Deutsche Forschungsgemeinschaft DFG

Climate - Biogeochemistry Interactions in the Tropical Ocean SFB- 754

Vertical Mixing in the Tropical North Atlantic Ocean; Results from a large scale Tracer Release Experiment

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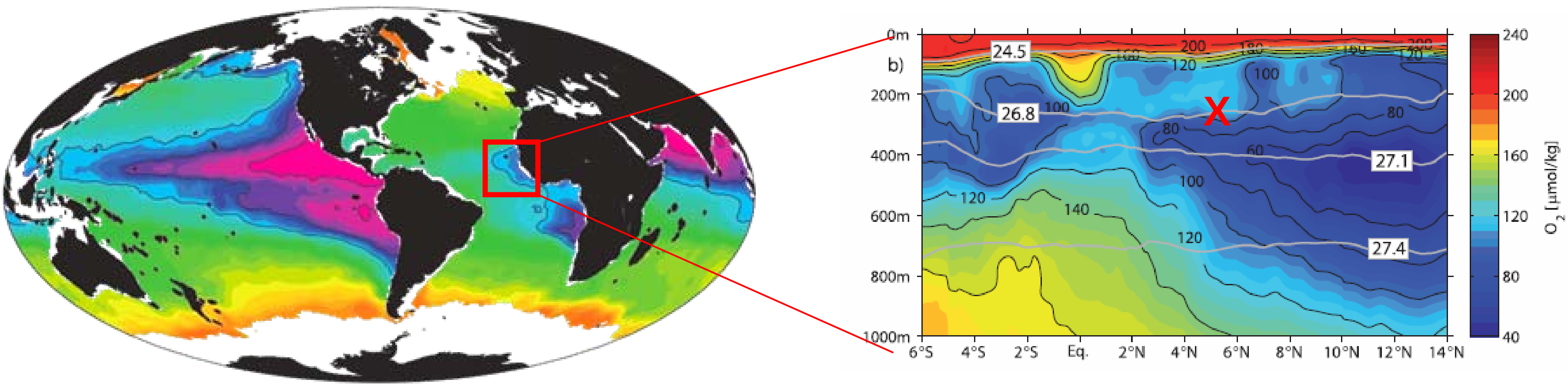
Background:

The Oxygen Minimum Zone in the Tropical North Atlantic Ocean – The Guinea Dome.



The “SFB 754”

Climate – Biogeochemistry Interactions in the Tropical Ocean

Guinea Upwelling Tracer Release Experiment (GUTRE)

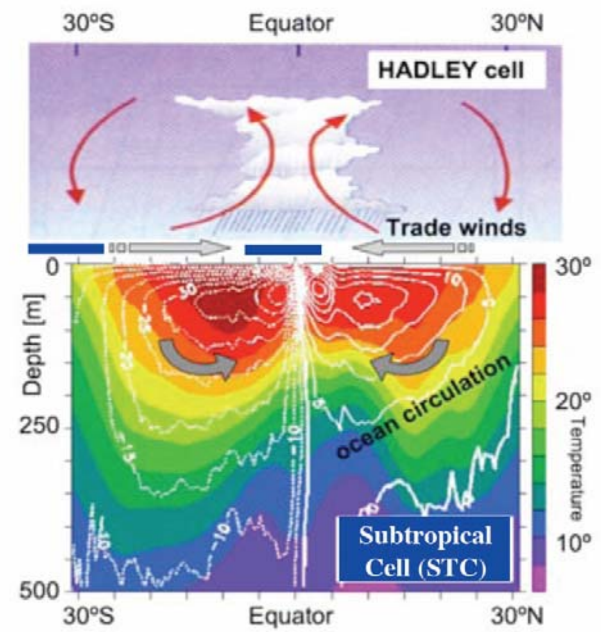
How does subsurface dissolved oxygen in the tropical ocean respond to variability in ocean circulation and ventilation?

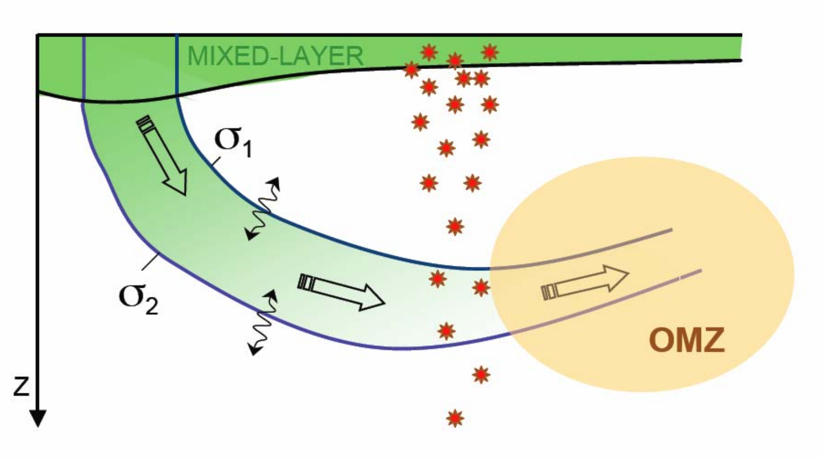
Circulation and Oxygen Concentration:

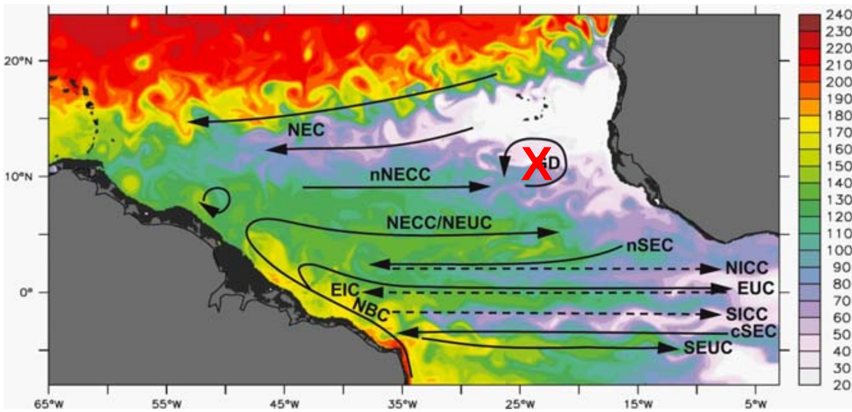
- Dissolved Oxygen can be supplied by:

  1) Lateral Pathways by mean and variable currents along isopycnals

  2) Vertical Pathways by mixing across isopycnals







Tracer Release Experiments:

Objective:

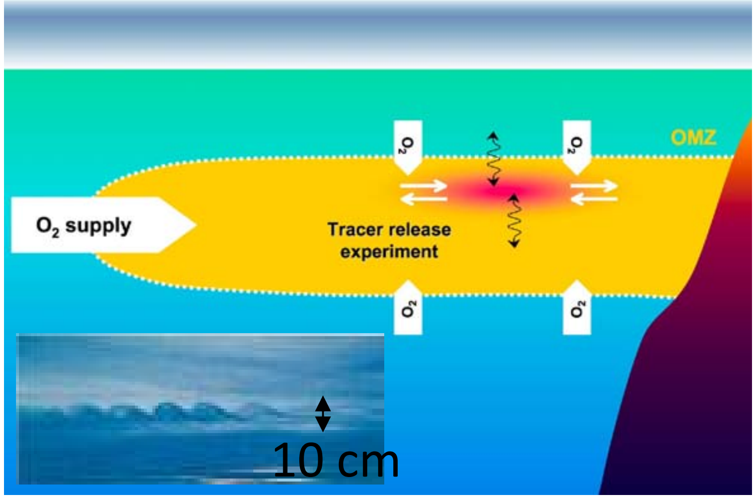
- Constrain estimates of diapycnal and isopycnal mixing in the ocean
- Observe advection of “labeled” water masses
- Study biogeochemical processes within the labeled water mass

Advantage:

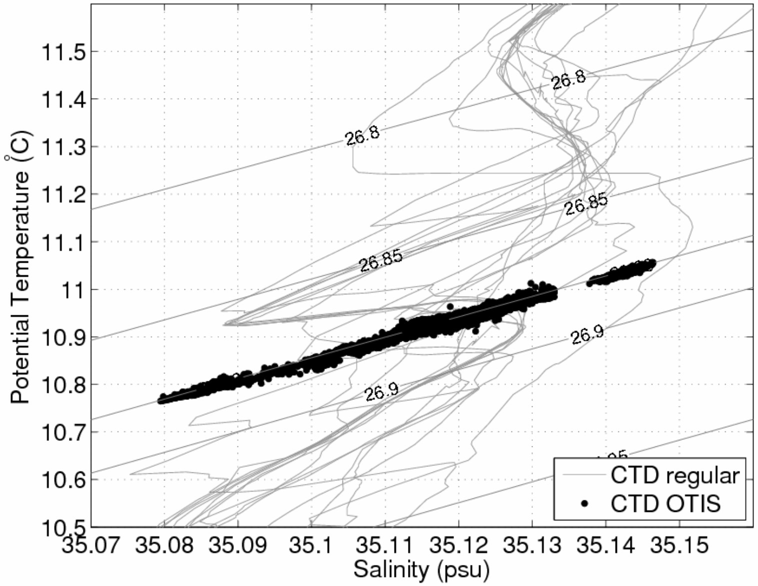
- Integrated value of all processes over a certain time period over a larger area
- Estimates to high accuracy is possible

Challenges:

- Only limited process understanding

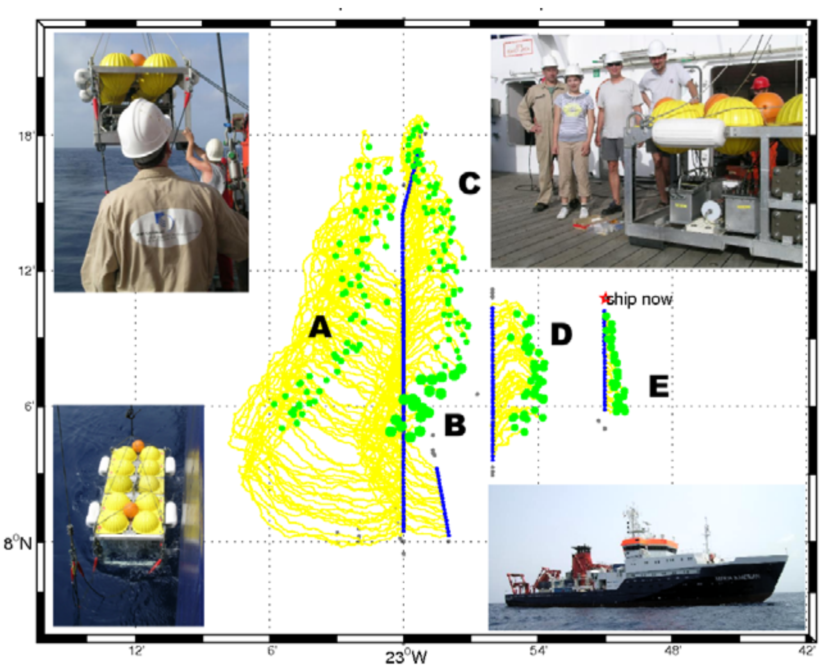


The Tracer Injection:

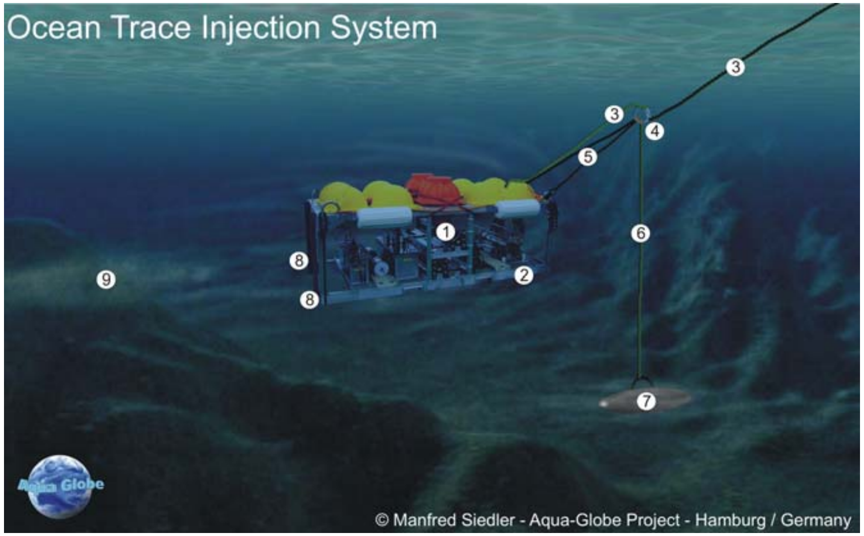


92 kg (470 mole) of CF_3SF_5 was Injected on the density surface σ_Θ = 26.88 kg m^{-3} and 8°N, 23°W
- In the upper oxygen gradient of the Tropical North Atlantic OMZ

CF_3SF_5 is an inert gas that does not vave any measurable background concentration in the ocean.

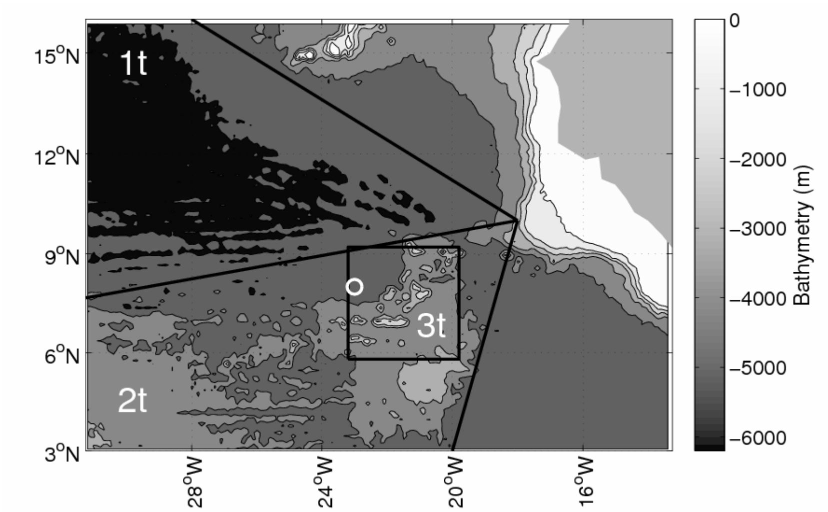


OTIS – Ocean Tracer Injection System



The Scene:

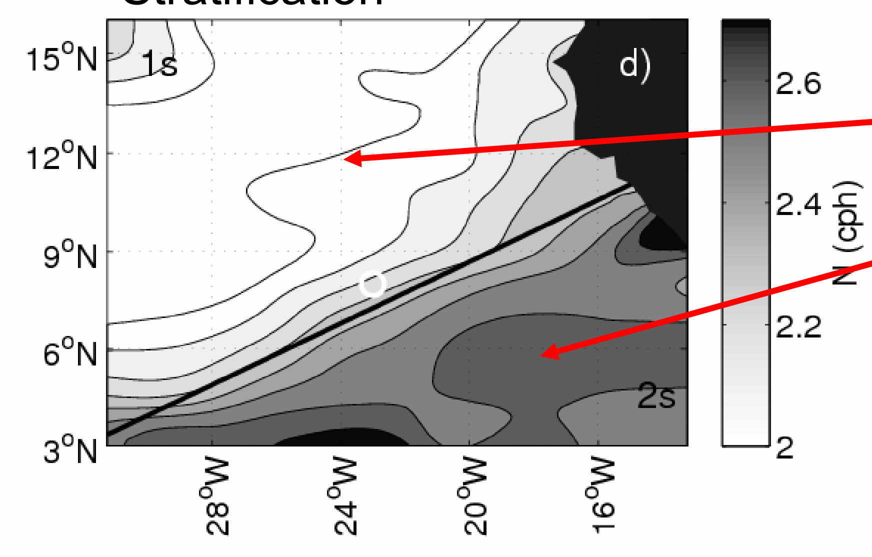
Topography

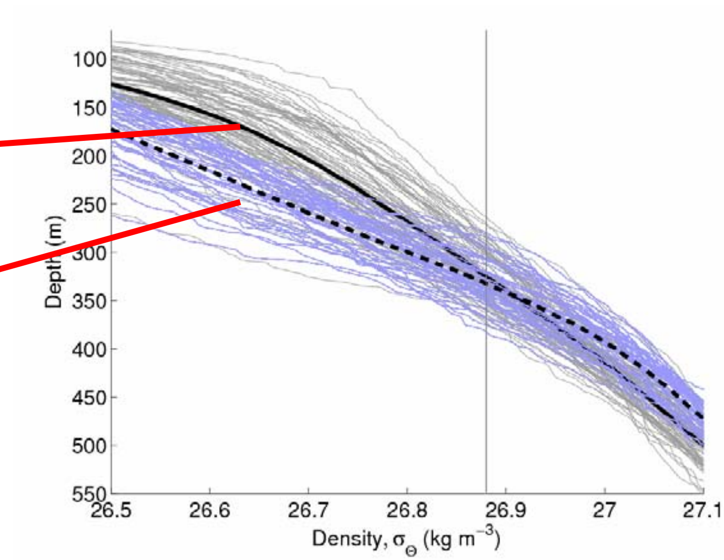


- •Seamount chain in the SE
- •Abyssal plain in the NW

- •High stratification in SE
- •Low stratification in NW

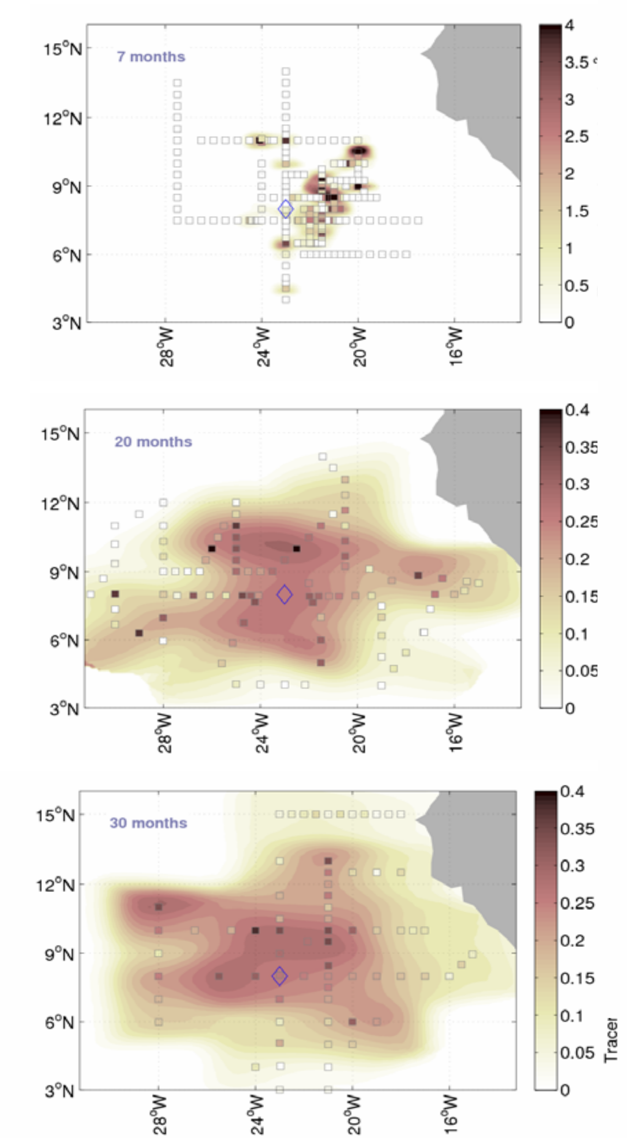
Stratification



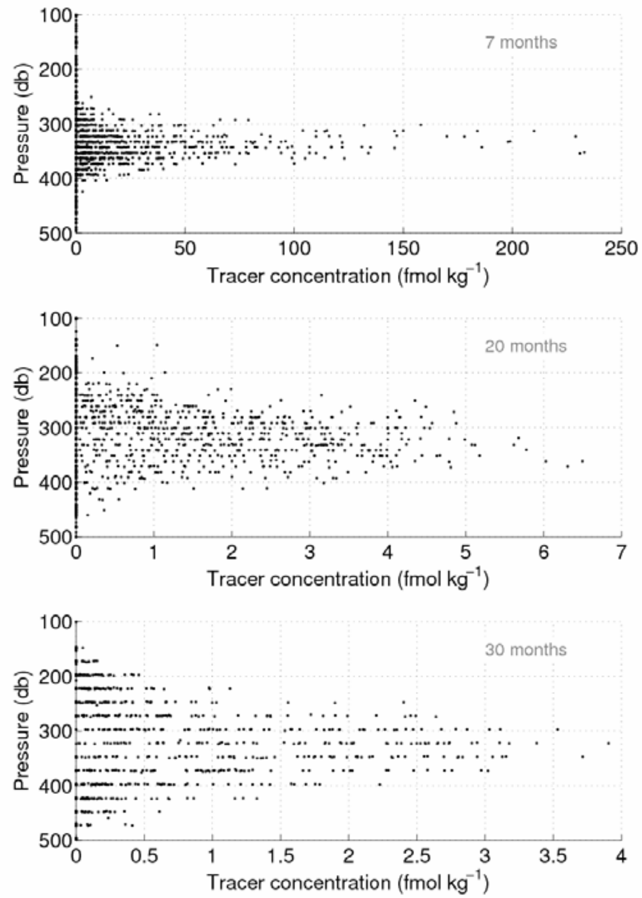


Tracer Observations:

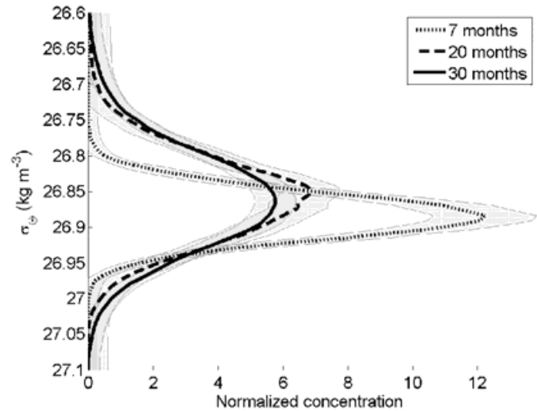
Horizontal spreading



Vertical spreading

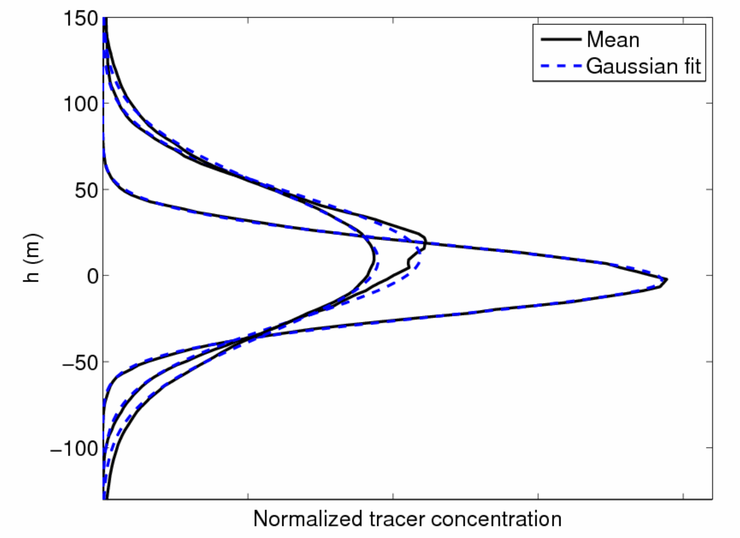


Diapycnal spreading



Calculating the mixing:

Assuming Gaussian distribution



Normalized vertical profiles closely resembles Gaussian distribution, so that the diffusivity can be calculated by the second moment of the Gaussian fit.

$K_z = S^2(t2) – S^2(t1) / 2(t2 - t1)$

Vertical advection diffusion model

$$\frac{\partial \bar{c}}{\partial t} + (\bar{w_z} - \frac{\partial D_z}{\partial z})\frac{\partial \bar{c}}{\partial z} = D_z \frac{\partial^2 \bar{c}}{\partial z^2},$$

$$\frac{\partial \bar{c}}{\partial t} + (\bar{w_\rho} - \frac{\partial D_\rho}{\partial \rho})\frac{\partial \bar{c}}{\partial \rho} = D_\rho \frac{\partial^2 \bar{c}}{\partial \rho^2}$$

We did these calculations in:

depth (D_z in $m^2\ s^{-1}$)

and $$D_z = \frac{D_\rho}{(\partial \rho / \partial z)^2}$$

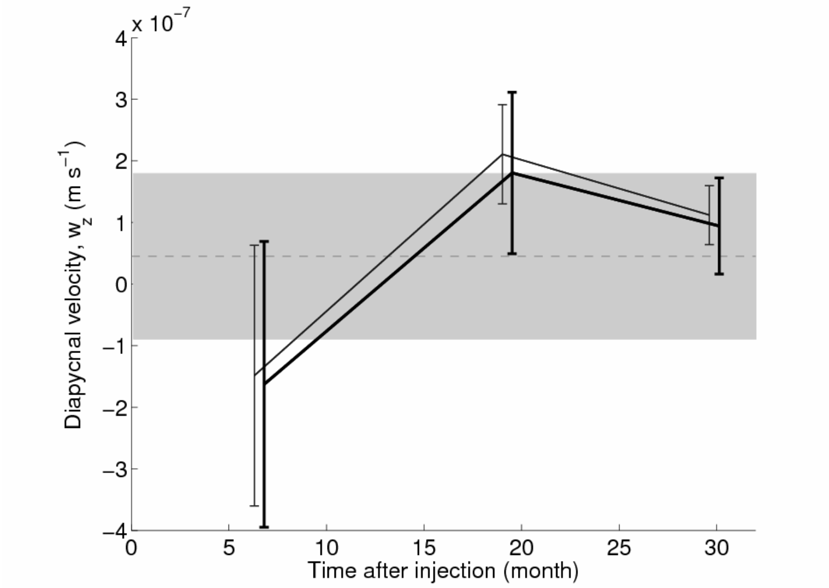
density (D_ρ in $(kg\ m^{-3})^2\ s^{-1}$)

Results:

Vertical velocity:

$\omega_z = 0.6 \pm 1.3 \times 10^{-7}$ m s^{-1}

$\omega_\rho = 1.3 \pm 2.0 \times 10^{-10}$ kg m^{-3} s^{-1}



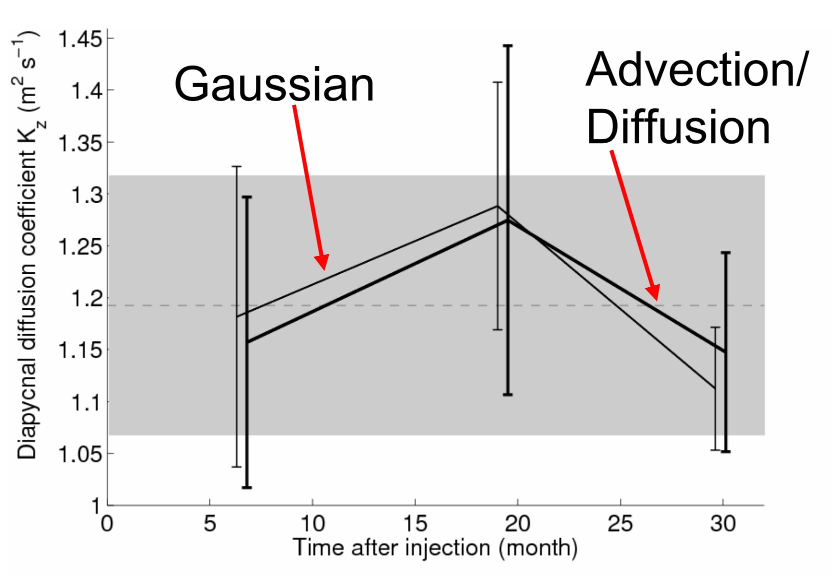
A significant upward velocity for the time between survey1 and 2/3

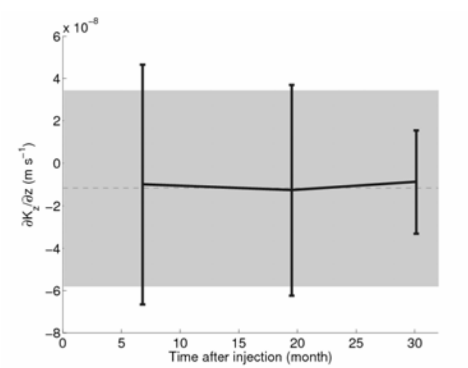
$1.6 \pm 0.6 \times 10^{-7}$ m s^{-1} (i.e. ~5 m y^{-1})

Vertical diffusivity:

$D_z = 1.18 \pm 0.13 \times 10^{-5}$ m^2 s^{-1}

$D_\rho = 3.10 \pm 0.28 \times 10^{-11}$ (kg m^{-3})^2 s^{-1}

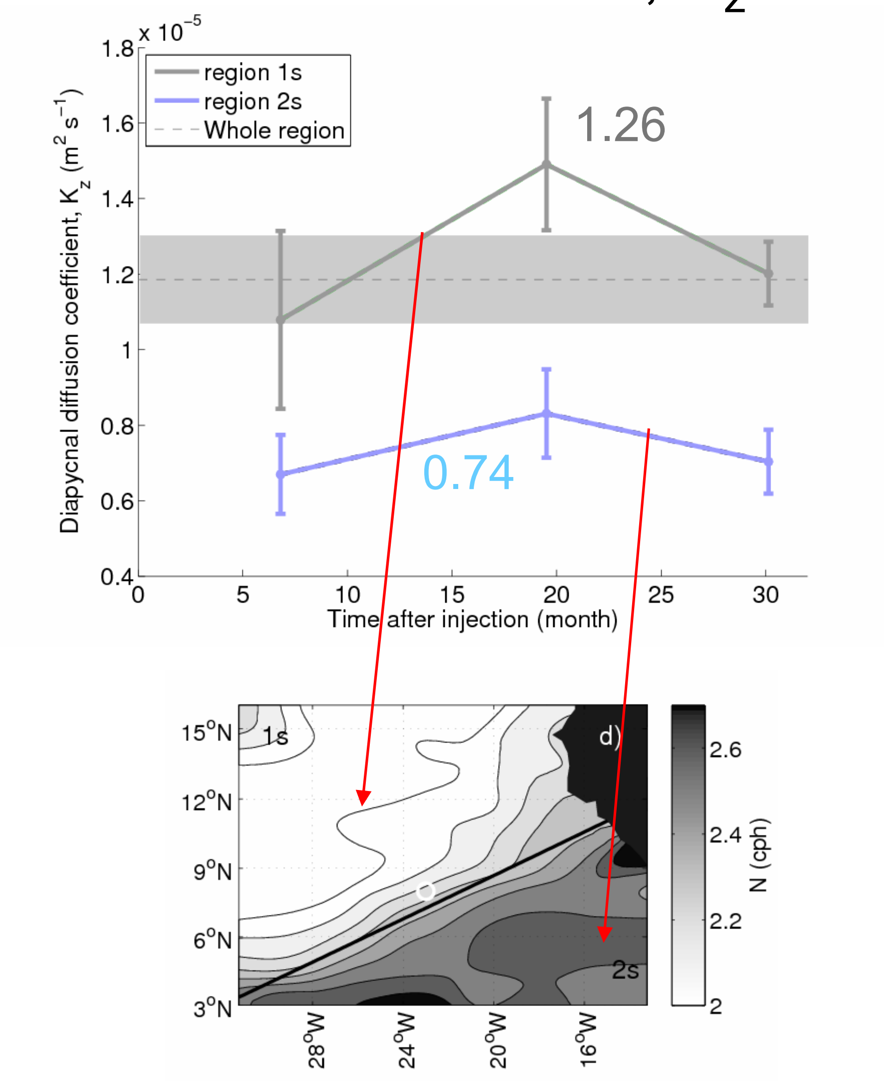




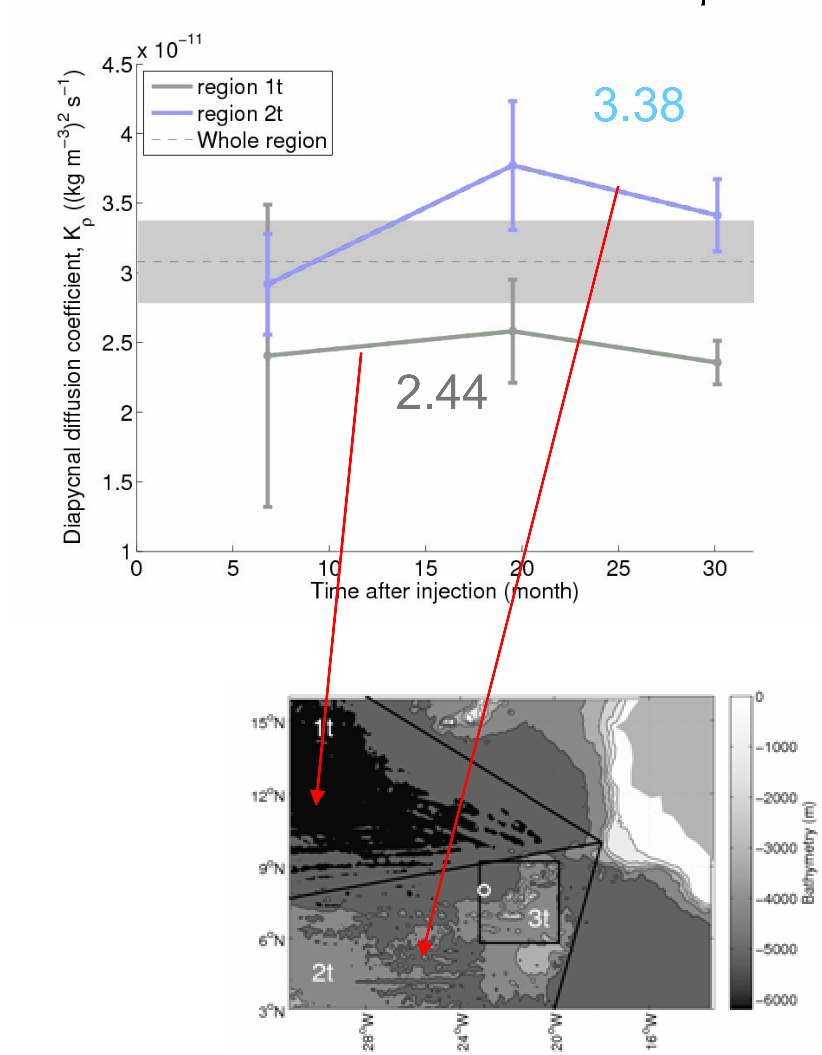
Insignificant vertical gradient in diffusion ($\delta D/\delta z$)

Regional variability:

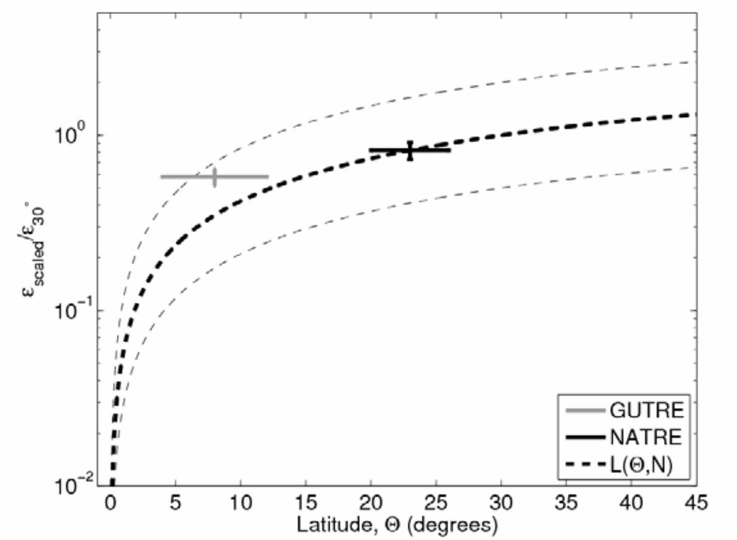
Stratification; D_z



Topography; D_ρ



Discussion:



The GUTRE experiment (Latitude 4° - 12° N) has somewhat higher diffusivity (dissipation rates) than predicted by Gregg et al., (2003) compared to the NATRE experiment (Latitude 10° - 26° N) (Ledwell et al., 1998).

Enhanced mixing over rough topography might be an explanation for this.

We have introduced the diapycnal diffusivity in density space (D_ρ) with the units of (kg $m^{-3})^2$ s^{-1}.
D_ρ is a useful property; in our experiment we see higher mixing over rough Topography only in D_ρ space, not in D_z (where we see the opposite pattern).

$$\langle w_\rho C'_{O2} \rangle = -D_z \frac{d\rho}{dz}\frac{dO_2}{dz} = -D_\rho \frac{dO_2}{d\rho},$$

D_ρ thus defines the concentration changes over time for parameters like oxygen.

A "tropical" TRE over the Oxygen Minimum Zone in the Atlantic Ocean

- We find diapycnal diffusivities that are slightly lower than for NATRE roughly 10° further north

$$D_z = 1.18 \pm 0.13 \times 10^{-5}\ m^2\ s^{-1}$$
$$D_\rho = 3.10 \pm 0.28 \times 10^{-11}\ (kg\ m^{-3})^2\ s^{-1}$$

- We find significant regional differences in D_ρ probably associated with topographic "roughness"