Growth and decay of northwestern tropical Atlantic barrier layers

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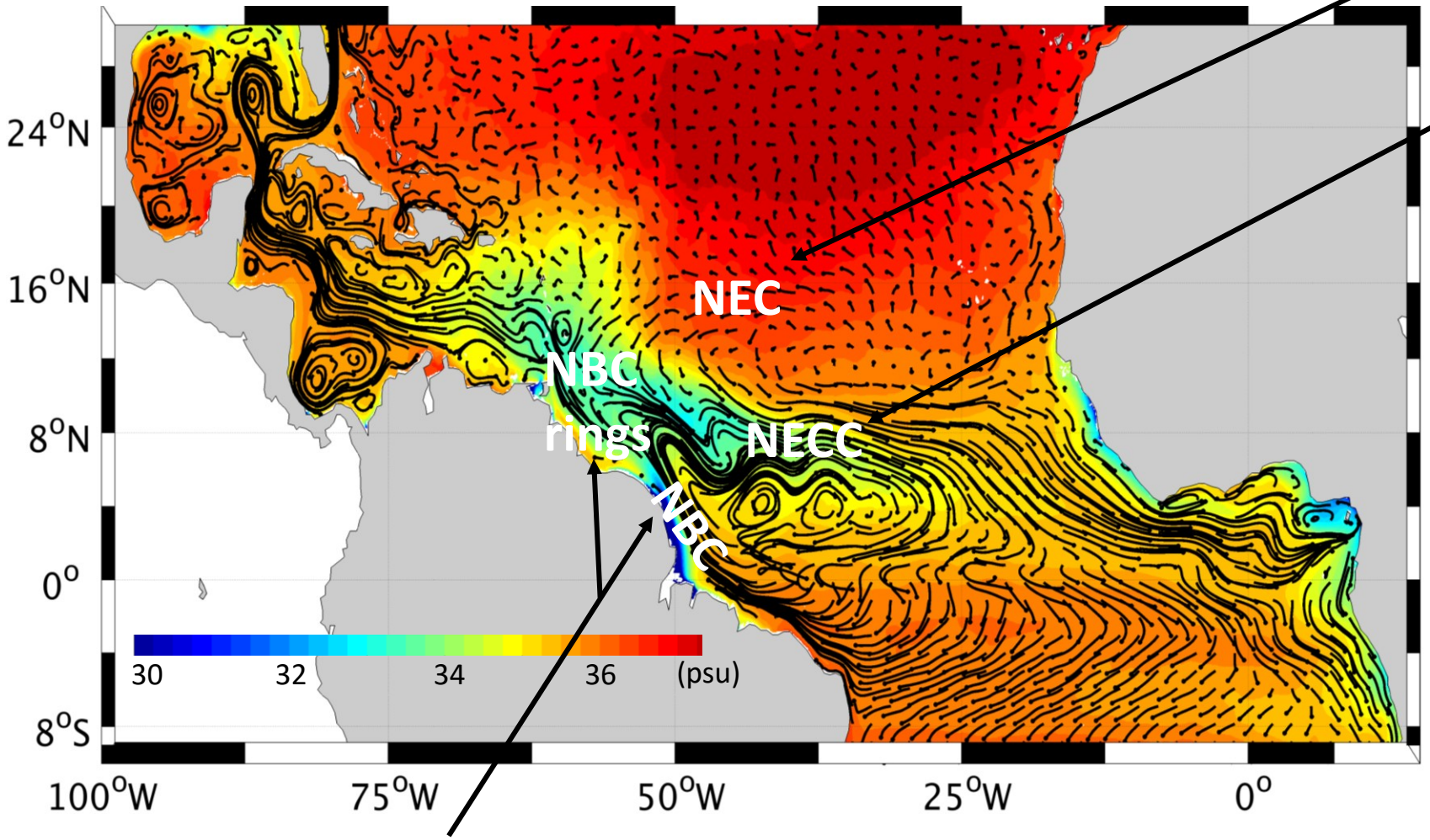
Background

Mixed layer salinity and flow at 20 m September



westward: **North Equatorial Current (NEC)**

eastward: North Equatorial Countercurrent (NECC)

northwestward: **North Brazil Current (NBC) and its rings**

- Spread of freshwater from **Amazon River + Intertropical Convergence Zone (ITCZ) rainfall** results in barrier layer formation.
- Seasonality of the barrier layers are roughly known. (Mignot et al., 2012; Balaguru et al., 2012; Foltz and McPhaden, 2008; de Boyer Montégut et al., 2007; Masson and Delecluse, 2001)

Research Question

With respect to the northwestern tropical Atlantic Ocean,

Q. What is the variability of the barrier layers and how do they grow and decay?

Barrier Layer Thickness (**BLT**) = Isothermal Layer Depth (**ILD**) - Mixed Layer Depth (**MLD**)

Data

Atlantic Ocean eddy-resolving numerical simulation (ATL4km)

MITgcm run forced by ECMWF ERA-Interim reanalysis

4 km
2003-2011,
daily output

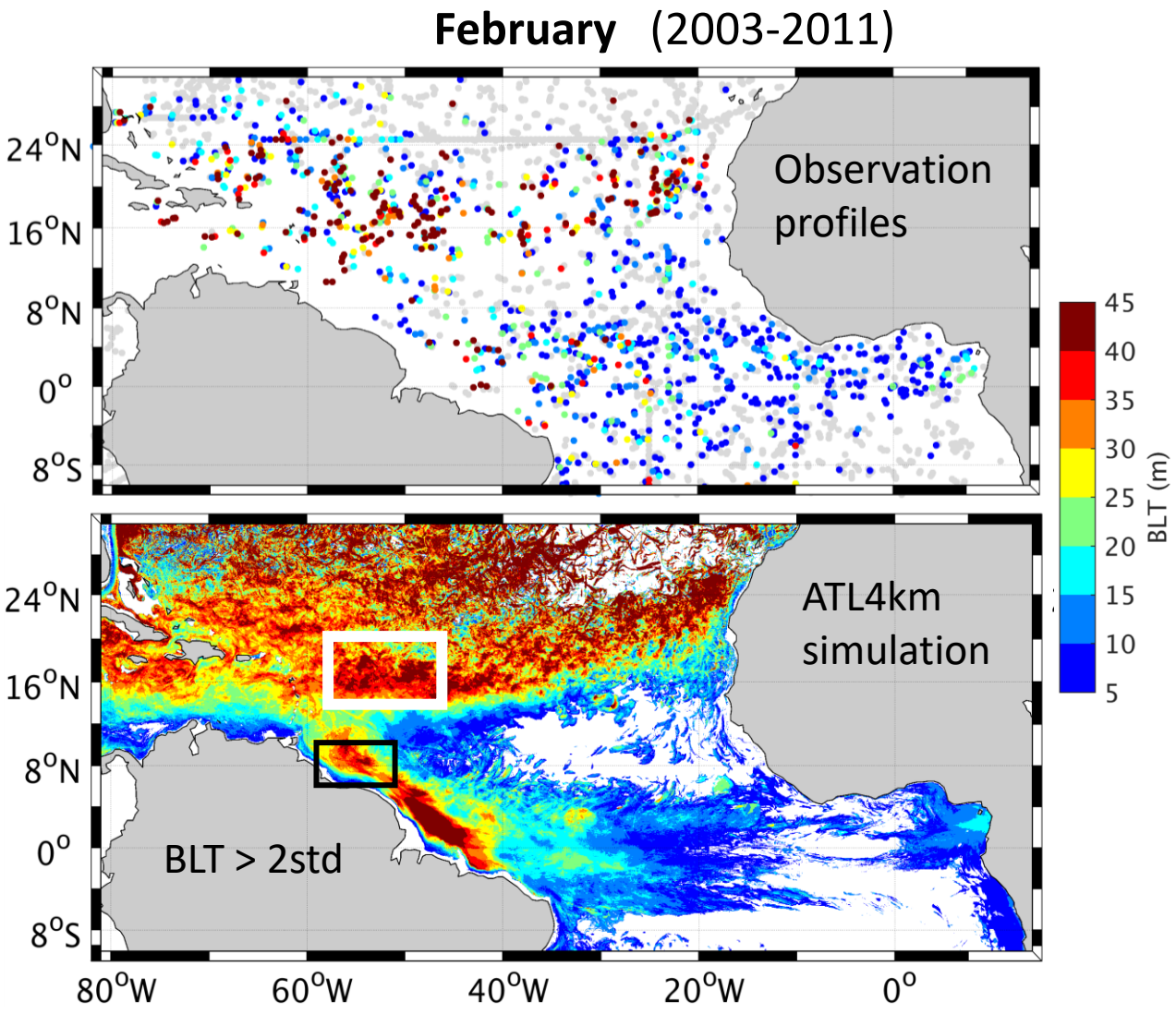
Observations

EN4 temperature and salinity database: **objective analysis**
1° x 1°
MetOffice, UK
1961-2008, monthly

In situ Argo, CTD, XBT **profiles**

De Boyer Montégut MLD, ILD, BLT **Climatology**
2° x 2°
Ifremer, France
1961-2008, monthly climatology

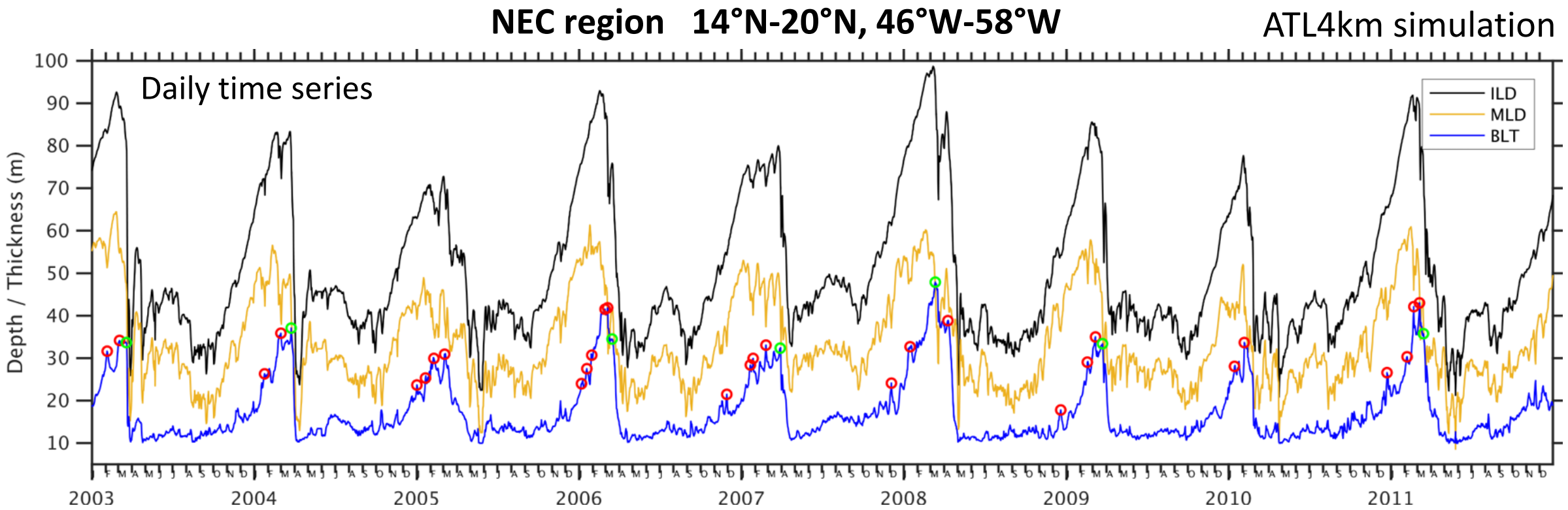
Spatial variability of observed and simulated barrier layers



- Barrier layers are very **localized** phenomena.

- Max. spatial coverage and magnitude is in the western tropical Atlantic, south of the subtropical gyre along the North Equatorial Current (NEC).

Temporal variability of barrier layers



- Barrier layers **grow from November to February**.
- ILD deepens more than MLD, increasing BLT.

Governing equations

The vertical derivative of salinity and temperature balance equations (Cronin and McPhaden, 2002):

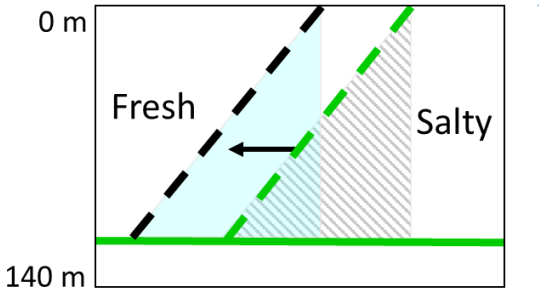
$$\frac{\partial}{\partial z}\left(\frac{\partial S}{\partial t}\right) = -U \cdot \frac{\partial}{\partial z}(\nabla S) - w\frac{\partial^2 S}{\partial z^2} - \frac{\partial U}{\partial z} \cdot \nabla S - \frac{\partial w}{\partial z}\frac{\partial S}{\partial z} - \frac{\partial^2(\overline{w'S'})}{\partial z^2}$$

$$\frac{\partial}{\partial z}\left(\frac{\partial T}{\partial t}\right) = -U \cdot \frac{\partial}{\partial z}(\nabla T) - w\frac{\partial^2 T}{\partial z^2} - \frac{\partial U}{\partial z} \cdot \nabla T - \frac{\partial w}{\partial z}\frac{\partial T}{\partial z} - \frac{\partial^2(\overline{w'T'})}{\partial z^2} + \frac{1}{\rho c_p}\frac{\partial^2 Q_{rad}}{\partial z^2}$$

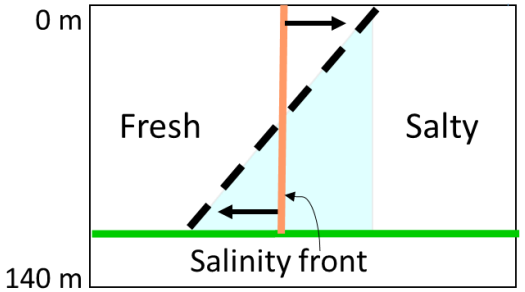
LHS 1 2 3 4 5

S : salinity
T : temperature
U = (u,v) horizontal velocity
w: vertical velocity
z : depth

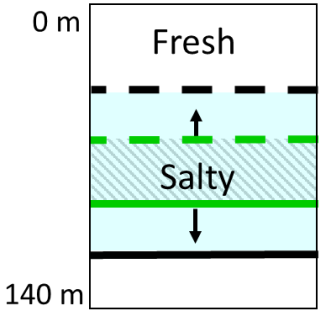
Term 1: Horizontal Advection



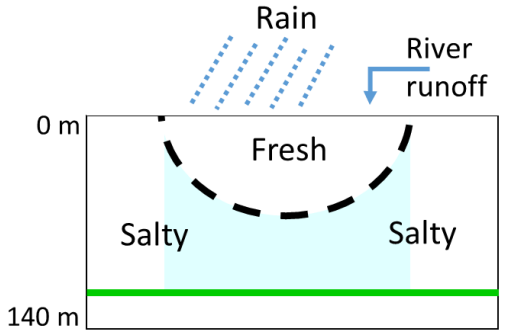
Term 3: Tilting



Term 4: Stretching



Term 5: Turbulent Mixing

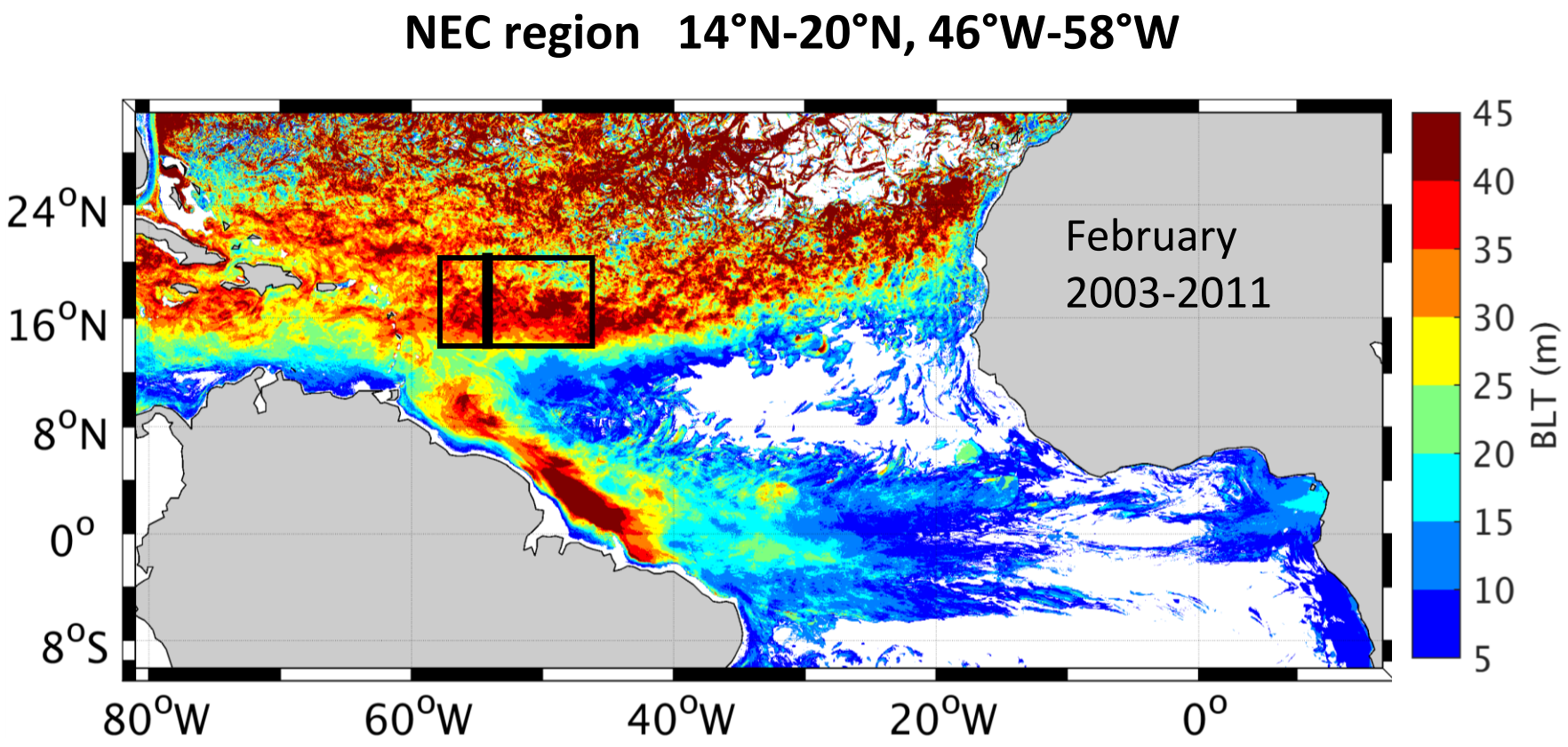


solid line —— ILD, dashed line - - - - MLD
green: existing
black: resulting

Hatched region : existing barrier layer

Blue shaded region : resulting barrier layer

Barrier layers in the NEC region: seasonal evolution

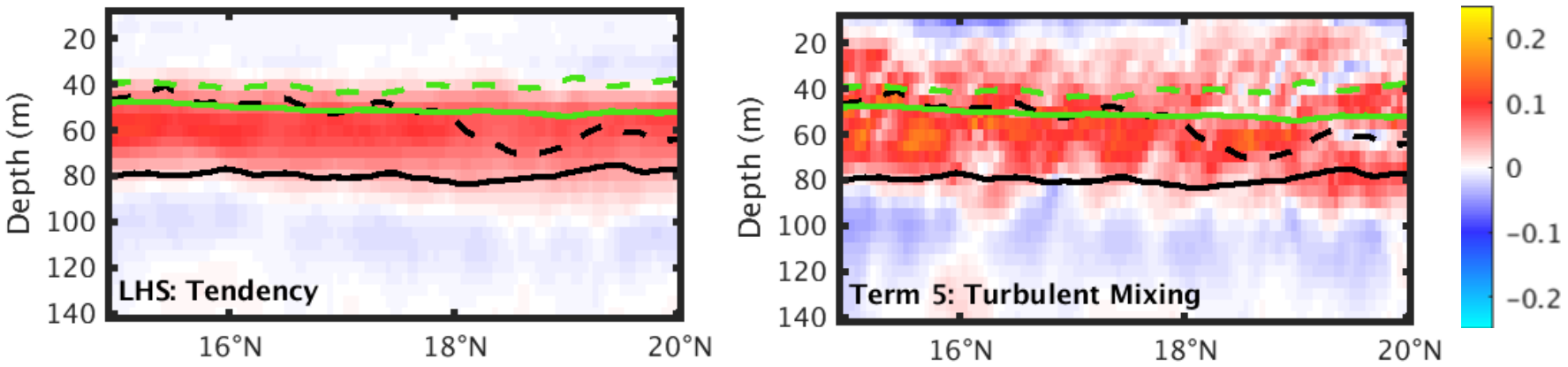


Barrier layers in the NEC region: seasonal growth mechanism

Section at 54°W

Temperature vertical gradient balance terms (10^{-7} °C / m.sec)

Averaged from November to February



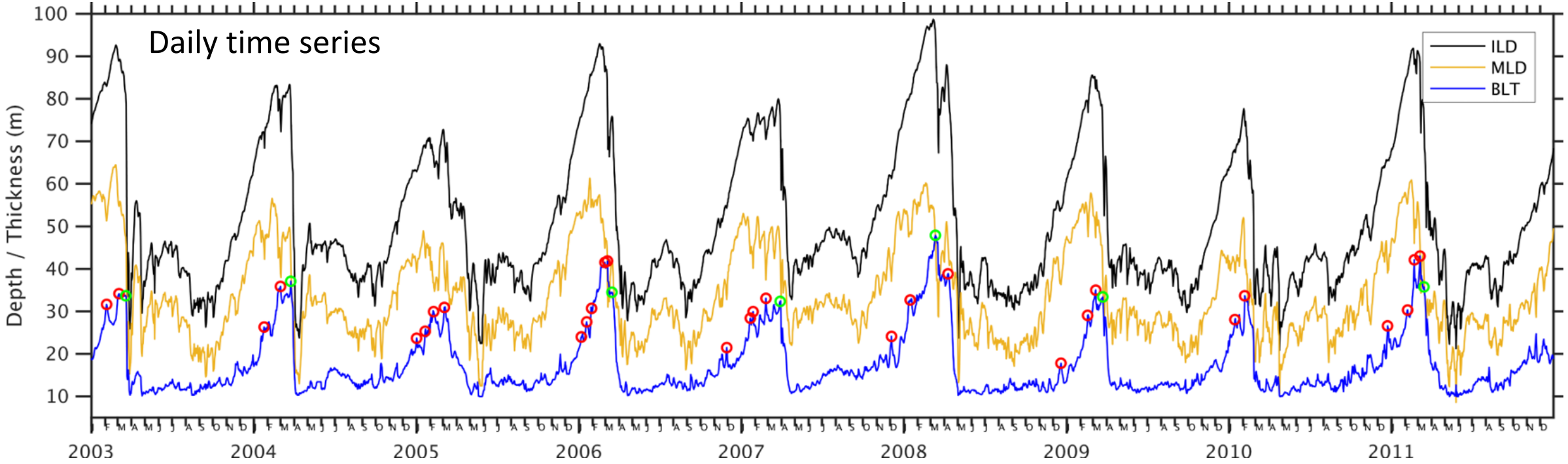
- **Deep ILD** in winter due to **turbulent mixing** by convection and trade winds.

solid line ——— ILD, **dashed line - - - - MLD**

green: November **black: February next year**

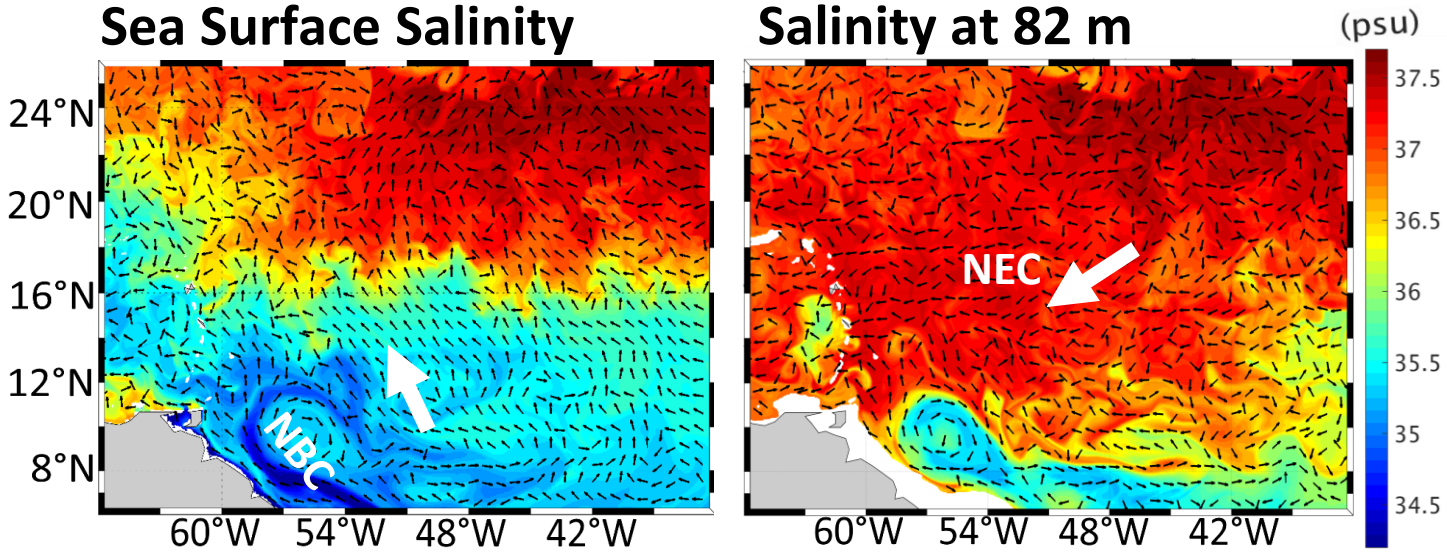
Temporal variability of barrier layers

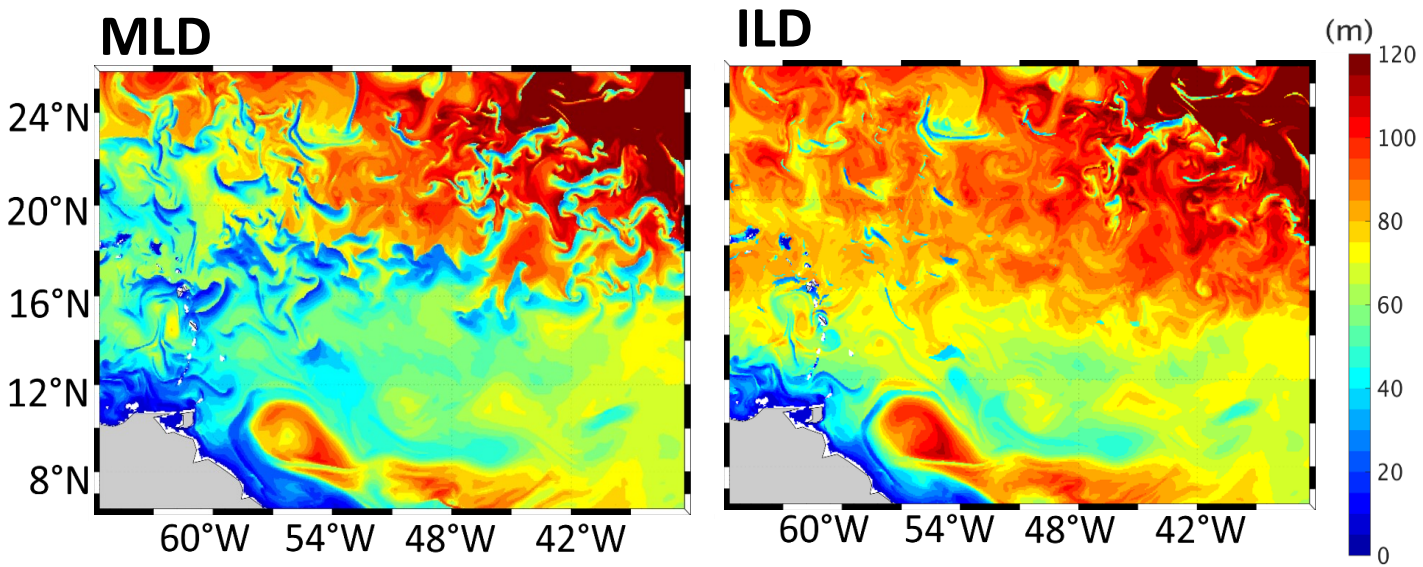
NEC region 14°N-20°N, 46°W-58°W



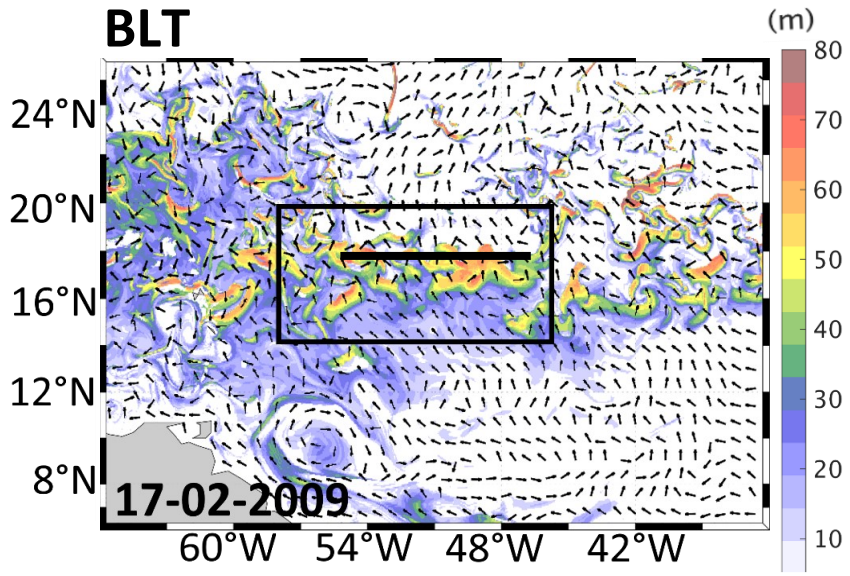
- **29 Red circles: events of large barrier layers superimposed on the seasonal cycle.**

Barrier layers in the NEC region: short-term events

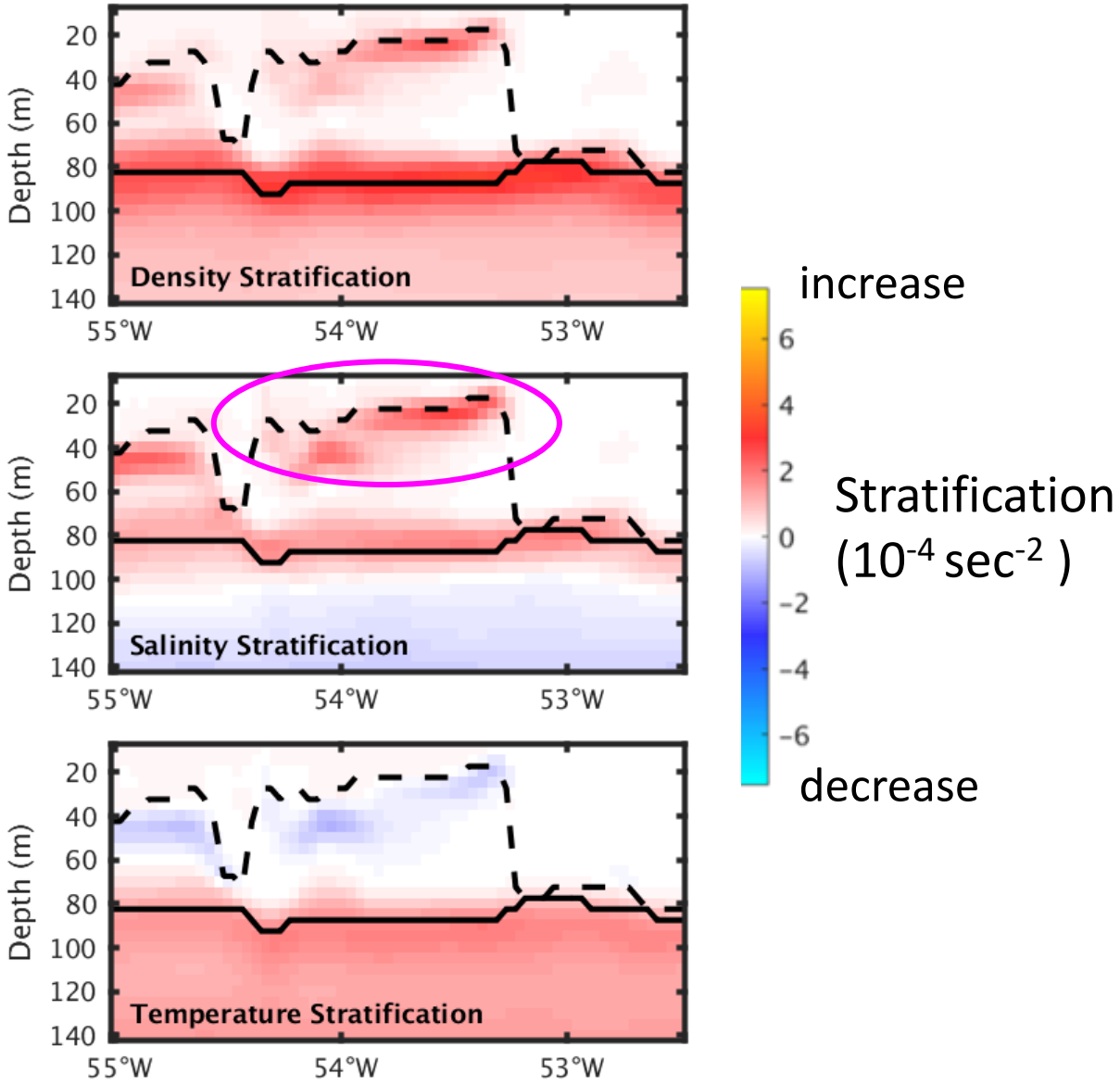




- **Surface northwestward freshwater advection** by Ekman currents and North Brazil Current (NBC). **Subsurface equatorward saline water advection** by NEC.
- MLD shoals and barrier layers occur on lower surface salinity side.



Barrier layers in the NEC region: growth mechanisms



Section at 18°N

17-02-2009

Black solid line —— ILD,

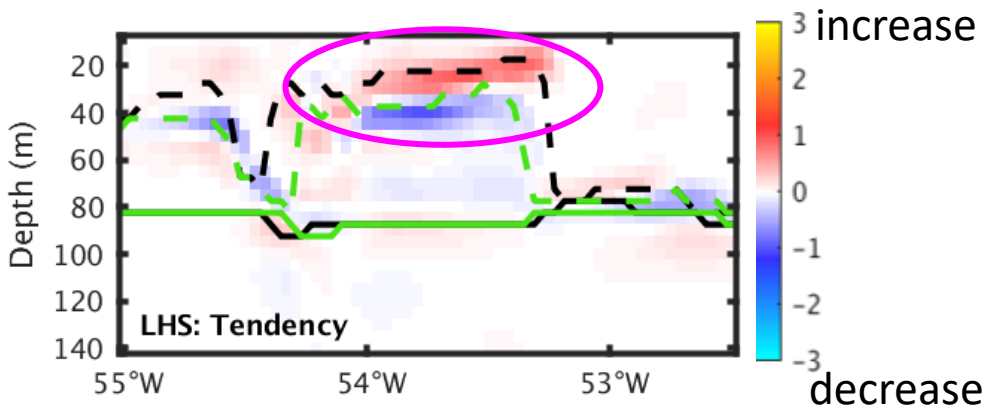
dashed line - - - - MLD

- Salinity stratification is dominant.

Barrier layers in the NEC region: growth mechanisms

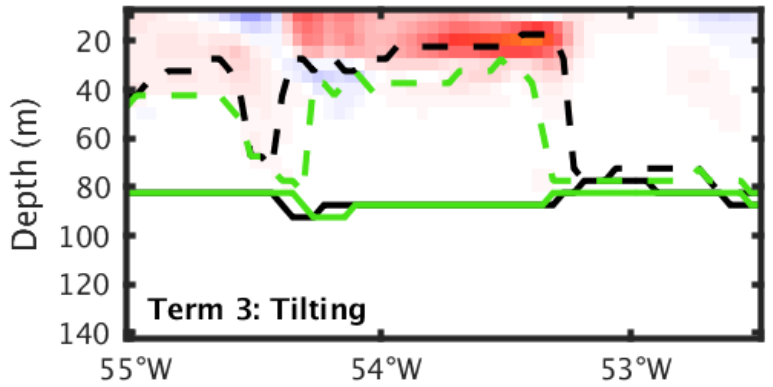
Salinity vertical gradient balance terms (10^{-7} psu / m.sec)

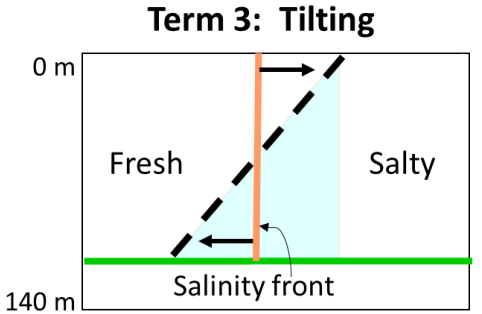
Averaged from 14-02-2009 to 17-02-2009

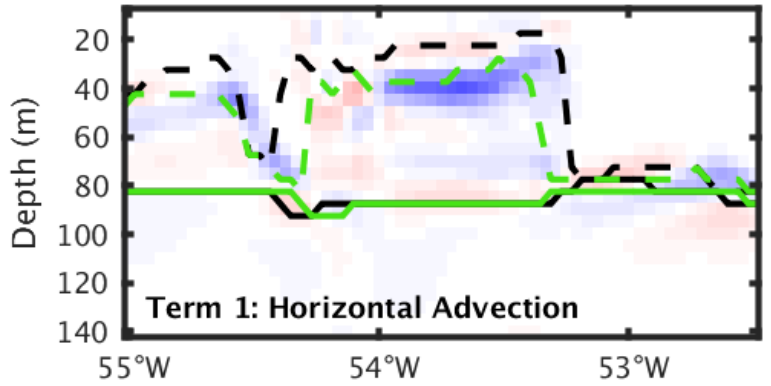


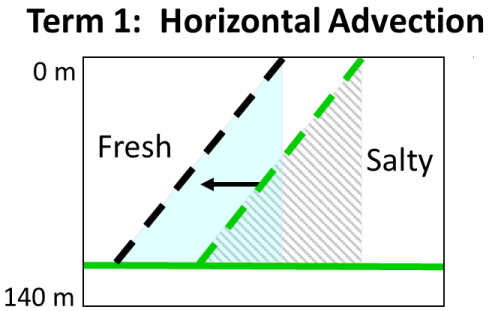
Black solid line —— ILD, dashed line - - - - MLD for 17-02-2009,

green lines the same for **3 days before**.





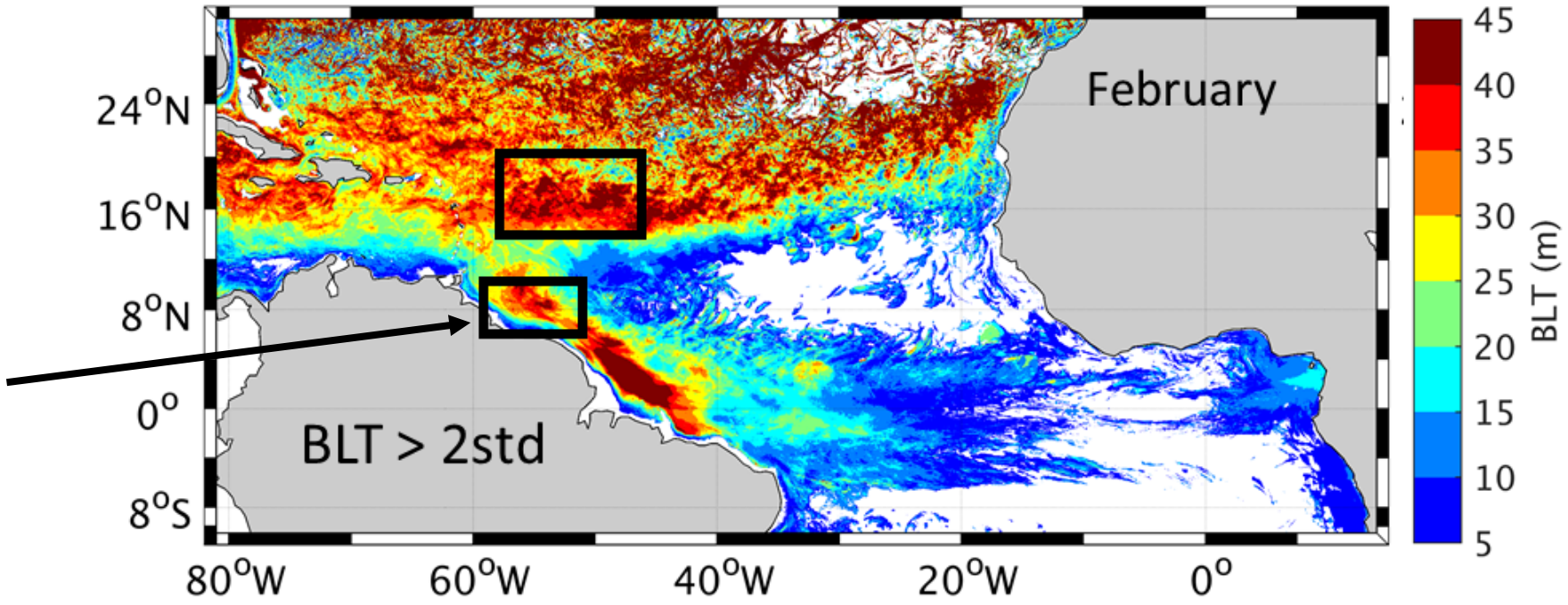




- **Tilting** of salinity front by northwestward North Brazil Current and Ekman currents carrying freshwater and equatorward horizontal advection of saline water by NEC.

Barrier layers in other regions of the tropical Atlantic Ocean

Max: June-July **Deepening of ILD** in the **North Brazil Current rings** by mainly **horizontal heat advection**.



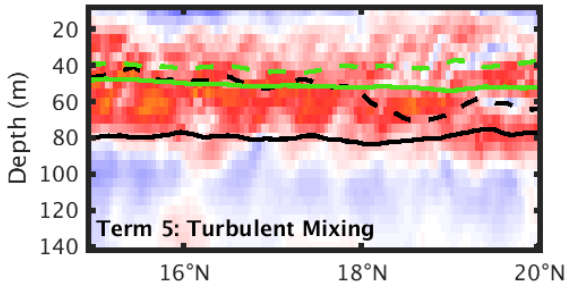
The dominating mechanisms are different in the different regions.

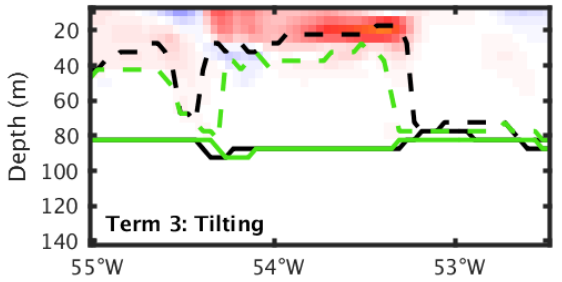
Conclusions

Q. What is the variability of the barrier layers and how do they grow and decay?

Barrier layers along North Equatorial Current

- Seasonal
  - **1.** Grow from November to February because **ILD deepens** due to convective and wind driven **turbulent mixing.**
- Short-term events
  - **2.** Grow because **MLD shoals** due to **tilting of salinity fronts** by northwestward surface freshwater flow and equatorward subduction of saline water.





3. The seasonal variability and growth and decay mechanisms of barrier layers are different in the different localized regions of the tropical Atlantic.

- Saha, A., Serra, N., & Stammer, D. (2021). Growth and decay of northwestern tropical Atlantic barrier layers. *Journal of Geophysical Research: Oceans*, 126, e2020JC016956. https://doi.org/10.1029/2020JC016956

- Saha, A. (2020). Barrier layers in the tropical Atlantic Ocean: Growth and decay mechanisms and impact of Amazon river runoff, *PhD Dissertation*, Institute of Oceanography, Universität Hamburg, Hamburg, Germany.

Thank you…

Questions and comments: aurpita.saha@uni-hamburg.de