# Seasonal cycle of nitrate in the euphotic layer of the Atlantic Cold Tongue

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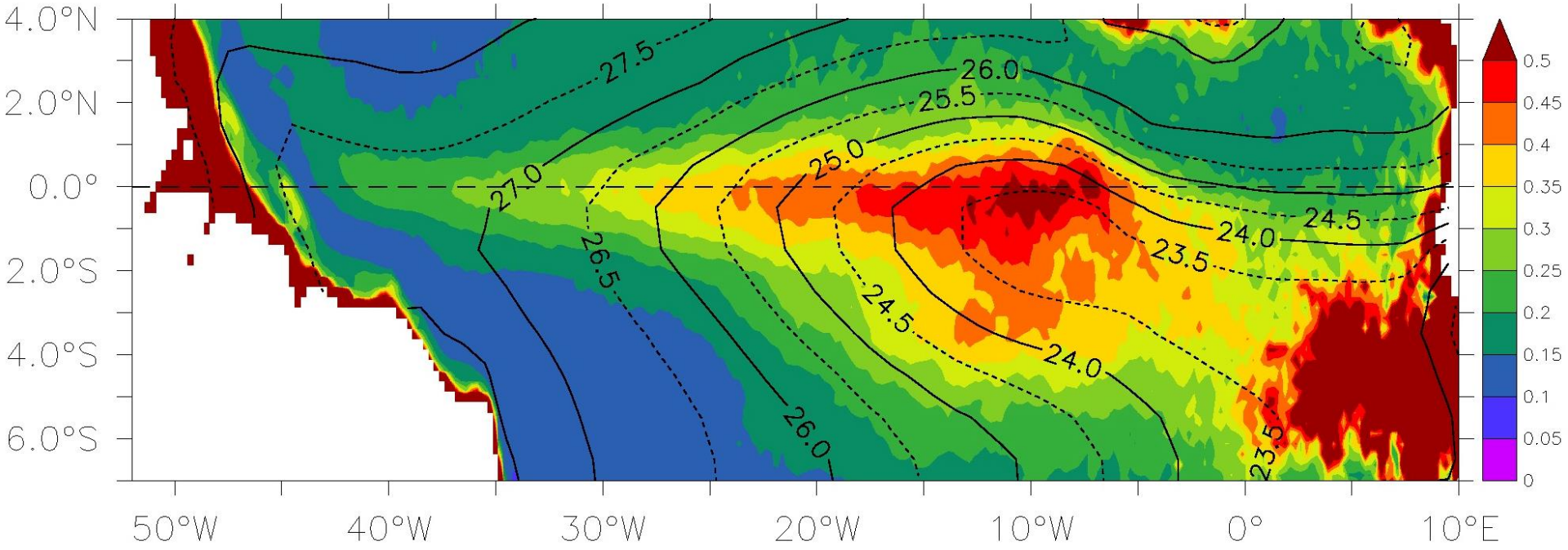
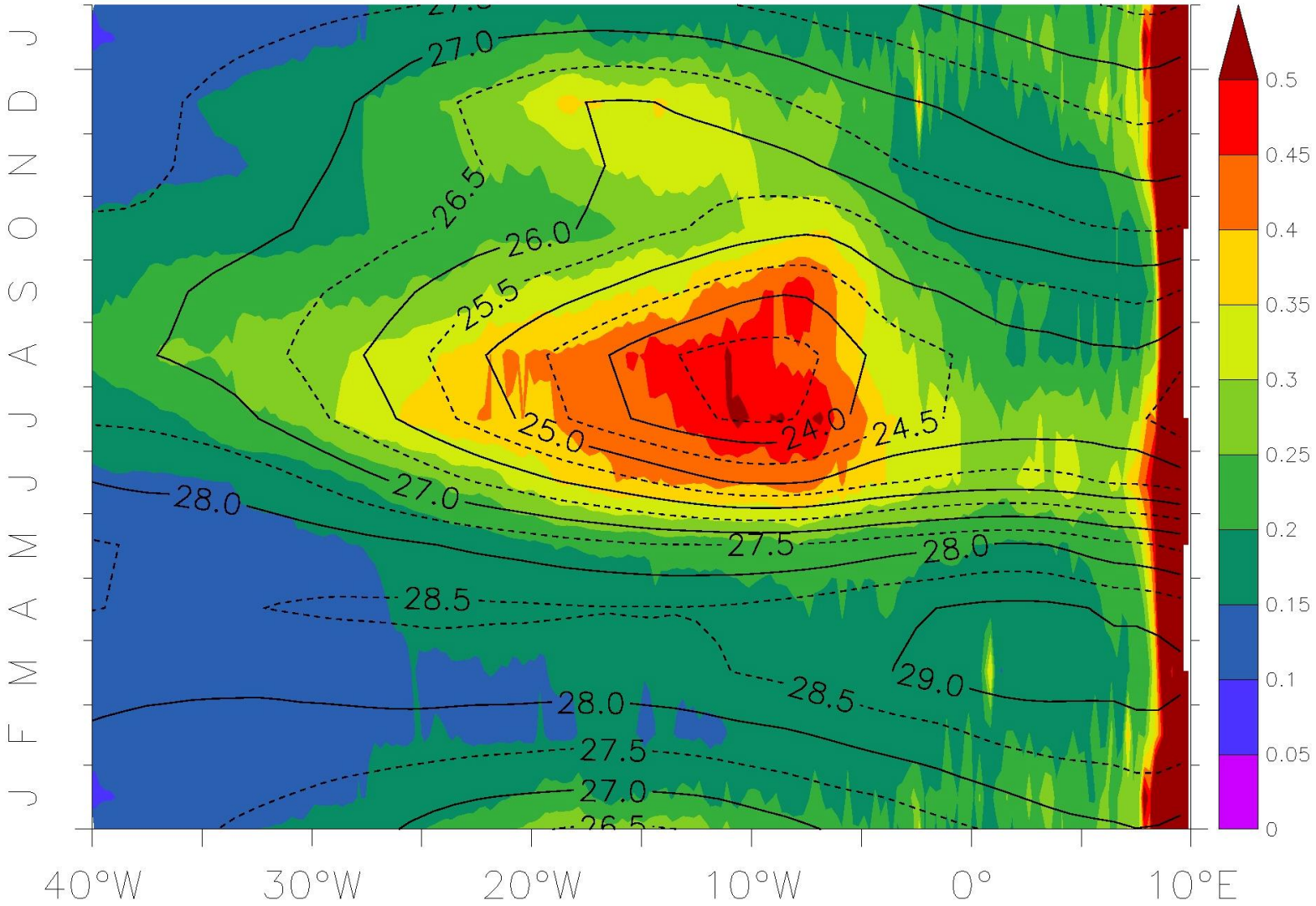
(1) LEGOS-IRD, Toulouse, (2) CIPMA, Cotonou, Benin, (3) LEGOS-IRD, Brest, (4) LOCEAN-IRD, Paris




Satellite chlorophyll and SST in July-August

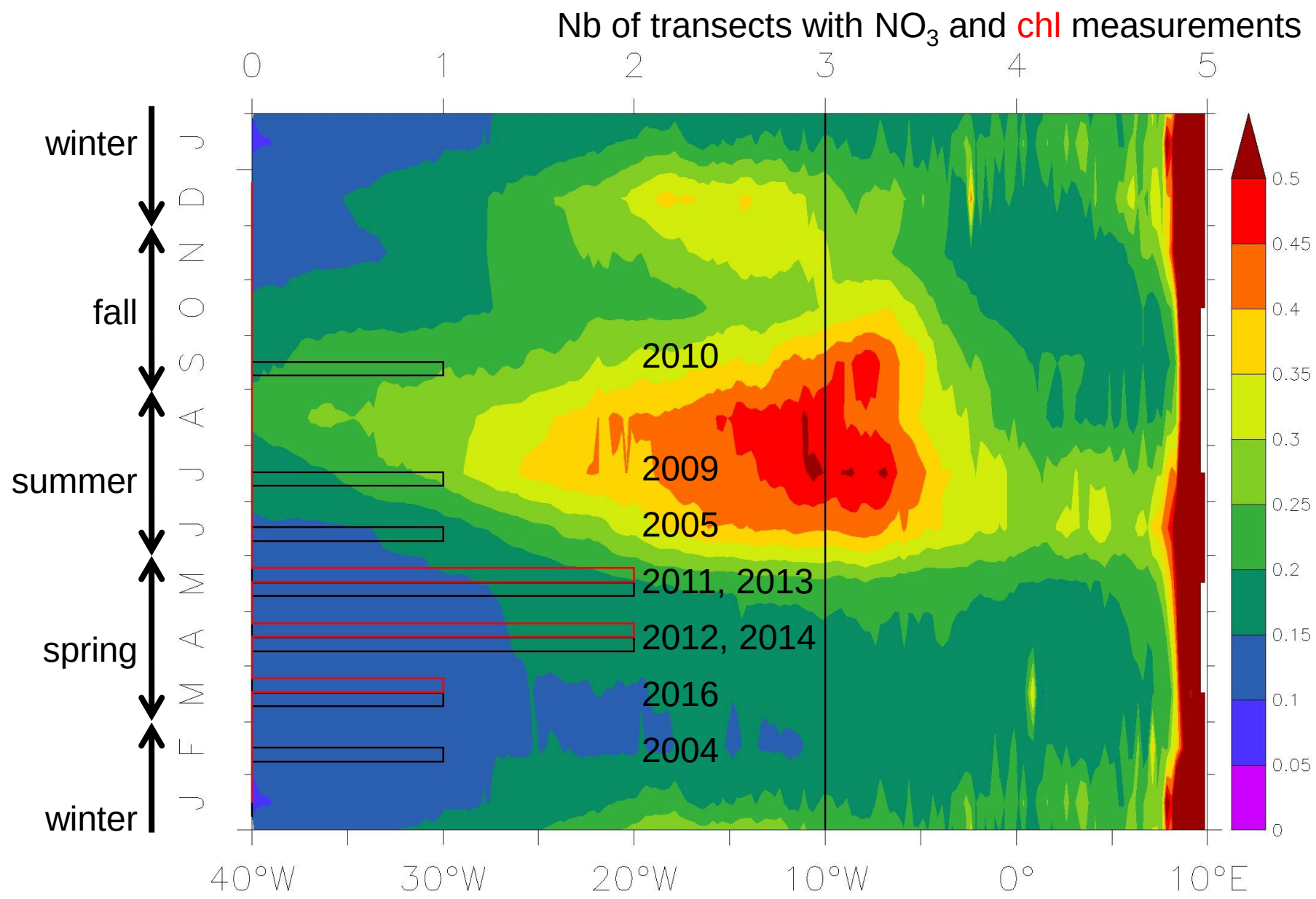
# Atlantic cold tongue: SST and chlorophyll

- Main chlorophyll peak: July-August
- Secondary peak: December *(Monger et al., 1999; Perez et al., 2005; Grodsky et al., 2008; Jouanno et al., 2011)*




Climatological satellite chlorophyll and SST in 1.5°S-0.5°N

# PIRATA cruises along 10°W



# Coupled dynamics-biogeochemical model

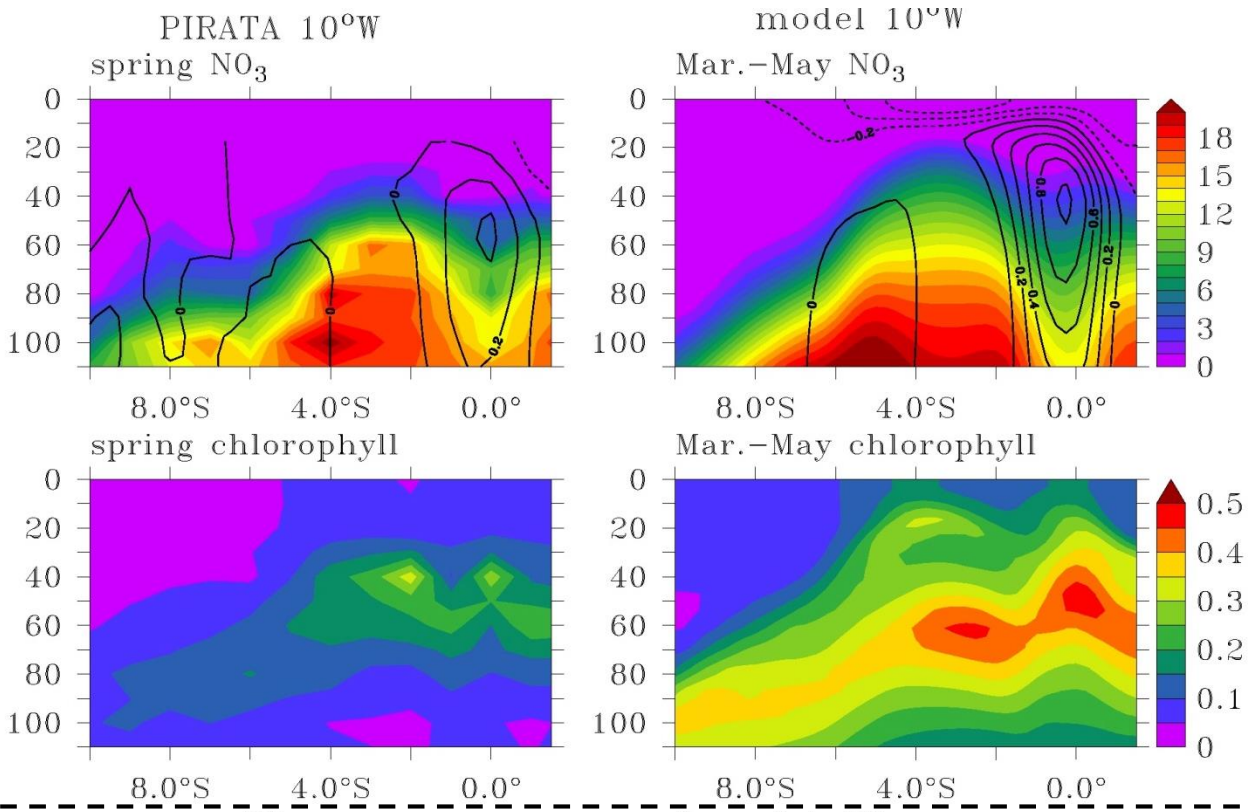
| **Dynamical model** | **NEMO *(Madec et al., 2016)*<br>Configuration TATL025 *(Hernandez et al., 2016; 2017)*** |
|---|---|
| Domain | 100°W-20°E, 35°S-35°N |
| Horizontal resolution | ¼° |
| Vertical resolution | 75 levels (25 in the upper 100 m)<br>1m in the upper 10 m<br>about 10 m at 100 m<br>200 m below 5000 m |
| Forcing | DFS5.2<br>Mercator GLORYS2V4 |
| Outputs | monthly |

# Coupled dynamics-biogeochemical model

| Biogeochemical model | PISCES *(Aumont et al., 2015)* |
|---|---|
| 5 nutrients | nitrate, ammonium, phosphate, silicate, and iron |
| 2 phytoplankton | nanophytoplankton and diatoms |
| 2 zooplankton | micro- and meso- zooplankton |
| 3 non-living compartments | dissolved organic matter, small and large sinking particles |
| Initialization, forcing | WOA |

$$\underbrace{\frac{\partial NO_3}{\partial t}}_{\text{NO}_3\text{ change rate}} = \underbrace{-u\frac{\partial NO_3}{\partial x}}_{\text{zonal advection}} \underbrace{- v\frac{\partial NO_3}{\partial y}}_{\text{meridional advection}} \underbrace{- w\frac{\partial NO_3}{\partial z}}_{\text{vertical advection}} \underbrace{+ D_l(NO_3)}_{\text{lateral diffusion}} \underbrace{+ \frac{\partial}{\partial z}\left(K_z\frac{\partial NO_3}{\partial z}\right)}_{\text{vertical diffusion}} \underbrace{+ \left(\frac{\partial NO_3}{\partial t}\right)_{bio}}_{\text{NO}_3\text{ source minus sink (SMS)}}$$

# 10°W: PIRATA cruises and the simulation



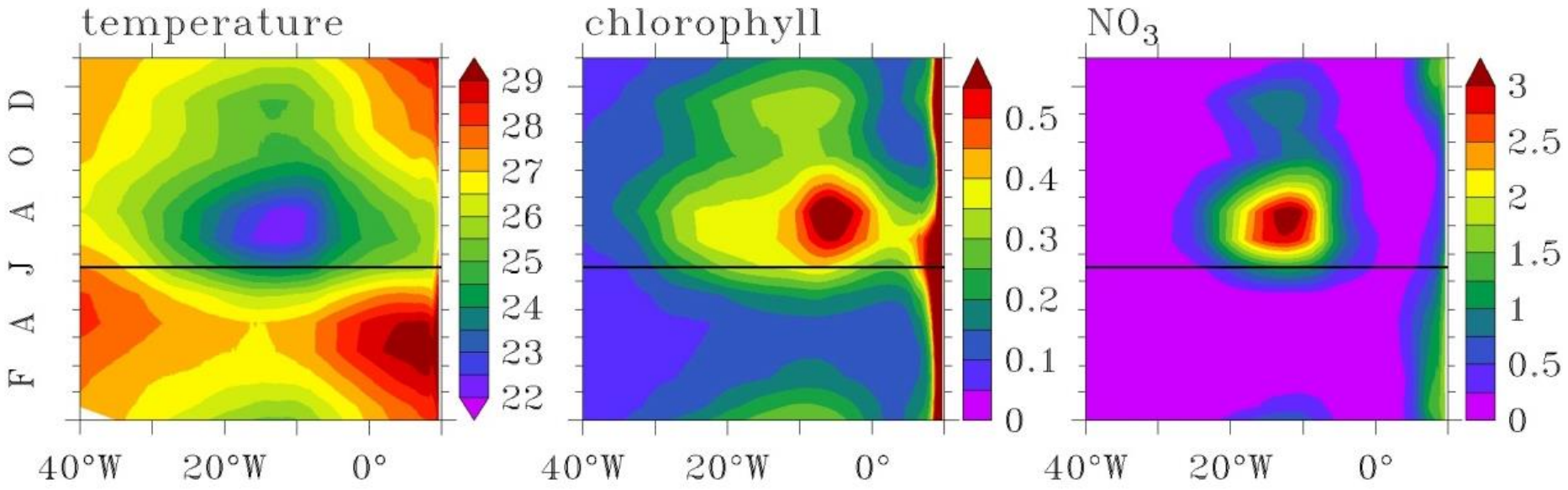

## Spring

- 5 transects
- $NO_3$ depleted surface layer
- EUC is $NO_3$ low
- Deep chlorophyll maximum

## Summer

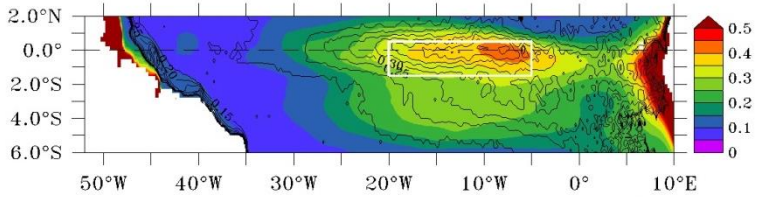
- 2 transects
- $NO_3$ in the surface layer
- EUC is $NO_3$ low

# Modeled mixed layer

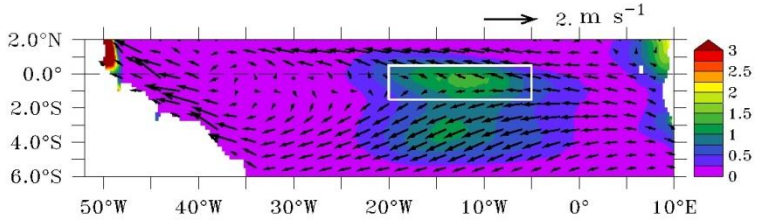



- Agreement with observations
- SST slightly too low; chlorophyll too high
- Main $NO_3$ and chlorophyll maximum in summer; secondary maximum in December
- Similarities between the location and timing of the SST minimum and nitrate maximum $\Rightarrow$ same processes?

# Modeled mixed layer: June

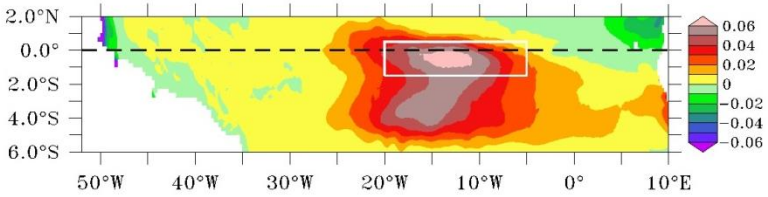



chl

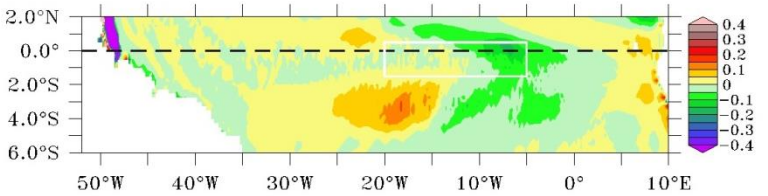



$NO_3$

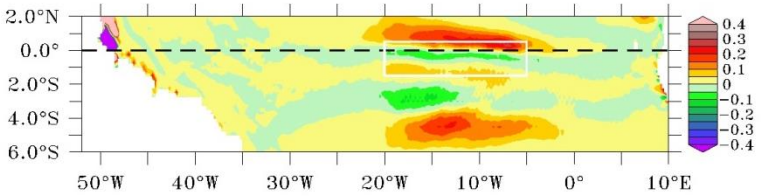
- June = maximum $NO_3$ increase
- Maximum chl, $NO_3$, $\partial NO_3/\partial t$ south of the equator in 20°W-5°W
- Strong vertical supply
- SEC $\Rightarrow$ $NO_3$ poor water from the east
- V $\Rightarrow$ spreads $NO_3$ rich upwelled water
- supply (physics) > loss (biology)



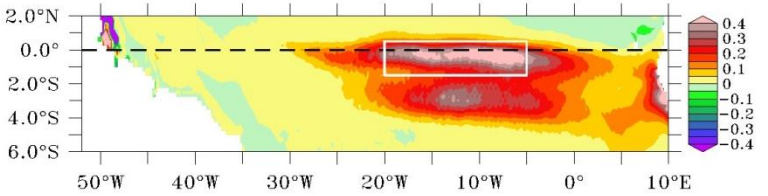

$NO_3$ change rate



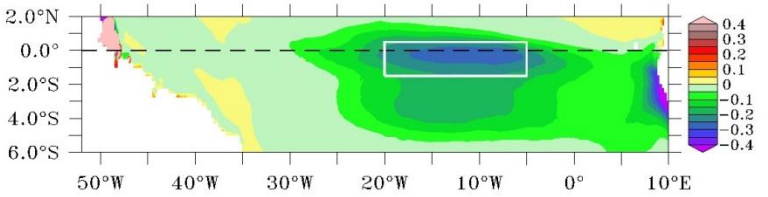

adv. $_X$




adv. $_Y$

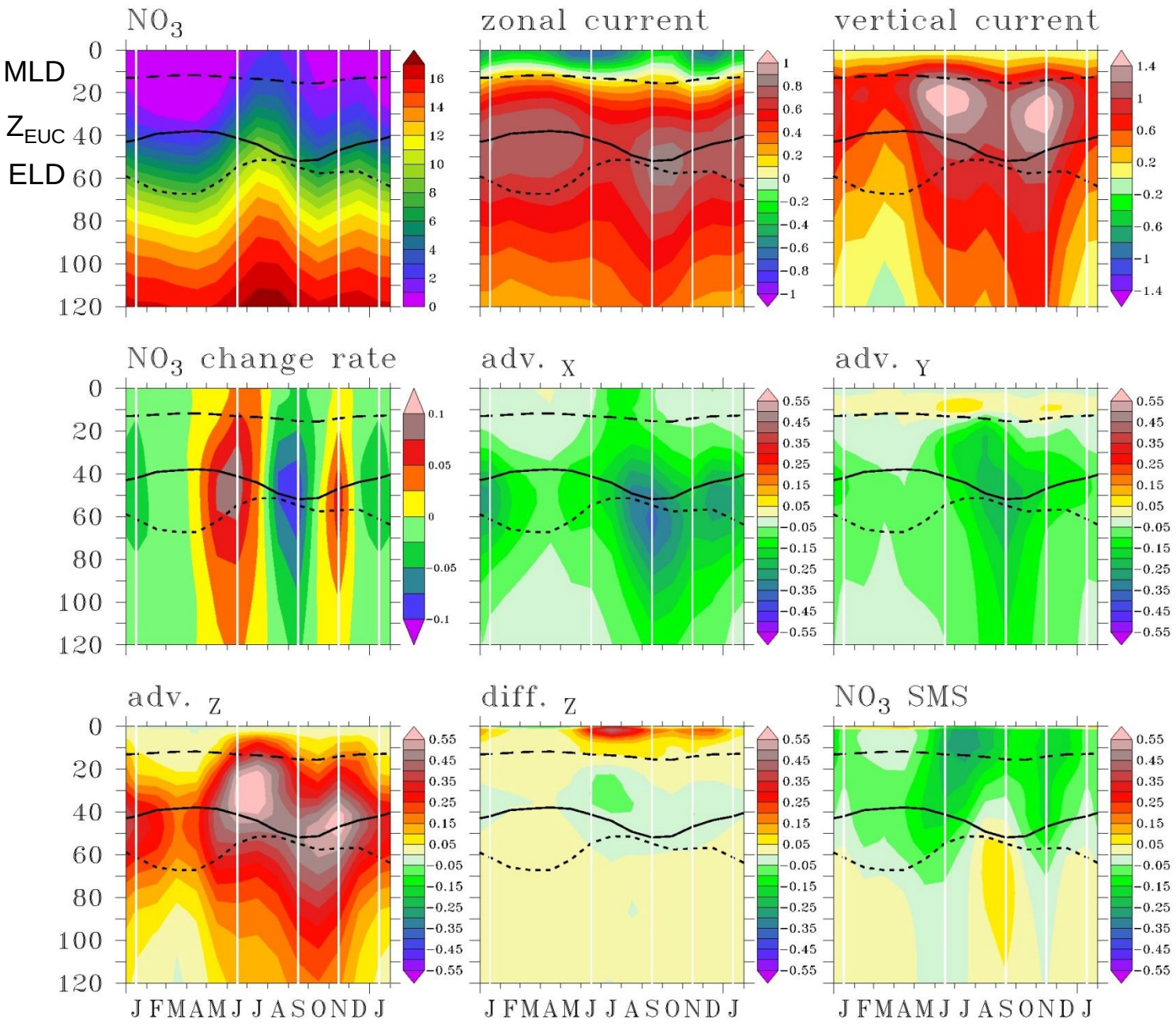



adv. $_Z$ + diff. $_Z$




$NO_3$ SMS

# Seasonal cycle of processes in 20°W-5°W, 1.5°S-0.5°N




**Jun.-Jul. and Dec.**

- Max $NO_3$

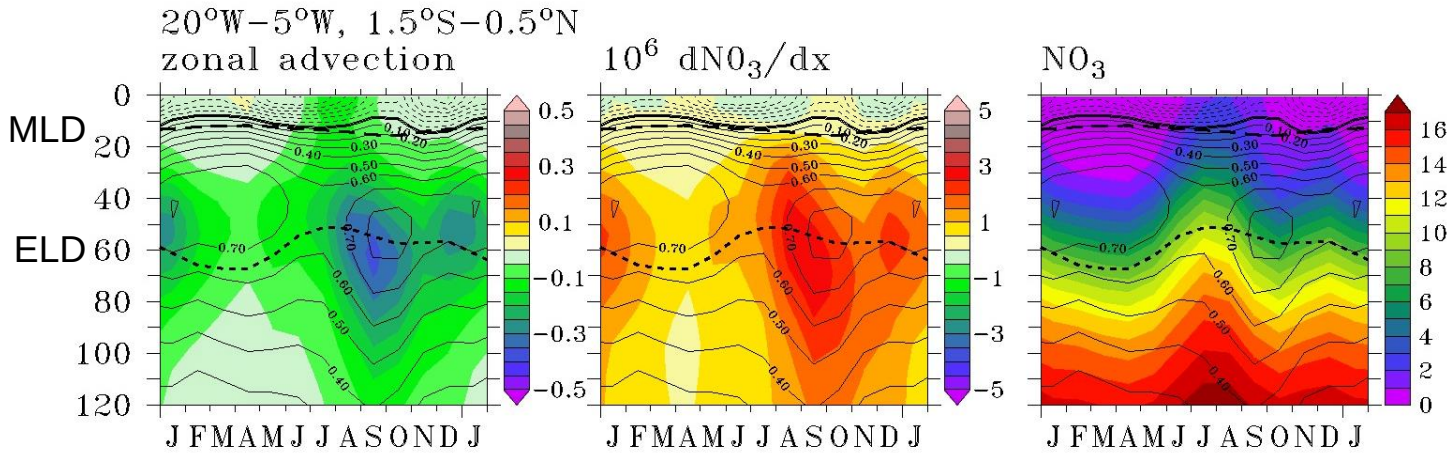
**May-Jun. and Nov.**

- $\partial NO_3/\partial t > 0$
- $adv._Z$ and $diff._Z$

**Aug.-Sep. and Jan.**

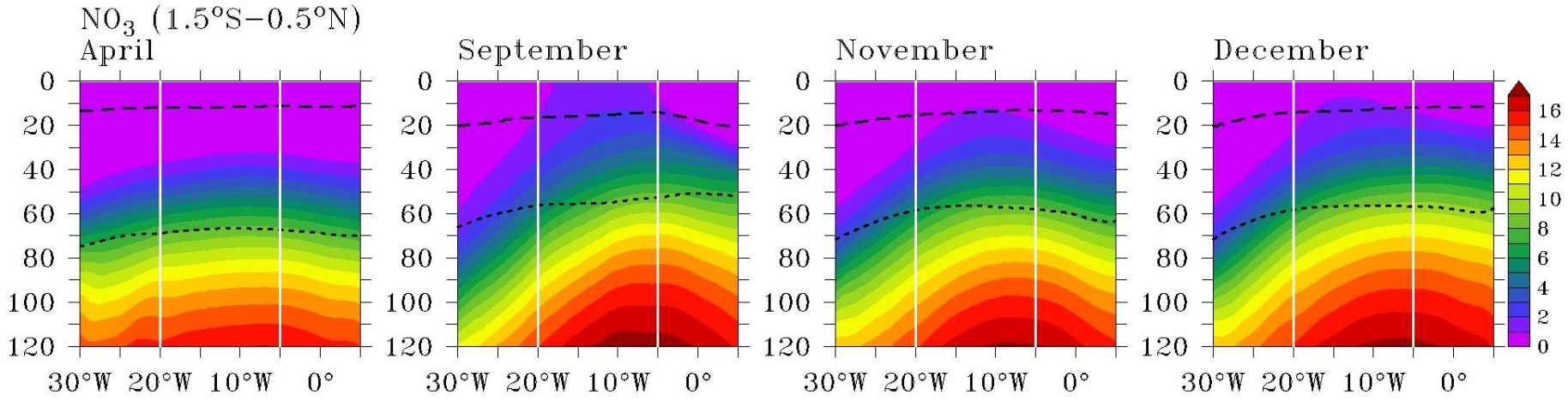
- $\partial NO_3/\partial t < 0$
- $adv._H$ and SMS

# Zonal advection in 20°W-5°W, 1.5°S-0.5°N

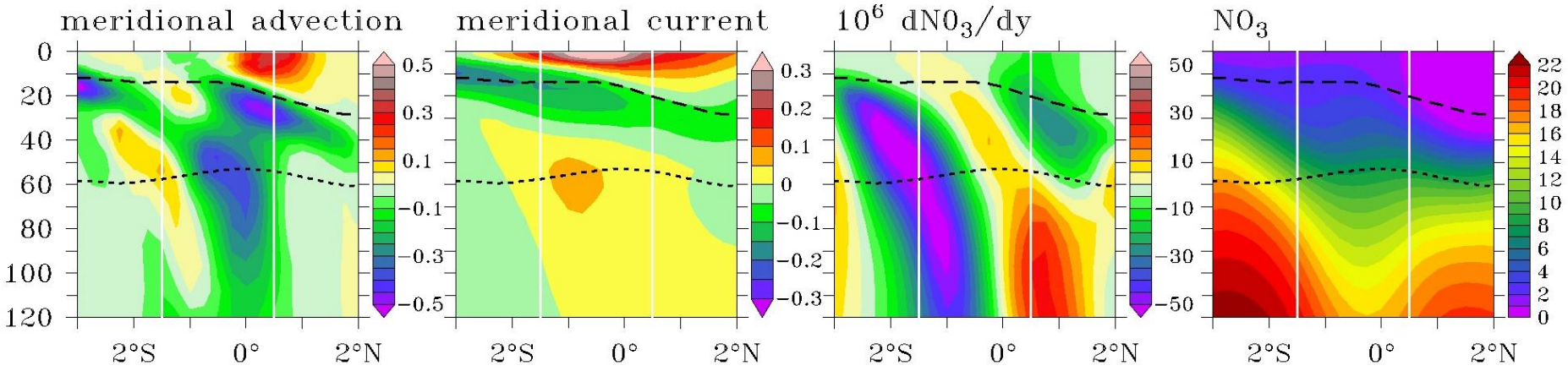



## Relevance of $\partial NO_3/\partial x$

- EUC transports $NO_3$ poor water from the west
- Nitracline uplift in the central Atlantic $\Rightarrow$ enhanced $\partial NO_3/\partial x$
- Semi-annual cycle of $\partial NO_3/\partial x$



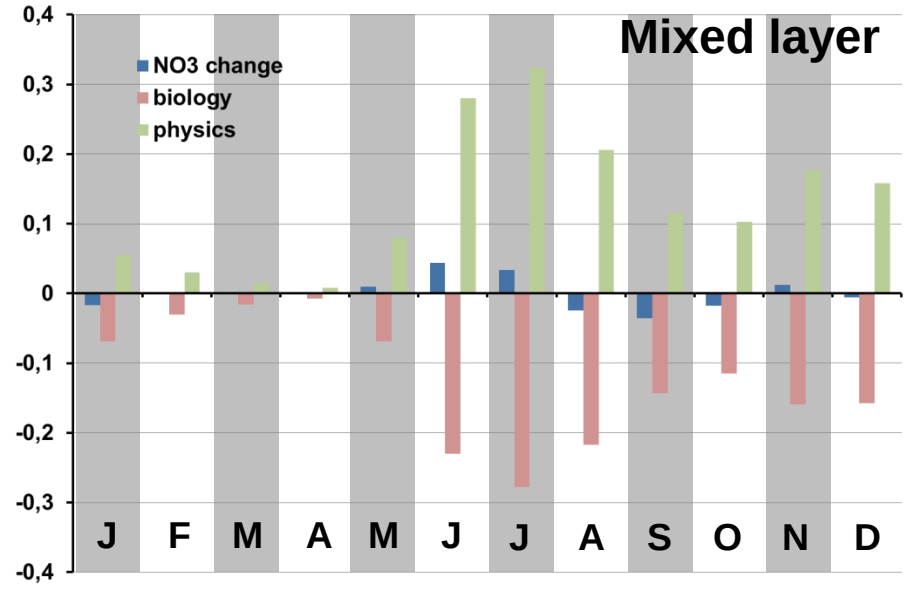
# Meridional advection in 20°W-5°W, 1.5°S-0.5°N

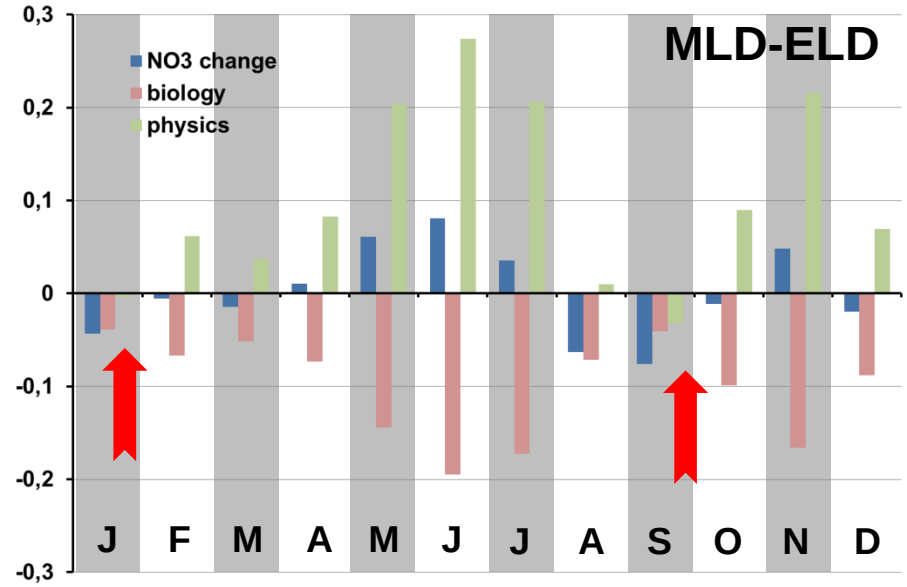



September

- Nitracline uplift ⇒ alternate positive and negative $\partial NO_3/\partial y$
- Southward V below the mixed layer
  Northward V at the base of the euphotic layer
- Negative meridional $NO_3$ advection between MLD and ELD on average
- Intraseasonal processes?

# Summary: physics vs. biology in 20°W-5°W, 1.5°S-0.5°N



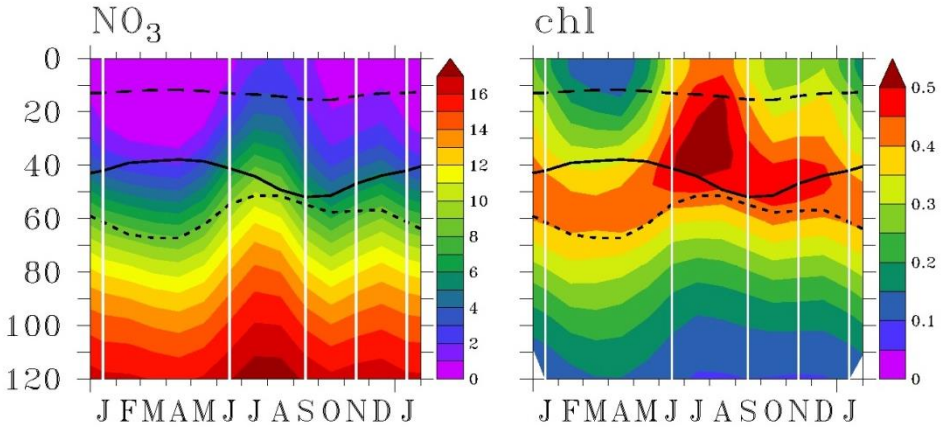




- Net $NO_3$ supply $\Rightarrow$ $\varphi$ input > bio loss
- Net $NO_3$ loss $\Rightarrow$ $\varphi$ input < bio loss

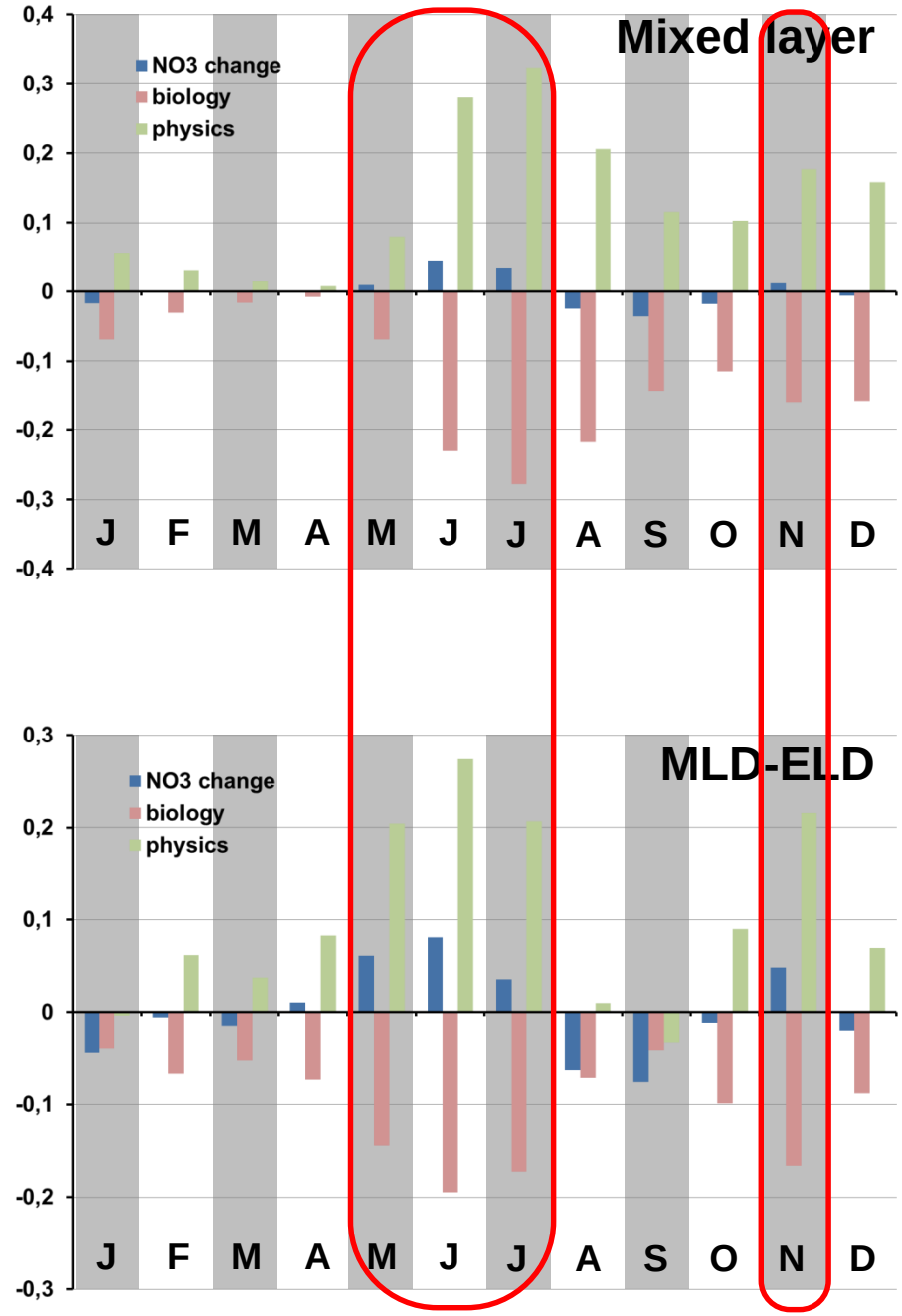
In both layers

- Semi-annual cycle of $\partial NO_3/\partial t$
- Semi-annual cycle of $NO_3$
- Semi-annual cycle of chlorophyll

Maximum in July-August and December



# Summary: physics vs. biology in 20°W-5°W, 1.5°S-0.5°N

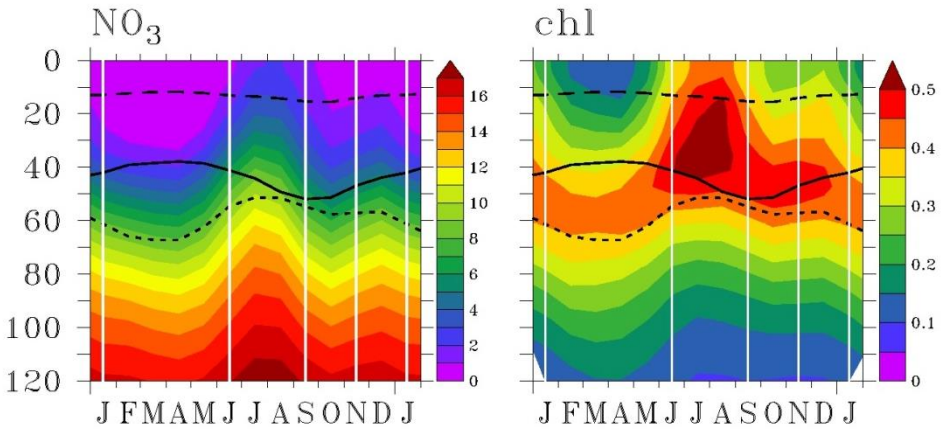



- Net $NO_3$ supply $\Rightarrow$ φ input > bio loss
- Net $NO_3$ loss $\Rightarrow$ φ input < bio loss

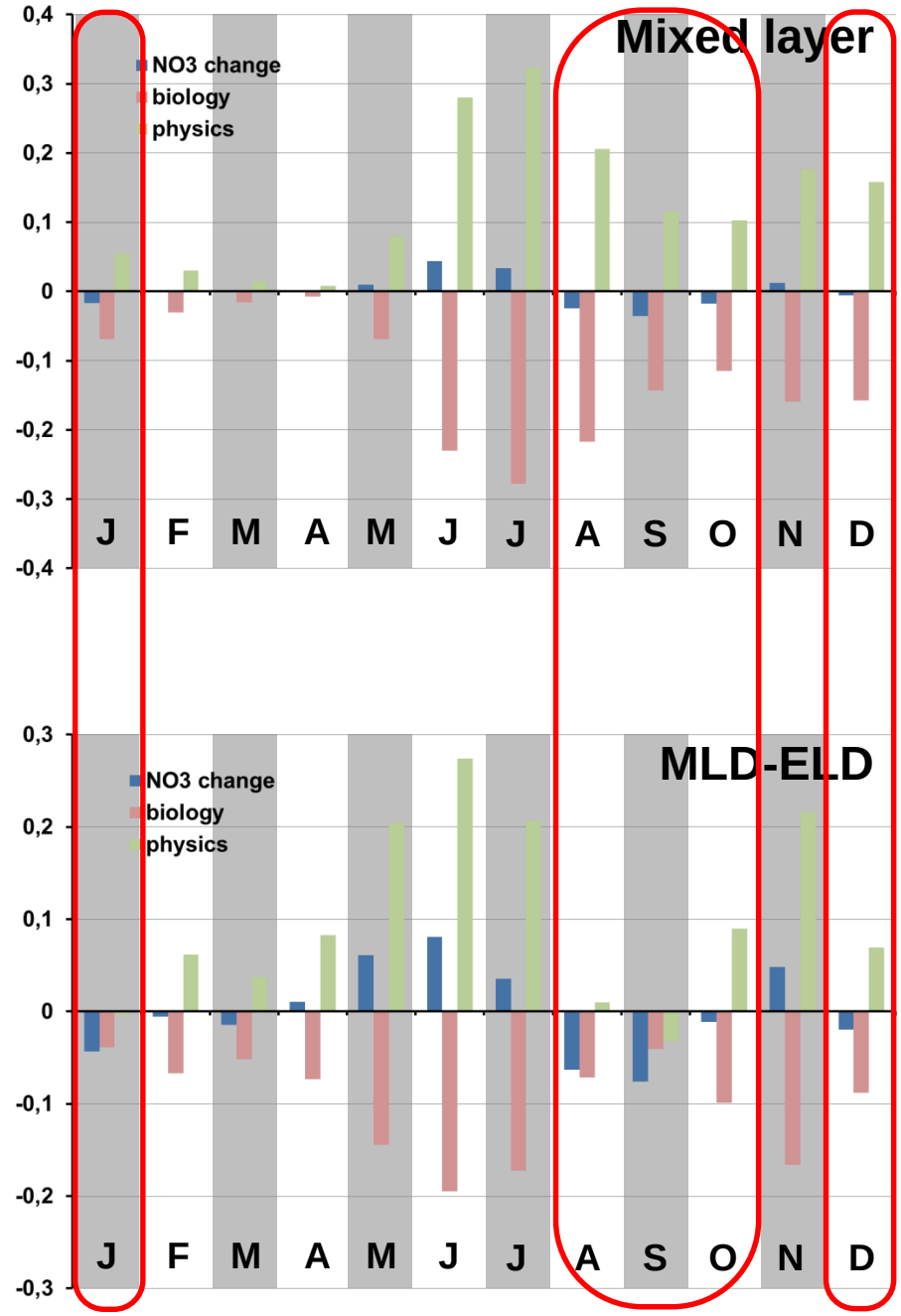
In both layers

- Semi-annual cycle of $\partial NO_3/\partial t$
- Semi-annual cycle of $NO_3$
- Semi-annual cycle of chlorophyll

Maximum in July-August and December



# Summary: physics vs. biology in 20°W-5°W, 1.5°S-0.5°N

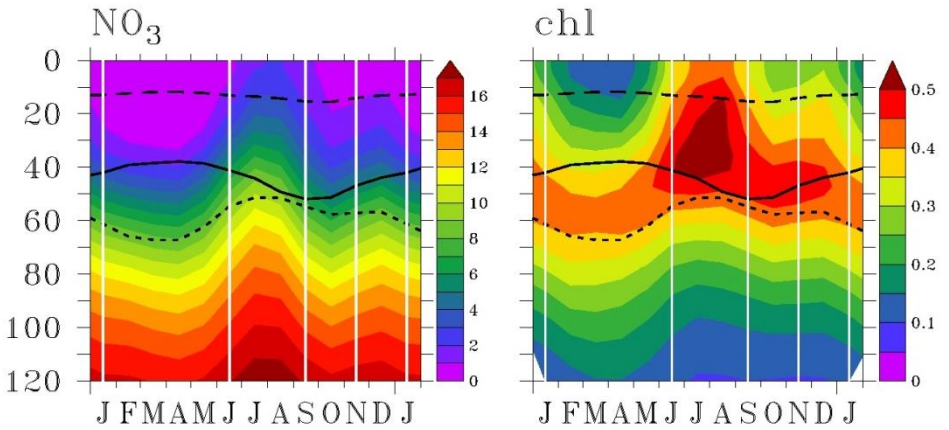



- Net $NO_3$ supply $\Rightarrow$ φ input > bio loss
- Net $NO_3$ loss $\Rightarrow$ φ input < bio loss

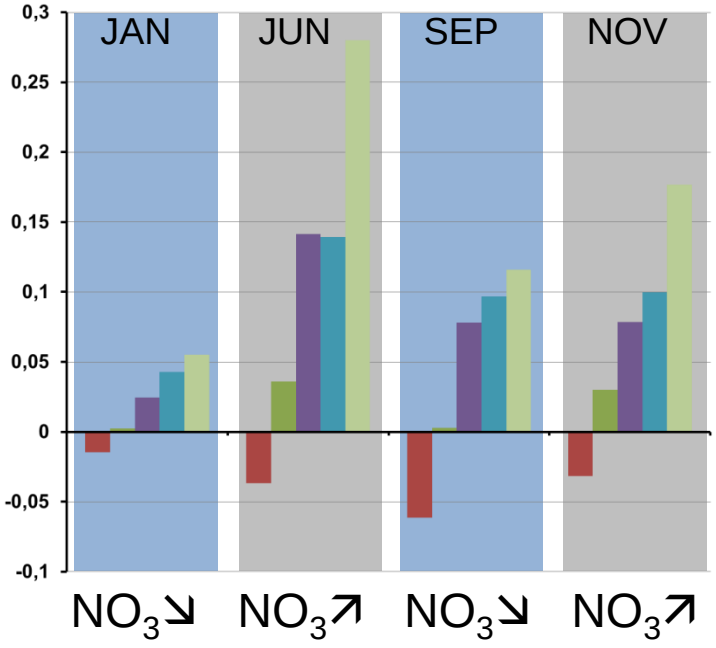
In both layers

- Semi-annual cycle of $\partial NO_3/\partial t$
- Semi-annual cycle of $NO_3$
- Semi-annual cycle of chlorophyll

Maximum in July-August and December



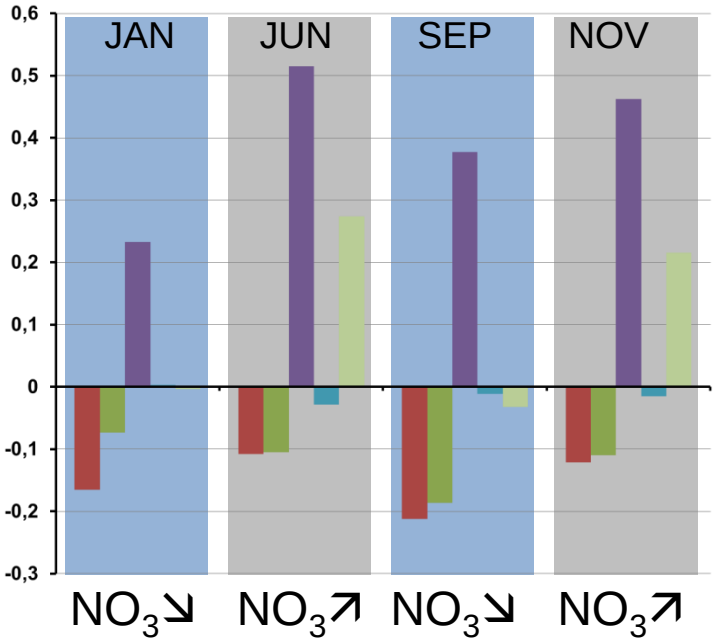
# Summary: vertical vs. horizontal processes in 20°W-5°W, 1.5°S-0.5°N




**Mixed layer**


## Mixed layer

- ≈ same processes for $NO_3$ and SST *(Foltz et al., 2003; Okumura and Xie, 2004; Grodsky et al., 2008; Jouanno et al., 2011)*
- Vertical advection and diffusion ⇒ $NO_3$ supply
- Semi-annual cycle of $\partial NO_3/\partial t$
  - Relevance of zonal $NO_3$ loss




**MLD-ELD**


## MLD-ELD

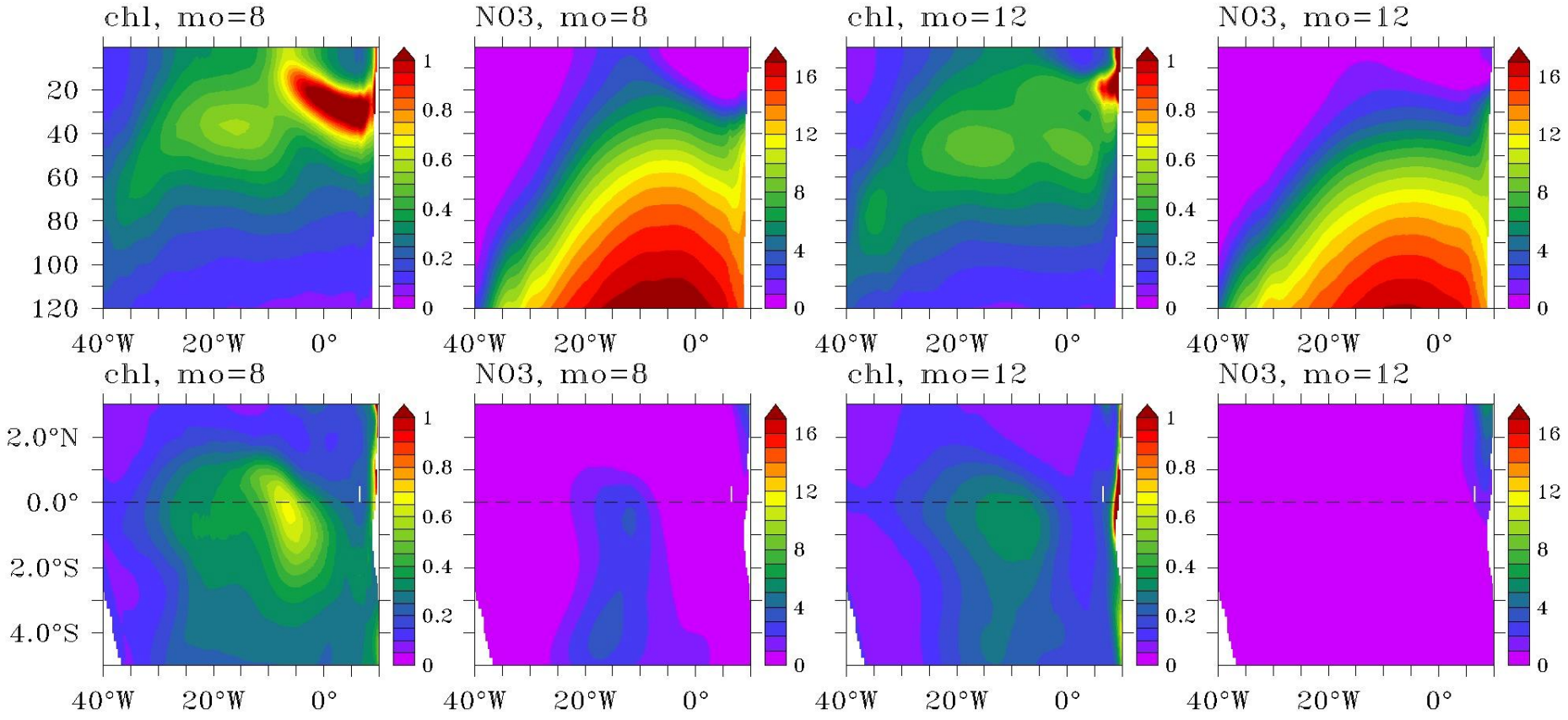
- Vertical advection ⇒ $NO_3$ supply
- Semi-annual cycle of $\partial NO_3/\partial t$
  - Relevance of $NO_3$ poor EUC
  - $NO_3$ poor water from the north

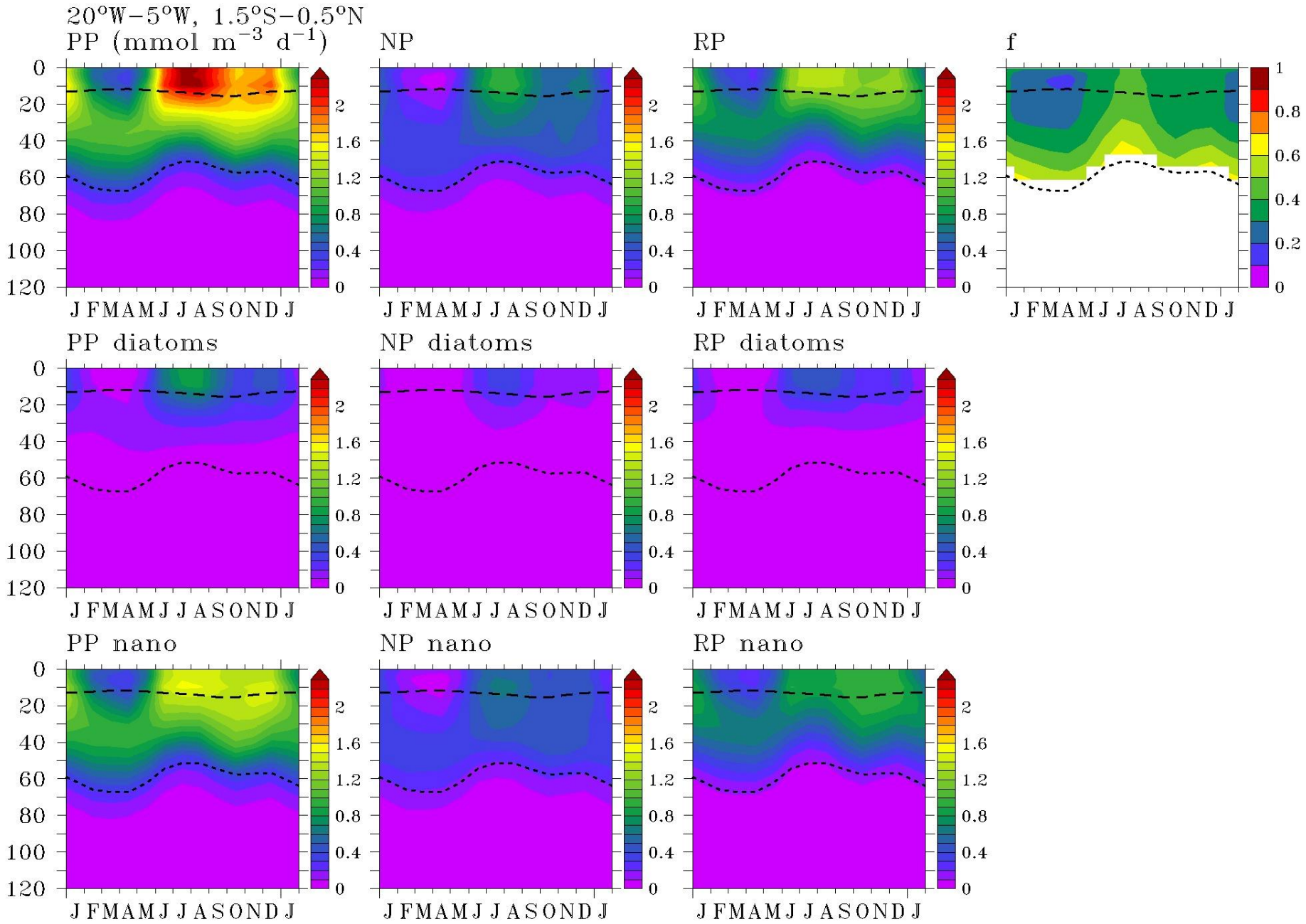
## Both layers

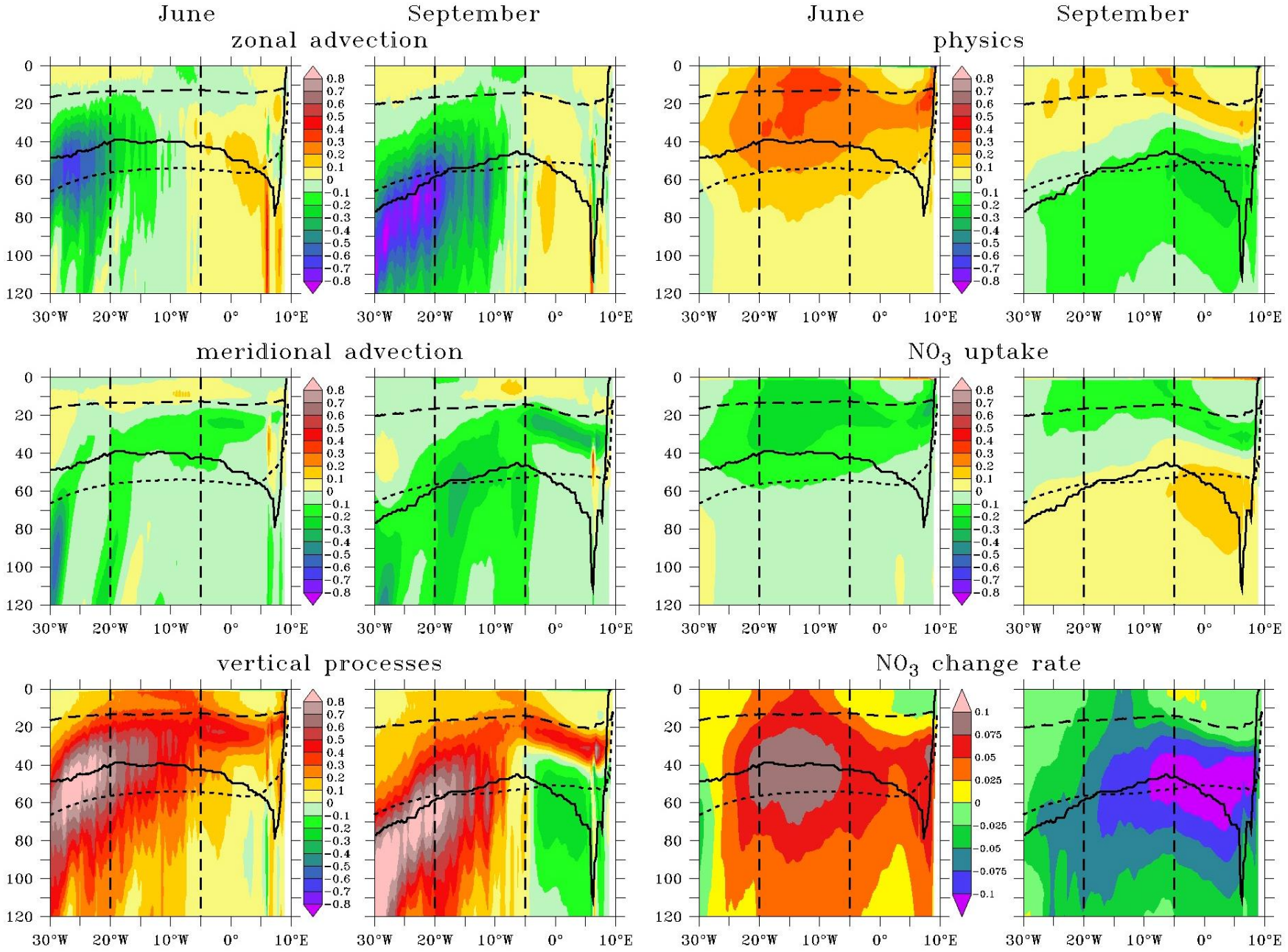
- Intraseasonal processes?

# PIRATA cruises along 10°W

| PIRATA cruises | Dates | $NO_3$ | chl | U |
|---|---|---|---|---|
| FR12 | February 2004 | × | | |
| FR14-EGEE1 | June 2005 | × | | |
| FR17 | June 2007 | | | × |
| FR18 | October 2008 | | | × |
| FR19 | July 2009 | × | | |
| FR20 | September 2010 | × | | |
| FR21 | May 2011 | × | × | × |
| FR22 | April 2012 | × | × | × |
| FR23 | May 2013 | × | × | × |
| FR24 | April 2014 | × | × | × |
| FR25 | April 2015 | | | × |
| FR26 | March 2016 | × | × | |


chl, mo=8
N03, mo=8
chl, mo=12
N03, mo=12
20
40
60
80
100
120
40°W
20°W
0°
1
0.8
0.6
0.4
0.2
0
16
12
8
4
chl, mo=8
N03, mo=8
chl, mo=12
N03, mo=12
2.0°N
0.0°
2.0°S
4.0°S
40°W
20°W
0°


20°W–5°W, 1.5°S–0.5°N
PP (mmol m$^{-3}$ d$^{-1}$)
NP
RP
f
PP diatoms
NP diatoms
RP diatoms
PP nano
NP nano
RP nano
0
20
40
60
80
100
120
J F M A M J J A S O N D J
0
0.4
0.8
1.2
1.6
2
0.2
0.6
1


June
September
zonal advection
June
September
physics
meridional advection
$NO_3$ uptake
vertical processes
$NO_3$ change rate
0
20
40
60
80
100
120
30°W
20°W
10°W
0°
10°E
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
−0.7
−0.8
0.1
0.075
0.05
0.025
0
−0.025
−0.05
−0.075
−0.1