GEOMAR
Helmholtz Centre for Ocean Research Kiel

RD 1 Ocean Circulation and Climate Dynamics
Düsternbrooker Weg 20
D-24105 Kiel

contact: tfischer@geomar.de www.geomar.de

Multi-day near-surface stratification and its impact on N_2O emission estimates in the Peruvian upwelling system

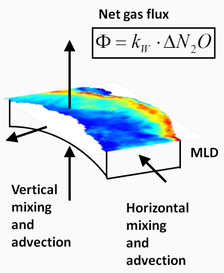
Surface Ocean Processes in the Anthropocene

BMBF-Verbundvorhaben
SOPRAN

T. Fischer, A. Kock, D.L. Arévalo-Martínez, M. Dengler, P. Brandt, H.W. Bange

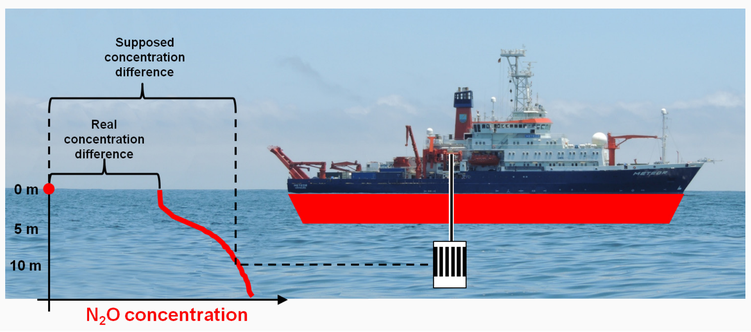
Measuring nitrous oxide (N_2O) in the top 10 meters of the Peruvian upwelling system

Motivation



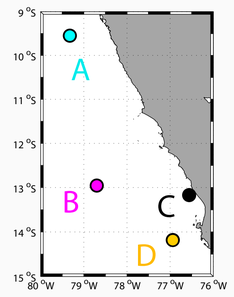
In the Mauritanian upwelling regime, N_2O supply from below is much lower than the calculated N_2O emissions. [Kock et al., 2012]

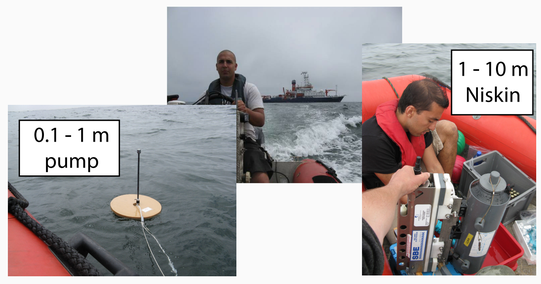
Do we estimate gas emissions from adequate concentrations ?



N_2O measurements during Meteor cruise M91 in December 2012

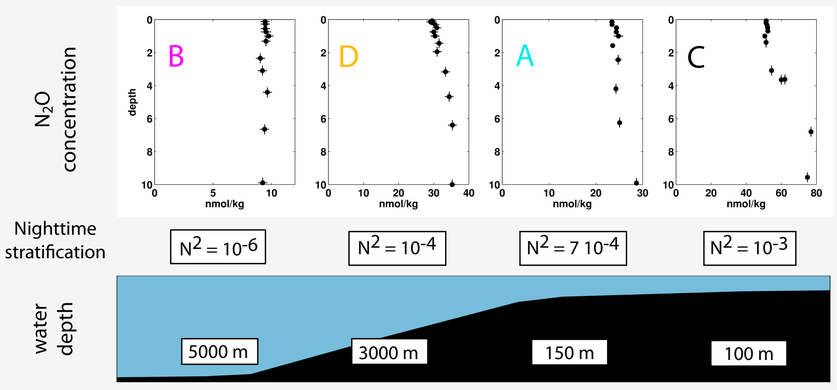
Shallow sampling away from ship's influence



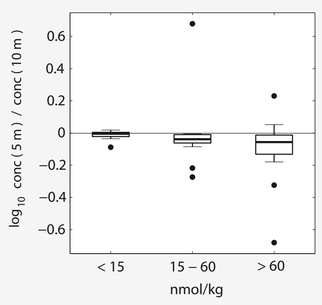


Near-surface N_2O gradients exist - associated with shallow nighttime stratification

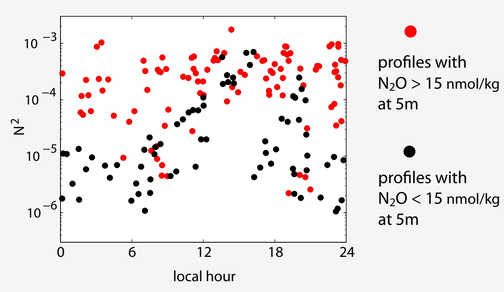
Vertical concentration gradients in top layer exist and vary regionally. Existence of strong N_2O gradient is related to strong N^2 during night.



Ship based observations also indicate that N_2O gradients are associated with higher N_2O concentrations and nighttime stratification.

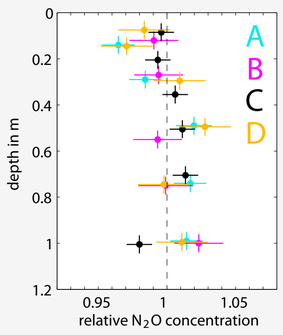


Ratio of N_2O at 5m and N_2O at 10m from 45 CTD casts



Stratification of top 10m vs. time of day for regions of high and low N_2O concentrations.

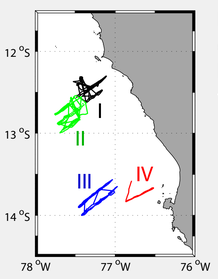
Top 1 meter: barely any gradient



Conc. at 10 cm : Conc. at 1 m ≈ 0.97

Existence of multi-day near-surface stratification is verified by glider surveys

Glider fleet in Jan/Feb 2013

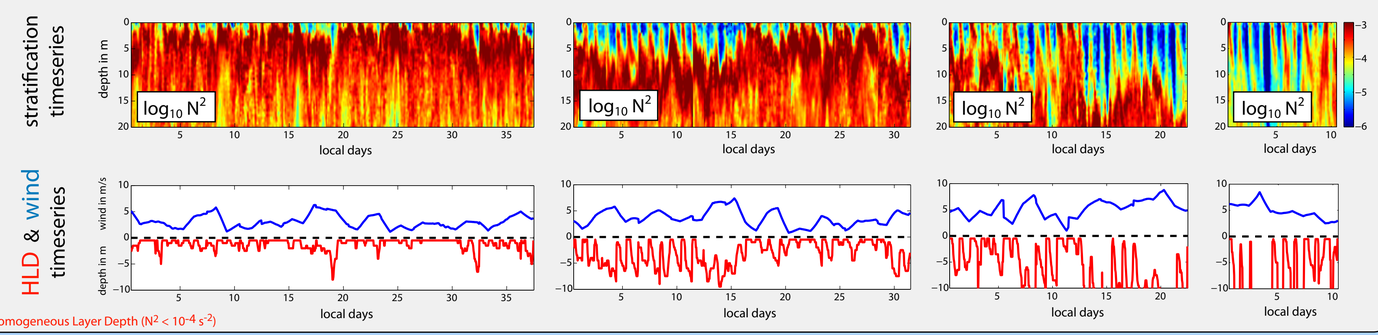


Extracted composite hydrographic timeseries:

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

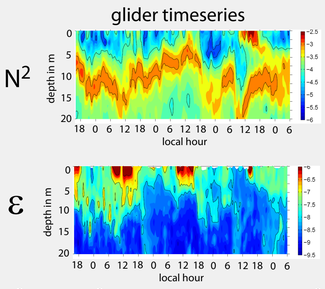
In total 250 glider days were performed by 8 gliders in 4 main regions, recording hydrography.

Regional stratification timeseries with different grades of multi-day stratification



The moving stratified layer is extremely low in mixing

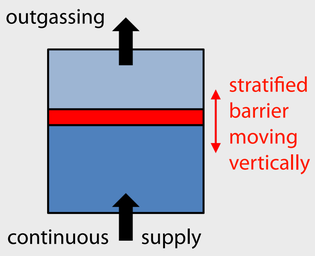
glider timeseries



N^2 of O (10^{-3}); dissipation rate of O (10^{-8}): vertical exchange coefficient K of O (10^{-6}).

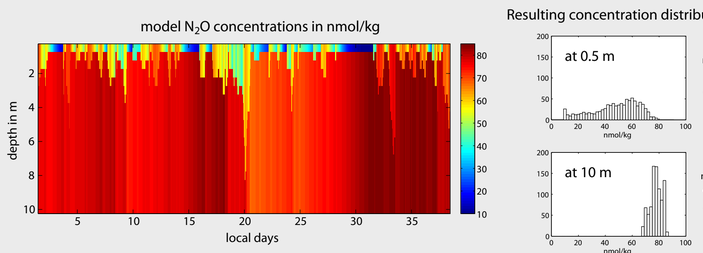
A 1-D model constrained by the glider timeseries can reproduce the N_2O gradients

1-D two layer model of N_2O transport



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

Example run: Region I - multi-day stratification causes distinct N_2O gradient



Integral effect:

emission overestimate of factor 1.67

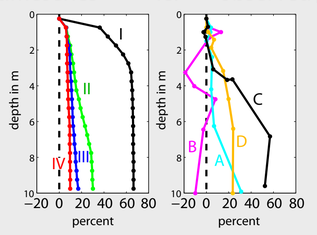
(if emission estimate is based on 10-m-concentrations instead of 0.5-m-concentrations)

Resulting overestimation of emissions :

model timeseries vs. observed profiles

- I + 67 %
- II + 30 %
- III + 17 %
- IV + 9 %

based on 10-m-concentrations



Conclusion: Multi-day (not diurnal) stratification seems the necessary condition here to cause considerable near-surface N_2O gradients and bias of emission estimates.

References

Calleja, M. Ll., Duarte, C. M., Vaquer-Sunyer, R., Agusti, S., and Herndl, G. J. (2013): Prevalence of strong vertical CO_2 and O_2 variability in the top meters of the ocean, Global Biogeochem. Cycles, 27, 941-949, doi: 10.1002/bgc.20081 ----- Kock, A., Schafstall, J., Dengler, M., Brandt, P., and Bange. H.W. (2012): Sea-to-air and diapycnal nitrous oxide fluxes in the eastern tropical North Atlantic Ocean, Biogeosciences, 9, 957-964 ----- Soloviev, A., Edson, J., McGillis, W., Schluessel, P., and Wanninkhof, R. (2002): Fine thermohaline structure and gas-exchange in the near-surface layer of the ocean during GasEx-98, in: Donelan, M.A., Drennan, W.M., Saltzman, E.S., and Wanninkhof, R. (eds.): Gas transfer at water surfaces, AGU Geophysical Monograph Series 127, Washington D.C., 181-185 -----

Acknowledgements

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