The Workshop on Future Directions for Arctic Research Logistics

7-9 October 2013
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Science Drivers of Logistics Needs

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And the Organizing Committee

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Cecilia Peralta-Ferriz photo Mi-9 deployment of Arctic Bottom Pressure Recorder at the North Pole 4/10/2010

How to have a fresh, forward-looking take on science issues without sidetracking the workshop:

Propose several candidate science issues whose resolution are likely to dictate future research logistics requirements.

and

Let the workshop participants expand on those in the course of discussing future logistics requirements.

Further Broad Breakdown

A major question facing NSF Research Support Logistics is what will be the balance between logistics requirements for

1) **Long-term repeat observations?**

versus

2) **Short-term intense process studies?**

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And we broke this down by science realm, e.g., marine physics (ocean, sea ice, atmosphere), terrestrial ecology, etc.

Examples of Science Drivers

Atmosphere Long-term: Role of the atmosphere in Arctic change, e.g., role of greenhouse gases in temperature and circulation changes; the feedbacks between changes to the surface and the large-scale circulation; the role of clouds in the changing Arctic system

Terrestrial Ecosystem Processes: How does altered biodiversity impact the structure and function and likely future state of arctic ecosystems, including examination of terrestrial, coastal, marine, aquatic systems

Sea Ice Long-term: Observations to significantly improve short and mid-term forecasting capabilities

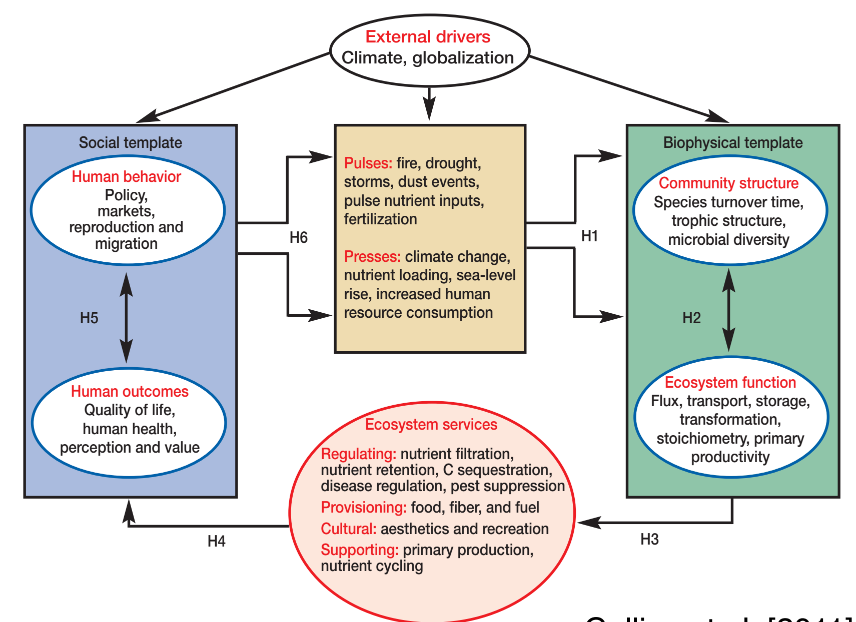
Ocean Processes: Understand how the spatially discontinuous fluxes of momentum, heat, and freshwater are aggregated to produce larger scale and longer term averages of these fluxes, particularly in air-sea-ice interaction and shelf basin exchange

Examples of Science Drivers

Social-Ecological Long-term: Understand the "Press" of climate change, sea-level rise, etc. on the social-ecological system.

Social-Ecological Processes: Understand the response of the social-ecological system to the "Pulses" imposed by events like fire and drought.

These also illustrate the increasing focus on cross-disciplinary, cross-realm investigations. Other examples ice sheet – ocean interaction and coastal zone studies



Collins et al. [2011]

Two Underlying Themes With Implications for Future Logistics

<u>Long-term/repeat Observations, Expanding the spatial and temporal coverage of observations:</u>

Paraphrasing Griffith on terrestrial ecology, the challenge is to start avoiding the trap of " the drunk looking for his keys under the streetlight because that's where the light is", and

from Shupe, the dearth of routine atmospheric measurements, particularly in remote locations and over the sea-ice…are hindering our ability to understand the Arctic climate system.

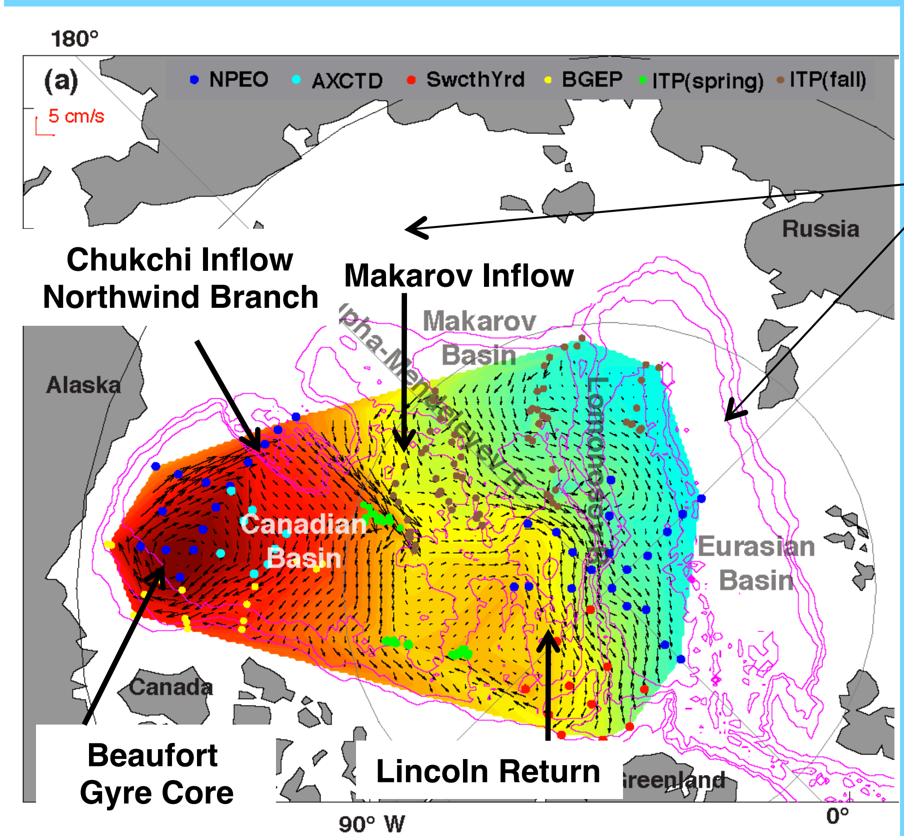
<u>An Ocean Example from *Kwok and Morison* [2011]:</u>

<u>Process Studies: Accounting for heterogeneity</u>:

Paraphrasing Tweedie the terrestrial ecology, understanding spatial heterogeneity is super important and implicit within answering the questions we've listed.

<u>An Ocean Example from *Morison and McPhee* [1998]:</u>

Spring 2008 Dynamic Height and Surface Geostrophic Current Relative to 500 dbar



Note: Critical areas have no observations

- **Agreement between dynamic height and DOT (*r* = 0.92)**
- **Measurement in under-sampled areas reveals cyclonic circulation on Russian side =>**
- **Transport of Eurasian runoff (radionuclides?) to the Canada Basin**

Kwok, R., and J. Morison (2011), Dynamic topography of the ice-covered Arctic Ocean from ICESat, *Geophysical Research Letters*, *38*(L02501), L02501.

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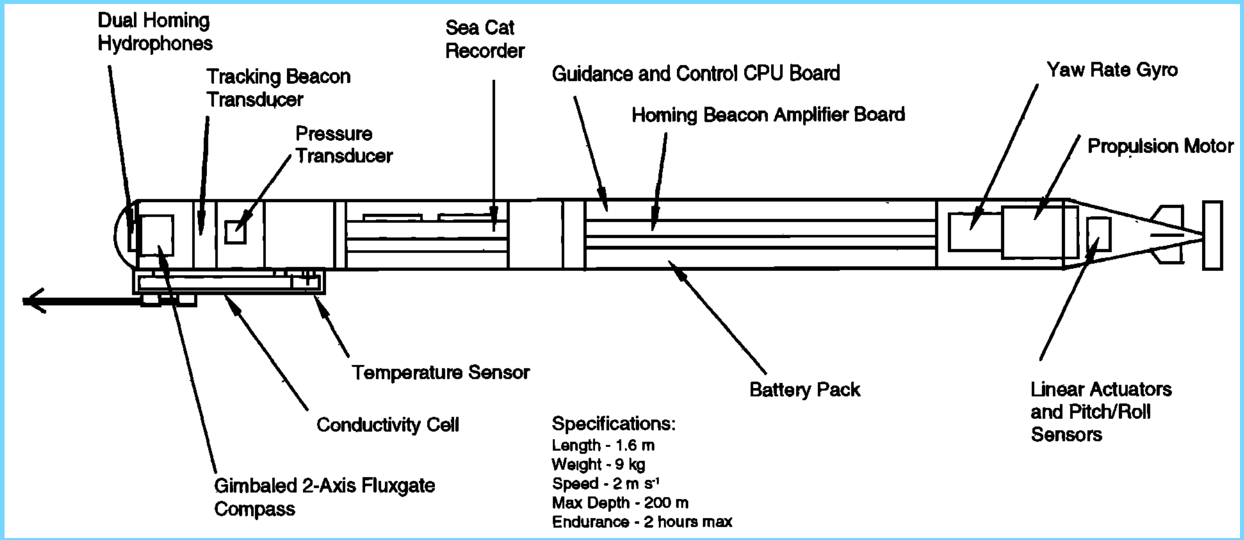
An Ocean Example from *Morison and McPhee* [1998]:

Autonomous Conductivity and Temperature Vehicle (ACTV) measured spatial variability under winter leads, LeadEx '92

ACTV is a 9 kg vehicle derived from M-38 target.

SBE-16 CTD, compass, tilt, pitch & yaw rate sensors

Programmed for ded-reckoned course with acoustic homing

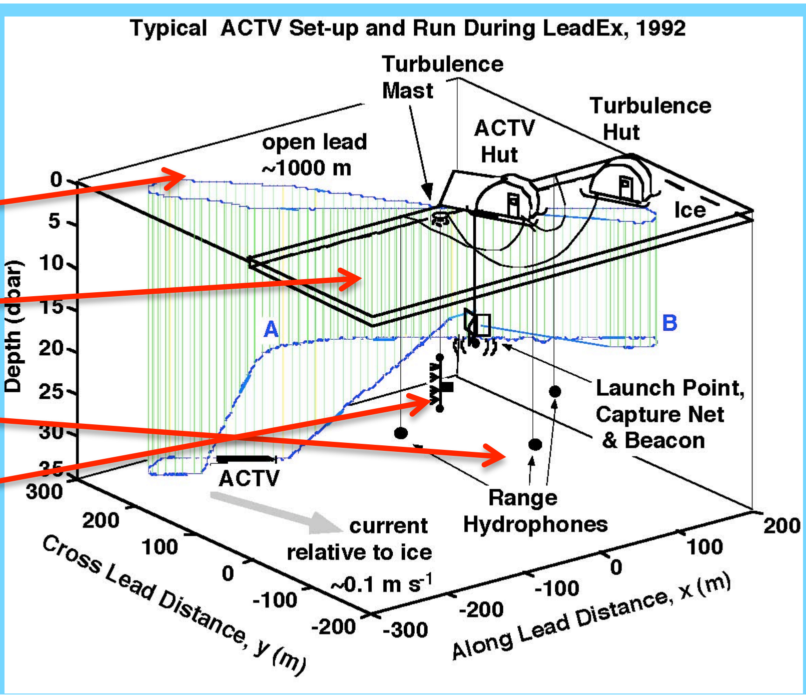


LeadEx application to convection in winter leads

Run under lead and surrounding ice

Track with acoustic range

Compare with turbulent instrument clusters at downstream edge



Salinity Measured at 5 m Under a Winter Lead with an AUV

Positive salinity, S', spike at downstream lead edge

But at 15 m depth salinity upstream of the lead ~ salinity downstream.

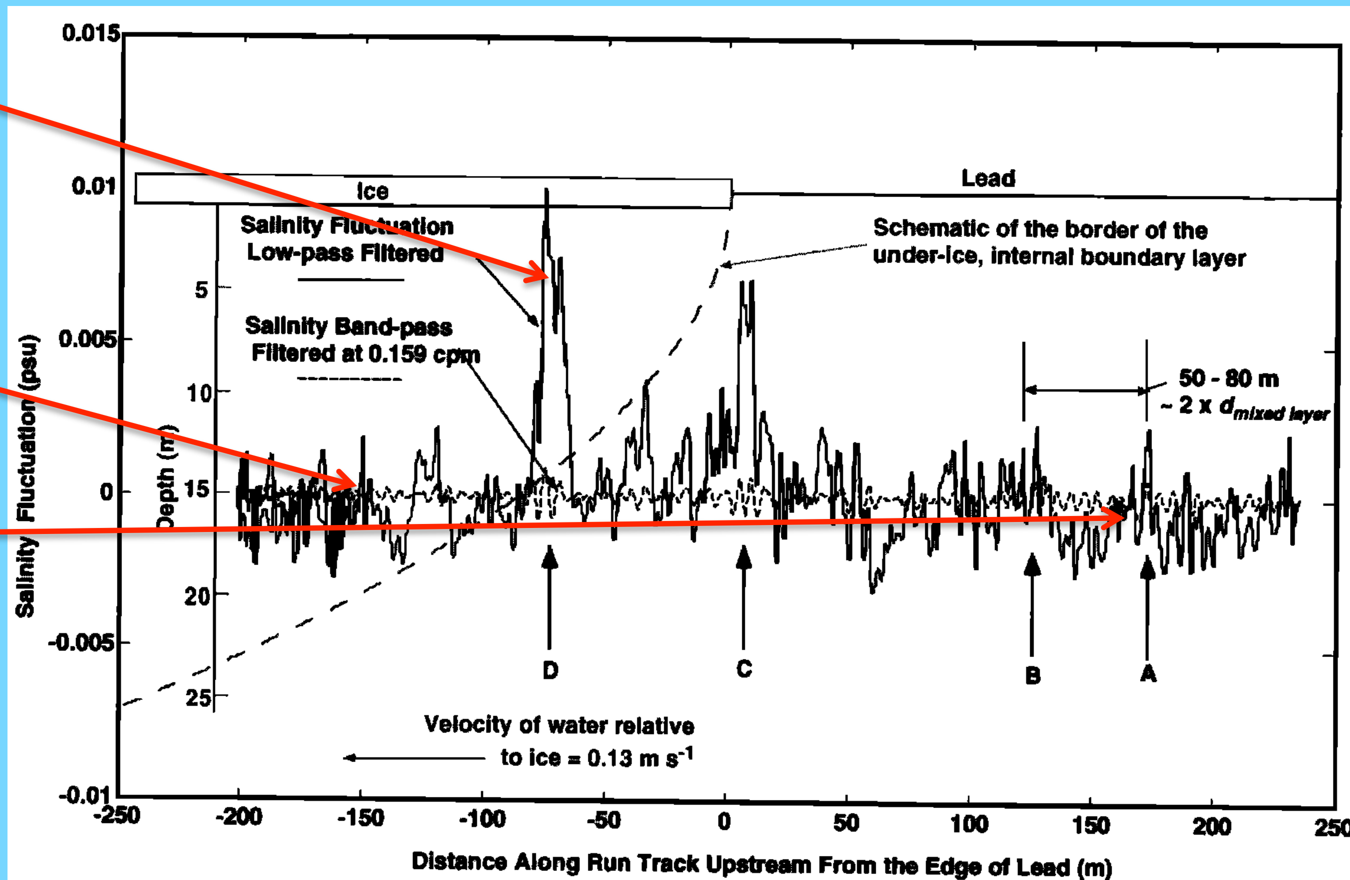


Figure 5a. ACTV salinity fluctuation low-pass filtered with cutoff frequency of 0.33 cpm and the salinity band-pass filtered at 1 rad m^{-1} (0.159 cpm) from run 5 at lead 3 of LeadEx. The dashed line suggests the border of the internal boundary layer under the ice.

W' and fluxes in winter leads measured with ACTV

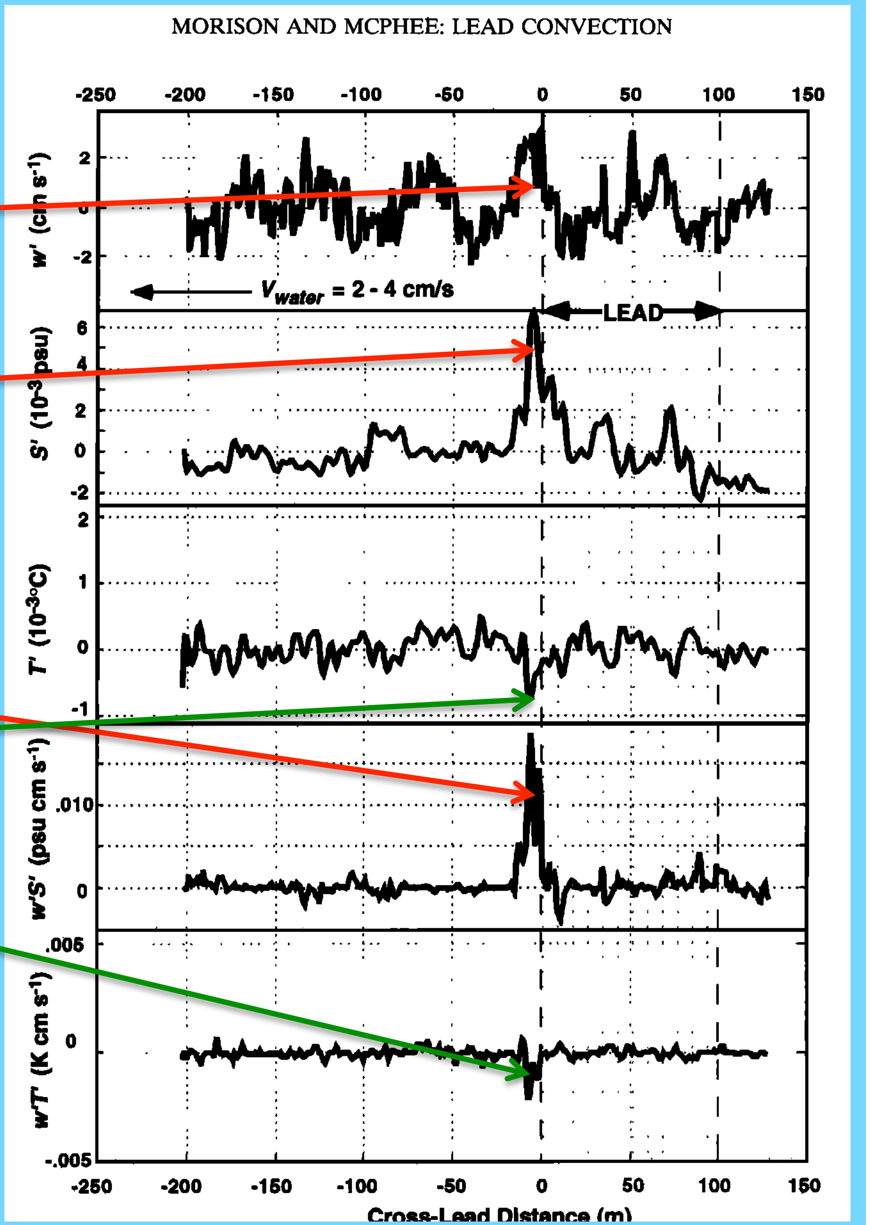
W' commonly shows positive (downward) pulse at downstream edges (9 m, lead 4)

With positive salinity, S', spike

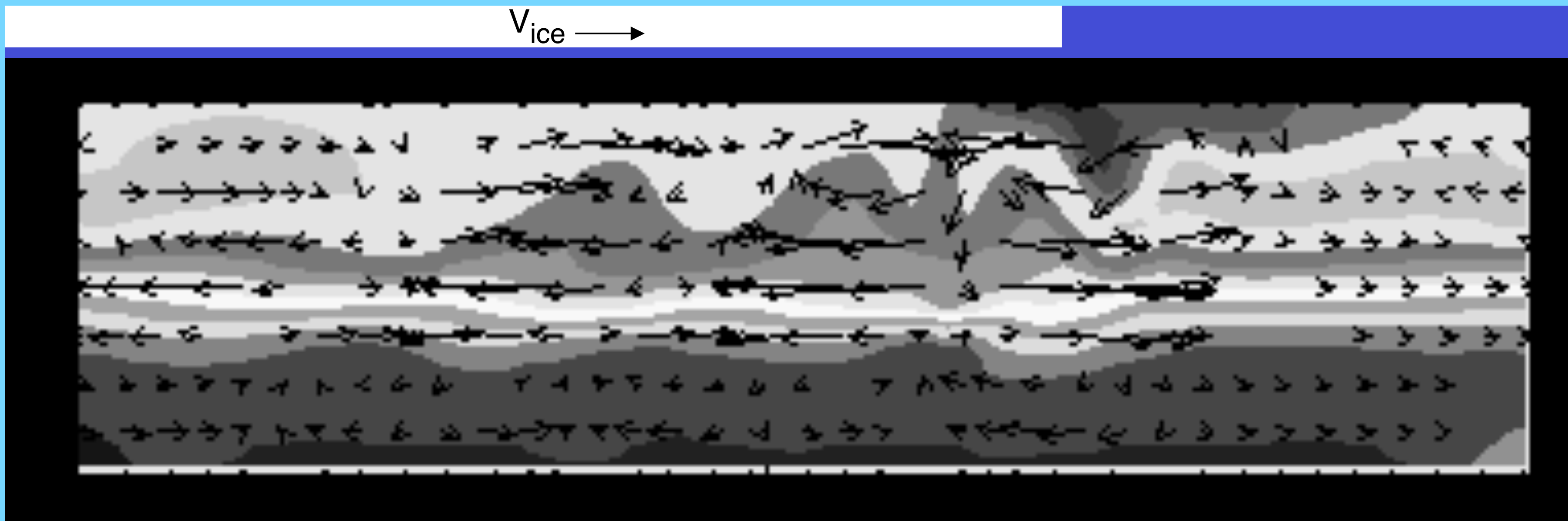
Produces pulse in downward salt flux w'S'

Similarly for T', and upward heat flux plume

Demonstration of convection dominated by plumes at downstream edge of buoyancy source



Similar to David Smith's 2-D Simulations of Lead Convection



- With mixed free-forced convection conditions representative of LeadEx, the episodic plumes occur predominantly at lead downstream edge and carry salt to the base of the mixed.
- Spatially discontinuous unstable buoyancy flux, instead of increasing mixed layer depth and salinity, decreases downstream mixed layer depth while leaving mixed layer salinity the same.

Smith & Morison , 1993 and 1998

Two Useful Strategies When Planning for Future Research Logistics Requirements

For long-term/repeat observations, ask where and when we haven't been making observations. Our successors will likely want to go there.

For Process Studies, ask what kind of observations will be needed to account for the heterogeneity that characterizes Arctic terrestrial and marine fluxes. Our successors will likely want to increase both the scale and resolution of their measurements.

Jay Simpkins photo of Lockheed L-100 (C-130) taking off from AIWEX sea ice (5’ thick) runway, April 1985

Examples of Science Drivers

Terrestrial Ecosystem Long-term: The net balance between terrestrial CO_2 (above and below ground) and CH_4 exchange with current and future changes in soil temperature and moisture status/water table

Terrestrial Ecosystem Processes: How does altered biodiversity impact the structure and function and likely future state of arctic ecosystems, including examination of terrestrial, coastal, marine, aquatic systems

Sea Ice Long-term: Observations to significantly improve short and mid-term forecasting capabilities

Sea Ice Processes: System- and process-level understanding of the coupling of the sea-ice-atmosphere-ocean system (with added emphasis on sea ice dynamics)

Examples of Science Drivers

Atmosphere Long-term: Role of the atmosphere in Arctic change, e.g., role of greenhouse gases in temperature and circulation changes; the feedbacks between changes to the surface and the large-scale circulation; the role of clouds in the changing Arctic system

Atmosphere Processes: System- and process-level understanding of the coupling of the sea-ice-atmosphere-ocean system system (with added emphasis on the atmosphere)

Ocean Long-term: Understand the variability of Arctic Ocean circulation, freshwater pathways, and heat transport, and the relation of these to the atmosphere, sea ice, and flux of freshwater from land and terrestrial ice

Ocean Processes: Understand how the spatially discontinuous fluxes of momentum, heat, and freshwater are aggregated to produce larger scale and longer term averages of these fluxes, particularly in air-sea-ice interaction and shelf basin exchange

Atmosphere Science Drivers

(Shupe)

Long-term/repeat Observations:

Climate change is, at its core, an atmospheric phenomenon driven by greenhouse gases. But there are substantial uncertainties regarding the total role of the atmosphere in Arctic change. Specifically, we don't fully understand: the direct role of greenhouse gases in bringing observed temperature changes; the larger-scale changes in atmospheric circulation as a result of greenhouse forcing; the feedbacks between changes to the surface (temperatures, sea-ice loss, etc.) and the large-scale circulation; the role of clouds in the changing Arctic system, and others. Long-term atmospheric measurements are difficult, and expensive, to make. These difficulties have lead to a dearth of routine atmospheric measurements (clouds, upper air, radiation, etc), particularly in remote locations and over the sea-ice. Lack of long-term atmospheric measurements is hindering our ability to understand the Arctic climate system, as outlined by the IPCC AR4 report.

Atmosphere Science Drivers

(Shupe)

Process Studies:

One of the biggest fingerprints of Arctic change is the decline in sea-ice, yet we lack a system- and process-level understanding of the coupled sea-ice-atmosphere-ocean system (particularly from the top side of the ice!). We lack an understanding of these processes in all seasons and for first year ice (which is now dominant!). Many sea-ice relevant processes that are represented in models are based on SHEBA.... which was 15 years ago in a multi-year ice environment that may not be applicable today. The ability to understand and forecast sea-ice requires models that can represent many interdependent processes, and this ability has never been in greater demand. All of these points together motivate the need for very detailed, interdisciplinary, year-round observations in the central Arctic ice pack. In response to this need, an international group of observers and modelers are teaming up to organize and conduct the MOSAiC* initiative, which is one of the "showcase" projects.

* Full disclosure: Shupe is one of the lead organizers for this effort.

Terrestrial Science Drivers

(Oberbauer)

Long-term/repeat Observations:

Understand the net balance between terrestrial CO_2 (above and below ground) and CH_4 exchange with current and future changes in soil temperature and moisture status/ water table. Arctic greening is part of the equation- greening can only happen if soil nutrient availability is increased, which must be tied to changes in active layer/ soil moisture/ aeration

Terrestrial Science Drivers

(Oberbauer)

Process Studies:

Understand the linkages between changes in active layer depth, soil moisture, aerobic and anaerobic respiration and nutrient availability and how these changes drive changes in aboveground production.

Terrestrial Ecology Science Drivers

(Tweedie)

Long-term/repeat Observations:

How does climate variability and change impact the fate and transport of Arctic soil organic carbon: includes biophysical interactions within landscapes and between land and the atmosphere, ocean, and aquatic systems.

Terrestrial Ecology Science Drivers

(Tweedie)

<u>Process Studies:</u>

How does altered biodiversity impact the structure and function and likely future state of arctic ecosystems: Should include examination of terrestrial, coastal, marine, aquatic systems in wild and managed environments.

Terrestrial Ecology Science Drivers

(Griffith)

Overarching question:
How vulnerable and resilient are ecosystems and society to environmental change in Arctic and boreal regions (ABR)?

1. How are disturbance regimes in ABR changing and what processes are controlling those changes?
2. What are the changes in the distribution and properties of permafrost in the ABR and what is controlling those changes?
3. What are the changes in the spatial distribution of water, and the amount and timing of water discharge in the ABR and what is controlling those changes?
4. How is the magnitude and fate of soil organic carbon pools in the ABR changing, and what are the processes controlling the rates of those changes?

Terrestrial Ecology Science Drivers

(Griffith)

5. How are ABR flora and fauna responding to changes in biotic and abiotic conditions, and what are the impacts on ecosystem structure and function?
6. How do complex interactions affect the trajectory of ecosystem structure and function and ecosystem services in the ABR?
7. How are environmental changes in the ABR affecting natural and cultural resources and climate regulation, and how are human societies within and beyond the region responding?

These questions clearly span a huge range scientifically and geographically, as would be expected for a major NASA field campaign. … Using remote sensing we can seek to upscale local field observations to regional and global scales; and to observe things that can't be seen in local field observations. Challenge is to avoid the trap of " the drunk looking for his keys under the streetlight because that's where the light is ".

Sea Ice Science Drivers

(Richter-Menge)

Long-term/repeat Observations:

Determining the key observations necessary to significantly improve short (day-week) and mid-term (months-year) forecasting capabilities. These forecasts are of immediate and critical need for a broad cross section of the user community (e.g. native communities, resource recovery, shipping industry, fisheries, etc.). They also are near the top of many priority lists (c.f. NOAA's Arctic Vision and Strategy, the SEARCH goal "Improve Understanding, Advance Prediction, and Explore Consequences of Changing Arctic Sea Ice", and the AON showcase project "Ocean Observations to Improve Sea Ice Forecasting"). As pointed out in the National Academies of Science report "Seasonal to Decadal Predictions of Arctic Sea Ice: Challenges and Opportunities", distinct from decadal-scale forecasts, short term forecasts require adequate, high quality real time and near-real time data….

Sea Ice Science Drivers

(Richter-Menge)

Process Studies:

There is a need for a system- and process-level understanding of the coupled sea-ice-atmosphere-ocean system (adding an emphasis on sea ice dynamics), calling for a year-long field program (ala SHEBA) in a region of the arctic that is dominated by seasonal ice. In addition to MOSAiC, this issue has motivated the ONR Marginal Ice Zone Project (with field program in spring/summer/fall 2014) and is listed as a high priority activity in the recent National Academies of Science report "Seasonal to Decadal Predictions of Arctic Sea Ice: Challenges and Opportunities".

Arctic Ocean Science Issues
(Morison)

<u>Long-term/repeat Observations:</u>

Measure and understand the variability of Arctic Ocean circulation, freshwater pathways, and heat transport and the relation of these to the atmosphere, sea ice, and flux of freshwater from land and terrestrial ice. This has been and will be an overarching composite issue. To varying degrees, it encompasses AON showcase projects 7. Ocean Observations to Improve Sea Ice Forecasting, 8. Long-term Sea Level Measurements along the Alaskan and Beaufort Coasts, and 9. Arctic Ocean Freshwater and Heat Observing System as well as the existing AON ocean observation programs (e.g., BGEP, NPEO, Switchyard, NABOS, ITP).Competing concepts of the relation between atmospheric circulation and ocean circulation, freshwater and heat have developed. The time-scales of the variations extends from seasonal to multi-decadal and longer and into critical regions that have been perpetually under-sampled, thus posing significant future logistical challenges.

Arctic Ocean Science Drivers

(Morison)

Process Studies:

Understand how the spatially discontinuous fluxes of momentum, heat, and freshwater are aggregated to produce larger scale and longer term averages of these fluxes. This is a particular problem in air-sea-ice interaction and shelf basin exchange where surface fluxes are inherently discontinuous. Such an understanding has been a concern since before the planning of SHEBA. It can benefit from such future programs as the AON showcase project 5. Mutltidisciplinary Drifting Observatory for the Study of Arctic Climate MOSAIC. However, conceptual science, operations, and logistics breakthroughs will be needed to obtain measurements with sufficient spatial/ temporal resolution and coverage to understand flux aggregation.