



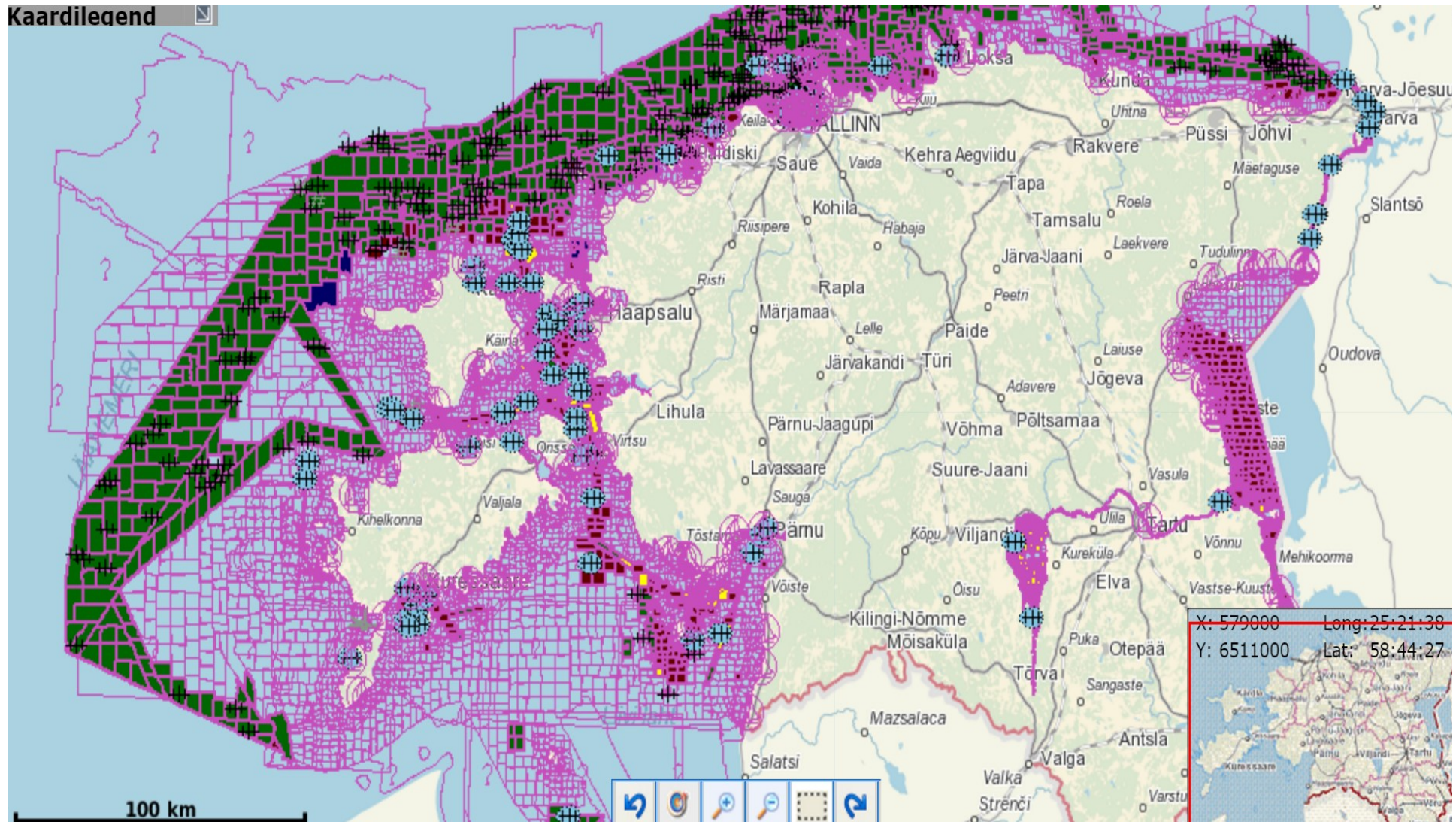
Physics based methods in satellite derived bathymetry

Tiit Kutser

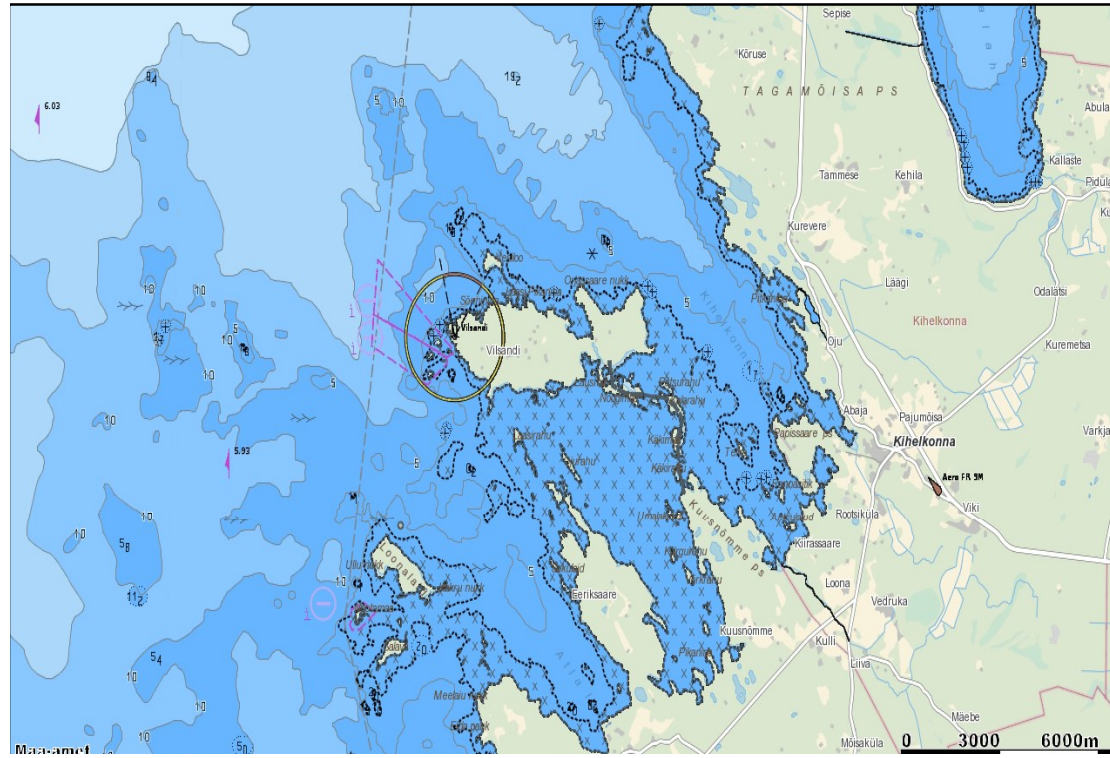
Estonian Marine Institute



Estonian coastal waters mapped with sonar



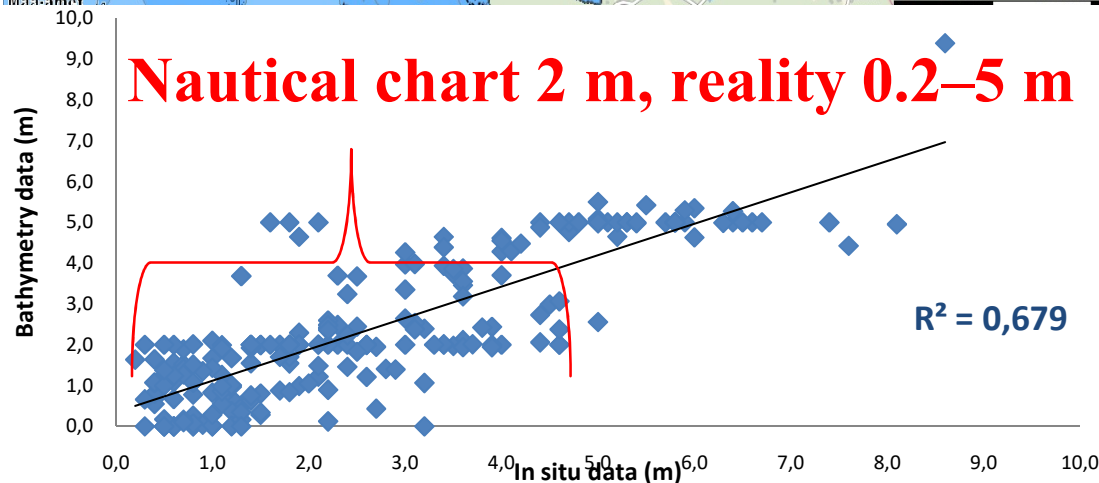
Nautical charts in Estonia



* Very shallow areas mapped before 1953

* A single storm and ice can change bathymetry

* Large areas inaccessible by hydrographic ships



SDB

```
graph TD; SDB[SDB] --> Empirical[Empirical methods]; SDB --> Physics[Physics based methods];
```

Empirical methods

Band ratios and their combinations

Physics based methods

Use full reflectance spectra and models

- * **SAMBUCA, BOMBER**
- Lee et al. inversion type**
- * **Spectral libraries (LUT)**
- with methods like SAM**
- * **Neural Networks**
- * **Machine learning**

SDB

```
graph TD; SDB[SDB] --> Empirical[Empirical methods]; SDB --> Physics[Physics based methods];
```

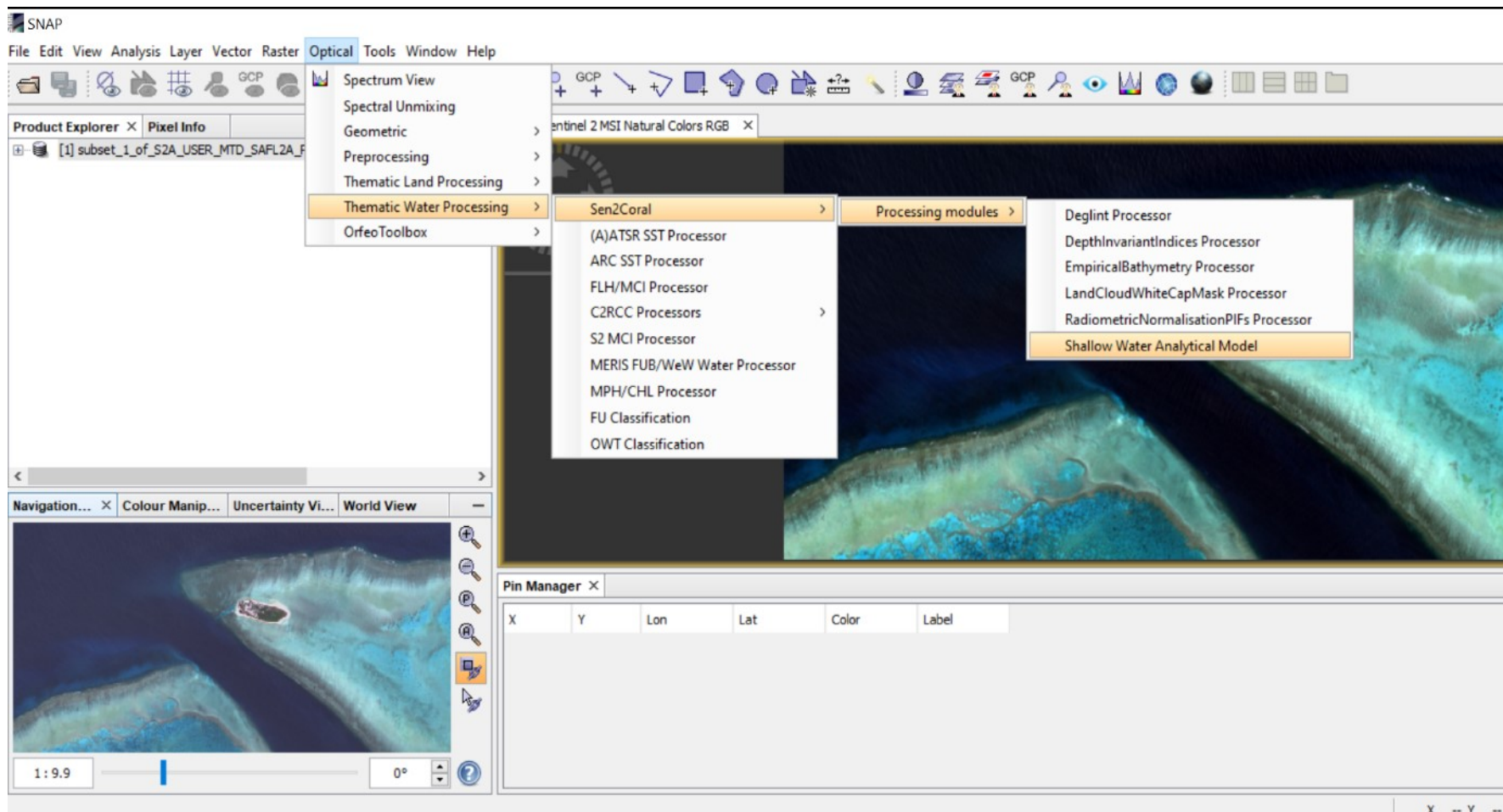
Empirical methods

- + computationally fast
- Either bottom reflectance or depth has to be known to estimate the other parameter
- Instrument specific
- Lots of *in situ* data needed

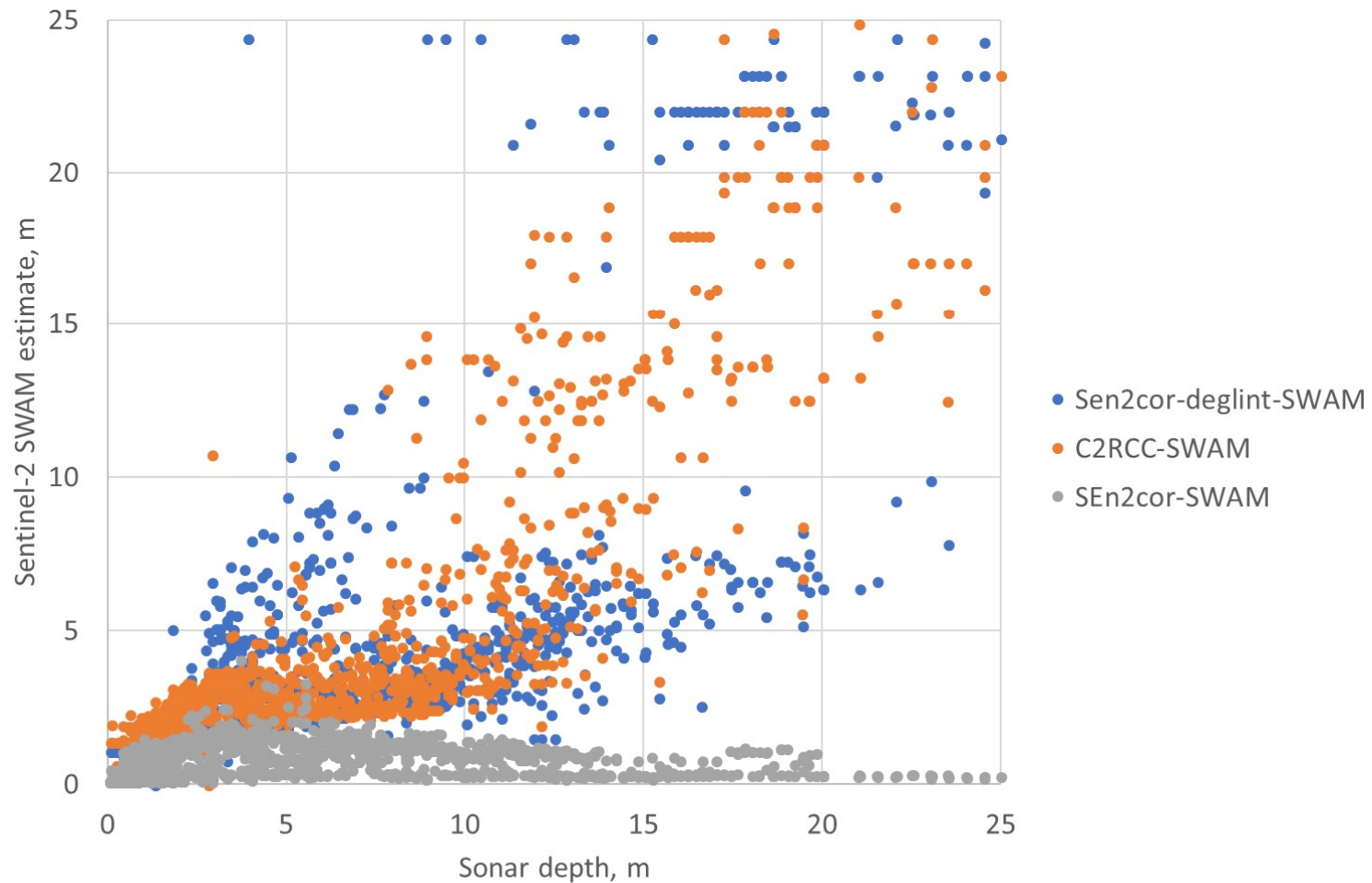
Physics based methods

- Many methods are slow
- + Depth and bottom type retrieved simultaneously
- + Universal from sensor point of view
- + No *in situ* data needed after optical properties for the model are defined

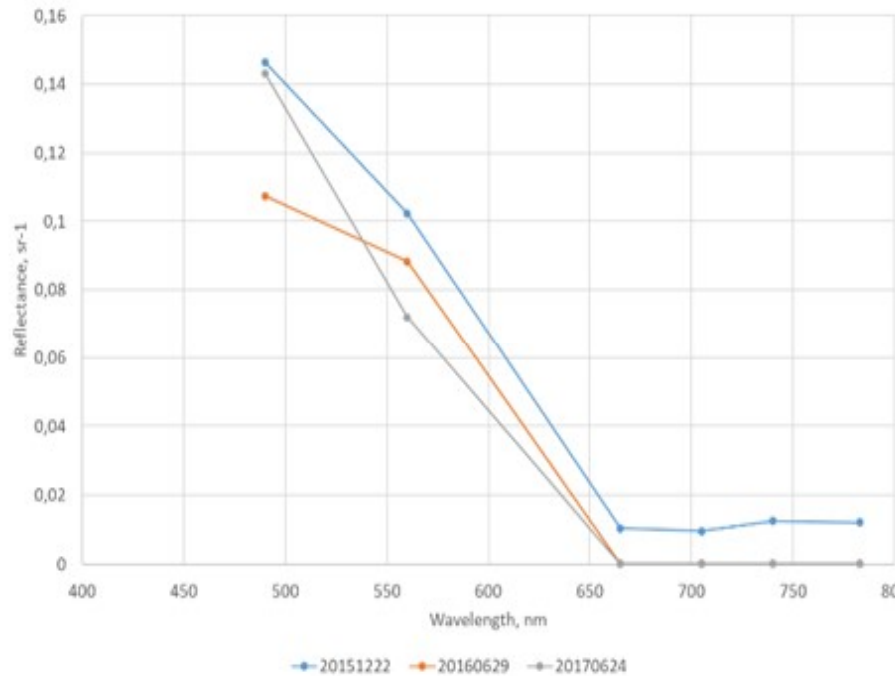
Depth Invariant Indices and SWAM available in SNAP



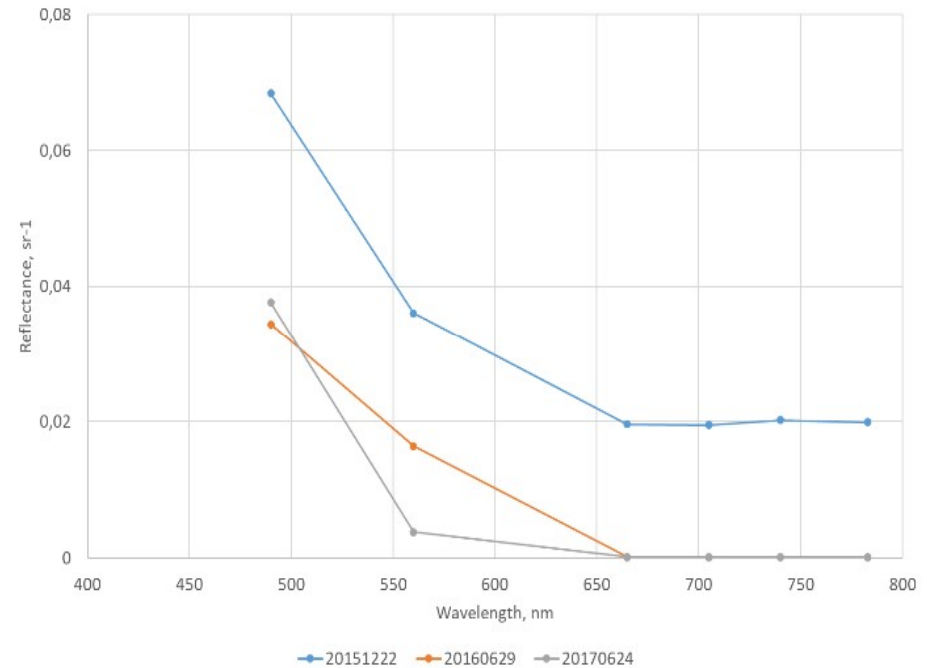
Analytical methods very sensitive to image quality



Glint and residual signal Sen2cor atmospheric correction

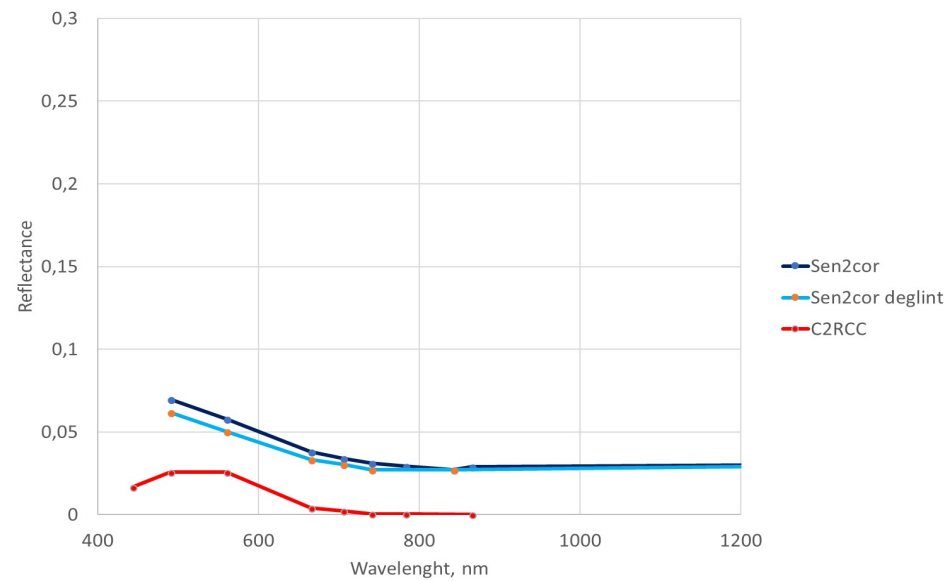
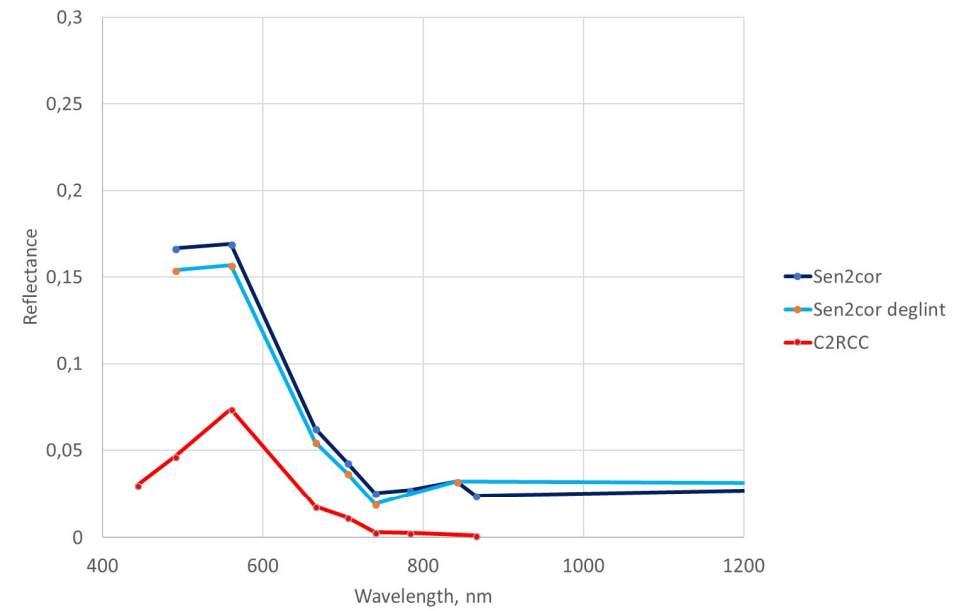
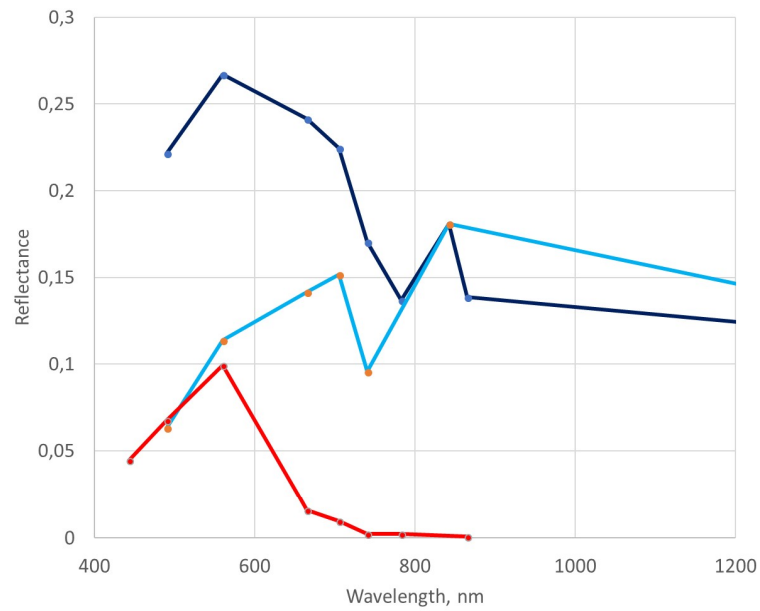


**Bright sand in few meter
deep water**

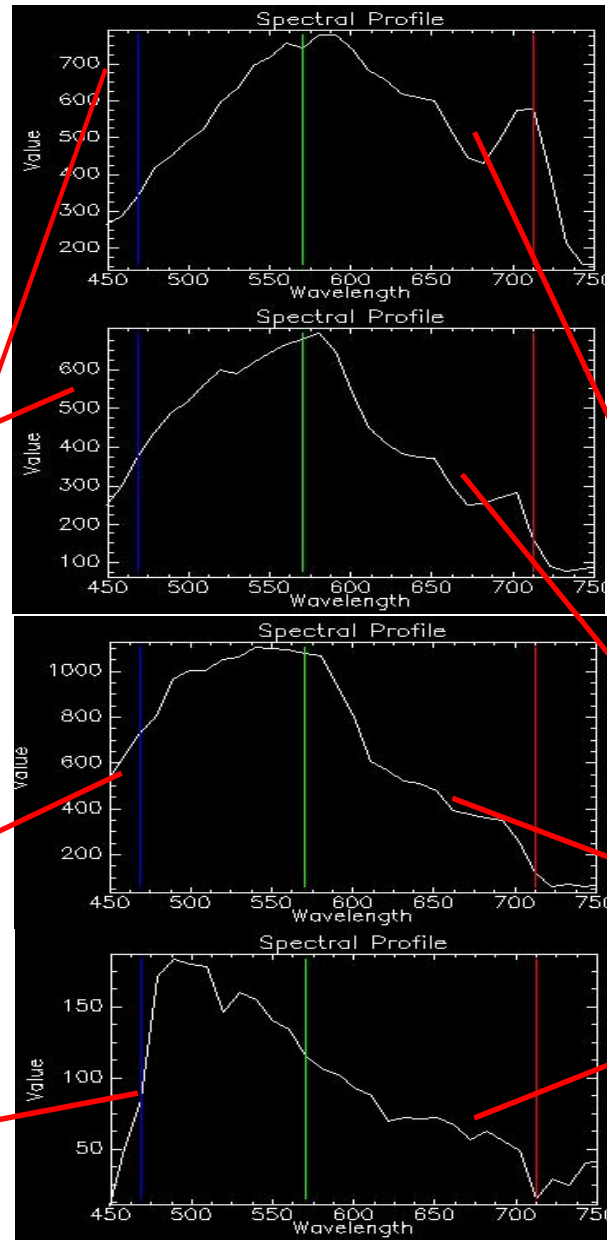
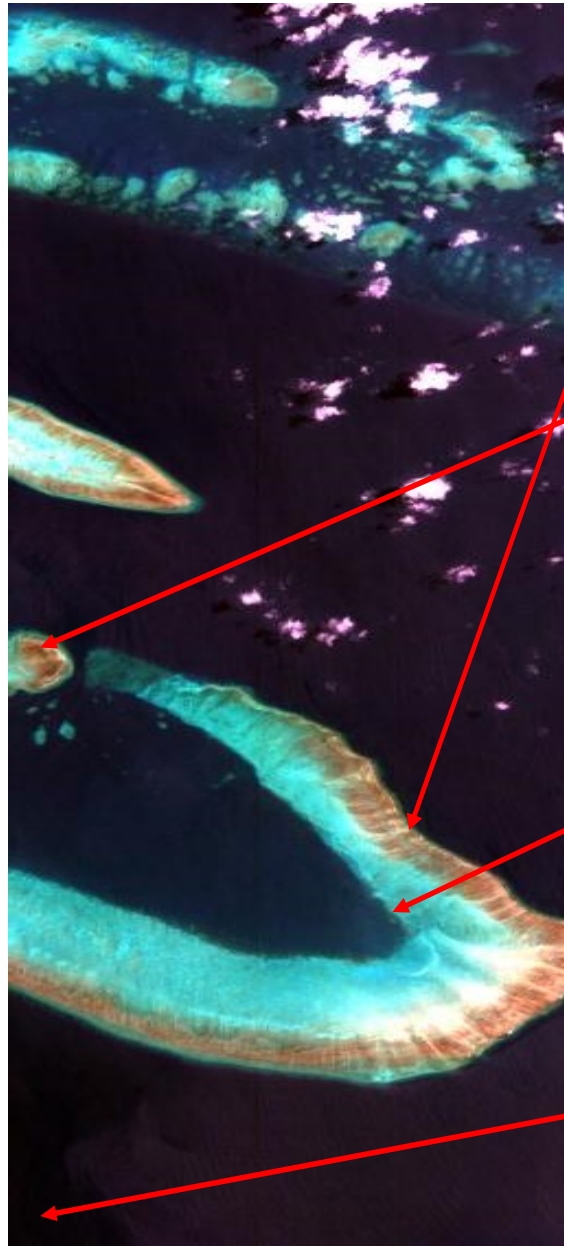


Deep water

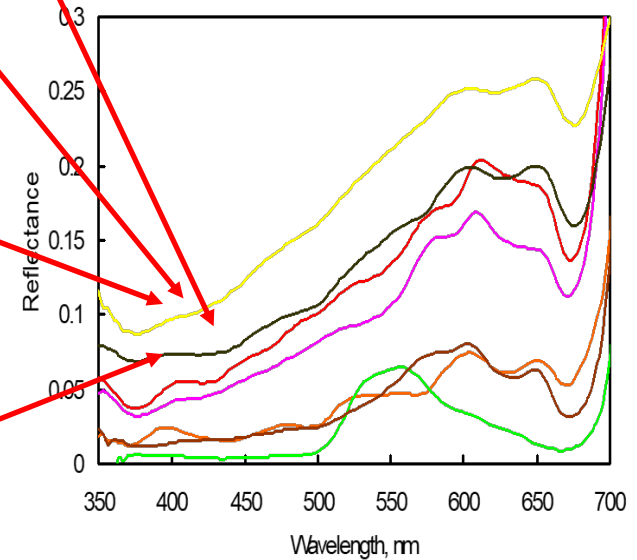
Glint removal



Spectral shape matching



**Modelled
spectral library
Different
bottom types at
different depths**





”Classical“ image processing

Top-of-atmosphere image



Atmospheric correction



Water processing

**(Water level spectral library +
SAM)**



Map



**”Alternative“
image processing**

Top-of-atmosphere image

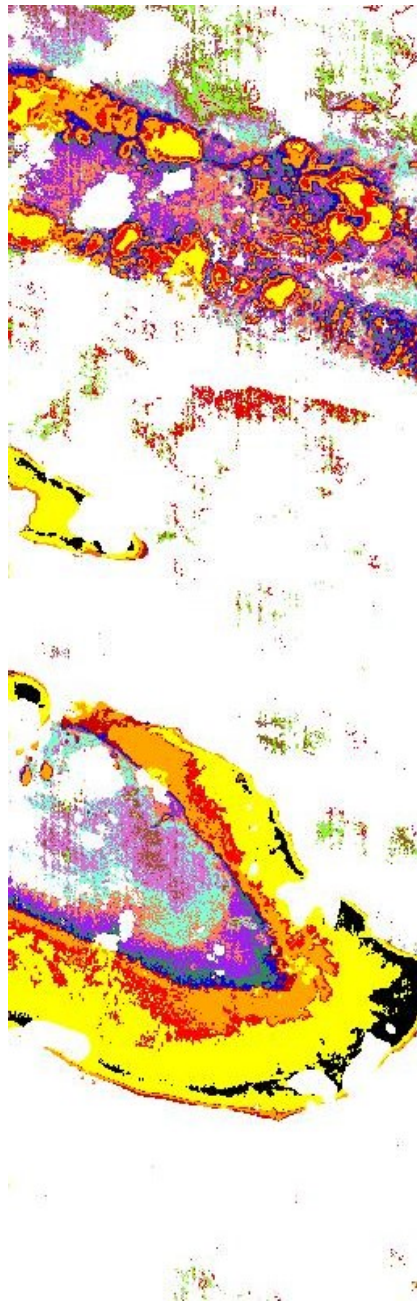


**Water processing
(TOA spectral library + SAM)**



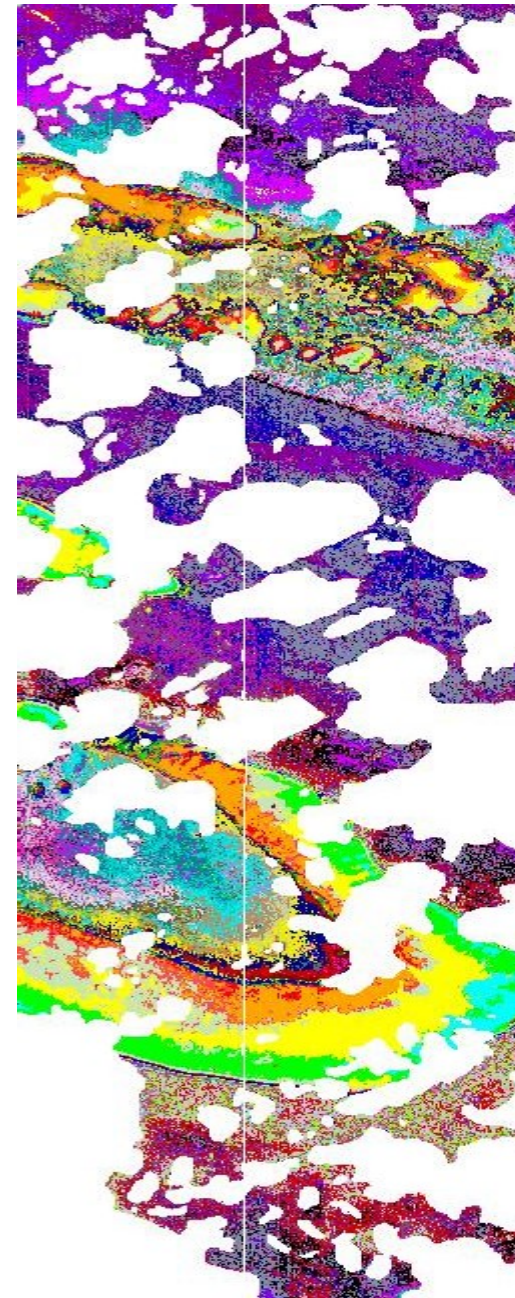
Map

Classical



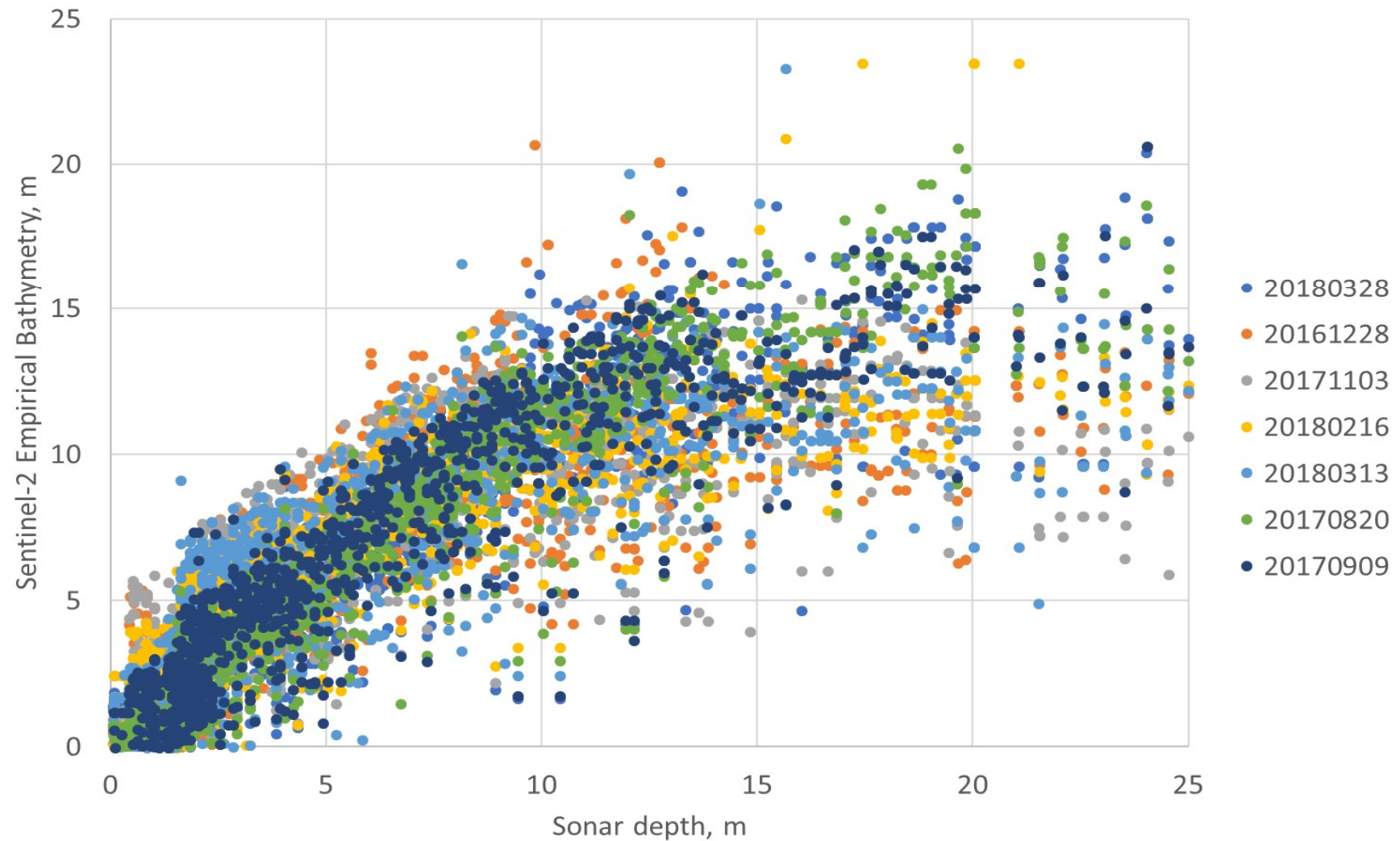
- Cloud & Unclassified
- brown algae 10 m
 - brown algae 11 m
 - brown algae 12 m
 - brown algae 13 m
 - brown algae 14 m
 - brown algae 15 m
 - brown algae 20 m
 - brown algae 25 m
 - dead coral 1 m
 - dead coral 2 m
 - dead coral 3 m
 - deep
 - live coral 1 m
 - live coral 2 m
 - live coral 3 m
 - live coral 20 m
 - red algae 2 m
 - red algae 6 m
 - red algae 7 m
 - red algae 8 m
 - red algae 9 m
 - red algae 10 m
 - red algae 11 m
 - red algae 12 m
 - red algae 13 m
 - red algae 14 m
 - red algae 15 m
 - red algae 20 m
 - red algae 25 m
 - sand 1 m
 - sand 2 m
 - sand 3 m
 - sand 4 m
 - sand 5 m
 - soft coral 1 m
 - green algae 20 m
 - green algae 25 m

Alternative



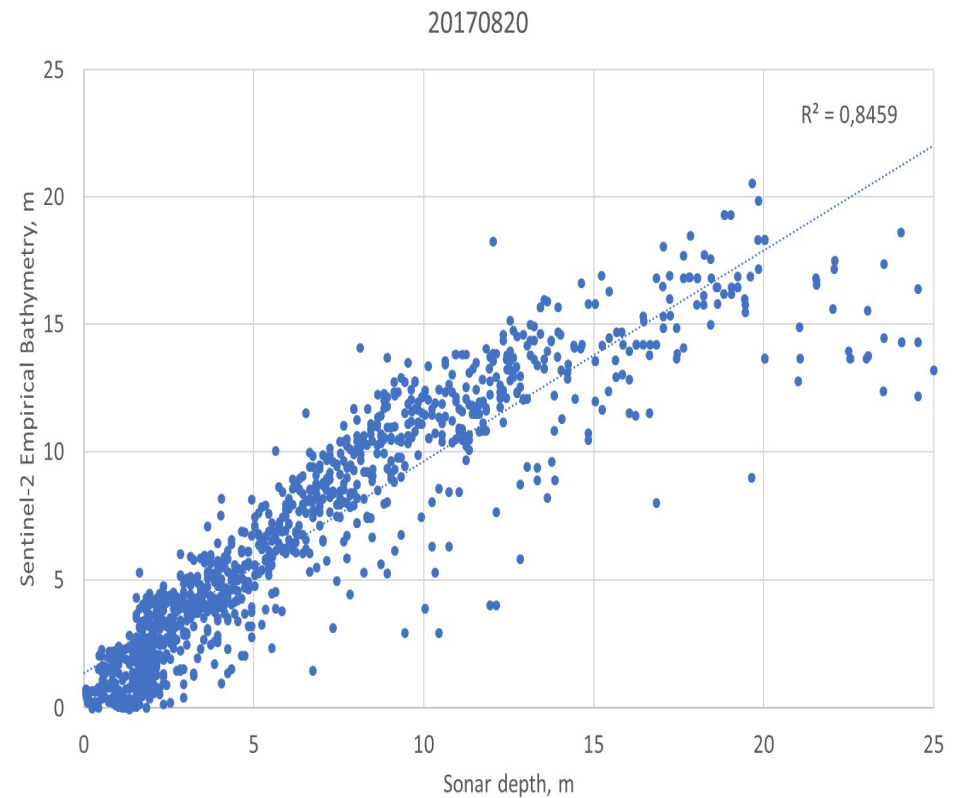
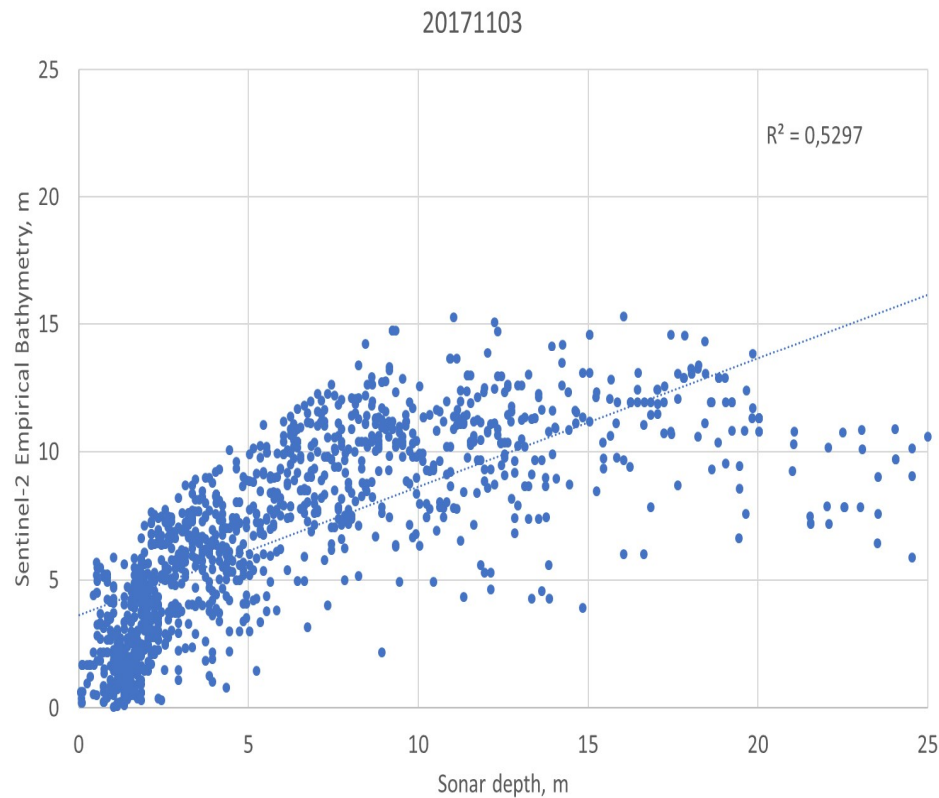
- Cloud
- Live 1m
 - Live 2m
 - Live 3m
 - Live 4m
 - Live 5m
 - Live 6m
 - Live 7m
 - Live 8m
 - Live 9m
 - Live 10m
 - Live 11m
 - Live 12m
 - Live 13m
 - Live 14m
 - Live 15m
 - Live 20m
 - Live 25m
 - Dead 1 m
 - Dead 2 m
 - Dead 3 m
 - Dead 4 m
 - Dead 5 m
 - Dead 6 m
 - Dead 7 m
 - Dead 8 m
 - Dead 9 m
 - Dead 10 m
 - Dead 11 m
 - Dead 12 m
 - Dead 13 m
 - Dead 14 m
 - Dead 15 m
 - Dead 20 m
 - Dead 25 m
 - Green algae 1 m
 - Green algac 2 m
 - Green algac 3 m
 - Green algac 4 m
 - Green algac 5 m
 - Green algac 6 m
 - Green algac 7 m
 - Green algac 8 m
 - Green algac 9 m
 - Green algac 10 m
 - Green algac 11 m
 - Green algac 12 m
 - Green algac 13 m

Empirical methods also sensitive to image quality



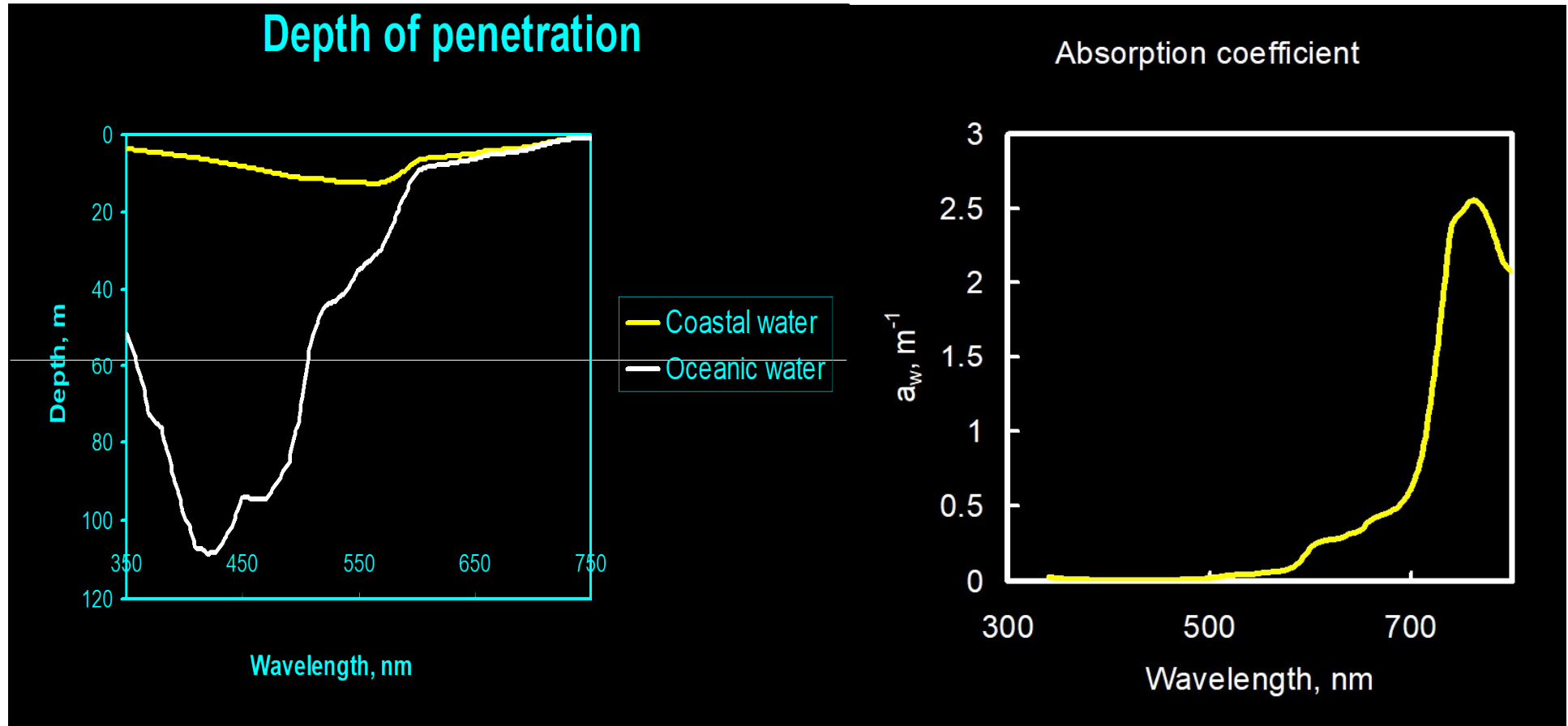
Lizard Island, Sentinel-2

Different dates



Exactly the same 1341 points

Reminder




Depth estimates much more accurate in 5-7 m deep water

Little change in water depth = large change in reflectance



Conclusions

- 
- * **Physics Based Methods have advantage in the locations where little or no *in situ* data is available**
 - * **PBM very sensitive to errors in input data (e.g. atmospheric correction, glint)**
 - * **Methods using only the shape of reflectance data (e.g spectral library + SAM) should be less sensitive to input data quality**



Conclusions

- * Working with top of atmosphere reflectances (i.e using forward model instead of inverse) is probably better than „classical“ approach
- * Machine learning and other new methods should be tested



**Thank you for your
attention!**