Seasonal predictability of ocean biogeochemistry and role of ESA CCI data assimilation

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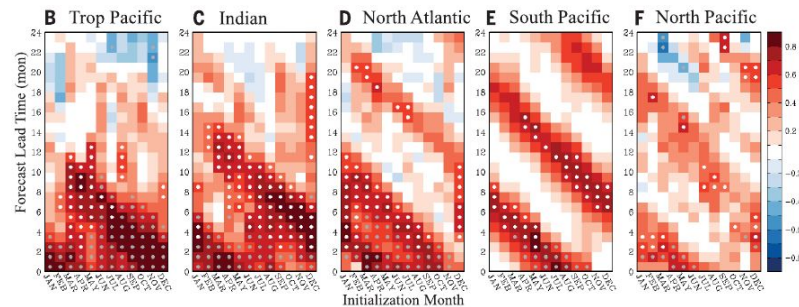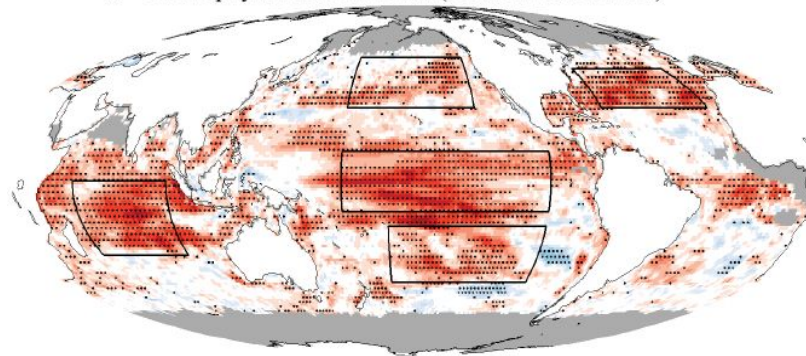[1]Barcelona Supercomputing Centre, [2]MetOffice

CMUG Integration & Climate Change Initiative colocation, ESRIN, 24-27 October 2022

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

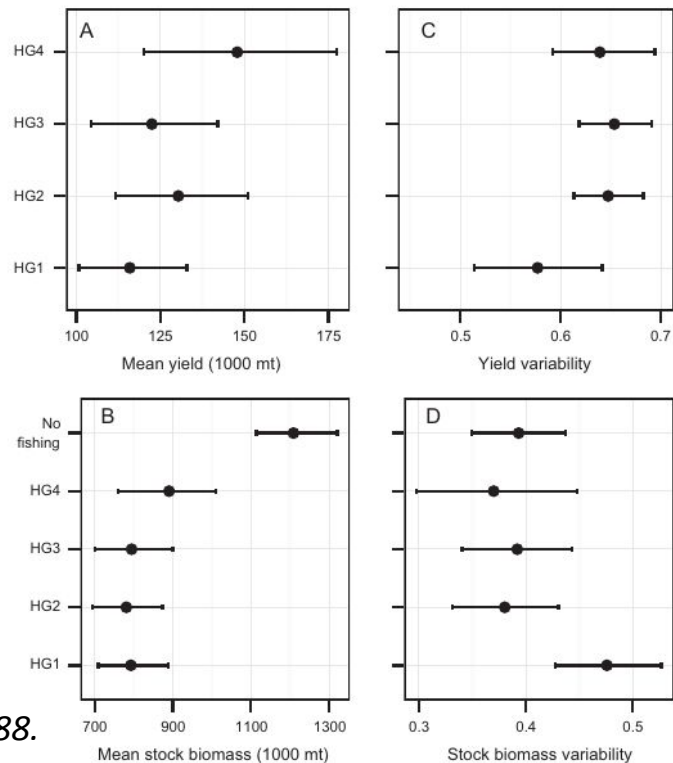A Chlorophyll Prediction Skill (Lead Time: 1-3 mon)

B Trop Pacific C Indian D North Atlantic E South Pacific F North Pacific

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.

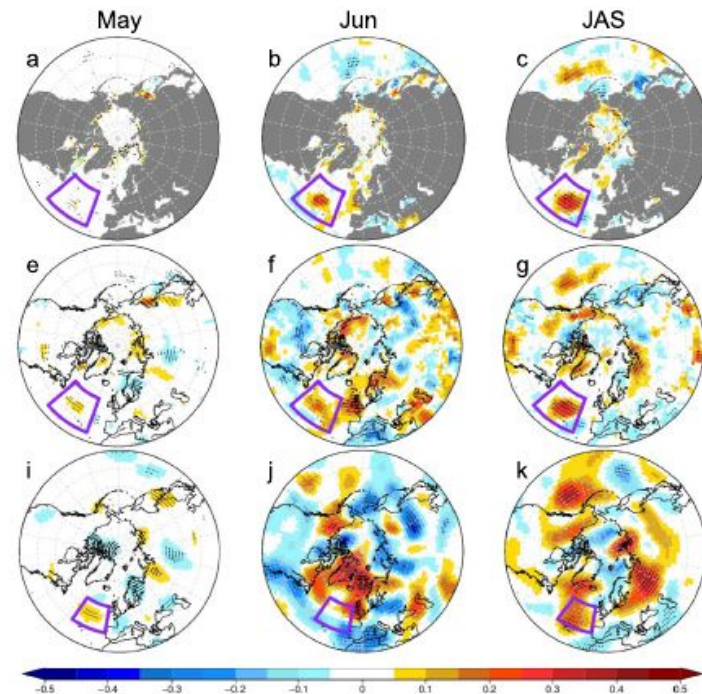*Tommasi, D.et al., Ecological Applications, 2017, 27(2), 378–388.*

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*

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

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

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.

CTR   WND-MEAN minus CTR   WND-FULL minus CTR
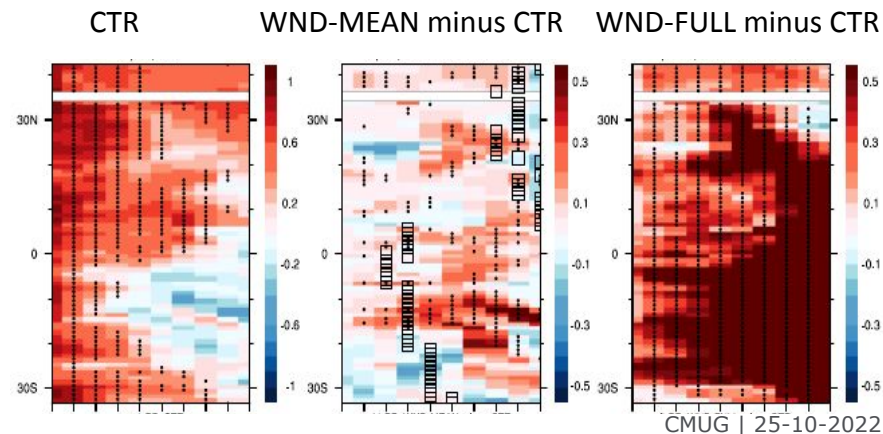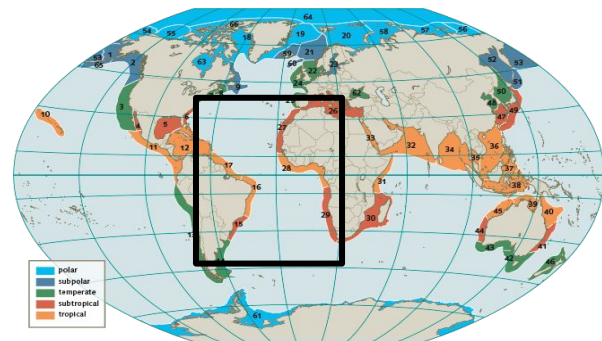
- What is the value of assimilating physical (e.g., SST, SSS) and biogeochemical (OC or OC-derived) CCI ocean ECVs in seasonal predictions of ocean biogeochemistry?

- 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?

- WP1: Assimilation of ESA CCI variables (SST, Sea Ice Concentration and 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

- WP3: Impact of assimilation choices of these reconstructions on climate predictions
  - Subtask 3.1: production of seasonal predictions
  - Subtask 3.2: evaluation of seasonal predictions (e.g., ACC, RMS Skill Score)

ECV	Product	Time Span	Resolution	Use of the Dataset
SST	ESA L4 v2.1 (new version v3)	01/1982-Present	0.05° (daily)	• Assimilation • Skill assessment
SSS	ESA v03.21	01/2010-09/2020 (end of 2021, available at beginning of 2023)	25km (monthly) (effective resolution is 50 km)	• Assimilation • Validation of reconstruction
Sea Level	C3S CMEMS L4	01/1993-08/2021 01/1993-12/2020	0.25° (daily) 0.25° (daily)	• Validation of reconstruction • Skill assessment
Sea Ice	SIC-OSISAF SIT C3S	01/1979-Present 10/2002-Present (only for winter Northern Hemisphere October through April)	25 km (daily) 25 km (monthly)	• Assimilation • Validation of reconstruction • Skill assessment • Validation of reconstruction • Skill assessment
Ocean Colour (primary production, phytoplankton carbon, others?)	OC-CCI v5.0	09/1997-07/2021	4km (daily)	• Assimilation • Validation of reconstruction • Skill assessment

- Assimilation of ESA CCI variables (SST, Sea Ice Concentration and Ocean Color) to produce forced ocean/sea-ice reconstructions with **EC-Earth3-CC & GloSea6/MEDUSA** predictions 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)

- Seasonal climate predictions, initialized from each reconstruction, will be performed using **EC-Earth3-CC & GloSea6/MEDUSA predictions systems.**

- Prediction skill of OBGC will be assessed with **CCI OC & ESA-derived PP & phytoplankton carbon data**, GLODAP carbon and nutrient data, and SOCAT carbon data.

- Other variables related to the carbon cycle, e.g. pH, will be assessed against in-situ data, or **ESA-OceanSODA** project (depending on availability). Skill in physical variables will be assessed with **CCI SSH, SIC & SIT data.**

Idealised perfect model study with two main goals:

1. Quantifying the predictive skill of OBGC within the model
2. Assessing the loss of skill due to imperfect initialization from observations

Two sets of <u>retrospective seasonal forecasts</u>, built to predict a 50-year period of the **picontrol:**

1) Using Perfect ICs
2) Initialised from a forced ocean reconstruction with nudging to 3D ocean T,S
   (*the same approach as in our real-world DCPP predictions*)

Experiments Completed ✓
Analysis to start soon…