



Demystifying Earth Observation Foundation Models

Overview & Demonstration with Pangaea

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Overview

- Foundation Model (FM) Introduction
- FM Process for Earth Observation
- Pangaea Overview
- Pangaea Example
- Summary

Old Way: AI/ML Models

Your own data

Your labels

Your compute

Your model
architecture



New model for every task

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New way: Foundation Models



Fine Tuning

- Less Compute
- Fewer Data
- Fewer Labels
- Pre-built architecture

Foundation Model (Encoder)

Image Source: Big Sky Mountain

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Foundation Models

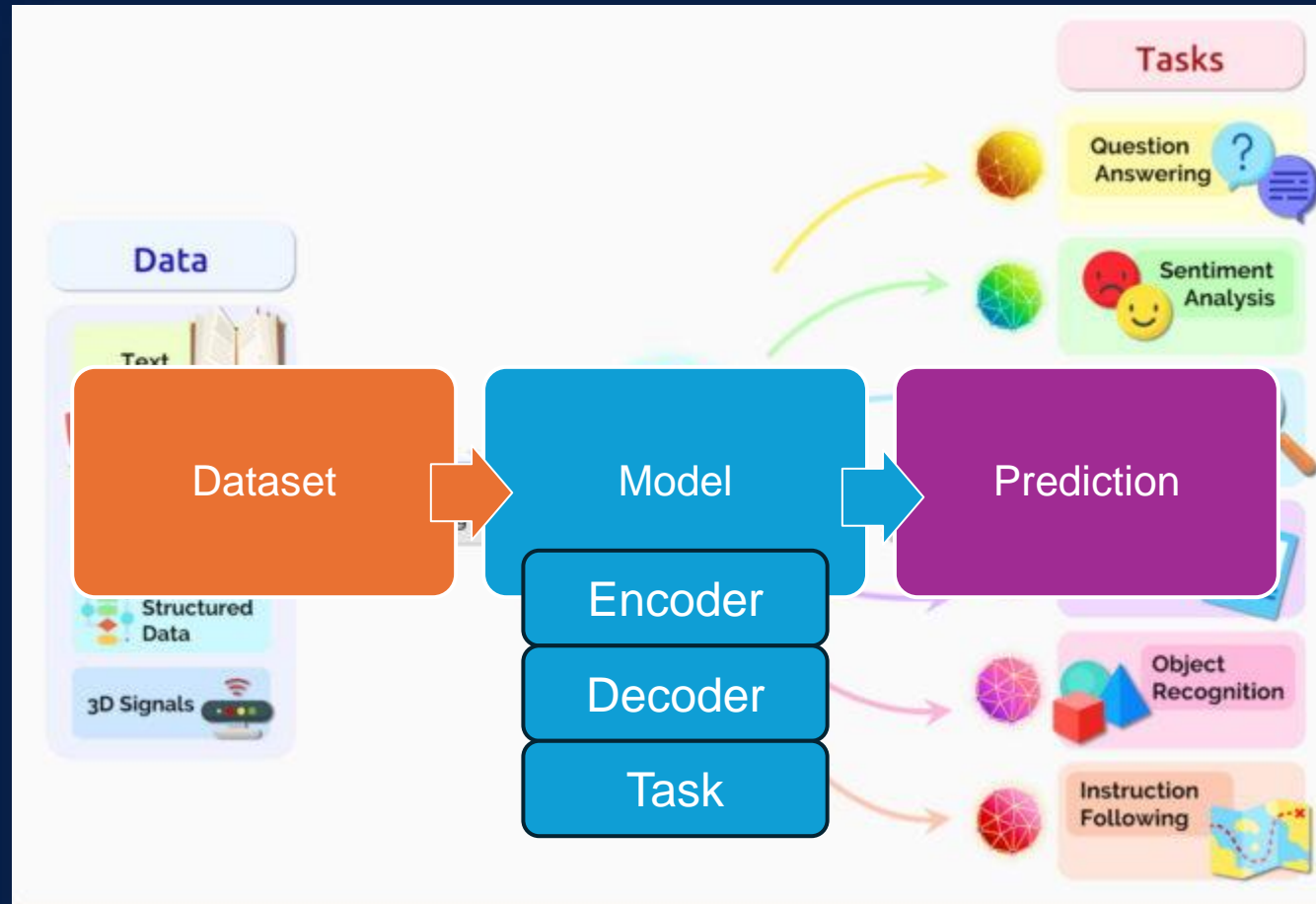


Image Source: [NVIDIA](#)

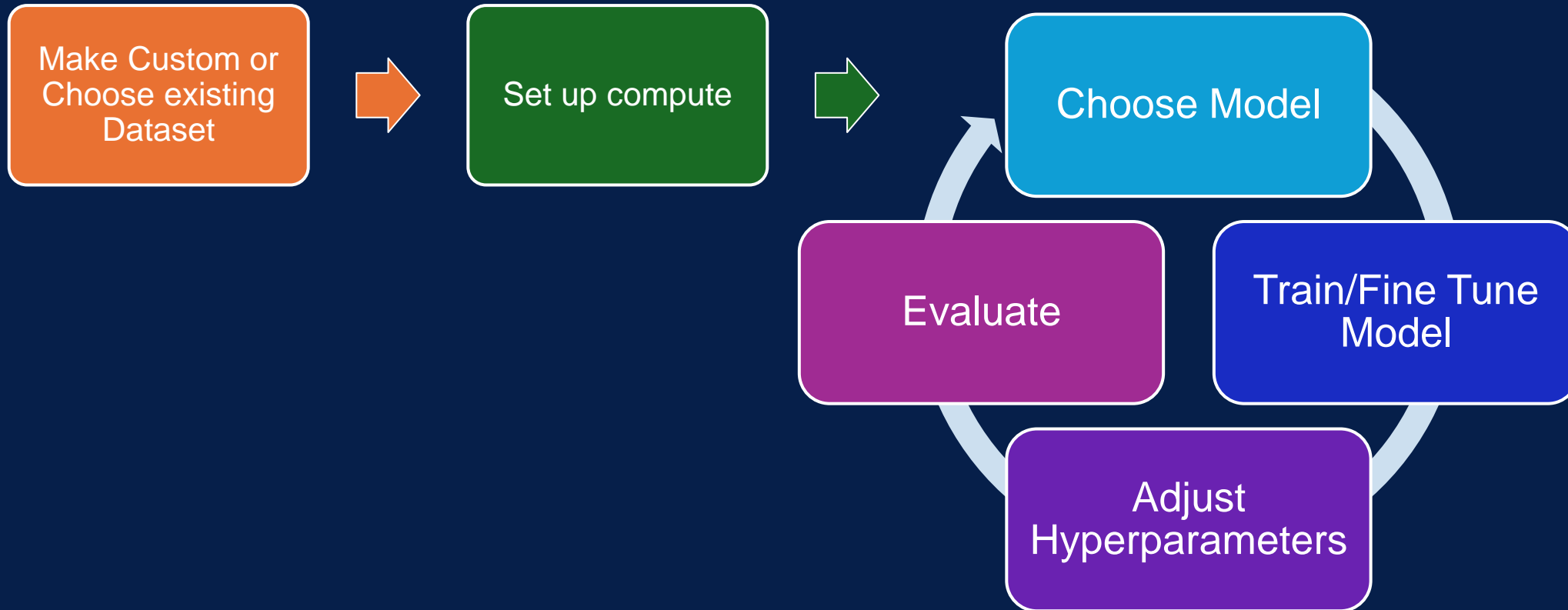
FM Overview

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Process



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Earth Observation Tasks

Semantic Segmentation	Continuous Prediction	Image Classification	Change Detection	Generative
<ul style="list-style-type: none">• Land Cover• Land Class• Object Detection	<ul style="list-style-type: none">• Canopy Height• Bathymetry	<ul style="list-style-type: none">• Object Detection• Location ID	<ul style="list-style-type: none">• Burn Scars• Biomass	<ul style="list-style-type: none">• Cloud Gap Filling• Captioning

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Earth Observation FMs

Remote Sensing <u>Vision</u> Foundation Models				
Abbreviation	Title	Publication	Paper	Code & Weights
GeoKR	Geographical Knowledge-Driven Representation Learning for Remote Sensing Images	TGRS2021	GeoKR	link
-	Self-Supervised Learning of Remote Sensing Scene Representations Using Contrastive Multiview Coding	CVPRW2021	Paper	link
GASSL	Geography-Aware Self-Supervised Learning	ICCV2021	GASSL	link
SeCo	Seasonal Contrast: Unsupervised Pre-Training From Uncurated Remote Sensing Data	ICCV2021	SeCo	link
DINO-MM	Self-supervised Vision Transformers for Joint SAR-optical Representation Learning	IGARSS2022	DINO-MM	link
SatMAE	SatMAE: Pre-training Transformers for Temporal and Multi-Spectral Satellite Imagery	NeurIPS2022	SatMAE	link
RS-BYOL	Self-Supervised Learning for Invariant Representations From Multi-Spectral and SAR Images	JSTARS2022	RS-BYOL	null
GeCo	Geographical Supervision Correction for Remote Sensing Representation Learning	TGRS2022	GeCo	null
RingMo	RingMo: A remote sensing foundation model with masked image modeling	TGRS2022	RingMo	Code
RVSA	Advancing plain vision transformer toward remote sensing foundation model	TGRS2022	RVSA	link
RSP	An Empirical Study of Remote Sensing Pretraining	TGRS2022	RSP	link
MATTER	Self-Supervised Material and Texture Representation Learning for Remote Sensing Tasks	CVPR2022	MATTER	null
CSPT	Consecutive Pre-Training: A Knowledge Transfer Learning Strategy with Relevant Unlabeled Data for Remote Sensing Domain	RS2022	CSPT	link
-	Self-supervised Vision Transformers for Land-cover Segmentation and Classification	CVPRW2022	Paper	link
RFM	A billion-scale foundation model for	Arxiv2023	RFM	null

... and more!

- Dozens of Earth Observation Foundation Models
- List of ~300 compiled by SkySense team:
<https://github.com/Jack-bo1220/Awesome-Remote-Sensing-Foundation-Models>

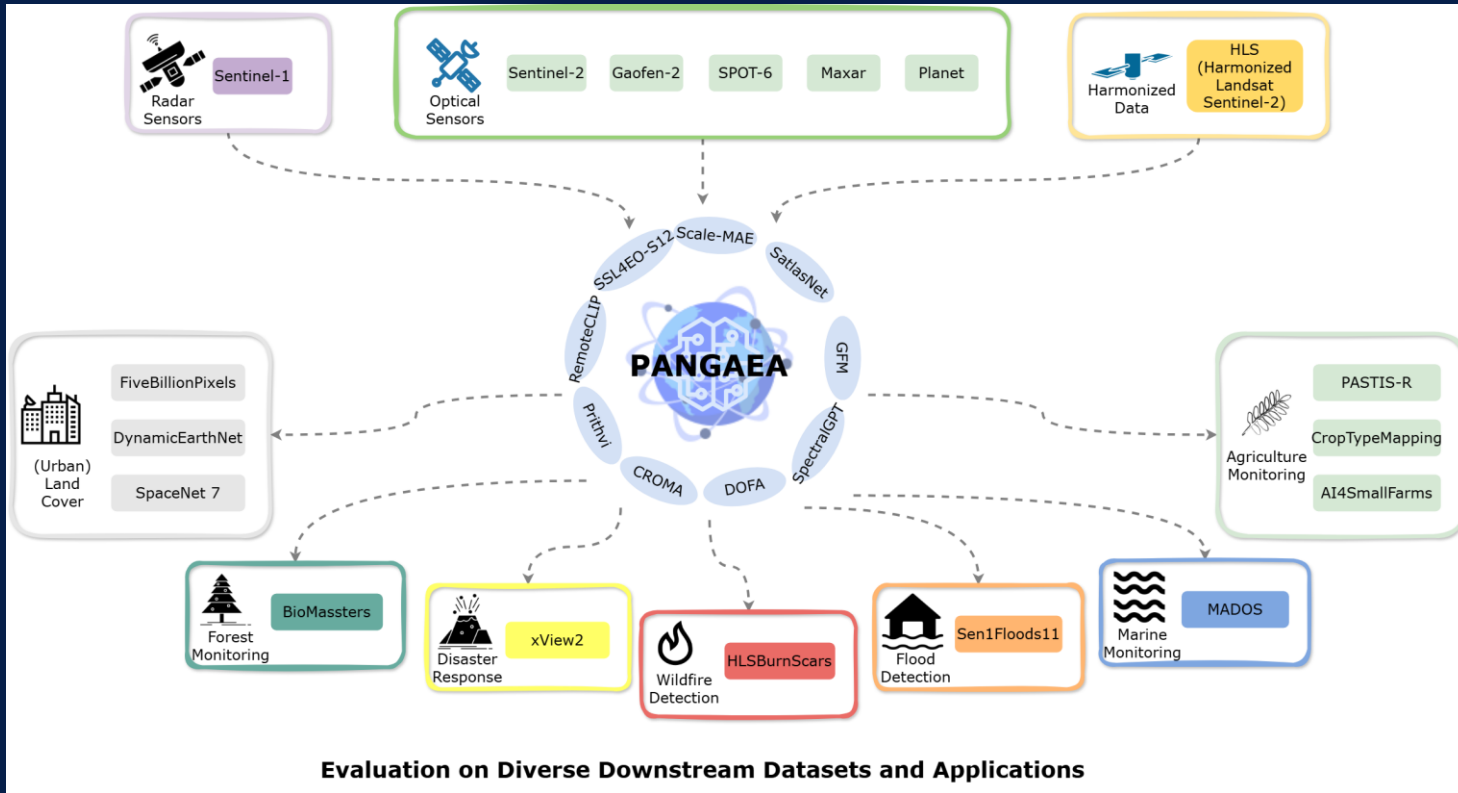
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- Global and Inclusive Benchmark for Geospatial Foundation Models
- Hosted on Git, Modified by NASA iLab team
- Link: <https://github.com/nasa-nccs-hpda/ilab-pangaea-bench>

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Datasets

- HLS Burn Scars
- MADOS
- PASTIS-R
- Sen1Floods11
- xView2
- Five Billion Pixels
- DynamicEarthNet
- CropTypeMapping-South Sudan
- SpaceNet 7
- AI4SmallFarms
- BioMassters

Customizations

- Preprocessing
- Learning Rate
- Optimizer

Encoders

- Base
- SSL4EO data2vec
- SSL4EO DINO
- SSL4EO MAE
- SSL4EO MoCo
- Scale-MAE
- SatlasNet
- GFM
- SpectralGPT
- DOFA
- CROMA
- Prithvi
- RemoteCLIP
- OpenCV
- ResNet
- Terramind
- ViT

Criteria

- Cross Entropy
- Weighted Cross Entropy
- Dice
- MAE

Decoders

- CLS KNN
- CLS KNN Multilabel
- CLS Linear
- Reg Upernet
- Reg Upernet MT Linear
- Reg Upernet MT LTAE
- Seg Siamunet Conc
- Seg Siamunet Diff
- Seg Siamupernet Conc
- Seg Siamupernet Diff
- Seg Unet
- Seg Upernet
- Seg Upernet MT Linear
- Seg Upernet MT LTAE
- Seg Upernet MT None

Tasks

- Single Temporal Semantic Segmentation
- Multi-Temporal Semantic Segmentation
- Change Detection
- Single Temporal Regression
- Multi-Temporal Regression
- Linear Classification
- KNN Probe Classification

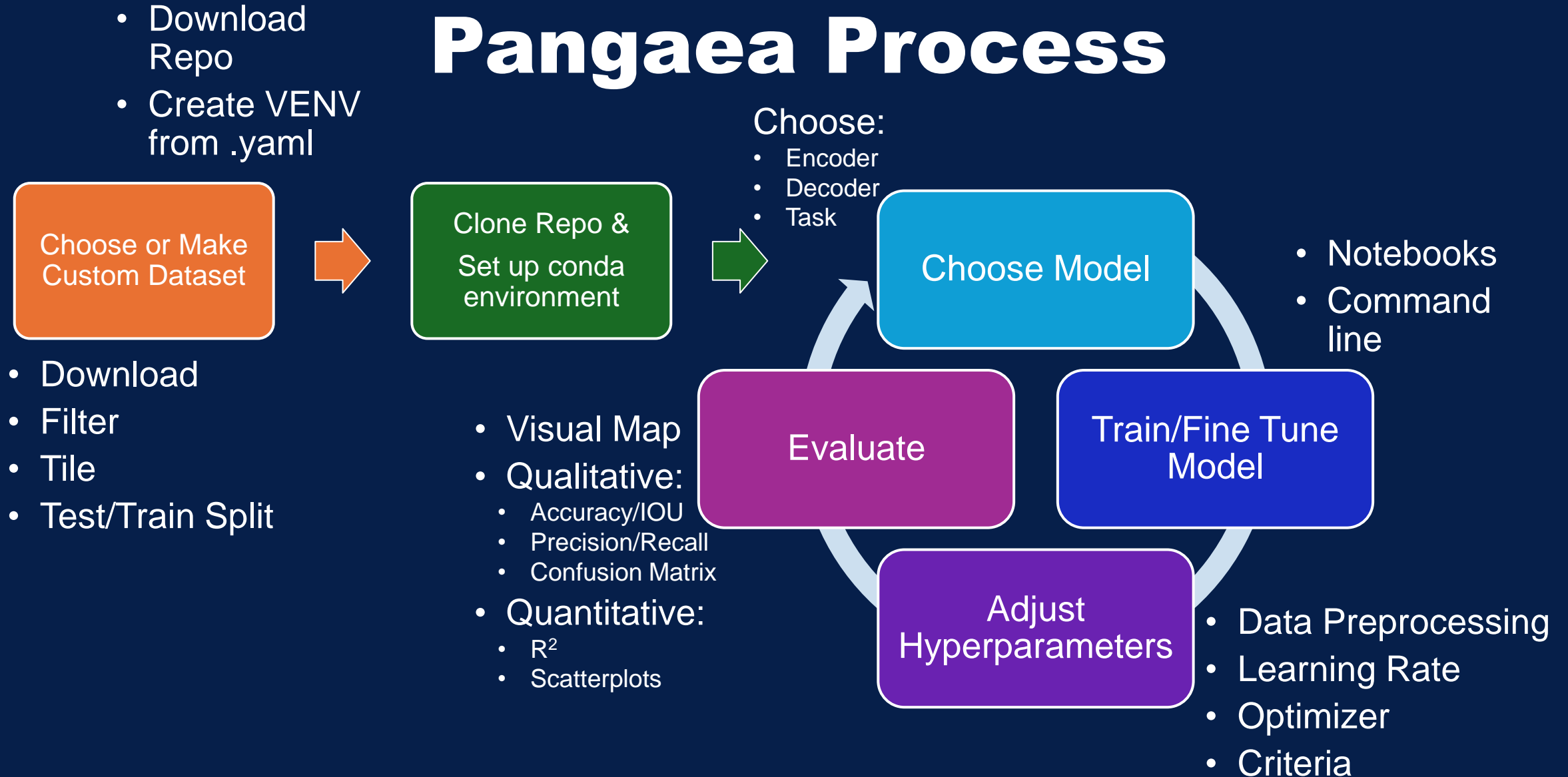
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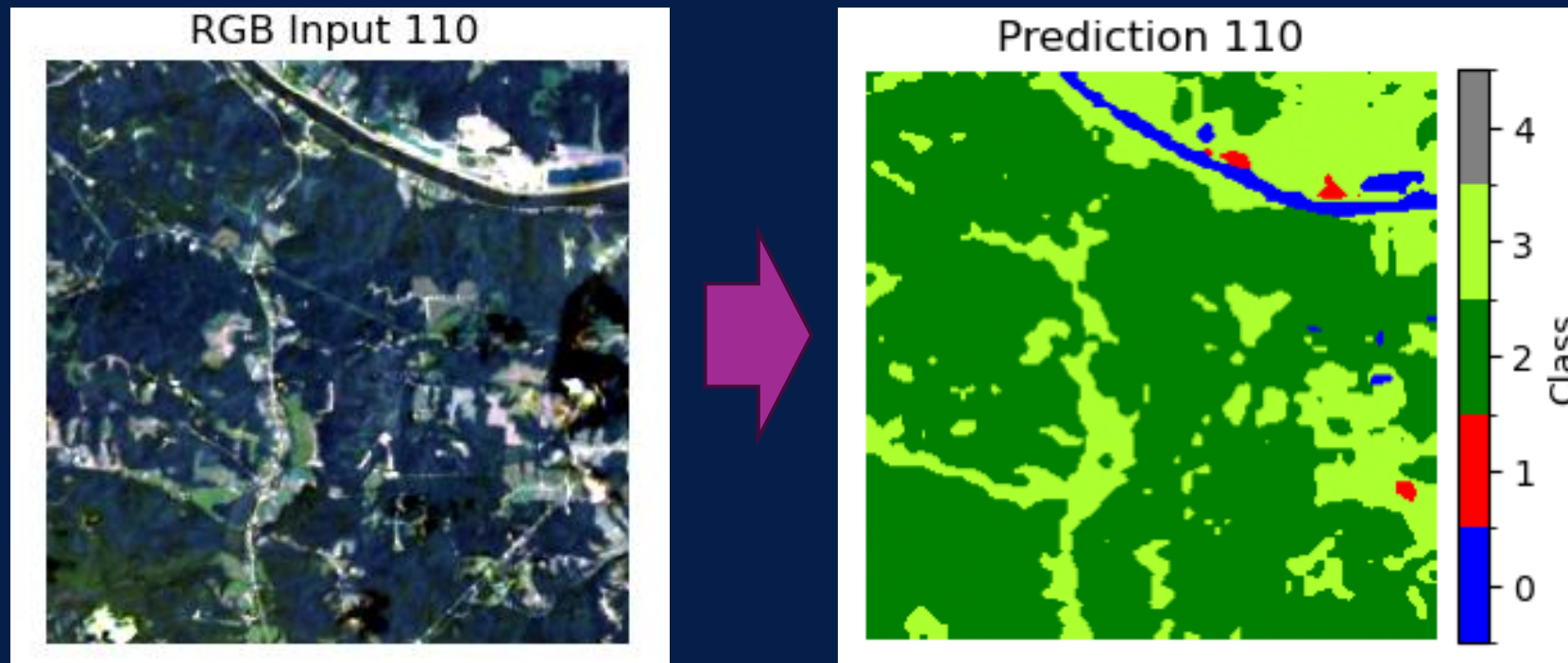
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Example

- Class 4 – N/A
- Class 3 – agriculture/grass/shrub
- Class 2 – forest/wetland
- Class 1 – developed
- Class 0 – water

Example: Using Foundation Models for Land Cover



FM Overview

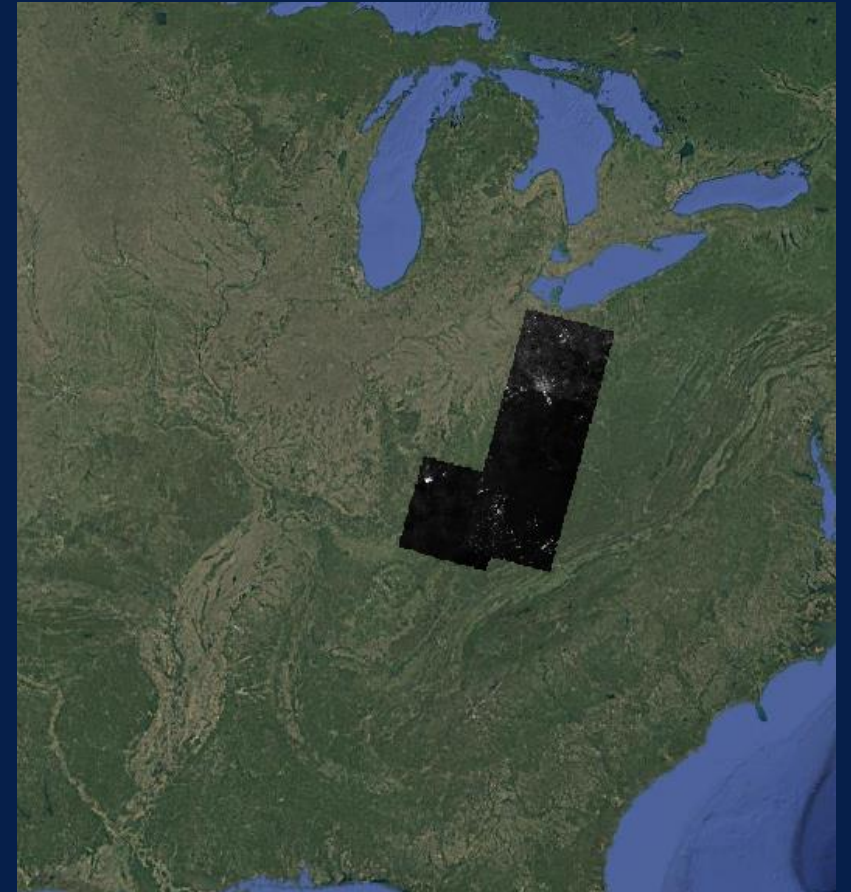
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Dataset Creation

- Landsat 8/9 SR
 - Bands 1-7 + QA Aerosol
 - June 25, 2024 – July 28, 2024
 - Fewest Clouds
 - 019032, 019033, 019034, 020034
 - Spread of NLCD values
- NLCD 2024
- Filtered on QA Aerosol
 - No Clouds
 - No NA values
- Total 224x224x7 tiles:
 - 5,000 train tiles
 - 1,418 test/1,418 validate tiles
- Preprocess: Remove Outliers & Normalize



Foundation Models for Land Cover: Encoders



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Repo

nasa-nccs-hpda / ilab-pangaea-bench

Public

forked from VMarsocci/pangaea-bench

main 3 Branches 0 Tags

Go to file

Add file

Code

About

Towards Robust Evaluation for Geospatial Foundation Models

Readme

GPL-3.0 license

Contributing

Activity

Custom properties

0 stars

0 watching

0 forks

Report repository

Releases

No releases published

Create a new release

Packages

No packages published

Publish your first package

Deployments 24

sandykerr updating notebook directories ✓ f205de8 · 9 hours ago 683 Commits

.github	updated github workflow for docs	2 weeks ago
.ipynb_checkpoints	mel checkpoint	last month
configs	adding support for read the docs	2 weeks ago
docs	added working example notebooks and related scripts	5 days ago
notebooks	updating notebook directories	9 hours ago
pangaea	updating notebook directories	9 hours ago
requirements	Merge remote-tracking branch 'refs/remotes/origin/main'	last month
tests	mel checkpoint	last month
.gitignore	mel merge	last month
CONTRIBUTING.md	mel checkpoint	last month
DATASET_GUIDE.md	mel checkpoint	last month
LICENSE	mel checkpoint	last month

<https://github.com/nasa-nccs-hpda/ilab-pangaea-bench>

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Training Notebook

Task Options

Filename 

```
# PRINT OPTIONS
```

```
task_options = get_folder_options("task")
```

```
print(task_options)
```

```
['change_detection', 'knn_probe', 'knn_probe_multi_label', 'linear_classification', 'linear_classification_multi_label', 'regression', 'segmentation']
```

```
task = "segmentation"
```

FM Overview

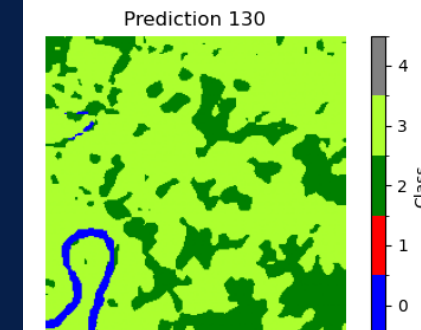
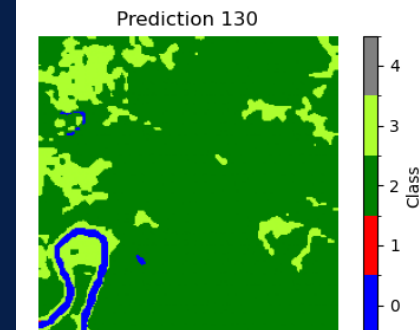
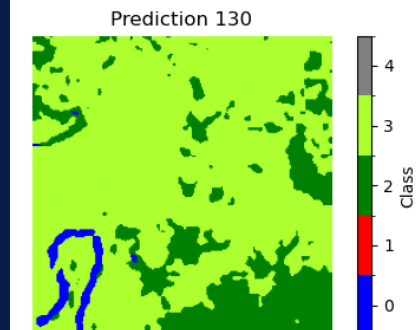
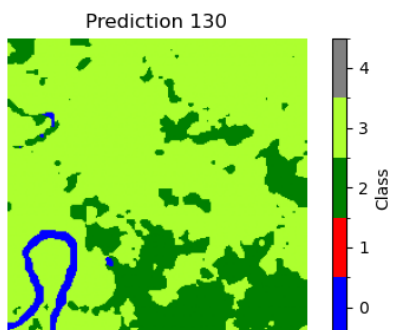
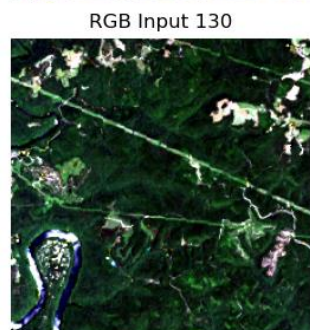
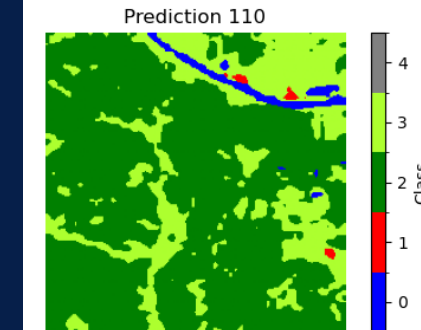
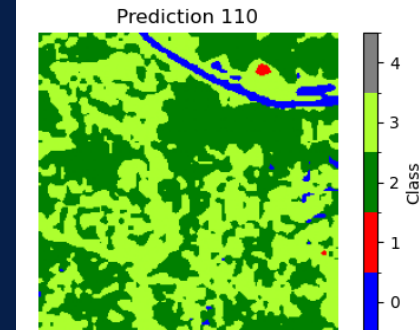
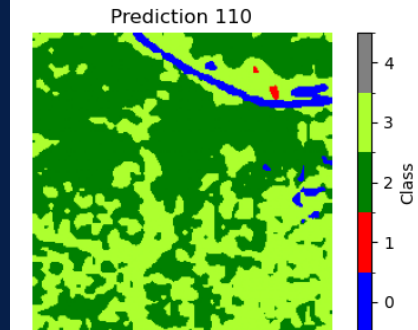
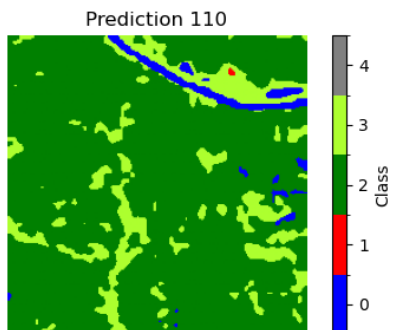
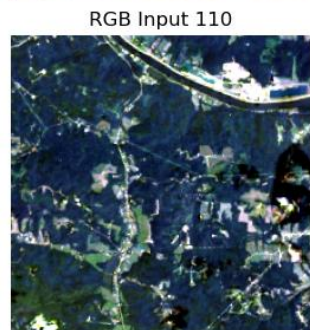
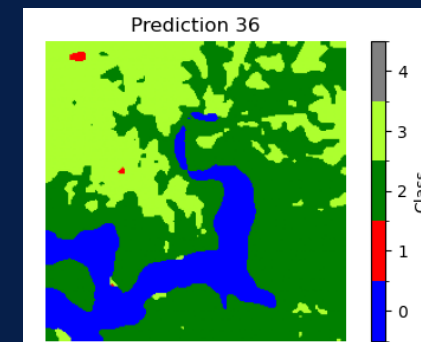
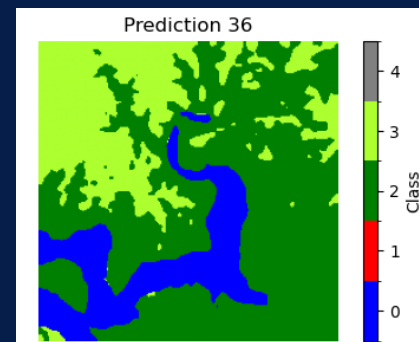
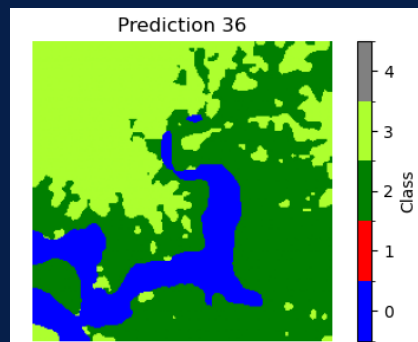
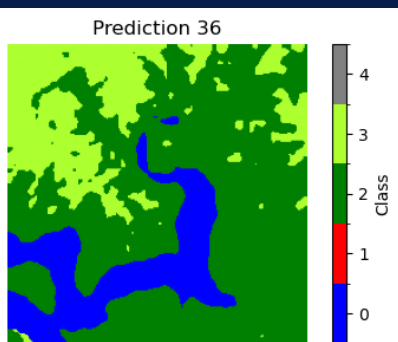
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Evaluation Notebook

- Class 4 – N/A
- Class 3 – agriculture/grass/shrub
- Class 2 – forest/wetland
- Class 1 – developed
- Class 0 – water



RGB Input

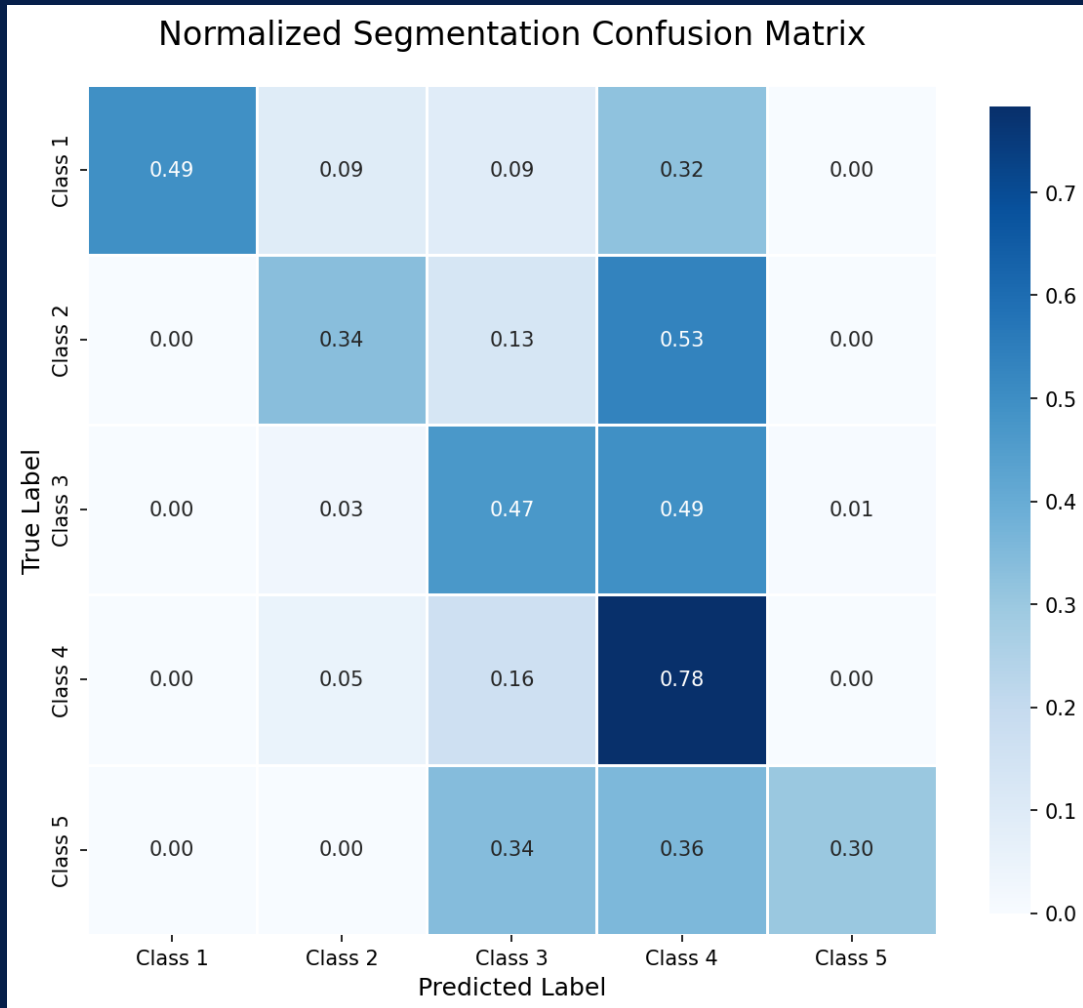
TerraMind

DINOV2

Prithvi

DOFA

Evaluation Notebook



Classification Report:

	precision	recall	f1-score	support
Class 1	0.82	0.49	0.62	470
Class 2	0.56	0.34	0.42	7191
Class 3	0.50	0.47	0.48	12483
Class 4	0.70	0.78	0.74	29707
Class 5	0.40	0.30	0.34	149
accuracy			0.64	50000
macro avg	0.59	0.48	0.52	50000
weighted avg	0.63	0.64	0.63	50000

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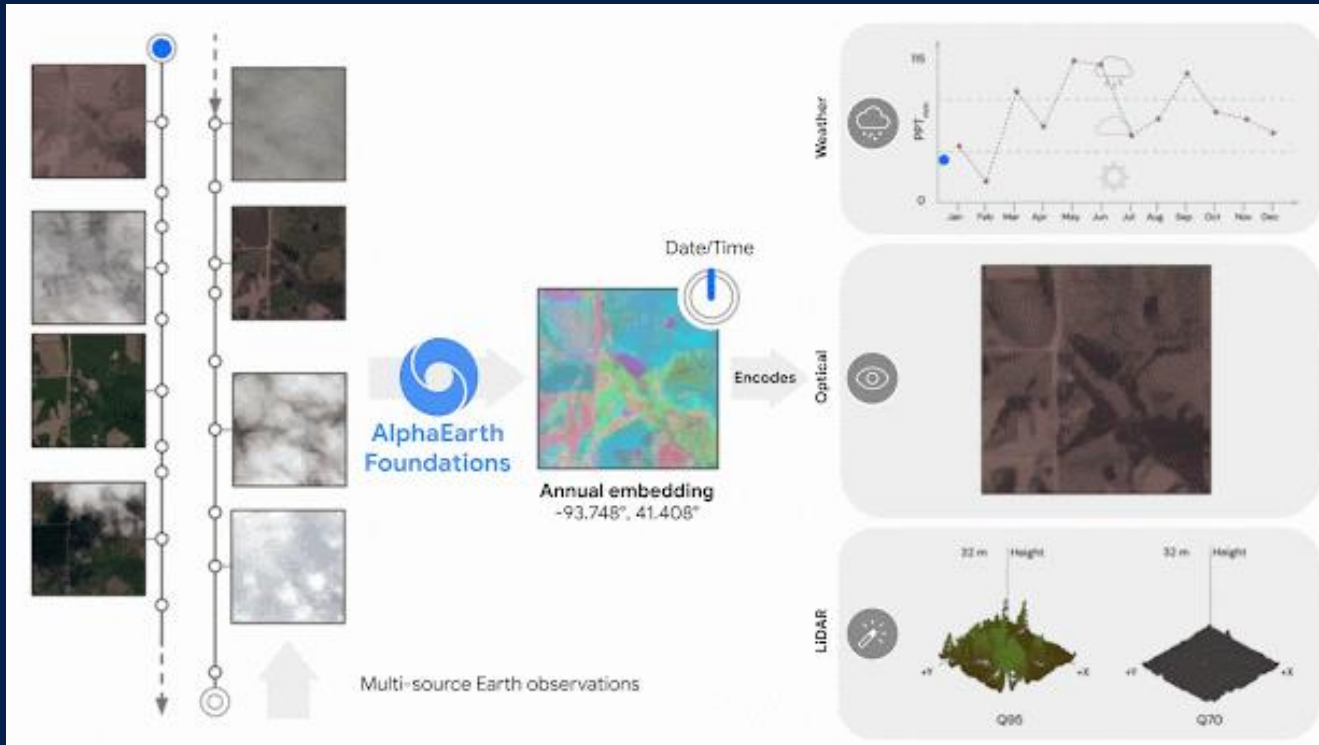
Summary

- Go ahead and try it out! <https://github.com/nasa-nccs-hpda/ilab-pangaea-bench>
- We'll be adding extra functionality to notebooks
- We welcome comments, questions, suggestions for improvement there!

Questions?



AlphaEarth Foundations



- Google DeepMind
- Embeddings Only
- Dozens of different public sources— optical satellite images, radar, 3D laser mapping, climate simulations, and more
- 10x10 meter squares

<https://deepmind.google/discover/blog/alphaearth-foundations-helps-map-our-planet-in-unprecedented-detail/>