Autonomous Vessels for International Polar Year Studies in the Ross Sea, Antarctica

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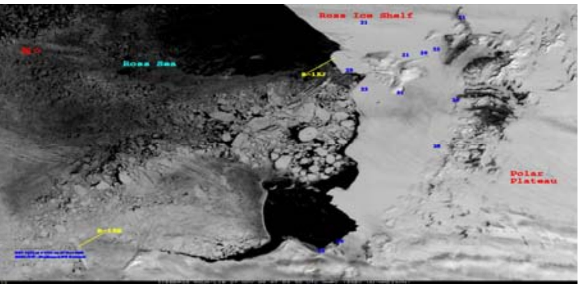
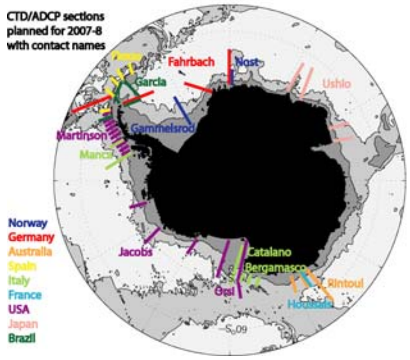


AQUA-LIB IR&VIZ satellite image from Nov. 27, 2005 showing ice production in Terra Nova Bay polynya, and its' export into the Ross Sea.



US Coast Guard Icebreaker POLAR SEA with 'giant' iceberg B15A in 2003. CG icebreakers can deploy autonomous vehicles at the start of annual McMurdo Station resupply operations, act as communications nodes during this period, and retrieve vehicles at the end of season for reuse/redeployment.

OBJECTIVE 1: AIR-SEA INTERACTION – HEAT & SALT FLUX

The International Polar Year physical oceanography program SASSI, Synoptic Antarctic Shelf-Slope Interactions Study, revolves around monitoring production of Antarctic bottom water via heat and salt fluxes over the continental shelf involved with ice production and export. Ice production occurs principally at the Mertz, Terra Nova, and McMurdo Polynyas. The Terra Nova Bay polynya has the simplest conformation, and a tractable size (order 50km), which make it the easiest to monitor. Measurements by SASSI ship transects and moorings will provide point data in the water column. These data would be amplified if the spatial extent of data could also be monitored by autonomous vehicles with hydrographic sensors.

OBJECTIVE 2: SEA ICE PRODUCTION AND THICKNESS

Measurements of sea ice production (and melt) are closely related to heat and salt fluxes. Upward looking AUV sensors can provide sea ice thickness in conjunction with satellite data to improve estimates of sea ice production and melting during seasonal dynamics.

The Scripps Marine Physics Lab maintains several modular autonomous underwater vehicles, including this modified Bluefin model.

Abstract Use of several types of autonomous vehicles are discussed as part of a proposed collaborative International Polar Year (IPY) program to monitor dynamics in the Western Ross Sea, Antarctica, from 2007-2009. IPY studies in the Ross Sea will focus on monitoring brine production at the Terra Nova Bay, Ross Sea, and McMurdo polynyas resulting from ice production and export from these areas. A second objective is to monitor off-shelf transport of brine and associated carbon and nutrients to assess its' contribution to the production of Antarctic Bottom Water. Understanding the contribution of lower salinity waters formed by melting of the Ross Ice Shelf is also critical. IPY plans for monitoring Ross Sea ocean dynamics from ship transects and current meter moorings can use autonomous vessels to abet time-space monitoring of the frequently event-based dynamics at the Ross Sea polynyas. Capabilities for AUVs to collect water samples for gas and radioisotope tracers are also possible in terms of available and developing technology. Finally, multibeam bottom mapping data have been reported from an AUV planned for deployment as part of the IPY effort. Use of this bottom mapping capability is intended to contribute to the recently initiated International Bathymetric Charting of the Southern Ocean program (IBCSO), which will be ongoing during the IPY period.

METHODS: AUTONOMOUS VEHICLE MEASUREMENTS

Autonomous Underwater Vehicles (AUVs). AUVs such as the Scripps Bluefin can measure hydrography and multi-beam bathymetry on transects of 10s of km for periods of a day or more before battery servicing. The less expensive FETCH can map hydrography over a polynya scale (@50km) before battery servicing.
Gliders, eg SeaGlider. For a similar price, Gliders, while limited in mapping rapid events, can provide surveys of extensive areas over periods of months.
Autonomous Surface Vehicles (ASVs). Several efforts are underway to develop ASVs, e.g. to track plankton blooms:
http://aaaprod.gsfc.nasa.gov/ASF/application-oasis.htm
Catamaran ASVs are also in use, and inexpensive 'Robo-kayaks' with real-time positioning can use a winched CTD for repeated hydrographic transects for periods of months.

The FETCH Autonomous Underwater Vehicle has been used extensively in the Southern Ocean for biological studies around Palmer Peninsula.

OBJECTIVE 3: BIOGEOCHEMICAL FLUXES

A third part of the IPY SASSI effort is use of sediment trap moorings to estimate integrated biogeochemical fluxes from shelf waters to the slope and deep sea. Fluorometers for chlorophyll measurement have already been developed and tested for Gliders and AUVs like FETCH. Fluorometer deployment from ASVs is simple, and provides carbon estimates. Water samplers for AUVs/ASVs are under development for estimation of iron and other nutrient elements.

OBJECTIVE 4: BATHYMETRIC CHARTING

Improving bathymetric charts is the focus of the International Bathymetric Charting of the Southern Ocean project. Many charts are long out of date, and new data is dispersed. As a priority for the future, ASVs can be equipped to map shallow, nearshore waters hazardous to ships, and multibeam AUVs could be used for data under the Ross Ice Shelf.

Naval Academy PICOSAT prior to launch in polar orbit.

METHODS: ADVANCED WIRELESS AND PICOSAT COMMS

Advanced Wireless Communications Protocols. Wireless technologies are developing rapidly to standardize 802.16 protocols. These include Delay-Tolerant Networking (DTN) wireless protocols for areas with unreliable or interrupted communications. Protocol extensions to DTN also improve ASV communications by providing order of magnitude increases in both bandwidth and distance.
PICOSAT Communications Capabilities. Small student-built communications satellites are already used for polar data communications. Additional PICOSATs are available, easily equipped with new DTN and related software that increase data communication periods, and provide additional bandwidth capacity.

University of Washington Gliders conduct hydrographic profiling operations for many months, transmitting data on a regular basis when surfacing.

SUMMARY AND CONCLUSIONS

Synoptic long-term measurements of Southern Ocean dynamics are critical for understanding physical and biological processes around Antarctica, as well as the Southern Ocean's role in global climate dynamics. Funding for ships is limited, and greater data collection would be facilitated by use of autonomous vehicles. Underwater vehicles remain expensive, but cheaper (@$30K) autonomous surface vehicles can provide twice daily hydrographic and atmospheric data for months without service. Existing PICOSATs can provide no cost communications, and use of recent advanced wireless communications will provide extended range, increased bandwidth, and accommodate error-prone transmission conditions.

MIT has built and demonstrated a mini-armada of inexpensive SCOUT "Robo-kayaks" which carry GPS-directed motors, and variable arrays of ocean sensors below.