Atlantic Biogeochemistry from Space

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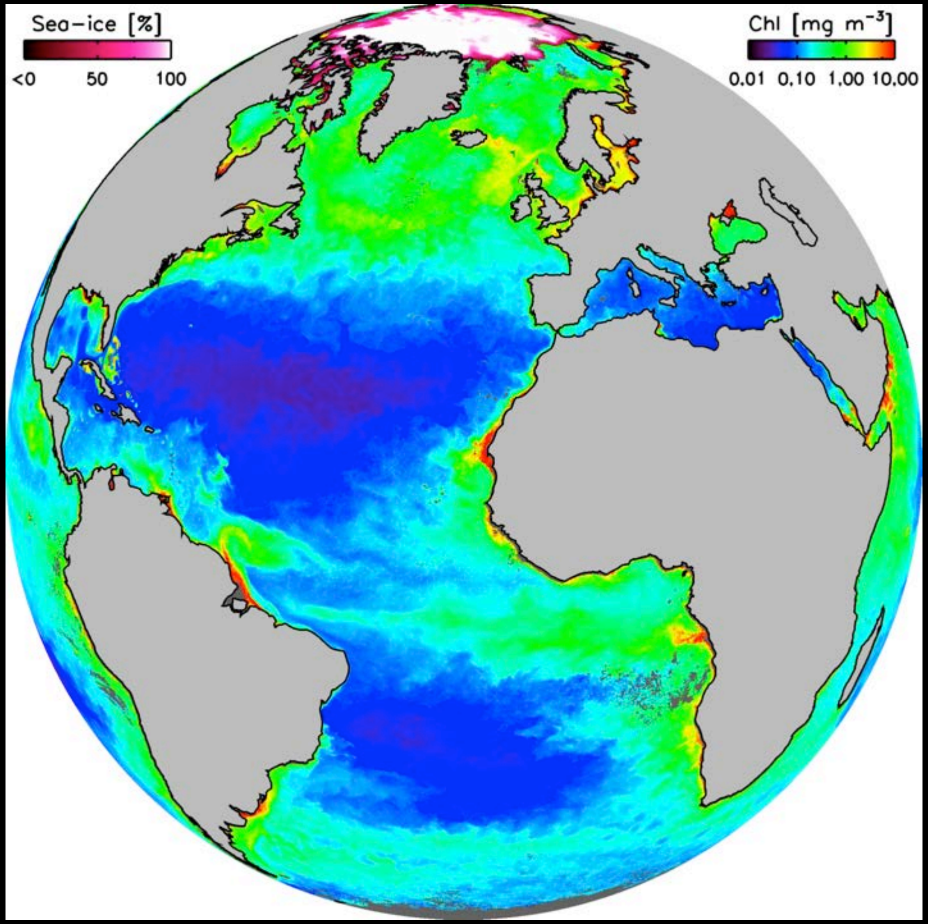
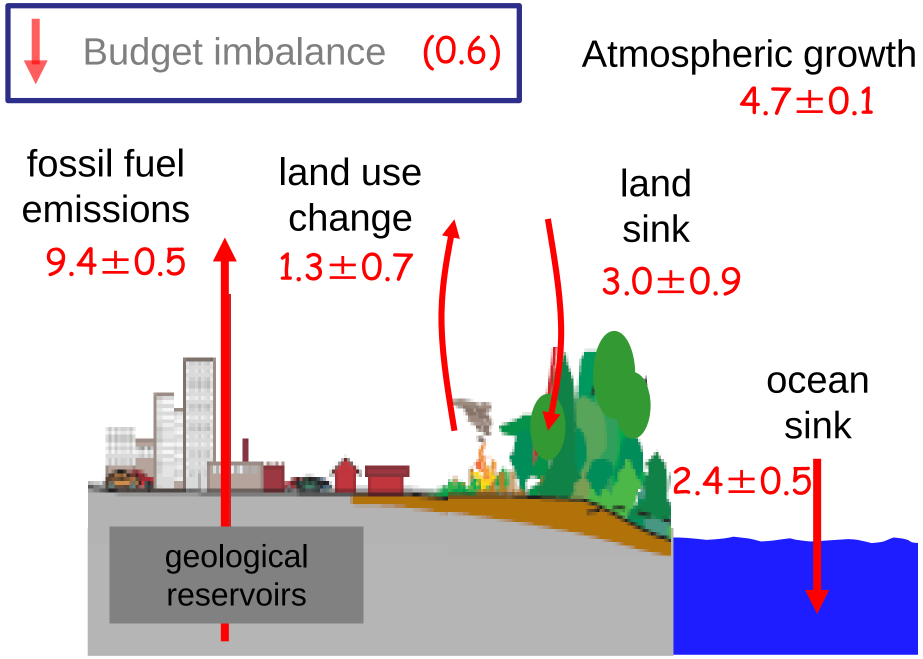


OC-CCI product

Why do we care about ocean biogeochemistry?

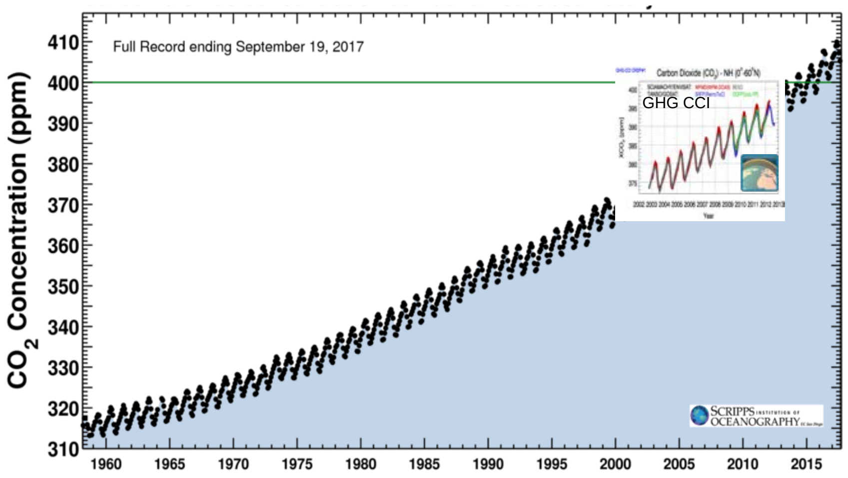
- To understand the role of the oceans in the global budget of important elements, notably carbon
- To understand the functioning of the marine ecosystem, on which we depend for a variety of services, including provision of food
- Relevance for human health
- In the context of climate change, we cannot assume steady state, and it becomes important to know not just the baseline solution, but also variability and trends

2007-2016 Earth Carbon budget (GtC y^{-1})

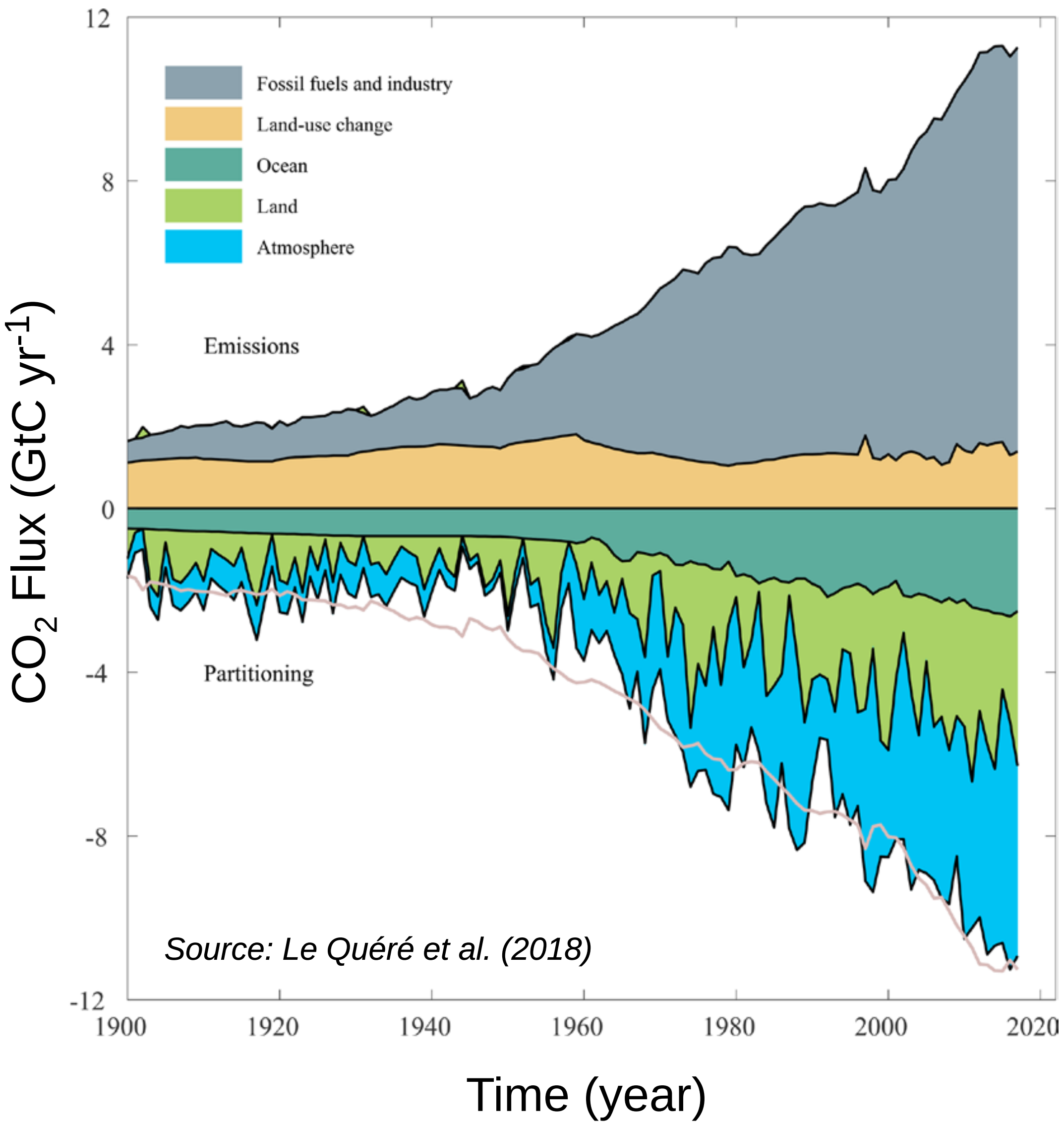


Source: Le Quéré et al. (2018)

Latest CO2 Reading, 3 Dec. 2018: 409 ppm
Carbon dioxide concentration at Mauna Loa Observatory



Global Carbon Budget



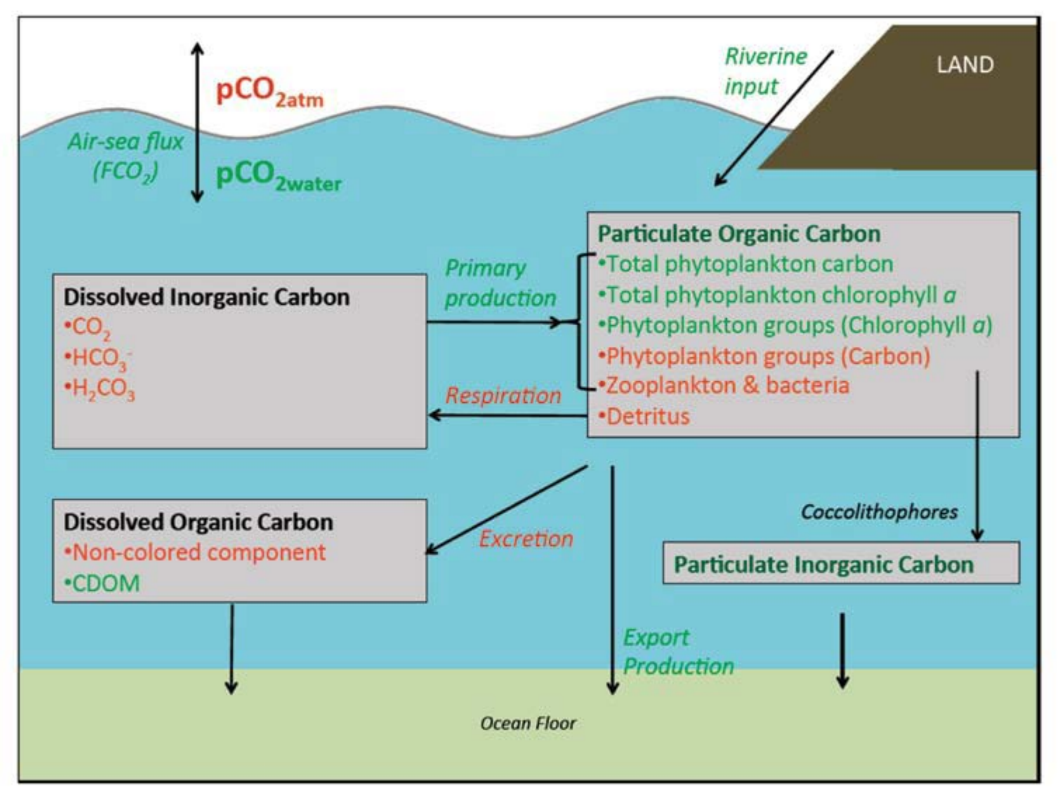
"The global carbon budget presented here refers to the mean, variations, and trends in the perturbation of CO_2 in the environment, referenced to the beginning of the industrial era."

Le Quéré et al. 2018

How can satellite-based observations contribute better to climate assessments?

Can we justify an Atlantic focus?

Ocean Pools and Fluxes of Carbon



CEOS Report 2014

- Green components: amenable to remote sensing
- Components not yet accessible to remote sensing

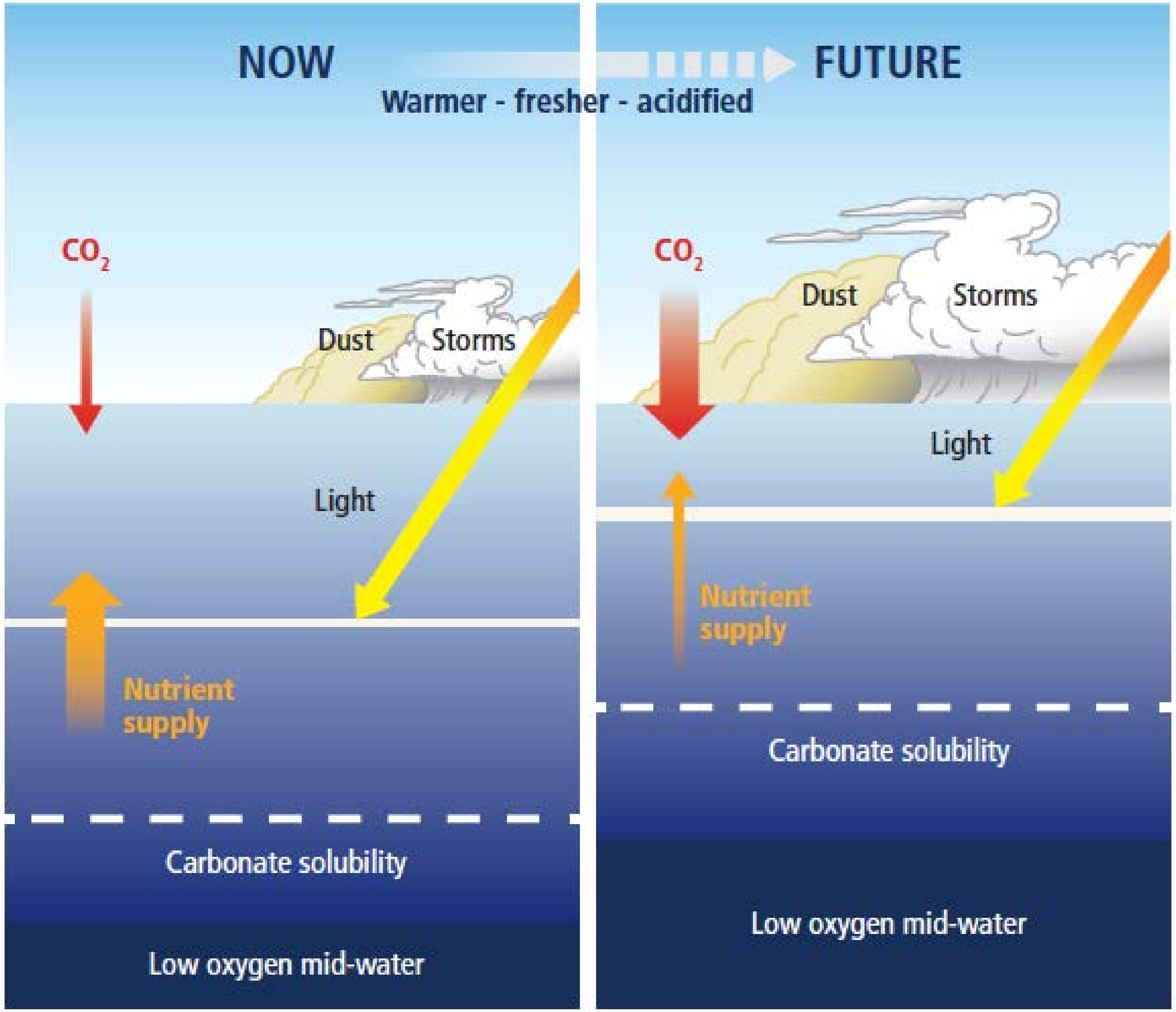
CEOS Carbon Strategy has identified many pools and fluxes of carbon in the ocean that are accessible to remote sensing.

But there are gaps as well.

What can be done to fill the gaps?

Can we arrive at a satellite-based carbon budget for the oceans?

Climate Change and the Oceanic Environment



Projected alteration (magnitude and frequency) of oceanic fluxes and atmospheric events due to changing climate in the coming decades. IPCC-WG II AR5 2014

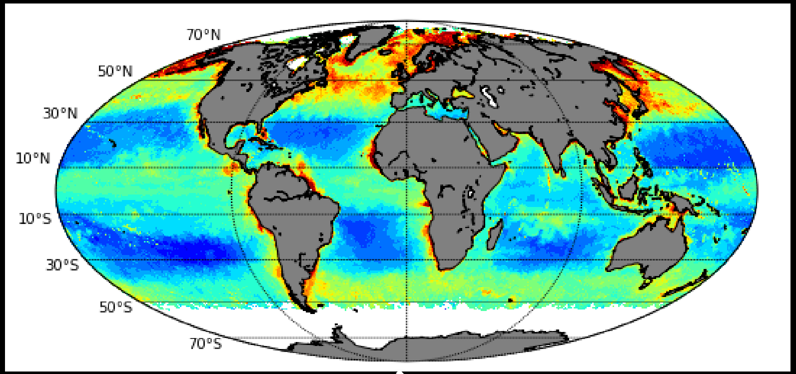
Are our models climate-ready?

For example, as ocean temperatures increase, how would it affect bio-geochemical processes?

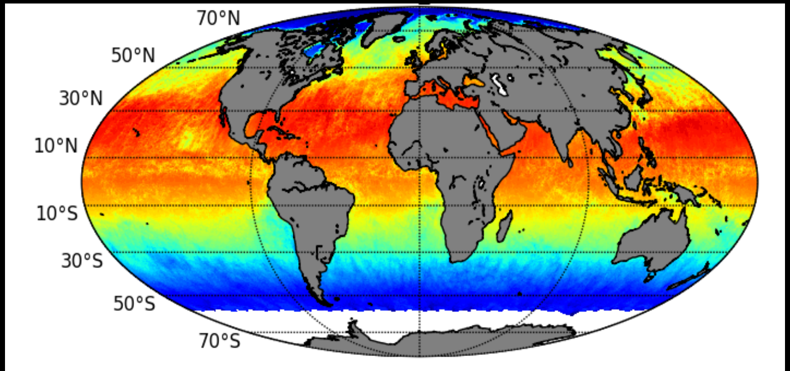
The answer is important to both ecosystem models as well as for satellite-based computations.

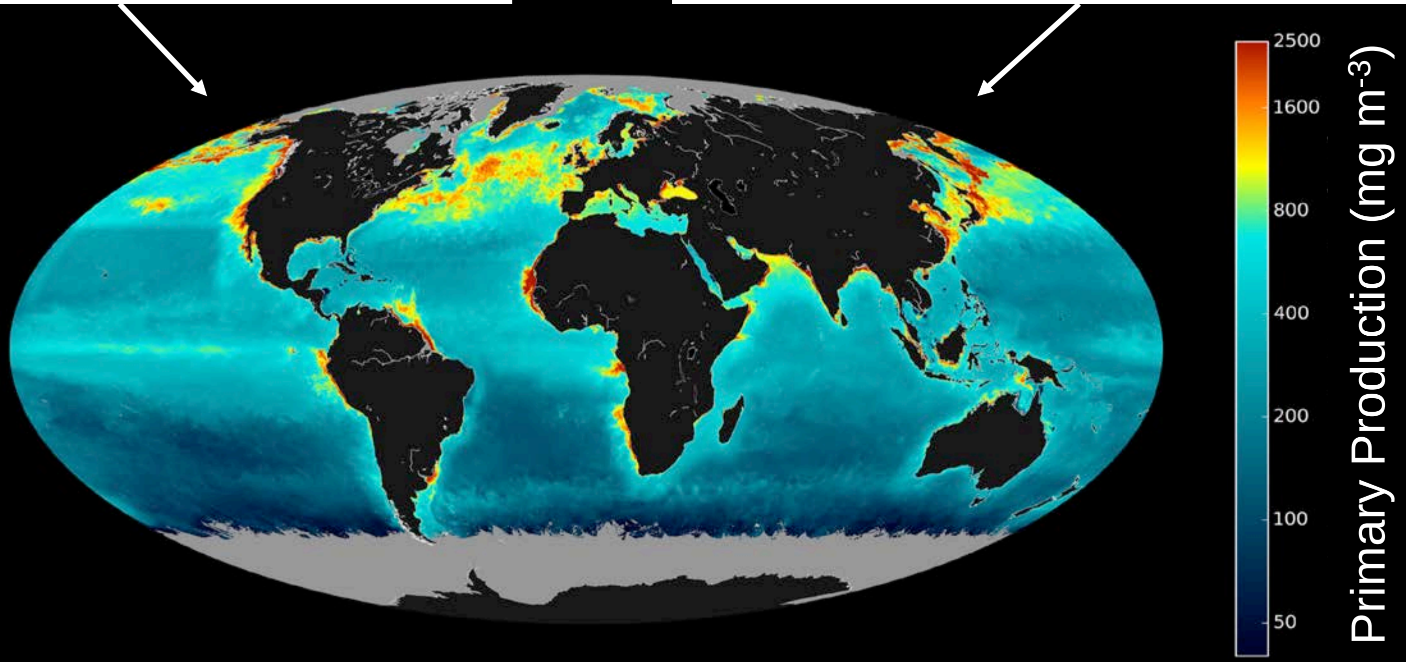
Marine Primary Production from Space

ESA OC-CCI CHL-A



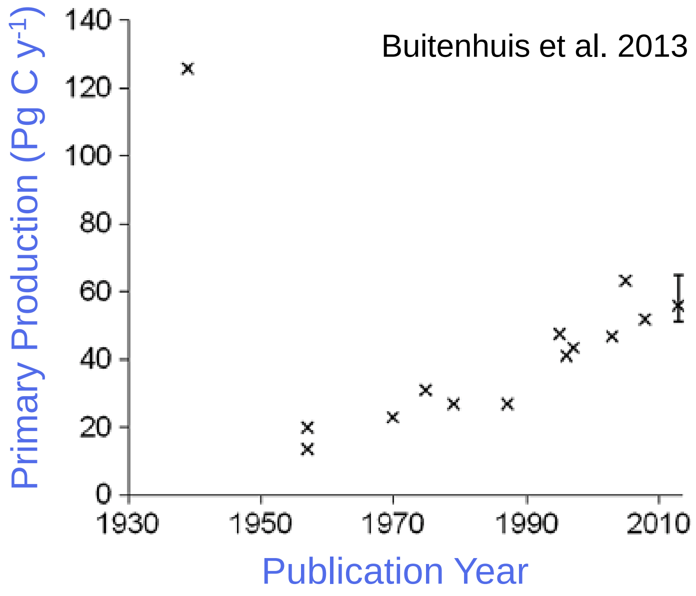
ESA PAR PRODUCT



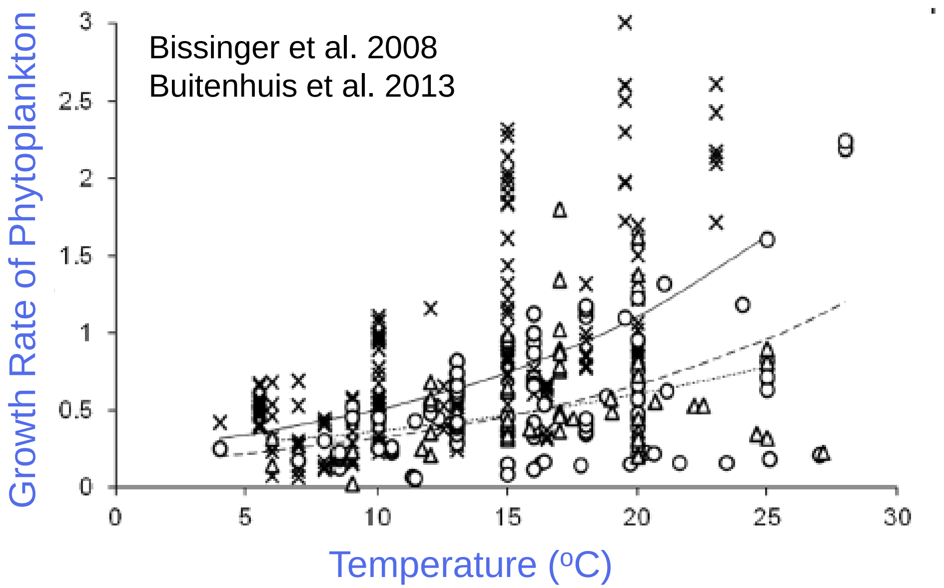


Annual marine primary production is ~50GT per annum

Computation of Marine Primary Production



Laboratory Data

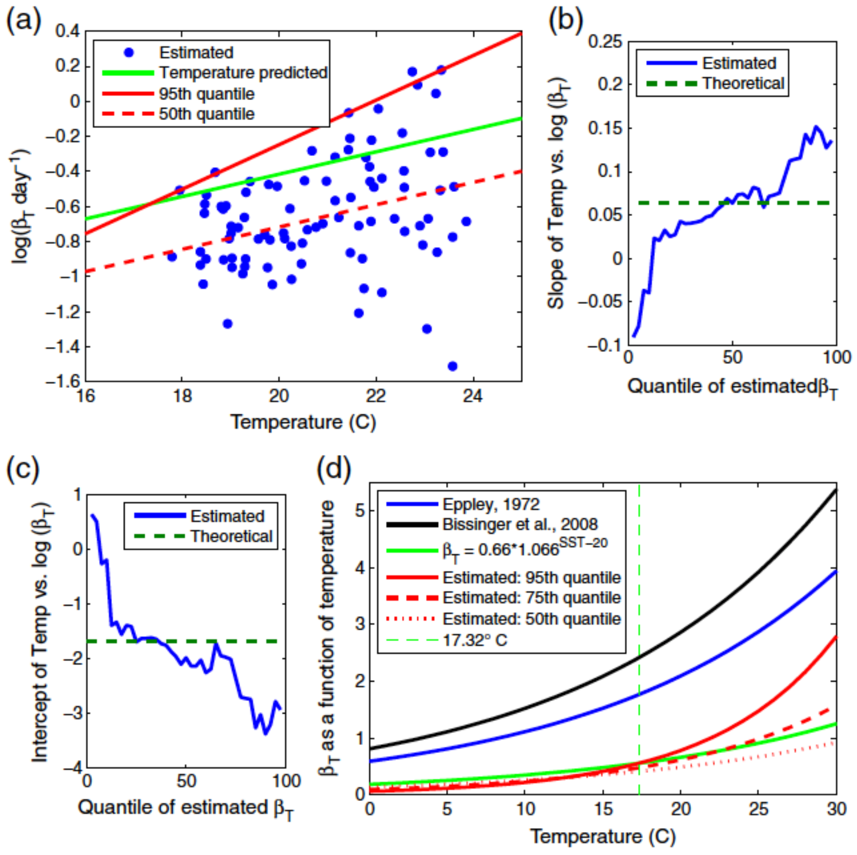


- Modern estimates of marine primary production are higher than classical estimates based on small number of in situ data
- But can we calculate trends in primary production accurately?

- Many models use temperature-dependent growth rates in primary-production models.
- Evidence from laboratory measurements
- Can we improve model parameters?
- Role of variables other than temperature?
- Model parameters from space?

How to improve our understanding of ecosystem model parameters?

One avenue is through assimilation of satellite-based observations into a model, to infer model parameters



Roy et al. (2012) used a sequential data-assimilation technique with satellite-based chlorophyll data to infer growth rates of phytoplankton and mortality rates for zooplankton

The results for a location in the Atlantic, off North-West Africa, showed temperature dependence quite at variance from what has been assumed based on laboratory observations alone

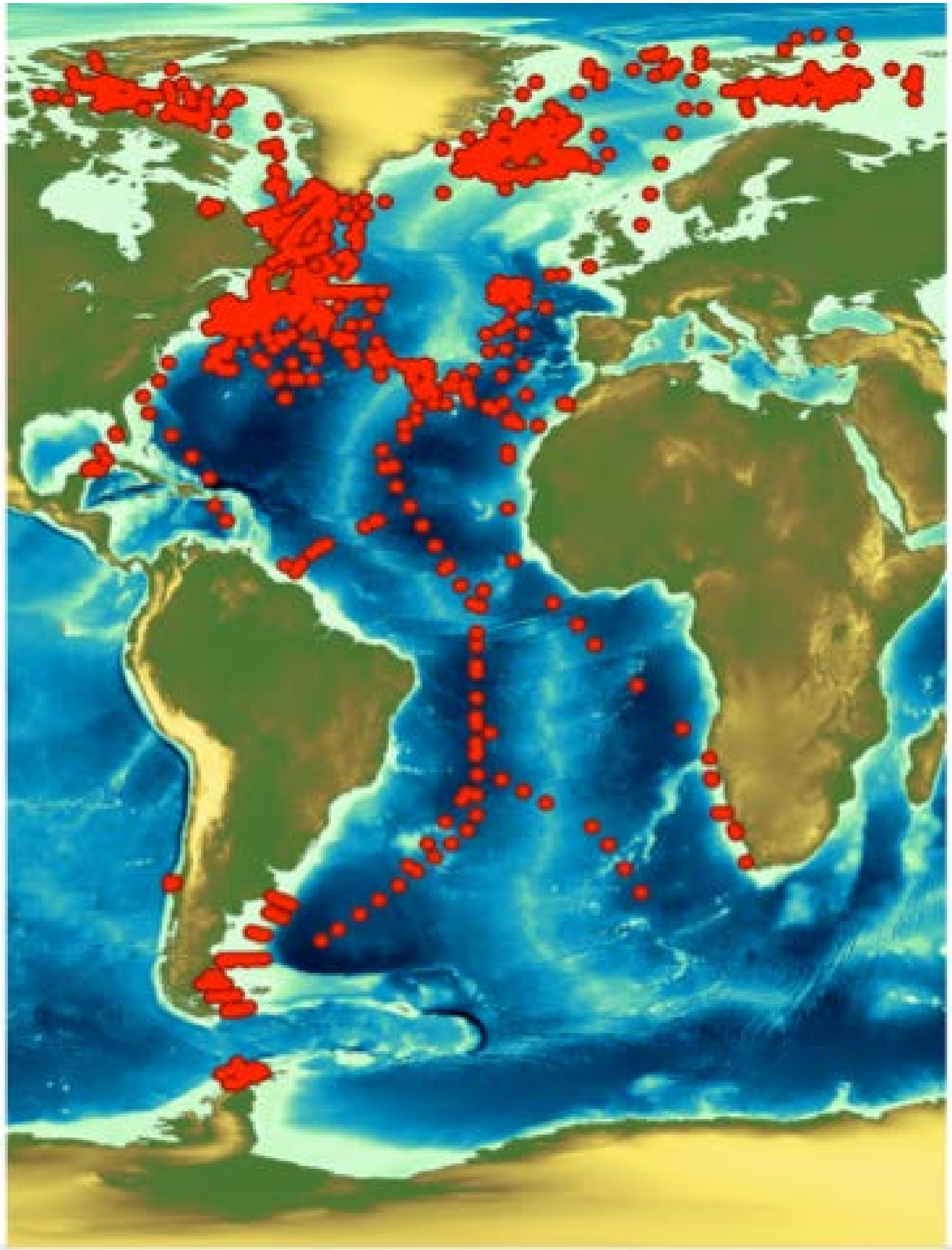


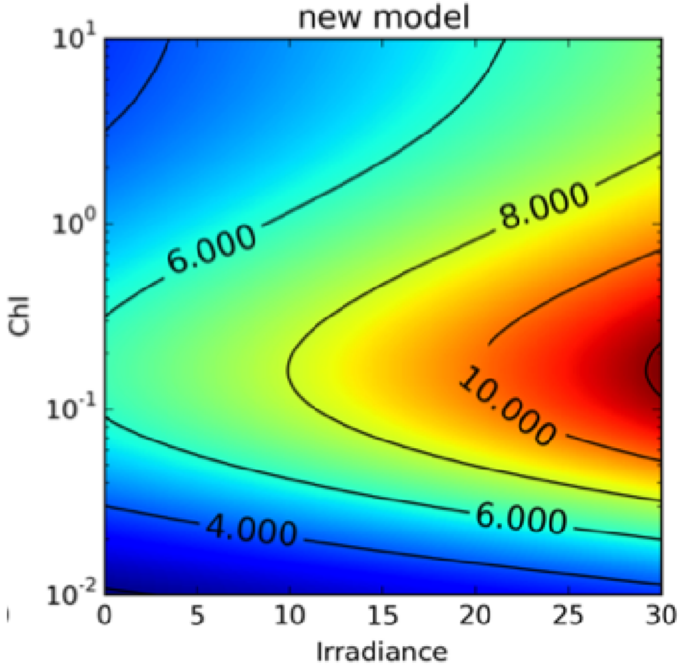
Figure courtesy Heather Bouman

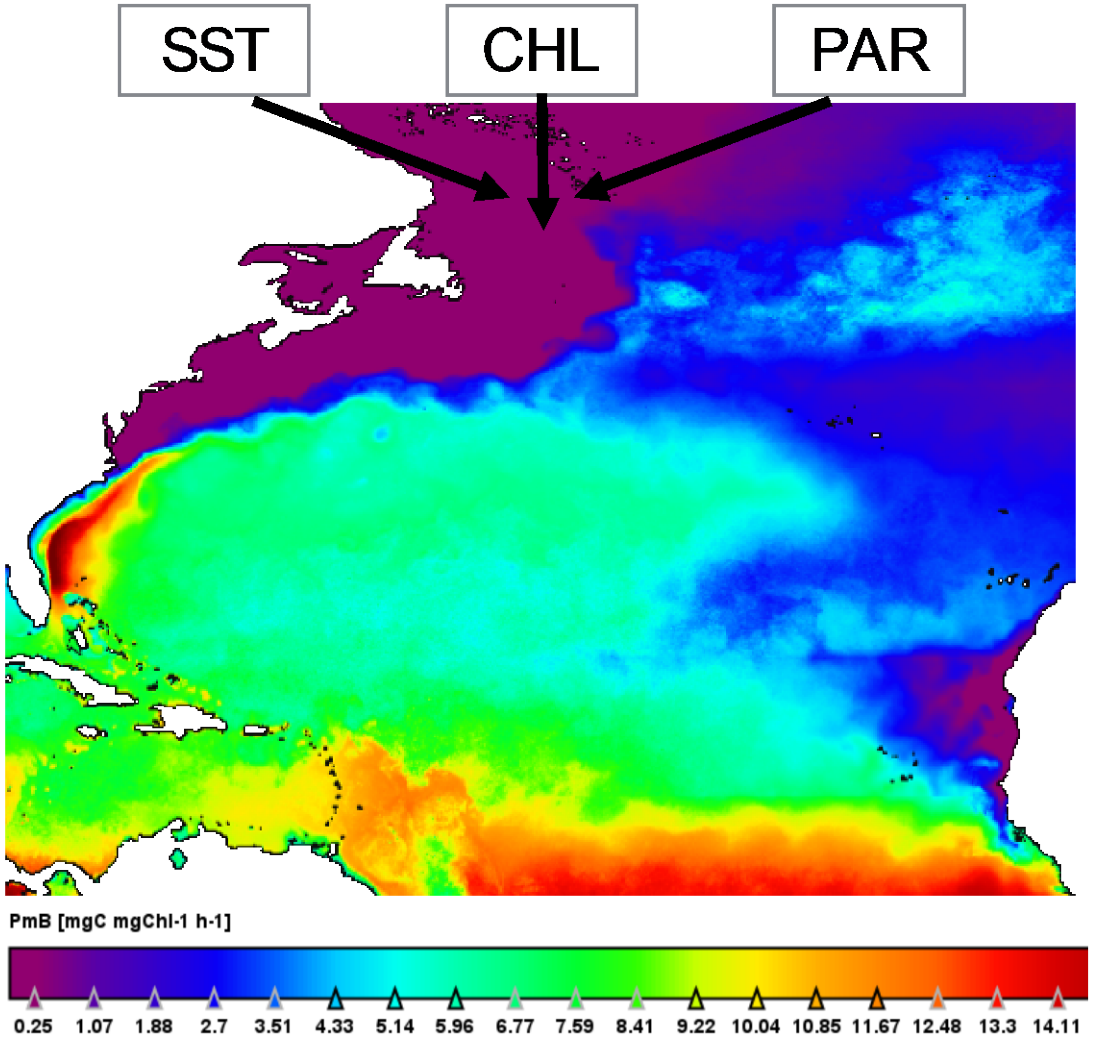
MAPPS database on
photosynthesis-irradiance parameters
Bouman et al. (2018)
ESA MAPPS Project

Database rich in the Atlantic and the Arctic waters

Invaluable data source for further development of primary production models for climate applications

Example of model at SST of 22°C

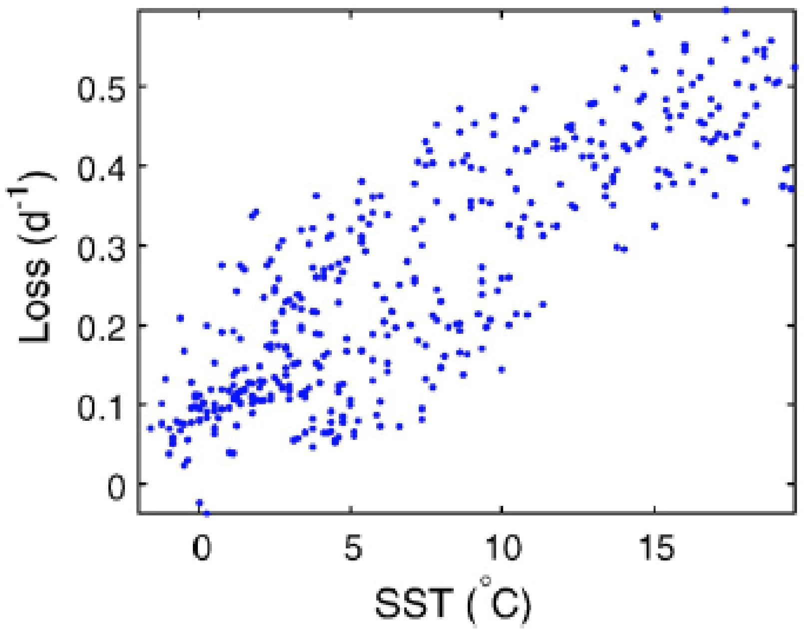




MAPPS

Global satellite products of photosynthesis-irradiance parameters

Inferring phytoplankton loss terms using remote sensing



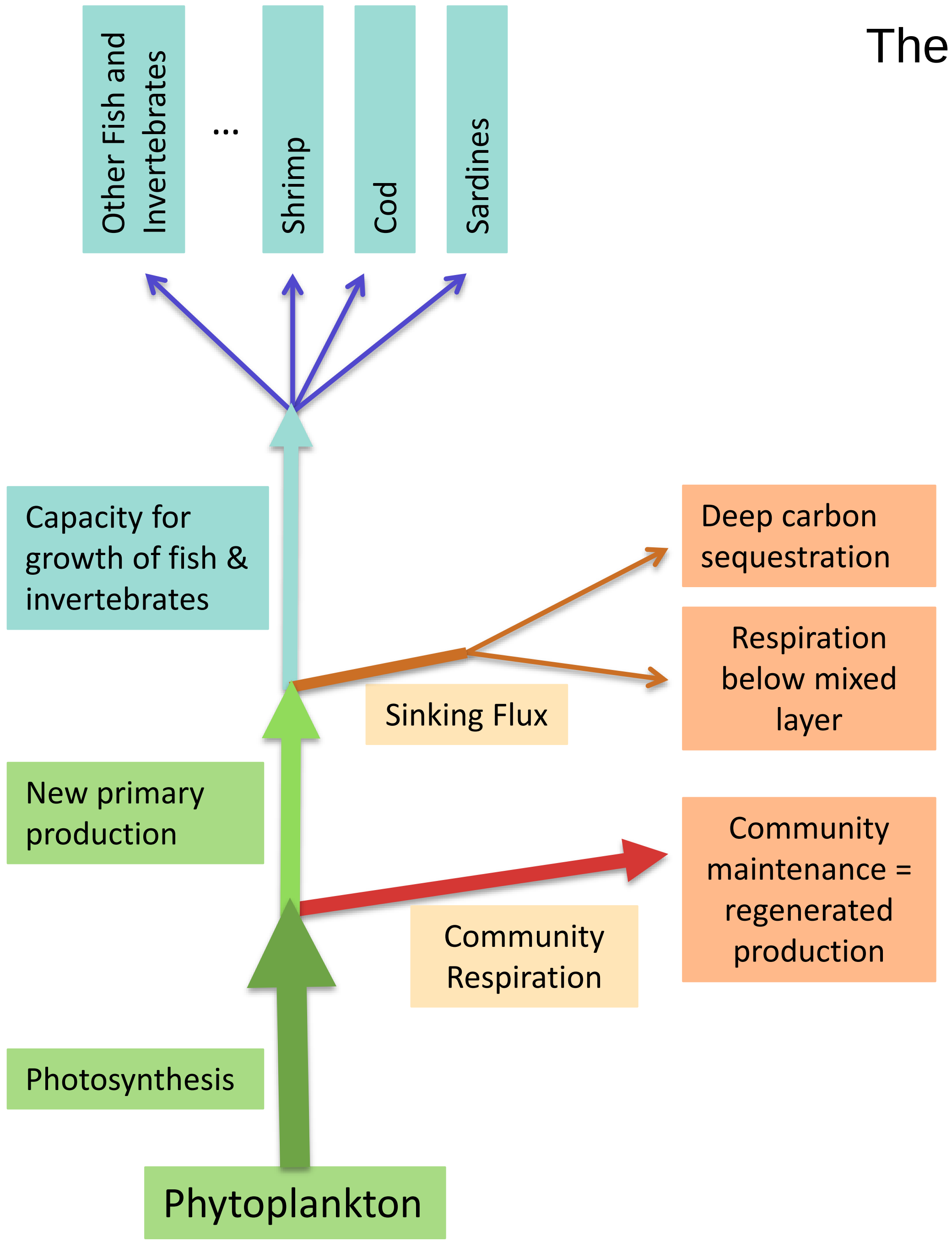
Phytoplankton loss terms can be inferred from sequential satellite-based chlorophyll data in combination with a phytoplankton growth model.

Application of the approach to NW Atlantic (Zhai et al. 2010) showed strong dependence on SST.

Closure error was generally less than 10% of total loss

A combination of satellite data and models can be used to tease out new information on fluxes of carbon in the ocean, even when they are not directly observable from satellites.

The fate of phytoplankton carbon



Organic carbon produced by phytoplankton may:

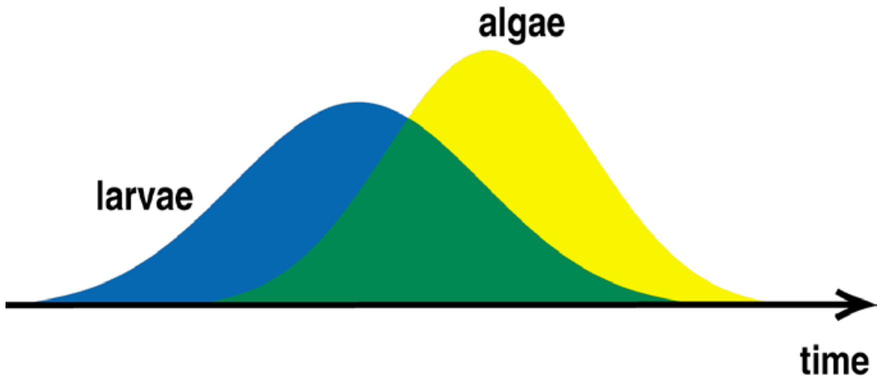
- Sink and be sequestered in the deep waters
- Sustain deep-water ecosystems
- Maintain pelagic communities
- Serve as food for fish and seafood

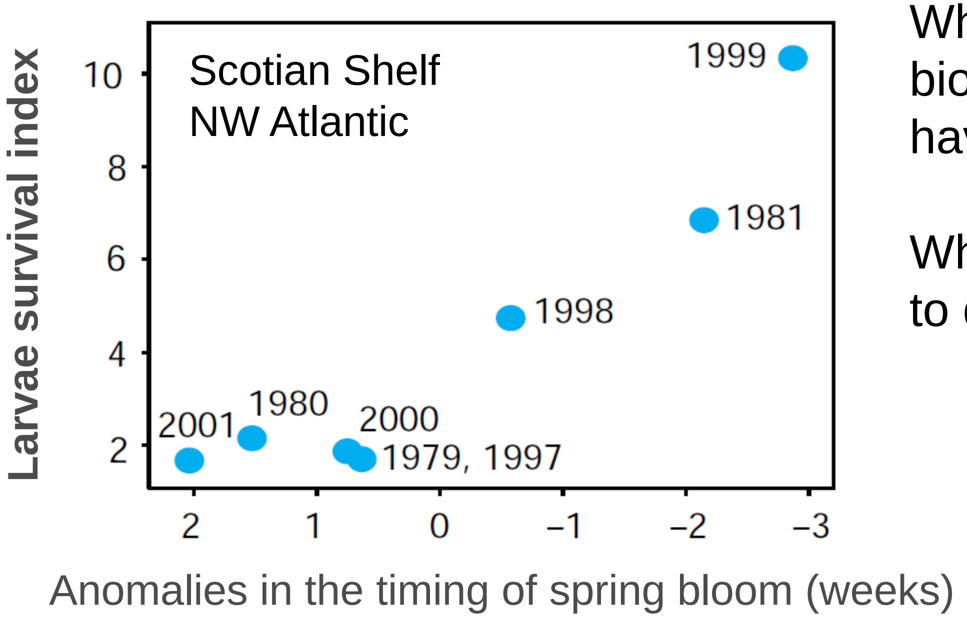
Survival of Haddock Larvae as Function of Timing of Spring Bloom Peak

Hundred-year-old hypothesis (Hjort-Cushing match-mismatch hypothesis)

Needed data at compatible temporal and spatial scales for testing hypothesis.

Remotely-sensed data key



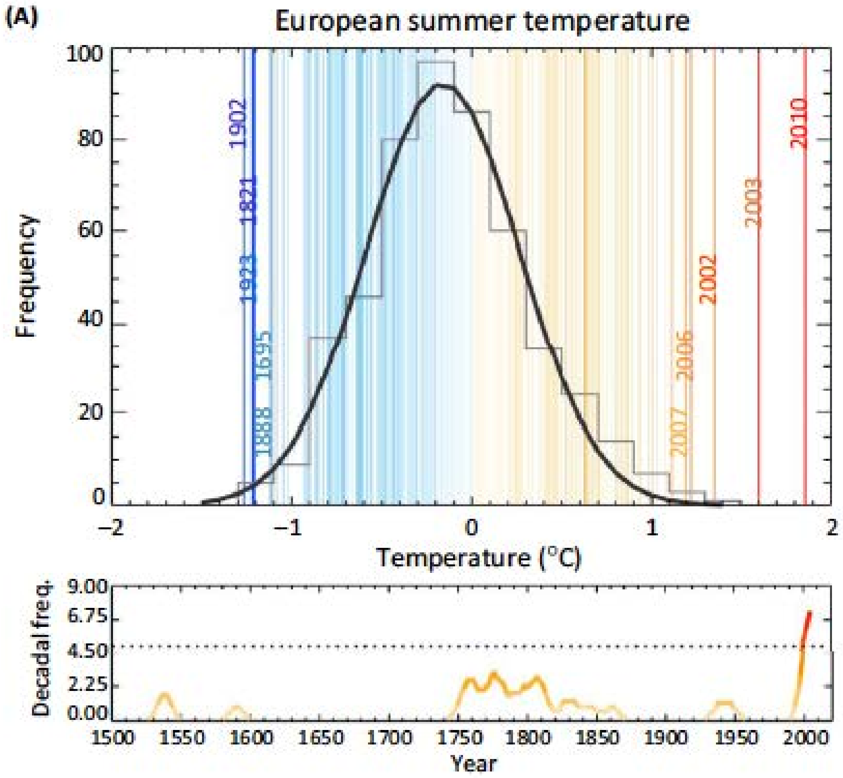


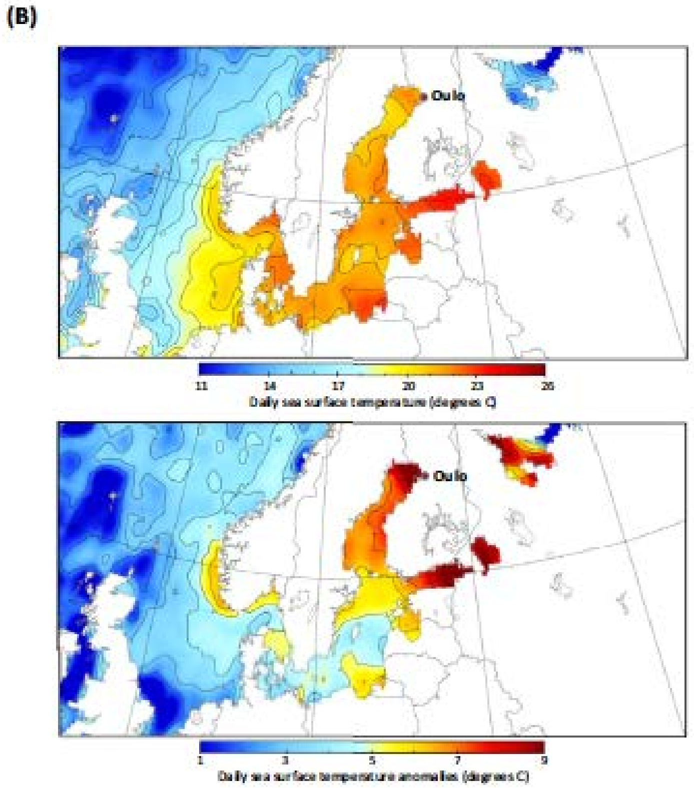
Where number of haddock larvae and biomass of phytoplankton overlap, larvae have food supply adequate for survival

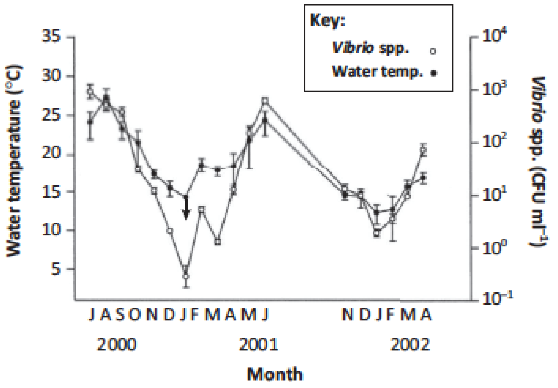
Where this is not so, larvae are vulnerable to death by starvation

Platt et al., 2003

Ecosystem health is also linked to human health:
Use of remote sensing to study water-borne infectious diseases







Reported incidences of *Vibrio* infections related to increase in temperature

Distribution of *Vibrio* bacteria is predicted to expand northward under warmer climate

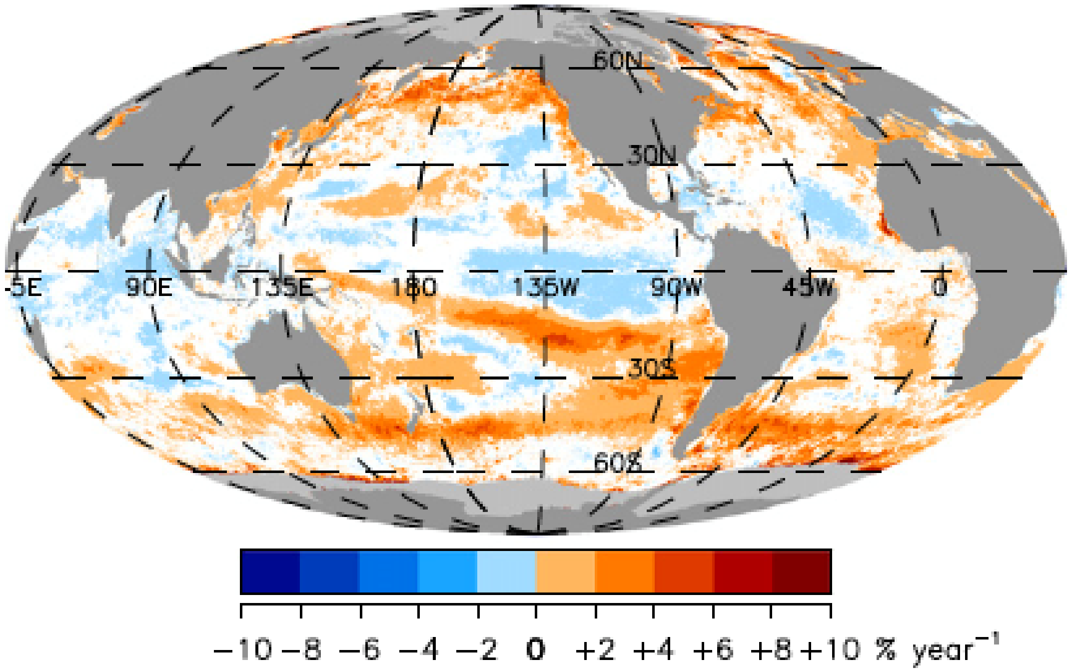
Poleward spread of vibriosis associated with higher water temperatures

Baker-Austin *et al.* 2018

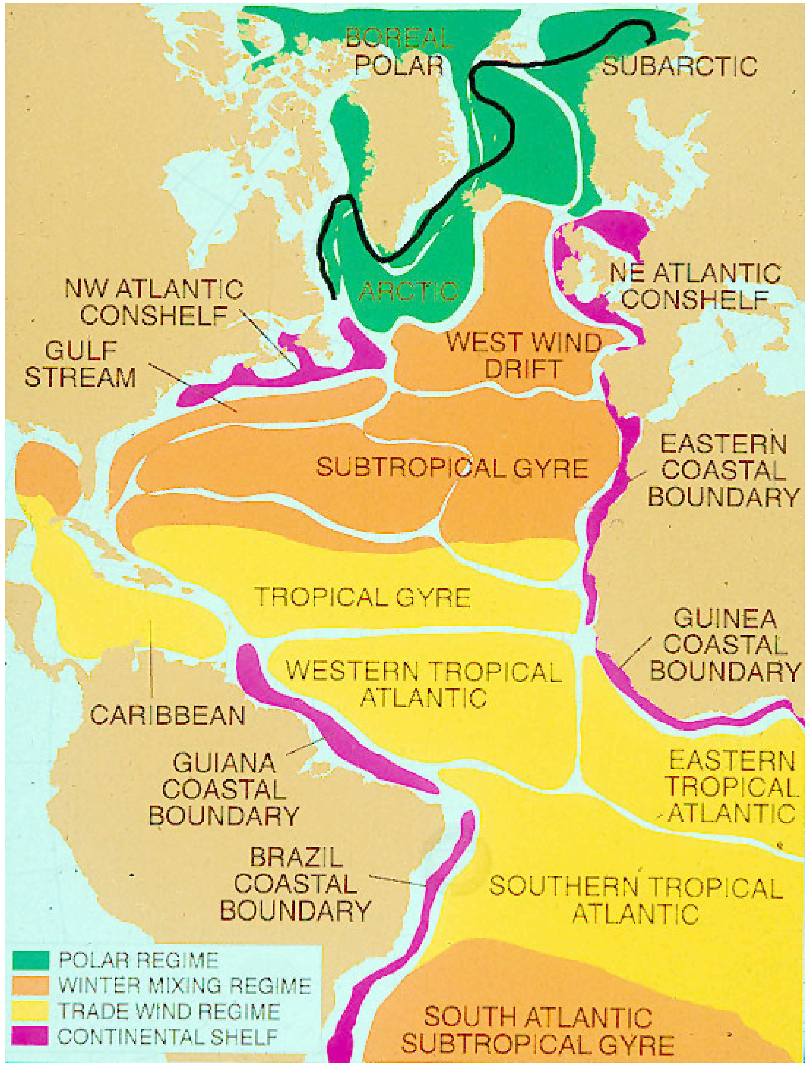
Climate change is a global phenomenon with regionally-distinct impacts

Global averages do not tell the whole story.

Imperative to know what is happening in our backyard.



Trends in OC-CCI chlorophyll over the period Oct. 1997 to Sep. 2015



Longhurst Provinces

Many distinct ecological provinces present in the Atlantic provide ideal test beds for algorithm development

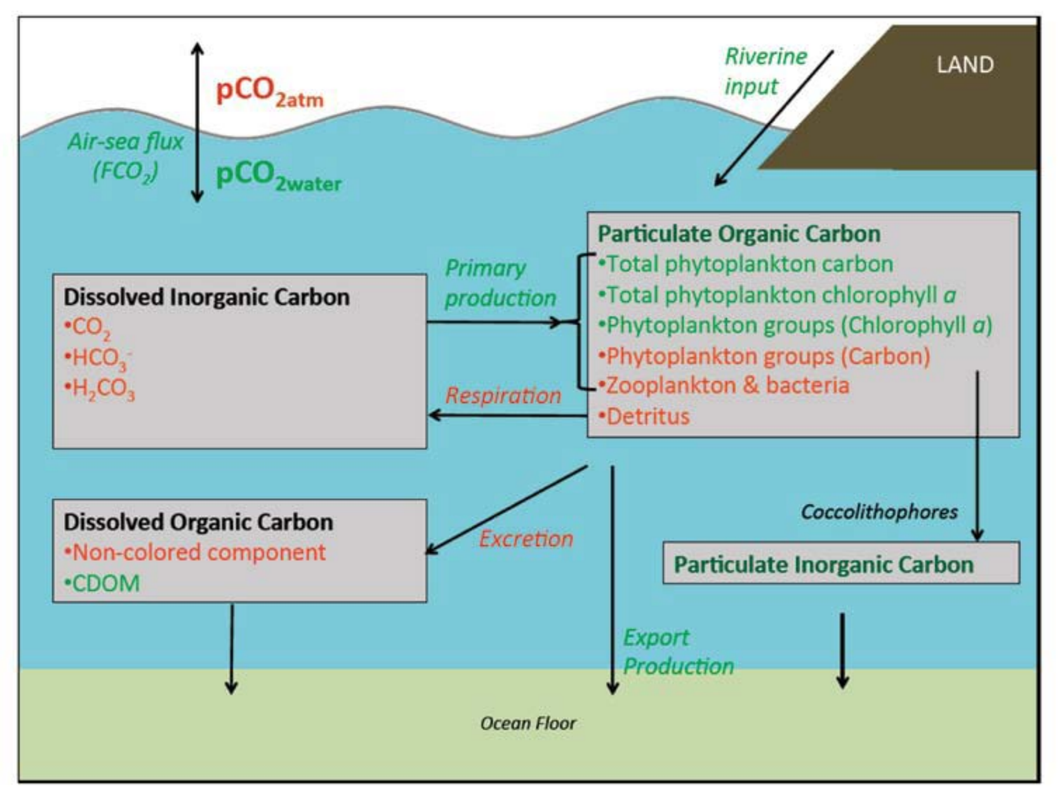
The Atlantic is rich in in situ datasets necessary for testing and validation of new algorithms

Many pieces of previous work in the Atlantic have set the stage

There are many ESA and related projects on which to build an integrated programme to study the ocean ecosystem and ocean biogeochemistry in a changing climate

Extrapolation to the global scale would be a motivation

A satellite-based Ocean-Carbon Budget?



CEOS Report 2014

- Green components: amenable to remote sensing
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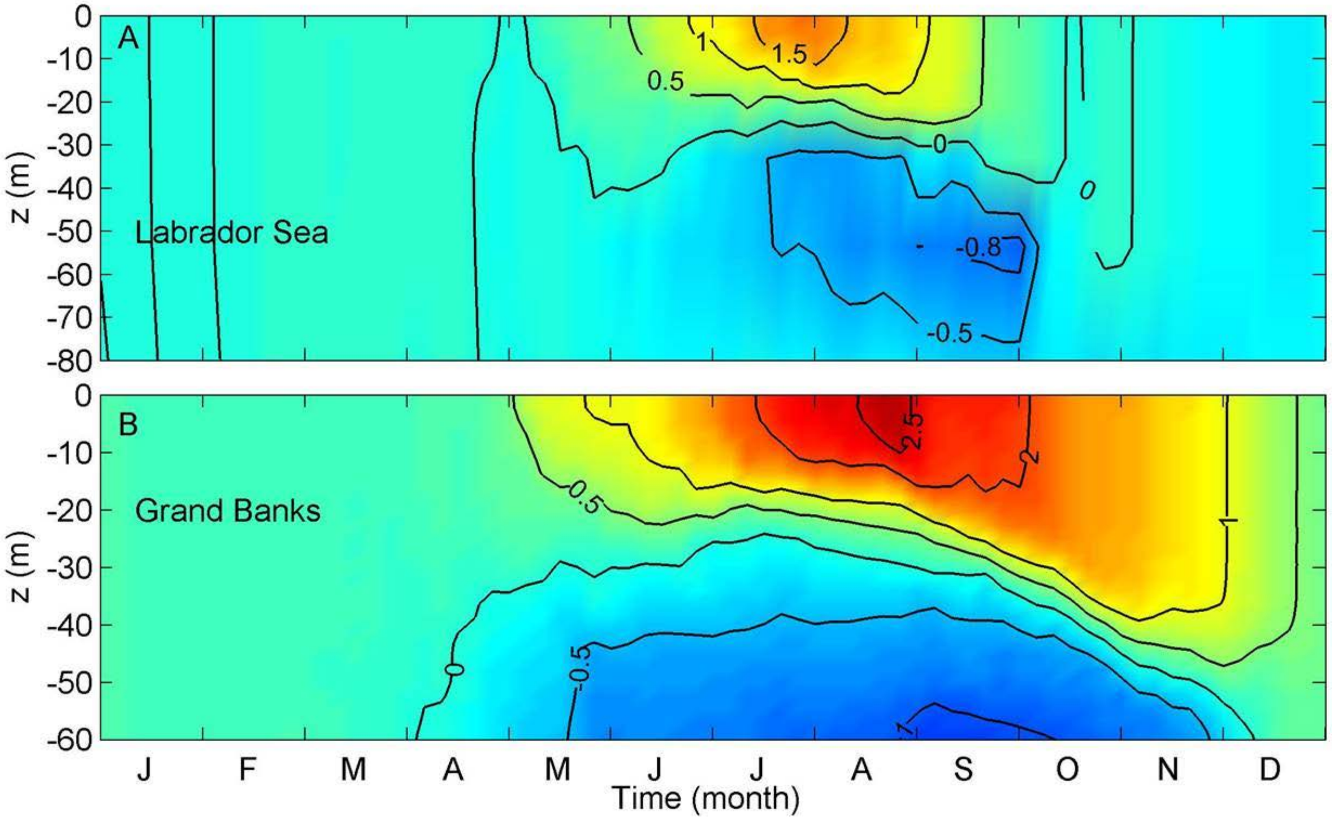
To produce a satellite-based report on the ocean carbon budget for climate research, we should:

- Select suitable algorithm(s) for each of the pools and fluxes
- Establish uncertainties
- Check for cross-component consistencies
- Carry out systematic, global, time series calculations
- Develop new algorithms to fill gaps
- Close budget
- Establish trends
- Compare with more traditional methods
- Important to explore implications for living resources, for human health
- Community effort is required

Questions:

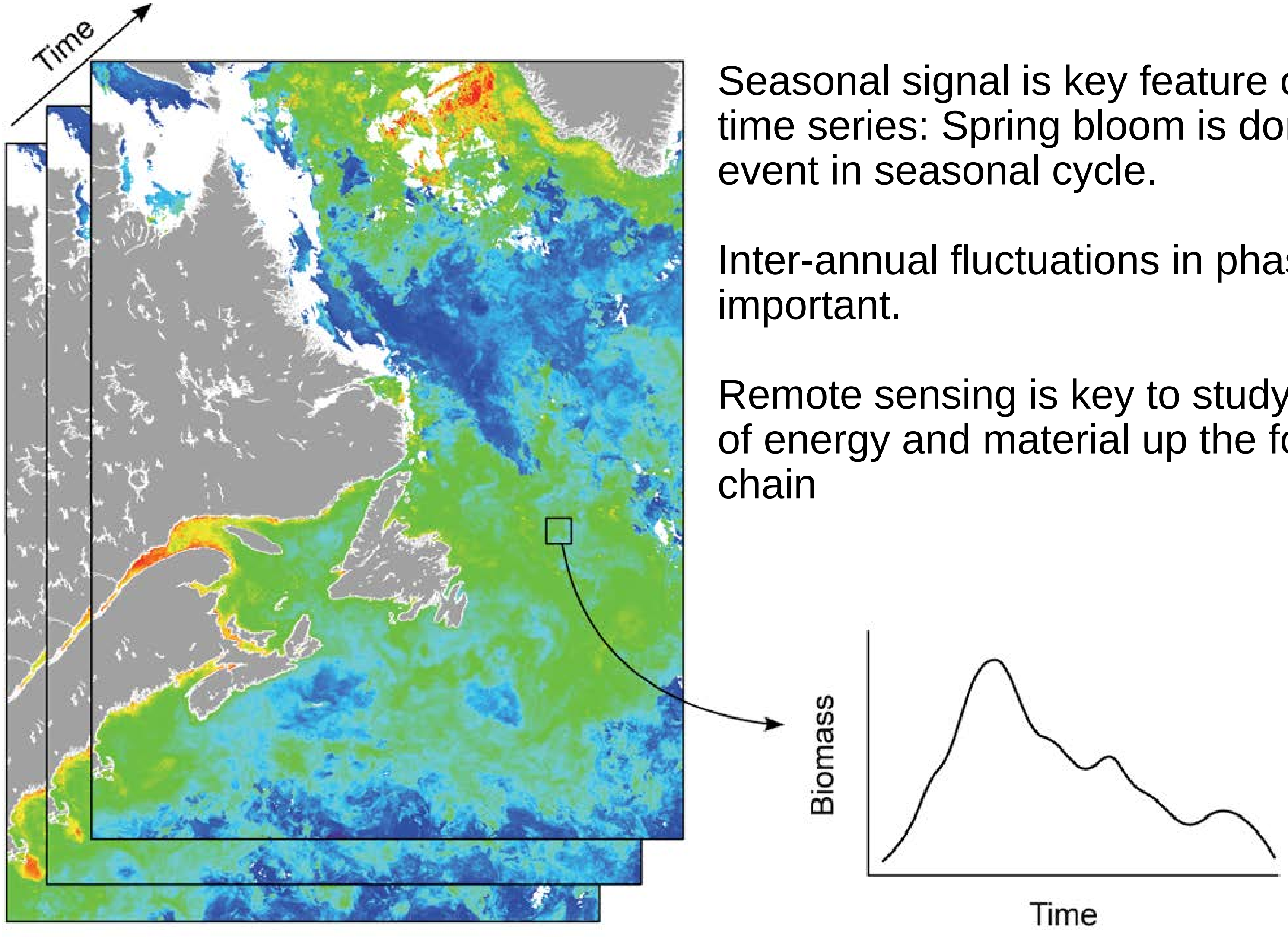
Are interactions and feedbacks between various ECVs (Essential Climate Variables) important?

Can we tease them out from satellite observations?



Biologically-induced temperature differences in the ocean (Wu et al. 2007)

Maintenance of marine biodiversity and Sustainability of higher organisms



Seasonal signal is key feature of the time series: Spring bloom is dominant event in seasonal cycle.

Inter-annual fluctuations in phase are important.

Remote sensing is key to study transfer of energy and material up the food chain

(Platt, Sathyendranath & Fuentes-Yaco, 2007)

Ocean Colour for
UN Sustainable Development Goals

The 16 SDGs are an expression of intergovernmental aspirations to make a better global society. Ocean colour is useful, and is being used, in helping meet the goals and the associated targets.

Relevant SDG	What can ocean colour do?
SDG 2: Zero Hunger	Responsible fisheries and aquaculture
SDG 3: Good Health	Food quality, water-borne diseases
SDG 6: Clean Water	Water quality
SDG 13: Climate Action	Essential Climate Variable, Biophysical dynamics, Carbon cycle
SDG 14: Life Below Water	Marine biodiversity, Marine food web