Continuous ocean colour products for ocean, coastal and inland waters

Martin Hieronymi & Rüdiger Röttgers

Supported by Kerstin Heymann, Eike Schütt, Shun Bi, Katharina Kordubel & Hereon Team

Department of Optical Oceanography, Institute of Carbon Cycles, Helmholtz-Zentrum Hereon*
(* former HZG & former GKSS but still in Geesthacht, Germany)

OCEAN CARBON FROM SPACE
2nd Workshop in the CLEO Series
Virtual Online Event | 14-18 February 2022

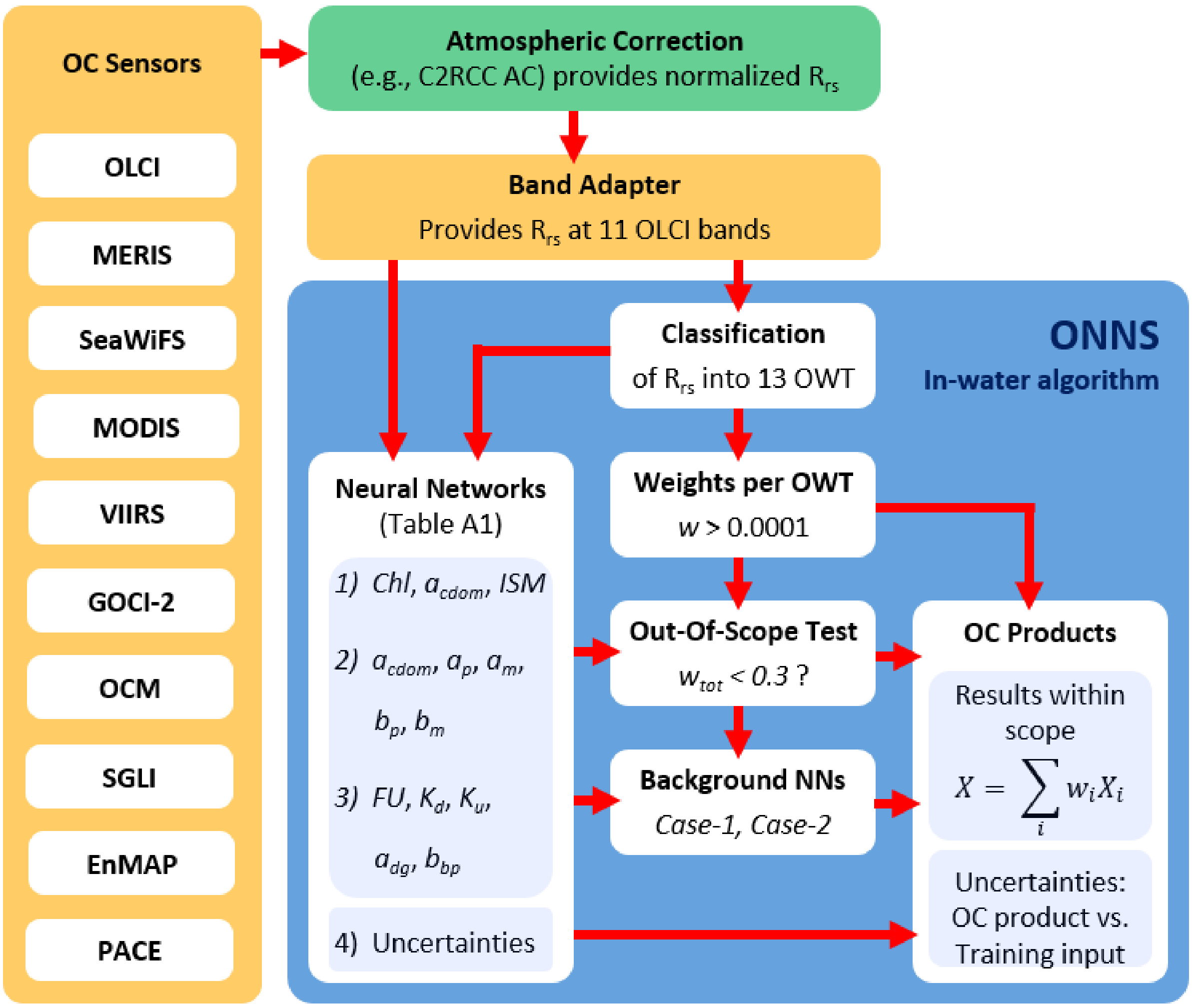
Helmholtz-Zentrum hereon

Continuous …

- Requires consideration of all optically active water constituents over full-spectral range
  - Water
  - Phytoplankton → Phytoplankton diversity
  - Inorganic & Organic Suspended Matter (TSM)
  - Coloured Dissolved Organic Matter (CDOM)
- Ocean Colour algorithms must be within scope
  - Work across Case-1 & Case-2 waters
  - Include cases with very high concentrations of phytoplankton, TSM & CDOM

Sentinel-3 OLCI Neural Network Swarm

- 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
- Related to Ocean Carbon from Space → DOC is estimated based on CDOM absorption at 440 nm



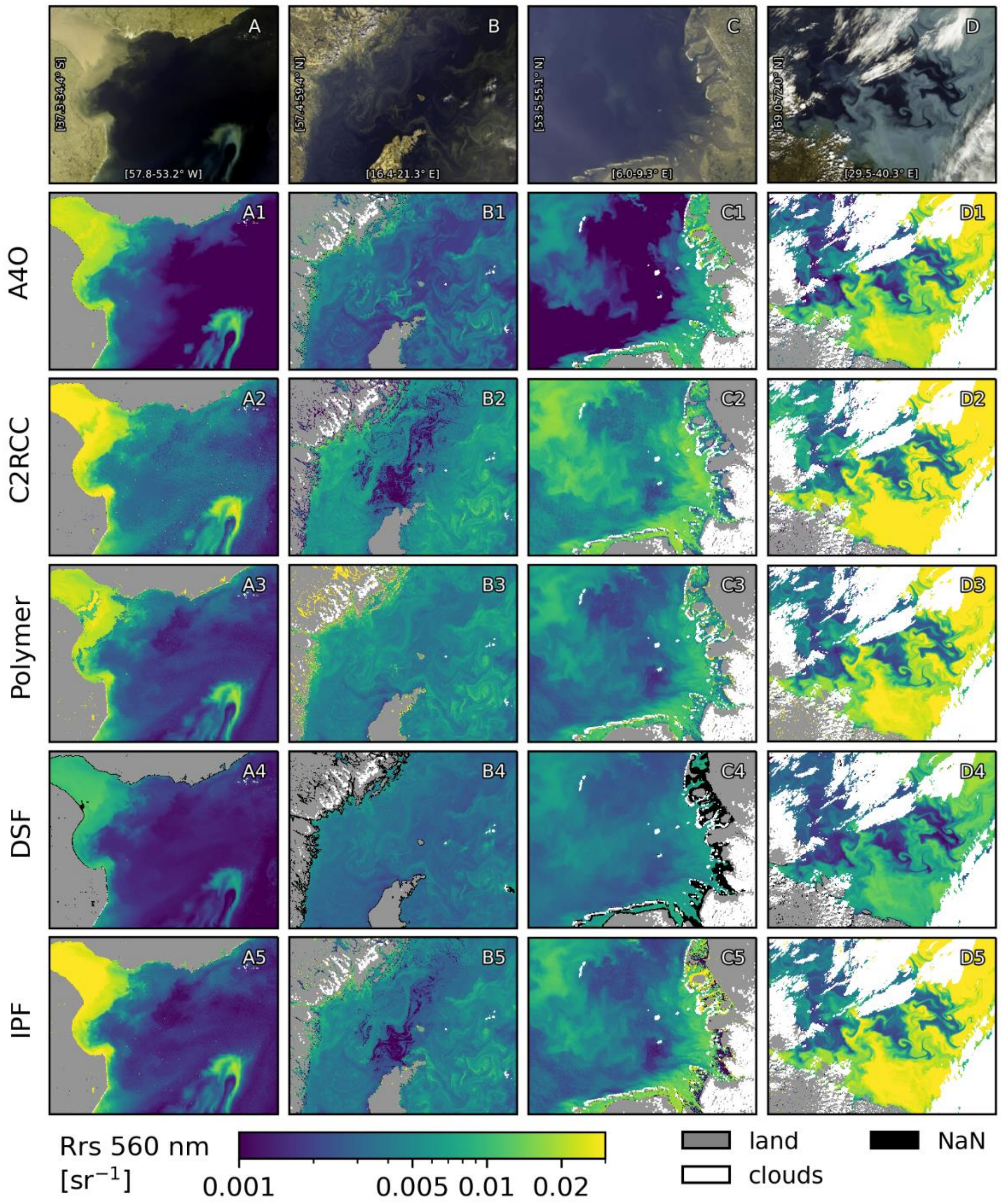
Hieronymi, M., Müller, D., & Doerffer, R. (2017). The OLCI Neural Network Swarm (ONNS): a bio-geo-optical algorithm for open ocean and coastal waters. *Frontiers in Marine Science*

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

Juhls, B., Overduin, P. P., Hölemann, J., Hieronymi, M., Matsuoka, A., Heim, B., & Fischer, J. (2019). Dissolved organic matter at the fluvial–marine transition in the Laptev Sea using in situ data and ocean colour remote sensing. *Biogeosciences*

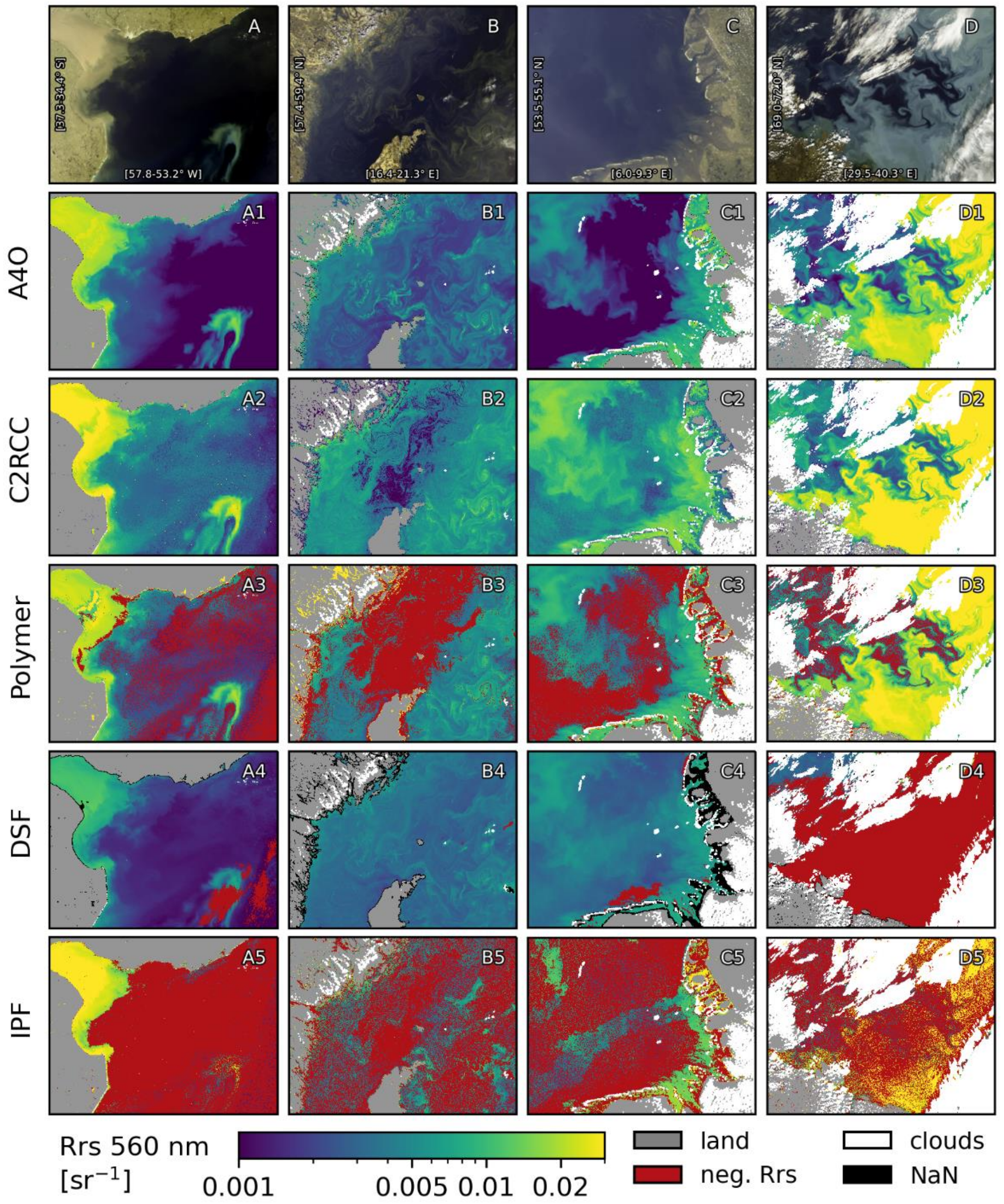
New Atmospheric Correction

- Atmospheric Correction for Optical Water Types (A4O)
- Ensemble of “globally valid” Neural Networks
  → enables uncertainty estimate
- Optimization on spectral shape of Rrs
  → well OWT classifiability



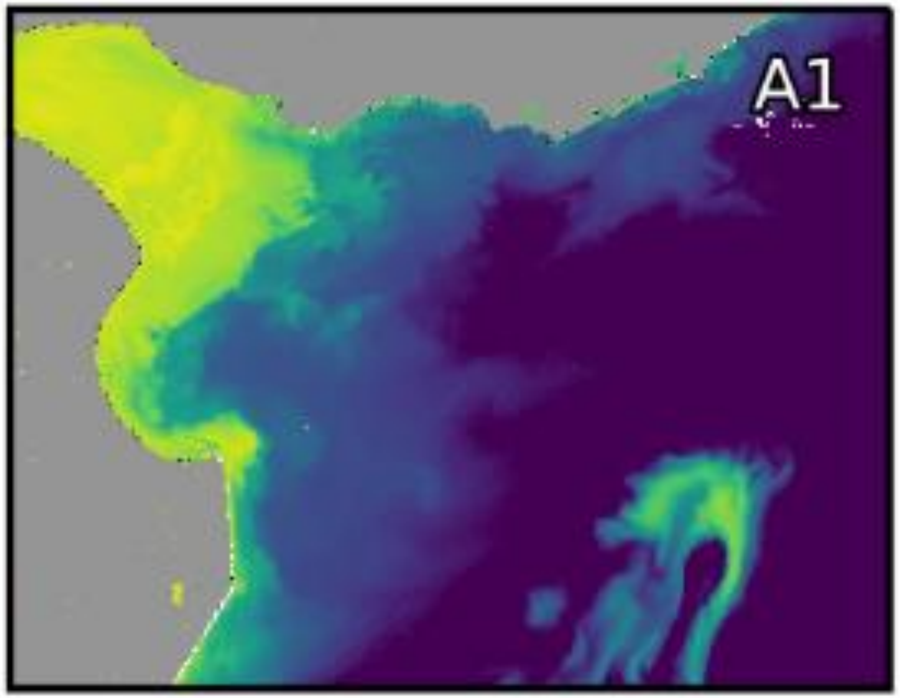
New Atmospheric Correction

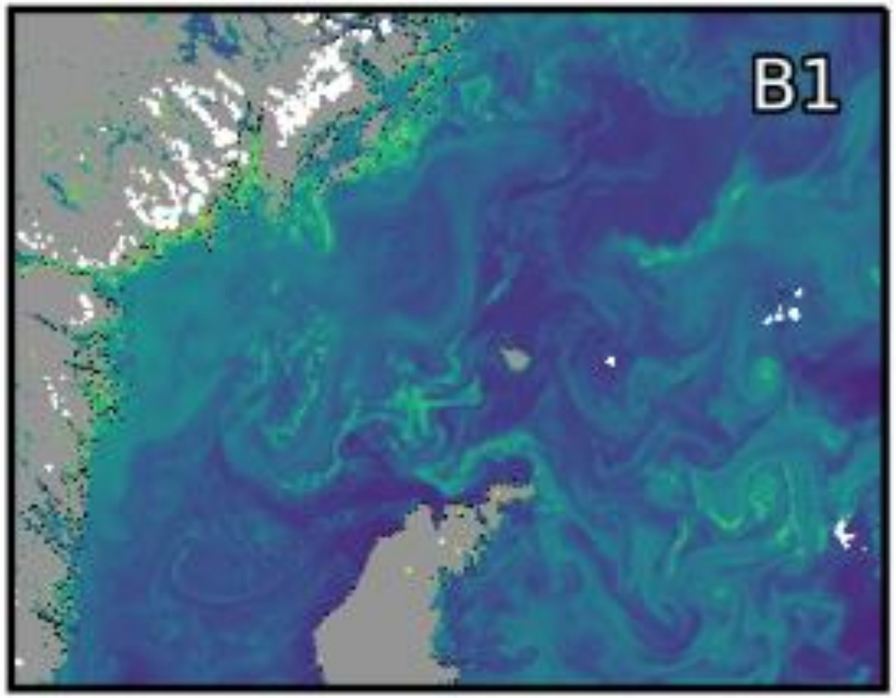
- Atmospheric Correction for Optical Water Types (A4O)
- Ensemble of “globally valid” Neural Networks
  → enables uncertainty estimate
- Optimization on spectral shape of Rrs
  → well OWT classifiability
- Generally useful Rrs



New Atmospheric Correction

- Atmospheric Correction for Optical Water Types (A4O)
- Ensemble of "globally valid" Neural Networks → enables uncertainty estimate
- Optimization on spectral shape of Rrs → well OWT classifiability
- Generally useful Rrs
- Reasonable results for Land-Coast-Ocean
- Features of phytoplankton diversity
- Reduced spatial and spectral noise
- By-product whitecap fraction
- Validation ongoing





Sentinel-3 OLCI Neural Network Swarm

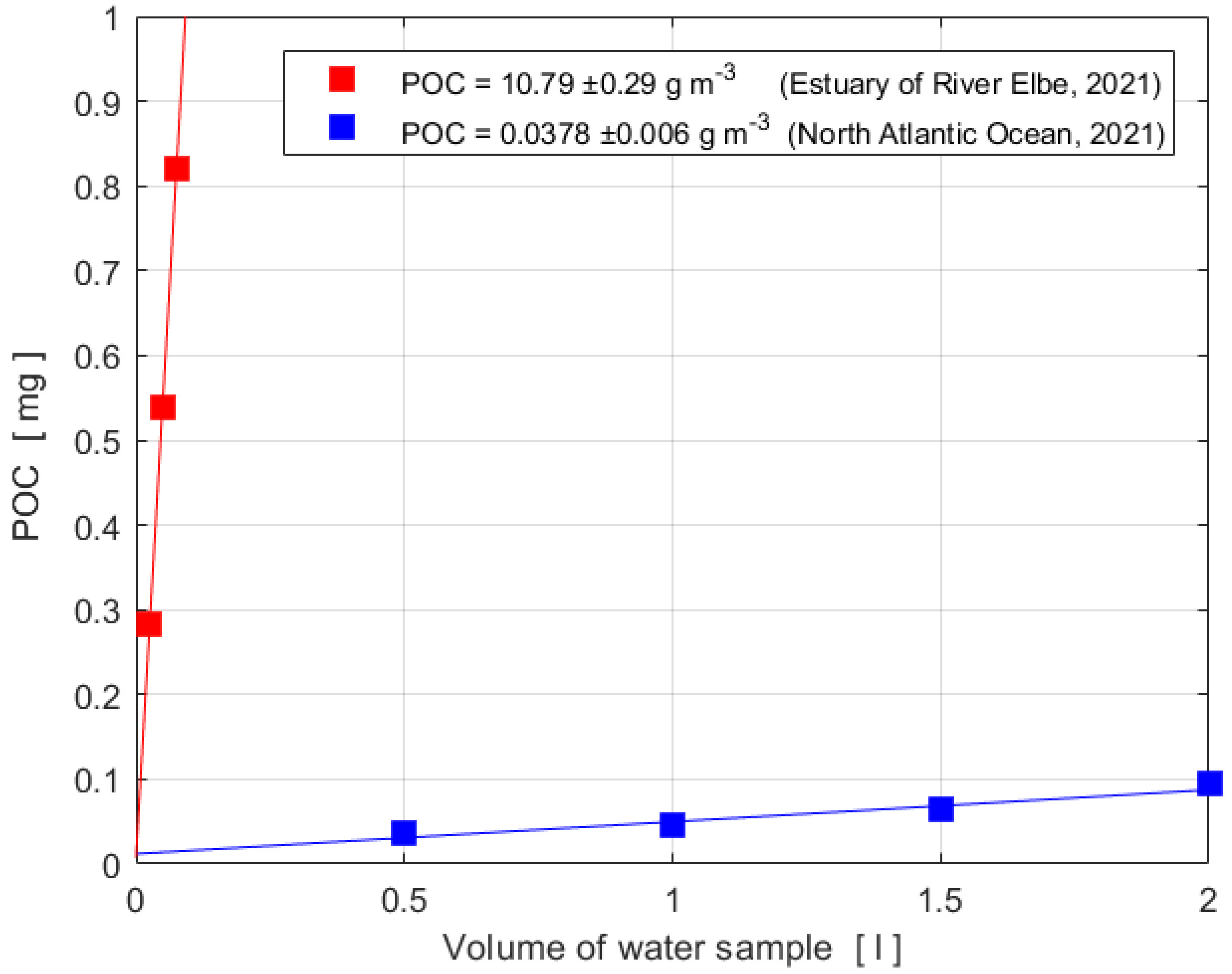
- Short- to Medium-term developments for ONNS
  - Revision of chlorophyll-specific absorption and scattering properties in view of phytoplankton diversity [Poster by Shun Bi]
  - Implementation of new products for primary productivity and phytoplankton diversity
  - OWT-based validation for all products

    → using Continuous Plankton Recorder and FerryBoxes [Poster by Katharina Kordubel]

    → e.g. of ONNS product on particulate organic carbon

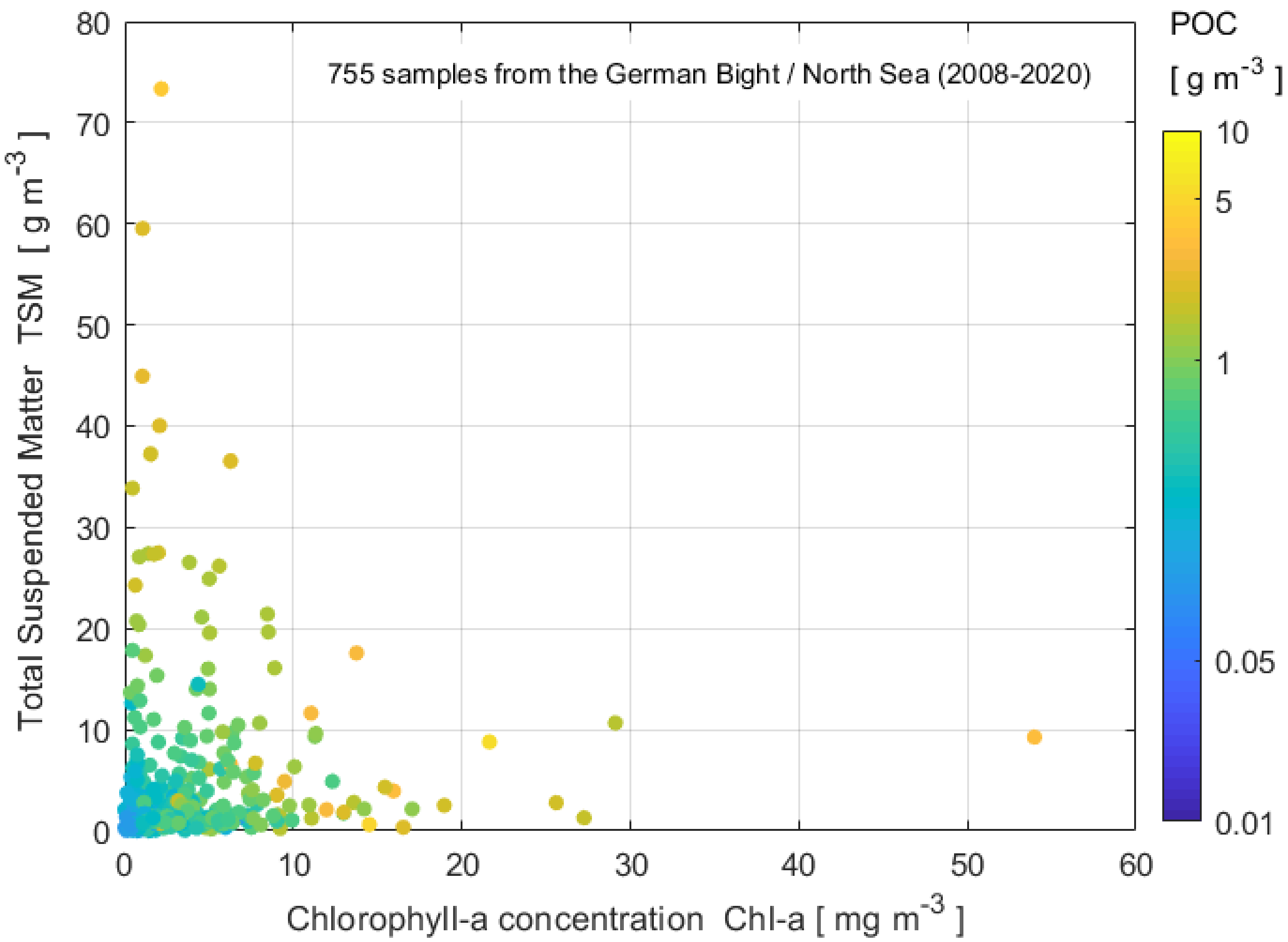
Particulate Organic Carbon

- POC varies several orders of magnitude between ocean, coastal and inland waters
- Offset bias only detectable with different volumes and not replicates of same volume
- Offset bias due to DOC in filter



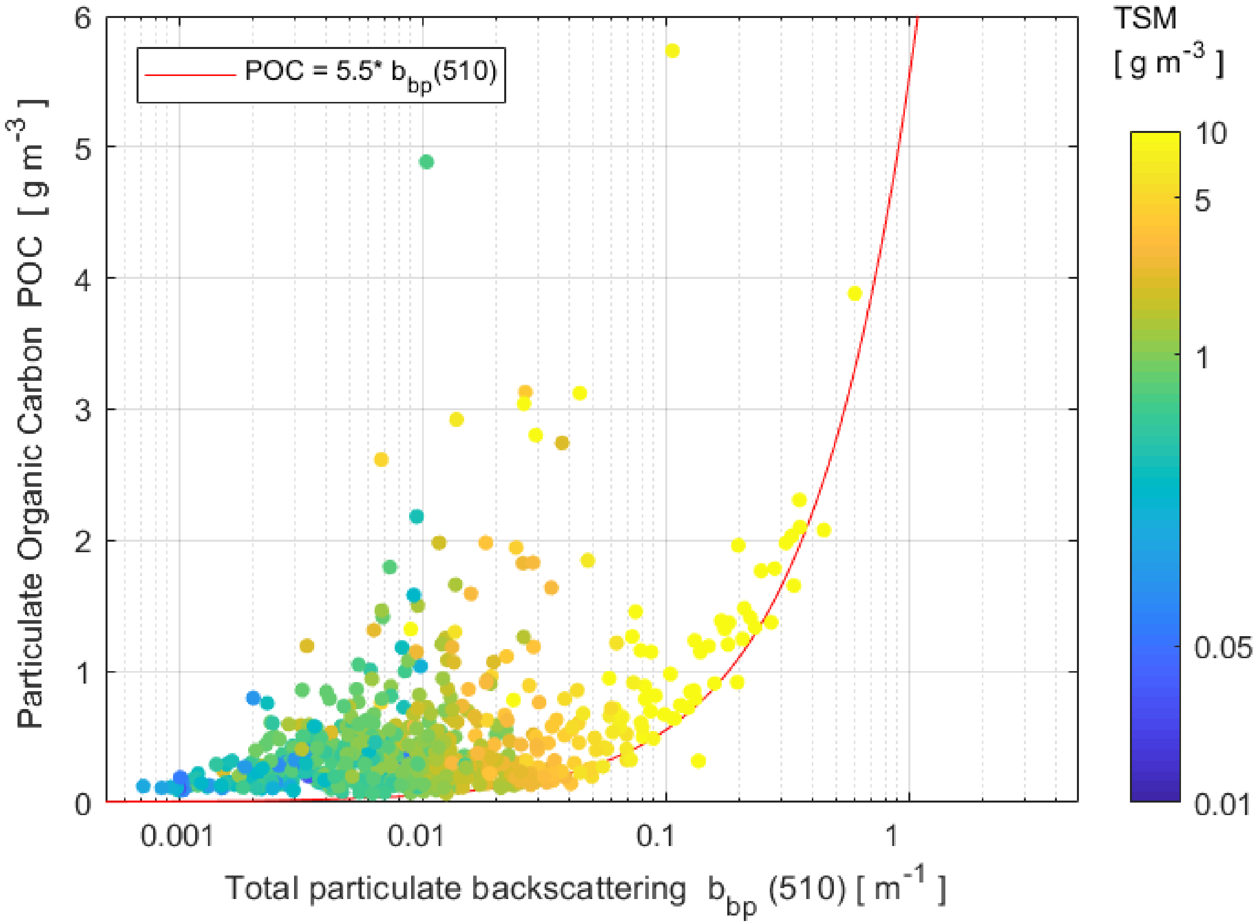
POC in Case-2 Waters

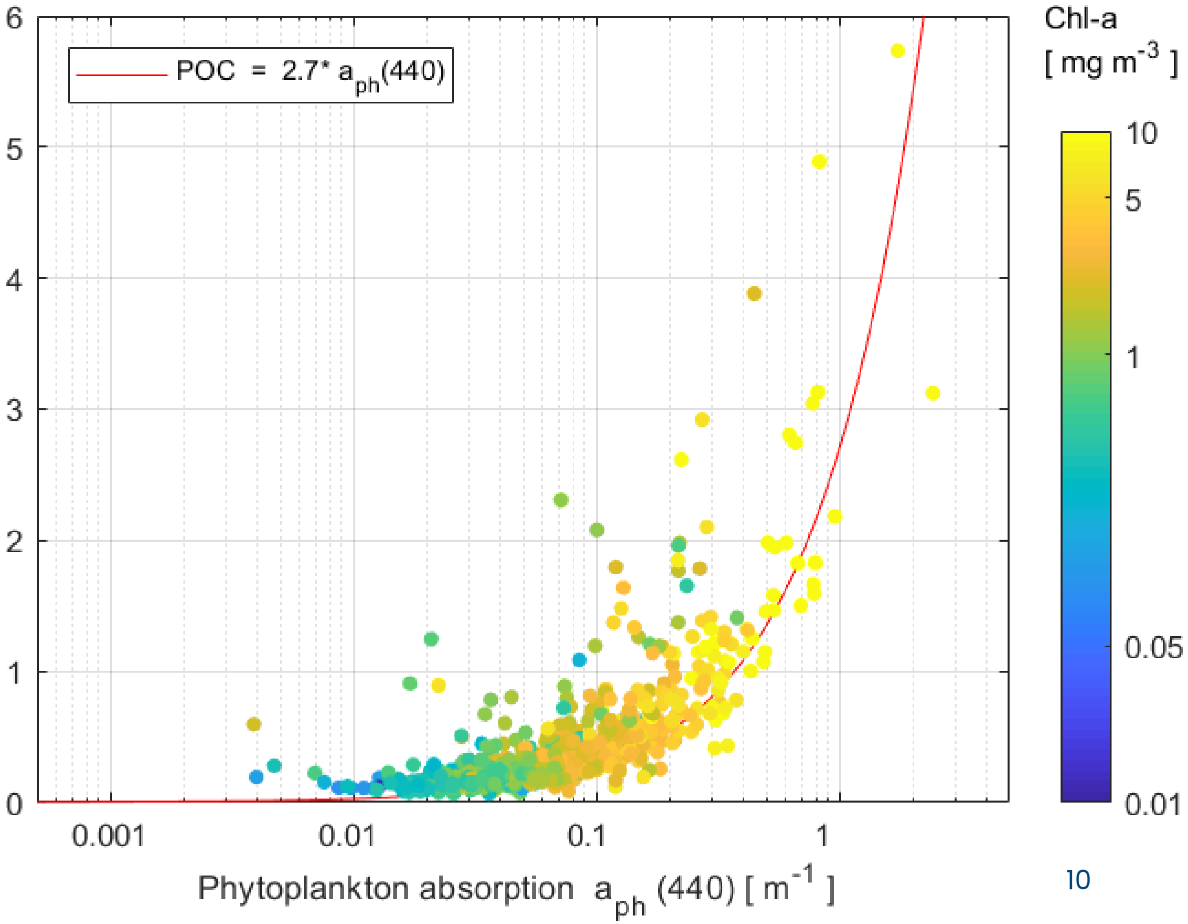
- Based on measurements in coastal waters of the German Bight, North Sea
- POC not related only to phytoplankton → POC associated with Inorganic Suspended Matter must be considered
- At first glace, POC correlates poorly with TSM or Chl-a concentrations
- Two branches of POC fractions visible



POC in Case-2 Waters

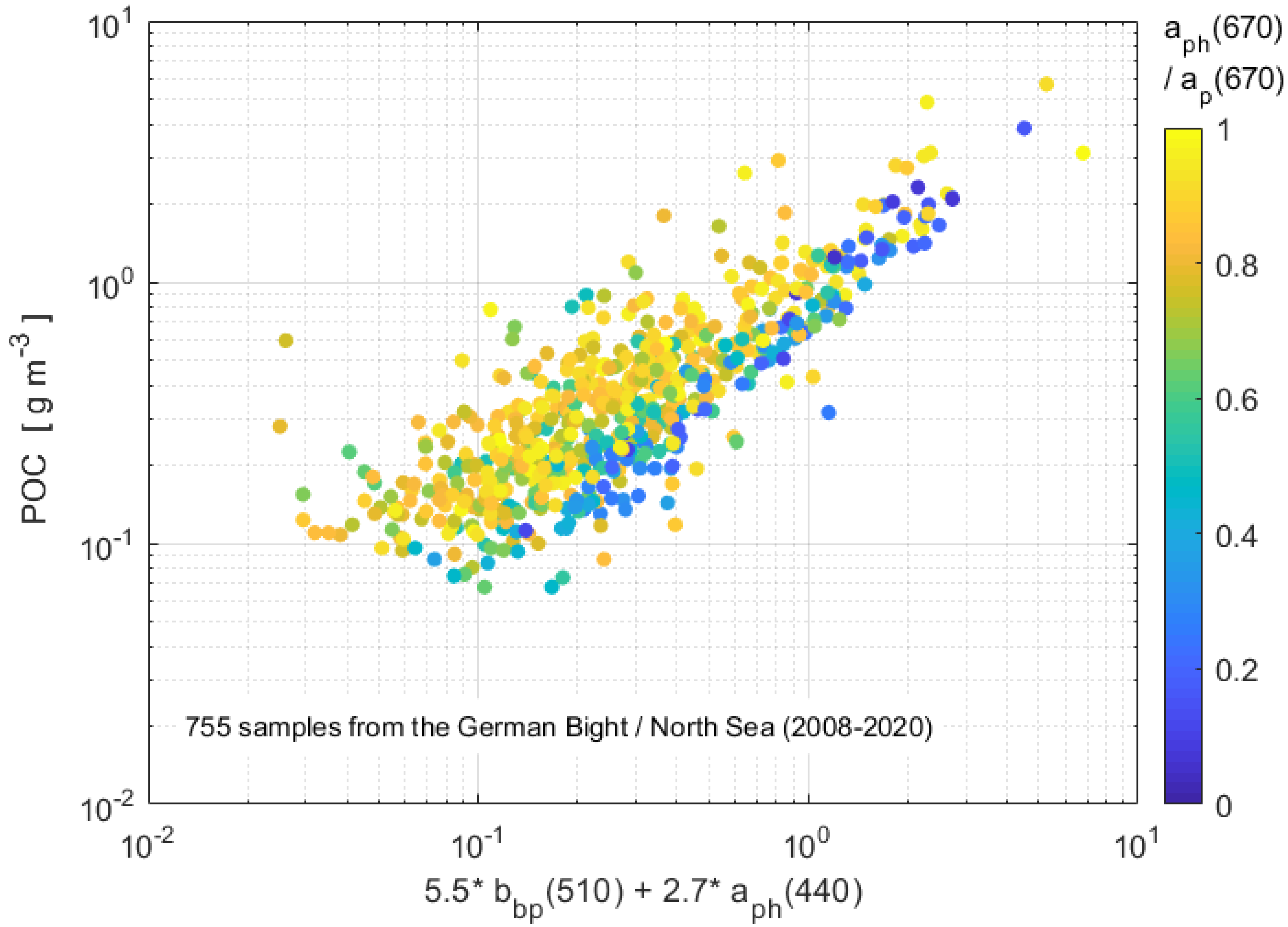
- Backscattering (or scattering or attenuation) is dominated by Inorganic Suspended Matter
- Phytoplankton concentration can be represented by pigment absorption (e.g. at 440 nm)





POC in Case-2 Waters

- Using combined information on Inorganic Suspended Matter and Phytoplankton yields better correlation with POC
- Important to separate IOPs associated with Inorganic Suspended Matter and Phytoplankton
- POC product of ONNS based on total particulate backscattering and phytoplankton absorption coefficients



Knowledge & Data Gaps

- Many ambiguities in Case-2 waters incl. inland waters
  → Joint measurements of IOPs, AOPs, DOC, POC, HPLC pigments … needed
- Dedicated research cruises into algae blooms should be organized & supported
  → Natural phytoplankton-specific IOPs needed (depending on phenology)
- Spectral scattering remains partly unclear → CLEO 2016 Roadmap
  → Hyperspectral VSF → back- and forward-scattering
- We need true uncertainties of measurements
  → Joint protocols and community processors
- Validation data are not available for all OWTs
  → Extremely absorbing and scattering waters missing → hyperspectral data needed
- All Ocean Colour products have strong sensitivity to applied Atmospheric Correction
  → AC-specific bio-geo-optical models needed → Concentrations derived from IOPs