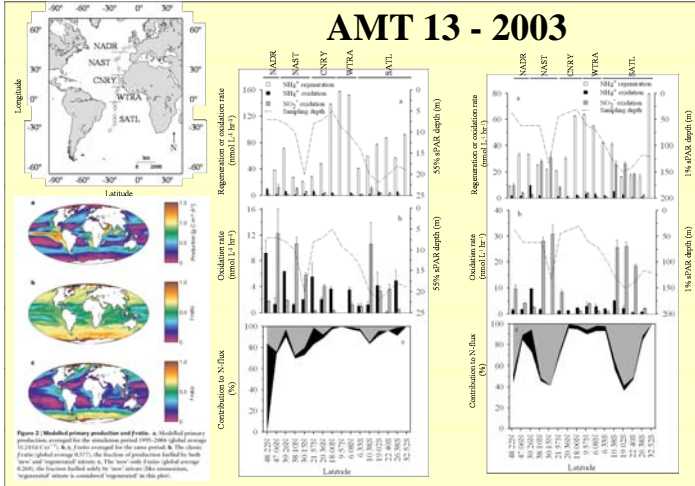


New concepts challenging old paradigms: nitrogen cycling in the sunlit ocean

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Nitrogen is an essential component in biological cells although its availability in the sunlit oceans frequently places an upper limit on the growth of photosynthetic micro-organisms. In upwelling systems (investigated during the UK-SOLAS programme (ICON) and PML's μ -layer cruise) nutrient rich waters are brought into the sunlit ocean from great depths and the elevated concentration of 'new' inorganic N supports phytoplankton proliferation. In contrast, for regions where new-N supply is very low, such as the oligotrophic gyres of the open oceans (e.g. AMT), phytoplankton productivity is sustained by the recycling of N through bacterial activity. Over recent years, N-cycling investigations in these contrasting regions have highlighted the importance of the interactions between N-assimilation by marine phytoplankton and N-regeneration by the heterotrophic microbial community. Most significantly, the concept that nitrification is insignificant in the sunlit ocean has been over-turned. Nitrification regenerates NO_3^- from NH_4^+ and was assumed to be restricted to the very low light or aphotic depths of the ocean. However, we now know that low rates of nitrification persist throughout the sunlit open ocean and rates in upwelling regions can be extremely high. The discovery that NO_3^- regeneration and assimilation takes place simultaneously in the sunlit ocean has forced a re-evaluation of global productivity and C-export flux since NO_3^- assimilation cannot be equated to the assimilation of new-N. Moving into the future, pelagic N-biochemistry in an acidified ocean is a new and important area of exploration.



Overview.

The marine environment supports the productivity of the oceans, modulates the composition of the atmosphere, and is crucially involved with the sequestration of carbon to the deep ocean through stoichiometric links with the nitrogen (N) and phosphorus (P) cycles. N and P availability frequently limits marine productivity. By improving our understanding of the N and P cycles and their intrinsic links to the C-cycle, the potential of the marine environment to sequester atmospheric CO₂ can be estimated through modelling studies.

N-cycling investigations have been undertaken at PML in a range of marine environments. These have included low nutrient oligotrophic oceans and very high nutrient upwelling systems. Studies have demonstrated that the processes of N-regeneration and N-assimilation operate simultaneously within the sunlit ocean. Importantly, nitrification can provide regenerated NO_3^- at a significant rate when compared to NO_3^- assimilation. Regenerated NO_3^- cannot be distinguished from 'new' NO_3^- , complicating the new production paradigm.

AMT13 – The oligotrophic Atlantic Ocean.

Investigating biogeochemical cycles within oligotrophic environments challenges many analytical detection limits. During AMT13, very sensitive isotopic methods^{1,2} for N-regeneration rate estimations were applied to the extremely low nutrient regime of the Atlantic Ocean for the first time³. Results demonstrated that nitrification could be measured throughout the photic zone, with domes of activity associated with the centres of the gyres. As part of a larger modelling study⁴, results demonstrated that the exclusion of nitrification in estimations of global productivity represented a significant source of error.

During AMT19, and in collaboration with the POGO programme, we conducted a more detailed investigation of nitrification within the oligotrophic Atlantic Ocean. We aimed to improve the sampling frequency across the AMT transect and to provide more detailed information about nitrification in the photic zone of the oligotrophic Atlantic. Sample analysis is to commence in the near future.

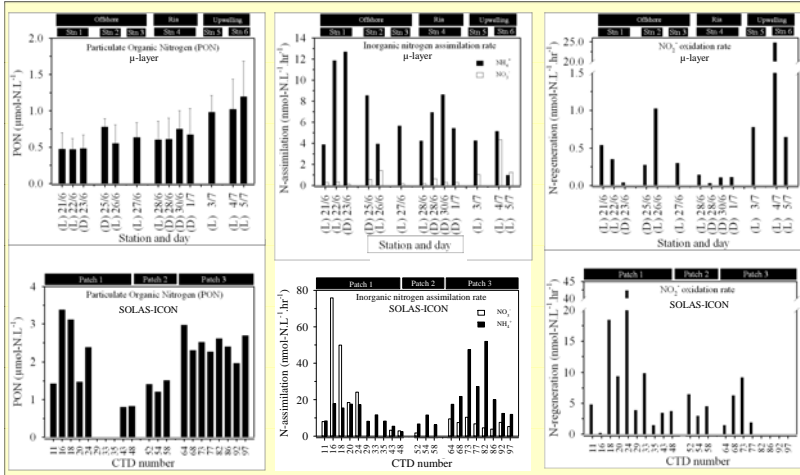
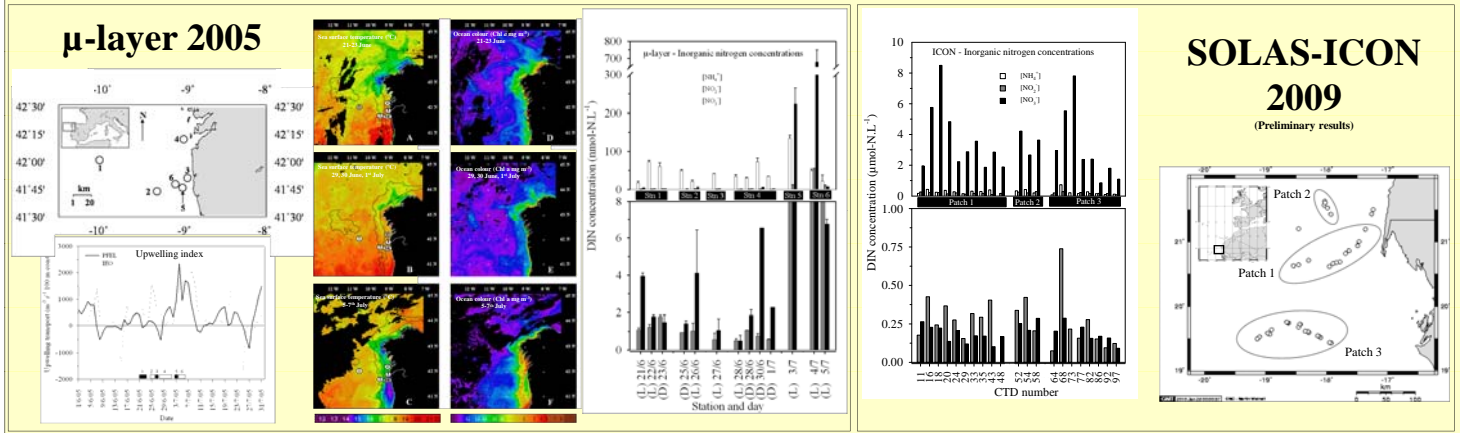
μ -layer and SOLAS-ICON – Upwelling regions within the North Atlantic.

Simultaneous measurements of N-regeneration and N-assimilation were made during investigations in 2 Atlantic upwelling regions. The Iberian Peninsula (PML's μ -layer cruise) is a relatively weak upwelling system when compared to the eastern boundary upwelling system off the coast of Mauritania (SOLAS-ICON).

The μ -layer cruise aimed to characterise surface ocean biogeochemistry at a range of contrasting stations, guided by near real time remote sensing data (ocean colour and temperature). When combined with upwelling indices, data demonstrated that stations 1-4 were not influenced by upwelling in contrast to stations 5 and 6. N concentration data confirmed this.

The SOLAS-ICON cruise combined near real time remote sensing data and hydro-graphic survey work in order to identify upwelling patches of seawater which were marked with the inert tracer SF_6 . The aim was to enable a lagrangian study of biogeochemical processes as the upwelled water mass moved offshore.

A fundamental difference between the 2 upwelling systems was demonstrated in the N concentration data. Seawater within the Mauritanian upwelling system contained substantially higher concentrations of N, setting the scene for a range of useful comparisons to be made between these systems in terms of N-biochemistry. Curiously, high NO_3^- concentrations persisted in ICON patches, suggesting that an unknown physicochemical factor limited potential biological productivity in this region.



PON concentrations demonstrated the difference in 'phytoplankton standing stock.' Higher concentrations were associated with the more productive Mauritanian upwelling, further supported by the substantially higher rates of NO_3^- and NH_4^+ assimilation. In both systems a transition in the preferred N-source took place as sampling stations moved off-shore. At the Mauritanian upwelling, a preference for NH_4^+ persisted in spite of relatively high NO_3^- concentrations, suggesting an unknown factor limited NO_3^- assimilation. In both systems, simultaneous N-regeneration (both NH_4^+ and NO_3^-) and N-assimilation was measured. Importantly, rates of nitrification were elevated within recently upwelled waters in both systems, as found by previous studies in the Iberian and Eastern Pacific upwelling regions. Previous studies suggested that nitrification within upwelled waters was a source of regenerated NO_3^- to the new- NO_3^- pool. However, a N mass balance for the Iberian Peninsula demonstrated that NO_2^- release from phytoplankton cells in the surface ocean following incomplete NO_3^- assimilation stimulated NO_2^- oxidation, uncoupling NO_2^- oxidation from NH_4^+ regeneration and subsequent oxidation. Consequently, elevated nitrification in upwelling regions may reflect new-N recycling (a nitrification 'short-circuit'). When the coupling between NH_4^+ regeneration and nitrification processes is re-established further offshore, nitrified NO_3^- is once again regarded as a regenerated form of N.

Future direction.

As a consequence of climate change, Ocean Acidification (OA) will provoke complex changes to the biogeochemistry of the pelagic marine environment. The resilience of microbial communities to OA will have important implications for marine ecosystems. A key scientific question is how will the biogeochemical cycling of nutrients be influenced by OA and what impacts will this have on the wider marine ecosystem, its resources and services? In future, we aim to address these import questions.

References

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