Phytoplankton UV-VIS spectral absorption in the Southern Ocean: preliminary results from the SO-GASEX Cruise

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Introduction

Southern Ocean Gas Exchange (SO-GASEX)

Cruise Objectives

- Improve parameterization of gas flux models using injection and tracking of dual deliberate tracer gases (He & SF6) with high winds and supporting physical, optical and biological measurements.
- Improve bio-optical models and remote sensing for spectral absorption and scattering of phytoplankton and CDOM and for photosynthesis in Southern Ocean where anomalous reflectance may be caused by calcareous skeletons of coccolithophore algae or by wind-driven bubbles.
- Better understanding of Southern Ocean ecosystem processes will help to predict global climate change.

Southern Ocean Gas Exchange (SO-GASEX)

My Objectives

- Characterize the phytoplankton community during the SO-GASEX field campaign to help determine its contribution to underwater PCO2.
- Test an improved method for measuring spectral absorption of particles and phytoplankton pigments by comparison with other methods for phytoplankton that vary in pigment composition and skeletal material.
- Explore alternate methods for detecting protective versus photosynthetic pigments (UV-VIS absorption versus HPLC) and relationship with measured photosynthetic efficiency.

Methods

- Solar PAR. A pair of LI-COR cosine PAR sensors mounted on roof of radiation van near stern, LI-1000 datalogger recorded 5-second data at 15 minute averages and highest values per record used to minimize impact of periodic sensor shading during the rare sunny days.
- Chlorophyll-a. Extracted pigment determined from discrete samples (via Niskin bottles, 200-500 mL filtered on GFF filters with nominal 0.7 μm retention; extracted in 100% methanol in freezer for 24 hr and fluorescence determined with Turner Designs fluorometer). In vivo fluorescence determined in depth profiles, 0-500 m (Turner Designs C6 profiling fluorometer and Cyclops chlor-a sensor).
- UV-VIS Spectral absorption of pigments and pigments and pigments measured in samples on GFF filters (1-2 liters) shortly after collection. An improved version of the Transmission-Reflectance-bleaching method of Tassan & Ferrari (1995) was used (Hargreaves 2007) with the inherent benefits of universal calibration and pigment & detritus separation from total absorption by brief period of bleaching, and with the following improvements:
  - Diode array spectrophotometer & lamp system offer portability (compact size, battery powered) & rapid measurement
  - UV-VIS signal with 2.7 nm bandwidth (FWHM)
  - Minimal handling of sample
  - Correction for fluorescence artifacts

Study Site Characteristics

- Site location near South Georgia Island (see map at right, ca. 51°S, 38°W, bottom depth ca 4000 m, chosen for predictable high winds, strong PCO2 gradient, shallow mixed depth, stable water mass, and deep enough to minimize bottom effects.
- Solar PAR record shows large daily variation with gradual decline.
- Mixed layer depth ca 50 m; surface temperature 3-5°C.
- Chlorophyll-a in the mixed layer declined during March (0.9 ⇒ 0.4 mg/m3) and rose slightly during early April.
- Chlorophyll-a fluorescence shows non-photochemical quenching in upper 10-20 m during day; abrupt drop to lower chlor-a below mixed layer. Constant ratio (390) for Fchl[a]-chl-a for night and below 20 m during day.

Results & Discussion A. Chlor-a in mixed layer appears to respond within 1-2 days to solar radiation (graph at right), suggesting rapid turnover of pigments and possibility of biomass. Absorption spectra (graphs below) demonstrate feasibility of shipboard analysis of spectral absorption. The temporal change in height of UV peaks (330-340 nm; typical of MAA photoprotective compounds) relative to blue and red peaks also suggests that UV wavebands will also have variable mix of photosynthetic and photoprotective roles.

![Graph showing spectral absorption data](image)

Results & Discussion B. Graph at right shows strong fit between measured pigment absorption at red peak and extracted chlor-phyl-a concentration. Slope is Chlorophyll-specific absorption at 674 nm 0.025 common value. Slightly reduced fit for blue peak suggests variable pigments (possibly for photoprotective).

![Graph showing spectral absorption data](image)

Results & Discussion C. Graph at right compares measured pigment absorption at 440nm, and for 440nm, absorption derived from above-water hyperspectral reflectance measurements using the OAA model of Lee et al. 2002. While absolute values from remote sensing model do not rise as rapidly as values from filter pack measurements, there is excellent agreement in the low range & a strong regression (r2 = 0.95).

![Graph showing spectral absorption data](image)

Conclusions

Preliminary analysis of data from the SO-GASEX cruise that ended just two weeks ago suggest that:

- We have begun to characterize phytoplankton community optical properties & its spatial and temporal trends during the Southern Ocean Gas Exchange field campaign.
- The improved filter pad technique worked well for shipboard analysis of spectral absorption.
- UV-VIS absorption appears to reveal phytoplanktonic variations in pigment composition possibly related to photoprotection. We will compare data with HPLC pigments & photosynthetic efficiency.
- The strong correlation of the red absorption peak with extracted chlorophyll-a is promising given the likelihood that samples varied in abundance of calcite skeletal material from coccolithophore algae, a situation that would cause calibration problems for the traditional filter pad method. Data on calcite abundance will be available from another SO-GASEX project.
- Accurate remote sensing of phytoplankton absorption and photosynthesis appear feasible.