Southern Ocean Gas Exchange Experiment

Funded Projects: Objectives and Work Plan

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September 12, 2007

Quantifying air-sea gas exchange at high wind speeds using a dual gas tracer (^{3}He/SF$_6$) technique during the Southern Ocean Gas Exchange Experiment

David Ho (LDEO of Columbia University)
Peter Schlosser (LDEO of Columbia University)
Rik Wanninkhof (NOAA/AOML)

Objectives:

Our primary objective is to constrain the gas transfer velocities during SO GasEx through a dual gas tracer release (SF$_6$ and ^{3}He) into the surface mixed layer. From the change in ratio of these gases over time, a robust and spatially (order of 100 km) and temporally (order of one day) integrative gas transfer velocity can be determined. The measurements can be used to validate the higher frequency but more uncertain micrometeorological flux measurements of CO$_2$ (McGillis, PI) and DMS (Huebert, PI). The deliberate tracer injection is also critical for water column studies by creating a virtual lab beaker in the ocean. The tracers delineate the parcel of water that will be studied extensively to determine the controls of surface water CO$_2$ levels and other climate relevant gases. From the change in SF$_6$ concentration, corrected for gas exchange, a quantitative estimate of dilution can be obtained that is critical to produce mass balances of carbon in the patch (Feely, PI). From the continuous real-time measurements of SF$_6$ in the surface water it can be determined when the ship is in the patch for the biogeochemical studies and rate measurements. Select stations will also be occupied outside the patch to fully quantify the effect of dilutions on mass balances and rate measurements.

Work plan:

We will fill a 4000 L tank situated on the fantail with seawater, and infuse it with ^{3}He and SF$_6$ over a period of 24-48 hours. We will create the tracer patch by injecting the tracer-infused seawater over a 12-h period in a hexagonal pattern of approximately 5-km diameter.

Subsequently we will map the tracer patch over time in its horizontal and vertical extent to determine the effective horizontal and vertical diffusion. From ^{3}He/SF$_6$ ratios collected with depth at regular intervals (every 12 h) throughout the experiment, the gas transfer velocity will be determined.

For each ^{3}He sample, about 40 ml of water will be collected in copper tubes sealed by stainless steel pinch-off clamps at each end and stored for ^{3}He analysis to be performed in the Noble Gas Laboratory at Lamont-Doherty Earth Observatory (LDEO). ^{3}He samples will be collected from CTD casts close to the center of the tracer patch as determined by the underway SF$_6$ measurements. SF$_6$ samples will be collected in 550 ml borosilicate glass bottles, and measured onboard the ship using a purge-and-trap GC/ECD system. We plan to collect 300 ^{3}He and 700 SF$_6$ samples.

The sampling plan is to collect depth profiles for ^{3}He/SF$_6$ samples at two CTD stations per day (total number of in-patch stations: ca. 30). We plan to collect ca. 10 samples per CTD station: 4 in the mixed layer, (i.e., at depth intervals of ca. 25 meters), four in the seasonal pycnocline and two below the pycnocline. These vertical profiles will typically be collected close to the center of the SF$_6$ patch, as determined by the surface water SF$_6$ survey. For background measurements we request 3 stations outside the patch during the experiment.

To determine the extent of the patch we request near-continuous mapping surveys every 5 days lasing about 24 hours utilizing shipboard ADCP and near-real time surface SF$_6$ concentrations to design an adaptive surveying scheme. The ship tracks will be determined by the SF$_6$ survey group and navigation called to the bridge.

Southern Ocean Air-Sea Carbon Dioxide Exchange

Wade McGillis (LDEO of Columbia University)
Chris Zappa (LDEO of Columbia University)
James Edson (University of Connecticut)
Penny Vlahos (University of Connecticut)

Objectives:
- Work as an atmospheric and ocean physics consortium to provide all project experimentalists, modelers, and remote sensing researches with the best possible meteorological data during the experiment;
- To investigate the processes controlling of air-sea gas exchange at high winds;
- To improve our parameterizations of the gas transfer velocity through consideration of these processes. In particular, the dependence of the gas transfer velocity on wind speed, wind stress, atmospheric stability, sea state, and wave breaking will be investigated;
- Determine the spatial and temporal distribution of various persistent organic pollutants in the Southern Ocean air and surface waters;
- To investigate the structural changes in DOM from surface to deep waters and how this varies temporally;
- To enhance air-sea CO_2 studies with determination of the DIC C-13 signatures in surface waters.

Work plan:
- In collaboration with Drs. Fairall (NOAA/ESRL), Helmig (NOAA CIRES/University of Colorado), and Huebert (University of Hawaii), momentum, sensible, latent, ozone, DMS, and CO_2 direct covariance flux systems (DCFS) will be deployed on the forward jackstaff of the NOAA ship Ronald H. Brown. These measurements will be combined with a variety of infrared gas analyzers (IRGAs) to directly measure the flux of CO_2 between the atmosphere and ocean. These systems will be run continuously and we request that the ship be pointed into the wind (i.e., a relative wind within +/- 60 degrees of bow-on) whenever possible for valid flux estimates.
- Additional mean meteorological measurements will be made in collaboration with Fairall's group to quantify the wind speed and direction; air temperature, relative humidity and pressure; and downwelling infrared and solar radiation.
- A WAMOS wave measurement system will be setup on the ship to remotely estimate directional wave spectra. This uses Doppler Radar mounted from the ship.
- Two high-resolution cameras will be mounted on either side of the deck above the bridge to provide wave-breaking statistics;
- High volume air samples will be collected over 24-hours during both steam time to and from the station and at the station. While on station several diurnal samples will also be collected;
- On station, every other day, approximately 8-L of water during daily hydrocasts will be collected at 3 depths (surface, mid, bottom) for DOM structural characterization studies. This can be during either the afternoon or mid-night casts but must be consistent. We will also investigate a diurnal signal in the surface water DOM that would require an additional 8-L of surface water during sampling days 12 hours prior to or post sampling.
- Surface water (4 L) through the in-line system will be collected every 4th day to determine POPs concentrations;
- DOC/POC/DIC-C13 and nutrients will be collected at all depths during both daily hydrocasts requiring a total of 500 milliliters per depth.

Measurement and Parameterization of Air-Sea Gas Transfer over the Southern Ocean in GasEx-III

Chris Fairall (NOAA Earth System Research Laboratory)
Detlev Helmig (University of Colorado INSTAAR)

Objectives:
- Work as an atmospheric and ocean physics consortium to provide all project experimentalists, modelers, and remote sensing researches with the best possible meteorological reference data during the experiment;
- To investigate the processes controlling of air-sea gas exchange at high winds;
- To improve our parameterizations of the gas transfer velocity through consideration of these processes. In particular, the dependence of the gas transfer velocity on wind speed, wind stress, atmospheric stability, sea state, and wave breaking will be investigated;

Work plan:
- In collaboration with Drs. McGillis (LDEO), Edson (UConn), and Huebert (University of Hawaii), momentum, sensible, latent, ozone, DMS, and CO_2 direct covariance flux systems (DCFS) will be deployed on the forward jackstaff of the NOAA ship Ronald H. Brown. These measurements will be combined with a variety of infrared gas analyzers (IRGAs) to directly measure the flux of CO_2 between the atmosphere and ocean. These systems will be run continuously and we request that the ship be pointed into the wind (i.e., a relative wind within +/- 60 degrees of bow-on) whenever possible for valid flux estimates.
- Additional mean meteorological measurements will be made to quantify the wind speed and direction; air temperature, relative humidity and pressure; and downwelling infrared and solar radiation (ESRL seagoing flux/meteorology system).
- A Riegl laser wave sensor will be operated from the jackstaff to record surface waves.

Measurement and Parameterization of Air-Sea DMS Transfer over the Southern Ocean in GasEx-III

Barry Huebert (University of Hawaii)
Byron Blomquist (University of Hawaii)

Objectives:

Flux of trace sulfur gases, chiefly dimethylsulfide (DMS), from the ocean surface contributes to the formation of aerosols and cloud condensation nuclei in remote marine environments. Several theoretical and empirical approaches have been used to develop predictive models. Comparison with direct measurements is the best way to adjudicate between competing approaches and refine gas transfer theory to the degree required by global climate models. This project seeks to advance our understanding of gas exchange using direct eddy covariance flux measurements of dimethylsulfide.

This is a three-year effort to deploy measurement systems for DMS flux: Atmospheric Pressure Ionization Mass Spectrometers using an Isotopically Labeled Standard (APIMS-ILS). Close collaboration with colleagues measuring seawater concentrations of DMS is necessary for us to derive exchange velocities from our flux measurements. Other ancillary measurements of physical ocean properties and tracer flux data will provide a rich database for examining the principle factors controlling gas exchange.

Work plan:

Chris Fairall has offered additional space in the NOAA lab van for us to install the APIMS system for DMS. Power requirements for our van are as before: 20 amps 440 volt/3 phase and connection to the ships compressed air system. No water requirements. We require as much time as possible with the ship bow into the wind, but have no other specific operational requirements.

CO$_2$ and Hydrographic Measurements During the GasEx-III Experiment

Dick Feely (NOAA/PMEL)
Chris Sabine (NOAA/PMEL)
Rik Wanninkhof, (NOAA/AOML)
Greg Johnson (NOAA/PMEL)
Molly Baringer (NOAA/AOML)

Objectives:
PMEL and AOML scientist will provide core measurements including: ADCP, CTD/O$_2$-based temperature, salinity, and oxygen, water-sample based TCO$_2$, TA, O$_2$, and pCO$_2$, as well as underway measurements of salinity, temperature, and pCO$_2$. We will also compare the airside measurement of gas transfer velocities with CO$_2$ mass balances in the ocean in the tracer patch that will also contain the drifting buoys. In addition, we will use the results of the GasEx III experiment to develop algorithms to determine the air-sea flux of CO$_2$ in the southeastern Atlantic utilizing the satellite-data.

Work plan:
During the GasEx III cruise our group will make underway air and water measurements of pCO$_2$, conduct CTD/rosette casts twice daily (nominally noon and midnight), and process the shipboard ADCP data. The CTD/rosette package will include 24-Niskin-type bottles. Water samples will be collected twice daily from these sample bottles and analyzed for DIC, TA, pCO$_2$, O$_2$, and salts.

Measurement of Nutrients During the Southern Ocean Gas Exchange Experiment (GasEx III)

Jia-Zhong Zhang (NOAA/AOML)

Objectives:
We propose to measure inorganic nutrients (phosphate, nitrate, nitrite, ammonium and silicic acid) from hydrographic casts and from biological production experiments during GasEx-III.

Work plan:
Concentrations of dissolved nitrite (NO_2^-), nitrate (NO_3^-), ammonium (NH_4^+), phosphate (PO_4^{3-}) and silicic acid (H_4SiO_4) will be measured using an automated continuous flow analyzer with air-segmented flow and colorimetric detection. The five-channel autoanalyzer consists one 24-channel Ismatek peristaltic pump and five high precision ThermoSeparation monochrometers. It has been modified from original Alpkem Flow Solution Model 3000 autoanalyzer for oceanographic application. The original autosampler has been replaced with a CETAC 510 high speed autosampler to allow a 50 ml of sample volume required for simultaneous 5-channel analysis. Large sample volume also minimizes the potential sample contamination. The original plastic mixing blocks have been replaced with micro-glass coils for convenience in monitoring the flow and trouble shooting if required. Software in commercial instrument is designed for freshwater analysis in which deionized water (nutrient free) is usually used as wash solution. Custom software developed for digitally logging and processing the chromatographs in our autoanalyzer allows the correction of refractive index and background nutrients in Low Nutrient Seawater that must be used as wash solution and matrix for standards in accurate seawater analysis.

Gas tracers of productivity and bubble-mediated gas exchange during the SO GasEx Experiment

Roberta Hamme (University of Victoria)
Michael Bender (Princeton University)
Steven Emerson (University of Washington)

Objectives:
Our objectives for this project are threefold. First, we will determine Net Community Production while on site using the O_2/Ar mass balance method. Measurements will be made continuously on the ship's seawater inflow by a membrane inlet mass spectrometer (MIMS) and by an optode O_2 sensor, while discrete samples from Niskin casts will be collected for high accuracy measurements to calibrate the system. Discrete samples for Gross Production by the triple oxygen isotope method will also be collected. Second, we will use inert gas tracers to constrain bubble dynamics through continuous and discrete measurements of the N_2/Ar ratio, which is an effective measure of bubble injection. Third, discrete samples will be collected to measure dissolved Ne, N_2, Ar, Kr and Xe concentrations and Ar isotopes by high accuracy mass spectrometric methods. This suite of gases has a large range of solubilities and temperature dependencies. The combination of all of these gases will enable us to separate the influences of multiple processes on the gases, including temperature change, bubble-mediated gas exchange by different mechanisms, and atmospheric pressure variation.

Work plan:
The MIMS and optode system require a continuous flow from the ship's seawater intake system at a rate of 3-5 L/min. We will need to collect discrete samples from regularly scheduled Niskin casts. MIMS calibration samples would be collected from the surface bottle on a maximum of four casts per day. Profiles of discrete samples would be collected at less regular intervals timed with events of interest. Sampling for these gases can take 5-10 minutes per Niskin, and is normally done just after oxygen samples are taken. It is important that the water in the Niskin not be exposed to a headspace for long intervals before our sampling, so we ask that others sampling a cast not get too far ahead of our sampling. Because of the time constraints, we would sample no more than eight Niskins on single cast. Water requirements are small, less than 250mL for a single sample, less than 1L if we collected samples for all the gases.

Autonomous Multi-parameter Measurements from a Drifting Buoy During the SO GasEx Experiment

Chris L. Sabine (NOAA/PMEL)
Mike DeGrandpre (University of Montana)
Wade McGillis (LDEO of Columbia University)

Objectives:
Our specific objectives for the 3-years of this project are to 1) modify a recently developed low profile, high payload buoy to act as a drogued drifter for the SO GasEx Experiment; 2) instrument the drifter with a variety of autonomous instruments capable of making a coordinated set of physical, geochemical, and biological measurements at high temporal resolutions to provide a key component in the study of processes controlling air-sea CO_2 exchange; 3) Integrate the multi-parameter measurements into a mass balance study of the surface ocean carbon system (in conjunction with shipboard water column studies) to provide an independent assessment of air-sea gas exchange; 4) evaluate the physical and biogeochemical mechanisms leading to short-term variability in air-sea gas exchange; and 5) evaluate potential biases in CO_2 flux estimates from high resolution data sets (e.g. CO_2 moorings) arising from the use of traditional gas exchange parameterizations. The basic hypothesis driving this study is that short-term variability in carbon system and physical parameters has a significant impact on gas exchange and the estimation of carbon mass balances on time scales of days to weeks.

Work plan:
We wish to deploy a drogued buoy in the center of the dye patch as soon as practical after the patch has been made. It should take about 2 hours to deploy the drifter. There is a possibility that during the course of the experiment that the drifter will move out of the patch. If this happens then we will want to recover the drifter and redeploy back in the center of the patch. There is a GPS system on the buoy and we will have satellite communication with the buoy so we can locate it at any time during the experiment. Recovery could take 3 hours from the time that the ship reaches the buoy. We anticipate doing this no more than once per week (hopefully less) during the experiment. We will need to recover the drifter at the end of the experiment.

Closing the carbon budget in the mixed layer during Southern Ocean GasEx

Burke Hales (Oregon State University)
Pete Strutton (Oregon State University)
Dave Hebert (University of Rhode Island)
David Ullman (University of Rhode Island)

Objectives:
Our goals are to provide the spatially and temporally comprehensive, high-resolution measurements of concentrations, biological rates, and physical transports that will allow rigorous closure of the carbon budget within the patch. Our efforts will consist of the following major themes:

1. Operation of the Lamont pumping SeaSoar (LPS) towed undulating sampling/sensing vehicle, including full-suite CTD measurements and high-volume sampling pump. In situ measurements will include dual T/S sensor pairs, O_2, beam-c, chlorophyll fluorescence, CDOM fluorescence, and PAR.
2. Operation of the TOMASI microstructure instrument aboard the LPS, which will measure microstructure temperature and conductivity and provide estimates of vertical turbulent mixing rates.
3. Incubation of C and N isotope-labeled samples from LPS and CTD rosette for constraint of primary and new productivity in the patch.
4. High-speed continuous shipboard measurement of nitrate, pCO_2, and TCO_2 in the sample stream provided by the LPS.
5. Analysis and display of shipboard ADCP data for quantification of lateral transport, and progressive-vector estimation of patch and drifter trajectories.
6. Processing and dissemination of the LPS/TOMASI data.
7. In addition, we will be providing sample splits to D. Ho for tracer analysis and 3-D quantification of the patch volume.

Work plan:
Our proposed work plan is to deploy the LPS/TOMASI every 2 to 5 days, for durations ranging from 6-24 hours, as described below and as allowed by the ship's schedule. It is absolutely essential to our project goals that we be able to sample the patch exhaustively (e.g. 4-5 lines spanning the patch) on each deployment.

Early in the evolution of the patch when it is small and sharply defined, these surveys will be short duration (6 hours) at low speed (~2 kts) and should be relatively frequent (every 2 to 3 days). During this period the concentration of tracer (SF_6) will be changing rapidly and it is important that we characterize that change at relatively high temporal resolution. Later in the experiment when the patch has spread and tracer concentration is changing more slowly, the deployments will need to be longer (24 hours) at higher speeds (6 kts), but may not need to happen as frequently (e.g. once every 5 days).

Deployment/recovery during the low-speed surveys will be rapid, under 30 minutes for each. Deployment/recovery for the higher-speed deployments will be slower, 30 minutes to an hour, as full cable lengths are paid out and optimal ship speeds are attained.

We will provide our own water samples from the LPS, but will need a way to accommodate excess water (2 GPM) continuously during in-water operations. During cruises on the Thomas G Thompson, a utility sink was set up in the main lab that drained into a gray-water tank that could be pumped out. During a 2003 cruise on the Revelle, a sink in the main lab was plumbed to drain directly overboard.

Quantifying the surface physical controls on CO_2 transfer during the Southern Ocean Gas Exchange Experiment

Will Drennan (RSMAS, University of Miami)

Objectives:

The proposed work will:

- Provide the ASIS and EASI buoys to explore the role of physics in the lower atmosphere and surface ocean on ocean-atmospheric CO_2 fluxes during the Southern Ocean Gas Exchange experiment.
- Perform continuous measurements of the (1) air-sea fluxes of momentum, heat, water vapor, and CO_2, (2) mean atmospheric properties and boundary layer stability, (3) surface wave characteristics (2D spectra and slopes), as well as sea spray aerosol and bubbles, and (4) TKE dissipation rate, currents and temperature, in the near surface of the ocean. Non-continuous measurements of whitecap coverage will also be made from the ship.
- Develop a parameterization for the gas exchange velocity in terms of physical forcing parameters (including wind speed, TKE dissipation, stability, surface waves).

Work plan:

Deploy EASI and ASIS buoy from the Brown in the vicinity of the study site. The two buoys will moored to the bottom, and tethered together. Wave and subsurface measurements will be conducted from ASIS; meteorological and flux measurements from EASI. The platforms would stay on site for about 1 month, and then be recovered. Deployment and recovery will each take about 1 day (daytime hours). In addition, we will supply a camera system on the Brown to measure whitecap coverage.

On the distribution of colored dissolved organic matter in the Southern Ocean and the potential for photoproduction of CO_2 and CO

Carlos Del Castillo (Johns Hopkins University)
Richard Miller (NASA Stennis Space Center)
Watson Gregg (NASA Goddard Space Flight Center)
Tom Haine (Johns Hopkins University)
Francis Monaldo (Johns Hopkins University)
Donald Thompson (Johns Hopkins University)

Objectives
We propose to use several remote sensing techniques, field and laboratory measurements, and DA modeling to answer the following questions:
1. What is the annual variability in abundance and distribution of CDOM in the SO?
2. What physical processes control the abundance and distribution of CDOM?
3. How much CO_2 and CO is produced from the photolysis of CDOM?

Work plan
Question 1 will be answered using historical ocean color data from SeaWiFS, MODIS-AQUA, and MERIS. We will use field and laboratory measurements, and radiative transfer modeling to develop a regional CDOM algorithm for the SO. The algorithm will be use to reprocess imagery from the aforementioned sensors from launch trough 2008, and the data will be merged to reduce the effect of prevalent cloud cover in the region.
Fieldwork involves collection of water samples for CDOM analysis, optical casts, and underway measurements of CDOM.

Question 2 will be answered through a combination of ocean circulation modeling and remote sensing. The ocean circulation model and data assimilation system will be developed for the GasEx cruise region from existing, similar, setups in the subpolar North Atlantic ocean. A package to simulate upper ocean CDOM will be included. From this perspective CDOM, is, essentially, a passive tracer with (complex) sources and sinks. The sources and sinks will be treated as weakly constrained parameters to be determined in the DA The model will use inputs from field measurements, and from remote sensing estimates of wind vectors, SSH, and SST, and photolysis loss term for CDOM. The model will be run retrospectively, and resulting CDOM field maps will be compared with remote in-situ and remote sensing measurements of CDOM.

Question 3 will be answered in two modalities. In the first approach, we will estimate the photoproduction of CO_2 and CO along the cruise track using underway measurements of CDOM, solar irradiance, radiative transfer modeling, and published values of photoproduction quantum efficiencies (Φ) for the gases. In the second approach we will use remote sensing estimates of CDOM (question 1), solar irradiance, radiative transfer modeling and published values of Φ to produce historical maps of CO_2 and CO photoproduction.

Phytoplankton absorption and carbon dioxide drawdown in the Southern Ocean: A consortium of observations

John Marra (LDEO of Columbia University)
Bob Vaillancourt (LDEO of Columbia University)
Ajit Subramaniam (LDEO of Columbia University)

Team Objectives:
- To improve the estimation/modeling of primary production in the Southern Ocean
- To test the hypothesis that primary production can be best estimated/modeled from spectral absorption of phytoplankton rather than using chlorophyll a concentration.
- To quantify and minimize uncertainties in estimates of phytoplankton absorption in order to parameterize photosynthesis models from in situ and satellite data.

LDEO Cruise Objectives:
- To measure phytoplankton spectral absorption concentrated on 25 mm GF/F filters (measured before and after extracting/bleaching pigments) over the spectral range 350-750 nm using the traditional filter pad transmission (FPT) method.
- To calculate phytoplankton spectral absorption of captured water samples based on pigment reconstruction of HPLC pigment concentrations.
- To compare phytoplankton absorption by the above 2 methods to same measured by Hargreaves and Lee.
- To measure daily-integrated CO_2 uptake by phytoplankton using ^{14}C-bicarbonate tracer.
- To measure photosynthesis-irradiance response of phytoplankton using ^{14}C-bicarbonate tracer by method of P vs. E experiments in photosynthetron. Water column daily PP can be derived from the PvsE parameters and compared to daily PP measured above.
- To measure CDOM absorption by method of capillary wave guide spectrophotometry.

Work plan and sampling requirements:
- We will collocate our optical sampling and measurements with similar measurements made by Hargreaves and Lee to enable direct comparison of method efficacies.
- Water for daily CO_2 uptake incubations will be captured from CTD bottle casts in early morning hours from several depths from surface to bottom of euphotic zone. Water for P vs. E experiments will be captured about an hour prior to local noon from similar depths. The sample timing is essential as there is a natural variation in PE parameters over the diurnal cycle, and these variations must be minimized by timing experiments near local noon on each day they are performed.
- FRR fluorometry will be measured by FRRF profiling. Ideal location for FRRF is to mount it on the same CTD/rosette that is capturing the samples for productivity measurements. This would require removal of 2 bottles from the cast, and limits the cast to max depth of 500 m. The FRRF instrument needs no power or data cable. Upcasts must be done at very slow speed to optimize sampling rate of FRRF. Alternatively the FRRF can be deployed separately but immediately following CTD/rosette casts using a different winch.

Optical properties in the Southern Ocean: In situ and satellite observations in support of Southern Ocean Carbon Program

ZhongPing Lee (Naval Research Lab)
Alan Weidemann (Naval Research Lab)
Paul Martinolich (Naval Research Lab)
Wesley Goode (Naval Research Lab)

Objectives:
- The overall objective is to improve the estimation/modeling of primary production in the southern ocean
- To quantify uncertainties of phytoplankton absorption derived from observation of ocean color (both in situ and from satellite sensor)
- To refine/improve remote-sensing algorithms for optical properties of the southern ocean

Work plan:
- Spectral remote-sensing reflectance will be measured over the ship with handheld spectralradiometer
- Water's volume scattering function will be measured from pumped water samples and from profiles
- Aerosol optical density will be measured with a sunphotometer (Microtops II)
- Water's optical properties and phytoplankton absorption coefficients will be derived from measured remote-sensing reflectance, and these properties will be compared with data from water sample measurements (taken by collaborators)
- Satellite (MODIS-Aqua and/or SeaWiFS, MERIS) data will be processed and be compared with in situ measurements

Optical Properties in the Southern Ocean: In situ measurements of phytoplankton absorption using the pFPT-TR instrument in support of the Southern Ocean Carbon Program

Bruce Hargreaves (Lehigh University)

Team Objectives:
- To improve the estimation/modeling of primary production in the Southern Ocean
- To test the hypothesis that primary production can be best estimated/modeled from spectral absorption of phytoplankton rather than using chlorophyll a concentration.
- To quantify and minimize uncertainties in estimates of phytoplankton absorption in order to parameterize photosynthesis models from in situ and satellite data.

Hargreaves' Cruise Objectives:
- To measure phytoplankton spectral absorption concentrated on 25 mm GF/F filters from 1-2 L discrete water samples (measured before and after extracting/bleaching pigments) over the spectral range 250-850 nm using an improved filterpad method (pFPT-TR instrument). The primary method of removing pigments will be 1-minute exposure to bleach (hypochlorite), but some comparisons may be made to the alcohol extraction method when sufficient resources (sample volumes and time) are available.
- To support water column and surface water characterization of bio-optical properties at sampling stations with a multisensor fluorescence profiler (Turner Designs C6 with sensors for Chl-a, CDOM, phycoerythrin, temperature, pressure/depth).
- To characterize fluorescence relative to CDOM UV absorption and DOC concentration, and chlorophyll a fluorescence and red peak absorption with extracted chlorophyll a concentration for different phytoplankton communities encountered over the ship's course.

Work plan:
- Will apply the above measurements of phytoplankton spectral absorption to all discrete water samples used by the NASA team for the partial or complete suite of measurements and primary production incubations using water collected from CTD rosette casts and from water pumped to the laboratory from the ship's seawater intake port while underway. Sample schedule/depth to be determined by others.
- Will support water column characterization at sampling stations by adding the C6 profiler to Vaillancourt's FRR instrument. In profiling mode this instrument logs data internally at 1-second intervals and is self-contained with battery pack. It is rated to 600 m depth.
- Will support surface water characterization while underway by using the C6 instrument in the laboratory in flow-through mode (equipped with flowcap and sensor wipers and downstream from debubbler provided by others) to monitor phytoplankton and CDOM along the ship's course. In flowthrough mode it can either log data or send it through a serial (RS-232) cable at programmable time intervals.

Differentiating sources of backscattering in the Southern Ocean: Calcite, bubbles, and other optical constituents

Heidi Dierssen (University of Connecticut)
Barney Balch (Bigelow Laboratory for Ocean Sciences)
Michael Twardowski (WET Labs, Inc.)
Penny Vlahos (University of Connecticut)

Objectives:

Satellite-derived remote sensing reflectance from the southern ocean is higher than most of the world's oceans. We propose to evaluate the following hypotheses for the high reflectance:

- Southern Ocean waters contain high levels of backscattering materials such as Particulate Inorganic Carbon (PIC) from coccolithophores
- High reflectance is primarily due to the excessive amounts of bubbles produced by consistently high winds in this region.
- High reflectance is due to enhanced bbp from other organic particles (e.g., specialized groups of phytoplankton, organic detritus that may include POC created by bubble dissolution associated with breaking waves)
- The standard atmospheric correction algorithms, including the whitecap/foam corrections, are not accurate in this region and result in overestimates of Rrs.

Work plan:

- Conduct an extensive field effort to measure a suite of bio-optical parameters and provide real-time imagery support to the field campaign
- Develop a backscattering budget that partitions the contributions due to:
  - a. Bubbles
  - b. Calcite, including coccolithophores and detached coccoliths
  - c. Other phytoplankton and organic detritus
  - d. Other mineral particles (polydisperse)
- Determine whether optical closure is achieved between measured R_{rs} (both in the field and from satellite) and that derived theoretically using our measured backscattering, VSF, and absorption properties
- Refine algorithms that use ocean color satellite imagery to estimate significant carbon pool components, including phytoplankton chlorophyll, calcite, and POC. Depending on results from satisfying previous objectives, this may involve developing a wind-based algorithm to estimate and correct for the bubble contribution to R_{rs} and/or using results from the existing calcite algorithm or refinements thereof to account for the calcite interference in other biogeochemical algorithms