Colocation Day 1 BOG2 Oceans & Cryosphere: TIME

Tipping points and abrupt changes In the Marine Ecosystem

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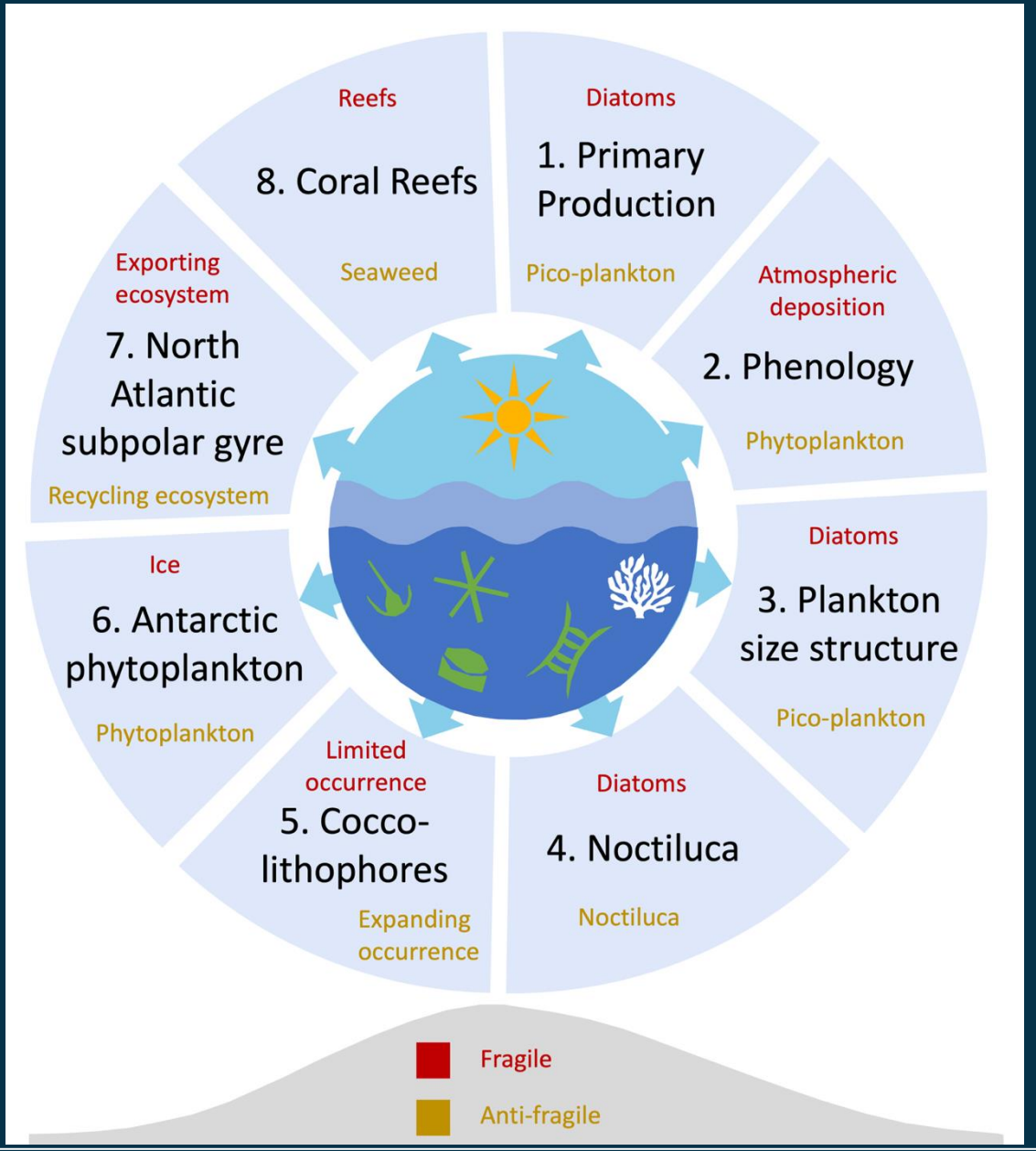
PML Plymouth Marine Laboratory
HELLENIC REPUBLIC National and Kapodistrian University of Athens EST. 1837
CSIC Consejo Superior de Investigaciones Científicas
University of Exeter

24/03/2026

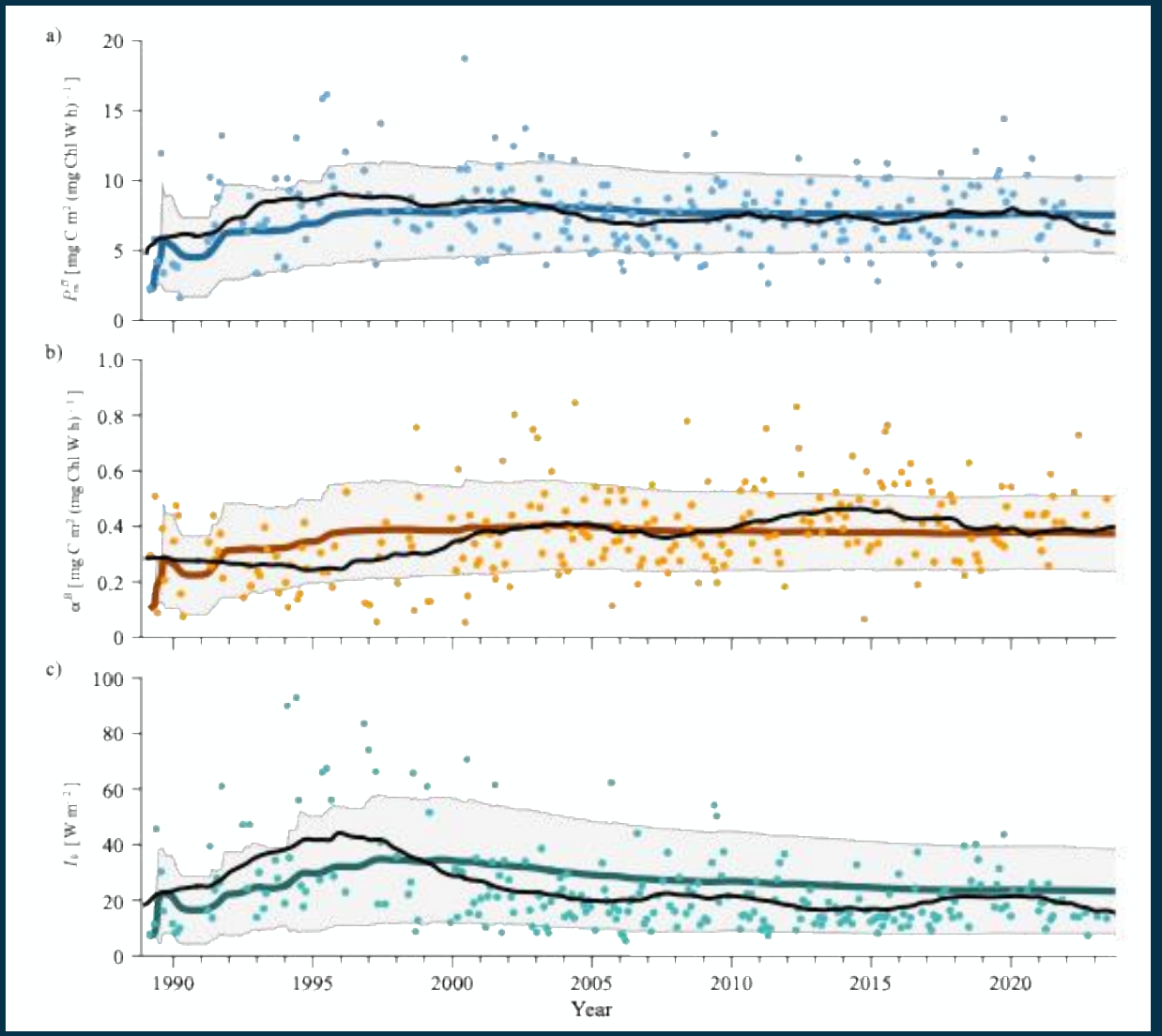

Reefs
8. Coral Reefs
Seaweed
Diatoms
1. Primary Production
Pico-plankton
Atmospheric deposition
2. Phenology
Phytoplankton
Diatoms
3. Plankton size structure
Pico-plankton
Diatoms
4. Noctiluca
Noctiluca
Limited occurrence
5. Cocco-lithophores
Expanding occurrence
Ice
6. Antarctic phytoplankton
Phytoplankton
Exporting ecosystem
7. North Atlantic subpolar gyre
Recycling ecosystem
Fragile
Anti-fragile

Tipping Element 1: Phytoplankton and Primary Production

Sathyendranath, Kovač, Chuprin, Kulk

In TIME, we propose to carry out a systematic analysis of satellite and in situ data on phytoplankton and primary production using OC-CCI data, to evaluate stability and resilience in the ecosystem, and for any evidence of approaching tipping points.

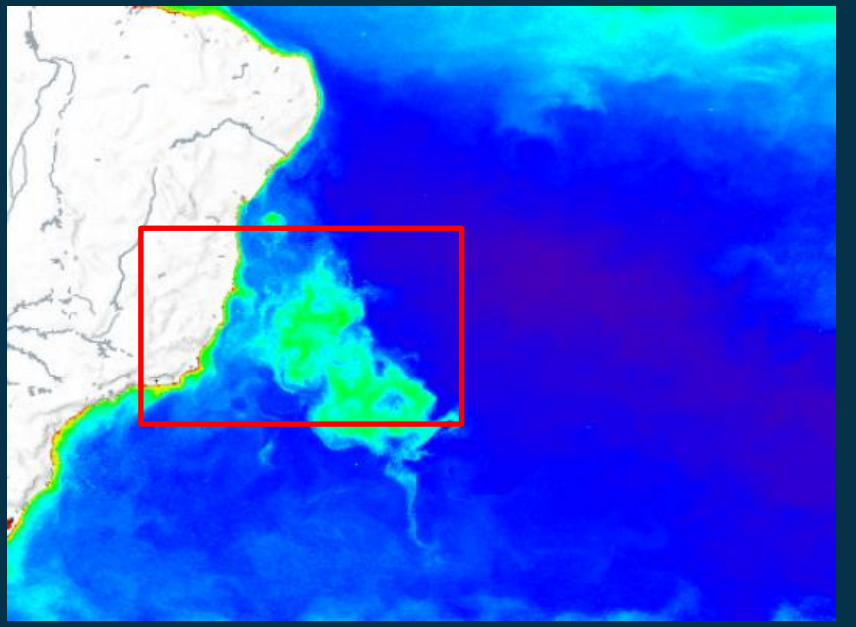
First results: Trends in photosynthesis-irradiance parameters at a 35-year in situ time series off Hawaii show no significant trends. (Kovač et al. submitted)



Tipping Element 2: Phytoplankton Phenology

Jittings, Raitsos

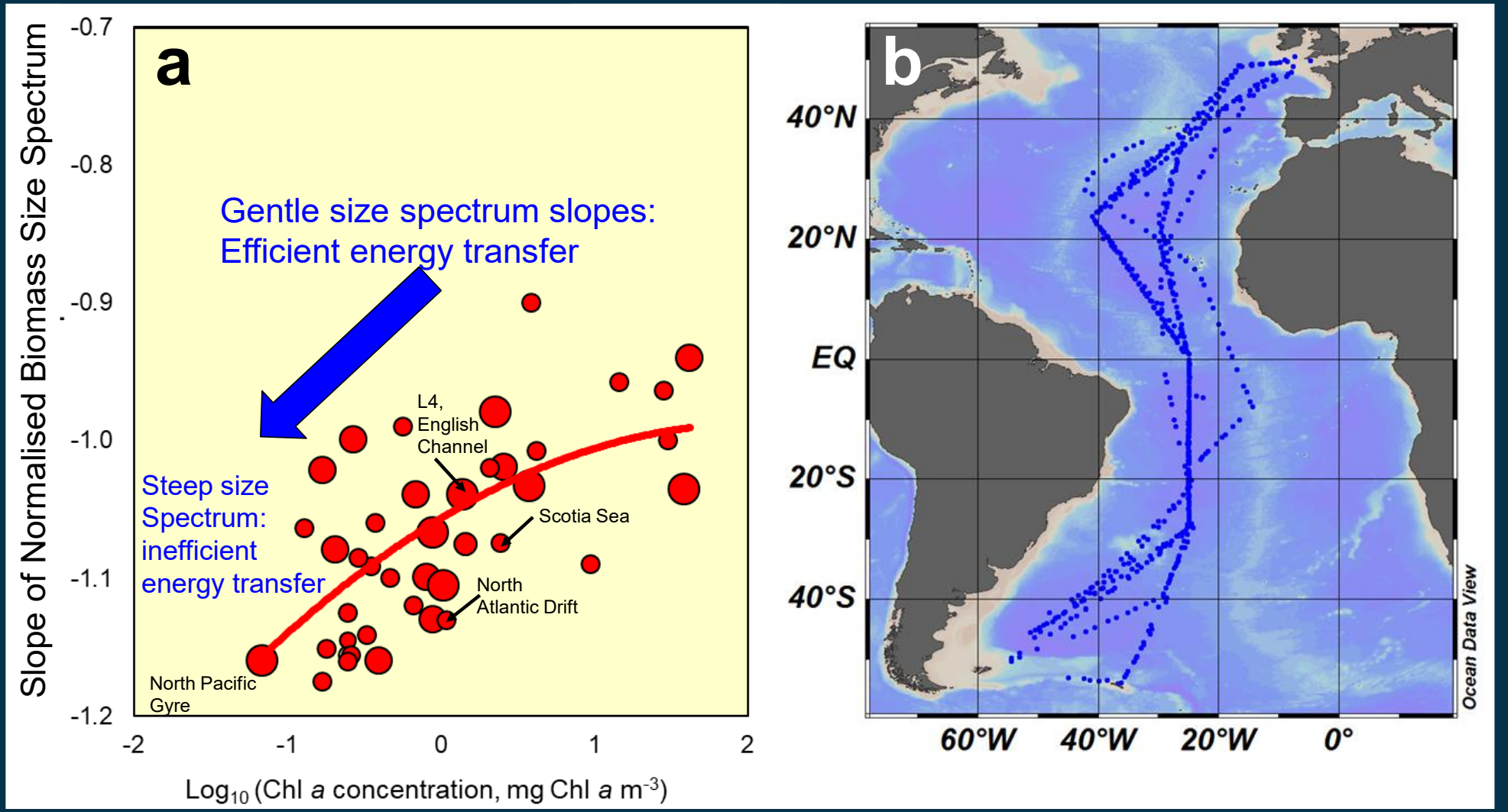
Hypothesis: *Increasing occurrences of extreme terrestrial events is contributing to abrupt shifts in phytoplankton phenology in the South Atlantic Subtropical Gyre*



Tipping Element 3: Plankton Size Structure

Atkinson, Warren

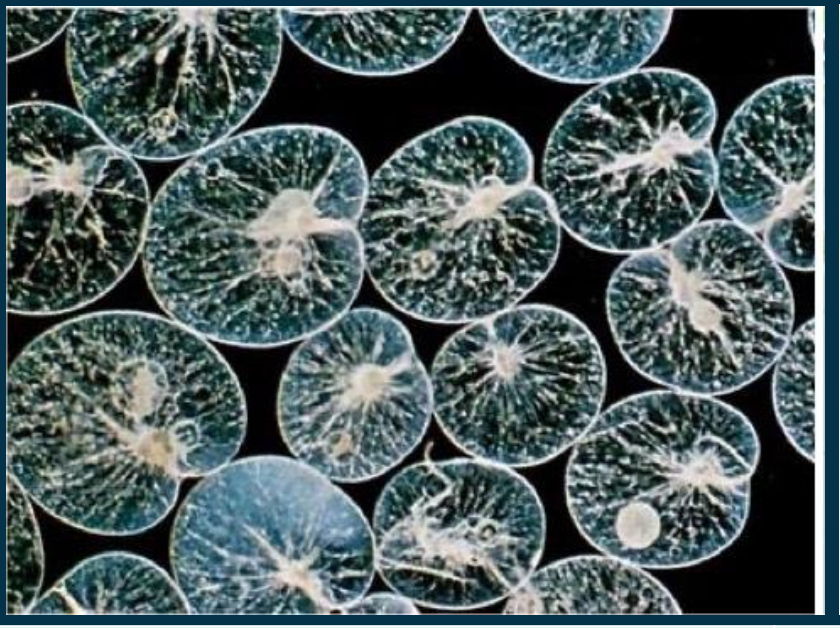
Hypothesis: *A non-linear expansion of "ocean deserts" with steepening size spectrum slopes and increasingly inefficient energy transfer*



Tipping Element 4: Noctiluca in the Arabian Sea

Salem, Fidai, Menon, Ranith R, Sathyendranath

Arabian Sea is shifting from a diatom-dominated to a *Noctiluca*-dominated ecosystem

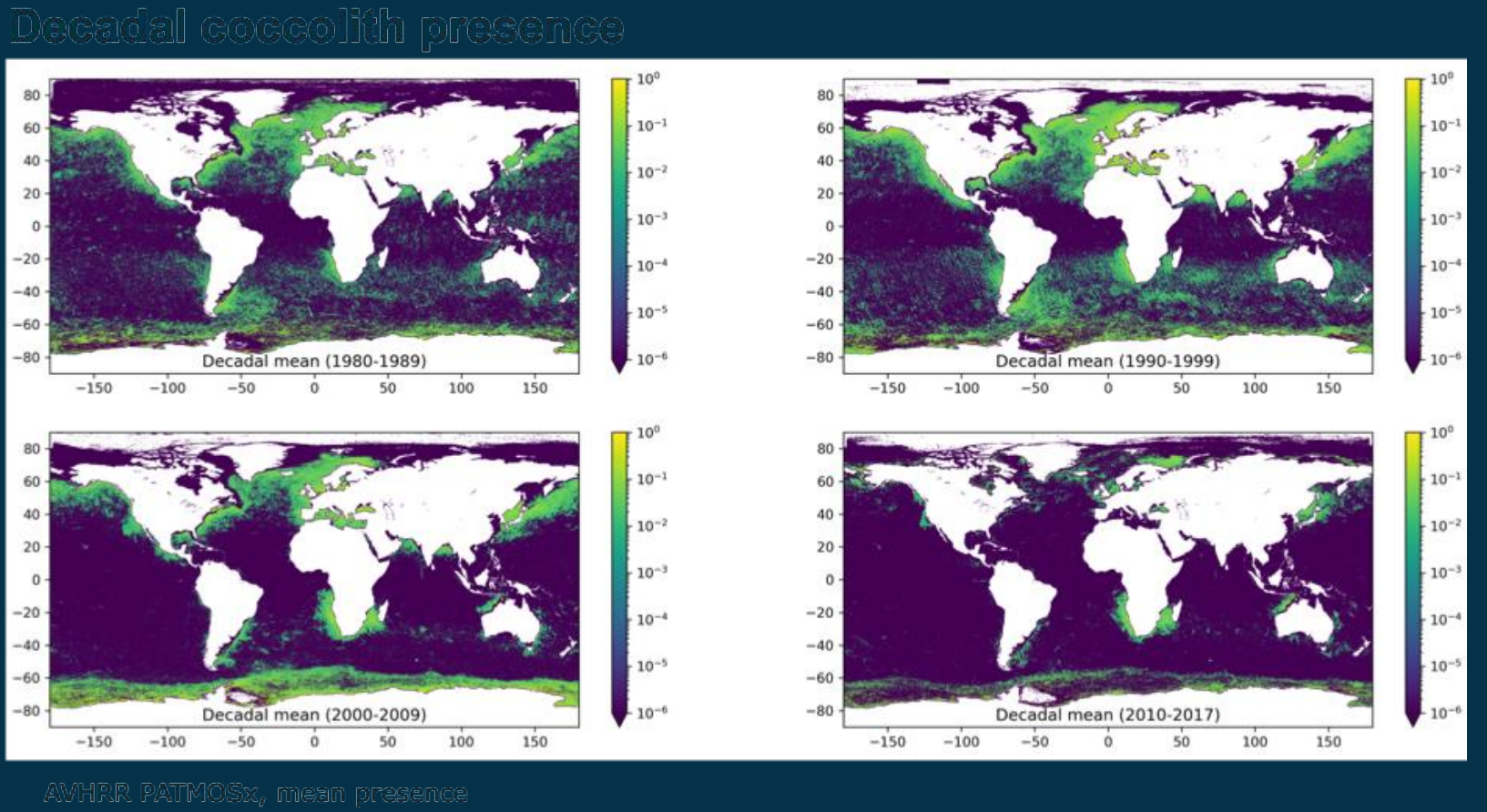


Traits	Diatoms	*Noctiluca*
Mode of nutrition	Autotrophic	Mixotrophic
Colour	Red or Green	Brownish green
Nutrient requirement	Nitrogen, phosphorus	Nitrogen, phosphorus, silicate
Community structure	Single species (low diversity)	Multi-species (high diversity)
Biogeochemistry	Hypoxia	Export production
Policy relevance	Harmful algal blooms	Support fisheries

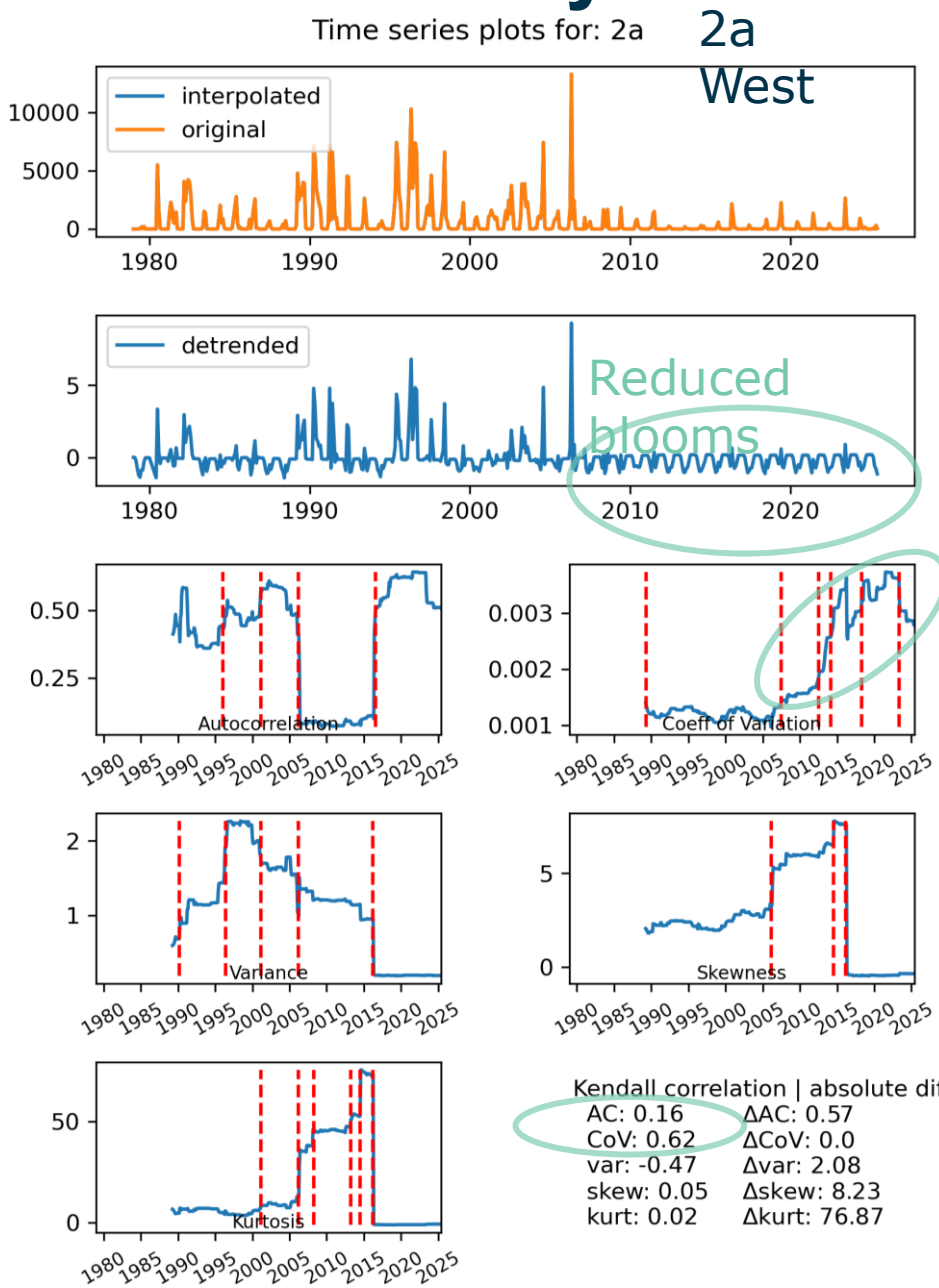
Tipping Element 5: Coccolithophores

Warren, Miller, Smyth, Sathyendranath

How do the observed shifts map onto tipping-point theories?

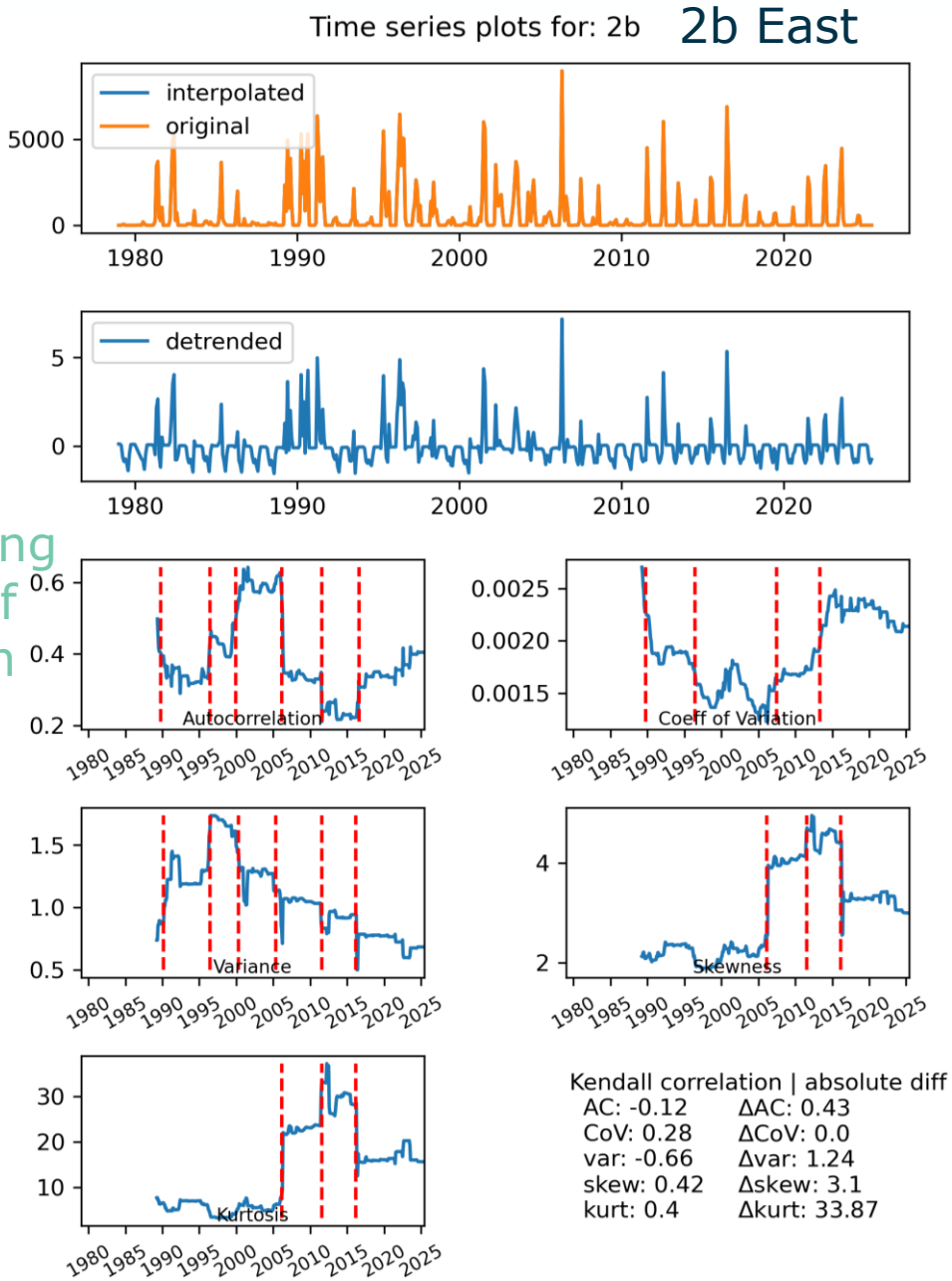


Time-series analysis of Barent Sea coccoliths



Reduced blooms

Increasing coeff. of variation

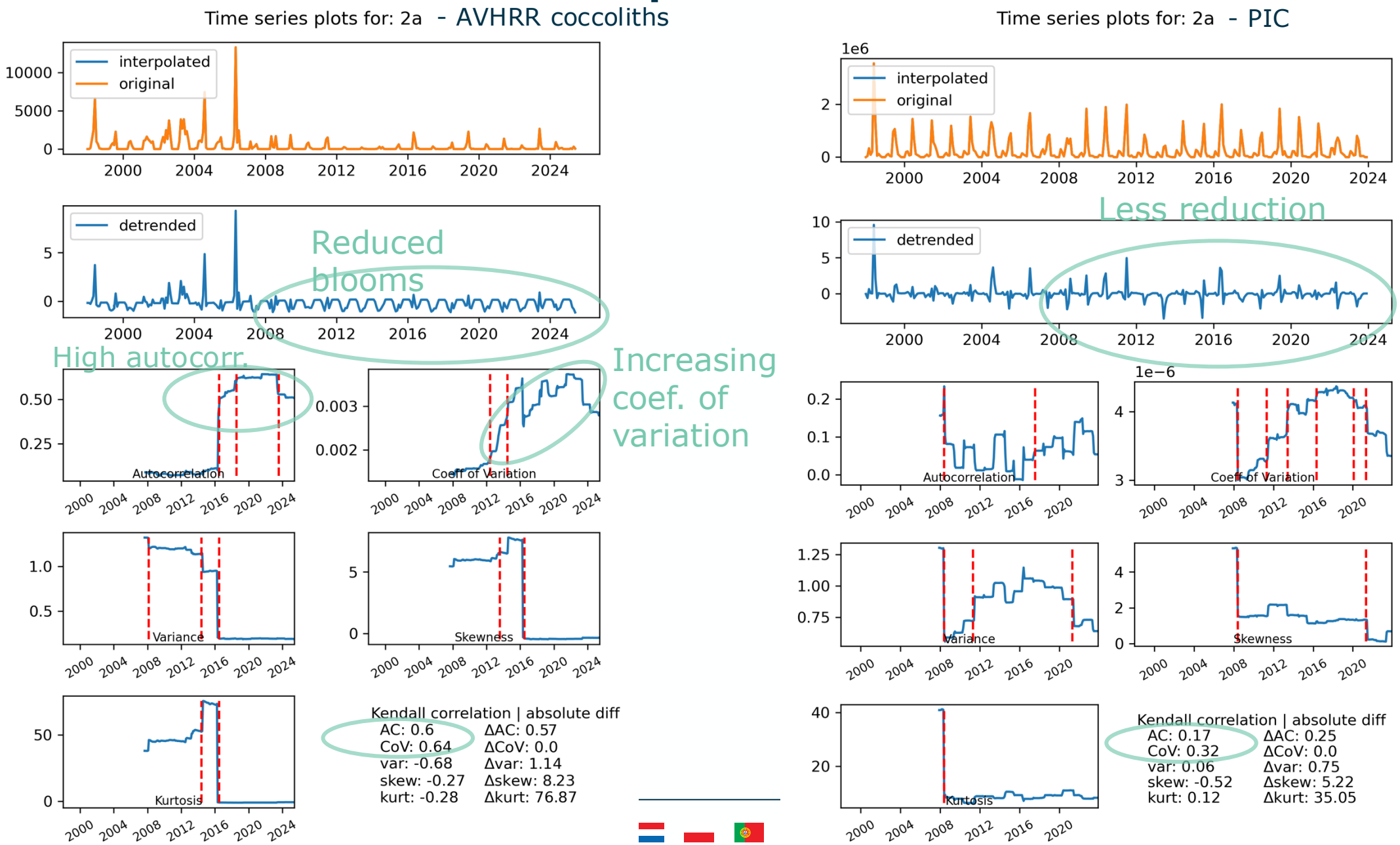


Key

Breakpoint

Compare AVHRR coccoliths to particulate inorganic carbon

2a West



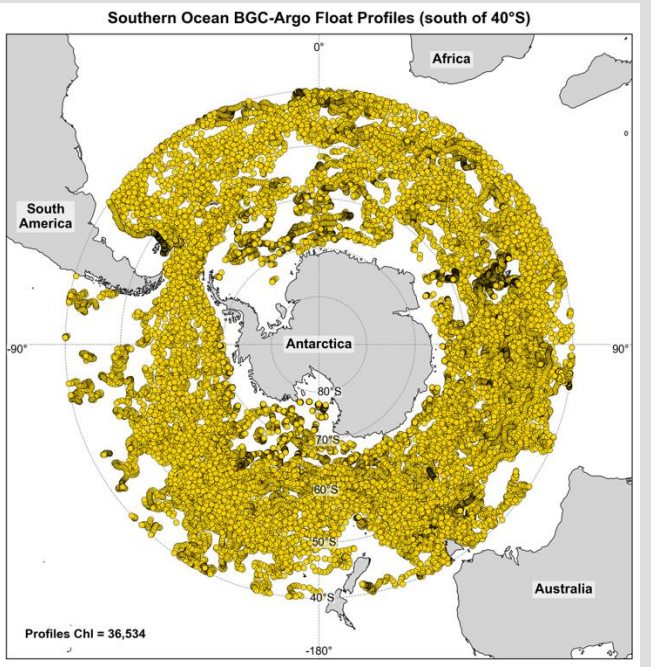
Tipping Element 6: Antarctic Ecosystem

Tipping Element 6: Antarctic Ecosystem

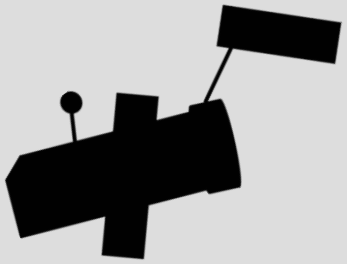
Response of oceanic phytoplankton to a changing Antarctic environment

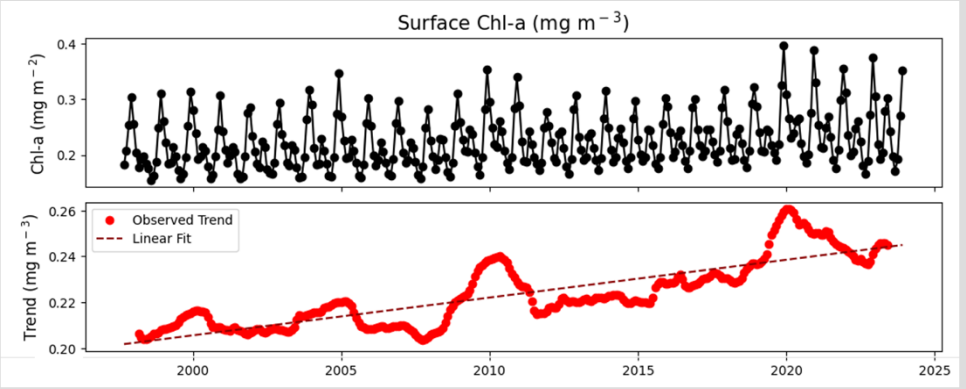
- Produce regionally-tuned, depth-resolved monthly products of seawater phytoplankton chlorophyll and community composition, over the CCI era.
- Explore the potential to produce sea-ice algal biomass products using ESA CCI datasets
- Quantify tipping metrics using statistical analysis that is consistent with other elements.

Subsurface



Surface





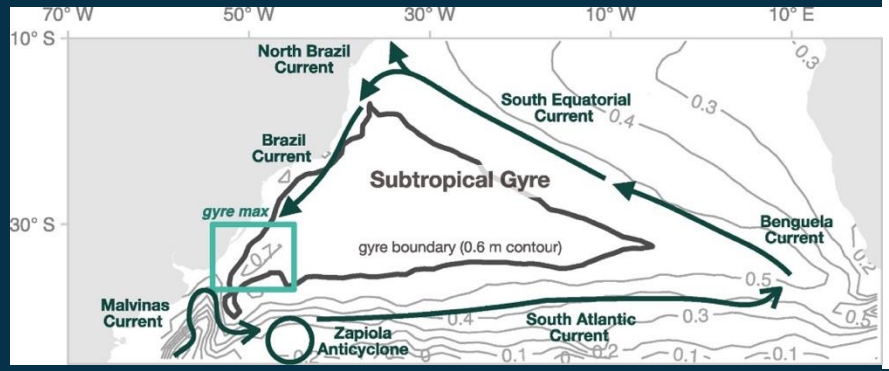
Sensitivity to the Southern Ocean Overturning?
Link to TIPSOO?

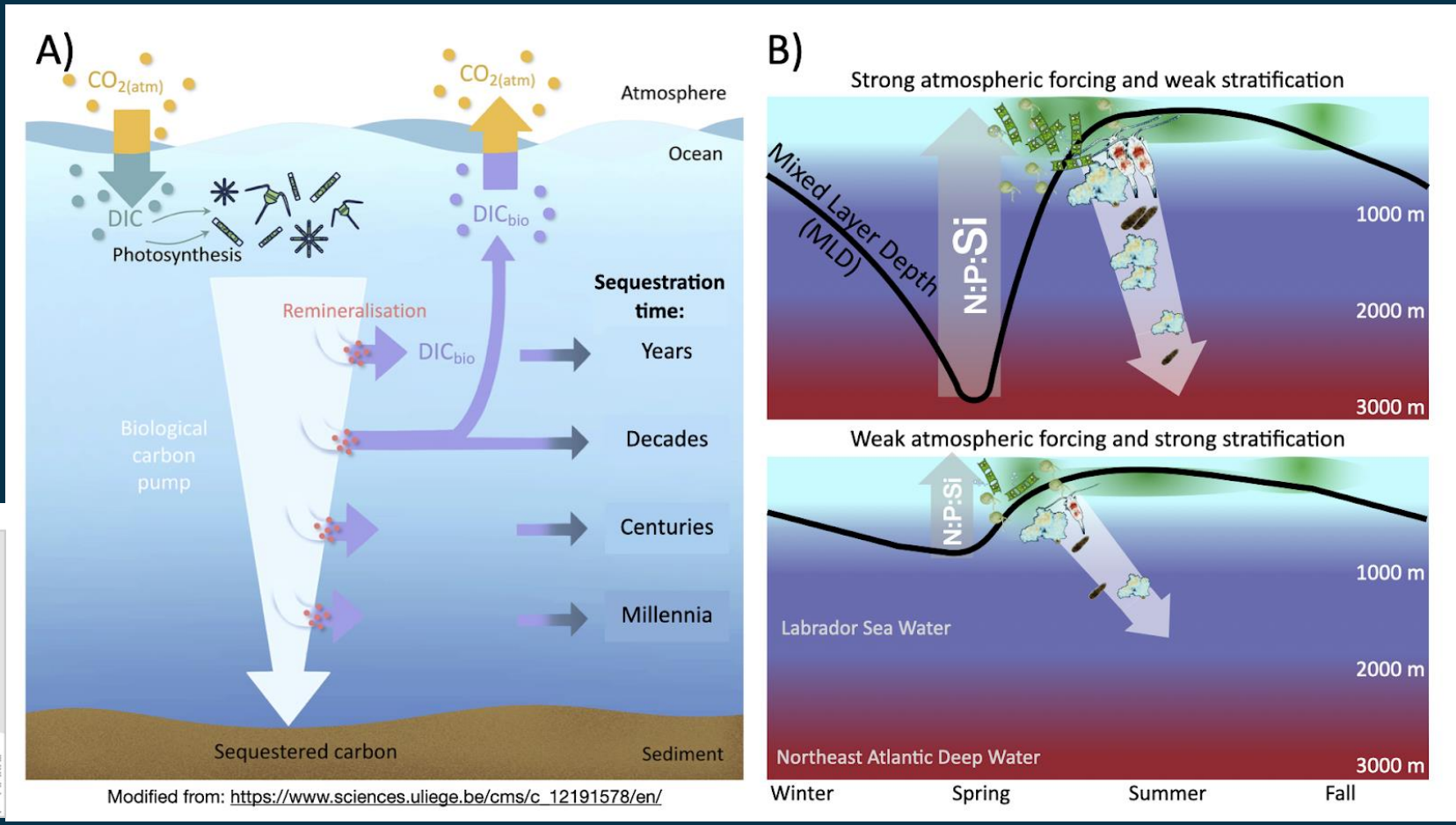
TIPSOO
TIPPING POINT OF THE SOUTHERN OCEAN OVERTURNING

Tipping Element 7: The North Atlantic Sub-Polar Gyre biological carbon pump

Martí Gali Tapias

Hypothesis: *Shutdown of deep convection in the North Atlantic sub-polar gyre will drastically reduce the efficiency of the biological carbon pump*



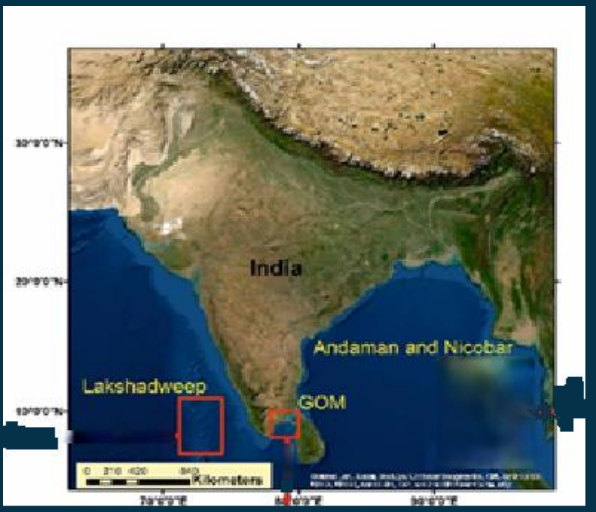


Modified from: https://www.sciences.uliege.be/cms/c_12191578/en/

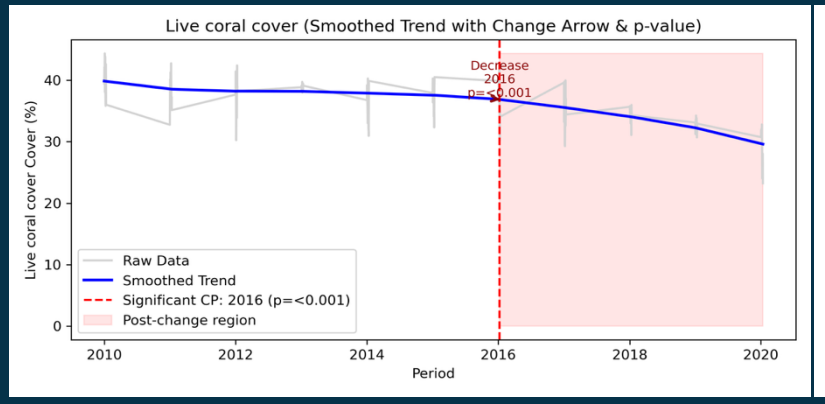
Tipping Element 8: Coral Reefs

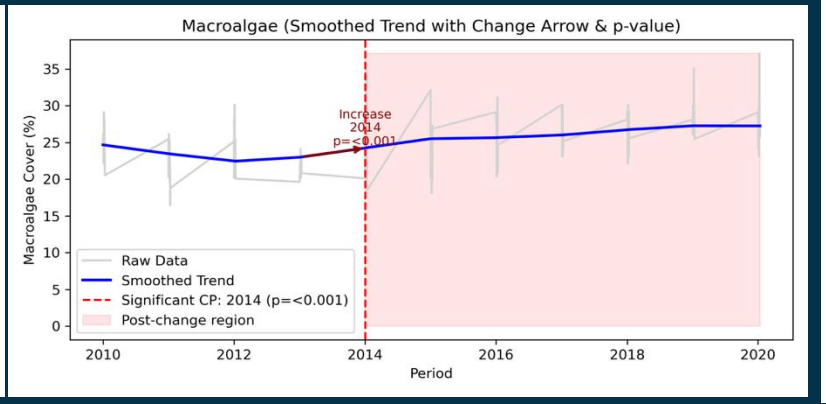
Menon, Ranith, R, Sathyendranath

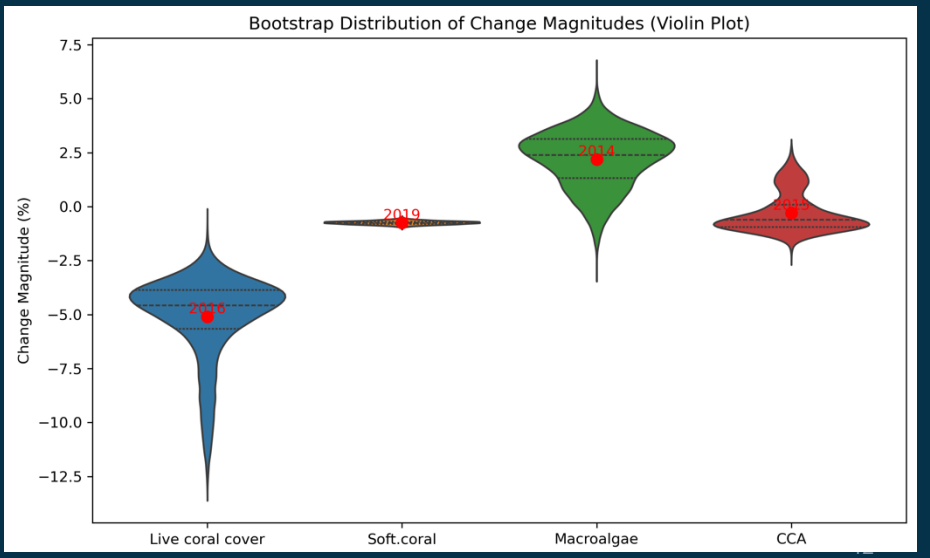
Hypothesis: *Frequent bleaching events and low recovery of warm water coral reefs in Indian waters lead to a regime shift to other communities such as macroalgae.*



Macroalgae overgrown coral system (2025)

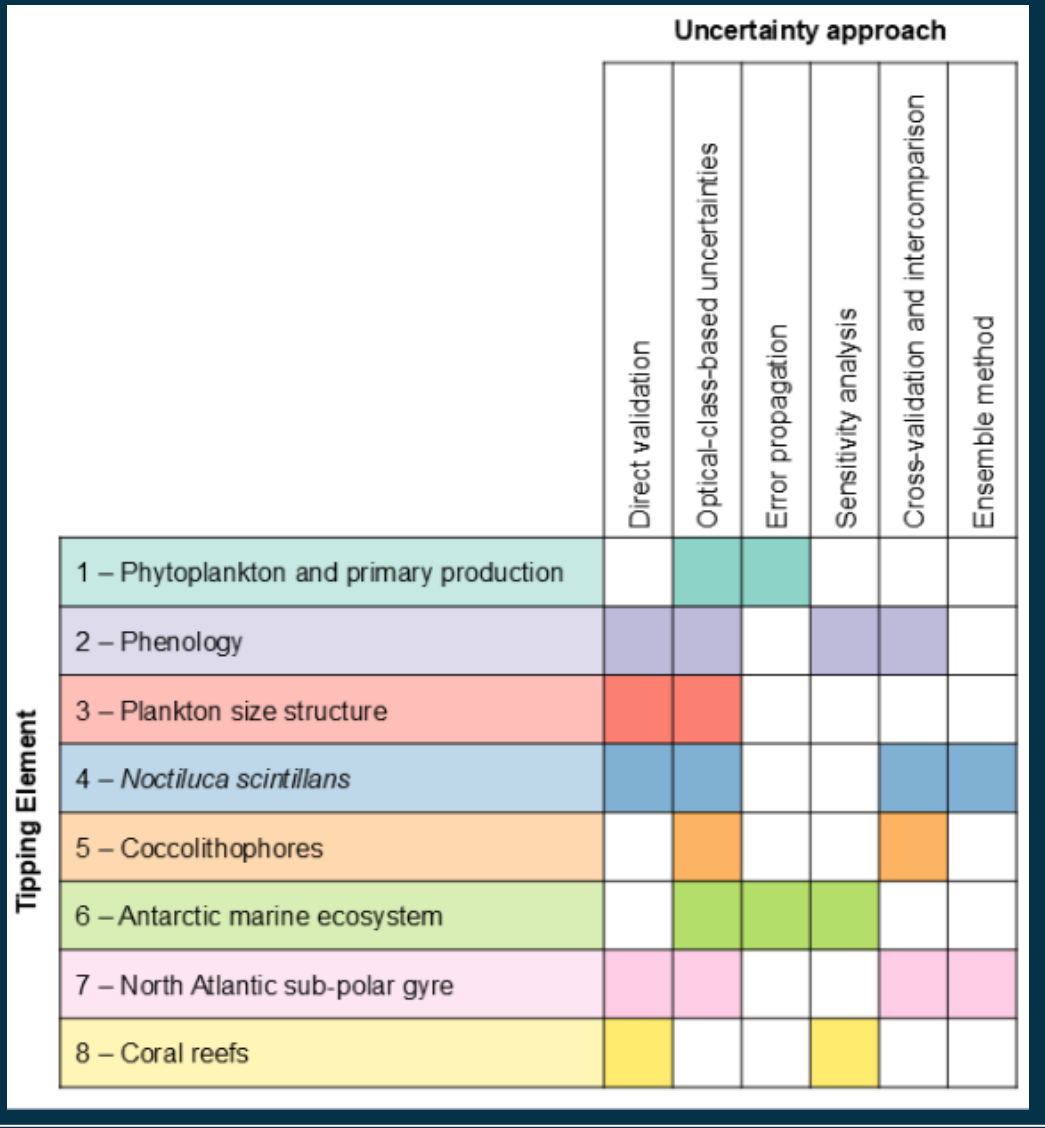






Change point in % cover of coral reefs and macroalgae

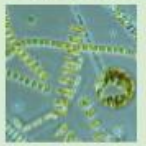
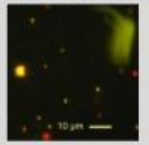
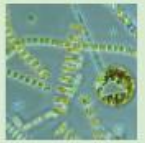
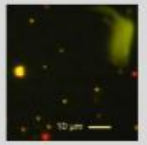
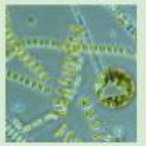
Uncertainty Characterisation

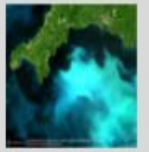


This is a three-year project. We are about to complete the first year.

And

We have promises to keep,
And miles to go before we sleep,
And miles to go before we sleep.

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