Nitrous Oxide (N_2O) in the Eastern Tropical Atlantic Ocean

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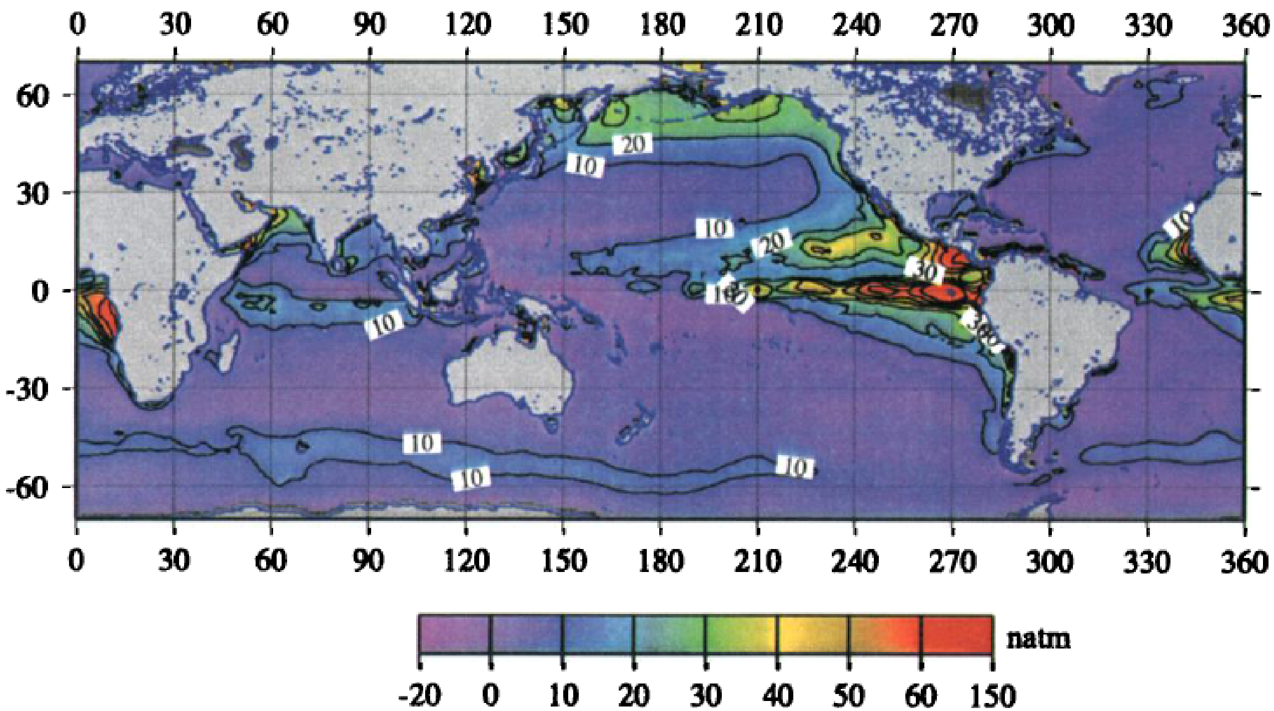
SOPRAN

NORDATLANTIK

N_2O in the Ocean

Excess N_2O dissolved in surface water

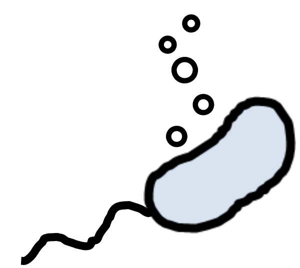


Suntharalingam and Sarmiento 2000
from Weiss et al. 1992 data

N_2O is 3rd most influential greenhouse gas and also ozone depleting.

About a fourth is from the oceans (IPCC 2007).

N_2O in the ocean is released accidentally by microorganisms.



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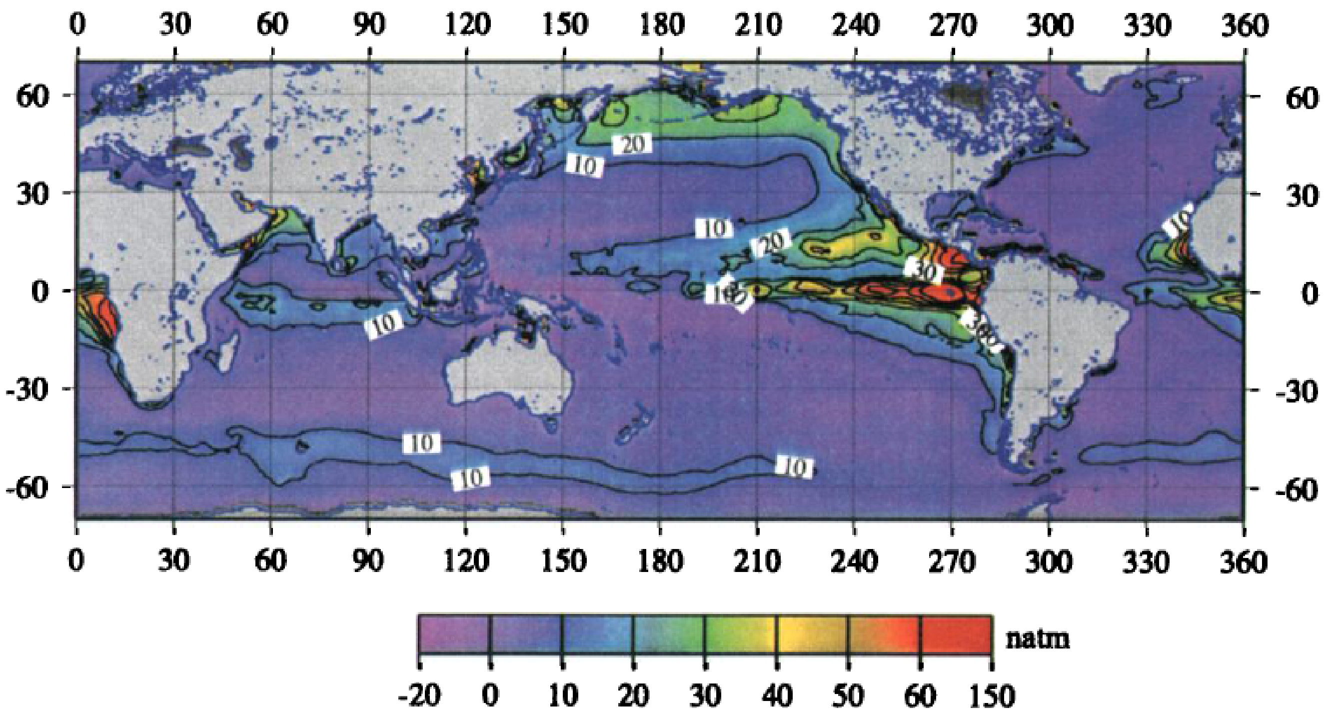

Suntharalingam and Sarmiento 2000
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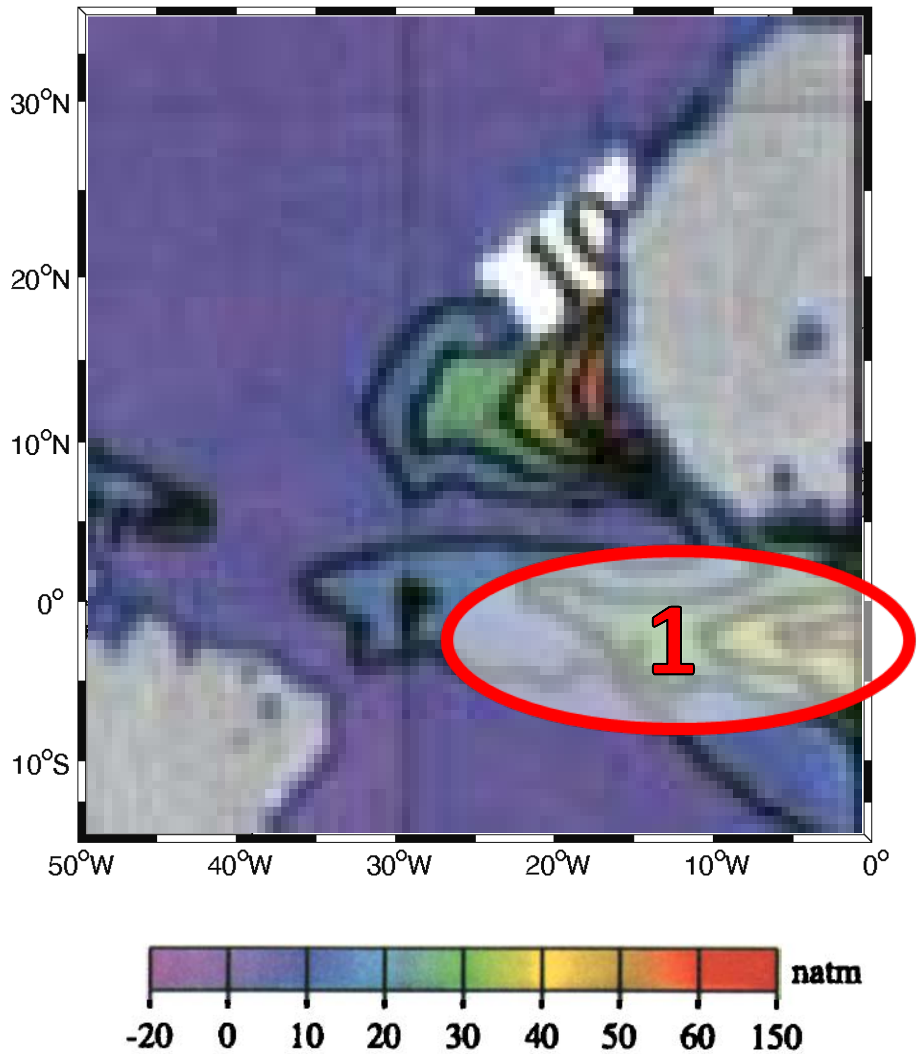
Surface distribution coincides with upwelling and low oxygen regions.

Distribution expected to be susceptible to climate change.

Eastern Tropical Atlantic shows elevated N_2O in surface waters.

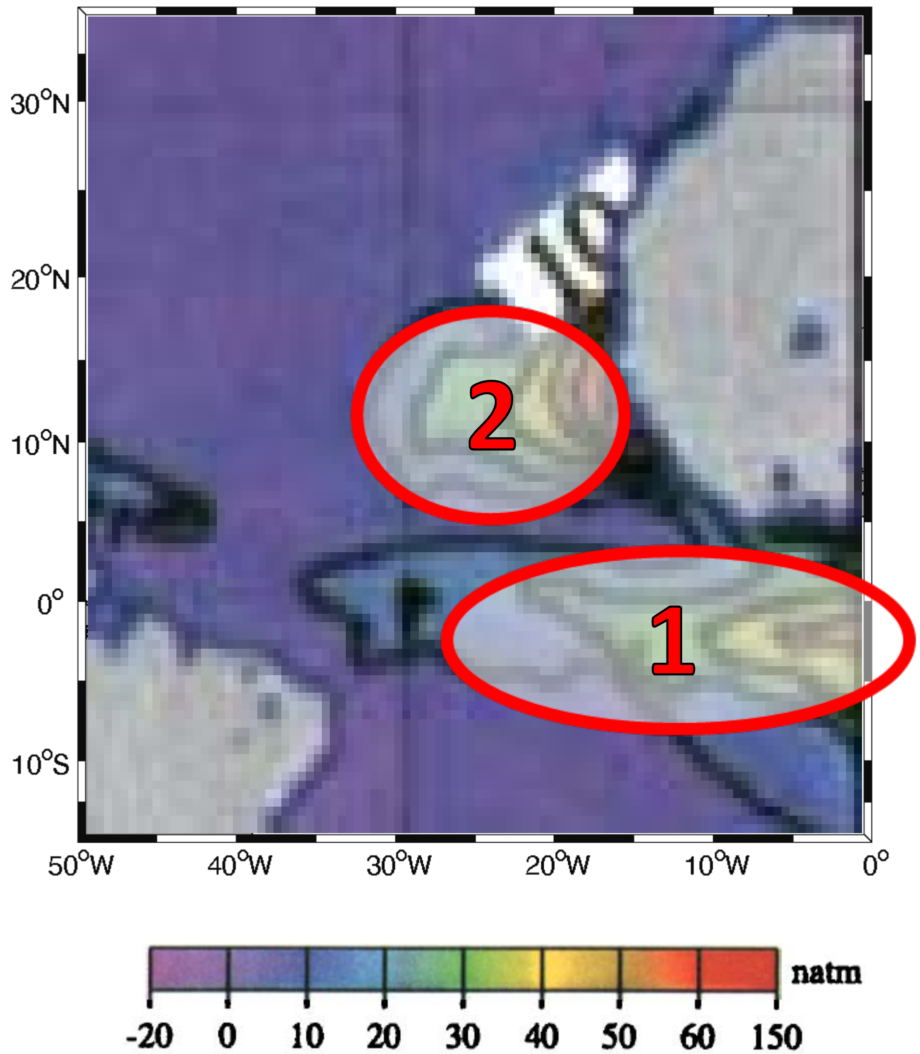
N_2O in the Eastern Tropical Atlantic Ocean



Three regions of elevated N_2O:

1. Equatorial cold tongue

N_2O in the Eastern Tropical Atlantic Ocean

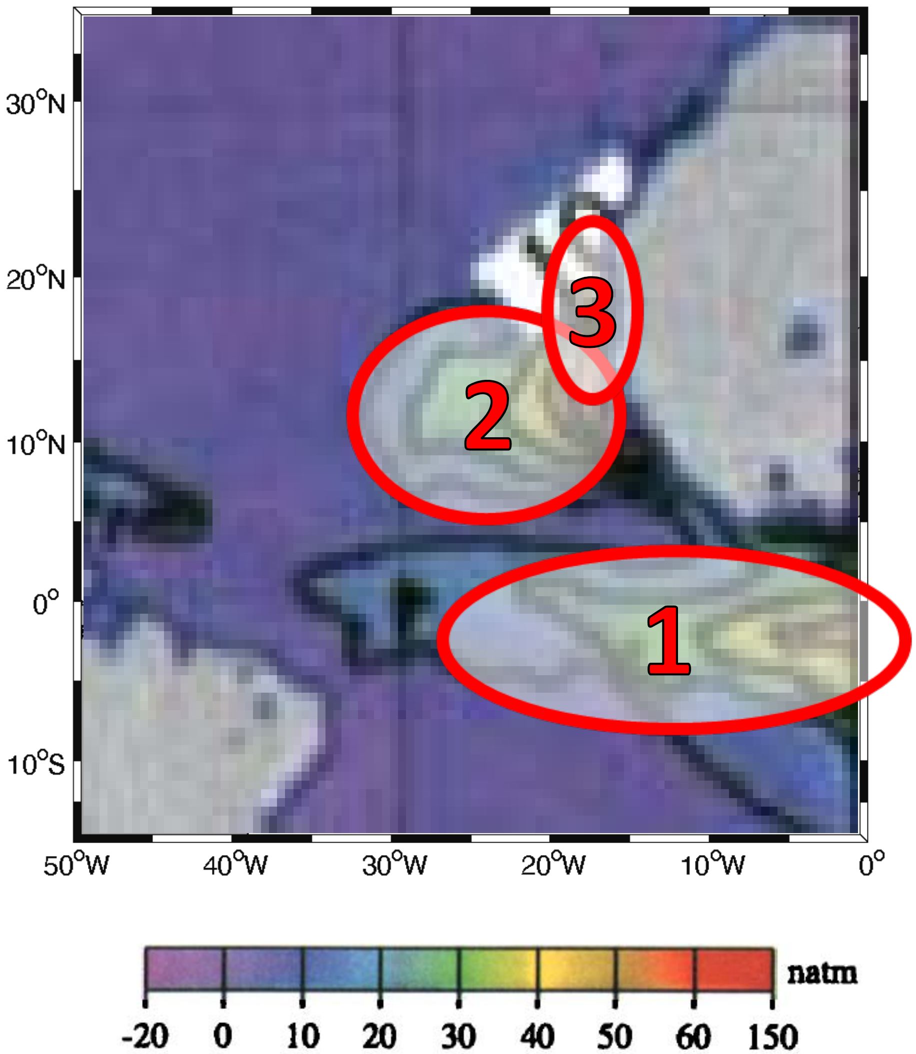


Three regions of elevated N_2O:

1. Equatorial cold tongue

2. Open Ocean Oxygen Minimum Zone (OMZ)

N_2O in the Eastern Tropical Atlantic Ocean



Three regions of elevated N_2O:

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2. Open Ocean Oxygen Minimum Zone (OMZ)
3. Coastal upwelling

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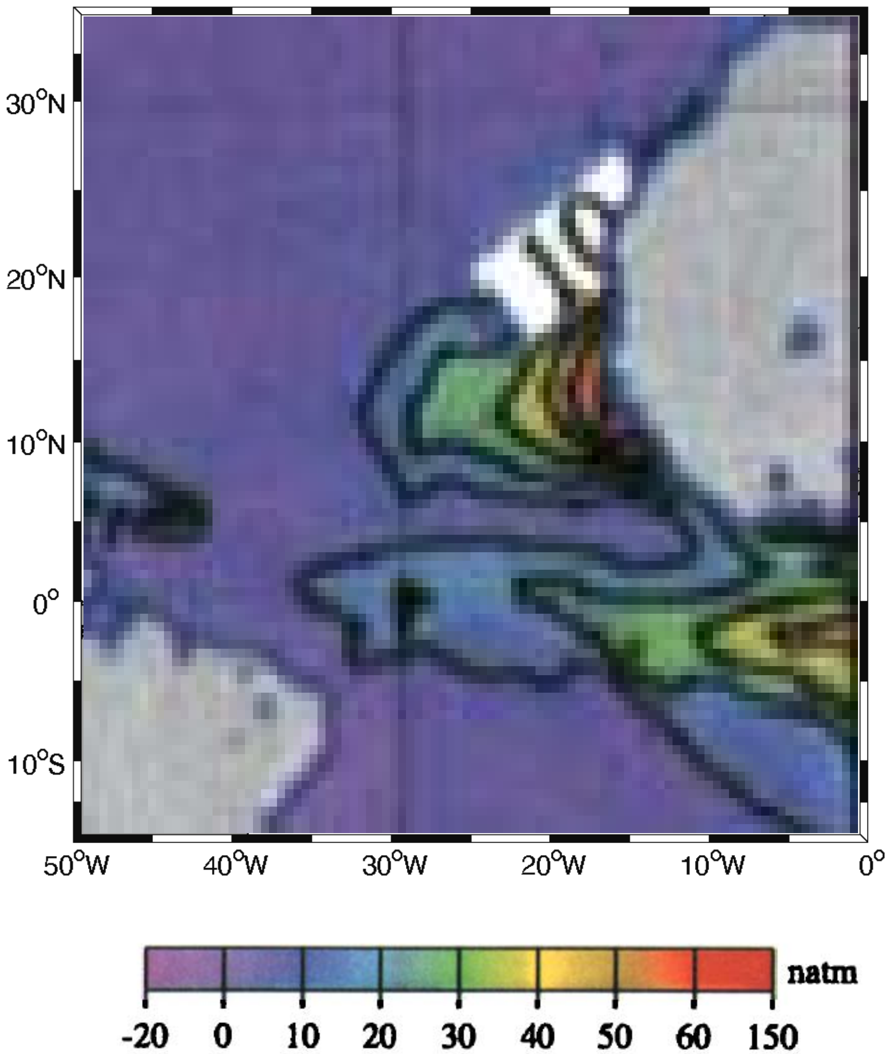
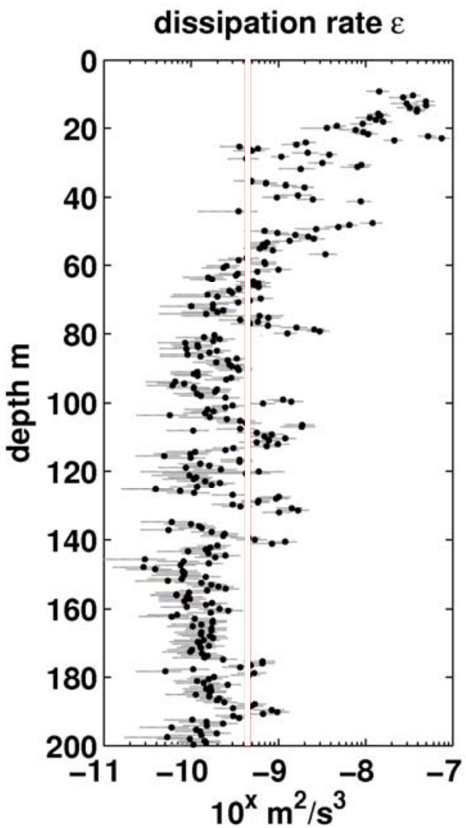


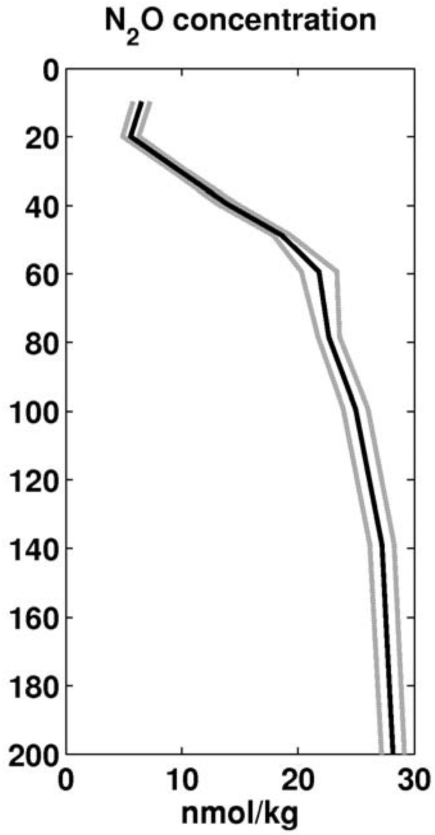
Objective:
Get insight into pathways, processes, sources in the interior.

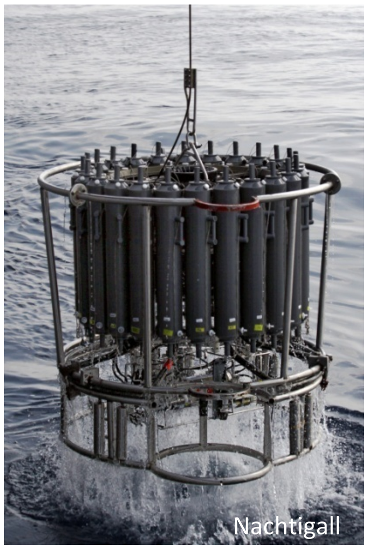
Workhorse method:
Simultaneous recording of N_2O profiles and diapycnal mixing to infer diapycnal fluxes.
Typical fluxes are fractions of a nmol per m^2 and second.

Workhorse method

Simultaneous measurement of mixing intensity and N_2O profile



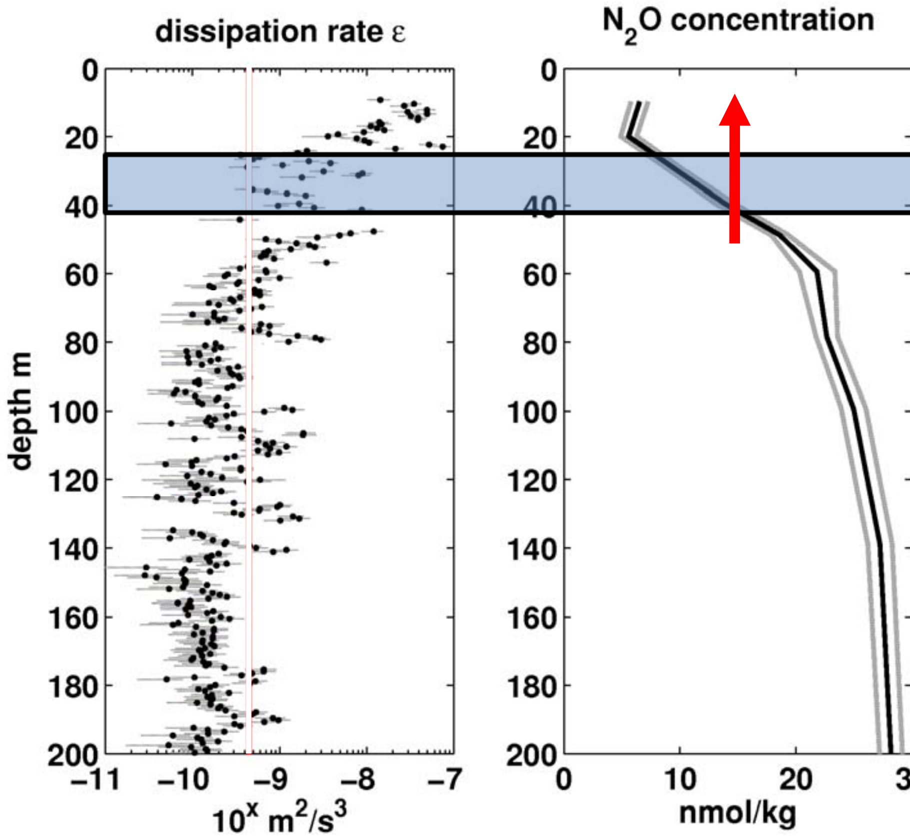




Diffusive flux: $K(\varepsilon)$ x $\dfrac{\partial c}{\partial z}$

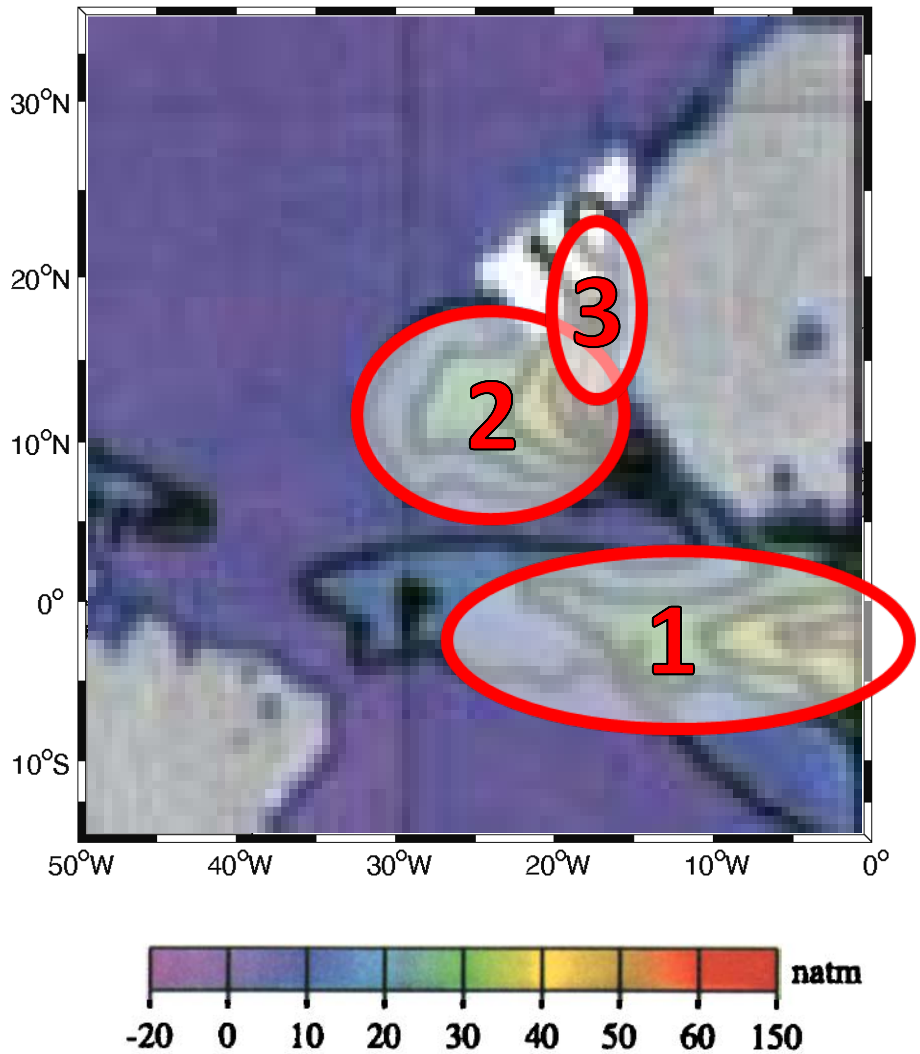
Workhorse method

One important aspect is diapycnal flux through base of mixed layer



Diffusive flux: $K(\varepsilon)$ x $\dfrac{\partial c}{\partial z}$

N_2O in the Eastern Tropical Atlantic Ocean



Three regions of elevated N_2O:

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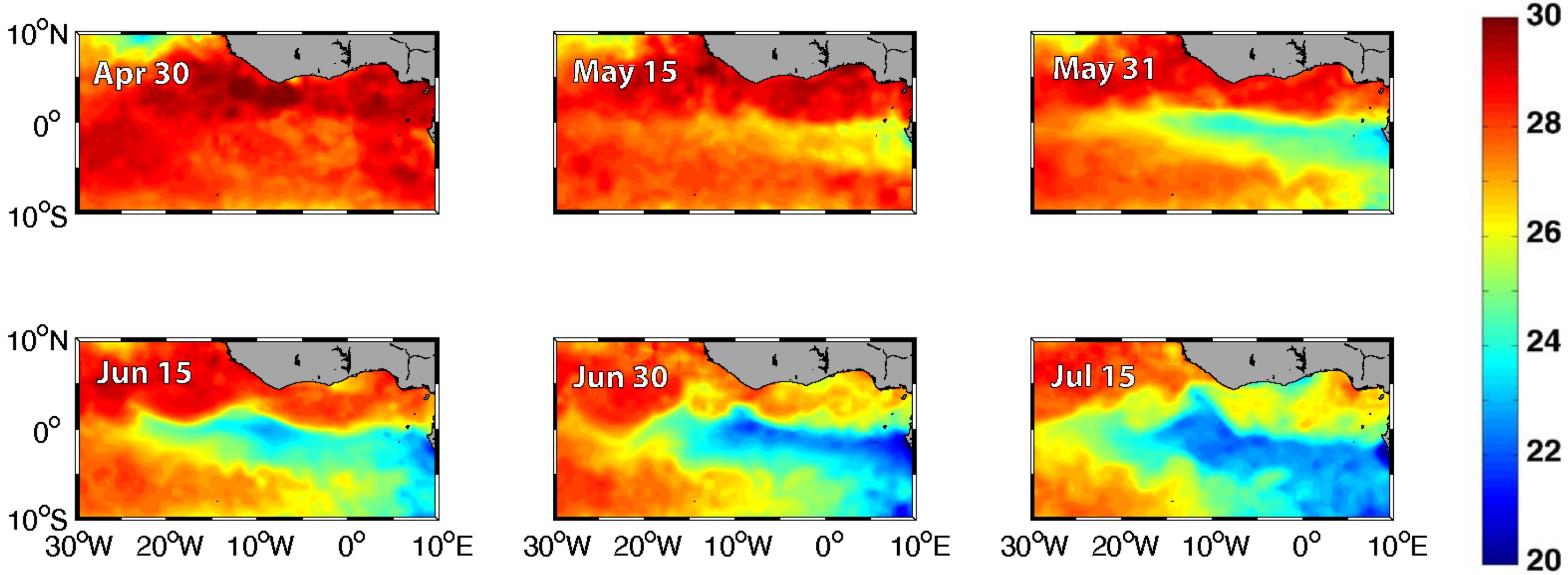
1. Equatorial cold tongue

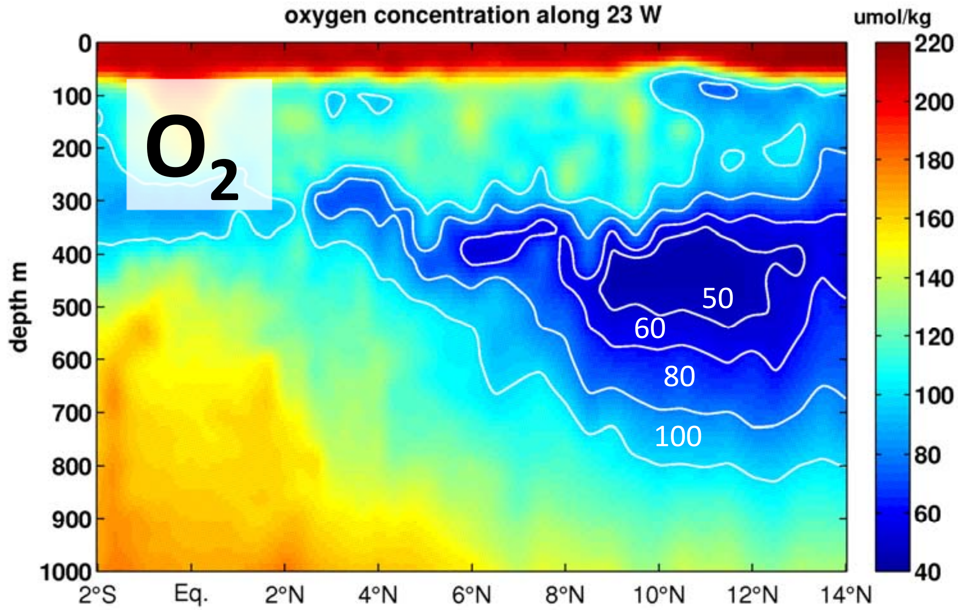
Sea Surface Temperature 2011



2 cruises took place in May to July 2011
during development phase of cold tongue.

NOAA High Resolution SST data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/

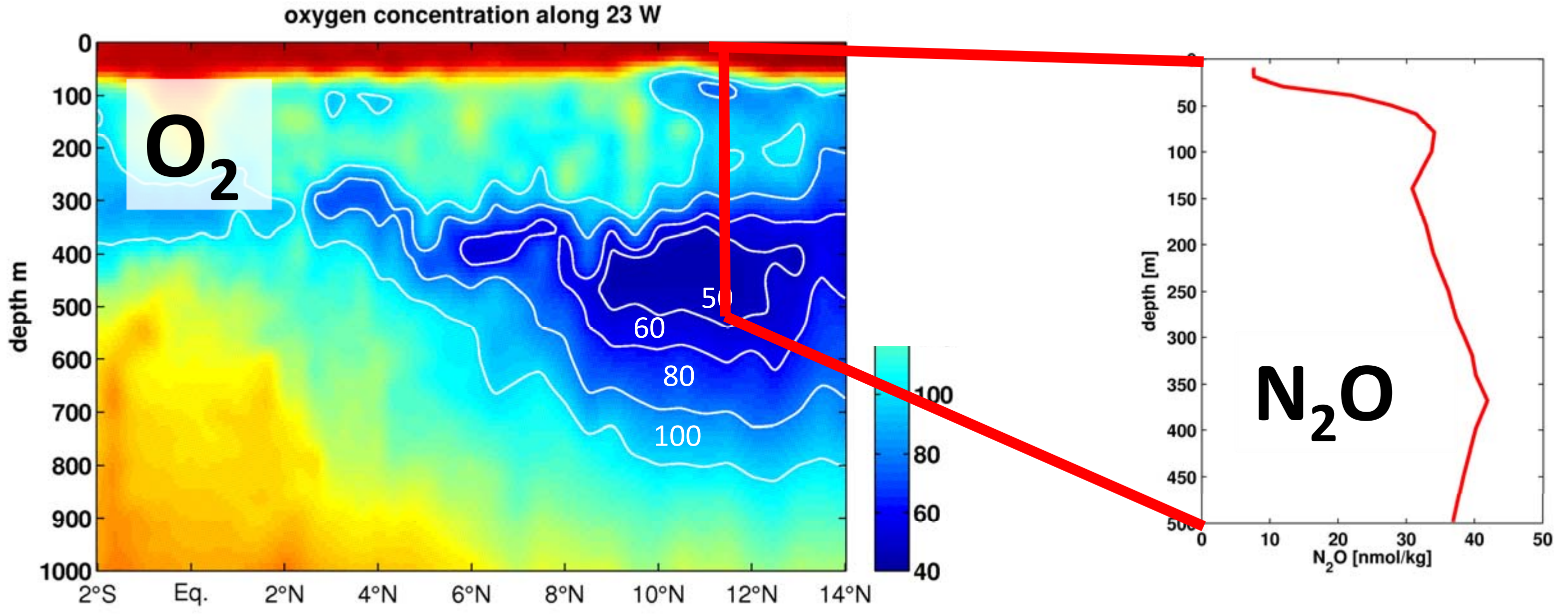
2. Open ocean oxygen minimum zone (OMZ)



This OMZ is less intense than other OMZs.

Oxygen and N_2O are largely anticorrelated.
A corresponding N_2O section would in wide parts look inverse.

2. Open ocean oxygen minimum zone (OMZ)

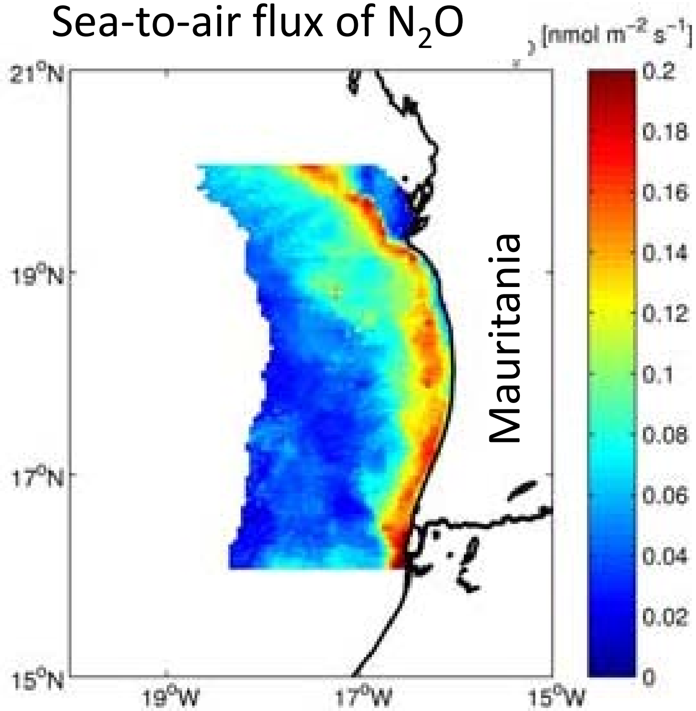


In large parts we not only find the deep OMZ but also a shallow oxygen minimum. A corresponding shallow N_2O maximum can also be found. Here is a particularly prominent example.

2 cruises took place in Nov. 2008 and Dec. 2009.

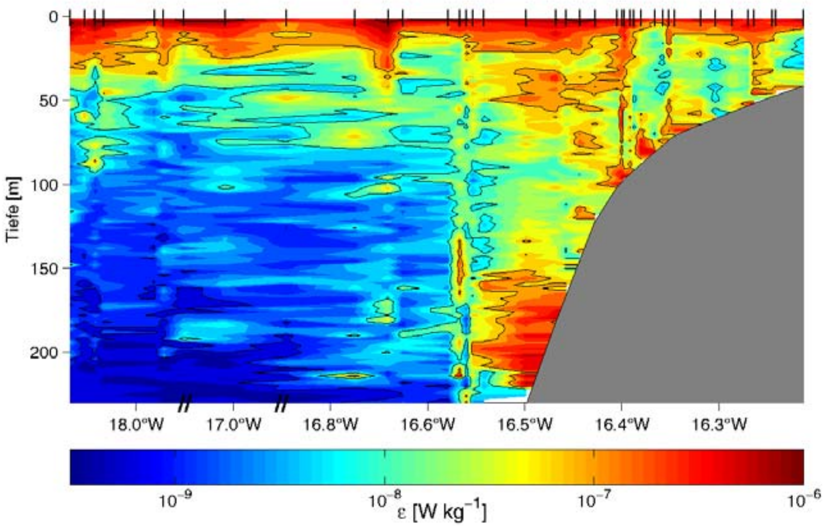
3. Coastal upwelling

Sea-to-air flux of N_2O



Kock et al. 2012

Shelf break: mixing enhanced



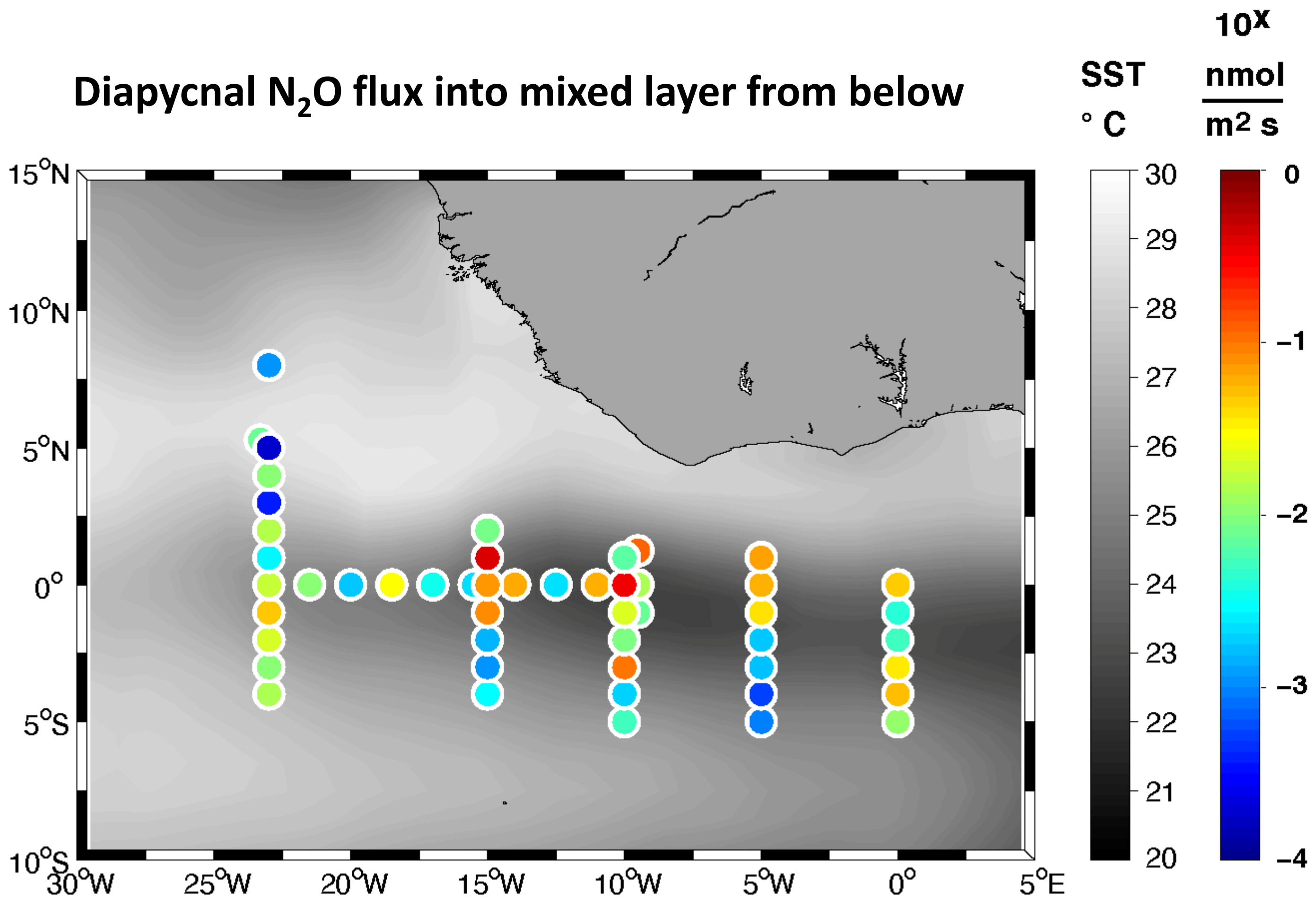
Schafstall et al. 2010

Seasonal upwelling in February and March.

From model study: there is a partial transport of shallow OMZ water to the coastal upwelling (Glessmer et al. 2009) .

5 cruises in 2005 – 2008 , mostly in upwelling season.

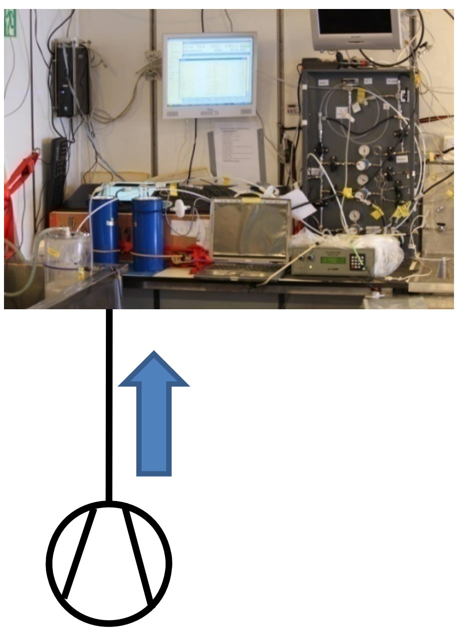
2011 results during cold tongue development



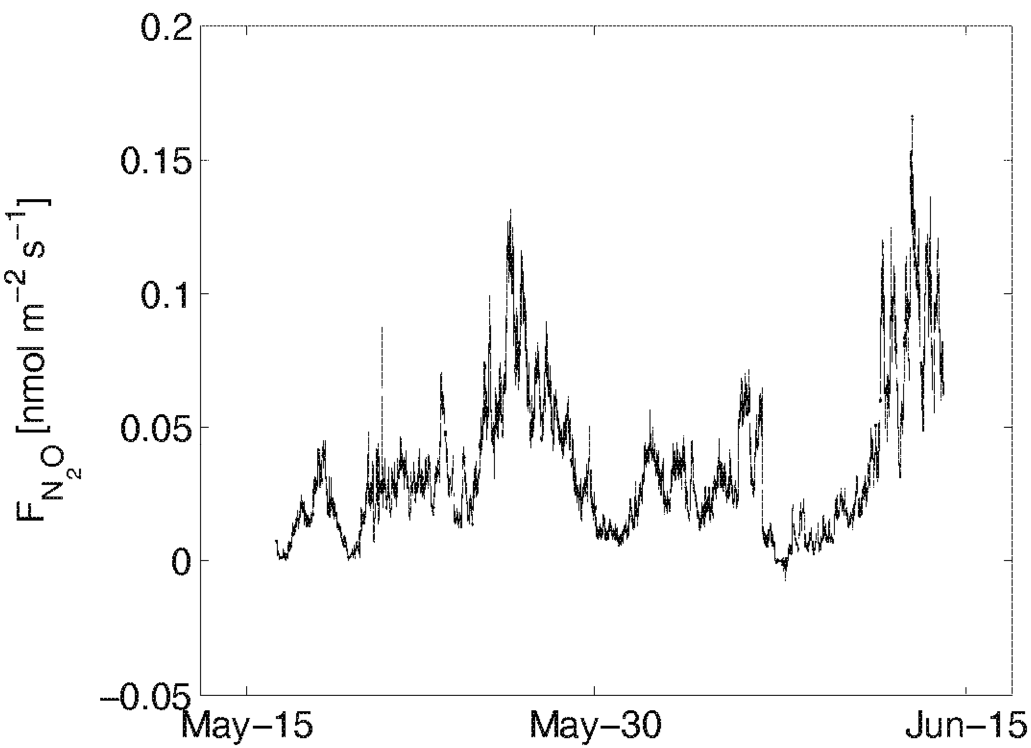
Average diapycnal flux: 0.04 nmol/m^2/s

2011 results during cold tongue development

N_2O sea-to-air flux from shipboard underway monitoring

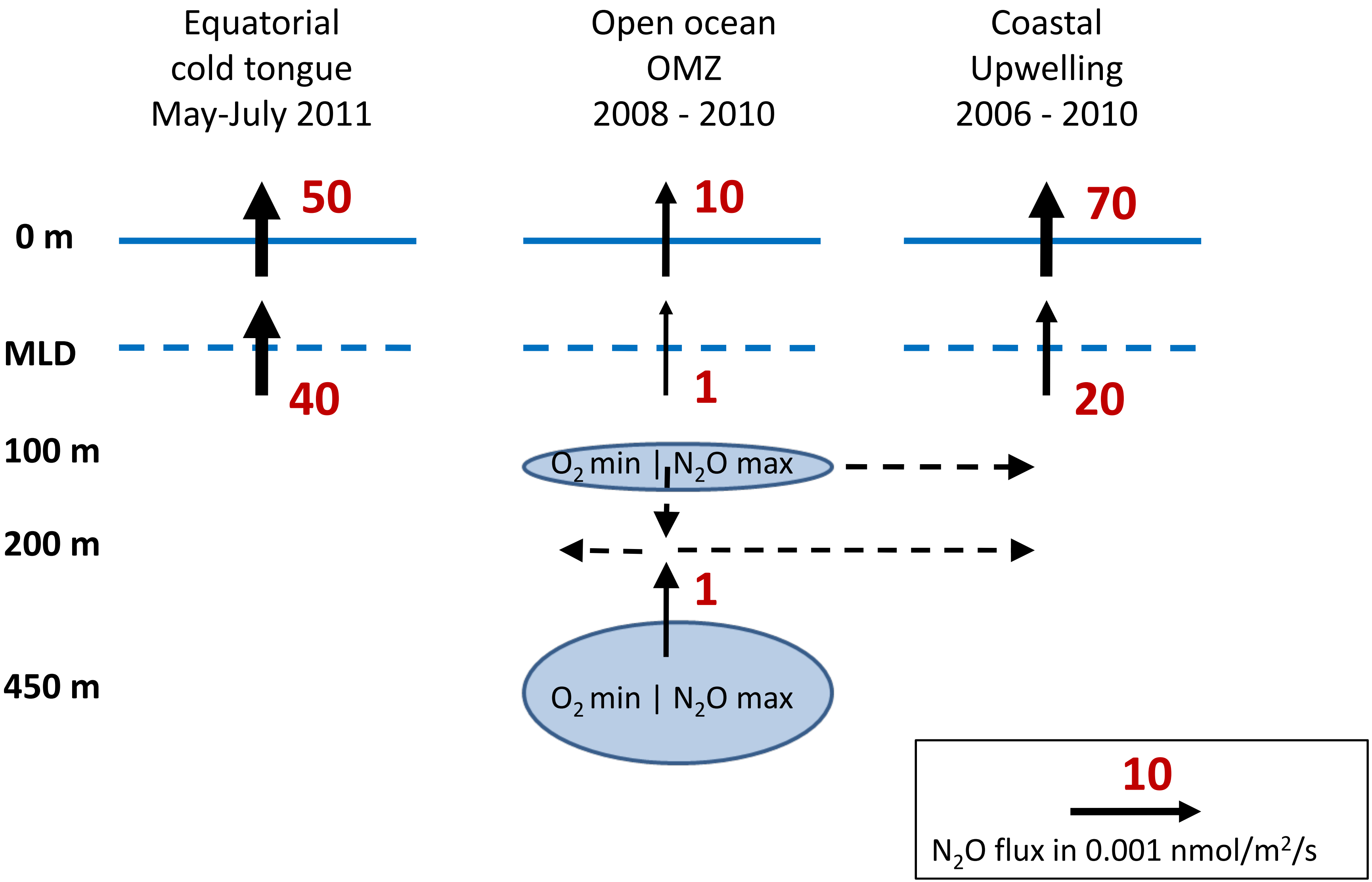


Pump in moon pool



Arevalo Martinez, Kock

More results and a preliminary synthesis



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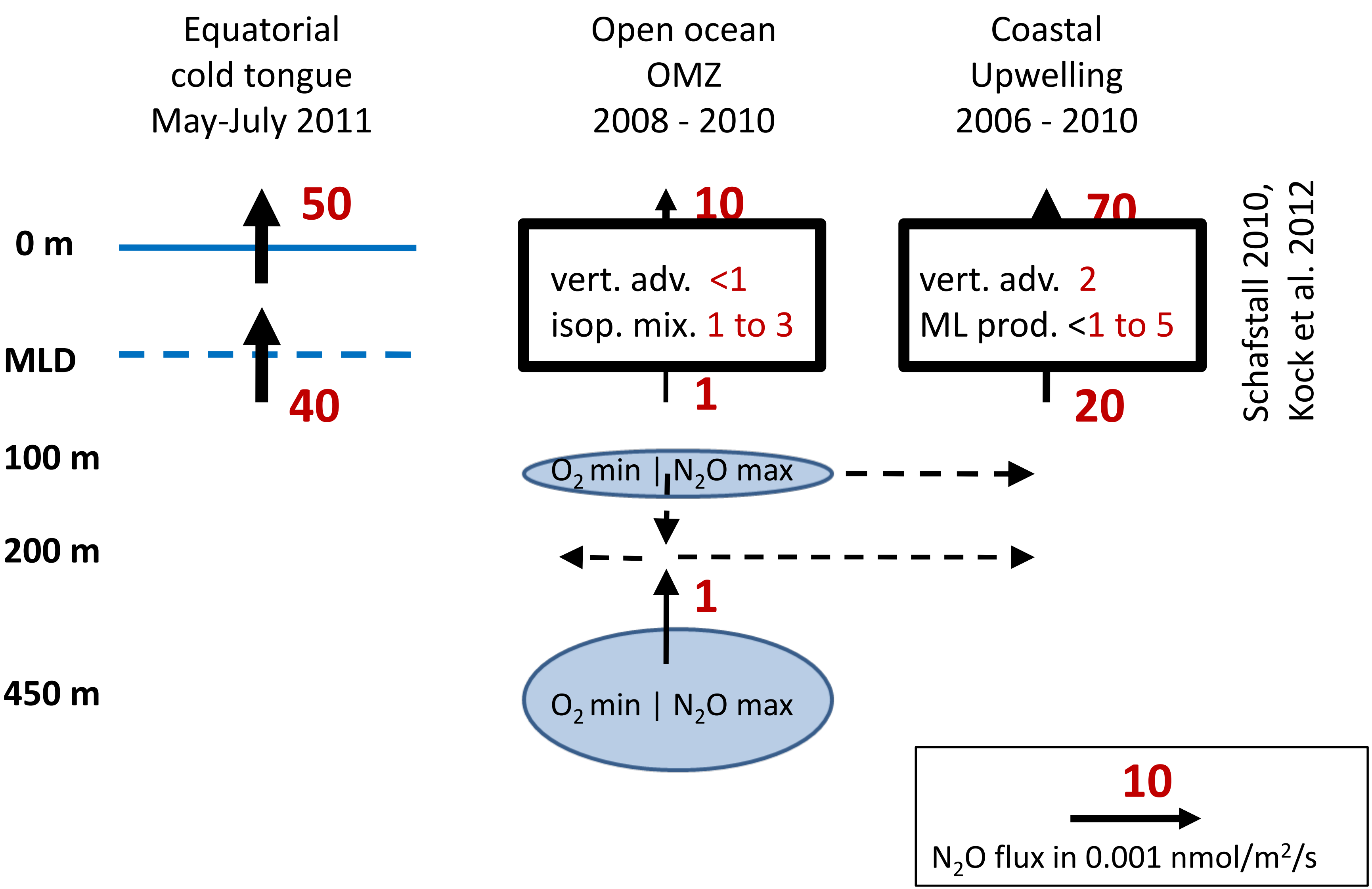

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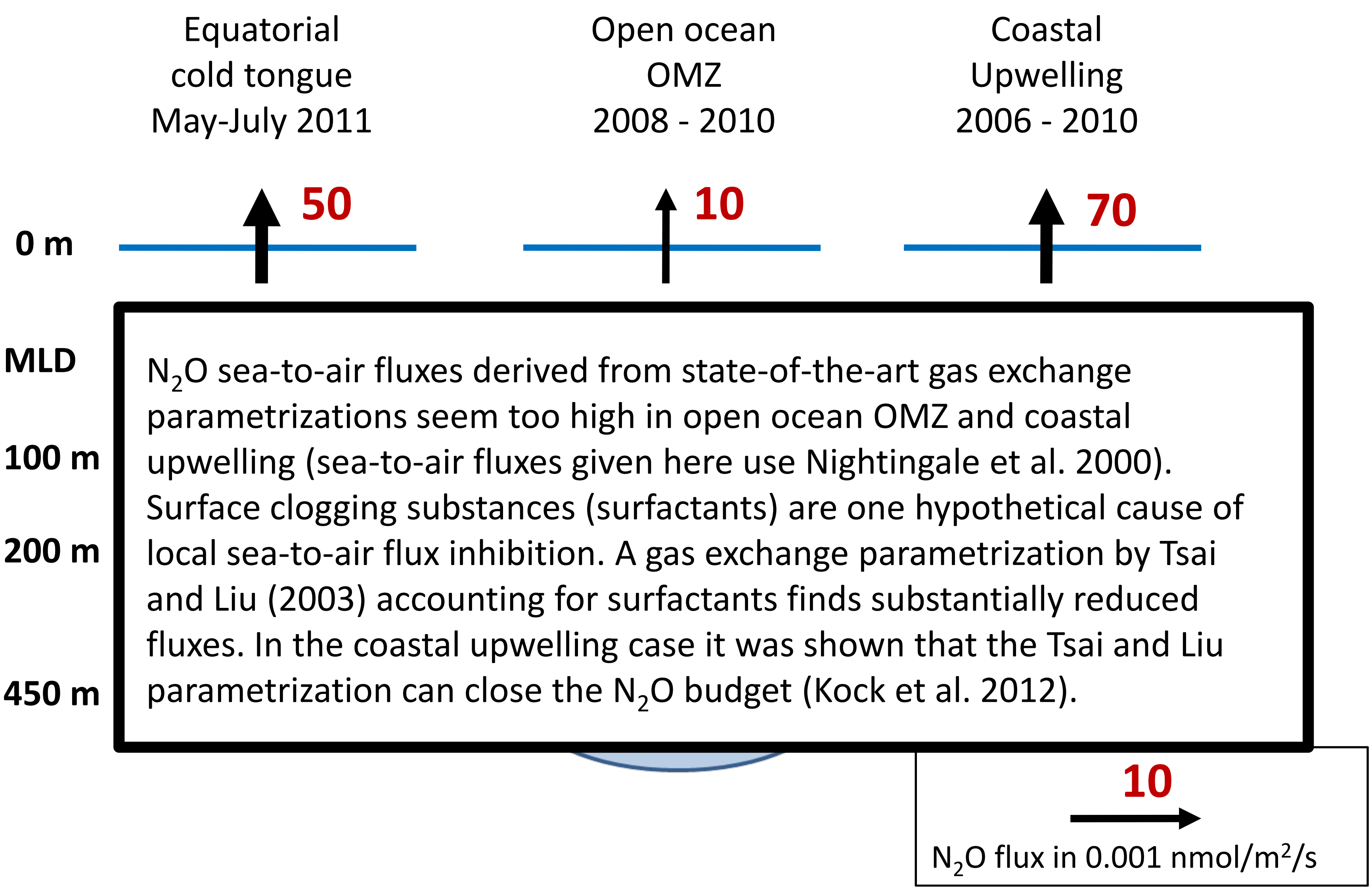
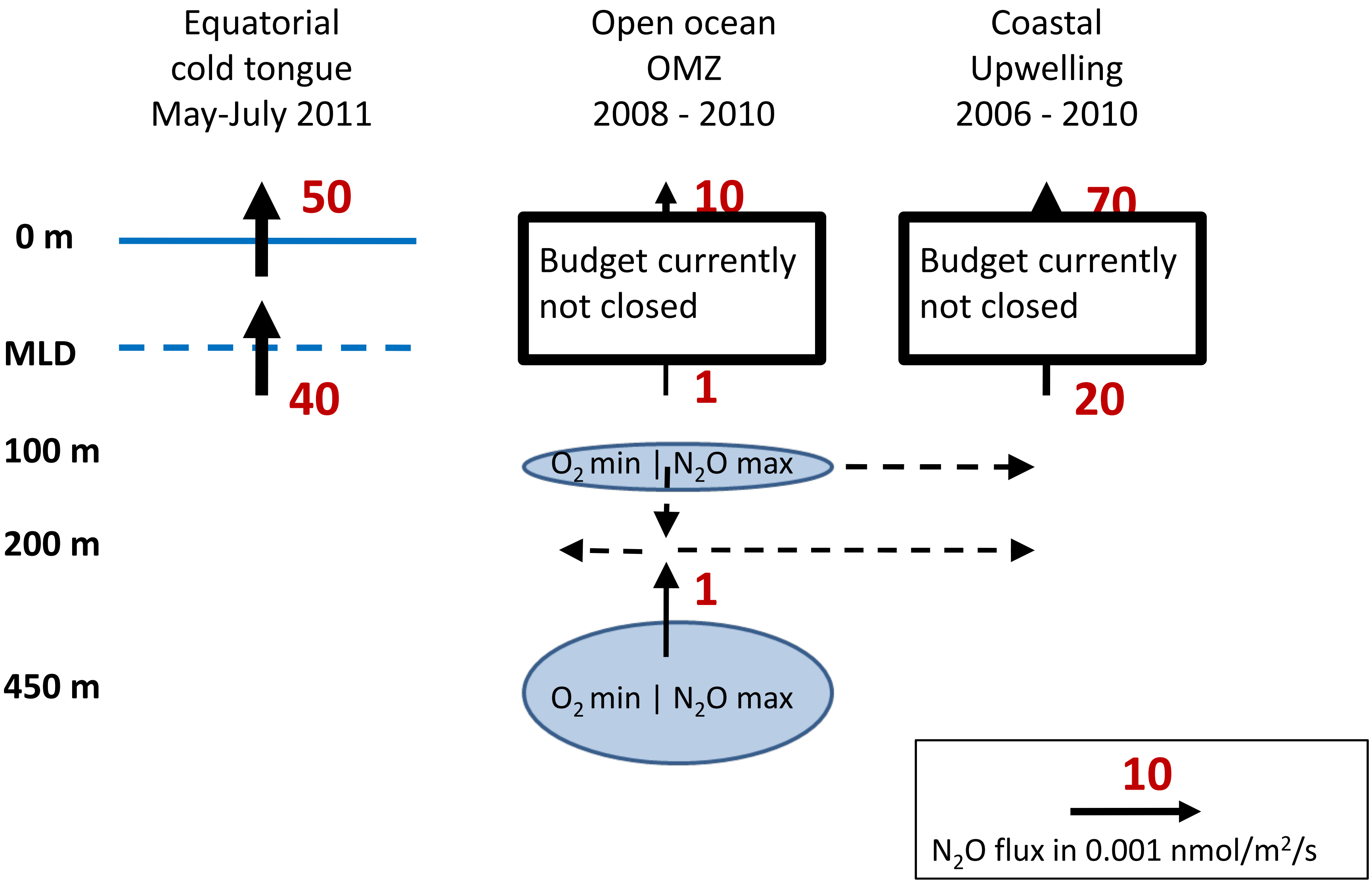


N_2O sea-to-air fluxes derived from state-of-the-art gas exchange parametrizations seem too high in open ocean OMZ and coastal upwelling (sea-to-air fluxes given here use Nightingale et al. 2000). Surface clogging substances (surfactants) are one hypothetical cause of local sea-to-air flux inhibition. A gas exchange parametrization by Tsai and Liu (2003) accounting for surfactants finds substantially reduced fluxes. In the coastal upwelling case it was shown that the Tsai and Liu parametrization can close the N_2O budget (Kock et al. 2012).

More results and a preliminary synthesis



Conclusions

In cold-tongue season 2011, diapycnal flux from below the mixed layer can account for most of N_2O sea-to-air-flux.

The deep OMZ seems to be no hotspot contributor of N_2O.

The N_2O mixed layer budget seems not closed with our current knowledge - at least for the OMZ region and the coastal upwelling region.
Other supply processes seem too weak to close the discrepancy to parametrized sea-to-air N_2O flux. But local inhibition of sea-to-air flux could be a solution.

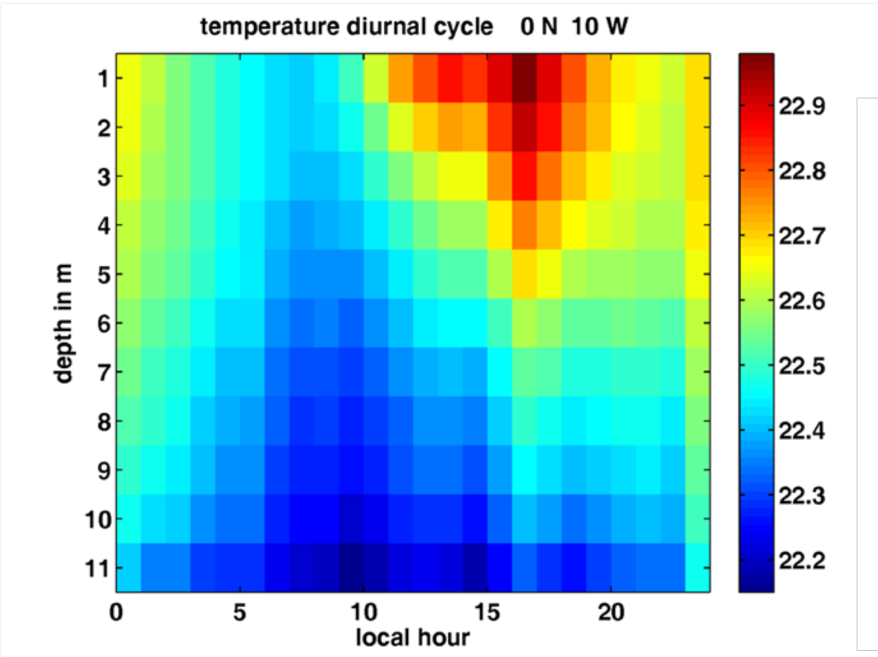
Outlook

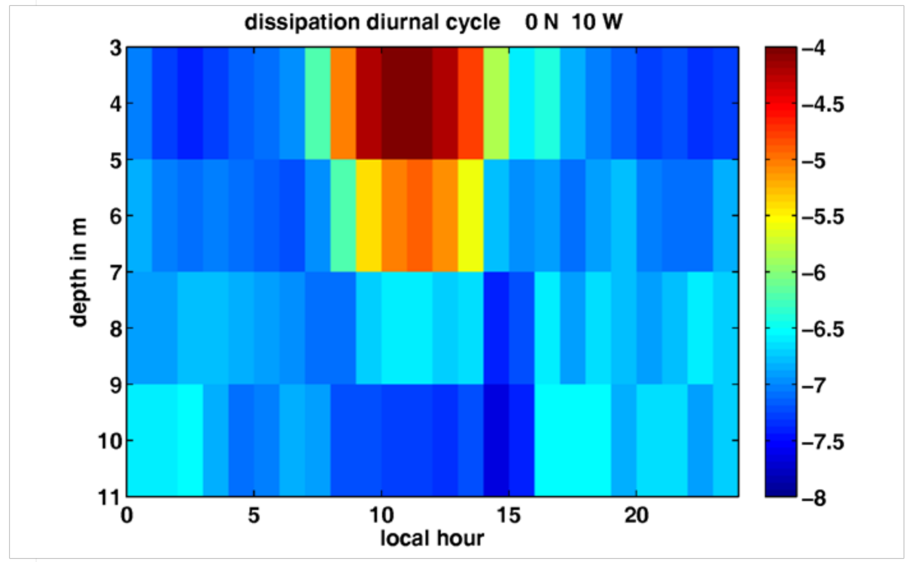
N_2O flux measurements in Peruvian upwelling Nov.2012 - Feb.2013.

During theses cruises:
Further explore the sea-to-air flux inhibition hypothesis:
- Surface clogging substances (by a SFB754 team)
- „Mixed layer stratification“ (more on next 2 slides)

Extreme shallow mixed layers are quite common in the Tropics and may lead to bulk flux overestimation.

Glider mission in June 2011 with MicroRider (Marcus Dengler)



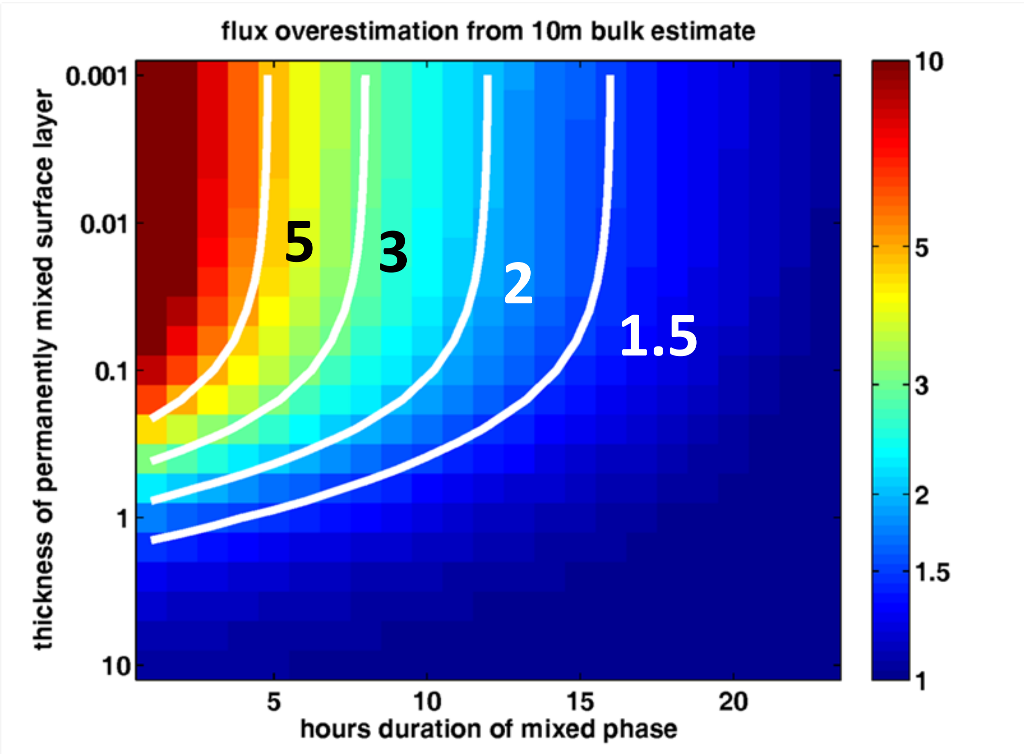


Appreciable stratification through more than half the day. Mixed layer extremely shallow.

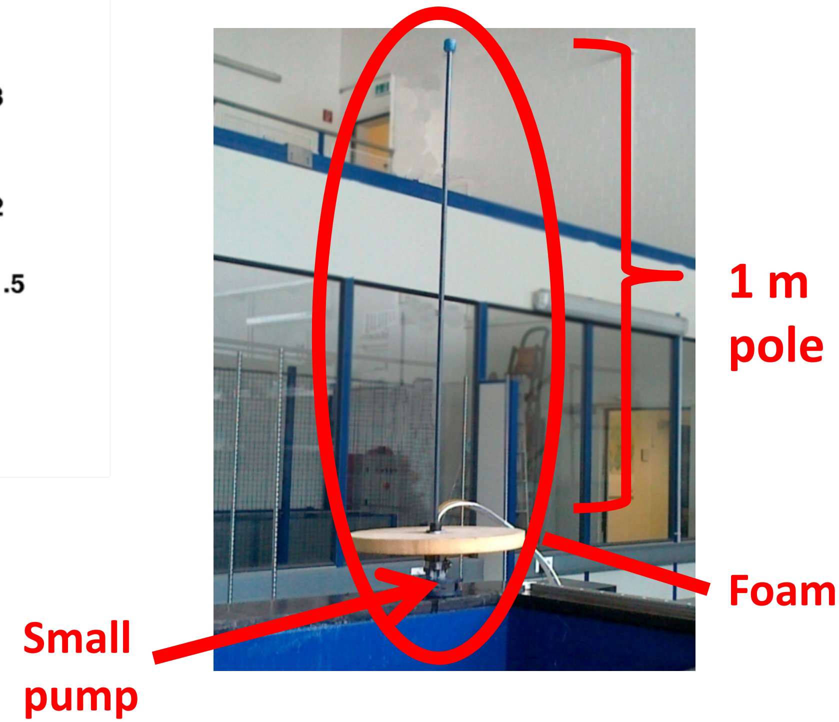
Shallow mixing period during early daytime.

Extreme shallow mixed layers are quite common in the Tropics and may lead to bulk flux overestimation.

From a simple 1-D-model of part-time-mixed layer:



If estimating sea-to-air flux from concentration at 10m, estimate will be X times too high. Depends on stratified time and depth of permanently mixed layer.



References

Glessmer, M. S., C. Eden, and A. Oschlies (2009): Contribution of oxygen minimum zone waters to the coastal upwelling off Mauritania, Progress in Oceanography, 83, 143-150
Use an eddy-resolving model and infer that OMZ and coastal upwelling are weakly connected, but that OMZ water that reaches the surface ocean does this to a major part in the coastal upwelling.

Kock, A., J. Schafstall, M. Dengler, P. Brandt, and H. W. Bange (2012): Sea-to-air and diapycnal nitrous oxide fluxes in the eastern tropical North Atlantic Ocean, Biogeosciences, 9, 957-964
Discuss possible reasons for their finding of a discrepancy between N_2O supply to the mixed layer and loss by sea-to-air flux in the Mauritanian upwelling. Unaccounted for supply processes like vertical and horizontal advection and production in the mixed layer are found insufficient. Sea-to-air flux parametrizations are diverse while usually high; but one of them by accounting for surfactants can close the budget.

Nightingale, P., G. Malin, C. S. Law, A. J. Watson, P. S. Liss, M. I. Liddicoat, J. Boutin, and R. C. Upstill-Goddard (2000): In situ evaluation of air-sea gas exchange parameterizations using novel conservative and volatile tracers, Global Biogeochemical Cycles, 14, 373-387

Schafstall, J. (2010): Turbulente Vermischungsprozesse und Zirkulation im Auftriebsgebiet vor Nordwestafrika, PhD thesis, University of Kiel

Schafstall, J., M. Dengler, P. Brandt, and H. W. Bange (2010): Tidal-induced mixing and diapycnal nutrient fluxes in the Mauritanian upwelling region, Journal of Geophysical Research, 115, C10014
Find shelf break a hotspot of diapycnal mixing that adds to the nutrient supply of the mixed layer, and attribute this to internal tides and nonlinear internal wave trains.

Suntharalingam, P., and J. L. Sarmiento (2000): Factors governing the oceanic nitrous oxide distribution: Simulations with an ocean general circulation model, Global Biogeochemical Cycles, 14, 429-454

Tsai, W. T., and K. K. Liu (2003): An assessment on the effect of sea surface surfactant on global atmosphere-ocean CO2 flux, Journal of Geophysical Research, 108, 3127

Weiss, R. F., F. A. Van Woy, and P. K. Salameh (1992): Surface water and atmospheric carbon dioxide and nitrous oxide observations by shipboard automated gas chromatography: results from expeditions between 1977 and 1990. Scripps Institution of Oceanography Reference 92-11.