SyntEO: Synthetic training data generation for offshore wind energy infrastructure detection in Sentinel-1 imagery

ECMWF-ESA 14-17 November 2022
Workshop on Machine Learning for Earth Observation and Prediction

Thorsten Hoeser
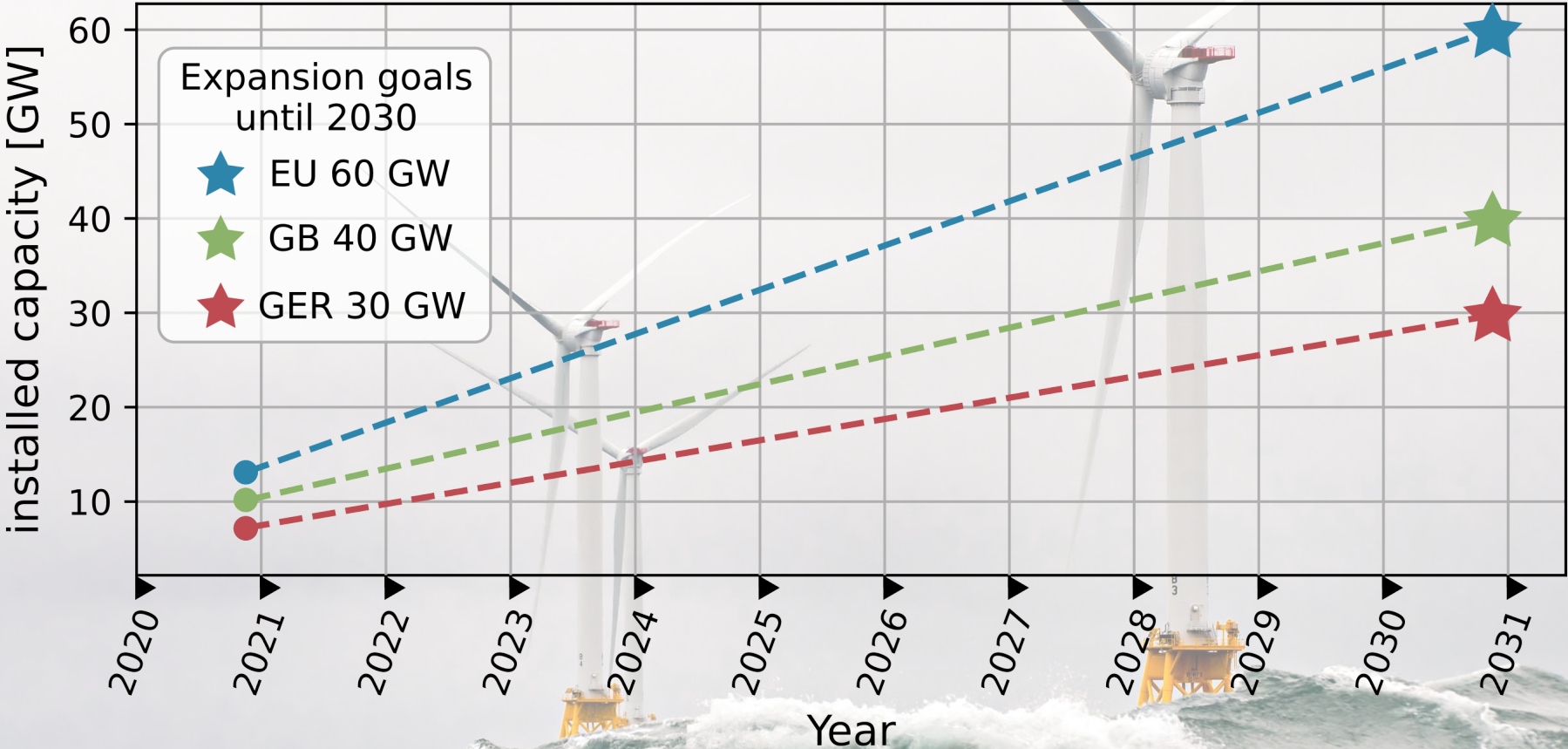**Prof. Dr. Claudia Kuenzer**
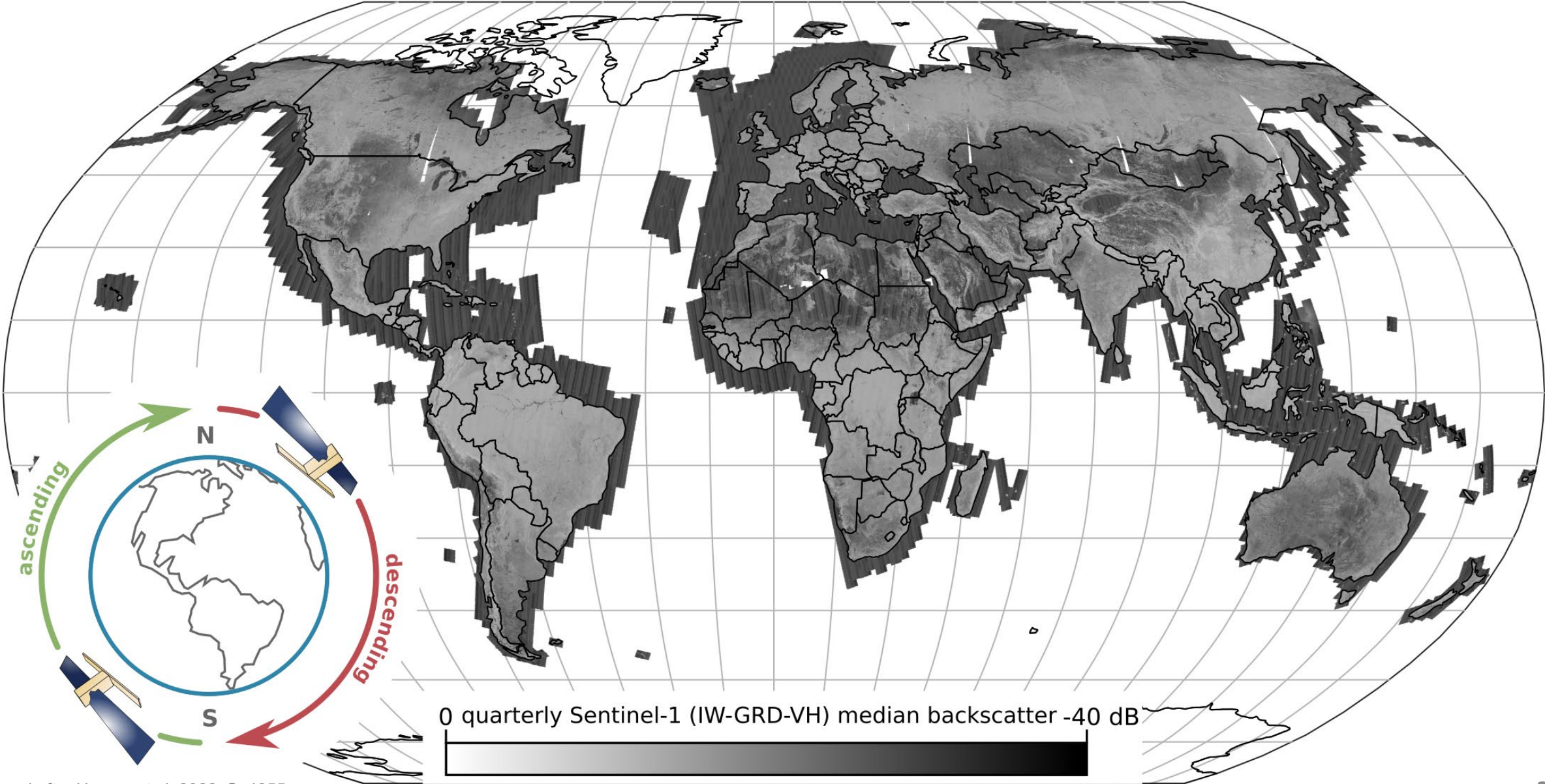
German Aerospace Center
German Remote Sensing Data Center

Knowledge for Tomorrow
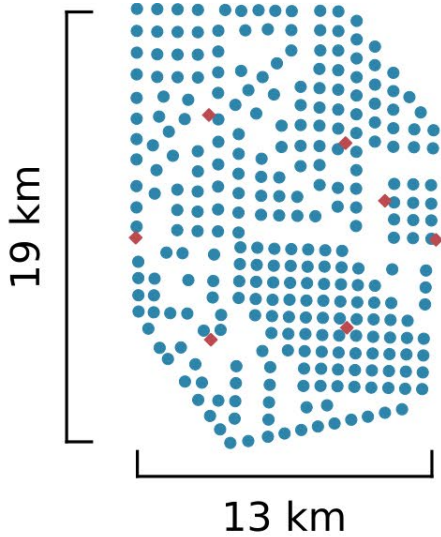
DLR

Offshore Wind Energy Expansion

Expansion goals until 2030
- ⭐ EU 60 GW
- ⭐ GB 40 GW
- ⭐ GER 30 GW

installed capacity [GW]

Year

Sentinel-1 Median Composite

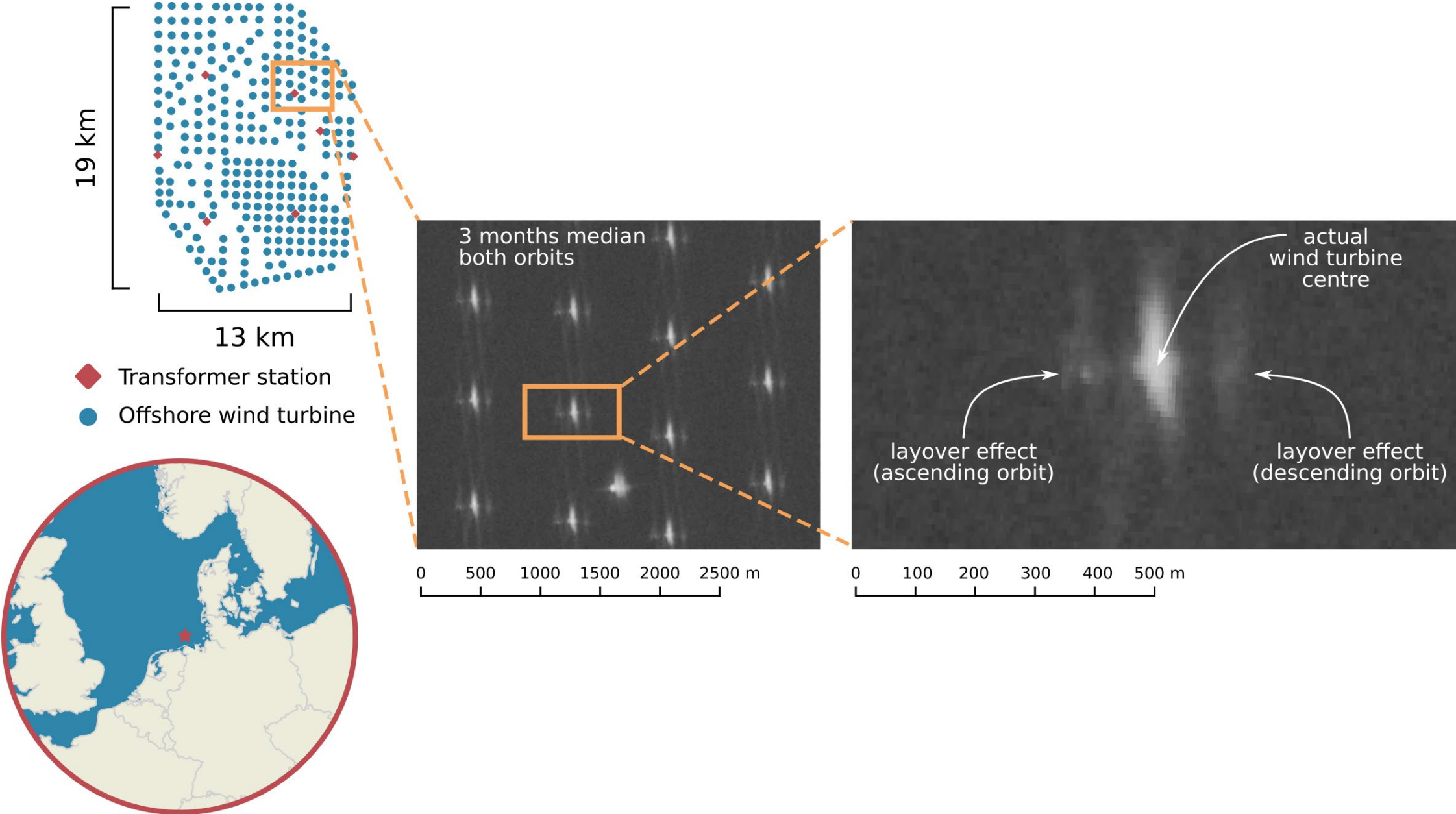quarterly Sentinel-1 (IW-GRD-VH) median backscatter

Offshore Wind Energy Infrastructure in Sentinel-1 imagery

19 km

13 km

◆ Transformer station

● Offshore wind turbine

0 2 4 6 8 10 km

Offshore Wind Energy Infrastructure in Sentinel-1 imagery

19 km

13 km

◆ Transformer station

● Offshore wind turbine

3 months median
both orbits

0   500   1000 1500 2000 2500 m

actual
wind turbine
centre

layover effect
(ascending orbit)

layover effect
(descending orbit)

0   100   200   300   400   500 m
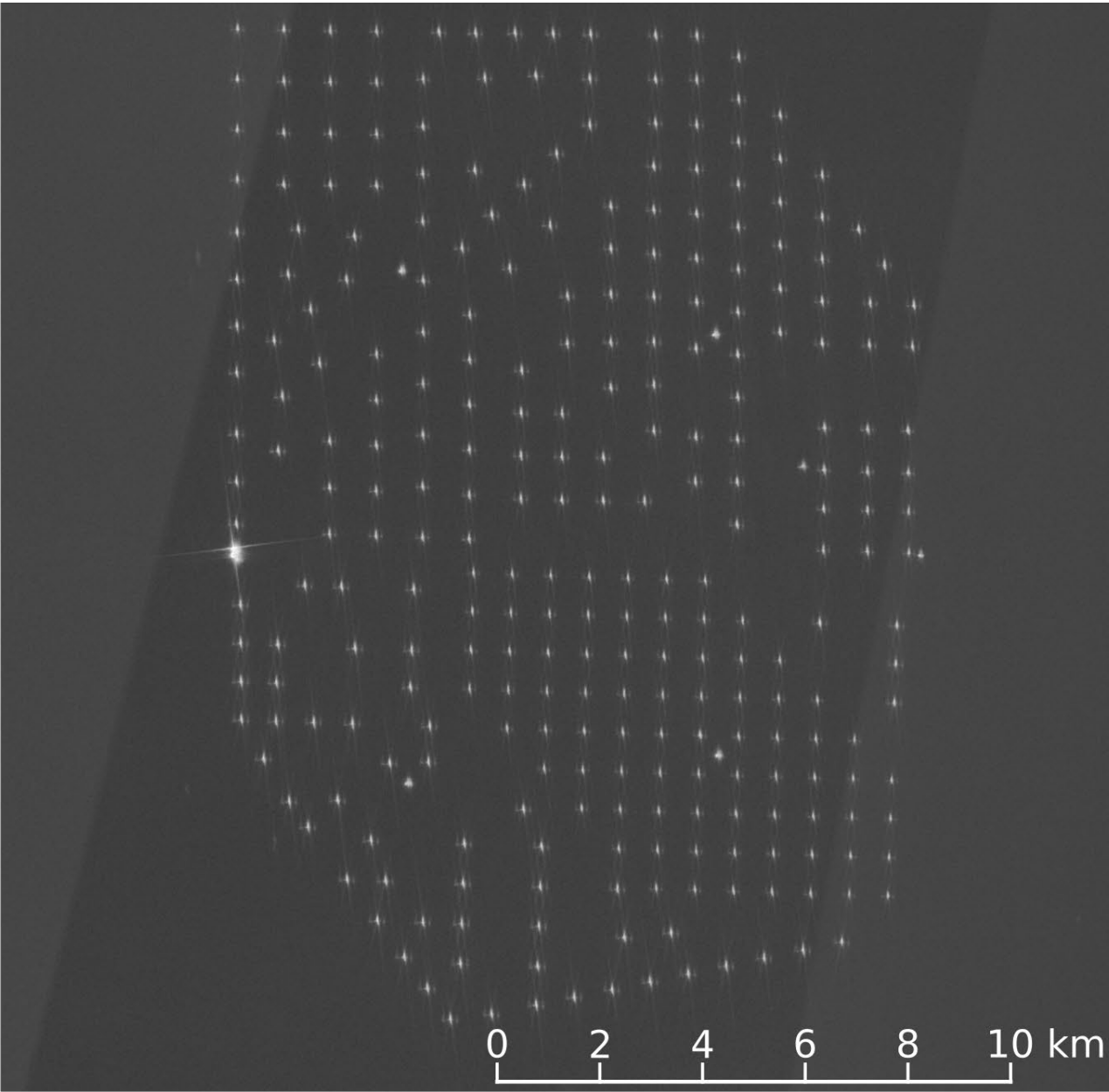
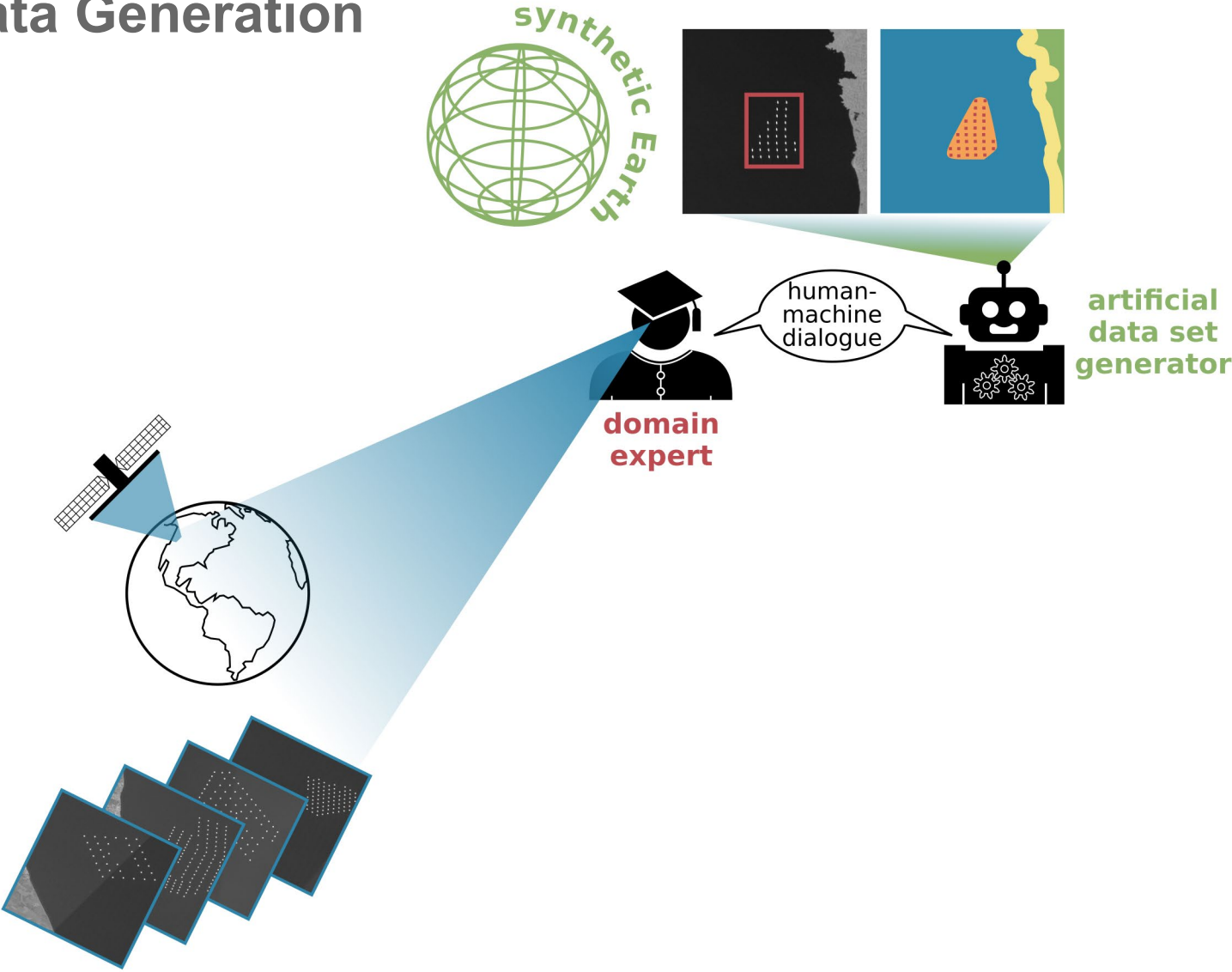# Offshore Wind Energy Infrastructure in Sentinel-1 imagery
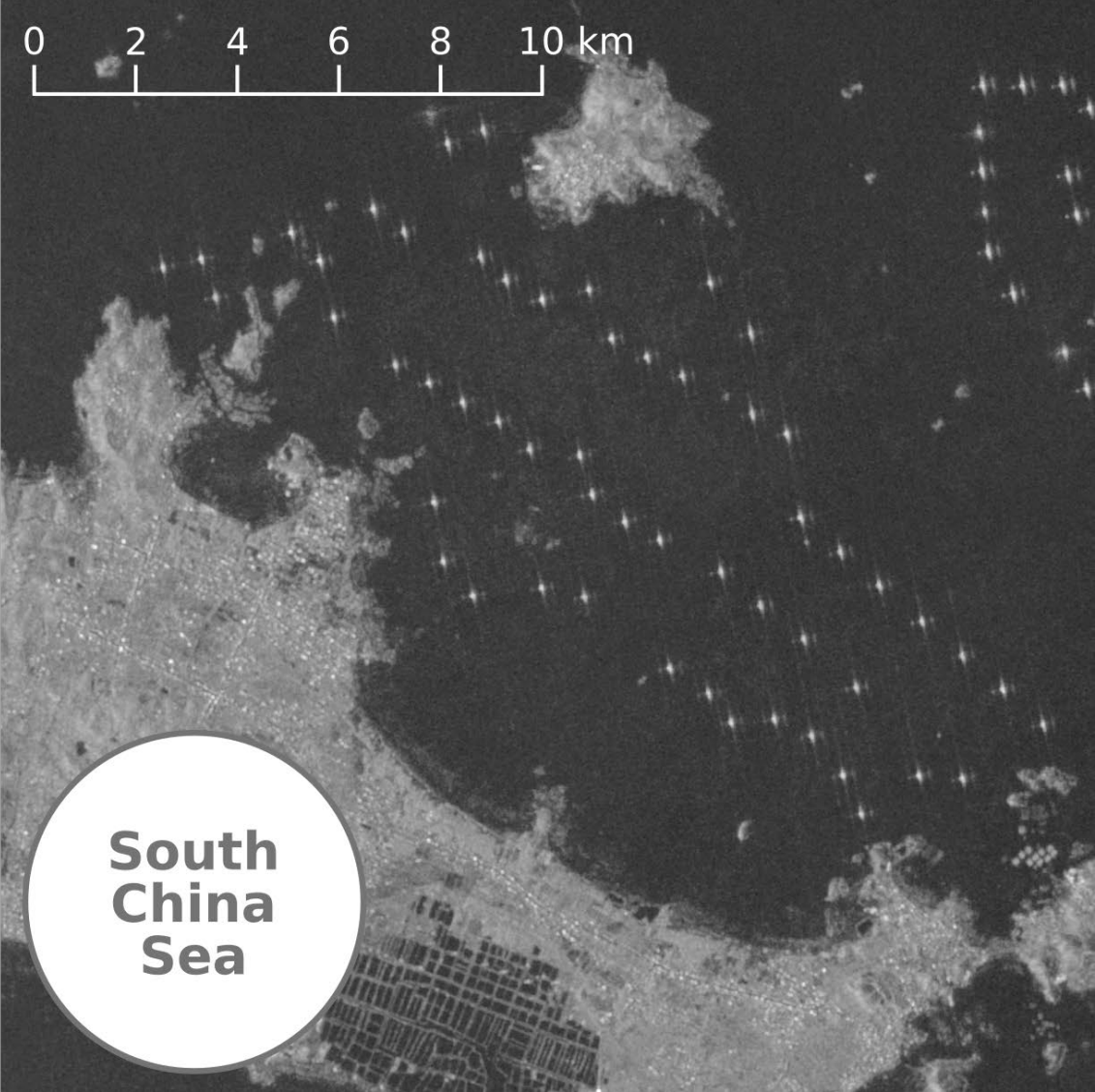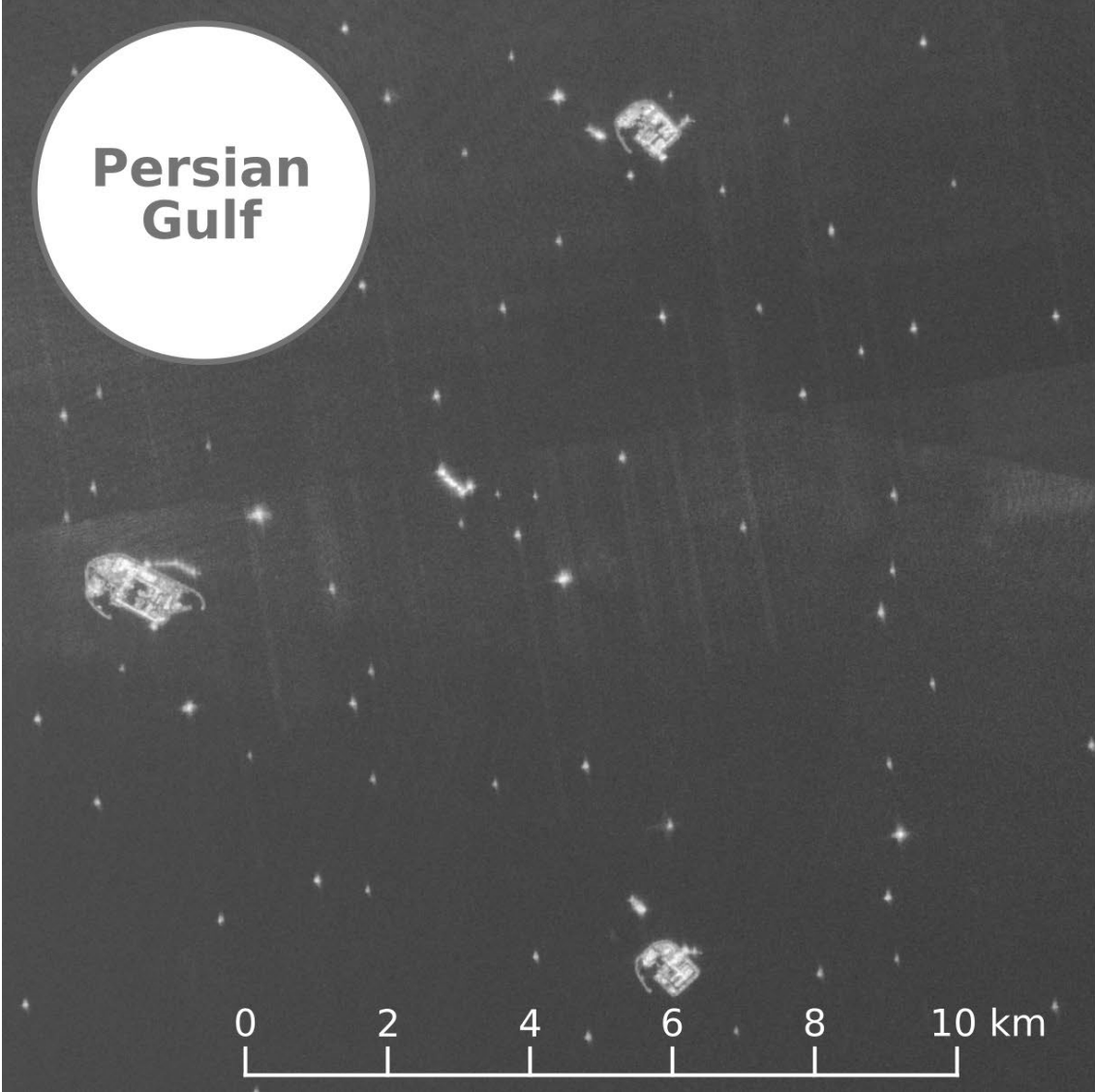
Supervised Deep Learning for Offshore Wind Energy Infrastructure detection
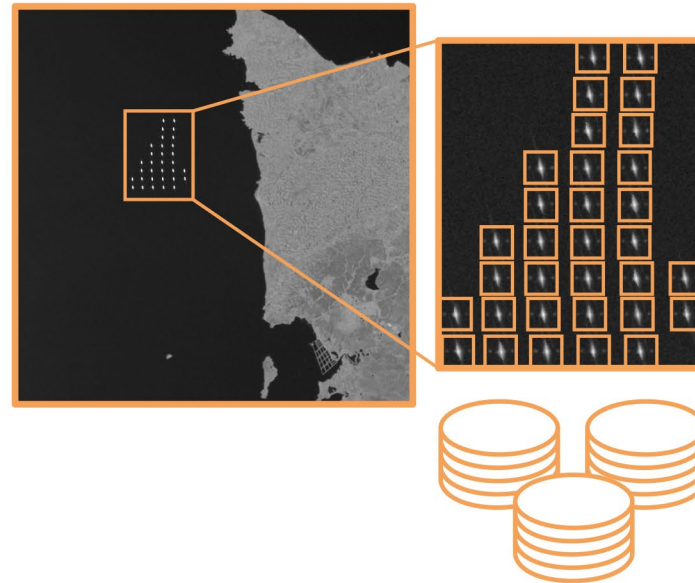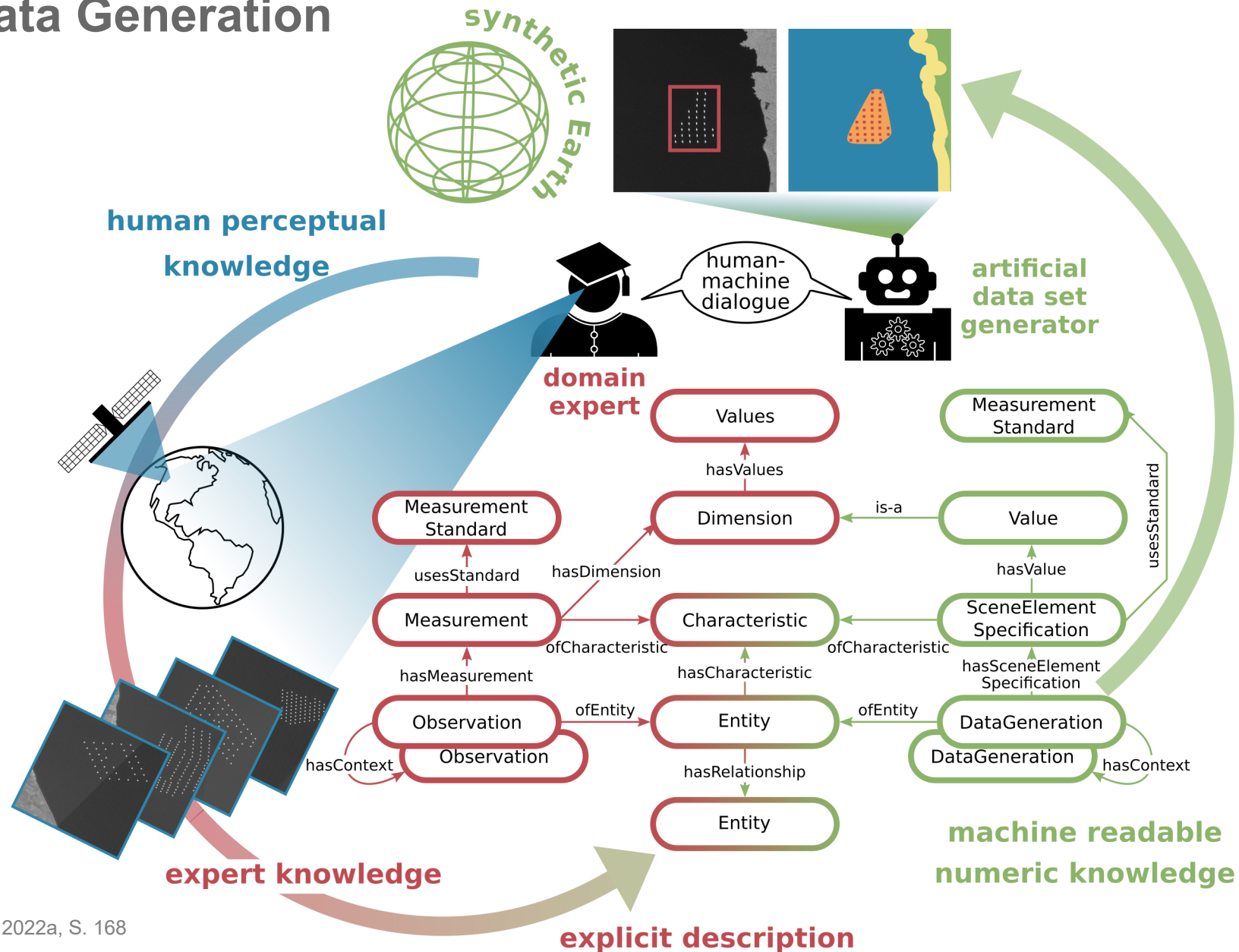

"With enough computation **and enough data,** learning beats programming

for complicated tasks that require the integration of many different, noisy cues."
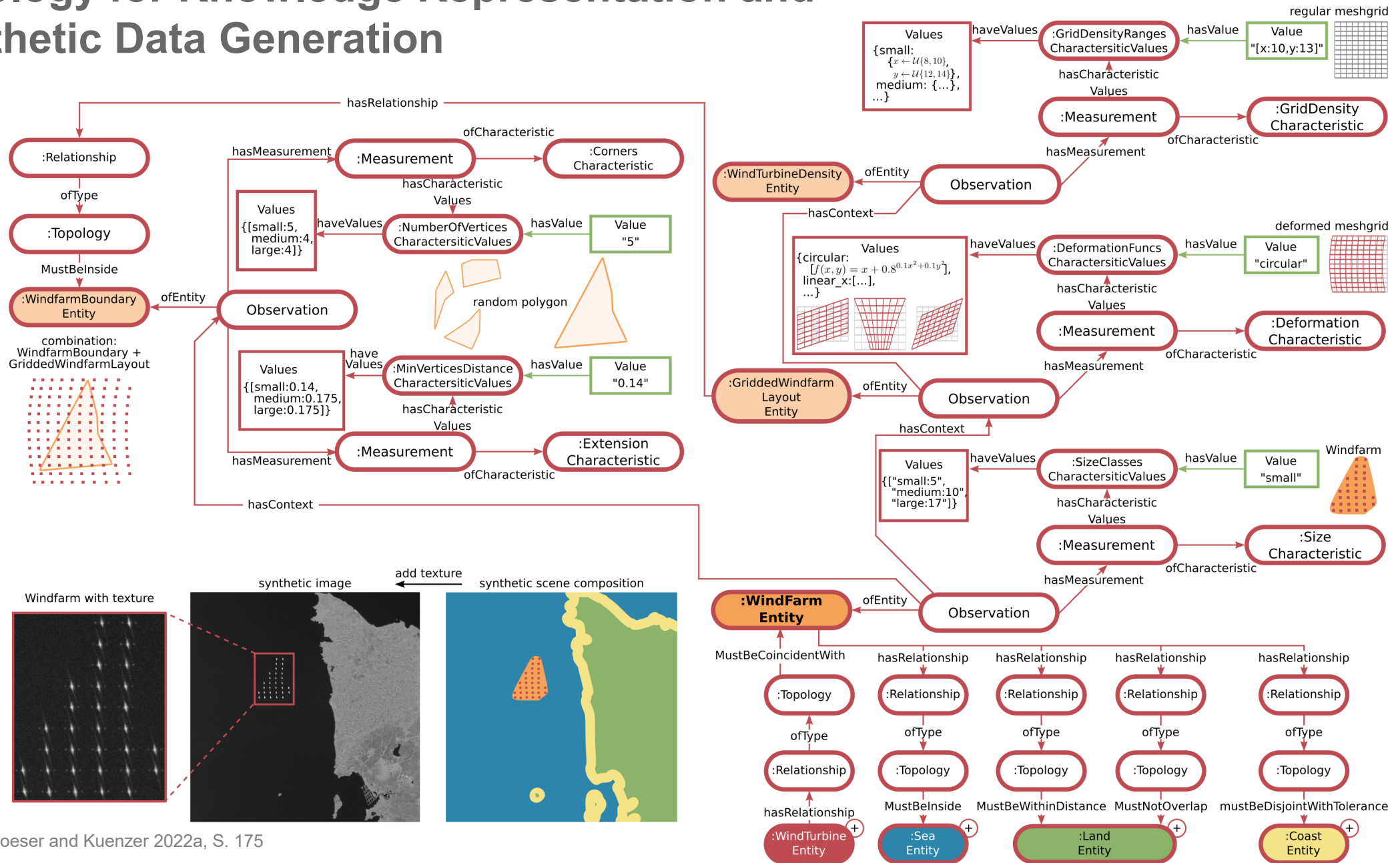
Krizhevsky, Sutskever and Hinton (2017, S. 84)

Ontology for Knowledge Representation and Synthetic Data Generation
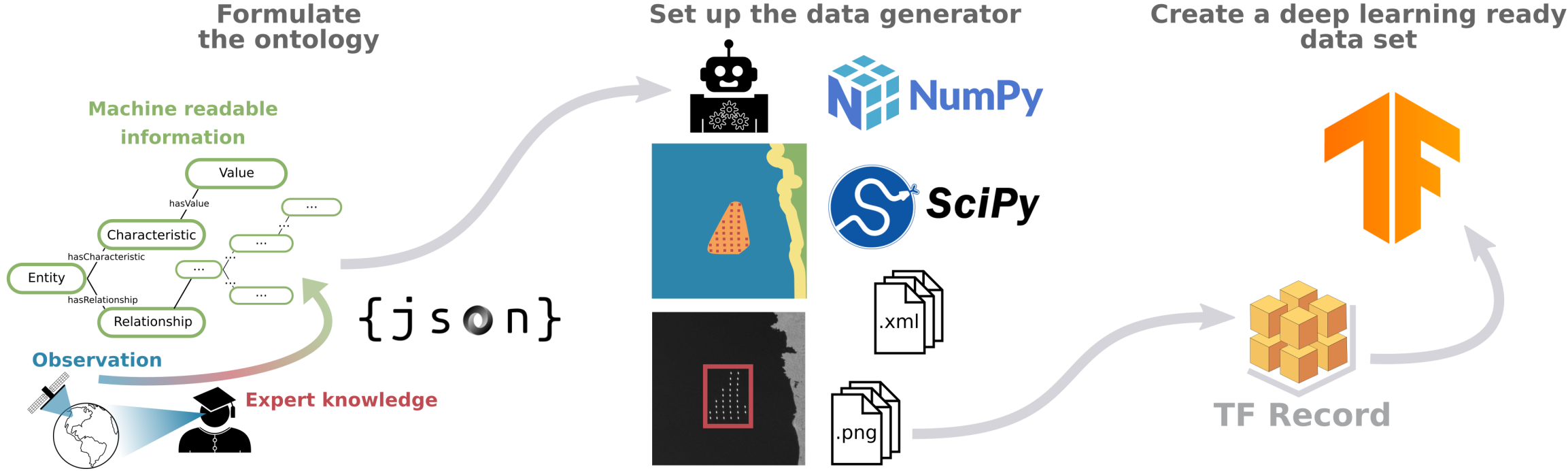
synthetic Earth

human-machine dialogue
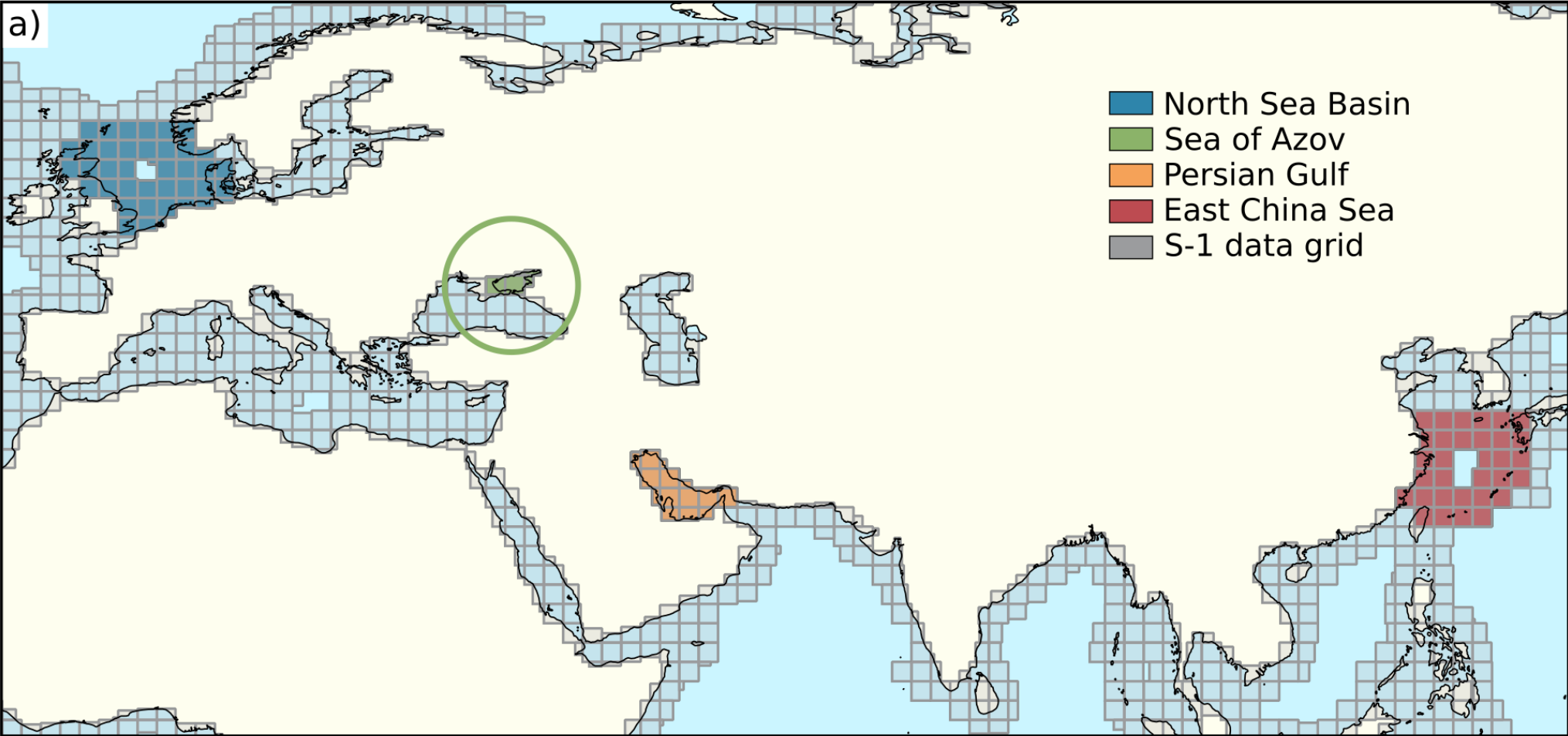
domain expert

artificial data set generator

Ontology for Knowledge Representation and Synthetic Data Generation

Ontology for Knowledge Representation and Synthetic Data Generation

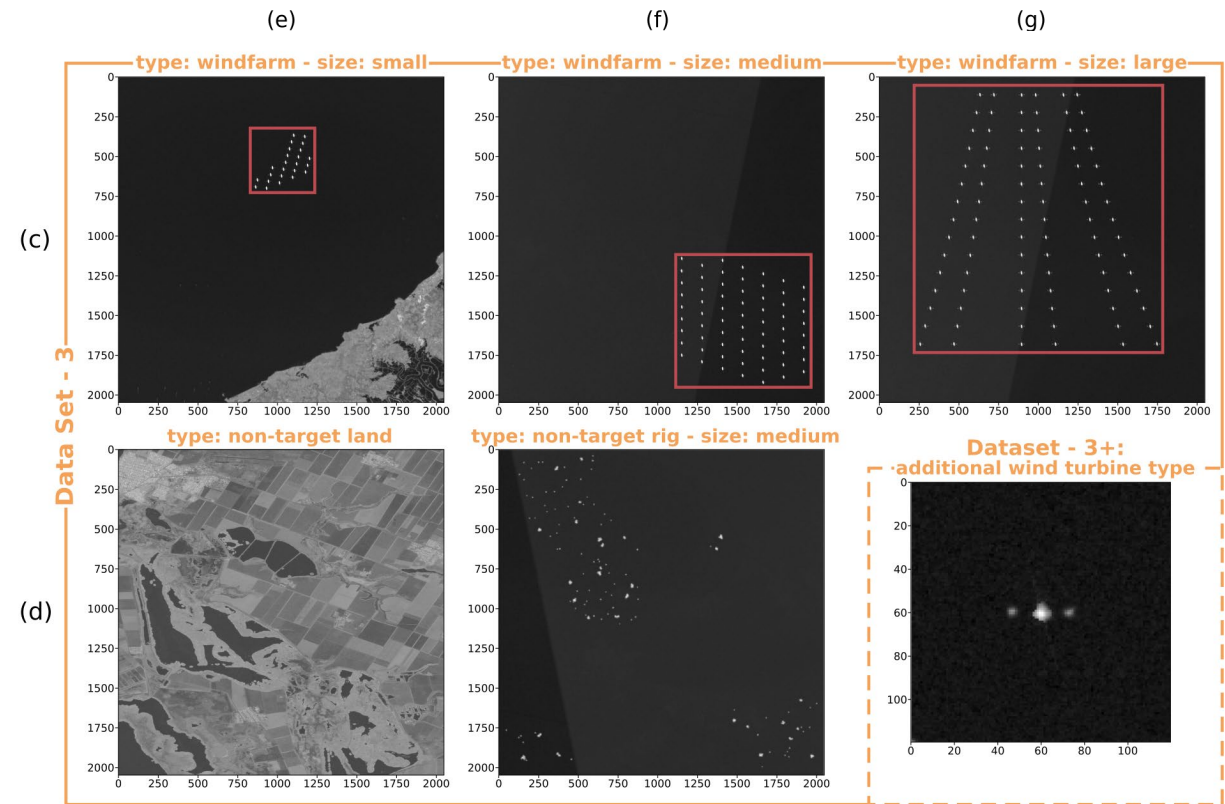# Ontology for Knowledge Representation and Synthetic Data Generation

Formulate the ontology

Machine readable information

Value

hasValue

Characteristic

hasCharacteristic

Entity

hasRelationship

Relationship

...
...
...
...

Observation

Expert knowledge

{ j s o n }

Set up the data generator

NumPy

SciPy

.xml

.png

Create a deep learning ready data set

TF Record

Real World Test Sites

Legend:
- North Sea Basin
- Sea of Azov
- Persian Gulf
- East China Sea
- S-1 data grid

Synthetic Training Data Sets

(a) Data Set - 1

(e) type: windfarm - size: small
(f)
(g)

wind turbine types in data sets 1-3+

(b) Data Set - 2

type: windfarm - size: small
type: windfarm - size: medium
type: windfarm - size: large

(c) Data Set - 3

(e) type: windfarm - size: small
(f) type: windfarm - size: medium
(g) type: windfarm - size: large

(d)

type: non-target land
type: non-target rig - size: medium
Dataset - 3+: additional wind turbine type

ResNet-50 Faster R-CNN Detection performances
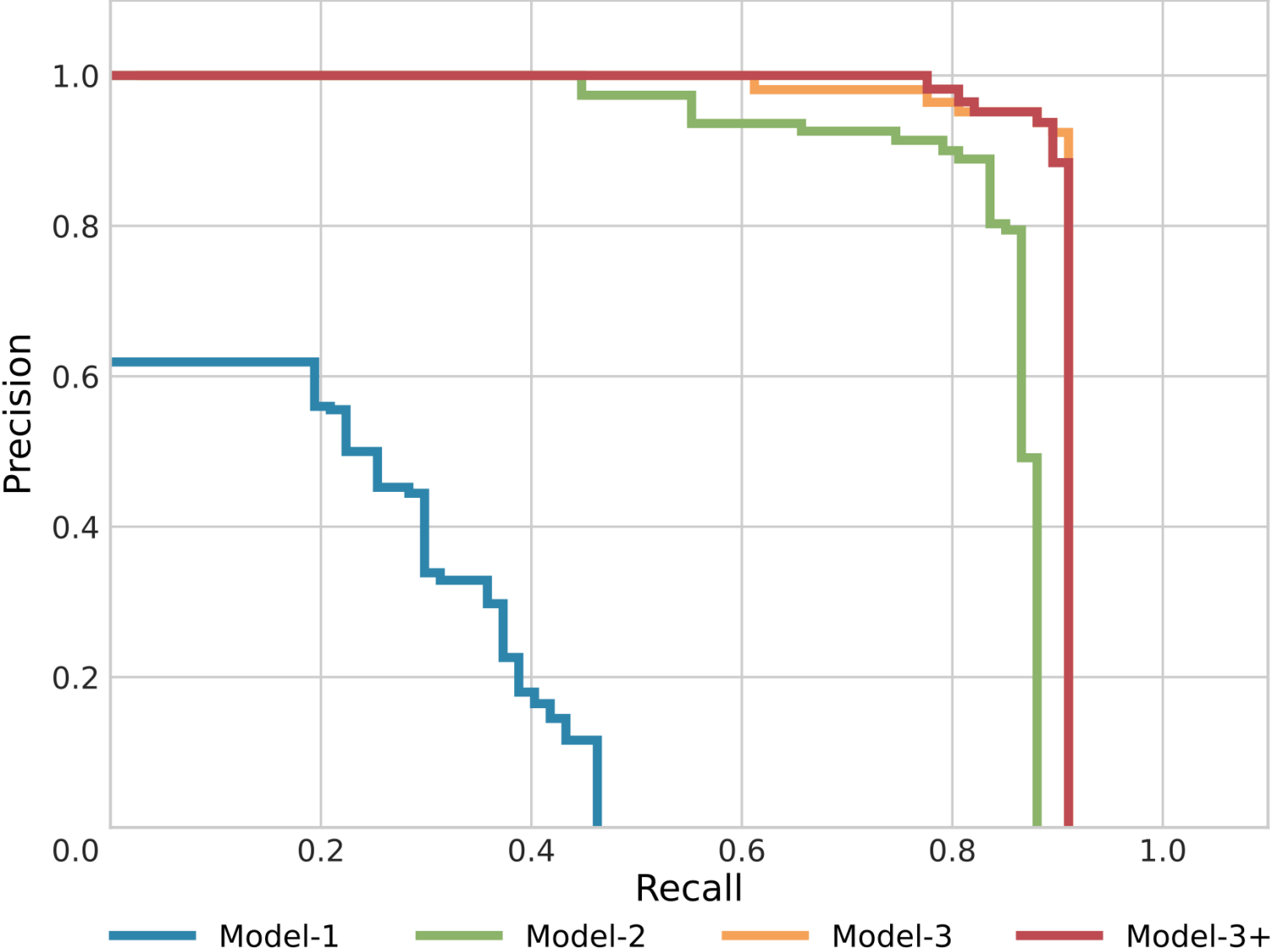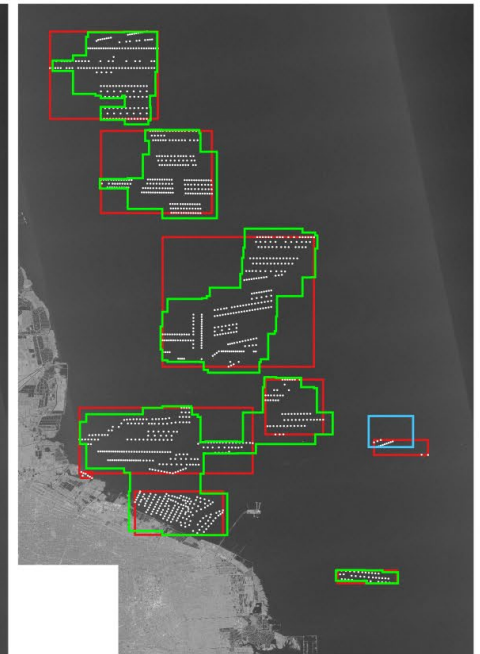
Detection Results – East China Sea and Sea of Azov
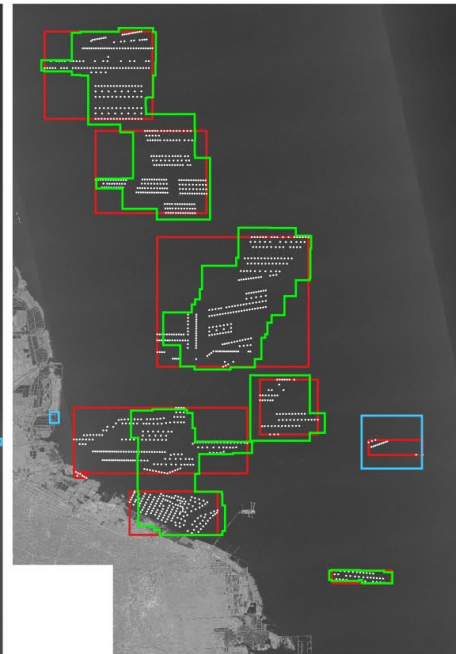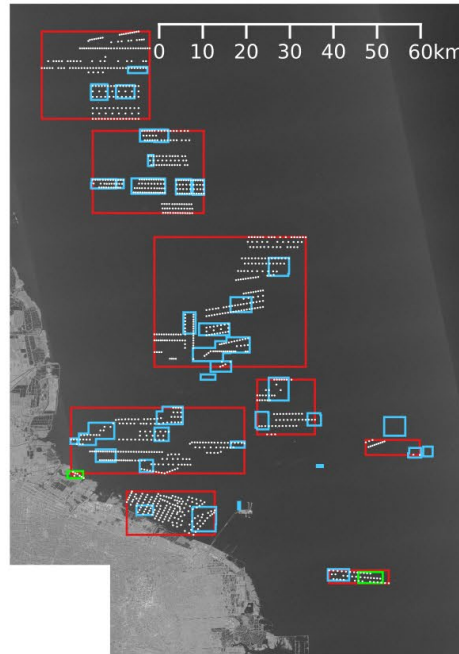

Model - 1   Model - 2   Model - 3   Model - 3+

East China Sea - Hangzhou Bay

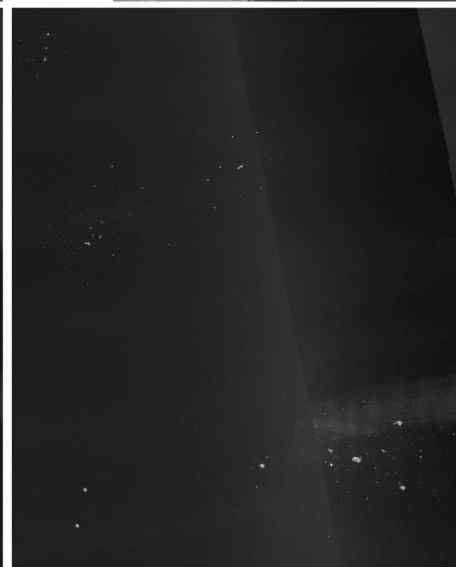Sea of Azov - Russia - Yeysk

Ground Truth
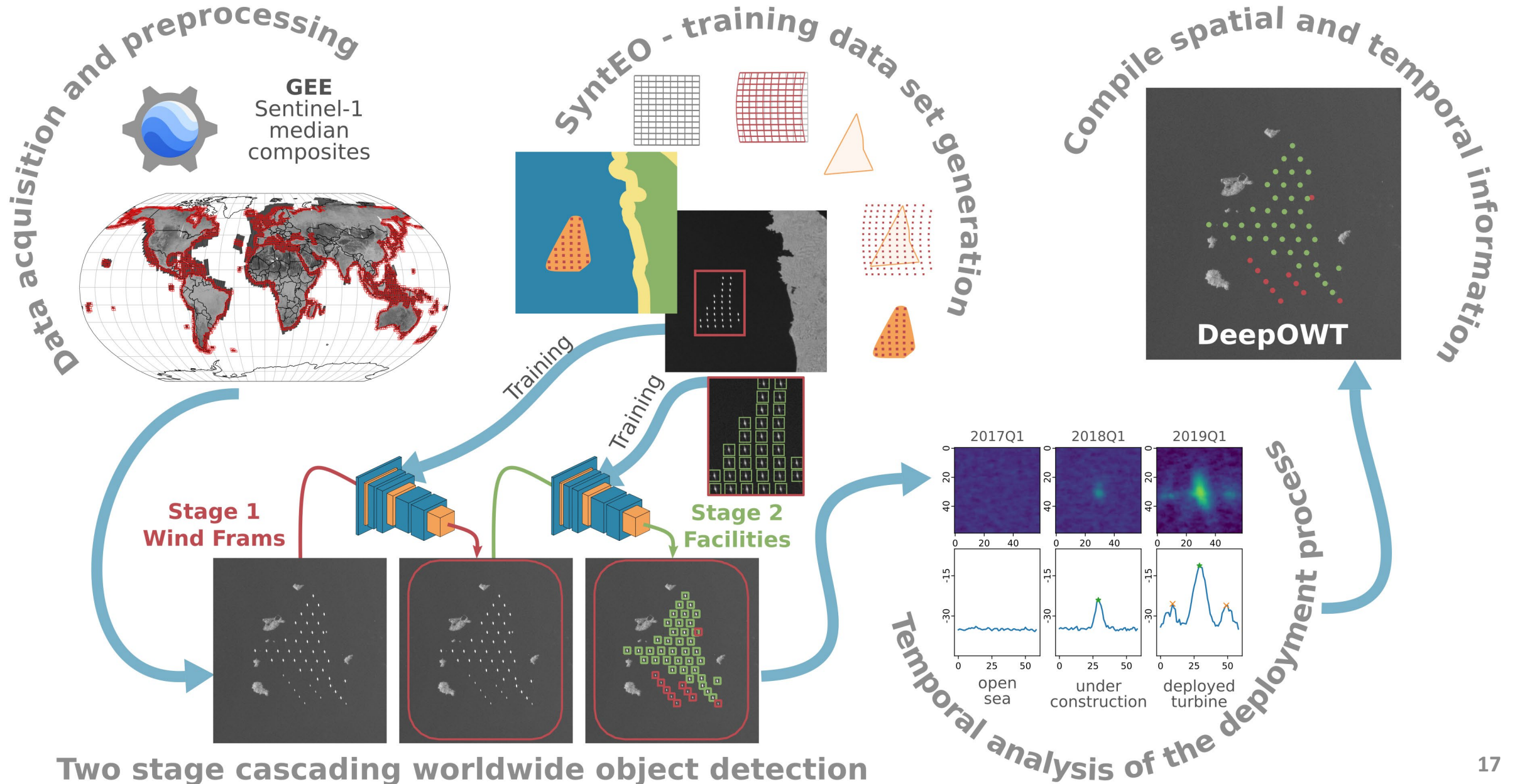
Prediction True Positive

Prediction False Positive
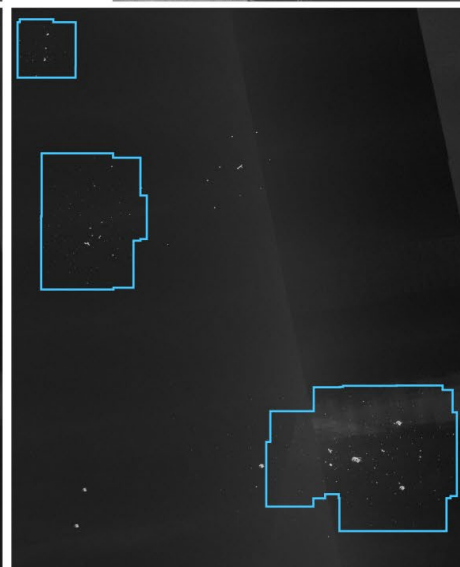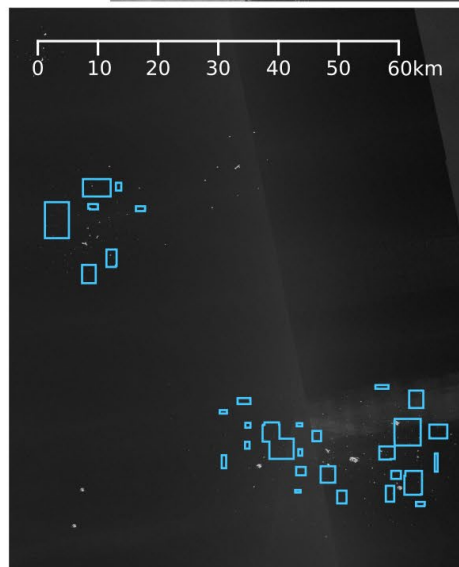
Changed after Hoeser and Kuenzer 2022a, S. 181-182

Detection Results – East China Sea and Persian Gulf

Changed after Hoeser and
Kuenzer 2022a, S. 181-182

Data acquisition and preprocessing

GEE
Sentinel-1 median composites

SyntEO - training data set generation

Training

Training

Stage 1 Wind Frams

Stage 2 Facilities

Compile spatial and temporal information

DeepOWT

2017Q1   2018Q1   2019Q1

open sea   under construction   deployed turbine

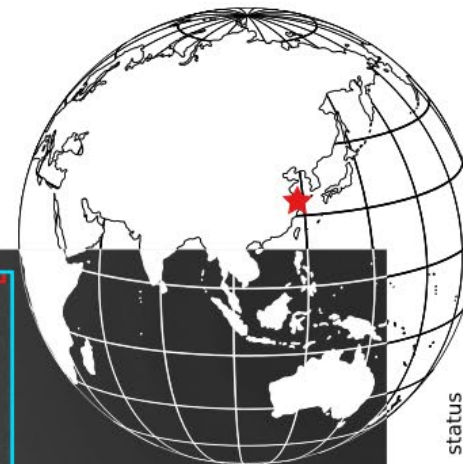**Temporal analysis of the deployment process**

Two stage cascading worldwide object detection

Global offshore wind turbine data set derived with deep learning - DeepOWT
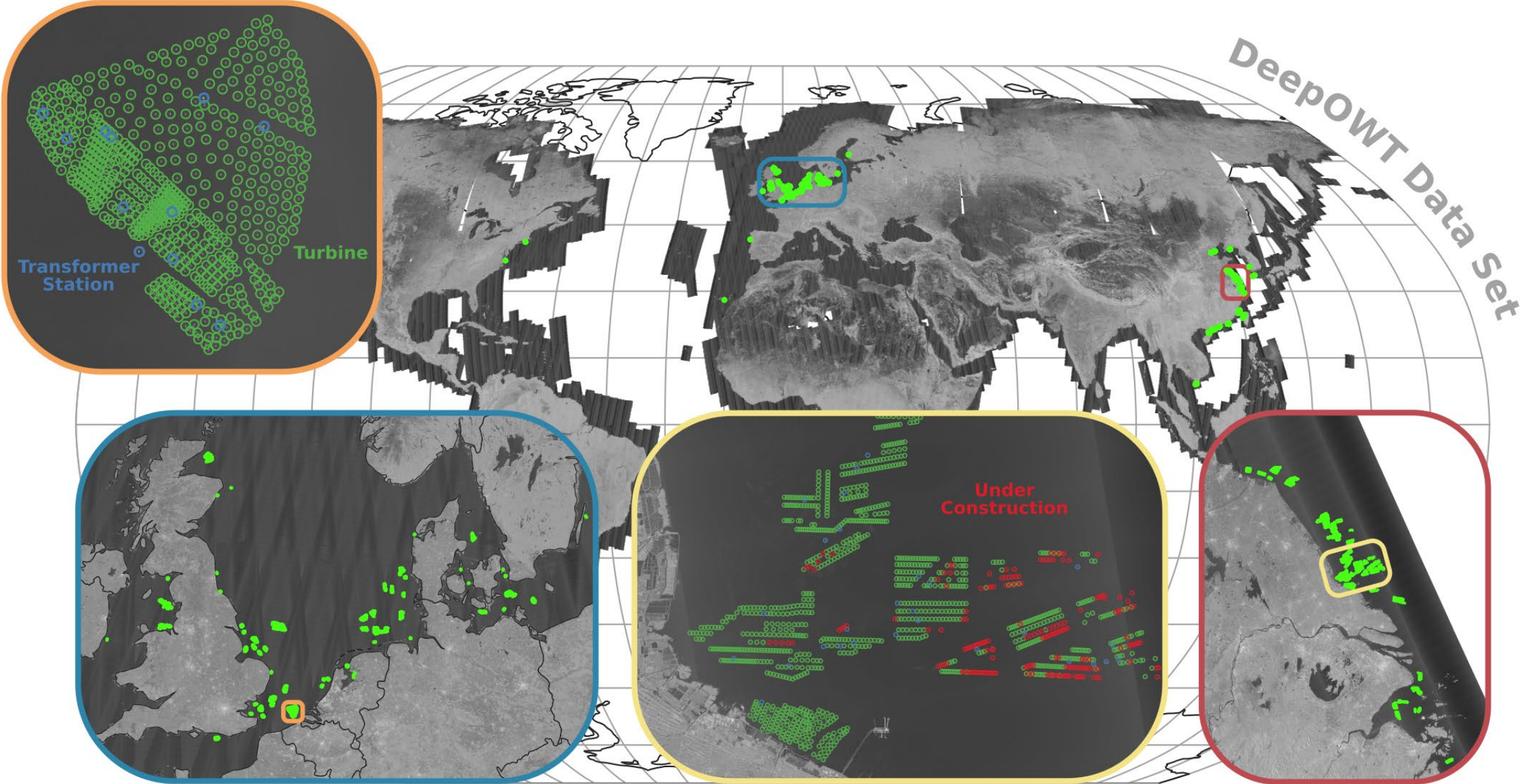
Offshore wind turbine deployment - China
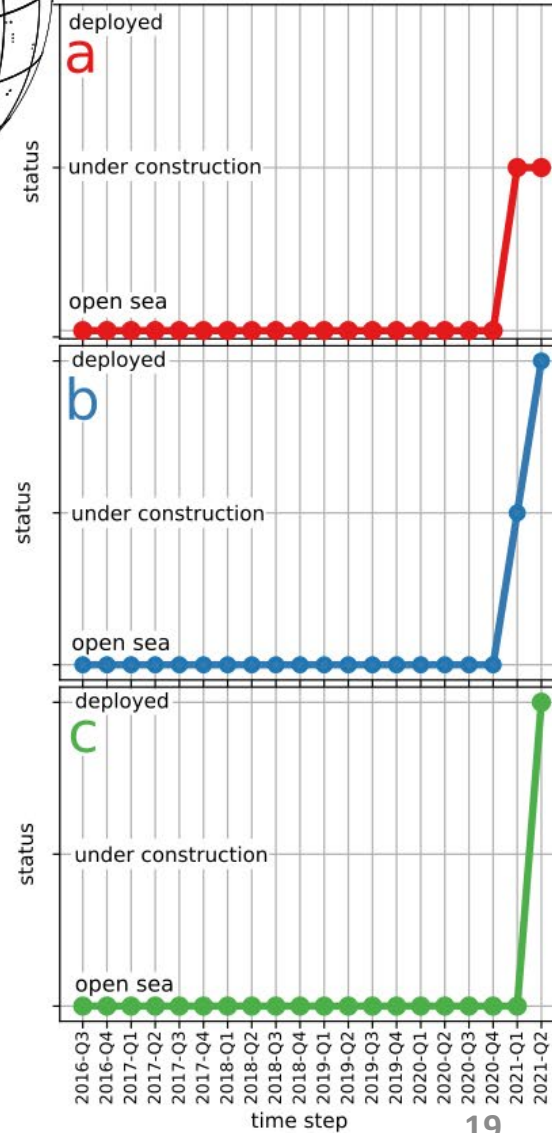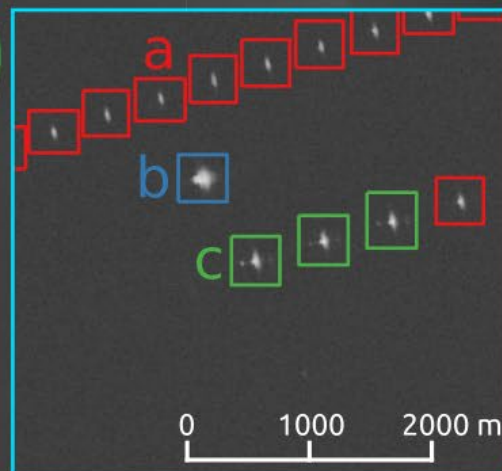
Offshore Wind Energy Expansion
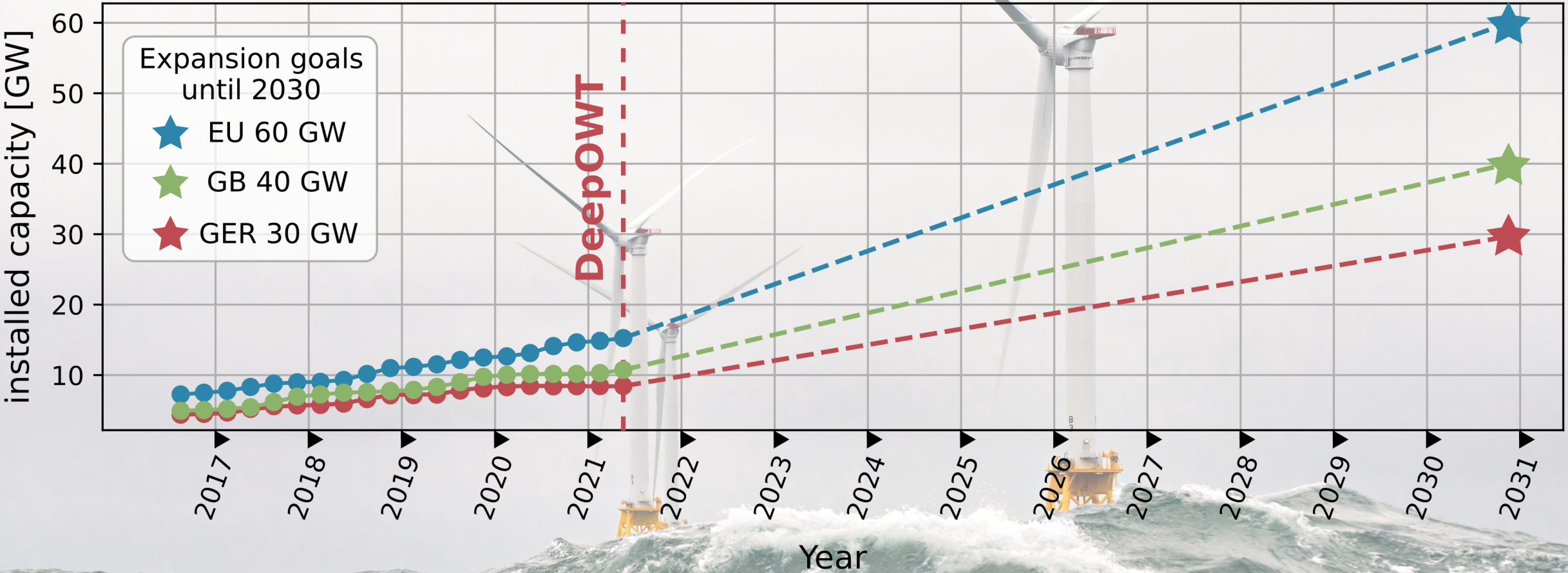
References

Hoeser, T., Feuerstein, S., Kuenzer, C., 2022. DeepOWT: A global offshore wind turbine data set derived with deep learning from Sentinel-1 data. Earth System Science Data 14, 4251-4270. doi: https://doi.org/10.5194/essd-14-4251-2022.

Hoeser, T., Kuenzer, C., 2022a. SyntEO: Synthetic Dataset Generation for Earth Observation and Deep Learning - Demonstrated for Offshore Wind Farm Detection. ISPRS Journal of Photogrammetry and Remote Sensing 189, 163-184. doi: https://doi.org/10.1016/j.isprsjprs.2022.04.029.

Hoeser, T., Kuenzer, C., 2022b. Global dynamics of the offshore wind energy sector monitored with Sentinel-1: Turbine count, installed capacity and site specifications. International Journal of Applied Earth Observation and Geoinformation 112, 102957. doi: https://doi.org/10.1016/j.jag.2022.102957.

Krizhevsky, A., Sutskever, I., Hinton, G.E., 2017. ImageNet Classification with Deep Convolutional Neural Networks. Communications of the ACM 60, 84–90. doi: https://doi.org/10.1145/3065386.

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- ⭕ map zoom
- 🛡 wind farm boundary
- ▭ wind turbine location
- ▭ wind farm substation
- ▭ wind turbine construction

8885 deployed

852 under construction

in June 2021