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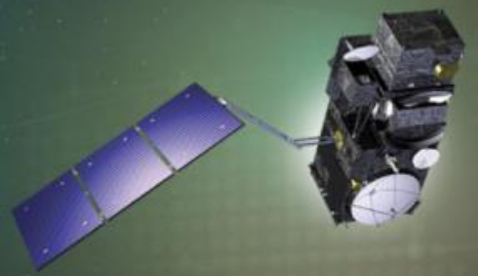


7th Sentinel-3 Validation Team Meeting 2022

18-20 October 2022 | ESA-ESRIN | Frascati (Rm), Italy

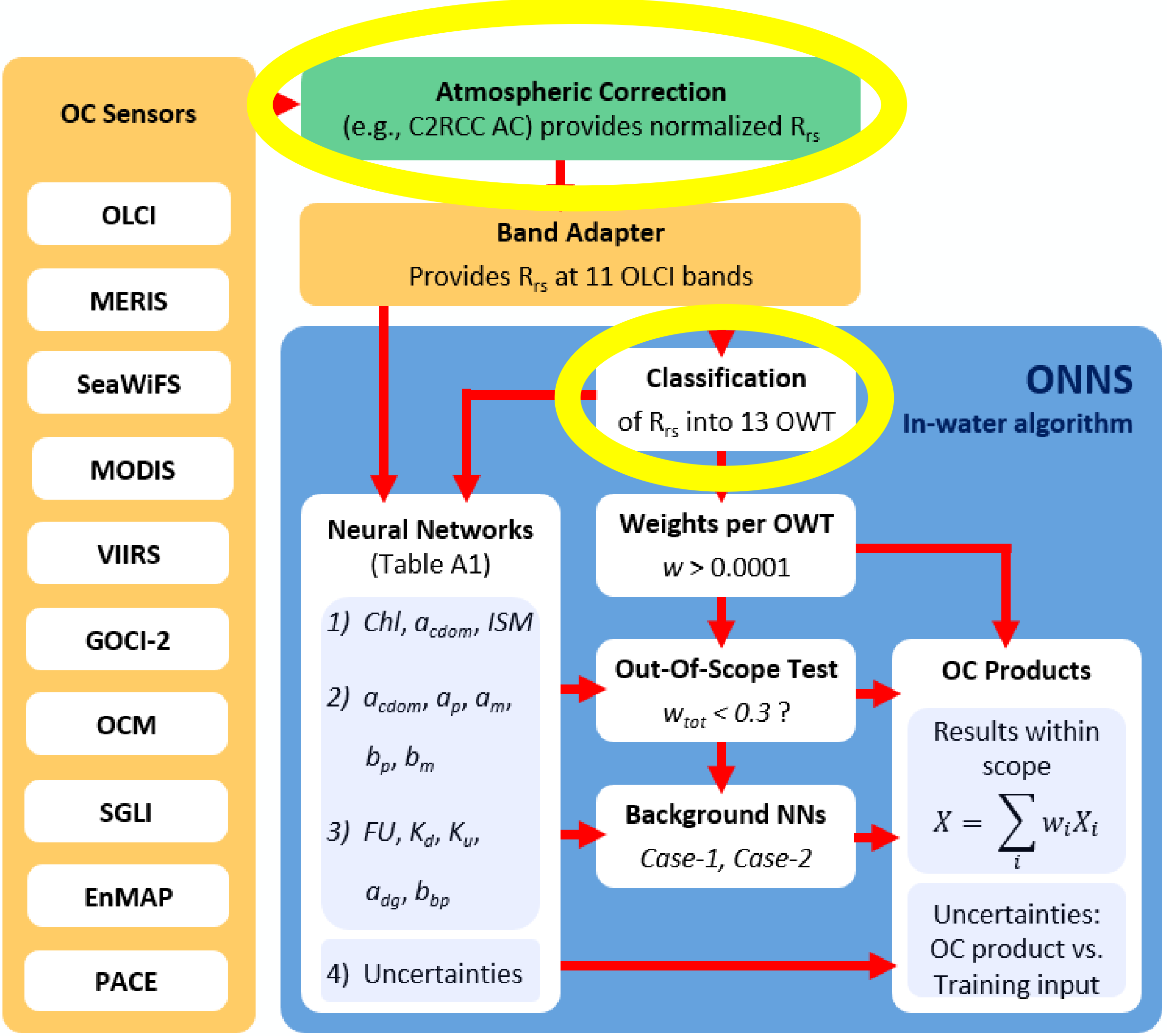
Atmospheric corrections in view of diverse optical water types

Martin Hieronymi[1], Shun Bi[1], Eike M. Schütt[1,2], Daniel Behr[1], Dagmar Müller[3], Kerstin Stelzer[3], Carsten Brockmann[3], Carole Lebreton[3], François Steinmetz[4] & Quinten Vanhellemont[5]

1) Helmholtz-Zentrum Hereon, Germany, 2) Kiel University, Germany, 3) Brockmann Consult, Germany, 4) HYGEOS, France, 5) Royal Belgian Institute of Natural Sciences, Belgium

Algorithm Developments at Hereon

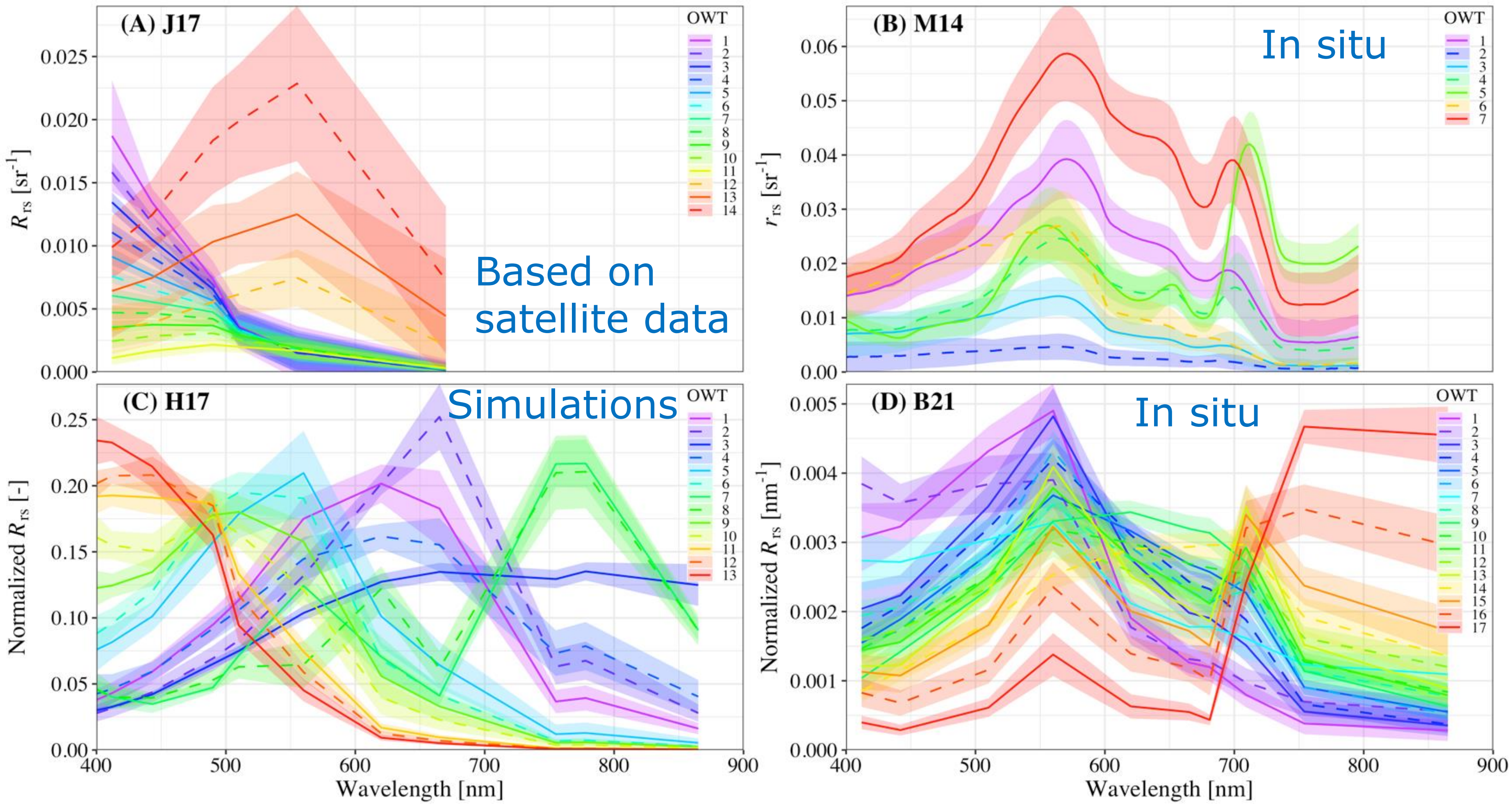
- OLCI Neural Network Swarm (ONNS)
- Ocean Colour algorithm for the aquatic continuum Land-Coast-Ocean
- Utilization of Fuzzy Logic-based Optical Water Type classification
- OWT-specialized Neural Networks
- Delivers diverse IOPs, concentrations, light field & uncertainties



Hieronymi, M., Müller, D., & Doerffer, R. (2017). The OLCI Neural Network Swarm (ONNS): a bio-geo-optical algorithm for open ocean and coastal waters. *Frontiers in Marine Science*

Hieronymi, M. (2019). Spectral band adaptation of ocean color sensors for applicability of the multi-water biogeo-optical algorithm ONNS. *Optics Express*

Optical Water Type Classification



Diverse OLCI-usable OWT frameworks for ocean and inland waters available for selecting of optimal algorithms and blending of results (beyond Case-1 & -2)

Jackson et al. 2017
Moore et al. 2014
Hieronymi et al. 2017
Bi et al. 2021

Requirements to Atmospheric Correction

- Provide results for the entire spectrum
  - For OLCI usually 16 (out of 21) bands from 400 to 1020 nm
- Cover all colours
  - Blue (oligotrophic) ocean, green (hyper-eutrophic) lakes, red tides, etc.
- Cover all magnitudes
  - Dark (high CDOM) to bright (high NAP)
- Provide realistic spectral shapes of Rrs that are requested by OWT frameworks

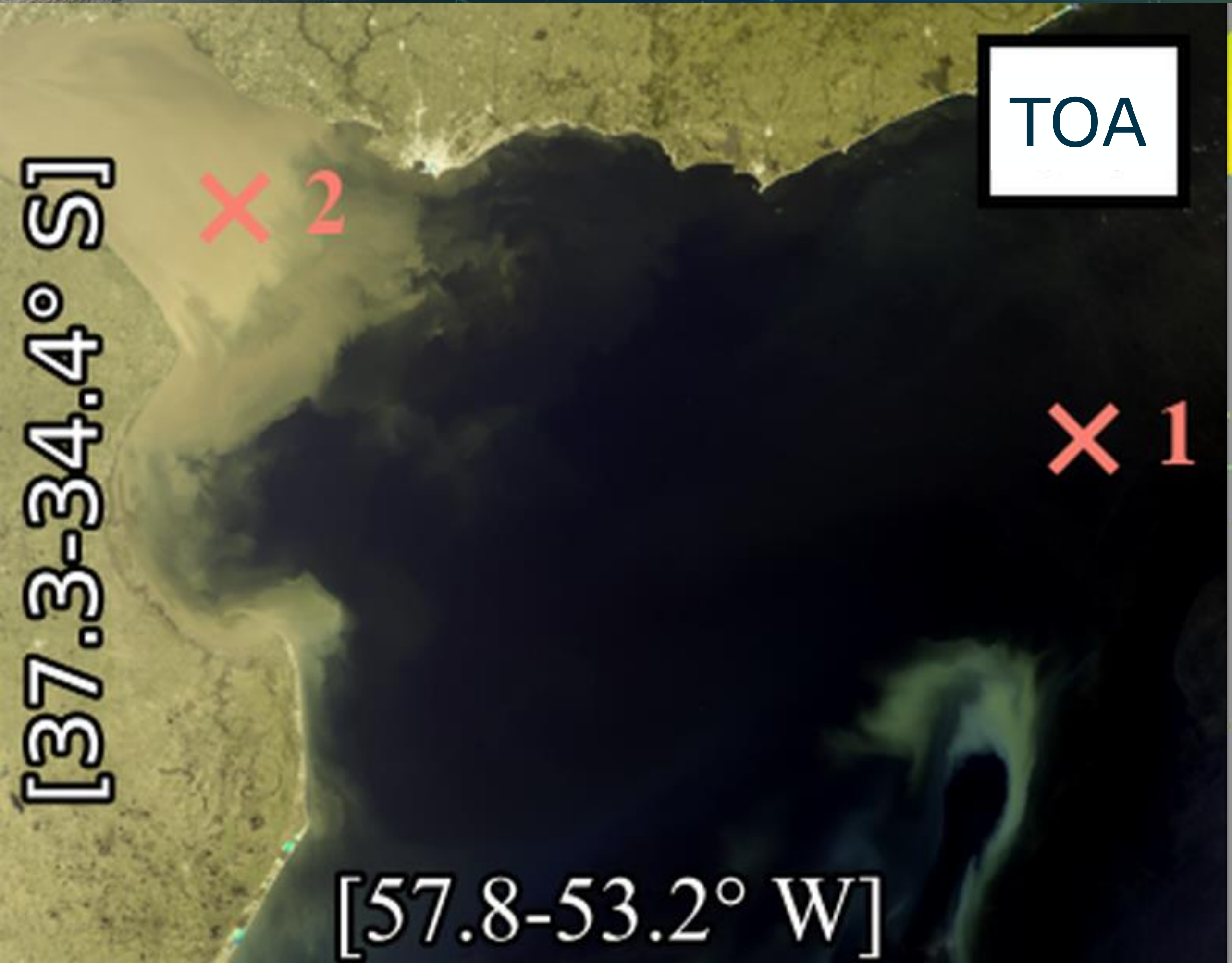
→ No available atmospheric correction methods can meet these requirements adequately

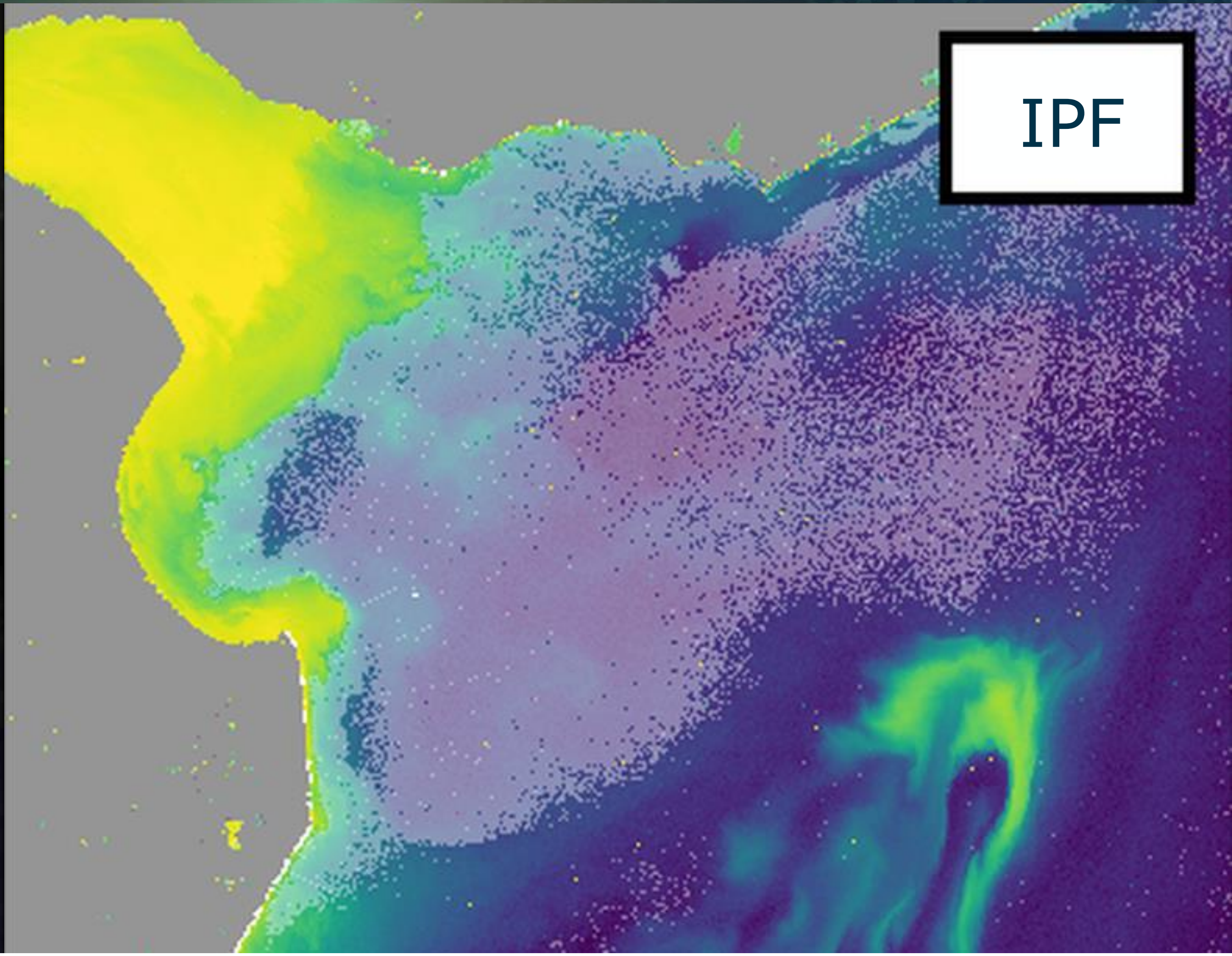
→ Rrs can be well classifiable in OWT framework, but is actually obviously wrong

New Atmospheric Correction for OLCI developed at Hereon

Atmospheric Correction for Optical Water Types → A4O

- Further-development of C2RCC
- Ensemble of “globally valid” Neural Networks → enables uncertainty estimate
- Optimization on spectral shape of Rrs → well OWT classifiability with ONNS framework
- Designed for inland, coastal and oceanic waters
- Consideration of phytoplankton diversity
- Reduction of spatial and spectral noise (e.g. South Atlantic Anomaly)
- Improved cloud flagging
- By-product whitecap fraction, mask for floating staff, …

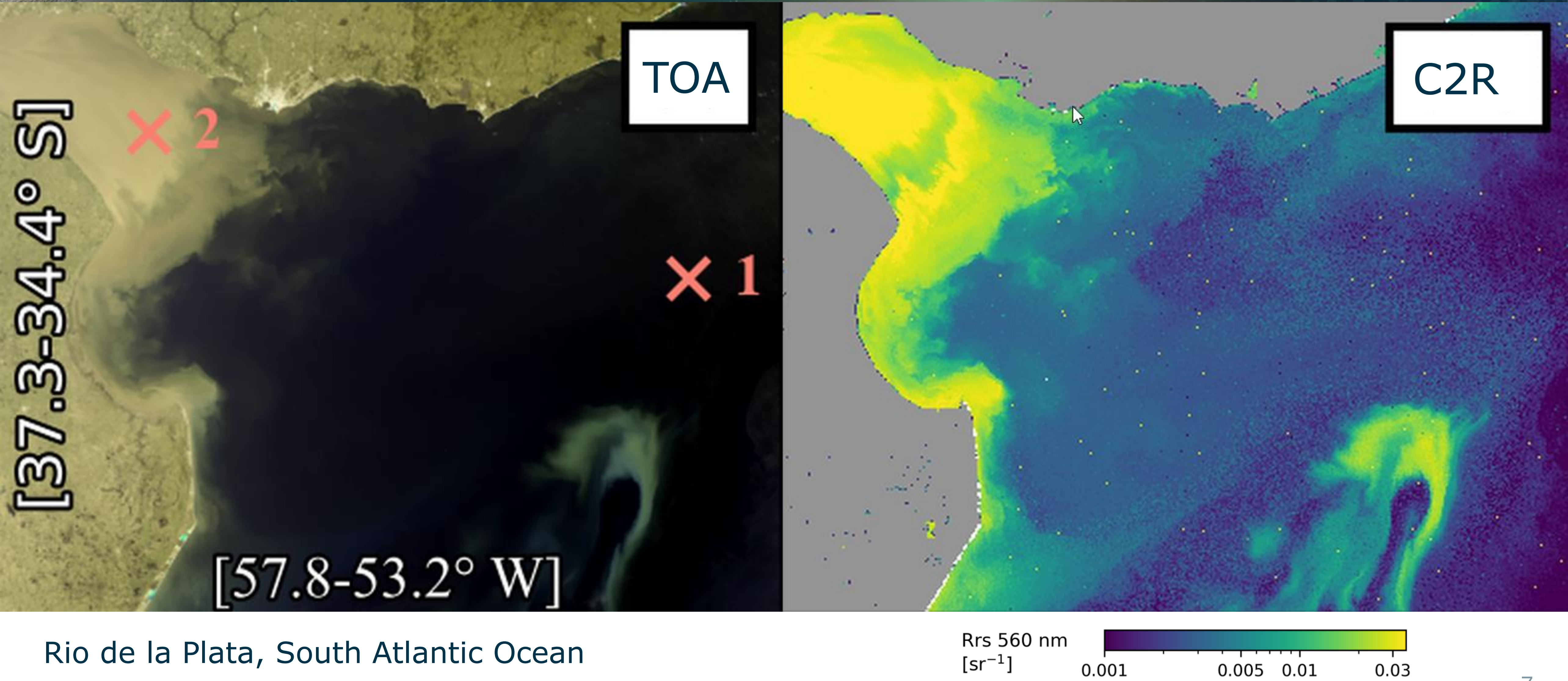




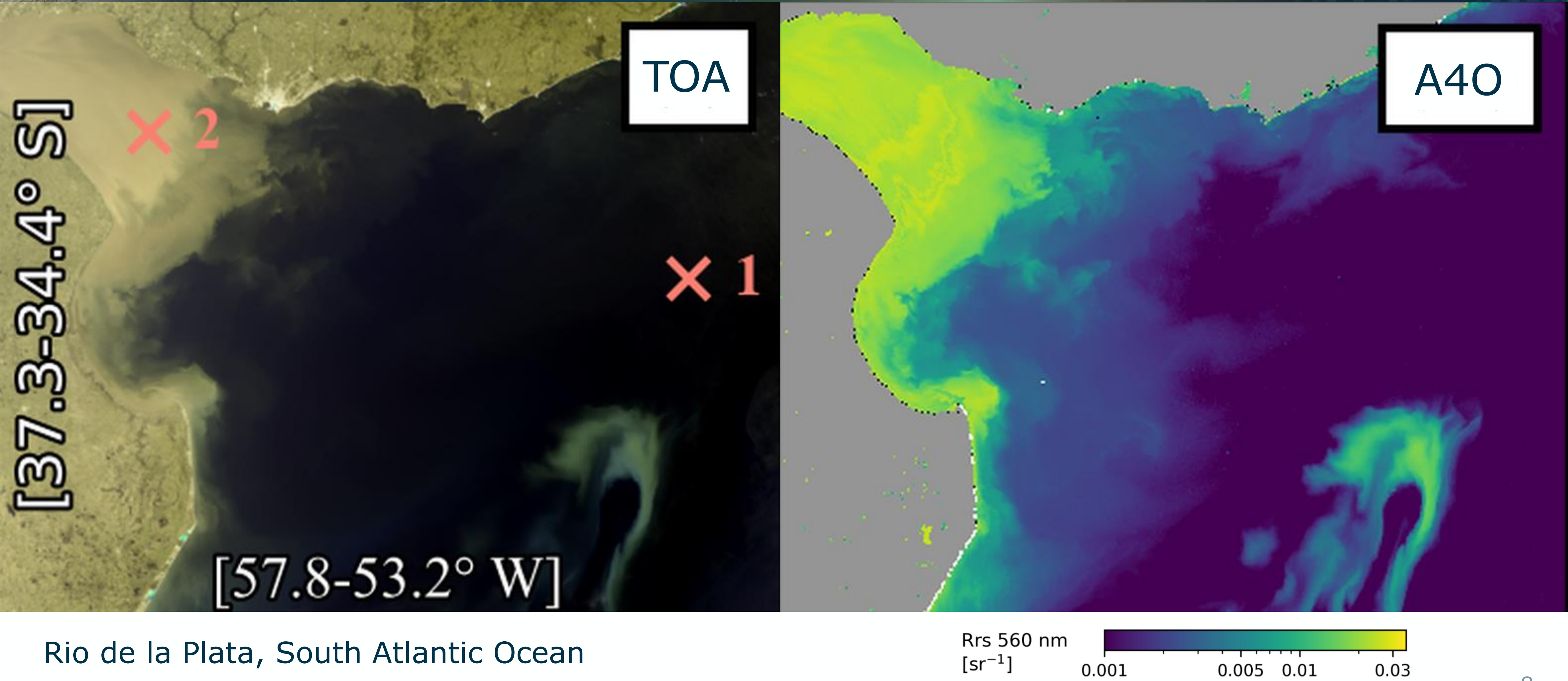
Rio de la Plata, Atlantic Ocean Rrs < 0 in grey transparent

Rrs 560 nm [sr^{-1}]

0.001 0.005 0.01 0.03



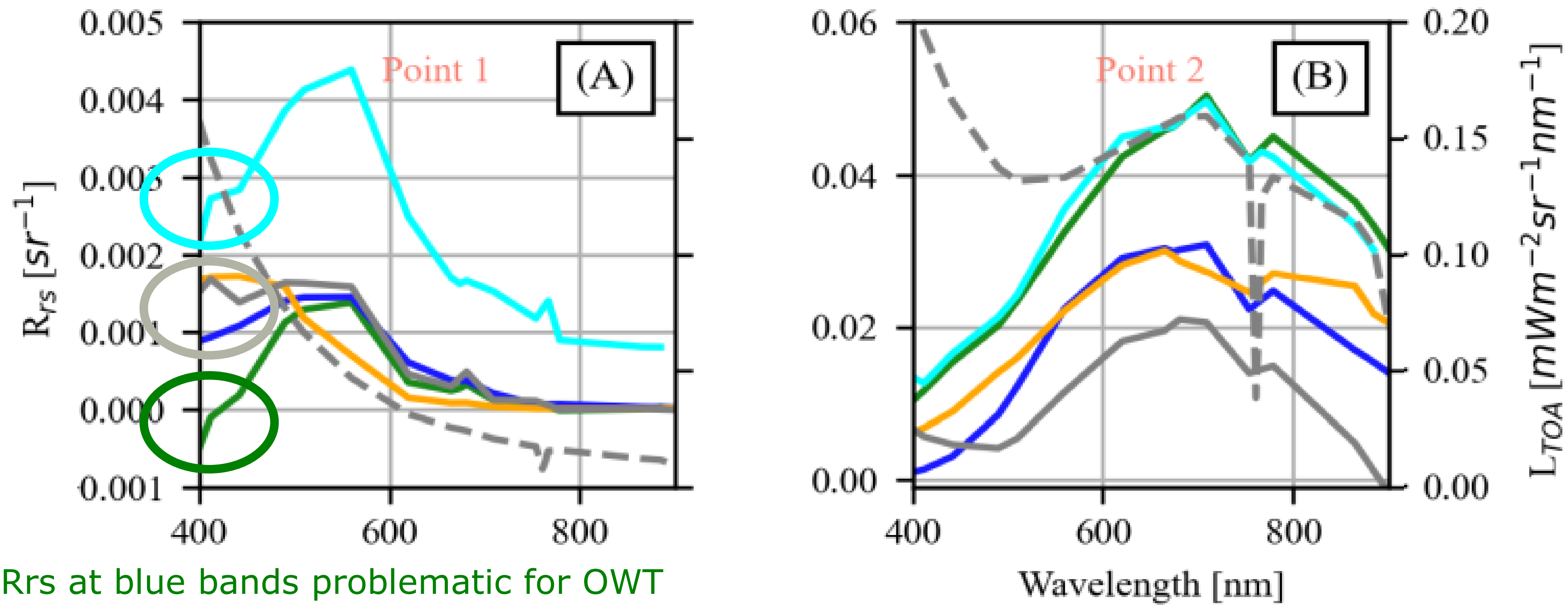
Rio de la Plata, South Atlantic Ocean



Rio de la Plata, South Atlantic Ocean

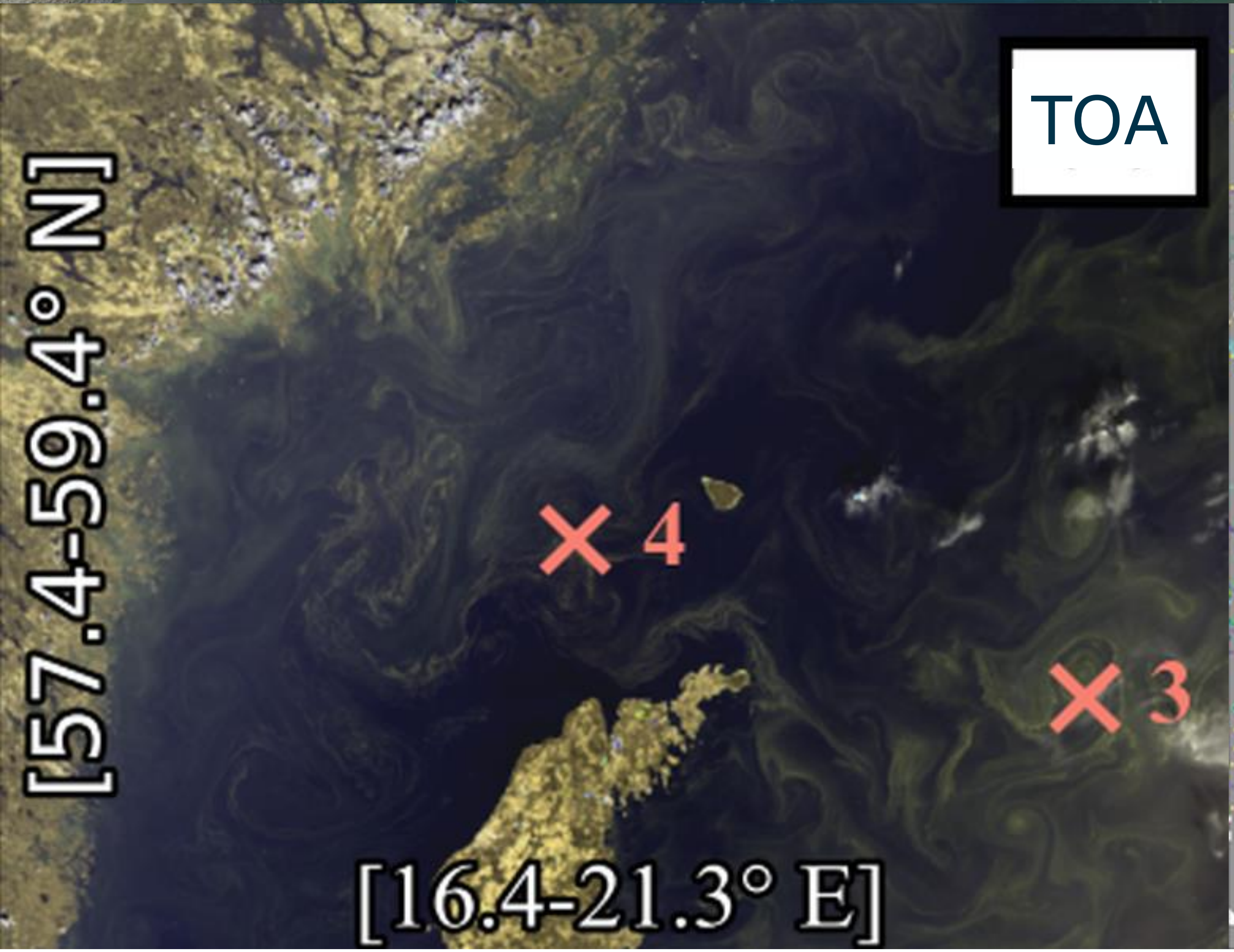
Dark Ocean (Shelf) & Bright Waters

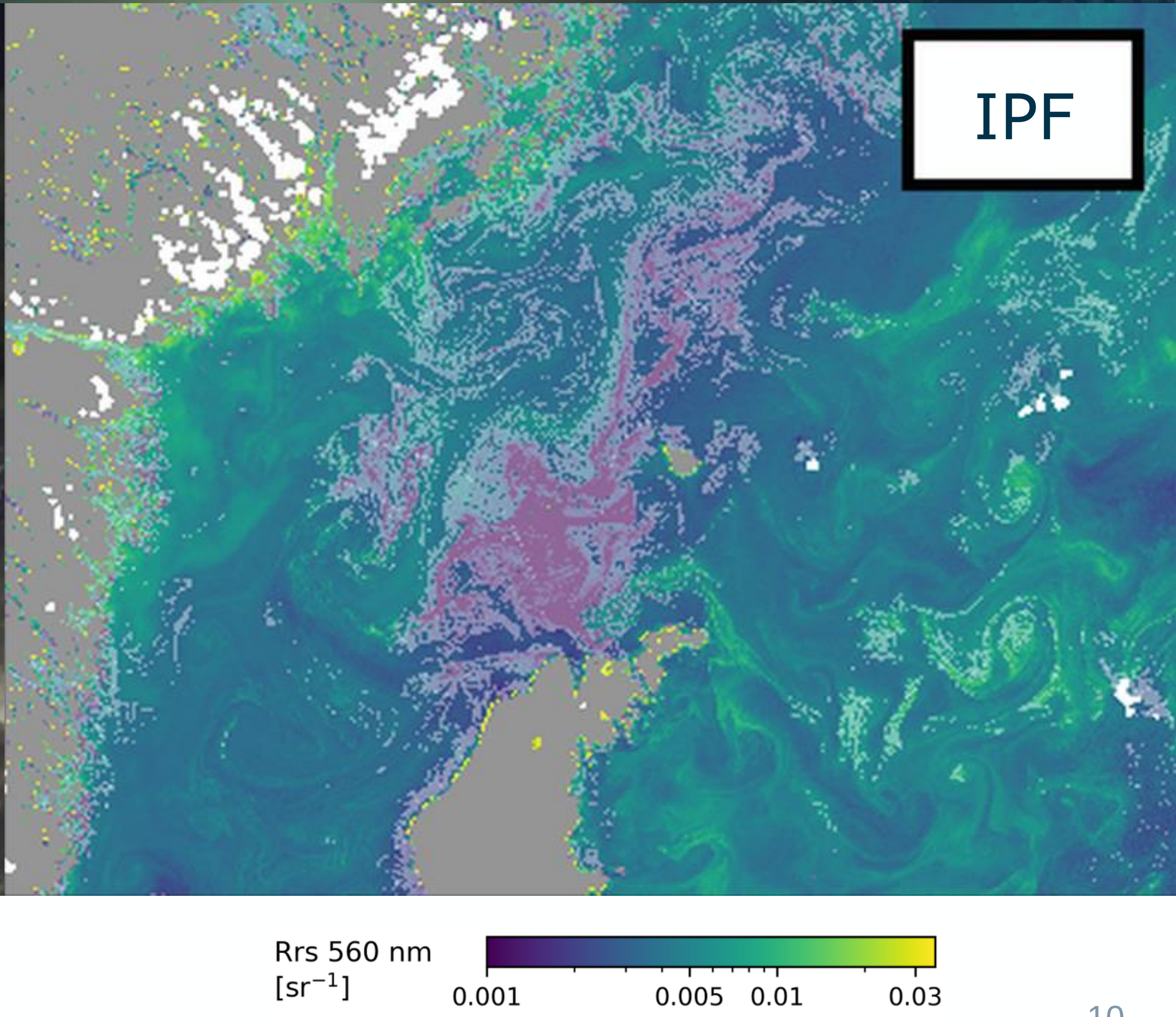
IPF Rrs shape reasonable



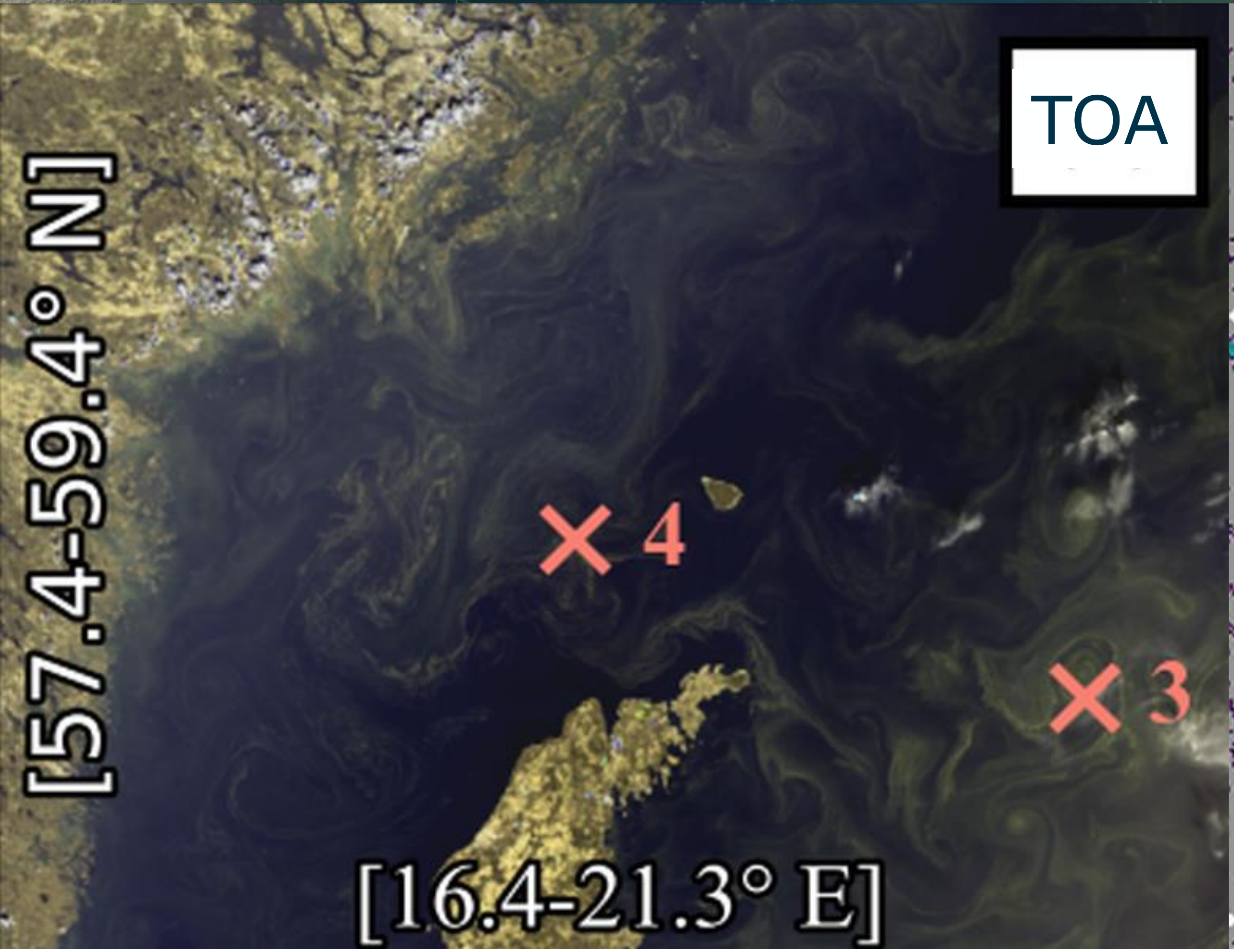
IPF Rrs at blue bands problematic for OWT

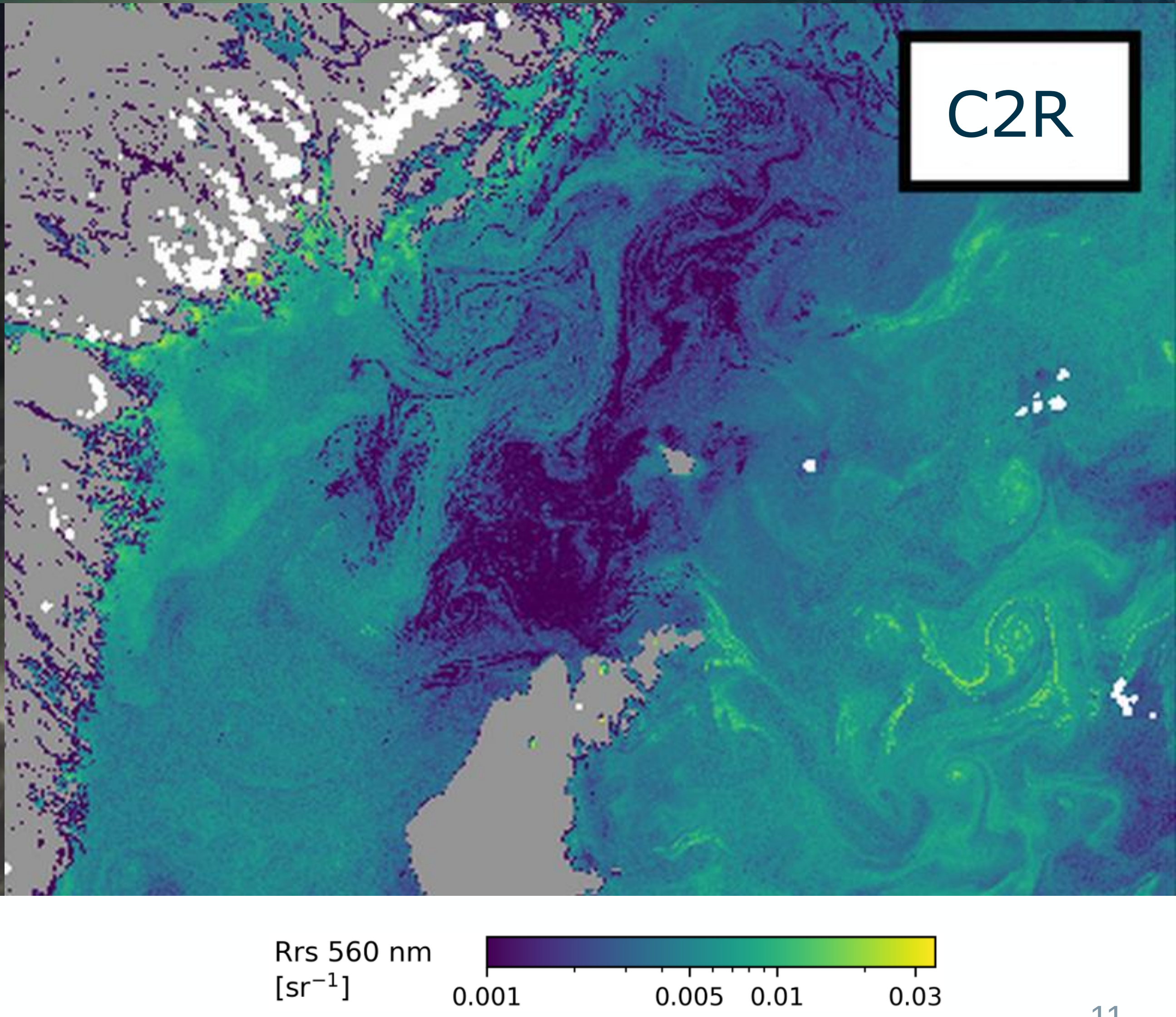
A4O L2 BAC: IPF L2 AAC: C2RCC POLYMER DSF-Acolite



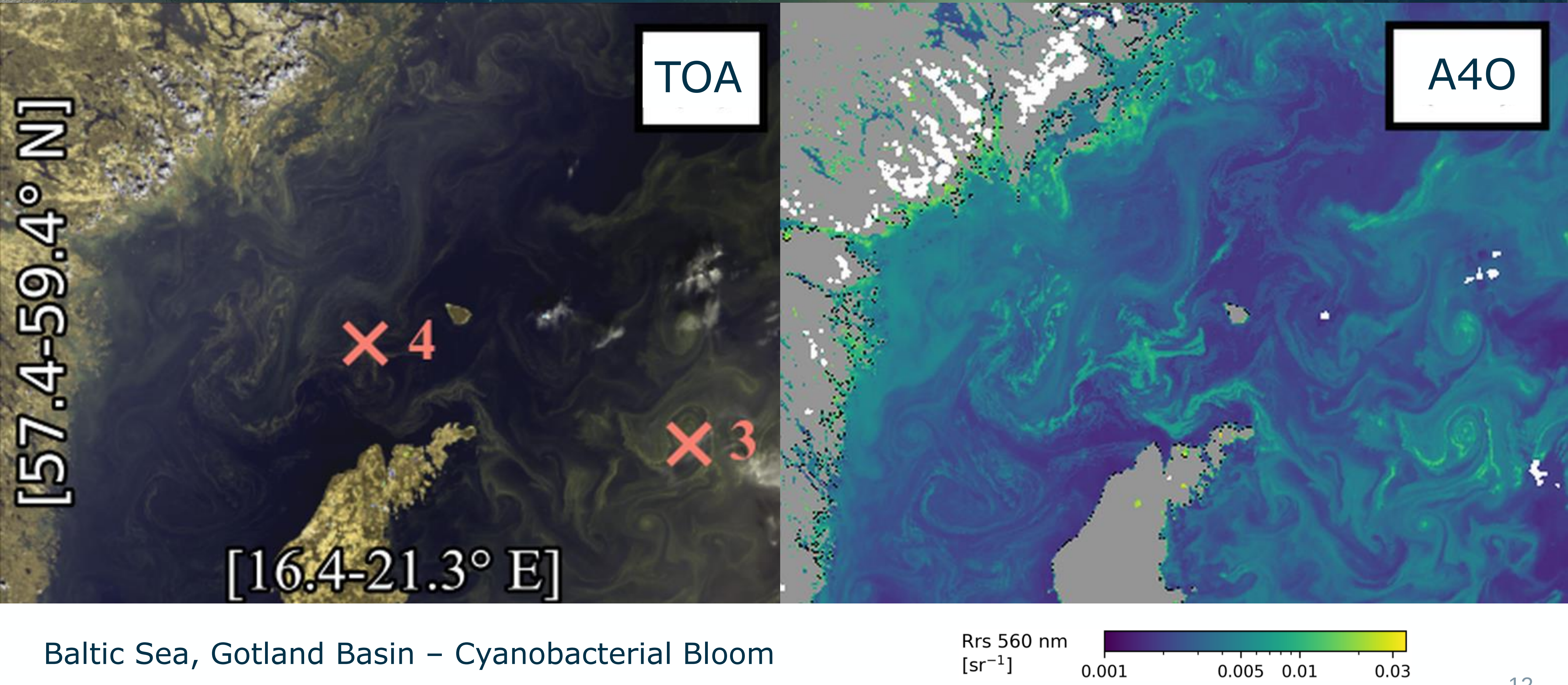


Baltic Sea, Gotland Basin – Cyanobacterial Bloom





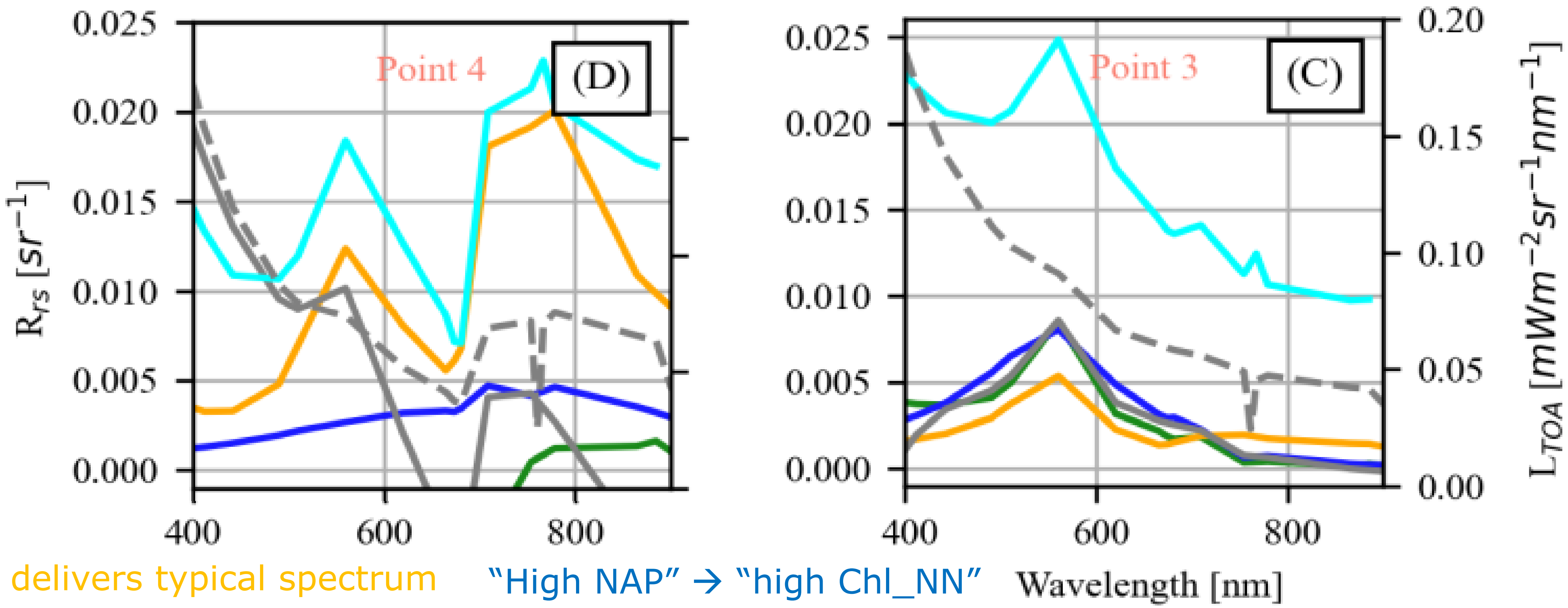
Baltic Sea, Gotland Basin – Cyanobacterial Bloom



Baltic Sea, Gotland Basin – Cyanobacterial Bloom

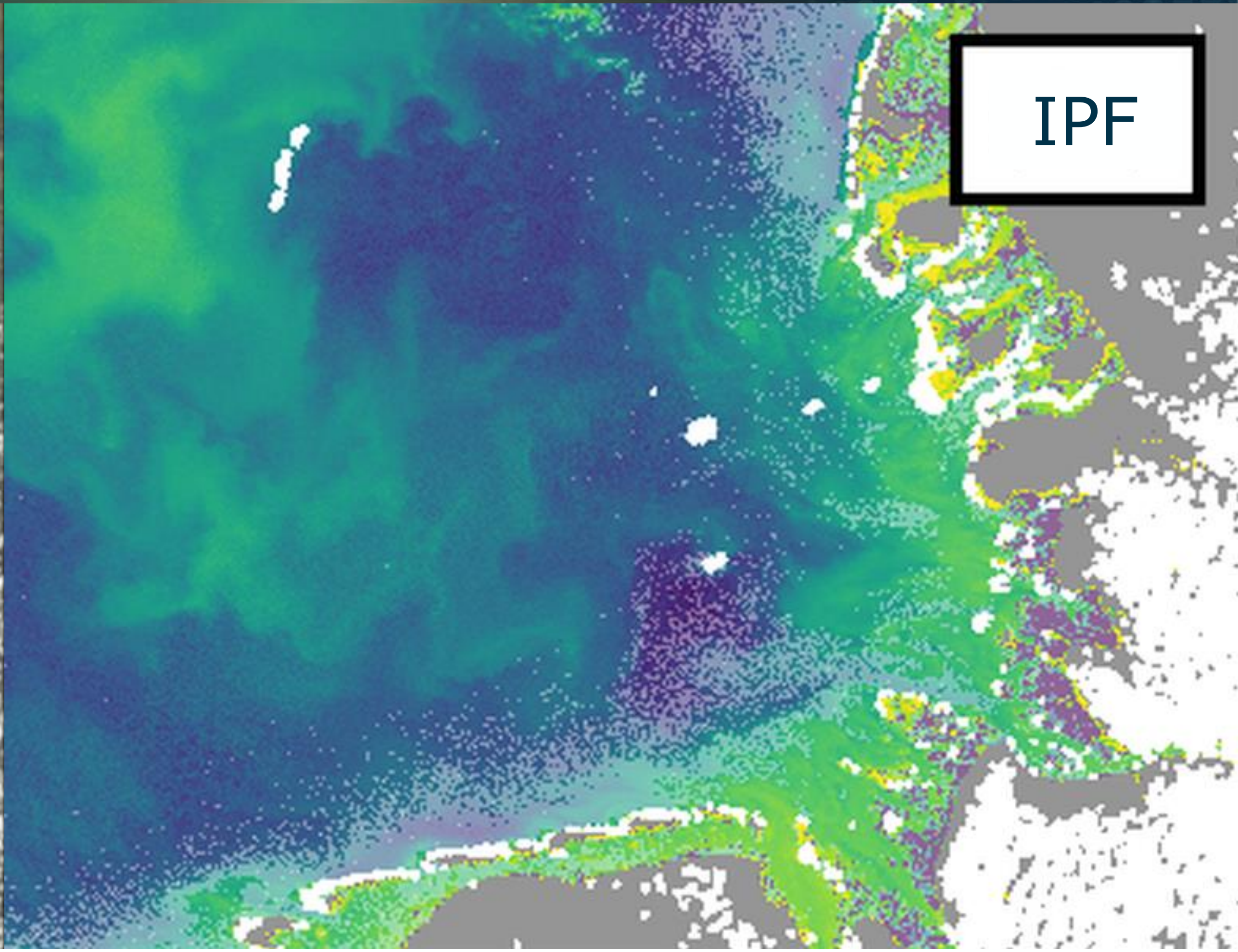
Cyanobacterial Blooms

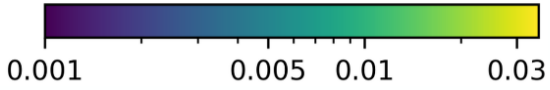
IPF Rrs shape reasonable, but too high in blue



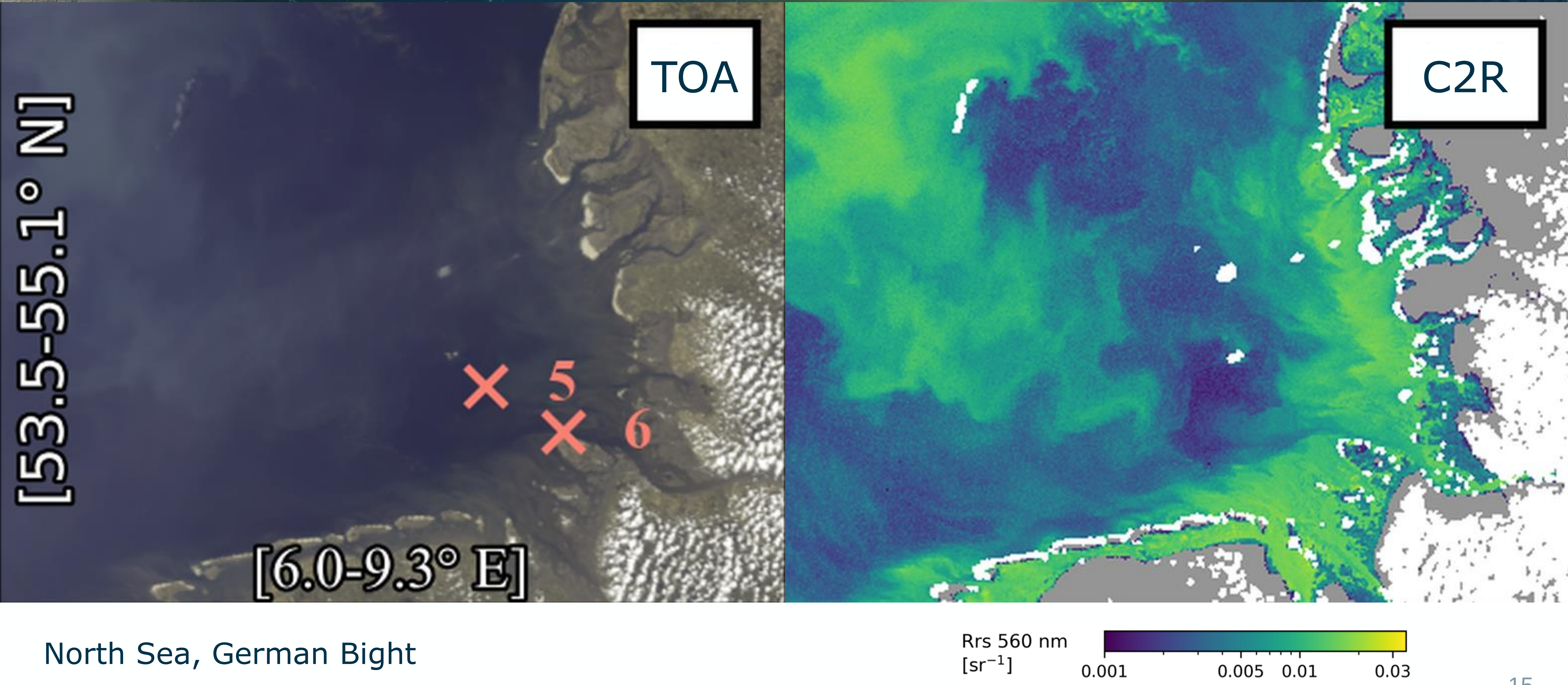
A4O delivers typical spectrum "High NAP" → "high Chl_NN"

A4O L2 BAC: IPF L2 AAC: C2RCC POLYMER DSF-Acolite

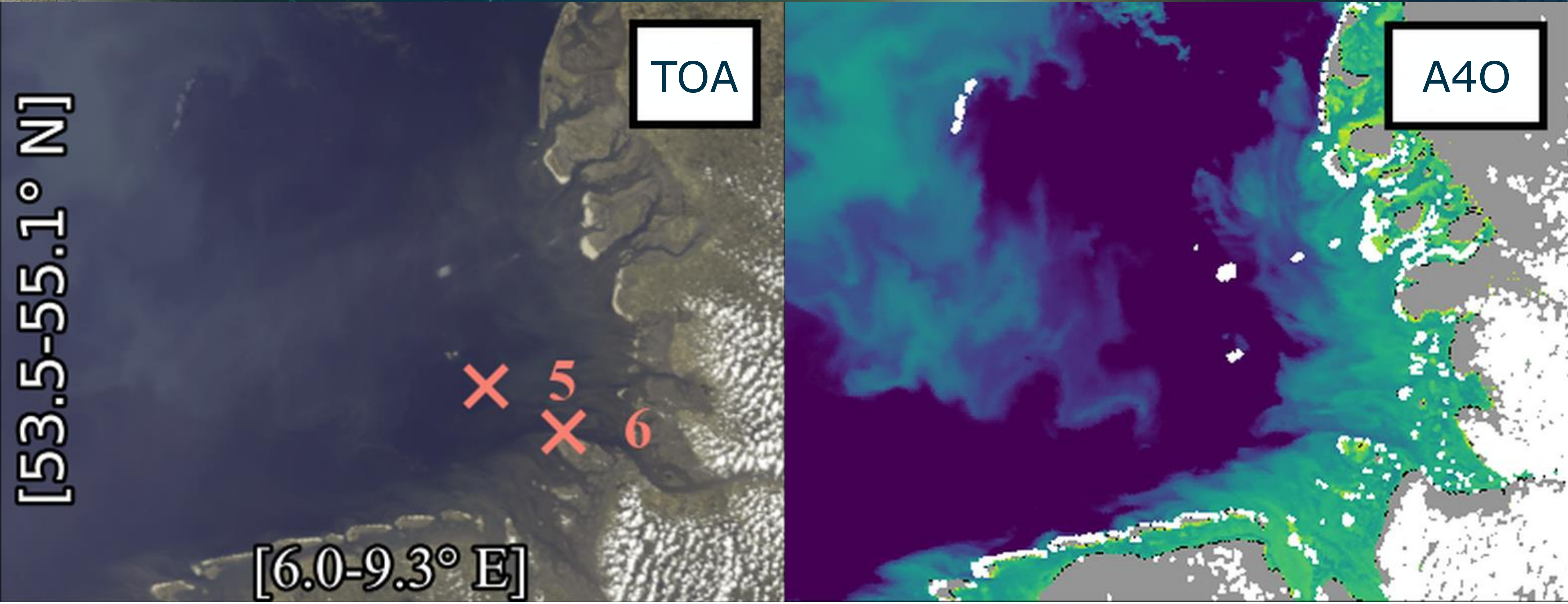




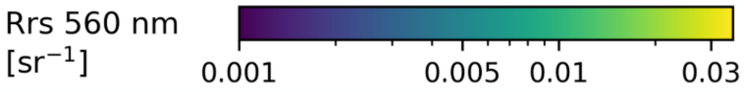
North Sea, German Bight



North Sea, German Bight

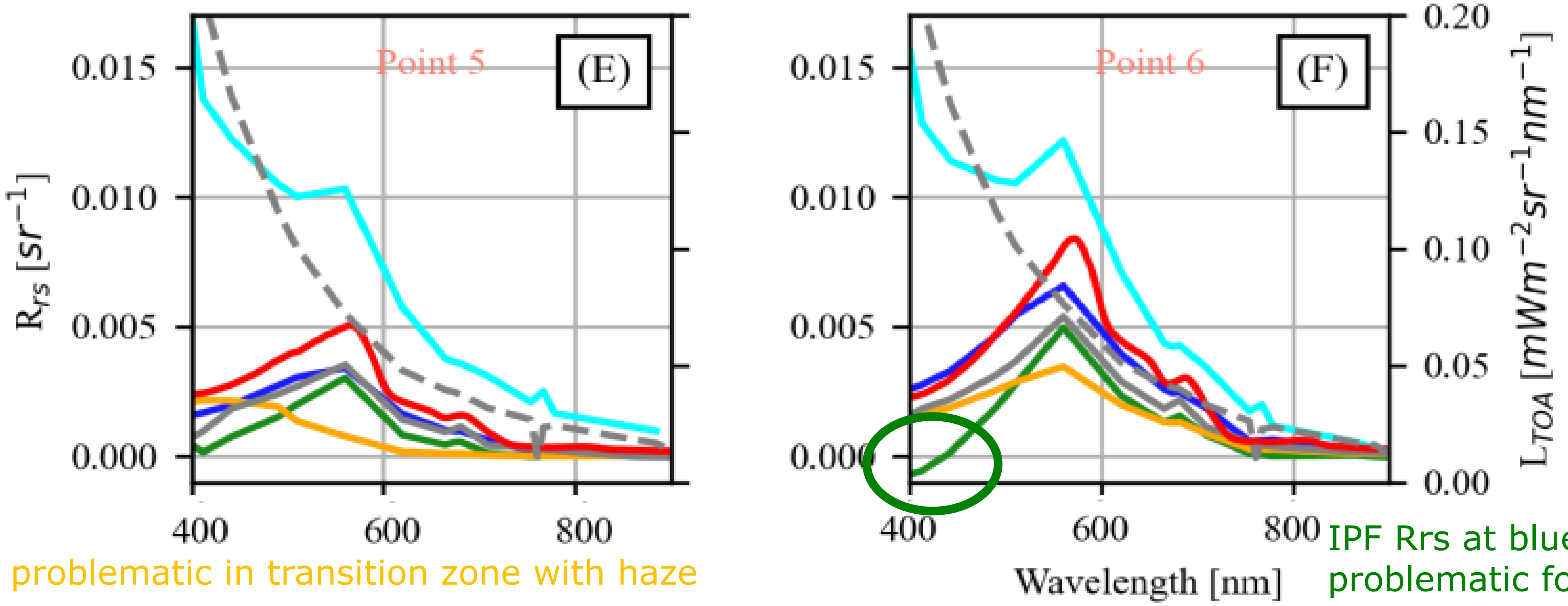


North Sea, German Bight



Cyanobacterial Blooms

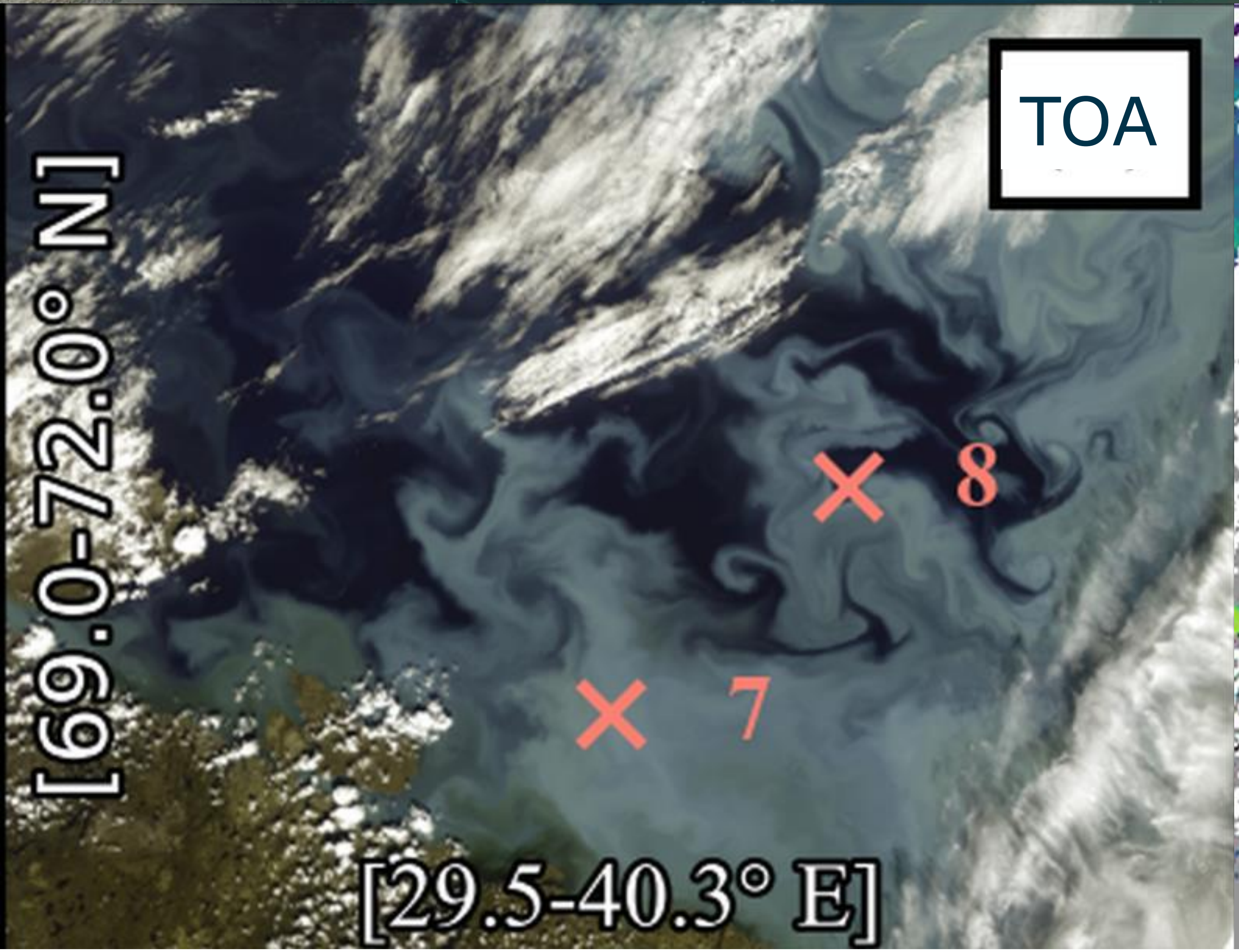
C2R matches relatively good (optimized here)

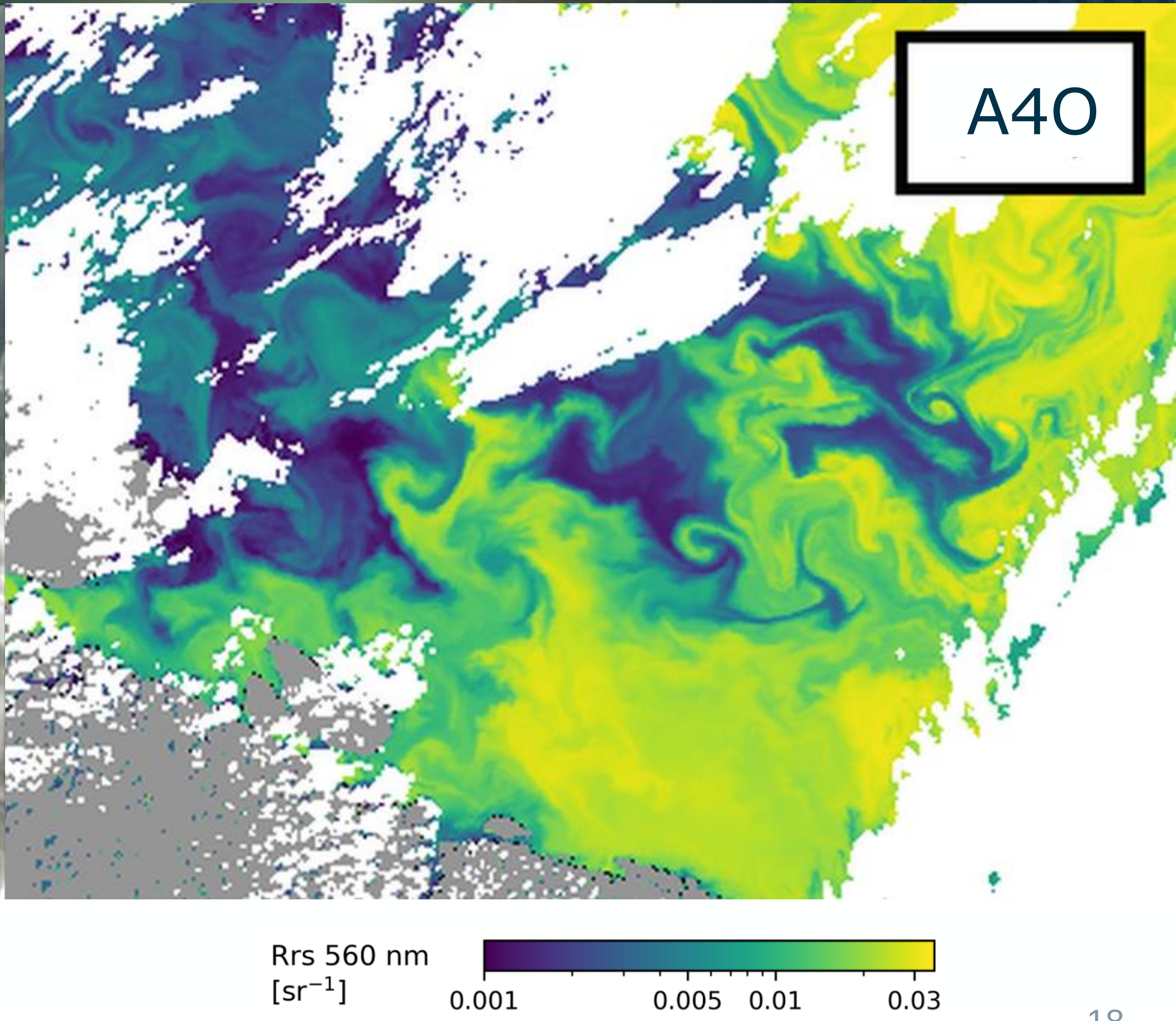


A4O problematic in transition zone with haze

IPF Rrs at blue bands problematic for OWT

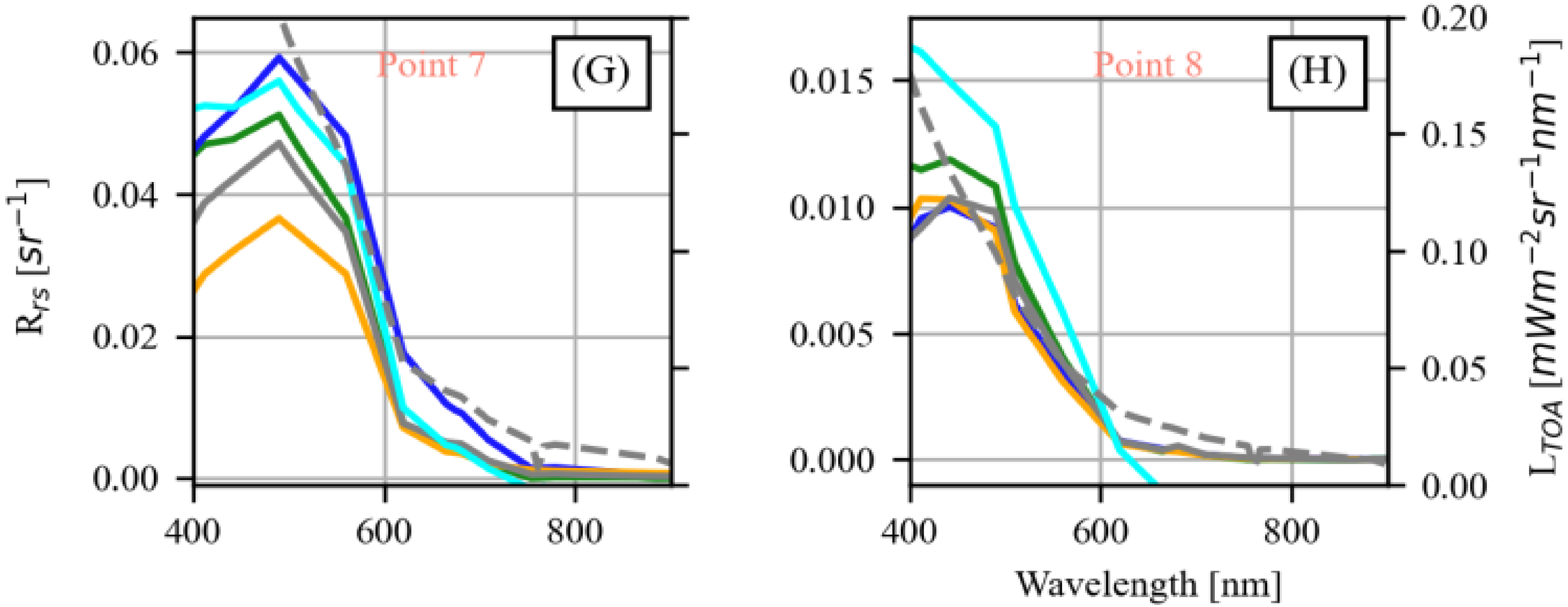
A4O L2 BAC: IPF L2 AAC: C2RCC POLYMER DSF-Acolite Hereon in situ





Barents Sea – Coccolithophores Bloom

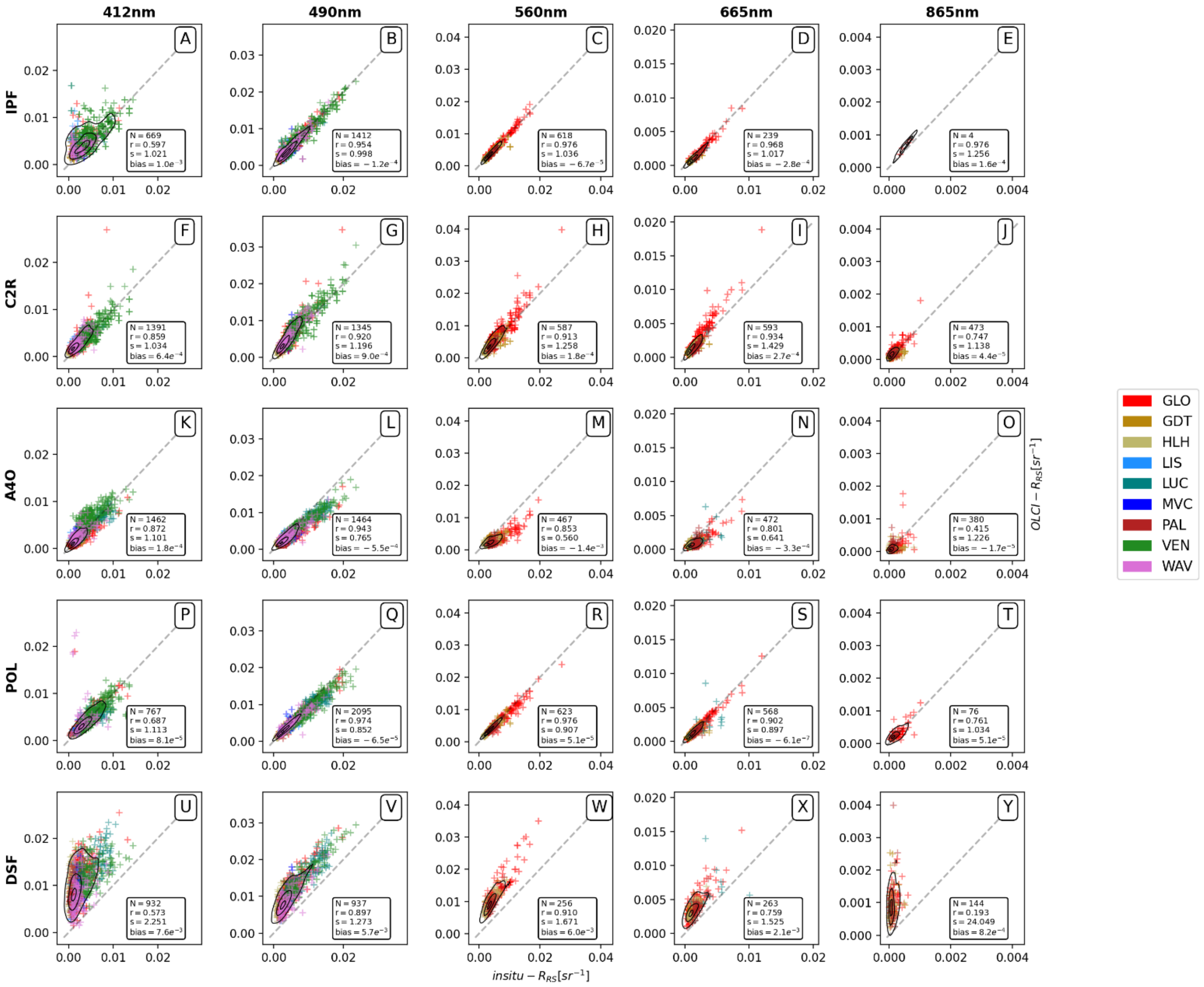
Coccolithophores Blooms



A4O L2 BAC: IPF L2 AAC: C2RCC POLYMER DSF-Acolite

Comparison with Aeronet-OC

- Mostly moderately turbid waters
- First comparison with A4O and DSF (designed for turbid waters)
- Massive flagging of IPF leads to fewer match-ups, but good performance
- Application of SVC gains to C2R improves metrics
- POL performs generally best



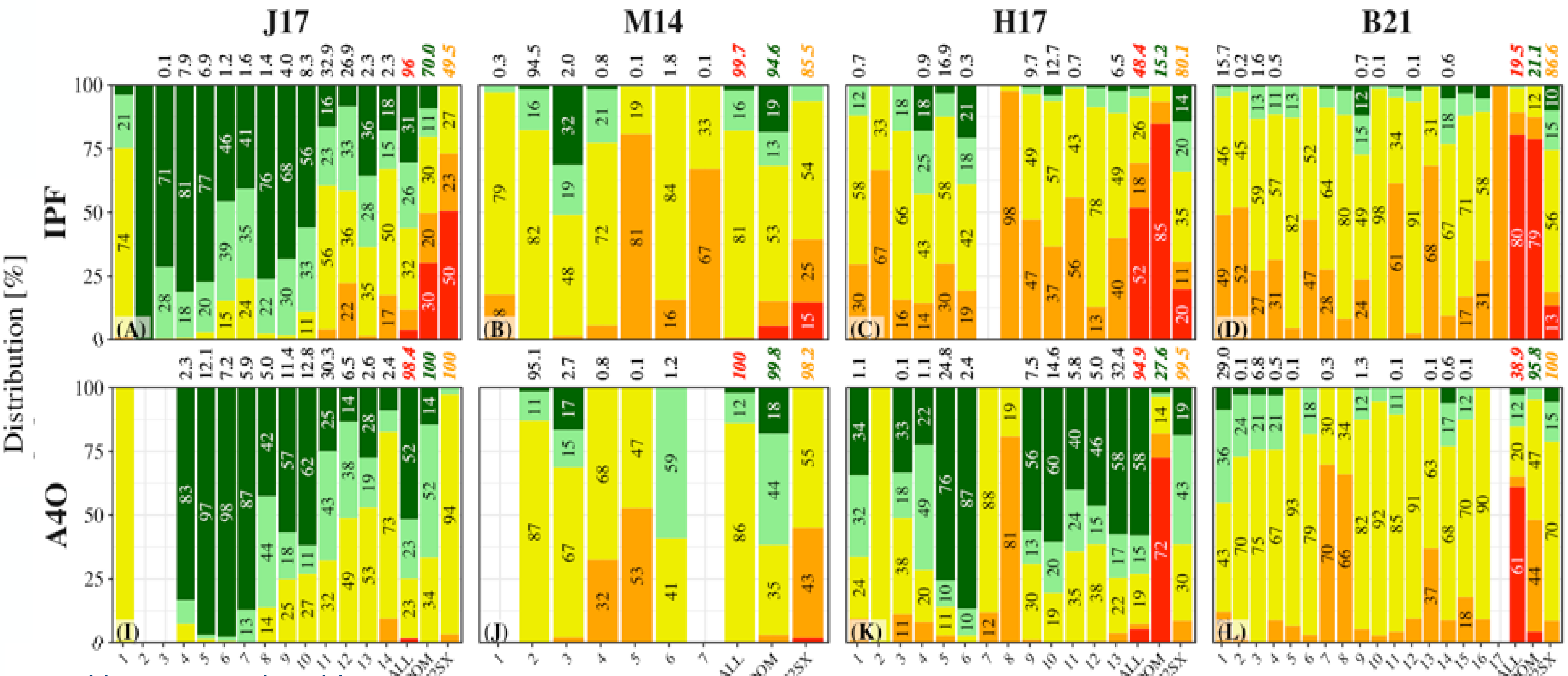
OWT Classifiability

- 10 OLCI test scenes with high optical diversity
- OWT total memberships usually between threshold 0.0001 and 1 (can be >1)

High | Medium | Low | Below threshold | Non-classifiable | NaN

Acceptable

- Rrs can be well classifiable in OWT framework, but actually wrong, e.g. high-NAP-shape in algae bloom
- Some OWT frameworks have narrow variance → small discontinuity leads to low memberships
- Negative Rrs problematic



OWT with max membership

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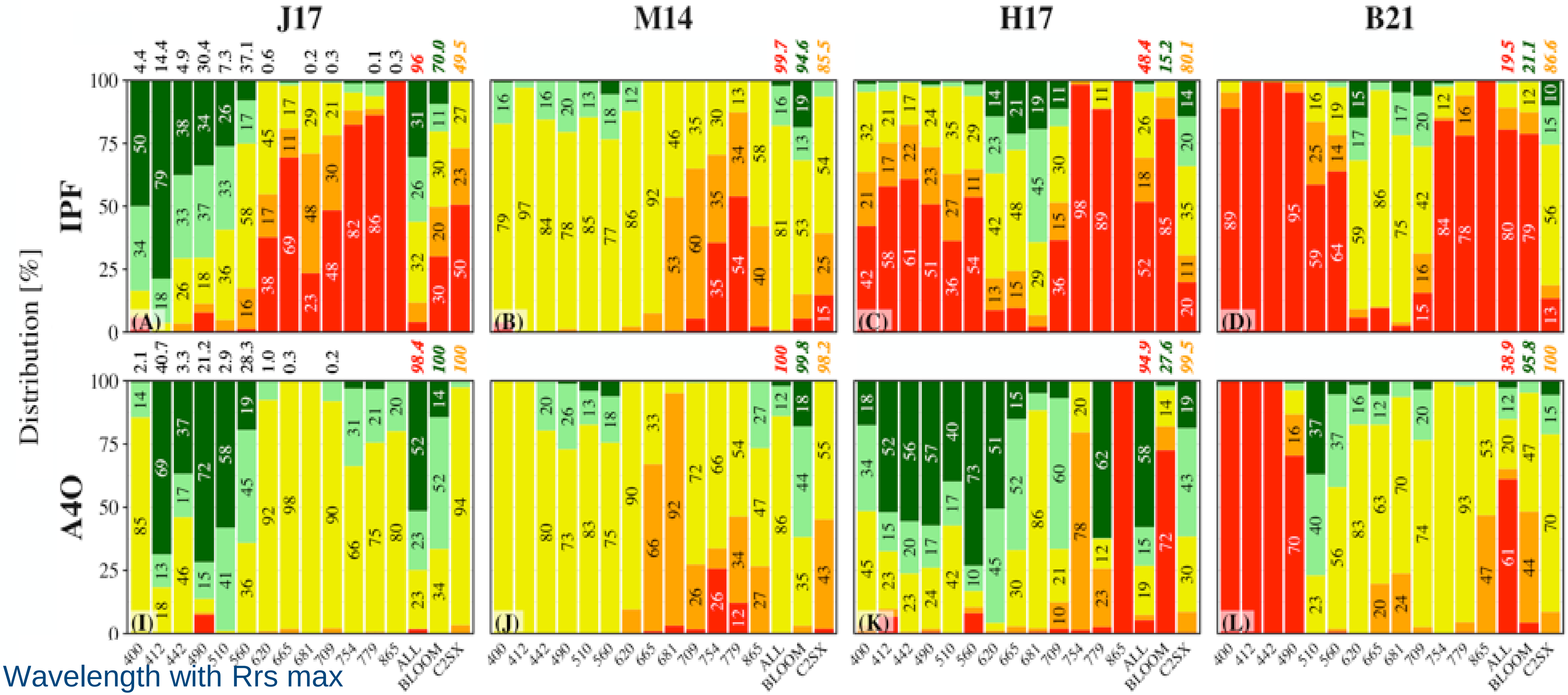

OWT Classifiability

- IPF → results for Case-1 waters classifiable with J17 & M14
  → but not well with H17 & B21 → narrow variance of OWT frameworks
  → Some Rrs shapes not delivered → less suitable for productive waters
- A4O → provides high optical diversity and generally expected Rrs shapes (but partly low memberships)
  → Some OWT classes not well captured, e.g. J17 oligotrophic & B21 hyper-eutrophic waters
- C2R → delivers useful spectra for J17 and H17
  → Out-of-scope solution often classifiable, but obviously wrong, e.g. high-NAP-shape in algae bloom
- POL → optimal for J17 (which was based on POL), but not useful for B21 and only low memberships for H17
- DSF → developed for scattering waters, otherwise problematic blue bands
  → but advantages for inland waters (as defined in M14 & B21, but not H17)

Conclusions

- New algorithms available for bridging optical Oceanography and Limnology
- Novel atmospheric correction A4O designed for "all" natural waters

  → Special emphasis of A4O: absorbing (dark) waters, scattering (bright) waters & phytoplankton diversity (cyanobacteria, coccolithophores)
- Ocean Colour products very sensitive to atmospheric correction → scope of AC must be considered
- OWT frameworks must be revised to cover all natural shapes and encounter for uncertainties of AC
- Negative reflectances provided by IPF, POL & DSF must be worked on
- Future (hyperspectral) AC must cover larger optical diversity

THANK YOU!

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