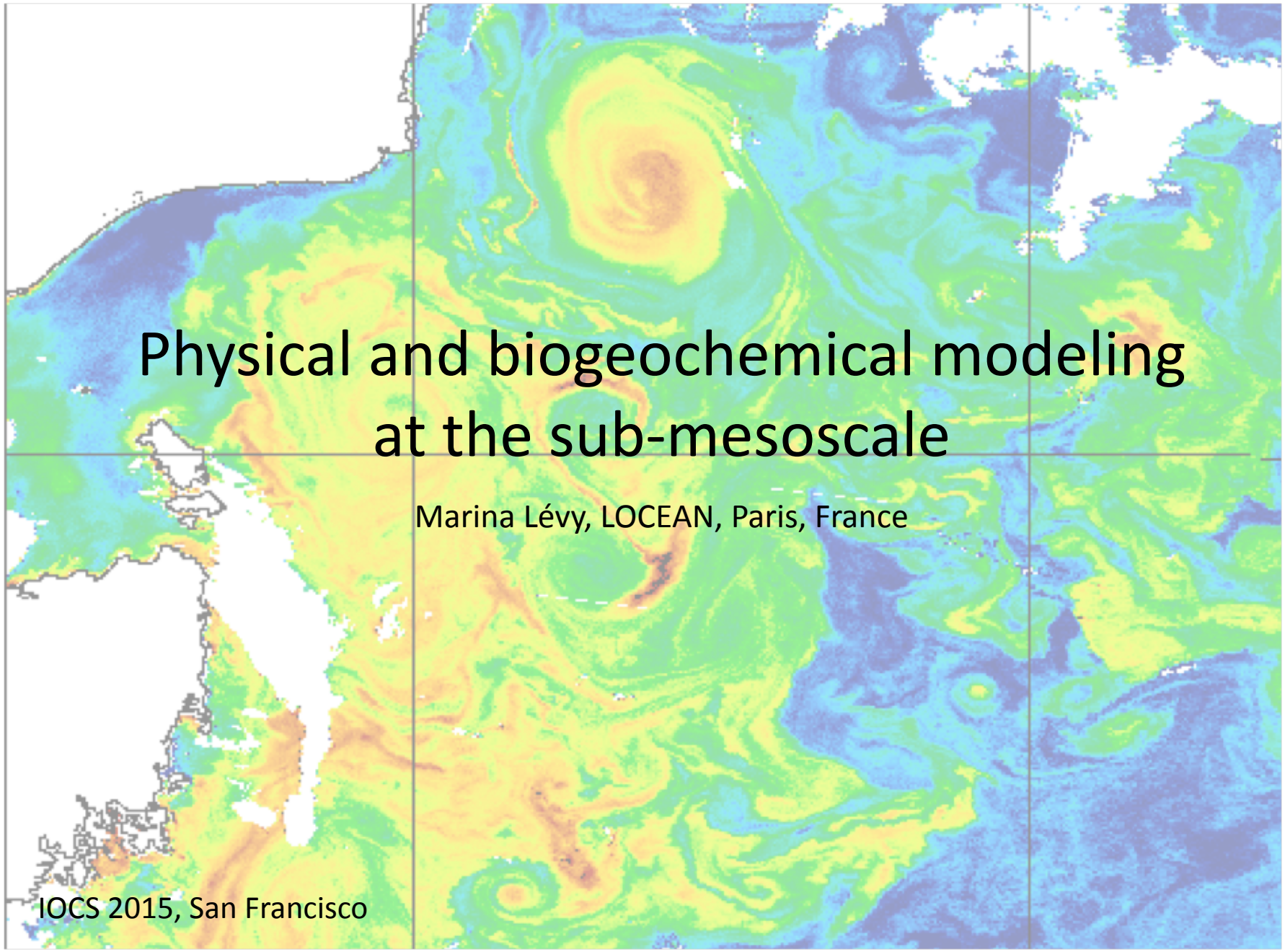
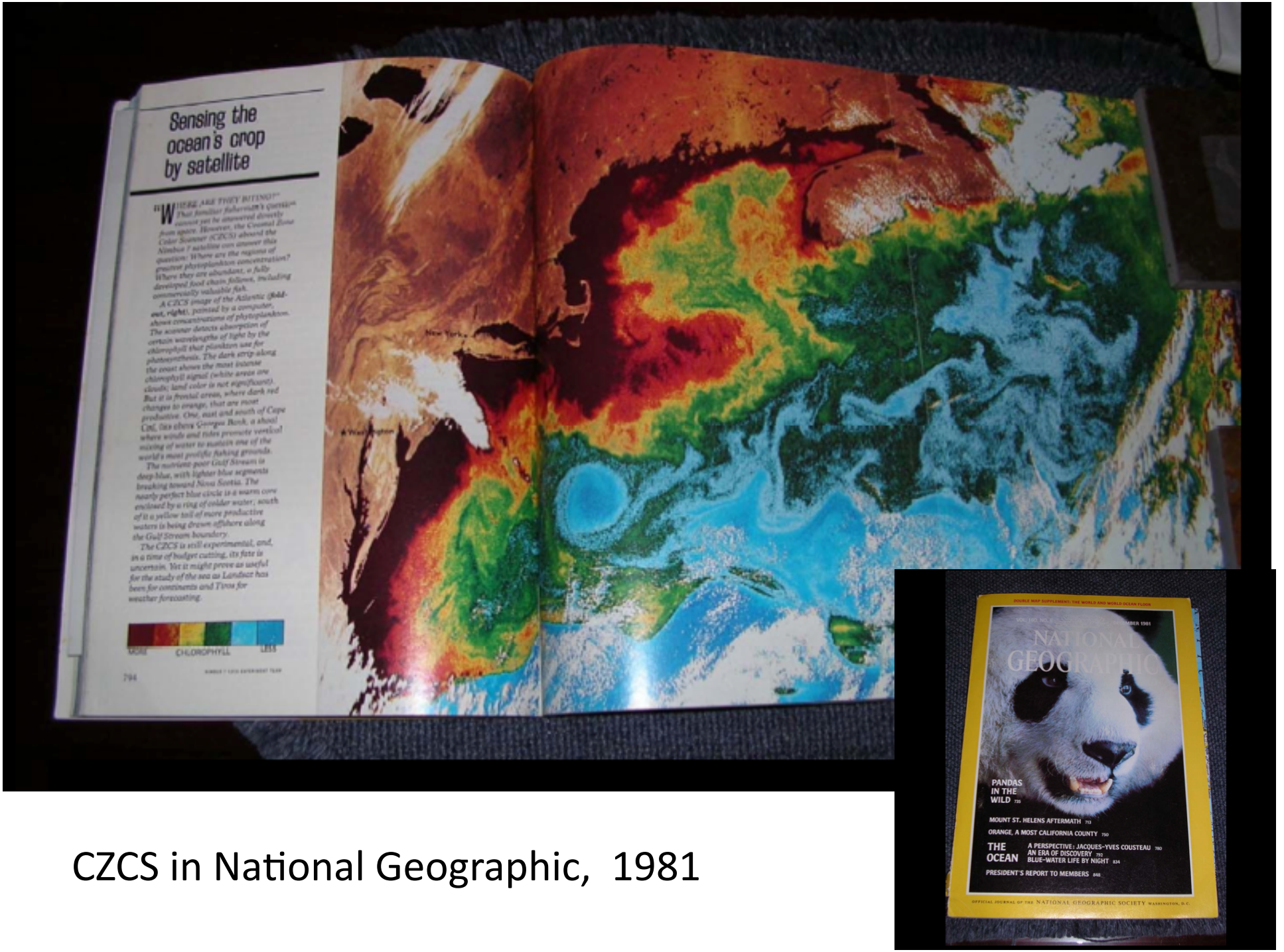


Physical and biogeochemical modeling at the sub-mesoscale

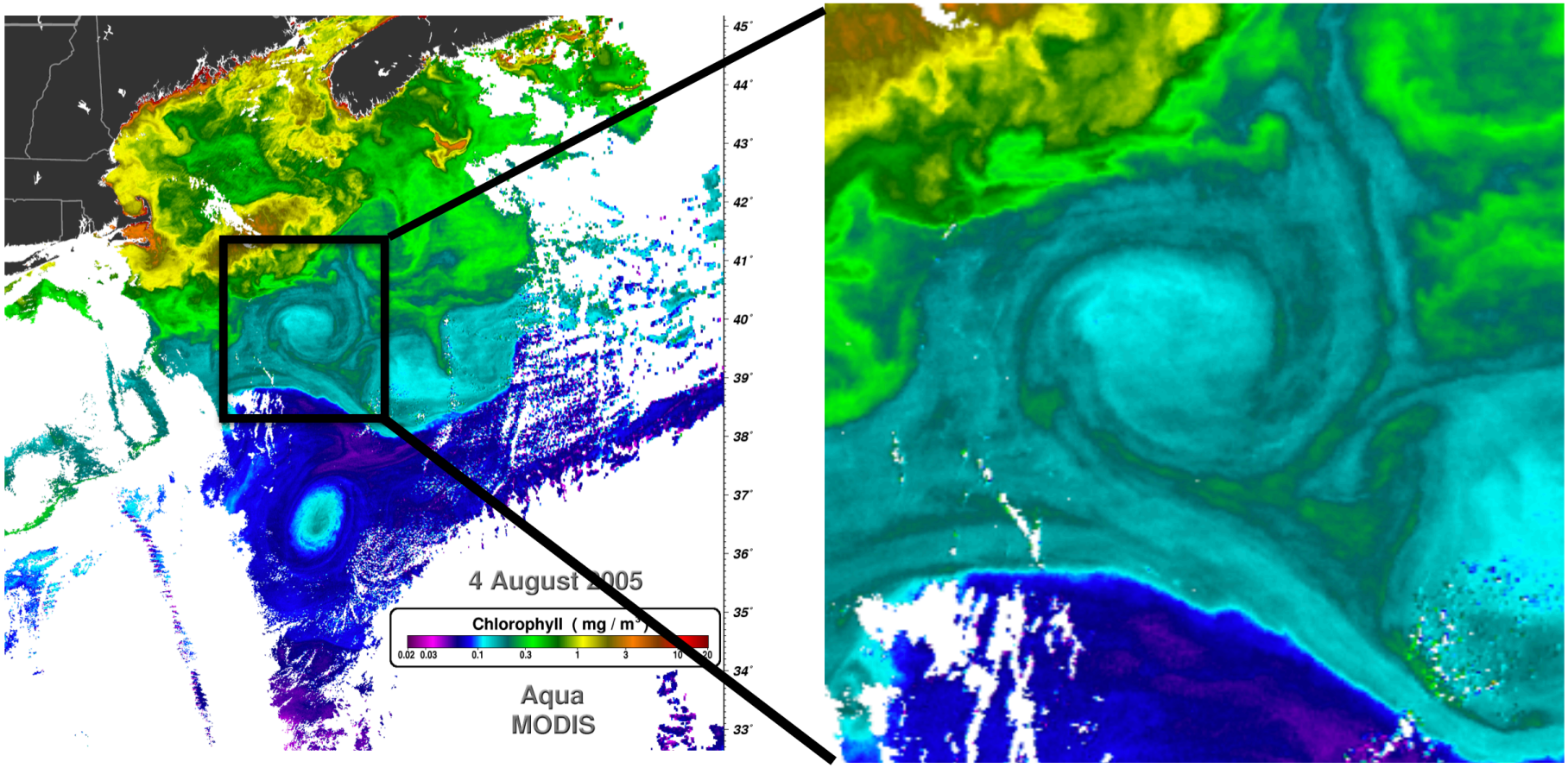
Marina Lévy, LOCEAN, Paris, France

IOCS 2015, San Francisco



CZCS in National Geographic, 1981

Mesoscale turbulence



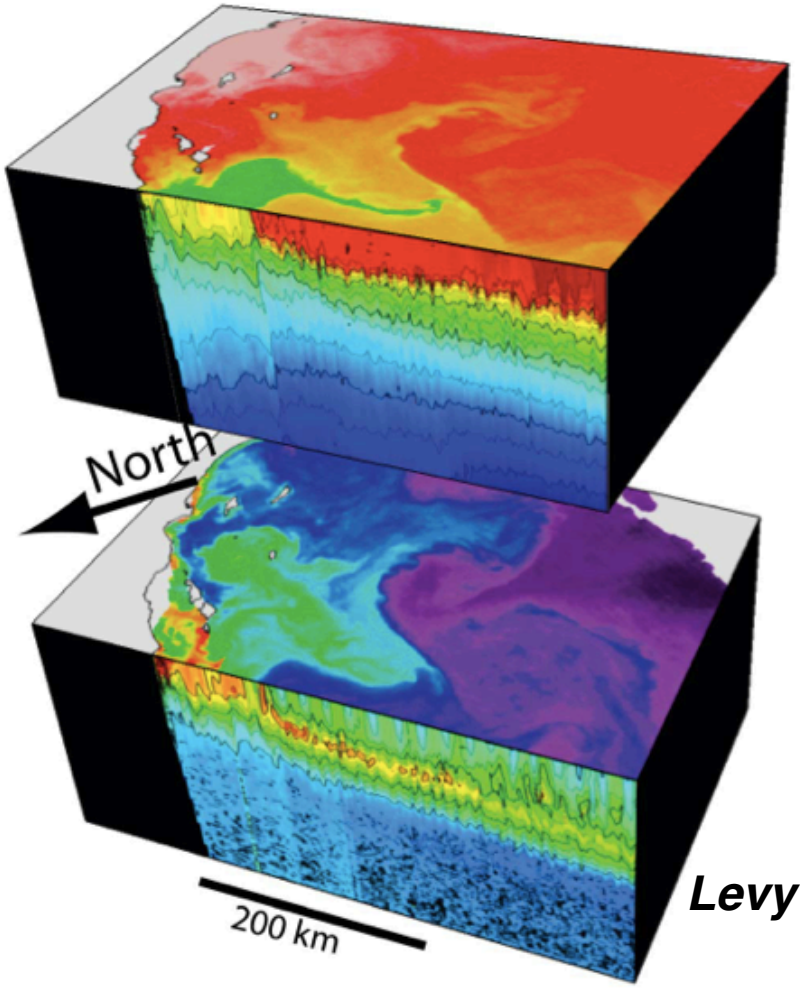
Mesoscale
100 km

Months

Submesoscale 1-10 km

Days

Synergy with other satellite and in-situ products: Chl and SST



MODIS SST + in situ Glider

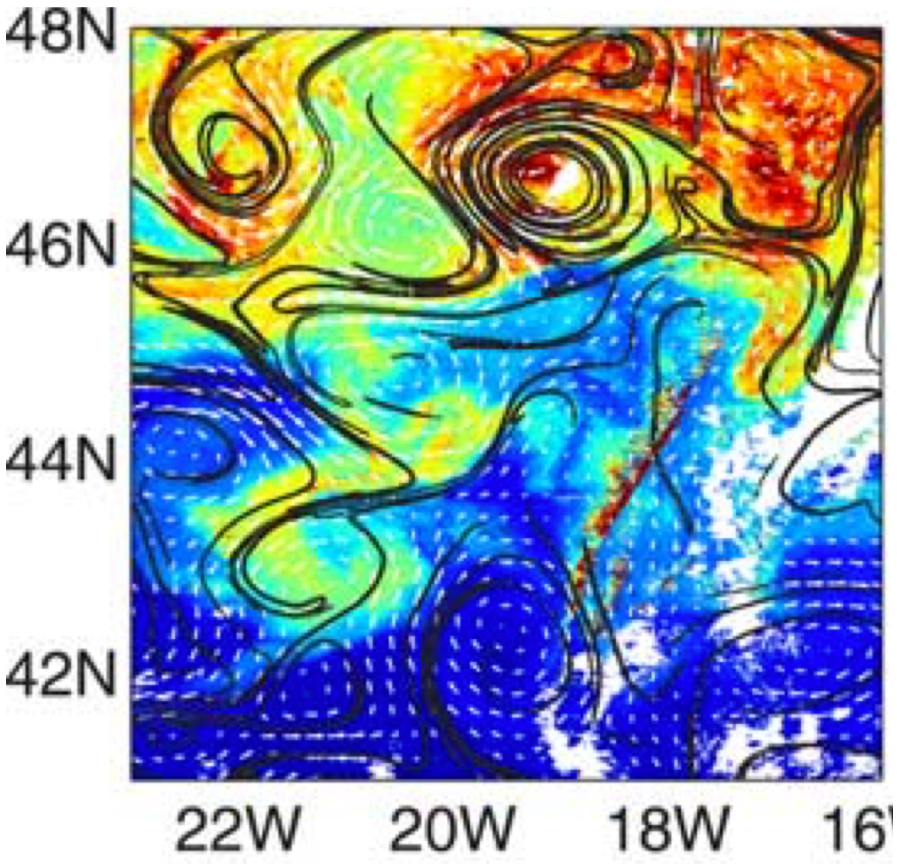
MODIS Chl+ in situ Glider

Levy et al, 2012, GRL

Meso and submesoscale Chl and SST patterns coincide

Synergy with other satellite products: Chl and Altimetry

Chl + FSLE



Submesoscale phytoplankton patterns and transport fronts coincide

Lehahn et al, 2007, JGR

Questions raised by these observations

- What are the drivers of this variability ?
- Does it induce inter-annual variability of the bloom ?
- Does it increase the ability of phytoplankton co-existence ?
- What is its contribution to biogeochemical (N, C, O) budgets ?

Sub-mesoscale models

- Resolving sub-mesoscales requires primitive-equation ocean models at high horizontal resolution (order 1 km)

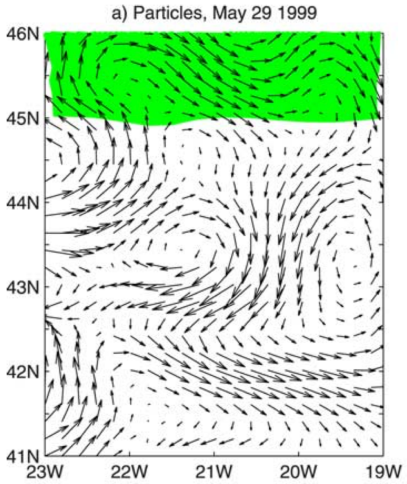
- This requires 10^5 more computer ressources than running coarse resolution (1°) IPCC-like models

- For this reason, submesoscale models are either very regional or with highly idealized geometry

Questions raised by these observations

- What are the drivers of this variability ?
- Does it induce inter-annual variability of the bloom ?
- Does it increase the ability of phytoplankton co-existence ?
- What is its contribution to biogeochemical (N, C, O) budgets ?

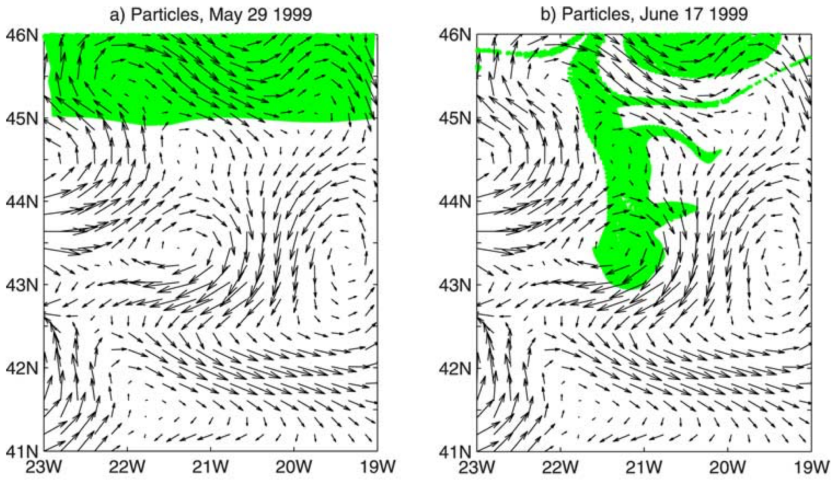
Drivers: stirring



Advection of a patch of dye with geostrophic velocity (AVISO)

Lehahn et al, 2007, JGR

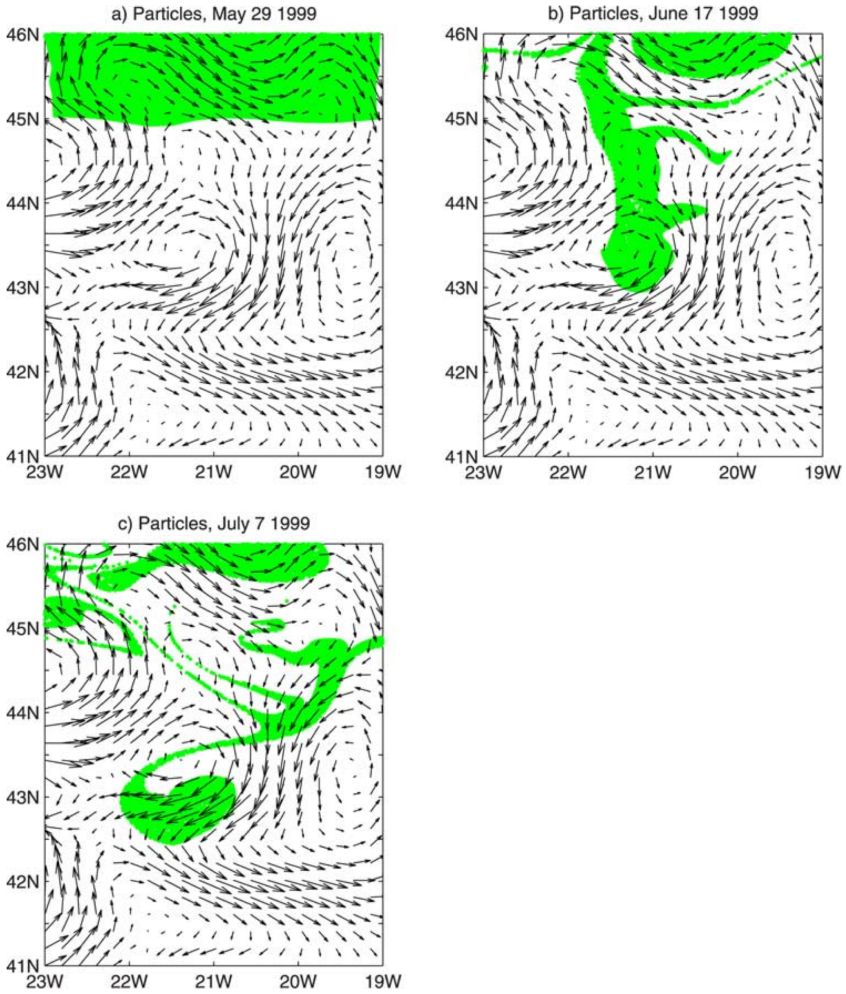
Drivers: stirring



Advection of a patch of dye with geostrophic velocity (AVISO)

Lehahn et al, 2007, JGR

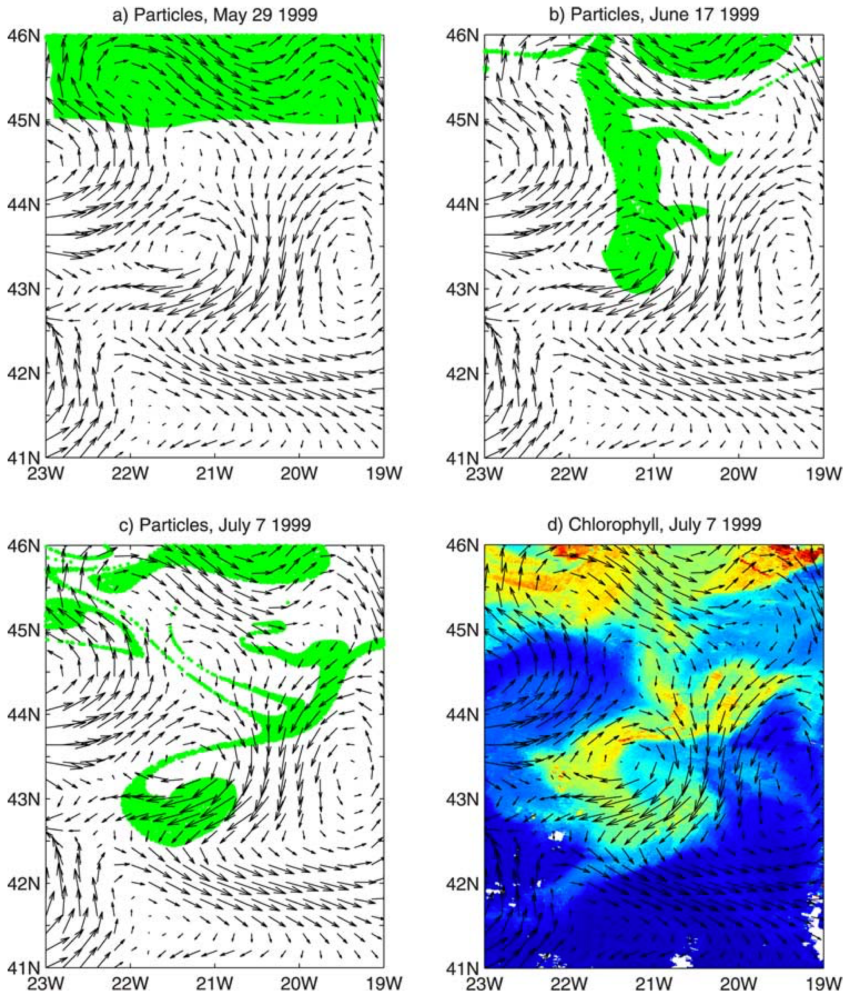
Drivers: stirring



Advection of a patch of dye with geostrophic velocity (AVISO)

Lehahn et al, 2007, JGR

Drivers: stirring



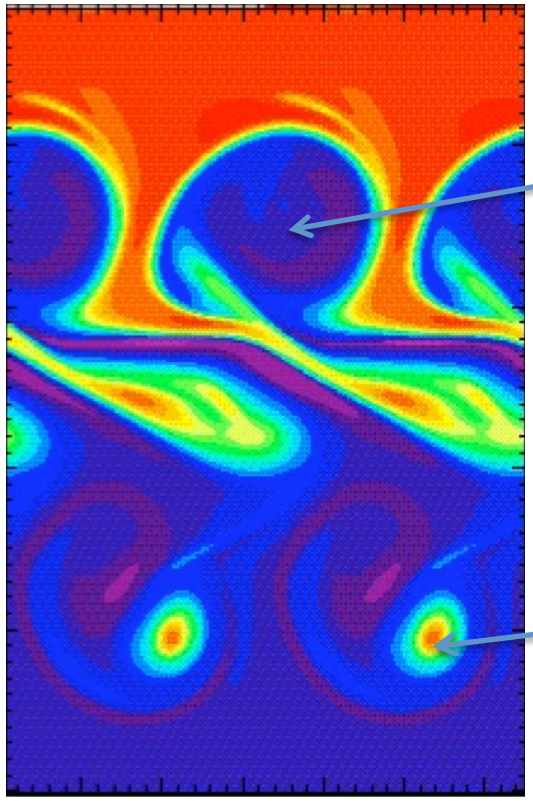
Advection of a patch of dye with geostrophic velocity (AVISO)

Leads to observed patterns in Chla

Lehahn et al, 2007, JGR

Drivers: vertical velocities

SST



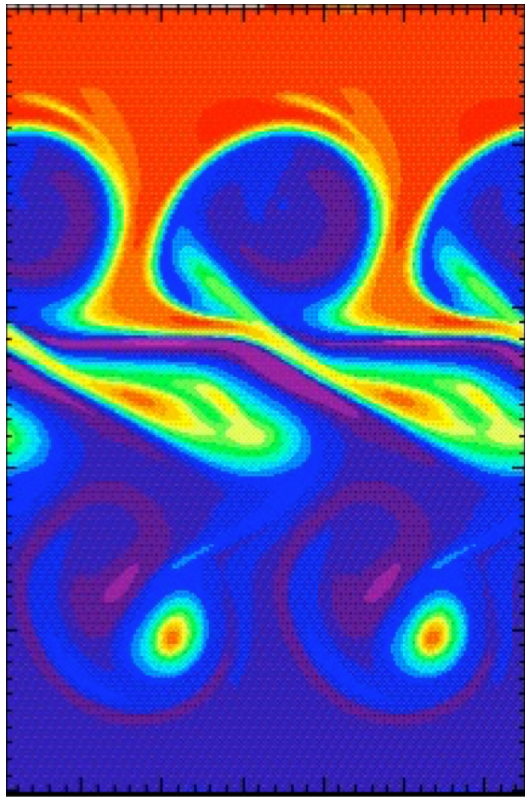
Warm Anticyclone

Cold cyclone

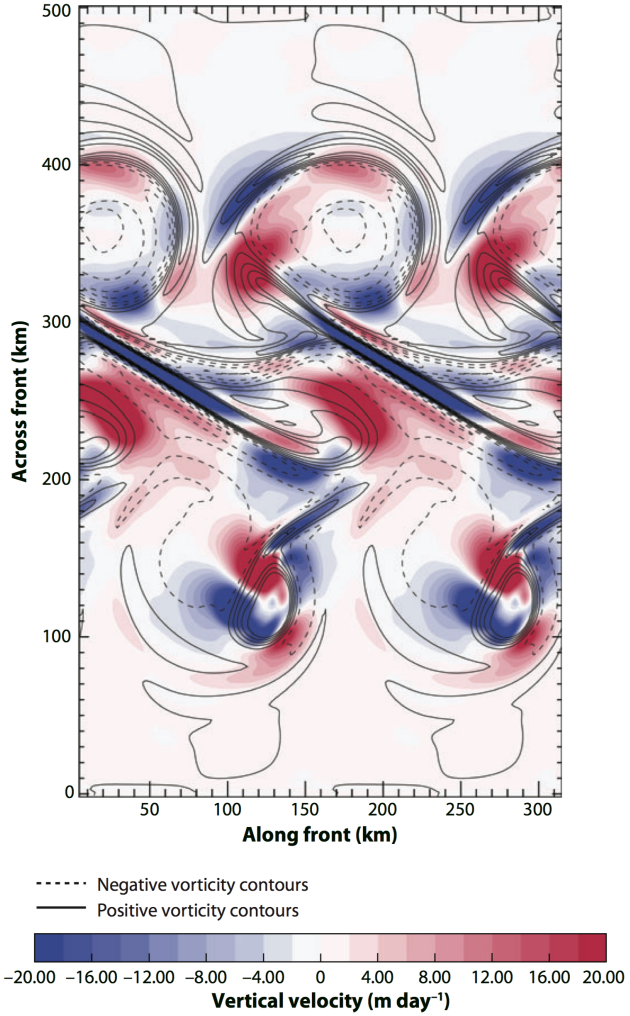
Levy et al, 2001, JMR

Drivers: vertical velocities

SST



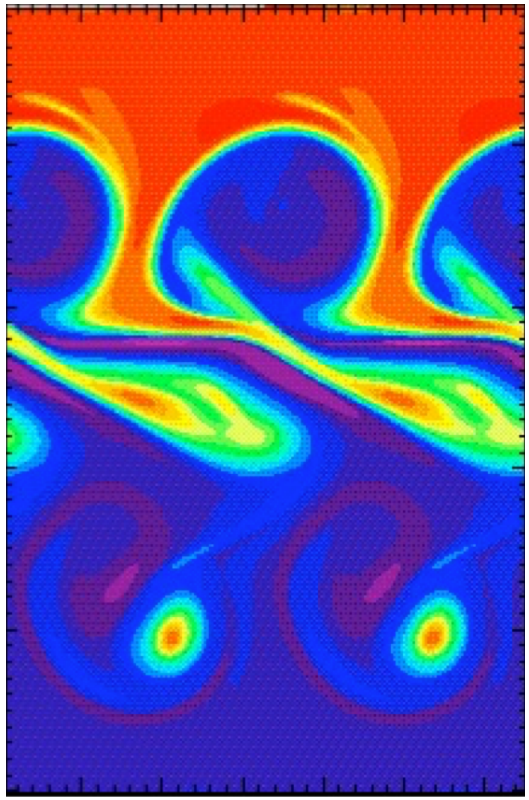
W



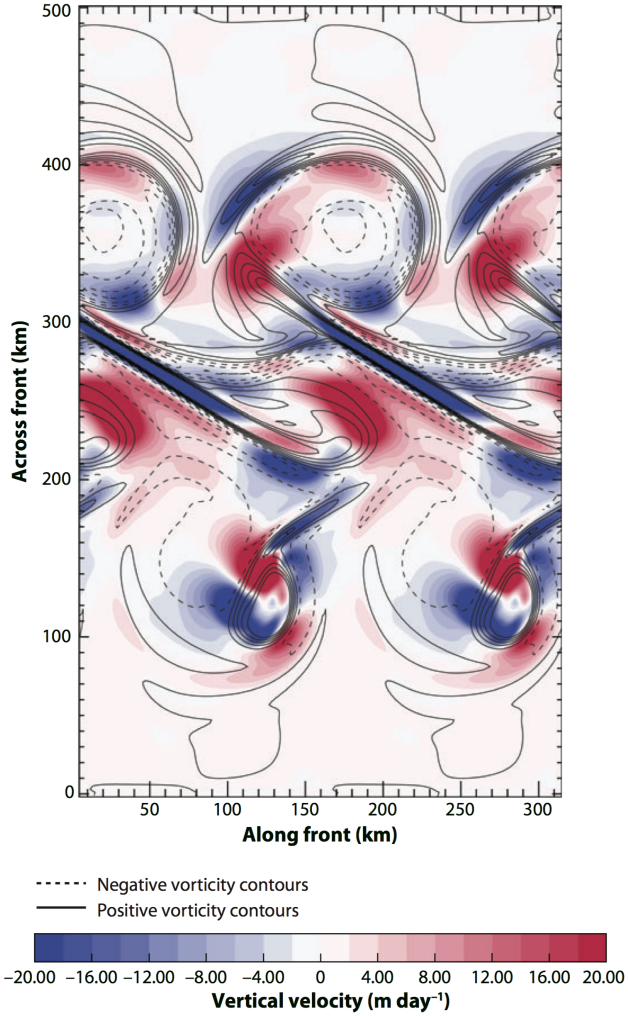
Levy et al, 2001, JMR

Drivers: vertical velocities

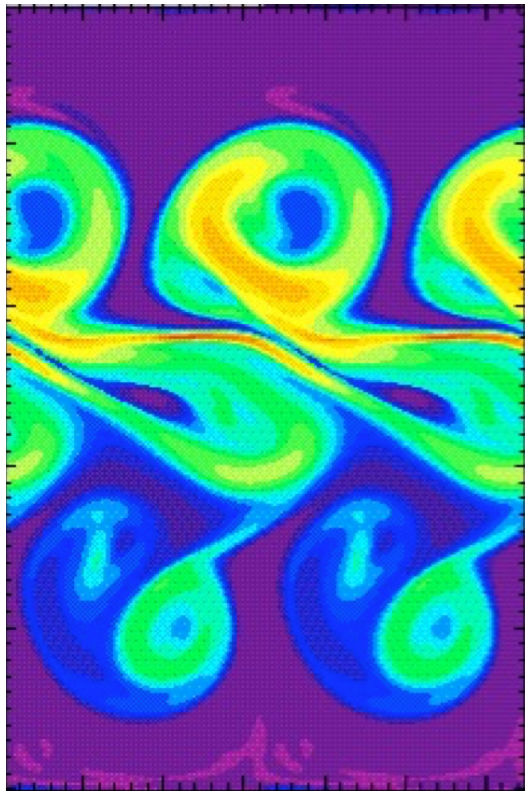
SST



W

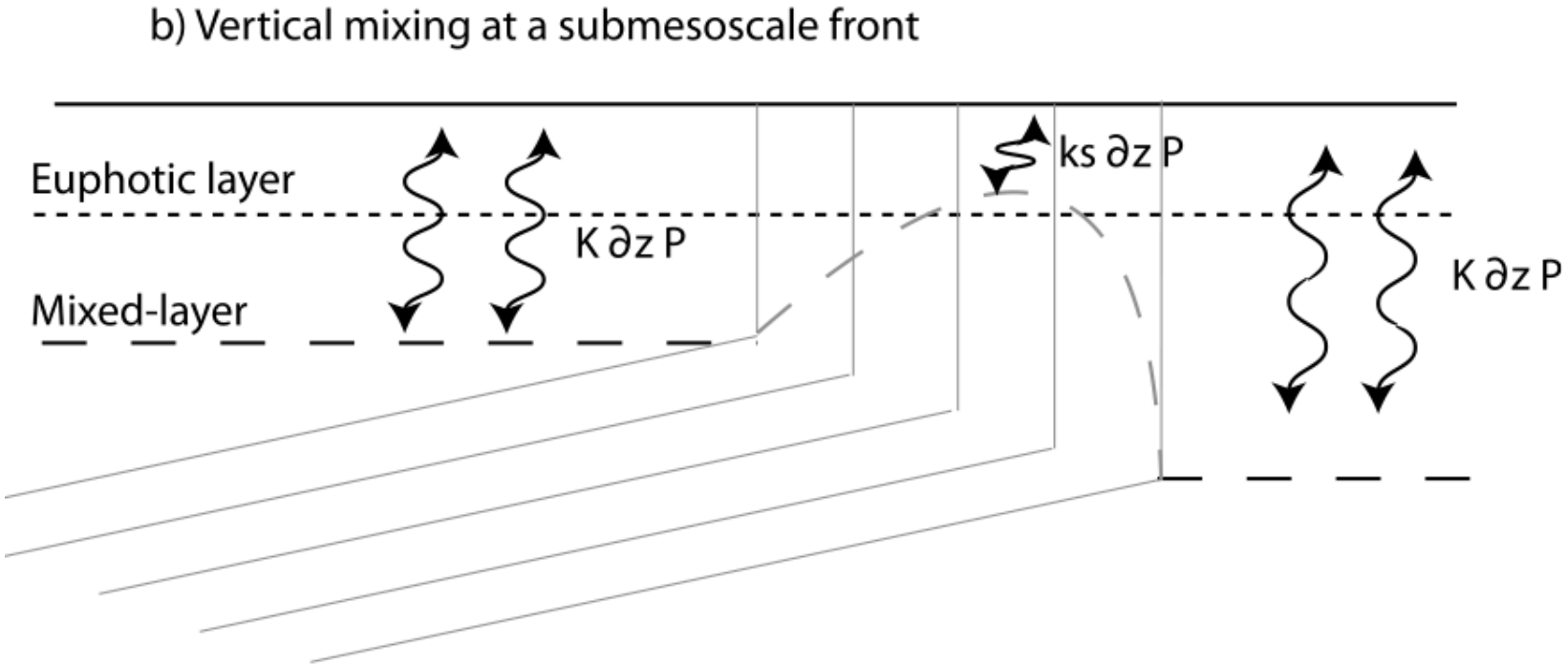


Chla



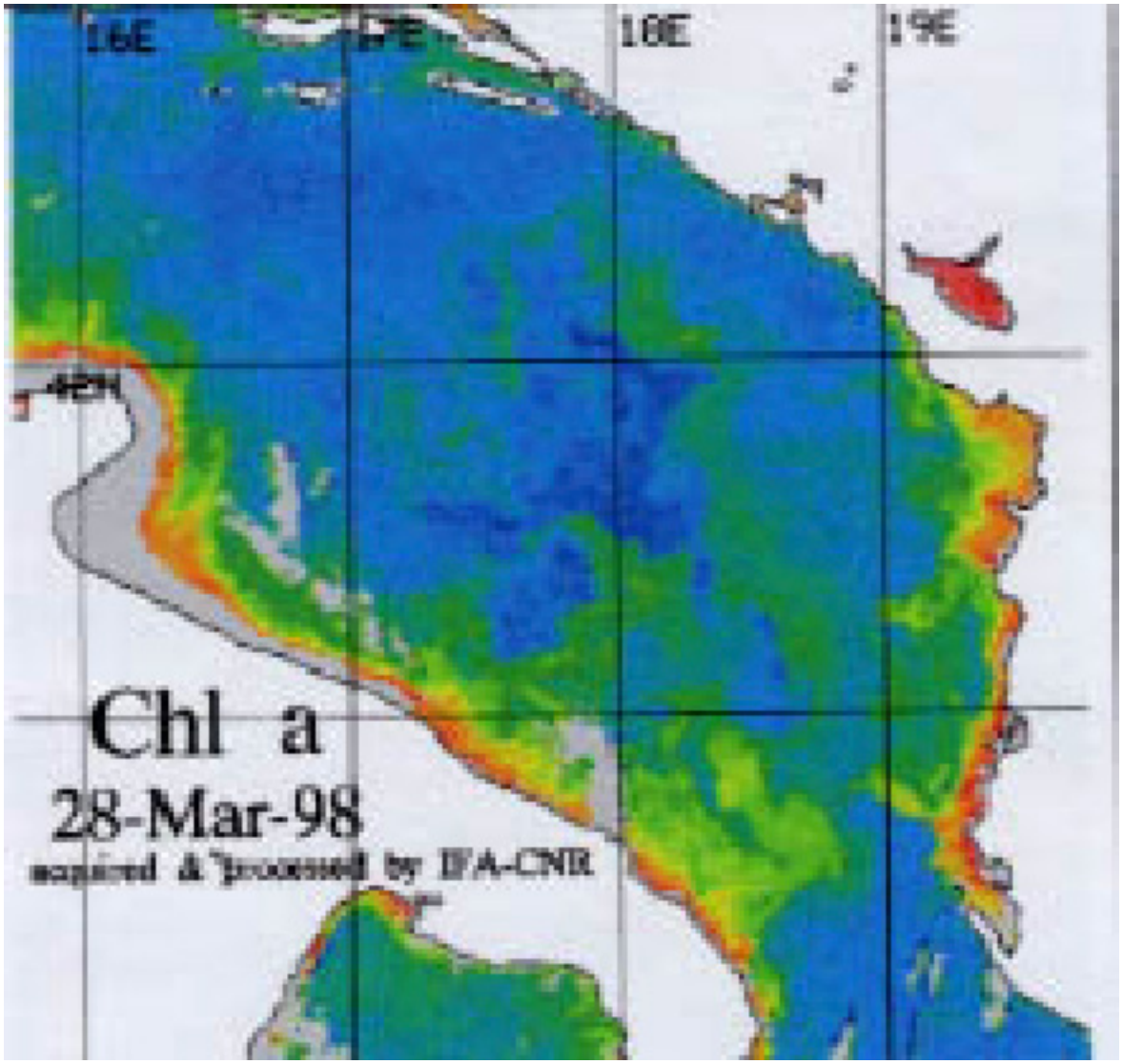
Levy et al, 2001, JMR

Drivers: stratification



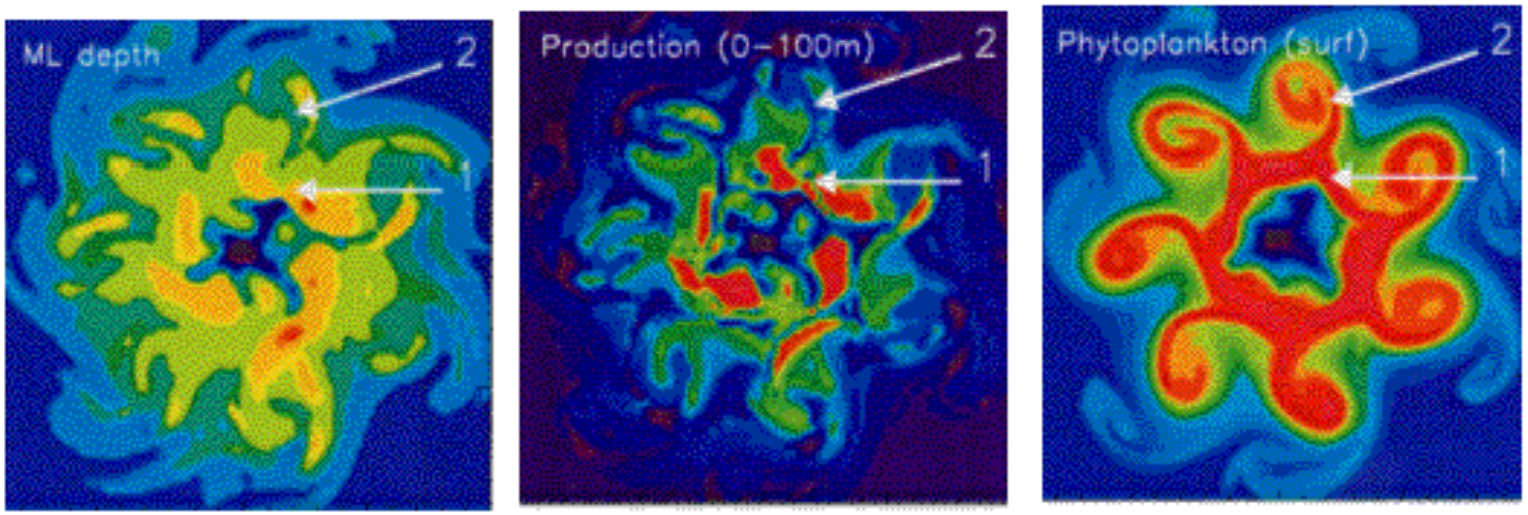
Increased stratification at submesoscale fronts can alleviate light limitation of phytoplankton growth

Levy et al, 2012, GRL



Santoleri et al., 2003

MLD PP Chla

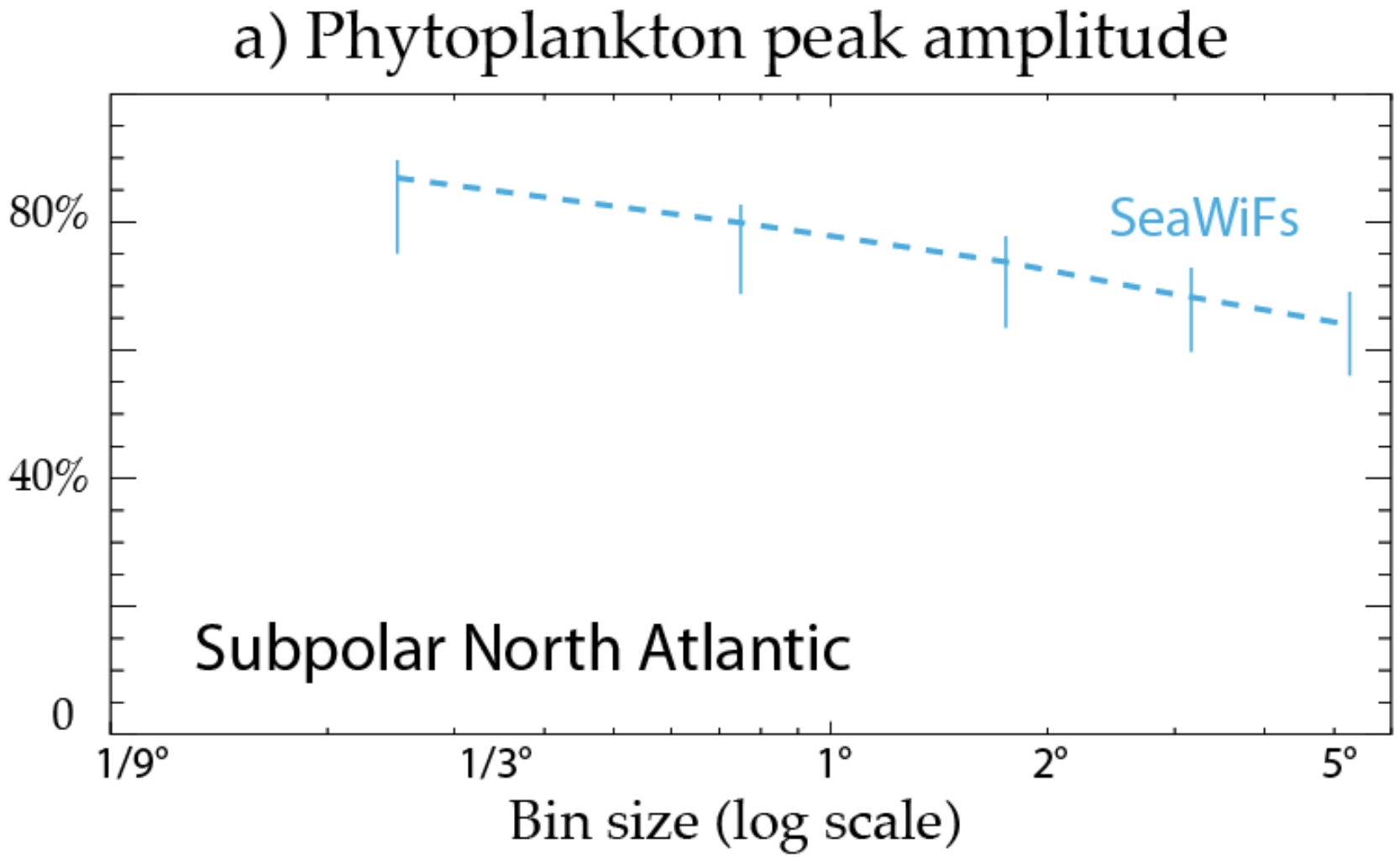


Lévy et al., 1998

Questions raised by these observations

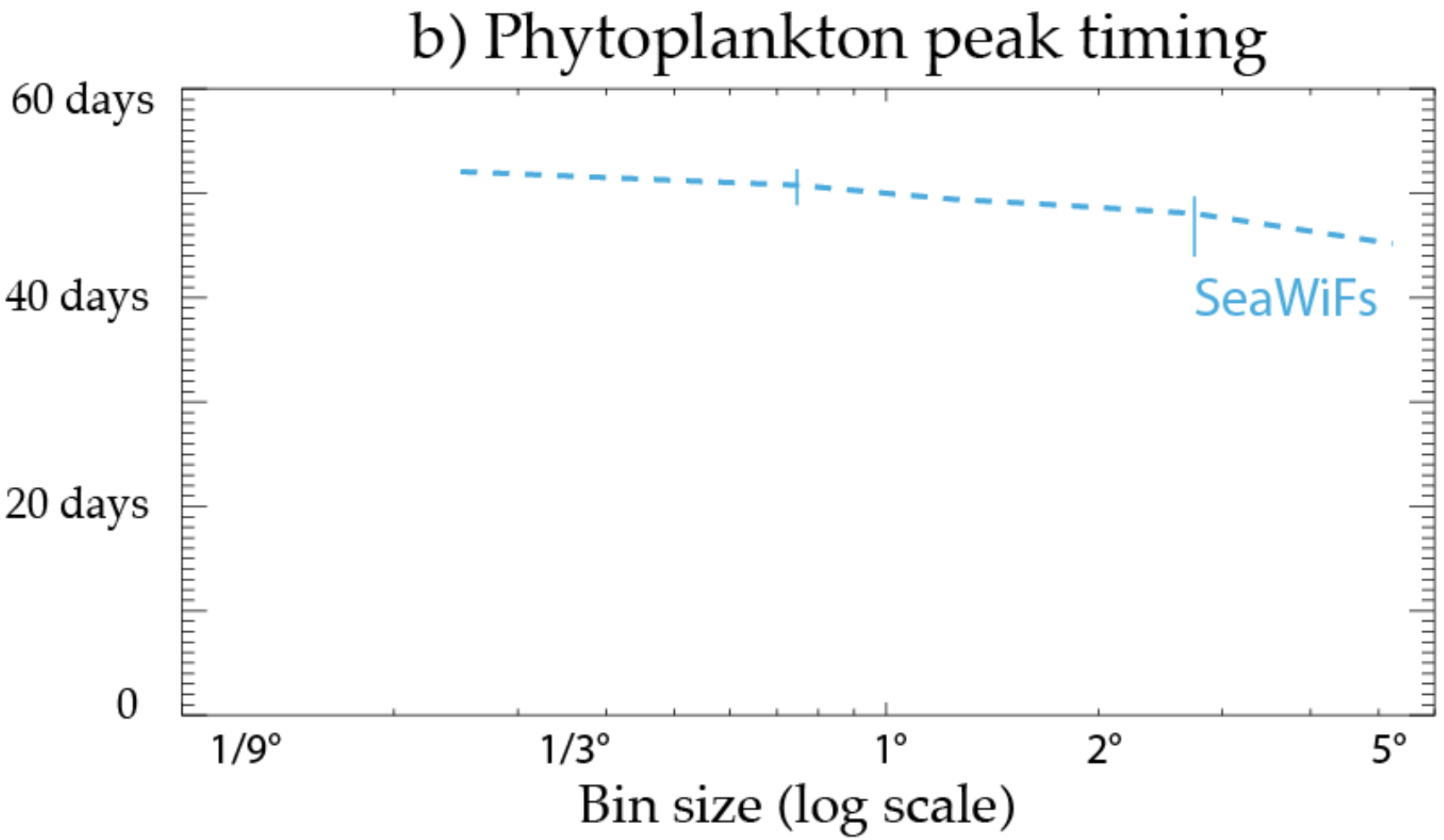
- What are the drivers of this variability ?
- Does it induce inter-annual variability of the bloom ?
- Does it increase the ability of phytoplankton co-existence ?
- What is its contribution to biogeochemical (N, C, O) budgets ?

Monitoring of inter-annual variability with OC



Levy et al, 2014, GRL

Monitoring of inter-annual variability with OC



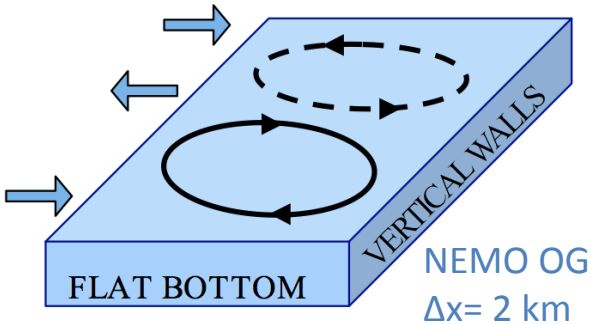
Levy et al, 2014, GRL

Inter-annual variability in bloom timing and intensity

Due to:
Changes in atmospheric heat fluxes (NAO, climate change)
Changes in winds (Storms, ..)

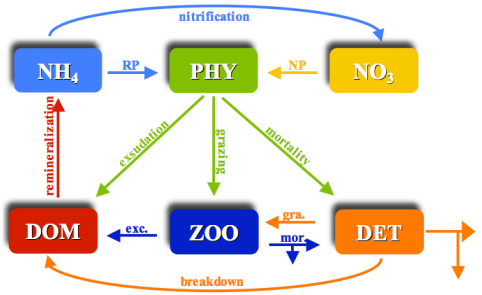
What part of the variability is due to submesoscales ?

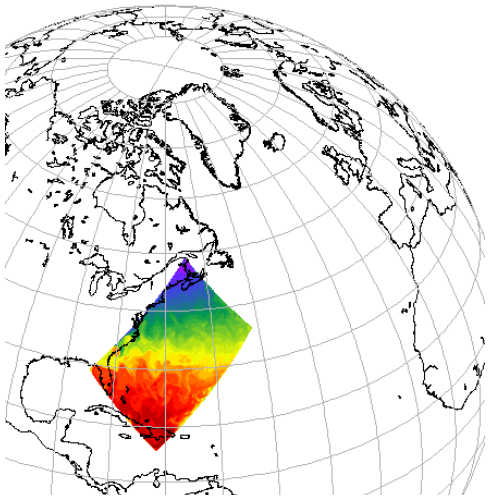
Submesoscale model with no external variability



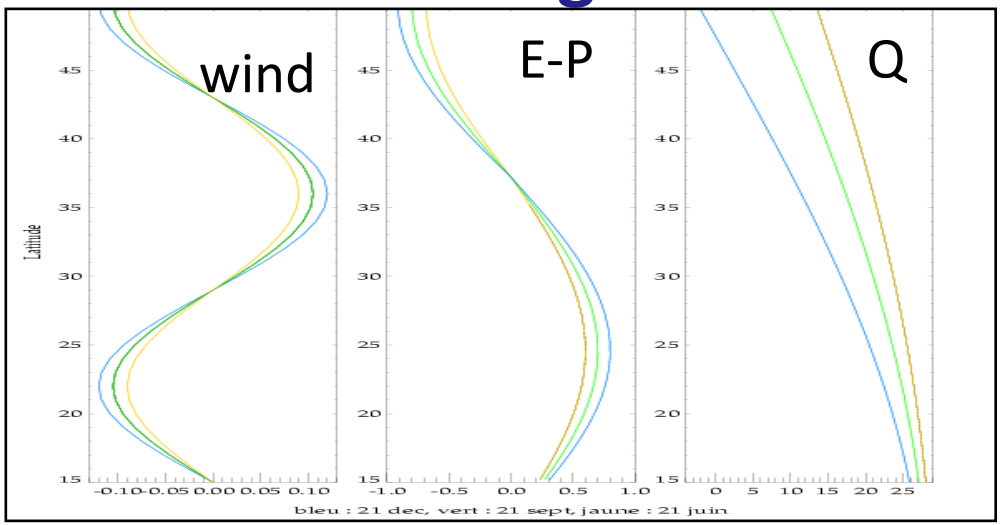
NEMO OGCM
Δx= 2 km

+

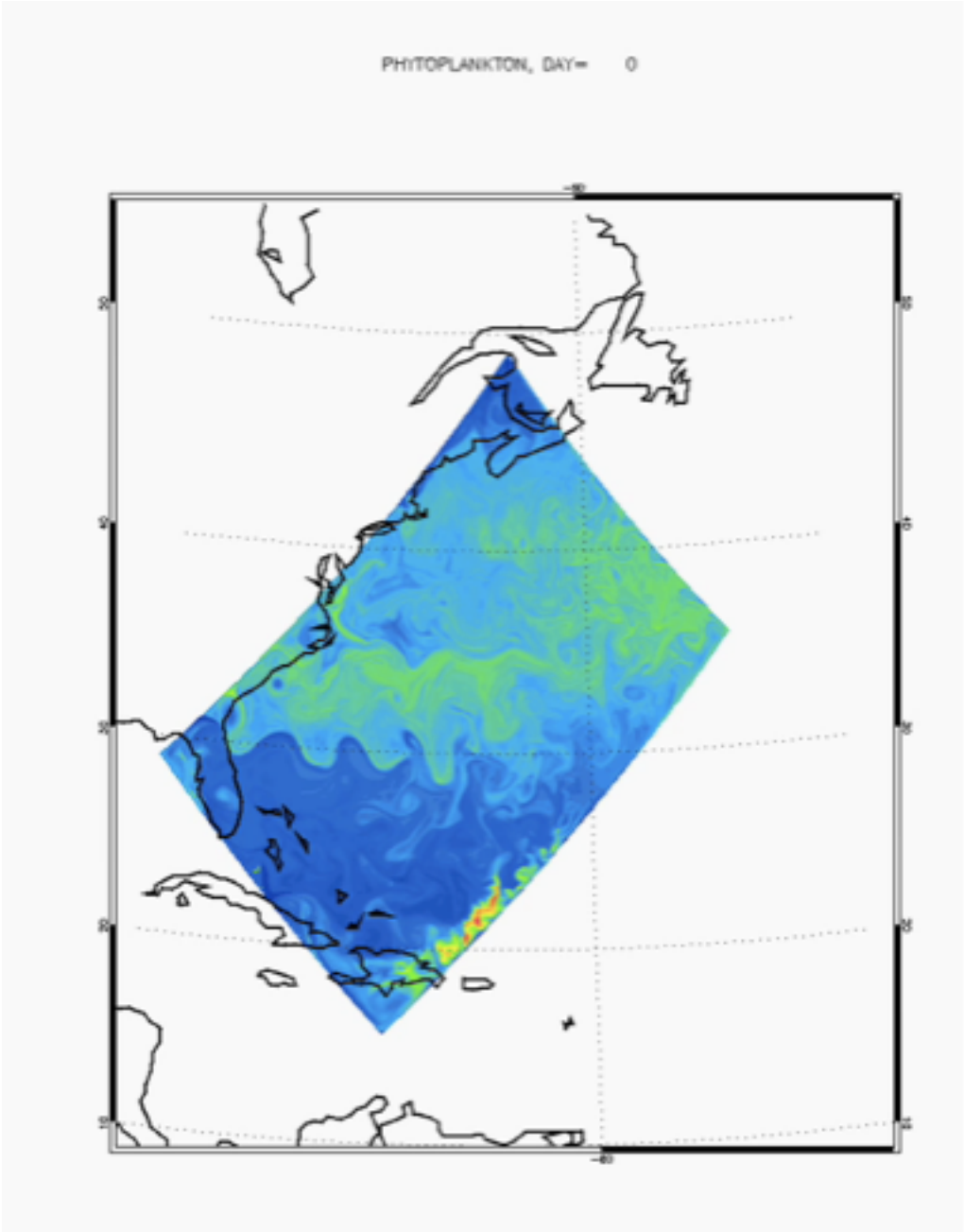




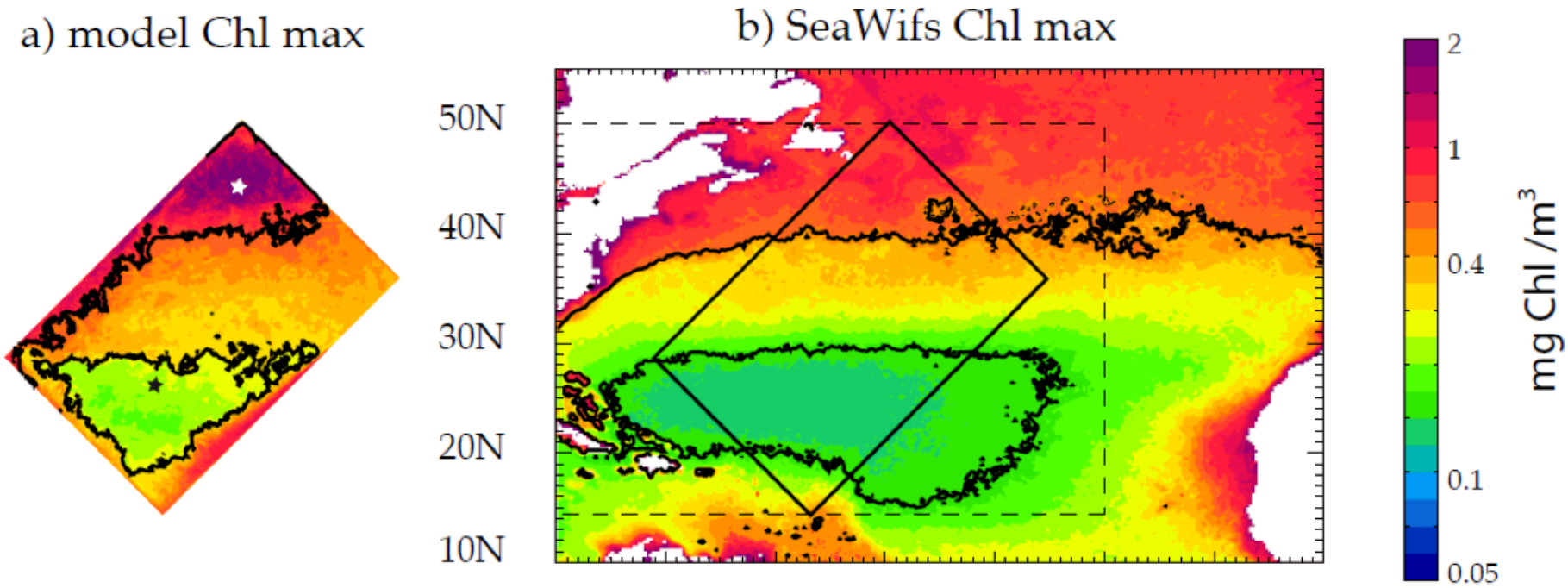
Seasonal forcing



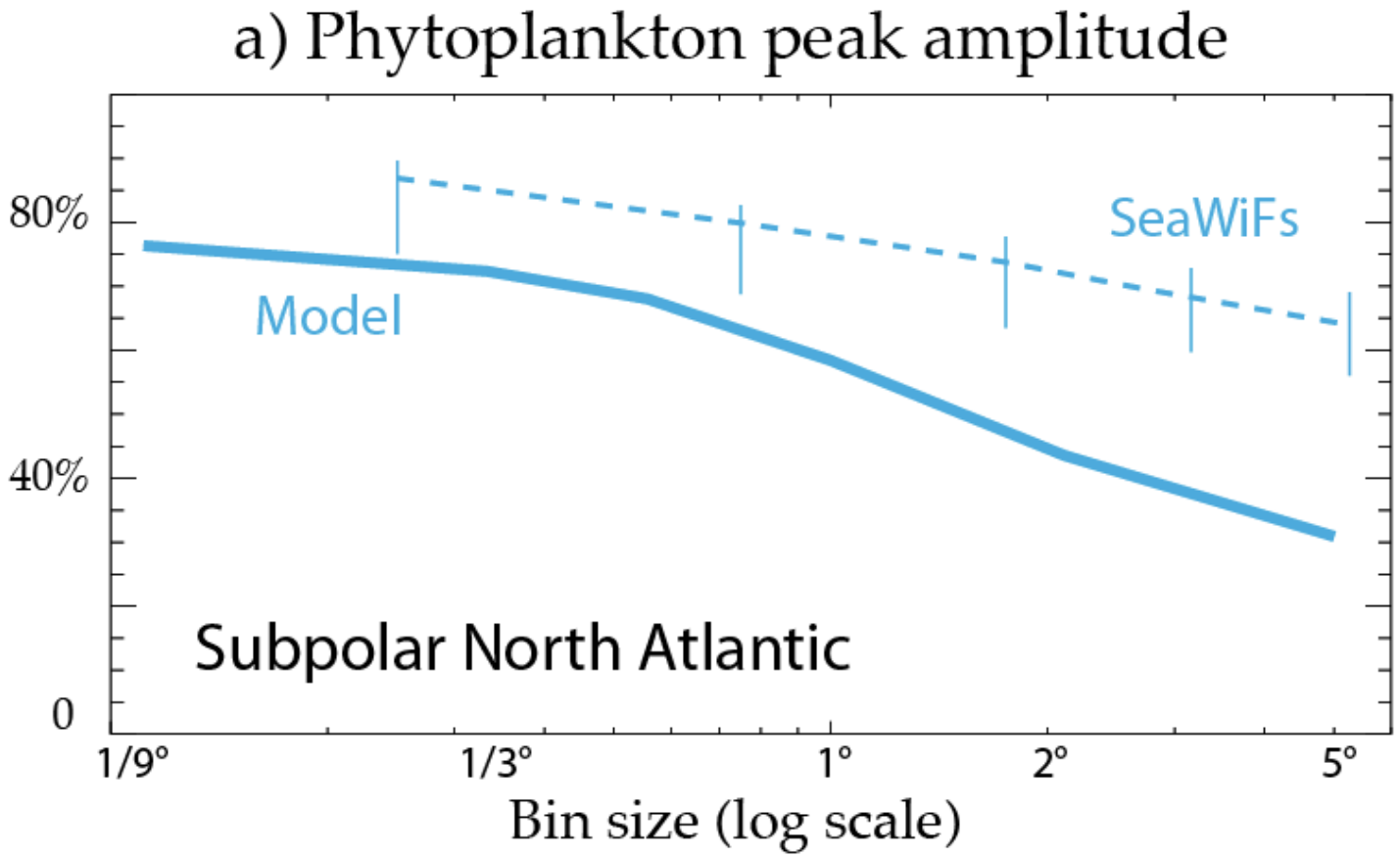
50 years of spin-up, daily outputs for last 5 years


PHYTOPLANKTON, DAY= 0

Bloom amplitude



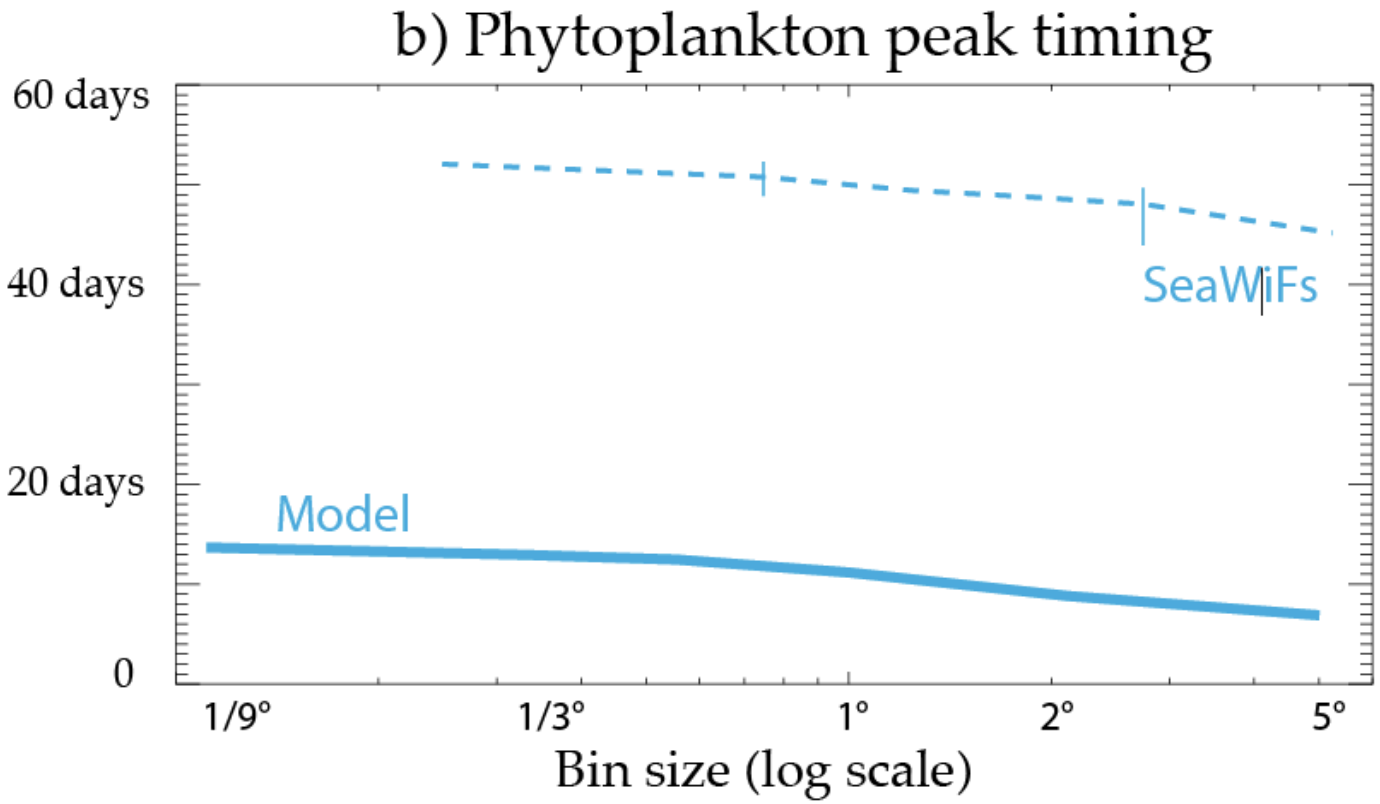
Model reveals intrinsic part of inter-annual variability



50% of the variability in bloom amplitude due to meso / submeso

Levy et al, 2014, GRL

Model reveals intrinsic part of inter-annual variability



20% of the variability in bloom timing due to meso / submeso

Levy et al, 2014, GRL

Questions raised by these observations

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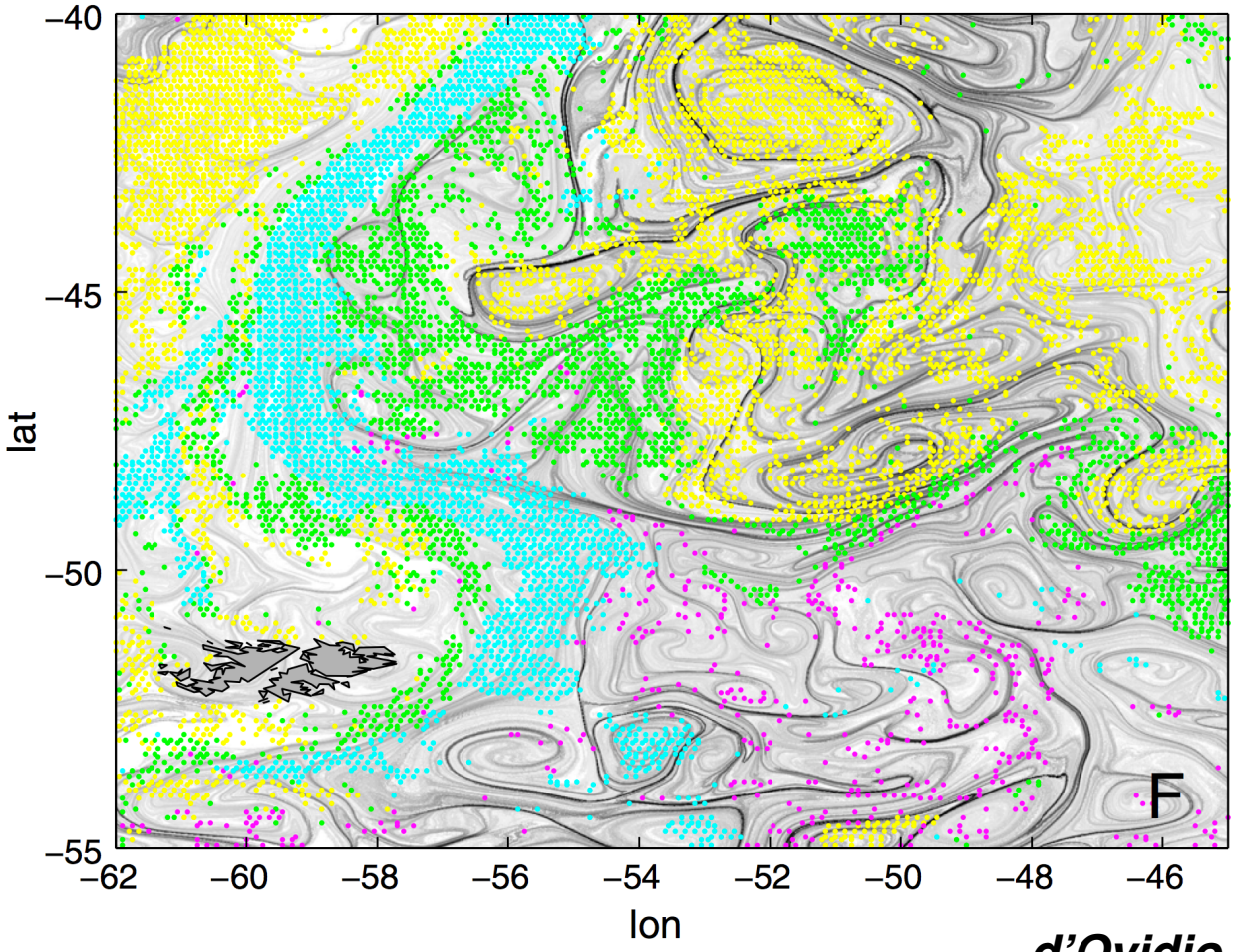
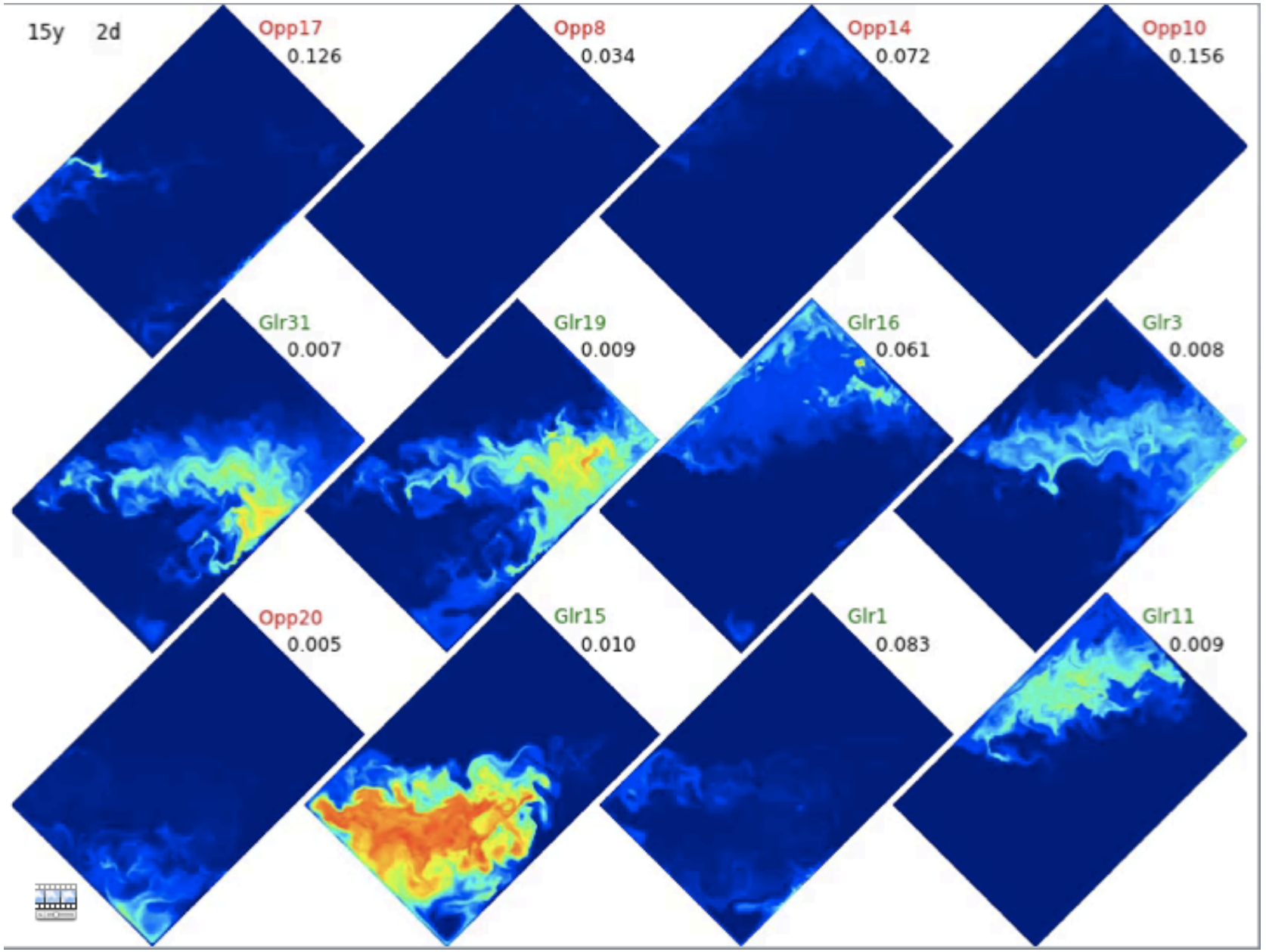
- What is its contribution to biogeochemical (N, C, O) budgets ?

Optical anomalies (Phyto types) + FSLE

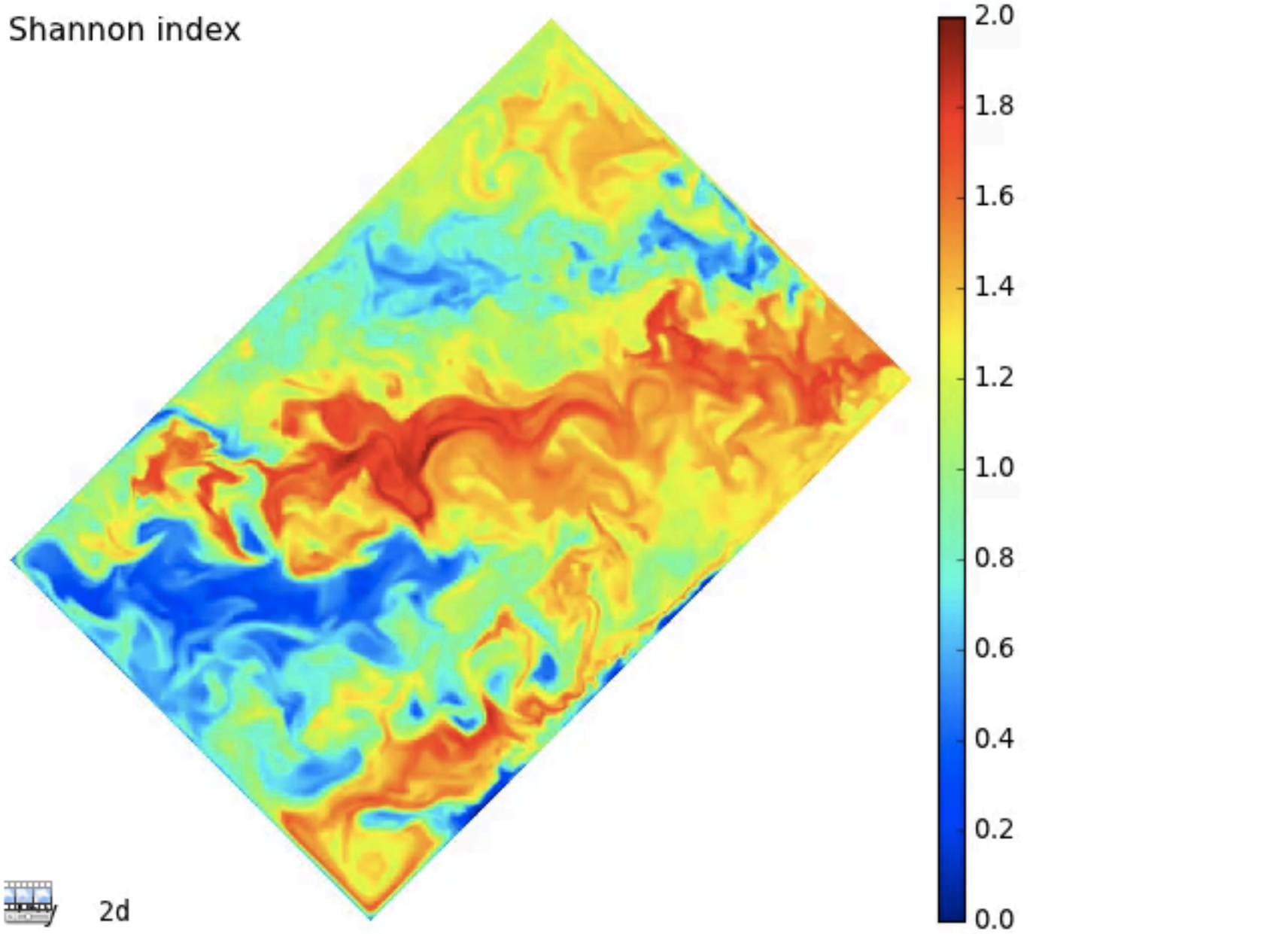


d'Ovidio et al, 2010, PNAS

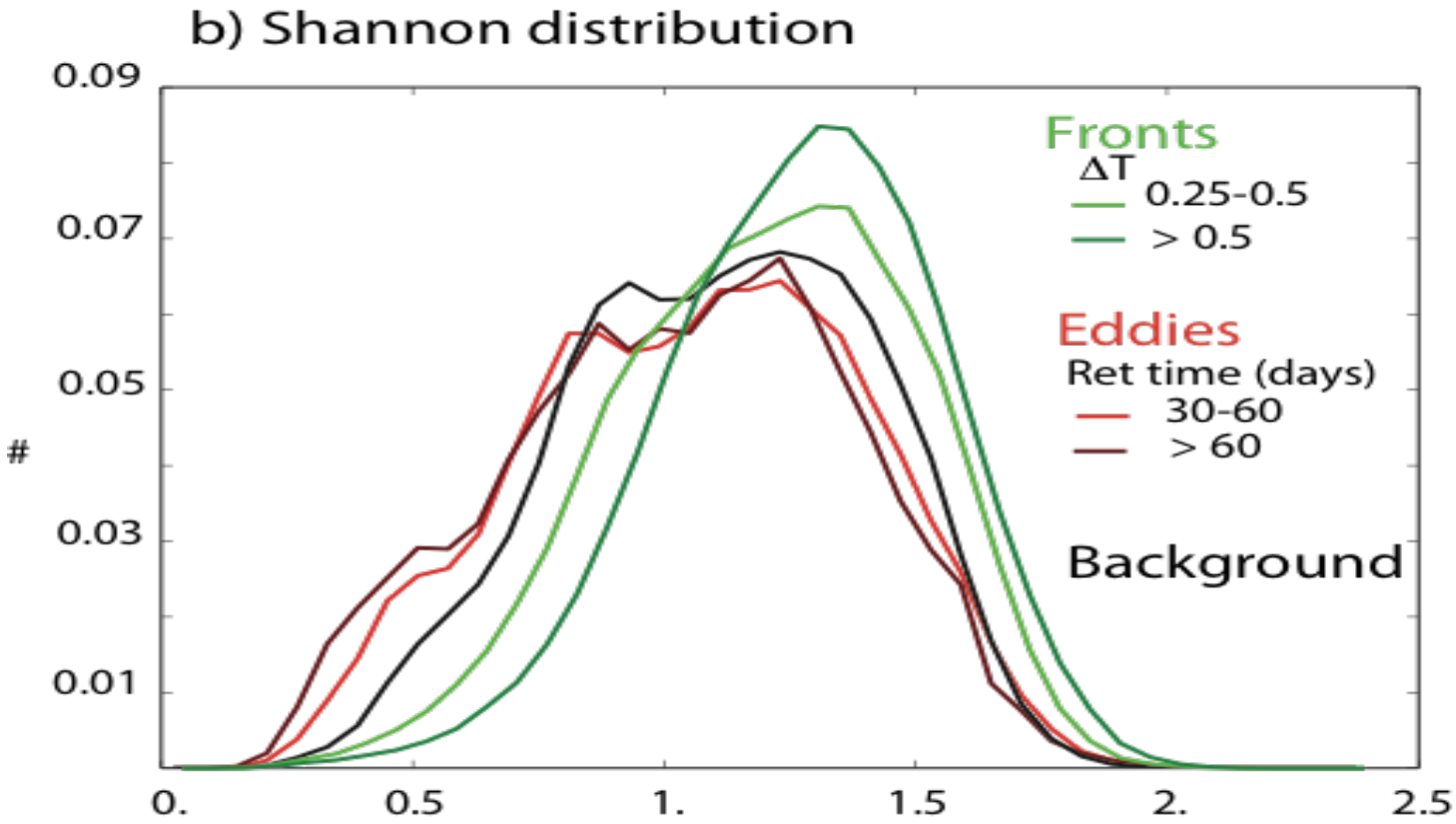
Meso/submesoscle shape the diversity landscape



Levy et al, L&0-F&E, 2014



Levy et al, submitted



Statistically:

More ability for coexistence at submesoscale fronts

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

Levy et al, submitted

Questions raised by these observations

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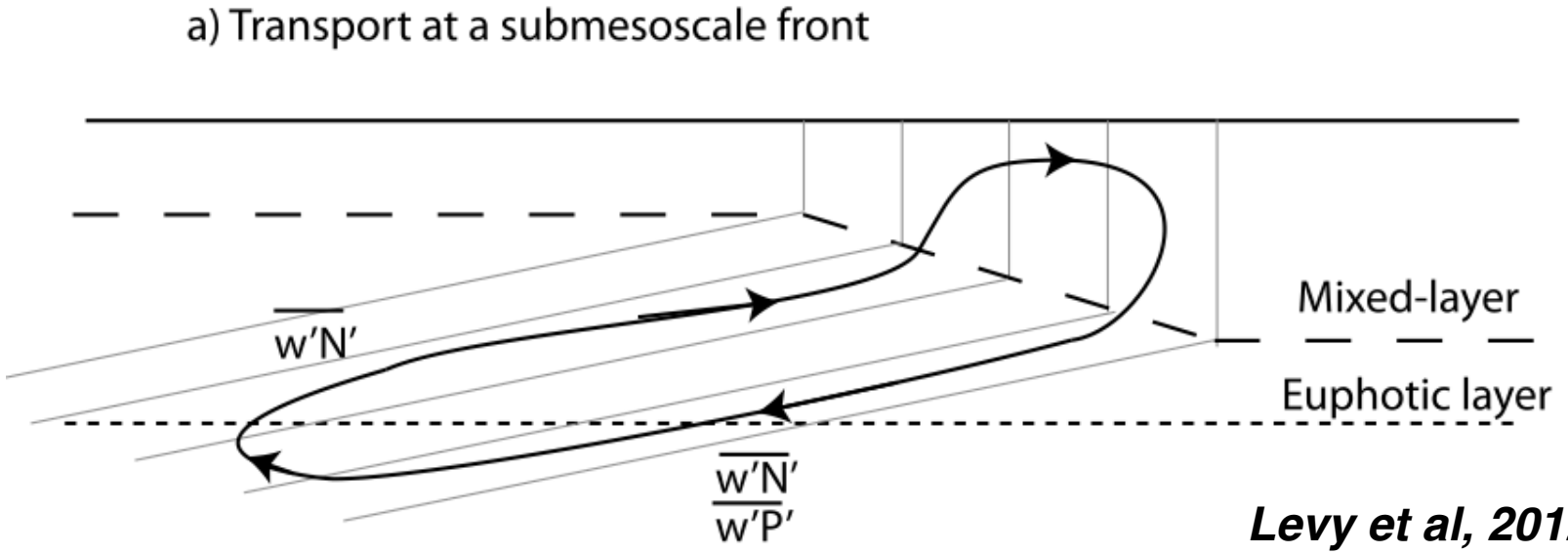
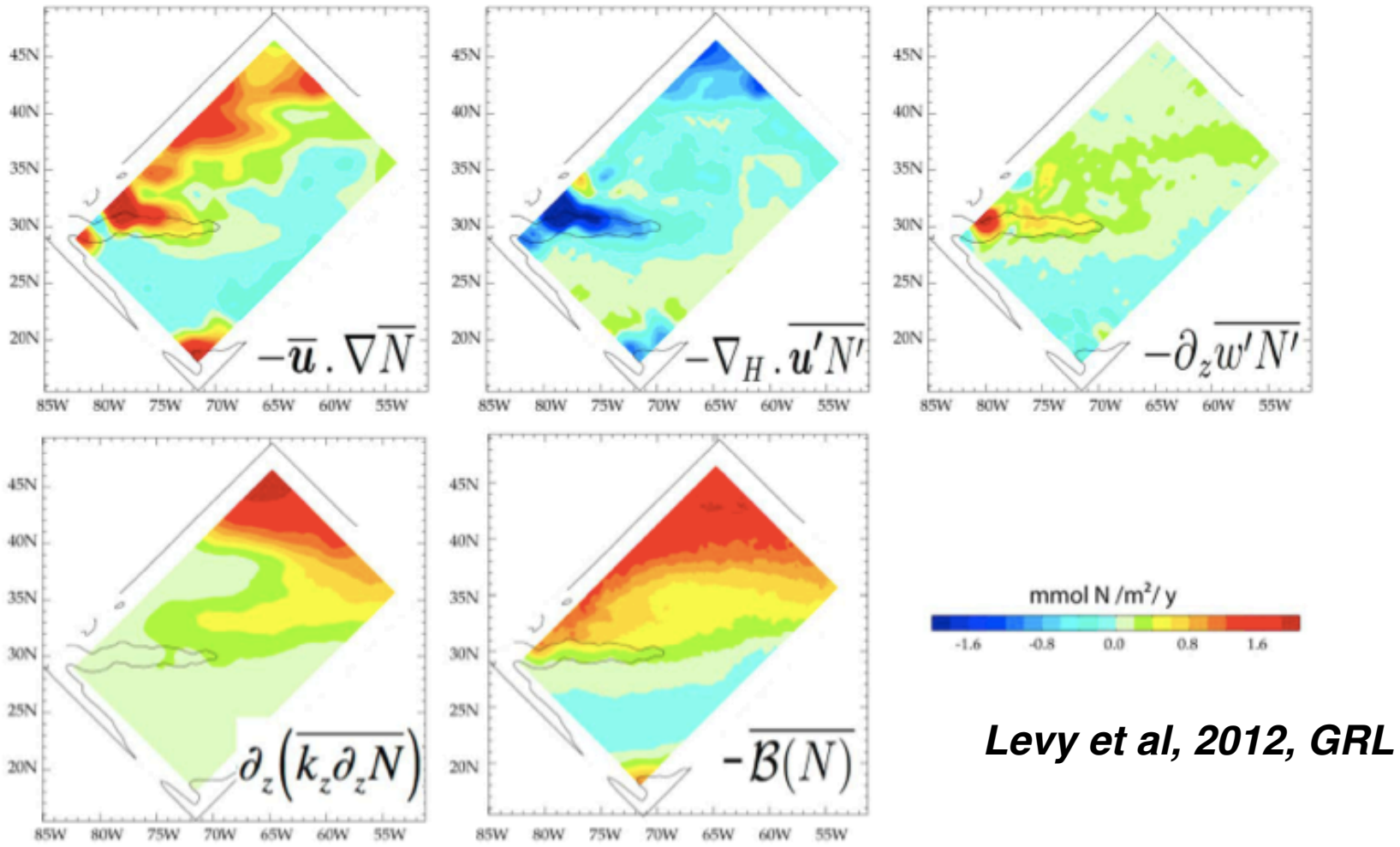


Levy et al, 2012, GRL

Two competing effects of upwelling and downwelling:

- Upwelling of Nutrients
- Subduction of Nutrients, Phytoplankton, OM, Oxygen, Canth..

Depends crucially on large scale environment



Levy et al, 2012, GRL

Vertical eddy advection dominates in the inter-gyre region

Concluding remarks

•Submesoscale variability of Chla is widespread in ocean color observations but this variability has long been neglected in both models and data analysis

•Understanding the implications requires synergetic use of different satellite products, in situ observations and models

•Need for high time and space resolution in both satellite products and models

•Future potential: Geostationary OC (GOCI, GEO-OCAPI, GEO-CAPE), HR altimetry (SWOT)