July 2005

SCAR Prince of Asturias Fellowship report

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Research topic: Phytoplankton photosynthetic kinetics of damage and repair in vertically mixed Antarctic waters

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INTRODUCTION. One of the most frequently observed consequences of UV induced molecular damage is the decrease of photosynthetic rates. Extension of short-term estimates of photoinhibition to full-day effects requires information on how inhibition and damage accumulate with time of exposure, and how fast effects are reversed when UV exposure ceases. Initial observations of the kinetics of photosynthetic response to UV were made using time series of ^{14}C incorporation (Cullen and Lesser 1991; Lesser et al. 1994). This is appropriate for time scales of 30 min to several hours (Neale et al. 1998a) but does not resolve responses on minutes to 10's of minutes time scales that are characteristic of light variation in the surface mixed layer (Denman and Gargett 1983). Better temporal resolution of the kinetics of inhibition and recovery of photosynthesis is now possible using active fluorometry to measure the quantum yield of PSII electron transport (F_v/F_m and F'_v/F'_m) (Neale et al. 1998b; Heraud and Beardall 2000; Neale et al. 2001; Sobrino et al. 2005).

Direct measurements of quantitative *in situ* effects, on the other hand, are difficult to make for most cases. However, estimates can be made using mathematical models. The quantitative response to UV exposure is characterized well enough for many processes that statements can be made about integrated effects over the water column as a function of vertical mixing in the surface layer (Neale et al. 1998c; Huot et al. 2000; Kuhn et al. 2000). These model results, together with profiles of UV-specific effects under qualitatively different mixing conditions, argue that mixing significantly modifies water-column effects. However, there are no instances where UV responses and vertical mixing have been quantitatively measured at the same time.

The aim of this project was to assess the impact of UV radiation on phytoplankton production in a vertically mixed system. The project was included in a larger scale project focused on the study of the effect of UV on the Ross Sea phytoplankton and bacterioplankton communities together with the vertical mixing as the primary physical factor controlling exposure of these communities to UV (P.J. Neale (Smithsonian Environmental Research Center), NSF-Polar Programs; *Interactive effects of UV and vertical mixing on phytoplankton and bacterioplankton in the Ross Sea*).

METHODOLOGY. The experimental work was performed in the Ross Sea Polynya region (near Ross Island) from 19th December 2004 to 27th January 2005 on the icebreaker Nathaniel B. Palmer. My work was focused on the analysis of the photoinhibition time-series experiments to clarify the rates of damage and repair as needed to model UV responses in a vertically mixed system. We also examined spectral responses (weighting functions or BWFs), phytoplankton biomass and pigmentation, incident and underwater UV irradiance and vertical mixing rates, among others. Rates of damage and repair were estimated from 14C measurements using UVT vs. UVO boxes in deck incubations. Fine time-scale responses of photosynthesis (important for scaling time responses in vertical mixing models) in UVT vs. UVO bags and in the water column were also measured using time-series of PSII quantum yield (F_v/F_m and F'_v/F'_m) by active fluorometry with a Fast Repetition Rate Fluorometer (FRRF). *In situ* incubations were also used to compare non-mixed vs. mixed phytoplanktonic photosynthetic rates under UV exposures.

RESULTS. Results obtained from time-series of photosynthesis in deck incubations demonstrated that phytoplankton photosynthetic rates of repair in the Ross Sea polynya during the experimental period were very low. In addition, a diel series of frequent profiles of the water column using the FRRF showed that phytoplankton photosynthesis only recovered partially during the hours of lower light intensities (Fig. 1). Consistent with these results, the spectral response of phytoplankton inhibition of photosynthesis by UVR showed higher sensitivity than other Antarctic phytoplanktonic assemblages. The results seem to be in agreement with previous work in the Ross Sea indicating that low iron concentration can play an important role in phytoplankton photoinhibition (Hiscock et al. 2003). The comparison between the photosynthetic response from water samples kept at constant depths in the water column and the response obtained from the vertical profiles using the FRRF confirmed the relevance of the mixing processes. The results showed that the vertical mixing is able to increase photoinhibition in cells with low capacity of repair when they are exposed to high light in the surface layer (Fig. 2).

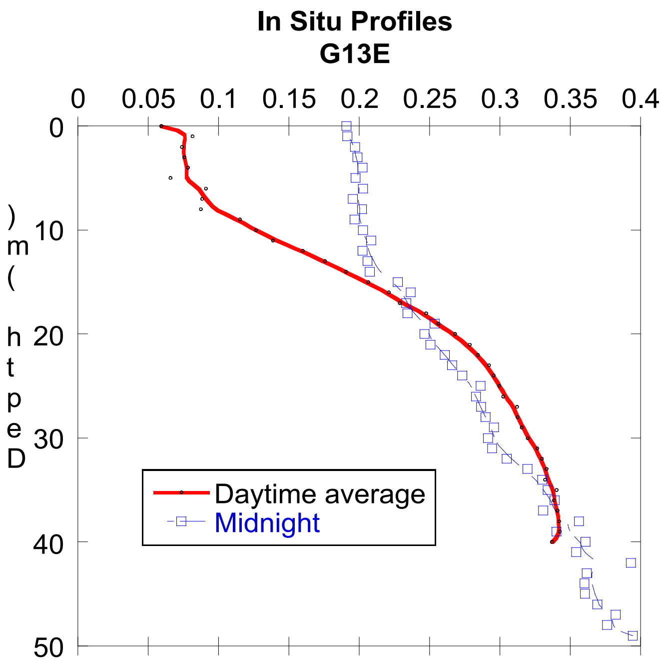

Figure 1. Photosynthetic efficiency (Fv/Fm) profiles of phytoplankton assemblages of the Ross Sea polynya (January 2005) assessed using the Fast Repetition Rate Fluorometer (FRRF).

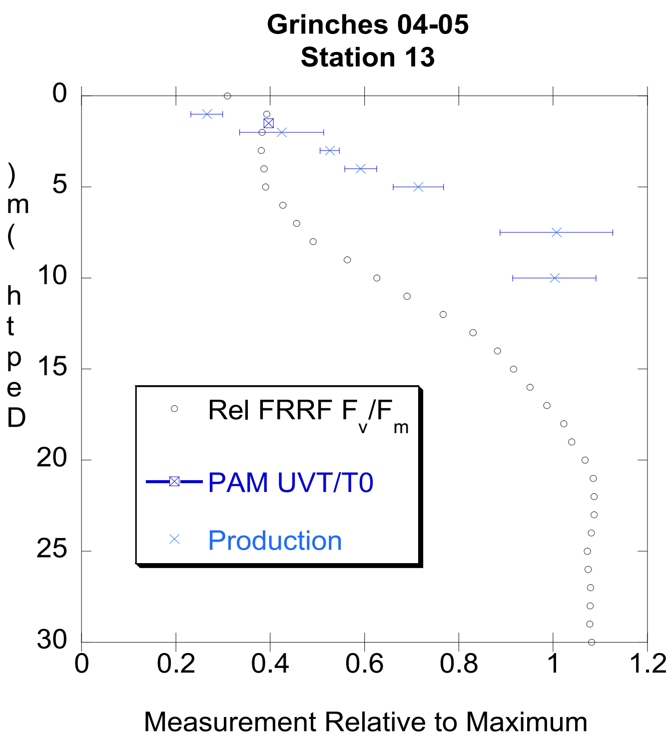

Figure 2. Measurements of the relative photosynthetic efficiency using the FRRF in the water column (mixed) vs. the relative production measured as 14C assimilation at specific depths in an *in situ* array (non-mixed). The PAM UVT/TO value shows an independent measurement of the relative photosynthetic efficiency measured with a Pulse Amplitude Modulated fluorometer. Mixing effects are indicated by the lower photosynthetic efficiency at depth in the FRRF profile than in the non-mixed array.

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One of my favorites moments, to be on deck preparing the FRRF for deployment. Special thanks to John Marra, Bob Vaillancourt, Jill Peloquin, Shasha Tozzi and all the Raytheon techs and crew of the NBP that made this "FRRF project" possible.

The GRINCHES 04-05 team

UV-INHIBITION OF PHYTOPLANKTON PHOTOSYNTHESIS DURING THE LATE STAGE OF AN EXTENSIVE ROSS SEA POLYNYA BLOOM

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The Ross Sea polynya is one of the highest production areas in the Southern Ocean, and the 2004-5 bloom was early (November), extensive and intense (>6 ugChl L-1). In late December-January, PAR (400-700 nm) was rapidly attenuated (1% PAR light depth approx. 20-25 m) but UV (290-400 nm) penetration was relatively high (1% light depth 305 nm > 10 m). Profiles with a fast repetition rate fluorometer showed low PSII quantum yield (< 0.35) even below 20 m, consistent with previous findings of iron limitation in the region. Quantum yield was strongly depressed in near surface waters. UV effects on photosynthesis were quantified using photoinhibitron-based biological weighting functions (BWFs), surface and in situ incubations. Weights for UV inhibition of photosynthesis are among the highest seen for S. Ocean phytoplankton. BWFs were similar among four regional stations with different surface layer depths (20-60 m) but similar phytoplankton species composition (diatoms and Phaeocystis). Differences in vertical mixing are expected to be an important source of regional variation in UV effects on water column productivity in the late December-January period.

Oral presentation presented at ASLO meeting. Santiago de Compostela (Spain) 19-24 June, 2005.