Self-Supervised Learning for SAR

Benchmarking Datasets & Performance on Diverse Downstream Tasks

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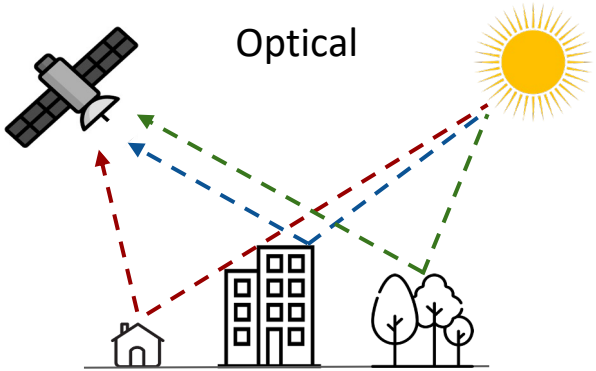
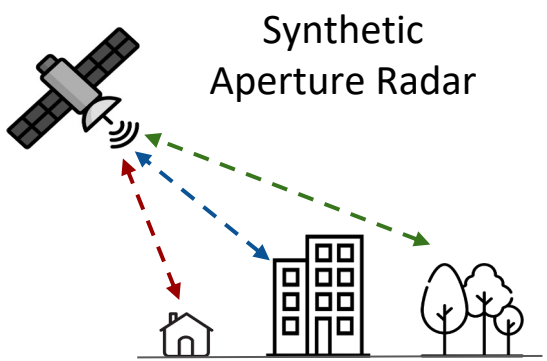
Monitoring using Earth Observation

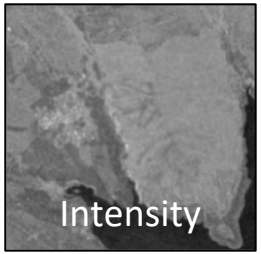
We are witnessing **land changes** and increasingly frequent **natural disasters**,

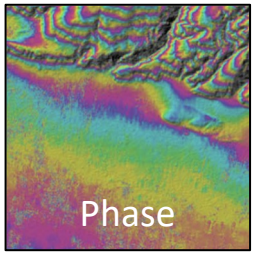
e.g. deforestation, heatwaves, severe floods and droughts.

Satellite Earth Observation









Benefits & Complexities of SAR Data

Light & Weather Independence

Solid Object Penetration

Sensitivity to Spatial Changes

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Light & Weather Independence

Solid Object Penetration

Sensitivity to Spatial Changes

SAR Pre-processing:

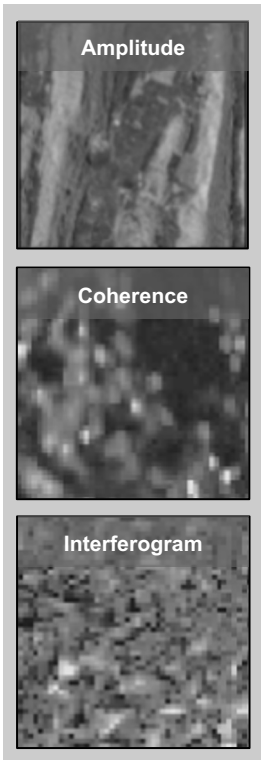
- Orbit Corrections
- Radiometric Calibration
- Speckle Filtering
- Terrain Correction
- …

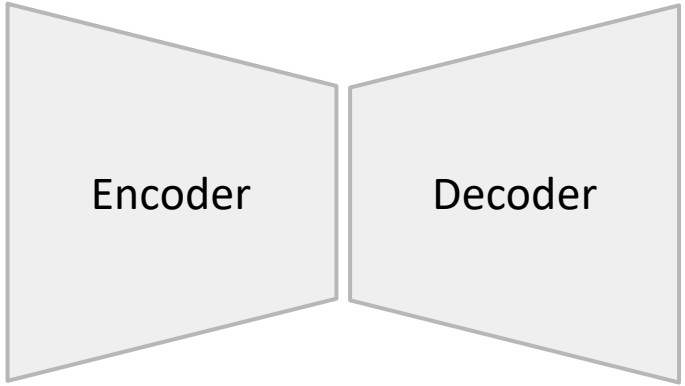
SAR Products:

- Polarimetry (VV/VH/HV/HH)
- Coherence
- Interferograms
- …

Self-Supervised Learning (Without Labels)

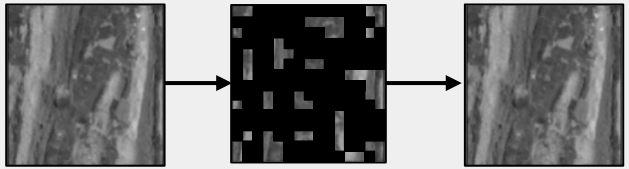
SAR Inputs



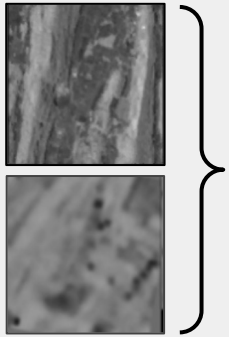


Pretext Tasks

Example Task 1: Predict Missing Pixels



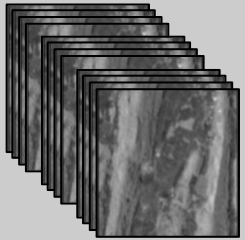
Example Task 2: Match Encodings



Shared information?
Same location?

Self-Supervised Learning Architectures

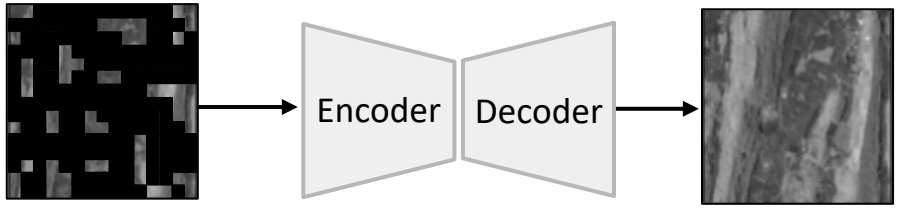
SAR Inputs



12 Channels

Sentinel-1 GRD
Amplitude
VV, VH, VV/VH
Seasonal Means

Masked Autoencoder (MAE)



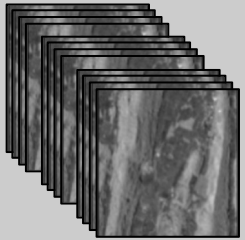
He et al., arxiv: 2111.06377

Why?

- Robustness to noise/ missing data

Self-Supervised Learning Architectures

SAR Inputs



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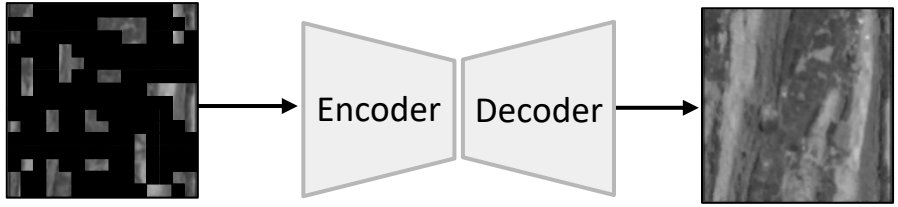
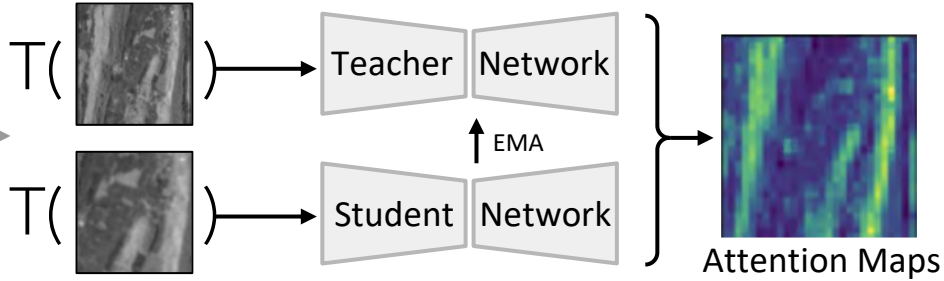


He et al., arxiv: 2111.06377

Self-Distillation with No Labels (DINO)



Caron et al., arxiv:2104.14294

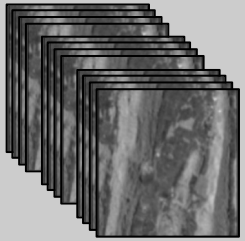
Why?

- Robustness to noise/ missing data

- Multiscale Invariance
- Emergent Segmentation

Downstream Fine-tuning (With Labels)

SAR Inputs



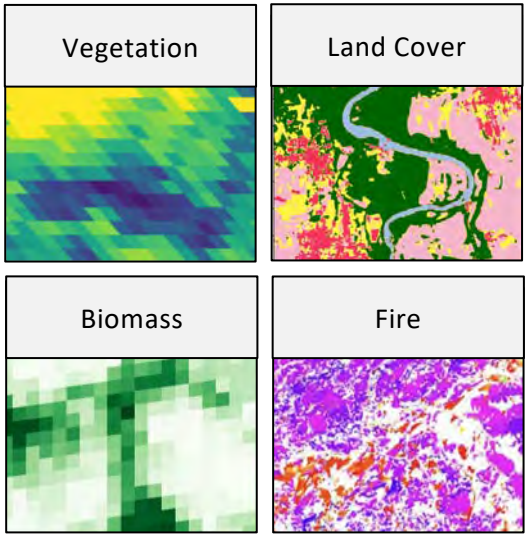
12 Channels

Sentinel-1 GRD
Amplitude
VV, VH, VV/VH
Seasonal Means

Pre-trained Encoder

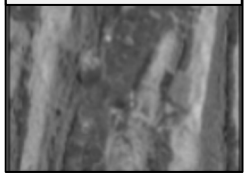
New Decoder

Downstream Tasks

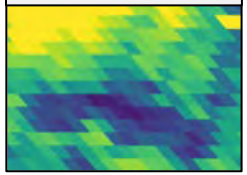


Benchmarking Datasets

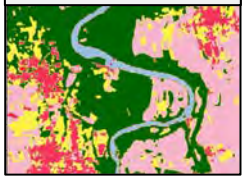
Amplitude



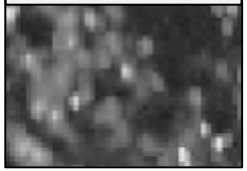
Vegetation



Land Cover

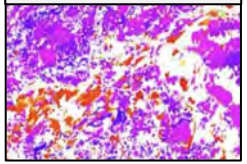


Coherence

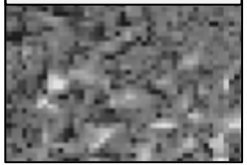


Biomass

Fire

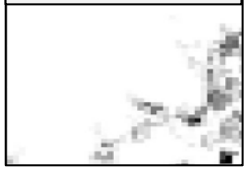


Interferogram



Optical

Built Area



Europe

Continental US

China

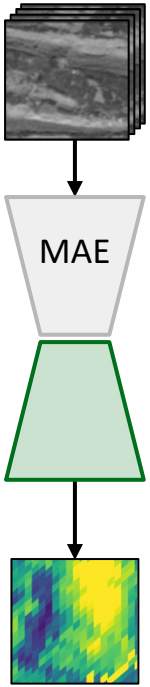
South America

South-East Asia

Middle East

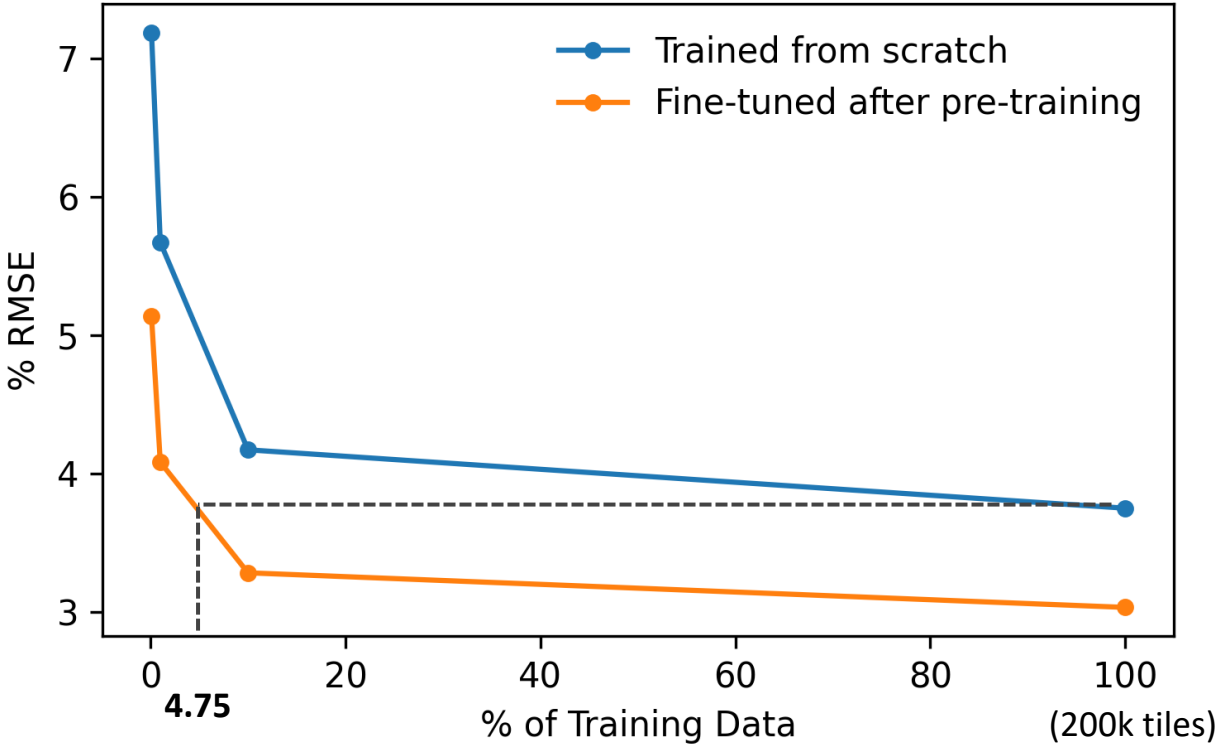
- 25+ TB of co-aligned data tiles
- Soon available on **spaceml.org**

Improved Vegetation Prediction with Pre-Training

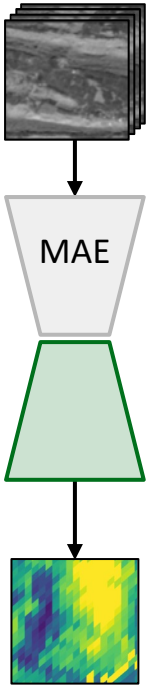


Pre-training:

Fine-tuning:

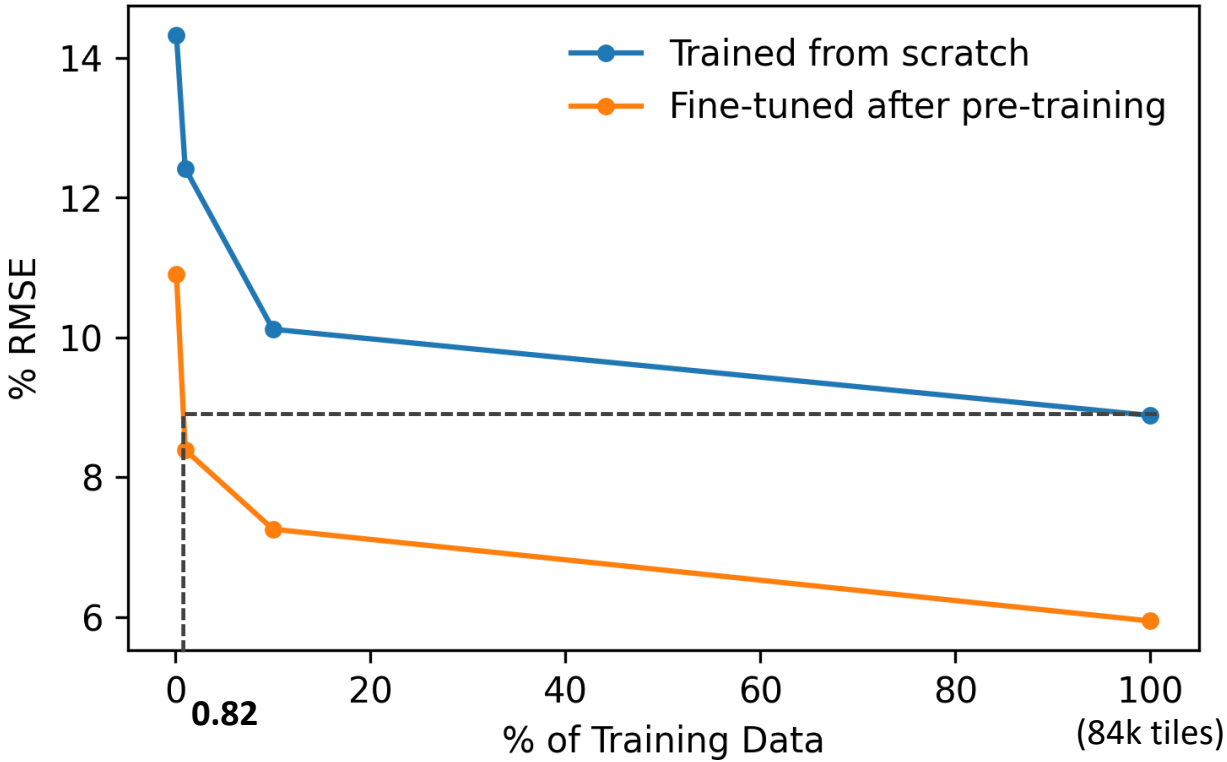


Improved Vegetation Prediction with Pre-Training



Pre-training:

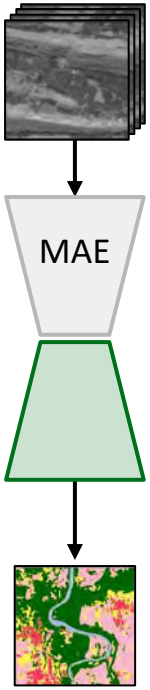
Fine-tuning:



Vegetation Prediction
(after training on 2000 tiles)

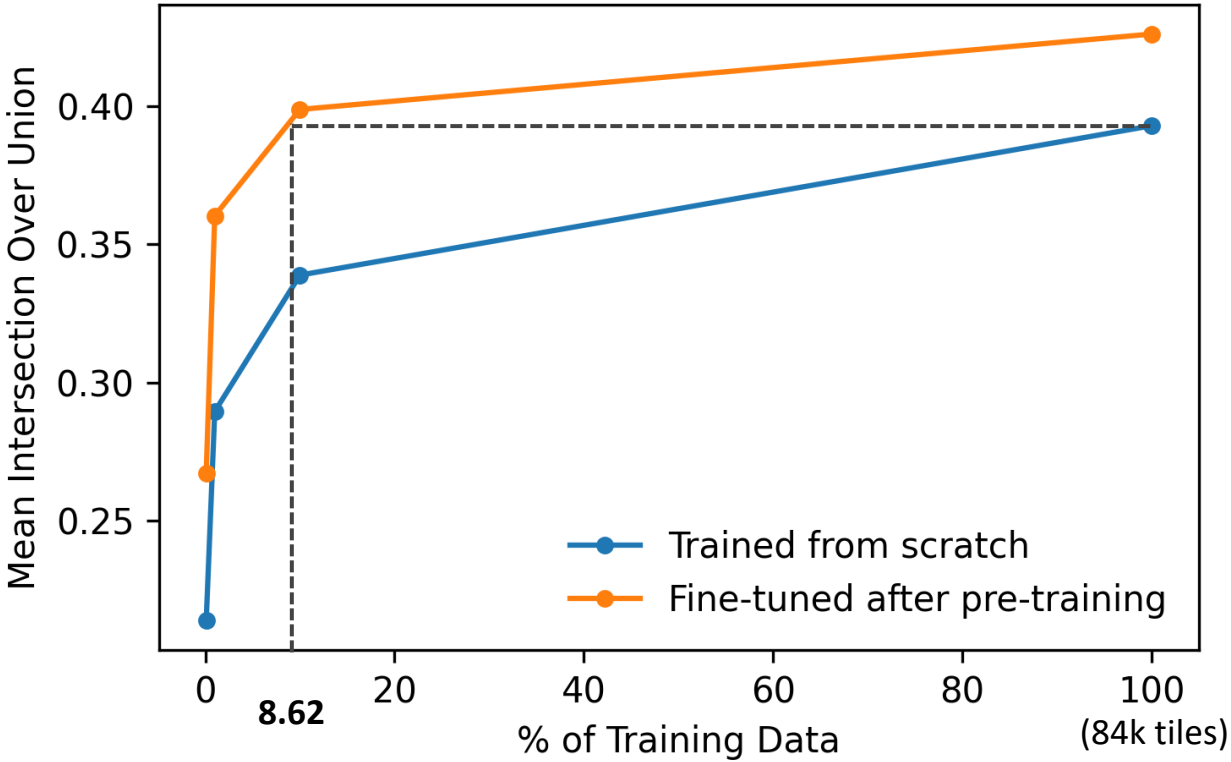
Ground Truth

Improved Land Cover Classification with Pre-Training

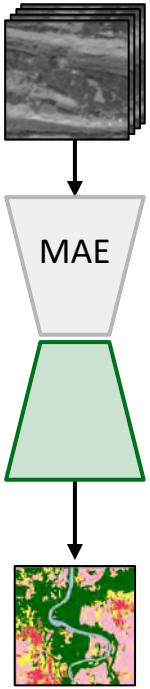


Pre-training:

Fine-tuning:

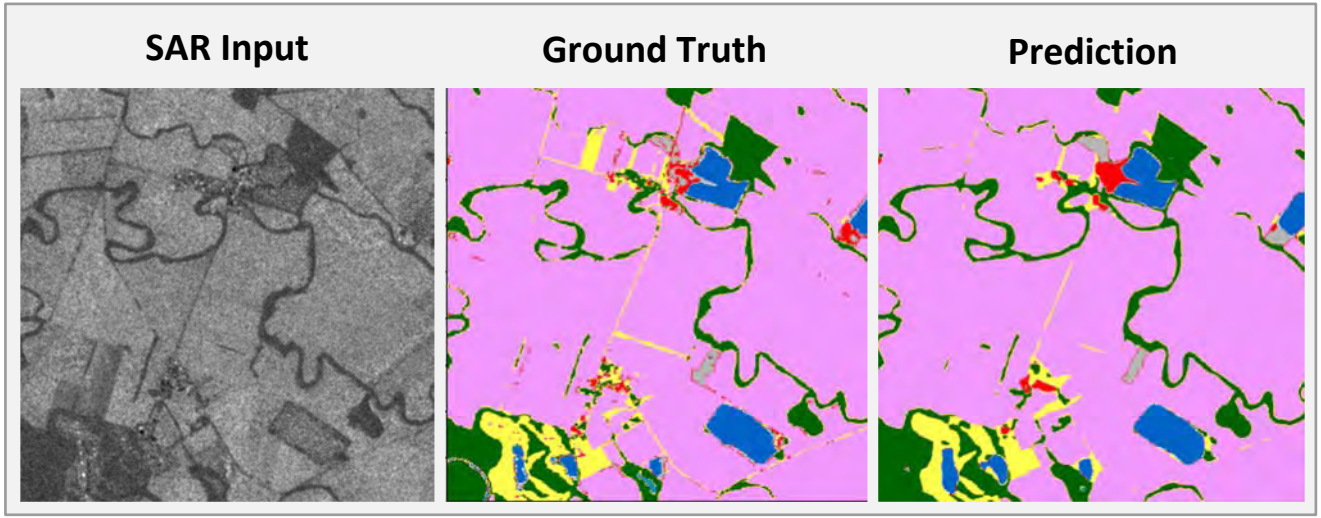


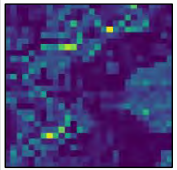
Improved Land Cover Classification with Pre-Training

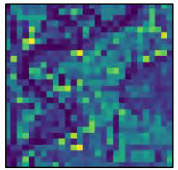


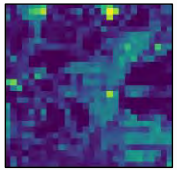
Pre-training:

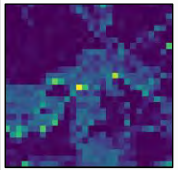
Fine-tuning:

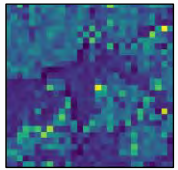


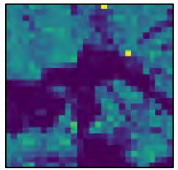


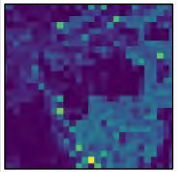


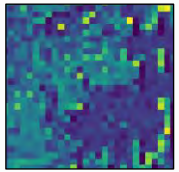


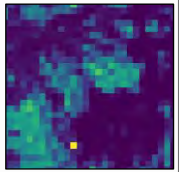


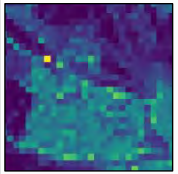


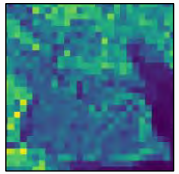


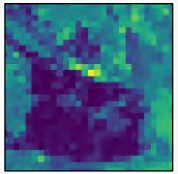






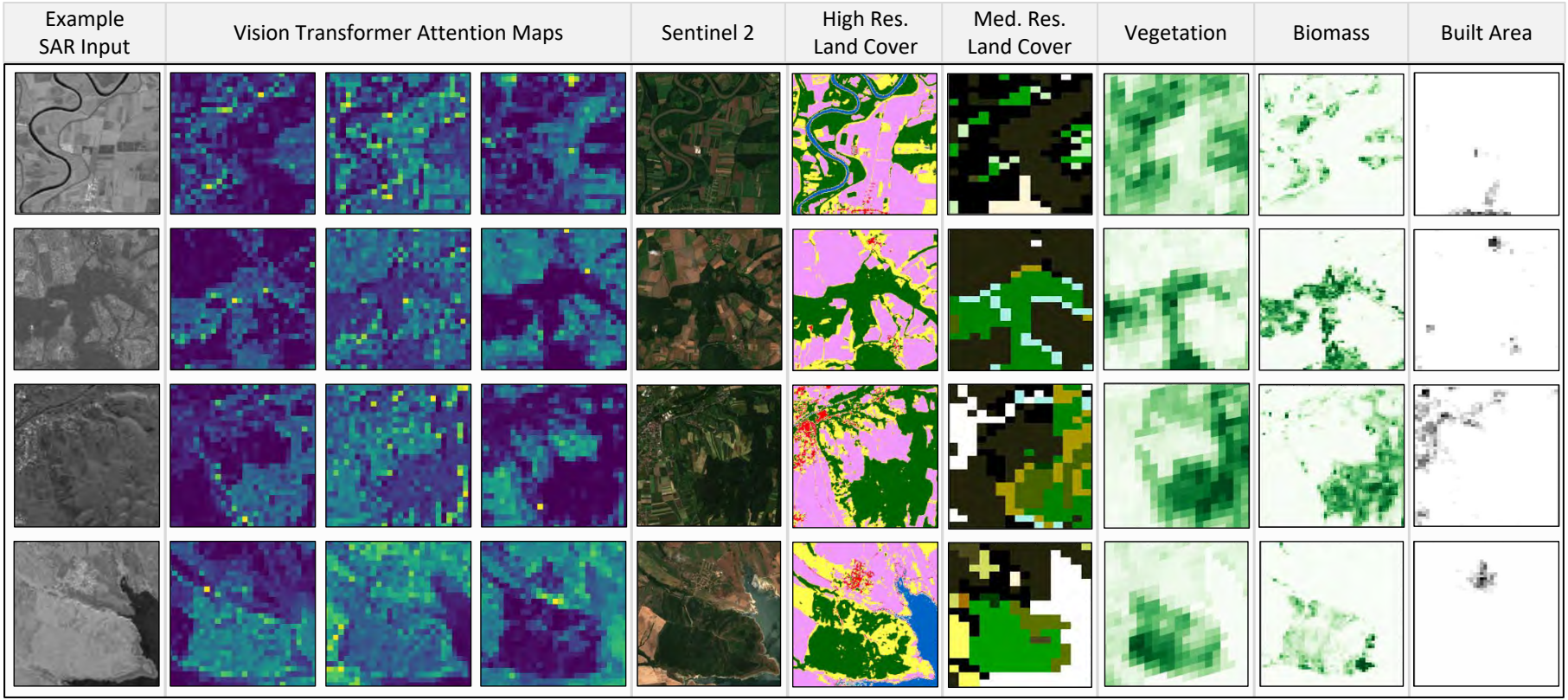






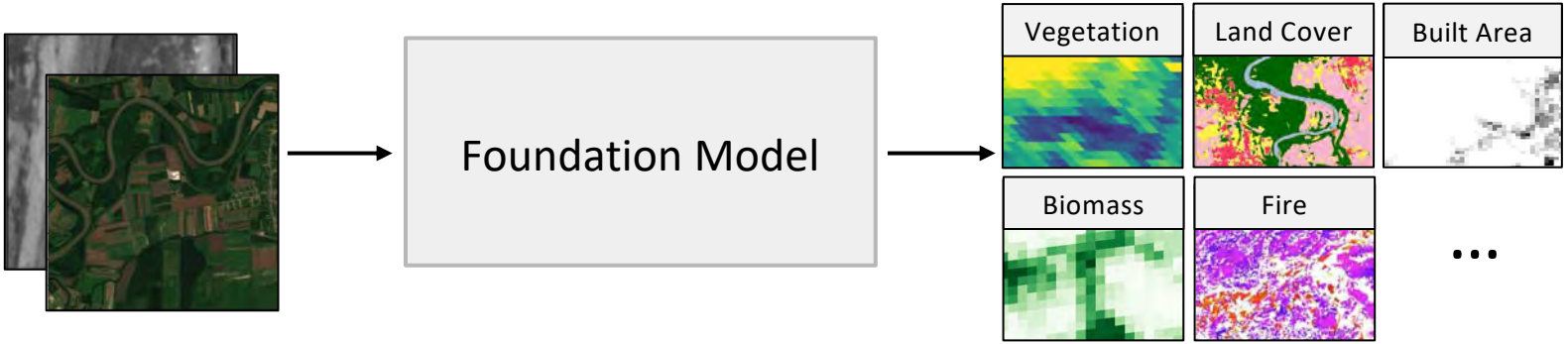
Emergent Segmentation in DINO Attention Maps

Emergent Segmentation in DINO Attention Maps



Summary & Conclusions

- Tested SOTA unsupervised models (MAE/DINO)
- Clear benefits of pre-training without labels
- Good performance even with small fine-tuning datasets
- Attention maps hold value for diverse tasks



Any EO Data

Any Downstream Task

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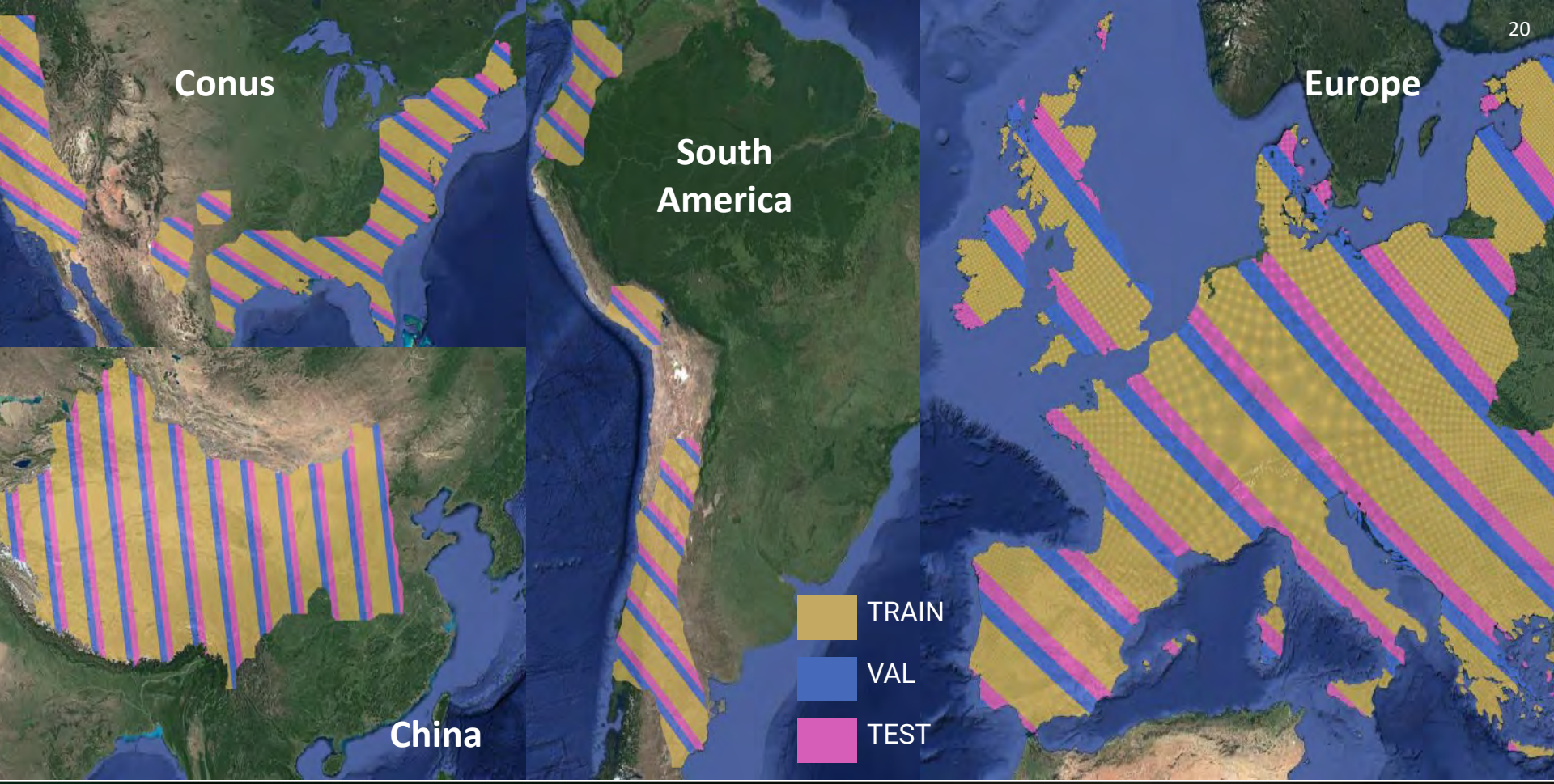
Conus
South America
Europe
China
TRAIN
VAL
TEST

Overview of DINO Architecture