EPFL

Meta-learning data-efficient Machine Learning Models for Diverse Earth Observation Problems

Marc Russwurm

postdoctoral researcher

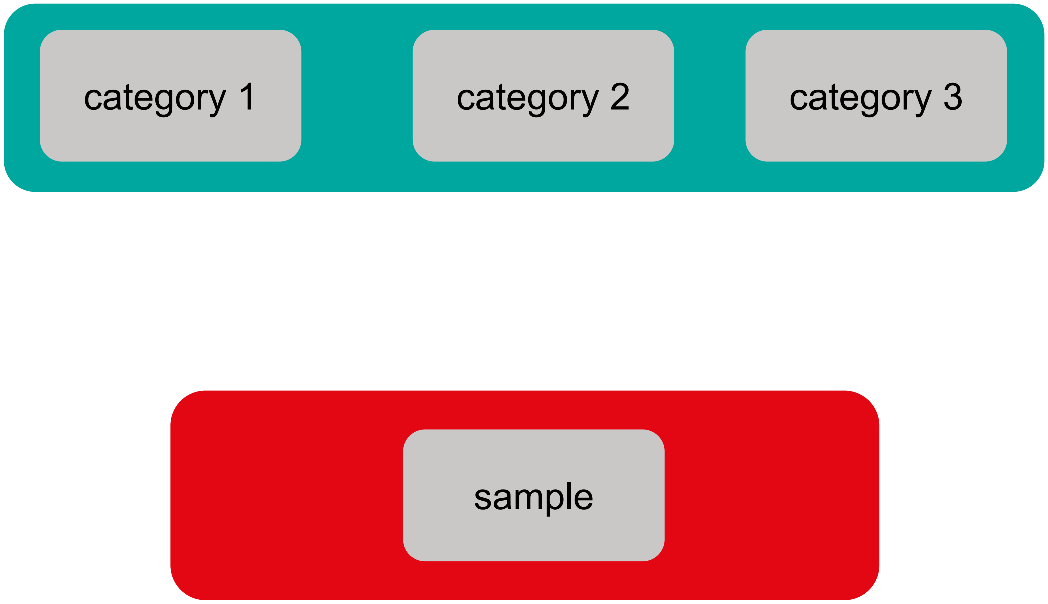
EPFL-ECEO Laboratory

Valais, Switzerland

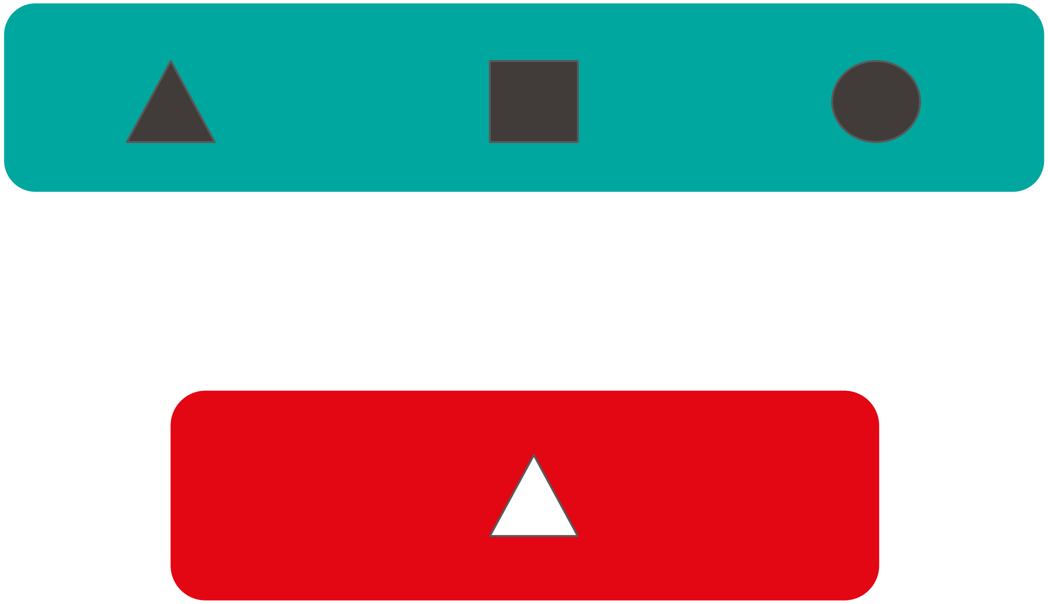
ECMWF ESA workshop

École
polytechnique
fédérale
de Lausanne

Category: One, two, oder three?

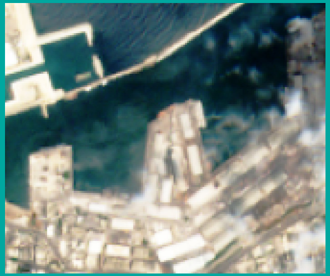


Triangle, square, or circle



Savanna, urban, or water?

Before or after?



Water or marine debris?

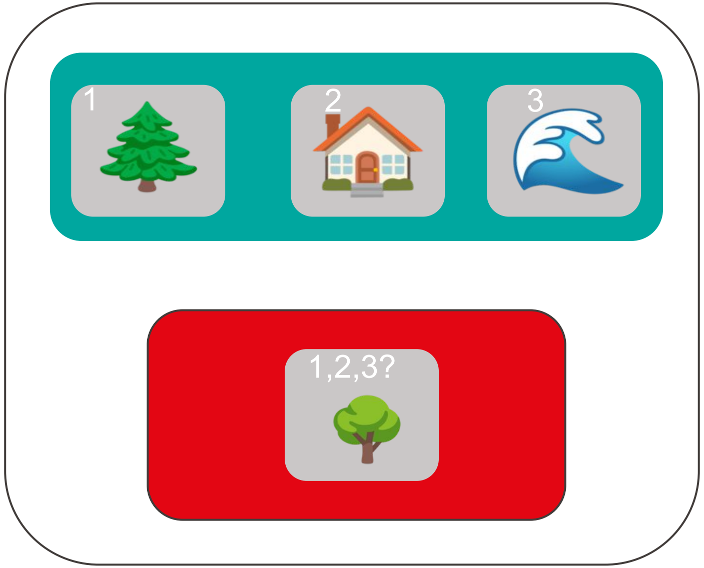
What is this?
...tasks!

within a single task:

- we learn from a **training set**
- to associate samples on a **test set**

We (humans) are really good at solving tasks with only few training images

task:

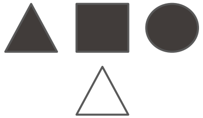


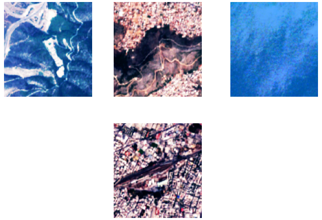
Why is it so easy for us to solve tasks?

… because our life consists of solving tasks!

a tiny bit more difficult

baby easy!





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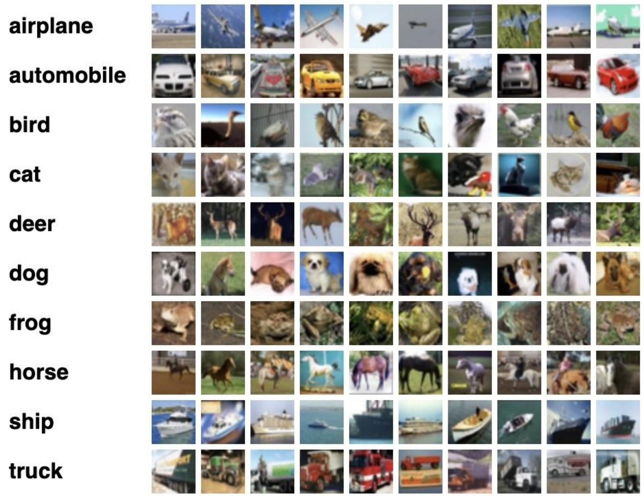
Deep learning needs a lot of labelled data to solve a single task

CIFAR-10: 6000 examples per class

CIFAR-100: 600 examples per class



600-6000 training examples per category

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… because we train deep learning models on one training dataset

The training dataset is a **window** through which the learner gets partial information about the world

[Shai Ben-David and Shai Shalev-Shwartz, 2014]

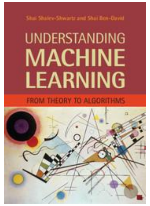

Photo by Nicolas Solerieu on Unsplash

To improve machine learning models

Strategy 1:

We can increase the size of our datasets

large "foundation" models

photo by Forbes Magazine

Strategy 2:

We can include many different datasets

many small adaptive models

photo by u/logatwork posted in /r/bizarrebuildings

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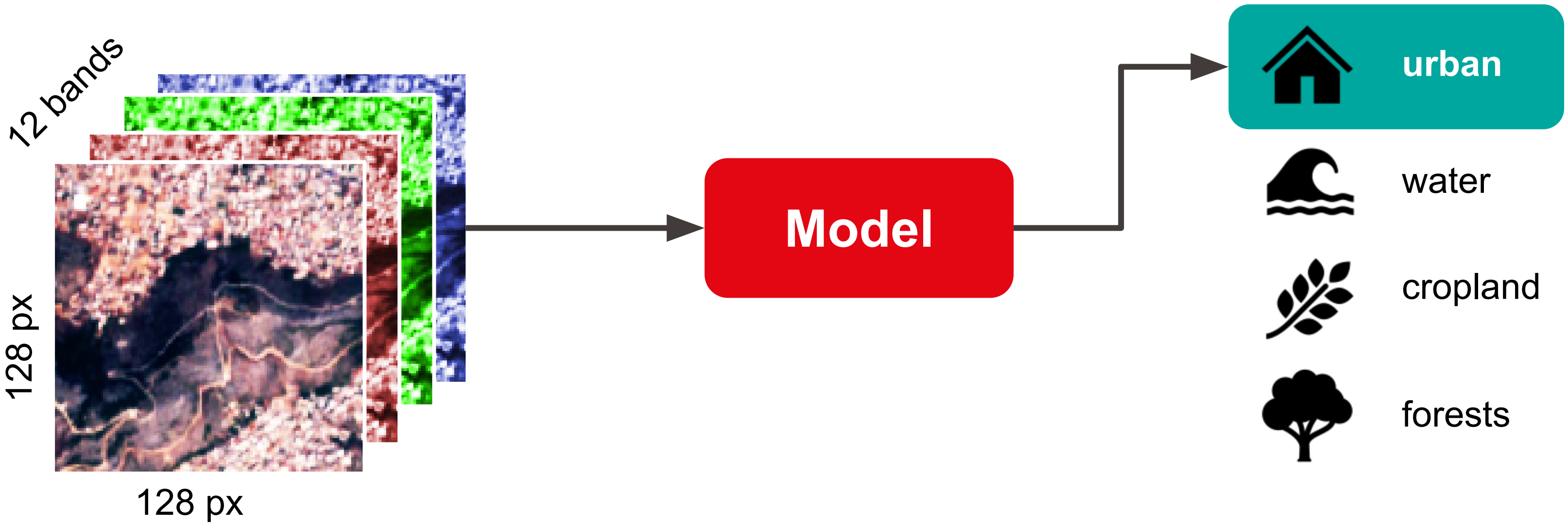
Concrete Example: Land Cover Classification

satellite image → **land cover class**



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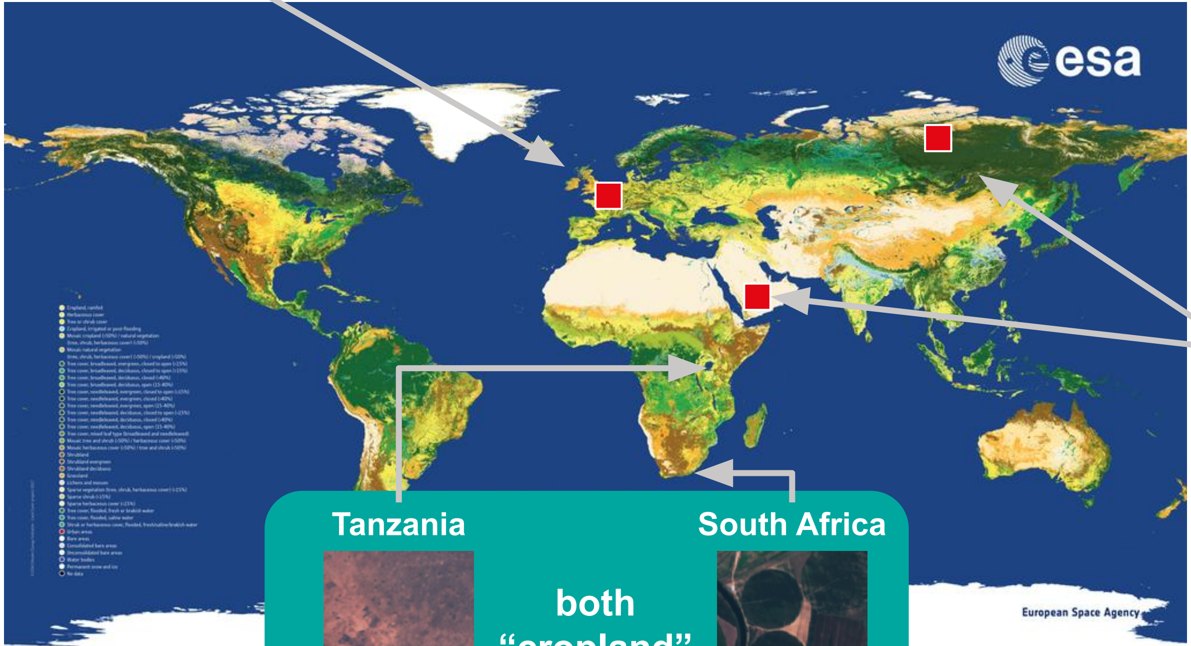
A Global Land Cover Model

→ are used to quantify urbanization and deforestations

often coarse on local scales



a fixed set of classes

some never appear together like

snow/ice and desert

Tanzania

both "cropland"

South Africa

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Learn-to-Learn Regional Models

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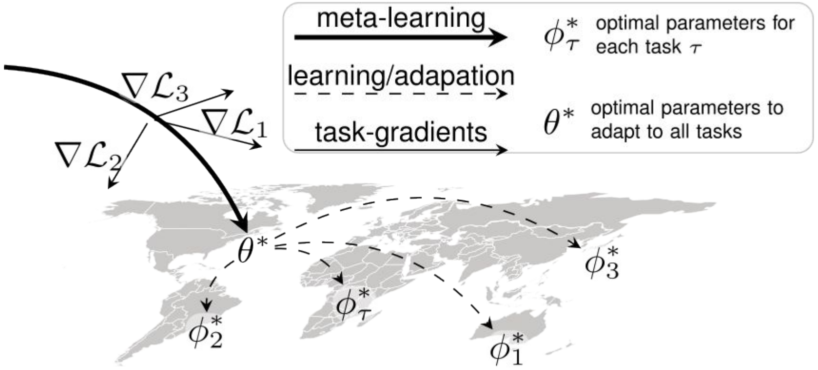
concept

meta-learning
a global adaptive model

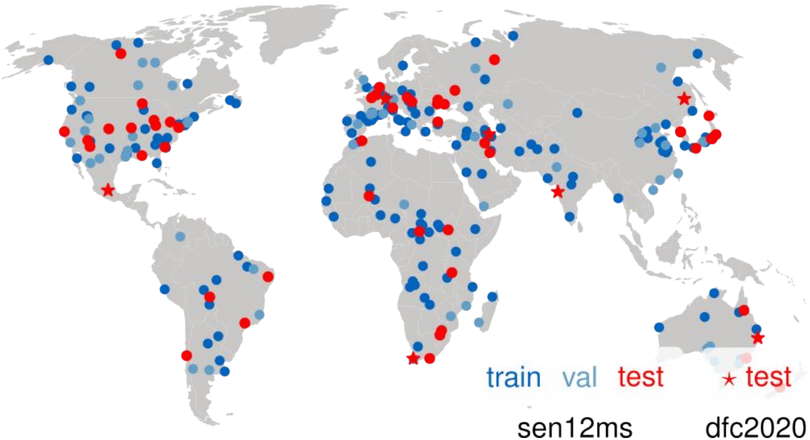
fine-tune

regional model
with few annotated samples

Model-agnostic meta-learning (Finn et al., 2017) **naturally allows for different data distributions** between tasks



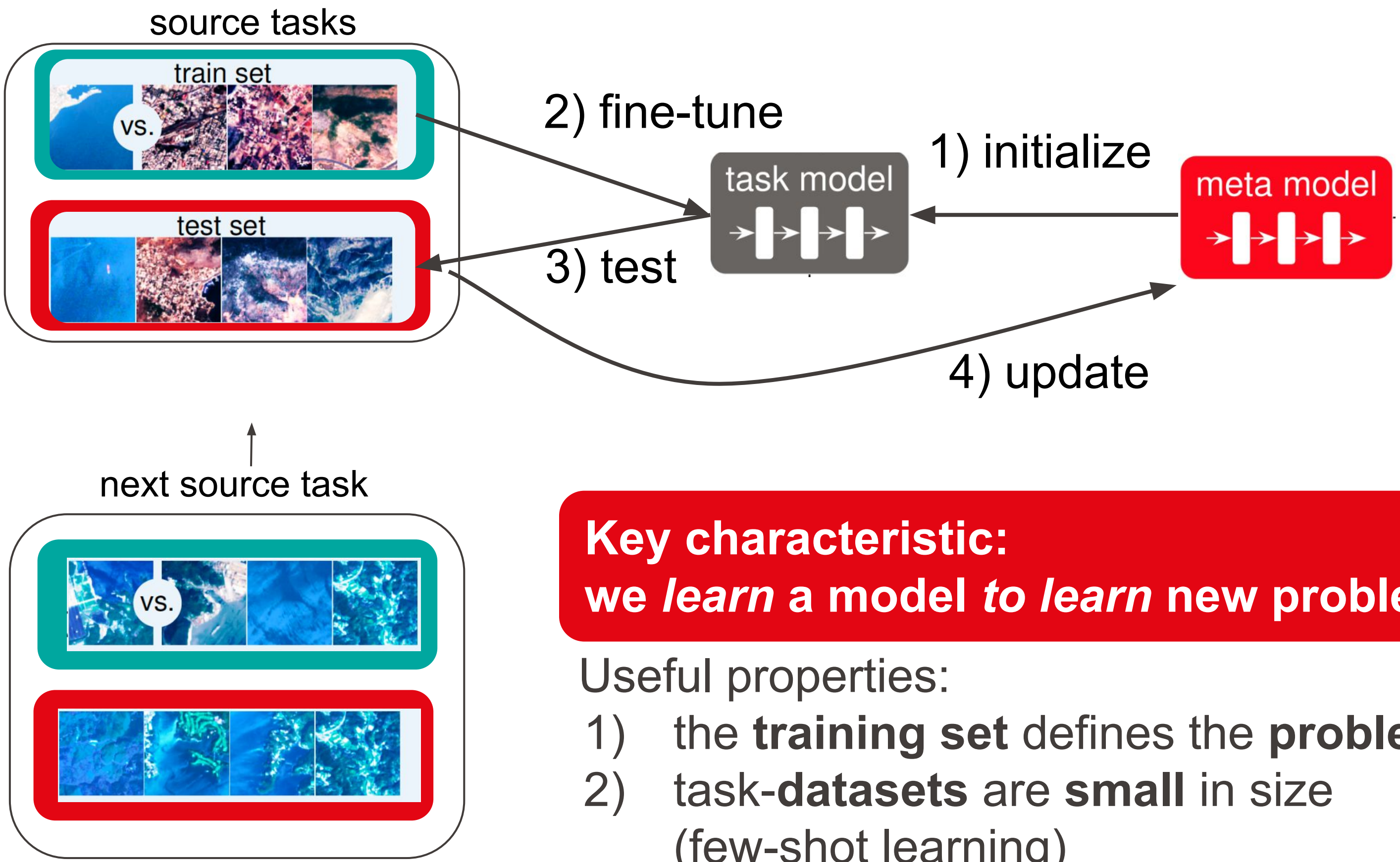
a dataset of tasks



Russwurm & Wang et al., (2020); CVPR Earthvision Workshop 2020 (best paper award)

Model-agnostic meta-learning (MAML)

Finn et. al., 2017

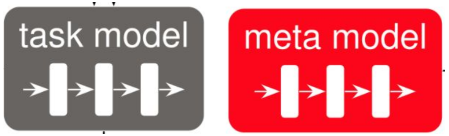


Key characteristic:
we *learn* a model *to learn* new problems

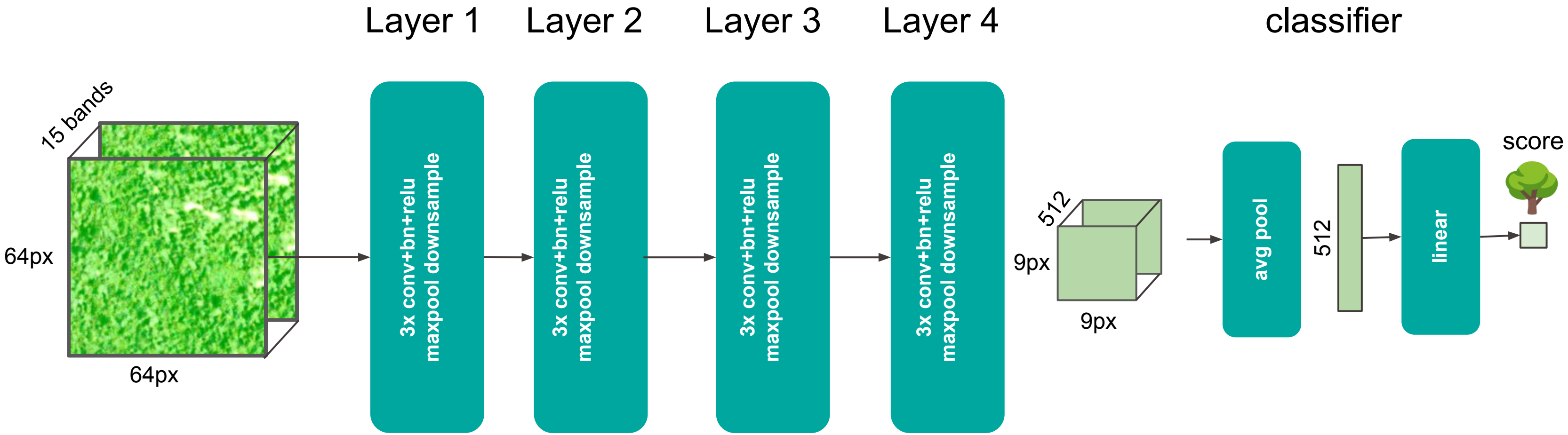
Useful properties:

1) the **training set** defines the **problem**
2) task-**datasets** are **small** in size (few-shot learning)

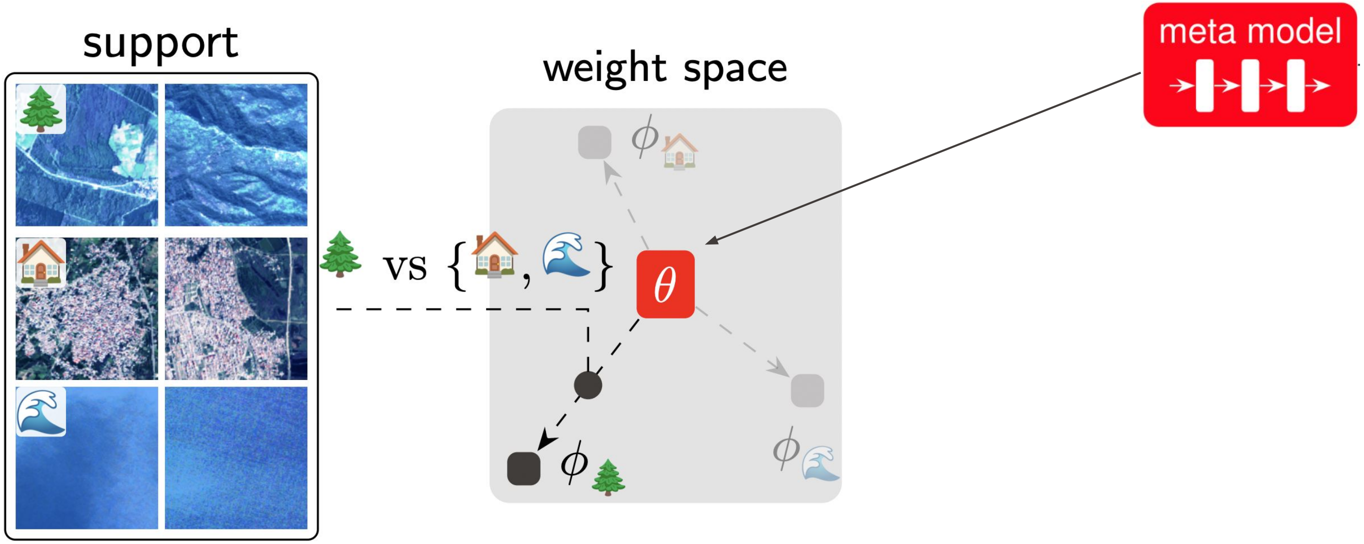
ResNet-12 one-versus-all classifier



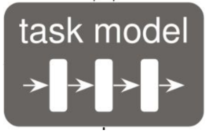
are deep neural networks with 11-million parameters

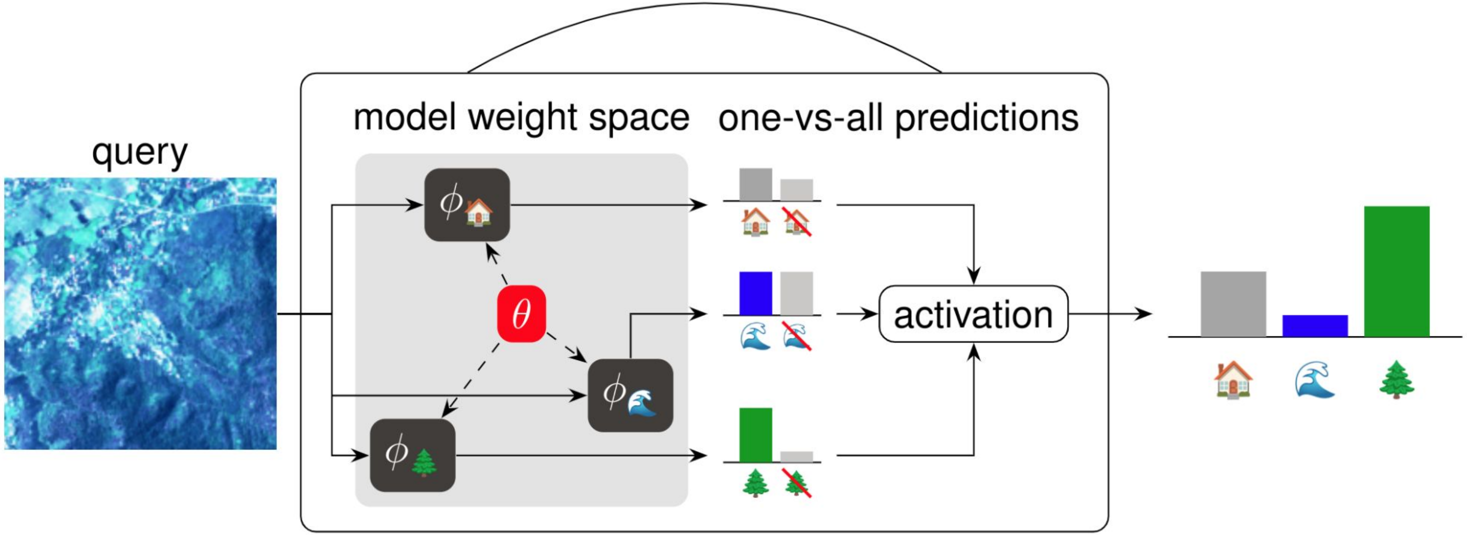


From binary to multi-class problems

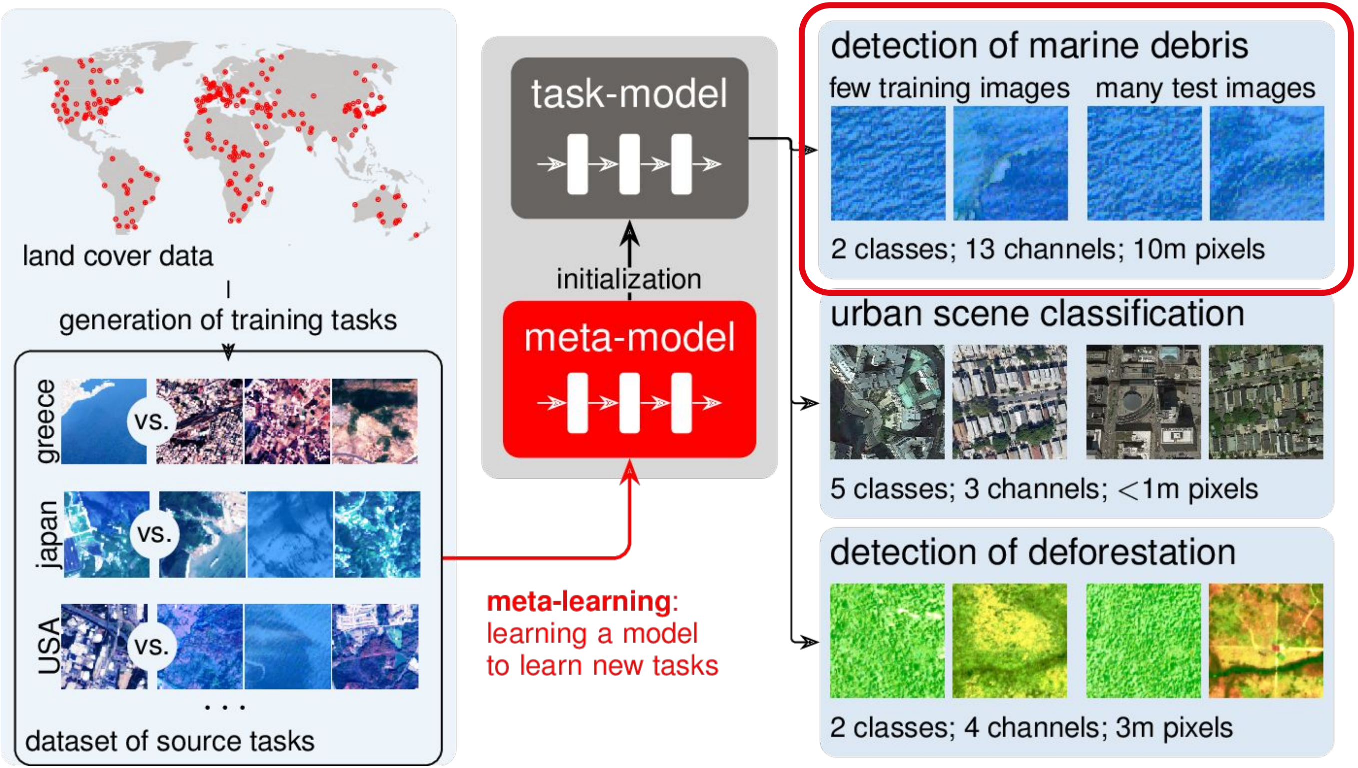


The multi-class task-model





Land Cover to Other Downstream Tasks



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Satellite-based marine litter monitoring

proxy

Detection of Marine Debris

“Fishing for Litter” Ruiz et al., 2020

photo @oihanecb

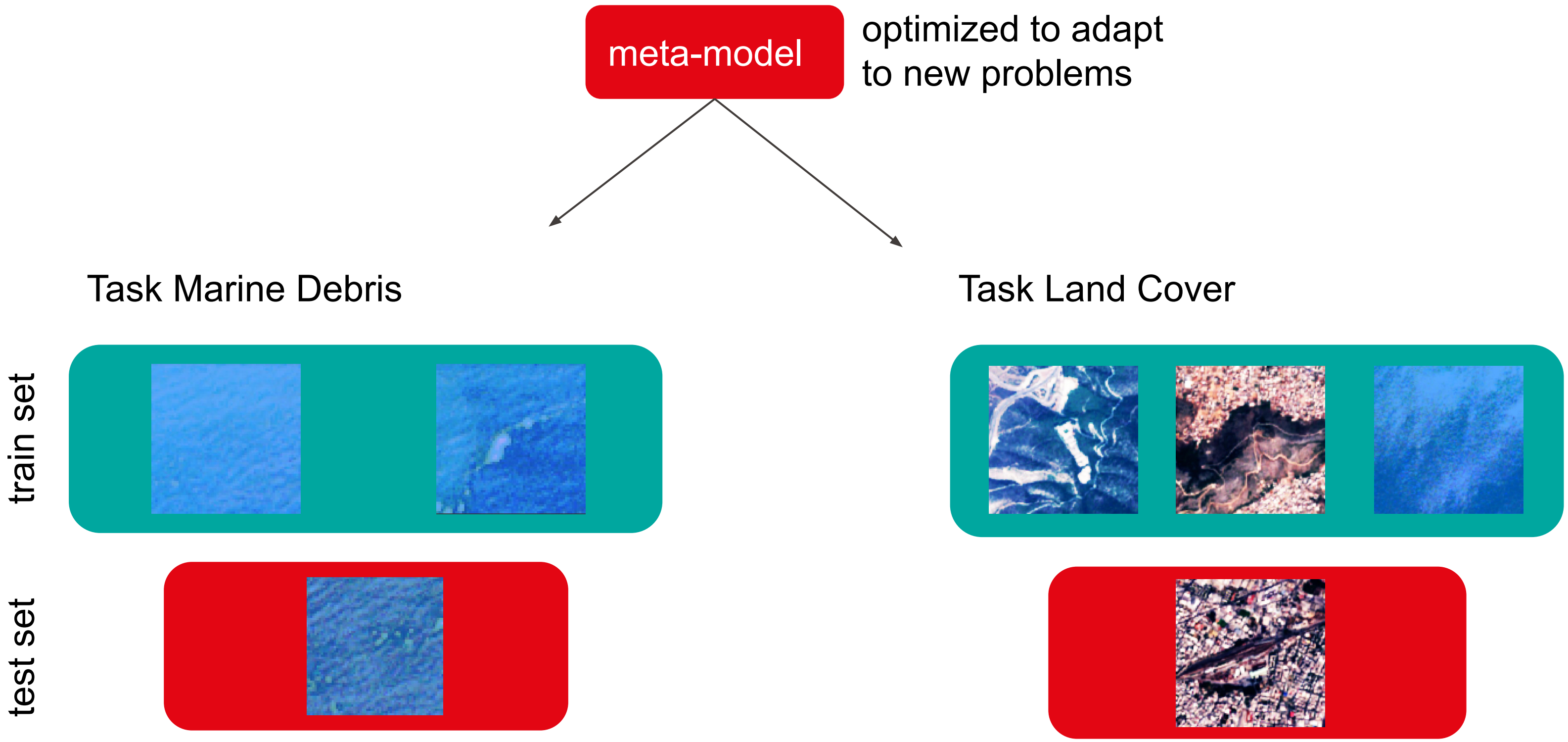
Oceanic processes aggregate debris on the water surface:
Here **windrows**

Windrows can contain plastic litter

Example:
16.2 tons in 68 working days collected plastic litter in the Bay of Biscay in 2018 by Ruiz et al., 2020

Ruiz, I., Basurko, O. C., Rubio, A., Delpey, M., Granado, I., Cózar, A. (2020). Litter windrows in the south-east coast of the Bay of Biscay: an ocean process enabling effective active fishing for litter. Frontiers in Marine Science, 7, 308.

Connection between Land Cover and Marine Debris?



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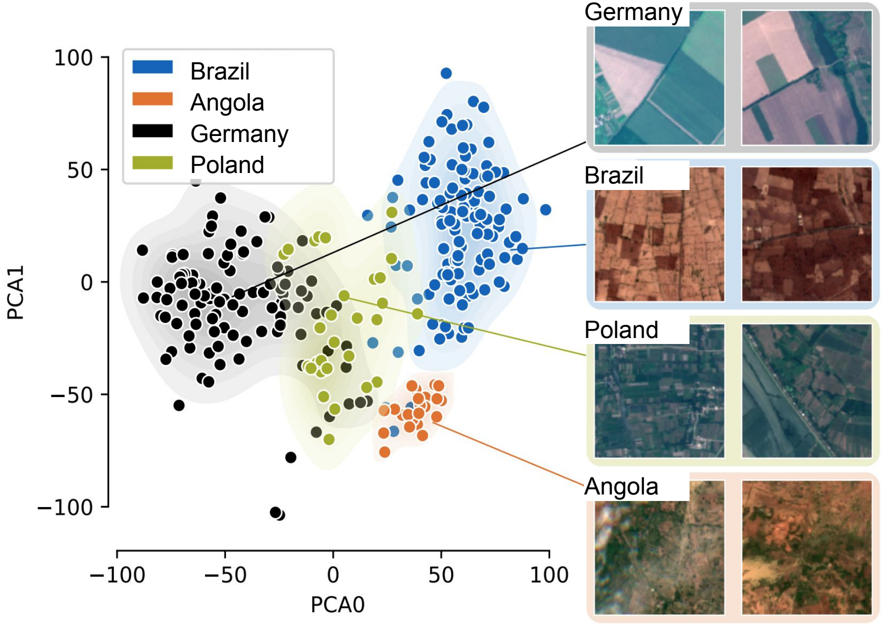
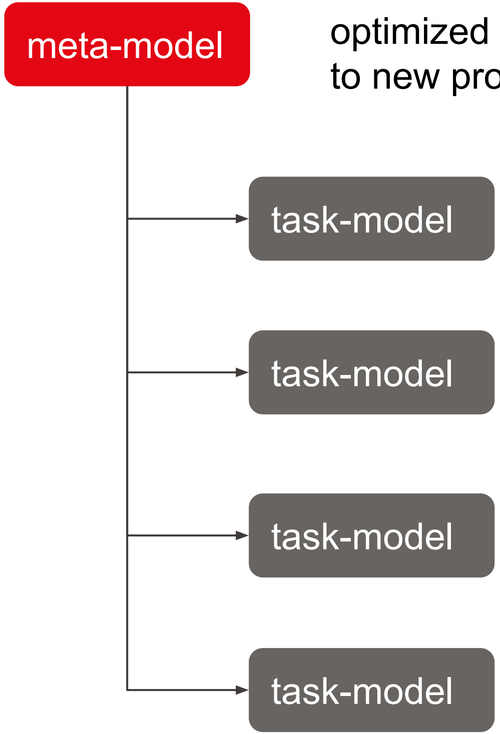
Cropland classification as different tasks

“cropland”





optimized to adapt to new problems

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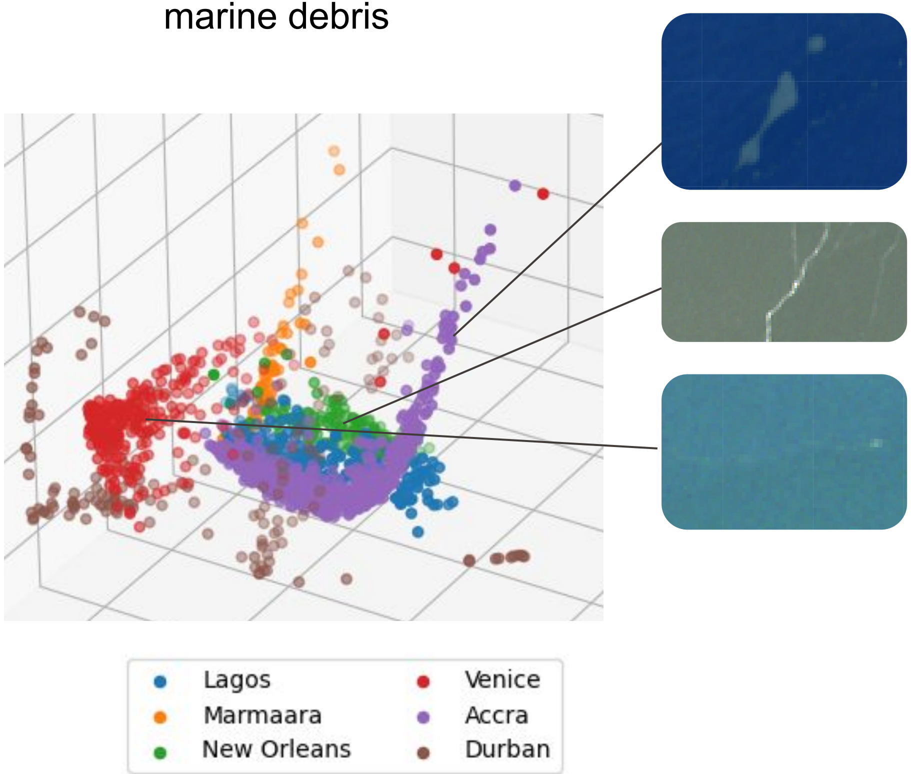
Marine Debris Detection as different Tasks

Different representations of

marine debris



meta-model

optimized to adapt to new problems

task-model

task-model

task-model

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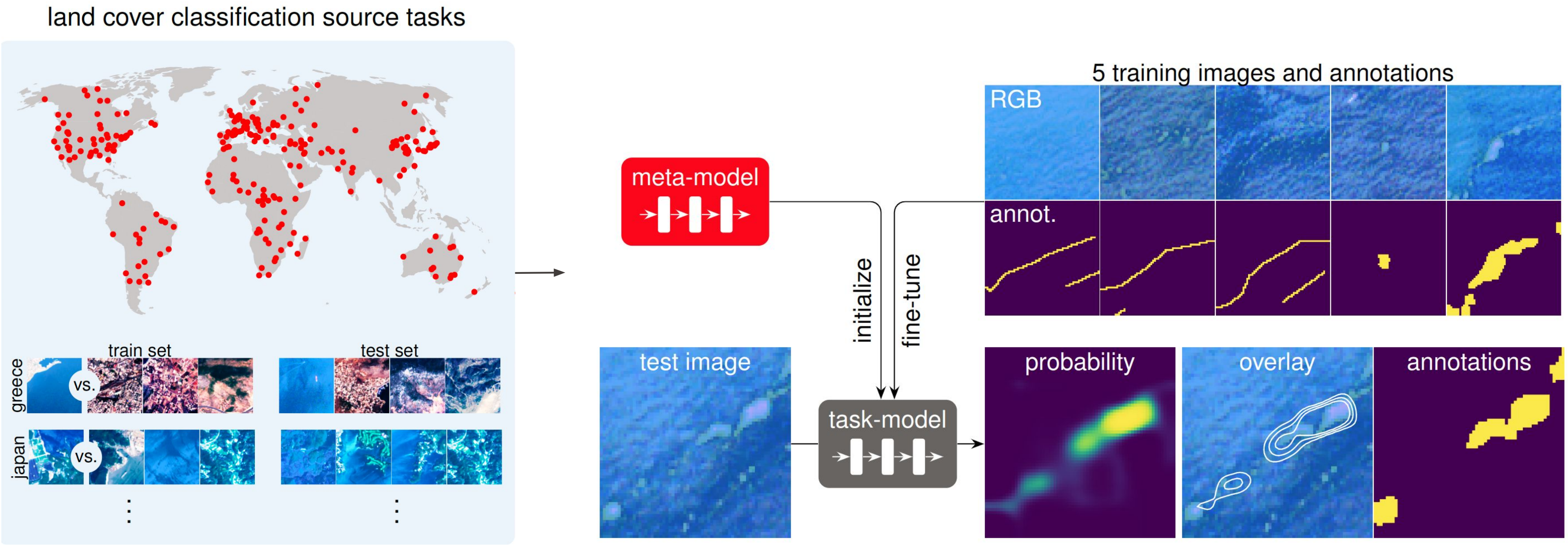
Meta-learned model fine-tuned for marine litter



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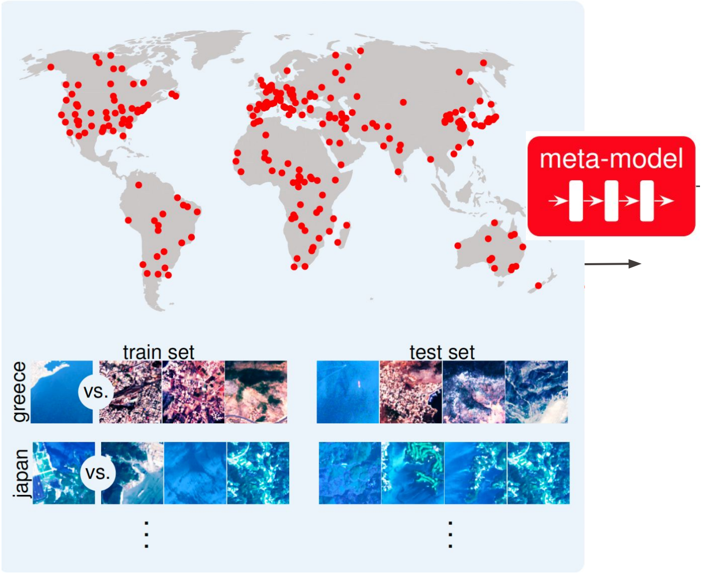
Meta-learned model fine-tuned for marine litter detection



single-shot (1-sample per class) classification

Conclusion

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- Meta-Learning as an algorithm to to “learn” new problems from a dataset of datasets.
- For geographic data, we represent the Earth as a “dataset of tasks” or a “dataset of datasets”
- Promising framework, given that we, as humans, also learn from problems rather than individual observations
- Complementary to existing approaches towards single large big-data models that aim to capture all global representations in one model

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Marc Rußwurm

marc.russwurm@epfl.ch
Twitter: @marccoru
marcrusswurm.com

work with collaborators: Devis Tuia, Benjamin Kellenberger, Sherrie Wang, Ribana Roscher, Dilge Gül, Jamila Mifdal, Raquel Carmo

Meta-learning data-efficient Machine Learning Models for Diverse Earth Observation Problems

Publications related to this presentation:

- Rußwurm, M., Wang, S., Körner, M. & Lobell, D. (2020). Meta-learning for Few-shot Land Cover Classification. In 2020 IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops (CVPRW), pages. 788–796. EarthVision 2020 Best Paper Award.
- Rußwurm, M., Wang S. & Tuia D. (2022). Humans are Poor Few-shot Classifiers. In IGARSS 2022 IEEE International Geoscience and Remote Sensing Symposium
- Rußwurm, M., & Tuia D. (2022). Instance norm improves meta-learning in class-imbalanced land cover classification. Distribution Shift Workshop 2022 at Conference and Workshop on Neural Information Processing Systems
- Mifdal, J., Longépé, N., Rußwurm, M. (2021). Towards Detecting Floating Objects on a Global Scale with Learned Spatial Features using Sentinel 2. ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., V-3-2021, 285–293, 2021, 169:421 – 435.

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