Oden Southern Ocean 2008-2012

Report from the Oden Southern Ocean Workshop

Lejondals Slott, Sweden

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1 General overview of the workshop

This report summarizes the results of a workshop for developing US-Swedish research cooperation on *Oden* in Antarctica held 10-13 February 2008 near Stockholm, Sweden. The five-year US-Swedish cooperative agreement for use of the Class 1A Icebreaker *Oden* includes approximately 20 dedicated science days each year in conjunction with ice breaking services for McMurdo resupply operations. The US National Science Foundation Office of Polar Programs (NSF/OPP), the Swedish Research Council (VR) and the Swedish Polar Research Secretariat (SPRS) wish to allow the science community to openly compete for this unprecedented opportunity for research, exploration and discovery. They also wish to encourage the development of collaborative research partnerships between and within the research communities of each country. The cognizant Program Directors at NSF are Roberta Marinelli (rmarinel@nsf.gov) and Kelly Falkner (kfalkner@nsf.gov). Scientists in Sweden are asked contact Lars M Nilsson at VR regarding the application procedure (lmn@vr.se) or Magnus Tannerfeldt at SPRS regarding logistics (magnus.tannerfeldt@polar.se). Relevant web sites are www.vr.se, www.polar.se/aktuellt and http://www.polar.se/english/index.html.

The Swedish Research Council hosted the workshop that was co-sponsored by the agencies. Approximately 20 scientists from each country representing a wide range of research specialties participated in the workshop (Appendix B), which was organized by Susanne Åkesson (Lund), Leif Anderson (Göteborg), Hugh Ducklow (Woods Hole) and Peter Minnett (Miami).

The Swedish Polar Research Secretariat opened the workshop by a presentation of the capabilities of the vessel. This was followed by a discussion of the experiences of the science community that participated in the 2007-2008 science cruise that constituted the first of this 5-year opportunity. With this background information, workshop participants were then asked to identify research themes and projects that are appropriate for the *Oden* under the arrangements of this special opportunity. This report summarizes the capabilities of the *Oden* and the research themes identified by the participants in order to assist the broader community in preparation of competitive proposals for the remaining period of the cooperative agreement.

2 Logistics

2.1 Ship schedule and cruise track(s)

The primary mission of the *Oden* in Antarctica is to lead the annual break-in of the McMurdo Ship Channel in the Ross Sea. In addition to the necessary 17 day transit from South America to the Ross Sea, NSF/OPP and SPRS will be providing 20 dedicated science days, including added steaming time. *Oden* will depart Sweden in October to reach Punta Arenas in late November. After a short port call a scientific leg will be performed during the sailing towards McMurdo (see Figure 1). The primary cruise track will go from Punta Arenas in Chile, across the Drake Passage towards Antarctica. At the Marginal Ice Zone the ship will follow the ice edge west through the Bellingshausen and Amundsen Seas, and then southwest through the Ross Sea polynya to McMurdo Sound. This primary track can be extended by up to 20 dedicated science days for transects and/or station work focusing on science within the sea ice.

Approximate cruise schedule

20 October 2008	*Oden* departs from Sweden
29 November 2008	*Oden* departs from Punta Arenas, Chile, with science party
6 January 2009	*Oden* arrives at the McMurdo Sound ice edge, Ross Sea
7 January 2009	Science party disembarks by helicopter to McMurdo Station
9 January 2009	Science party redeploys by air to Christchurch, New Zealand

A similar schedule is anticipated for the cruises in the following years.

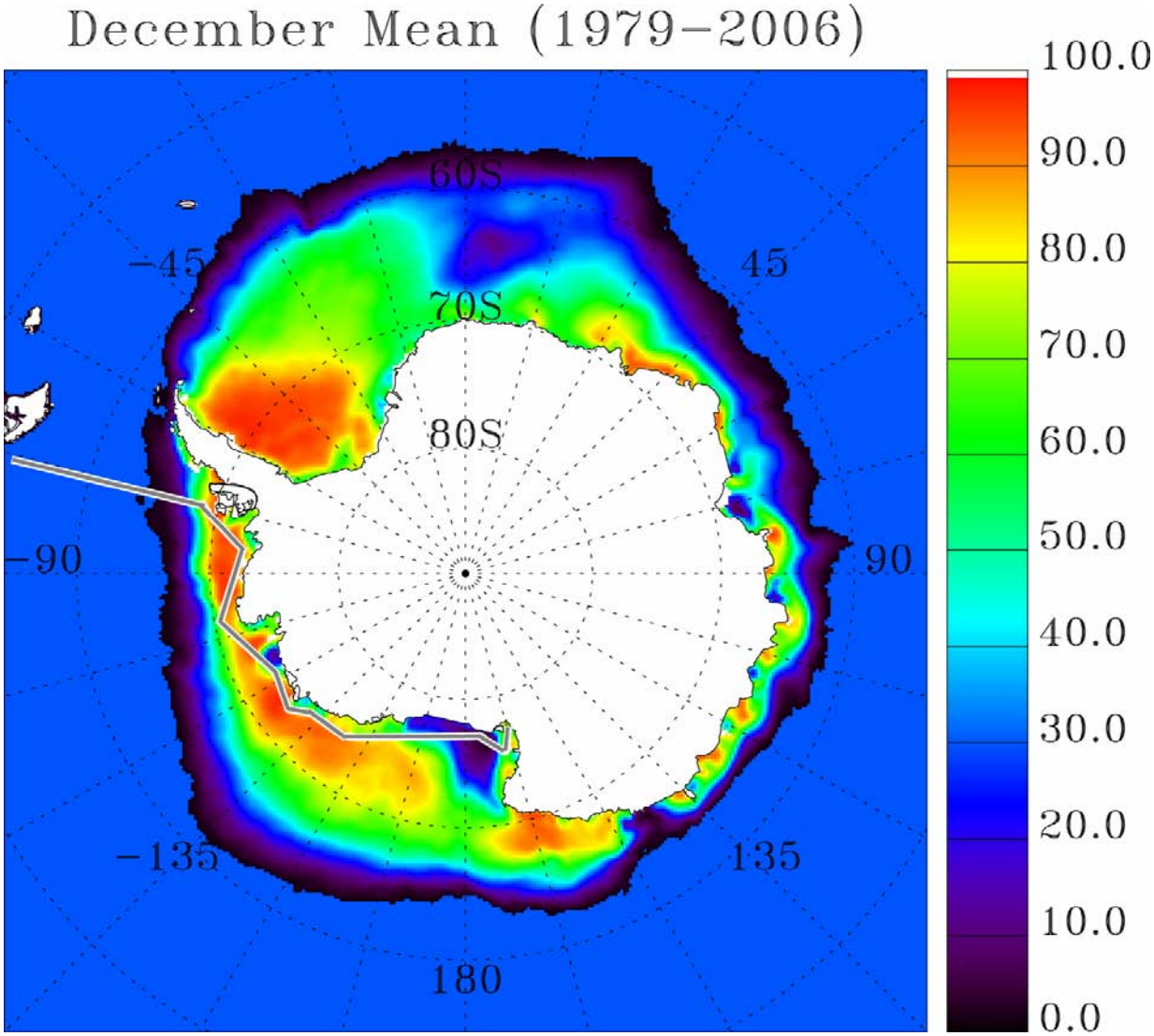

Figure 1. Map of the area with a potential science cruise track. The colors (key on the right) represent mean ice concentrations for December (1979-2006). The December 1978-2006 climatology is based on the GSFC SMMR-SSM/I Bootstrap Algorithm and the data were acquired from the National Snow and Ice Data Center (http://nsidc.org).

The total number of scientists, science technicians, teachers and media participants is approximately 32. There will not be opportunities for terrestrial research or helicopter support on the 2008/09 cruise. However, proposals for the subsequent *Oden* cruises to this region may possibly include such activities. Opportunities will be announced accordingly through a joint release by NSF, SPRS and VR.

2.2 Ship capabilities

The *Oden* is a Class 1A icebreaker that is also capable as a research platform in ice covered waters. *Oden* can break ice of several meters thickness. Research facilities include winches capable of handling CTD-rosette packages and nets for plankton sampling, for example, and there is some ability to add winches for other sampling, such as trace metal clean system. There is also a small (60 cm diameter) moon pool. *Oden* has a 90 m^2 permanently installed laboratory that is divided into three units, including one clean room. As *Oden* is not primarily a research vessel, scientists are expected to bring necessary laboratory equipment aboard and install it in the main lab or in containers/vans. The laboratory is supplied by seawater from a hull inlet at ~8 m depth as well as several independent gas lines. There is access to MilliQ equipment, and storage at –80^{o}C, -20^{o}C and +4^{o}C. In addition there are options for up to 12 container laboratories (20ft vans) with electric and waste water connections. An advanced multibeam sonar with a sub bottom profiler was installed on *Oden* in 2007 (Table 1). Ship navigational data can be accessed in most areas of the ship.

Table 1. Specifications of *Oden* multibeam and sub-bottom profiler:

EM120 (1°)
Depth range: 20 to 11000 m
Swath width: up to 6 times water depth
Beam width: 1°x1°
Beams: 191 covering a sector up to 150°
Frequency: 12 kHz

SBP120 (3°)
Frequency range: 3-7 kHz, chirp
Vertical resolution: 0.35 ms
Horizontal resolution: 3°x3°
Integrated with EM120 by using the same receiving transducer array

The EM120 12 kHz multibeam echo sounder is designed to perform seabed mapping – bathymetry and seabed imagery- to full ocean depth. During the spring of 2008, Kongsberg Maritime will upgrade the EM120 installation to the new EM122. This system upgrade does not involve new hull installations of the transmitting or receiving arrays, but new signal processing capabilities. EM122 will be capable of handling 288 simultaneous beams and multi pinging giving improved resolution. The signal-to-noise ration will be improved through the use of FM (Frequency Modulated) chirps.

2.3 Science operational constraints

Time constraints limit the scope of modifications that can be made to the *Oden* and to equipment prior to the 2008-09 cruise. Some limitations will carry over to the subsequent cruises, while others could be addressed if compelling scientific arguments are made and funds are available to support the modification.

2.3.1 All cruises

Technical support

The *Oden* is an excellent ice-breaking platform, with limited capabilities as a multi-disciplinary research vessel, and it will be necessary to augment the ship-based personnel for scientific operations. There is no routine support available from the ship for deck operations, winch control on CTD stations, equipment handling nor analytical or observational services. PIs should take this into account and requisite personnel for technical support in their proposals. Technical support needs will be re-assessed by US and Sweden once research teams are selected for participation in *Oden* cruises.

Station keeping in open water.

Oden has limited station-keeping ability in open water. The ship is subject to windage and has a tendency to roll. Over-the-side operations in open water in even moderate conditions are constrained by wire-angle considerations as well as the safety of personnel.

Radioisotopic tracers

No tritium is allowed on-board because of the risk of residual contamination that could invalidate subsequent research involving environmental levels of the tracer. Work with carbon-14 radioisotopes may be allowed in a designated isotope laboratory van. US scientists should follow radioisotope handling procedures for their designated institution, as well as protocols developed by the Office of Polar Programs and the Swedish Polar Research Secretariat

Permits

The *Oden* is a Swedish vessel operating under Swedish law. US investigators must also comply with US regulations.

2.3.2 2008-09 cruise

Additional considerations for the 2008-09 cruise include:

Aft decks

The aft decks have to remain clear of equipment for the event that the *Oden* will have to tow other vessels through the ice. No equipment (including an A-Frame) can be permanently installed that might compromise this part of the mission. Most scientific operations will therefore be conducted from the foredeck.

Net tows and seafloor sampling

Net tows are limited by the currently available winch and wire to lengths of ~240m. This could be used for vertical tows or limited lateral tows. No benthic sampling or sediment coring will be feasible.

Helicopter

No helicopter support will be available.

Deck incubators

No ambient seawater supply to control the temperature of incubators is available.

3 Science Themes

The science programs should take advantage of the special capabilities of *Oden* to work in regions of congested, extensive multiyear pack ice. The cruise tracks allow access to poorly-investigated and under-sampled regions of the southern Bellingshausen and Amundsen Seas (Figure 1). The following sections describe opportunities for a wide array of multidisciplinary studies in the geological, physical, chemical and biological sciences. There was a strong consensus among the workshop participants in support of scientific investigations within the pack ice and other difficult-to-access regions, such as the Amundsen Sea Polynya.

3.1 Geology and Geophysics

Oden is equipped with high-resolution, wide-swath multibeam and sub-bottom profiling systems providing an excellent resource for scientific studies requiring advanced geophysical mapping.

As the Bellingshausen and Amundsen Seas are among the least mapped regions of the oceans, multibeam bathymetry along *Oden's* path could be collected in consideration of existing tracks of multibeam data. Earlier multibeam mapping has primarily been carried out by US icebreaker *Palmer*, German *Polarstern* and British *James Clarke Ross*. This coordination could be done through the International Bathymetric Chart of the Southern Ocean (IBCSO) project. Scientific applications of the measurements could include: past and present ice sheet dynamics in the Bellingshausen and Amundsen Seas; cross disciplinary research using *Oden*'s multibeam capabilities to map bottom morphology and acoustic imaging of the water column to study bottom/water properties interactions; seafloor acoustic characterization for the purpose of benthic habitat mapping; and underway seafloor mapping for tectonic features.

Furthermore *Oden* can be equipped with a core launching system which, in the past, has relied on an A-frame installed on the aft deck of *Oden*. This will not be available during the first of the series of cruises, but there are several possibilities for a coring/bottom sampling program during later cruises depending on how a coring system could be installed on the aft deck without interfering with *Oden's* primary mission to open up the McMurdo Ship Channel.. Smaller sediment samples using a small box corer or grab sampler can be taken from the fore deck.

3.2 Ecology of ice-covered seas

Abundance, distribution and diversity of organisms in ice-covered seas; food web structure and function; evolution and adaptation, and molecular studies.

The *Oden* offers the possibility to observe and sample phytoplankton, zooplankton, nekton, and benthos that inhabit ice covered seas and sea ice. Observations and samples can be facilitated with nets and bottom-samplers, divers, instruments such as multifrequency acoustics or plankton imaging packages or via deployment of AUVs or ROVs through the ice. These capabilities allow the study of a broad range of questions related to ecology, evolution and adaptation in cryospheric habitats. Underway sampling of the seawater system may also provide a broader geographic context. Studies that include oceanographic measurements, sea ice, and seafloor topography (discussed below) further provide an excellent opportunity to address physical-biological coupling and trophic relationships in the ice and under-ice environments. The multidisciplinary approach of the projected research program provides an opportunity to interpret patterns of sympagic, pelagic and benthic abundance and diversity (complementing the current

International Census of Antarctic Marine Life) in the context of physical and biogeochemical properties of the sea ice habitat. Within the context of climate change, studies on *Oden* not only provide an opportunity for baseline and future comparative studies of benthic communities in ice-covered seas that have yet to be impacted to the same degree as the western Antarctic Peninsula, but also to exploit plankton and benthic sampling or ROV observations to track the ongoing reappearance of invasive species across this major region of Antarctica.

The *Oden*'s transits to rarely-explored areas also allow the observation and sampling rarely-encountered species. Studies of marine mammals and seabirds are particularly feasible, as population surveys, observations, short-term captures, deployment of instruments and acquisition of tissue samples are easily accommodated and integrated with other thematic studies. Such studies allow assessment of foraging habitat, trophic relationships, contaminant levels, overall physiological condition and molecular studies.

The trans-Atlantic crossings offer limited opportunities for supplemental studies of underway air or water sampling, and wildlife observations. Scientists interested in trans-Atlantic data collection, bottom sampling, and the use of ROVs and AUVs should consult agency representatives to further discuss feasibility.

3.3 Oceanography & marine biogeochemistry

This component considers studies of the water column as distinct from the sea ice, but it includes the water column under the ice as well as leads and polynyas within the sea ice zone. Specific physical, chemical and biological oceanographic studies of the water column and benthos may be proposed.

The workshop participants identified priorities for: 1) coordinated physical oceanographic and biogeochemical observations along cross-shelf transects through the pack ice, and 2) intensive ecological studies of physical-biological processes and biogeochemistry within the Amundsen Sea Polynya. Hydrographic observations along cross-shelf transects may include, but are not limited to, those variables necessary to define the distribution of water masses and identify the source regions and flow pathways of glacial meltwater along the shelf: temperature, salinity, oxygen, macronutrients and trace elements and isotopes, carbonate system properties, chlorophyll fluorescence and isotopic tracers. Sampling and observations according to the international GEOTRACES program along ocean basin cruise transects could be extended into the pack ice as part of *Oden*'s chemical oceanographic observations to improve knowledge of trace element sources, transformations and influence on biological productivity. Related work might include underway surface and meteorological measurements and XBT/XCTD casting, deployment of floats and drifters, CTD/LADCP/rosette casts along specific WOCE/CLIVAR/IPY and other transects, and deployment and servicing of bottom-moored or ice tethered instruments and Automatic Weather Stations.

The repeat *Oden* cruises in the Amundsen Sea enable pursuit of a climate change theme focused on changes in the stratification of the Amundsen Sea leading to changes in the ventilation of locally-produced Antarctic deep and bottom waters. The *Oden* expeditions are well-suited to studies of variability in sea-ice/SST anomalies and of processes that precondition the waters that ultimately erode the base of the Pine Island and Thwaites glaciers. The *Oden*'s icebreaking

capabilities permit new investigations of CO_2 exchanges in leads and polynyas in the extensive sea ice in the region.

The Amundsen Sea Polynya is the second-most productive of the Antarctic polynyas but has been rarely visited and never intensively investigated. Coordinated physical, biogeochemical and ecological studies of biological productivity, microbial ecology, physical-biological interactions and relationships between foodweb structure and chemical fluxes are feasible (see also 3.2). Studies of the Amundsen Polynya could be coordinated with ongoing research on the Ross Sea polynya, enabling comparison of polynya ecology in regions of opposing trends of declining (Amundsen) and increasing (Ross) sea ice extent and duration.

3.4 Sea ice

The ultimate goal of this theme is to better understand the role of sea ice in the Antarctic system. The region to be traversed by the Oden is an under-sampled area of prime importance due to the large amount of multiyear ice.

The scientific issues which could be addressed include heat and salt fluxes from the ice and their impact on deepwater formation and climate; physical-optical-biogeochemical interactions in sea ice and connections with the carbon cycle, sulfur cycle, krill and top predator life cycles; and ship-based validation studies of remote sensing of sea ice. Ship-board measurements could be augmented by aerial surveys, and by autonomous buoys deployed on the ice.

The general observational approach could include four broad types of measurements; underway, on-ice stations, airborne, and autonomous buoys. The underway measurements could include ice concentration, snow depth, ice thickness, floe size, deformation, photography (visible, infrared), and spectral reflectance of the surface. Both manual and automated methods could be used to make these observations. Ice station measurements could include snow depth and ice thickness profiles made by drilling and by electromagnetic means. Snow stratigraphy could be measured and ice cores could be taken. Under-ice profiles could be made using ROVs or AUVs. Optical measurements could be made of the snow and ice cover including spectral albedo and transmittance plus PAR. *Oden's* capability to penetrate deep into the sea ice zone in this region provides a prime opportunity to extend our knowledge of sympagic and epontic ecology.

Scientists interested in the use of ROVs and AUVs should consult agency representatives to further discuss feasibility.

3.5 Atmospheric Sciences

The state of the atmosphere, and the energy fluxes between the atmosphere and underlying surface, are important parameters that help control the environmental conditions in the study areas, yet are poorly known from existing observational data in this region. The measurements taken from the Oden could contribute to validating numerical models and satellite retrievals as well as to process studies.

The *Oden* will traverse large areas devoid of atmospheric measurements and any meteorological measurements will therefore be of great value to address a wide range of applied and basic

atmospheric science problems. At a minimum it would be appropriate to collect standard surface measurements (temperature, pressure, wind, humidity, precipitation, cloud) and upper air observations (temperature, pressure, wind, and humidity), using well calibrated and well-maintained sensors. In addition the *Oden* could also install automatic weather stations (AWS) along the track, which would provide longer-term atmospheric observations in this region. Information regarding precipitation in this area could be provided by installing acoustic depth gauges at selected AWS sites. Autonomous sensor packages could be deployed in remote areas inaccessible to the *Oden* by helicopter or small boat. Atmospheric measurements could be made over a mesoscale region (radius of ~500 km) using UAVs, which could be launched and retrieved from the ship.

Scientific issues which could be addressed with such data include, but are not limited to, improving numerical weather prediction, such as the Antarctic Mesoscale Prediction System (AMPS) and climate model validation studies, case studies of the dynamic and thermodynamic processes in synoptic and mesoscale systems, flows along the steep coastal margin of the Antarctic peninsula and the West Antarctic ice sheet, cloud radiative forcing and feedbacks, radiative effects of aerosols (including black carbon) and halocarbons, and boundary layer/air-sea-ice interactions over a range of surfaces including various types of frozen surfaces, the marginal ice zone and in the vicinity of leads and polynyas. (See also 3.6.)

3.6 Anthropogenic contaminants

Anthropogenic contaminants enter Antarctic ecosystems via atmospheric transport, migrating animals and local sources. The Oden is an ideal platform for studying the atmospheric transport and fate of these substances in remote polar environments.

Anthropogenic contaminants include: persistent organic pollutants (POPs) including emerging contaminants that are bio-accumulative and toxic, anthropogenic aerosols (e.g. black carbon) that may impact climate change, volatile halocarbons such as chlorofluorocarbons that impact ozone depletion, and metals such as lead and mercury.

Clean air sampling is possible on the *Oden*; the ship provides ready access to sea ice for snow, ice, and biological sampling, and a built-in surface seawater sampling system and clean lab allow for continuous measurements in surface water. The following priority research themes have been identified concerning anthropogenic pollutants in Antarctica: 1) Atmospheric transport and transformation, defining the sources (geographic, anthropogenic/natural) of pollutants to Antarctica; 2) Climate impacts of black carbon, potentially contributing to changes in radiation budgets and cryospheric change; 3) Impacts of glacier melting on pollutant loads to coastal Antarctic seas and 4) Impacts on biota. These and other important research questions can be readily evaluated during the transit of the *Oden* through western Antarctic coastal seas with its currently available infrastructure. In addition, the transit of the *Oden* between Sweden and Antarctica provides an opportunity to evaluate the global sources and transport pathways of anthropogenic pollutants.

4 Data Policy

The Director of the Office of Polar Programs has established Guidelines and Award Conditions for OPP Scientific Data effective in FY-99. The full document is available on the OPP webpages at: (http://www.nsf.gov/pubs/1999/opp991/opp991.txt).

Principal Investigators of OPP awards should make their data available to all reasonable requests. Where applicable, the Principal Investigators should submit the data collected to designated data centers as soon as possible, but no later than two (2) years after the data are collected. For continuing observations, data inventories should be submitted periodically if and when there is a significant change in location, type or frequency of such observations.

Principal Investigators of OPP-funded awards are REQUIRED to submit to appropriate electronic data directories, a description of their data (i.e., metadata) resulting from OPP-funded research in the form of a Directory Interchange Format (DIF) entry. Submission of the DIF may be at any time during the tenure of the grant. At the time of submission of the Final Report to NSF, a copy of the DIF must be sent to the cognizant program official in OPP.

For OPP-supported Antarctic projects, DIF submission should be to the Antarctic Master Directory, via the National Antarctic Data Coordination Center at http://www-nsidc.colorado.edu/NSF/NADCC. For OPP-supported Arctic projects, DIF submission should be to the Arctic System Science Data Coordination Center at http://arcss.colorado.edu.

5 Proposal submission

US scientists should submit proposals to the NSF according to the Antarctic Research Program Solicitation (NSF 08-535). The deadlines for submission are May 2, 2008 for research to be conducted on the 2008-9 cruise, and June 6 for subsequent cruises.

Swedish scientists should submit proposals to the Swedish Research Council (Vetenskapsrådet) by following instructions in the call for proposals to the US-SWE Antarctic Programme (http://www.vr.se/huvudmeny/sokabidrag/vetenskapsradetsutlysningar.4.aad30e310abcb9735780004372.html). The call will open March 17 and close May 6, and June 5 for subsequent cruises.

US-Swedish collaboration is encouraged. In US proposals this should be made clear in the text and a substantive letter of collaboration from the Swedish counterpart should be included as a "supplemental document."

PIs should anticipate attending pre-cruise planning meetings in the DC area, in August, and on the *Oden* in Gothenburg, Sweden in October, and should calculate their budgets accordingly. Equipment could be embarked in Sweden or Punta Arenas.

Appendix A – Characteristics of the Icebreaker *Oden*

Oden was built in 1989
110 m L, 32 m B, 8,5 m D
Economy speed open water 11 kts
Average speed in Arctic ice 4 kts
Bunker capacity, 4500m^3

Flexible research platform
- Stationary lab of 90m^2
- 12 lab containers
- A-frame
- Moon pool
- Seawater intake system
- Flexible winch solution
- 20ft container fittings

7 Arctic scientific expeditions
1991, 1996, 2001, 2002, 2004, 2005, 2007
2 Antarctic scientific expeditions
2006/07, 2007/08
5 times to the North Pole

4 September	1991
10 September	1996
31 July	2001
12 September	2004
8 September	2005

Diesel machinery 24000 hp
4 engines and 2 propellers with nozzles
Water flush
Healing system

<u>Foredeck</u>
- CTD-winch, 8mm x 6000m
- CTD A-frame 1500 kg instrument weight
- CTD container for rosette sampling

Network
Telephone

<u>Main deck/stern</u>
6 x 20ft lab containers
2 x 20ft CTD container
A-frame

CTD winch 6000 m
8 mm wire
Seabird deck unit

Main laboratory
90m^2 lab in 3 rooms
Seawater intake systems
- Stainless steel
- PVDF plastic
- 50 litres/min/pipe
Gas distribution system
2 fume hoods
LAF bench
Clean water system

Aft deck[*]
20 tonnes A-frame
Flexible winch system
Winch control container
Container mounted winches
20ft storage containers
20ft ISO container fittings
Network
Telephone

Oden deck 4
6 x 20ft lab containers
Systems for:
- Hot/cold fresh water
- Compressed air
Gas distribution system

Bridge/deck 7
Multibeam (Kongsberg 122 1x1 system)
Sub bottom profiler (Kongsberg)
Meteorology system
HRPT satellite receiver
Iridium Communication (+80 deg)
Inmarsat on request (Lower latitudes)

Lab container
Helicopter deck (10t TOW)
Workboat (3.5 tonnes)

[*] The aft deck must remain clear to permit towing operations if required. Please see section 2.3.

Appendix B – Workshop participants

ACKLEY, Stephen
Dept of Earth & Environmental Science, University of Texas at San Antonio

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Animal Ecology, Lund University

ALDAHAN, Ala
Geosciences, Uppsala University

ANDERSON, Leif
Marine chemistry, University of Gothenburg

ANDERSSON, Inger
Molecular Biophysics, Uppsala University

ANDERSSON, Per
Isotope geology, Swedish Museum of Natural History

ARRIGO, Kevin
Department of Geophysics, Stanford University

ASHJIAN, Carin
Woods Hole Oceanographic Institution

BJÖRK, Göran
Oceanography, University of Gothenburg

CASSANO, John
Cooperative Institute for Research in Environmental Sciences and Department of Atmospheric and Oceanic Sciences, University of Colorado at Boulder

CHERESKIN, Teresa
Scripps Institution of Oceanography

CHIERICI, Melissa
Marine Chemistry, University of Gothenburg

DICKHUT, Rebecca
Virginia Inst of Marine Science

DUCKLOW, Hugh
The Ecosystems Center, MBL, Woods Hole, MA

FALKNER, Kelly K.
US National Science Foundation

FRANSSON, Agneta
Geosciences, University of Gothenburg

FRIBERG, Magnus
Swedish Research Council

GUEST, Peter
Naval Postgraduate School, Monterey, CA

GUSTAFSSON, Örjan
Applied Environmental Research, Stockholm University

HÄRKÖNEN, Tero
Swedish Museum of Natural History

HEDMAN, Ulf
Swedish Polar Research Secretariat

HJORT, Christian
Quarternary Geology, Lund University

JAKOBSSON, Martin
Geology and geochemistry, Stockholm University

KARLQVIST, Anders
Swedish Polar Research Secretariat

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Marine Chemistry, University of Gothenburg

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Environmental Assessment, Swedish University for Agriculture Sciences

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NDUNGU, Kuria
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PEROVICH, Don
USACE Cold Regions Research and Engineering Laboratory

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Department of Geography, UCLA

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Marine sciences, University College Kalmar

SHERRELL, Rob
Institute of Marine and Coastal Sciences, Rutgers University

SJÖLING, Sara
Life Sciences, University College Södertörn

STAMMERJOHN, Sharon
Lamont-Doherty Earth Observatory of Columbia University

STEWART, Brent
Hubbs-SeaWorld Research Institute, San Diego

SWEENEY, Colm
NOAA/ESRL/GMD, Boulder CO

TANNERFELDT, Magnus
Swedish Polar Research Secretariat

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Danish Environmental Research, Roskilde, Denmark

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Oceanography, University of Gothenburg

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Swedish Research Council

YAGER, Patricia
School of Marine Programs, University of Georgia

Appendix C – Acronyms

AMPS	Antarctic Mesoscale Prediction System
AUV	Autonomous Underwater Vehicle
AWS	Automated Weather Station
CLIVAR	Climate Variability and Predictability Program
CO_2	Carbon Dioxide
CTD	Conductivity-Temperature-Depth sensor package
GEOTRACES	International study of the global marine biogeochemical cycles of trace elements and their isotopes.
IPY	International Polar Year
LADCP	Lowered Acoustic Doppler Current Profiler
NADCC	National Antarctic Data Coordination Center
NSF	US National Science Foundation
OPP	Office of Polar Programs at NSF
PAR	Photosynthetically-Active Radiation
POPs	Persistent Organic Pollutants
ROV	Remotely-Operated Vehicle
SPRS	Swedish Polar Research Secretariat
SST	Sea Surface Temperature
UAV	Unmanned Aerial Vehicle
VR	Swedish Research Council
WOCE	World Ocean Circulation Experiment
XBT	Expendable Bathythermograph
XCTD	Expendable CTD