Phytoplankton functional types from multi-sensor satellite observations – towards a long-term monitoring (2002-2020)

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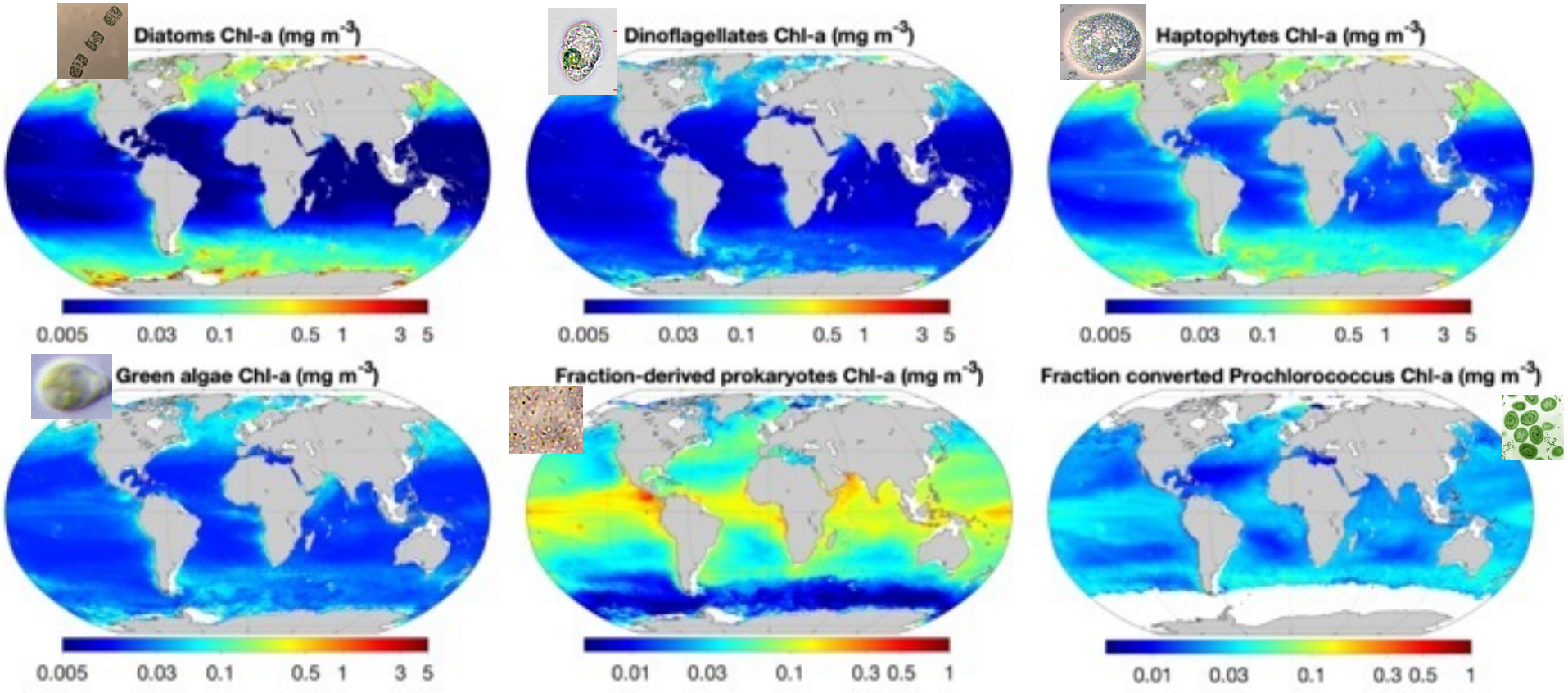
- Phytoplankton regulate the key biogeochemical processes – nutrient uptake, carbon and energy export…
- PFT - various taxonomic groups that function differently in the marine ecosystem
- Critical to perform long term observation of PFT – changes in community structure influence the entire ocean environment
- Aids in modeling w.r.t. global carbon cycle and ecological/ biogeochemical processes

Outline

- Satellite PFT products derived using EOF-PFT approach
- Evaluation of satellite products of PFTs in different regions
  - Arctic Fram Strait (high latitude)
  - Trans-Atlantic region (temperate to tropical region)
- Long-term monitoring in the Fram Strait
  - Time series of PFTs from 2002 to 2020 (separating water masses)
  - Fram Strait phytoplankton phenology, inter-annual variation, changes in composition

Phytoplankton functional type products from satellites

- **A global approach for PFT chlorophyll retrieval using ocean color reflectance data and SST** (Xi et al. 2020, 2021)
  - A set of empirical orthogonal function based algorithms
  - Capability of retrieving Chla of 6 groups- diatoms, haptophytes and others
- **Data products available** in **CMEMS** at https://marine.copernicus.eu/



Note that different color scales are used

Timeline of satellite PFT products and in situ data

SeaWiFS/MODIS/MERIS merged product
July 2002 - April 2012

PS74 (2009)
PS76 (2010)
PS78 (2011)

MODIS/VIIRS merged product
Jan 2012 – present

PS80 (2012)
PS85 (2014)
PS93 (2015)
PS99 (2016)
PS107(2017)

Sentinel 3A OLCI
May 2016 - present

PS120 (2019)
AMT28 (2019)
PS121(2019)

- 9 expeditions to the Arctic Fram Strait since 2009 **(AWI data PS74-PS121)**
- 2 expeditions in the trans-Atlantic Ocean **PS120 (FCUL) and AMT28 (PML)**

- Diagnostic pigment analysis of pigment data (HPLC) for in situ PFT Chla estimation

2002 2012 2020

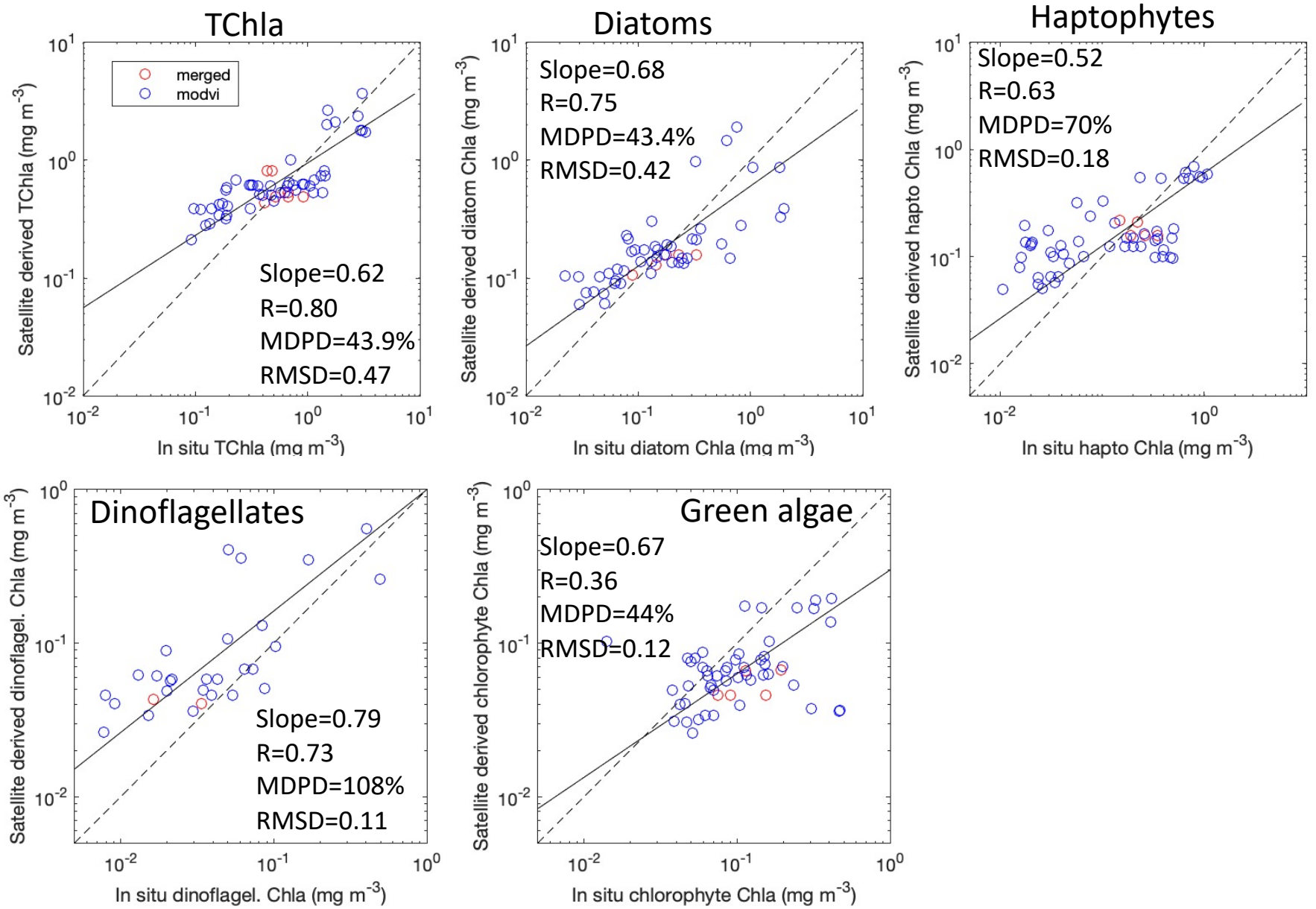
Evaluation of satellite products

Criterion for matchups:

- mean of 3x3 pixels
- with > 4 valid pixels
- CV>0.2

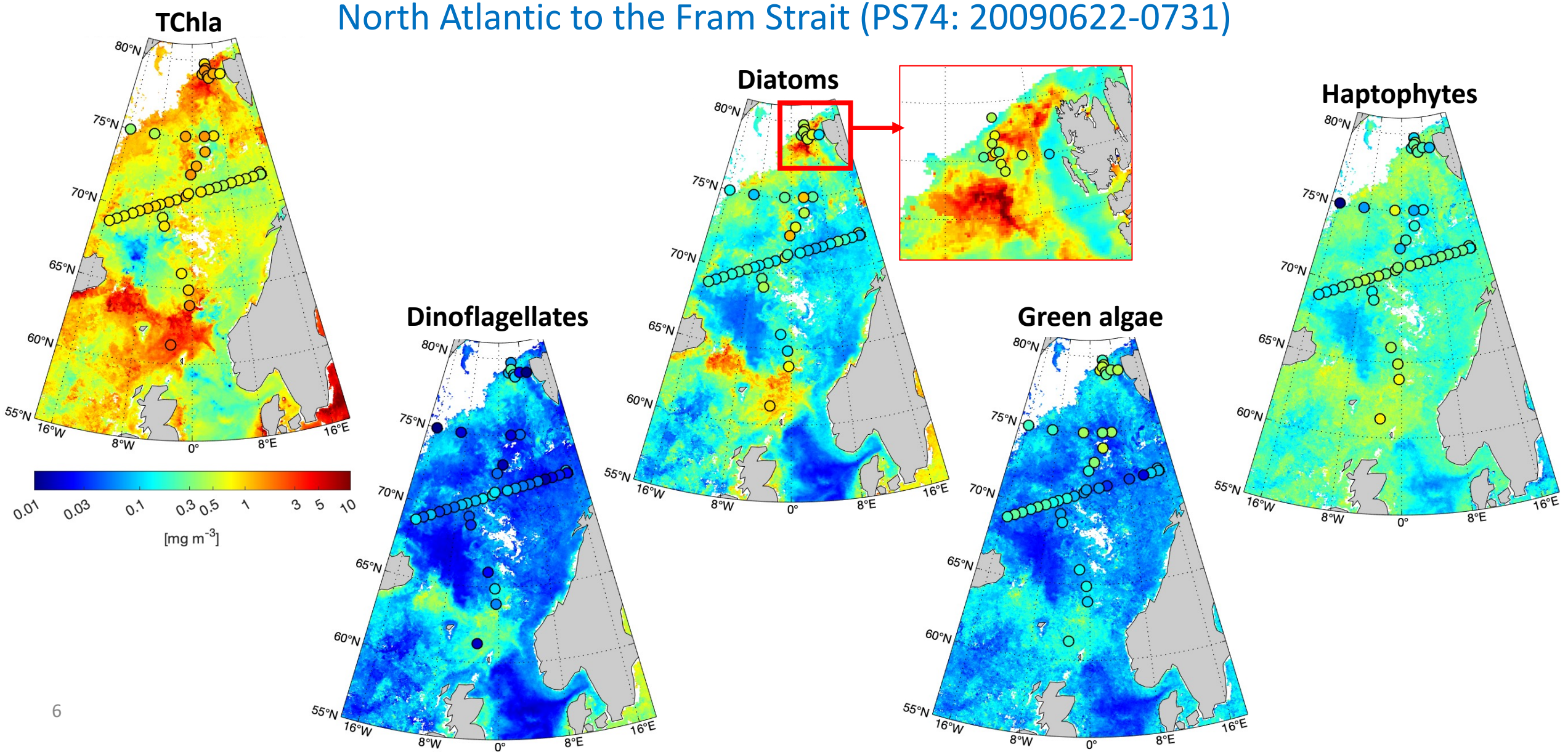
- ~60 matchups among >1000 in situ data points

- In general good match



Satellite composites during expedition (example 1)

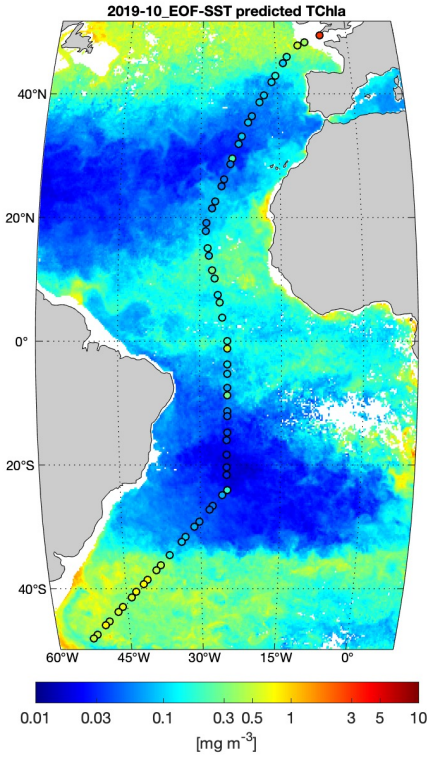
North Atlantic to the Fram Strait (PS74: 20090622-0731)



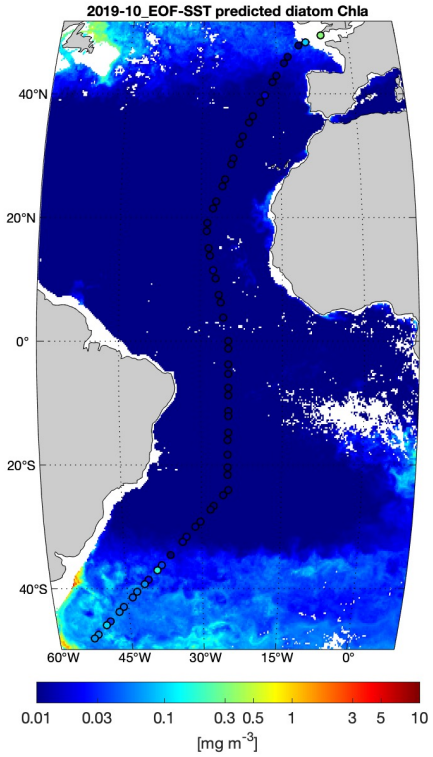
Satellite composites during expedition (example 2)

Trans-Atlantic region AMT28 (PML): 20190925-1027

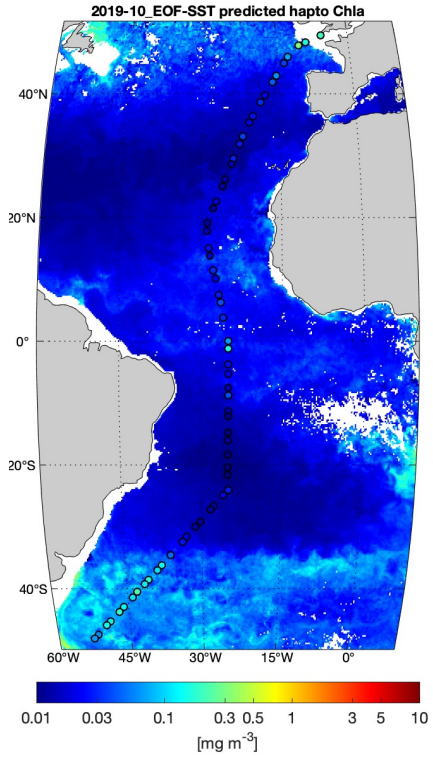
TChla



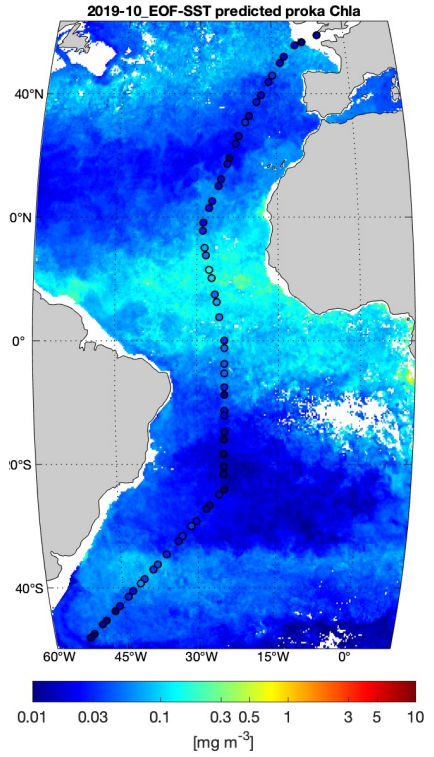
Diatoms



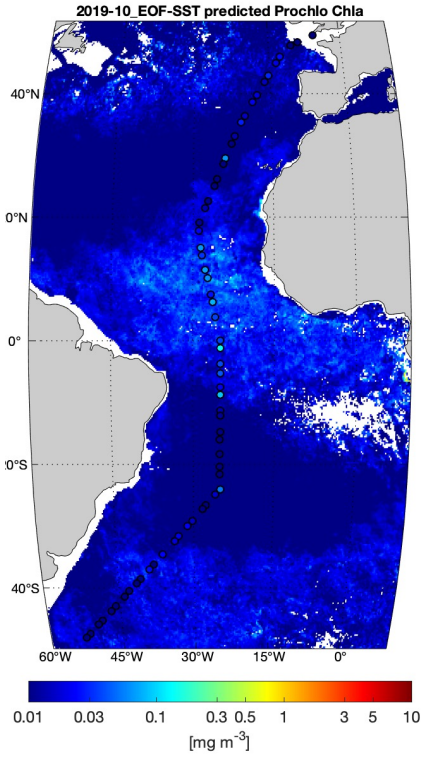
Haptophytes



Prokaryotes



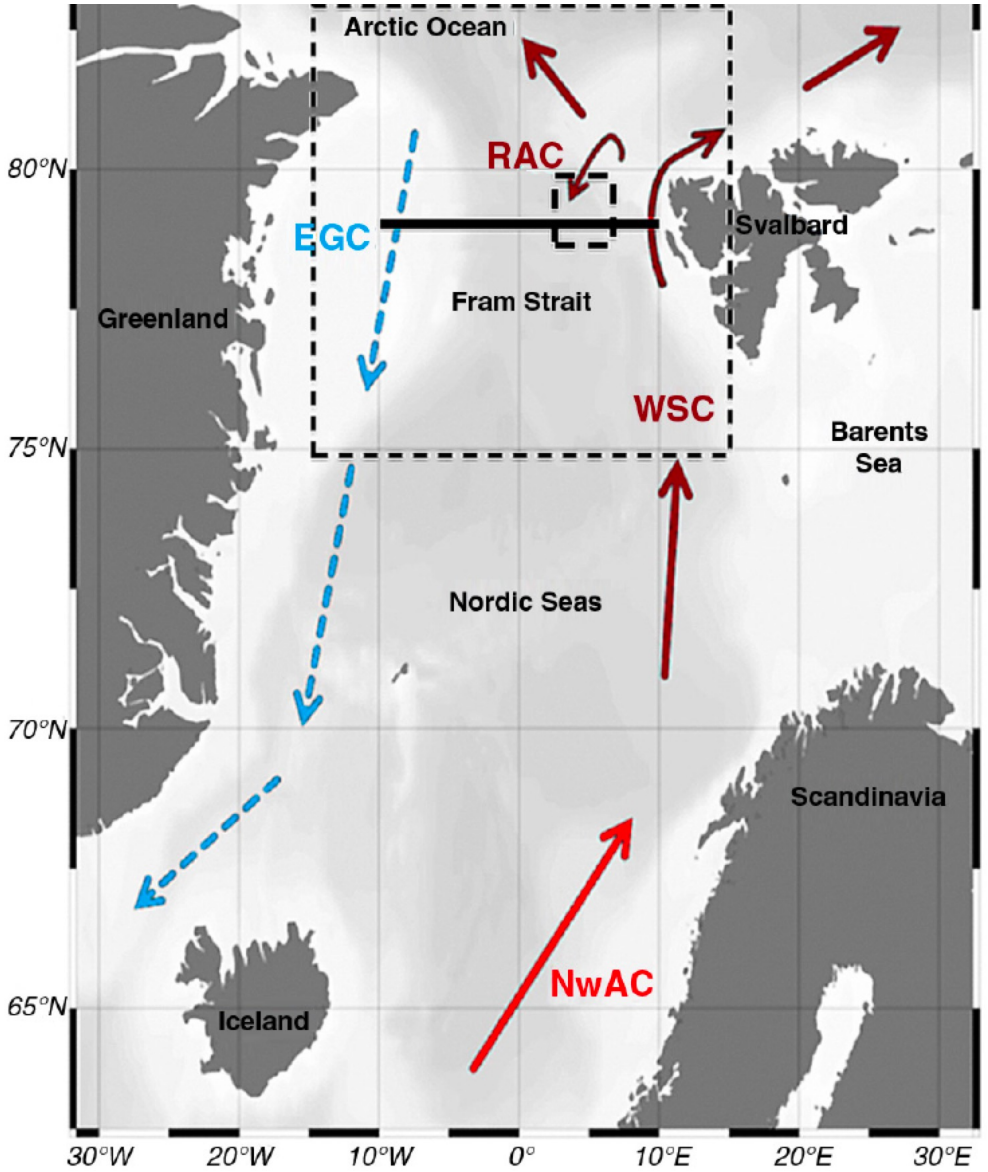
Prochlorococcus



- Satellite PFTs derived using EOF-PFT approach match well with the in situ data
- Satellite retrievals reveal plausible PFT distribution:
  - Arctic region: larger-sized phytoplankton dominating – diatoms and haptophytes
  - Temperate and tropical region: picophytoplankton dominating – Prokaryotes/cyanobacteria

PFT time series in the Fram Strait

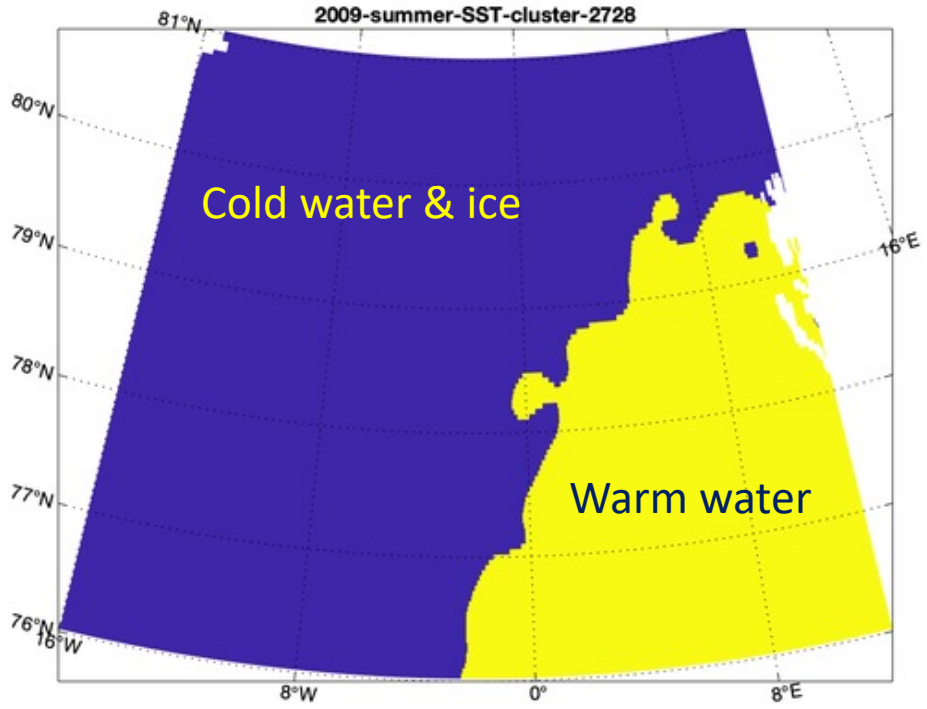
- Fram Strait - gateway to the Arctic
- Warmer nutrient-rich water (West Spitsbergen Current) entering the polar ocean meets the cold fresher Arctic water (East Greenland Current)
- Complex ecosystem subject to severe climate-induced environmental changes

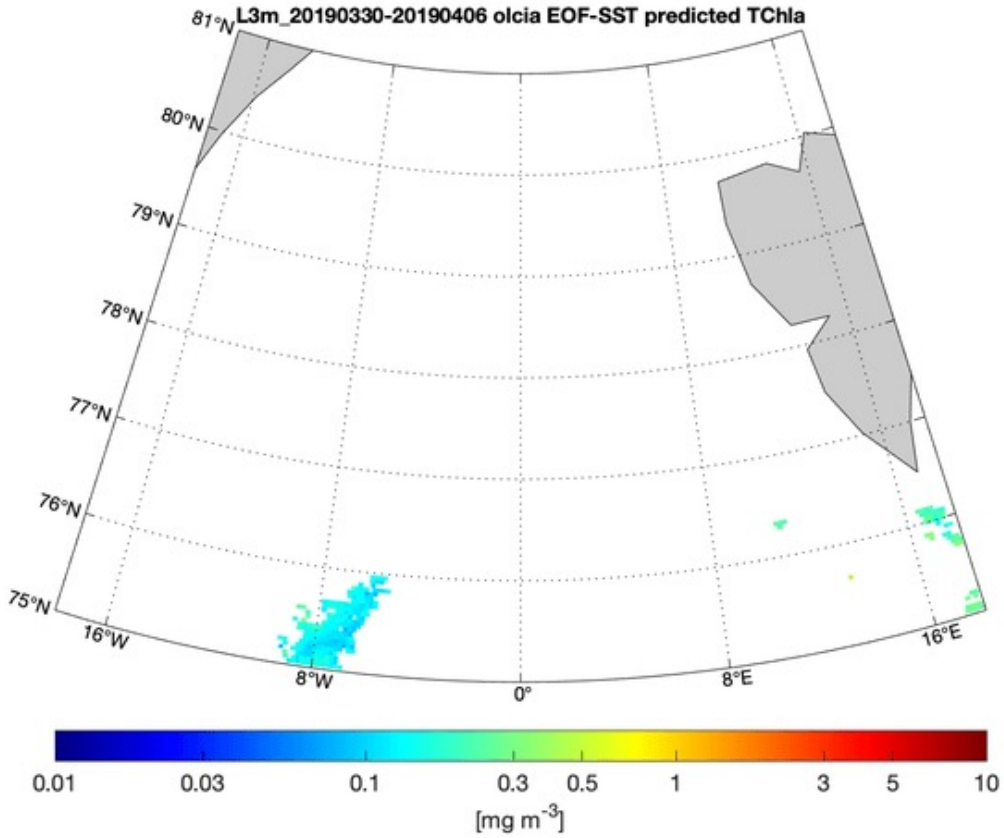


Nöthig et al. (2015)

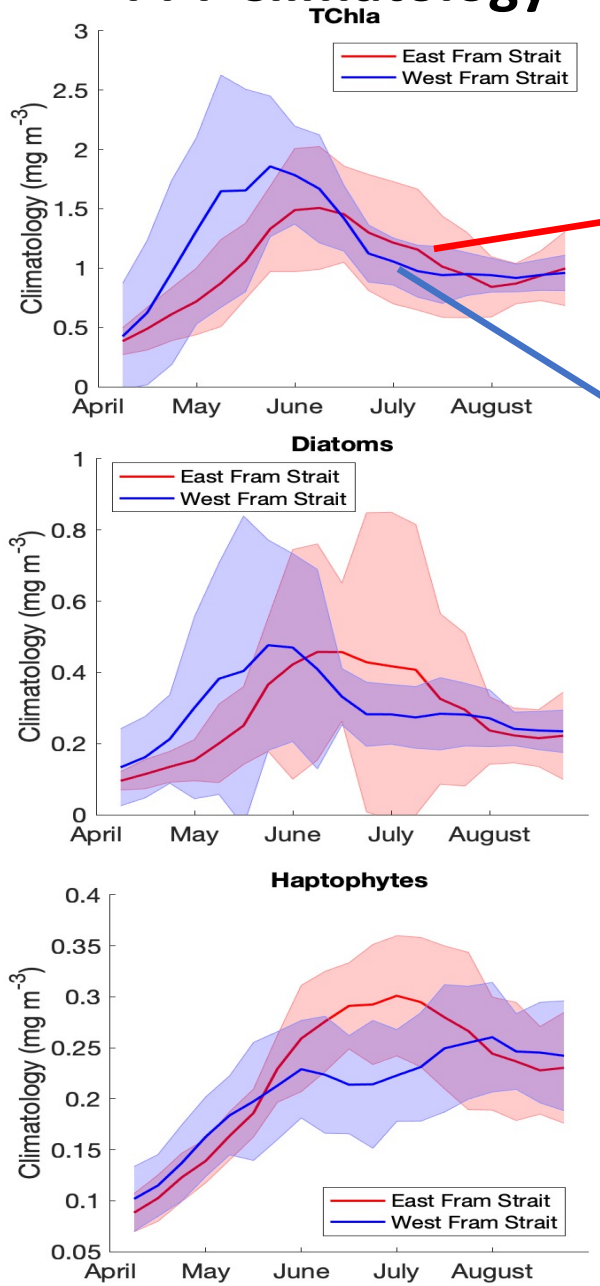
Phytoplankton observation in West and East Fram Strait

- Whole region: 16W – 12E, 75N – 81N
- Period: April to August (2002-2020)
- A dynamic clustering of the water masses based on CMEMS daily SST

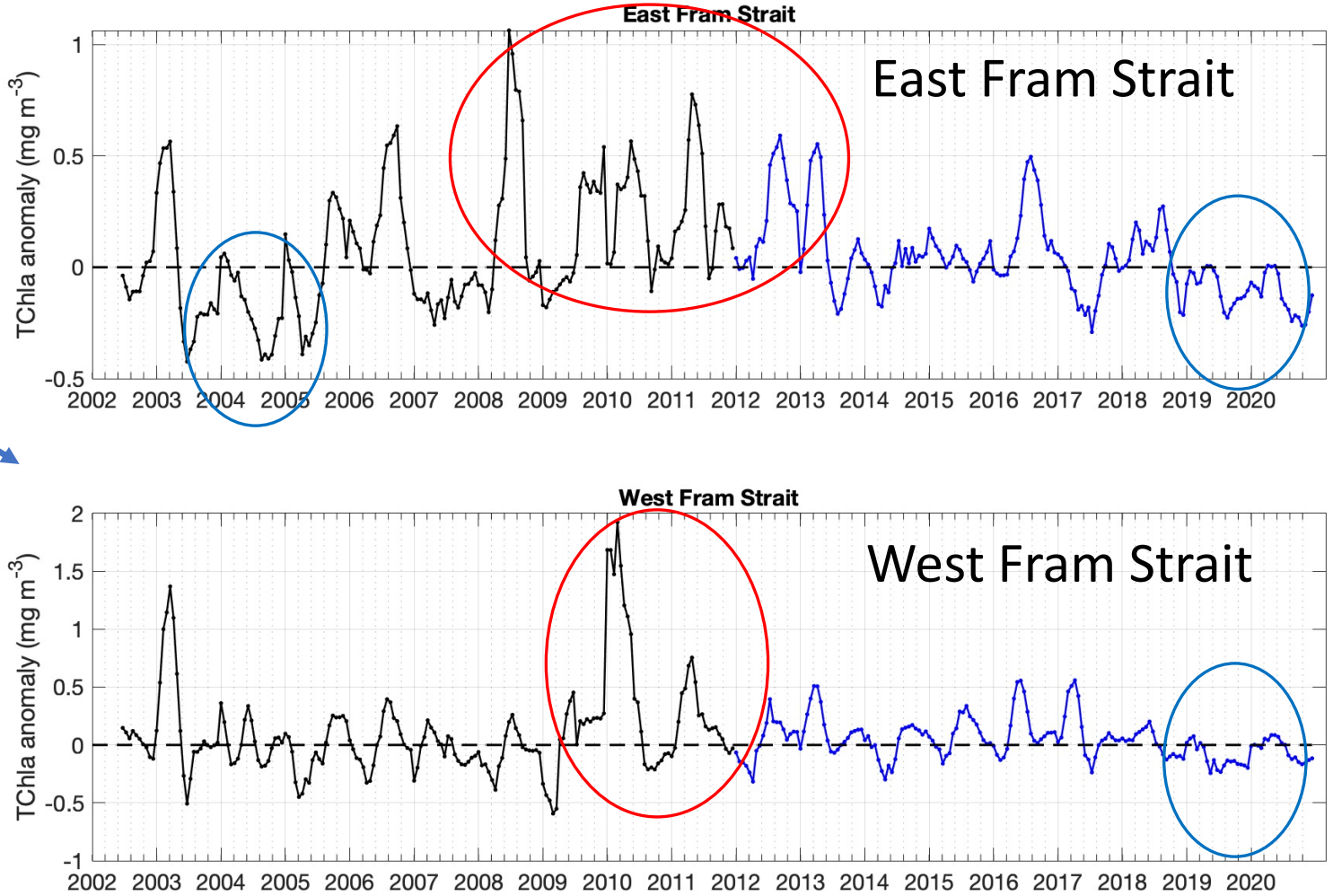




PFT Climatology



TChla Anomaly



TChla observations coincide with the previous reported patterns in the FS (e.g., Cherkasheva et al., 2014; Nöthig et al. 2015; Engel et al. 2019)

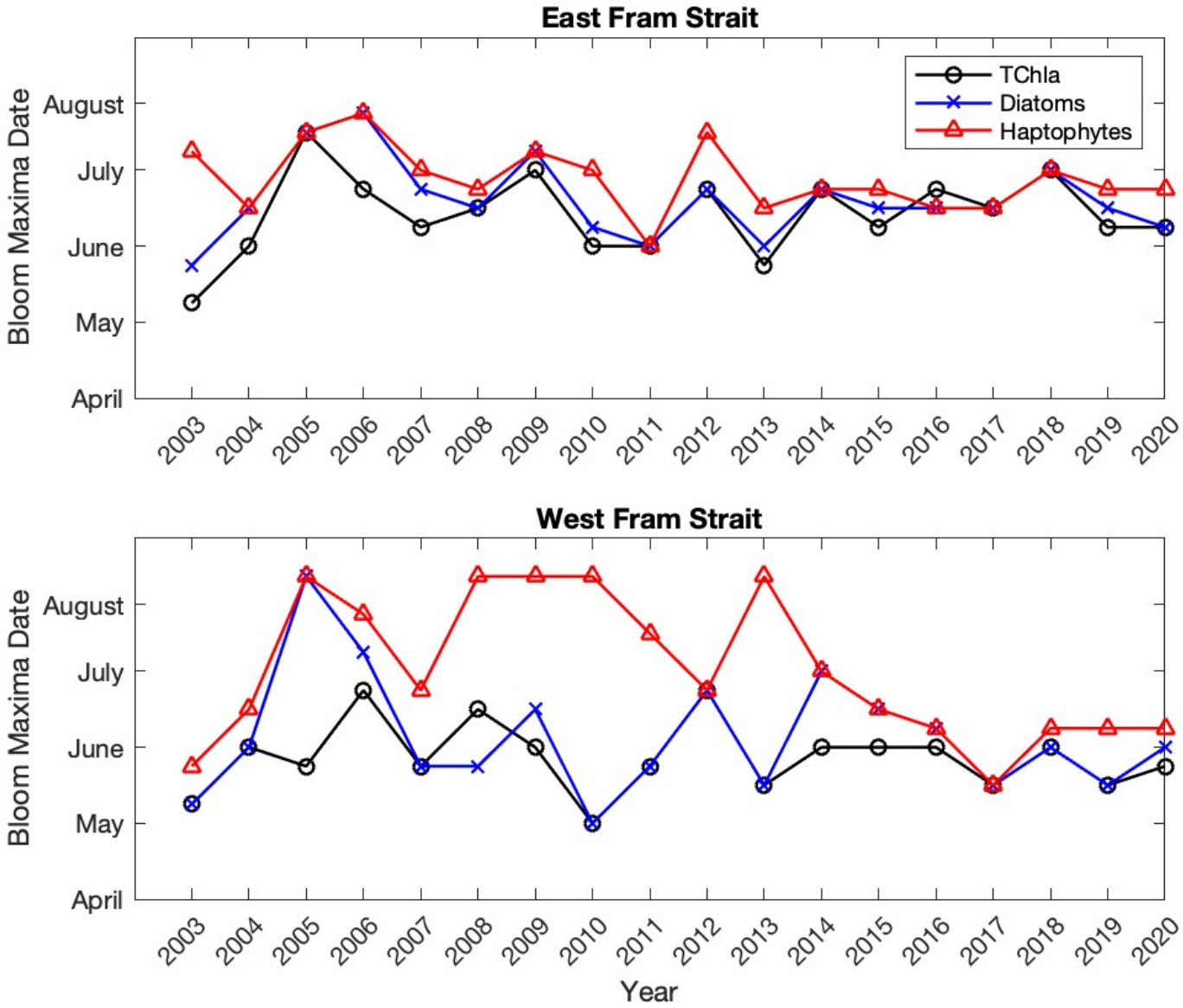
1998-2009 | 1998-2012 | 2009-2017

Phytoplankton Phenology

- East FS (Atlantic water mass):
  - Diatoms start to bloom 8~30 days earlier than haptophytes;
  - Pattern of total phytoplankton bloom in general follows the diatom; haptophytes tend to rapidly reach maxima since 2014

- West FS (Arctic water mass):
  - Similar to the east FS, but haptophytes takes longer to reach maxima
  - Haptophytes phenology since 2015 similar to diatoms

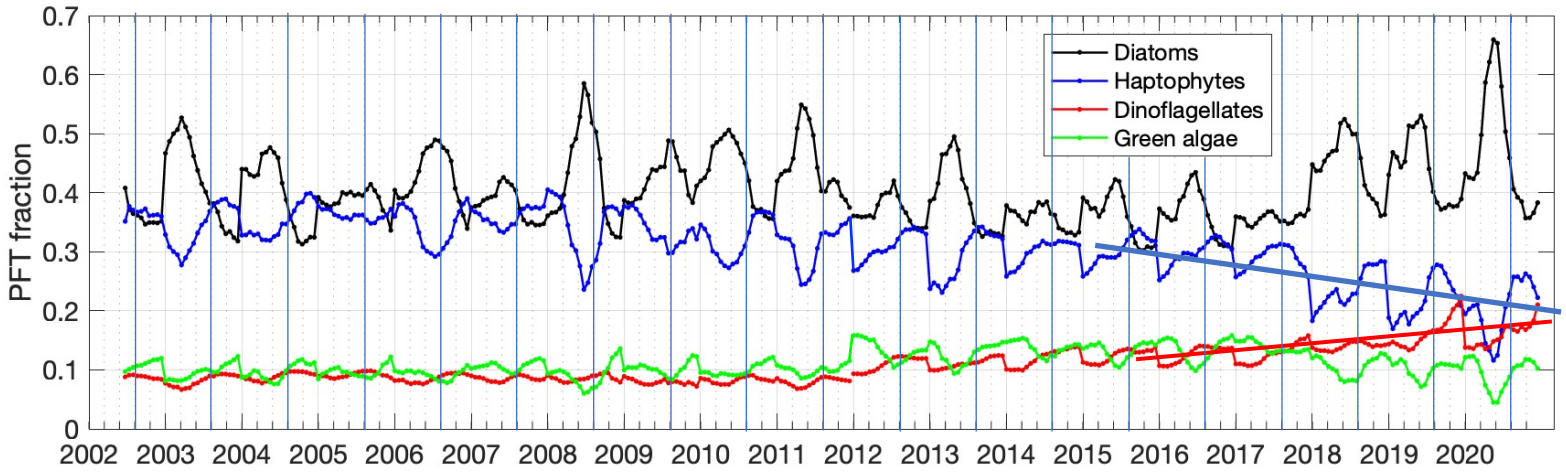
Bloom Maxima Date



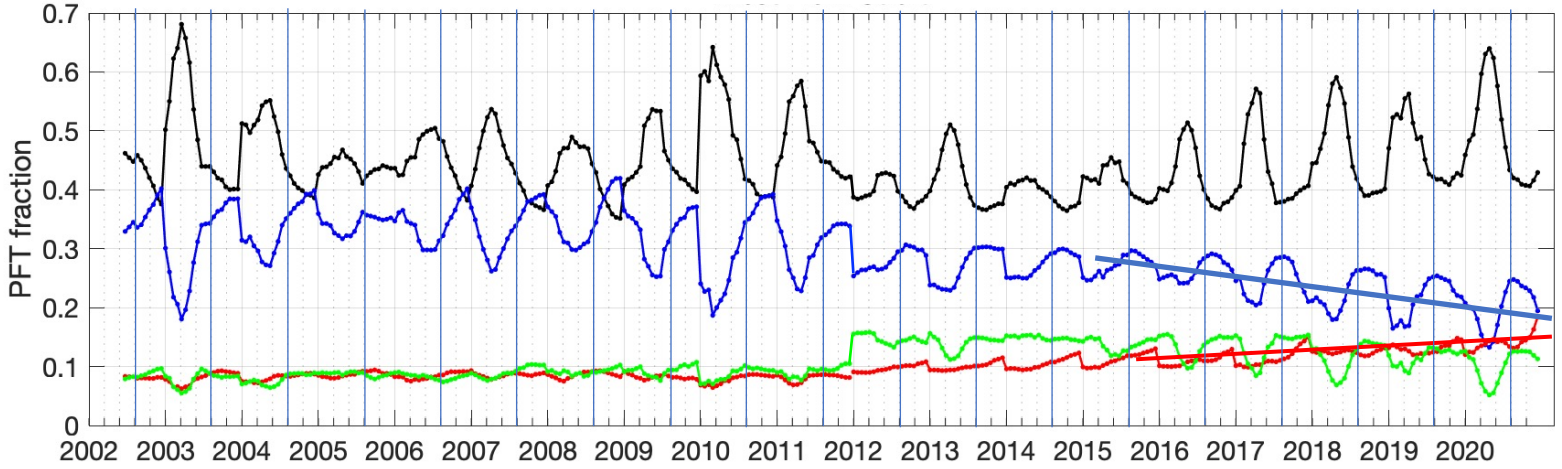
Changes in phytoplankton composition

- Diatoms and haptophytes take up 70-80% of the total biomass, diatoms dominate in early months
- Haptophytes fraction – an obvious decline since 2015
- Dinoflagellates as a minor contributing group increase in the proportion
- Microphytoplankton (diatoms + dinos) contribute more in recent years (2017-2020)?

East Fram Strait



West Fram Strait



Summary

- Satellite global PFT products derived from EOF-PFT approach present plausible distribution patterns in different regions
- Phytoplankton time series
  - Satellite PFTs show great potential in observing PFT composition in regional scales
  - Fram Strait phytoplankton
    - High interannual variability
    - Annual cycles of phytoplankton growth are different in the west and east
    - Blooms start slightly earlier in the west FS (more related to the marginal ice zone)
    - Haptophytes grow after diatoms and last until August
    - Obvious changes in the last few years

Outlook

- Produce consistent PFT products from different OC sensors
- Further investigate the changes found for satellite PFTs in linkage to other biogeochemical/physical parameters

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Thanks for your attention!