Seasonal predictability of ocean biogeochemistry and potential benefits of ESA CCI data assimilation

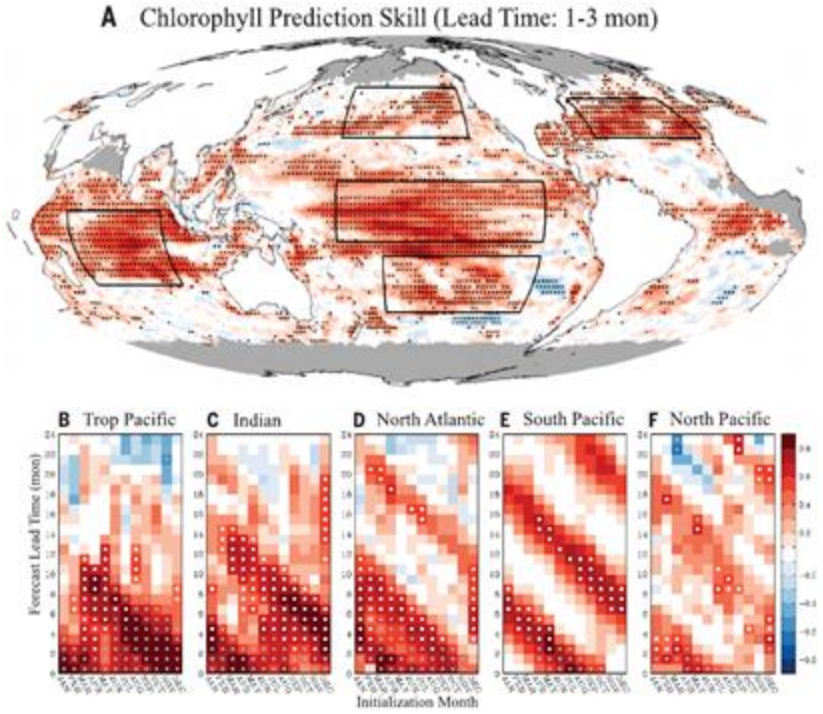
David Ford[1], Joan Llort[2], Pablo Ortega[2], Andrea Rochner[1]

[1]Met Office, [2]Barcelona Supercomputing Center

CMUG Integration Meeting, 16 October 2024

Background

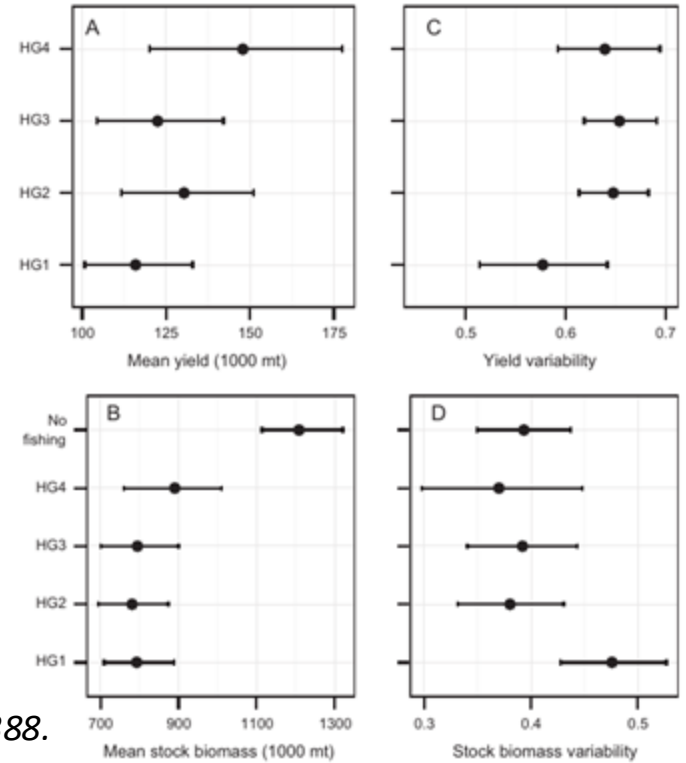
Recent progress in Earth System Models (ESM), in particular the incorporation of biogeochemistry in the ocean models, has enabled the use of ESMs for predicting changes in key biogeochemical variables that act as ecosystem drivers (e.g., pH, oxygen, net primary production, chlorophyll) at seasonal to decadal time scales.



Park, J.-Y. et al., Science 2019, 365, 284–288

Background

Such ESM-based predictions have the potential to be used for predicting variations in fish populations and yields, and provide useful information to aquaculture, fishers and policy makers.

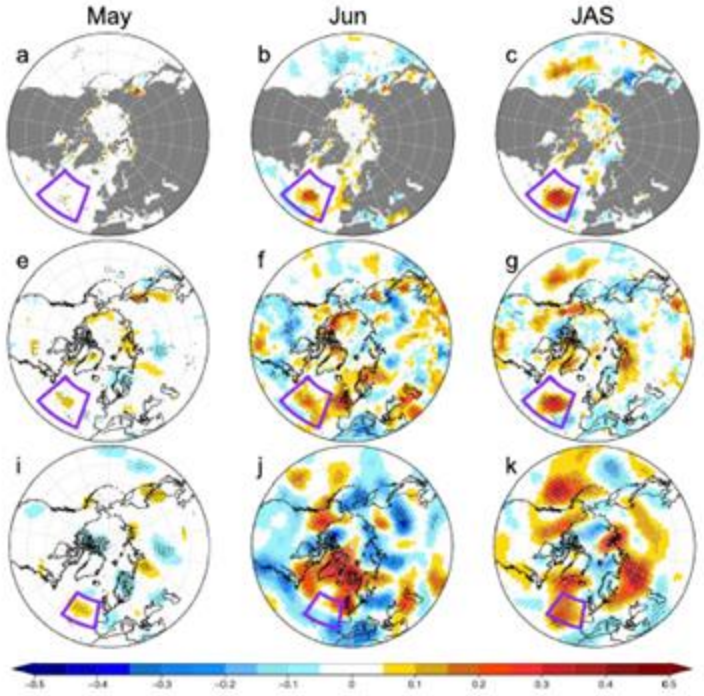


Tommasi, D.et al., Ecological Applications, 2017, 27(2), 378–388.

Background

Seasonal predictions are commonly initialized from reanalyses that assimilate observations into the dynamical forecasting systems.

Assimilation of CCI Sea Ice Concentration (WP3.8 in the previous phase of CMUG) demonstrated added value on summer prediction in the Northern Hemisphere

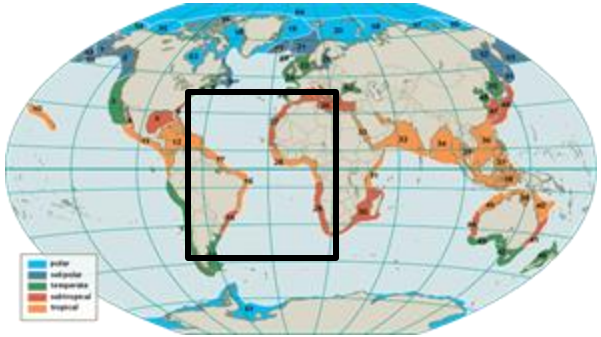


J C Acosta Navarro et al 2022 Environ. Res. Lett. 17 064008

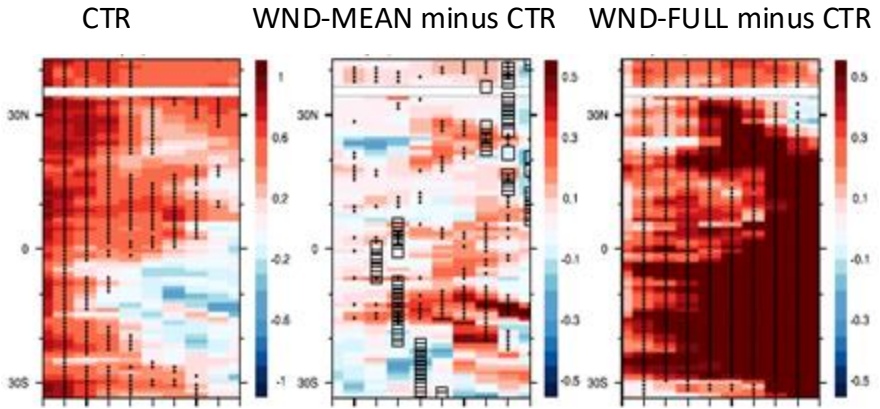
State-of-the-art in EC-Earth3-CC

$$(\overline{\tau}+\tau)'_{mod} \longrightarrow (\overline{\tau}+\tau)'_{obs}$$

$$(\overline{\tau}+\tau)'_{mod} \longrightarrow \overline{\tau}_{obs} + \tau'_{mod}$$



Mean state wind stress correction leads to a modest but significant improvement in predictive skill in ecosystem drivers (SST, Chlorophyll, PP). Correcting the full field leads to large predictive skill, demonstrating the dominant role of the wind in ocean BGC.



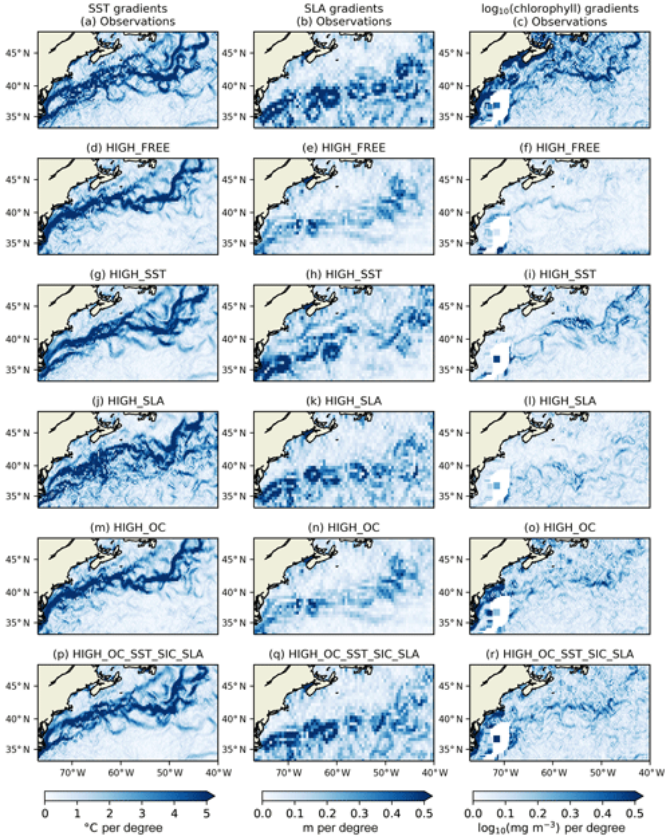
Exarchou et al. (in preparation)

Background

Previous phase of CMUG demonstrated that assimilating CCI data (SST, SIC, SLA, OC) into reanalyses could coherently improve features in physics and biogeochemistry.

Some challenges remain due to excessive vertical mixing when assimilating some data types, especially near the equator.

Ford, D. (2021), Ocean Science, 16, 875–893



Science questions

- What is the value of assimilating physical (SST, SSS, SLA, SIC) and biogeochemical (OC or OC-derived) CCI ocean ECVs in generating initial conditions for seasonal predictions of ocean biogeochemistry?

- What is the dominant factor at initialization (the physical or the biogeochemical state) in determining the ocean biogeochemistry predictive skill at global and regional scales?

- What is the best strategy for constraining initial conditions in order to achieve the highest prediction skill in ocean biogeochemistry?

Methodology

- WP1: Assimilate ESA CCI variables (SST, Sea Ice, SSS, Sea Level, Ocean Color) to produce reconstructions
  - Subtask 1.1: assimilate only physical CCI variables
  - Subtask 1.2: assimilate physical and biogeochemical CCI variables

- WP2: Impact of assimilation choices of these reconstructions on physical and biogeochemical properties
  - Subtask 2.1: evaluate physical properties of reconstructions
  - Subtask 2.2: identify best strategy to reconstruct ocean biogeochemistry

- [Option, TBC] WP3: Impact of assimilation choices on seasonal predictability
  - Subtask 3.1: produce and evaluate seasonal predictions starting from reconstructions

Models

- Met Office: NEMO-SI^3-MEDUSA + NEMOVAR
  - Ocean/ice components of GloSea / UKESM / HadGEM / FOAM
  - 1/4° horizontal resolution
  - Run period TBC, will coordinate with SSS CRG work at Met Office

- BSC: NEMO-LIM3-PISCES
  - Ocean/ice components of EC-Earth3-CC
  - 1° horizontal resolution (refinement to 1/3° meridionally near equator)
  - Planned run period 1997-2021

Datasets

ECV	Product	Assimilation	Validation
SST	CCI v3.0	Along-track L2P/L3U (MO) Daily L4 (BSC)	Daily and monthly L4 (MO, BSC)
SSS	CCI v4.41	Along-track L2P (MO)	Weekly and monthly L4 (MO, BSC)
Sea Level	CMEMS L2 C3S L4 CMEMS L4	Along-track L2 (MO)	Daily and Monthly L4 (MO, BSC)
Sea Ice	CCI/OSI SAF v3.0 C3S SIT	Daily L4 ice concentration (MO, BSC)	Daily and monthly L4 ice concentration (MO, BSC) Daily and monthly L4 ice thickness (MO, BSC)
Ocean Colour	CCI v6.0 BICEP/NCEO	Daily L3 chlorophyll (MO) Monthly L3 particulate organic carbon (BSC)	Daily and monthly L3 chlorophyll (MO, BSC) Monthly L3 primary production (MO, BSC) Monthly L3 phytoplankton carbon (MO, BSC) Monthly L3 particulate organic carbon (MO, BSC)

- Uncertainty information supplied with ECVs will be used during the validation process
- EN4 in situ temperature and salinity data will be used for assimilation and validation
- ESA OceanSODA satellite/in situ derived carbon, SOCAT in situ carbon, and GLODAP in situ carbon and nutrient data will be used for validation

Methodology

- Assimilation of ESA CCI variables to produce forced ocean/sea-ice reconstructions with **EC-Earth3-CC** (BSC) & **GloSea6/MEDUSA** (MO) prediction systems. E.g.,

Reconstruction 1	Assimilation of physical variables: **CCI SST, CCI SIC** & 3D ocean temperatures from EN4 below the ocean mixed layer
Reconstruction 2	Additional assimilation of **CCI OC** to determine the role of non-physical variables to BGC predictability.
Reconstruction 3	Additional assimilation of **CCI SSH, SSS** & 3D ocean salinity from EN4 (GloSea6/MEDUSA)

Schedule

Apr 2024 ↓ Jan 2025 ↓ Jul 2025 ↓

WP / Month	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24
WP5.4.1																	
WP5.4.2																	
DELIVERABLES										D2.0d (5.4.2)				D2.2d (5.4.1)	D2.3D (5.4.3)	D3.1d (5.4.4)	

D2.0D (5.4.2): INTERIM PROGRESS REPORT (M17)

D2.2D (5.4.1): STUDY DESCRIPTION PUBLISHED ON THE CMUG WEBSITE (M21)

D2.3D (5.4.3): TECHNICAL NOTE PROVIDING FEEDBACK TO THE ECV-CCI PROJECTS ON THE USEABILITY AND DOCUMENTATION OF THE DATA USED (M22)

D3.1d (5.4.4): Draft paper outlining the main results of the case study (M23)

Progress

- BSC:
  - Technical setup and HPC porting completed over summer
  - Control run underway
  - Physics assimilation run ready to begin
  - Run adding ocean colour assimilation to follow

- Met Office
  - Technical setup and HPC porting ongoing
  - Runs should begin later this autumn

Coming soon!