Multidiurnal warm layer and inhibited gas exchange in the Peruvian upwelling regime

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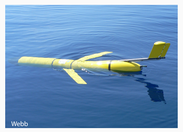
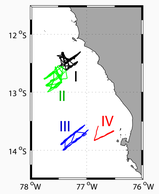
Multidiurnal shallow stratification exists in the upwelling regime, observed by glider fleet.

4 regions of dense hydrographic observations



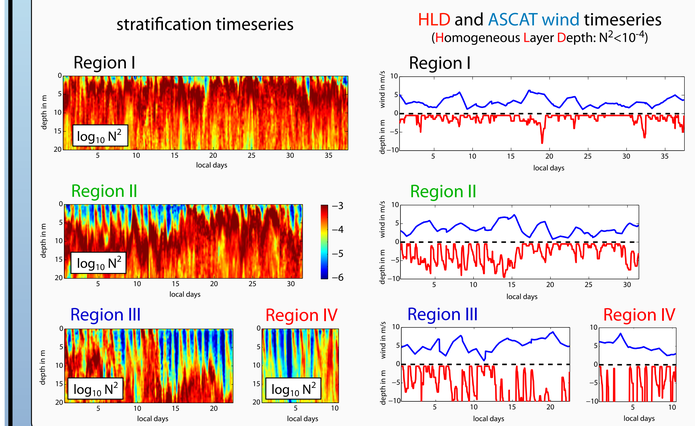
7 gliders, 250 gliderdays in total, in Jan. and Feb. 2013



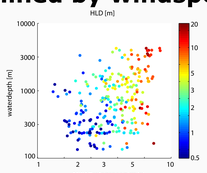
Extracted composite hydrographic timeseries:

- I 37 days
- II 31 days
- III 22 days
- IV 10 days

Found different grades of persistent stratification

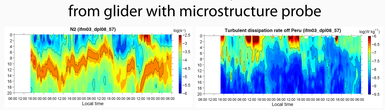


HLD is mainly determined by windspeed



The stratified layer is extremely low in mixing

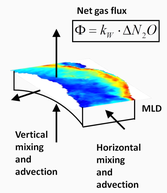
stratification and dissipation rate, from glider with microstructure probe



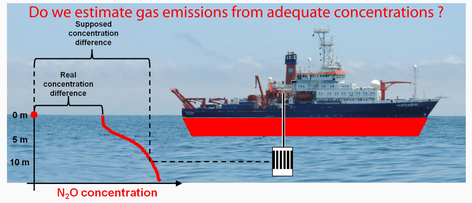
N^2 of $O(10^{-3})$ and dissipation rate of $O(10^{-8})$ result in a vertical exchange coefficient K of $O(10^{-6})$.

Nitrous oxide (N_2O) observations in top 10 m show vertical concentration gradients.

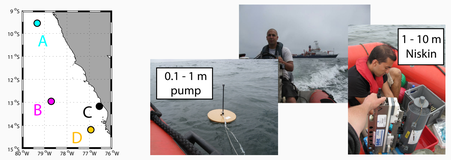
Motivation to look for gas gradients in top 10 meters



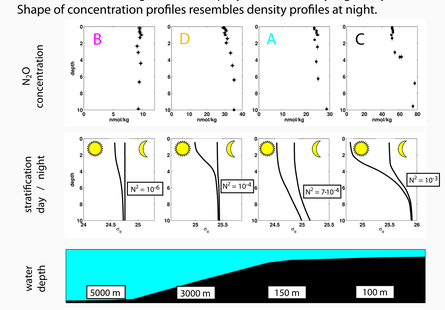
In the Mauritanian upwelling regime, N_2O supply from below is much lower than the calculated N_2O emissions. [Kock et al., 2012]



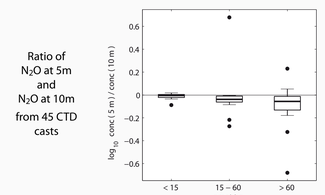
Profiles far from ship's influence allow detection of shallow gradients

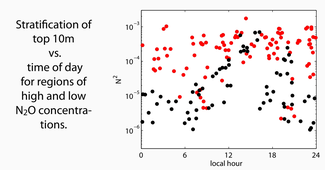


Vertical concentration gradients in top layer exist and vary regionally.
Shape of concentration profiles resembles density profiles at night.



Night time stratification, high concentrations and strong gradients are associated



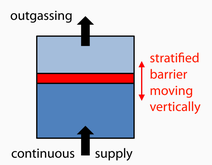


Hypothetic mechanism:

Mixing is inhibited in a thin stratified layer that is not eroded for one or more nights. The surface layer (the 'multidiurnal warm layer') is thus isolated from gas supply from below, while the continuing outgassing causes surface depletion.

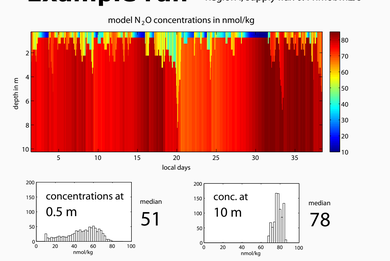
A 1-D model constrained by the glider timeseries reproduces N_2O gradients of the observed kind.

Model schematic



Example run

Region I, supply flux 0.4 nmol/m2/s



Exchange across the stratified barrier layer is only via entrainment. For the vertical movement of the barrier the observed HLD timeseries are used.

Modelled gradients vs. region and supply

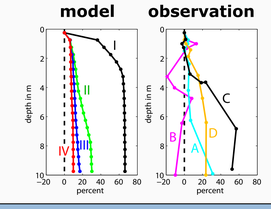
constant supply flux in nmol/m²/s

Region	0.025	0.05	0.1	0.2	0.4	0.8	1.5
I	10 / 12	13 / 16	18 / 25	29 / 43	51 / 78	95 / 149	171 / 272
II	8.9 / 9.5	11 / 12	15 / 17	23 / 27	39 / 48	72 / 88	128 / 160
III	8.2 / 8.5	9.5 / 10	12 / 13	18 / 20	28 / 33	49 / 59	86 / 105
IV	9.3 / 9.4	10.6 / 11	13 / 14	19 / 20	29 / 32	51 / 56	89 / 97

x1 / x2 conc. at 0.5 m / conc. at 10 m

best match to concentrations observed in the region

Resulting emission overestimation when sampling at a specified depth



Conclusions

Multidiurnal shallow stratification (MDSS) with persistent mixing inhibition is a plausible cause for substantial surface N_2O depletion observed.

Just diurnal shallow stratification would not be sufficient.

Bias of N_2O emission estimates is highest where strongest MDSS and highest concentrations occur, i.e. where impact of bias is highest.

References

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