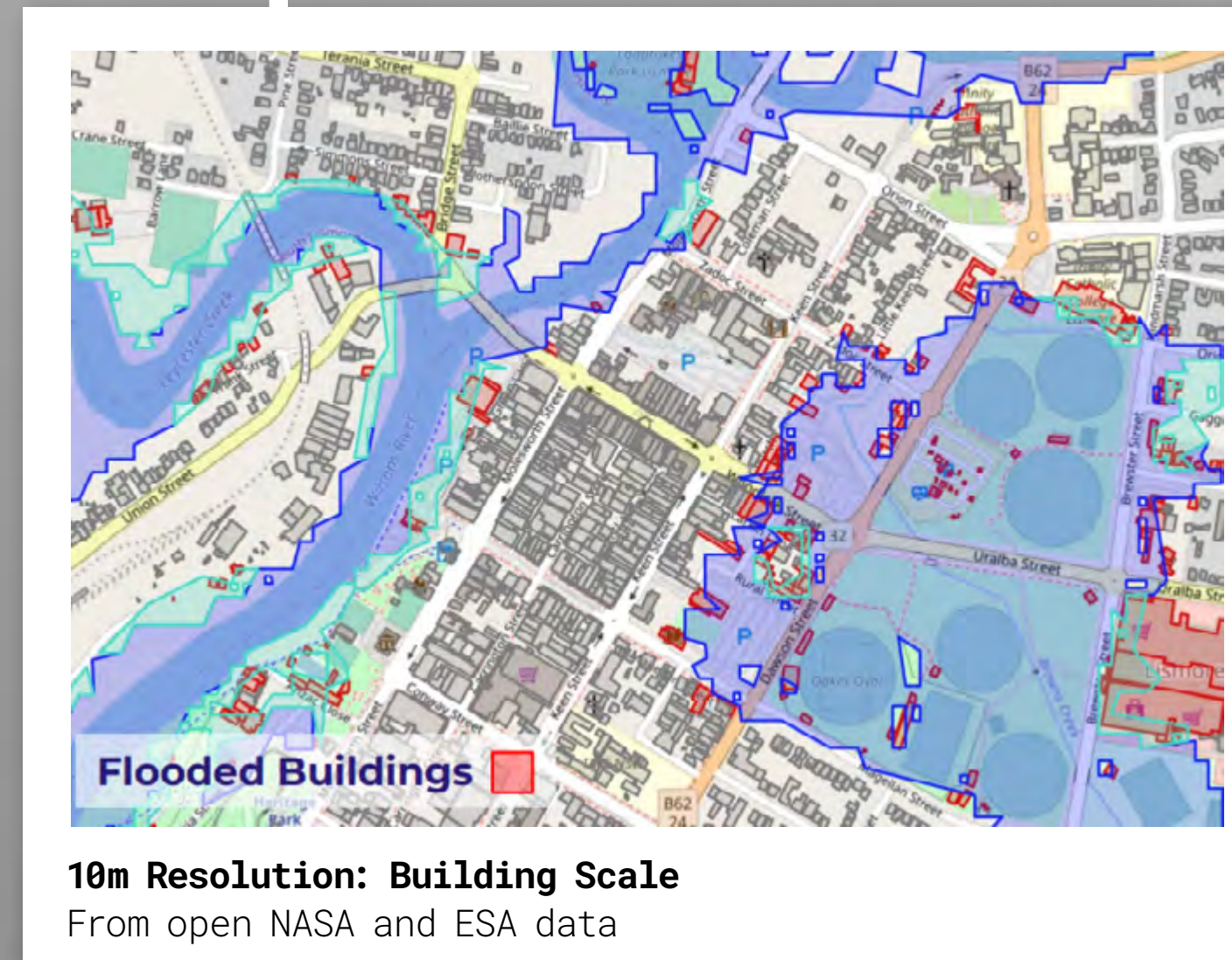
Trillium has developed a robust and scalable flood mapping toolkit based on cutting-edge machine learning technology - FloodMapper. We used FloodMapper to generate highly accurate maps of the East Australian floods from satellite imagery in only a few days.

Further reading
https://trillium.tech/floodmapper

FLOODMAPPER

Rapidly create detailed flood extent maps on huge scales.

Tasmania (68,401 km²)   Launceston Area

400.000 km: Country Scale
Mapped in less than a week

Map Scale

10m Resolution: Building Scale
From open NASA and ESA data

Flooded Buildings

In 2022, prolonged and heavy rain gave rise to multiple flooding events in eastern Australia. FloodMapper was one of the few systems capable of mapping the flood extent on timescales necessary to inform support and recovery efforts led by the Australian federal government.
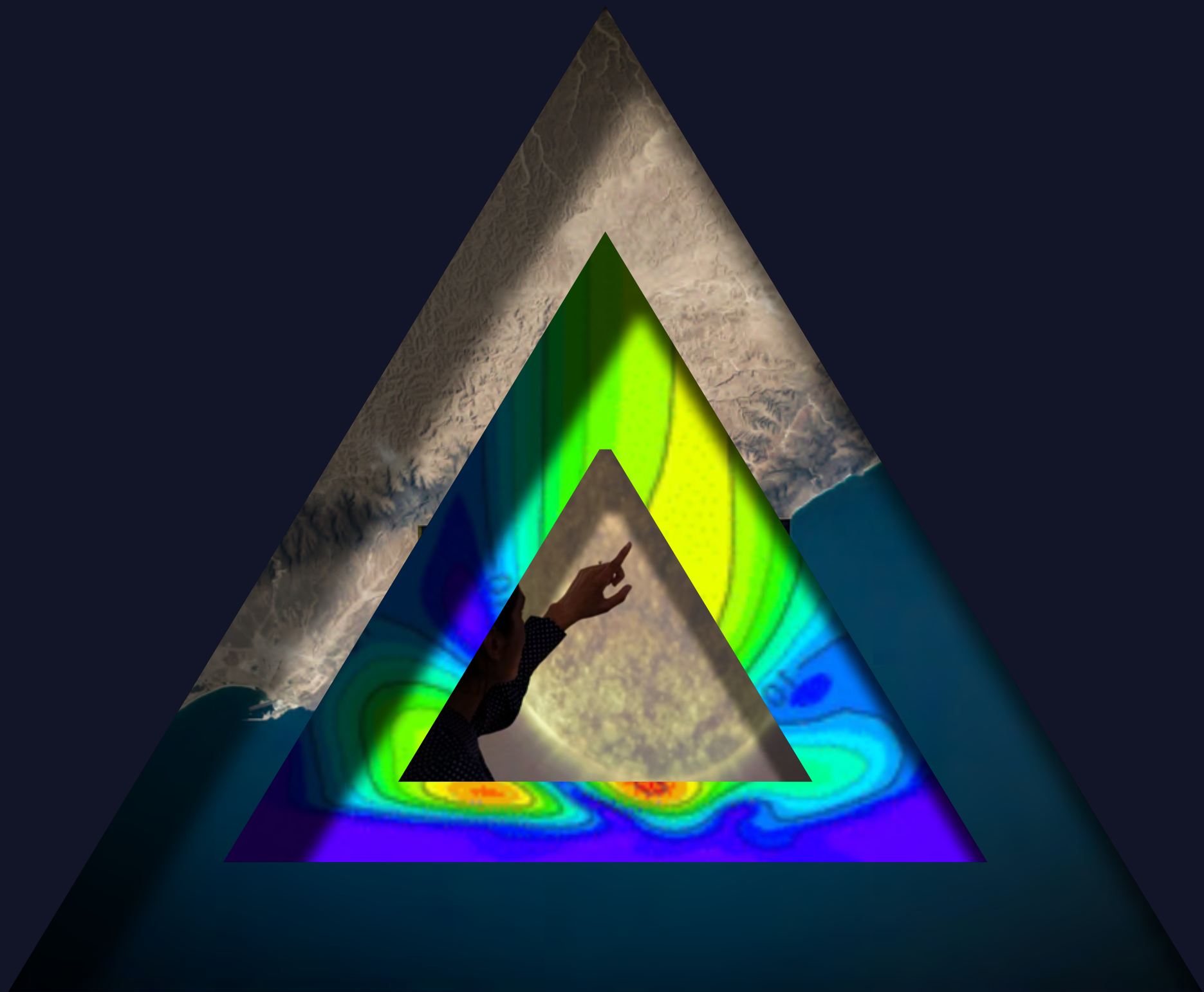
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Work with us to create and deploy trailblazing applied AI.

If you'd like to set up a no-obligation call to discuss technical feasibility and possibilities, explore the potential, please email us at: **team@trillium.tech**

Let's build an intelligent future

The world is changing.

As our problems get more complex and solutions become more nuanced, systemic and intelligence, laser-focused problem definition is more critical than ever.

Trillium has over a decade of experience providing professional consulting services to leading global organisations, from **Nike** (Better World, Designed to Move) to **NASA** (Asteroid Grand Challenge, FDL), **Launch.org**, the **US Department of Energy**, **ESA**, **USGS**, **British Telecom**, **Cancer Research UK** and many others.

Trillium Applied's AI capabilities build on our deep experience in developing AI for global space agencies for both exploration ('looking up') and Earth system science ('looking down'); blending world class research depth through our close partnership with leading universities and community of 100+ data science PhDs.

Targeting your actual problem

We've learned how to produce cutting-edge AI outcomes that target the actual nugget of the problem and do it quickly without scope drift, junkets, lock-in, alpha-geeks, black-boxes, betamaxing, bloat-ware or boondoggles.

Trillium Applied's problem definition approach blends the best of design thinking and concurrent design methods, which places emphasis on stakeholder partnership, interdisciplinarity, rapid prototyping and systems thinking to ensure precision problem scoping and AI solutions that are fit-for-purpose, explainable and reproducible within your organisation.

Our mission is to lead humanity into the era of 'Intelligence Age', enabling humankind to feel empowered to acheive excellence in tackling complex systemic, or multi-actor problems.

Launch.org

We ensured Launch.org achieved success in its yearly cycle to find and accelerate the world's most exciting sustainability technologies.

Asteroid Grand Challenge

The Ultrascope is an Open Hardware Robotic Observatory. Future Generations of the Ultrascope will be able to contribute to the Asteroid Grand Challenge.

Frontier Development Lab

Our AI and Space Science research accelerator for NASA and ESA.

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