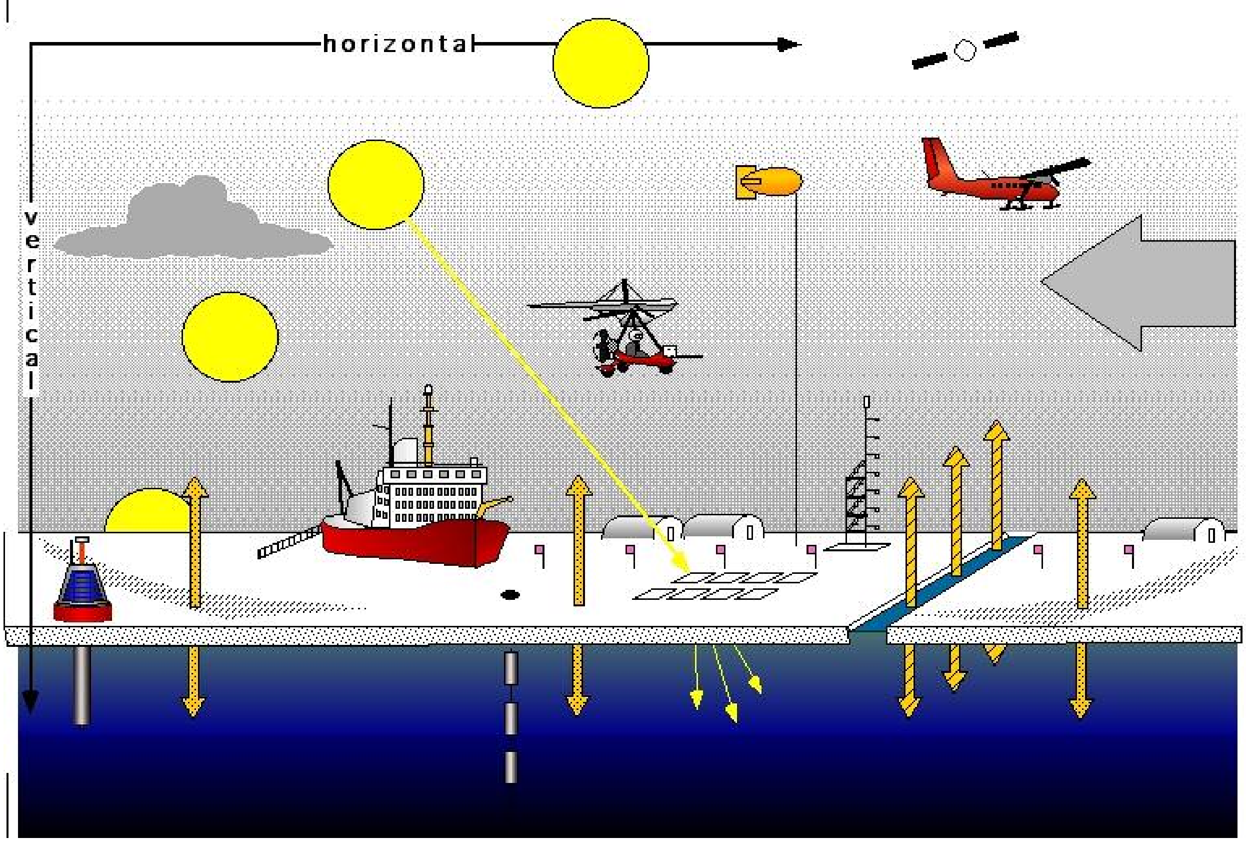
OASIS Implementation Plan Outline v3.1

Mar 3, 2005; edited HB
Items in yellow require writing / editing

OASIS Front Cover Cartoon



1. Introduction and Background for the OASIS Implementation Plan

This Implementation Plan (IP) follows logically from the OASIS Science Plan (SP) (http://www.chem.purdue.edu/arctic/OASISHomePage.htm) that has been extensively vetted by the international science community involved in studies of air-surface chemical exchange in the Arctic. Although the Science Plan will continue to be edited and fine-tuned by the community (and we encourage continued input), the four foci are not likely to change in the near future.

The conceptual outline for this IP was developed at the IP Workshop conducted at and hosted by C.N.R. – IIA (Rome, Italy), January 10-12, 2005. At the Workshop, it was discussed that many of the scientific objectives laid out in the SP, although diverse in scope, could nonetheless be simultaneously pursued from a limited number of types of logistics bases of operation. For example, several of the objectives require access to open leads. Since there are significant safety and logistical hurdles with respect to this need, it is clear that many science questions, ranging from studies of fluxes of organic matter and sea salt and organohalogens out, to studies of the impact of the large heat flux on Arctic atmospheric structure, to studies of the impact of fluxes of atmospheric constituents in, could be pursued from an ice breaker platform. It is also clear that an icebreaker represents a critically valuable base of operations (refuge, laboratory space, etc) from which smaller time and spatial scale ice camps could be deployed. There is thus a clearly defined and critical need for icebreaker access. However, it is also clear that this is an expensive component of OASIS logistics needs, and many things can also be done at lower cost. Thus, we decided to organize the IP workshop, and this IP according to logistical approaches to the SP issues. The IP is organized according to the following technical approaches, and pursuits: Arctic Ocean Chemical Measurement Buoys, icebreakers and associated ice camps, stand-alone icecamps and ice islands, aircraft and other airborne platforms, instrument development needs, connections to other programs and long-term coastal measurement sites, laboratory studies and modeling activities, and support from remote sensing platforms. Connections between these and other activities are discussed in each section as appropriate. The IP also discusses data management and QA issues and activities, funding approaches, outreach and educational activities, and broader impacts in general. This IP will present a timeline of anticipated events and objectives, and a discussion of some of the anticipated outputs and publications.

The IP workshop was conducted and this IP prepared in part in the context of the plans for the International Polar Year (IPY). The international OASIS community has submitted to the ICSU/WMO Joint Committee a proposal for an OASISI-IPY effort. As part of that proposal and the OASIS IP in general, connections to other Arctic research and education activities are essential. In the OASIS-IPY proposal, we discussed connections to other IPY efforts (such as AICI-IPY; ITCT-Arctic; ISAPIE, CMRWA, SANTAS, and others). OASIS will be linked to a number of international organizations and activities, including AMAP, and the IGBP/IGAC projects SOLAS and AICI.

This IP will be released for international input, with opportunities for input and editing via the OASIS web site. We expect a final draft to be ready by May 2005. It is of course the case that the actual details of the implementation of OASIS will change as funding and logistics opportunities arise and change, on both national and international scales. As this occurs, the IP will be modified and updated accordingly, via the OASIS web site.

OASIS is currently coordinated via the OASIS coordination office, situated at C.N.R. – IIA, Rome. www.iia.cnr.it/OASIS , harry@iia.cnr.it, (39) 06.906.72.262, fax (39) 06.906.72.660

OASIS is administered via an Executive Committee (EC). The OASIS EC membership is as follows:

Len Barrie	WMO, Geneva, Switzerland
Harry Beine (coordinator)	C.N.R. – IIA, Rome, Italy
Jan Bottenheim	MSC, Toronto, Canada
Florent Dominé	CNRS – LGGE, Grenoble, France
Chris Krembs	U. Washington, Seattle, WA, USA
Seelye Martin	U. Washington, Seattle, WA, USA
Paty Matrai	Bigelow Laboratory, W. Boothbay Harbor, ME, USA
Jozef Pacyna	NILU, Kjeller, Norway
Don Perovic	USACE-CRREL, Hanover, NH, USA
Paul Shepson	Purdue U., West Lafayette, IN, USA
Matthew Sturm	USACE-CRREL, Hanover, NH, USA

2. Field Studies

2.1. Autonomous Atmospheric Chemistry Buoys

2.1.1. Background

Ozone is a key atmospheric constituent that is at the same time essential, and toxic. It provides, through its photolysis to produce OH radicals, much of the atmosphere's cleaning, i.e. oxidizing power. However, it is an important greenhouse gas (Houghton et al., 2001; Mickley et al., 2001), and is both phytoxic and a human respiratory irritant, that is regulated by numerous national air quality regulatory agencies. Thus, understanding what controls its atmospheric concentrations, in the face of climate change, is essential. It has been known for 2 decades that tropospheric surface ozone undergoes a catastrophic depletion at the time of polar sunrise. More recently it has been found that elemental gas phase mercury also is depleted in concert with ozone, the gas and particulate phase Hg-containing products then depositing to the surface. It has also been known for more than 12 years (Hausmann and Platt, 1994) that ozone is depleted by a chain reaction involving bromine radicals (Br and BrO). Measurements from the GOME ERS-2 satellite instrument have indicated that this is a widespread phenomenon in polar sea-ice impacted environments (Richter et al., 1998). However, in spite of many years of observations of ozone and mercury (Lindberg et al., 2002) depletion in the Arctic, the state of our understanding is very primitive, in large part due to access to the surface environment at which this process is initiated and propagates. Specifically, the Arctic research community needs to answer the following questions:

- What is the nature of the Arctic Ocean surface properties that promote mobilization of the halogen atom precursors that destroy ozone and Hg, e.g. it is open leads, first year ice on which frost flowers occur, or sea-salt laden ventilated snowpacks that sit atop the ice cap?
- What is the time scale for ozone and Hg depletion, and how does that time scale compare with potentially limiting long range transport and vertical transport of ozone and Hg?
- What is the spatial scale of ozone and Hg depletion?
- Does halogen activation occur in the Fall?

To answer these questions requires measurement of ozone and BrO from a variety of surface types on the Arctic Ocean surface. To date, there are only two sets of short term (~2 week) ozone measurements reported from the Arctic Ocean, from independent ice camps, without benefit of BrO measurement. Because of the need for temporal and spatial information, the best available approach is development and deployment of a set of Arctic Ocean buoys that will be instrumented for measurement of a well-defined set of chemical species, from well-characterized sensor instruments, specifically O_3, BrO, and CO_2. CO_2 is important in the OASIS context of air-surface exchange of important greenhouse gases, and the current lack of understanding of CO_2 uptake and storage in the Arctic Ocean reservoir. In addition, there is a complete lack of long-term observational data for CO_2 over the Arctic Ocean surface.

We propose a program for design, development, testing, validation, and deployment of a network of 5 chemical-sensing Arctic Ocean buoys, for initial deployment as part of the International Polar Year (IPY). The buoys will be built and deployed via an international collaboration, involving scientists from Canada, the U.S., Germany, Russia, and Italy. The buoys will be deployed in the East Siberian Sea, in the Beaufort Gyre, at the North Pole Environmental Observatory, near Franz-Josef Land, and in the Hudson Bay, where the highest column BrO observations have been made. From these buoys instruments would then conduct year-round measurements of these gases. This would result in an unprecedented data set, for these critically important chemical species. Buoy deployment and management of the network would occur in association and collaboration with the International Arctic Buoy Program (IABP). Deployment and data management and analysis will occur in association with long term coastal monitoring stations, e.g. the Global Atmospheric Watch (GAW) stations at Barrow, AK, Alert, Nunavut, and Ny-Ålesund, as well as coastal stations in Russia. The data collection and analysis will also be coordinated with OASIS ice camps that will be operating during IPY in 2007 and 2008.

2.1.2. Deployment Strategy

Deployment of chemical buoys is part of an integrated chemical observation strategy for ozone, BrO and CO_2 involving an expanded WMO/GAW and AMAP arctic observatory network as well as satellite measurements of BrO and surface ice structure. These activities are described in a separate section of this implementation plan.

The specific sites for deployment and testing will be influenced by terrestrial stations, and the availability of ship and aircraft platforms of opportunity.

Testing locations: Possible testing locations include Ny-Ålesund Spitsbergen, and Resolute Bay, Canada. Both locations have good access by commercial aircraft and are close to undeformed ice that is readily accessible via snowmobiles.

Deployment locations:
Ideally buoys would be deployed in five different locations. The locations will be selected to cover areas of intense ozone and mercury depletion indicated by observations such as the satellite BrO pattern, as well as different atmospheric, oceanographic, and sea ice regimes. The deployment locations (★) are:

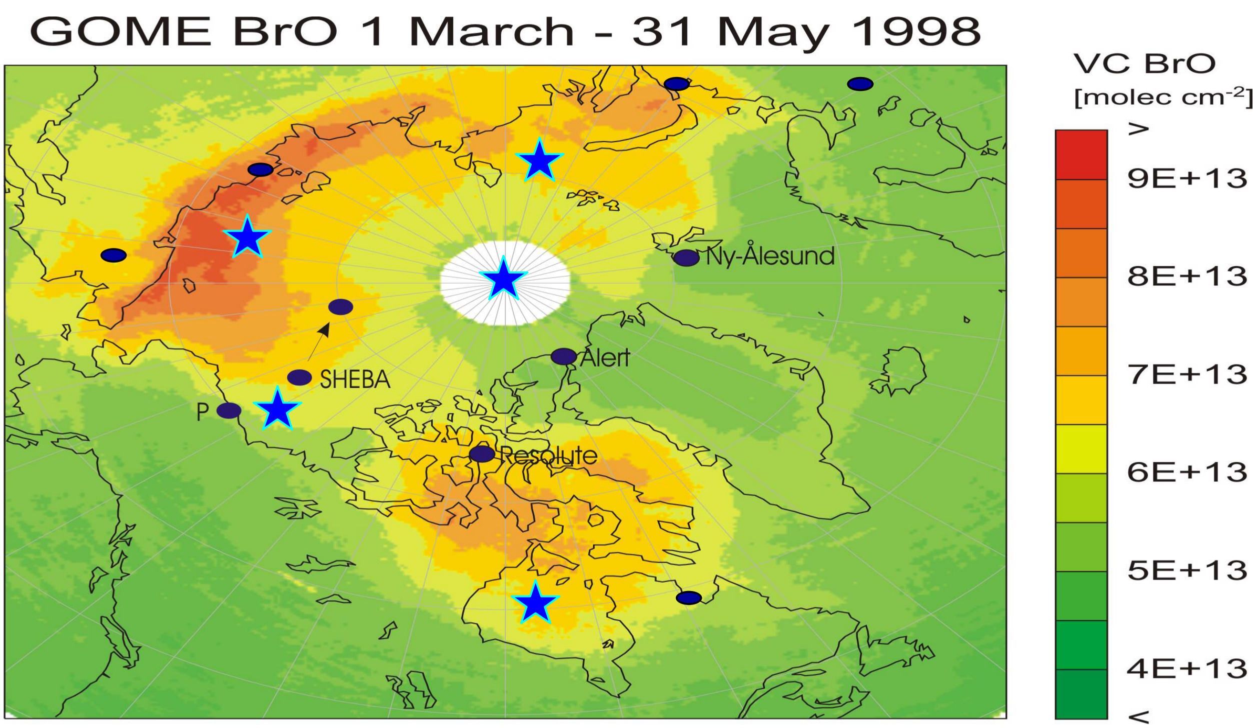


Figure 2.1.2. Buoy deployment locations on the background map of Spatial Distribution of Tropospheric BrO In The Arctic from GOME Satellite Observations [Lu, J.Y. , W. H. Schroeder, L. A. Barrie et al, 2001, Magnification of atmospheric mercury deposition to polar regions in springtime: the link to tropospheric ozone depletion chemistry, *Geophys. Res. Letters*, 28, 3219-3222].

1) Hudson Bay – most southerly region of observed ozone and mercury depletion. Easiest to access (ship, daylight also during winter); problem: no multi year ice, buoy needs to float (test also at Ny-Ålesund). Canadian navy (part of the CA proposal). Power less an issue.
2) Arctic Ocean (North Pole or similar), links to NPEO (good for PR, logistics, deployment flights) accessible from Alert and in a region often sampled from Alert
3) Beaufort Gyre, access from Barrow, Tuktouyuktuk or Prudhoe Bay; deploy in early spring as soon as daylight allows flying.
4) East of Franz Josef Land/ Nova Zemlya. Access from Russia. (depending on new stations). Support from Russians for deployment / large helicopter (Sikorsky).
5) Far East Siberia, in the path of drifting ice. 3 drifting buoys follow similar path. Russian support for deployment.

Buoy package requires assembly and on-site installation, and cannot be simply dropped out on the ice. (5 m tube to be immersed in ice).

2.1.3. Project Schedule

The buoy project schedule is divided into 3 distinct phases: development, testing, and deployment. The buoys need to be operational and ready to be deployed to deploy during IPY as part of the OASIS observational network. The IPY legacy of this project is not just the data measured by the buoys, but the development of an atmospheric chemistry buoy.

2.1.3.1. Development

2.1.3.1.1. Planning and Funding

Building the same buoy in two or three different locations with funds from various sources requires joint technical planning. This has to happen ideally before the funding process, so that it is clear what will be proposed from the partners involved.
Milestones / deliverables are

- Key design / Technical plan / blueprint of buoy (including scientific instrumentation, etc)
- Joint proposal to be submitted to two (or more) funding agencies (e.g. US/Canadian/European consortium)

2.1.3.1.2. Construction

Construction of various parts of the buoy will take place in one location (i.e. one group builds one part for all buoys), or according to joint plan in various locations (i.e. one group builds all parts of the buoy according to common specs).

2.1.3.2. Testing

Ideally the buoy should be tested for several seasons; issues to be tested include power management in the dark and twilight, and measurement performance during daylight. However, deployment during IPY may limit testing to one year. Possible testing locations are:

- Ny-Ålesund – seasonally frozen fjord w/ variable ice thickness is accessible by snow machine/skis/ or even on foot. Multi-national (European/Asian) research community and possibilities for intercalibrations. Disadvantage: the ice melts entirely in the summer.
- Barrow – sea ice short distance off the coast, full logistical support available, local community college for educational outreach activities
- Resolute – first year ice nearby, logistical support available.

2.1.3.3. Deployment during IPY

The goal will be to deploy the buoys as soon as possible after Arctic sunrise. This is the period of greatest interest and deployment will ensure that important data are collected right away. Initial servicing of the buoys will possible during daylight. The buoy will be designed to last for 2-3 years.

2.1.3.4. Timeline:

			IPY			
Year	2005	2006	2007	2008	2009	>

Season	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Action																					
Planning	x	x																			
Key design		x	x																		
Joint Proposal			x																		
Funding			x	x																	
Construction				x	x	x															
Testing						x	x	x	X												
Deployment										x											
Data										x	x	x	x	x	x	x	x	x	x	x	x
Legacy													x	x	x	x	x	x	x	x	x

2.1.4. <u>Methods:</u>

2.1.4.1. Buoy design

The buoy will consist of 3 fundamental components:

- An above ice surface part will contain the gas inlets, optical inlet, transmitting antenna. It will be covered with solar panels.
- A middle section (normally in the ice) will have room for batteries data acquisition system.
- A ocean part will be used for the main instruments to keep them thermally stable at the ocean temperature of about -1.7 C.

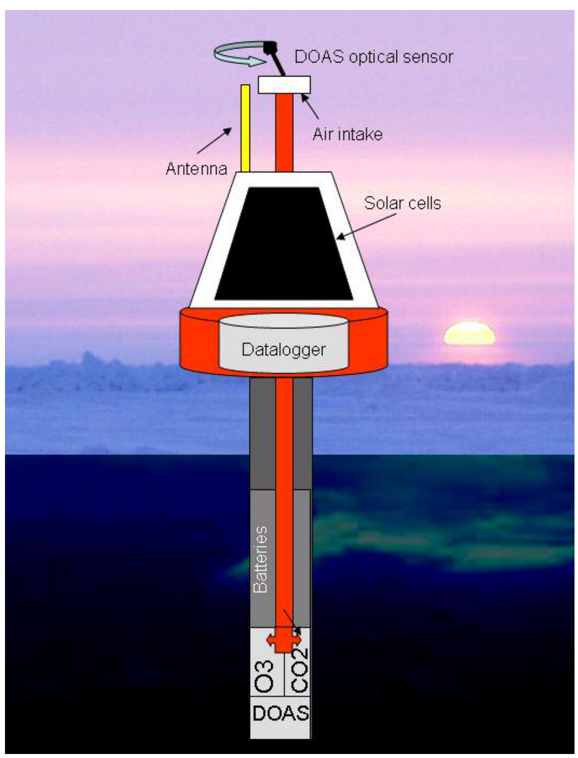


Figure 2.1.4.1. Schematic of autonomous atmospheric chemistry buoy.

2.1.4.2. Instrumentation:

This buoy will be designed to autonomously make atmospheric chemistry measurements of the several key species of prime interest to OASIS: surface ozone, boundary layer BrO profiles and CO_2.
The atmospheric chemistry buoy consists of three instruments, a small UV absorption ozone monitor, a MAX-DOAS instrument and a CO_2 sensor. In order to guarantee instrument stability, the essential parts of all instruments will be thermally coupled to the ocean which is at ~ -2°C.

- Ozone instrument: currently available instrumentation will be tested fully under conditions encountered on the Arctic Ocean. Long-term stability of the instrument is essential. Most parts of the instrument will be kept stable at ocean temperature, only few components will need to be preheated prior to operation (e.g. light source). Teflon inlet tubing will connect to the inlet mounted at the above surface part of the buoy (~2m to prevent influence of snowdrift).
- MAX-DOAS: a stable, fully automated instrument package exists and will be adapted to the buoy deployment. The thermal coupling of the DOAS spectrometer to the ocean water temperature eliminates any need for additional temperature control. An optical fiber bundle connects to the optical port at the top of the buoy. A small optical arrangement can be adjusted both in elevation and azimuth direction to allow MAX-DOAS vertical profile measurements of BrO and possibly other species.
- CO_2 instrument: commercially available CO_2 sensor will be adapted to the buoy deployment. The inlet will be combined with the ozone inlet.

Ideally the atmospheric chemistry will be deployed in conjunction with a standard meteorological buoy. Measurements of particular value are air temperature, wind speed, longwave and shortwave radiative fluxes, and photographs from a Web camera. Measurements of low wind speeds are of particular importance and of particular difficulty. The detection limit of the standard cup anemometer is not capable of measuring low wind speeds. Other devices to consider include: a triaxial sonic anemometer; a biaxial sonic anemometer, a tripropellor anemometer; and a hot wire anemometer. Power requirements will likely dictate the choice of a wind sensor.

2.1.4.3. Power management:

The main power source will be lithium batteries. It is feasible to have ~ 500-1000Ah of lithium batteries in the buoy to guarantee operation during the twilight period. Solar panels provide continuous power (up to 100W) during the sunlit period.
The batteries will be in the middle part of the buoy which will be normally in the ice.

2.1.4.4. Data acquisition system/transfer:

A robust data acquisition system will be used consisting of a data logger / microprocessor combination. A bidirectional Iridium link will be included to allow both data transmission and also possible remote control/modification of measurements frequency etc. to allow modifications of the standard built-in measurement programs.

2.1.5. Data Management

To facilitate widespread and timely distribution of data collected by the atmospheric chemistry buoys, we plan to establish a Web site where both the original data and derived results will be archived together with detailed metadata. Whenever practical, data will be presented in graphical form with links making it possible to download the numerical data directly from the Web site. In addition, all data and metadata from the buoys will be analyzed, archived, and submitted to the National Snow and Ice Data Center a World Meteorological Data Center.

2.1.6. References

Houghton et al., 2001;
Mickley et al., 2001
Hausmann and Platt, 1994
Richter et al., 1998).
(Lindberg et al., 2002

2.2. *Ice camps & Ice breakers*

2.2.1. What kind of studies? General considerations

- Process studies on the vertical of OASIS related processes across relevant interfaces (Ocean/Ice/Snow/Atmosphere)
- Define repetitive standardized measurements of variables that are repeated at different sites and times
- Process studies using time series, manipulation and experimentation
- Account for ice heterogeneity between different scales (cm-km).
- Comparison ice camp processes with a (several) coastal site to account for transitions between land influenced and open water processes in Arctic model approach.

2.2.2. What are the possible platforms?

2.2.2.1. Pros and Cons of possible platforms:

Pros	Ice camp	Ice breaker	Coastal station
Scientific aspects	-Clean environment possible -Vertical process studies -Horizontal coverage only occasional by plain -Drift allows area coverage over time	-Equipped for water column studies -Allows many scientific projects simultaneously -Allows use of delicate lab equipment -Allows toxic waste streams -Horizontal and vertical process studies possible -Leads can be artificially created -Continuous horizontal coverage by helicopter -Drift allows gradual area coverage -Propulsion allows relocation and transects -Prepackaged communication and data transfer node, does not to be installed -Computer on board -Data communication remotely	-Allows many scientific projects -Vertical and horizontal process studies -Allows toxic waste streams -Land ocean gradient studies -Continuous horizontal coverage by plane and helicopter. -Fixed geographic location -Computer no problem

		possible -Good for outreach has higher public visibility -can be installed in very thin ice and rotting ice	
Seasonal aspect	Good until ice breakup	Good year round	Good as long the ice and snow lasts
Safety	-Limited safety Polar bear/ food storage/garbage 24h bear and ice watch -Power failure -Sensitive to ice dynamic	-Very safe no concern of hypothermia, polar bears etc. -Smaller injuries can be treated on board -Less sensitive to ice dynamic,	-Very safe -Injured people can be flown out immediately -Independent of ice dynamic during winter
Logistics:			
Installation of site		Site selection planed and predictable Equipment (heavy or delicate) can be already on board	Not required
Occupants	Low number of occupants, Experienced people	-High number of occupants -Polar inexperienced possible -Technical support staff -People can stay longer time -High living and food quality keeps moral up -Visitor easily accommodated (outreach)	-High number -Technical support staff -People can stay longer time and rotate out quick -Visitor easily accommodated (outreach)
Energy	-Clean energy possible	-Unlimited energy, climate independent	Good energy supply climate independent
Access	Moderate	Moderate	Easy access
Supply/Storage	Supply good from Feb-April	Unlimited storage Heavy equipment no problem Air supply not as often needed	Unlimited Easier access to rotate equipment
Costs		-Price per overall volume of scientific data output is better than an ice camp due to the scope and number of measurements that can be performed.	Lowest cost

Cons	**Ice camp**	**Ice breaker**	**Coastal station**
Scientific aspects	-Does not allow delicate lab equipment -Allows limited amount of instruments to be on the power grid. -Temperature sensetive equipment not possible -can not be installed on very thin ice	-Affects studies in its vicinity by air pollution	-Ice and snow near land is not representative of the entire Arctic basin. -Human impact accumulates in the snow -Unexpected human activities possible (villagers) -no access to sea ice if thin or rotting
Seasonal aspect	-Safety during summer and breakup is low		-No good during summer
Safety	-Polar bear/ food storage/garbage problem		-Safety is less guaranteed during excursions on the ice. Ice can

	-24h bear and ice watch necessary -Power failure easy -Sensitive to ice dynamic Hypothermia, injuries etc. -Has to be in easy flying distance to coast if something happens		break out. Polar bears, hypothermia etc.
Logistics:			
Installation of site	-Difficult by plane -Site selection by opportunity -Has to be in flying distance to coast and need long runway! -Installation in the dark of winter not possible -Communication and data processing needs to be installed	-Ice breaker affects ice in its direct vicinity	-Logistics are influenced by field station e.g. national interests etc.
Occupants	-Scientists burn out quick -In the winter occupancy low -Food and living quality limited -Visitor not easily accommodated		Activity of many people increases pollution
Energy	Very limited if it is clean Climatic sensitive	-Energy associated with emission except atomic ice breaker	-Energy mostly involves emissions
Access	Air supply depends on weather light and ice condition.	Air supply depends on weather light and ice condition	Air supply only depends on weather
Supply/Storage	Supply in the dark and during summer is difficult Very limited storage capacity Supply has to occur more often Heavy equipment difficult to deliver		-HAZMAT is subject to field station policy. E.g. no radioactivity for certain field stations
Costs	High	Very high	

2.2.2.2. Possible form and combinations of platforms for OASIS:

Combinations:	**Pros**	**Cons**
OASIS ice breaker with ice camp cluster	-Central icebreaker node offers all advantages of logistical support (see above). -Ice camp cluster can be visited and occupied but require less logistical support which allows a cleaner local environment and a focus on the scientific objectives. -A centralized icebreaker allows for more and smaller ice camps scattered around the ship (100m to 1 mile), which enhance area coverage and can be accessed by foot, snowmobile or helicopter. -Management of ice camps is easier and safety, moral, data communication, and technical support are increased. -Scientifically a broader range of measurements can be carried out than if we use only an ice camp or icebreaker.	The air polluting influence of icebreaker requires ice camps with different contamination priority to be located at different distances to the ship.
Ice camps of opportunity	-Low cost -Allows several Arctic regions to be	-Limited amount of measurements and occupants possible,

	compared -Overlap of OASIS projects with other programs	-Pollution aspects not solved, -Integration and coordination of OASIS scientific activities of such camps requires careful data evaluation
Ice breakers of opportunity	-Low cost -Allows several Arctic regions to be compared -Overlap of OASIS projects with other programs	-Limited amount of measurements and occupants possible, -Pollution aspects not solved, -Integration and coordination of OASIS scientific activities of such camps requires careful data evaluation
Reference coastal field station	-Much lower cost, -Allows a reference of processes that influenced by landmasses -Many field station allow historical data to be included (temporal aspect) -IPY historically relied on field stations	-Limited amount of measurements and occupants possible, -Measurements require travel from land to sea (sea ice) -Pollution aspects not solved

2.2.2.3. Icebreakers

An icebreaker offers a unique logistical platform that can be used as large mobile platform to conduct transect work in ice covered seas or frozen directly into sea ice. During transect work geographical gradients can be assessed prior to freeze up in fall, likewise large scale spatial gradients can be determined again at the end of deployment. A fundamental advantage of icebreakers as logistical hub frozen into the ice is the flexibility in site selection during transect work which allows to place measurements into a larger spatial context. The sites of freeze in can be chosen independent of ice thickness which significantly extends the time period in the fall during which fluxes and processes relevant to the science objectives of OASIS can be studied; in particular through very thin an permeable sea ice. Icebreakers may carry a full suite of instruments already on board which allows an immediate start of scientific activities as the ship is brought into position and freezes in. This creates a unique scientific opportunity to conduct process studies around an artificially created lead. As icebreakers can reposition over small distances in winter, predictable leads of several 10-100's of meters can be renewed allowing a predictable opportunity for synoptic comparative flux and process studies between leads and a consolidated ice pack.

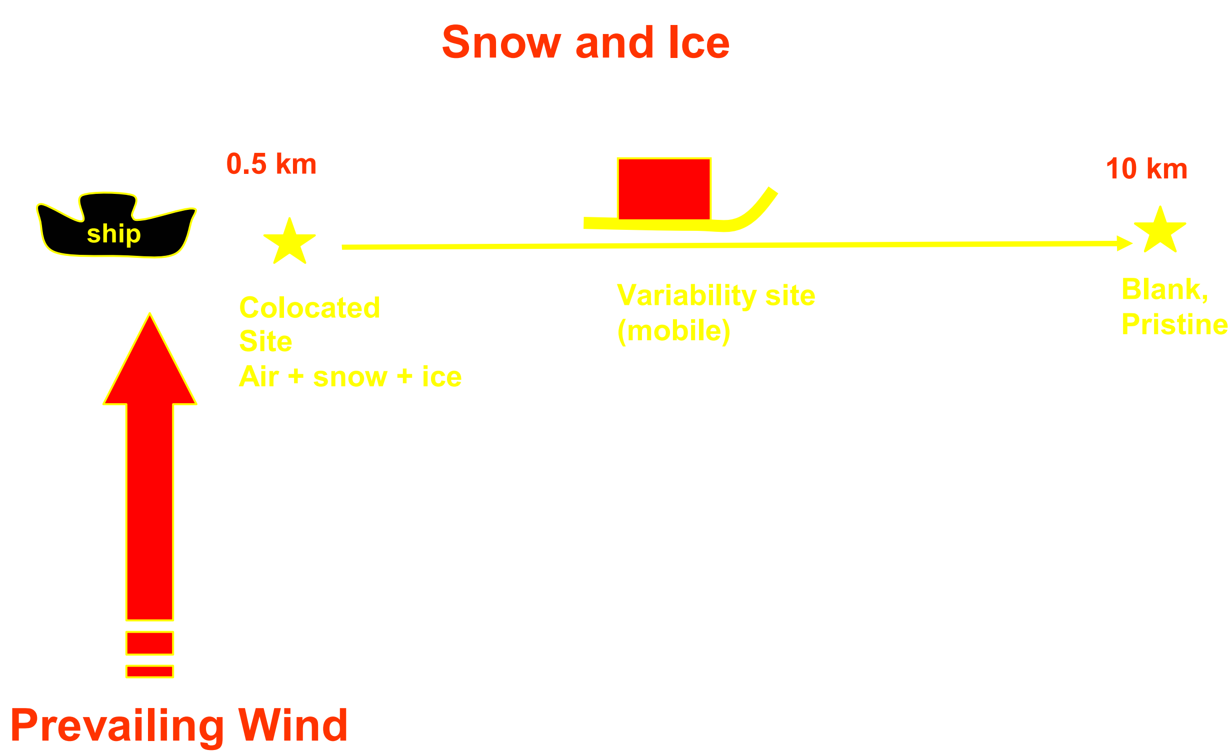
2.2.2.4. Ice camps

Ice camps are required where measurements are compromised if performed from the ship. Such camps will typically involve an assessment of the natural background processes free of anthropogenic pollutants or processes that are sensitive to contamination by ship exhaust. 2- 5 ice camps will be operated during winter until summer at different distances and directions from the ship in a range of 100-1000 meters according to scientific requirements and prevailing wind directions. Occupation of ice camps depends on the temporal resolution of processes, automated instrument capabilities and remote power supply. We anticipate having a minimum of two classes of ice camps separated with respect to their contamination tolerances. It is anticipated that the cleanest ice camps be situated furthest away from the ship to minimize ship exhaust. These ice camps will have an alternative means of nonpolluting energy supply and the option of sleeping facilities for 3- 5 people. Continuous communication with the ship will allow researchers to stay uninterrupted on site for a maximum of one week before supplies have to be brought in. Ice camps with regular requirements will be clustered around the ship at distances <100 m. These camps will harbor automated instrumentation measuring fluxes continuously across the OASIS interfaces. Daily occupation of the camp will be possible through a sheltered facility, however with no sleep over opportunities.

2.2.2.5. Location of independent ice camps

Frequency and extent of leads, and permeability of ice and snow are key environmental variables which regulate the fluxes across the OASIS interfaces. For the implementation of OASIS, relevant measurements from comparative sites that offer a mix of multi- and first-year ice interspersed with opening and refreezing leads and sediments are preferred. To allow for Arctic Ocean basin wide scaling of processes, the site has to selected along the criteria of remoteness from terrestrial influence and pollution. Basin wide representative ice cover and sediment load have to be considered since the ice breakers capabilities to withstand ice deformation have to be met. Pack ice consisting of first- and multi-year sea ice appears to be the primary choice of sea ice. Pack ice in the Eurasian sector of the Arctic is less subject to deformation than the Canadian sector and has supported the drift of Fridjof Nansen in the past (Link to IPY). It appears therefore more suitable for a pack ice drift station. Logistic support from a land-based hub, preferentially a low populated island, has to be within flying distance. Tentatively we have outlined a geographic location that best overlaps with the spatial coverage which are potentially provided with other icebreaker cruises during the IPY activities, for example the icebreaker Oden. Currently we are looking at positioning and drift with the transpolar drift from the northern extends of the Laptev sea to the Fram straight with logistical supply from Spitzbergen and potentially a land based field reference site in Franz Josef Land which has a Biological field station operated from Murmansk Russia.

2.2.2.6. Requirements at each site



Imperative to the success of OASIS is a consistent core measurement program that will allow integration of individual comprehensive case studies targeting detailed processes into a comprehensive annual and geographical context. This basic core program is outlined in the following section along with its logistical requirements. At the base of the core program is the annual evolution of stocks and vertical fluxes of reactive chemical species and atmospherically relevant particles across the respective OASIS interfaces and boundary layer. Scientific activities will change and increase as critical photochemical processes during sunrise and vertical fluxes in warming sea ice during springtime change.

A site is a location where numerous pits and ice cores will be studied in order to obtain representative samples. There are basically three types of sites:

- 1 colocated measurement site (at the air/snow chemistry site) (ca. 0.5 km)
- 1 blank site (as removed as possible from pollution, for snow chemistry blank measurement) (ca. 10 km). This site MUST be kept pristine.
- variable sites to investigate spatial variability between colocated and blank sites, and beyond

2.2.2.6.1. Blank site or "ultra-clean" site

This site will be located approx 10-20 km upwind from the main ice camp and will be largely dedicated to automated atmospheric instruments, including an ozone analyzer, DOAS and meteorological instruments. Passive air samplers (consisting of housed PUF-disks) for POPs will be deployed on a horizontal transect away from the ship and out to the blank site, to assess the influence of the contamination 'halo' associated with the ice-breaker and associated activities. The site will be installed with wireless communications (for data download) and a web-cam so that conditions can be assessed remotely before travel. Electrical power will be supplied from an array of batteries, providing approx 200 W, sufficient for the instrumentation. Trips to this site to replace the batteries, as well as conduct specific short-term experiments, will require that the site is equipped with basic emergency equipment and a shelter.

- Bear proof work shelter
- Emergency equipment (food, first aid, gun, sleeping bags etc.)
- Very restricted access

2.2.2.6.2. Co-located site

- Power
- Shelter
- Clear access rules to protect snow study zones

2.2.2.6.3. Variability sites

- Limited clean power (fuel cells, batteries ….?)
- Portable Bear proof work shelter
- Survival kit

2.2.2.6.4. Aboard ship

Cold sample storage (< -10°C), liquid nitrogen, chemical storage, and cold laboratory space (-20°C for ice thick and thin sections), (this could be also at co-located ice measurement site) are required on the ship. A wet chemistry laboratory is required for sample processing for trace metals and organic contaminants. This lab will have sufficient floor and bench space for snow-can storage and handling (cans will have to be stored to allow snow melt). The laboratory will require a fume hood for the use of solvents like methanol, acetone and hexane. Solvent storage (flammables) cabinets will also be part of this lab, along with running water and an ultra-clean water supply (i.e. Milli-Q). A laminar flow hood would be required to prepare air samples prior to deployment. Cold facilities would also be required for sample storage. Ideally, a clean air laboratory would also be required for sample media preparation and analytical work.

2.2.3. Basic core measurement program

2.2.3.1. Atmospheric Boundary Layer Characterization (CWF)

The surface fluxes of interest to OASIS are the result of interactions between the surface and the lower atmospheric boundary layer (ABL). Thus, the OASIS program requires extensive monitoring of ABL structure. Height profiles of conventional meteorological variables (wind speed/direction, temperature, and humidity), selected chemical constituents (e.g., ozone, N-species), aerosols, and cloud properties are all of interest (Table 1). A combination of continuous monitoring by surface-based remote sensors and periodic samples by profiling instruments such as e.g. rawindsondes and/or tethersondes will be used. The approach used in the SHEBA program (Uttal et al., 2002 BAMS) will be updated and adapted for OASIS purposes.

A combination of measurements of wind-profiles, temperature and humidity polarizing capabilities, ozone, and LIDAR applications will allow connections between cloud microphysics and the ABL aerosol properties.

Most of these systems can be operated directed from a central ice camp or installed on the deck of the ship. Chemical measurements need to be performed directly at the ice/atmosphere interface.

2.2.3.2. Surface Fluxes and Heat Budget (TNP)

The surface exchanges of heat, mass and momentum represent boundary forcing for OASIS processes and fluxes that are ultimately affected by ice in its varied forms. Vertical exchange fluxes (Table 1) can be monitored through the deployment of tower and ground-based automated sensors (e.g., SHEBA-type tower – Person et al., 2002) within the surface boundary layer in conjunction with a sampling routine to monitor the surface and surface volume morphologic, biogeophysical and biogeochemical properties of ice and water. It is important that a deployment plan caters to both time series (at a place over time) and distributed (at several different places) sampling so that variation can be characterized. We propose the deployment of a central flux monitoring facility (main facility - MF) around which a number of smaller distributed stations (distributed facility – DF) can be located (Figure – to follow). Power required by the MF will be supplied by diesel generator. Power requirements at the DF will be met using solar panel, wind generator, battery array. The high data volumes associated with each node of such a network can be directed to one central data acquisition depot given recent technological advances in data monitoring and wireless data transmission.

Table 2.2.2.2. Targeted surface fluxes and variables in support of OASIS objectives.

Subgroup	Measurement	Frequency	Method
Surface Turbulent Fluxes[1]	heat[2], H_2O^2, CO_2^2, O_3^2, NOx/HONO, DMS, particulates, Hg (RGM, EM)	sub-hourly	tower-based EC, EA, profile

Radiation Fluxes[2]	solar, long-wave, par, uv	sub-hourly	radiometers
Surface-Meteorology[2]	u, air, snow and ice temperature structure, atm pressure, humidity structure	sub-hourly	tower-based
ABL Sounding	temperature, wind, pressure, humidity, ozone	12 hrs	sonding
Surface-Based Atm. Remote Sensing	temperature, wind, ozone, aerosol, cloud micro, liquid content	sub-hourly	sodar/radar/lidar/MW profiler

[1] Deployment to support eddy correlation (given the availability of fast response sensors) or eddy accumulation and profile techniques in those instances where fast response sensors are not available.
[2] Also monitored at distributed sites.

2.2.3.3. Measurements on the moving platform

Variables monitored while the ship is underway are shown in Table 2.2.2.3. Fluxes of heat, moisture, CO_2, O_3, and DMS will be monitored using fast response sensors that will be deployed 10 m above the bow of the ship using the eddy correlation technique with fast response sensors for wind, temperature, H_2O, CO_2, O_3. Incident radiation fluxes. Up-welling solar radiation and surface temperature.

Table 2.2.2.3: Proposed variables for the mobile phase.

Variable	No.	Frequency
$U_{u,v,w}$	one level	fast
CO_2	"	fast
H_2O	"	fast
O_3	"	fast
$U_{u,y}$	"	slow
T,RH	"	slow
$T_{snow/ice}$	"	slow
Ts	"	slow
SW↓,↑	"	slow
LW↓	"	slow
UV↓		slow
PAR	"	Slow

2.2.4. <u>Snow-Ice Geophysics</u>

Snow and sea ice geophysics will characterize the snow and sea ice with respect to its volume structure, composition, reactivity and thermal and optical properties, spatial and temporal variability, and evolution and connectivity to the atmosphere and sea ice system. The variables associated with snow and sea ice geophysics are listed in Table 3.

Table 2.2.3.1: Proposed variables associated with snow/ice geophysics.

Symbol	Variable	No.	Medium
ρ_b	bulk density	profile	ice/snow
σ_b	bulk salinity	"	ice/snow
microstructure	microstructure	"	ice/snow

Periodic snow and ice thickness surveys will monitor spatial patterns of snow accumulation and redistribution.

During the overwinter phase, surface-based radiometer (19, 27, 36 GHz) and scatterometer (5 GHz) will be deployed on the ice within an EMR sampling region. Sampling will cover a variety of snow accumulation environments. Similarly, for the mobile phase, surface-based radiometer

(19, 27, 36 GHz) and scatterometer (5 GHz) will be mounted on the side of the ice breaker, imaging different ice/water environments within sensor fov. Airboat sampling will support EMR interpretation.
Snow and sea ice geophysical measurements are included along with measurements of snow chemistry and contaminants in Table 2.2.3.2.

Table 2.2.3.2: Targeted snow and sea ice properties in support of OASIS objectives.

Subgroup	Measurement	Frequency	Method
Snow Chemistry	Major ions, Hg, VOCs semi-volatile organic compounds (SVOCs) including POPs/pesticides POP-isotope tracer experiments	days	snow pit sampling and analysis
Snow Geophysics	stratigraphy, density, wetness, μ structure, surface area, permeability, diffusivity, thermal conductivity	days	Snow observations, snowthick sections, tracers
Snow Optical Properties	(reflection, transmission	days	radiometers, photocells and light transducers
Snow	trace gas	days	syringe, flow intakes, GCs
Snow Distribution	depth distribution	days	EM induction, stakes, transects
Sea Ice Geophysics	stratigraphy, density, μ structure, surface area, permeability, diffusivity, thermal conductivity	days	cores, thin and thick section analysis, tracers
Sea Ice/Brine Chemistry	isotopes, carbon biogeochemistry, chlorophyl a, brine pollutants, particles, organic contaminants/POPs	days	cores, brine extraction and analysis
Mass Balance (snow and ice)	depth, thickness, SWE, accumulation	days	EM induction, stakes, transects, sonic range finders
Melt pond studies	area, distribution, depth/dimension, chemistry, basal geophysics	days	airborne remote sensing, water/ice sampling

2.2.5. Chemical contaminants, POPs and mercury

A site will be dedicated to large volume snow sampling for the analysis of POPs, pesticides and mercury. This work will be supported by air sampling for these chemicals. For POPs this will involve the use of a Hi-Vol air sampler operating at a sampling frequency of approx. one sample every 24h (~1000-1200 m^3 air). Ideally this Hi-Vol will be located close to the contaminants snow sampling site. Snow samples will be collected (upwards of 100 L of fresh snow) and transported back to the ship for melting and processing. Ideally, the sample site will be co-located with the Snow Sea-Ice Geophysics site, in order for appropriate snow types and snow layers to be identified, and accompanying physical measurements to support contaminant data. Large volume snow cans (50 L), will require the use of sledges/paulks for transport away from the immediate vicinity of the sample area, with subsequent use of a snowmobile (with trailer) to transport the cans to and from the ice-breaker. The contaminants snow site will also be used for ice-coring (manual) as well as access to underlying seawater. Again, large volume samples of both ice and seawater will be required for POPs analysis. Meltwater samples and brine drainage sampling would be conducted in this area. This site will also be used for the deployment of both mercury flux chambers and diffusion cylinders; the latter to examine POPs migration into the snow pack. Tracer experiments to determine contaminant fate, will also be conducted and involve the introduction of small quantities (ng) of isotopically-labelled organic tracers into the sea-ice snow pack. This sample area would require erection of a shelter for ice and seawater sampling. The shelter should be able to accommodate four people comfortably, as well as a storage area and bench space.

2.2.6. Biology and Biogeochemistry

In order to understand the role played by sea ice in contributing and shaping the exchange of CO_2 and organic gases, halogens, molecules and particulate material between OASIS, the temporal and spatial evolution of bulk biogeochemical variables (Table. 2.2.5.) in the ice, snow and opening leads has to be known. Imperative to the objectives of OASIS is to determine the source of constituents and their fluxes through the respective OASIS interfaces. It will be critical to sample different ice types, under different snow loads and in opening and refreezing leads to account for the large spatial variability in biogeochemical variables. We envision an experimental test site that will maintain 5 levels of standardized snow depth (light levels and thermal properties) to allow extrapolation of measurements to larger scales. The key core variables to measure include pCO_2, total inorganic carbon, alkalinity, pH, total organic carbon (DOM and POM), molecular and elemental composition, macronutrients (nitrate, phosphate, silicate), and carbon-13 ratios in both the organic and inorganic fractions.

To assess continuously the biogeochemical activity and fluxes of microbial sea ice communities across the ice water and ice snow interface we will deploy a suite of *in situ* sensors and measuring instrumentation for oxygen, CO2, and PAR, DMS.

Ice cores will be collected on a regular basis (at least weekly, possibly more often) for measurements of the parameters that cannot be determined by high-temporal-resolution probes, as well as for ground-truthing and calibration of the *in situ* probes. Measurements on melted samples are listed in Table 2.2.5.

In support of the ice biogeochemistry work, surface water samples representative of the ice-water interface down to the euphotic depth will be measured and analyzed according to variables listed in Table 2.2.5. Vertical density structure is pertinent to understanding the vertical exchange processes and will be measured with a CTD.

Logistical requirement: quick transport between sampling sites and the ship, power for instrumented sampling, both for *in situ* probes in the ice and at the surface water sampling sites; cold and warm ship-board labs for processing samples; frozen and cold sample storage.

Table 2.2.5.1 Biological, biogeochemical, and contaminant measurements in melted ice and surface sweater.

Variable	Measurement	Frequency	Duration	Aut/manual	Man power	Method

Trace gases (cryomatrix)	halogenated , DMS, CCN	2-5 days	Fall-summer	Collection manual	2-(4)	core/sample/water column?
Inorganic carbon cycling	nutrients, carbonate system, organic carbon, oxygen	minutes – 1 per week	Fall-summer	Collection manual; automated		air, ice, surface water
Organic material	Molecular composition, Reactivity, Size spectrum Concentration POC, DOC, Elementary composition, Chl a; pH; stable isotopes	2-5 days	Fall-summer	Collection manual	2-(3)	ice/snow/upper ocean
Vertical organic carbon flux	Molecular composition, Reactivity, Size spectrum Concentration POC, DOC, Elementary composition, Chl a Species composition; stable isotopes	2-5 days	Fall-summer	Collection manual	1	
Species composition and abundance and activity	Bacteria, Protists, (Invertebrates) Size, cell growth	1 per week	Fall-summer	Collection manual	1-(3)	snow/ice/water
Contaminants	Hg, organo-halogen species, stable isotopes (C,N,O) AND OTHERS TO COME?	2-5 days	Fall-summer	Collection manual	2	snow/ice/water/air/biota

Table 2.2.5.2. Biological, biogeochemical, and contaminant measurements from mobile ship (before and after freeze-in).

Subgroup	Measurement	Frequency	Duration	Aut/manual	Man power
Trace gases	halogenated , DMS, CCN	**On route**	**For process 12h station**	**Automated and manual**	**3**
Water chemistry	nutrients, carbonate system, oxygen	**Stations**	**For process 12h station**	**manual**	**1**
Organic material	Molecular	**Station**	**For process 12h**	**manual**	**2**

	composition, Reactivity, Size spectrum Concentration POC, DOC, Elementary composition, Chl a		**station**		
Biota	Species composition and abundance and activity	**Station**	**For process 12h station**	**manual**	**2**
Contaminants	Hg, PCBs	**Station**	**For process 12h station**	**manual**	**2**
Boundary layer air flux	organic halogens and DMS and CCN ice surface	**Station**	**For process 12h station**	**Automated**	**1**

2.2.7. Atmospheric Chemistry

The atmospheric chemistry community will be interested in the following types of measurements at the surface (e.g. ice camps and ice breakers) during OASIS-IPY: ozone, mercury, reactive radicals (HOx, NOx, XO, and SO2), inorganic reservoirs, intermediates, and aerosol precursors (e.g. Br2, BrCl, Cl2, I2, H2CO, HNO3, NOy, HONO, PAN, N2O5, HOX, H2SO4), tracers of pollution (HCs, POPs, CO2 and CO), uv-visible radiation, aerosols (number, size, and composition), aerosol precursors (VOCs, oVOCs, iodocarbons, and DMS), and the state parameters humidity, temperature, pressure, and heat flux. For a variety of reasons, including sampling issues, instrument power and operation considerations, and availability, it is necessary for these instruments to be located in different places and, quite likely, so sample at different times. Two classes of experiments are envisioned, the first to consist of intensives focused at times of maximum photochemical activity (e.g. transit to/from the winter base, with the second consisting of long-term, generally autonomous sampling. Location of the instruments depends largely on the main scientific objectives addressed by the particular measurements as well as logistical constraints.

2.2.7.1. Timing

- August 2007- **Integration** of instruments on ice breaker
- September/October 2007 – **Intensive 1**, measurements in transit to winter ‘freeze-in’ location
- November 2007-March 2008 – **Winter** monitoring phase
- March 2008-May 2008 – **Intensive 2**, polar sunrise (rapid photochemical release of reactives after winter buildup)
- June/July 2008 – **Intensive 3**, Summer photochemical period
- August 2008 – monitoring in **return** to port.

2.2.7.2. Science Themes

2.2.7.2.1. Transit

- emission of biogenic precursors and constituent fluxes, characterization of background long-lived species and radical sources (DMS, halocarbons, CO2, POPs, IO, OIO, BrO, HNO3, NO, NO2, HONO, NOy, oVOCs)

2.2.7.2.2. Intensive 1 (Freeze-in)

- pre-winter 'background' photochemical mechanisms, high NOx, low sulphate/nitrate conditions, aerosol composition and evolution, net deposition to surface for most species, air-sea exchange and fluxes from multi-surfaces (all)
- CO2 fluxes (up or down?) (CO2)

2.2.7.2.3. Winter (monitoring)

- monitoring of important chemical species and Arctic Haze in support of other OASIS activities (e.g human impacts), including characterization of air masses with long lived tracers.
- Evolution of ozone under low halogen oxide loading conditions (aerosol size, number, composition, O3, CO, HCs, halocarbons, oVOCs, PAN, HONO, N2O5, HNO3, NOy, NO, NO2, H2SO4).
- Build up of halogen oxide source gases (Br2, BrCl, and I2)

2.2.7.2.4. Intensive 2 (Polar sunrise)

- rapid photochemical production of halogen oxides, rapid ozone destruction and oxidation and deposition of mercury.
- Partitioning of HOx, NOx, and XO, oxidation of hydrocarbons and air/ice, air/sea fluxes
- Diurnal photochemistry, emphasis on mechanisms of ozone loss
- Particle nucleation

2.2.7.2.5. Intensive 3 (summer)

- Aerosol formation processes, evolution with season, continued emissions of biogenics from ocean w/ breakup of sea-ice
- Photochemistry in 24 hr sun (reduced formation of reservoirs)
- Snowpack emissions of NOx, removal of halogens
- Air/sea fluxes and variability due to melting sea ice, biogenic influences.

2.2.7.3. Potential Participating Institutions

(to be all-inclusive for proposing purposes, so not a complete list, but surely not all will necessarily participate or be funded)

- Georgia Institute of Technology (VOCs, HNO3, H2SO4, HOx, PAN, N2O5)
- Indiana University (HOx)
- University of Colorado (in situ BrO, IO, ozone, NOx, CO2, particle size, number, composition)
- Aerodyne Research, Inc. (particle composition)
- Uni Heidelberg (remote BrO, OIO, IO)
- University of California, Irvine (DMS, Cl2)
- University of Virginia (Cl2, Br2, BrCl, ozone)
- NOAA (many)

- Oak Ridge (Hg)
- CNRS Grenoble (Hg)
- Purdue University (VOCs including formaldehyde)
- University of New Hampshire (NOx, HNO3)
- University of Rome (NOx)
- University of East Anglia (DMS, iodocarbons, HCs, halocarbons, and oVOCs, BrO, IO, OIO, I2, NO2, NO3)
- University of York (DMS, iodocarbons, HCs, halocarbons, and oVOCs)
- Lancaster University (POPs, oVOCs, DMS)
- University of Leeds (HOx, IO)
- Imperial College (HONO, HNO3, HO2/RO2, org-NO2)
- British Antarctic Survey (NOx, CO, O3, actinic flux, H2CO, CPC)
- University of Manchester (aerosol composition)
- C.N.R. – IIA (atmospheric NOx, NO3·, HONO, HNO3, NO3-, NO2- mixing ratios and fluxes, snow ionic composition)
- and many more…

2.2.7.4. Number of participants

- During the intensive periods, approximately 25-30 participants are possible, with some overlap with other groups (e.g. flux, biologists). Individual instruments will be operated by many of the groups, especially for those that are mission critical and difficult to operate.
- During monitoring periods, approximately 5-8 participants are expected, with some shifting in/out of individual members of groups. Multiple instruments will be operated/serviced by the participants.

2.2.8. Chemistry requirements for platforms

Types of chemistry: atmospheric, oceanic, snow and ice

Remote camp - ultra clean
- of order 20km away, "upstream"
- not manned
- would need safety kit
- total power of order 1kW
- remote access to data and remote control of instruments necessary

Main camp - less-clean-but-still-as-clean-as-possible
- power supplied from the ship using power cable (?)

Safety issues - Polar bear!
- travel; electric/4-stroke skidoos..?

2.2.8.1. Atmosphere:

Gases:

- O3 monitor (remote and main camp): 20W (Jan) or 150W (eg. Thermo electron)
- Oxygenated/VOCs – 3 x GCs (2kW) + PTRMS (600W) (main camp)

- Halogens (radicals – BrO; and longer lived - Br2, BrCl)
- Mercury (Tekran analyzer) – (1kW) (main camp + remote camp)
- Passive samplers (POPs) –remote site, main camp

Total power main camp: 4kW + halogens
Total power remote camp: 20W + new, low-power Tekran for Hg

Particles:

- Particle counter – number density, number density vs size, chemical composition (2kW) – main camp
- CPC – (100W) ship
- hi-vol x 3 (spec: m^3/min) (3kW) main camp
- aerosol mass spec AMS (600W), main camp, ship if necessary
- Snow precipitation sampler (plus analysis for pH, conductivity, IC) (500W – ship)
- Fog mesh (1kW) (main)

Total power main camp: 6.6kW
Total power remote camp: 0

2.2.8.2. Snow/ice chemistry:

- Bulk sampling for analysis on ship (POPs etc)
- Hg chamber + interstial air (150w) Main camp
- Brine channels (including cores)

Total power main camp: 150W
Total power remote camp: 0

2.2.8.3. Meteorology:

- Wind speed/direction (std met/sonic anemometer)
- BL structure (sodar) (main camp) (2kW)
- Temperature
- Humidity
- Ultrasonic to measure snow layer height

Total power main camp:3kW
Total power remote camp: 200W

2.2.8.4. Ocean:

- Sampling gear to sample melt water from surface of sea ice
- Sampling surface/depth oceanic water – large volumes
- Surface microlayer sampler
- Sediment traps
- Inflatable boat
- Diving – big tent, warmed

Total power main camp:0
Total power remote camp: 0

2.2.8.5. Heat/vent/lighting

Total power main camp: ?
Total power remote camp: ?

2.2.8.6. General facilities:

Web camera
Radio communication apparatus, wireless technology –link remote camp to ship

- Tower for chemical fluxes (of order 20m) (main camp)
- freezers/fridges at different temperatures
- MilliQ (ship)
- Gas cylinder storage (both ship and main camp)
- Wet chemistry lab - fume hood (re-circulating), flammables store, chemicals store, laminar flow hood (clean for filter changing and mercury)
- "moon pool" or equivalent for launching ocean probes and samplers
- Liquid N2 ? (large volume) production volume ?

Total power: Main camp -14kW + halogens + heat/vent & lighting
Remote camp – 220W + new low-powered Tekran + lighting (& heat?)

2.2.8.7. Manpower:

Issues:
Time of year of interesting science questions
Man-made leads….
Starting point likely to be in Russian waters if science focus off shore of Siberia
Availability of ship might determine the ultimate location
Assume number of science berths available of order up to 50

2.2.8.8. Measurements

Measurement	Frequency	Duration	Activity (automated or no)	Power	Manpower
Gas phase					
NO/NOx	10s	Cont.	Yes		0
NOy	1	Cont.	Yes		1
OH/HO2	10s	Int.	No		2
BrO/IO	1 min	Cont.	Yes		1
Br2/Cl2/BrCl	10 min	Int.	No		2
O3	1s	Cont.	Yes		0
Os smaller	1s	Cont	Yes		0
Met data	1s	Cont.	Yes		0
Hg,RGM-PM	5 min	Cont.	Yes		1
HC	2 H	Int.	No		2
PM					
CPC,	1s	Cont.	Yes		0
SMPS	1s	Cont.	Yes		0
ToF-AMS	1 H	Int.	No		1
Hi-Vol	4 to 24 H	Cont.	No		2
Snow					
Hi-vol	48H	Int.	No		2
Water, Ice,					
Hg					
Total	1s to 24H			15KW	≤ 14

2.2.9. Access

Logistical supply from Spitzbergen and potentially a land based field reference site in Franz Josef Land which has a Biological field station operated from Murmansk Russia.

2.2.9.1. Geographic domain requirements:

1. Important to be far enough away to omit anthropogenic and terrestrial contamination
2. Frozen-in ice breaker as a base of logistic support with a cluster of decentralized ice camps gives more geographic flexibility than a stand alone ice camp
3. Land fast ice although it has the advantage of a fixed location and easier logistical access is thought to be too close to terrestrial influence.
4. To diversify locations it is suggested to use short term opportunity of e.g. nuclear submarine, (ice camp of Arctic Submarine Lab (contact Jeff Gossitt) out of Prudow Bay).
5. Beaufort Gyre vs. polar drift (still open for open discussion)
6. Polyna proximity would be good since a continuous gradient is continuously available (drawback almost to close proximity to land!)
7. Pack ice has logistical support disadvantages (Twinotters also fly in the dark but need a runway) Helicopter can only fly 3 hours but requires visibility.
8. Alternative platform: Franz Josef Land Murmansk Biological station as logistical hub. Ice camps clustered around it.
9. Spitzbergen as terrestrial landstation and logistical hub.

2.2.9.2. Discussion geographic location

- Multi year sea ice vs first year ice what is the scinetific objective. First year sea ice is what the Arctic is changing to therfore more interest for first year sea ice.
- Involvement of OASIS also in short term ice camps of opportunity. Navy ice camp russion ice islands, Oden cruise, Polarstern cruise
- What ice breaker (Russian ice breaker low chnace to get it)
- The critical contamination radius around a ship is 10's of kilometers which can be reached by flight.
- Site selection characteristist site with prevailing winds

2.2.10. When and How long

A continuous ice camp is needed for one ice season (consolidation to ice melt).
To conduct science over a 2-year period a relocation during summer is suggested (reason cumulative contamination and ice to insecure). Different scientific objectives may require different timeframes?

2.2.11. Clean power alternatives for remote clean camps

- **i) Electricity**
- **ii) Heating**
- **iii) Transportation**

2.2.12. Overwintering

2.2.13. Spring Intensives

Scientific activities will change and increase as critical photochemical processes during sunrise and vertical fluxes in warming sea ice during springtime change.

2.2.14. How much would it cost

Back-of-the-envelope calculation of various options?

2.2.15. Specific options, contact information, deadlines for applications

2.2.16. WHO will contact specific groups

2.2.17. First aid training, bear protection

2.2.18. Logistical support

- PCSP (Polar continental shelf project) (Canada logistical support)
- VECO (USA logistic support

2.2.19. Links to other programs

- SEARCH (Unami, Change in the entire Arctic),

- Circumpolar flaw lead Polyna System (Joint North Canadian and Russian project on flaw leads using the icebreaker Amundson).
- Arctic net of excellence (Canadian project; physics, biological chemical medical social of coastal zones, 7 years funding culminating in compressive models)
- ISAPIE (IPY proposal) Interdisciplinary studies of Arctic …… (Olec Piercen). Frozen-in ice breaker. Good time complementary to OASIS time requirements.
- Shelf Basin Interactions (Jackie Grebmayer) spring early summer

2.2.20. <u>Funding opportunities</u>

2.3. Airborne platforms

Needs argumentation where, why and what to measure. Right now ist more a summary or wish list. (cite introduction) and derive an aircraft application plan. That depends critically on the sites, position, number of ice camps, duration of activities and the availability of the ice breaker.

If I write this section it will be dominated by low flying SERA's. I would need some help in argumentation from the bigger aircraft community.

Put all aircraft together according to size (step up or step down) and include only proven technology. Any development that not yet ready now is most likely not to fly within the arctic environment. The wish list of instruments / parameters on page 38/39 needs arguments

Airborne platforms of various sizes and capabilities can play critical roles during OASIS, a campaign whose focus is on elucidating the mechanisms of chemical change in the polar regions, as well as the controls and magnitudes of fluxes of important precursors, products, and intermediates. In particular, equipped with appropriate remote sensors these platforms can be used to characterize important aspects of the surface, including surface temperature and roughness, extent and nature of leads in sea ice, and sea-ice thickness, while mapping out regions of frost flowers for subsequent trajectory analyses critical in defining emissions of reactive halogens. Such information will be critical for defining the two-dimensional environment around fixed measurement sites, such as the buoys, ice breaker, and ice camps. In addition, small aircraft can be used in a 'response' mode to investigate interesting events that might appear in the data from fixed stations. This would include searching for regions of new frost flowers following detection of bursts of BrO, documenting the evolution of leads behind the ice breaker, and examining the meteorological structure of the boundary layer, including the extent of aerosol/cloud layers and depth and severity of ozone depletion.

It is envisioned that four classes of airborne platforms will be useful for these studies. These will be presented and discussed in order going from smallest to largest (e.g., also from least to most complicated logistical considerations). These classes are (1) tethered systems operated by individual investigators located at the fixed stations, (2) miniature autonomous aerial vehicles such as the Aerosondes and helicopters operated by small teams of investigators, (3) small (piloted) environmental research aircraft (SERAs), and (4) medium-lift, multi-investigator aircraft. We will also address the potential use of vehicles of opportunity, such as large aircraft (e.g. DC-8) and aircraft and helicopters used to service the fixed sites (e.g. buoys, ice camps, and ice breaker). With the exception of the medium-lift aircraft, the roles for the airborne platforms will be in providing a broader geographic context in support of the science objectives of the surface measurements (e.g. like satellites, only more local and immediate response). The medium-lift aircraft will be equipped with instruments to examine issues that cannot be addressed adequately from the surface sites, such as variability of important constituents over broad regional scales and the impact of surface and boundary layer processes on the free troposphere.

Note: The airborne group decided that the DC-8 is not the appropriate platform for OASIS. However, the OASIS group should encourage augmentation of the DC-8 payload during 2007-8 with instruments that can address OASIS goals. Examples include measurements of free radicals (HOx, NOx, ROx, XO) and nitric acid, aerosol composition, CO2, formaldehyde, CN, SO2, VOC, ozone and aerosol lidar, etc.). Emphasis must be on obtaining profiles in the boundary layer, presumably on approaches and landings. Is it possible to do downward looking remote sensing (e.g. of sea ice, surface roughness, chlorophyll).

2.3.1. Medium lift aircraft (e.g. NCAR C-130, BAe-146, NOAA P-3)

Two aircraft equipped with different, yet complementary, payloads are envisioned for important operations during OASIS. Additional aircraft may be useful (e.g. Dornier, Falcon, etc.), however this group focused on those platforms that could make essential contributions to OASIS. Additional input on contributions by small-to-medium aircraft is encouraged.

2.3.1.1. Science objectives

<u>The following will be carried out with medium-lift aircraft equipped with instruments outlined in Section 2.4.X.3:</u>

1. Elucidate mechanisms and rates for chemical transformation and cycling in the boundary layer at the sea-ice/ocean interface
2. Examine aerosol/gas interactions, particle evolution, and new particle formation.
3. Determine fluxes of reactive and radiatively important chemical constituents, heat, and momentum and their relationships with underlying surface characteristics.
4. Characterize the surface (e.g. roughness, ice thickness, temperature) at *10 m resolution* over broad regions and at high resolution (*ca. meters*) around the “ice camps” (100 km x 100 km region).
5. Examine the influences of boundary layer/free troposphere exchange on regional chemistry.
6. Determine the particulate sources of chemical impurities to the snowpack.
7. Examine the relative roles of anthropogenic and natural processes in the Arctic region.
8. Linking measurements and cross validation of sensors from surface sites.
9. Validation of satellite observations (e.g. ice thickness, surface roughness, tropospheric constituents).

2.3.1.2. Logistics

Main Bases of Operation - There are a number of air strips in the Arctic from which to stage flights that address the objectives listed above.Possibilities include Churchill, Alert/Thule, Longyearbyen, Barrow, Sondrestrom, , and Tromso, among others. Selection of several optimal locations will be based on proximity to the ice breaker and fixed camps, but if possible they should be located on opposite sides of the Atlantic Ocean for maximum sampling range over the course of a campaign. Ground support personnel for the specific aircraft recommended will assist in preparation of plans for logistical support, including arrangements for local ground support, fuel, and working with local authorities and air traffic control for operations. Because the aircraft essentially operate as 'flying laboratories', support for individual investigators at each base is expected to be minimal. Instrument teams will stay in local hotels.

Flight Plans – Two types of flights are envisioned, transit and local. Transit flights included those to and from the home base of the aircraft and between main bases. Local flights are those for which the aircraft take off and land at the same base. A typical series of flights includes:

- Days 1-2: transit flights from home base to the Main Base I with one stopover
- Day 3: down day for instrument maintenance
- Day 4-7: several local flights of 5 hour duration from Main Base I
- Day 8: down day for instrument maintenance
- Days 9-10: transit flights from Main Base I to the Main Base II with one stopover
- Day 11: down day for instrument maintenance
- Day 12-15: several local flights of 5 hour duration from Main Base II
- Day 16: down day for instrument maintenance
- Days 17-18: Transit flights back to home base with one stopover

Transit flights from the home base will take place predominantly in the free troposphere. The transit flights between Main Bases will include some profiling and segments in the boundary layer for limited periods. Local flights will include frequent sampling in the boundary layer and profiling over regions of interest, including areas with frost flowers, leads, sea-ice margins, and open ocean. Extensive profiling will occur near surface measurement sites, especially the ice breaker and ice camps. At least one of the local flights in each series will concentrate on mapping of the surface around the ice breaker and/or ice camps. Finally, flight legs to link buoy measurements will be an important priority? The aircraft may also engage in Lagrangian flights guided by balloons launched from regions of particular interest.

1. Dates – Likely 3 intensives of 3-4weeks and staggered approximately 6 months apart. E.g. Sept-Oct 07, April-May 08, July-Aug 08. Exact dates will depend on the schedules for the ice breaker intensives and overlapping objectives of the surface and airborne campaigns.

2.3.1.3. Payload

Two payloads with different emphases are envisioned for this contribution to the OASIS-IPY project. The first, with a surface remote sensing emphasis, is best suited for an aircraft such as the NCAR C-130. The second, with an emphasis on in situ measurements of aerosols and reactive gases, is best suited for an aircraft such as the BAe-146. There would be some overlap between payloads to allow some critical measurements to be extended in space and time. The following table lists the measurements that are possible from each aircraft, with prioritisation to correspond with the main science objectives outlined in the Science Plan. For purposes of this document, these objectives are broken down into three categories: (A) surface characteristics, including ice thickness, roughness, and temperature, (B) photochemistry, (C) long-range transport and regional impacts, and (D) aerosol and cloud properties.

The *instrument list that was originally here will be put in a table – with columns representing (1) Measurement, (2) organizations, (3) frequency or resolution, (4) platform, (5) Scientific issue addressed.*

2.3.1.4. Data Management

Data protocols have already been developed for these aircraft, and it is proposed to use those protocols for OASIS. In particular, preliminary or 'first look' data are generally made available to all aircraft investigators within 6 hours of landing for flight planning purposes. When an internet connection is available, these data will be placed on an archive that can be accessed by all OASIS investigators. A post-flight report will be circulated by voice/fax/email to the investigators at the surface sites and other aircraft to assist in their operations. Final data will be made available 6-12 months after the campaign. A typical format for data might be the NASA STEP (Gaines-Hipskind) time series for most constituents. Remotely sensed data will be in the format that is normal for those instruments (e.g. image or curtain files).

During periods when instruments will be measuring on the ground, protocols that are consistent with those generally used for ground-based measurements with UT as the time base. Preliminary data will be generated once every 24 hours with final data being submitted to the OASIS archive within 6-12 months after the last campaign.

2.3.1.5. Links to other programs

The primary links of the aircraft component will be:

(1) With surface sites (icebreaker, ice camps, etc.)

- To characterize ocean, snow, and ice in order to place the surface measurements in a broader geographic context
- To characterize the horizontal variability of parameters and constituents around the surface sites
- To characterize air masses that 'feed' the surface sites.
- To provide vertical profiles of parameters and important constituents that are also measured at the surface sites
- To provide measurements of complementary parameters and species that are not measured at the surface sites.
- With the assistance of trajectory analyses or lagrangian balloons, aircraft measurements downwind of the surface sites can address rates of important processes.

(2) Between medium-size aircraft

- Coordinated and stacked flights will serve to intercompare measurements, expand the data set from that of a single aircraft, and evaluate the radiative budget.
- Flights at different times and dates can serve to extend geographic and temporal coverage.

(3) With Aerosondes and SERAs

- Assimilation and integration of remotely sensed data from multiple platforms will serve to put the higher resolution, smaller footprint data in a larger geographic context.
- With real time communication, the medium sized aircraft can be used to guide the smaller aircraft to regions of particular interest, such as leads and regions of frost flowers.

(4) With buoys

- The medium sized aircraft will be the only feasible way of interconnecting the buoy measurements.

(5) External links

- The aircraft measurements of atmospheric constituents are an obvious augmentation to programs such as ITCT-Arctic.
- Sea ice measurements will be of great value to the ocean sciences and climate communities.
- Links with satellite communities, including intercomparison and validation (e.g. ICESat, SeaWIFS, GOME, SCIAMACHY, OMI, TES, MODIS, MERIS, Cryosat)

2.3.1.6. Organizations and People

- FAAM and NCAR (NSF) essential for aircraft allocation
- Multi-investigator – too long a list to go into detail – for individual instruments. Should identify a team of PIs to propose the use of these aircraft for OASIS. Possibilities are:
- PIs on proposal for aircraft
    - 146 - Hugh Coe, Alistair Lewis, Dwayne Heard, Claire Reeves, Bill Sturges, John Methven, Rod Jones
    - 130 – Fred Eisele, Barry Lefer, Darin Toohey, Greg Huey, Jennie Moody, Julie Haggerty

2.3.1.7. Special considerations –

large project, with considerable logistics issues, including hangar, support, gases, fuel, etc. POPs maybe not available on aircraft. There should be reliable real-time radio contact between aircraft during coordinated flights and between the aircraft and the surface sites during fly-bys.

2.3.2. Small Environmental Research Aircraft (SERAs)

SERA's are increasingly used for regional three dimensional studies in lower elevations covering the planetary boundary layer. Their properties allow to fly very low above the surface and the low cruising speed compared to large aircraft facilitates high spatial resolution measurements. Additional the ground logistics necessary are less stringent compared to large aircraft. These aircraft are a necessary requirement to link local measurements on the ground to regional scale processes.

2.3.2.1. Science questions:

1. The quantification of emission and flux of surface compounds into the atmosphere where these compounds either can photochemically react or contribute to secondary aerosol production. End products of both photochemical reactions and aerosol production have significant impact on the arctic environment by changes in the regional radiation budget

in the lower troposphere. Quantification of the source processes and the budget of regionally produced climate relevant compounds as well as the transport of these compounds into the free troposphere is a requirement for future scenarios considering shrinking sea ice surface areas following future global warming.

2. Detailed observations of surface properties like spectral albedo, frost flower distribution, snow surface optical properties, frequency of leads and polynas that are more difficult from high flying aircraft or impossible from satellites are also required to be able to quantify the importance of surface processes investigated in local or laboratory studies.
3. Surface observations or data gathered in the planetary boundary layer on a regional scale of about 100 to 100 km also can be used to link ground based measurements to satellite remote sensing investigations and serve as ground truthing activities.

2.3.2.2. Logistics

1. SERA's are typically available on a campaign basis of about 4-6 weeks duration and are likely to be used in connection with other ground based measurement intensives although there are also demonstrated possibilities to perform routine vertical soundings with a limited set of automatically running experiments.
2. The harsh environmental conditions afford a limited ground infrastructure that includes a shelter for the aircraft and some facilities for storage of instruments under moderate ambient conditions. Thus SERA's are most likely to be operated from existing airfields around the Arctic Ocean like Barrow or Alert, that offer also other important logistical facilities like radio communication networks. SERA's mostly can be disassembled within a short time and stored in Containers if no hangar is available.
3. In case that the position of the icebreaker or the icecamps is out of reach of the limited range of these aircraft a local application at the location of the icebreacker can be considered as well with additional logistical efforts. The very small versions of the SERA's might be also by transported by mid size aircraft like the Twin Otter to their final location of application. Leaving a basic Trike (gravity controlled aircraft) like the microlight operated by the FZK (see also www.eufar.net) on an icebreaker for the whole duration of the activity and transporting only the instrumentation to the arctic would be another cost effective option.

2.3.2.3. Data Management

Data management on the small standalone platforms is a well established procedure due to the continuous involvement of these aircraft into international projects. Standard aircraft data protocols apply similar to the large aircraft facilities and standard sets of aircraft data are typically available within hours after landing for campaign planning or modifications of flight plans throughout a campaign.

2.3.2.4. Links

Links to other programs: The use of small aircraft enables to link icebreacker , ice island and other local studies within OASIS to regional investigations and finally to satellite remote sensing. The surface studies planned in OASIS provide among other parameters a wide data base for radiation and energy budget studies in the context of other proposals (see for example 'Polar light effects'), the characterisation of the changing albedo and the structure of the planetary boundary layer is a basic requirement for any satellite retrievals.

Especially the open versions of the SERA's allow easy attachment of sampling devices for other research in access to the already installed sensors. Many SERA's also use a modular pod system for the instrumentation. Depending on the application, the instrument set thus can be very flexible adjusted in short time to different science questions.

2.3.2.5. Funding

Likely funding comes from national funding agencies where costs for aircraft compared to larger aircraft facilities are not the main cost in the program. The scientific payload, the operation of the instruments and the data processing are typically the main fraction of the cost of the operation of small environmental aircraft.

Advance planning is similar to the larger aircraft and has to be finalized typically one to two years in advance due to the involvement of the limited number of instrumented aircraft into several national and international programs.

Communication to the ground stations is normally done through radio communication.

2.3.2.6. Instrumentation

Most of these aircraft that are proposed to be used within OASIS carry instrumentation for detailed micrometeorological studies like turbulence and flux measurements of CO_2 and heat and water vapour. Others add remote sensing instruments like multispectral analysis or surface properties.

A short list of proposed aircraft is added in the following table: a detailed description of these aircraft can be found under the links given in the table

Aircraft	Operator	Instrumentation	Link
Sky Arrow	SDSU	Micromet, CO_2, H_2O Fluxes, Remote sensing Surface properties	http://www.sci.sdsu.edu/GCRG/ www.naers.org www.eufar.net
+ Several Sky Arrows with flux instrumentation available in Italy			
Microlight	FZK-IMK-IFU	Micromet, CO_2, H_2O Fluxes Shortwave radiation Budgets, Albedo Aerosol size distr. Aerosol optics Surface temperature Video documentation	www.ifu-fhg.de www.eufar.net www.naers.org
DIMONA	Metair	Micromet, CO_2, H_2O Heat Fluxes Air Chemistry, VOC's CH_2O, NO_x, NO_y	www.metair.ch www.naers.org www.eufar.net
DIMONA	ARA	Micromet, CO_2, H_2O	http://www.airborneresearch.com.au/

Heat Fluxes	www.naers.org
Aerosol, Chemistry	
Shared with FZK or Metair	

DIMONA's and Microlight are using exchangeable Pod's for flexible applications.

2.3.3. UAVs (e.g. helicopter, aerosonde, pilot optional Sky Arrow, Predator).

UAVs have advantages in cost and/or where conditions are not conducive to piloted operations. Payloads and capabilities vary widely with the platform type and size.

2.3.3.1. Science questions to be addressed.

1. **Helicopter:** Determine the surface heterogeneity in surface conditions around operator/base station/icebreaker. Coverage 2x2 km. Multi-spectral (three band), surface temperature, true color, Gyro stabilized, remote controlled cameras.
2. **Light winged aircraft (e.g. Aerosonde):** Determine air temperature, humidity, pressure, wind speed and direction, multi-spectral digital photographs, true color photographs, video photography, and skin temperatures over distances as great as 1000km from the launch site. Map ice conditions, including ice and lead features, melt ponds, and surface temperature, photograph the surrounding area, and acquire concurrent atmospheric data along transects and vertical profiles over the sea ice. Determine ice roughness (laser profiler), surface moisture (using a miniaturized synthetic aperture radar in development), radiative fluxes (pyranometer in development).
3. **Pilot Optional Sky Arrow**: The PO Sky Arrow is in development. Science objectives and capabilities would be similar to those listed below, except that once "trained", the Sky Arrow would operate without a pilot in conditions not sufficiently safe for human flight, or where VFR conditions do not apply.
4. **Predator**: Capabilities and science objectives are similar to the Sky Arrow below except for greater range and extended airborne duration.

2.3.3.2. Logistics (where, when, how).

1. **Helicopter:** Helicopter package is cheap and easily transported. It could come and go with operator. It requires only unleaded gasoline for operation. Currently, it operates on visual control, with a base station LCD to track it's field of view. Laser altimeter gives height for scale. GPS gives location. Payload, about 2 pounds. Three band imaging camera is about 1.5 pounds. Includes laser altimeter, infrared thermometer, three band camera. Alternatively, it will fly non-imaging hyperspectral. These should be deployed with all ice camps and base stations, and at Barrow to fly from Barrow.
2. **Light, winged aircraft (aerosonde):** These require a heated base station with maintenance tools, communication devices, and diagnostic tools. The base station materials would be installed for the duration of the project. Components could travel with investigators. Aerosondes should be operated at all large operational centers (e.g. Ice Camp, Barrow, Ice Breaker).
3. **Pilot optional aircraft (e.g. Sky Arrow):** These aircraft are still in development, but could be ready for the beginning of the OASIS campaign. Since flight distance is limited (ca. 400 km) at the current time (it could be extended to 2,000 miles), the POA will need to

be shipped in a container, or airlifted in a container to its area of operation. Needs included a heater hangar, power, basestation, diagnostic and repair equipment. An FAA certified mechanic may need to be transported to the aircraft, should their be problems. At least two support persons are required with the aircraft (mechanic and pilot/imprinter). To be deployed at Barrow and Ice Camp.

4. **Predator:** Support equipment to be determined. Range may allow it to be flown in from mainland as needed. Portable, heated hanger, diagnostic tools. To be deployed at Barrow and Ice Camp.

2.3.3.3. Links to other programs

This UAV program is synergistic with a number of other programs, including NSFs UAV program, OPP's ARCSS SNACS program, NSF's Biocomplexity Program, NSF's NEON program, other IPY projects (e.g. Back to the Future).
Data from the UAVs will be provided to the public and to K-12 education through existing programs including PISCES, LTER School Yard Program, Inupiat Heritage Museum, and the NSF DTS real time data project.

2.3.3.4. Funding

Funding will be solicited from NSF OPP and the EU for their contributions to the IPY, as well as from NSF OPP's SNACS, MRI, sensors, and UAV programs.

2.3.3.5. Timeline

No special time line is required for the unmanned helicopter and the Aerosonde or equivalent programs. Communication among PIs will be necessary to finalize payloads and instrumentation and timelines. Small UAVs will be available, as needed, throughout the course of the experiment. Timing will be PI handled, with arrangements made through the appropriate arctic logistic support offices (e.g. VECO, Arctic Operators, Canadian Polar Shelf, etc.).

POA will require additional development. Significant progress has been made by the Americans and Italians working with the Italian firm 3I in Rome. A finished, tested, product is possible by the start of the campaign. It is proposed that this product be dedicated to arctic research for the course of the OASIS campaign. The SkyArrow has folding wings, and can be moved among intensive sites by ship, cargo plane, huey, and or semi truck or trailer.

Cost, availability, and timing of the Predator needs to be evaluated. If feasible, the predator can take the place of the Sky Arrow POA described above.

2.3.3.6. Options – other considerations

2.3.4. <u>Tethered Balloon measurements</u>

2.3.4.1. Science objectives:

This kind of platforms can be useful for describing the dynamic of atmospheric boundary layer and for estimating fluxes of trace gases from and to the surface, as well as for characterizing the chemistry of the boundary layer. In contrast to aircraft the tethered balloon can also be used to investigate in detail diurnal variations.

2.3.4.2. Logistics:

- Vertical profile measurements of the different trace gases will be performed at the same places where micrometeorological and deposition fluxes will be carried out to be able to estimate trace gas fluxes.
- The electric winch should be connected to line or generator power.
- In case of high wind will be necessary to store the balloon in a dry area.
- Transport of 5-6 helium tanks will be necessary for each field campaign.

(Chemical sampling aboard the tethered-balloon platform is constrained by weight, power consumption, physical size. Payload is in the range of 3-6 Kg. Combination of tethered balloon and blimps can used to increase the payload and the lift under condition of low winds).

2.3.4.3. Data Management

Data will be collected online and off-line. O_3, CO_2, meteorological meaurements will be continuos and on-line. VOC will be measured by integrated samplings (VOCs on solid adsorbent): sampling time needed generally is around 20-30 minutes. Two baloon will be necessary to obtained continuous profile of chemical species measured with fast response sensors and profiles for chemical species such as VOCs wich requires a certain sampling time during which the sampling systemn had to be kept at costant height. Analysis of VOC analysis will be performed off line in the lab by using GC-MS.

To estimate the trace gas fluxes the Mixed Box approach (MB) will be applied which has the advantages to estimates fluxes over a spatial scales of ten km, to quantify all the processes that influence the concentration within a special domain, and is based on robust measurement of the mean mixing ratio. The calculation of trace gas fluxes with the MB approach requires that concentration measurements are performed within the ABL approach. It requires meteorological observations, measurement of O_3 and OH concentrations to derive fluxes of reactive VOC species, and to determine the height reached by the ABL during sampling. The height of the atmospheric boundary layer will be determined from the tethersonde measurements, computed by turbulence measurements at the surface performed by sonic anemometer. Friction velocity and turbulent heat flux will be used as input parameter for the PBL model.

2.3.4.4. Links to other programs

- Tethered-balloon samplings characterize the boundary layer with a footprint of 10 km, and maybe deployed for long periods of time without significantly increased costs.
- The measurement support the local surface measurements by displaying the development of the boundary layer at the different stations and by revealing the potential role of transport and mixing processes in the local trace gas budgets. They help to understand and interpret the temporal progression of trace gas concentrations measured near ground level. The vertical profiles also complement the aircraft measurements in obtaining a more comprehensive picture of the advection pattern and trace gas budgets of the area of the polar campaign.

2.3.4.5. Fundings:

Consorzio Antartico, PRNA, CNR, 2006

2.3.4.6. Timeline:.

3-4 days of vertical profile of the different chemical species and meteorological values are necessary during each field campaign. The first campaign would likely occur in spring 2007.

2.3.4.7. Additional Considerations:

It is recommended that a NCAR ISS (Integrated Sounding System) be explored as an option for continuous measurements of boundary layer depth. Such a request would have to be made through the Observing Facilities process (i.e. via OFAP) in Fall 2006 to be ready by Spring 2007. Alternatively, a ceilometer may work under certain conditions.

2.3.5. Helicopter based measurements (Ice Breaker)

2.3.5.1. Science Objectives

There are two helicopters based on the German R/V POLARSTERN. Measurements from this platforms could contribute to a range of OASIS science objectives, i.e. to observe the spatial characteristics of the sea ice surface and to measure the mesoscale meteorological state of the polar atmospheric boundary layer. The operational range is about 400 km in the horizontal and between 10 m and 4 km in the vertical. The systems are normally used for the following tasks:

- Sea ice remote sensing
- Mesoscale meteorologic measurements
- To support ship navigation (i.e. searching for leads)
- Search and rescue
- Support of camps and stations

2.3.5.2. Instrumentation

The systems can be equipped with sensors which are usually mounted at the skip or that are carried in a special pod behind the aircraft. There are some sensors available which have already been used:

- EM-Bird
- HELISCAT multifrequency polarimetric scatterometer
- Laser altimeter
- CCD-Camera
- HELIPOD meteorologic device

Other sensors, i.e. an Ozone sensor, especially the mounting device has to be developed.

- GPS is standard equipment in EM-Bird and HELIPOD
- ice thickness profiles (EM-Bird)
- radar backscatter coefficient profiles (HELISCAT)
- surface elevation profiles (laser altimeter) -> surface roughness
- meteorological parameters (HELIPOD)
- 2D images (CCD-Camera)

In situ sensors (such as a balloon payload) could be carried to altitudes for profile measurements that cannot be obtained with smaller vehicles with more limited payload capabilities. Potentially useful for routine profiling at the ice breaker site.

2.3.5.3. Links

Some IPY ideas already refer to the helicopter systems, i.e. idea 173 (Prof. Stammer). The EM-Bird will be used for the validation of ESA's CRYOSAT (to be launched in 2005) mission.

2.3.5.4. References and contact information

EM-Bird: Dr. Christian Haas, AWI-Bremerhaven
HELIPOD: Dr. Christof Lüpkes, AWI
Ozone: Dr. Hans-Werner Jacobi, AWI
HELISCAT: Dr. Stefan Kern, IfM Hamburg

2.4. Development of New Instrumentation

2.4.1. Time line:

Task	01/2005	02/2005	03/2005	04/2005	01/2006	02/2006	03/2006	04/2006	IPY period
Approach possible partners	X								
Proposals		X	X						
Funding		X	X	X	X				
Instrument Development		X	X	X	X	X			
Field tests					X	X	X	X	
Deployment									X

2.4.2. People/Groups involved/Funding possibilities:

Funding sources of the instrument development will be secured by task teams in charge of specific methods to be developed by approaching national and international funding agencies. Collaboration of industry partners and university groups who have in the past shown their expertise and interest in instrument development will be necessary.

2.4.3. Links to other programs:

IGAC (AICI, HitT), SOLAS (HitT)

2.4.4. Overview/Motivation:

Currently this is strongly biased towards atmospheric chemistry…what about the need to include new instrument/sampling method development on the marine biology/ocean side in order to achieve better detection limits in the fall/winter period?

1. Measurement techniques for key species currently not accessible or not yet suitable for Arctic Ocean (buoy, icebreaker, icecamp) deployment: halogens (molecular halogens, in-situ halogen oxides, halogen atoms, HOBr/HOCl, $XONO_2$, XNO_2, etc.), specific Hg

compounds (oxidized mercury Hg Cl2, HgBr2, Me-Hg,…), at sub-ppt sensitivity. Aerosol speciation, organics, etc.

2. Many measurements, which have been done successfully at lower latitudes in different environments, have never been deployed in the Polar Regions (OH, HO2, AMS, etc.)
3. in order to measure fluxes fast response methods (~1s) are needed. These do not exist (yet) for most of the species of interest.
4. Development of low power, automated, autonomous, reliable instrumentation is needed for deployment in remote hostile Polar Regions (buoy, remote clean icecamp).
5. Development of non-intrusive methods: most measurement techniques require some form of sample preparation before analysis is possible. Techniques must address the issue of possible change of the physical/chemical state of the measured quantity.

2.4.5. What is currently available?

- Active DOAS (BrO, IO, OIO, I_2, ClO, OClO, O3, NO2, HCHO, HONO, NO3, SO2, aromatic hydrocarbons, …), passive DOAS (total column BrO from satellite, boundary layer BrO, IO, NO2, HCHO from MAX-DOAS)
- Chemical conversion/Resonance Fluorescence (in-situ BrO)
- APCIMS (in-situ Br_2, BrCl and Cl_2)
- photolysable bromine species (HOBr, BrO, …)
- Hg instruments (total gaseous mercury, "reactive gaseous mercury", total particulate mercury)

2.4.6. Specific tasks to be addressed:

- Buoy design and development (O3, BrO, CO2) -> see buoy section
- AMS deployment (Boudries) -> see icebreaker/icecamp section
- Small, low power, fast response ozone for fluxes (Toohey, Avallone) -> see icebreaker/clean icecamp section
- In-situ BrO by chemical conversion/resonance fluorescence (Toohey, Avallone) and CIMS (using DMS/DMSO conversion, Arnold) -> icebreaker/icecamp, deploy instruments to measure spatial distribution (vertical profile, horizontal)
- Quantitative/specific measurements of oxidized mercury (what is RGM?)
- Build small footprint, low power, automated instruments for measurement of Hg species
- Develop non-intrusive methods (CRDS, DOAS, LIF, RF, etc.)
- Develop algorithms to derive more IO from satellite measurements

2.5. Existing Arctic observatories and OASIS

Existing Arctic stations (see table) deliver boundary conditions necessary for tracking of long range transport of chemicals and necessary for modeling (support of trajectory studies). Later on, OASIS results will improve the understanding of atmospheric chemistry time series recorded at individual observatories. Due to easy access, existing stations such as Ny-Ålesund, are ideal for testing of newly developed instrument setups and experiments designed for use in the central Arctic. For some sites, historical data from ice cores (Greenland, Svalbard, Franz Josef Land) complement time series recorded at existing stations and go longer back in time.

Table 2.5: Existing stations with information on atmospheric data.

Station, websites	Pos.	Atmospheric measurements	Sea ice accessibility	Accessibility
Barrow (Alaska) http://www.cmdl.noaa.gov/obop/brw/	71 N 157 W	Pt. Barrow observatory. Aerosol, ozone, meteorology etc.	Ice usually from November to July.	Scheduled flights
Alert (Nunavut) http://www.tscm.com/alert.html	82 N 62 W	Aerosol chemistry since 1980, Trace gas and weekly ozone since 1987, POPs since early 1990s, Hg since mid-late 1990s	Y	Military plane or charter plane
Ny-Ålesund (Svalbard) http://www.nilu.no/niluweb/services/zeppelin/, http://www.npolar.no/sverdrup/	79 N 12 E	Aerosol and trace gas since mid 1980s, Ozone soundings since 1991, POPs since early 1990s, Hg since mid-late 1990s, LIDAR, other optical instrumentation.	Sea ice monitoring ongoing (since 2003). Some ice usually from February to June.	By scheduled aircraft (twice a week) from Longyearbyen (daily scheduled flights from Oslo)
Hornsund (Svalbard) http://hornsund.igf.edu.pl/index_en.php	77 N 15.5 E	Ozone conc. from 2005, precipitation chemistry (since 1988). Ice core	Sea ice monitoring ongoing (since 2004). Ice usually from December to June.	By ship, snow mobile or helicopter from Longyearbyen
Pallas (Finland)	68 N 26 E	Ozone, SO_2, CO_2, VOCs, radon, aerosol and precipitation chemical properties (incl. Hg, POPs) since mid 1990s, aerosol physical properties since early 2000s, trace gases, CO_2 flux	N	By road
Stat. Nord (Greenl.) http://www.dpc.dk/Res&Log/ProjectPlanner/Platforms/Nord.html	81 N 17 W	Yes, Hg in late 1990s, sulfur, atmospheric chemistry	Y	By aircraft
Hayes/Heiss Isl., Krenkel Station, Franz Josef Land (Russia)	80.6 N 58 E	Unknown	Y	Ship or helicopter (from Dickson)
Summit (Greenland)	72.5N 38.5 W	Current measurements (US.). Historical data from ice cores GRIP and GISP2 (paleochemistry)	N	
Svalbard, Lomonossov-fonna, Austfonna	79 N and 80 N	Historical data from ice cores (paleochemistry &contaminants)	N	
Graham Bell Isl., Franz Josef Land	81 N 64 E	Historical data from ice cores (paleochemistry)	N	

2.6. *Satellite Observations*

The overarching question of the effect of OASIS exchange processes on global climate can only be answered by appropriate modeling and long-term observations. The OASIS IPY field measurements will provide a variety of parameters that will be useful for the development and validation of chemical transport models.

Aircraft and satellite based measurements of the surface and the atmosphere are necessary in order to extrapolate the field measurements on a larger scale. In the following we describe what kind of surface information can be obtained from satellites in respect of the needs for the models.

The sea ice concentration, multi-year ice concentration and sea ice drift are "standard" products and are reasonably validated. However, there are still large errors in particular during the melting period, which need some further improvement.
The sea ice and snow thickness, information about thin ice types, the melt pond coverage, as well as the microphysical properties, i.e. snow grain size, are desirable parameters to be obtained. New retrieval methods have to be developed for this parameters.
Information about the salinity at the sea ice surface is crucial for the halogen chemistry. Up to now, the sea ice salinity can not be retrieved with remote sensing techniques. But the information about the ice thickness or the ice type can serve as a proxy for the salinity. However, it is still a challenge to retrieve more than two sea ice types, namely first-year and old/multi-year ice, from microwave sensors. Some thin ice types can be resolved under favorable circumstances.
Old ice is up to 3 m or more thick and is almost salt-free. First-year ice of not more than one winter's growth exhibits salinities of about four (~2 m) to twelve psu (~30 cm). The highest salinities can be found in thin ice (up to 30 cm). The amount of salt initially entrapped by the growing ice depends strongly on the growth rate of the sea ice. The WMO defined different types of thin ice: new ice, nilas and young ice. New ice is a general term for recently formed ice which includes frazil ice, grease ice, slush and shuga. Nilas is a thin elastic crust of ice. Dark nilas is under 5 cm in thickness. Light nilas is more than 5 cm in thickness and lighter in colour. Young ice is ice in the transition stage between nilas and first-year ice, 10-30 cm in thickness. Young ice may be subdivided into grey ice (10-15 cm) and grey-white ice (15-30 cm). Pancake ice, predominantly circular pieces of ice from 30 cm - 3 m in diameter, and up to about 10 cm in thickness, is formed under the influence of waves mostly in the marginal ice zone.
The microwave radiometric signature of sea ice changes considerably during the first days of growth. This causes ambiguities for the retrieval if only a reduced set of channels (frequency, polarization) is available. The synergistic combination of different satellite sensors can help to resolve these ambiguities. New satellites carrying advanced sensor technology will be available in the next years. Therefore, we expect considerable progress in the ability to retrieve information about thin ice types.
For the development of thin ice and snow retrieval methods we need the following parameters repeatedly observed during the campaign:

2.6.1. Field data

+ Vertical resolved sea ice and snow microphysical properties from ice cores
+ Temperature gradient through the ice and the snowpack

2.6.2. Comprehensive aircraft based sea ice remote sensing in the vicinity of field measurements including:

+ Sea ice thickness profiles (EM-Bird)
+ Snow thickness profiles (Ultra Wideband Radar)
+ Microwave backscatter properties at L-, C-, X- and Ku-Ban (HELISCAT)
+ Microwave radiometry at 19 and 37 GHz. Best at 7, 10, 19, 37 and 85 GHz.
+ Surface roughness (laser altimeter)
+ Visible and IR imaging (camera/line scanner)

2.6.3. Acquisition of high resolution satellite data including microwave and optical sensors:

2.6.3.1. Microwave:

+ C-Band: Envisat, ASAR AP-Mode
+ C-Band: Radarsat-2, Ultra-fine and Fine Quad-Pol
+ X-Band: TerraSAR-X, Spotlight and Stripmap-Mode
+ L-Band: ALOS PALSAR, High Resolution Mode

2.6.3.2. Optical:

+ ALOS PRISM
+ ALOS AVNIR-2
+ Terra ASTER, MISR
+ Others?

2.6.4. Still missing is a chapter about atmospheric remote sensing, in particular remote sensing of trace gases, aerosols and clouds.

2.7. An Expanded WMO/GAW & AMAP Coastal Arctic Ocean Lower Tropospheric Chemistry Observatory Network

As part of the long term WMO/GAW and AMAP networks, air chemistry observatories measuring ozone, greenhouse gases, aerosols, mercury and POPs are operated at Alert, Canada; Barrow Alaska; Ny Alesund, Spitsbergen; Pallas-Sodankyla, Finnland. During IPY, it is proposed that this network is augmented by three stations in the Russian Arctic at Amderma, Dunai Island/Tiksi and Pewek. These stations will conduct observations consistent with the requirements of GAW and AMAP. In particular, as a complement to the arctic chemical buoy network that will be tested for the first time for surface in situ O_3, column BrO and surface in situ CO_2, the observatory network will provide land based coastal observations of the same parameters.

3. Laboratory Studies within the Context of OASIS[·]

In order to properly interpret field observations resulting from the focused and coordinated efforts of the OASIS research team, fundamental studies of the physics and chemistry of ice over broad temperature ranges are needed. For example, one of the key ice science problems that must be addressed to fully understand and interpret field observations include the physical and chemical characterization of the 'quasi liquid layer' (QLL[1-6]) or disordered layer that exists on the surface of ice and snow crystals over broad temperature and pressure ranges (e.g., 200 to 273 K; 1 to 5 bar). This disordered layer[7-14] accumulates ionic and non-ionic species, which are not accommodated within the hexagonal ice structure, as the freezing front moves forward and solutes are excluded from the crystalline matrix. Microphysical models must be developed that can be implemented in larger-scale, comprehensive models of the polar environment. Other facets of this problem include 1) the development of new thermodynamic treatments (e.g., activity coefficients at high ionic strength, dielectric parameters, and electrical double layer considerations relevant to surface complexation of chemical species) of the QLL that can be used more appropriately to describe gas-to-particle partitioning of small (Hg, Br_2, HOBr, NO and NO_2) and large molecules (e.g., POPs); 2) the determination of appropriate treatments of chemical and photochemical reaction kinetics within the QLL (i.e., determination of activation free energies, enthalpies, entropies over the temperature range of 200 – 280 K), 3) the determination of light propagation pathways (i.e., effective pathlengths due to multiple internal reflections) through polycrystalline ice as impacted by multiple, interconnected quasi liquid domains; 4) determination of diffusion coefficients, accommodation coefficients (α), and reactivity coefficients (γ) for gas-to-QQL collisions; determination of the growth of the QLL as a function of the rate of freezing and the electrical charging due to relative effects of accommodation of ions inside or outside of crystalline hexagonal ice; determination of chemical changes due to charge separation during freezing at the crystalline ice to solute-water boundary (i.e., the

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· (1) Sadtchenko, V.; Ewing, G. E.; Nutt, D. R.; Stone, A. J. *Langmuir* **2002**, *18*, 4632-4636.
(2) Sadtchenko, V.; Ewing, G. E. *Journal of Chemical Physics* **2002**, *116*, 4686-4697.
(3) Sadtchenko, V.; Ewing, G. E. *Canadian Journal of Physics* **2003**, *81*, 333-341.
(4) Ewing, G. E. *Journal of Physical Chemistry B* **2004**, *108*, 15953-15961.
(5) Doppenschmidt, A.; Butt, H. J. *Langmuir* **2000**, *16*, 6709-6714.
(6) Furukawa, Y.; Nada, H. *Journal of Physical Chemistry B* **1997**, *101*, 6167-6170.
(7) Cho, H.; Shepson, P. B.; Barrie, L. A.; Cowin, J. P.; Zaveri, R. *Journal of Physical Chemistry B* **2002**, *106*, 11226-11232.
(8) Ryzhkin, I. A.; Petrenko, V. F. *Physical Review B* **2002**, *65*.
(9) Kouchi, A.; Furukawa, Y.; Kuroda, T. *Journal De Physique* **1987**, *48*, 675-677.
(10) Henson, B. F.; Robinson, J. M. *Physical Review Letters* **2004**, *92*.
(11) Pittenger, B.; Fain, S. C.; Cochran, M. J.; Donev, J. M. K.; Robertson, B. E.; Szuchmacher, A.; Overney, R. M. *Physical Review B* **2001**, *6313*, art. no.-134102.
(12) Wei, X.; Miranda, P. B.; Shen, Y. R. *Physical Review Letters* **2001**, *86*, 1554-1557.
(13) Gross, G. W. *Canadian Journal of Physics* **2003**, *81*, 439-450.
(14) Dash, J. G.; Fu, H. Y.; Wettlaufer, J. S. *Reports on Progress in Physics* **1995**, *58*, 115-167.
(15) Workman, E. J.; Reynolds, S. E. *Nature* **1952**, *169*, 1108-1109.
(16) Workman, E. J.; Reynolds, S. E. *Physical Review* **1950**, *78*, 254-259.
(17) Reynolds, S. E.; Workman, E. J. *Physical Review* **1949**, *75*, 347-348.
(18) Workman, E. J.; Reynolds, S. E. *Physical Review* **1949**, *75*, 347-347.
(19) Reynolds, S. E.; Workman, E. J. *Nature* **1949**, *164*, 922-923.
(20) Workman, E. J.; Reynolds, S. E. *Physical Review* **1948**, *74*, 1231-1232.
(21) Reynolds, S. E.; Workman, E. J. *Physical Review* **1948**, *74*, 1231-1231.
(22) Workman, E. J.; Reynolds, S. E. *Physical Review* **1948**, *74*, 709-709.

'Workman-Reynolds Effect[15-22], which can generate transient electrical potentials over the range of -200 to +200 volts).

In light of these concerns, the planning group recommends that a focused workshop of experts who have an interest in ice and snow take place to fully define the needed areas of research relative to the overall OASIS mission. This group of experts will include ice physicists, ice chemists, cryo-microbiologists, atmospheric modelers, large-scale model developers, and Arctic field-oriented scientists. Plans are underway to hold a problem-definition and research-frontier workshop on ice and snow fundamentals during August 2005 at Environment Canada in Toronto. This workshop will be hosted by Dr. Jan Bottenheim.

4. Model Development

3D models will be developed to simulate the many different environments and address many of the science questions. This development has already begun. Initially, it will be important to extend and improve 1D and box models already in existence and adapt them to Polar environmental conditions. This applies in particular to snow chemistry, but gas phase and aerosol chemistry will also require modifications. These models will then form a core component of the more elaborate 3D models. It is not clear whether there will be a need for simplification of 1D models since it appears that, at present, computer power is further ahead than our knowledge base for input.

4.1. 1D models

4.1.1. Boundary layer models.

For both meteorology and chemistry it is important to accurately define the mixing in the marine or atmospheric boundary layer (MBL, ABL).

4.1.2. Gas and aerosol chemistry modifications.

Comprehensive heterogeneous and gas-phase chemistry such as that for halogen and Hg species and reactions that are known to drive ozone and mercury depletion will be included. Aerosol modules should be capable of coping with the influence of Arctic temperatures and humidities and long periods of darkness and light.
The updated chemistry modules will be merged with the 1D model so that the contribution of chemical processing versus turbulent transport processes to a complete ozone/mercury depletion episode can be numerically resolved.

4.1.3. Snow layer models:

One of the most crucial components of the modeling system will be a snow layer model. The thermodynamic and dynamic attributes of the boundary layer also govern the deposition of aerosols and gaseous materials to the snowpack. The evolution of the physics and chemistry of snow interacting with other OASIS components must be parameterized. In this regard, the evolution of snow permeability, surface area, light attenuation, heat conductivity and snow chemical composition, with metamorphism, currently not in models for snow metamorphism will be considered. Again, in a next step the snow layer model will be added to the 1D model in order to define the important and necessary physical and chemical processes for inclusion in 3D models.

4.1.4. Ocean layer models:

Similarly to the atmosphere, mixing in the ocean does not only affect the temperature and salinity distribution, but also the vertical transport of organisms and chemical tracers. To simulate those accurately and evaluate the influence on gas and material exchanges at the ocean surface, coupled ocean-biogeochemical models are indispensable. A variety of these models are already in use. Another example in the public domain is the General Ocean Turbulence Model GOTM (www.gotm.net), designed to accurately simulate vertical exchange processes in the marine environment. GOTM has already been successfully used to study DMS fluxes and ecosystem responses. Further efforts are required towards the adaptation of ecosystem components to polar environments, and improve the ice-snow compartment. Simple ice models are not sufficient. To evaluate gas transport through and within the ice it is necessary to account for
1.) the physical evolution of brine channels (aging),
2.) the chemical composition and reactions within the brine (e.g. $CaCO_3$ precipitation), and
3.) the biological growth and decay of ice algae (e.g. Lavoie et al 2004).
4.) the influence of factors (e.g. light, salinity, temperature, grazing) on biological production of gases (i.e. DMS)

4.1.5. Sea Ice Models?

This should be here as a necessary component of a 3D multi-phase coupled ocean-atmosphere model.

4.1.6. Synthesis

To be able to simulate gas and material exchanges at the atmosphere-ocean/ice/snow interface, the final step will be to couple the atmospheric boundary layer model to the ocean-ice-snow-ecosystem component. Although partial component combinations have been coupled to the atmosphere a fully coupled 1-D-OASIS model does not exist, and will be emphasized within the OASIS modeling efforts. Such a model will allow for numerical studies on fluxes of DMS, CO_2, halocarbons and other active and inert gases like O_2, N_2 etc. It will also provide a tool to test hypotheses on sea-air fluxes of organic particles, which have been found to contribute significantly to cloud forming aerosols, and surface triggered atmospheric reactions (e.g. frost flowers and their effect on Br_2 formation and consequent zone destruction).

4.2. 3D models and experiments

4.2.1. 3-D model building

A logical progression from 1-D to 3-D models will enable us to obtain a more complete ecosystem-wide picture of the Arctic environment and the role of OASIS processes. Several excellent 3-D chemical transport models exist (3-D CTMs), but these models will require substantial modifications (as outlined above) to make them suitable for Arctic

applications. Work of this nature has begun with several groups (e.g. the Danish DEHM model, GEM-AQ in Canada, the GEOS-CHEM- MM5 (polar version)., EMEP models MSCE-Hem-Hg and MSCE-Hem-POP). As each model contains inherent unique uncertainties, it is important to use set of different models for more reliable assessment of the Arctic's environment.
There are a variety of coupled ice-ocean models (e.g. AOMIP) as well as atmosphere-ice-ocean models (ARCMIP) available. Based on 1-D-model developments those models can be extended to include ecosystem components that are applicable for polar regions. Although computer resources are still a limiting factor for 3D models in terms of complexity, especially with respect to ecosystem components, the addition of the horizontal component will add important information on transport processes both in the atmosphere and ocean.

4.2.2. 3-D model experiments

3D models can be applied to verify the source attribution based on chemical fingerprinting, and delineate the prevailing transport routes of pollutants to and from the Arctic. This will then allow us to place the data obtained at the few Arctic chemical observatories in an Arctic wide context, and determine the seasonal variations in sources and transport routes. The prevailing transport routes from Asia to North America and from North America to Europe are believed to be via the Pacific and Atlantic oceans. However, there is evidence that Eurasian pollution is transported via the Arctic to the North American continent. This process will be studied in detail, and quantitative estimates of its importance will be made.

4.2.3. 3-D dimensional models as planning tools:

3D models will have the feature of being operable in a forecast mode. Once developed and evaluated, they will be particularly suitable as a tools to plan future research endeavors in the Arctic, especially for the planning of the OASIS.

4.3. Model Outline (contribution from Roland von Glasow, IUP Heidelberg, Germany)

This is a collection of some thoughts on the various aspects of modeling in the framework of OASIS. Many have been mentioned by others before and others (esp. measurements) are already being done. I know that some of the "necessary measurements" are very hard to achieve but might still be very useful. The most important ones are in bold.

4.3.1. Main research questions for modeling

- source and possible triggers for bromine explosion
- importance of boundary layer structure
- release of bromine from frost flowers on the ground vs. frost flower "aerosol"
- complete life cycle of an ODE from "birth" to "death" and possible upwards transport of bromine-rich air into the free troposphere
- links between Arctic Haze and ODEs

- regional and global impact of ozone depletion events (ODE) and mercury depletion events (MDE)
- how widespread are situations during which BrO could be mixed up into the FT?
- past and future climate studies with different chemical conditions, different sea ice coverage (esp. fresh sea ice)
- importance of convection around leads for BL mixing and transport

4.3.2. Different model types and their applications

- box and vertically resolved one-dimensional models: detailed process studies
- Lagrangian 1D and regional 3D models: evolution of a bromine explosion event/ODE from its start (possibly at leads) to maximum ozone loss and mixing with ozone rich air or merging of several O_3 depleted air masses
- regional and global 3D models: regional and global impact for photochemistry and mercury
- climate models: ODEs in past and future climates

4.3.3. Information needed as boundary and initial conditions for models

- **surface cover and concentration/composition** of brine on ice, around leads, frost flower fields
- evolution with time of composition of frost flowers
- **salt aerosol flux** from frost flower fields as function of wind speed (and temp??)
- **vertical structure** of the boundary layer (it's usually stable and not well mixed, note: box models implicitly assume a well-mixed boundary layer)
- **exchange (emission/deposition) with surface** (snow pack, ice, ocean)
- gas phase concentrations to initialize and validate models:
- **O_3, CO, NO_x**, **CH_4**, **VOC**, HCHO, **H_2O_2**, HNO_3
- OH, HO_2, NO, NO_3
- SO_2, H_2SO_4, MSA, DMS, DMSO (if interest in S-cycle)
- Br, **BrO**, **Cl**, ClO, I, **IO**
- **Hg speciation**
- HCl, HOCl, Cl_2, HBr, HOBr, **Br_2, BrCl**, IBr, HOI, I_2, ICl, IBr
- **organic halogens**
- tracers like Radon, acetonitrile (biomass burning): to characterize airmass, might not be of major importance for OASIS studies
- aerosol concentrations to initialize and validate models:
- **size distribution**
- size resolved composition
- gas and aerosol information as function of height
- meteorology to initialize and validate models:
- **T, rh, p, wind speed and direction**
- **photolysis rates**
- heat fluxes
- info on cloud: height, vertical extent, LWC but at least **presence and type**

- best: everything as function of height!
- How strong is convection around leads for mixing of BL and transport? Needed: temperature difference air vs. ice vs. lead water

4.3.4. Suggested model - field integration

I think that the following type of field studies would be most helpful to advance our knowledge and to be able to compare models with data:

- Lagrangian studies of the evolution of an air mass
- long term studies at single locations but esp. from space to get the "big picture"
- detailed process studies to investigate processes around leads/frost flowers, cycling of air through snow pack, fluxes from and into the snow pack

5. Data Management

OASIS places priority on developing a comprehensive data management plan to ensure that the resources towards conducting experiments and collecting data facilitate the widest research and utility of the data for the broadest benefit.

A comprehensive data management plan at must consider the following:

- Establishment of effective means for coordinating data management activities
- Funding agency requirements
- Metadata and documentation standards
- Archival standards
- Data formats
- Data Archival
- Data Access and Use Support

Because OASIS is an international effort that will be funded by a variety of agencies OASIS recognizes that there may be data management requirements that are unique to specific funding agencies. It is anticipated that the driving force behind data management requirements will be the IPY Committee and OASIS intends to meet IPY requirements, but will also consider additional international requirements and OASIS-specific needs to develop an integrated approach.

The OASIS team will produce documentation identifying IPY data sets along with the characteristics of those data sets, and requirements and procedures for ensuring that the data sets are ingested, documented, archived and distributed according to OASIS specifications

Documentation detailing OASIS data management requirements will address required metadata and documentation for all data sets collected under the campaign and will be vetted by the OASIS team, and then distributed to all team members. A procedure will be developed to facilitate the collection of metadata and documentation, and ingest of data as appropriate. Participation and commitment by the PI's to this effort will be important to ensure the legacy of the data collected, but every effort will be made to make the process as efficient as possible by creating awareness of requirements before experimentation begins, and efficient means of transferring data and supporting information post-experiment.

Key aspects that the OASIS team needs to determine include whether there will be a central archive for the data, or whether a portal approach or some combination of the two is preferred. A central archive has responsibility for archiving the data, and typically has responsibility for collecting metadata, developing standard documentation, distributing and providing support of the data. A portal approach usually involves the collection of metadata or a subset of metadata, to provide a central but standardized approach to publishing access to the data, but typically the data, distribution and support are handled in a distributed fashion either by designated national agencies or by PIs. Each approach has pros and cons and resource implications that must be addressed by the science team.

Additional issues to consider are whether there are any periods of time where data will be restricted to the PI's, (this is likely to be dependent on IPY policy), the level of user support the project anticipates wanting to be able to provide, and whether there are any web/software tools that need to be developed or supported as part of the data management plan.

The OASIS program is an ambitious project that fills a gap in understanding of interactions and dynamics in the Arctic, and involves many different disciplines and international partners. As such there are unique challenges to data management, but a strong commitment from the OASIS team towards developing a solid data management plan and effective methods for addressing data management that follows international standards will ensure that the resources to collect data for this program will leave a legacy that will be available for a wide ranging community of users.

6. Proposal and Funding Opportunities

OASIS is a multidisciplinary research program that addresses research agendas of many funding agencies and organizations. Therefore, research proposals to be defined within OASIS will be submitted to a number of funding agencies and organizations. The International Polar Year provides an excellent opportunity for OASIS to start a coherent and multidisciplinary program to study various processes responsible for human/ecosystem impacts, contaminant cycling and climate change in the polar regions.

An important aspect in the application for funding is the role of OASIS in international environmental research. In the Arctic, OASIS will cooperate with the Arctic Monitoring and Assessment Programme (AMAP) and the WMO Global Atmosphere Watch (GAW). The OASIS research agenda responds directly to a list of gaps in knowledge defined after 15 years and 2 major assessments of the state of the Arctic environment. Process studies defined within OASIS can be used to better understandobserved changes in the Arctic environment. Cooperation with AMAP will connect OASIS research with issues that impact communities in the north, northern ecosystems and the global climate system.

It is also important to note that OASIS can be regarded as an implementation of research agendas of the IGBP/IHDP programs, such as SOLAS, LOICZ, IGAC. Cooperation with existing observational programs, such as NPEO, AOOS and GAW will be an added value to OASIS and to these programs.

The gaps in understanding addressed by OASIS should be contained in the research agenda of the EU framework Programme 7 which is now in a final stage of negotiations and discussions. The EU 7th FP will no doubt call for further research of climate change and its impact on the environment. Various aspects of this topic are the key issues in OASIS. North American scientists, international organizations, such as WMO, and international programs, such asAMAP are welcome partners in research consortia to be organized to address the EU calls for proposals within the EU FP 7th. There are also specific EU programs where the Russian scientists are eligible for project funding from the EU. The above mentioned funding opportunities from the EU will be used. A meeting between respective scientific officers of the EU DG on Research, and the representatives of the U.S. National Science Foundation, Canadian research authorities, WMO and AMAP is proposed to facilitate the process of potential financial support of polar research in the near future, also the research identified in OASIS. The OASIS partners shall provide input through their national contacts in the EU to the science program for funding within the EU FP 7th.

National research foundations will be approached for financial support of specific studies defined within OASIS. In some countries funds will soon become available for research in connection with the IPY 2007/2008. For example, a program of approximately 9 million EURO program will be announced in the U.K. in March 2005 with the submission of application deadline 1 June, 2005. Similar programs are expected in other countries, particularly in the Arctic nations. There are also existing national and bi-lateral programs, e.g. the U.S. and Italian program where funds for supporting polar research on mercury cycling and buoy deployment are available. The OASIS partners are expected to investigate the opportunities for funding in these programs and submit proposals in due time.

The Global Environmental Facility (GEF) operated by UNEP, UNDP and the World Bank is another potential source of financial support of selected OASIS studies, particularly those to be carried out in the Russian Arctic and/or by Russian scientists. Contact between OASIS and the Land-Ocean Interactions in the Russian Arctic (LOIRA) will be established with the goal to explore the possibilities for cooperation and joint field experiments. The GEF Secretariat in Washington will be approached for exchange of information on supporting OASIS and eventually submission of proposals.

Developers of energy resources in the polar regions are also potential OASIS sponsors. Possibilities of funding will be investigated particularly with large oil companies, such as STATOIL, Shell, Esso, British Petroleum. Some of these companies have supported polar research in the past.

Other large companies, known for their interest in supporting environmental protection programs, such as Microsoft will also be approached for funding selected OASIS studies.

Various actions will be undertaken to assist fund raising:

- establishment of a network of OASIS partners for exchange of information on funding possibilities, both national and international,
- preparation of an information kit with a PowerPoint presentation on OASIS for better communication with funding agencies and organizations.

6.1. Immediate Action for Europeans!!!

The OASIS partners shall provide input through their national contacts in the EU to the science program for funding within the EU FP 7th.

Contact funding agencies
Framework preparation

7. Links to existing projects

7.1. SNACS

Starting this year, and funded for 3 years, we have a project called SNACS: Studies of the Northern Alaskan Coastal System. The PIs are Matthew Sturm (coordinator), Don Perovich, Tom Douglas (all CRREL), Bill Simpson (UAF), and Joel Blum (University of Michigan). Our project is looking at mercury deposition and fate in the coastal zone. Matthew and Don are snow/ice experts and are leading the project. Tom Douglas is doing the snow mercury and what happens to it upon melt. I'm doing BrO DOAS with the goals of understanding halogen activation mechanisms and hopefully observing the relationship between BrO and amount of deposited Hg. Joel Blum is doing transformations of Hg from inorganic deposited mercury to biologically available methyl mercury. We'll be in Barrow this spring with Shep on his pre-OASIS project. We hope these activities will give us a good understanding of pollutant exchanges in the coastal and inland zones and provide background for OASIS. I would say that SNACS is more focused on inland and coastal processes than OASIS, and thus they are quite complementary.

Plans for OASIS:

All of the SNACS PIs would like to continue in these directions for OASIS. Don put in a lot of information regarding these activities already, but there are a few that I think could be strengthened. I wrote with Gerd and proposed a plan of expanding my existing collaboration with IUP Heidelberg to work on the Buoy project. I got a hold of Don Perovich on this, but not yet Paul. I would assist in development and integration. I would do testing against the MAX-DOAS instrument that we'll have at Barrow (as a part of the existing SNACS project). For the icebreaker, I would like to continue our work on halogens in snow as it is clearly important for halogen activation. This involves primarily IC work with a focus on bromide. I'm attaching a pre-print of a paper we just had accepted in GRL that is relevant to bromide activation. The reference is "Halogens in the coastal snow pack near Barrow, Alaska:Evidence for active bromine air-snow chemistry during springtime", William R. Simpson, Laura Alvarez-Aviles, Thomas A. Douglas, Matthew Sturm, and Florent Domine, Accepted for publication in Geophysical Research Letters, 2005. We have also been looking at mercury near leads, where we see huge values associated with convective leads. That is also the subject of a recently accepted GRL apper, "Elevated mercury measured in snow and frost flowers near arctic sea ice leads," T. A. Douglas, M. Sturm, W. R. Simpson, S. Brooks, S. E. Lindberg, and D. K. Perovich, Accepted to GRL, 2005. We'll also be doing MAX-DOAS work, which I will coordinate with Gerd's activities.

8. Outreach activities

8.1. ERCA

ERCA is a course for thesis students, scientists and engineers from universities, research institutes and industrial laboratories. It is a high level international course on the Physics and Chemistry of the atmosphere of the Earth, the climate system, atmospheric pollution at different scales, human dimensions of environmental changes, and other planets, satellites and objects of the solar system. It is designed as a multidisciplinary course with a wide diversity of subject matter. It provides an excellent opportunity for the participants to broaden their scientific horizon. The course also provides the ideal setting to interact and discuss research with lecturers who are leaders in their respective fields. This is fostered by poster sessions which will feature current research of the participants. The participants come from the different European countries (Western and Eastern Europe) and from non European countries (developed and developing countries). Since it was created in 1993, 12 sessions have already been organized. They were attended by more than 550 participants from 40 different countries.

For the IPY 2007-2008, we propose to organize during the ERCA course a special session devoted to OASIS with the contribution of specialists in the field.

8.2. Schools on Board (David Barber)

Schools on Board is an outreach program of the Canadian Arctic Shelf Exchange Study (CASES) and ArcticNet. The program promotes the integration of Arctic sciences in high school science programs across Canada and aims to increase awareness of environmental issues related to the Arctic by targeting high school students, their teachers, and their extended communities.

Schools on Board creates educational tools and opportunities for classrooms and takes high school students on-board the CCGS Amundsen (Canadian research icebreaker) where they are integrated into the activities of numerous science teams conducting multidisciplinary research in the Arctic. The field program is designed to introduce participants to the breadth of the science involved in Arctic research and to inspire students to consider careers in science, engineering and technology. It is anticipated that the experiences of those chosen to participate will be shared with their fellow classmates, families, communities, local politicians, and that schools, particularly teachers, who participate in the program, will be more inclined to integrate Arctic sciences in their science programs.

The field program includes science lectures, lab activities and fieldwork delivered by graduate students and senior scientists on-board the ship. Details of the on-board program are posted on the website (www.arcticnet-ulaval.ca) The adventures into Arctic research exposes students and teachers to the research objectives and methods of numerous science teams representing a number of research disciplines from institutions across Canada and beyond.

In addition to hands-on research activities the program introduces participants to many aspects of Canada's North, including local knowledge, culture, history, and politics. Planned 'community visits' in northern communities near the field site complement the evening sessions on-board the ship dedicated to social issues i.e. sovereignty, governance, resource management, Inuit art and legends, history, economic development, northern culture and tradition, Inuit knowledge etc.

The 2004 pilot program on board the CASES program was a spectacular success promoting Arctic sciences, increasing awareness of environmental issues related to the Arctic and climate change, and providing new and exciting learning opportunities to this country's next generation of science enthusiasts. The media attention and the presentations that resulted from the program were successful in showcasing CASES and its network of scientists to audiences not previously targeted. The overwhelming positive feedback received from all stakeholders (students, teachers, schools and scientists) indicates that this program is welcomed in both the science and education communities.

"This has been one of the most exciting and memorable experience ...I will have walked away smarter, and most of all, happier. (NWT)

"This has been an incredible journey of exploration and growth." (British Columbia)

"It helped me to put into perspective a career that I would like to pursue (Marine Biology)...it has been a life-altering experience." (Manitoba).

"Schools on Board turned me onto studying science and opened my eyes to what science is about and how it relates to daily life...I feel honored to have been a part of it." (Manitoba).

"I must say that I found the trip incredible and it has inspired me and my teaching in many ways. I want to thank you again for your encouragement of [student]. It is

something he needed and I am hoping that what he experienced will inspire him to chase his dreams. "(NWT)

8.2.1. Schools on Board and OASIS

Schools on Board proposes to use its infrastructure and program model to create an international student field program linked to OASIS. We would select students from each of the countries participating in the OASIS program (or subset) and design a science program which highlights the linkages between climate change, polar marine science and atmospheric chemistry. We would require a buy-on from the science teams aboard the OASIS vessel to deliver the program (as per the CASES model). The blend of adventure, curiosity and exposure inherent is this research study enables us to create an energized learning environment where scientists are able to share their passion for science and research with students – both on the ship and in classrooms. The program would also coordinate communications pertaining to this program with the international media and assist countries to select the best students available for this innovative program.

8.2.2. Funding Request:

In Kind Contributions:

- - Funded spaces on board the ship; all other costs of the program will be incurred by the student; minimum of 2/country; student and an accompanying teacher.
- Cooperation by scientists and graduate students to assist in developing and delivering materials for the website, and the field program.
- Cooperation by scientists in participating countries to promote the program and recruit from their country.

Cash Contributions:

- Funds for special promotional materials specific to OASIS
- Funds to support program coordination; travel of program coordinator
- Estimated at approximately $50,000C$/annum

8.3. "Got Snow?" Education and Outreach for the IPY

Turrin, M (mkt@ldeo.columbia.edu) , Barnard College, Columbia University, 3009 Broadway, New York, NY 10027 United States
Turrin, M (mkt@ldeo.columbia.edu) , Lamont-Doherty Earth Observatory, Torrey Cliffs, Palisades, NY 10964 United States
Bell, R E (robinb@ldeo.columbia.edu) , Lamont-Doherty Earth Observatory, Torrey Cliffs, Palisades, NY 10964 United States
* Pfirman, S (spfirman@barnard.edu) , Barnard College, Columbia University, 3009 Broadway, New York, NY 10027 United States
* Pfirman, S (spfirman@barnard.edu) , Lamont-Doherty Earth Observatory, Torrey Cliffs, Palisades, NY 10964 United States

Maru, P (pm2127@barnard.edu) , Barnard College, Columbia University, 3009 Broadway, New York, NY 10027 United States

The "Bridging the Poles: Education Linked with Research" workshop of June 23-25, brought together an international group of 65 scientists, educators and media specialists to define strategies to engage the next generation of polar scientists, engineers and leaders, and inspire the general public. The workshop results emphasized the need to leverage emerging science programs with meaningful education and outreach programming that is rolled out to the public as major media events. Participants advocated a broad interdisciplinary approach, recognizing that the poles have a rich cultural heritage and fascinating history. Linking research events with student fascination about polar environments, peoples and histories of exploration, can help improve science, math, reading, and other skills. Distance learning with web course delivery is a powerful tool to reach advanced students and to help develop a new generation of researchers among Arctic indigenous peoples. Successful examples of this approach include the University of the Arctic's PhD network, and collaborative field courses. Field experiences build life-long advocates of the poles for students, teachers, and the media alike. Establishing connections among scientists, educators and informal outreach venues in their own community, can have long-lasting impact. "Think Globally/Act Locally" and the complementary "Think Locally/Act Globally" will be important themes for local, national and international IPY programming. Imagine a semi-trailer truck labeled "Got Snow?" traversing the country loaded with polar gear, interactive activities and a snowmaker; polar exhibitions opening at natural history and art museums and zoos; polar-themed postage stamps; national polar book-of-the-month recommendations; made-for-TV polar documentaries; and a rich, multidisciplinary and multilingual web portal. To meet these opportunities requires coordination, linking communities, and high-bandwidth access to high quality content from the polar regions. We need to start now to develop an integrated research/media/education strategy; establish partners among the research, media, and education communities; and diversify participation and audiences.

9. Output and Publications

10. Socio – Economic & Broader Impact

Gary Stern - Regarding the text for the Socio - Economic & Broader Impact section. As I mentioned during the meeting this is not at all my area of expertise. I had only volunteered to try and approach someone who is doing this type of study as part of ArcticNet. I've got no response so far but will keep trying.

Regarding the outreach activities section. Both Dave and Lucette Barber were very keen on developing an international student field program on-board OASIS - to coincide with IPY.

11. Summary Graphic of Timeline

									IPY					

Year	2005				2006				2007				2008				2009				>
Season	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Action																					

12. Synthesis and Integration

13. additional comments:

In the section '2.3.3.4 Potential Participating Institutions' you could add the Alfred Wegener Institute. We have the possibilities to measure NO, NO2, NOy, O3, H2O2, HCHO, CO.
Also in the section '2.3.4.1 Types of measurements' about snow chemistry

measurements we could contribute the following measurements: 'Snow chemistry analysis (ions)'

14. List of participating organizations, contact info, etc.

14.1. Workshop participants:

Katarina Abrahamsson
Dept. Chemistry and Bioscience, Chalmers University of Technology
Kemigården 3
412 96
Göteborg
Sweden
46 31 772 27 80
46 31 772 27 85
katarina.abrahamsson@chembio.chalmers.se

Mary Albert
CRREL
72 Lyme Road
03755
Hanover, N.H.
USA
603-646-4422
603-646-4278
mary.r.albert@erdc.usace.army.mil

Leonard A. Barrie
Environment Division, AREP - World Meteorological Organization
7 bis, Avenue de la Paix

Harry Beine
C.N.R. – IIA
Via Salaria Km 29,3
00016 Monterotondo Scalo (Roma)

BP2300, 1211
Geneva
Switzerland
LBarrie@wmo.int

Italy
+39.06.906.72.262
+39.06.906.72.660 (fax)
harry@iia.cnr.it

Jan W Bottenheim
Meteorological Service of Canada
4905 Dufferin Street
M3H 5T4
Toronto
Canada
416 739 4838
416 739 5704
Jan.Bottenheim@ec.gc.ca

Hacene Boudries
Aerodyne Research, Inc
45 Manning Road
01810
Billerica, MA
USA
978-663-9500
978-663-4918
hboudries@aerodyne.com

Alessandra Cincinelli
Dipartimento di Chimica - Università di Firenze
Via della Lastruccia 3
50019
S. Fiorentino
Italy
0554573324
0554573385
alessandra.cincinelli@unifi.it

Clara (Jodwalis) Deal
University of Alaska Fairbanks, International Arctic Research
930 Koyukuk Dr.
99775-7335
Fairbanks
USA
907 474-1875
907 474-2643
deal@iarc.uaf.edu

Florent Domine
CNRS - LGGE
BP 96, 54 rue Moliere
38402
Saint Martin d'Hères
France
+33 476 82 42 69
+33 476 82 42 01
florent@lgge.obs.ujf-grenoble.fr

Chris Fairall
NOAA Environmental Technology Laboratory
325 Broadway
80305
Boulder
USA
303-497-3253
303-497-6101
chris.fairall@noaa.gov

Christophe Ferrari
LGGE/CNRS
54, rue Molière-BP 96
38402
Saint Martin d'Hères
France
+33 4 76 82 42 39
+33 4 76 82 42 01
ferrari@lgge.obs.ujf-grenoble.fr

Teodoro Georgiadis
CNR-IBIMET sez.Bologna
via Gobetti 101
40129
Bologna
Italy
0516399006
0516399024
t.georgiadis@ibimet.cnr.it

Sebastian Gerland
Norwegian Polar Institute
Polar Environmental Centre
9296
Tromsø
Norway
47 777 50 554
47 777 50 501
gerland@npolar.no

Piotr Glowacki
"Institute of Geophysics, Polish
Academy of
Sciences"
ul. Ksiecia Janusza 64
01-452
Warszawa
Poland
48-22-6915890
48-22-6915893
glowacki@igf.edu.pl

Crispin Halsall
Lancaster University
Environmental Science Dept
LA1 4YQ
Lancaster
UK
44(0)1524 594330
44(0)1524 593985
c.halsall@lancaster.ac.uk

Michael Hoffman
California Institute of Technology
1200 E. California Blvd.
91125
Pasadena, CA
USA
001-626-395-4391
001-626-395-2940
mrh@caltech.edu

Lars R. Hole
"University Centre on Svalbard / Norwegian
Institute of Air Research"
PO Box 156
9170
Longyearbyen
Norway
47 79023339
47 79023301
lrh@nilu.no

Michelle Holm
University of Colorado, National Snow
and Ice Data Center
CIRES, Campus Box 449
80309
Boulder
USA
1 303.492.1834
1 303.492.2468
mholm@kryos.colorado.edu

Gerd Hönninger
Meteorological Service of Canada / Uni
Heidelberg
4905 Dufferin St.
M3H 5T4
Toronto
Canada
001 416 739 4856
001 416 739 5704
Gerd.Hoenninger@ec.gc.ca

Elisabeth Isaksson
Norwegian Polar Institute
The Polar Environmental Centre
N-9296
Tromsø
Norway
47-77 75 05 15
47- 77 75 05 01
elli@npolar.no

Anna Jones
British Antarctic Survey
High Cross, Madingley Road
CB3 0ET
Cambridge
UK
44 (0) 1223 221435
44 (0) 1223 221279
a.jones@bas.ac.uk

Wolfgang Junkermann
Forschungszentrum Karlsruhe, IMK-IFU
Kreuzeckbahnstr. 19
82490
Garmisch
Germany
08821 183180
08821 73573
wolfgang.junkermann@imk.fzk.de

Lars Kaleschke
Institute of Environmental Physics,
University of Bremen
Otto-Hahn-Allee 1
D-28334
Bremen
Germany
49 421 218 - 4726
49 421 218 - 4555
lkalesch@iup.physik.uni-bremen.de

Christopher Krembs
Polar Science Center, University of Washington
1013 NE 40th Street
98105-6698
Seattle
USA
206 685 0272
206-616-3142
ckrembs@apl.washington.edu

Olga Mangoni
University of Naples Federico II
Via Mezzocannone 8
80134
Napoli
Italy
+39 081 2535149
olga.mangoni@unina.it

Patricia Matrai
Bigelow Laboratory for Ocean Sciences
180 McKown Point
04575-475
W. B. Harbor
USA
1 207 633 9614
1 207 633 9641
pmatrai@bigelow.org

Wade McGillis
Columbia University
927 Seeley Mudd Building
10027
New York
USA
845-365-8562
wrm2102@columbia.edu

Monica Modigh
Stazione Zoologica A Dohrn di Napoli
Villa Comunale
80121
Napoli
Italy
0039 081 5833 317
0039 081 7641355
modigh@szn.it

Samuel Morin
"Laboratoire de Glaciologie et Géophysique de l'Environnement
(LGGE)"
54 rue Molière, BP 96

Jürgen Müller
Fed.Environmental Agency,
Experim.Monitoring
Paul-Ehrlich-Str.29
63225

38402
St Martin d'Hères
France
33 476 82 42 51
33 476 82 42 01
samuel.morin@lgge.obs.ujf-grenoble.fr

Langen
Germany
49 6103 704134
49 6103 87141
ecomueller@hotmail.com

Marianna Nardino
Institute of Biometeorology
Sez. Bologna
Via P. Gobetti, 101
40129 Bologna
Italy
+39.051.63.99.001
nardino@ibimet.cnr.it

Walter Oechel
San Diego State University
Dept. of Biology, 5500 Campanile Dr.
92182
San Diego, CA
USA
(619) 594-6613
619 594 7831
oechel@sunstroke.sdsu.edu

Jozef Pacyna
Norwegian Institute for Air Research
Instituttveien 18
2027
Kjeller
Norway
004763898155
004763898050
jp@nilu.no

Tim Papakyriakou
"Faculty of Environment, Earth and Resources; University of Manitoba"
University of Manitoba, 183 Dafoe Road
R3L 2N2
Winnipeg
Canada
1-204-474-8513
1-204-474-7699
papakyri@ms.umanitoba.ca

Don Perovich
ERDC-CRREL
72 Lyme Road
03755
Hanover, NH
USA
603-646-4255
603-6464644
donald.k.perovich@erdc.usace.army.mil

Francesca Rapparini
Institute of Biometeorology
Sez. Bologna
Via P. Gobetti, 101
40129 Bologna
Italy
+39.051.63.99.005
f.rapparini@ibimet.cnr.it

Lars Otto Reiersen
Executive Secretary of AMAP
P.B. 8100
0032
Oslo
Norway
47-23241632

Vincenzo Saggiomo
Stazione Zoologica A Dohrn di Napoli
Villa Comunale
80121
Napoli
Italy
0039 081 5833 240

4723241631
lars-otto.reiersen@amap.no

0039 081 5833 240
saggiomo@szn.it

Paul Shepson
Purdue University
560 Oval Dr.
47907
West Lafayette
USA
765-494-7441
765-496-2874
pshepson@purdue.edu

Gary Stern
Department of Fisheries and Oceans
501 University Crescent
R3T 2N6
Winnipeg
Canada
204 984-6761
204 984-2403
Sterng@dfo-mpo.gc.a

Bill Sturges
University of East Anglia
Earlham Road
NR15 1RL
Norwich
UK
44 (0)1603 592018
44(0)1603 452420
w.sturges@uea.ac.uk

Kimmo Teinilä
Finnish Meteorological Institute
Sahaajankatu 20E
FIN-00880 Helsinki
FINLAND
+358919295414
+358919295403
kimmo.teinila@fmi.fi

Darin Toohey
University of Colorado
Stadium 255 - PAOS/311 UCB
80309
Boulder
USA
303-735-0002
toohey@colorado.edu