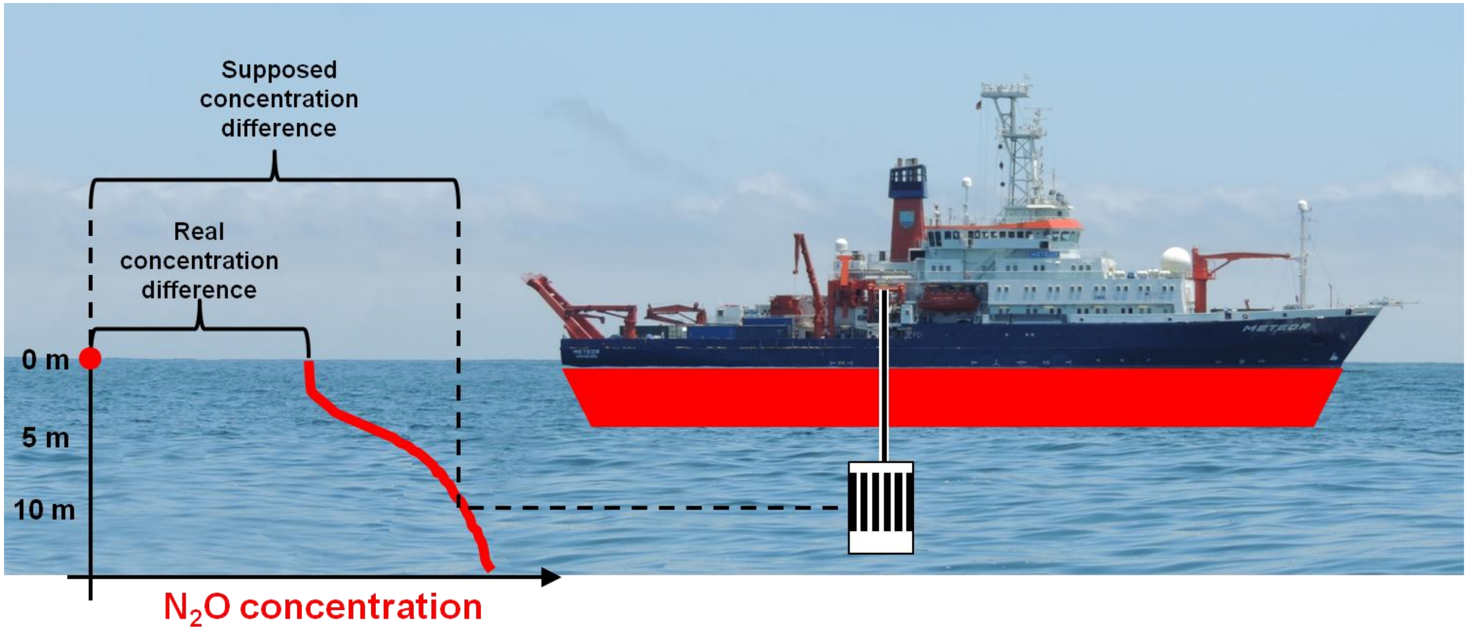
Gas gradient in top 10 meters of coastal upwelling biases sea-to-air flux estimates

Nitrous oxide observations off Peru



SOPRAN

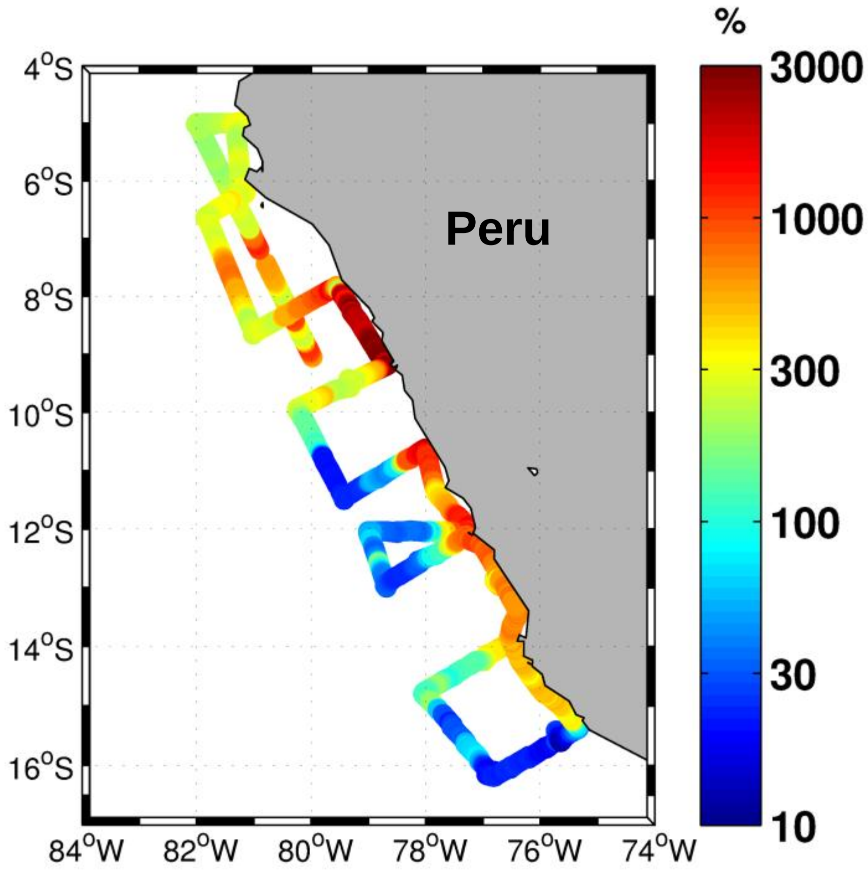
Tim Fischer, Annette Kock, Marcus Dengler, Hermann W. Bange, Damian L. Arévalo-Martínez, Peter Brandt

GEOMAR Helmholtz Centre Kiel

Coastal upwelling regions are often strong emitters of nitrous oxide (N_2O) and other trace gases

[Nevison et al. 2004, Naqvi et al. 2010]

N_2O supersaturation of surface water off Peru, Dec. 2012



Damian Arévalo-Martínez et al., Session 043: Nitrous oxide in the eastern tropical South Pacific Ocean

Our motivating hypothesis to look for gas gradients in the top meters of the ocean:

Emissions from coastal upwelling systems may be overestimated, when using gas exchange bulk formulae.

Substantially more N_2O outgassing than supply from below found in Canary Upwelling. Surface production seems unlikely as sole explanation [Kock et al., 2012].

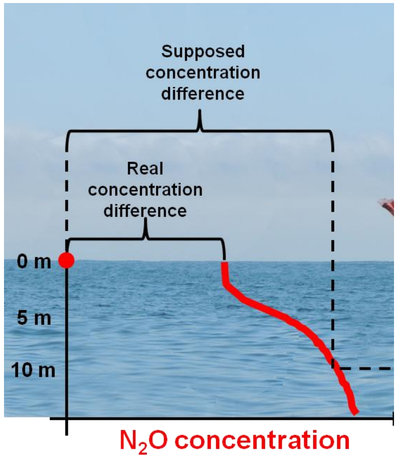
The flux equation indicates two possible sources of error:

$$F = -k_W \cdot (c - c_{sat})$$

Surface slicks reducing transfer velocity

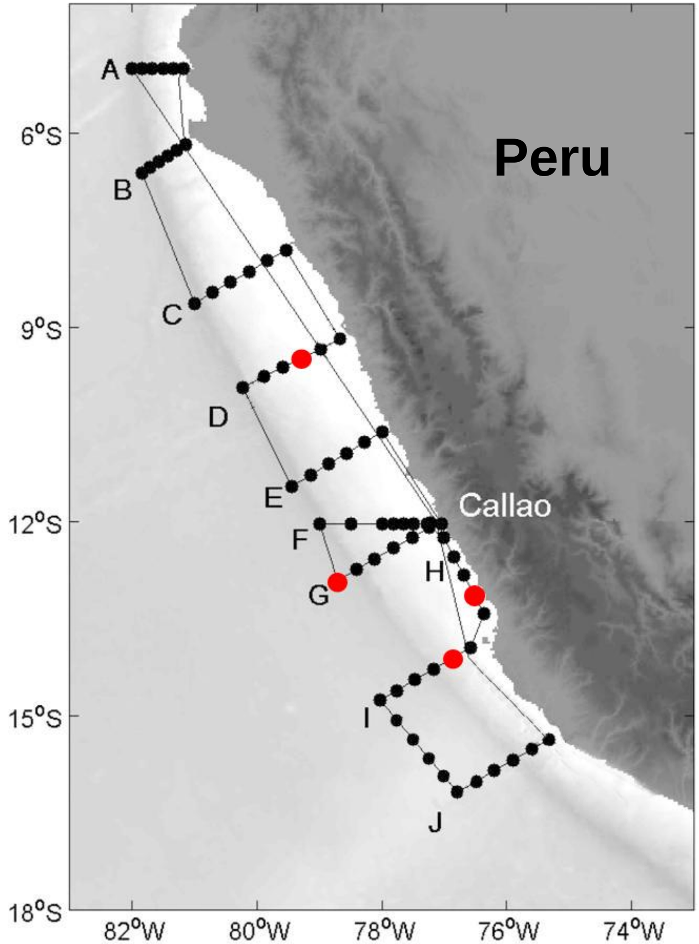
A. Loginova et al.; poster #125, distribution of slicks in the Peruvian upwelling

Incorrect estimate of surface concentration due to vertical gas gradient.
[e.g. Soloviev et al. 2002, Calleja et al. 2013]



Checking gas gradient hypothesis using N_2O as observable

During Meteor M91 SOPRAN cruise, Dec. 2012:
An integrated biogeochemical study of the upwelling off Peru.



- CTD-O_2

  Currents

  Microstructure

  11 biogeochemistry working groups

  Underway 5m chemistry, (e.g. N_2O)

  Resolved concentration profiles at stations (e.g. N_2O)

  Surface Microlayer

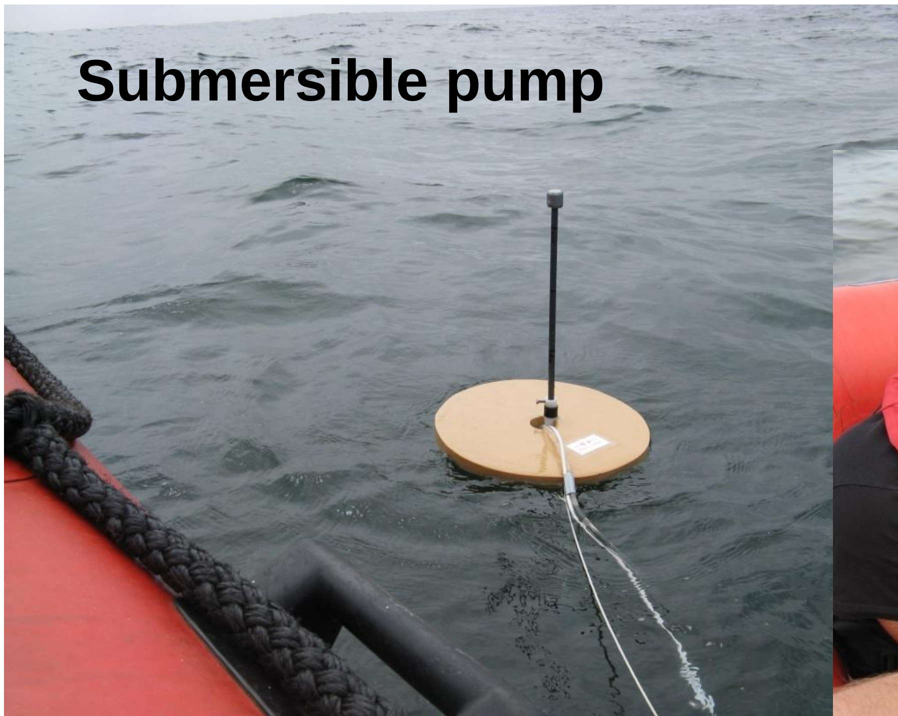
  Tropospheric chemistry

  24h-stations, during which

- **4 N_2O profiles of top 10m away from ship influence could be performed.**

Sampling N_2O near the ocean surface

Submersible pump

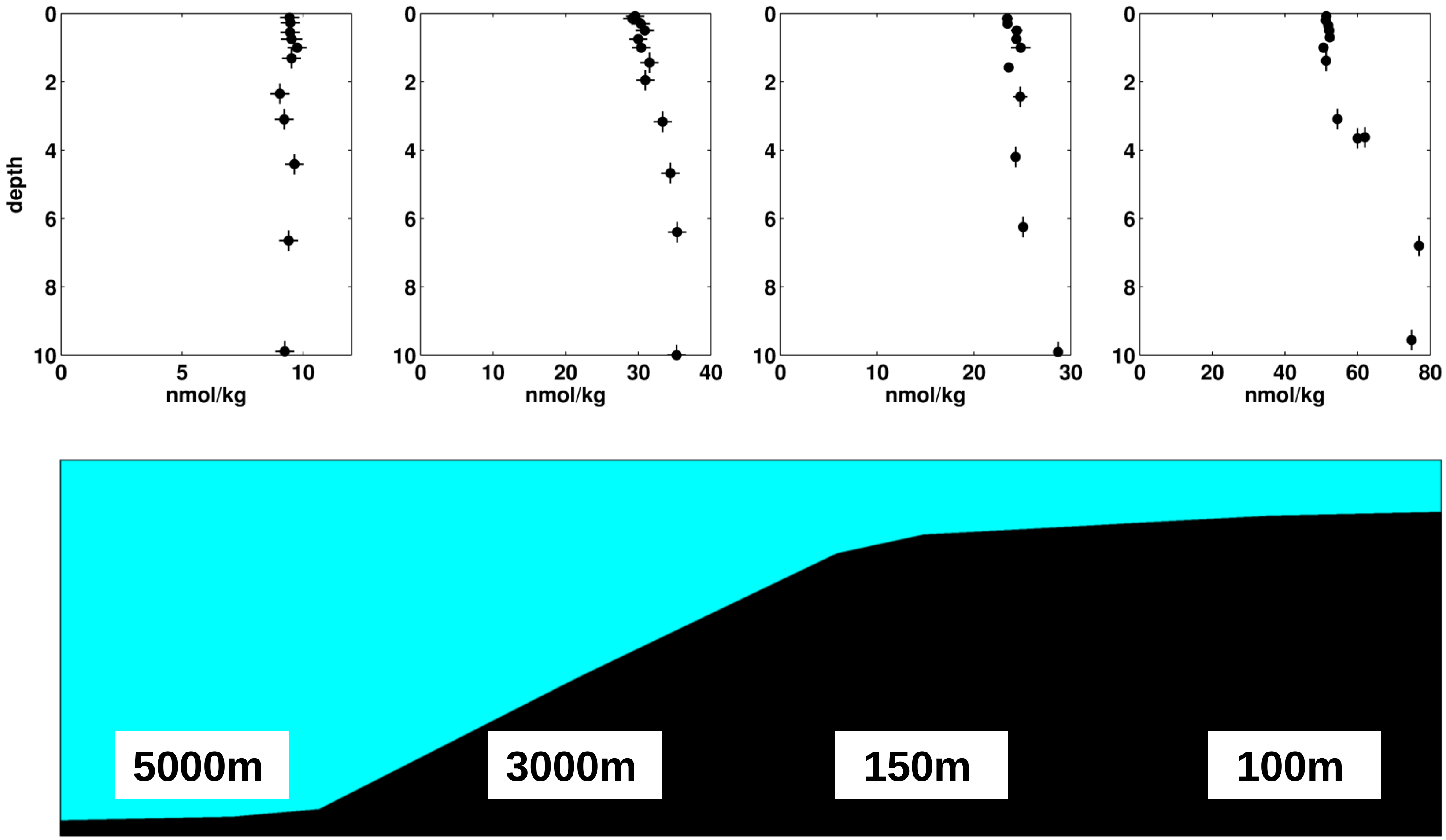


0.1 – 1 m depth

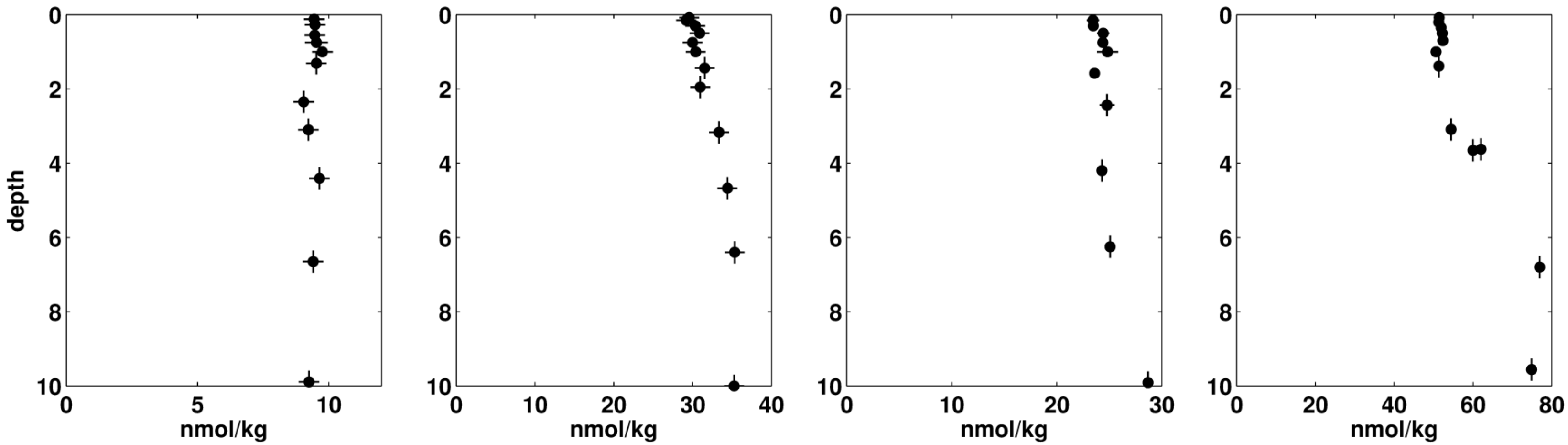
Niskin plus MicroCat

1 – 10 m depth

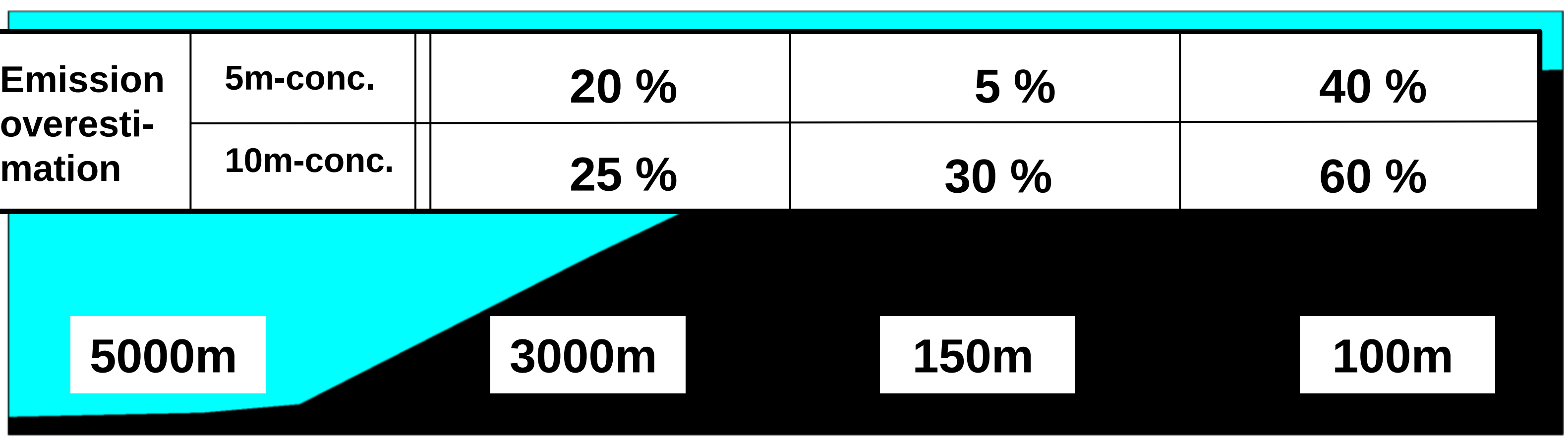
N_2O gradients exist at sites of elevated N_2O concentrations



N_2O gradients exist at sites of elevated N_2O concentrations

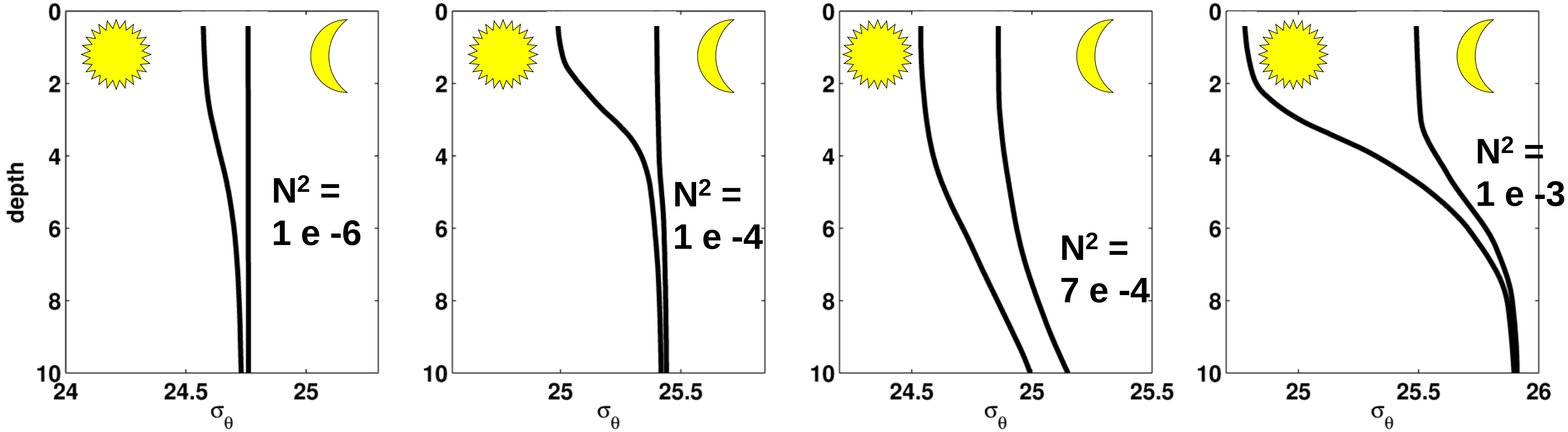


Emission overestimation				
	5m-conc.	20 %	5 %	40 %
	10m-conc.	25 %	30 %	60 %



… where shallow stratification is not completely eroded at night

Density profiles day vs. night



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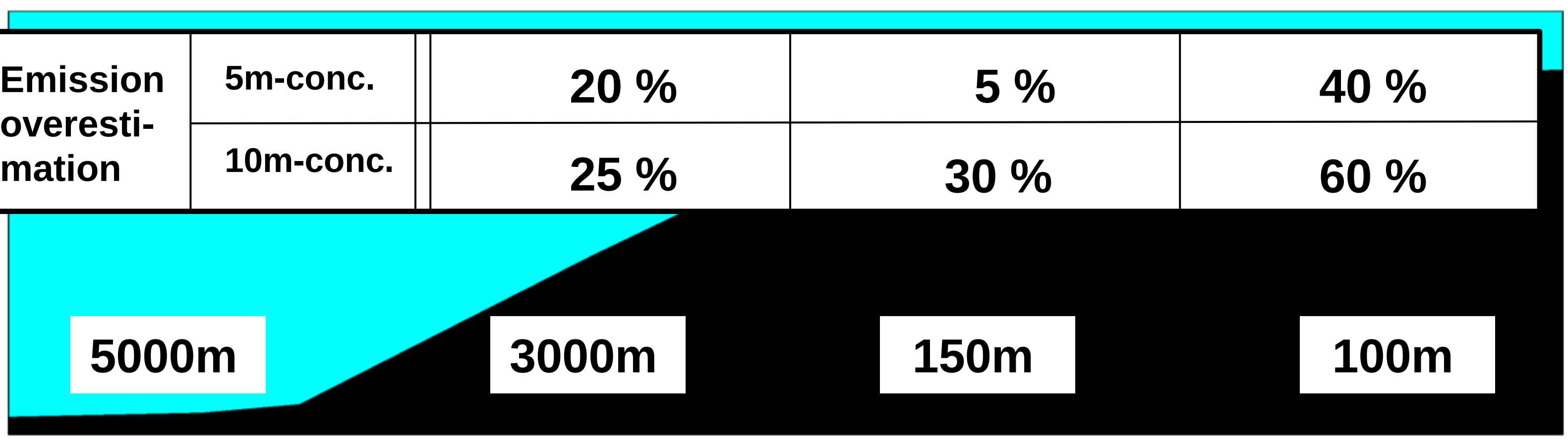
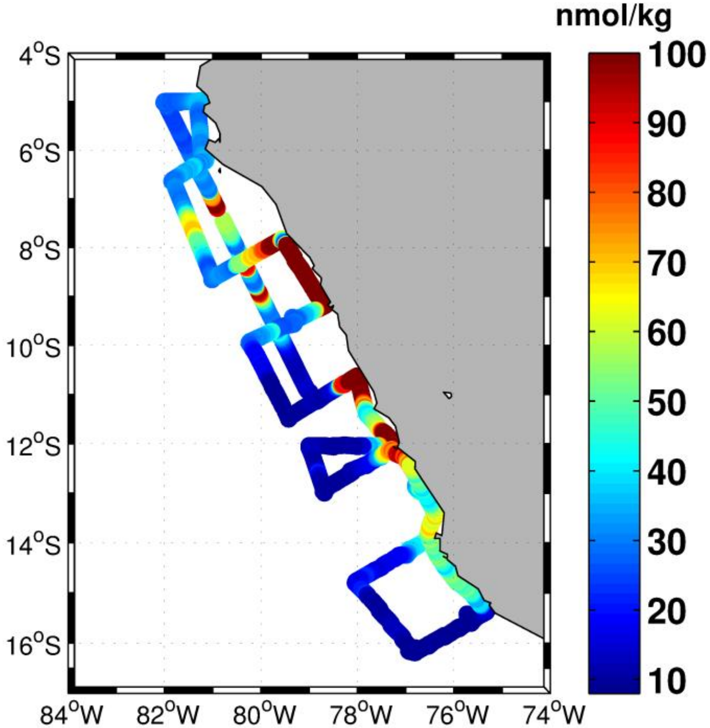
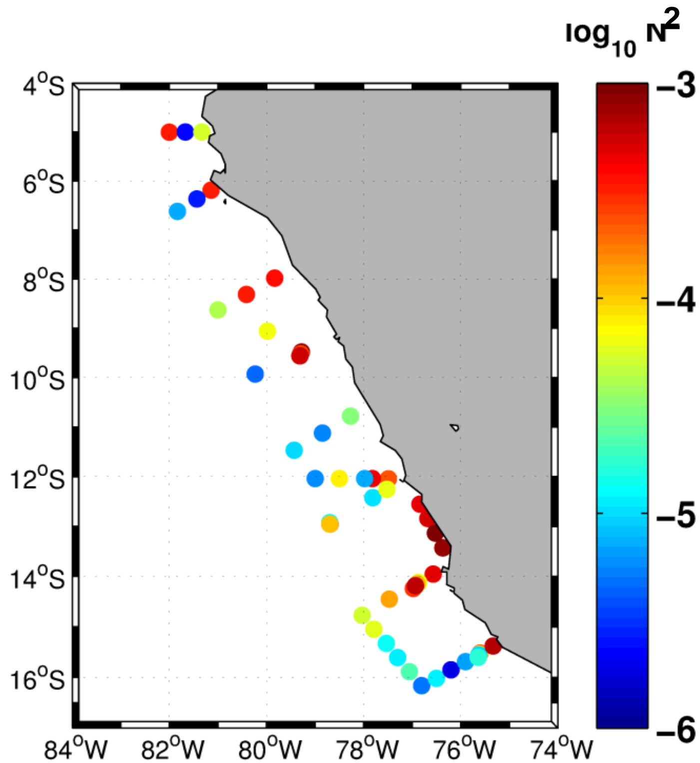


Is this more than a random finding?

N_2O concentration at 5m



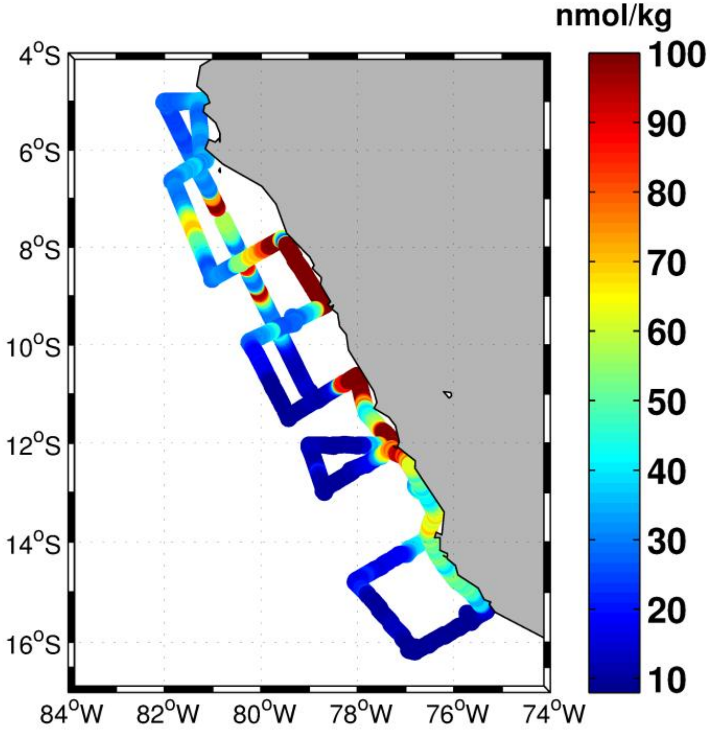
Stratification of top 10m (from microstructure profiler)



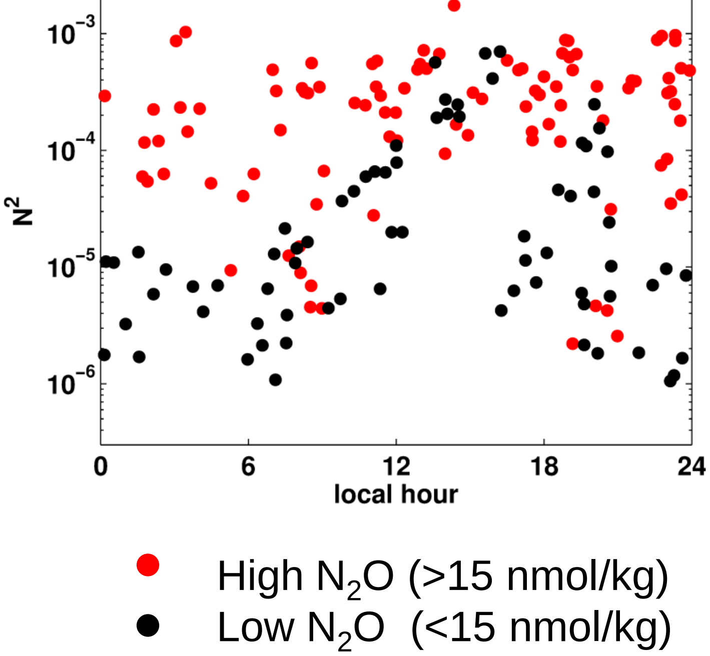
Top 10 m stratification is strong in most of the area;
Seems roughly correlated to high N_2O concentrations.

Is this more than a random finding?

N_2O concentration at 5m

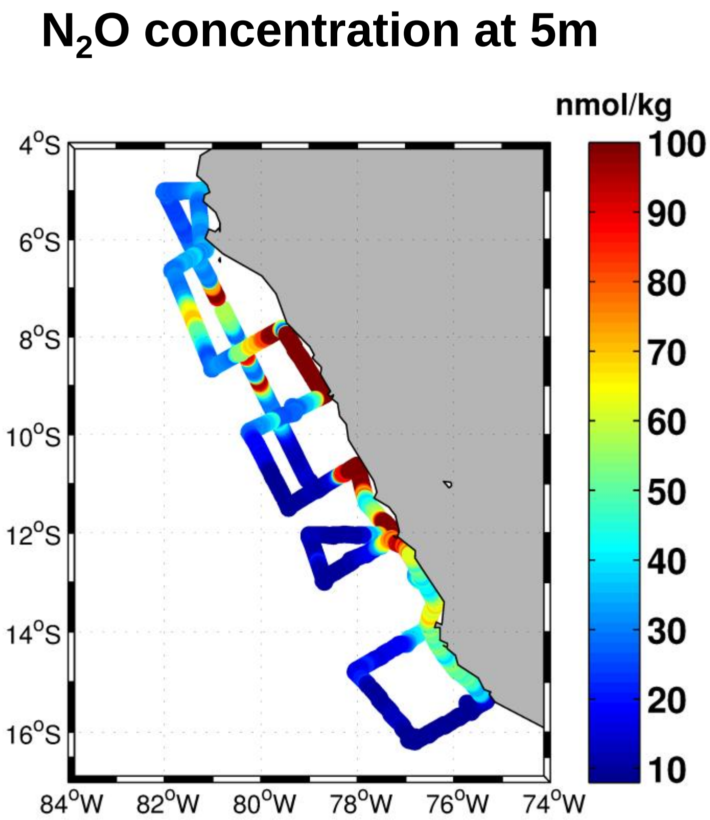


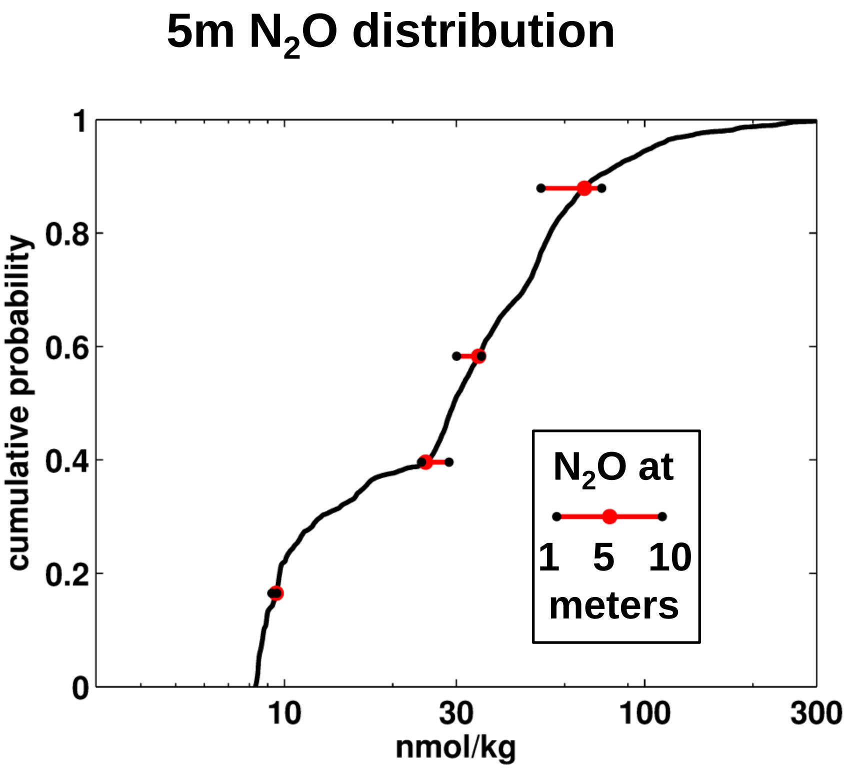
Stratification of top 10m vs. local time



Suggests: Stratification not completely eroded at night = high N_2O

Is this more than a random finding?



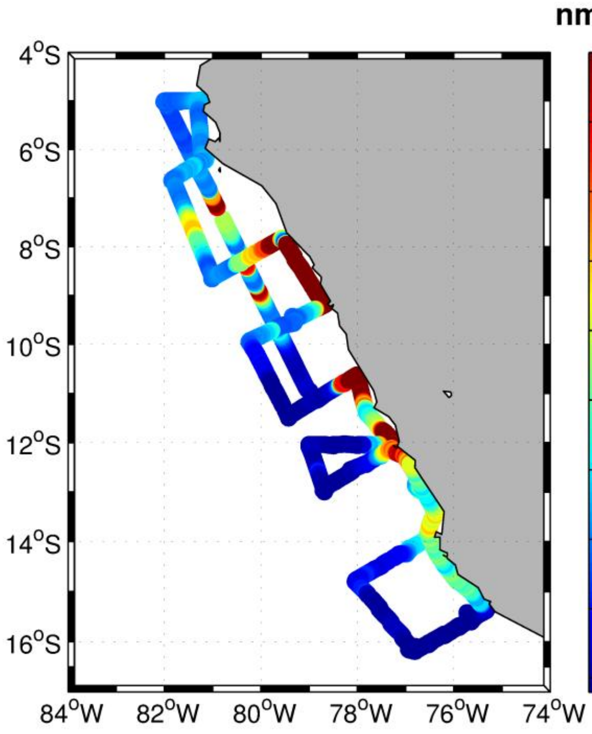


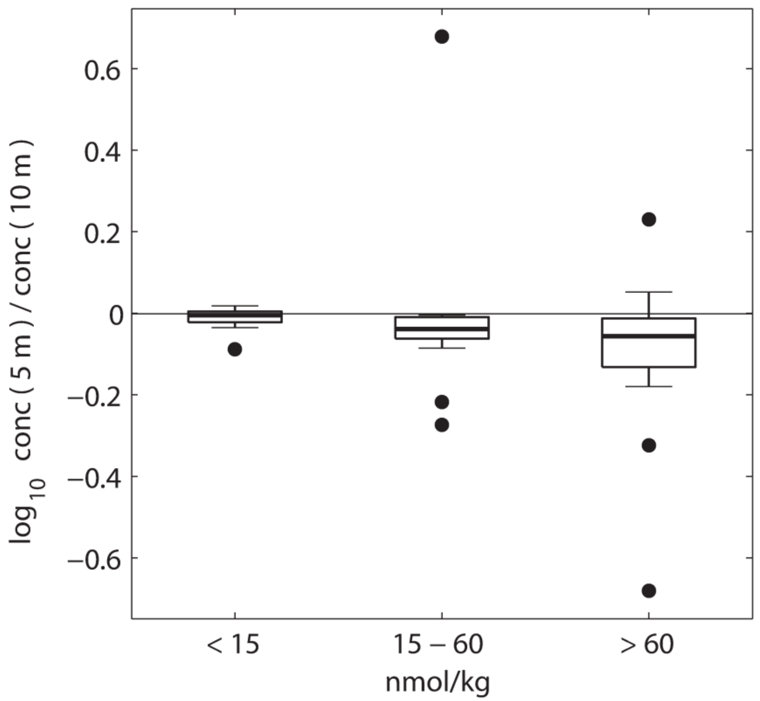
The 4 profiles suggest: high N$_2$O = stronger N$_2$O gradients

Is this more than a random finding?

$$\frac{N_2O \text{ at 5m}}{N_2O \text{ at 10m}} \quad \text{(CTD)}$$

N_2O concentration at 5m



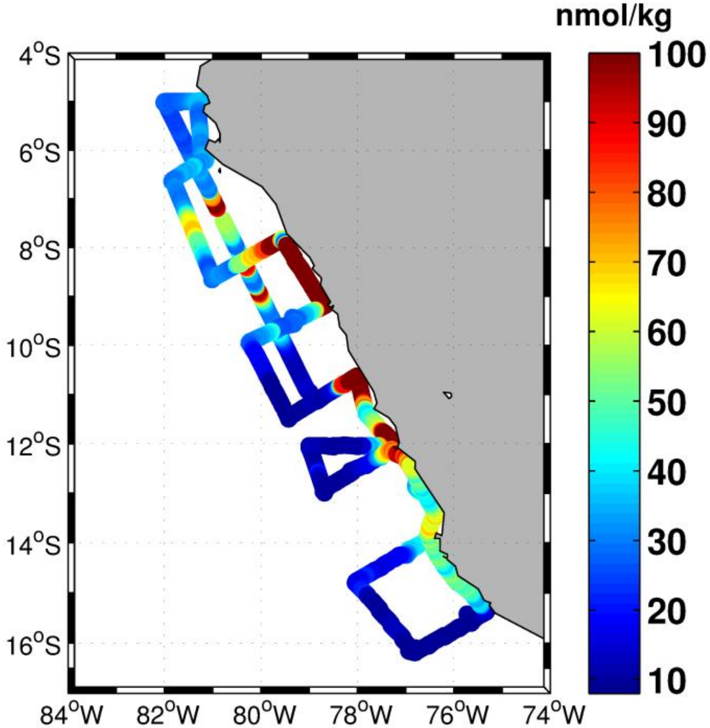


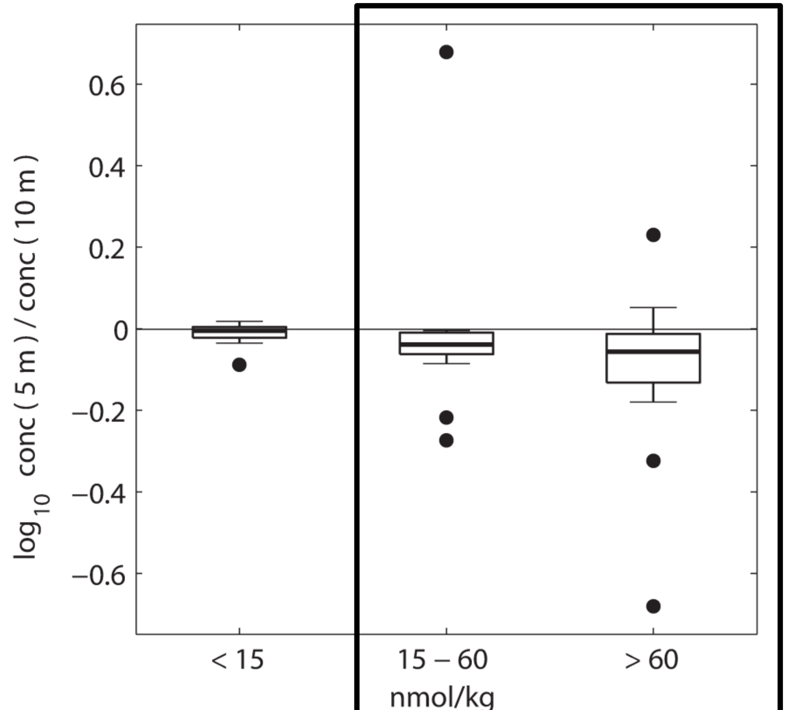
$C_{5\,m} / C_{10\,m}$	99 %	92 %	88 %
$C_{1\,m} / C_{5\,m}$	?	?	?
(Our profiles)	(100 %)	(97/87 %)	(76 %)

Is this more than a random finding?

$$\frac{N_2O \text{ at } 5m}{N_2O \text{ at } 10m} \quad \text{(CTD)}$$

N_2O concentration at 5m





$C_{5\,m} / C_{10\,m}$	99 %	**2/3 of the survey area**
$C_{1\,m} / C_{5\,m}$	?	
(Our profiles)	(100 %)	

Summary

Gas gradient in top 10m exists, seemingly throughout large parts of the coastal upwelling off Peru.

Associated with a strong shallow stratification not eroded at night.

Effect: emission estimates biased, strongest bias where emission estimates most affected.

Open questions

Quantification of total bias for emission estimates off Peru.

Is there such phenomenon in other coastal upwelling systems ?

Need more high resolution profiles.

References

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