HPC AND QC FOR EARTH OBSERVATION

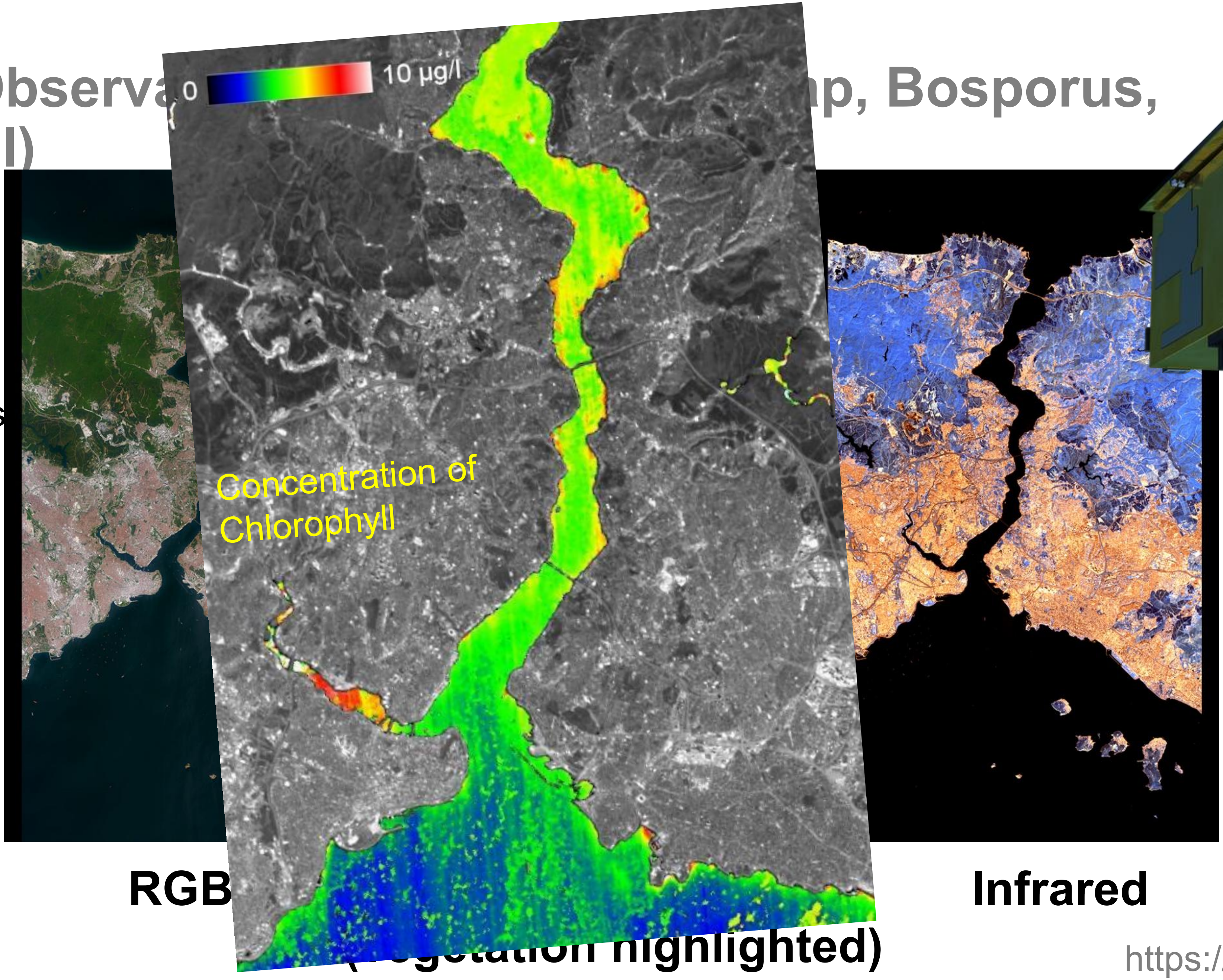
Tobias Guggemos

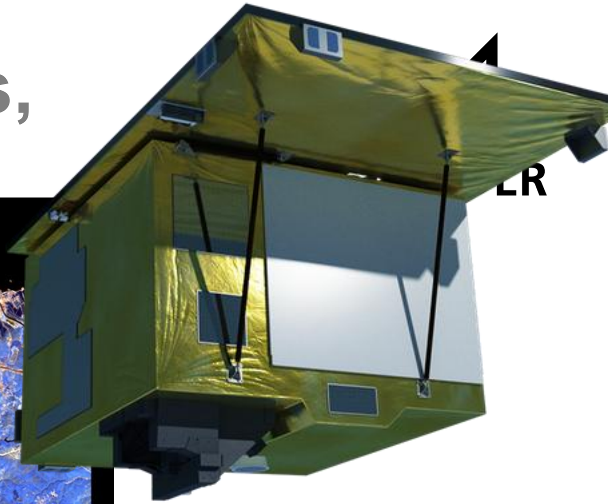
Earth Observation Center, German Aerospace Center

Earth Observa… …p, Bosporus, Istanbul)

1,000x1,024
Pixels
each 244 Bands

Resolution:
30x30m





RGB

Infrared

…highlighted)

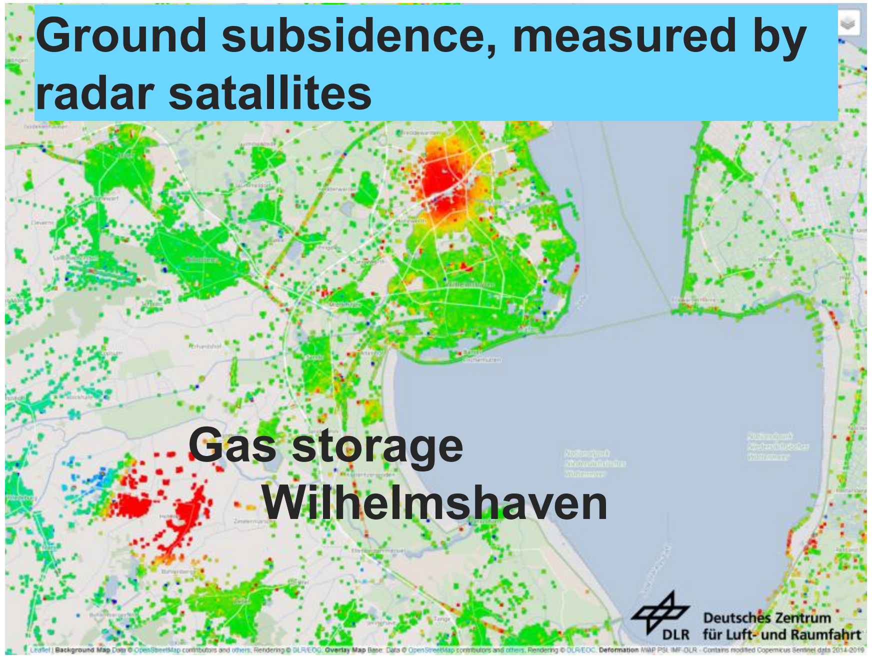
https://www.enmap.org/

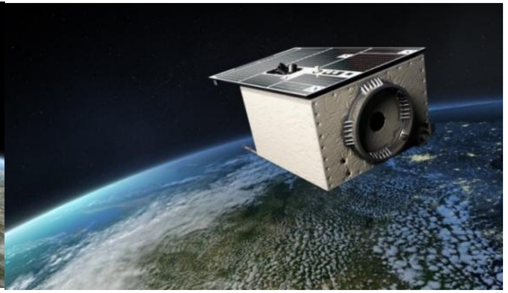
Earth Observation

Earth Observation Center

Algorithms and processes to analyse EO Data

- Radar sensing
- Optical sensing
- Remote sensing the atmosphere
- Big Data Analytics and Artificial In






Credit: PIXNIO
Disaster management


Wikipedia CC-BY-SA-3.0
Urban development


SAND STORM
LUMINOSITY
Public health
EU CC-BY-ND-2.0


Public education
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How HPC?

terrabyte [1]

- 16 GPU nodes (with multiple GPUs)
- 60 CPU nodes (with multiple CPUs)
- 40PB GPFS storage system

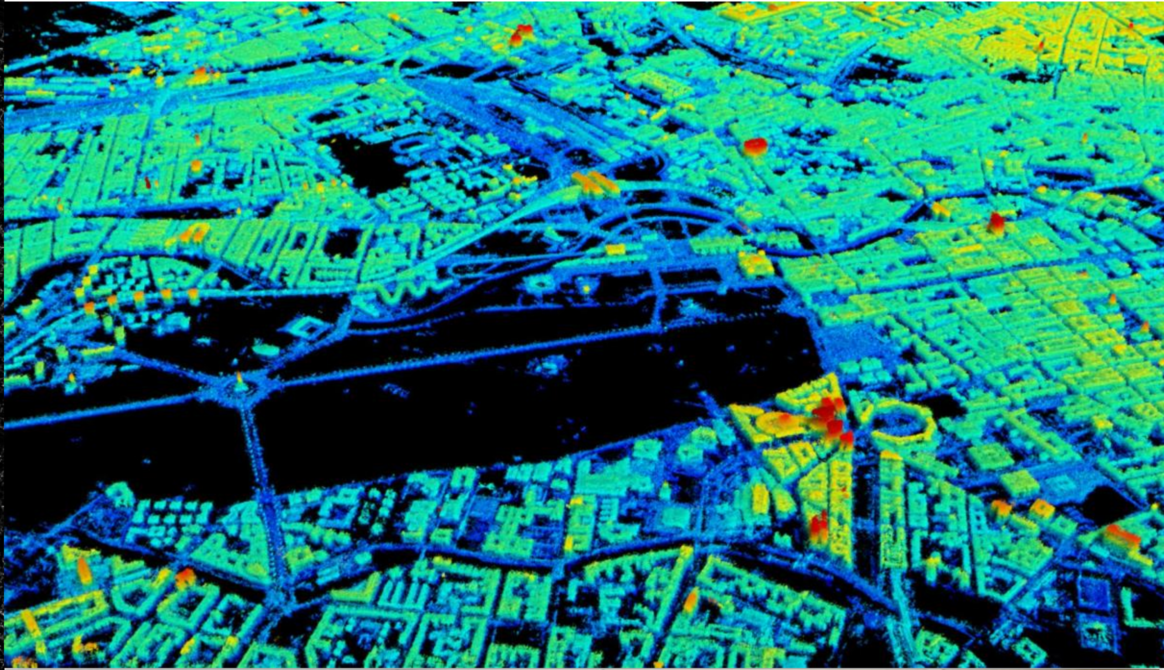
[1] https://www.lrz.de/presse/ereignisse/2021-07-22-terrabyte_ENG_/

Why HPC?

TUM IGSSE Project @ LRZ – 4D City (SuperMUC)

Calculation for **every single pixel =** solving optimization problem with **a matrix dimension of ca. $10^2 \times 10^6$**

since 2012, 26mio CPU hours granted



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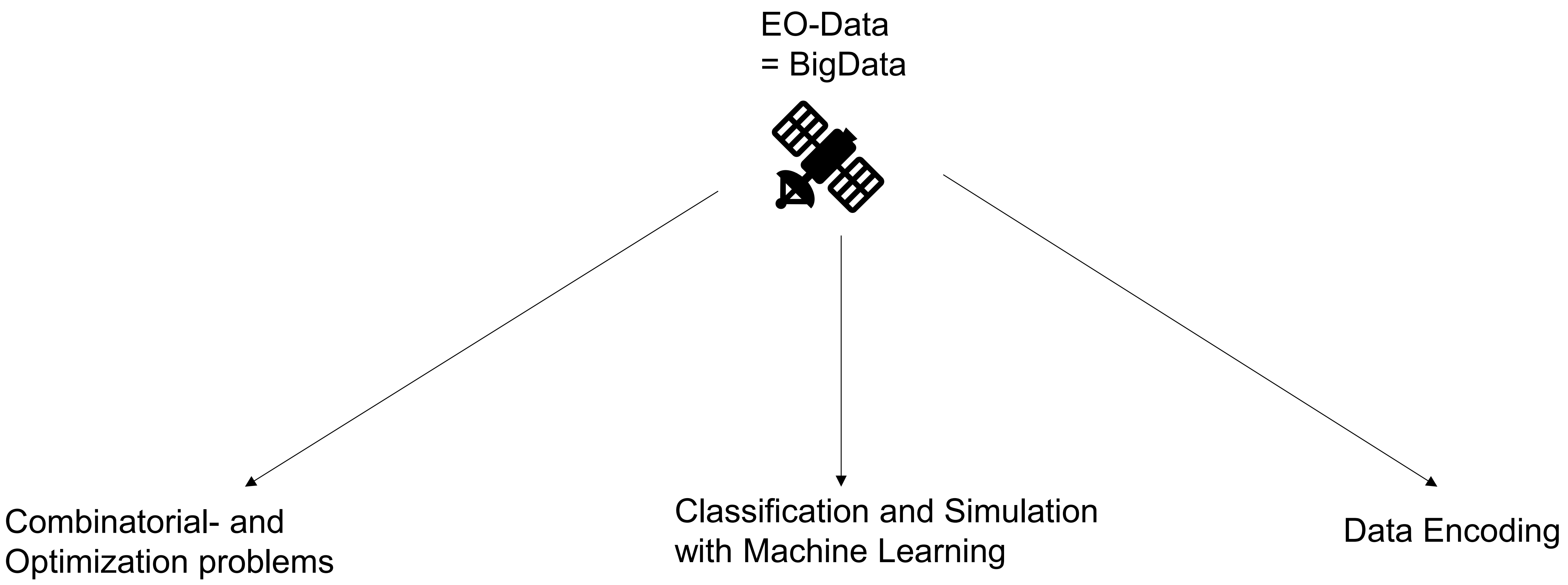
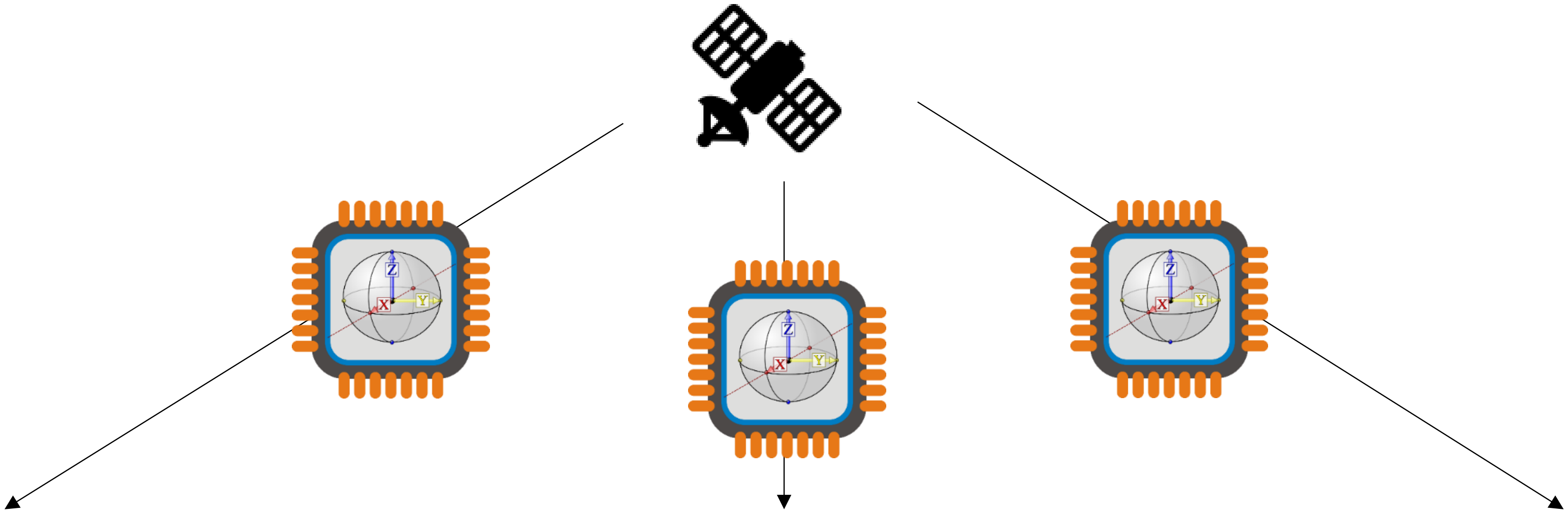
Overview


EO-Data
= BigData
Combinatorial- and
Optimization problems
Classification and Simulation
with Machine Learning
Data Encoding

Quantum?

EO-Data
= BigData



Combinatorial- and
Optimization problems

Classification and Simulation
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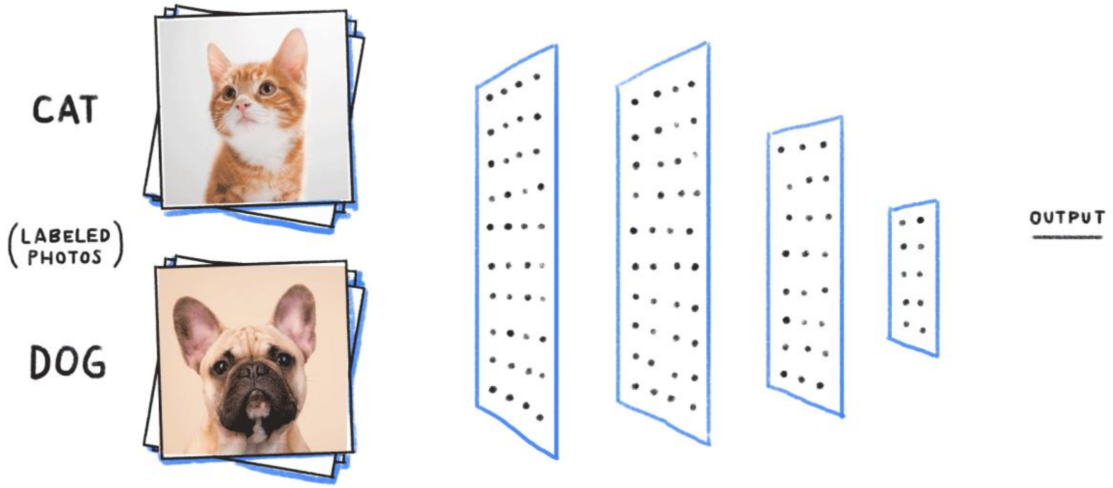
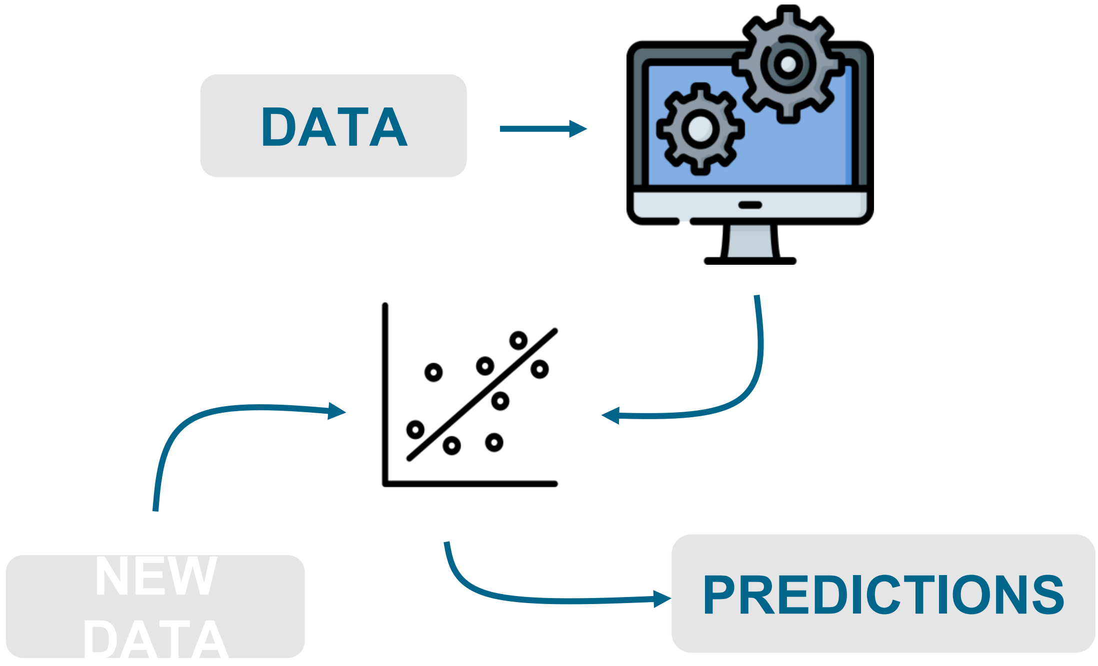
Data Encoding

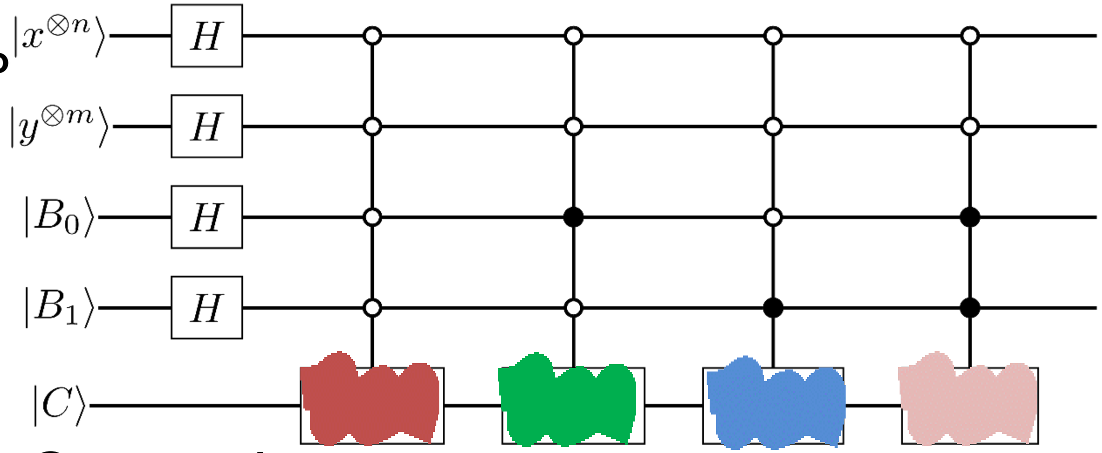
Machine Learning for Classification

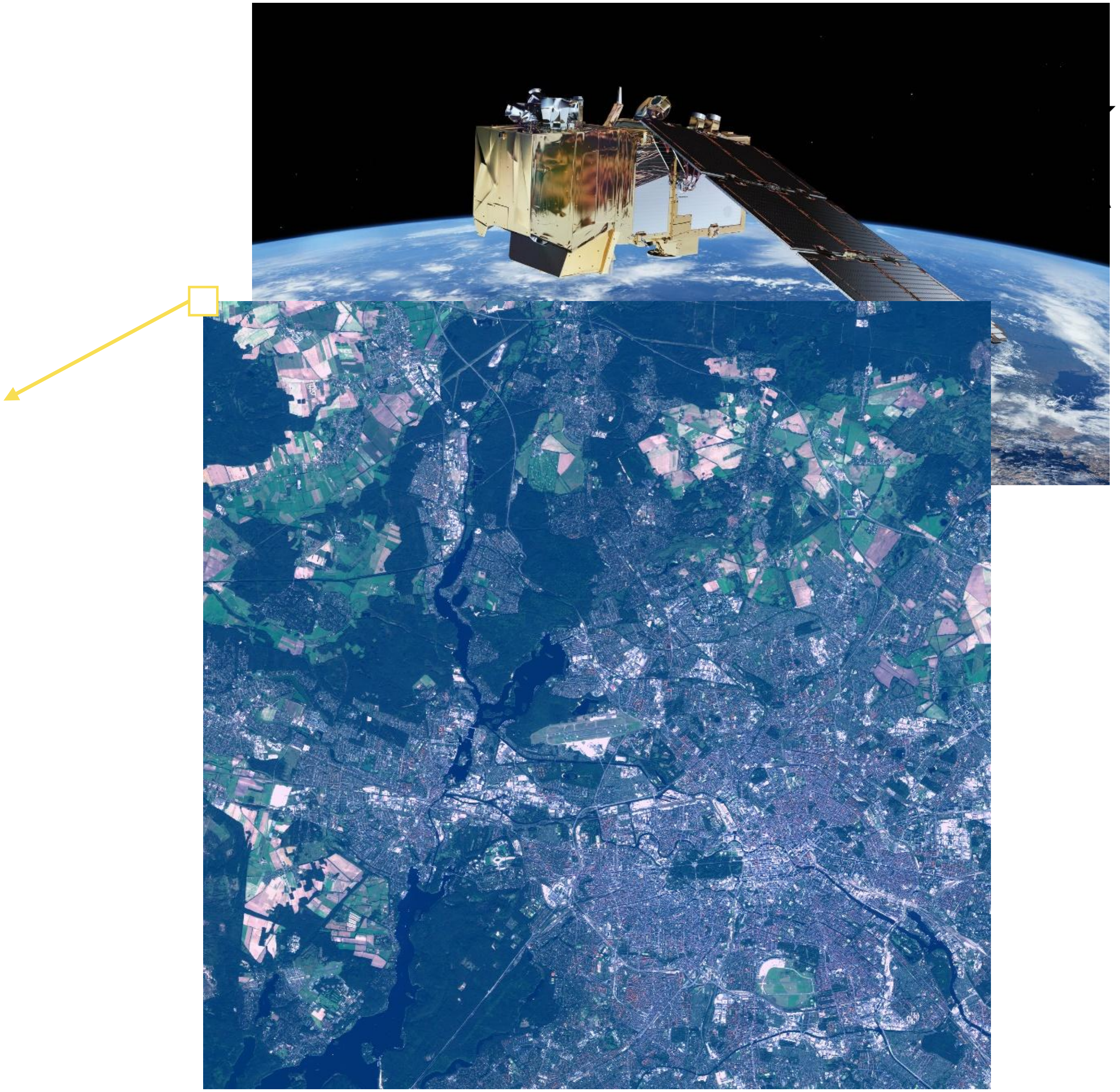




Experiments with Multispectral EO data

Lo



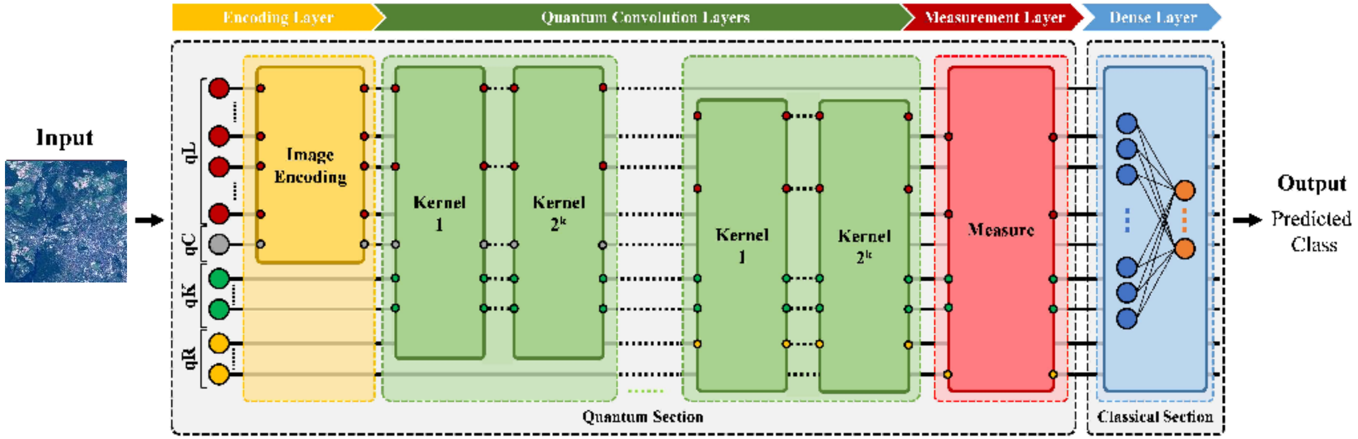


- Categories:

Label	Semantic Class	LCZ
1	Compact built-up area	1, 2, 3
2	Open built-up area	4, 5, 6
3	Large Low-rise, Heavy industry	8, 10
4	Vegetation	A, B, C, D
5	Water	G

[1] X. X. Zhu, J. Hu, C. Qiu, Y. Shi, J. Kang, L. Mou, H. Bagheri, M. H ̈aberle, Y. Hua, R. Huang, et al., “So2sat lcz42: A benchmark dataset for global local climate zones classification,”

Quantum Classical-CNN for Multispectral Data

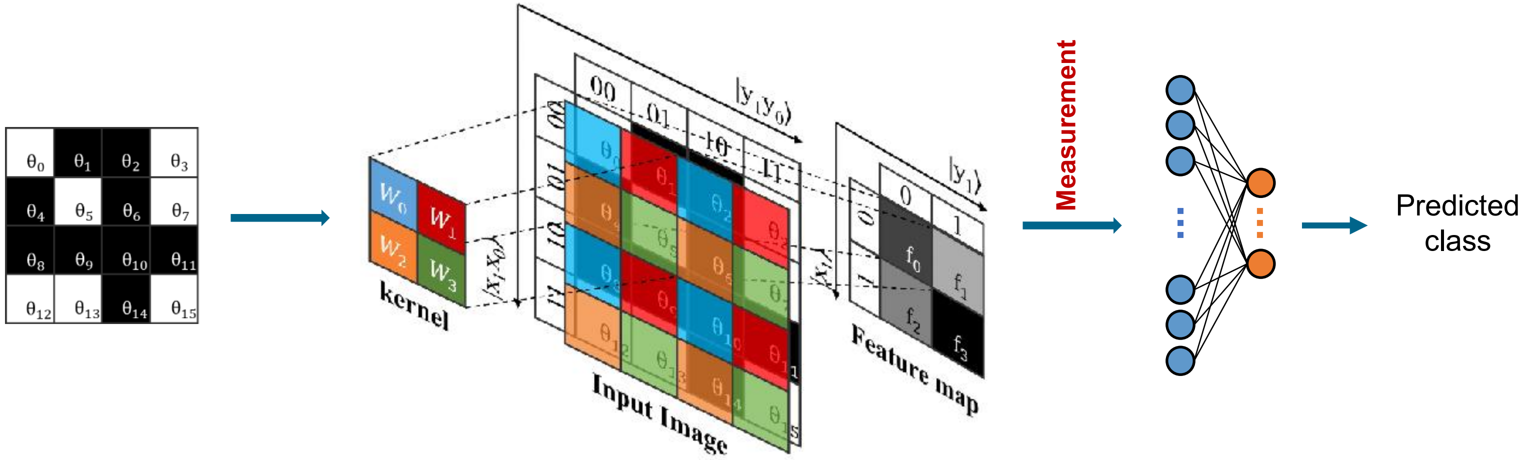


Model:

- Two quantum convolution layers and each layer applies 2 kernels
- Noiseless simulator provided by the Tensorflow Quantum platform

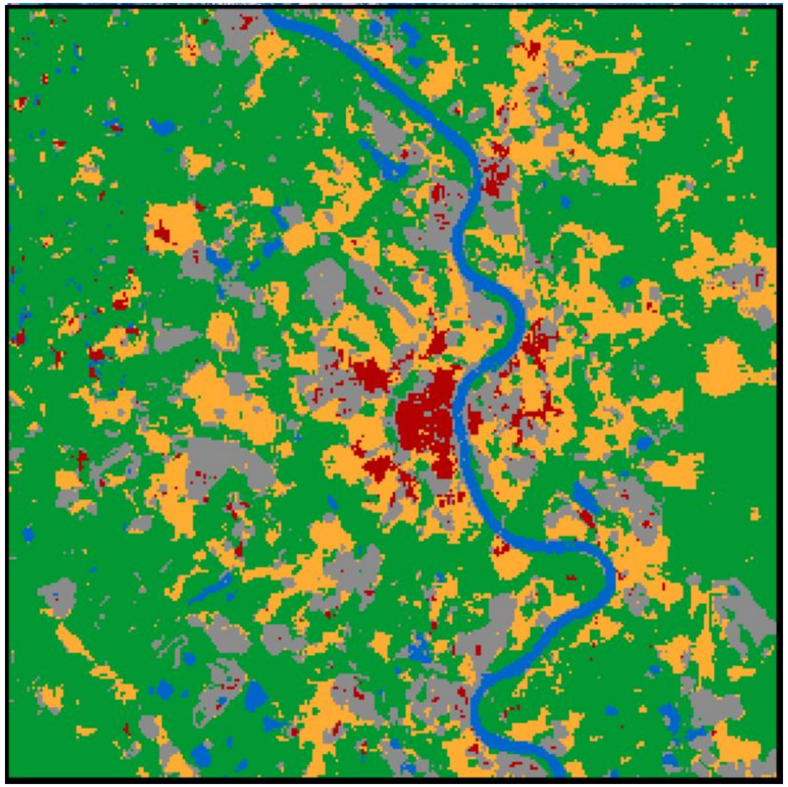
Pre-Processing:

- Reducing Input to 8x8 pixels



QML for EO (Classification)

Cologne (Pic. by Sentinel-2)



Classification

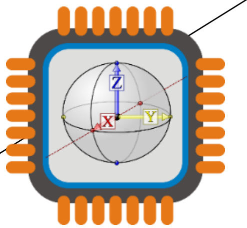
CNN (8x8)	CNN (8x10)	CNN(8x24)
QNN (8x24)	FQCNN (8x8)	MQCNN(8x8)

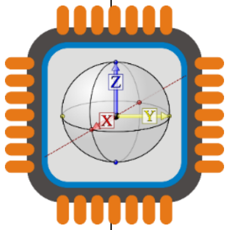
Compact built-up area | Open built-up area | Large Low-rise, Heavy industry | Vegetation | Water

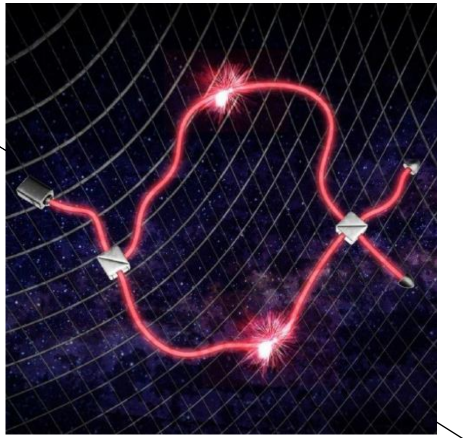
Fan, F., Shi, Y., Guggemos, T., & Zhu, X. X. (2023). Hybrid quantum-classical convolutional neural network model for image classification. *IEEE transactions on neural networks and learning systems*.

More Quantum?

EO-Data
= BigData







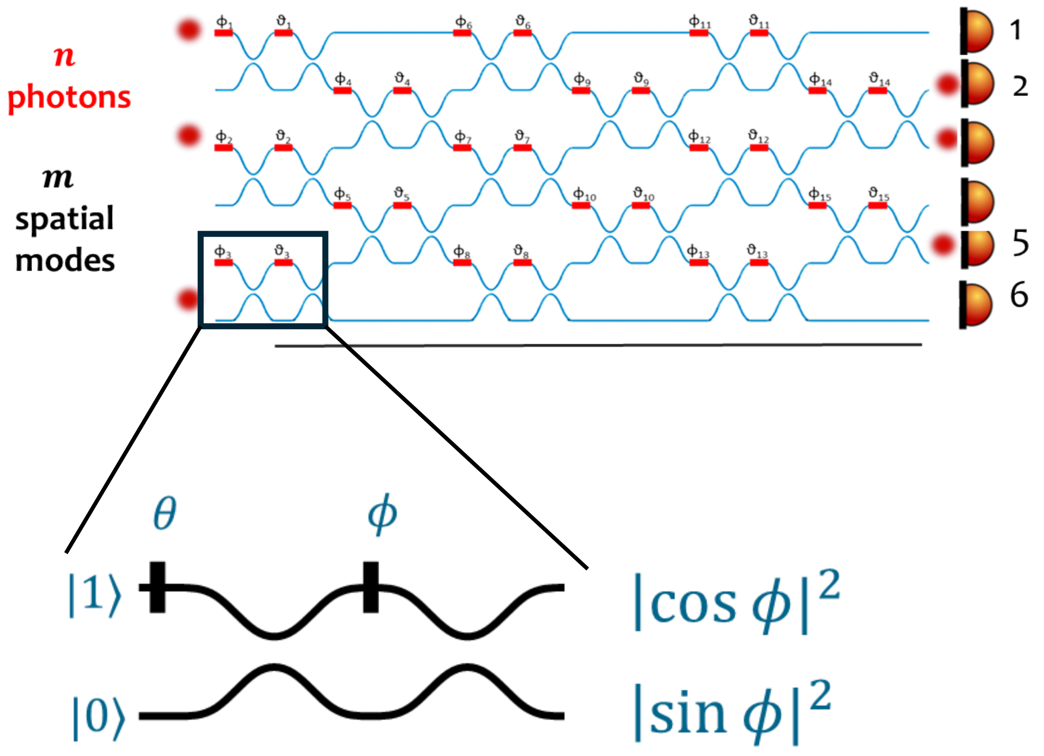
Combinatorial- and
Optimization problems

Classification and Simulation
with Machine Learning

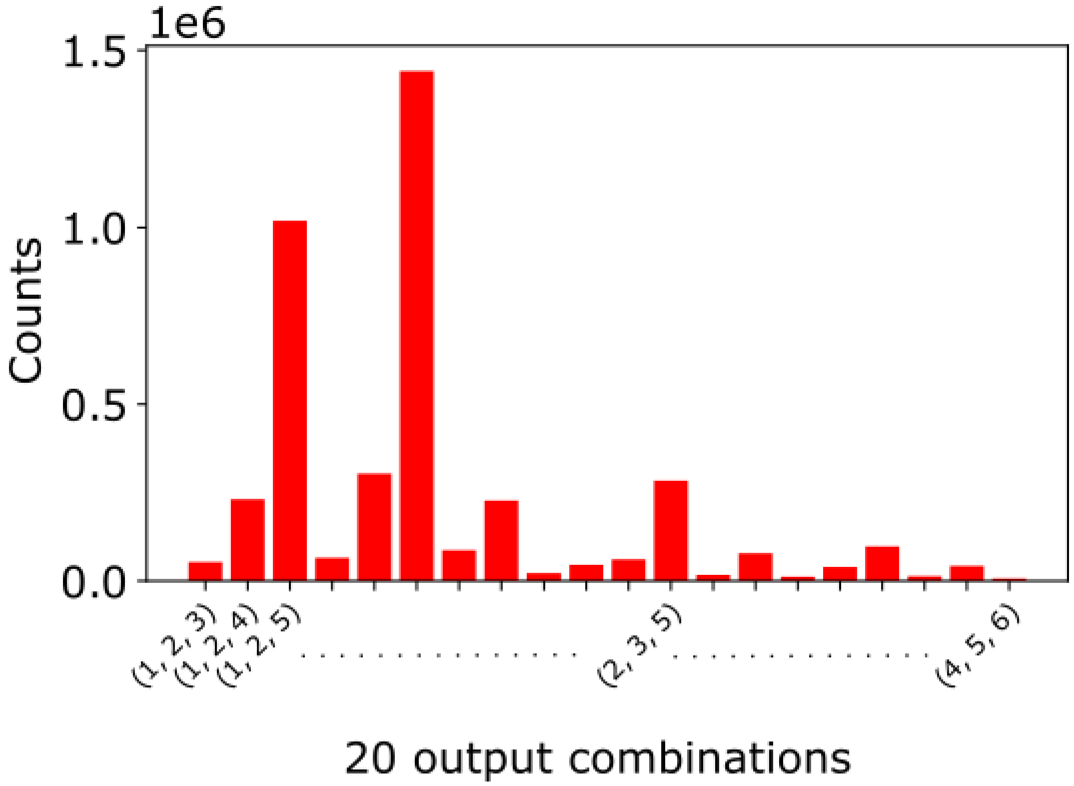
Data Encoding

How to achieve nonlinearity in quantum computing?

Data Encoding

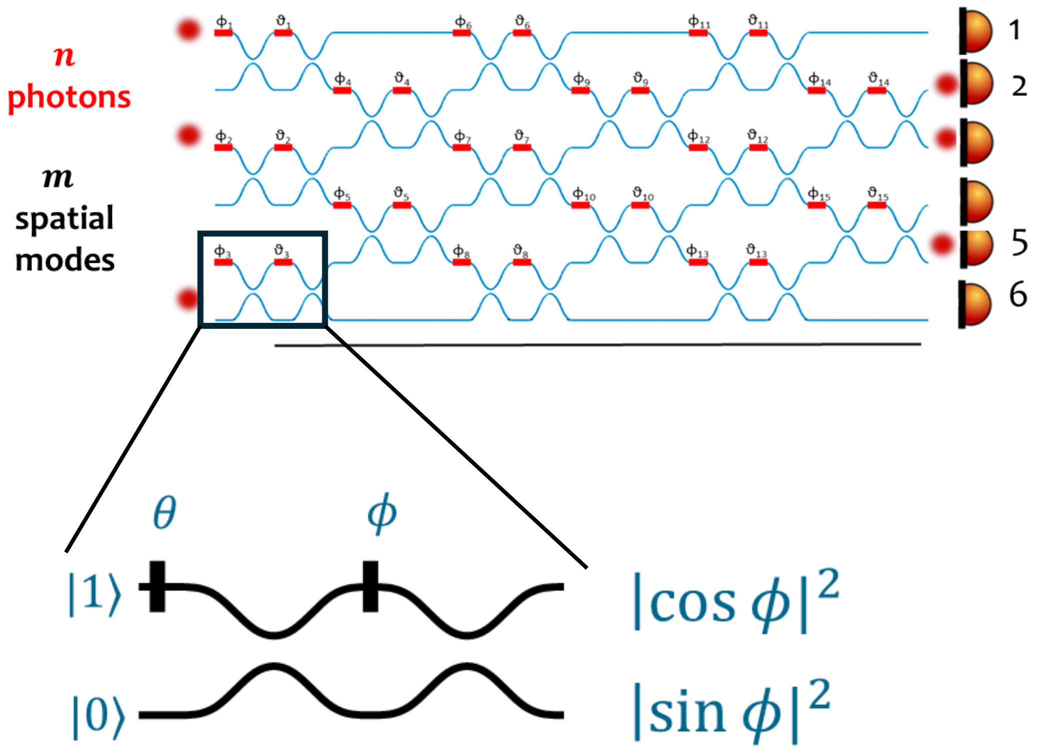


Collect statistics

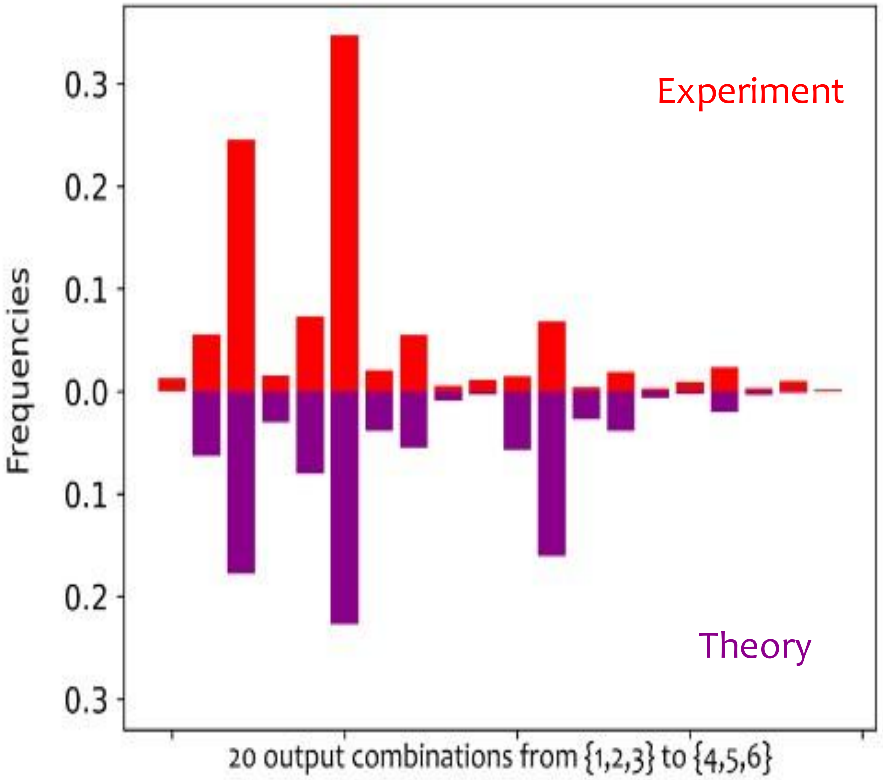


How to achieve nonlinearity in quantum computing?

Data Encoding

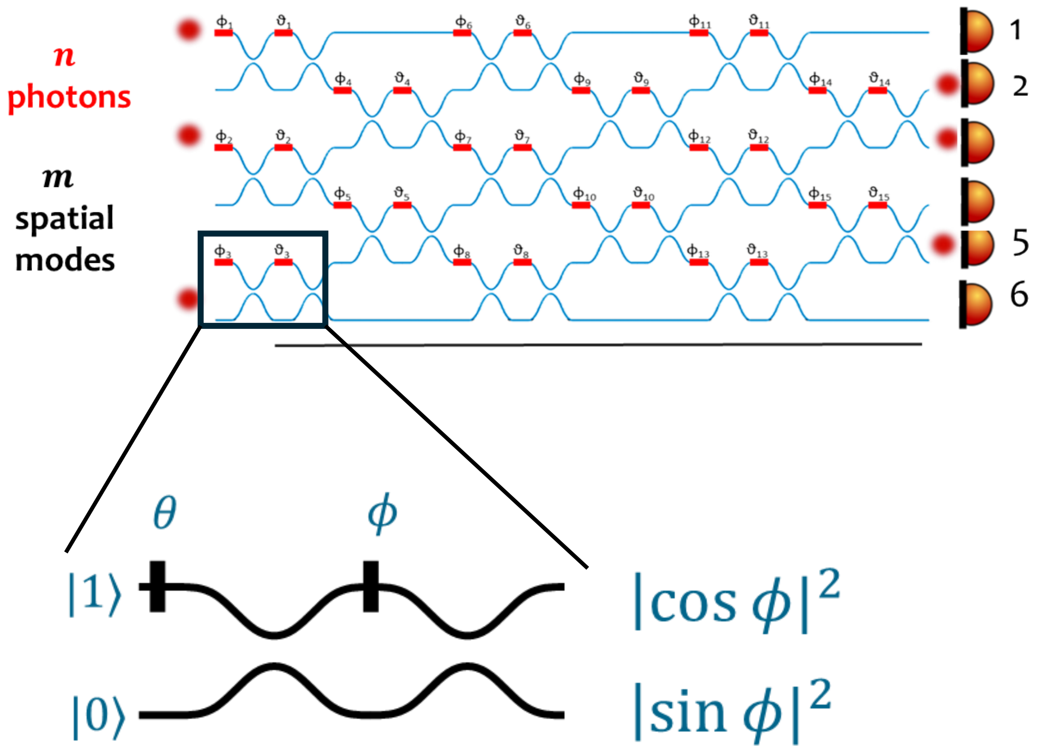


Distinguishable Photons

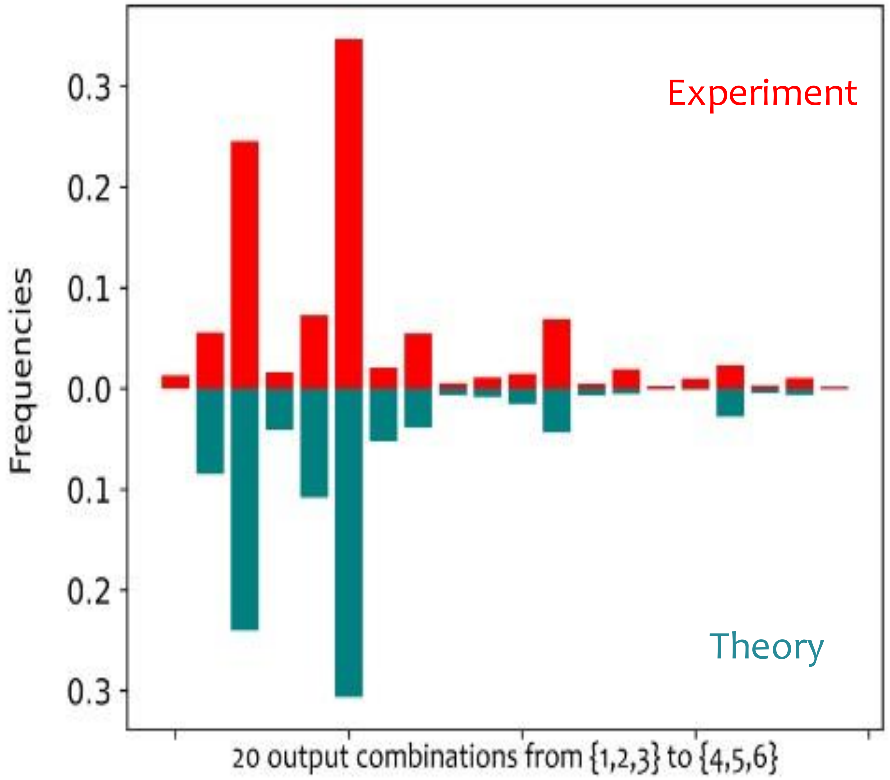


How to achieve nonlinearity in quantum computing?

Data Encoding



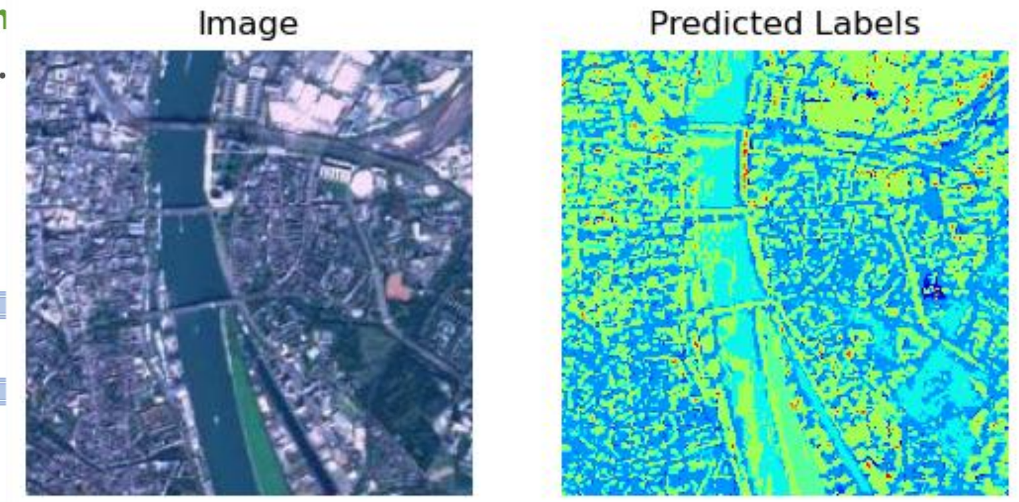
Indistinguishable Photons



Neuromorphic QC for EO

In

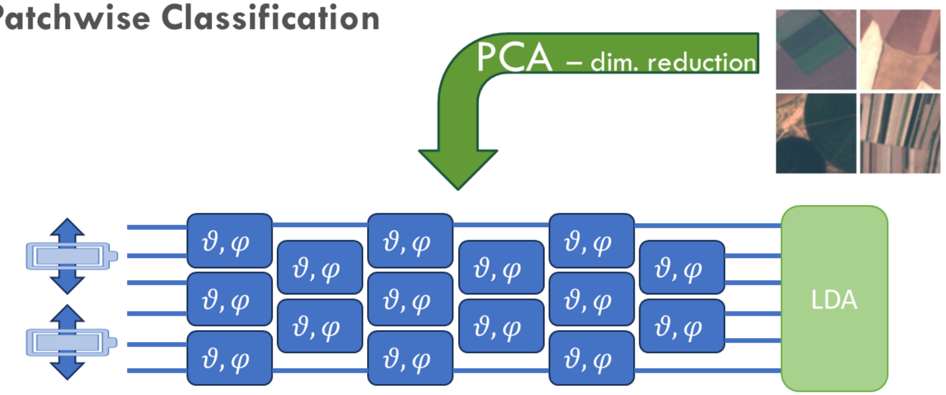
1.



Model	Train %	Test %	Train %	Test %	Train %	Test %
Linear Discriminant Analysis (LDA)	15.40	15.13	39.21	39.83	57.75	53.75
Photonic Chip + LDA	18.33	17.75	43.04	44.67	61.31	60.00

Image Classification (in Space)

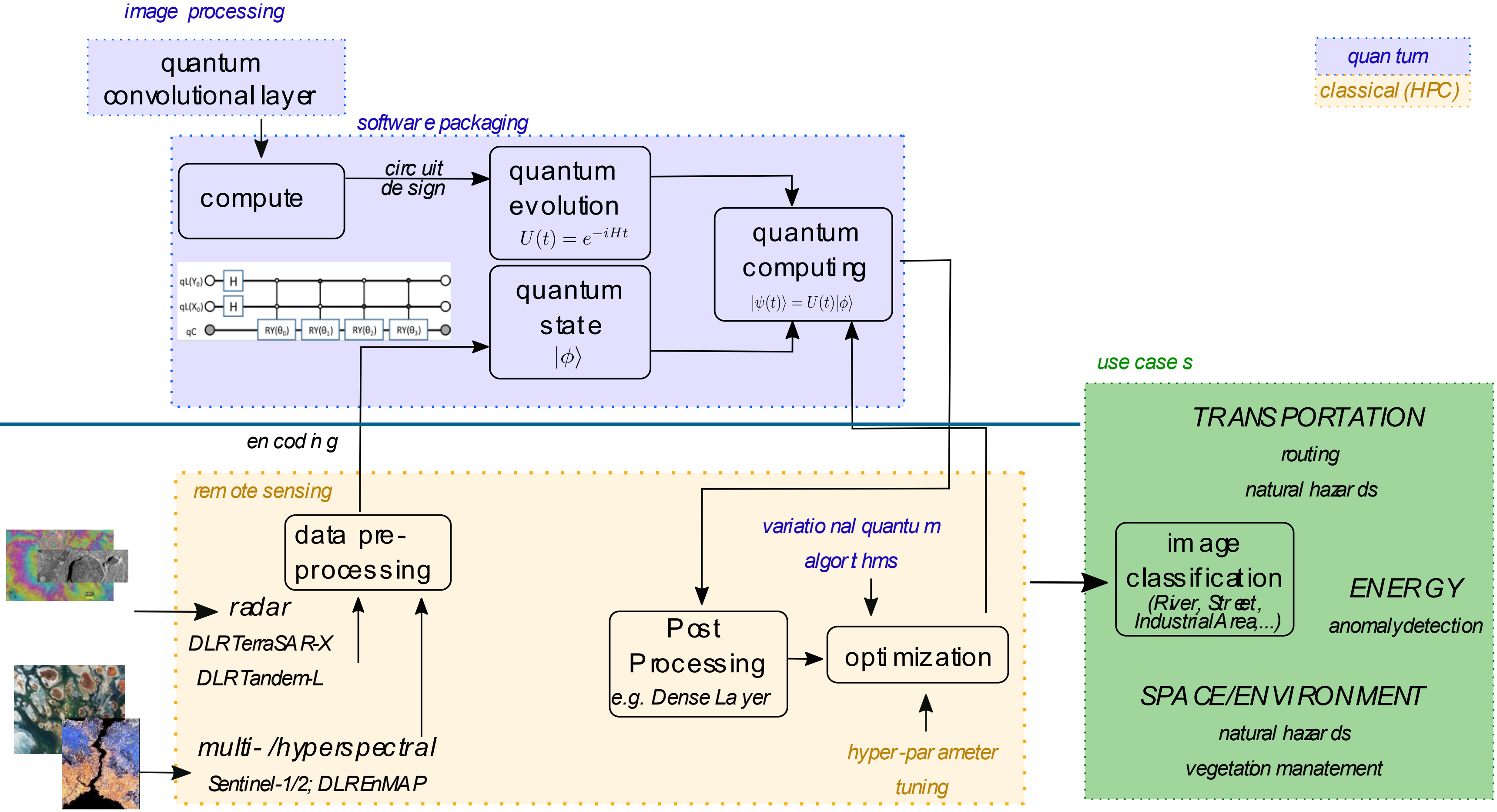
2. Patchwise Classification



Model	Train (3 feat.)	Test (3 feat.)	Train (15 feat.)	Test (15 feat.)
LDA	31.10 %	29.02 %	42.28 %	42.31 %
Photonic Chip + LDA	40.74 %	39.06 %	59.52 %	57.63 %

HPC and QC for Earth Observation
EuroQHPC-Integration

Euro-Q-EXA
EuroQCS-Spain
EuroQCS-Poland
EuroQCS-Italy
EuroQCS-France
LUMI-Q



HPC and QC for Earth Observation
Quantum Excellence Center (QEX)