Nitrous oxide (N_2O) gradient in top 10 meters of coastal upwelling waters off Peru

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

Surface Ocean Processes in the Anthropocene

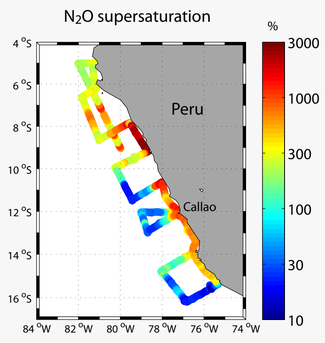
BMBF-Verbundvorhaben
SOPRAN

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

Motivation to look for N_2O gradients in the top 10 meters of the Peruvian upwelling

Coastal upwelling regions contribute substantially to oceanic N_2O emissions [Nevison et al., 2004, Naqvi et al., 2010].

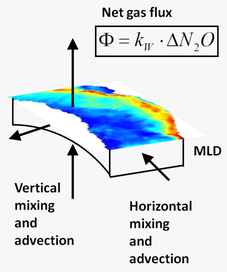
E.g. off Peru, very high subsurface supersaturations indicate very high N_2O emissions. [Underway measurements: D.L. Arévalo-Martínez]



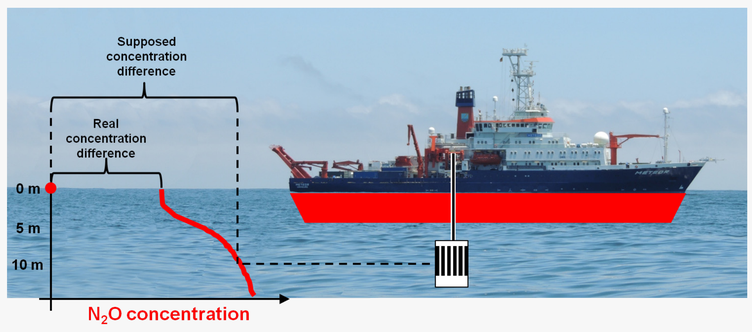
But emissions may be overestimated in upwelling regions.

Kock et al. [2012] found that estimated N_2O outgassing in Mauritanian upwelling could not be provided by supply processes:

70 pmol/m²/s outgassing
vs.
20-40 pmol/m²/s supply.



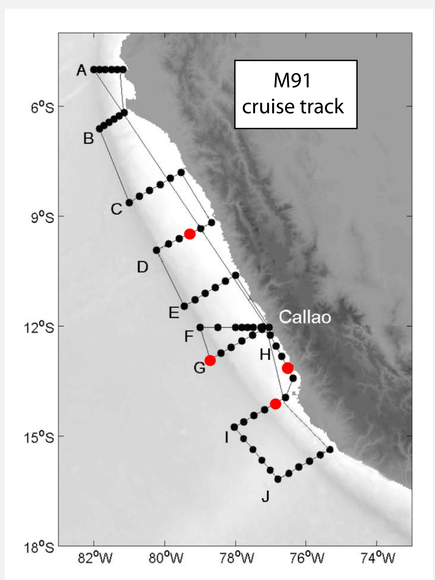
One possible explanation would be a shallow gradient in N_2O concentration combined with measurements not shallow enough.



For CO_2 and O_2, variance in the top 10 meters has been described [Soloviev et al. 2002, Calleja et al. 2013].

High-resolution profiles of N_2O performed during Meteor cruise M91 in December 2012

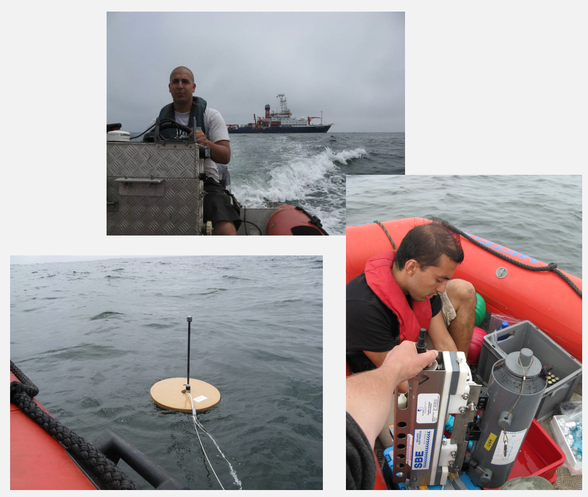
4 high-resolution N_2O profiles in top 10 meters at different distance to the coast.



● CTD O_2 partly MSS partly N_2O ...

● 24-h-stations, incl. high-resolution N_2O profiles

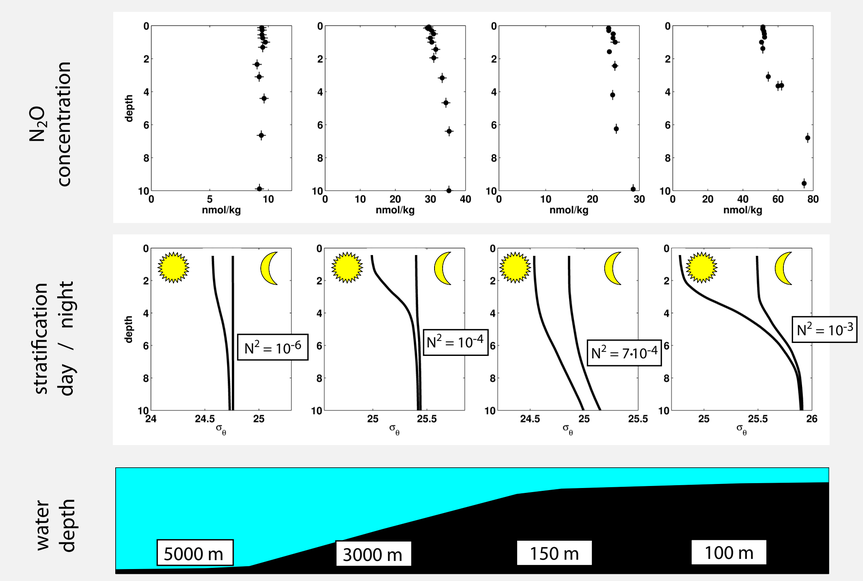
Shallow sampling away from ship's influence



0.1 to 1 m: submersible pump

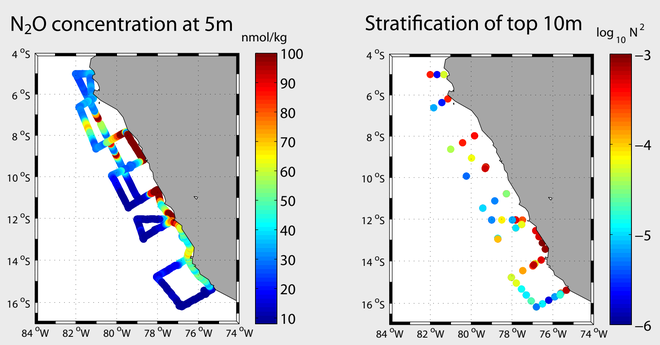
1 to 10 m: Niskin + MicroCat

Shallow N_2O gradients exist. Strongest gradient observed on the shelf (->bias of factor 1.5). They correspond to shallow stratification, that was not completely eroded the night before.



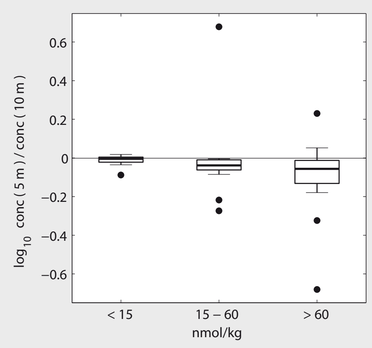
Major fraction of Peruvian waters shows favourable conditions for N_2O gradient

High N_2O concentrations are associated with nighttime stratification



Higher N_2O concentrations are associated with stronger N_2O gradients

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



2/3 of the survey area show:

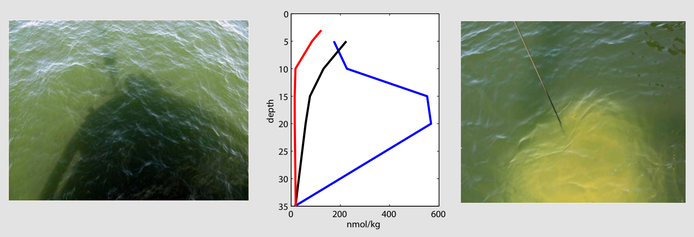
- high N_2O > 15 nmol/kg
- shallow N_2O gradient
- nighttime stratification

Conclusions

- Significant shallow N_2O gradients exist off Peru.
- Effect: Emission estimates are biased high.
- Suggested cause:
  Shallow stratification fails to be eroded for at least one night.
  Such condition is met in majority of Peruvian waters.
- Gradient seems strongest where expected impact on emission estimates is largest: at high N_2O concentrations near the coast.

Open questions

- More shallow profiles needed to:
  verify assumed cause of N_2O gradients,
  quantify the bias on total emission estimates.
- How much do surfactants reduce outgassing in addition ?
- How to measure N_2O underway at <1m and 12 kts ?
- How do ultra-high N_2O profiles continue to the surface?



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 ----- Naqvi, S.W.A., Bange, H.W., Farías, L., Monteiro, P.M.S., Scranton, M.I., and Zhang, J. (2010): Marine hypoxia/anoxia as a source of CH_4 and N_2O, Biogeosciences, 7, 2159-2190, doi:10.5194/bg-7-2159-2010 ----- Nevison, C.D., Lueker, T.J., , and Weiss, R.F. (2004): Quantifying the nitrous oxide source from coastal upweling, Global Biogeochem. Cycles, 18, GB1018, doi:10.1029/2003GB002110 ---- 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 -----

Acknowledgments

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