Ocean Colour for Climate Change Studies

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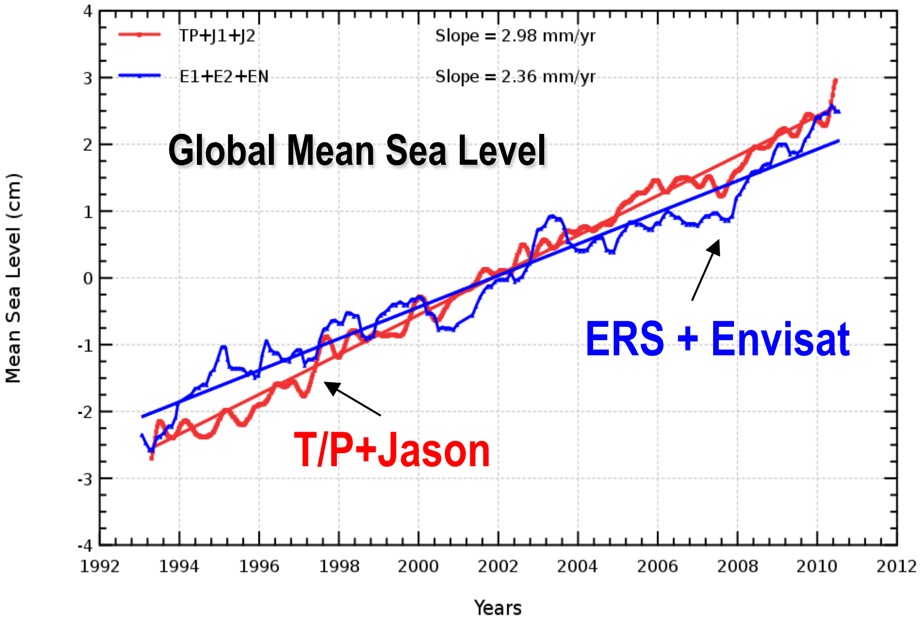
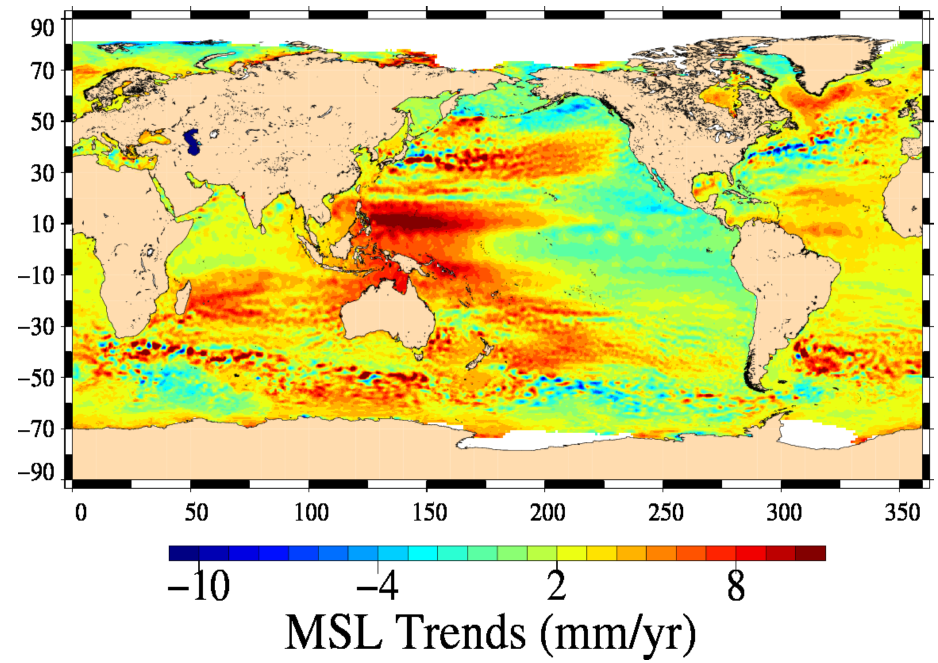
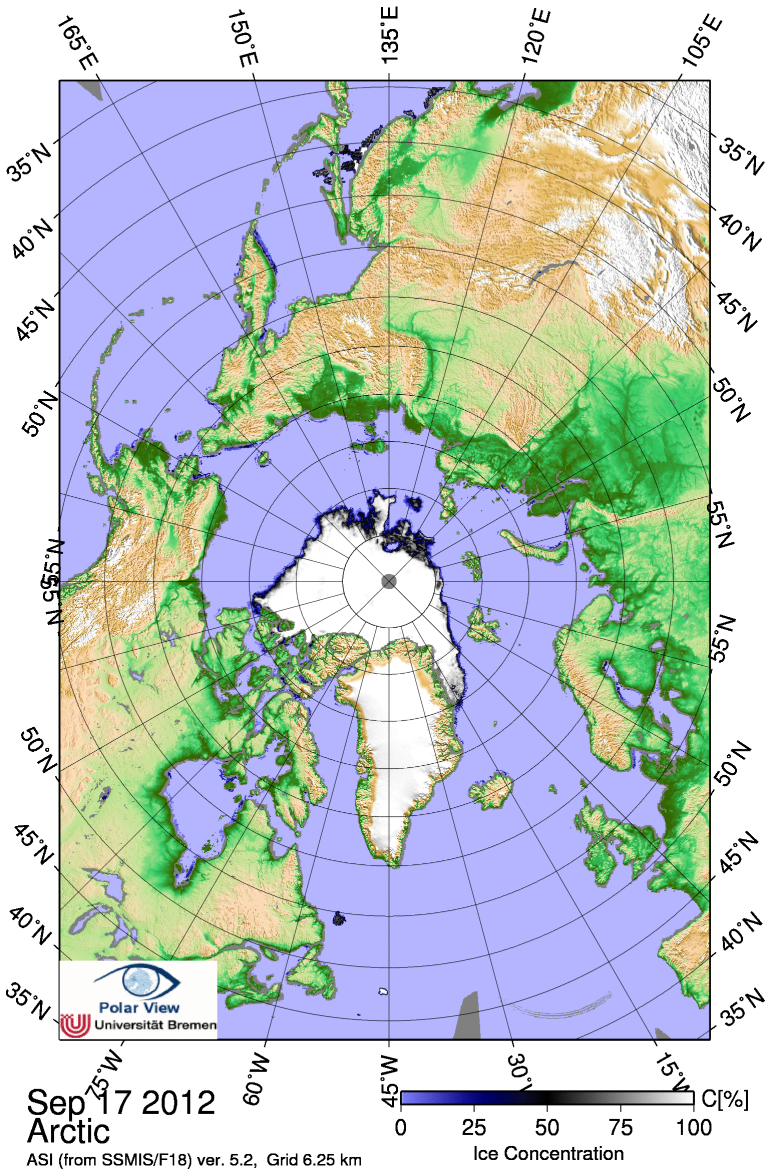
Global and Regional Sea Level

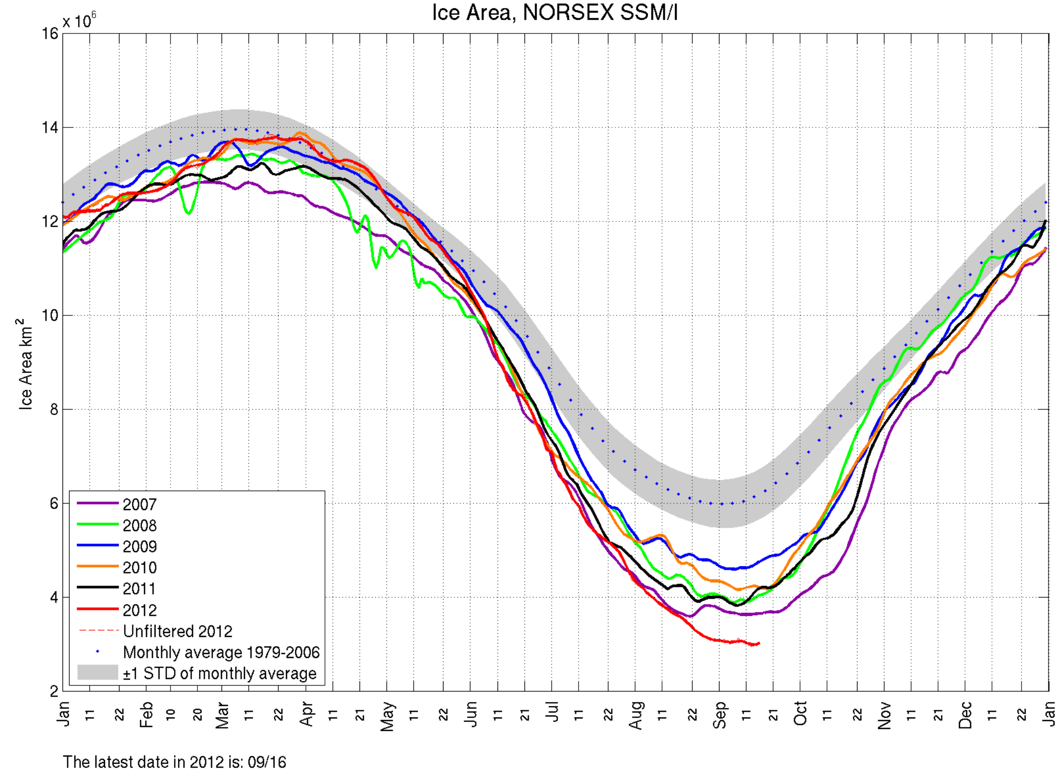
Results from SL-CCI Project





Record low Arctic sea ice extent in September 2012





September shows the lowest ice area in the Arctic since satellite observation started in 1979.

Ocean Colour and Climate Change

Ocean colour sensors are designed to study the marine ecosystem

In a changing-climate, how do we expect the marine ecosystem to be affected?

How can we select the best algorithms for use in climate-change studies?

This talk based on what we learned in the Ocean-Colour Clomate Change Initiative of the European Space Agency

Potential Responses of the Marine Ecosystem to a Changing Climate

- Total amount of phytoplankton (as indexed by chlorophyll-a concentration) might change
- The community structure associated with the chlorophyll concentration might change
- Other substances that absorb and scatter light in the visible domain might change, relative to chlorophyll-a
- The phenology might change (e.g. timing, amplitude and duration of blooms)

Implications:

- Algorithms have to be robust in a changing environment (for example, if community structure changes, or if associated variables change, these changes should not interfere with the algorithm for estimating chlorophyll-a)
- Retrieval of properties of the ecosystem should not rely on correlations between each other (i.e., emphasis on optical estimates of ecosystem properties)
- Use of empirical relationships in the algorithms should be minimal: the past state of the ecosystem may not be a faithful guide to the future

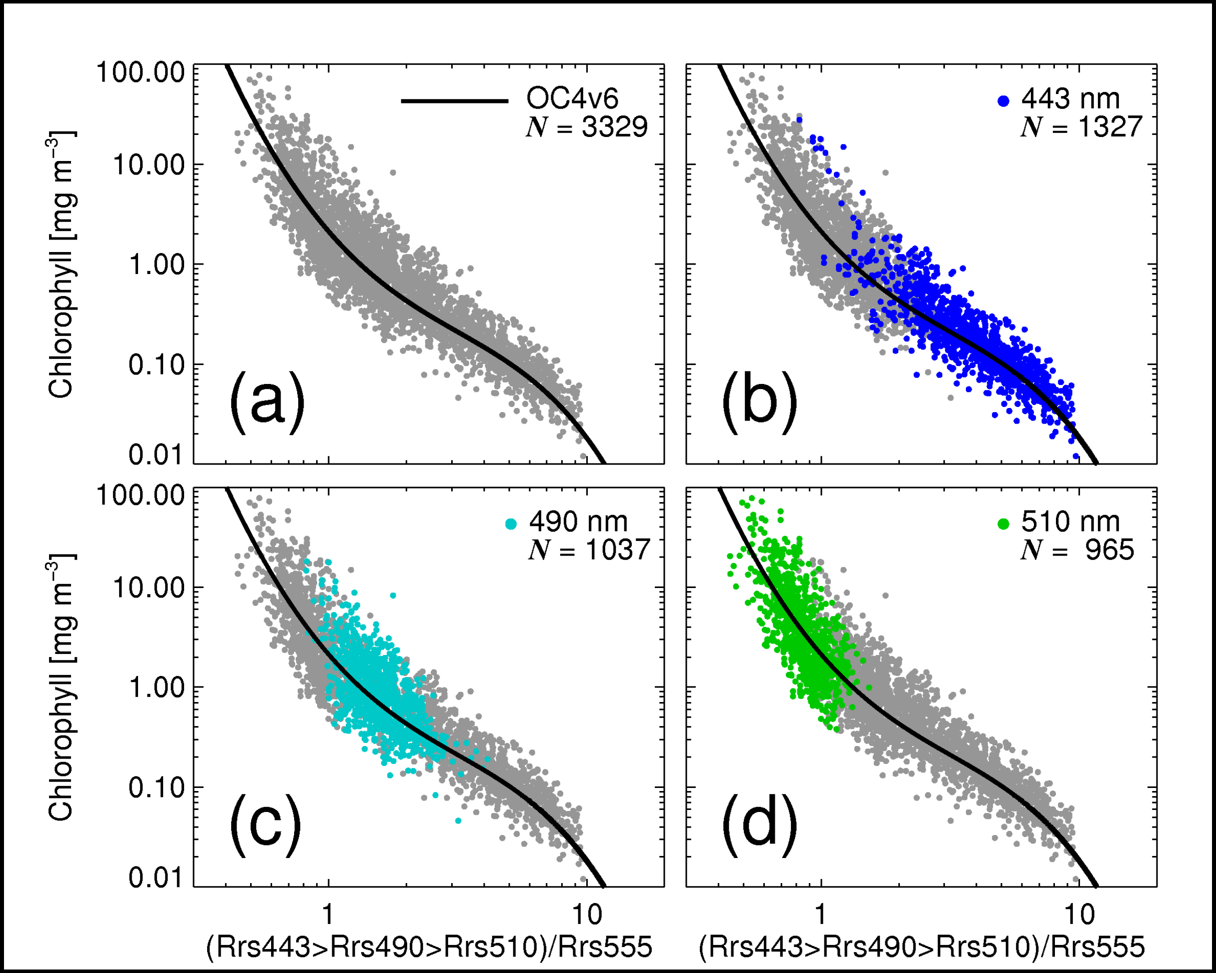
NASA OC4 algorithm

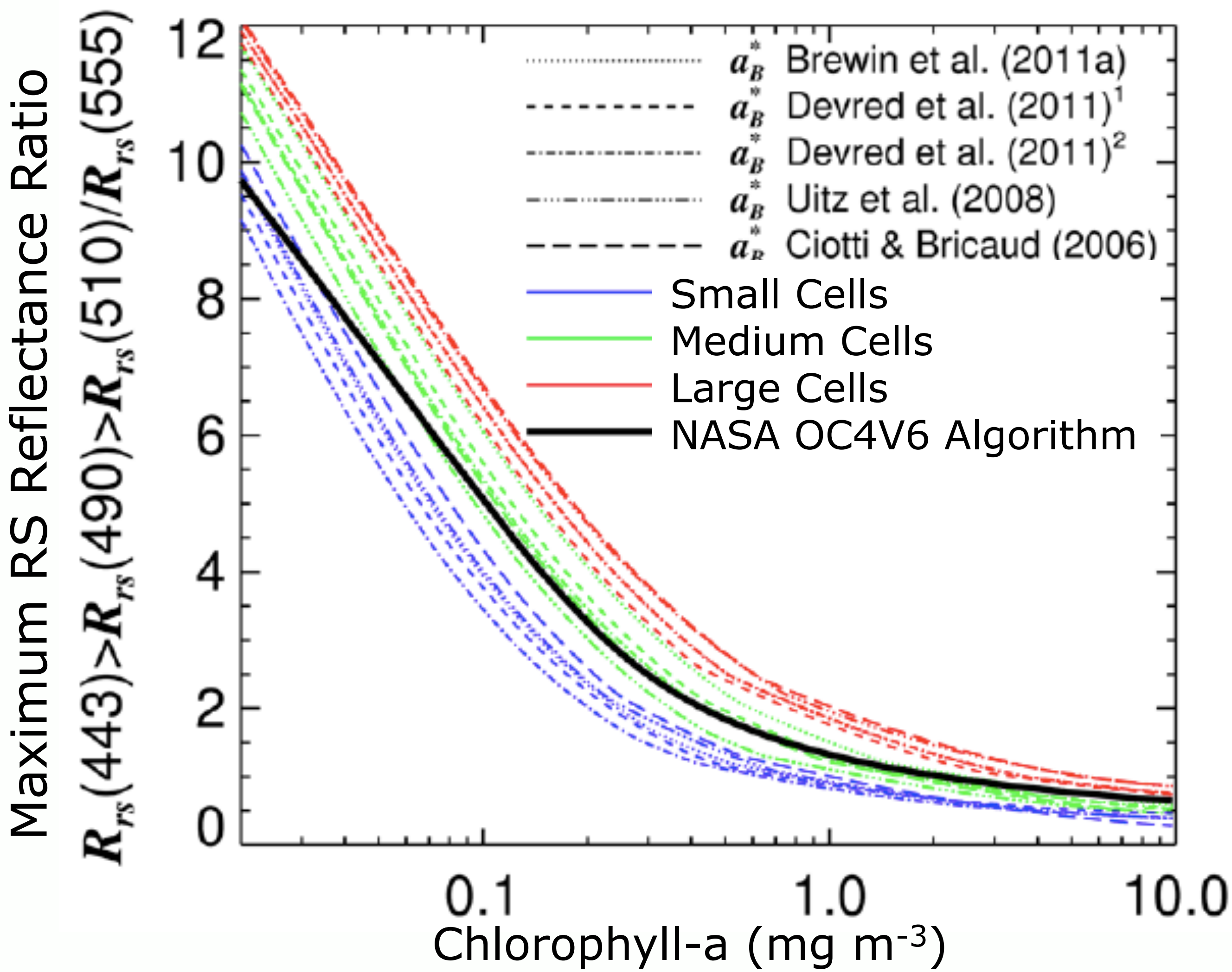
Statistical, empirical relationship between reflectance ratios and chlorophyll concentration

Based on extensive in situ data

Highly successful, globally applicable

But does not by itself provide insight on the underlying causes for the observed relationship.





Reflectance Ratio changes not only with chlorophyll concentration, but also with the type of phytoplankton cells present.

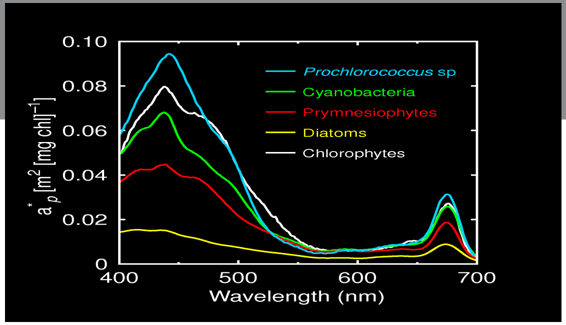
Under climate change, phytoplankton composition as well as concentration is vulnerable to change.

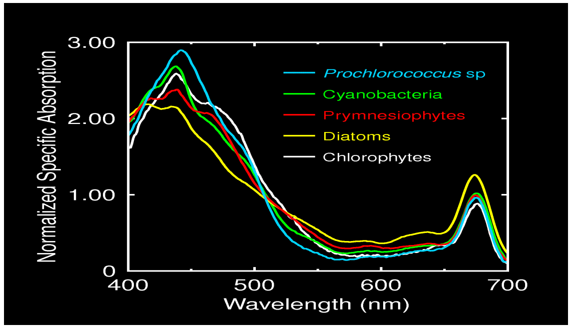
So if a reflectance ratio changes, we cannot be sure what is changing.

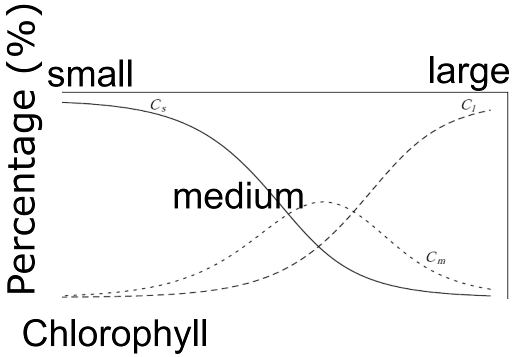
Implication: Simple band ratios may not be sufficient for climate-change studies

Figure from Brewin et al. IOCCG PFT Report, Draft

Developing New Products: e.g., Phytoplankton Functional Types







- Absorption characteristics of phytoplankton vary often with functional types of phytoplankton
- Function and size are often related
- Changes in shape, and not magnitude, provide remote-sensing signal for discrimination of type
- Methods exist (and are being developed) to exploit differences in shape for detection of PFTs
- General trends have been established linking phytoplankton composition and chlorophyll concentration. Trends vulnerable in a changing climate?

$$a(\lambda) = a_w(\lambda) + \underline{Ba^B(\lambda)} + a_y(\lambda) + \ldots$$

$$\Downarrow$$

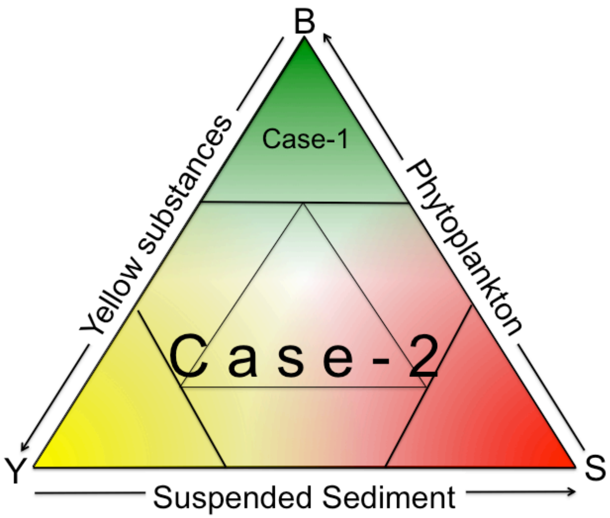
$$Ba^B(\lambda) = \sum_{i=1}^{N} B_i a_i^B(\lambda)$$

Implications:

•In a climate-change context, direct estimates of PFT’s are to be preferred over indirect ones.

•Spectrally-resolved water-leaving radiances and bio-optical models that allow spectral variations in phytoplankton absorption are key

Case-1 and Case-2 Waters



- Qualitative classification
- Based on inherent optical properties of variable components
- Wavelength-dependent
- Any partition between the two would be arbitrary
- Case-1 waters are single-variable systems
- May be seen as subset of Case-2 waters

$$a(\lambda) = a_w(\lambda) + \underline{Ba^B(\lambda)} + \underline{a_y(\lambda) + \ldots}$$

Principal source of variation in Case-1 waters (other substances, if present, co-vary with phytoplankton)

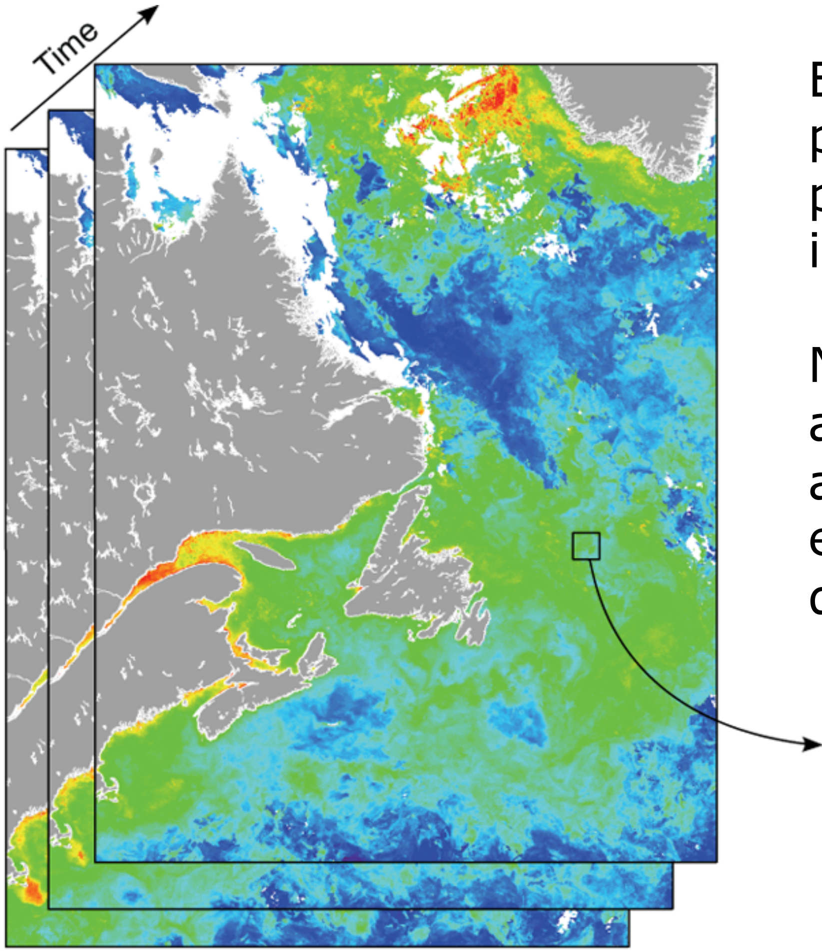
Independent variation of other components cannot be ignored in Case-2 waters

Implications:

Case-1 algorithm should aim to discriminate between contributions of different components to ocean-colour, but for conditions that might reasonably be expected in open-ocean waters.

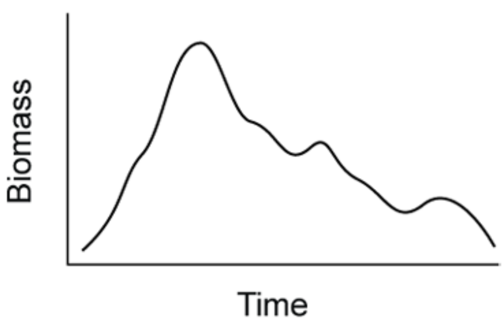
Move from single-variable approaches to multi-variable approaches.

Construction of time series possible at any chosen scale of spatial averaging



Establishing phytoplankton phenology requires access to products as a time series. Gaps introduce errors.

Note: Therefore inclusion of atmospheric correction algorithms in inter-comparison exercise that reduce gaps in data.



We conclude that

Analysis favours algorithms based on a theoretical approach, over purely empirical ones. Ideally, the two approaches would be reconciled.

Multi-spectral approaches are to be preferred over simple band-ratios.

Empirical relationships that tie one property to another are to be avoided in both the underlying model, and in the retrieval method.

Retrieval should allow for variability in the spectral form of phytoplankton absorption (key to phytoplankton functional types) independently of total phytoplankton concentration.

Should minimise gaps in data.

GCOS Ocean Colour requirements: a major challenge

Goal: create the most complete and consistent possible error-characterized time series of multi-sensor global satellite ECV products for climate research and modeling meeting GCOS requirements

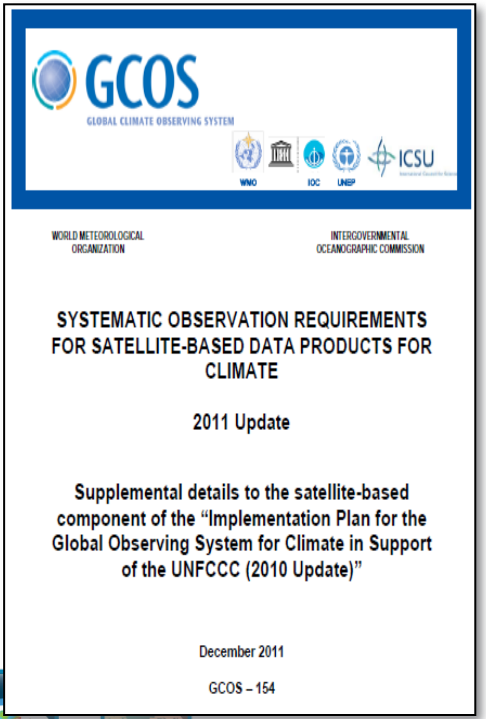
Note: OC-CCI to create time series of IOPs as well.

GCOS-107 September 2006 SYSTEMATIC OBSERVATION REQUIREMENTS FOR SATELLITE-BASED PRODUCTS FOR CLIMATE

Variable/ Parameter	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy	Stability
Water Leaving Radiance	1km	N/A	daily	5%	1.%

GCOS-154 updated December 2011

Variable/ Parameter	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy	Stability
Water Leaving Radiance	4km	N/A	daily	5%	0.5%
Chlorophyll-a concentration	30km	N/A	weekly averages	30%	3%


GCOS
GLOBAL CLIMATE OBSERVING SYSTEM
WMO IOC UNEP ICSU

WORLD METEOROLOGICAL ORGANIZATION

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

SYSTEMATIC OBSERVATION REQUIREMENTS FOR SATELLITE-BASED DATA PRODUCTS FOR CLIMATE

2011 Update

Supplemental details to the satellite-based component of the "Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)"

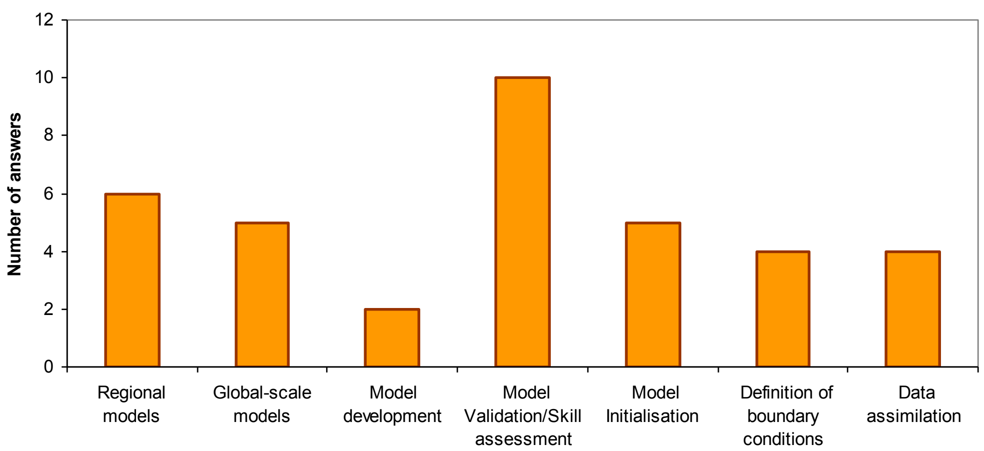
December 2011

GCOS – 154

ECV Product Tables

- Forward-looking document – addressed additional aspects than strictly required by GCOS
- First of its kind
- Set the goal for the rest of the activities
- Clearly identified the need for multiple ocean-colour products

Area of research interest from climate modellers



Partition of the sampled population by location