EUMETSAT

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Europe's eyes on Earth

The use of OCR in modelling

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IOCCG Summer Lecture Series, 2022

An essential reference for this topic....

IOCCG report 19 (2020)
Synergy between Ocean Colour
and Biogeochemical Ecosystem Models

https://ioccg.org/what-we-do/ioccg-publications/ioccg-reports/

Agenda

How do OCR and models work together?

Research examples

Challenges (opportunities!)

What do we mean by models here?

- Generally we'll be talking about various forms of 'Earth System' type models.
  - Used for understanding processes – hindcast
  - Used for predicting future scenarios – forecast
- But models are also a broad concept in OCR itself (will link to these)…
  - Radiative transfer
  - IOP models
  - Particle models
  - Primary production
  - And product generation/analyses – statistical models (gap filling), AI/ML

What does OCR need from models?

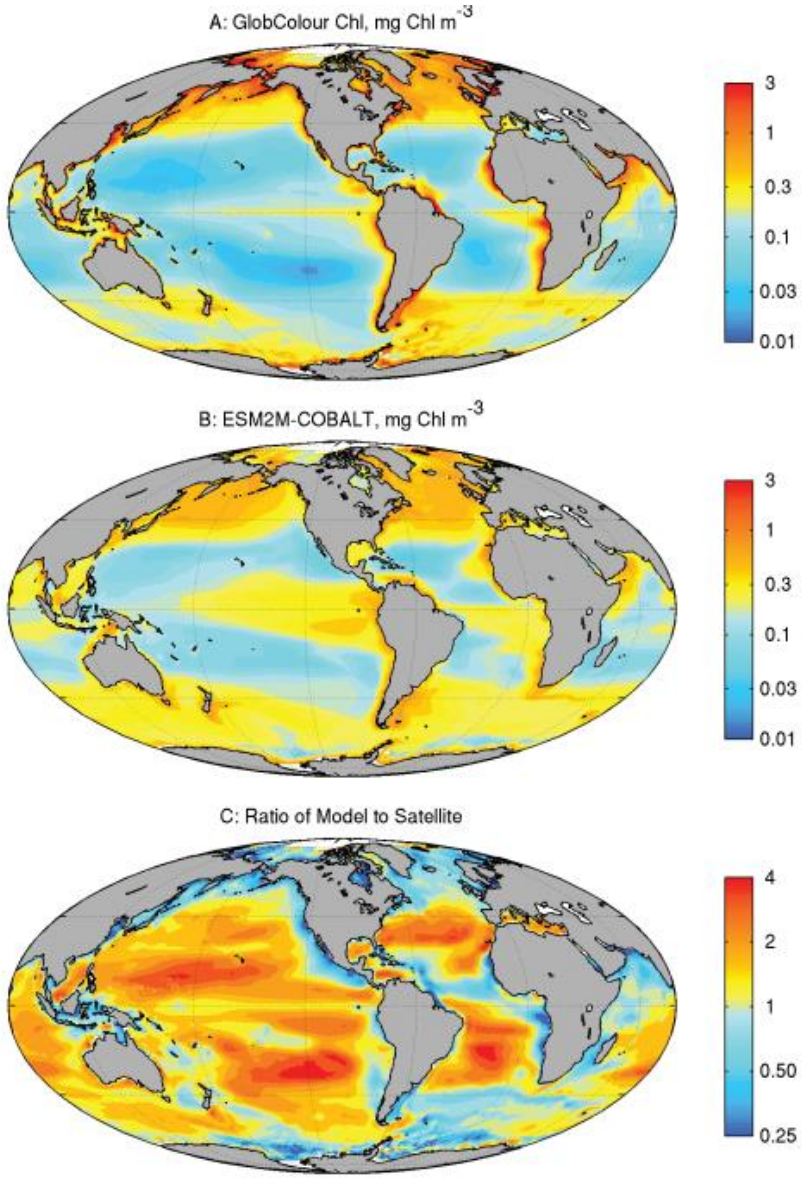
- Extending what we can see from OCR measurements.
  - Extending spatial and temporal scales of measurements
  - Gap filling
  - Bringing together additional data for added-value products e.g. calculation of primary production.
- Understanding the consequences of missing data for understanding variability
- Estimating uncertainty

What do models need from OCR?

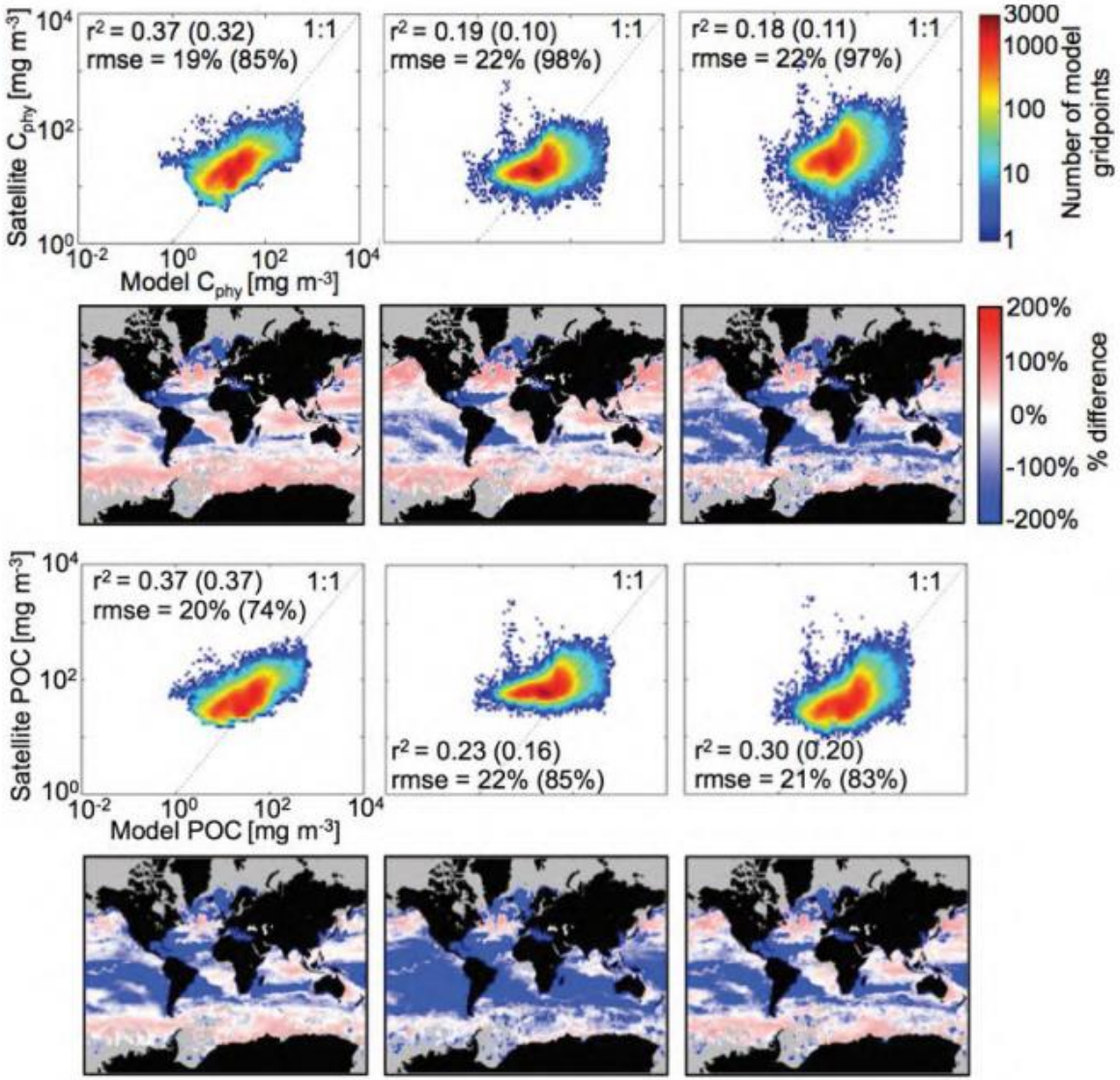
- Validation:
  - Ocean colour radiometry is useful for validating model outputs and processes.
  - Particularly from satellites we can get a synoptic view of the surface distribution of variables that are important in biogeochemical modelling – e.g. Chlorophyll but also many others.
  - Parameters like Chlorophyll-a are listed as Essential Climate Variables. In part due to their importance in climate/Earth system modelling.
- Boundary conditions (for regional models)
- Parameterisation/process understanding:
  - Of light related processes e.g. Attenuation
  - Of community responses to environmental conditions
- Assimilation:
  - For chlorophyll-a predominantly but also other variables

Research Examples: model validation/skill assessment

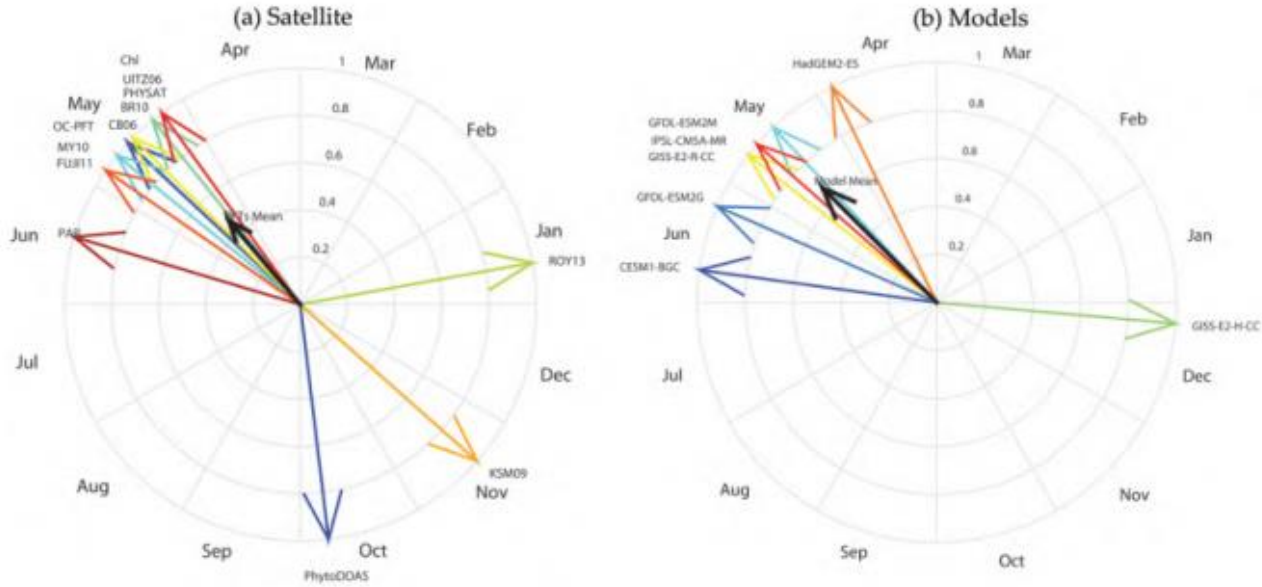
- Can compare as directly as possible where variables are available in both.
- Common with Chlorophyll-a (e.g. from Dunne et al., 2013)
- Statistical metrics developed to assess skill.
- Can also look at probabilistic skill assessments (does model detect x identifiable feature?)



Research Examples: Validation – Carbon and PFTs



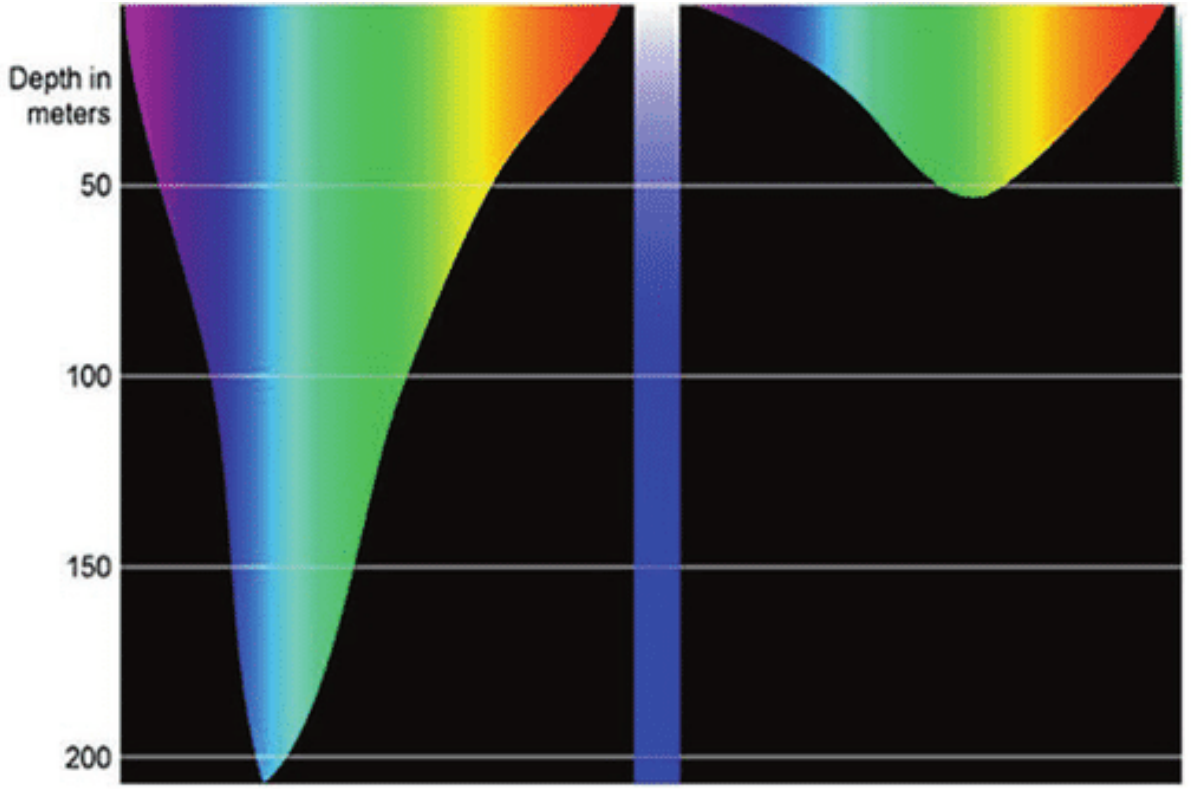
ESA POCO project



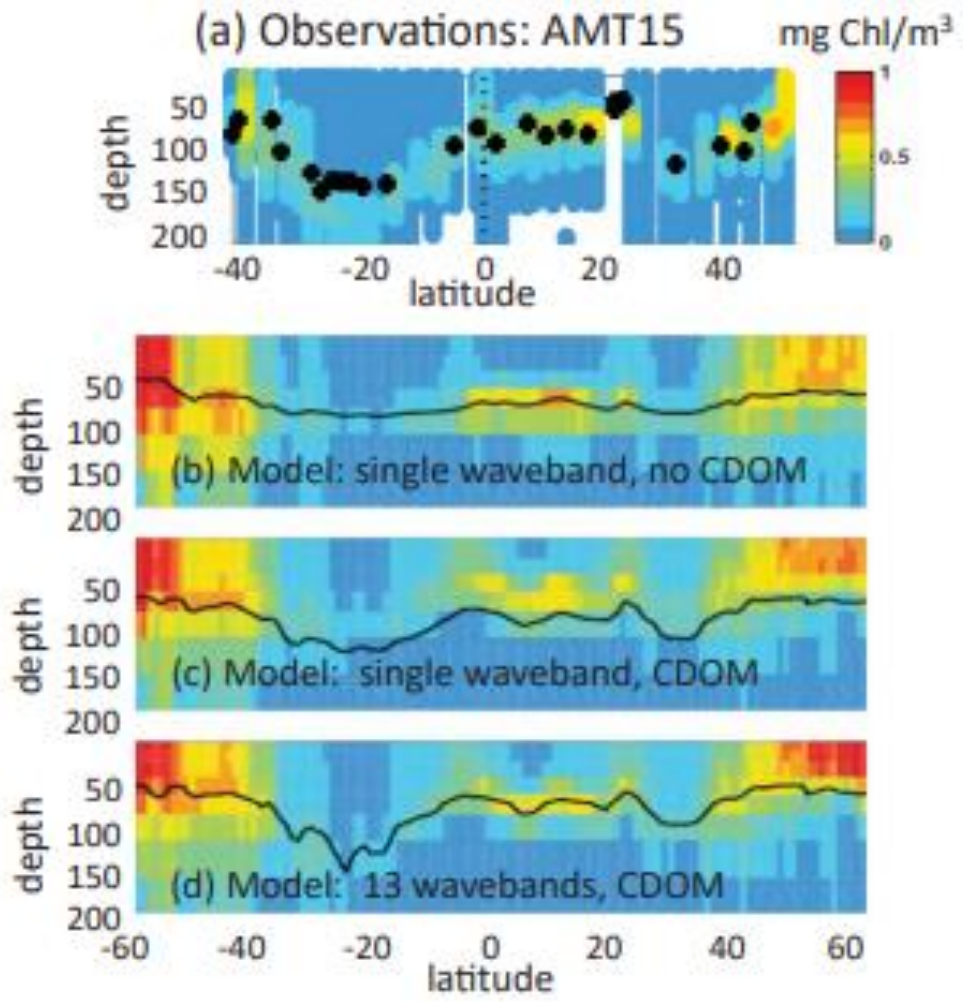
Kostadinov et al., 2017

Research examples: getting the light right…

- Representation of light attenuation in the upper water column influences:
  - Heating
    - And thus potentially stability
  - Availability at depth
    - And thus potentially photosynthesis…
- Models use a wide variety of approaches
  - Simple non spectrally variant exponentials through to radiative transfer
- With and without feedback



Research Examples: Getting the light right



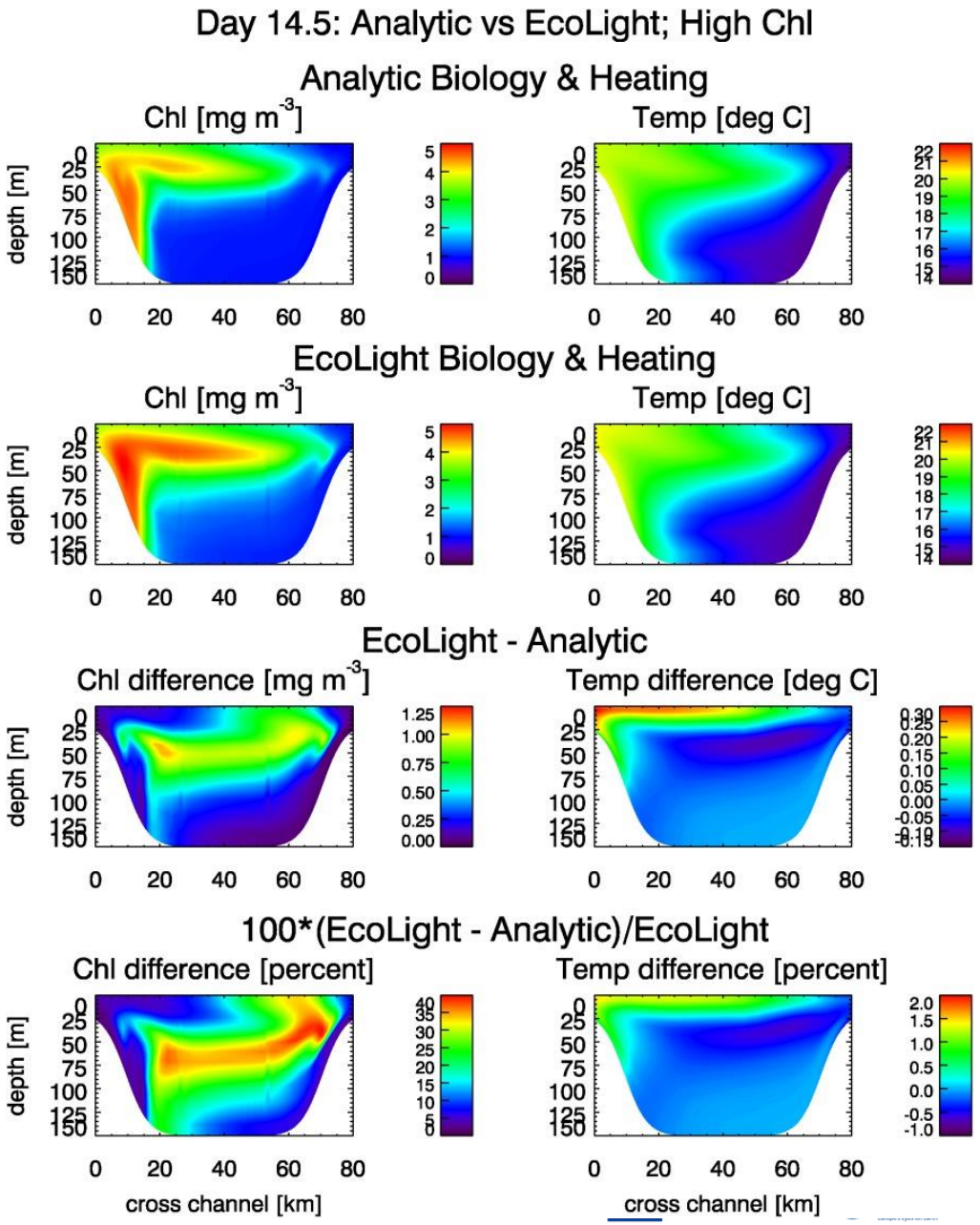
Dutkiewicz et al.,2015

- As one would assume – variability in how one parameterizes the light environment, can have impacts on model phytoplankton growth (here represented by Chlorophyll-a concentrations in examples from Dutkiewicz et al., 2015).

Research Examples: Getting the light right

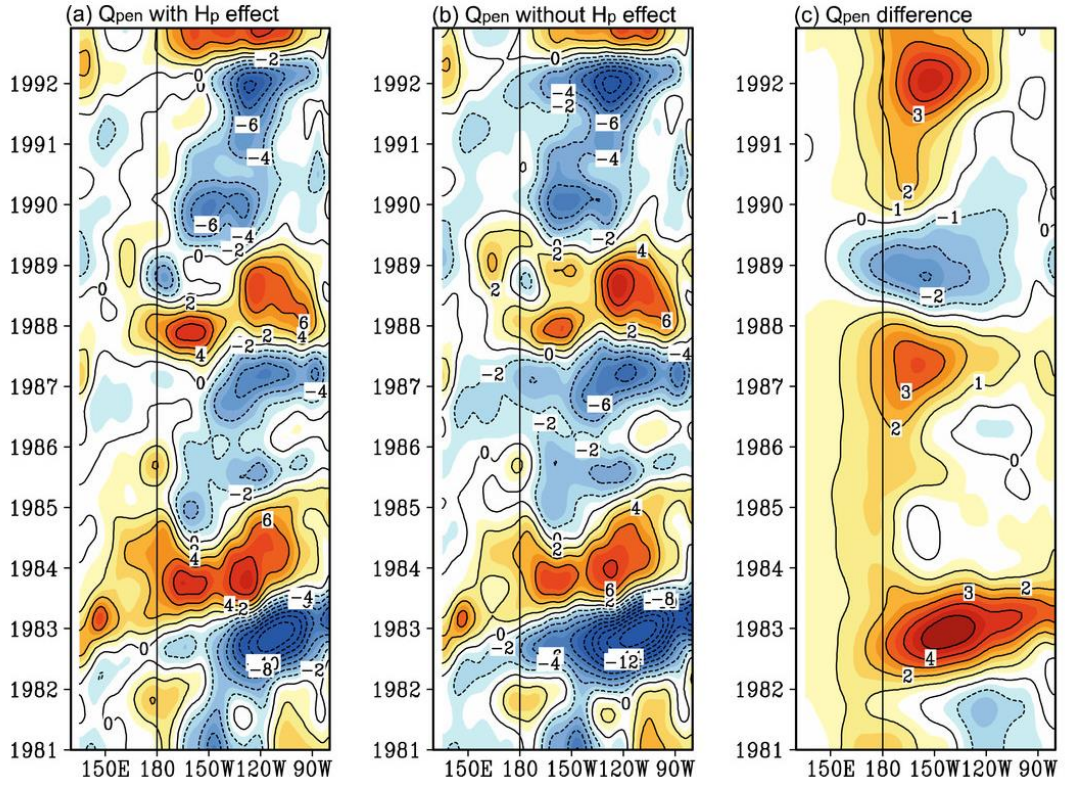
"The use of accurate irradiances gave up to 57% differences in chlorophyll concentrations after two weeks of simulated time, compared to predictions based on irradiances obtained using a simple exponential attenuation formula"

(Mobley et al., 2015)



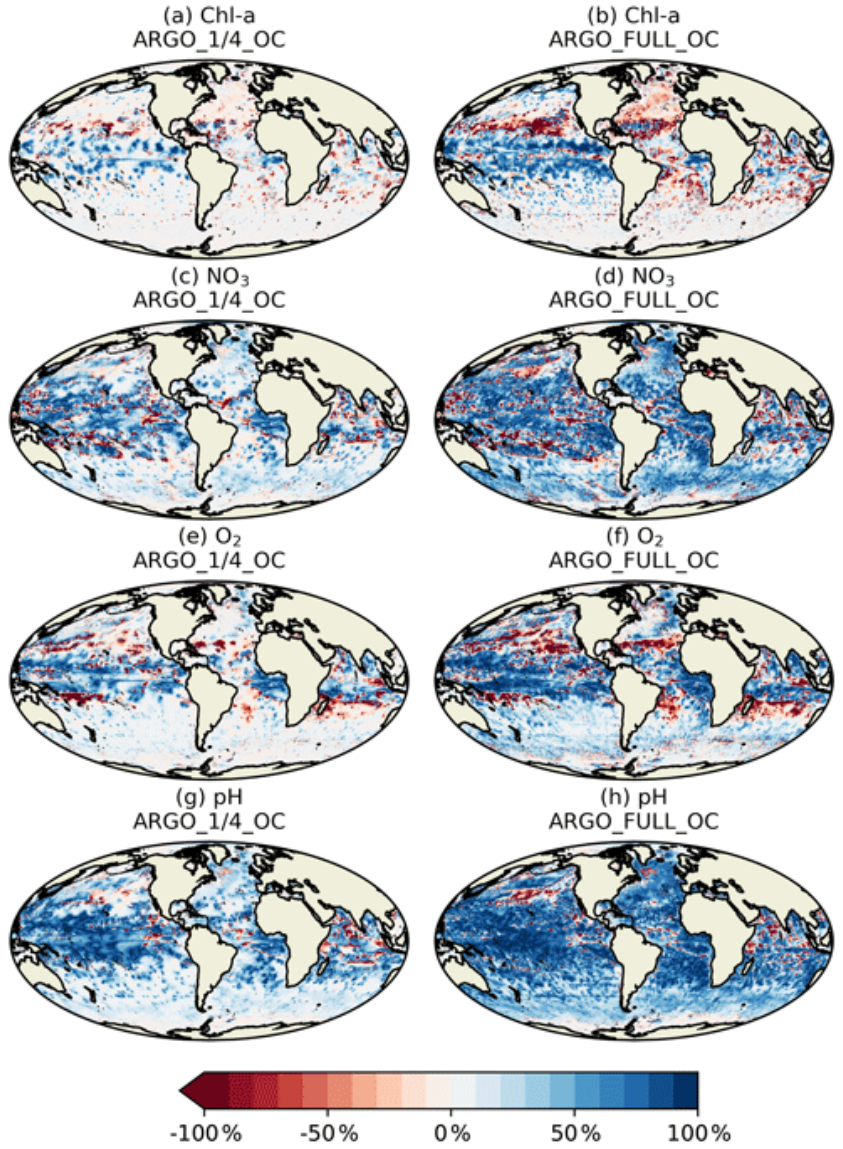
Research Examples: Getting the light/[Chl-a] right…

- Coupling between optical properties, light penetration and heating effects can have important impacts on model performance at different scales.
- Example from Zhang et al., 2018 – ENSO related effects when using model with/without feedbacks and a [Chl-a] climatology.
  - "a cooling effect was associated with a low Chl concentration during El Niño events, and a strong warming effect was associated with a high Chl concentration during La Niña event"



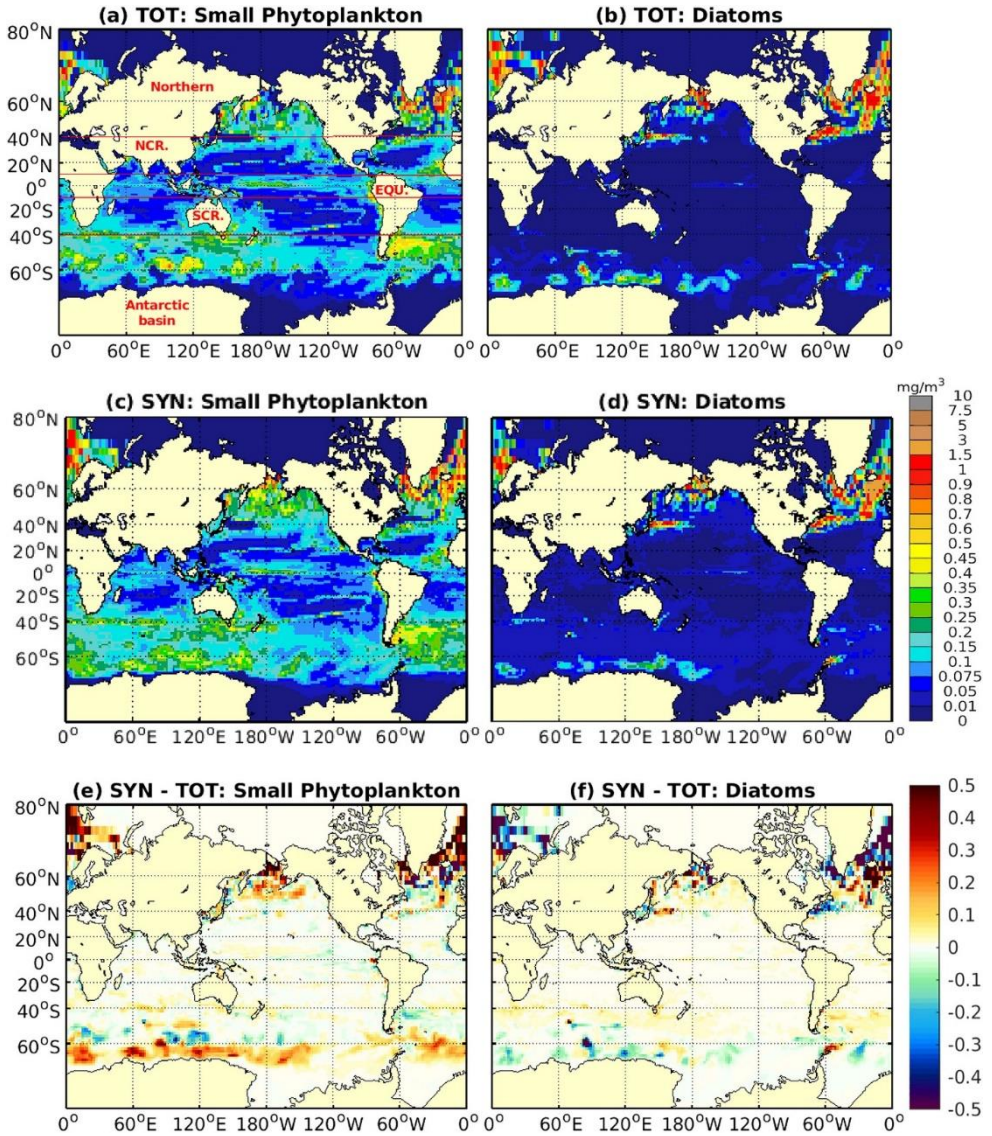
Research Examples: Assimilation for system design

- **Assimilating synthetic Biogeochemical-Argo and ocean colour observations into a global ocean model to inform observing system design** – Ford, 2020
- Complementary benefits of ocean colour and BIO-ARGO assimilation.



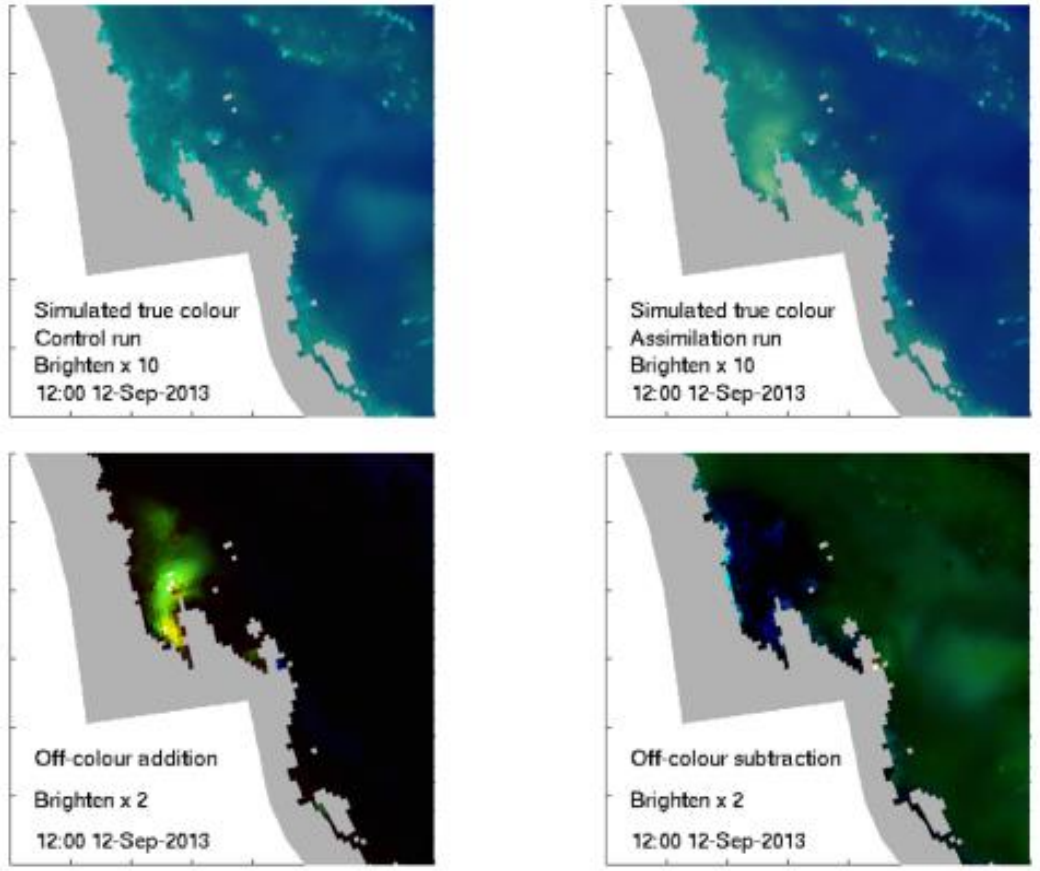
Research Examples: Assimilation beyond Chlorophyll-a

- "Overall, the assimilation experiments show that the assimilation of satellite data of PFTs can improve their model representation compared to the case when only TChla data are assimilated. In the case of a global model with two PFTs used here, the diatoms group was improved to a large degree while the improvement of the SP group was smaller." Pradhan et al., 2020



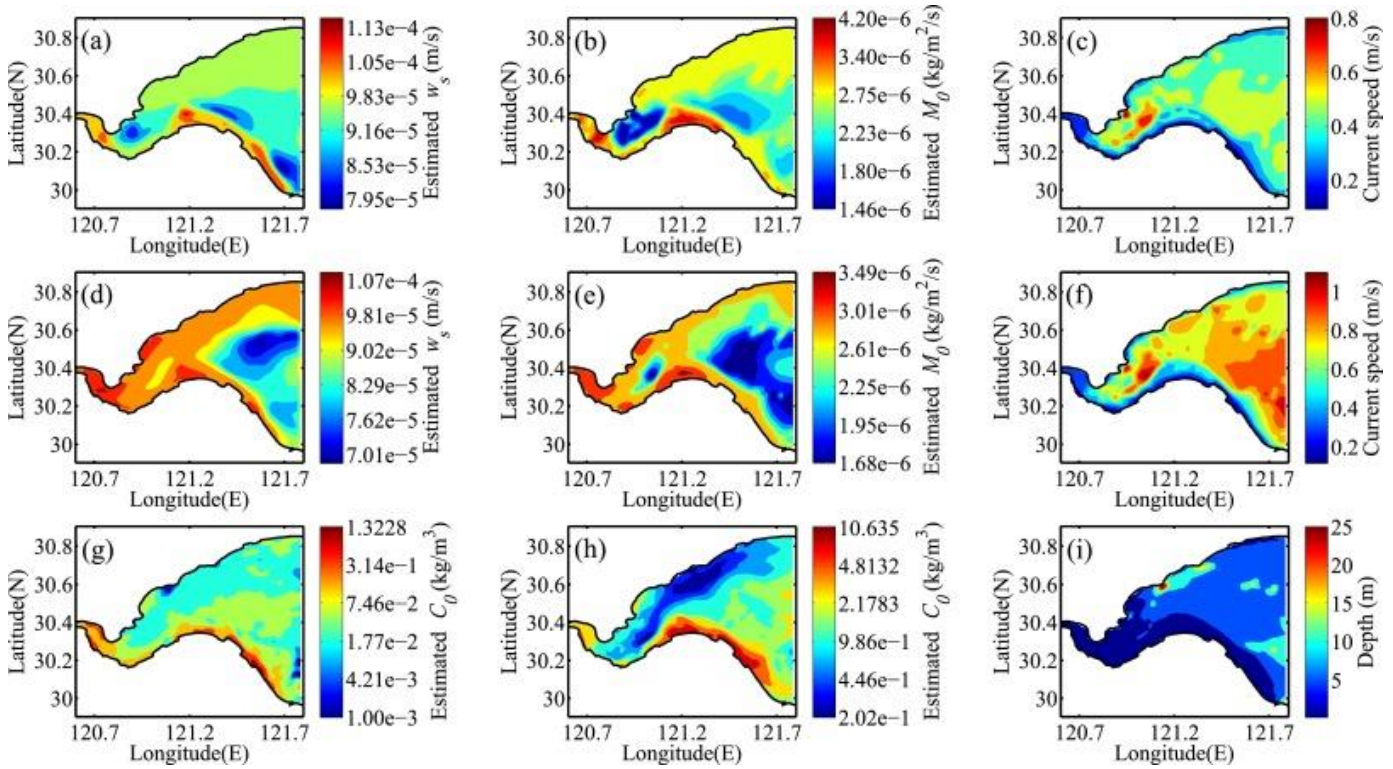
Research Examples: Assimilation of reflectances

- Questions about benefits in assimilating earlier in processing chain…especially in complex waters.
- Example over GBR from Jones et al., 2016., showing improvements in BGC model prediction.



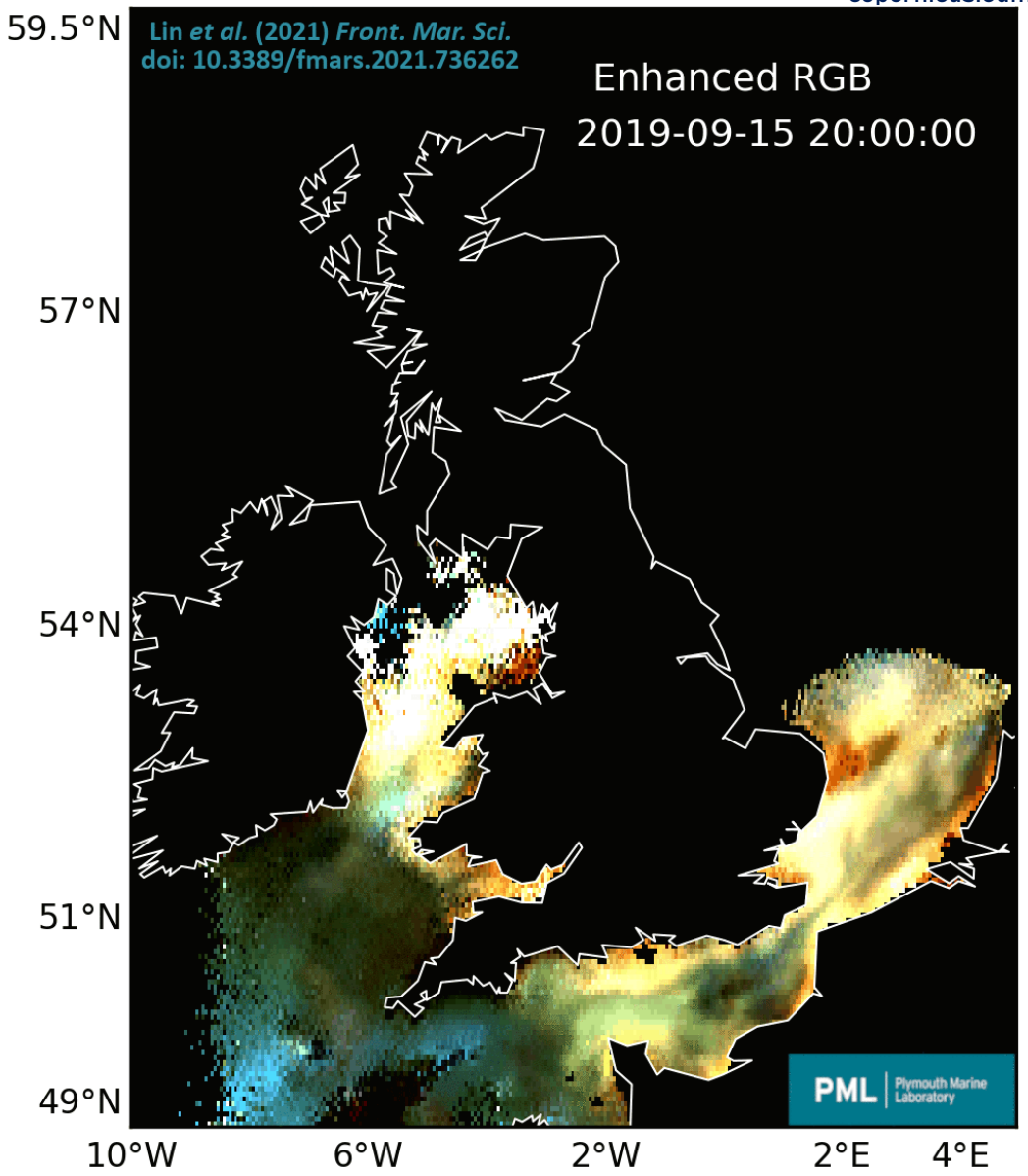
Research Examples: Assimilation of SPM

- Very useful for coastal infrastructure management, EIA assessment etc.
- However, often tidally dependent so best using GEO OC.
- Example from Wang et al., 2018



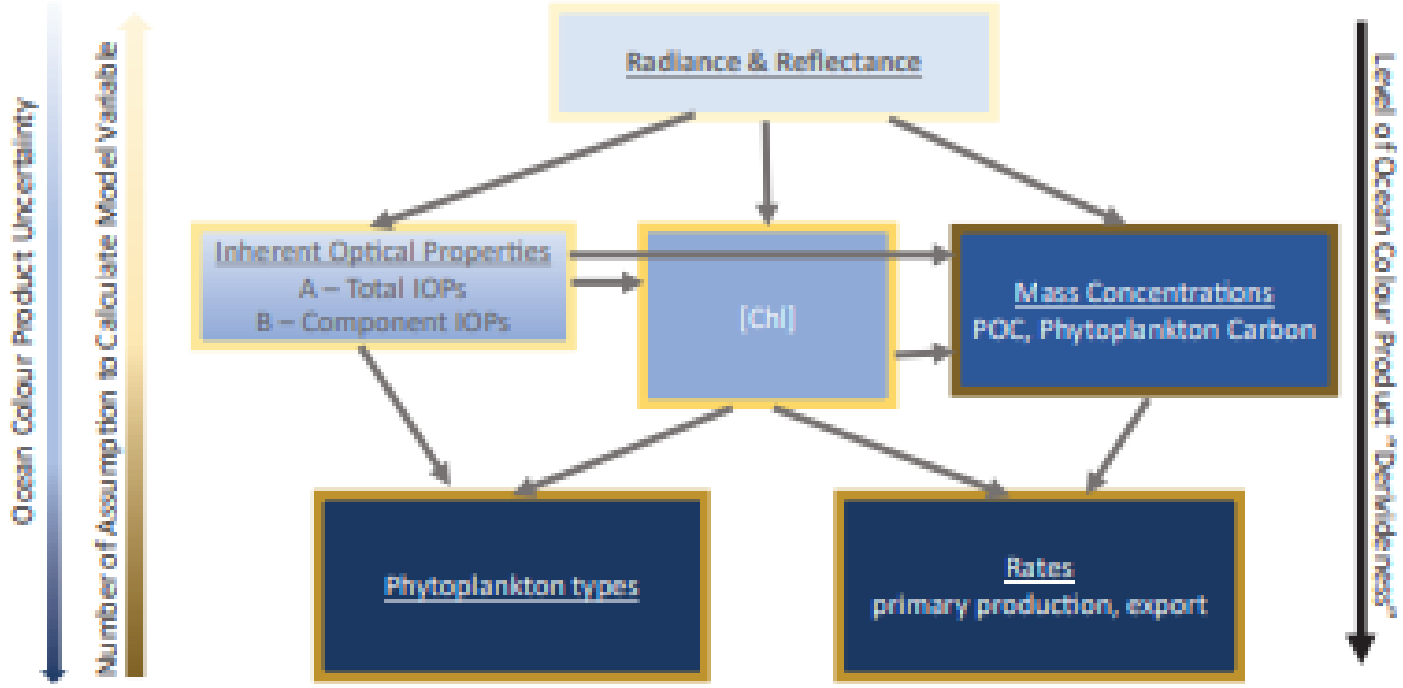
Research Examples: OC and particle tracking

- Combining ocean colour and lagrangian particle tracking based on model velocity fields.
- Used towards early warning systems for HABs.
- Example here from Lin et al., 2021



Challenges around this topic…

- Mismatches between satellite data products and model variables:
  - Spatial/temporal resolution
  - Gaps (and bias)
  - Apples and oranges…



Other topics to look in to….

- Different types of assimilation schemes
- Incorporation and propagation of uncertainty

- Using models to support OC science
  - What are consequences of missing data?
    - On averages (Gregg and Casey 2007)
    - On phenology (Cole et al., 2012)
  - Contribution of PFTs etc to OC uncertainty (Mouw et al., 2012)
  - What's a trend and what's a bias in multi-sensor data sets?
  - Informing future mission design…

References

- Dutkiewicz S, Hickman AE, Jahn O. Modelling ocean-colour-derived chlorophyll a. Biogeosciences. 2018 Jan 30;15(2):613-30.
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- Zhang, R.H., Tian, F. and Wang, X., 2018. Ocean chlorophyll-induced heating feedbacks on ENSO in a coupled ocean physics–biology model forced by prescribed wind anomalies. *Journal of Climate*, *31*(5), pp.1811-1832.

A few notes before tomorrow

- 3 days of practicals coming up!
- Myself, Kevin Ruddick, Quinten Vanhellemont, Ana Ruescas.
- Learning objectives:
  - Understanding signal in complex waters – forward model.
  - Accessing and processing satellite data in complex waters
    - Sentinel-2 and 3 (plus some discussion of others)
    - Acolite, C2RCC, machine learning approaches
  - Batch downloads through API and batch processing with SNAP
- We really want feedback on the resources we share with you ☺

A few notes before tomorrow…

- Wednesday
  - 0900-0930: Checking technical set up.
  - 0930-1030: Kevin Ruddick – Forward modelling in complex waters
  - 1030-1100: Break
  - 1100-1145: Forward model practical:
  - 1145-1230: Quinten Vanhellemont - Acolite practical
  - 1400-1530: Acolite practical
  - 1600-1730: Hayley Evers-King - Accessing and processing Sentinel-3 data
- Thursday
  - 0900-1030: Ana Ruescas – Machine learning and Ocean Colour
- Friday
  - Sharing what you've done.

A few notes before tomorrow…

- More time for working if we get a few things done first ☺
  - Forward modelling practical
    - Install Anaconda
    - Clone code from Gitlab: https://gitlab.com/benloveday/oc_forward_model
    - Set up Python environment from .yml file
  - Acolite practical
    - Install Acolite
    - Download some Sentinel-2 data
  - Sentinel-3 practical
    - Clone code from Gitlab: https://gitlab.eumetsat.int/eumetlab/oceans/ocean-training/sensors/learn-olci
    - Set up Python environment from .yml file
    - Sign up for an account – eoportal.eumetsat.int
  - Machine learning practical
    - Clone code from Gitlab https://gitlab.com/benloveday/mlregocean_cdom
    - Set up Python environment from .yml file

Thank you!

Questions are welcome.