

An aerial photograph of a river, likely the Waterville Valley, showing intense green phytoplankton blooms. The water is dark, and the green filaments of the blooms are concentrated in swirling eddies and along the riverbanks, creating a complex, textured pattern. A thin, dark line, possibly a cable or a small boat, is visible in the upper center of the image.

The dynamical landscape of phytoplankton diversity

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Trait-based approaches to ocean life, 2015, Waterville Valley

Sensing the ocean's crop by satellite

"WHERE ARE THEY BITING?"
That familiar fisherman's question cannot yet be answered directly from space. However, the Coastal Zone Color Scanner (CZCS) aboard the Nimbus II satellite can answer the question: "Where are the regions of greatest phytoplankton concentration?" Where they are abundant, a fully developed food chain follows, including commercially valuable fish.

A CZCS image of the Atlantic, shown right, processed by a computer, shows concentrations of phytoplankton. The warmer colors absorption of certain wavelengths of light by the phytoplankton that photosynthesize. The dark strip along the coast shows the near-infrared chlorophyll signal (which areas are cloudy, land color is not significant). But it is fresh water, where dark red changes to orange, that are most productive. One, east and south of Cape Cod, like where Georges Bank, a shoal where winds and tides promote vertical mixing of water to nourish one of the world's most prolific fishing grounds. The western part of the Gulf Stream is deep blue, with lighter blue segments breaking toward Nova Scotia. The nearly perfect blue circle is a warm core, surrounded by a ring of colder water, south of it a yellow tail of more productive waters is being drawn offshore along the Gulf Stream boundary.

The CZCS is still experimental, and, as a time of budget cutting, its fate is uncertain. Yet it might prove as useful for the study of the sea as Landsat has been for continents and Tropic for weather forecasting.



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IMAGE © 1981 NATIONAL GEOGRAPHIC SOCIETY



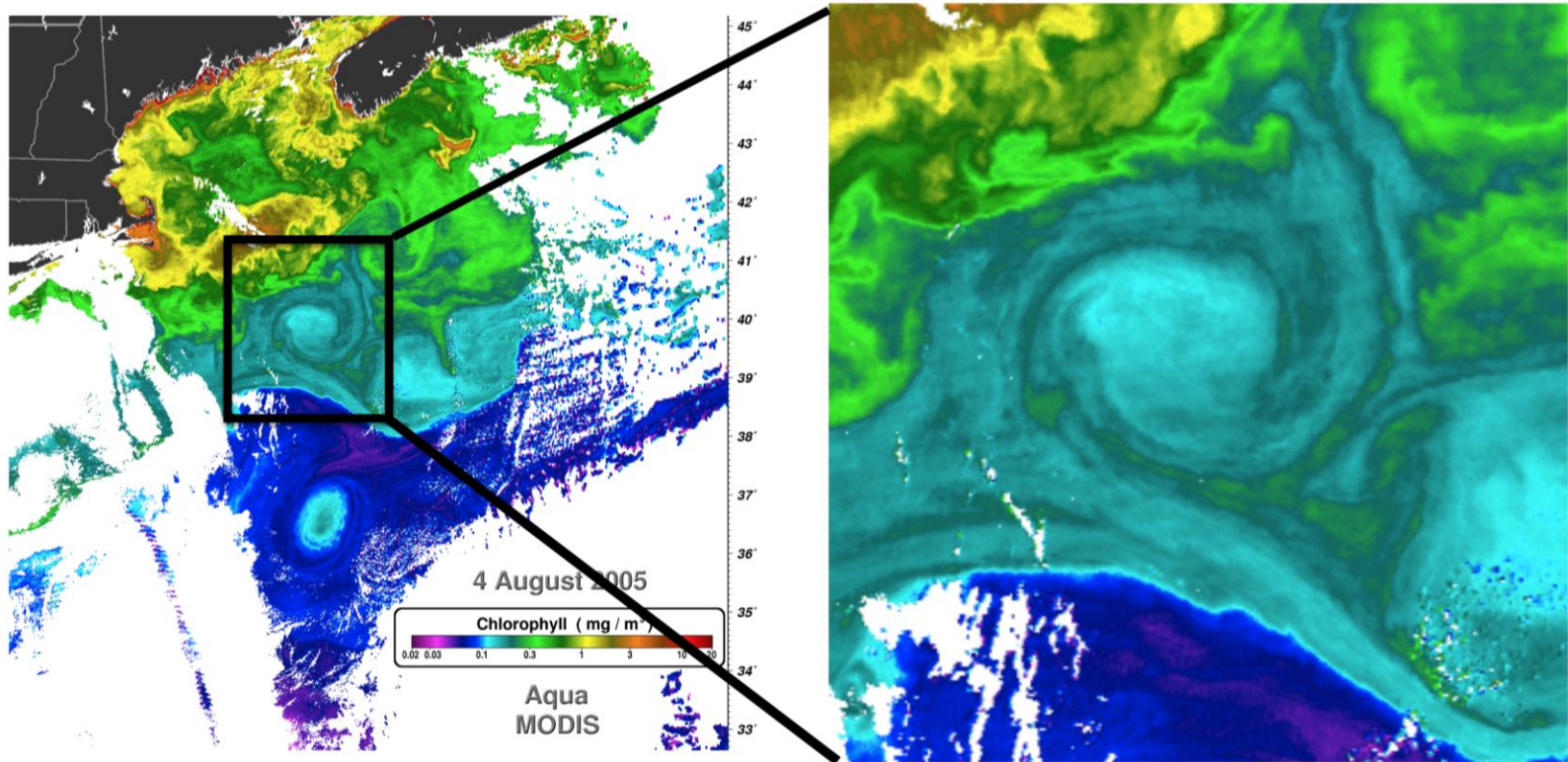
CZCS in National Geographic, 1981



Mesoscale turbulence

Eddies

Fronts



Mesoscale
100 km

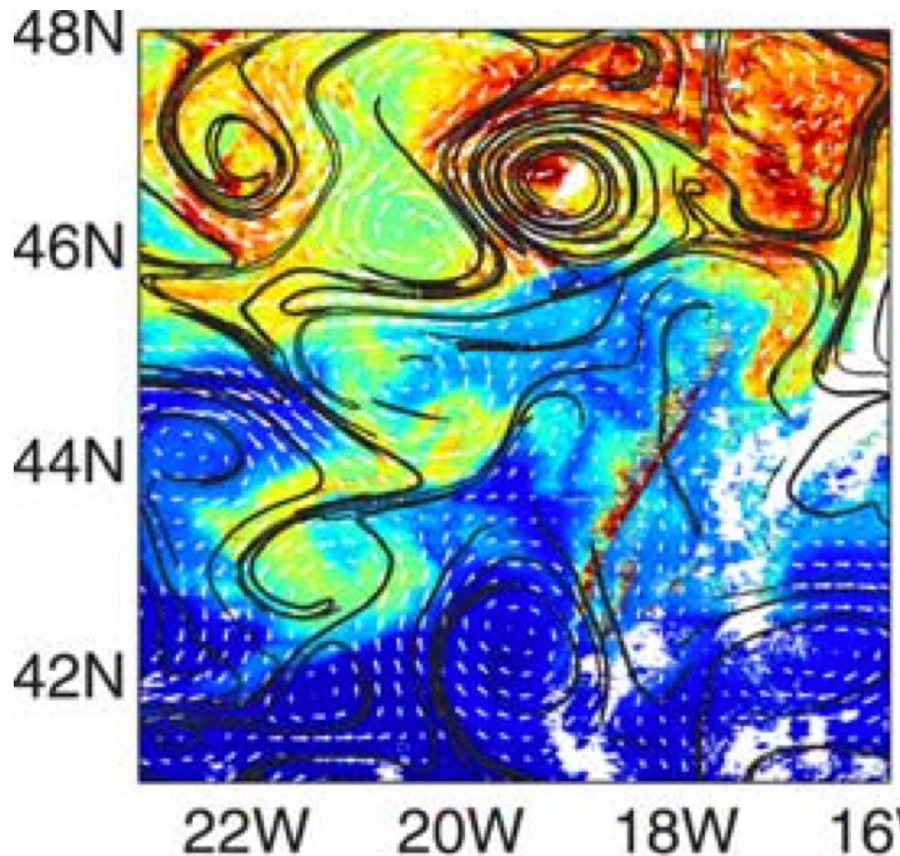
Submesoscale 1-10 km

Months

Days

Synergy with other satellite products: Chl and Altimetry

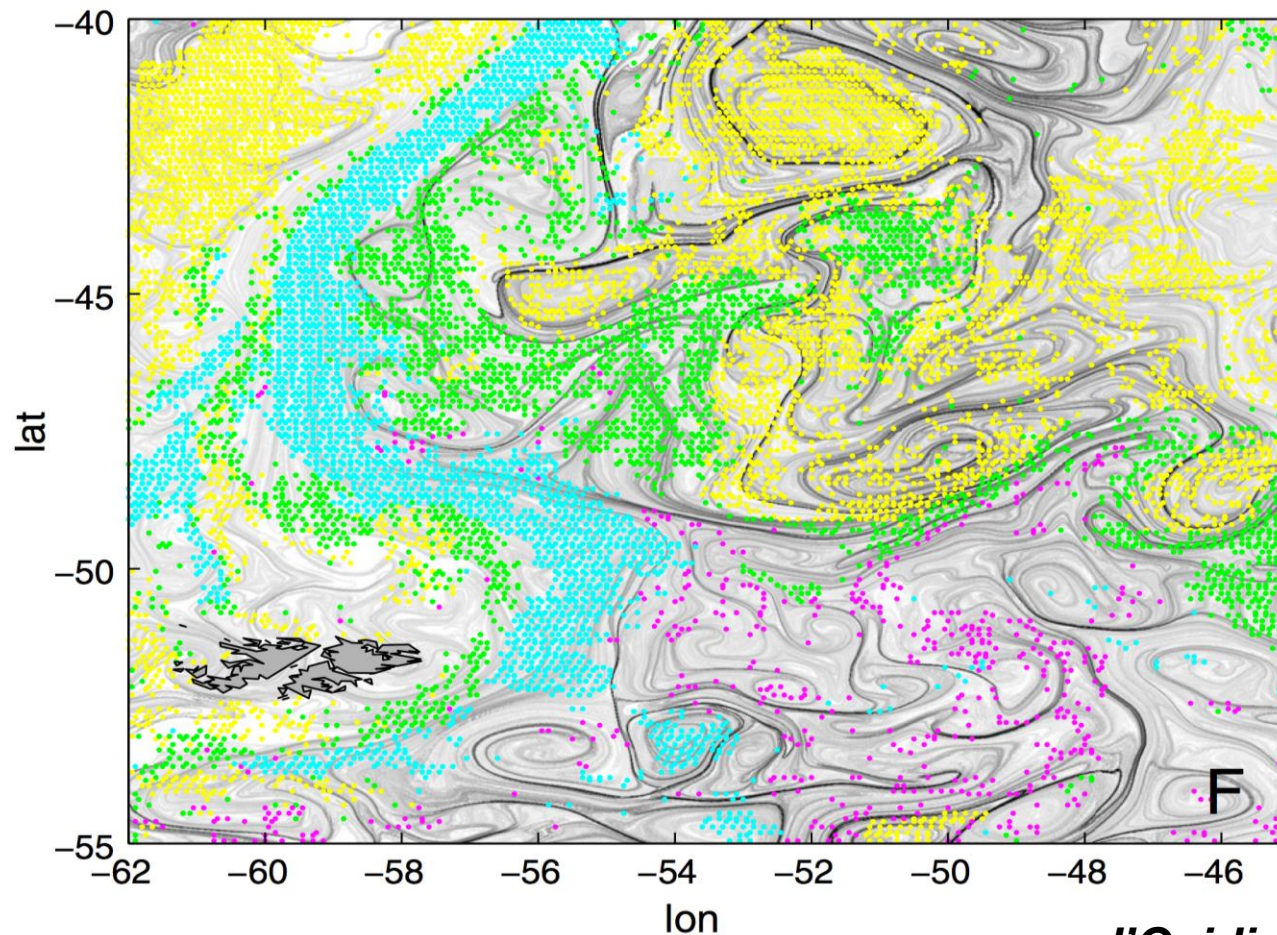
Chl + FSLE



The total Chla landscape is shaped by the currents

Lehahn et al, 2007, JGR

Optical anomalies from PHYSAT (Phyto types) + FSLE



d'Ovidio et al, 2010, PNAS

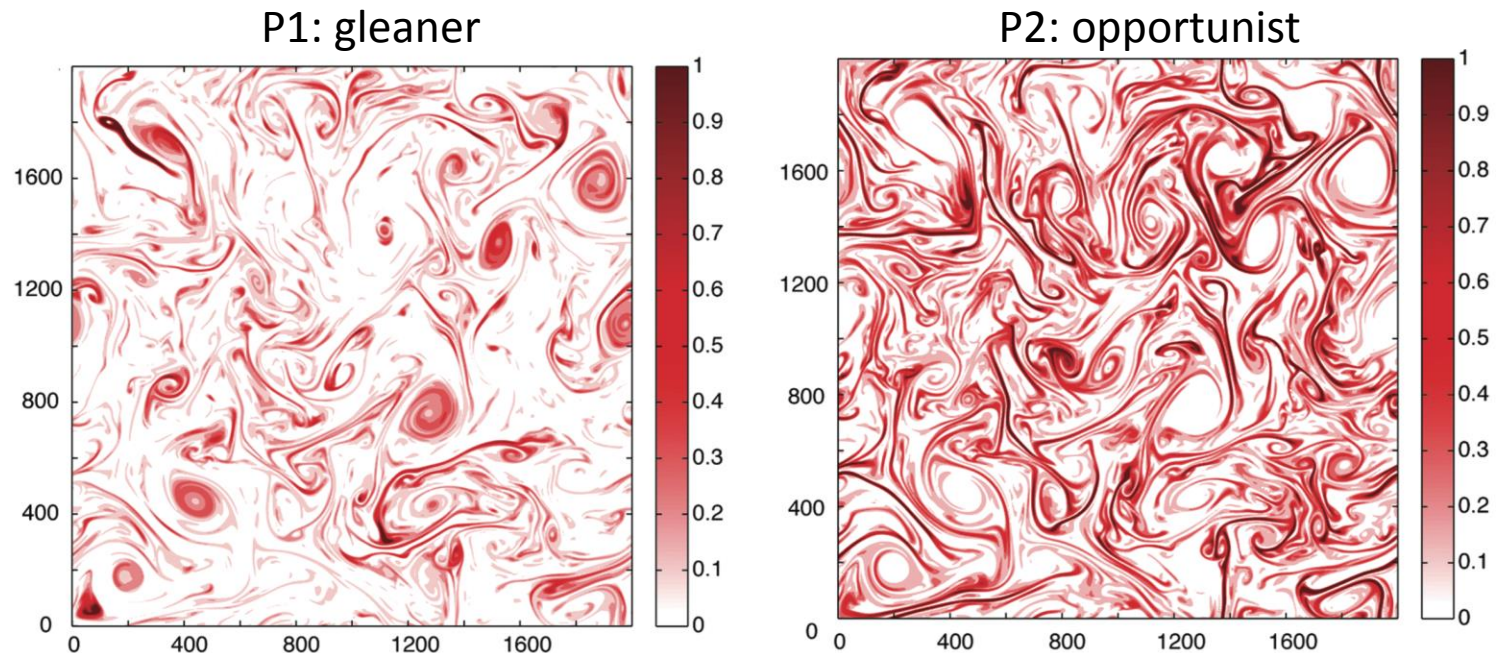
Meso currents shape the optical anomaly landscape

Questions raised by these observations

- Is phytoplankton diversity shaped by mesoscale turbulence ?
- How are different phytoplankton types (gleaners/opportunists) distributed within eddies and fronts ?
- Consequences on terms of in-situ observations of biodiversity ?

Hypothesis:

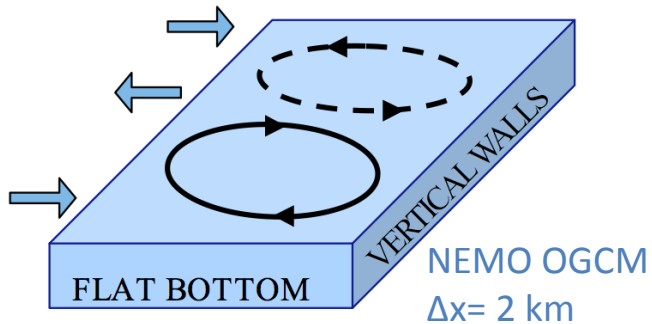
- Phytoplankton community described with 2 types
- No environmental gradient
- No seasonality



Conclusions:

Gleaner dominates in eddies, the Opportunist dominates in fronts
The two types co-exist in fronts

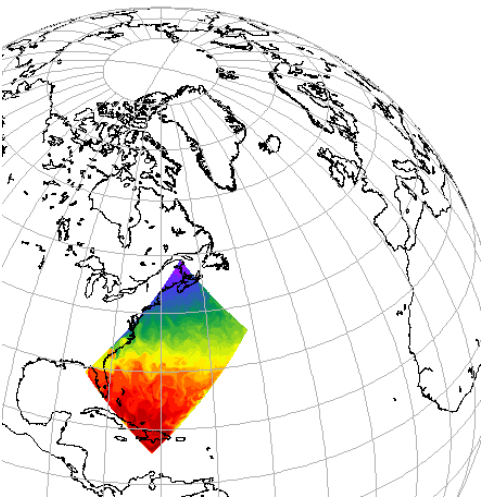
Submesoscale model



+

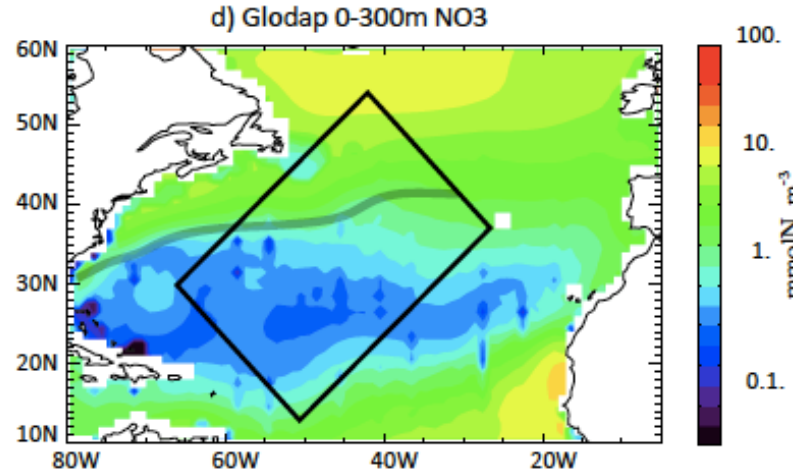
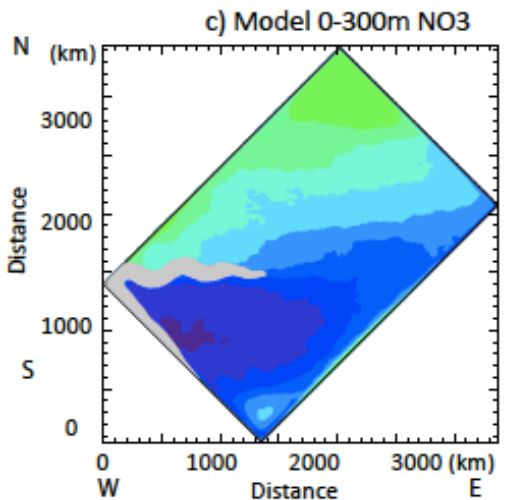
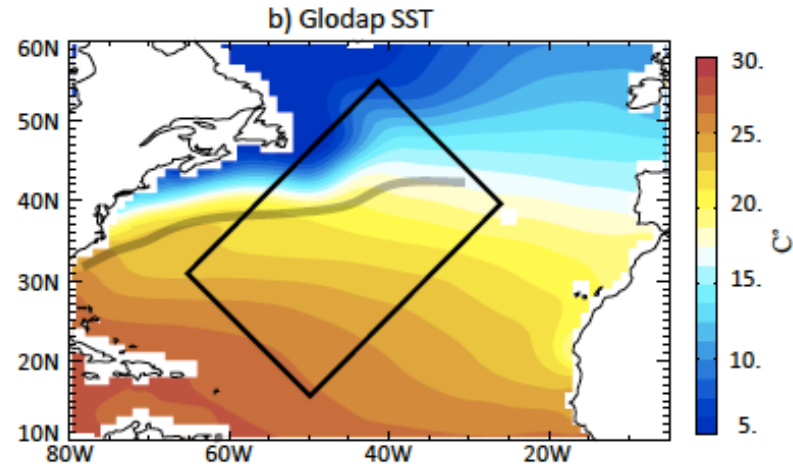
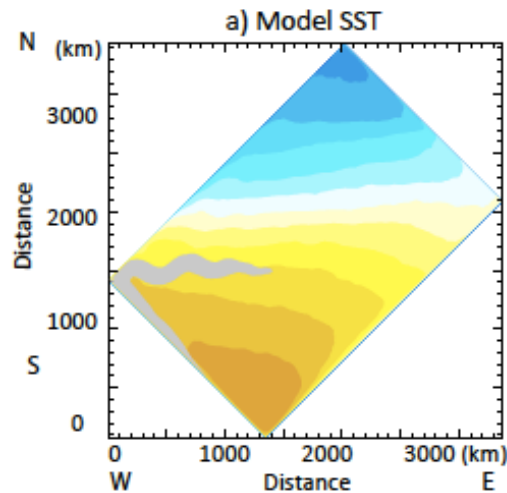
DARWIN model
100 phytoplankton types

+ Seasonally varying
Environmental gradients
(Temperature, Nutrient)

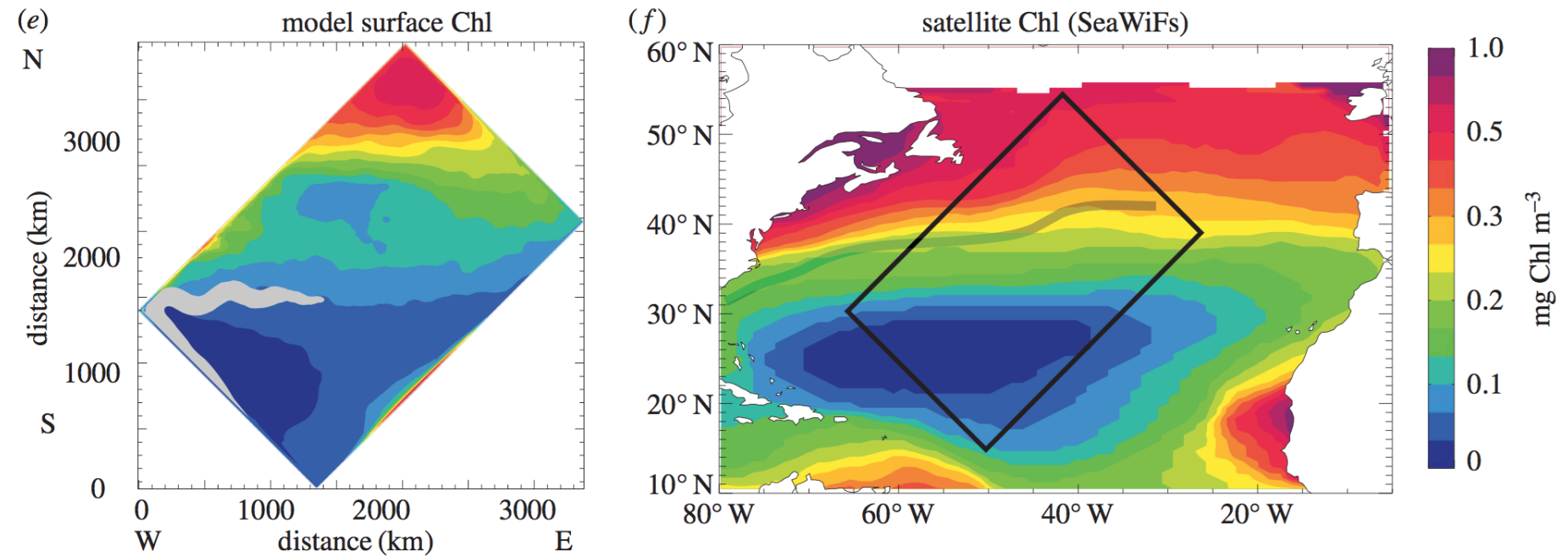


MIT GCM

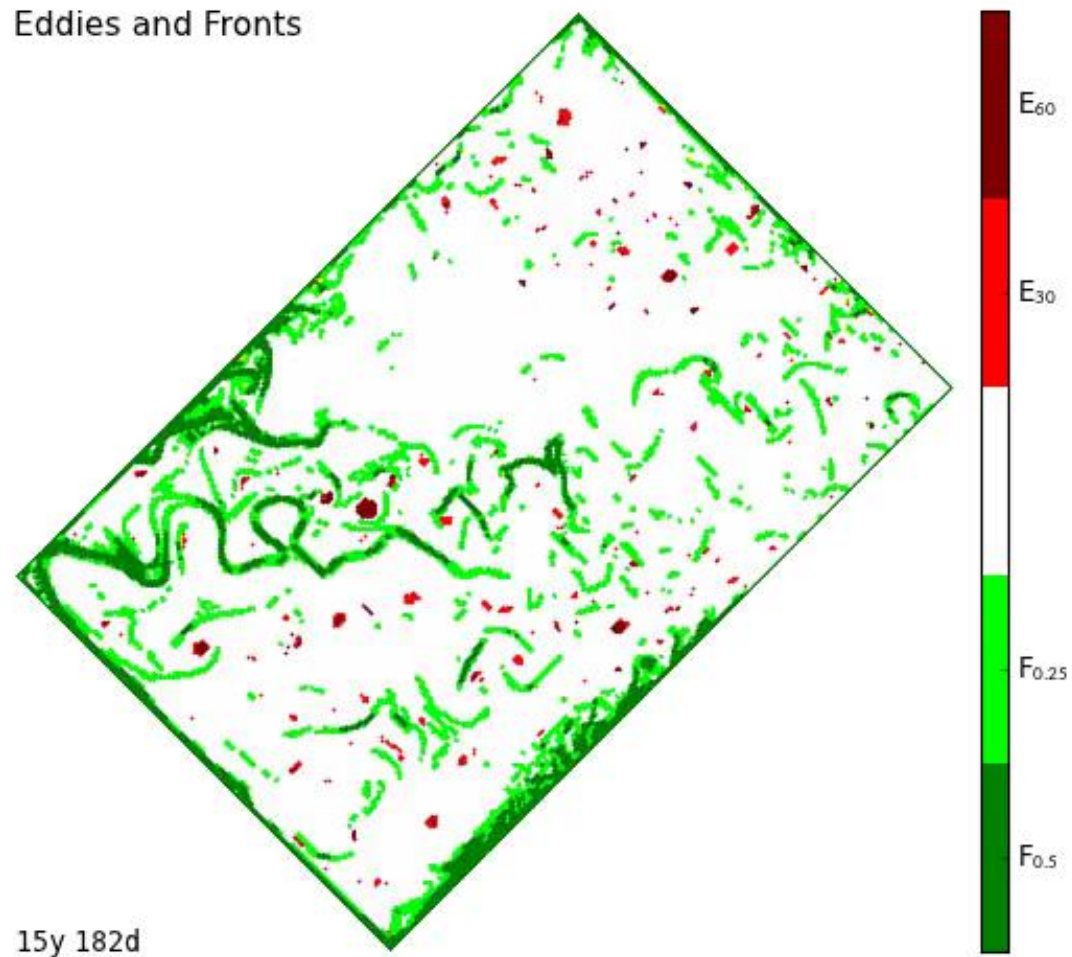
Environmental gradients



Total Chla distribution annual mean



Identification of mesoscale eddies and submesoscale fronts



15y 2d

Opp17
0.126

Opp8
0.034

Opp14
0.072

Opp10
0.156

Glr31
0.007

Glr19
0.009

Glr16
0.061

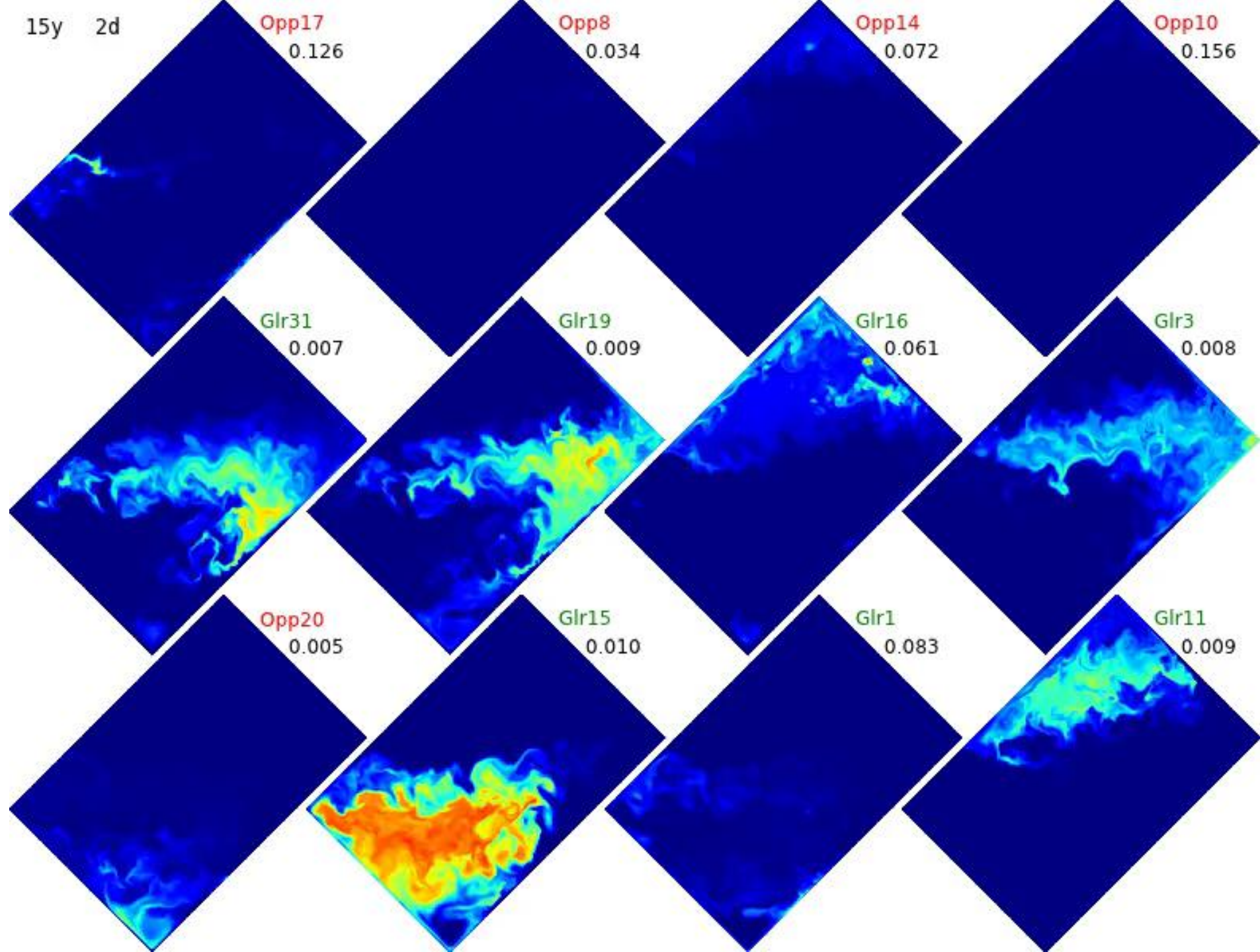
Glr3
0.008

Opp20
0.005

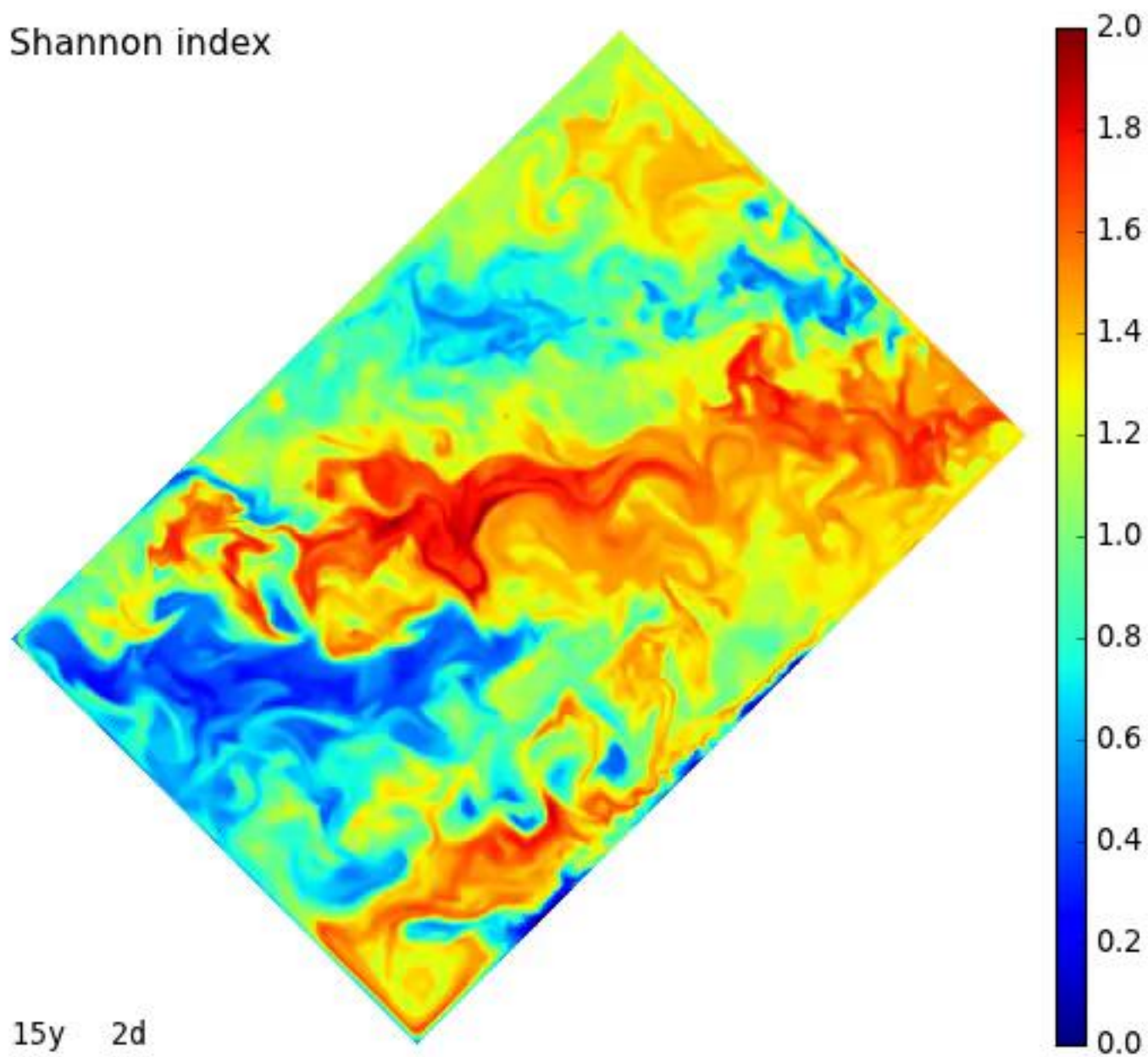
Glr15
0.010

Glr1
0.083

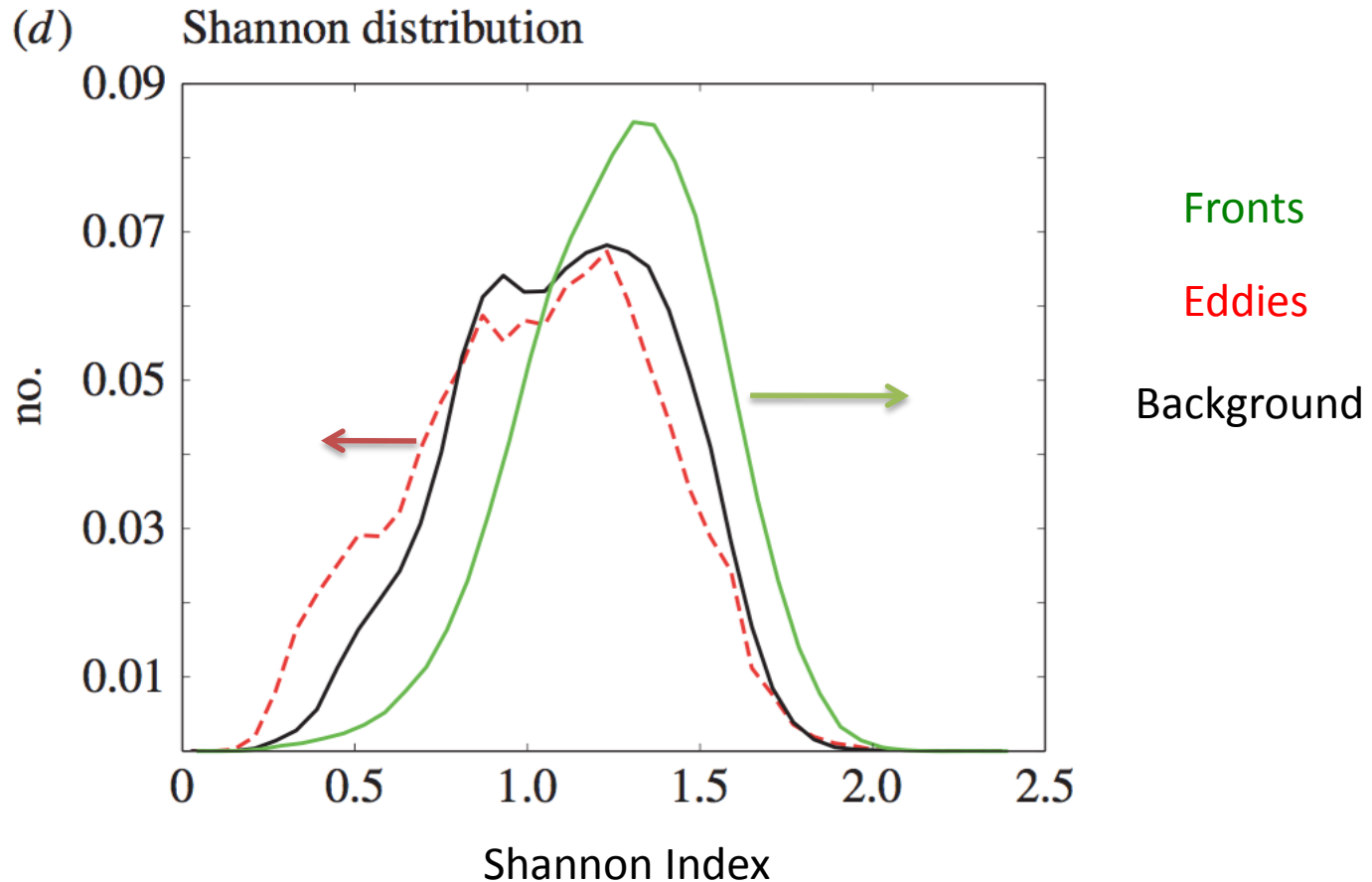
Glr11
0.009



Shannon index



15y 2d

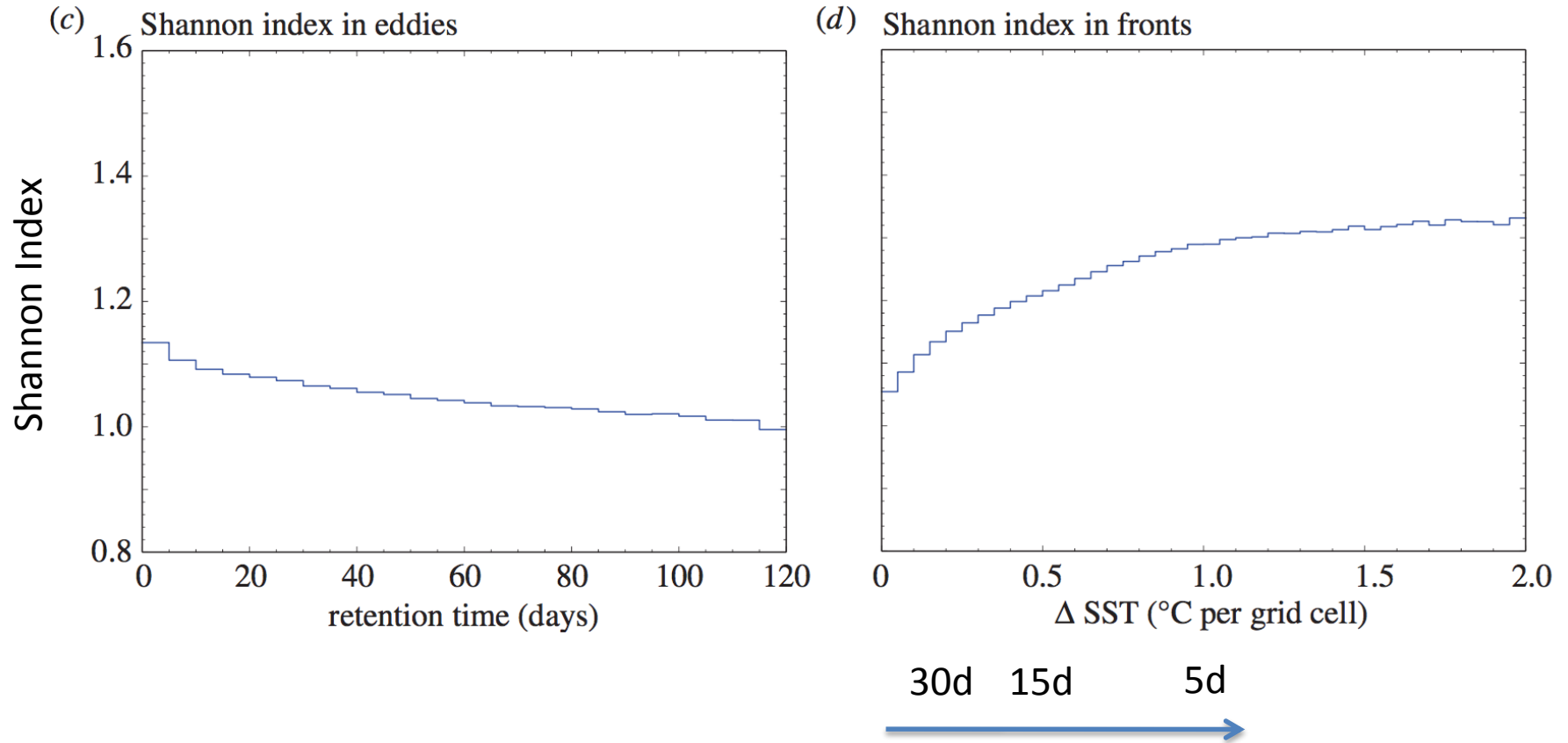


Statistically:

More ability for coexistence at submesoscale fronts

Less ability for co-existence in the core of mesoscale eddies

Time scale

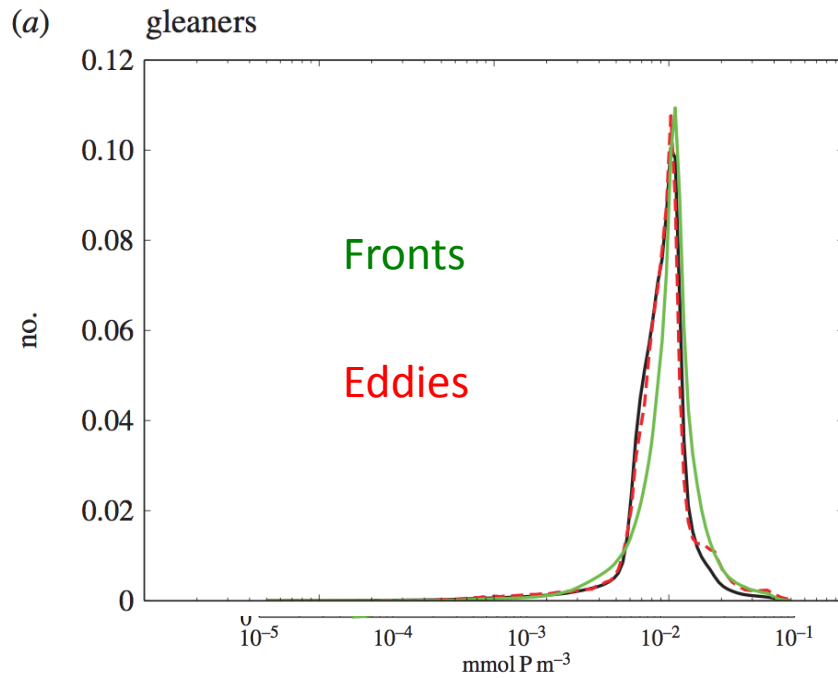


Short time scale: more coexistence

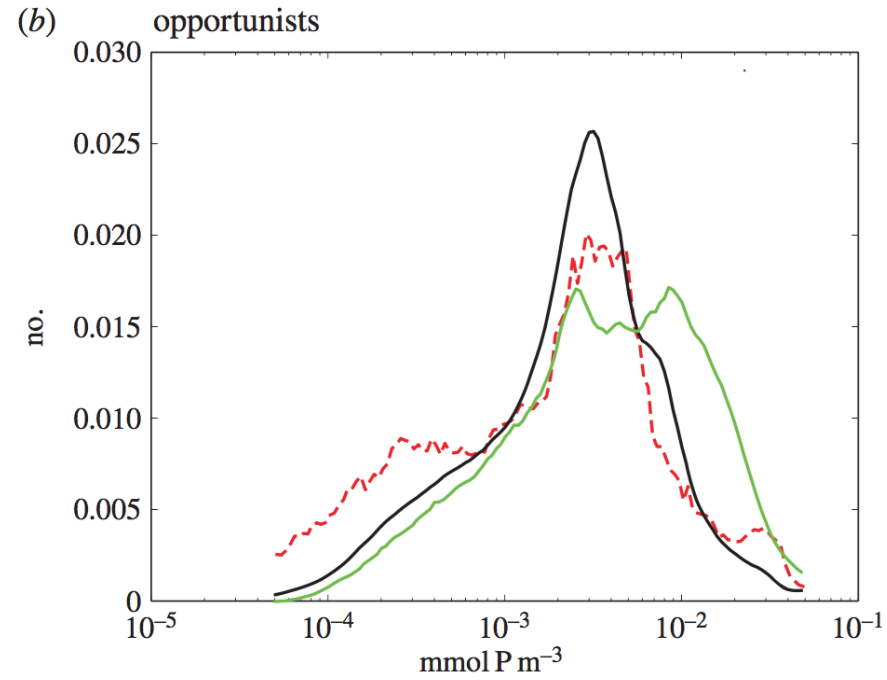
Long time-scale: less coexistence

Related to competitive exclusion

Statistics within eddies and fronts



Gleaners



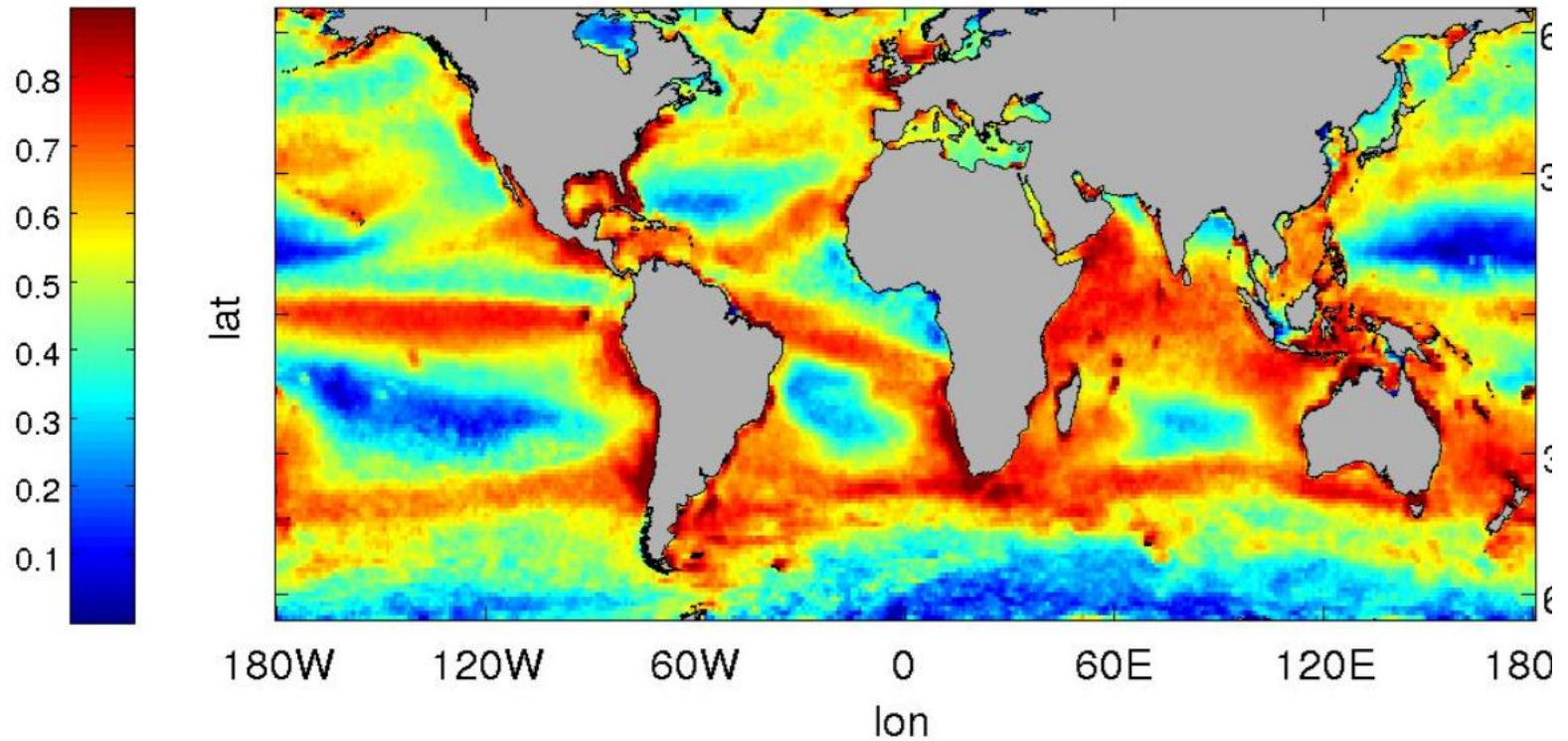
Opportunists

Conclusions

- Things move in the ocean !
- The phytoplankton diversity landscape is very dynamic and shaped by eddies and fronts at time scales of days to months
- Time scales of mesoscale turbulence interact with the time scales of competitive exclusion
- Challenging to evaluate biodiversity from point measurements: Time or space variations ?
Need for interdisciplinary approach
- Potential of satellite ocean color by combining information on local mixing and group distribution

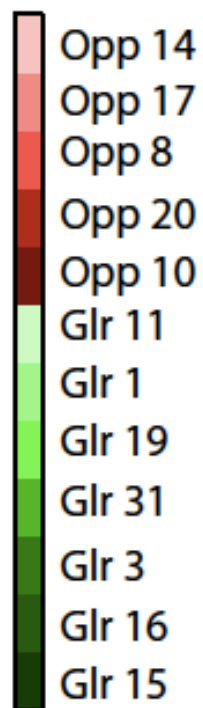
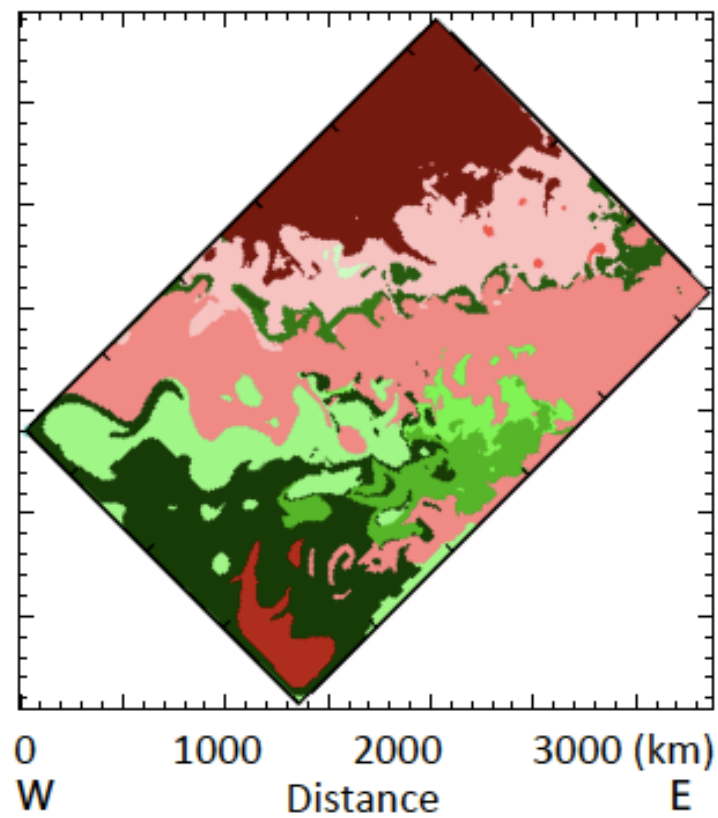
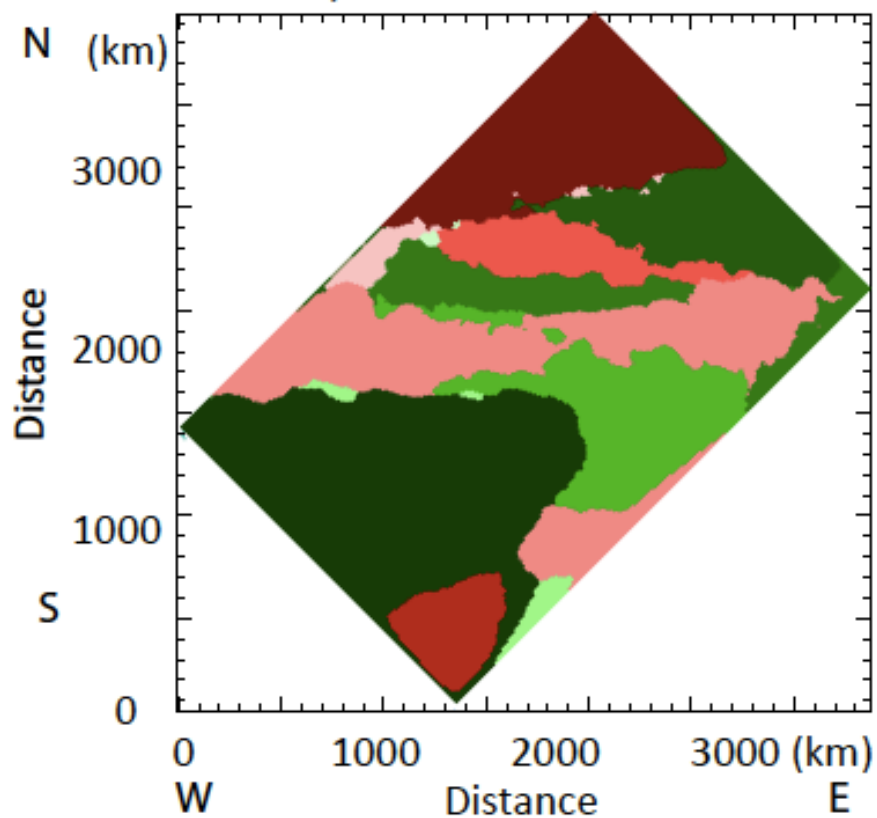
Levy et al., 2015, Royal Society Interface

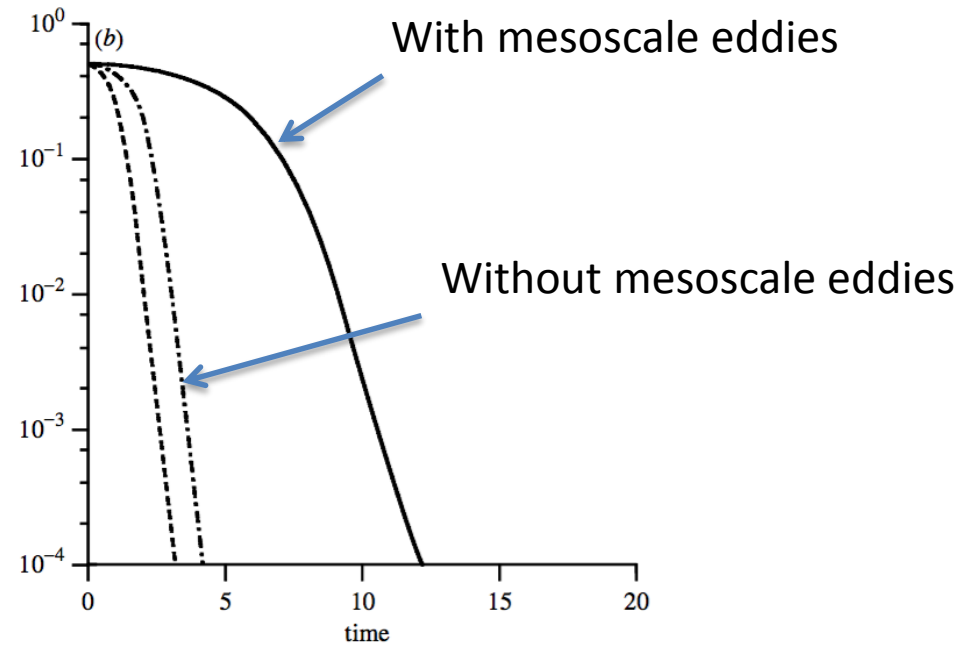
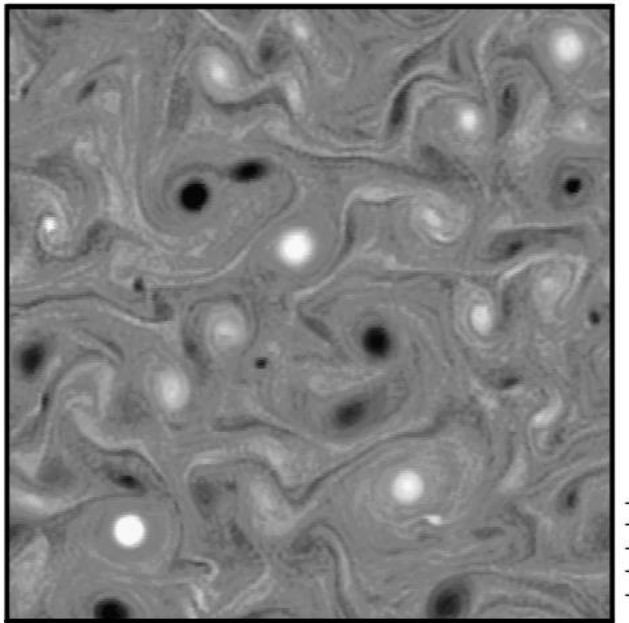
Satellite biodiversity index based on PHYSAT



a) Annual niches

b) Instantaneous niches





- Phytoplankton community described with 2 types
- No environmental gradient
- No seasonality
- One type dominates over the other

The less fitted type is sheltered by eddies

Bracco et al, 2000