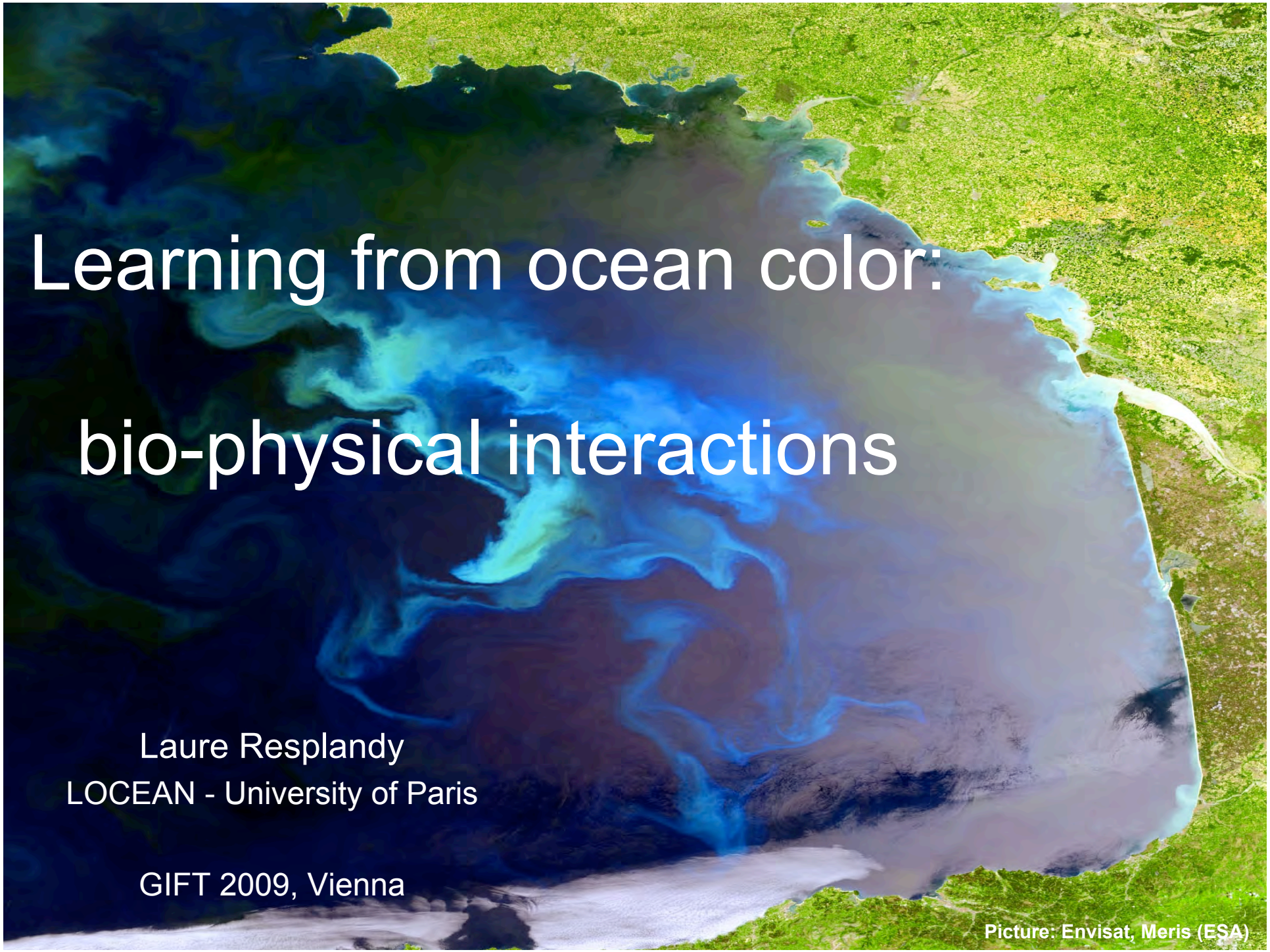


Learning from ocean color:

bio-physical interactions

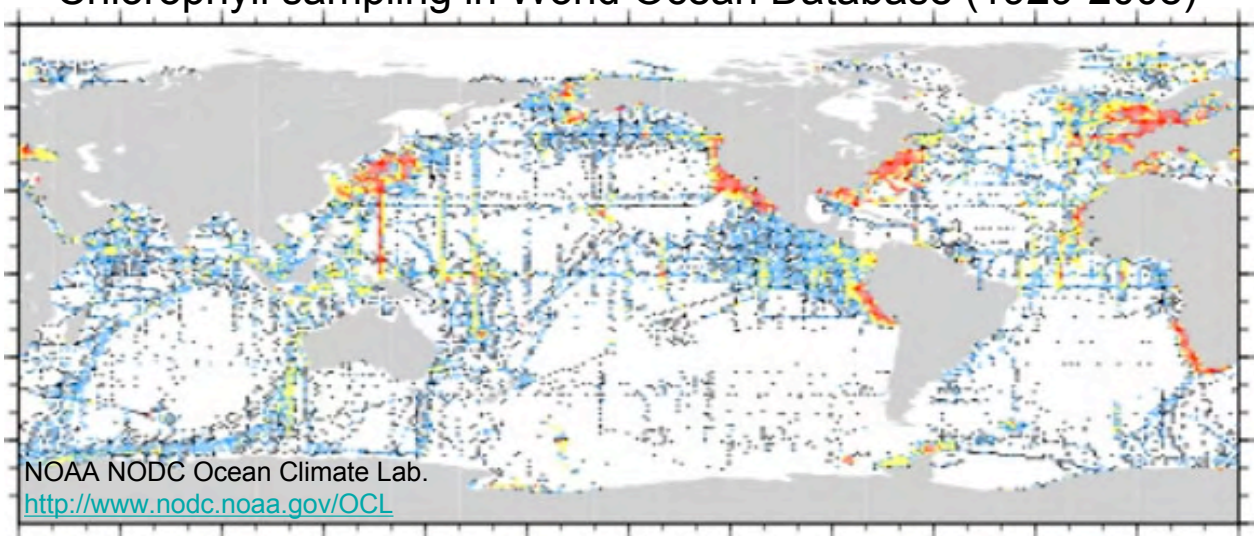
Laure Resplandy
LOCEAN - University of Paris

GIFT 2009, Vienna

Picture: Envisat, Meris (ESA)

Why is satellite attractive for ocean survey?

Chlorophyll sampling in World Ocean Database (1929-2008)



Number of samples in box of ~100km x 100km

=1 2-5 6-20 >20

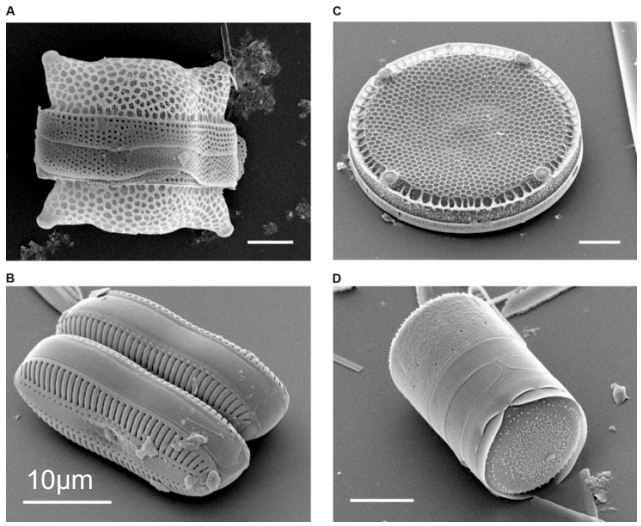
- Ocean sampling: need a ship => expensive
- No global coverage
- Asynoptic view: no view of very large areas of the world in a very short time
  cruises limited in time and space

→ Satellites give global view in a very short time

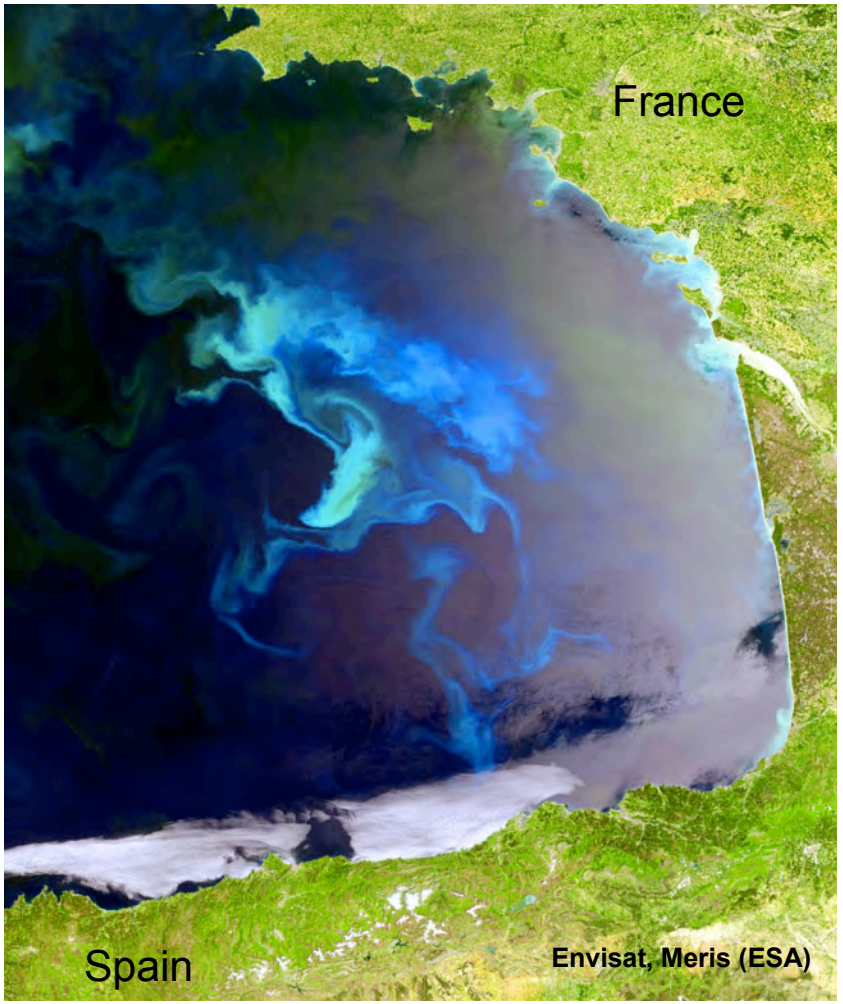
What color is the ocean?

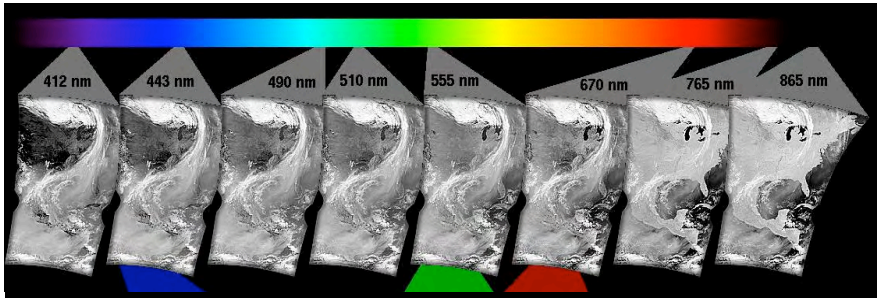
Blue … and green!

- Green = phytoplankton pigment
  => chlorophyll
- The more phytoplankton the greener
  => relation color & chlorophyll
- Some satellites see ocean colors
  => chlorophyll concentration



Diatoms
(phytoplankton)
Bradbury J.

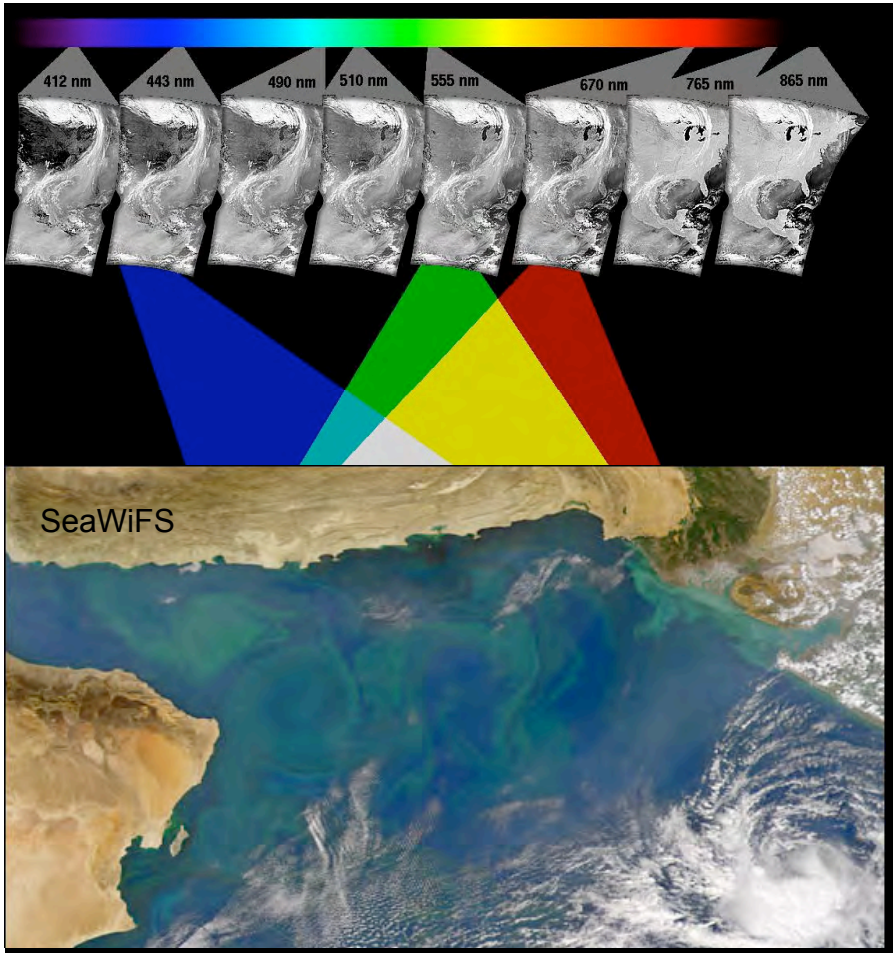




How does it work?

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

http://oceancolor.gsfc.nasa.gov/
http://earthobservatory.nasa.gov/



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“true color”:
how human eye would view the scene

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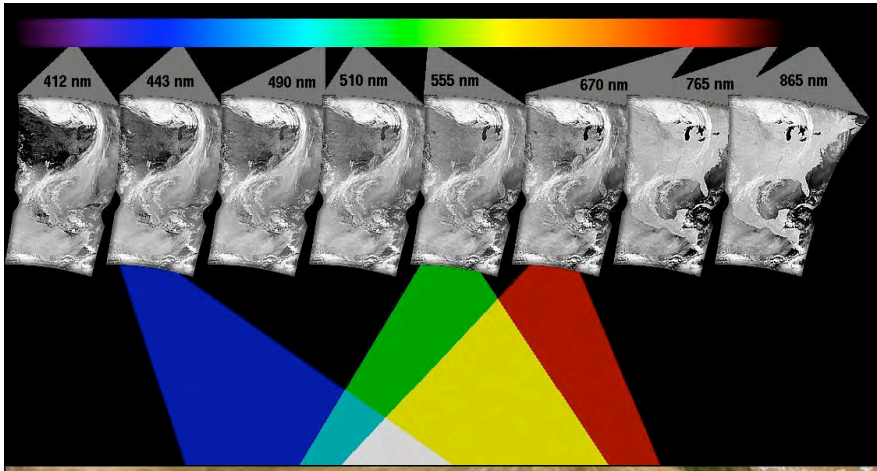
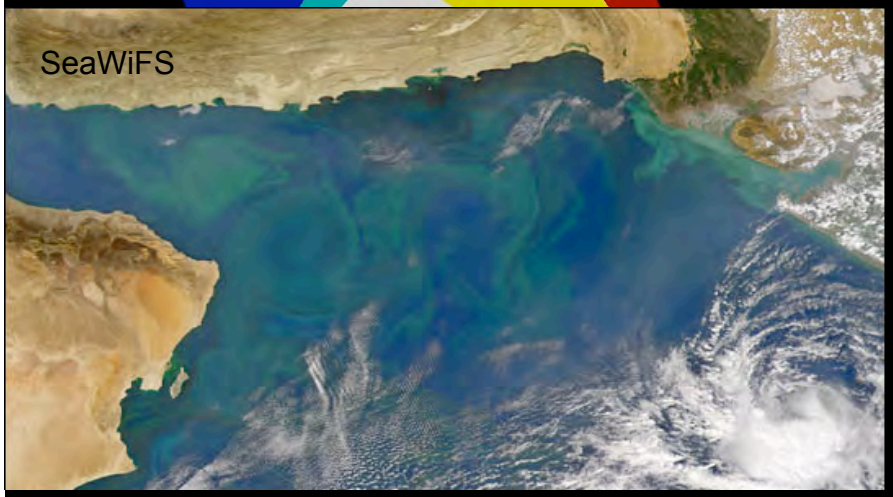
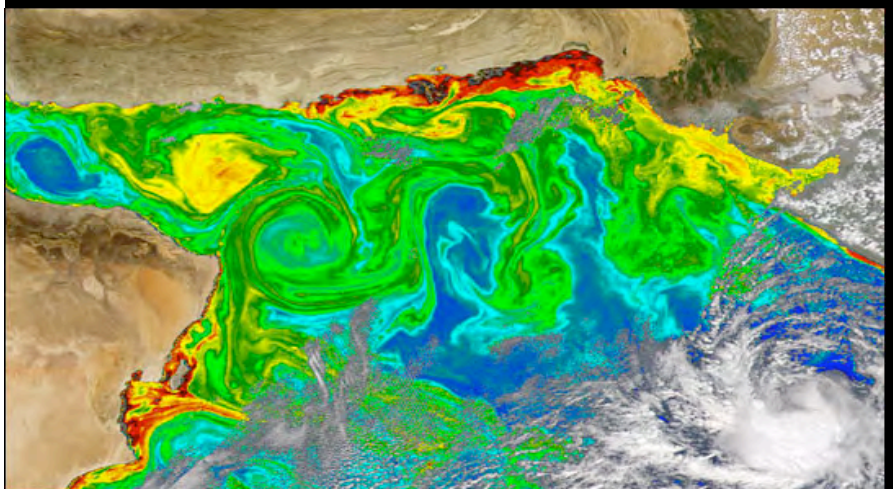






How does it work?

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/

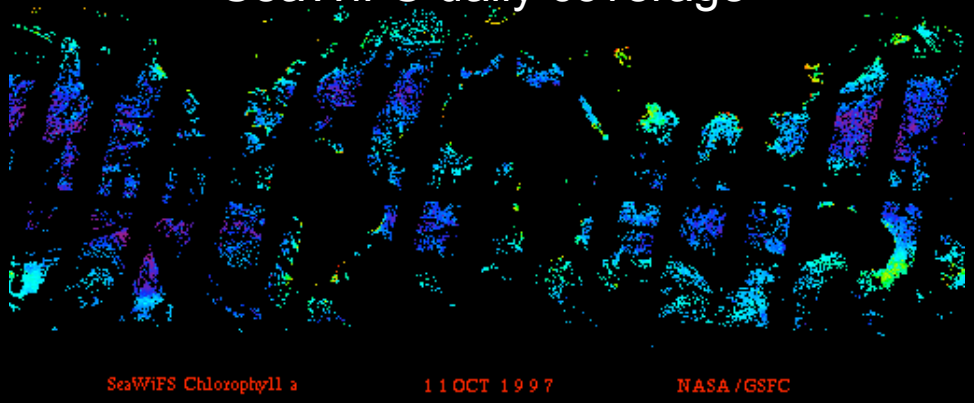
How are the data we get?

SeaWiFS covers the globe in 2 days

but

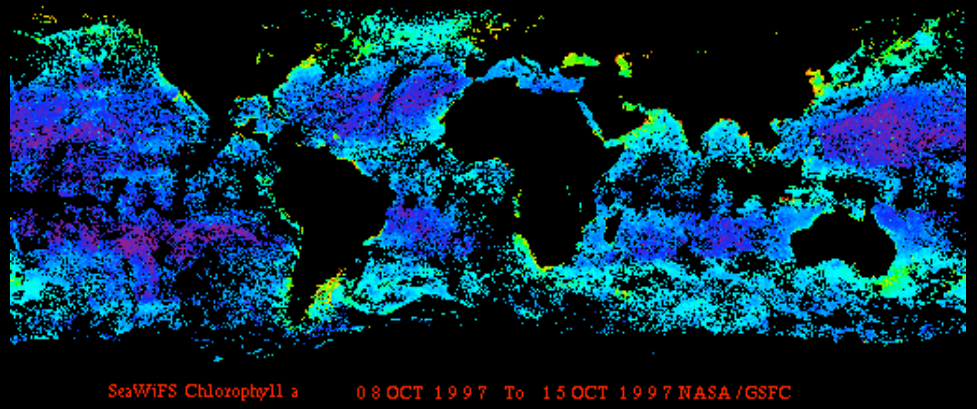
problem of cloud cover

SeaWiFS daily coverage



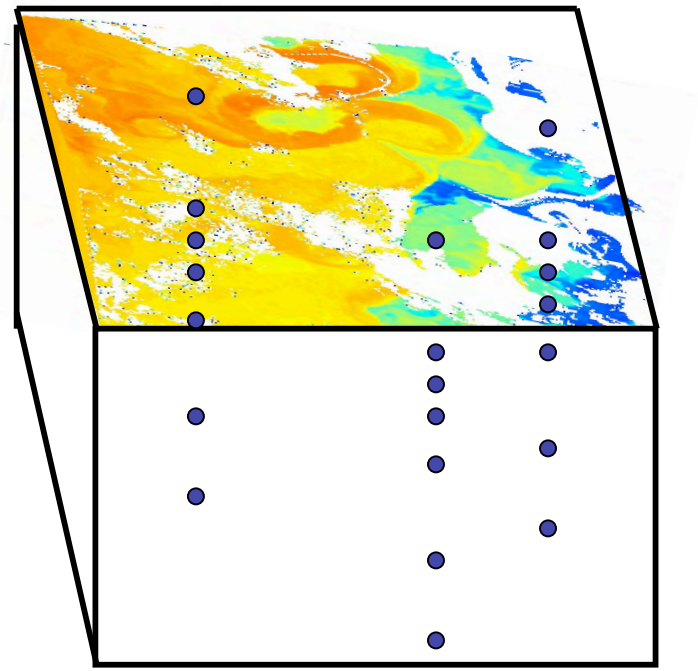
Weekly composite to get a better coverage

SeaWiFS weekly coverage



An important fact about chlorophyll observations

In real world: data

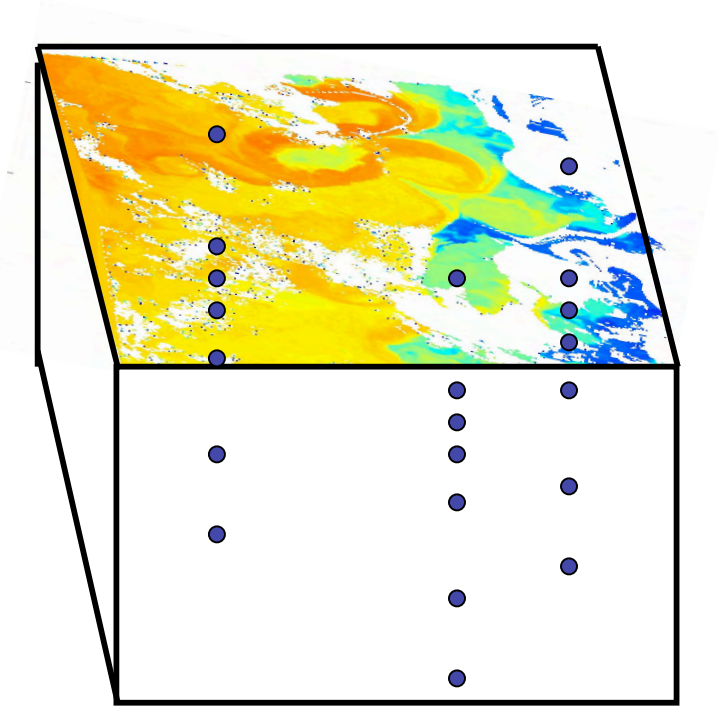


In-situ data

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

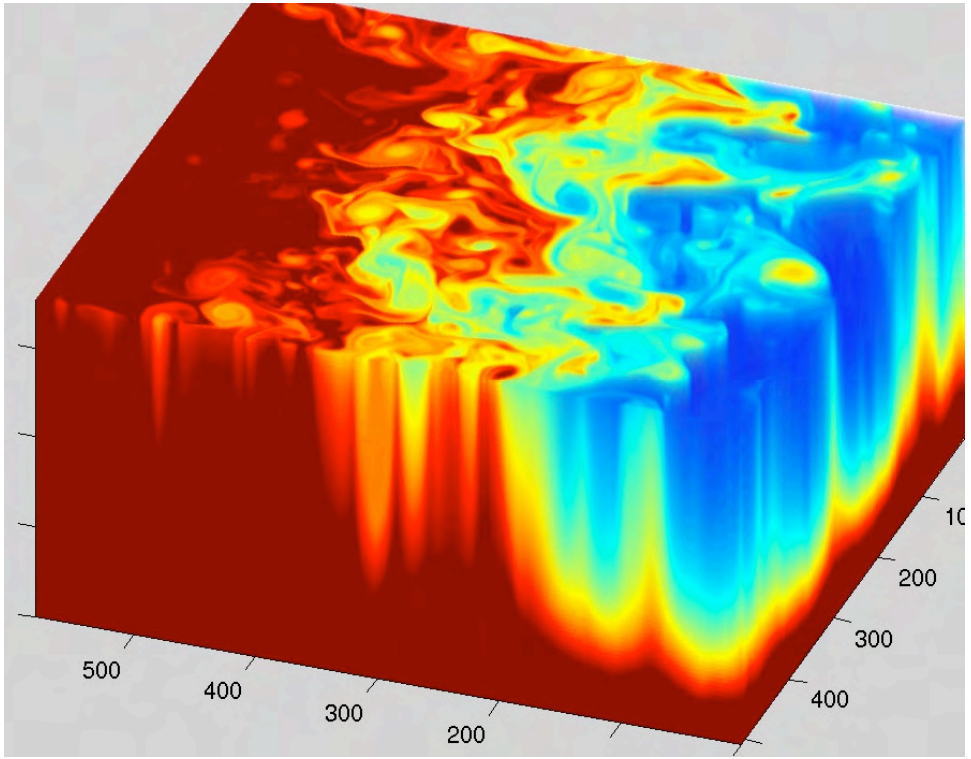
An important fact about chlorophyll observations

In real world: data



- In-situ data

In model world

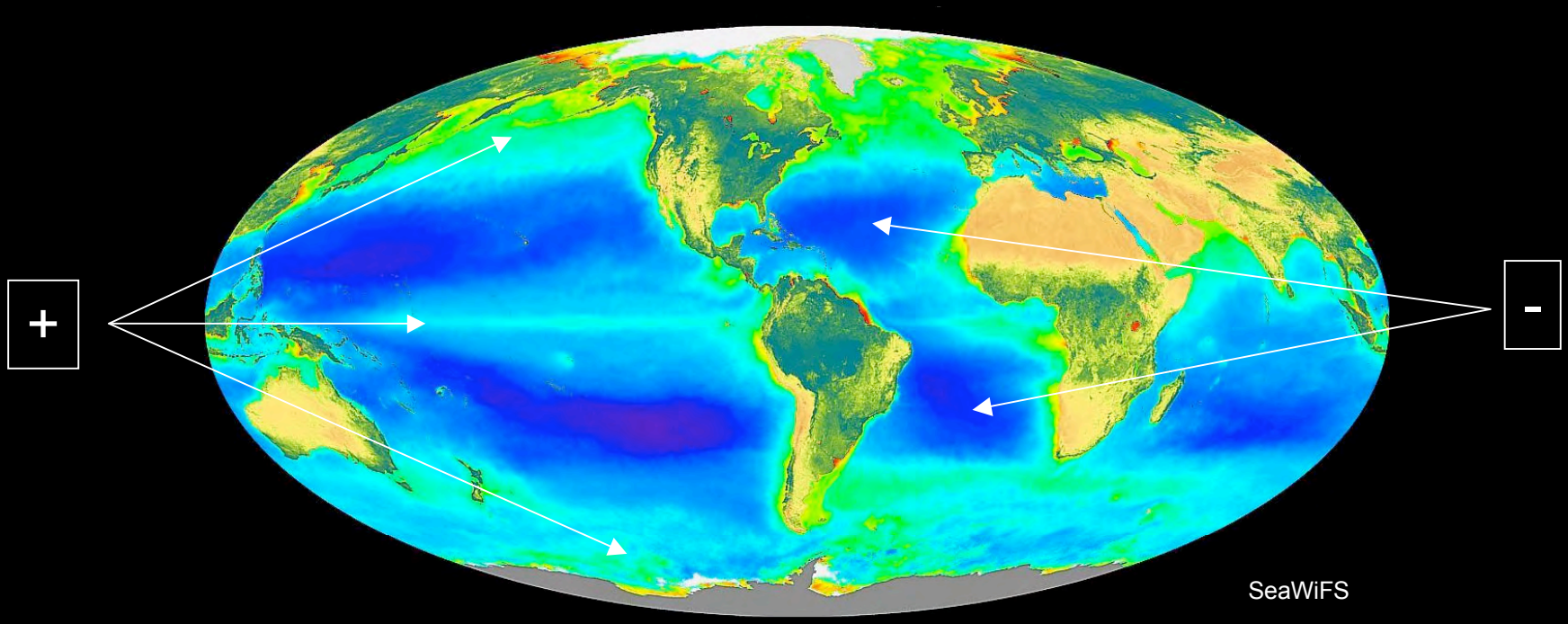


Guillaume Lapeyre http://www.lmd.ens.fr/glapeyre/ocean/index.html

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

⇒ Models help reconstruct the gaps and understand the processes

Global surface chlorophyll map

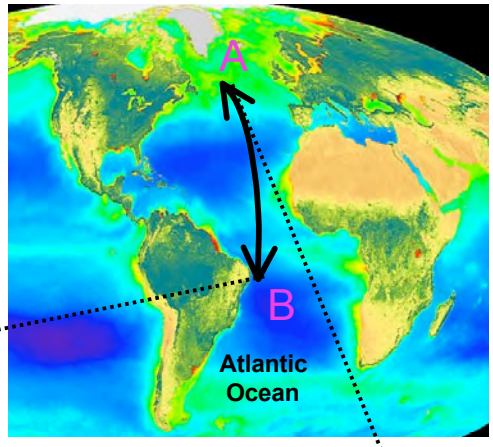


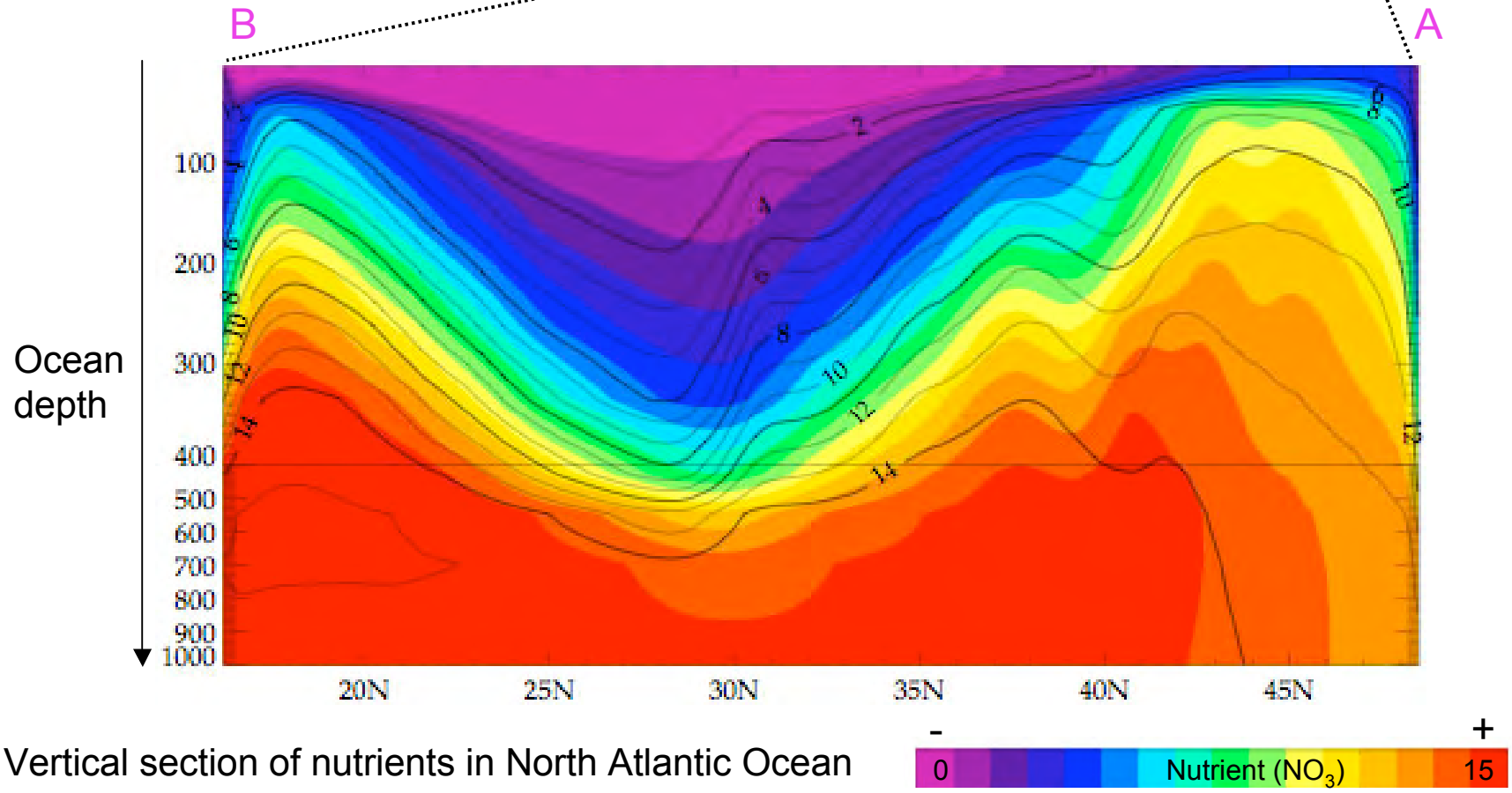
Chlorophyll - phytoplankton distribution is not homogeneous

=> *What does phytoplankton need?*

What does phytoplankton need?

nutrients

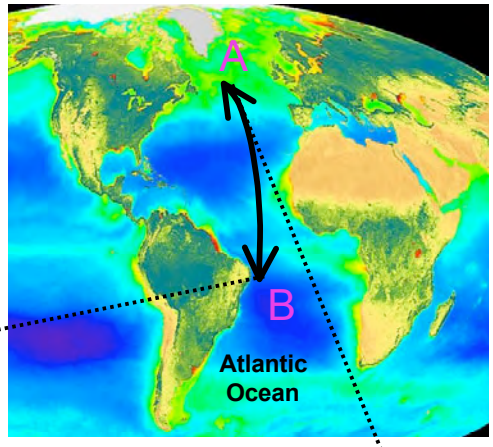


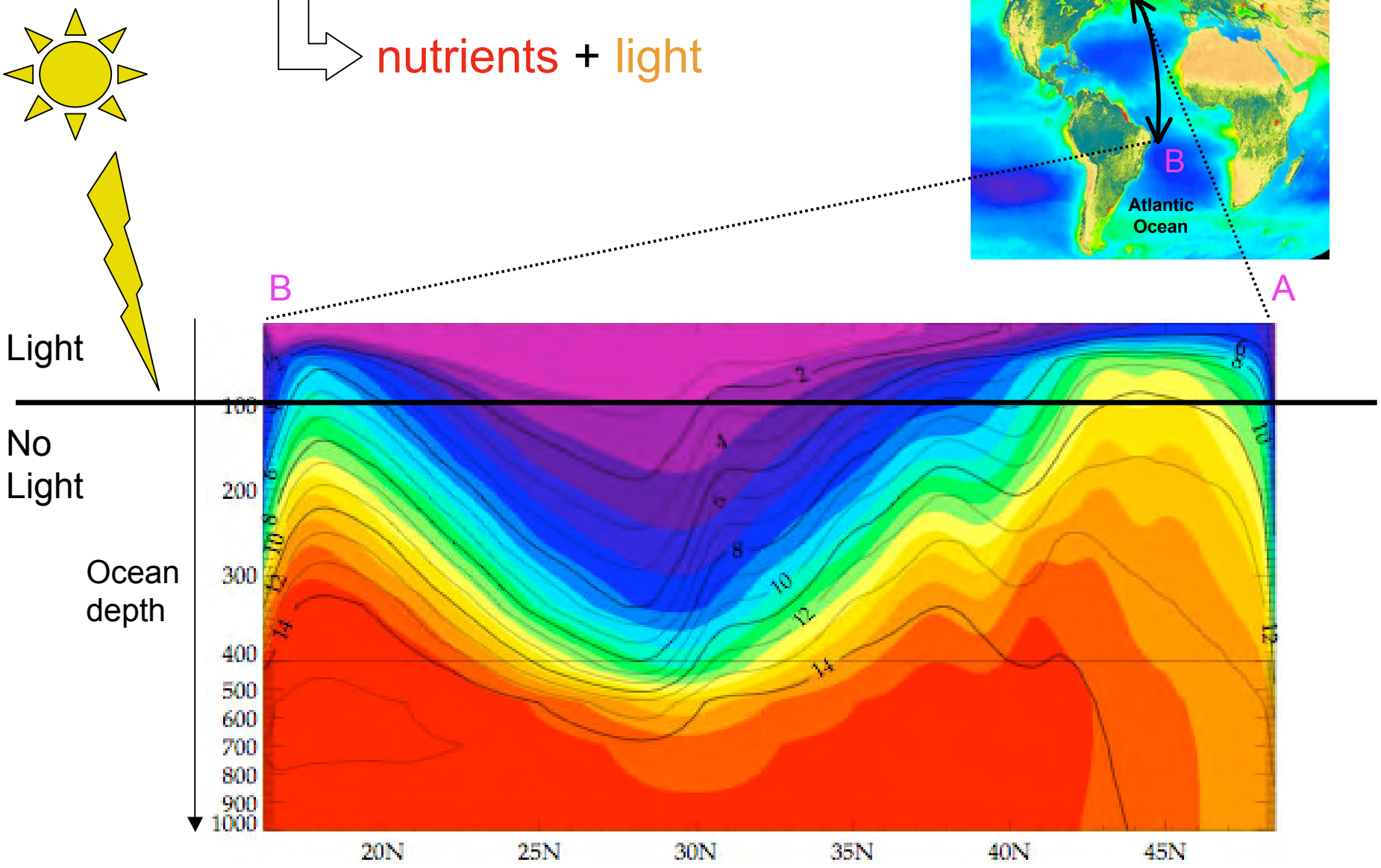


Vertical section of nutrients in North Atlantic Ocean

What does phytoplankton need?

nutrients + light





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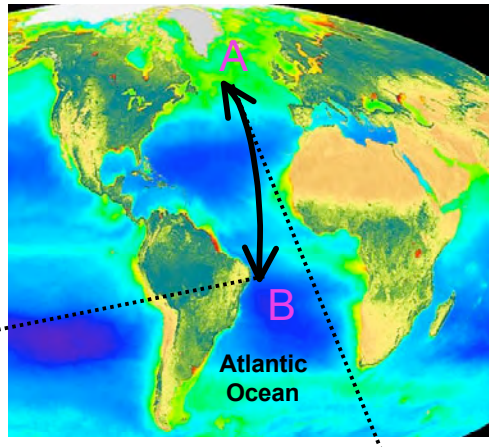


B phytoplankton

phytoplankton A

Light

No
Light

Ocean
depth

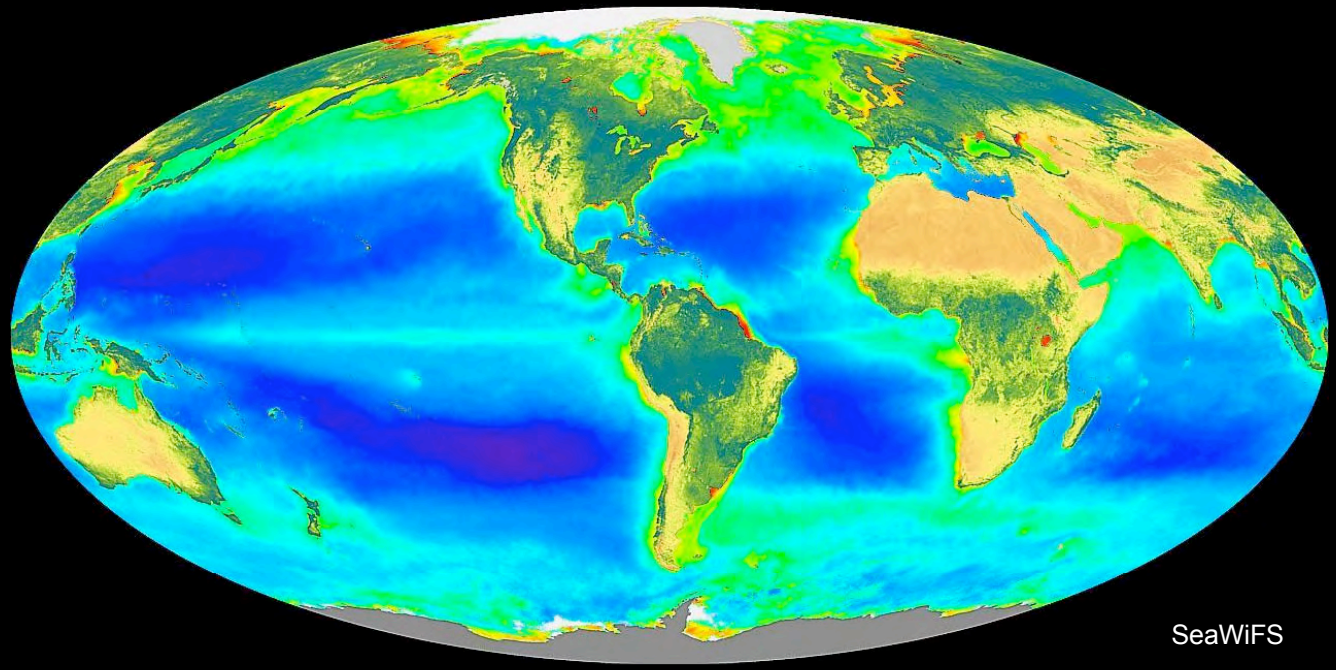
100
200
300
400
500
600
700
800
900
1000

20N 25N 30N 35N 40N 45N

Vertical section of nutrients in North Atlantic Ocean

0 Nutrient (NO_3) 15

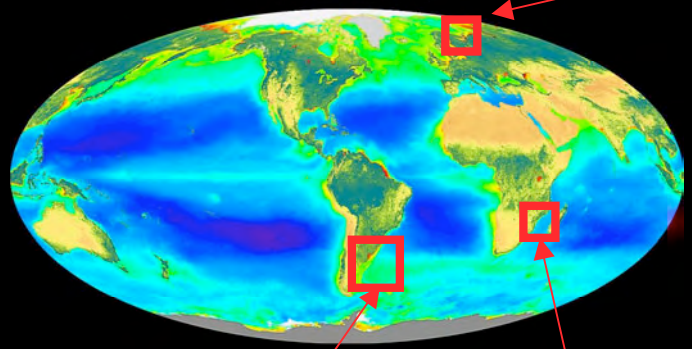
Global surface chlorophyll map

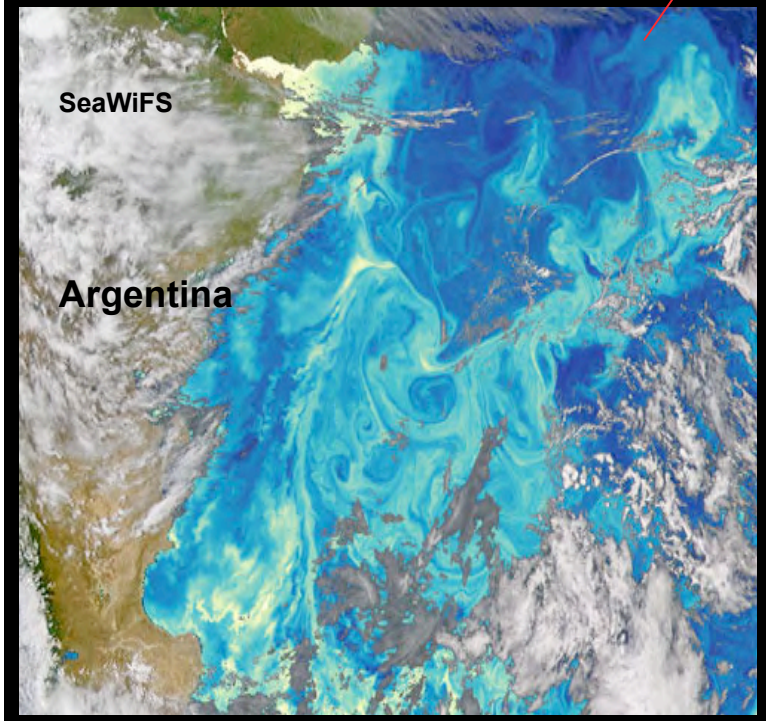


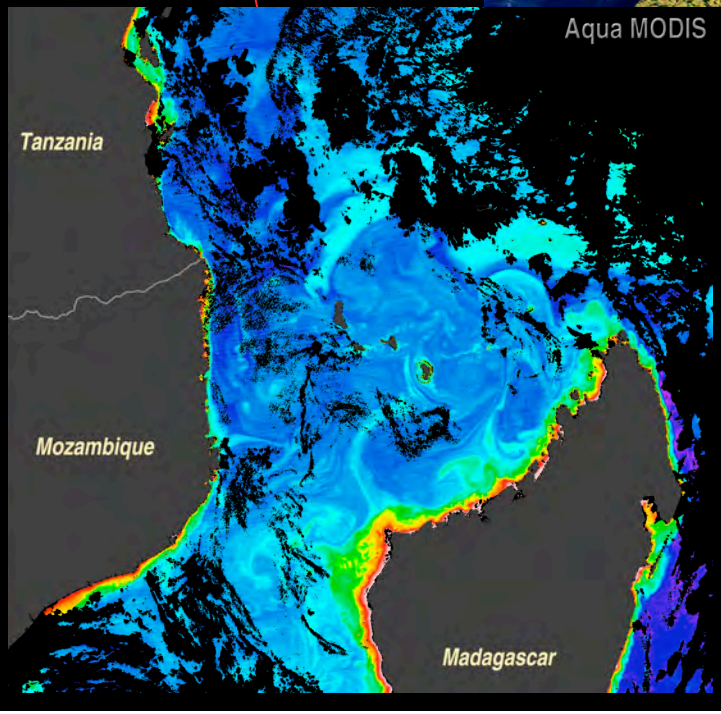
Large scale chlorophyll patterns comes from distribution of light and nutrients
i.e. ocean circulation = physics!

What happens if we look closer? … at small scale

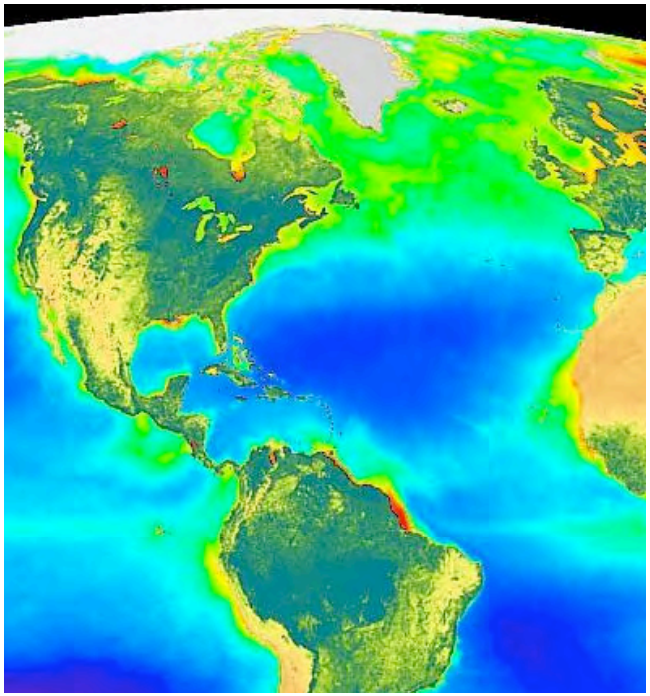
Chlorophyll organized in small scale structures







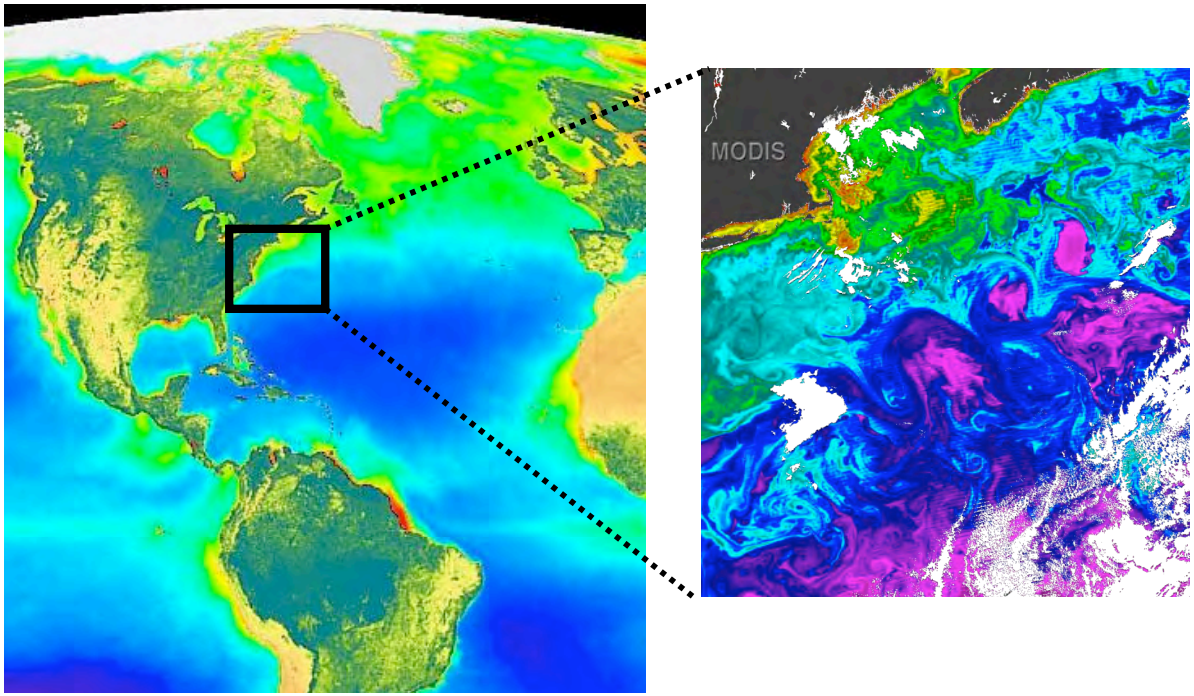
Chlorophyll spatial distribution at different scales



~ 1000 km
Global circulation

Large scale

Chlorophyll spatial distribution at different scales

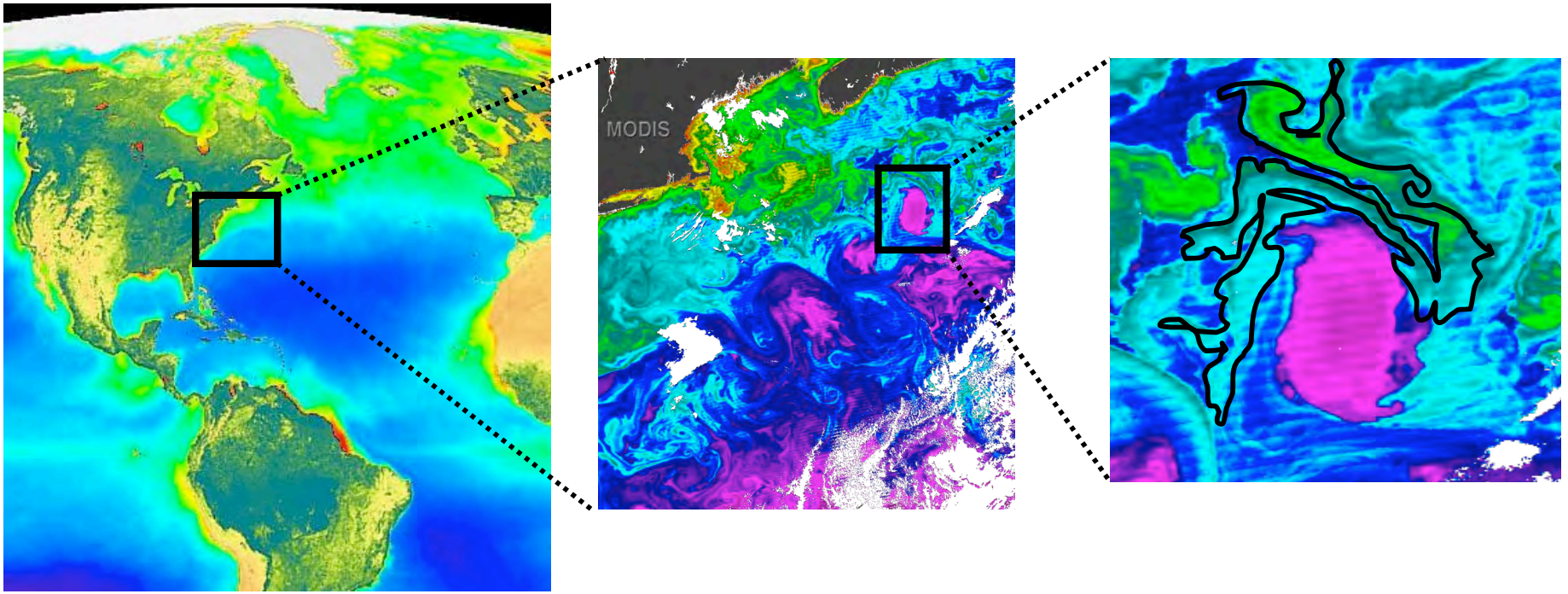


~ 1000 km
Global circulation

~ 100 km
Eddies

Large scale

Chlorophyll spatial distribution at different scales



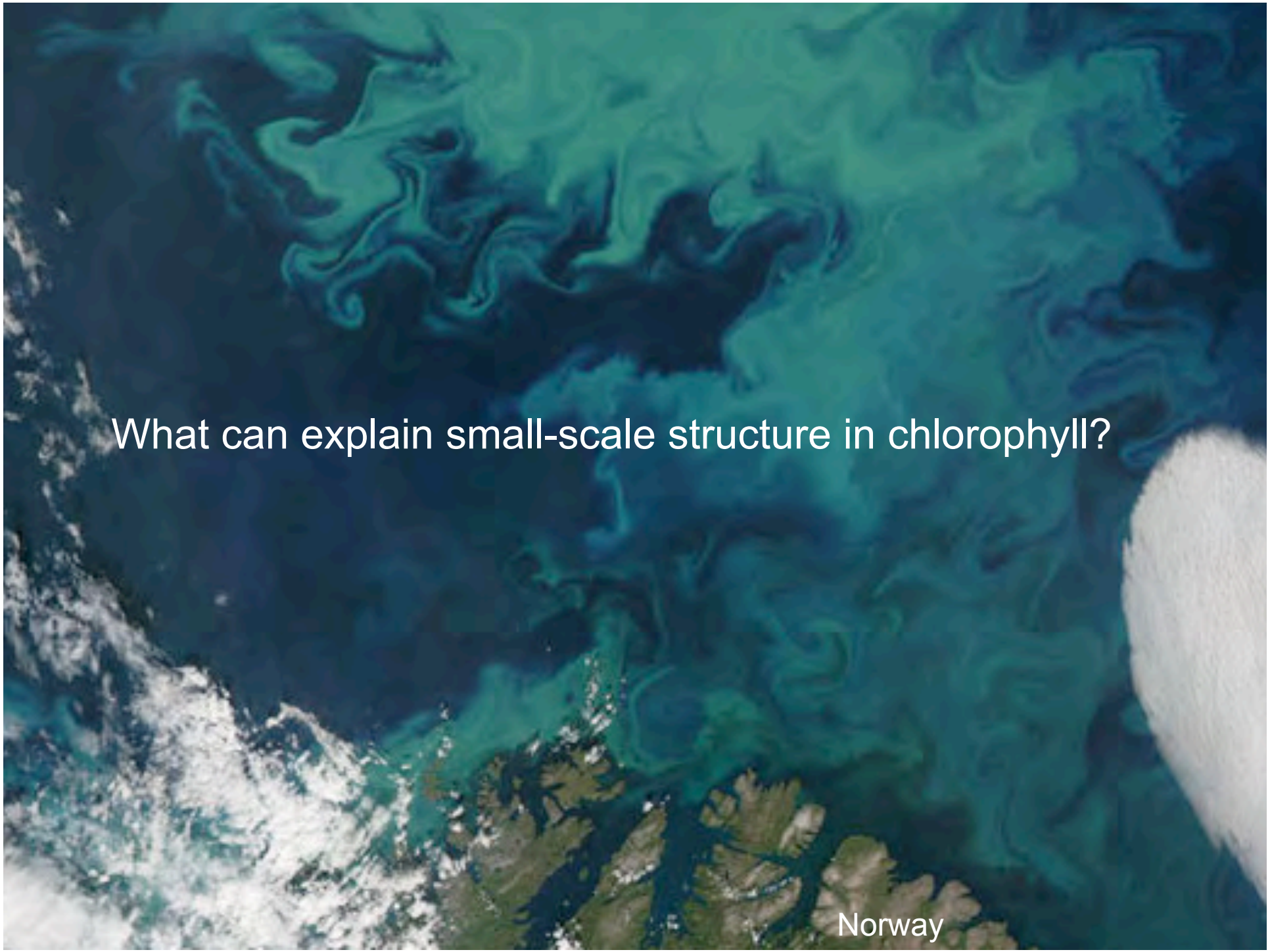
~ 1000 km
Global circulation

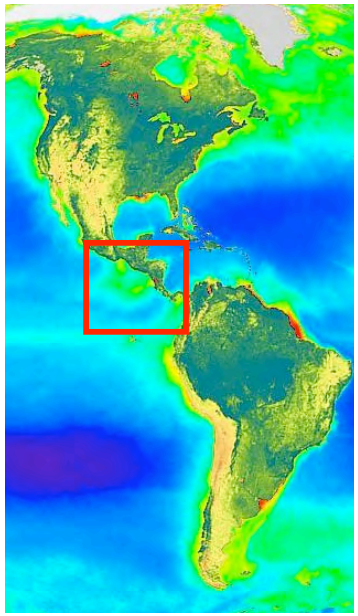
~ 100 km
Eddies

~ 1-10 km
Filaments

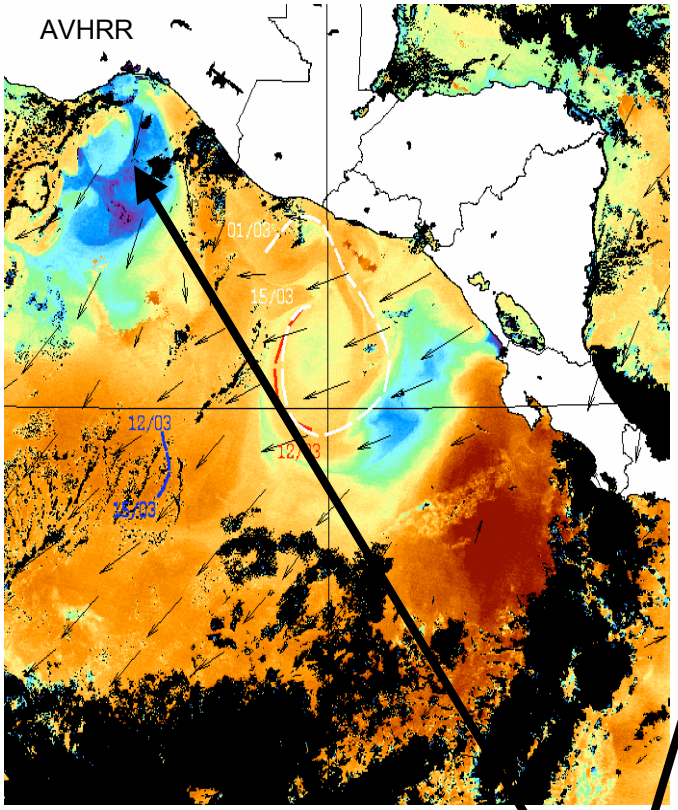
Large scale

Small-scale

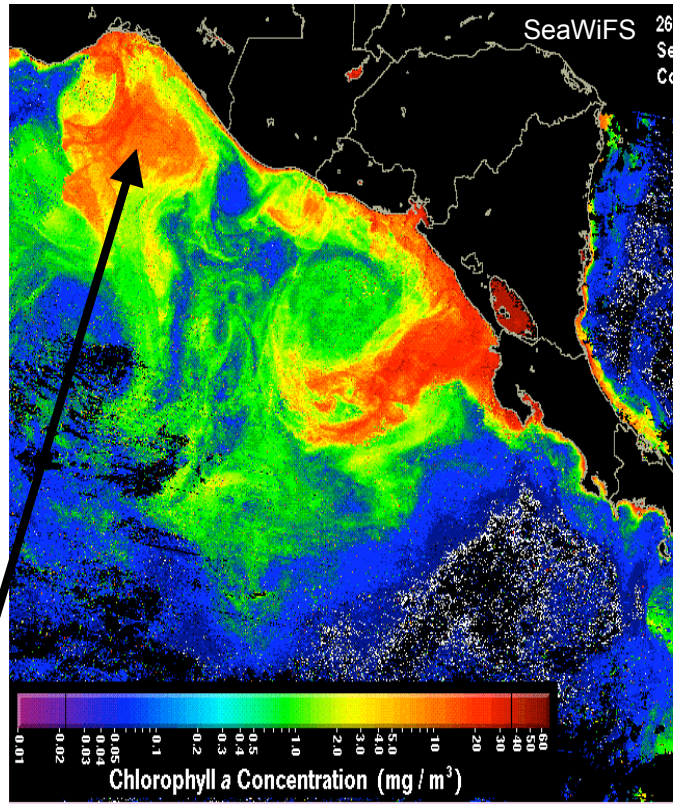

What can explain small-scale structure in chlorophyll?
Norway



Ocean Temperature

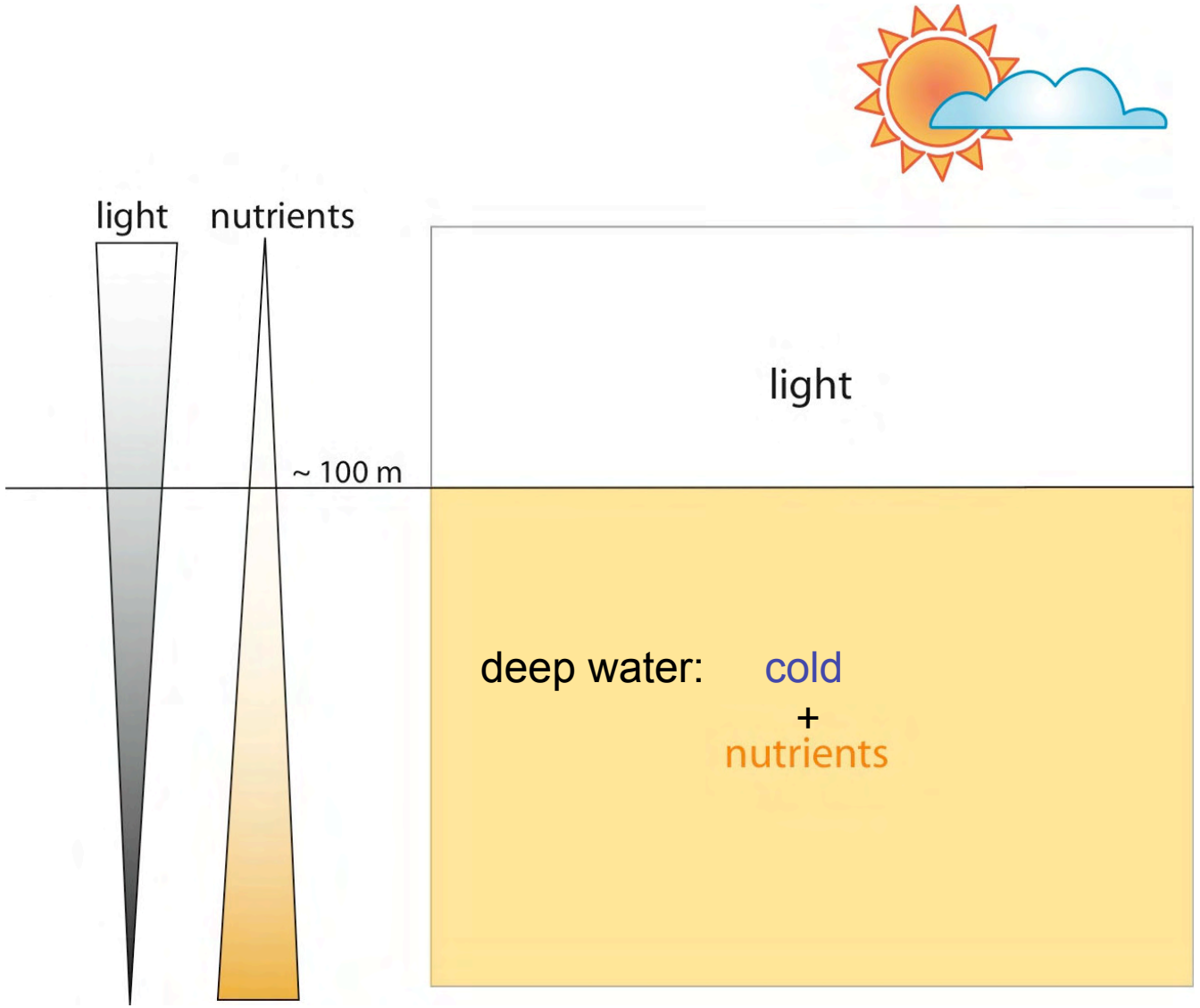


Chlorophyll



Relation chlorophyll - temperature
=> bio-physical interactions?

Why do we talk about bio-physical interactions?



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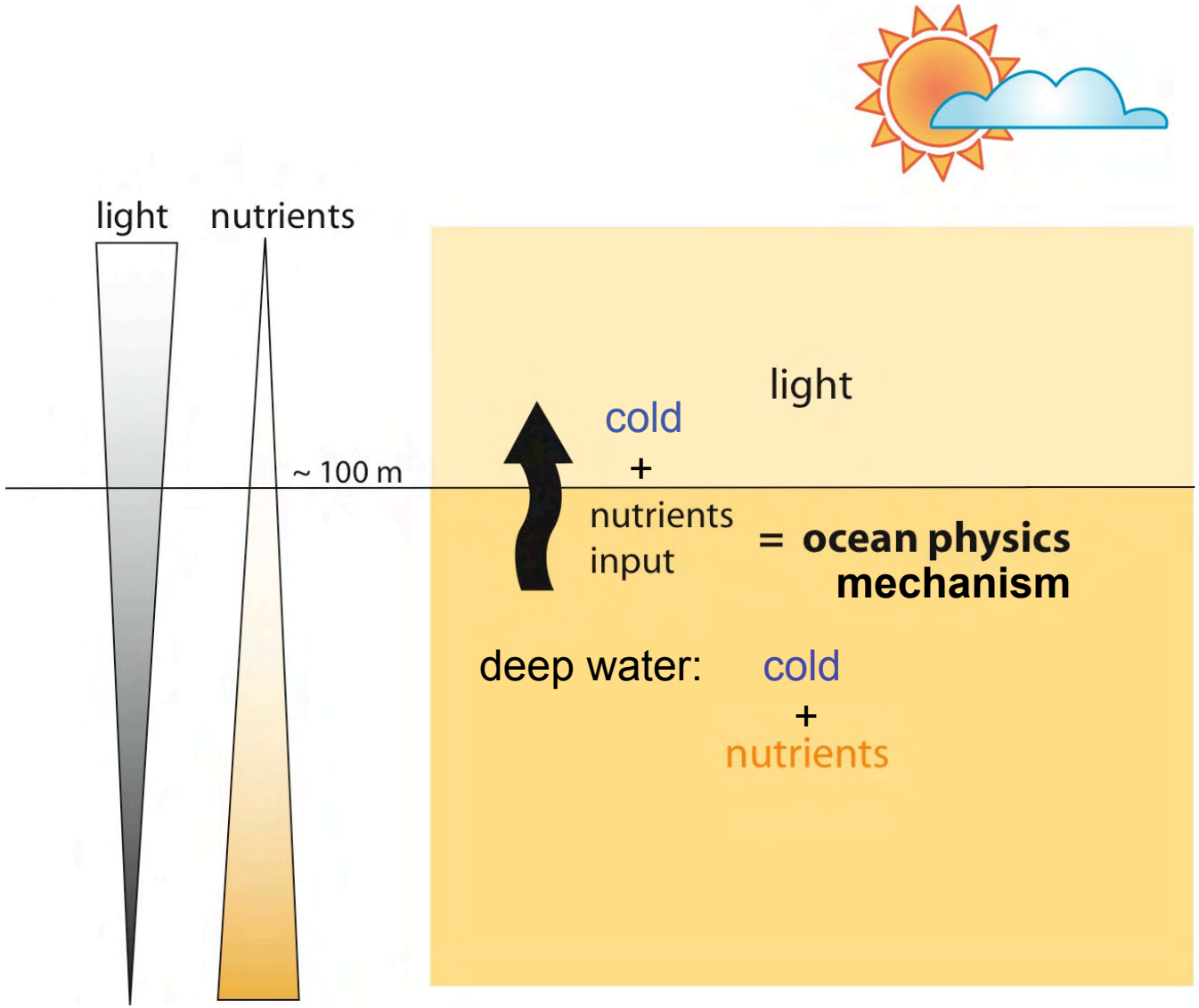
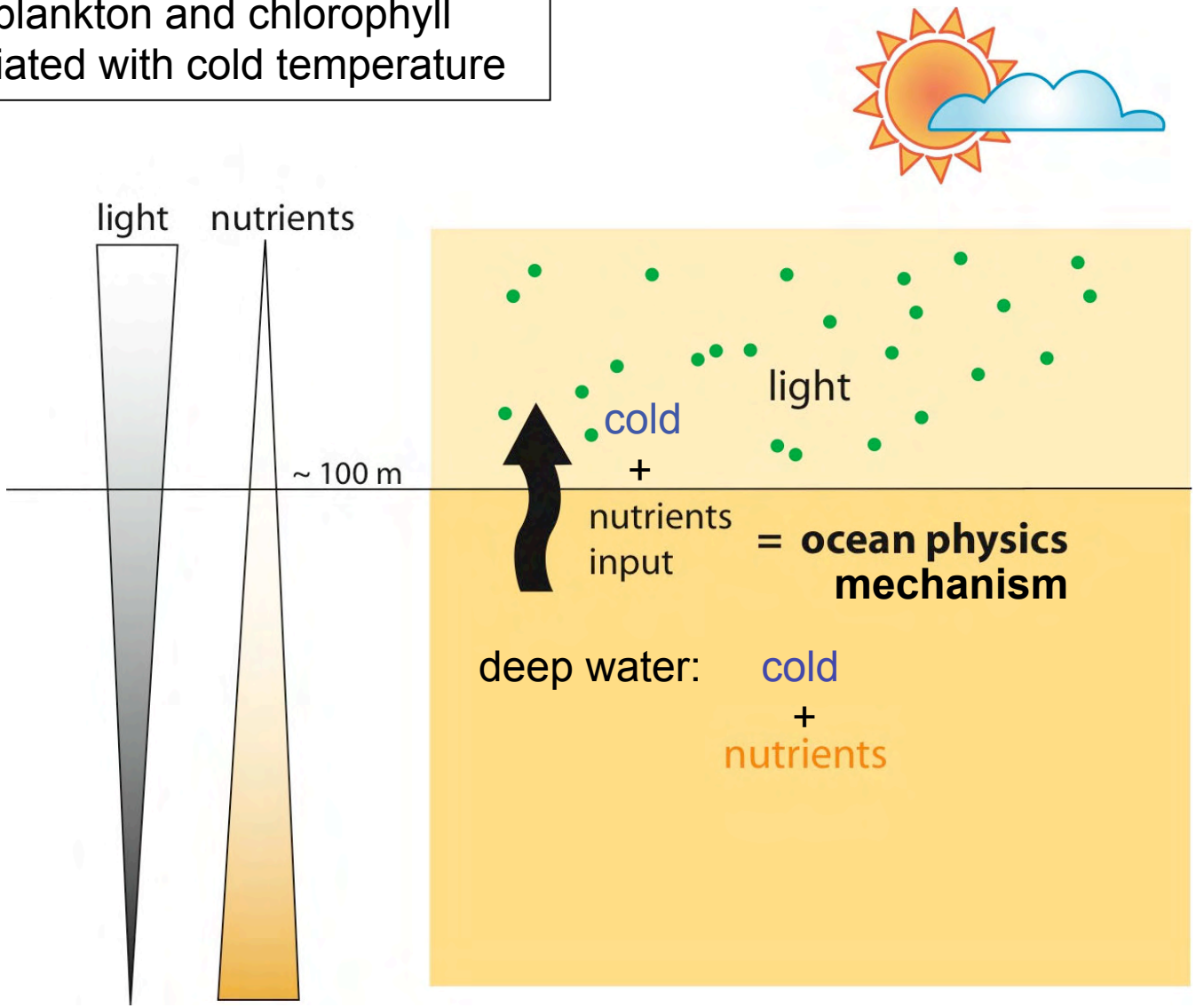


Why do we talk about bio-physical interactions?

Phytoplankton and chlorophyll associated with cold temperature

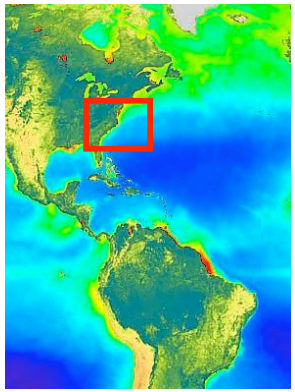


Small-scale mechanisms that shape chlorophyll?

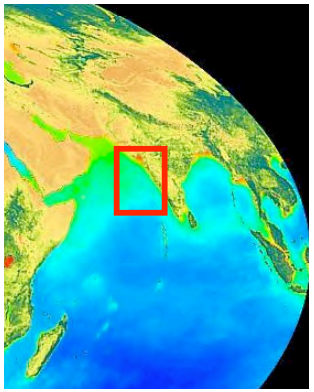
1. Small-scale transports chlorophyll

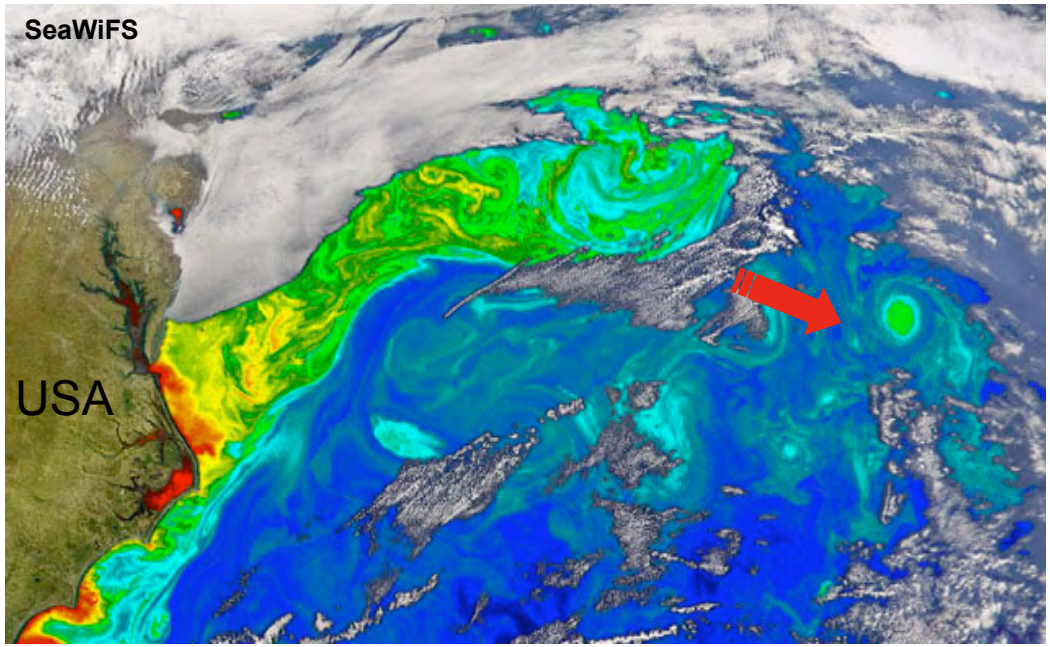
2. Small-scale re-organizes chlorophyll

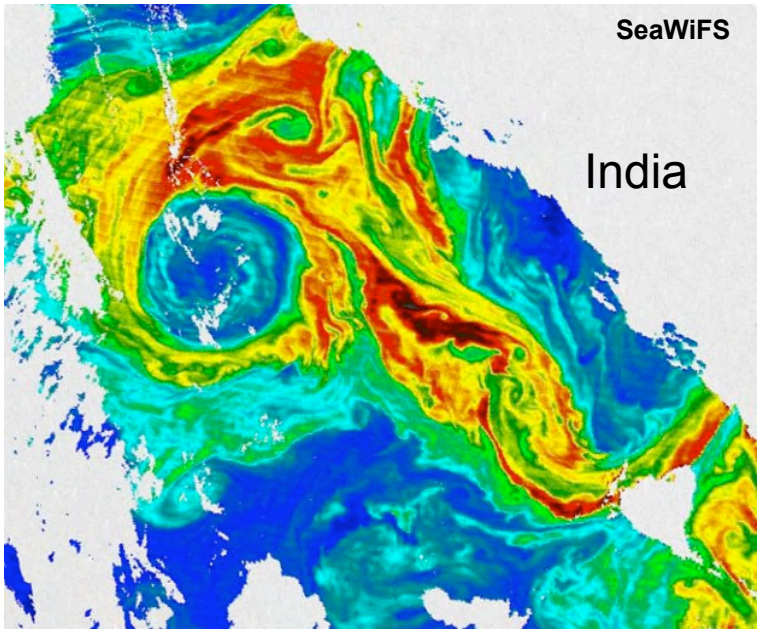
3. Small-scale is an ocean fertilizer
   $\Rightarrow$ bring nutrients to the surface



1. Small-scale transports chlorophyll



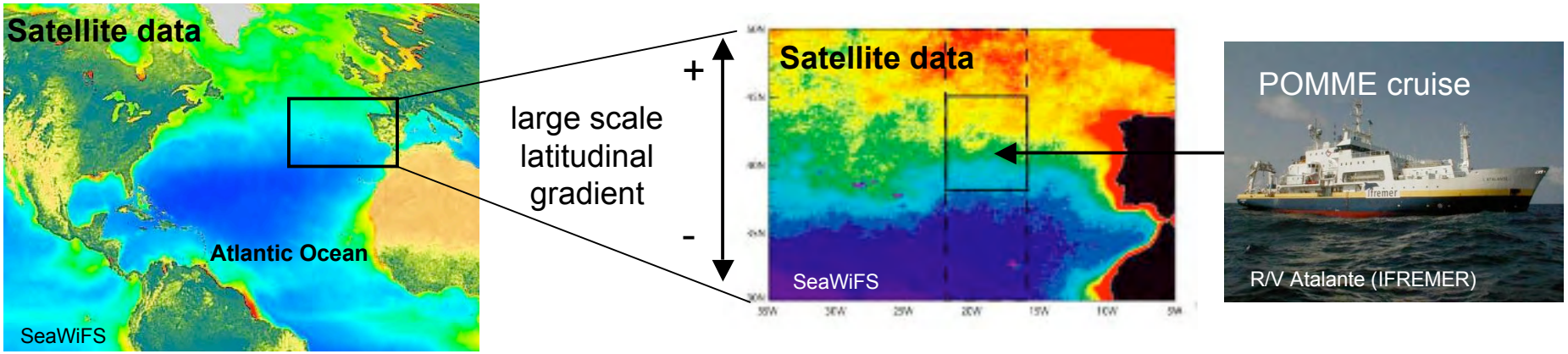




Inside eddies or filaments, water is "**isolated**"
=> Water mass properties (temperature, chlorophyll…) can **travel for month**

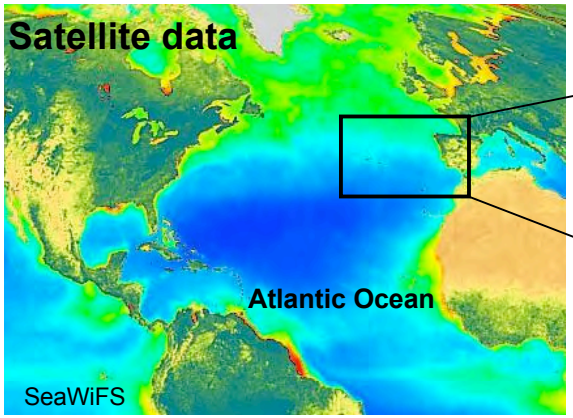
⇒ *Horizontal process*

2. Small-scale re-organized large-scale gradients



To reconstruct the evolution of chlorophyll we use **high resolution model**:

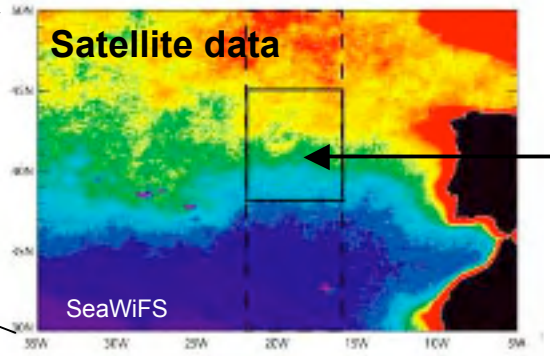
3. Small-scale re-organized large-scale gradients



large scale latitudinal gradient

+

-



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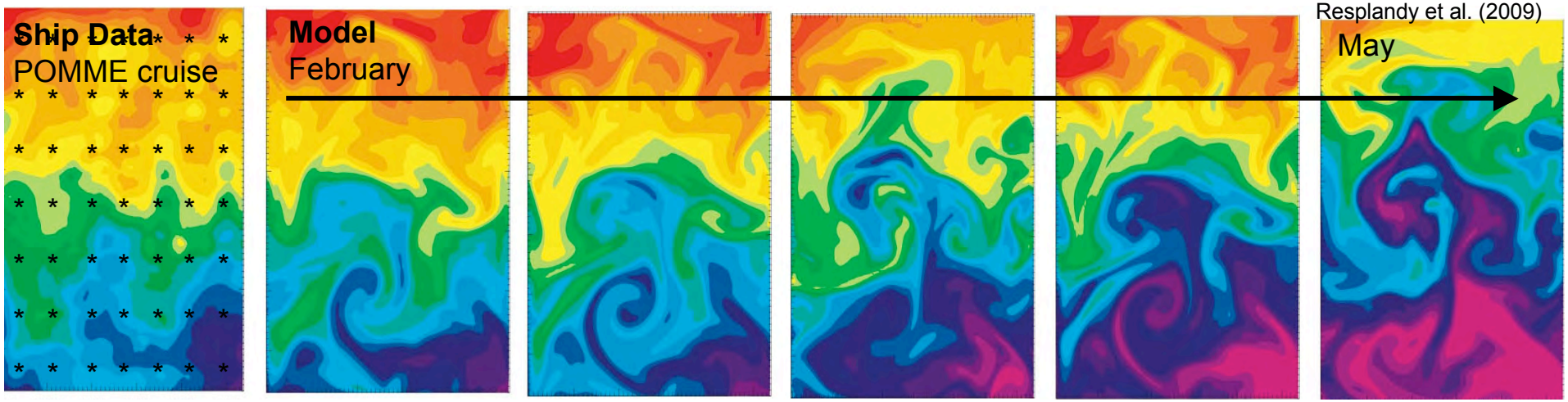
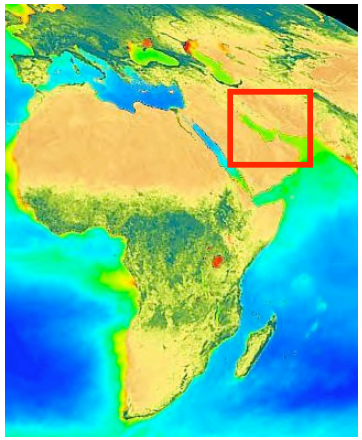
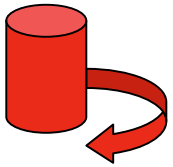


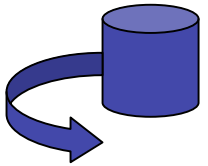
⇒ *Horizontal process*



3. Small-scale = ocean fertilizer



Northern hemisphere

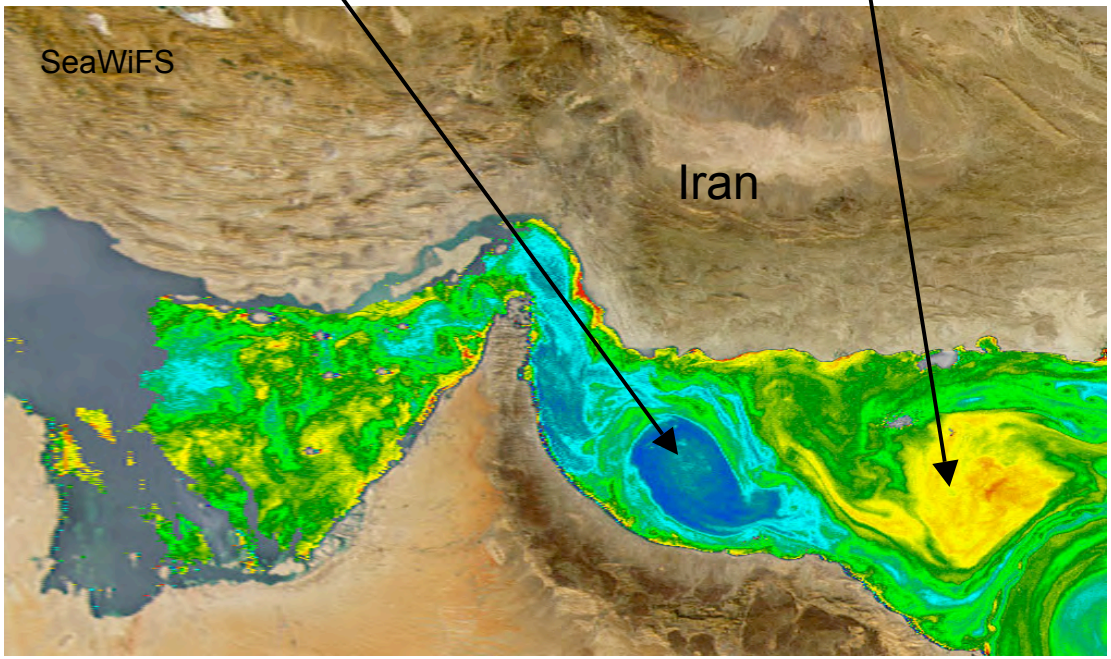


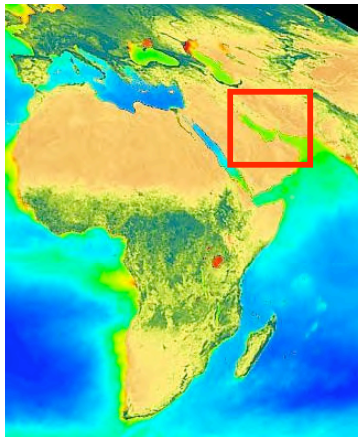
Anti-cyclonic

Cyclonic

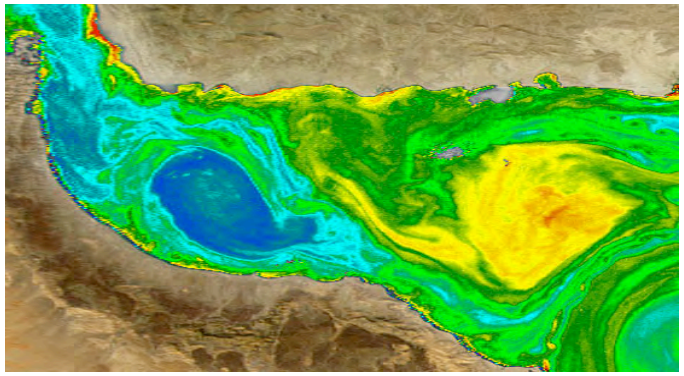
Eddy poor in chlorophyll

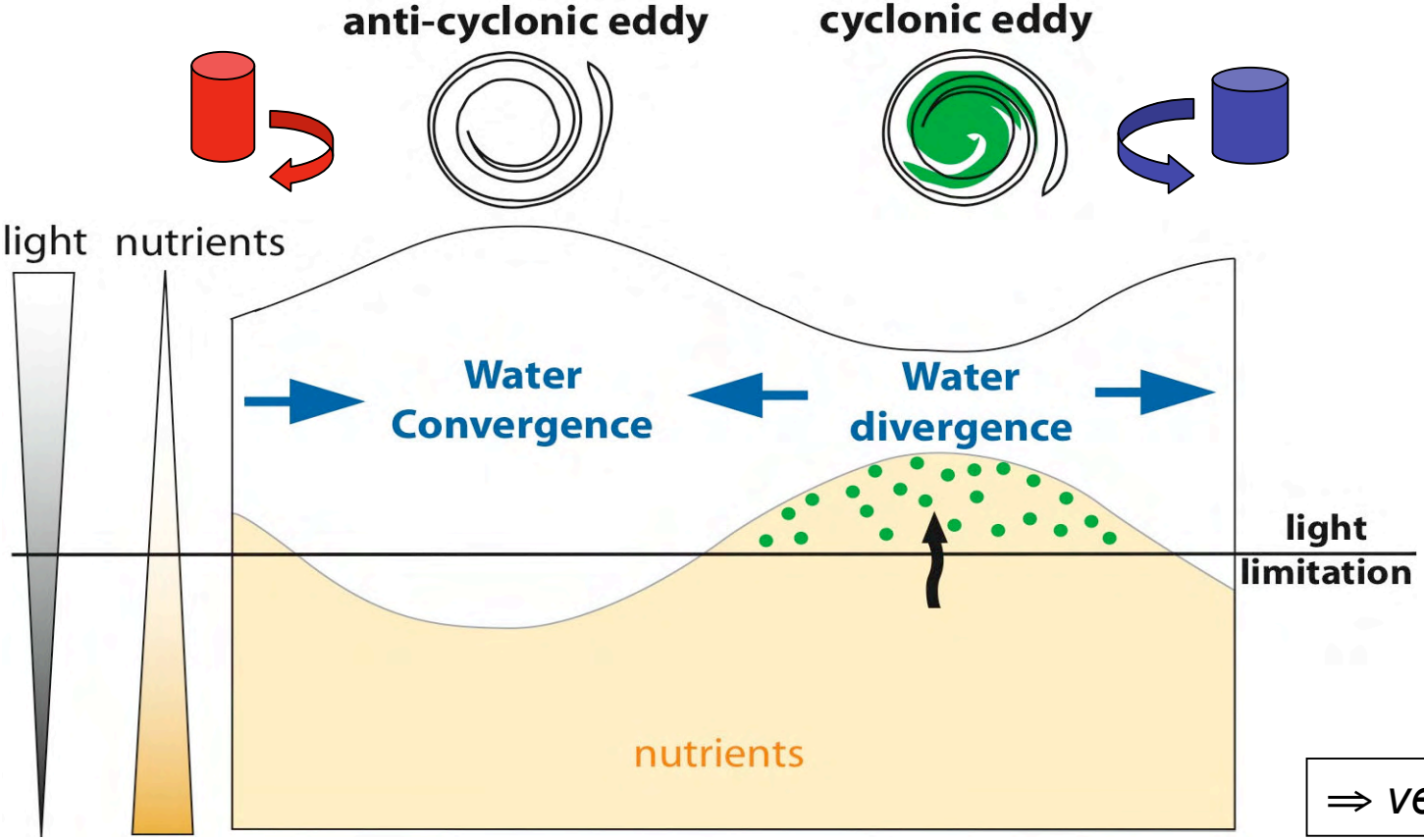
Eddy rich in chlorophyll





3. Small-scale = ocean fertilizer



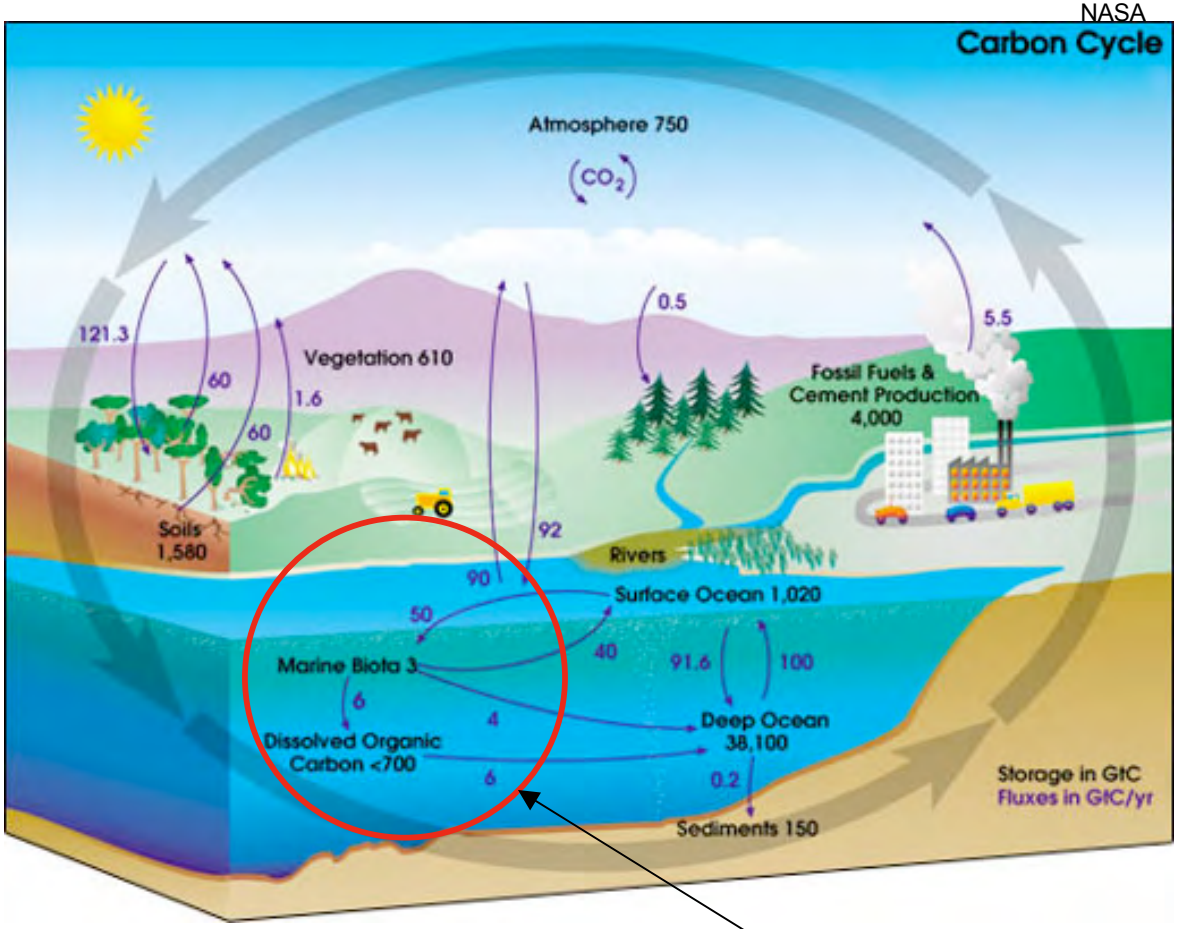


⇒ *vertical process*

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

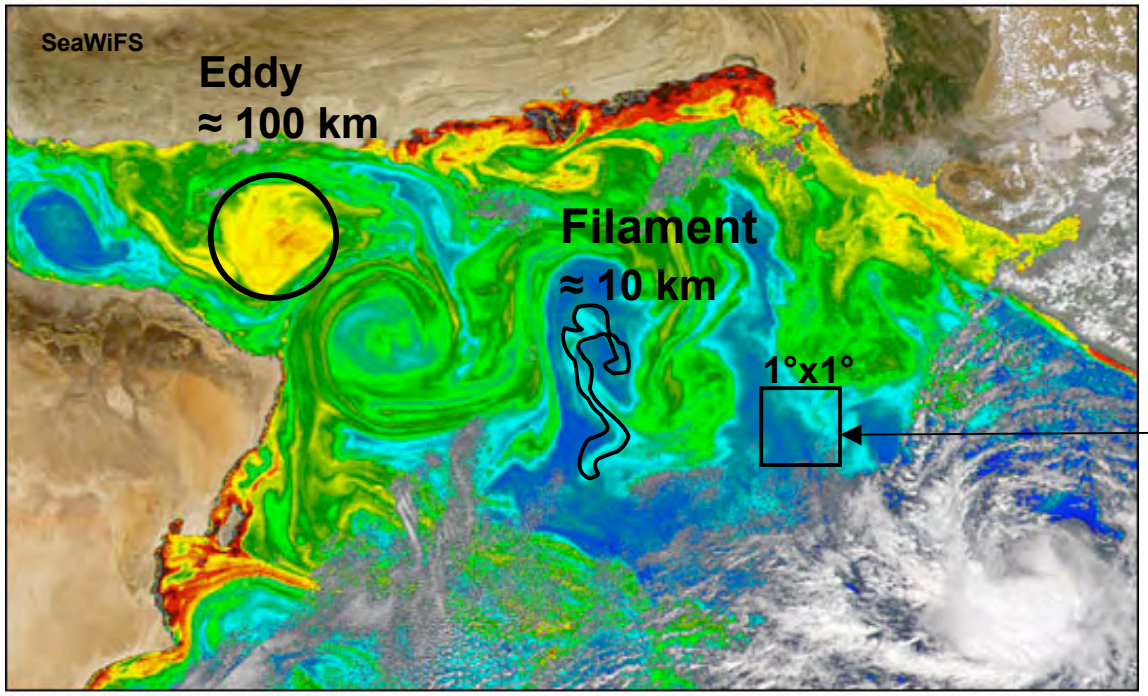
Carbon cycle in climate models:

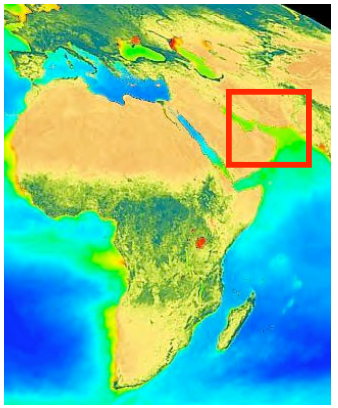
NASA



Phytoplankton plays a role in carbon cycle

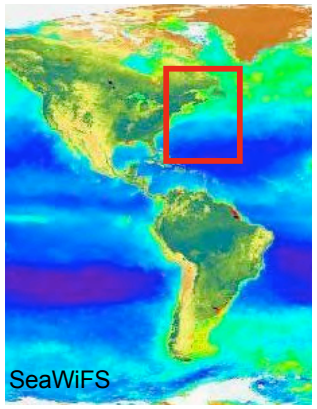
Do we need small-scale to understand the global picture?





Climate model
≈ 100 x 100 km
Simulations 1000 years

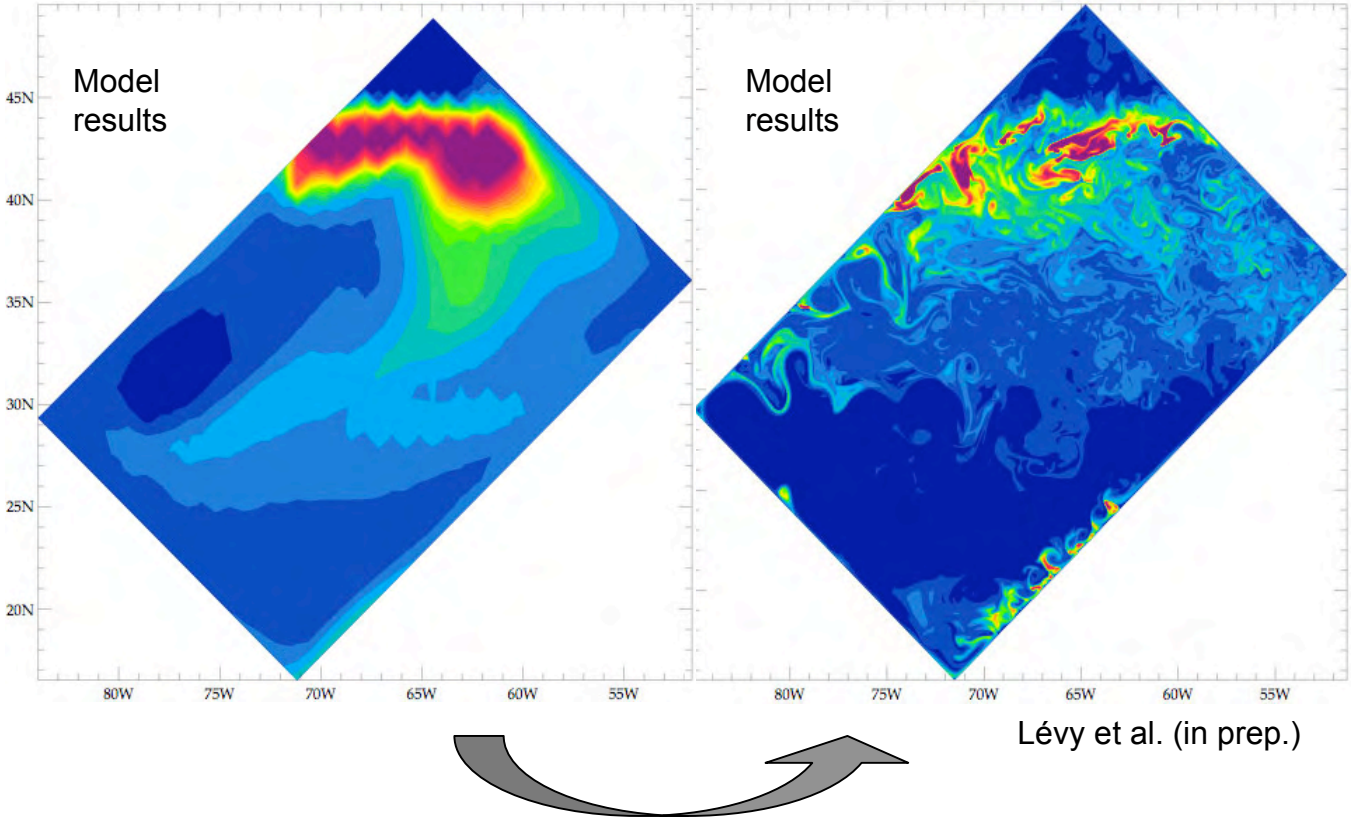
Climate models can not simulate small-scale (computers limit)
Need of **high resolution bio-physical models to quantify the impact**



1. Modelling study: “Gulf Stream”

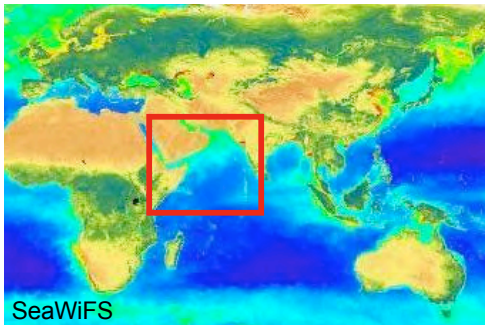
~ Climate model resolution
100 km

High resolution
2 km



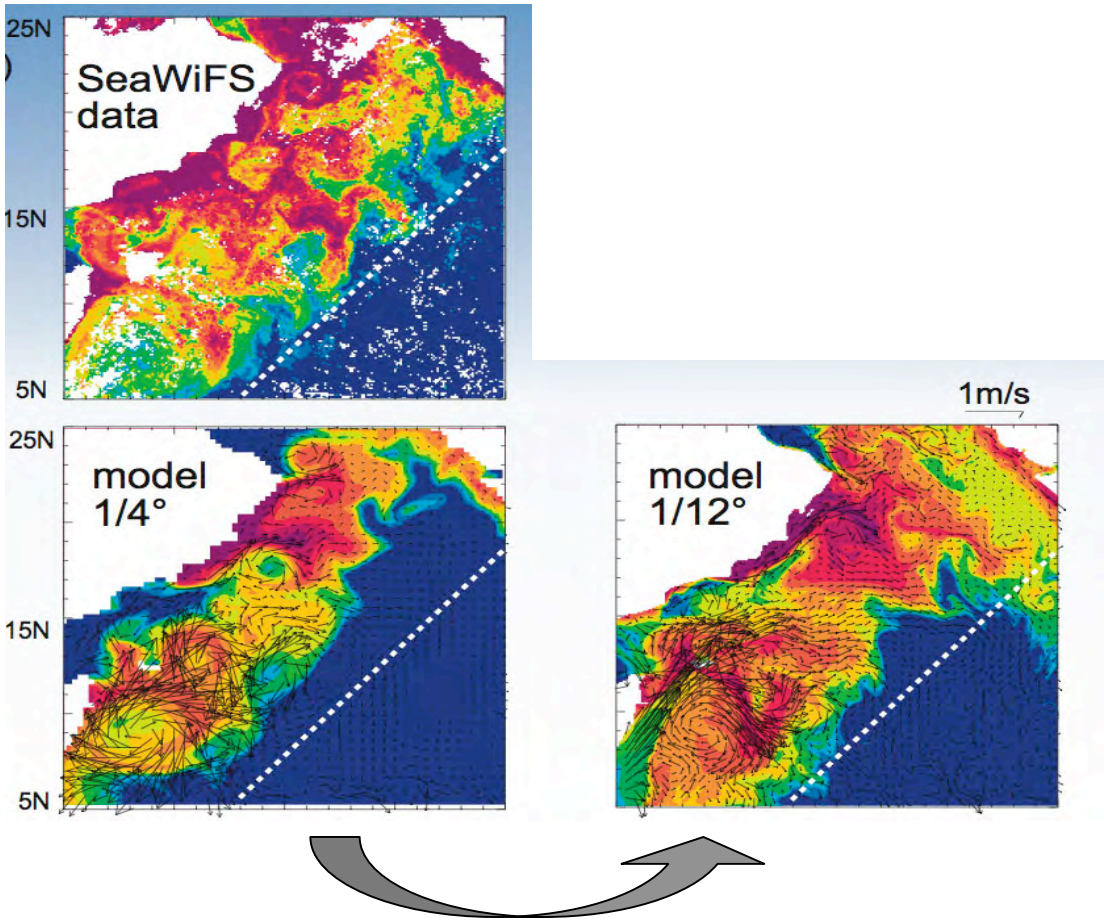
Lévy et al. (in prep.)

chlorophyll decreases



2. Modelling study: Arabian Sea

Satellite data

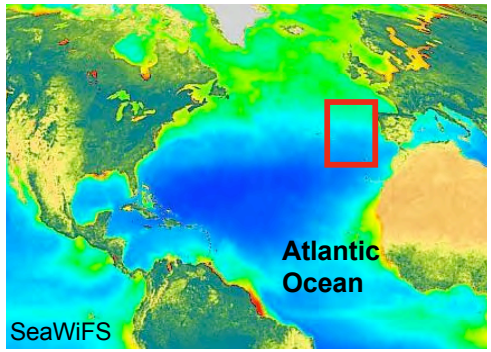


Intermediate resolution
25 km

High resolution
8 km

Resplandy et al. (in prep.)

chlorophyll increases



3. Modelling study: offshore Portugal

~ Climate model resolution

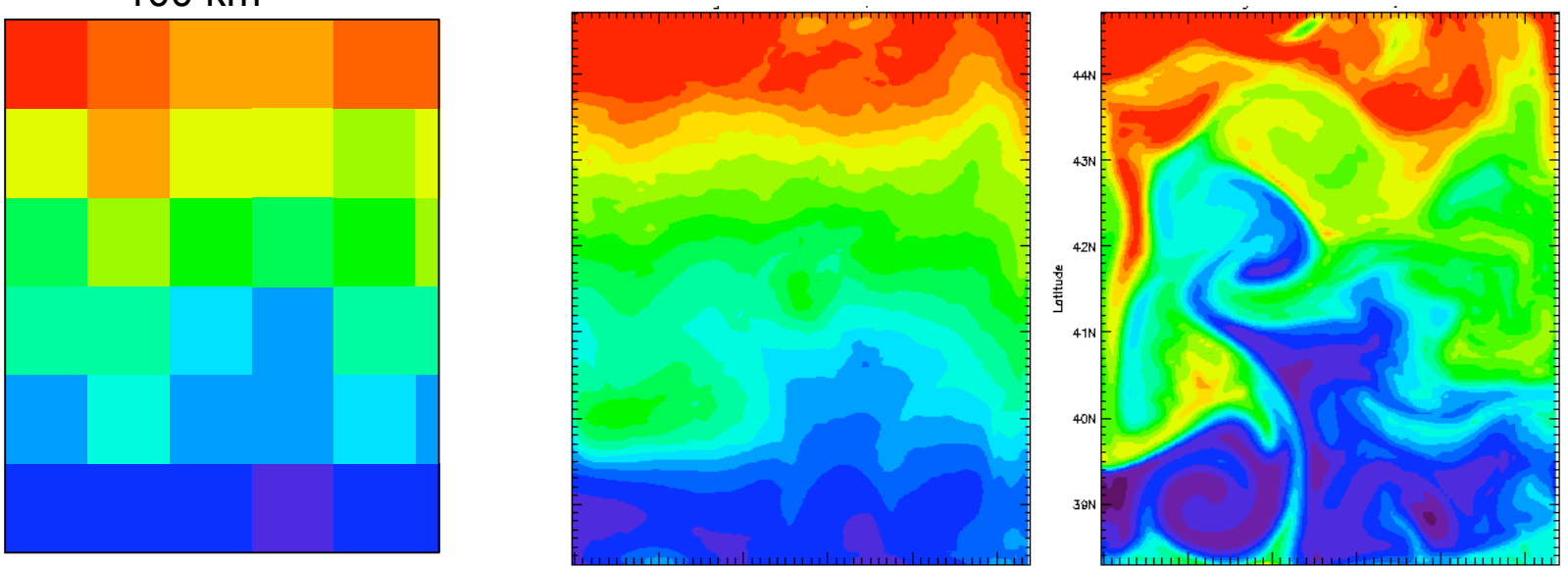
100 km

Intermediate resolution

25 km

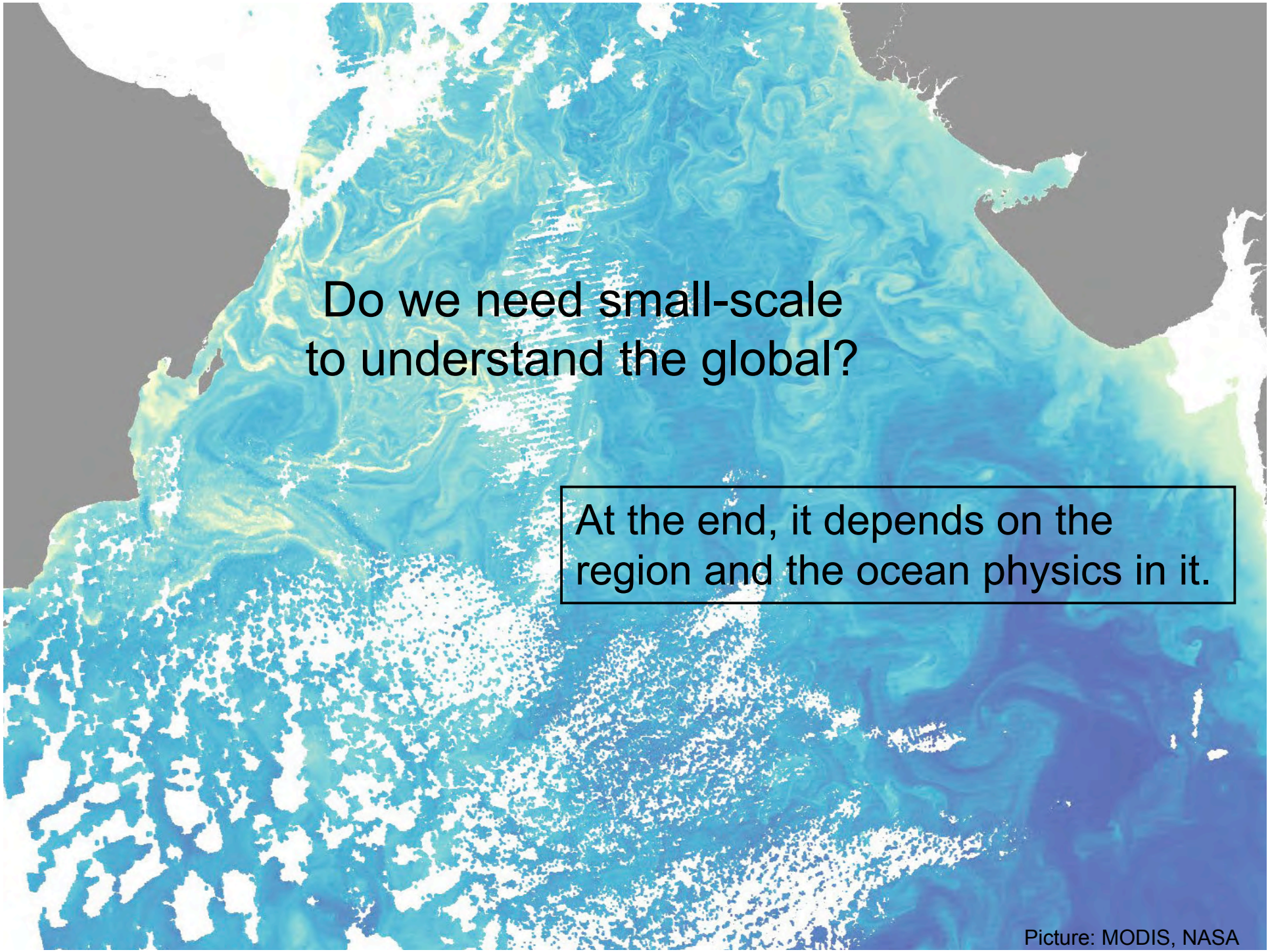
High resolution

5 km



Resplandy et al. (2009)

chlorophyll does not change but is re-organized


Do we need small-scale
to understand the global?
At the end, it depends on the
region and the ocean physics in it.
Picture: MODIS, NASA

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

Bio-physical interactions

- We can not understand ocean biology without looking at physics

- Looking at biology helps understanding physics

References

Bradbury J: Nature's Nanotechnologists: Unveiling the Secrets of Diatoms. PLoS Biol 2/10/2004: e306. http://dx.doi.org/10.1371/journal.pbio.0020306

Resplandy, L., M. Lévy, F. d'Ovidio, and L. Merlivat (2009), Impact of submesoscale variability in estimating the air-sea CO2 exchange: Results from a model study of the POMME experiment, Global Biogeochem. Cycles, 23, GB1017, doi:10.1029/2008GB003239.

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