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Extended satellite time-series of coccolithophore blooms for investigating tipping points

Peter Miller, Tim Smyth, Mark Warren

Ocean Carbon from Space, 24-25 Nov. 2025

SCIENCE FOR OCEAN ACTION

CLIMATE-SPACE: TIPPING ELEMENTS ACTIVITY

Tipping points and abrupt changes In the Marine Ecosystem (TIME)

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UoS: Žarko Kovač

https://climate.esa.int/en/tipping-points-research/about-TIME/

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ESA TIME: Tipping Elements

TIPPING ELEMENTS	FRAGILE	ANTI - FRAGILE
TIPPING ELEMENT 1 Phytoplankton & Primary Production	DIATOMS	PICOPLANKTON
TIPPING ELEMENT 2 Phenology (Subtropical areas)	LAND DESERTIFICATION	PHYTOPLANKTON
TIPPING ELEMENT 3 Plankton Size & Structure (Atlantic Ocean)	DIATOMS	PICOPLANKTON
TIPPING ELEMENT 4 Noctiluca (Arabian Sea)	DIATOMS	NOCTILUCA

TIPPING ELEMENTS	FRAGILE	ANTI - FRAGILE
TIPPING ELEMENT 5 Coccolithophores	LIMITED OCCURRENCE	EXPANDING OCCURRENCE
TIPPING ELEMENT 6 Antarctic Marine Ecosystem	ICE	PHYTOPLANKTON
TIPPING ELEMENT 7 North Atlantic Subpolar Gyre	EXPORTING ECOSYSTEM	RECYCLING ECOSYSTEM
TIPPING ELEMENT 8 Coral Reefs (Gulf of Mannar)	REEFS	SEAWEED

Particulate inorganic carbon (PIC)

Earth observation time-series for coccoliths

GEOPHYSICAL RESEARCH LETTERS, VOL. 31, L11302, doi:10.1029/2004GL019735, 2004

Time series of coccolithophore activity in the Barents Sea, from twenty years of satellite imagery

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Earth Syst. Sci. Data, 10, 2043–2054, 2018
https://doi.org/10.5194/essd-10-2043-2018

Open Access Earth System Science Data

-year global data set of visible-channel sing reflectances and coccolithophore bloom nce derived from the Advanced Very High Resolution Radiometer catalogue

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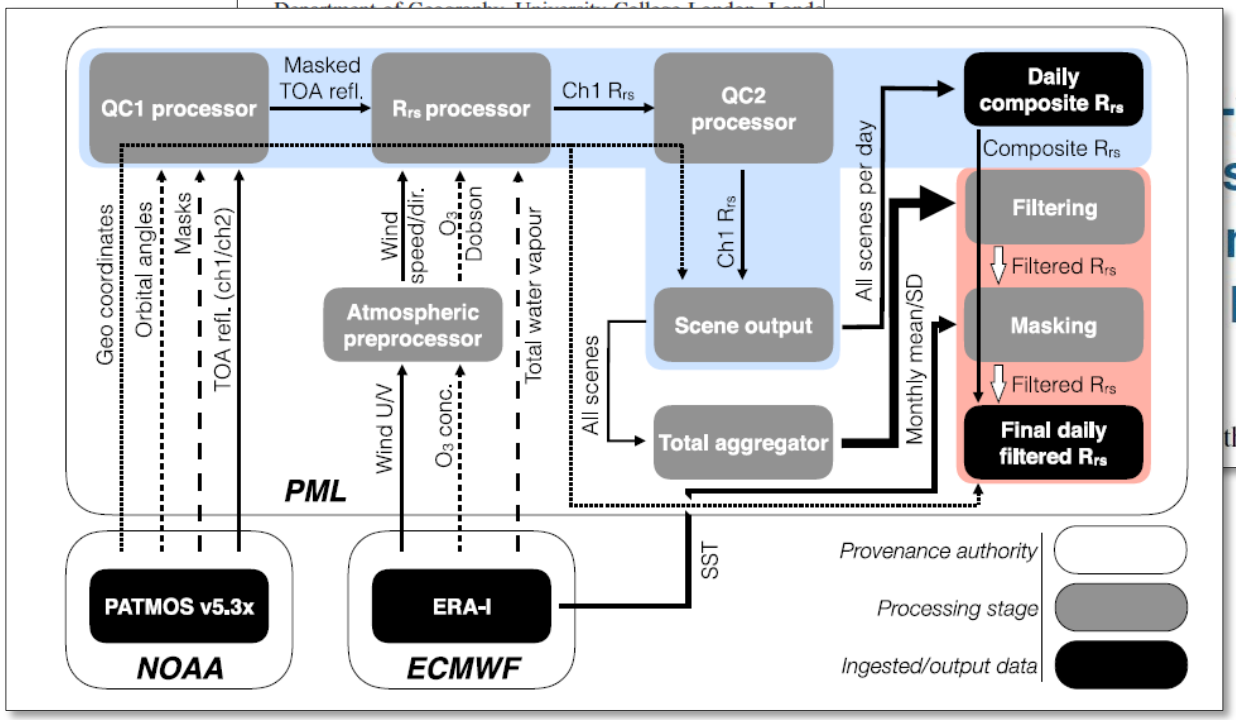
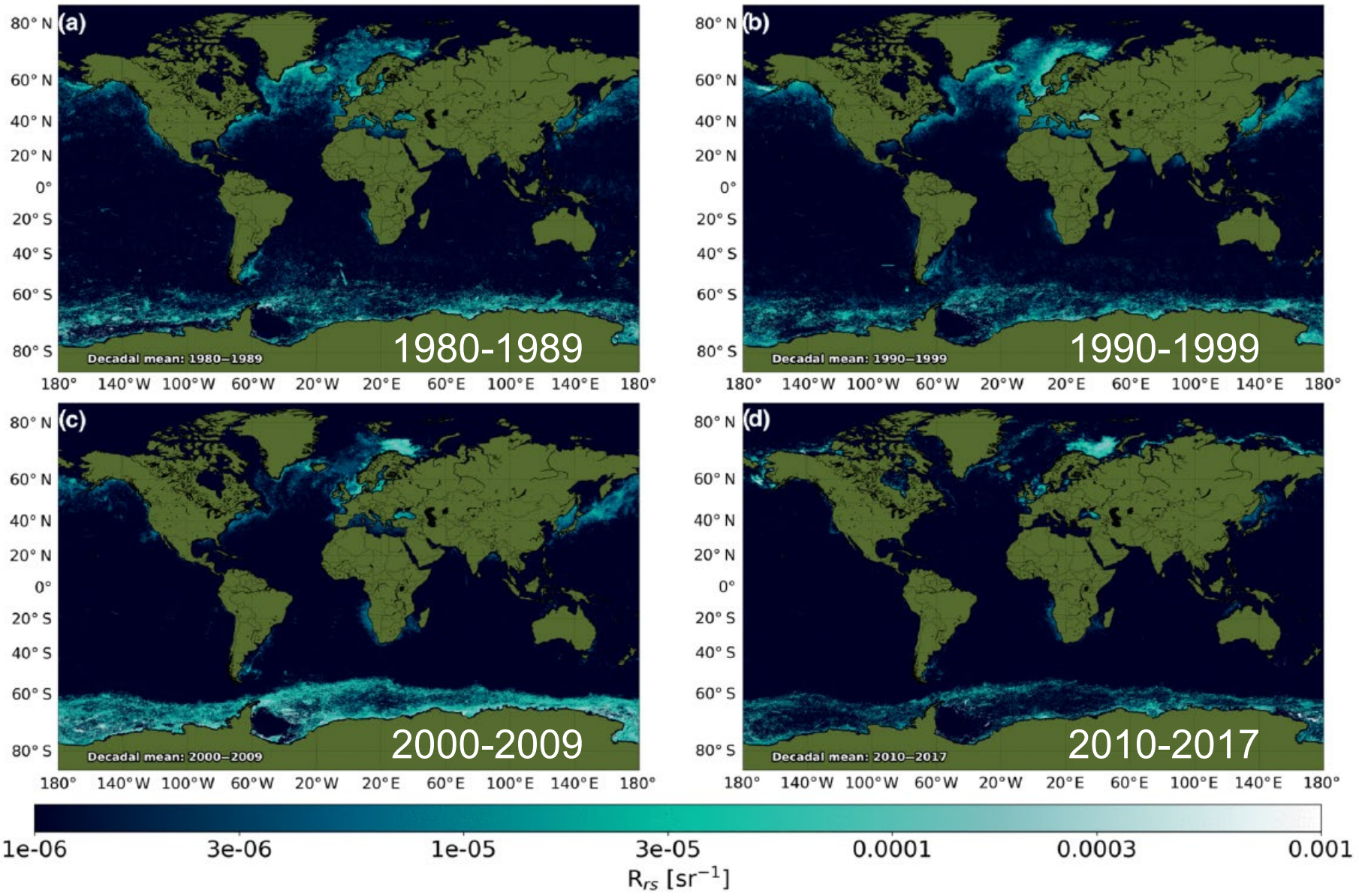


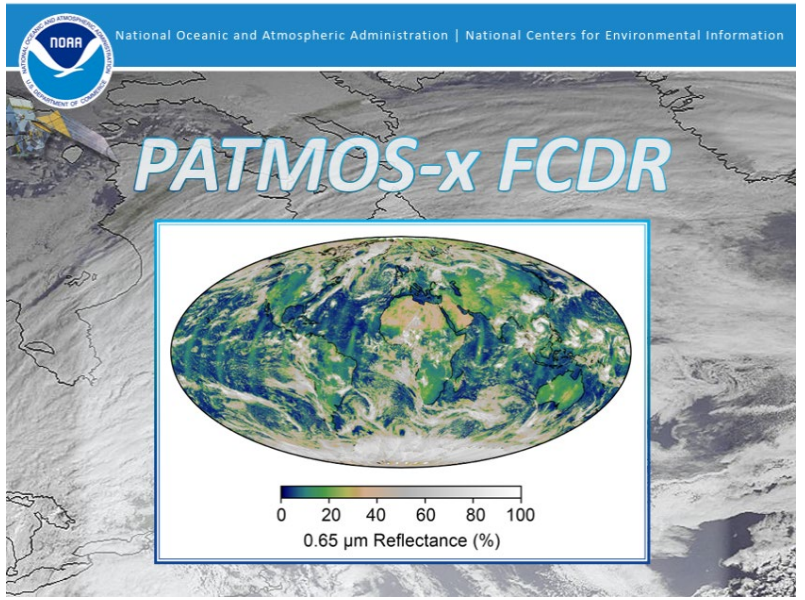
Decadal changes in coccolith occurence



Loveday & Smyth, 2018

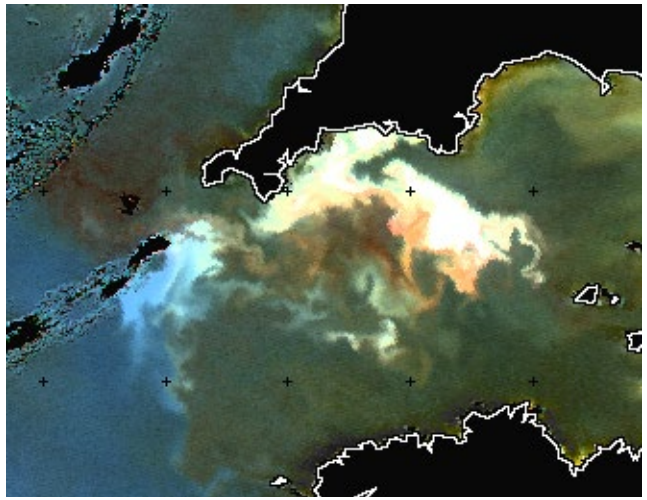
Coccolith bloom dataset - progress

- We needed to extend the dataset beyond 2017.
- Two major changes:
  - NOAA PATMOS v5 discontinued, replaced by v6.
  - ERA-Interim meteorological data discontinued, replaced by ERA5.
- Rewrote software to use ERA5 and PATMOS v6.
- Downloaded v6 global daily data for 2018 to 2024: 16 TB!
- Tested consistency with previous products.
- Finished processing the remainder of the corrected Rrs global time-series until Jun. 2025.



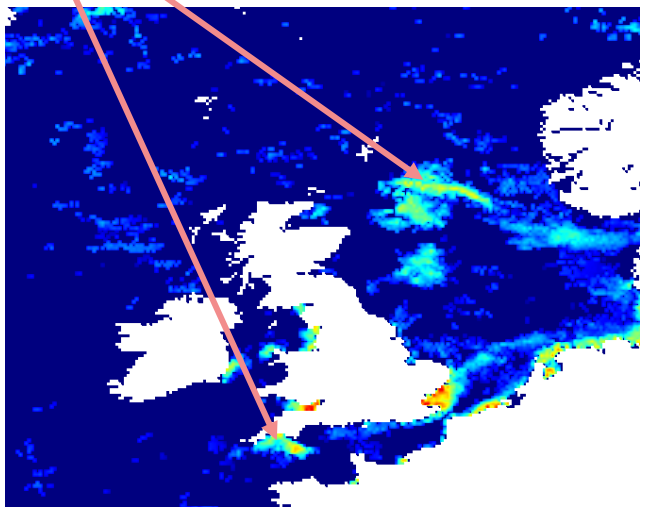
Testing reflectance processing for Jul. 1999

SeaWiFS enhanced ocean colour 24 Jul. 1999

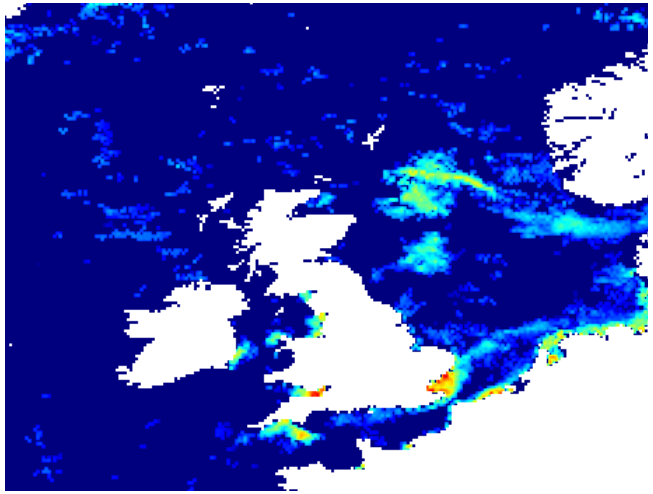


Landsat true colour 24 Jul. 1999

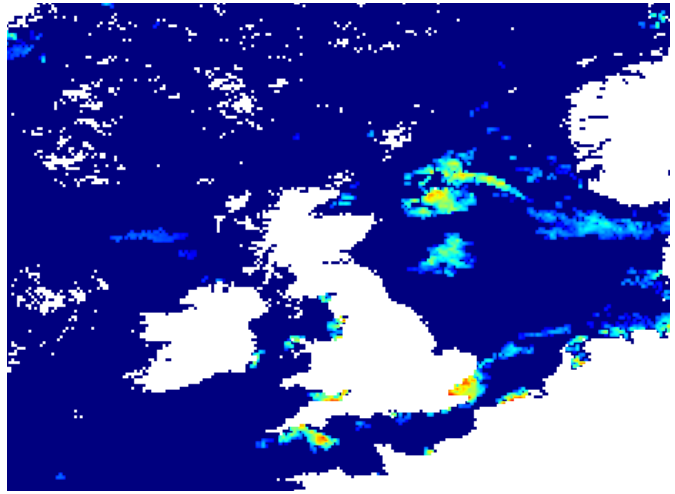
Coccolith blooms



Original processing of Patmos v5 Rrs

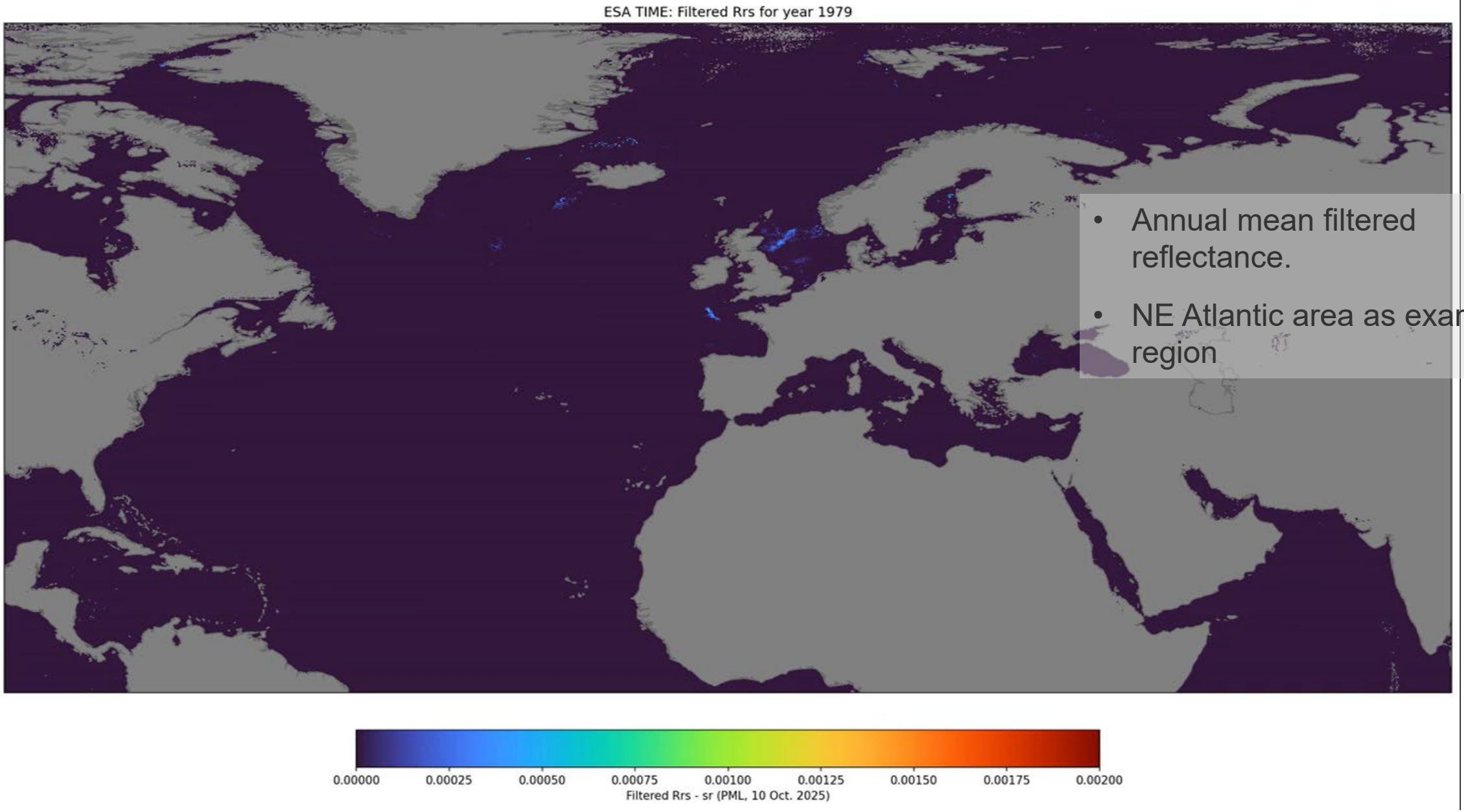


New processing of Patmos v5 using new ERA5 met data



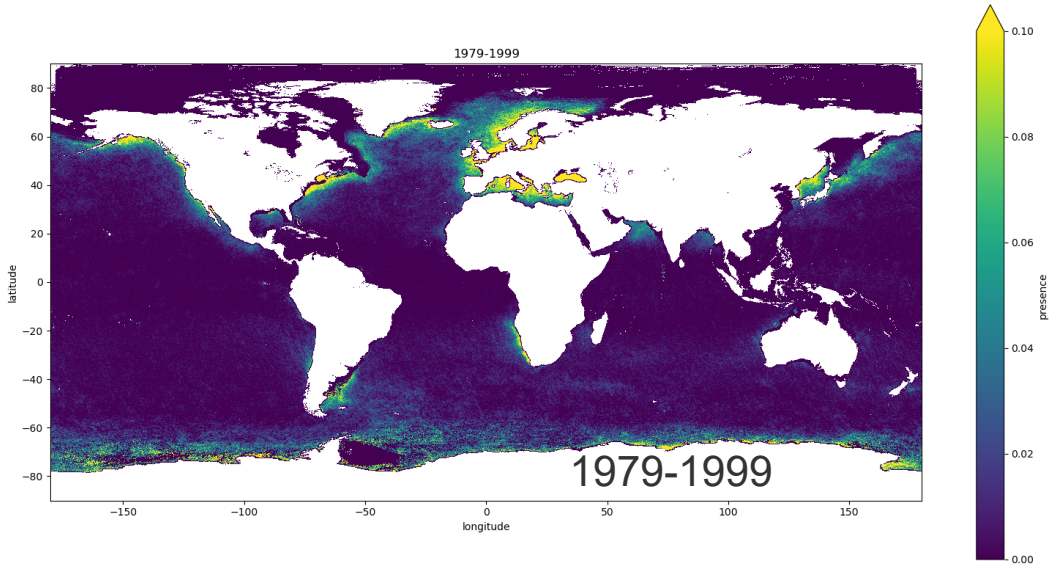
New processing of Patmos v6 Rrs

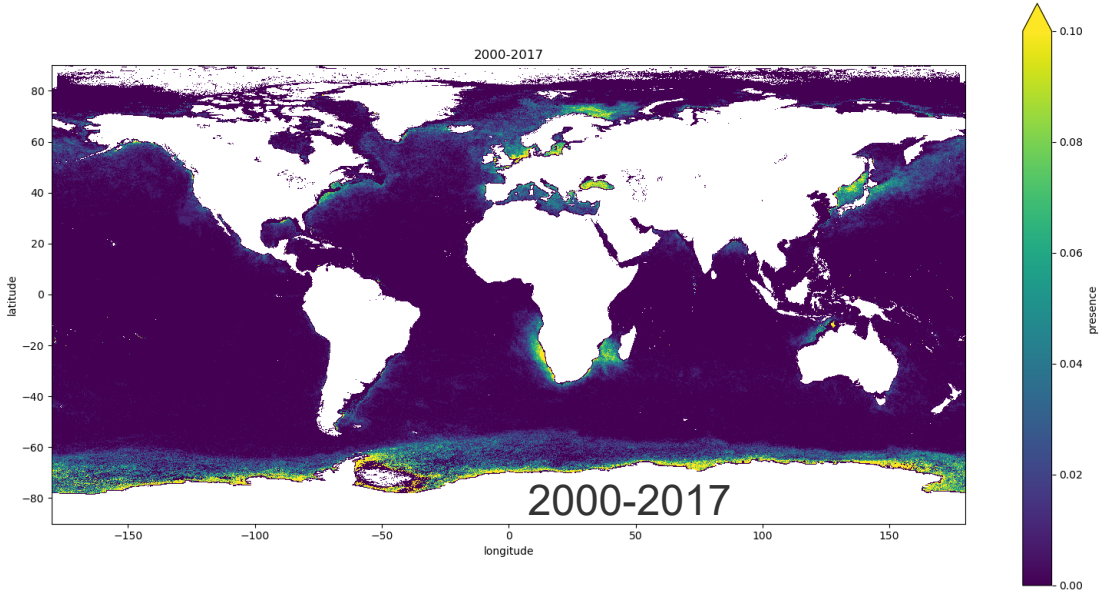
Consistency of global time-series 1979 to 2024 - Mean

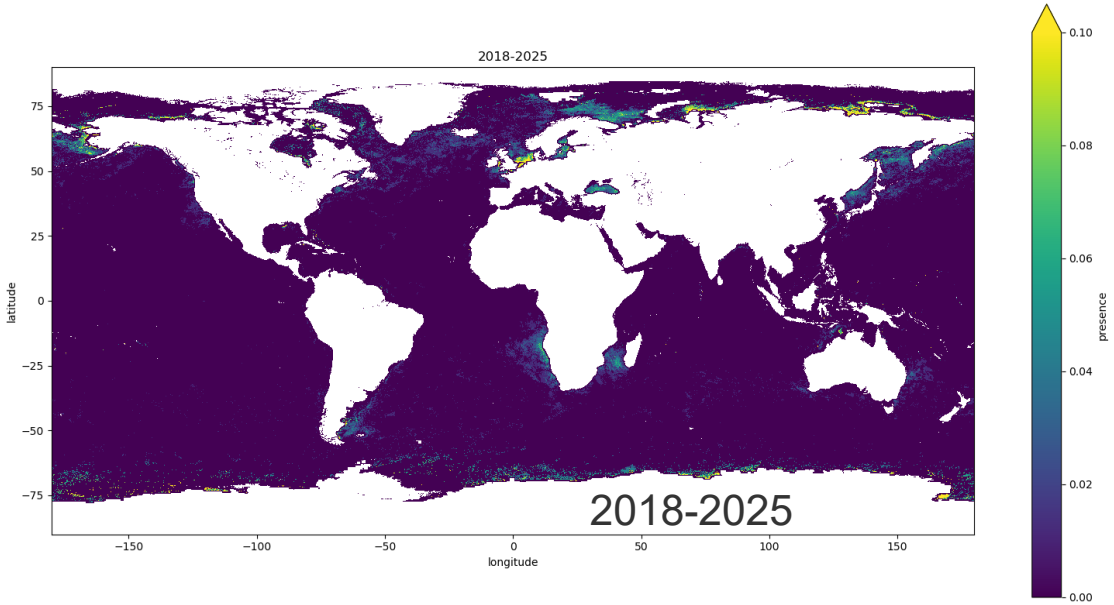


- Annual mean filtered reflectance.
- NE Atlantic area as example region

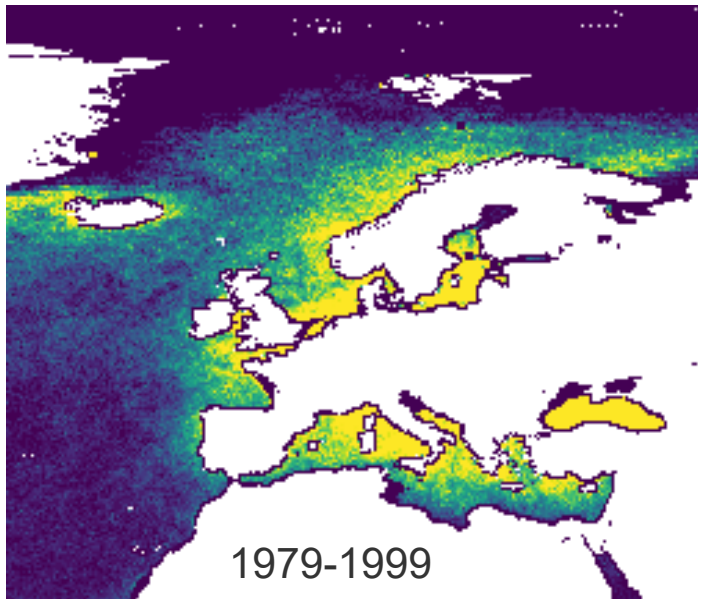
Testing consistency via decadal maps

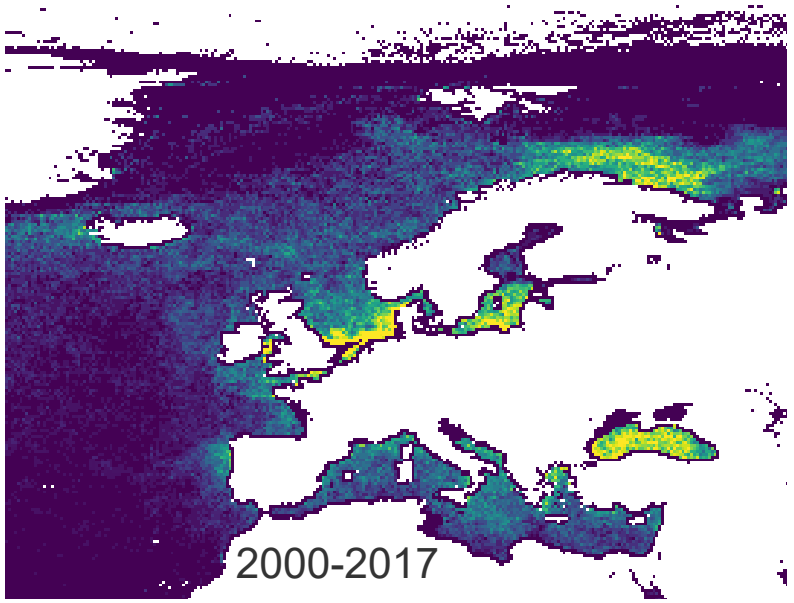


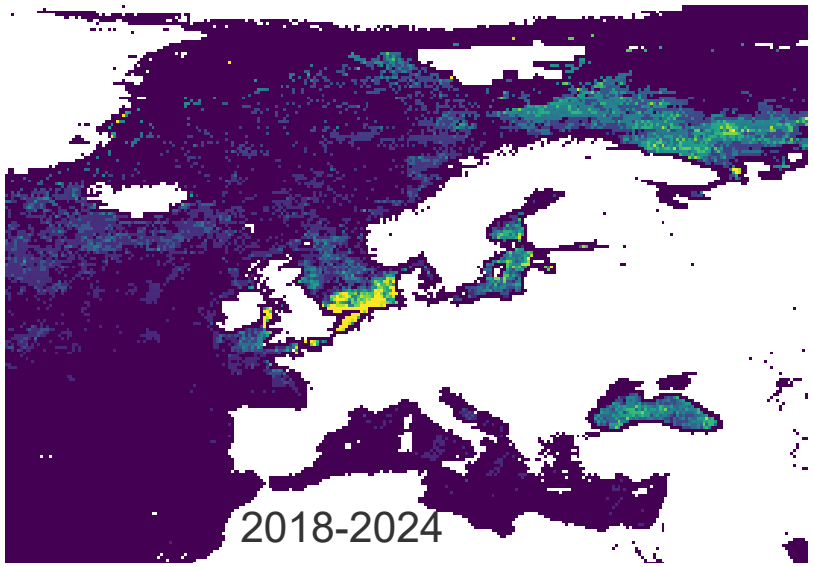




Testing consistency via decadal maps



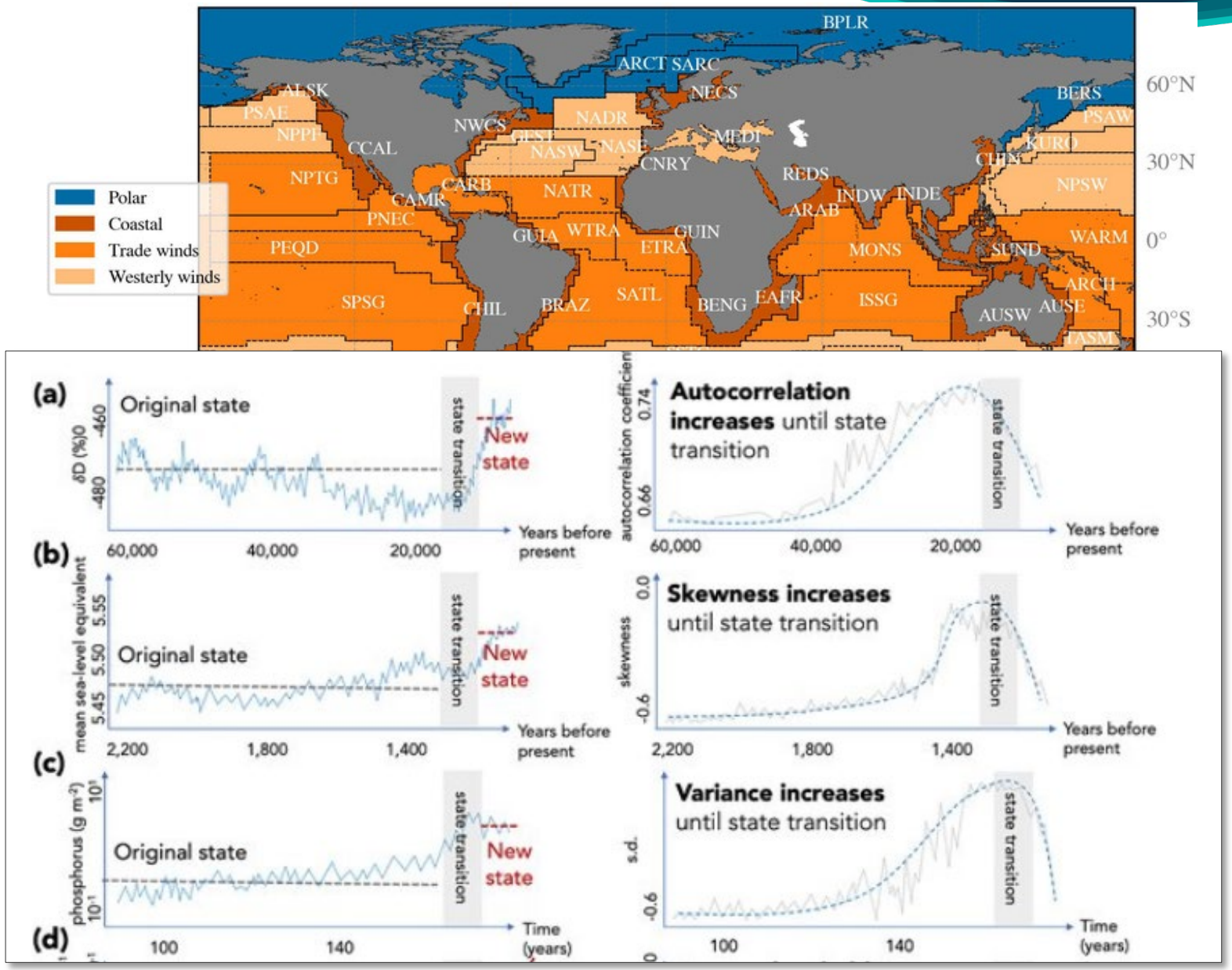




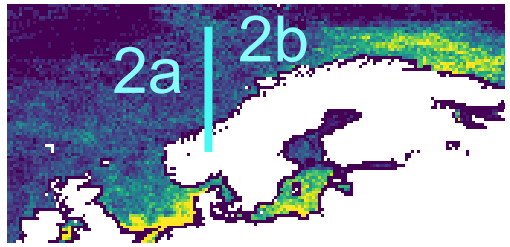
Preparing for tipping point analysis

- Analysis of coccolith occurrence in Longhurst provinces.

- Just started to analyse tipping points:

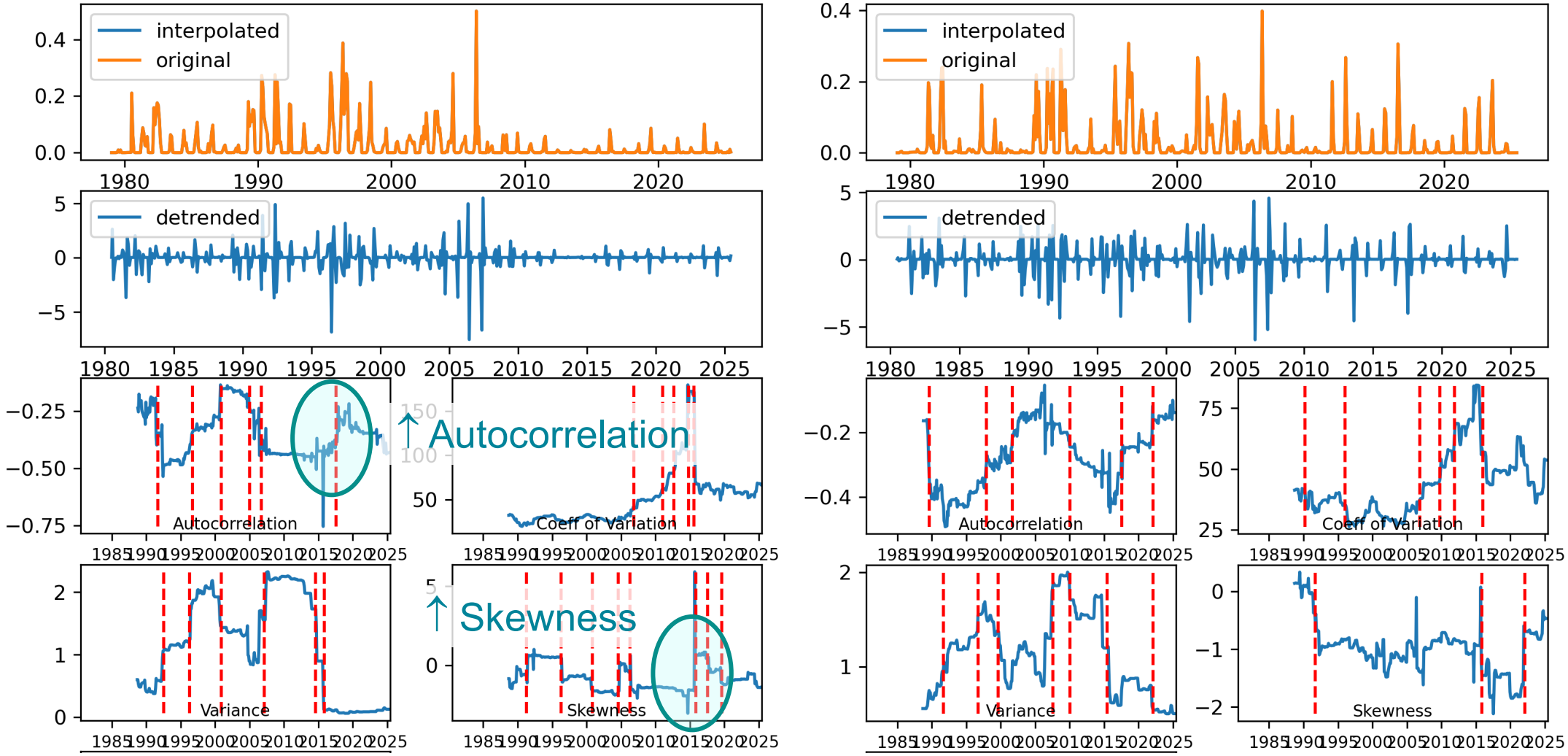


Initial tipping point analysis



Norwegian Sea 2a

Barents Sea 2b



Ocean Carbon from Space: gaps and priorities

Next steps:

Study tipping points in 45-year AVHRR reflectance time-series

Gaps:

Validation and uncertainty of AVHRR coccolith time-series

- Validation using more recent ocean colour data:
  - ESA SCOPE global Particulate Inorganic Carbon (PIC) product.
- Validation using in situ data:
  - On Monday of this workshop: Qiming Sun (Univ. of Ghent): *An Optical Sensor for Autonomous Detection of Particulate Inorganic Carbon (PIC) Concentration in Seawater.*

Priorities:

Consider AVHRR remote sensing reflectance as a Climate Data Record

- Support additional applications, e.g. suspended particulate matter.

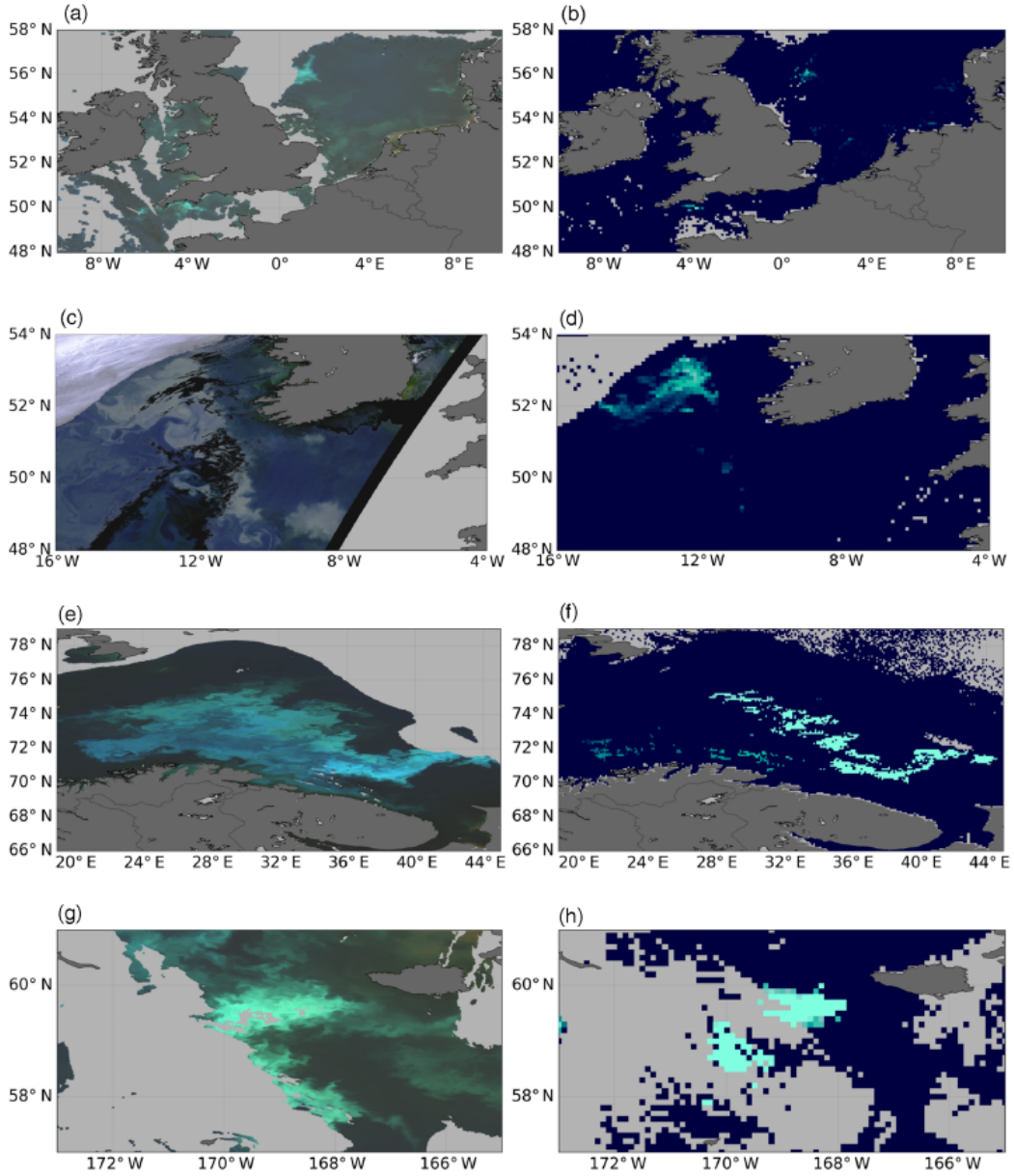


Figure 3. Examples of ocean-colour-derived red–green–blue (RGB) images of coccolithophore blooms matched to their filtered bloom product counterparts. Panels are as follows. (**a, c, e, g**) Level 2 RGB images for the North Sea and English Channel (SeaWIFS; 30 July 1999), North Atlantic and Irish Sea (MERIS; 23 May 2010), Barents Sea (MODIS; 17 August 2011) and Bering Sea (MODIS; 4 September 2014). (**b, d, f, h**) Matching, contemporaneous filtered bloom product composite for each location and date. Dark grey indicates land, and light grey indicates cloud, throughout. For bloom products, dark blue indicates that no bloom is present; lighter cyan colours indicate that a bloom is present.

Ocean colour scenes from SeaWiFS, MERIS, MODIS to verify AVHRR coccolithophore product.

Also PIC global maps.