Monitoring Biodiversity Change to Guide Conservation Action Using AI and Satellite Time-Series

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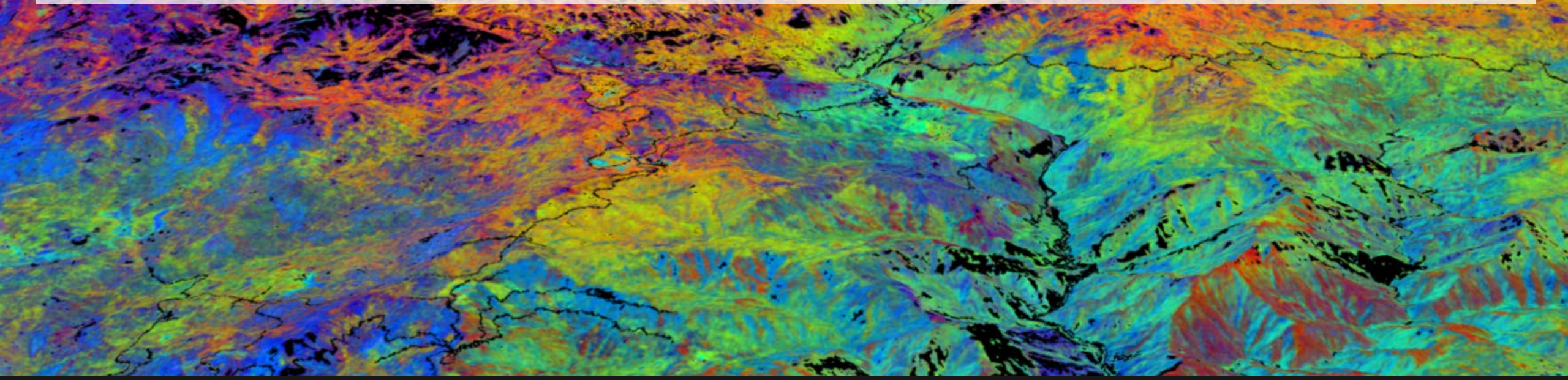

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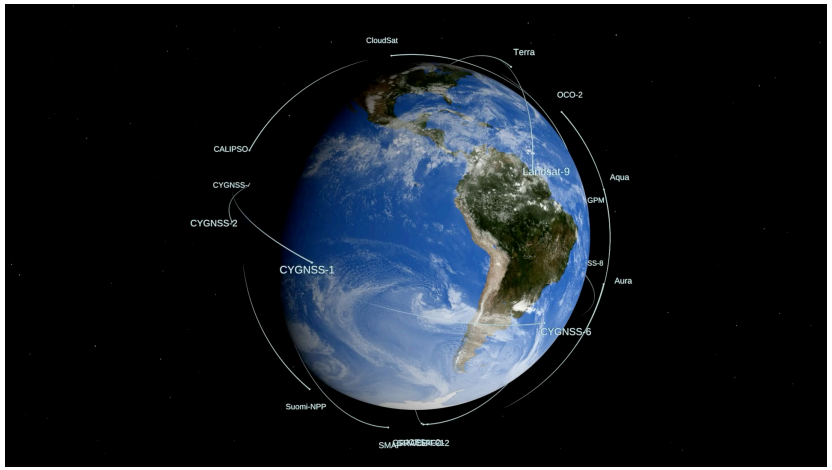
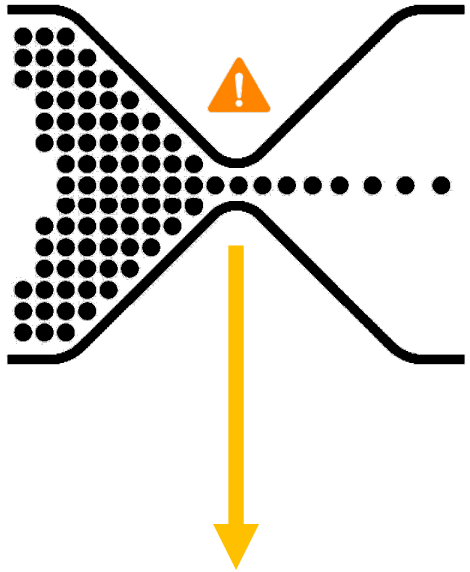
We are evidencing widespread declines in biodiversity.

Addressing this challenge requires global monitoring frameworks. This is key to :

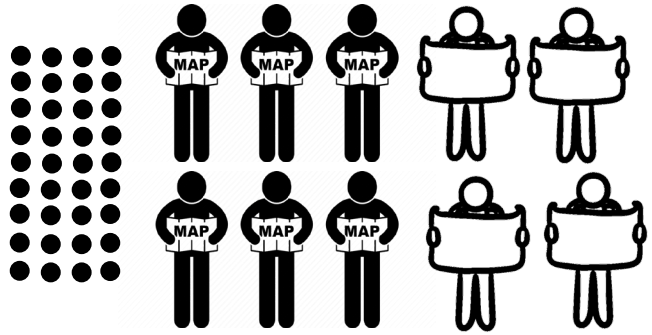
- Understanding biodiversity distribution, change and resilience across space and time
- Inform biodiversity conservation and management action

Increasing fleet of sensors with relevance for Biodiversity monitoring





End user needs



we lack tools to convert massive amounts of existing and upcoming Spaceborne Observations into regularly updated data products required to inform Biodiversity Management & Conservation

In this context, biodiversity refers to → the variety of **habitat forms**, including their **structure** (3D organization), **composition** (variety of plant species), and **function** (ecological roles and processes).

Main requirements of our tool to convert EO data into Biodiversity data prodcuts :

1. Multi-Modal : Combines sensing **Structure** (e.g., SAR, LiDAR), **Composition** (Optical, Spectroscopy), **Function** (SIF, GPP, ET)

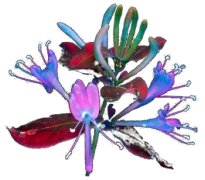
Structure

GEDI, ICESAT-2
Sentinel-1, ALOS-PALSAR
NISAR, BIOMASS, L-ROSE

Composition

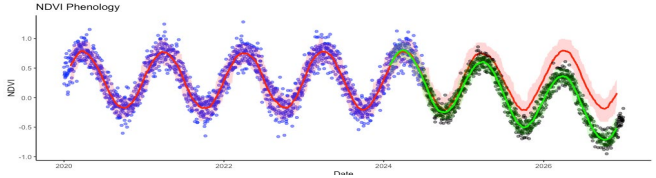
Landsat, Sentinel-2
EMIT, PRISMA, DESIS, EnMAP
SBG,EMIT, CHIME

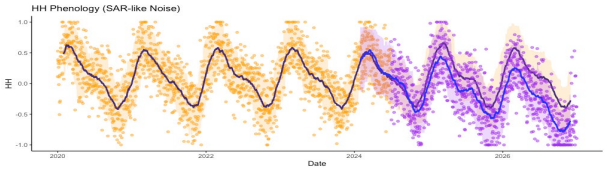
Function



MODIS, OCO-2/3
TROPOMI, SCHIAMACHY
SBG, FLEX, CHIME

2: Time-Series: Assess **reference conditions** and track **resilience** and **recovery**

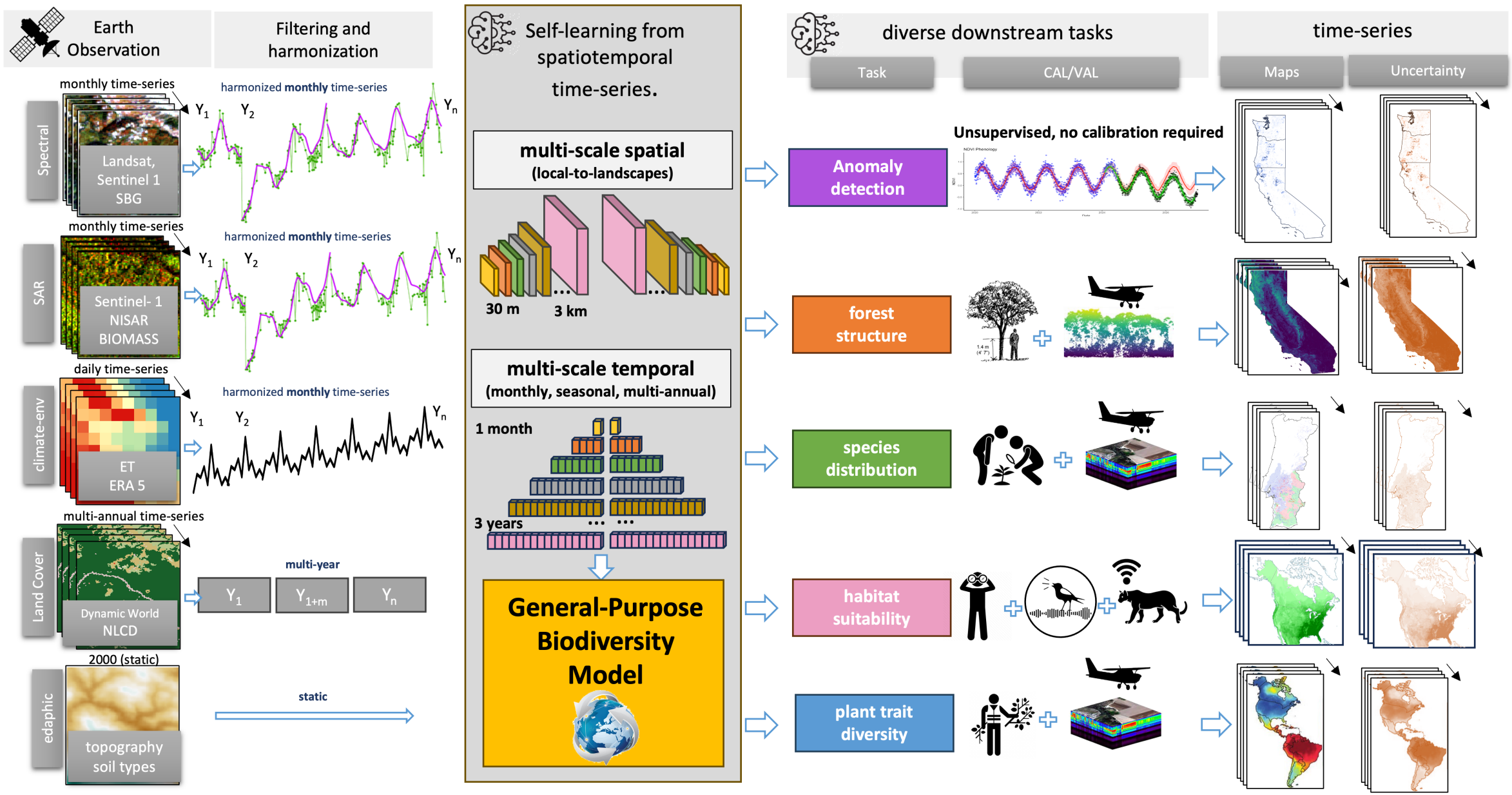




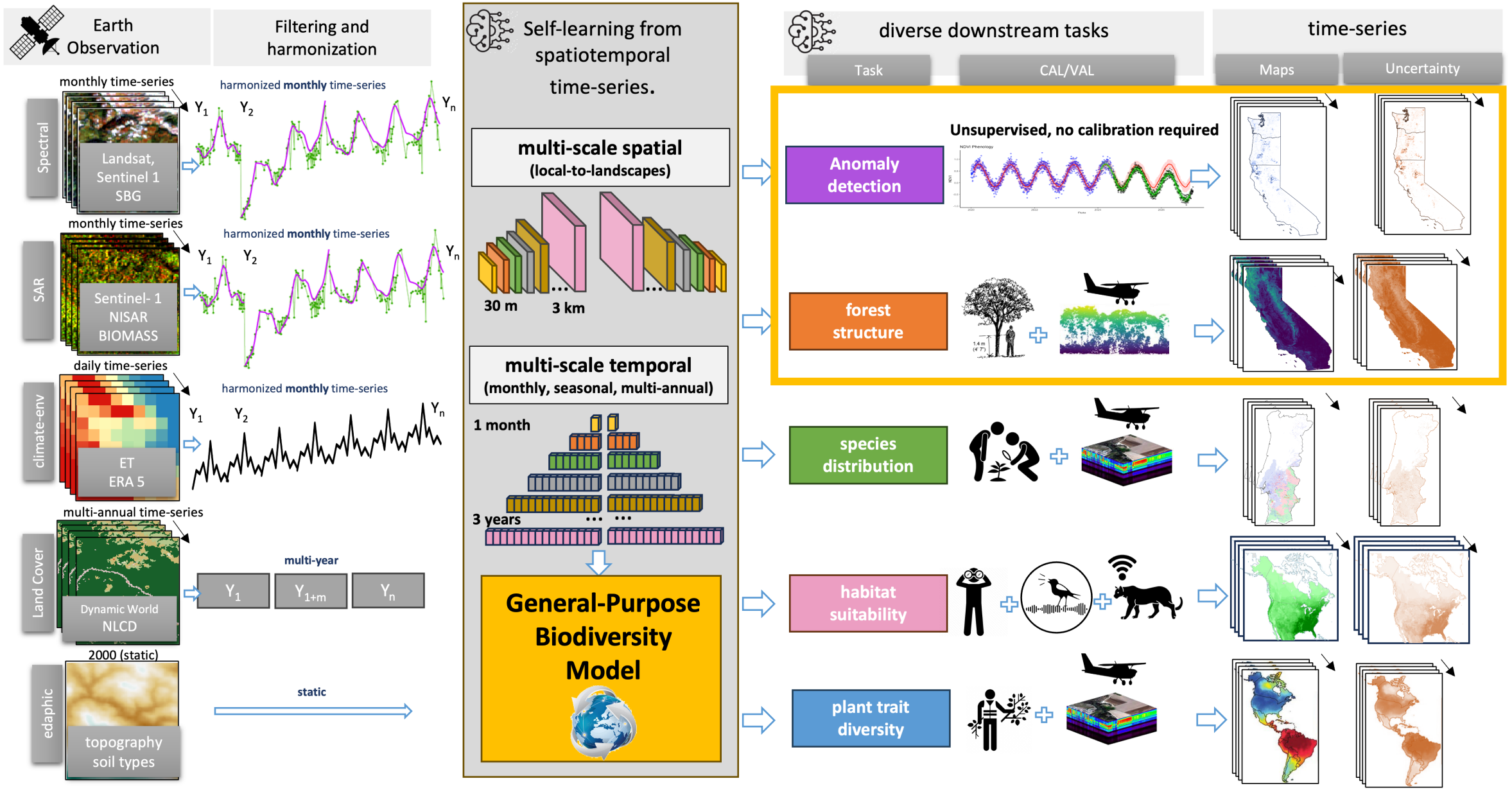
3: Generalizable and adaptable: Avoid single-task tool, develop an open-ended solution for producing diverse thematic maps

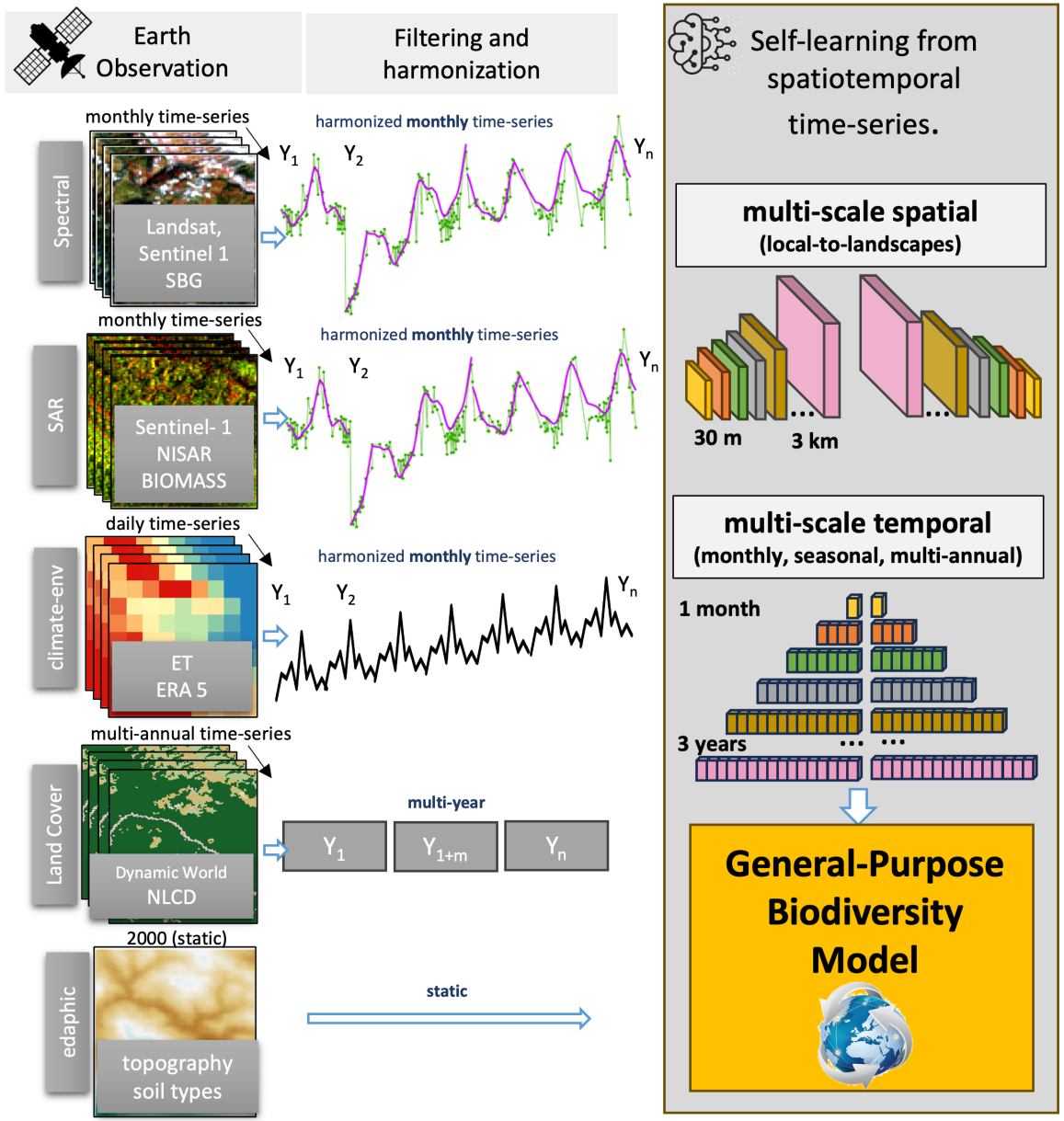
species distribution | **forest structure** | **plant trait diversity** | **habitat suitability** | **...**

Tracking Biodiversity Change: a general-purpose model using Dense Multi-Modal Remote Sensing Time-Series



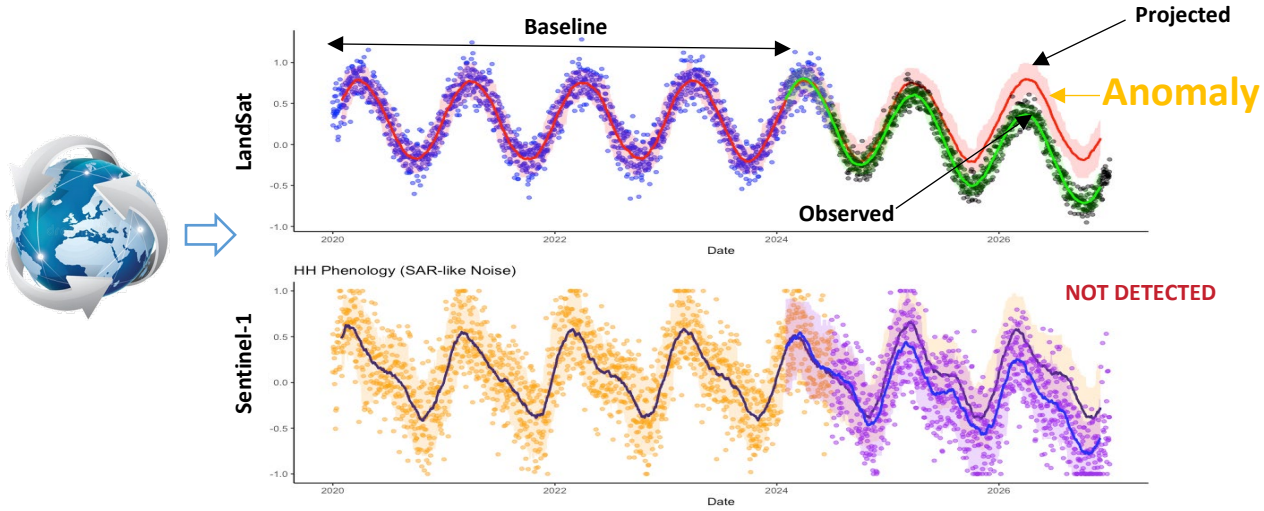
Tracking Biodiversity Change: a general-purpose model using Dense Multi-Modal Remote Sensing Time-Series





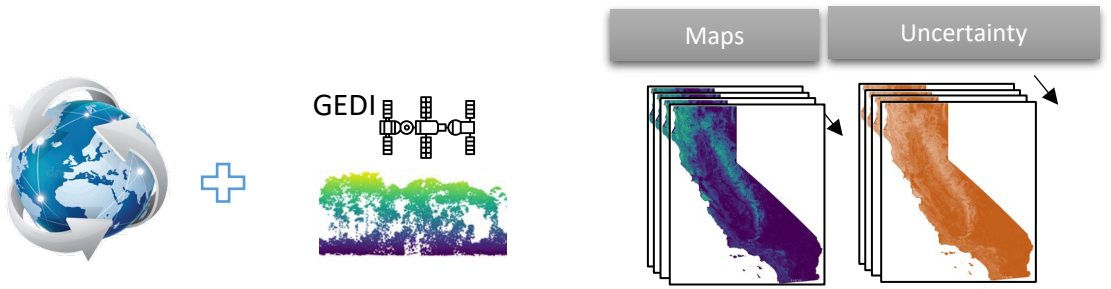
Anomaly detection (annual, 2015-2022, 30 m resolution)

unsupervised detection of anomalies in multimodal phenology cycles (2015-2024)

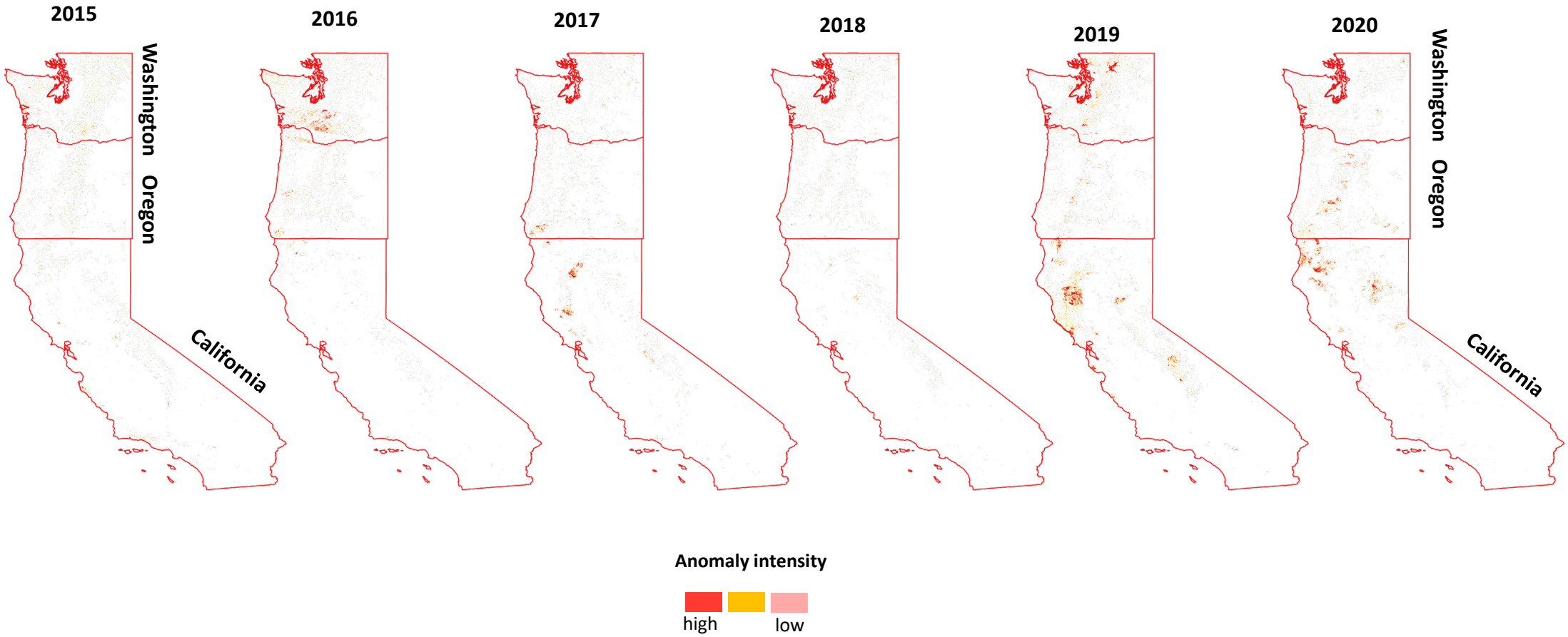


forest height change (annual, 2015-2022, 30 m resolution)

we use GEDI to train the general-purpose model to track forest structure change



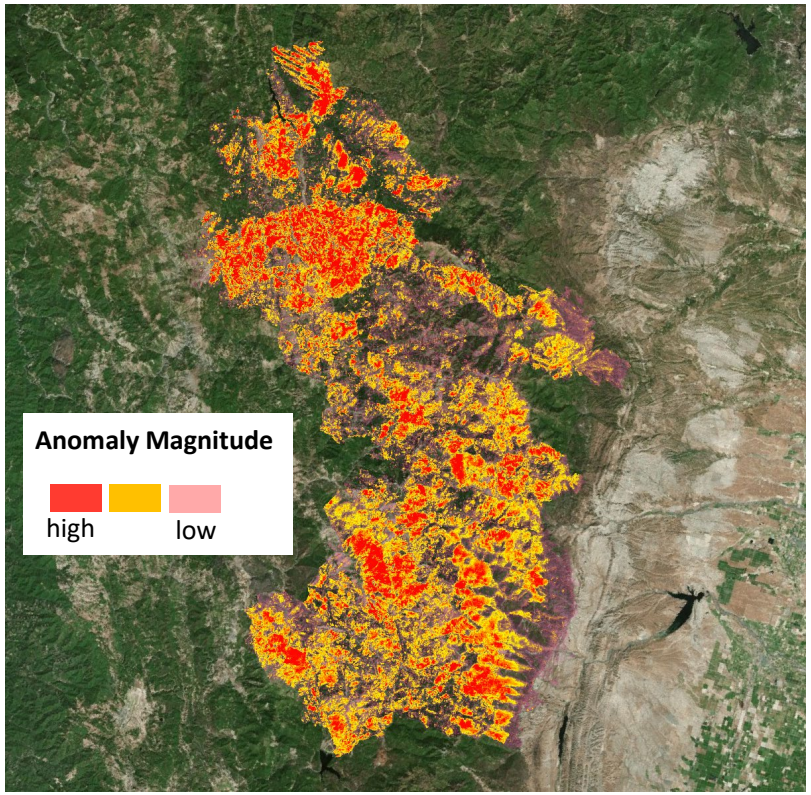
Preliminary Results: Anomalies across US Pacific Coast (annual, 30 meter resolution)



Preliminary Results: zoom into August Complex Fire, California, 2018

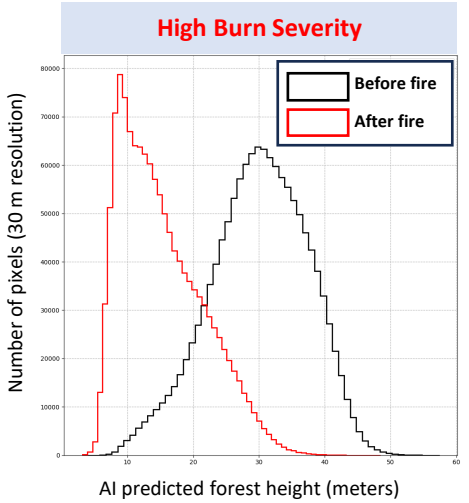
Anomaly detection annual (30 m resolution)

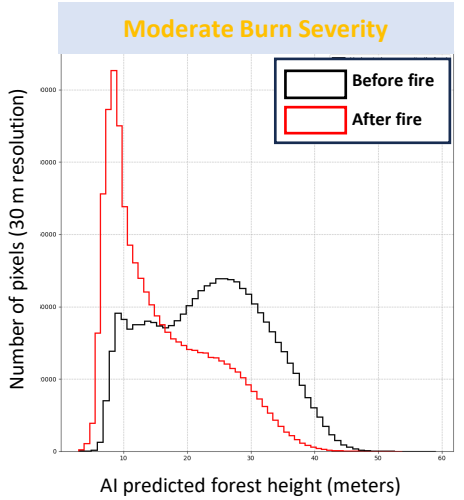
Effectively detects anomalies across a gradient of wildfire burn severity

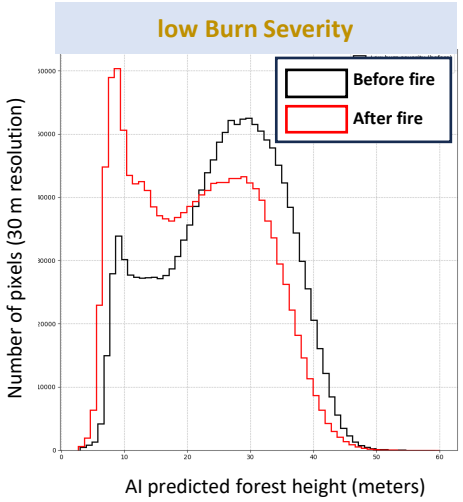


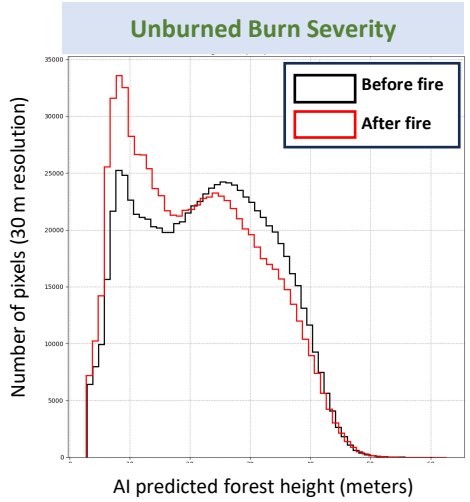
forest height change (30 m resolution)

After training with GEDI measurements, our model accurately maps forest height changes across burn severity gradients









Conclusions

Preliminary results indicate that our general-purpose model generalizes well between two distinct tasks

We are looking for partners to further validate and test additional downstream tasks (e.g. species distribution models)

We will test the ability of our model to monitor resilience and recovery trajectories

Recommendations for the so-called golden era of biodiversity from space

- **Opportunity:** Existing and upcoming (NISAR, SBG, BIOMASS, L-ROSE) missions enable biodiversity monitoring across multiple dimensions and improved spatiotemporal scales.

- **Challenge:** Massive data flows risk overwhelming the community, leaving valuable patterns, trends and insights unexplored.

- **Potential Solution #1:** Define a set of **Key Biodiversity Indicators** co-produced by space agencies, balancing minimal modeling effort with maximum decision-making impact.

- **Potential Solution #2:** Tackle data complexity using **general-purpose models** (e.g., Self-Supervised and/or Foundation Models) to extract biodiversity-relevant spatiotemporal patterns efficiently, that can be relatively easily leveraged by users

Either solution, requires interdisciplinary work

Biodiversity Scientists

Remote Sensing Scientists

Biodiversity Practitioners & Policy-makers

Data scientists

Thank for your attention

Credits: Fabian Schneider, NASA JPL,

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Earth Observation

Filtering and harmonization

Spectral — Landsat, Sentinel 1, SBG — monthly time-series → harmonized **monthly** time-series (Y_1, Y_2, … Y_n)

SAR — Sentinel- 1, NISAR, BIOMASS — monthly time-series → harmonized **monthly** time-series (Y_1, Y_2, … Y_n)

climate-env — ET, ERA 5 — daily time-series → harmonized **monthly** time-series (Y_1, Y_2, … Y_n)

Land Cover — Dynamic World, NLCD — multi-annual time-series → **multi-year** (Y_1, Y_{1+m}, Y_n)

edaphic — topography, soil types — 2000 (static) → **static**

Self-learning from spatiotemporal time-series.

multi-scale spatial
(local-to-landscapes)

30 m … 3 km

multi-scale temporal
(monthly, seasonal, multi-annual)

1 month … 3 years

General-Purpose Biodiversity Model

diverse downstream tasks

Task	CAL/VAL	Maps	Uncertainty

- **Anomaly detection** — Unsupervised, no calibration required
- **forest structure**
- **species distribution**
- **habitat suitability**
- **plant trait diversity**

time-series