Co-Chairs: Cara Wilson (NOAA/NMFS) and Paul DiGiacomo (NOAA/NESDIS)

09:00-09:30 What can we say about long-term changes in the ocean ecosystem as observed from space?
David Antoine, Laboratoire d'Océanographie de Villefranche, France

09:30-10:00 What have we learned about harmful algal blooms from ocean color data?
Raphael Kudela, University of California, Santa Cruz, USA

10:00-10:30 What are the challenges and opportunities for using ocean color data for ecological forecasting?
Marion Gehlen, Laboratoire des Sciences du Climat et de L'Environnement, France

10:30-12:00 Discussion, moderated by the co-chairs

The three invited talks were designed to give an overview of the applications of ocean color data over the full suite of timescales – retrospective analyses, near real-time monitoring, and, forecasting and predictions – relative to ecosystem dynamics and climate change.

-

Our overarching goal is to apply scientific knowledge and lessons learned from ocean color radiometry data to improve ecological assessments, monitoring and forecasts along all of these timescales.

Co-Chairs: Cara Wilson (NOAA/NMFS) and Paul DiGiacomo (NOAA/NESDIS)

09:00-09:30 What can we say about long-term changes in the ocean ecosystem as observed from space?
David Antoine, Laboratoire d'Océanographie de Villefranche, France

09:30-10:00 What have we learned about harmful algal blooms from ocean color data?
Raphael Kudela, University of California, Santa Cruz, USA

10:00-10:30 What are the challenges and opportunities for using ocean color data for ecological forecasting?
Marion Gehlen, Laboratoire des Sciences du Climat et de L'Environnement, France

10:30-12:00 Discussion, moderated by the co-chairs

The three invited talks were designed to give an overview of the applications of ocean color data over the full suite of timescales – retrospective analyses, near real-time monitoring, and, forecasting and predictions – relative to ecosystem dynamics and climate change.

-

Our overarching goal is to apply scientific knowledge and lessons learned from ocean color radiometry data to improve ecological assessments, monitoring and forecasts along all of these timescales.

Important factors determining uncertainties in trend detection/quantification

- Number of observations, autocorrelation, and noise variance.
- 30-40 years of observations seem to be a minimum
- Bias correction ("bringing one time series to the other") before determining trends leads to underestimate parameters uncertainties.
- Overlap between missions is critical.
- Uncertainty on trends rapidly increase when gaps are present.

However: what is the question?

- Do we have to concentrate on a supposedly existing long-term trend?
- May not exist; may reveal extremely hazardous to quantify
- Even if we manage to do so, what's the meaning of a global long-term trend? Generated by only a few "hotspots"? Or more generalized increases/decreases?
- Should we rather look at changes in phenology? PFTs? Regional trends?…

What can't we say about long-term changes in the ocean ecosystem as observed from space?

Well, quite a lot...

- Inter-annual / decadal / long-term changes still difficult to quantify and to separate
- Attribution (natural decadal oscillations? Warming/stratification trend? Acidification?...)
- Changes in community structures and their impact on production and export
- ....

Some issues (more work ahead!)

1 About “what we can see”

- Chl *vs*. CDOM
- Chl *vs*. biomass (photo-adaptation)
- Phytoplankton carbon from b_{bp}
- b_{bp} in clear waters
- PFTs validation

2 Assuming (1) is solved, other issues are

- Spatial and temporal coverage
- Length & consistency of the time series (calibration)
- Vertical distribution

3 Assuming (1) & (2) are solved, it still remains to:

- Improve modeling of phytoplankton PP & export
- Assimilate OC-derived parameters into coupled physical-BGC models
- Interpret (joint use of other sources of information)

What do we need to solve these issues? A few things (far from exhaustive)

1 About "what we can see"

- Hyperspectral measurements (field and satellite)
- Phytoplankton Carbon measurements (*e.g.*, Graff *et al.*, 2012;2015)
- More b_{bp} values in clear waters (appropriate instrumentation?)
- PFTs validation

2 About spatial and temporal coverage, length & consistency of the time series (calibration), and the vertical distribution

- (virtual) constellations, geostationary sensors
- Inter-comparison of time series and of the trends they show
- Permanent long-term cal/val sites+ long-term BGC sites
- BioArgo program to become operational

3 About models & assimilation:

- Photophysiology in Chl-based or absorption-based photosynthesis models (how to make it more dynamic?)
- Assimilation schemes for BGC properties
- Modeling of optical properties and the satellite signal from the state variable of the BGC models (PSD, nutrients, etc..)?

Co-Chairs: Cara Wilson (NOAA/NMFS) and Paul DiGiacomo (NOAA/NESDIS)

09:00-09:30 What can we say about long-term changes in the ocean ecosystem as observed from space?
David Antoine, Laboratoire d'Océanographie de Villefranche, France

09:30-10:00 What have we learned about harmful algal blooms from ocean color data?
Raphael Kudela, University of California, Santa Cruz, USA

10:00-10:30 What are the challenges and opportunities for using ocean color data for ecological forecasting?
Marion Gehlen, Laboratoire des Sciences du Climat et de L'Environnement, France

10:30-12:00 Discussion, moderated by the co-chairs

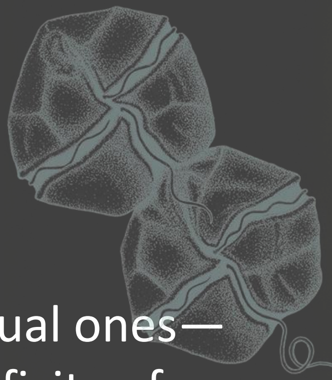
The three invited talks were designed to give an overview of the applications of ocean color data over the full suite of timescales – retrospective analyses, near real-time monitoring, and, forecasting and predictions – relative to ecosystem dynamics and climate change.

-

Our overarching goal is to apply scientific knowledge and lessons learned from ocean color radiometry data to improve ecological assessments, monitoring and forecasts along all of these timescales.

What Can Ocean Colour Provide to the HAB Research/Monitoring Community?

- Typical Answer:
  - Nothing. You must identify species… my organism is low-biomass but highly toxic… my organism is in the subsurface.
- What would you like?
  - HAB species, abundance, toxicity. Predictions of where HABs will be. And I want it now!



Summary

Challenges

- The primary challenges for effective use of ocean color are the usual ones—poor atmospheric correction, optically complex waters, non-specificity of algorithms, spatial and spectral resolution

Progress

- We have successfully extended spectral shape algorithms to multiple sensors
- We can separate non-toxic and toxic species, providing predictive capability;
- Remote Sensing data are being used for semi-operational applications in challenging systems

Opportunities

- Sensors are getting better—there are promising applications for HABs
- Spectral Shape functions provide rapid, sensitive detection
- IOCCG/GEOHAB Monograph provides an opportunity to bridge communities
- **We MUST take an ecosystem perspective!**

Co-Chairs: Cara Wilson (NOAA/NMFS) and Paul DiGiacomo (NOAA/NESDIS)

09:00-09:30 What can we say about long-term changes in the ocean ecosystem as observed from space?
David Antoine, Laboratoire d'Océanographie de Villefranche, France

09:30-10:00 What have we learned about harmful algal blooms from ocean color data?
Raphael Kudela, University of California, Santa Cruz, USA

10:00-10:30 What are the challenges and opportunities for using ocean color data for ecological forecasting?
Marion Gehlen, Laboratoire des Sciences du Climat et de L'Environnement, France

10:30-12:00 Discussion, moderated by the co-chairs

The three invited talks were designed to give an overview of the applications of ocean color data over the full suite of timescales – retrospective analyses, near real-time monitoring, and, forecasting and predictions – relative to ecosystem dynamics and climate change.

-

Our overarching goal is to apply scientific knowledge and lessons learned from ocean color radiometry data to improve ecological assessments, monitoring and forecasts along all of these timescales.

anthropogenic climate change

synoptic variability

natural climate variability
seasonal, inter-annual to
decadal modes

time

days to weeks
- harmful algae
- jelly fish
- OA events
- coastal hypoxia
- larval drift

...

seasons to decades
- marine productivity
- biomasses
- fish stocks

...

centennial
projections

Main characteristics of selected GODAE/GOV forecasting systems

System	Ocean model	Biogeo-chemical model	Configuration	Data assimilation scheme		Assimilated data		System status
				PHYS[1]	BGC[2]	PHYS	BGC	
FOAM-HadOCC	NEMO3.2-CICE	HadOCC	global, 1/4°cos(lat) resolution	3D-Var	analysis correction + multi-	satellite SLA, SST, sea ice, in situ SST	chlorophyll-a or pCO	pre-operational (BGC) operational (PHYS)
FOAM-ERSI								erational
TOPAZ-NORWECO								operational
TOPAZ-NORWECO								erational
MERCATOR OCEAN/ BIOMER		off-line coupled[3]	resolution, 50 vertical layers			T/S profiles		erational
MFS	NEMO3.4 +waves+ atm.press ure	BFM (OPATM) off-line coupled[3]	Mediterranean Sea (1/16°), 72 vertical layers	3D-Var	3D-VAR	Satellite SSH, in situ T/S profiles	chlorophyll-a	operational
CANOPA-GSBM	OPA9-LIM2	GSBM	East-Canadian shelf (1/12°), 46 vertical layers	no	no	no	no	non-assimilative hindcast

[1] PHYS = physics; [2] BGC = biogeochemistry; [3] biogeochemical model coupled off-line (run sequential) to physical model;

biogeochemical/ecological forecasting

=

a young, but rapidly evolving field

Gehlen et al., 2015, JOO

Use of ocean colour products : ecological forecasting

- re-analyses
- realtime and forecasts

Requirements :

- continuous observational records for re-analyses
- high resolution for realtime and forecasts

Problems :

- undersamplig of key regions (cloud cover)
- coherence between spatial/temporal scales of physical and biogeochemical fields
- from open ocean to shelf seas: changes in optical properties of ocean waters, needed corrections

Use of ocean colour products : model evaluation & skill assessments

- model mean state
- variability : seasonal, inter-annual to decadal

Requirements :

- continuous observational records

Q: to what extent are merged products suitable for study of variability and trend?

Problems (shared with OO applications):

- undersamplig of key regions (cloud cover)
- from open ocean to shelf seas: changes in optical properties of ocean waters, needed corrections

Use of ocean colour products : process studies

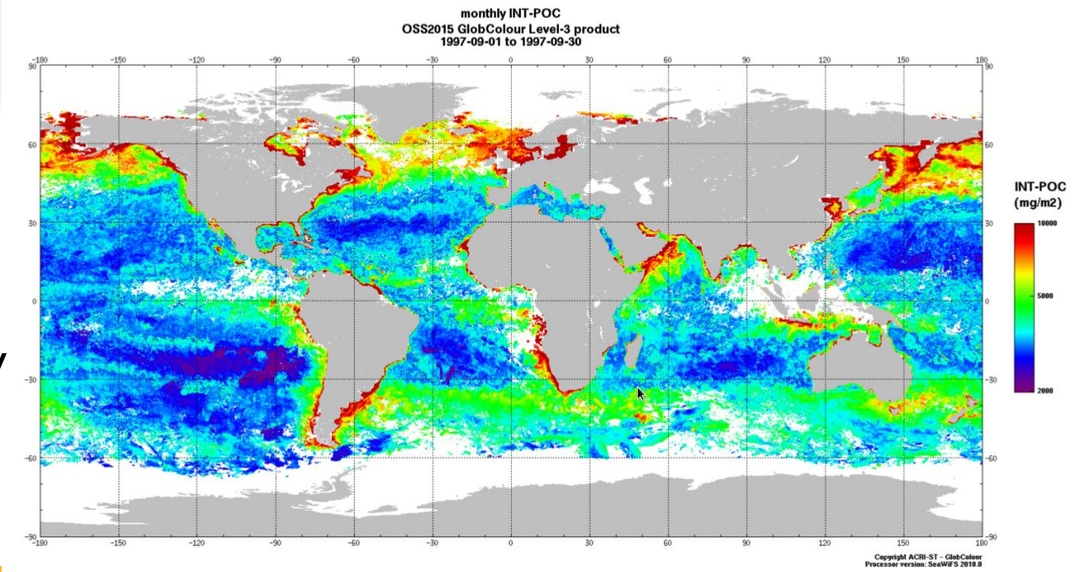
- detection of trends in response to climate change
- ecosystem dynamics : from NPP to export production
- 'diversity' of surface ocean ecosystem : PFTs

Requirements:

- continuous observational records
- further development and improvement of downstream products: e.g. algorithms for PFT identification
  suspended particle and size spectra
  chlorophyll to C ratio

Problems:

- undersamplig of key regions (cloud cover)
- open ocean to shelf seas: changes in optical properties
- poorly constraint uncertainty



Summary

Requirements: - a modeller's wish list -

- continuity in space and time of observational records
- matching of spatial (eddy resolving) and temporal (high frequency) resolution: model – ocean colour products
- information uncertainty associated to specific products
- continuous development of algorithms suitable for shelf seas and coastal ocean
- continuous development and improvement of downstream products for ecosystem studies

Break-Out Session #8:
Ecosystem Dynamics and Climate Change: Applications of Ocean Color Data

Specific questions:

1. **What are the gaps/issues in our scientific knowledge, and/or underpinning observing system and modeling capabilities, relative to the above goal?**

2. **Are there specific challenges or obstacles that affect our ability to address these specific gaps and issues? How can/should these be addressed? By whom?**

3. **What are the key priorities relative to addressing these gaps and challenges?**

4. **What are some success stories that we can use to better promote the utility of ocean color, and the need to sustain but more so improve our existing/planned OCR capabilities?**

Break-Out Session #8:
Ecosystem Dynamics and Climate Change: Applications of Ocean Color Data

Specific questions:

1. **What are the gaps/issues in our scientific knowledge, and/or underpinning observing system and modeling capabilities, relative to the above goal?**

   - Lots of tools, products and capabilities, but difficult for users to readily apply and integrate them – lack of time, guidance, expertise
   - Uncertainties needed, especially on regional basis. And also an immediate priority before we make sweeping conclusions (e.g., changes over long-periods of time) . Ensure products are validated in a thorough manner
   - Value of simplicity – not try to solve everything immediately in a holistic context, but take components and specific issues and improve our capabilities – e.g. modeling phenology
   - Better understanding needed of best practices in modelling, exchange of information across groups who are doing BGC modelling etc

Break-Out Session #8:
Ecosystem Dynamics and Climate Change: Applications of Ocean Color Data

Specific questions:

1. **What are the gaps/issues in our scientific knowledge, and/or underpinning observing system and modeling capabilities, relative to the above goal?**

- Comment made that we need more focus on fluorescence. That said limitations and challenges to properly interpret – still very much a research topic (and opportunity). Need more in situ measurements also
- Need to observe, model, resolve and forecast/predict at all relevant spatio-temporal scales – NRT, seasonal, interannual, decadal; local to global
- Need long term, sustained record of radiances - this on a global basis, but more difficult to derive accurate, fit for purpose products and that scale – need regional approaches

Break-Out Session #8:
Ecosystem Dynamics and Climate Change: Applications of Ocean Color Data

Specific questions:

2. **Are there specific challenges or obstacles that affect our ability to address these specific gaps and issues? How can/should these be addressed? By whom?**

- Computational challenges for biologists/ecologists/BGC folks – demands for significant computational time, particularly wrt to using global models
- "dust-off" and apply 1-D models to provide a home for research that can ultimately be incorporated into global circulation models – test ideas, etc. But need to be careful how employ – can leave out exchanges etc
- Need better coordination between data providers, modellers/DA folks, and end users – can't work in a vacuum – has to be close coordination and communication across these groups – mechanisms? By whom?

Break-Out Session #8:
Ecosystem Dynamics and Climate Change: Applications of Ocean Color Data

Specific questions:

3. What are the key priorities relative to addressing these gaps and challenges?

- Uncertainties needed, especially on regional basis. And also an immediate priority before we make sweeping conclusions (e.g., changes over long-periods of time) . Ensure products are validated in a thorough manner
- Good at measuring radiances, need to get to ecosystems, linking especially to higher trophic levels
- Model/forecast performance could be measurably improved through use of ocean color data. But largely only done in demonstration mode – not so much vis-à-vis routine assimilation, esp on operational basis. Need more work to incorporate OCR data and evaluate skill/performance relative to its use…
- Greater opportunities to use ocean color in modeling for fisheries, CO_2 uptake, ocean acidification (forcing and responses), climate change predictions/scenarios

Break-Out Session #8:
Ecosystem Dynamics and Climate Change: Applications of Ocean Color Data

Specific questions:

4. **What are some success stories that we can use to better promote the utility of ocean color, and the need to sustain but more so improve our existing/planned OCR capabilities?**

   - Using remote sensing to go back to managers to guide and optimize sampling by managers (recent paper cited by Raef as example) – potential exists, but needs to happen in routine practice. Resource constrained though…
   - HAB forecasting – being done increasingly on an operational basis, supporting management needs