CERTO
Copernicus Evolution – Research for harmonised and Transitional water Observation

A generalised algorithmic pipeline for the generation and application of optical water type clusters across a range of optical environments.

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Image courtesy of NERC Airborne Research Facility

Optical Water Type (OWT) "basics"

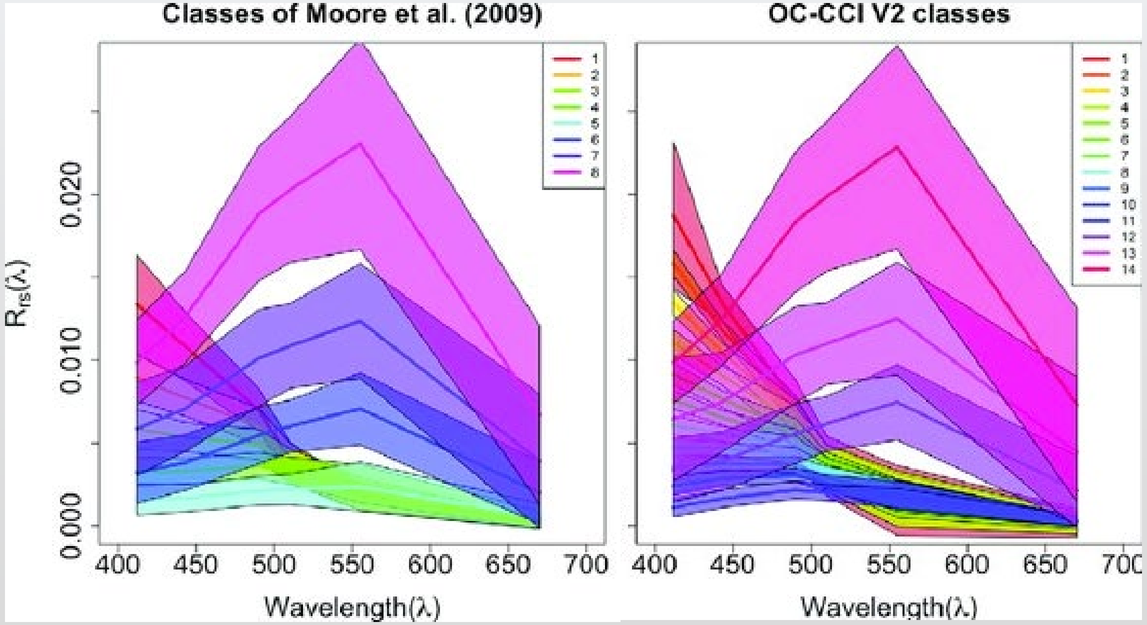
- Water colour governed by multiple optical constituents including phytoplankton, sediments, coloured dissolved matter
- Water mass mixing together and non-conservative factors (algal growth, sediment sinking) creates a continuum of potential optical properties
- Boundaries can be sharp or gradational

Sentinel-2 image, Plymouth Sound, "Enhanced True Colour"

OWT uptake and evolution

IOCCG (2000). [Adapted from Prieur and Sathyendranath (1981)]

- Binary classification of case 1/case 2 [Morel and Prieur (1977)]
- A move to a fuzzy-classification scheme across a range of waters (clustering on in-situ reflectance) (Moore et al. 2001, 2009)
- Clustering on larger satellite-derived remote-sensing reflectance dataset (Jackson et al. 2017)
- Increasingly prevalent tool within limnological and oceanographic remote sensing research.



Comparison of global ocean water types from in-situ and remote sensing derived training datasets (Jackson et al 2017)

OWT uses and growing pains

Uses of OWT include:

- algorithm blending (Moore et al. 2001, Neil et al. 2019)
- product uncertainty estimation (Jackson et al. 2017)
- data quality flagging (Wei et al. 2016)
- water quality monitoring (Uudeberg et al. 2020)
- environmental phenology (Trochta et al. 2015)

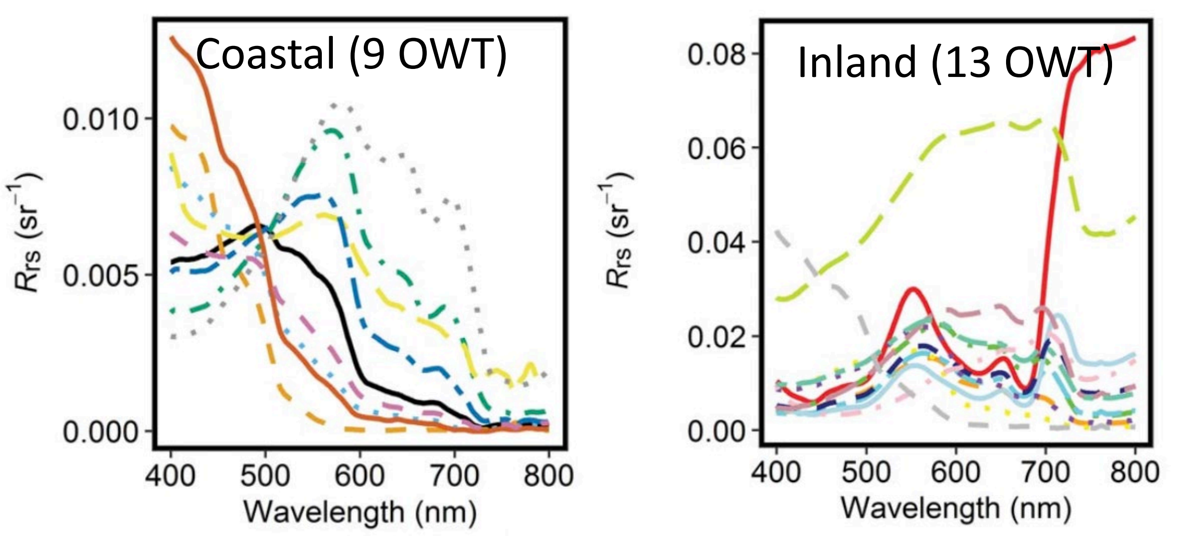
Diversity of distance metrics, data transformations and cluster optimization schemes applied at local scales [Bi et al. 2019, Botha et al. 2020, da Silva et al. 2020, Uudeberg et al. 2020]

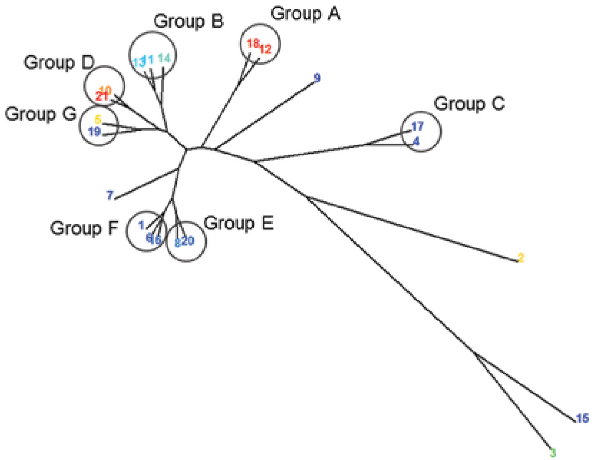
Harmonized approach to classification has yet to emerge, though unified fuzzy logic scheme suggested by Jia et al.(2021)

Fragmented nature makes comparison of OWT difficult, impeding collaboration and optimization of methods

OWT classification in hyperspectral space

- Fuzzy c-means algorithm (FCM; Bezdek, 1984) has known issues in high dimensional spaces (e.g. Winkler et al., 2010)
- In-situ hyperspectral k-means (Spyrakos et al., 2017)
- Chl algorithm development within distinct OWT clusters prior to blending improves Chl retrievals on global scale (Neil et al., 2019)
    - Performance improvement of 25%





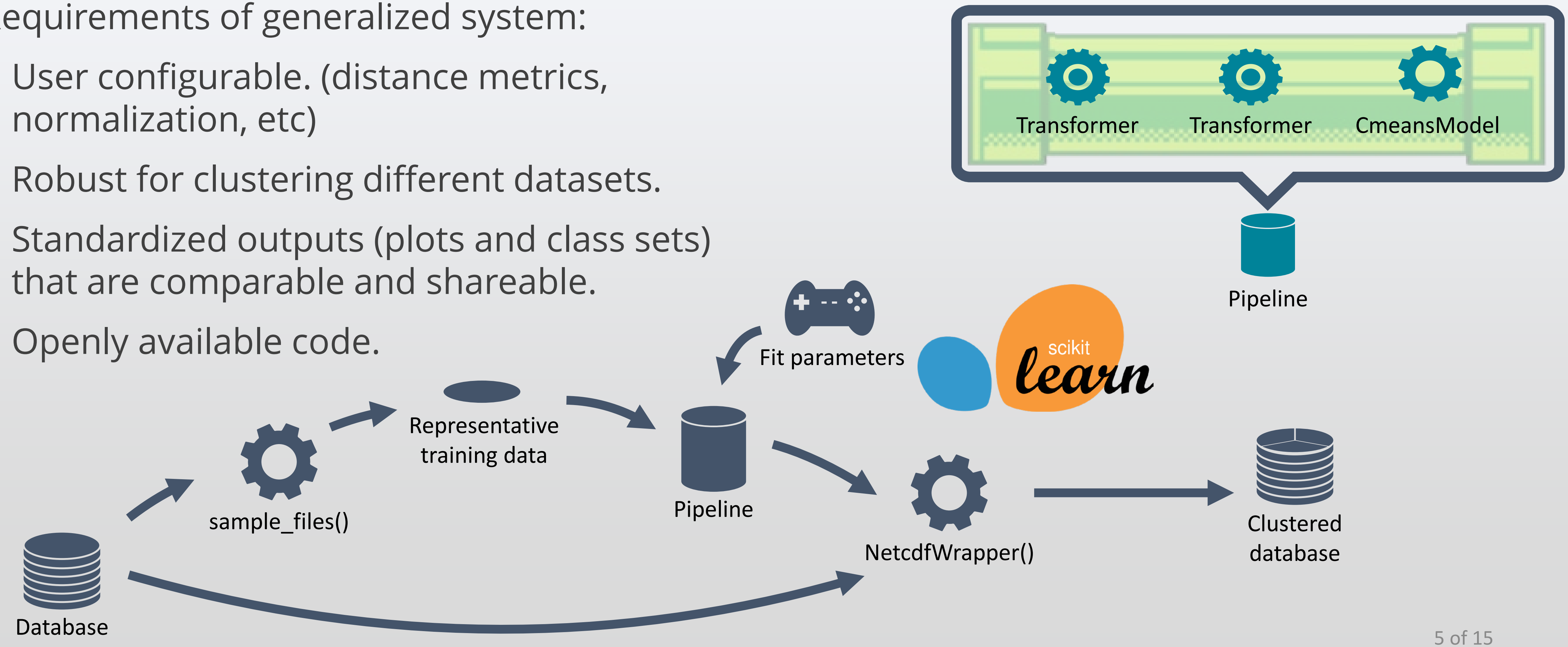
Phylogentic tree similarity
2nd derivatives cluster means, L2 norm distances

➢ seven major groups

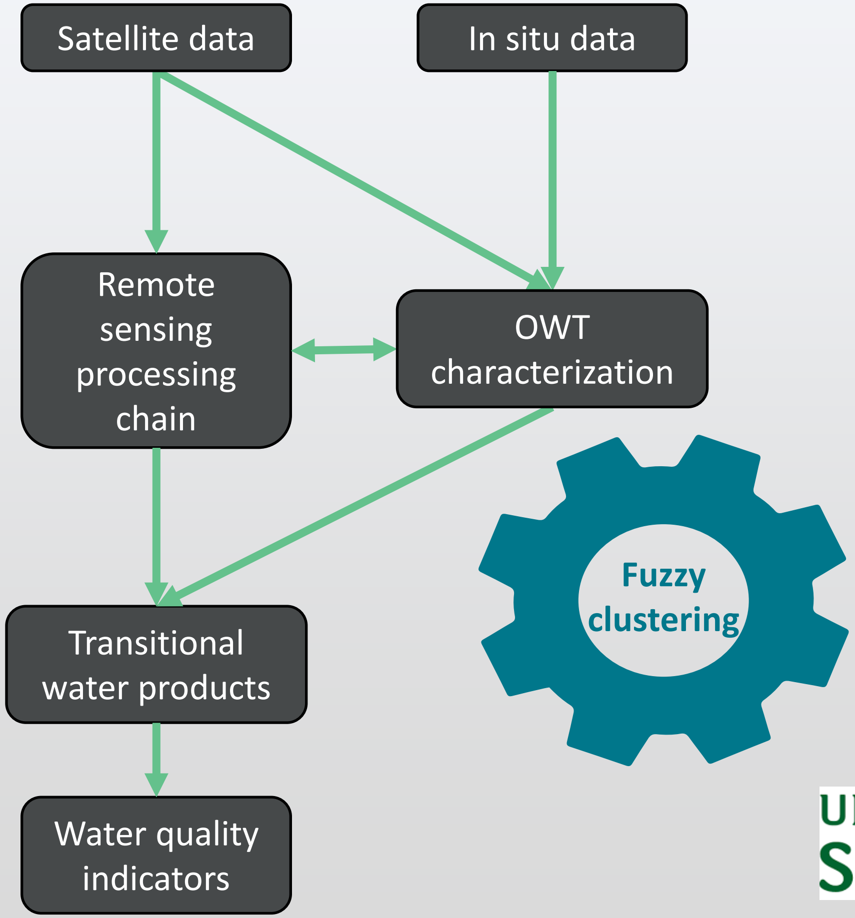
A generalised system for creation and application

Requirements of generalized system:

- User configurable. (distance metrics, normalization, etc)
- Robust for clustering different datasets.
- Standardized outputs (plots and class sets) that are comparable and shareable.
- Openly available code.



Developments within CERTO project

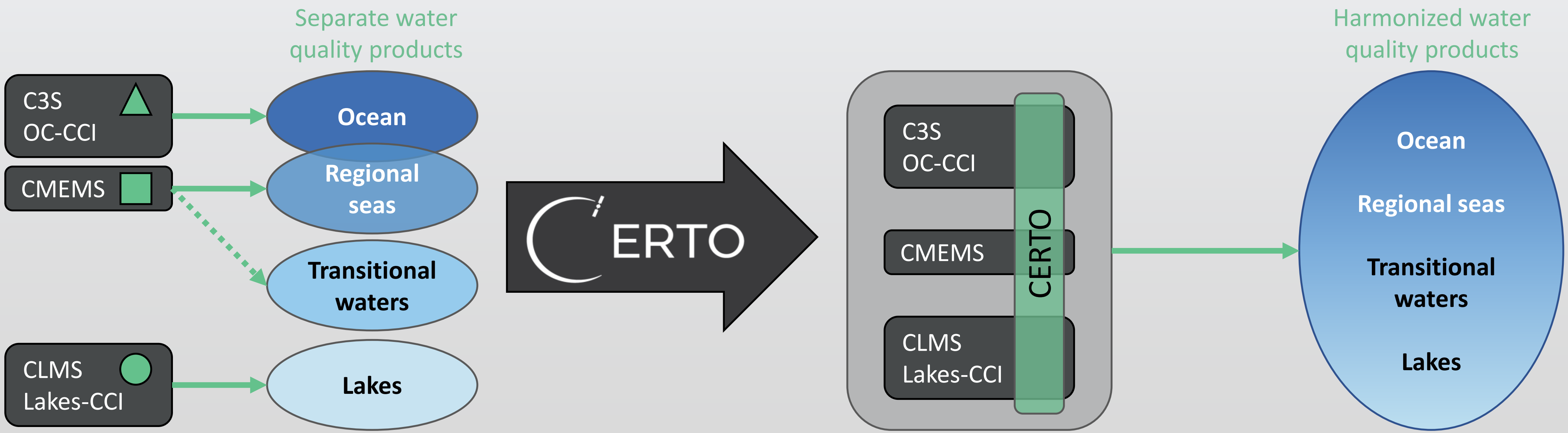


Creation of Fuzzy clustering module built to plug into ocean color research & operational processing chains:

- **Creation of clusters.** Within CERTO we are using the package to create regional pan-regional cluster sets for investigation.
- **Application of clusters.** Remotely sensed spectral datasets processed to create timeseries remote sensing datasets of OWT fields.

Developments within CERTO project

Draw on the experience and work for OC-CCI, Lakes-CCI, CMEMS, C3S and CLMS to apply the same approaches and techniques for all 'water' regions.



CERTO study sites

Six diverse transitional waters

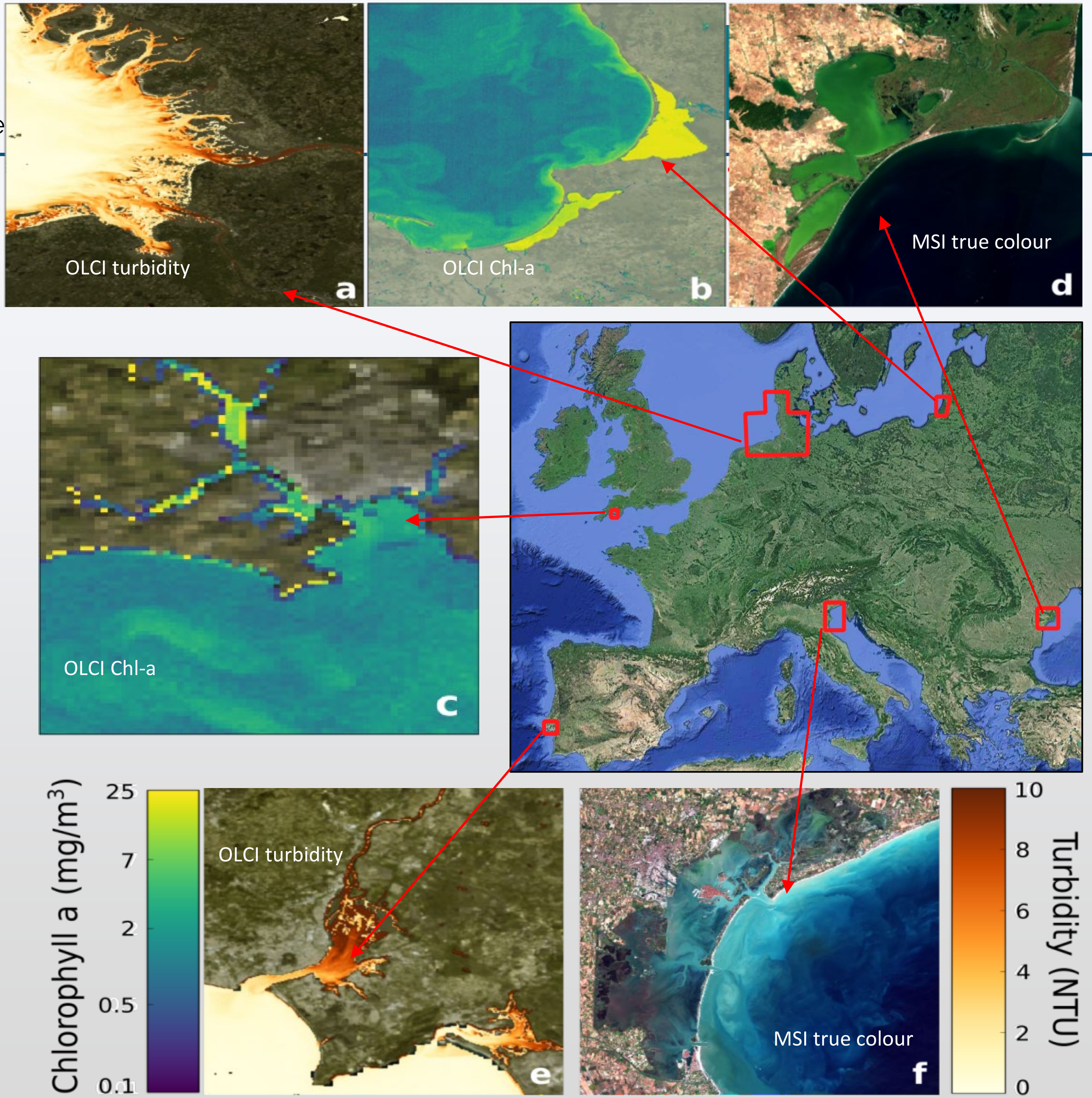
- 3 estuaries: (a) Elbe, DE; (c) Plymouth Sound, UK; (e) Tagus, PT
- 3 lagoons: (b) Curonian, LI; (d) Danube Delta, RO; (f) Venice, IT

Full suite of in-situ parameters

- Chl-a, TSM, R_{rs}, PABs, CDOM, AOT, Z_{SD}

Earth observation datasets

- Sentinel-2 MSI
- Sentinel-3 OLCI
- Nov. 2016 – present
- POLYMER atmospheric correction and IDEPIX masking
- Weighted distance to land sampling



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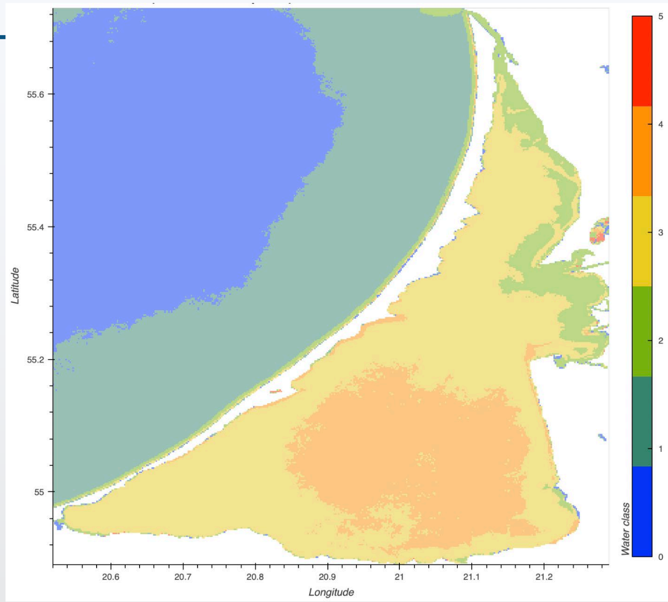
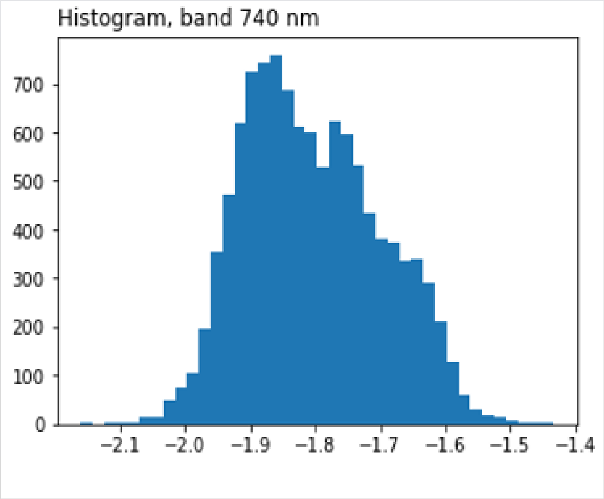
Example of regional OWT: Curonian Lagoon

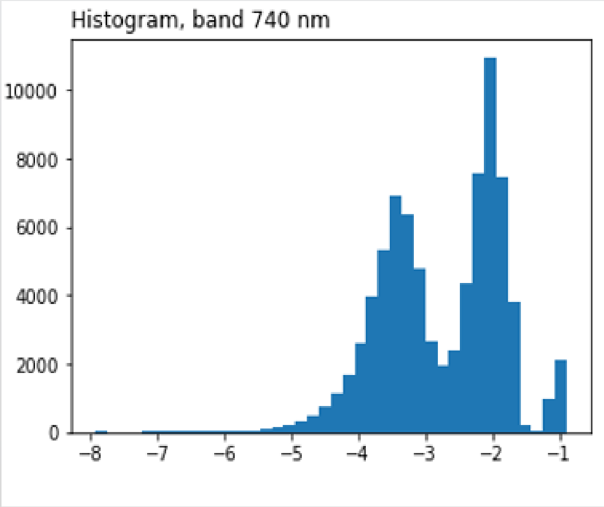
- Spectra transformed [additive shift, log transform, principal component analysis (PCA)]
- Cluster center optimization using Euclidian distance in PCA-space
- Grid search over variety of cluster center (c) and fuzziness factor (m)

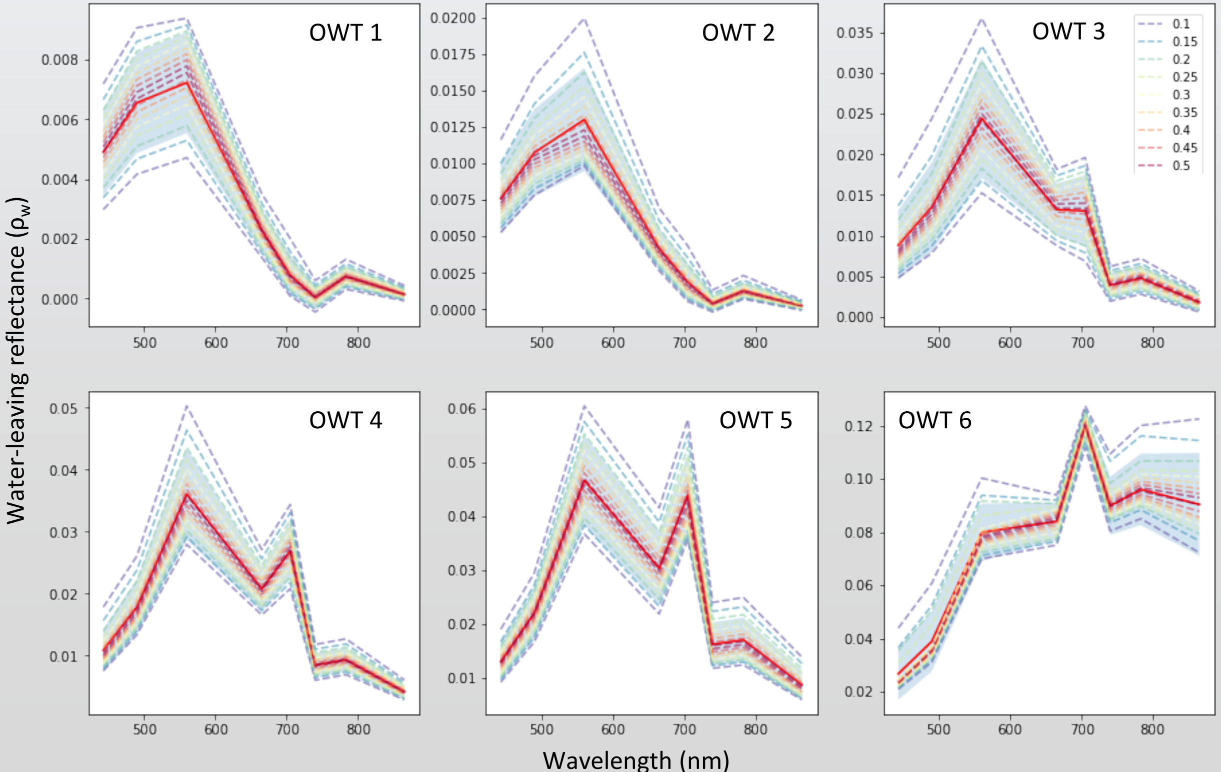


Cluster data (OWT 5)

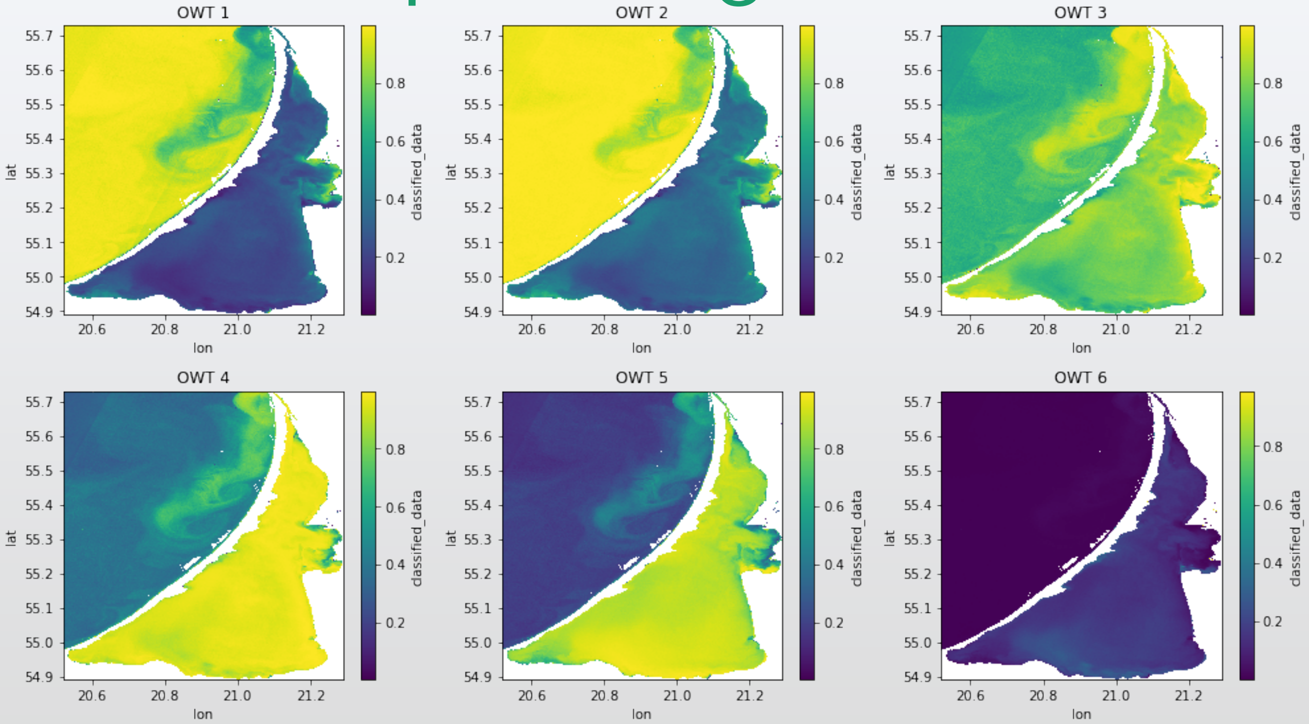


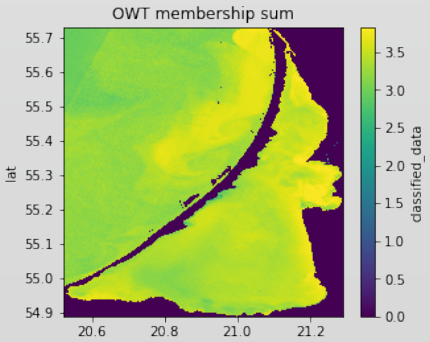
Training data





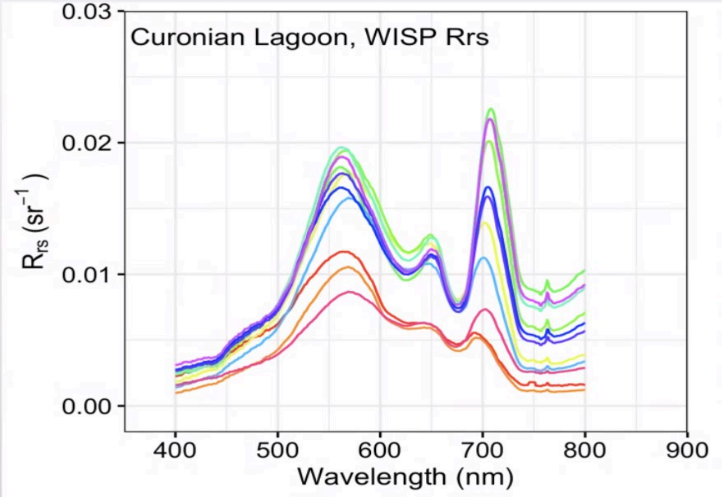
Example of regional OWT: Curonian Lagoon

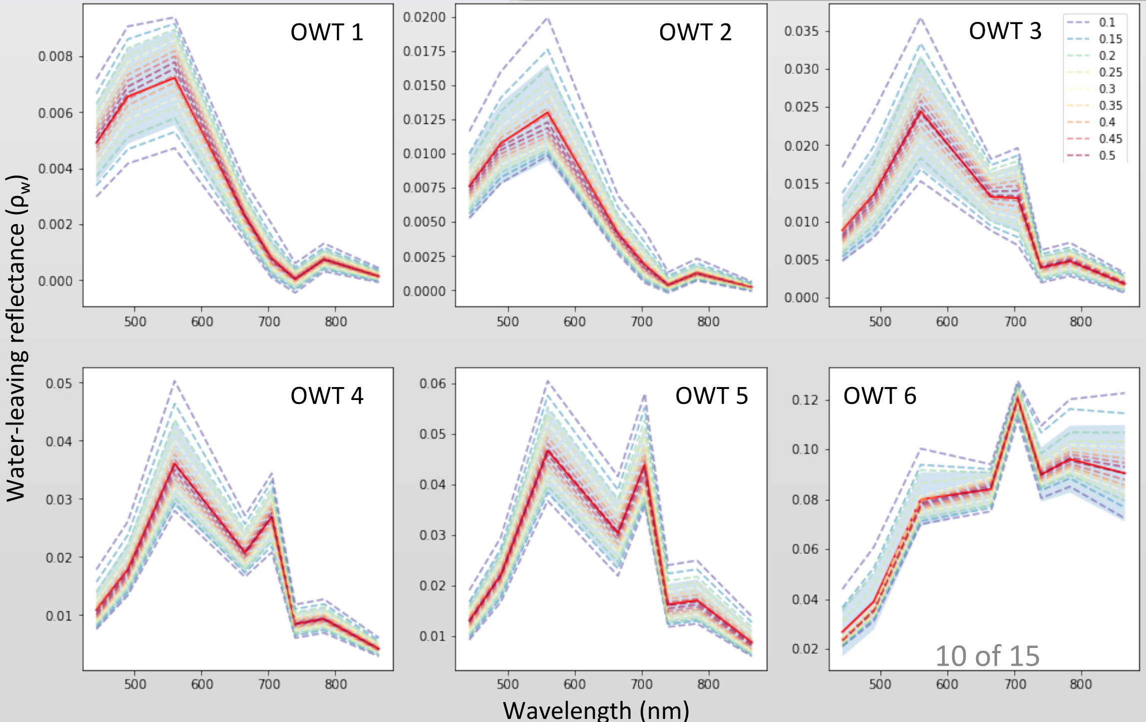




OWT 1-6 spatial distribution, membership sum

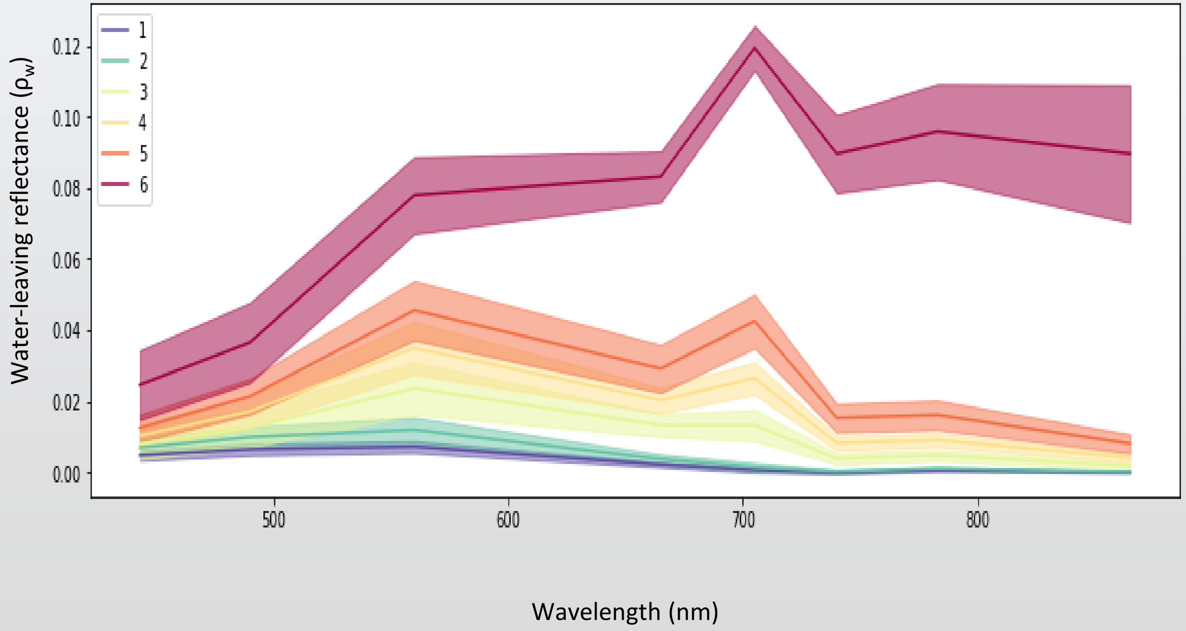
In-situ reflectance



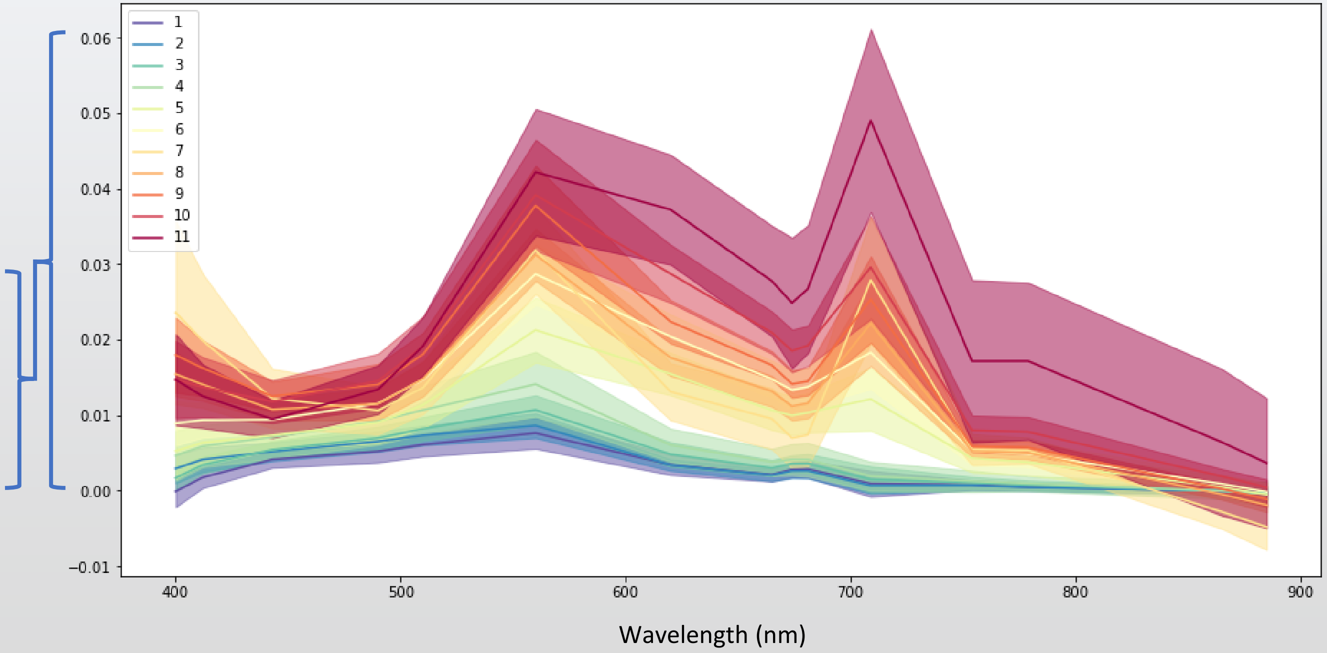


Differences OWT based on MR vs HR data

MSI



OLCI



- Greater spectral resolution results in increase in number of clusters (more independent spectral features)
- We also see significantly different NIR ranges between sensors.

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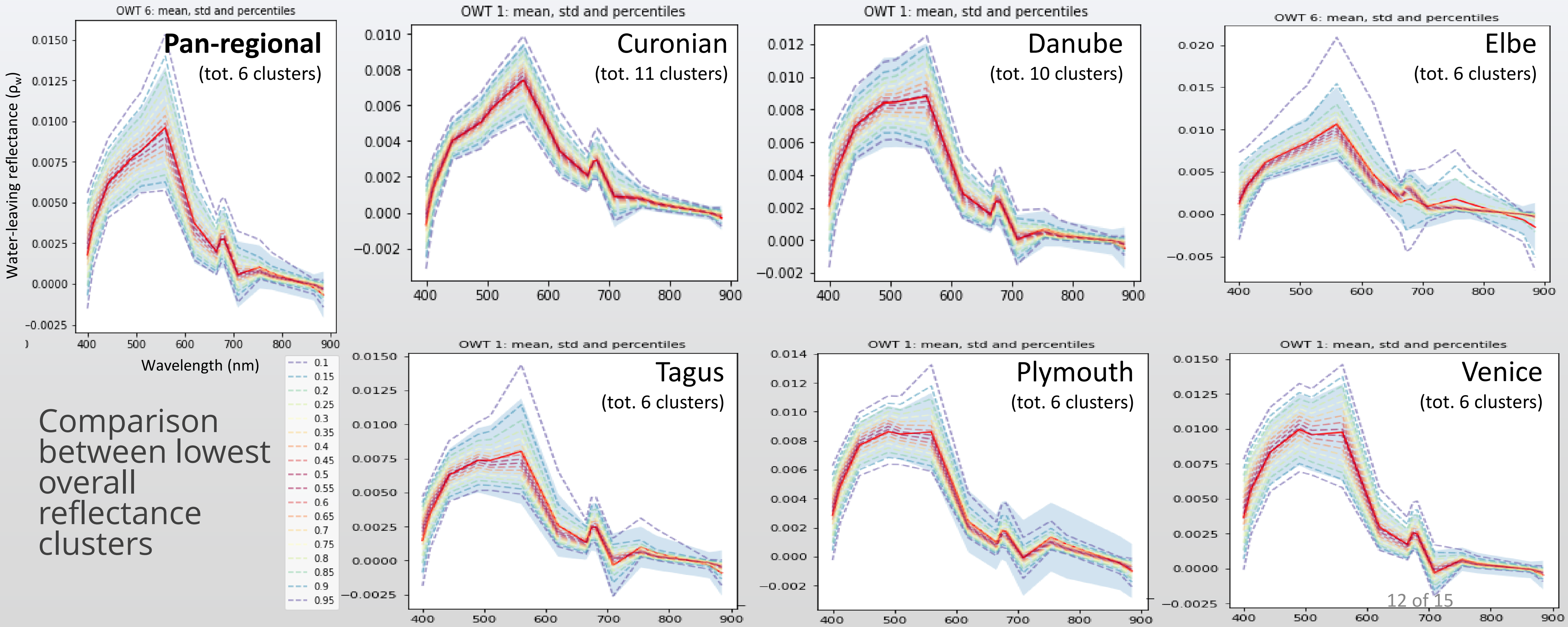
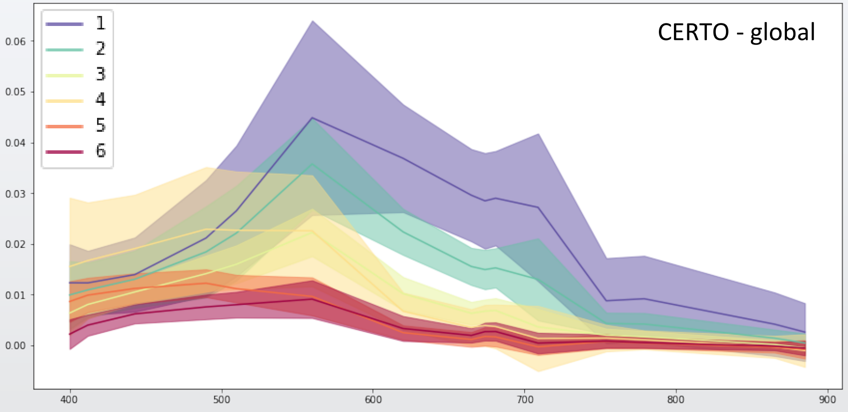
PML Plymouth Marine Laboratory

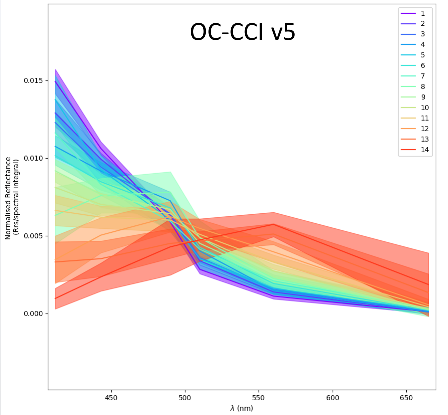
Comparing OWT sets: CERTO OLCI example



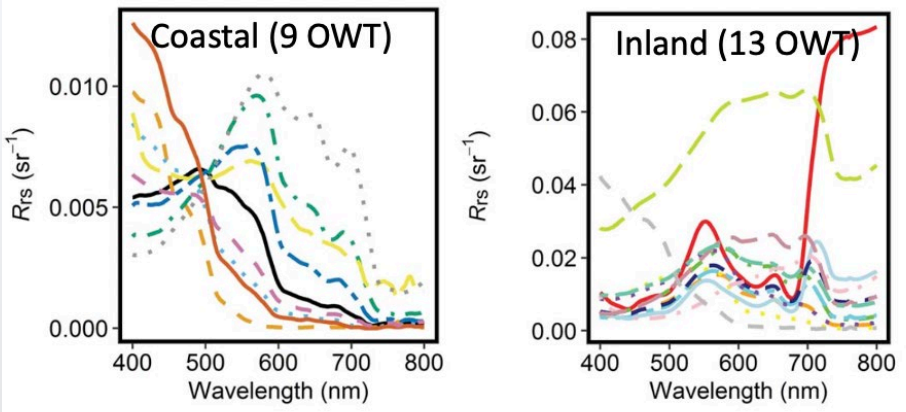
Comparison between lowest overall reflectance clusters

Comparing OWT sets

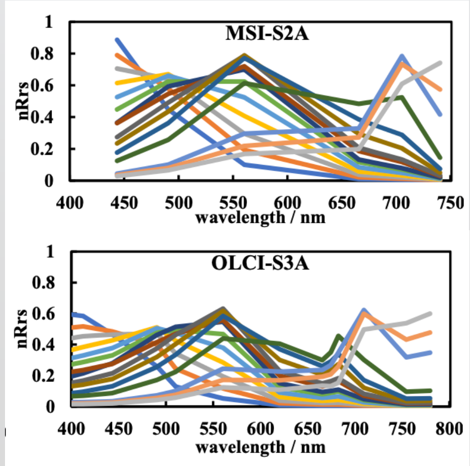




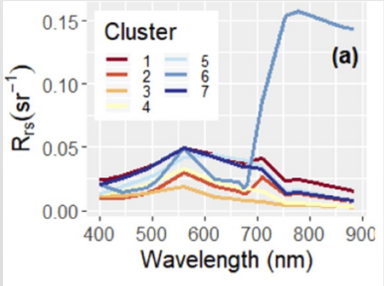
Spyrakos et al., 2017



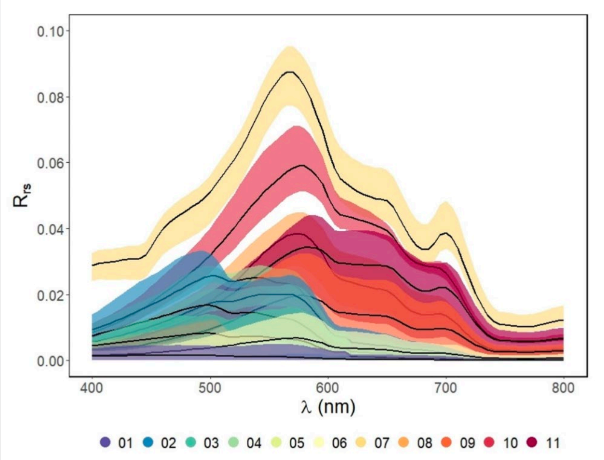
Jia et al., 2021



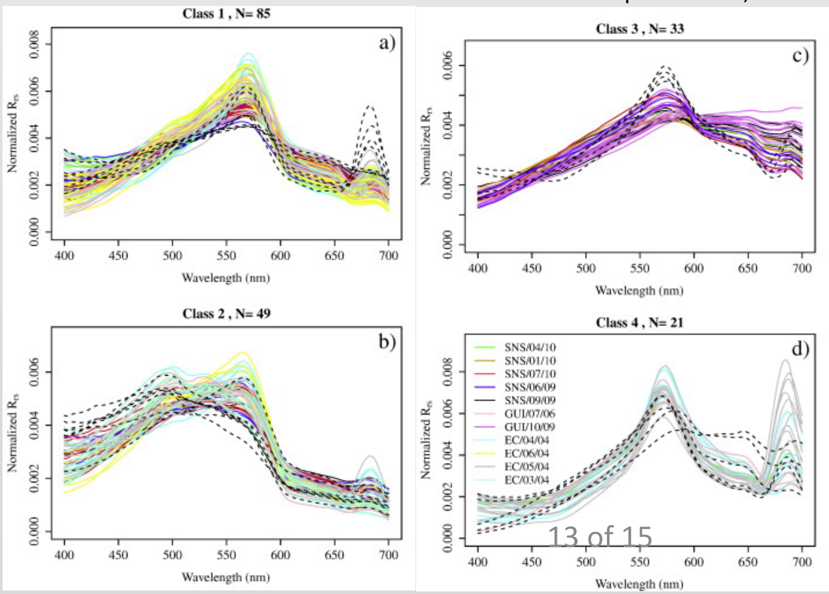
Bi et al., 2019



Botha et al., 2020



Vantrepotte et al., 2012

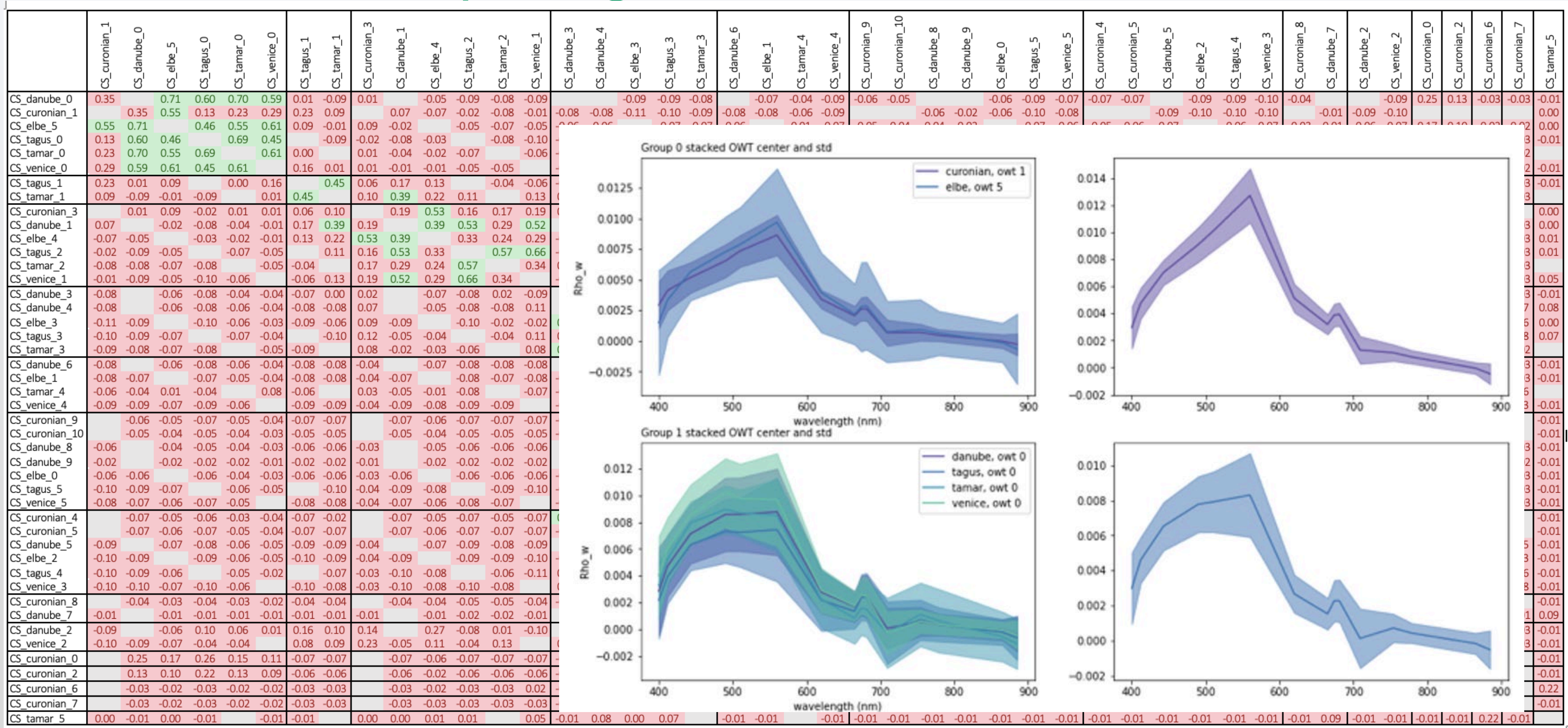


- Difficult to compare, similarity metric needed

Comparing OWT sets

Use Adjusted Rand Index to compare cluster centers between sets and find equivalences and 'unique' clusters.

Subgroups were averaged and used to initialise semi-supervised final pan-regional clustering.



Conclusions

- Single package for use with multiple datasets.
- User configurable for testing with variable fuzziness, distance metrics, performance metrics available.
- Implemented in regional and pan-regional modes within CERTO.
- Advice given to CERTO field campaigns for sampling strategy design.
- Next steps:
    - Testing with a forward look to hyperspectral sensors.
    - Refining similarity metric for comparing clustering outputs.
    - CERTO algorithm round robins across OWT sets.
    - Share and discuss with the community.
    - Take up through other projects such as DOORS.

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