Learning from ocean color: bio-physical interactions

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Picture: Envisat, Meris (ESA)
Why is satellite attractive for ocean survey?

- Ocean sampling: need a ship => expensive
- No global coverage
- Asynoptic view: no view of very large areas of the world in a very short time cruises limited in time and space

→ Satellites give global view in a very short time
What color is the ocean?

Blue … and green!

- Green = phytoplankton pigment
  => chlorophyll

- The more phytoplankton the greener
  => relation color & chlorophyll

- Some satellites see ocean colors
  => chlorophyll concentration
How does it work?

SeaWiFS samples 8 wavelength
Meris (15), Modis (36)
How does it work?

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1. colors are recombined

“true color”: how human eye would view the scene
How does it work?

SeaWiFS samples 8 wavelength: Meris (15), Modis (36)

1. Colors are recombined

"true color": how human eye would view the scene from an altitude of 705 km

2. From color to chlorophyll concentration

chlorophyll concentration or phytoplankton concentration

http://oceancolor.gsfc.nasa.gov/
http://earthobservatory.nasa.gov/
SeaWiFS covers the globe in 2 days but problem of cloud cover. Weekly composite to get a better coverage.
An important fact about chlorophyll observations

In real world: data

- Ocean color satellites only see the surface … or the clouds
- In-situ data are sparse
Ocean color satellites only see the surface … or the clouds

- In-situ data are sparse

⇒ Models help reconstruct the gaps and understand the processes
Chlorophyll - phytoplankton distribution is not homogeneous

=> *What does phytoplankton need?*
What does phytoplankton need?

nutrients

Vertical section of nutrients in North Atlantic Ocean

Ocean depth
What does phytoplankton need?

- **nutrients**
- **light**

Vertical section of nutrients in North Atlantic Ocean
What does phytoplankton need?

- nutrients
- light

Vertical section of nutrients in North Atlantic Ocean
Large scale chlorophyll patterns comes from distribution of light and nutrients i.e. ocean circulation = physics!

What happens if we look closer? ... at small scale
Chlorophyll organized in small scale structures

SeaWiFS
Argentina

Stockholm
Envisat, Meris
Chlorophyll spatial distribution at different scales

~ 1000 km
Global circulation

Large scale
Chlorophyll spatial distribution at different scales

~ 1000 km
Global circulation

~ 100 km
Eddies

Large scale
Chlorophyll spatial distribution at different scales

~ 1000 km
Global circulation

~ 100 km
Eddies

~ 1-10 km
Filaments

Large scale

Small-scale
What can explain small-scale structure in chlorophyll?
Relation chlorophyll - temperature => bio-physical interactions?
Why do we talk about bio-physical interactions?
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Phytoplankton and chlorophyll associated with cold temperature

= ocean physics mechanism
Small-scale mechanisms that shape chlorophyll?

1. Small-scale transports chlorophyll

2. Small-scale re-organizes chlorophyll

3. Small-scale is an ocean fertilizer
   ⇒ bring nutrients to the surface
1. Small-scale transports chlorophyll

Inside eddies or filaments, water is “isolated”

⇒ Water mass properties (temperature, chlorophyll…) can travel for month

⇒ Horizontal process
2. Small-scale re-organized large-scale gradients

To reconstruct the evolution of chlorophyll we use **high resolution model**:
3. **Small-scale re-organized large-scale gradients**

To reconstruct the evolution of chlorophyll we use **high resolution model**: 
3. Small-scale = ocean fertilizer

Northern hemisphere

Anti-cyclonic

Eddy poor in chlorophyll

Cyclonic

Eddy rich in chlorophyll

SeaWiFS

Iran
3. Small-scale = ocean fertilizer

⇒ vertical process
Do we need small-scale to understand the global picture?

Carbon cycle in climate models:

Phytoplankton plays a role in carbon cycle.
Do we need **small-scale** to understand the **global** picture?

Climate models cannot simulate small-scale (computers limit)

Need of **high resolution bio-physical models** to quantify the impact
1. Modelling study: “Gulf Stream”

~ Climate model resolution
100 km

High resolution
2 km

Model results

Model results

chlorophyll decreases

SeaWiFS

Lévy et al. (in prep.)
2. Modelling study: Arabian Sea

SeaWiFS data

Intermediate resolution
25 km

Resplandy et al. (in prep.)

High resolution
8 km

chlorophyll increases

SeaWiFS

model 1/4°

model 1/12°
3. Modelling study: offshore Portugal

~ Climate model resolution
100 km

Intermediate resolution
25 km

High resolution
5 km

chlorophyll does not change but is re-organized

Resplandy et al. (2009)
Do we need small-scale to understand the global?

At the end, it depends on the region and the ocean physics in it.
Summary

- Satellites see ocean colors
  ⇒ chlorophyll concentration
  ⇒ estimation of phytoplankton i.e. biological ecosystems

- Chlorophyll structured from large scale to small-scale by physical processes

- From ocean color, small-scale appears as a horizontal process ... but also vertical process

- We cannot understand ocean biology without looking at physics
- Looking at biology helps understanding physics
References

http://dx.doi.org/10.1371/journal.pbio.0020306


SeaWiFS and MODIS images are provided by NASA and ENVISAT MERIS by the European Spatial Agency.