Airborne Remote Sensing in High Latitude Systems

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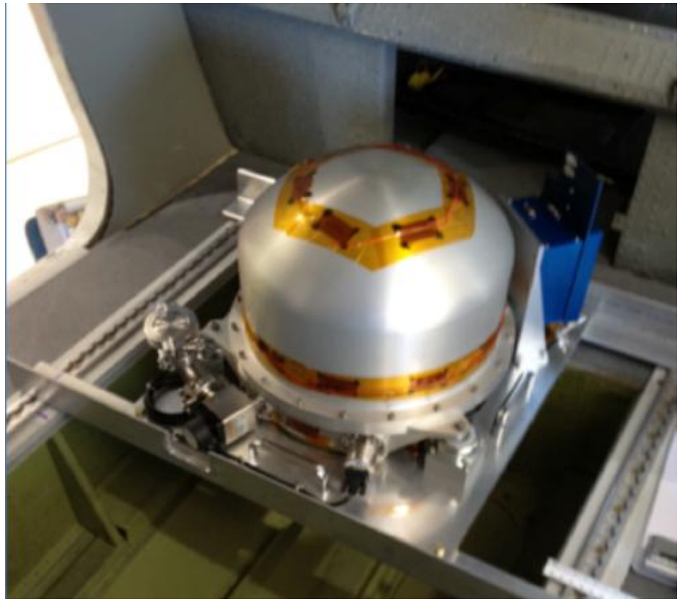
Reasons for Airborne Overflights

- Test bed for Hyperspectral Algorithms
  - Phytoplankton functional types
  - Algorithms into the Near Infrared (glacial flour, whitecaps, etc..)
- High Spatial Resolution Processes
  - Submesoscale and smaller
  - Internal Waves, Fronts, River/Meltwater Plumes
- Fly with other airborne sensors for process studies
  - O_2/N_2 and CO_2 Flux studies
  - Depth penetrating LIDAR

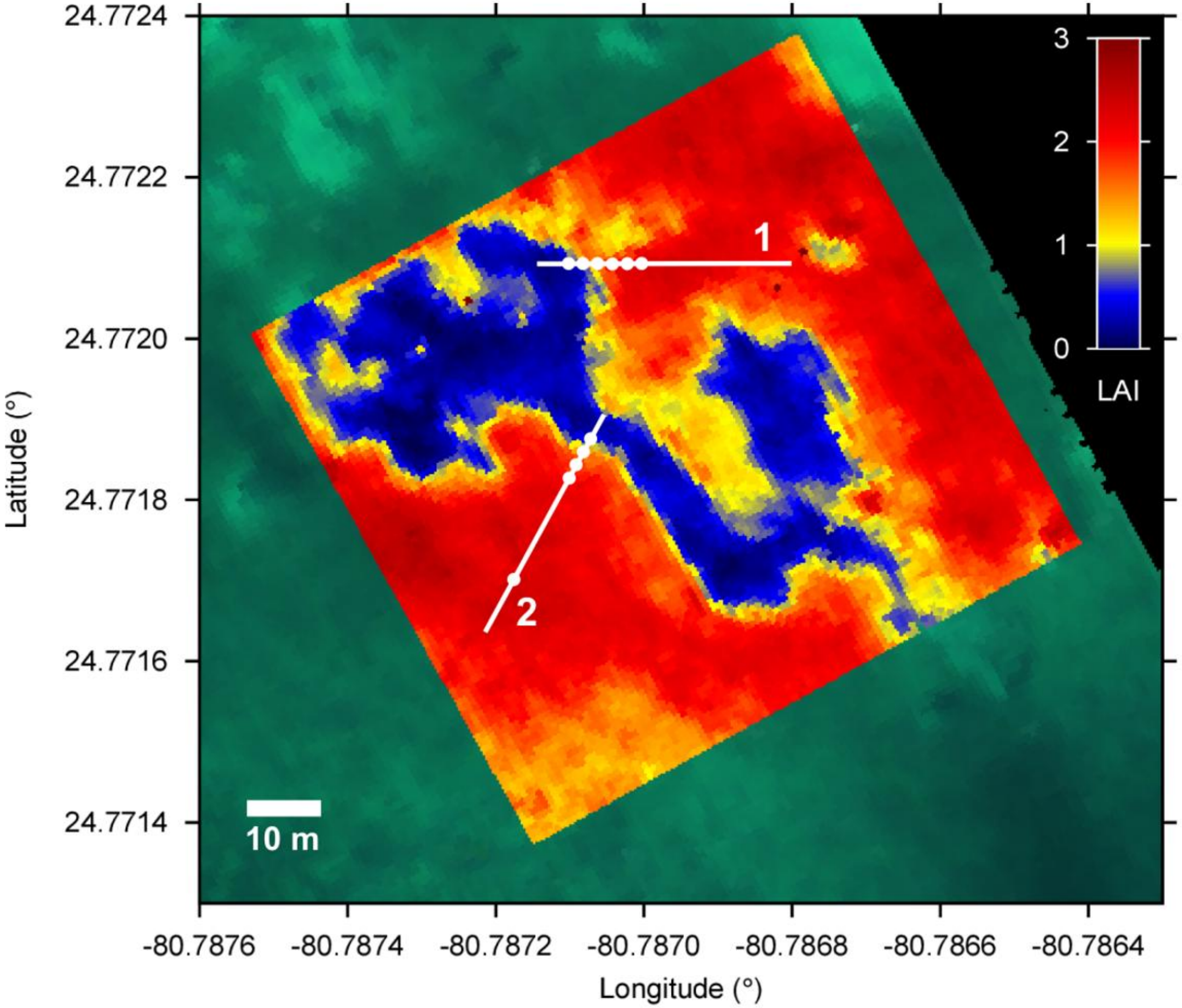
PRISM Sensor

- UV-NIR sensor
  - 350-1050 nm
- Approx. 3 nm spectral resolution
- Depending on platform (30 cm – 10 m) spatial resolution
- Two-channel SWIR radiometer
- Following from Mouroulis et al 2008/2014



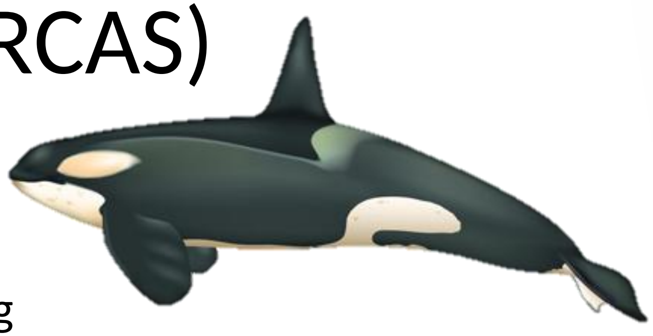
PRISM -- Seagrass Leaf Area Index at 1 m

J. Hedley



(a)

The O_2/N_2 Ratio and CO_2 Airborne Southern Ocean Study (ORCAS)



Principal Investigators:

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Collaborative Science Team:

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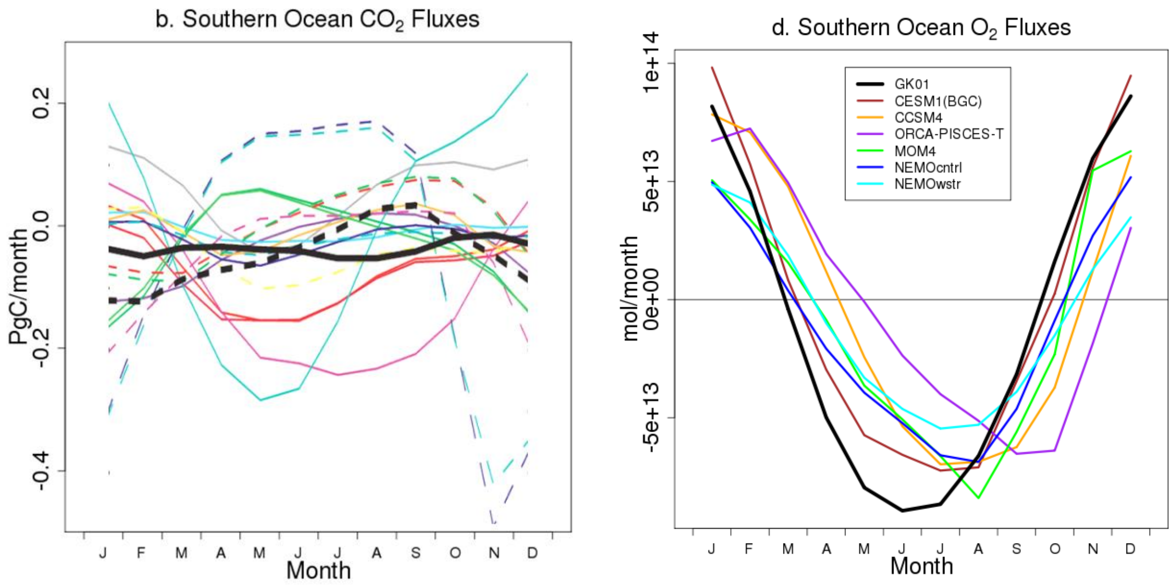
ORCAS Motivation:

- The Southern Ocean is a large sink for anthropogenic CO_2 with particular sensitivity to climate change.
- State-of-the-art Earth System Models diverge for seasonal Southern Ocean air-sea CO_2 and O_2 fluxes, and for Southern Ocean climate-carbon feedbacks.
- Atmospheric O_2 (reported as deviations in the O_2/N_2 ratio) provides unique constraints on the biological, thermal, and anthropogenic drivers of Southern Ocean CO_2 exchange.

Figure 1. Model and data-based Southern Ocean (> 44 S) seasonal CO_2 and O_2 sea-to-air fluxes (for CO_2 black dash = Takahashi et al. 2009, black solid = atmospheric inversion, colors = CMIP5 models from Anav et al. 2013; for O_2 black solid = Garcia and Keeling, 2001, colors = models).



Overarching Science Questions:

What are the magnitudes and interrelationships of summertime air-sea O_2 and CO_2 fluxes over the Southern Ocean at regional to zonal scales, and what are the dominant processes driving their seasonal evolution and spatial variability?

ORCAS Project Overview:

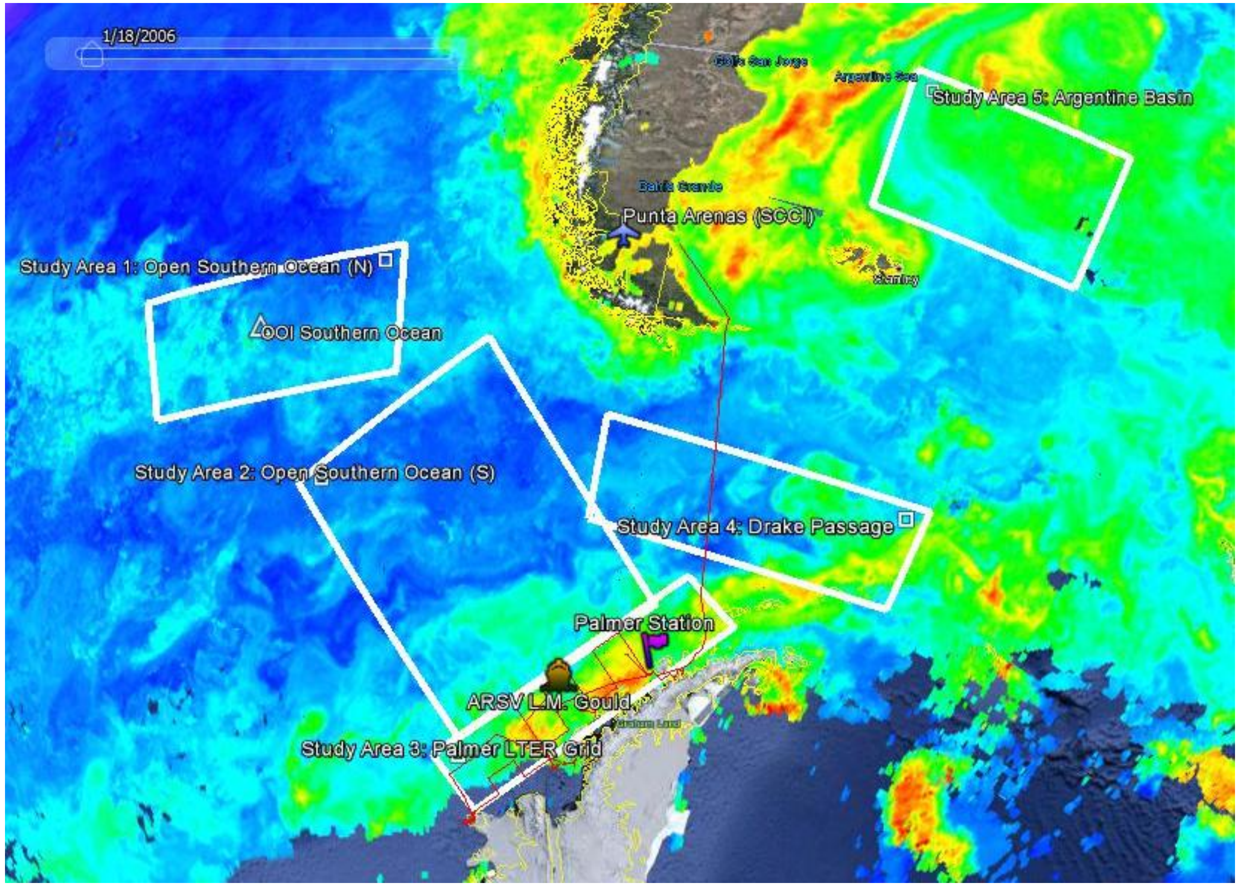
- **Dates:** six weeks from early January to mid February, 2016, to coincide with high productivity and peak atmospheric O_2 conditions and to overlap with the 2016 Palmer LTER cruise
- **Location:** Punta Arenas, Chile
- **Facilities requested:** GV with QCLS, TOGA, and AWAS HAIS instruments
- **Other participating instruments:** NCAR AO2, NCAR/Scripps Medusa, NOAA/CU Picarro, NASA PRISM
- **Synergistic observations:** Palmer LTER cruise and $\Delta O_2/Ar$ sampling aboard the NSF ARSV L.M. Gould, NSF OOI Southern Ocean node, SOCCOM biogeochemical profiling floats
- **Operations:** 14 × 7-hour flights for a total of 98 research flight hours, plus 10 hours of test flights and ferry time, allowing 3-4 large-scale survey flights, 2-3 flights per study area, 1 dedicated Antarctic Peninsula remote sensing flight, and 1 dedicated student flight

GV Scientific Payload:

Instrument	Measurement	Institution
Airborne Oxygen Instrument (AO2)	$\delta(O_2/N_2)$, CO_2	NCAR EOL
Quantum Cascade Laser Spectrometer (QCLS)	CO_2, CH_4, N_2O, CO	Harvard/Aerodyne/NCAR
Picarro	CO_2, CH_4, H_2O	NOAA/CU
Medusa Flask Sampler	$\delta(O_2/N_2)$, CO_2, $\delta(Ar/N_2)$, $\delta^{13}C$, $d^{18}O$, and $\Delta^{14}C$ of CO_2	NCAR/Scripps
Portable Remote Imaging Spectrometer (PRISM)	Hyperspectral water-leaving radiance	JPL
Advanced Whole Air Sampler (AWAS)	Over 80 trace gases, including DMS, OCS, halocarbons, $MeONO_2$, isoprene	NCAR/U. Miami
HIAPER Trace Organic Gas Analyzer (TOGA)	Over 60 VOCs, including nitrate species, DMS, and VSL halocarbons	NCAR

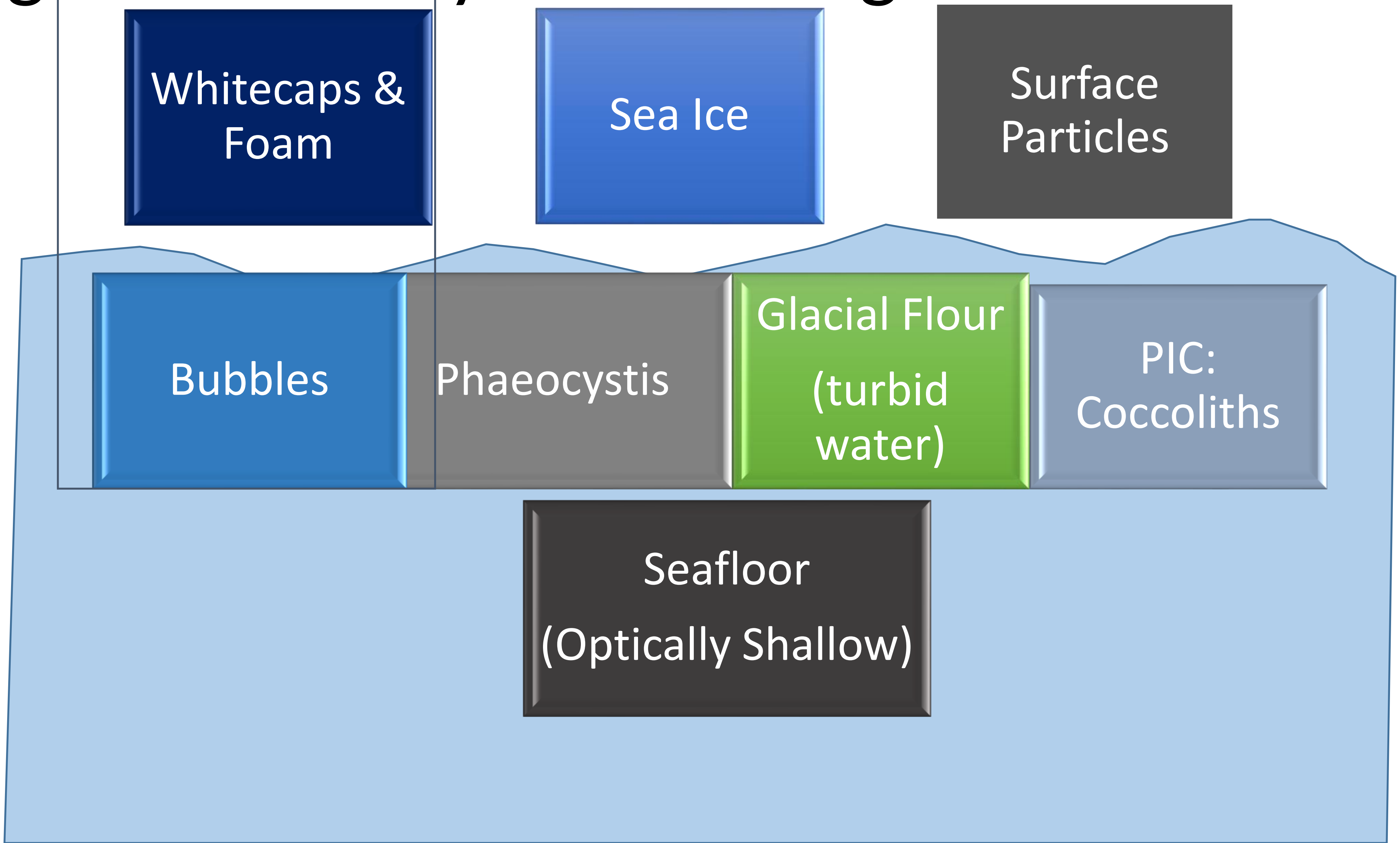
ORCAS Study Areas:

Figure 3. Map showing the four ORCAS study areas (white boxes) overlain on a MODIS chlorophyll map from January 2006. The ARSV Gould ship track from the 2013 Palmer LTER cruise is shown as a thin red line. The locations of the OOI Southern Ocean is shown as a white triangle.



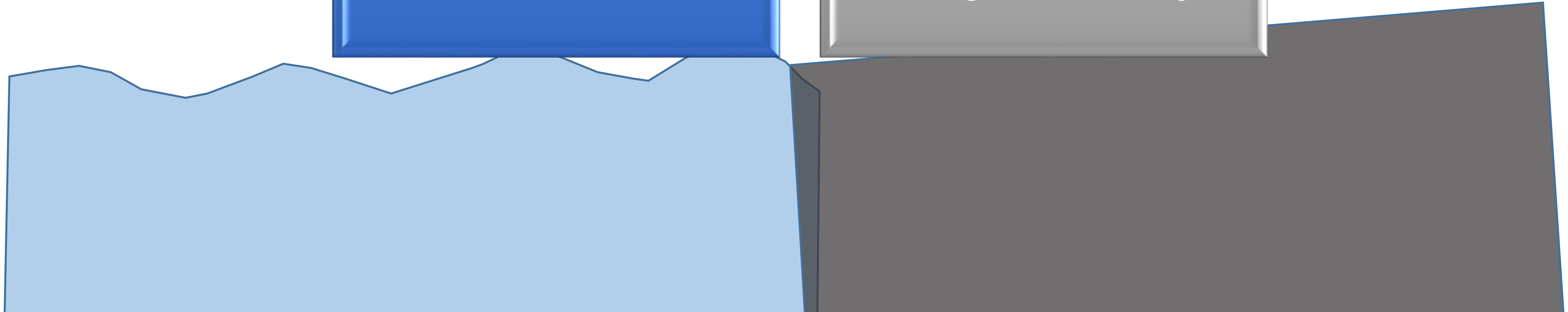
Study Area	Unique Features
Open Southern Ocean (north)	Representative of much of the low-iron, relatively warm, subantarctic Southern Ocean. Contains OOI Southern Ocean Node.
Open Southern Ocean (south)	Relatively cold polar frontal and Antarctic zone. Adjacent to LTER grid allowing additional constraints from Gould atmospheric O_2 and CO_2 measurements.
Palmer LTER Grid	Coastal region of high productivity. Coincident with long-term ecological study locations and planned location of the Gould during the ORCAS campaign.
Drake Passage	Compressed frontal region with enhanced eddy activity. Overlaps decadal time-series from underway Gould crossings.
Argentine Basin	Region of high iron input and high productivity.

High Latitude Systems: “Bright Water”

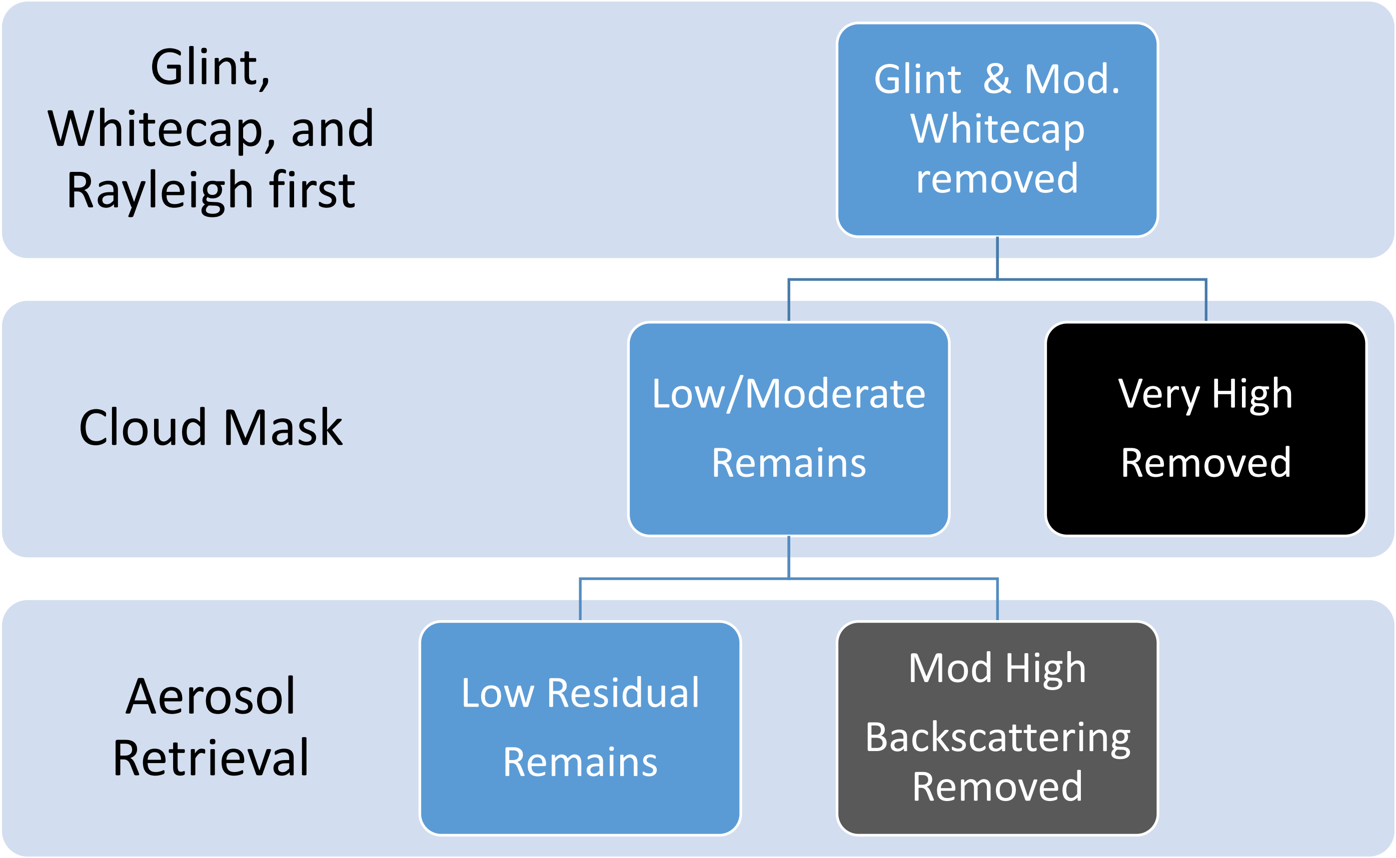


What can appear like “Bright Water”, but isn’t in water at all

- Thin Clouds
- Atmospheric dust
- Sun Glint
- Land/Ocean Adjacency



Current NASA AC processing removes highly reflective waters

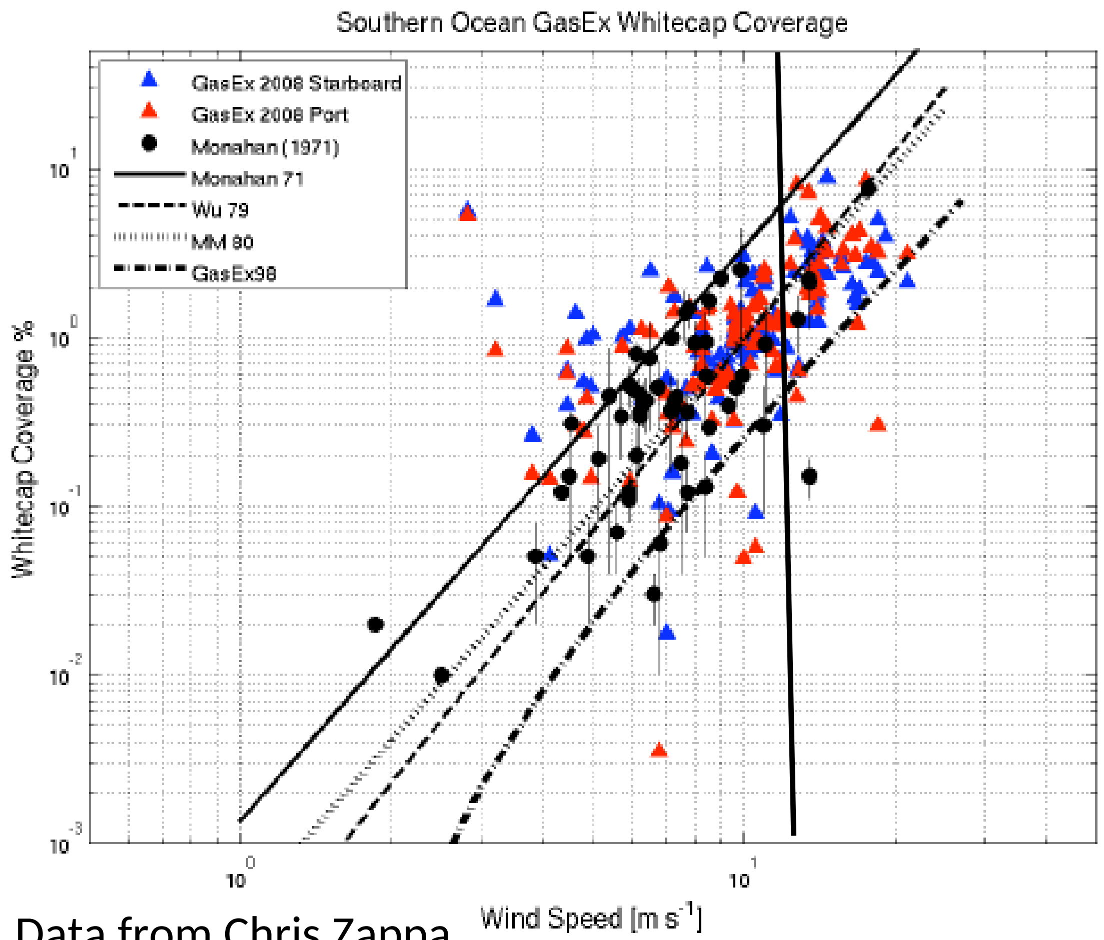


Errors are not simple "quantitative" numbers.
Error of Omission excluding from one category
Error of Commission adding this stream to another category

Windspeed is not an accurate predictor of Whitecap coverage

Photo by Scott Freeman

Field Experiments:
UCONN
Rrs (350-2500 nm) above water
In-water reflectance
LISST
Critical angle backscattering



Data from Chris Zappa

AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Oceans

RESEARCH ARTICLE

10.1002/2013JC009227

Key Points:

- Bubble size distributions (0.5–60 μm radius) were measured during wave breaking
- Bubbles ≤30 μm in radius supplied ~30% of the void fraction at 4 m depth
- Bubble populations were presented

Optical measurements of small deeply penetrating bubble populations generated by breaking waves in the Southern Ocean

Kaylan Randolph[1], Heidi M. Dierssen[1], Michael Twardowski[2], Alejandro Cifuentes-Lorenzen[1], and Christopher J. Zappa[3]

[1]Department of Marine Sciences, University of Connecticut, Groton, Connecticut, USA, [2]WET Labs Inc., Narragansett, Rhode Island, USA, [3]Lamont-Doherty Earth Observatory of Columbia University, Palisades, New York, USA

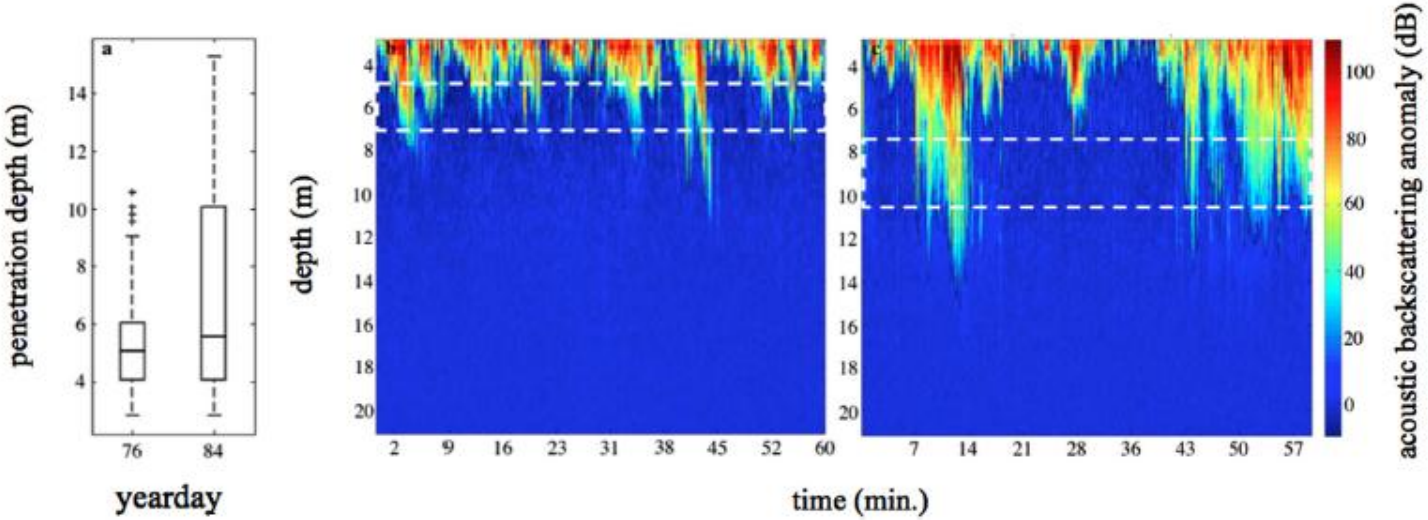
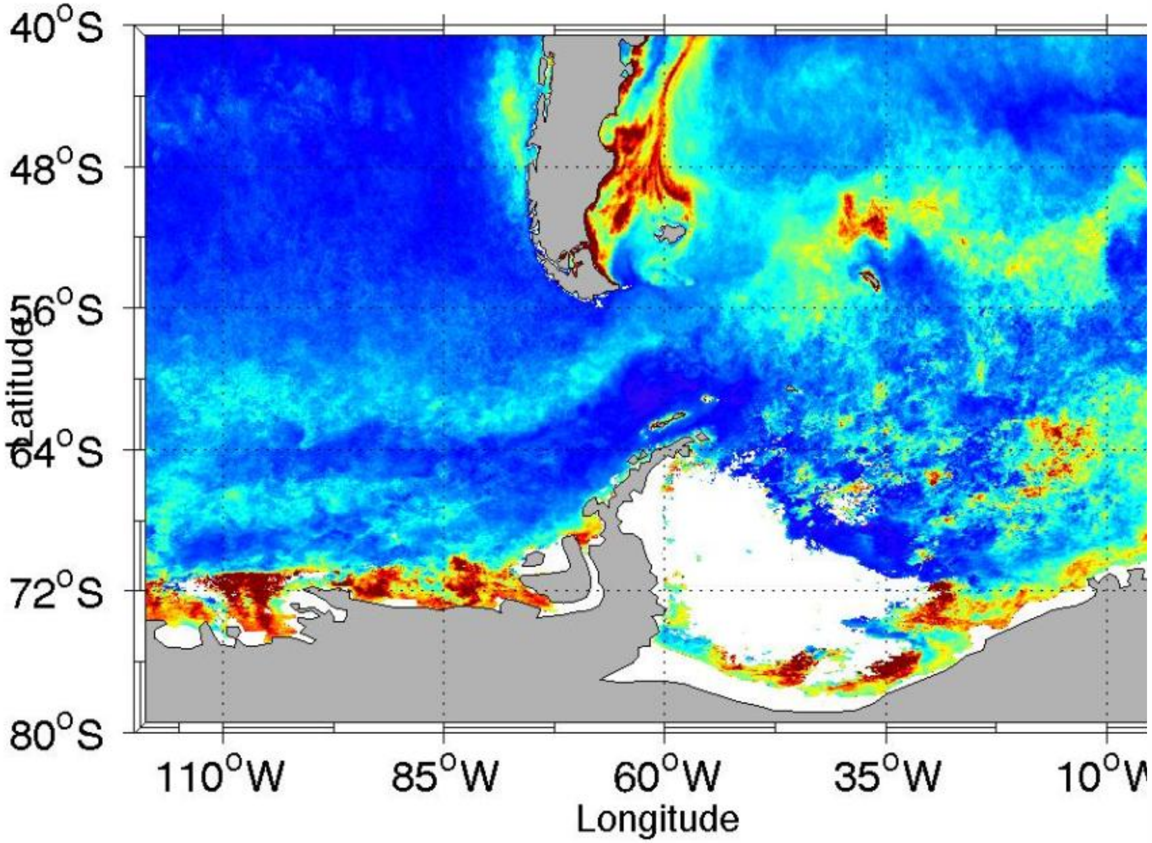


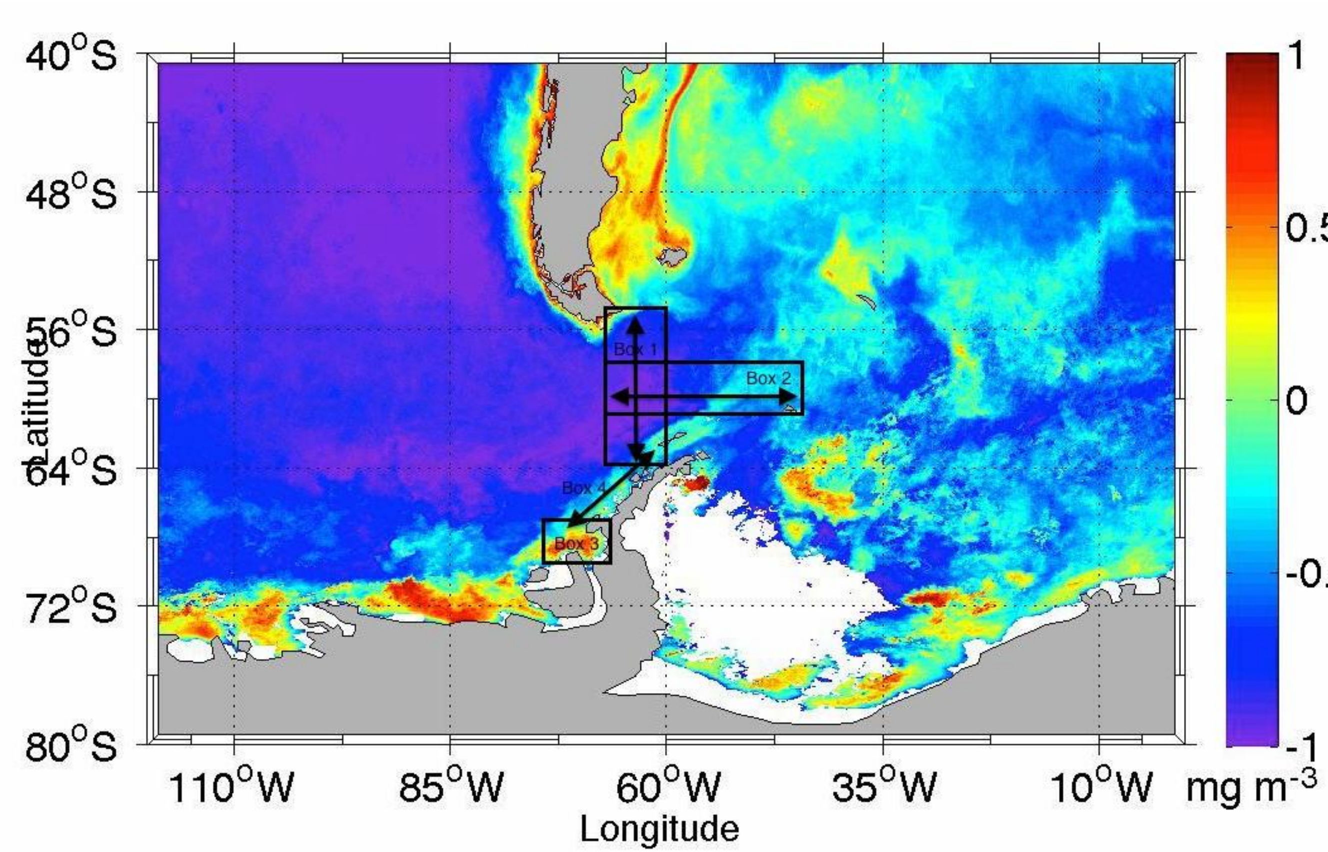
Figure 11. (a) Bubble plume penetration depths estimated using time series measurements of acoustic backscatter anomaly (dB) collected on yeardays, (b) 76, and (c) 84. In Figure 11a, the box denotes the lower quartile, median, and upper quartile penetration depth values. The whiskers show the range of the data and the pluses denote outliers. High temporal resolution plots of the acoustic backscatter anomaly over the 1 h sampling period show intense breaking on (a) yeardays 76 and (b) 84 days produced bubble plumes that extended to 10 and 15 m, respectively. No acoustic data were collected on yearday 80.

PIC, Phaeocystis or Glacial Flour "Bright Water" Pixels

- PIC Product



Chlorophyll



Science Questions

- Carbon dynamics – Models diverge in Southern Ocean
  - Phytoplankton Dynamics
    - (diatoms, cryptophytes, coccolithophores, phaeocystis)
  - How does phytoplankton assemblage relate to O_2 and CO_2 flux in high latitude
  - Response to a Changing Ocean

- Glacial Meltwater dynamics
  - Highly Scattering water
  - Shift phytoplankton dynamics
  - Change stratification

Oceans and Climate

- CDOM, Phytoplankton and Heating
- Albedo for heating rates including whitecaps and bubbles

HIS

Arctic