OASIS2009 Draft Science Plan

OASIS2009 will pursue key big-picture science issues regarding air-surface chemical interactions in the Arctic, and how these will evolve in future climates. The focus will be on topics that follow recent developments as well as a number of issues that have been previously under-studied, or simply haven't been adequately pursued, and need to be. Central in this regard is the goal of quantitative and reliable determination of chemical and biological fluxes to and from ice and snow surfaces, as a function of the nature of the surface and other relevant environmental conditions. This will be pursued using state-of-the-art chemical and biological sensors, as well as available tools such as micrometeorological instrumentation, Lidars, balloons, and a walk up tower.

We intend to create the optimum blend of solvable science questions with appropriate logistics platforms and support infrastructure. Specifically, we intend to conduct two studies in series, with some overlap, the first at Barrow starting in early February 2009, which will be aimed at studies of the fluxes/exchange of various gas and aerosol species between the atmosphere and the snowpack, and the resultant vertical profiles and nature of the vertical scale of the atmospheric impacts. Key to this experiment will be an instrumented walk-up tower. This experiment will be followed by an ice camp study, at the Navy Ice Camp in the Beaufort Sea to augment the land based flux measurements with data obtained over the frozen ocean surface. This will represent an unprecedented opportunity to study atmosphere-surface exchange and ozone depletion events (ODEs)/mercury depletion events (MDEs) from the sea ice on the frozen Arctic Ocean. The location of the ice island will be in an area that has been reported to be rich in column BrO according to satellite measurements (GOME, SCIAMACHY, OMI). It will permit a comparison of sea ice surface chemistry and fluxes with those previously studied from coastal saline snowpacks. This project also affords the opportunity to conduct simultaneous comparisons of the air chemistry at the two contrasting sites, roughly connected by the prevailing winds.

OASIS 2009 centers on the following specific Science Questions/Issues:

A. Snow physical, chemical and optical properties, processes, and their changes with climate change.

- *Where are the important reactants located (surface, bulk, brine layer,quasi-liquid layer, aerosol,…)?*
- *What are the factors determining light absorbance in snow?*
- *What are the processes that generate oxidants in the snowpack?*
- *Are fluxes of organic compounds from snowpack correlated to OH radical and/or halogen atom photo-chemical production in snow or organic photochemistry?*
- *What processes are involved in halogen activation in the snowpack?*
- *How does coupling snow and sea-ice in layers affect light penetration and albedo in the snow and sea-ice and subsequently the J rates and PAR (photosynthetically active radiation)?*

B. Fluxes out of the snow pack, impact on overlying atmosphere

- *Are the processes driving snowpack emissions of molecular halogens, Hg, NO_x, HONO, and OVOCs understood? How are they interrelated?*
- *Do snowpack emissions impact the 'oxidative capacity' of the atmosphere, and if so, how and to what extent?*
- *What is the vertical structure of reactive halogens (e.g. BrO) and how is this structure related to surface fluxes of halogens/precursors (e.g. HO_x)?*
- *Can we reconcile the significantly elevated airborne HCHO observations in the Arctic boundary layer? Does this imply poorly understood gas phase organic chemistry?*
- *How do Hg species behave around the snow pack and in the vertical column and how will this change with changes in the oxidative capacity of the atmosphere?*
- *What is the role of the sea ice on MDEs versus the snow pack?*

C. What is the role of microbial communities in the cryosphere and water for the emission/transport/transformation of climate-relevant gases and compounds?

Our ability to predict the impacts of global warming is limited by a number of key uncertainties, significant among which is the role of biotic feedbacks. Our knowledge is poor indeed and even more so at high latitudes.

- *What is the distribution, composition and activity of microbial (bacteria, microalgae) communities associated with the biological-mediated chemical exchange processes between the Arctic Ocean, cryosphere and atmosphere?*
- *Does oxidation of organics in snowpack provide a carbon resource for microbes? More generally – how does organic/inorganic/halogen photochemistry impact biological activity?*
- *What are the impacts of a changing sea ice environment on ice algae, and in turn fluxes that impact the sulfur and halogen cycles?*
- *Do biological processes transform Hg and other species deposited to the surface during MDEs? In particular, how do and what bacteria transform Hg species?*
- *Do biological processes transform Hg species in the atmosphere prior to deposition?*
- *Is Hg methylated in the snow pack by microbial activity or photochemistry or resulting from oceanic evolution?*
- *What is the impact of ODEs on the springtime Arctic Ocean biosphere? Is there a positive impact of low ozone?*
- *How does PAR (photosynthetic active radiation) behave in sea-ice and more importantly snow covered sea-ice, and what impact does the distribution have on algae and other autotrophs and their emissions of reactive gases?*

D. Atmospheric boundary layer chemistry, and its oxidizing capacity in the Arctic

The oxidizing capacity of the Arctic boundary layer is defined by O_3, HO_x, XO_x, and possibly NO_3 radical chemistry.

- *What are sources of ClO_x, and impact of Cl-chemistry on HO_x?*
- *Are the sources and the partitioning of BrO_x understood?*
- *Are the sources and sinks of HO_x understood?*
- *What is the importance of iodine chemistry in the Arctic boundary layer?*
- *What are the key oxidizers of Hg (gaseous elemental mercury)?*
- *Does PAN impact the oxidizing capacity of the Arctic troposphere? Do we understand low temperature/Arctic PAN chemistry?*

Among the key species that need to be accurately measured at Barrow to address these questions are: the three XO_x species, ClO, BrO, and IO; HO_x species (OH, HO_2, and RO_2, which have never before been measured in the Arctic Ocean environment; other inorganic Br species; and acetaldehyde, a key PAN precursor. Particularly with the addition of the HO_x measurements, we are in a position to do the most thorough job to date in terms of testing our understanding of the chemical processes operative in the Arctic.

E. Is there a connection between halogen chemistry and Arctic Haze?

- *How does halogen chemistry influence the production of H_2SO_4/sulfate aerosol?*
- *Does the increased oxidation power from chlorine chemistry impact aerosol production, e.g. from oxidation of organics?*
- *What is the impact of organics that accumulate over the winter (transport from Eurasia)?*

- *What is the role of marine biogenics and marine/ice-pack/snowpack (secondary) organics in Arctic aerosol?*
- *How important are air-surface interactions (e.g. halogen chemistry, organics) in the production of CCN, and thus how will changes in the surface characteristics feed back into changes in Arctic cloud cover?*
- *What role does arctic haze play in the deposition of Hg to the Arctic?*

F. What is role of meteorology and boundary layer stability in surface layer chemistry?

- *What is the role of BL stability in the initiation and termination of ODEs/MDEs?*
- *How important is BL stability as a driver of surface layer chemistry (e.g, halogens, NO_y, O_3, etc.)?*
- *Does dispersion of salt from blowing snow contribute to/impact halogen activation?*

G. How is Hg and Persistent Organic Pollutant (POPs) chemistry and fate impacted by halogen or oxidant chemistry, and the physical/chemical nature of the snow and sea ice?

- *How important are sea-ice leads in Hg deposition, and are they a Br- control?*
- *Is there a strong vertical gradient in Hg enrichment in hydrometeorites?*
- *What transformations of Hg occur in the snow pack and what is the lifetime of Hg in the snow pack after deposition?*
- *What is the relationship between halogens and the species of Hg measured in the snow pack?*
- *How are POPs lifetimes influenced by halogen or HO_x chemistry in the gas and/or condensed phase?*
- *Does snowpack photochemistry influence POPs fate?*

H. Can air-surface interactions in the Arctic be accurately described by models?

- *Can we model this unique oxidative environment in the boundary layer and the impacts on atmospheric chemistry (organics, Hg, aerosols, etc.)?*
- *Will increasing first year sea ice cover increase the importance of halogen chemistry?*
- *How will POPs lifetime and fate change with changing sea ice/snowpack cover?*