Opportunities and Challenges for SBG in the Arctic System

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The Arctic System

The Arctic System includes land areas >50 N + Arctic Ocean (blue)

Characterized by:
- ~5 M km² Tundra
- ~12 M km² Boreal Forest
- Long, brutally cold winters (up to 300 days per year)
- Short, intense thaw/growing season (typically < 90 days)
- Snow cover 8 – 10 months of the year
- Permafrost (white dots)
The Arctic Is Already Experiencing Abrupt Climate Change

Arctic arguably exhibiting the first signs of dangerous climate change (UNFCCC)
  • New “Arctic Rapid Change” climate pattern

Arctic climate change is now faster than ecosystems can adapt to naturally

The Arctic has the greatest concentration of potential tipping elements in the Earth system
  • Tightly linked, non-separable system

The Arctic provides a test of our ability to respond to abrupt climate change
  • Develop early warning indicators of abrupt climate change

Duarte, Nature Climate Change (2012)
Arctic Amplification & the Snow-Ice-Albedo Feedback

TOA Imbalance: -114
-54, -66, -82
-85, -72, -45

OLR: 198
194, 199, 209
181, 195, 213

Incoming Solar: 183
241, 229, 218
200, 221, 283

OSR: 99
101, 96, 90
104, 98, 115

DLR: 232
219, 235, 283
183, 219, 271

ULW: 264
248, 265, 318
216, 250, 307

DSR: 96
111, 106, 79
129, 116, 126

USW: 53
84, 53, 13
93, 62, 38

Surface Imbalance: 11
-2, 22, 30
3, 22, 51

All sea ice, mixed sea ice/open ocean, all open ocean
All snow, mixed snow/bare land, all bare land

All sky fluxes in Wm$^{-2}$

Photo: Glaciers Online: J. Alean and M. Hambrey
Vegetation Change Drives Arctic Amplification

- Snow-Ice-Albedo feedback is the key to Arctic Amplification
- Boreal forest expansion alters the albedo and increases air temperatures in both summer and winter [Bonan, 1993]
- Increased tundra shrub cover reduces winter albedo [Loranty, 2011]
Arctic Greening 1984-2012

Ju + Masek, Remote Sens (2016)
Trait Diversity

Foliar %N variation derived from 2009 Hyperion data

High variability despite low species diversity

Lake Myvatn, Iceland

Dreyer, Townsend et al. (2015, Ecology)
Thermokarst & Fire Reshape the Landscape Annually

Thermokarst Hydrology: lakes appear/disappear with permafrost degradation and changes in sub-surface hydrology
- Ponds < 1 ha are particularly challenging to track
- Seasonal inundation and retreat of low lying areas (laida)
Fires burn up to 10 Mha of boreal forest each year → Landscape reconfiguration, thermokarst, biodiversity (succession)

D Olefeldt, Nature Comm (2016)
Snowscapes Are Critical to Arctic Biodiversity

• Depth
• Density
• Ice layers

Insulative capacity

Craighead and Craighead 1972; Jonkel 1980; Vroom et al. 1980

Snow Albedo
Predator-Prey Relationships

Zimova et al. 2014; Mills et al. 2013; Henden et al. 2017
Snow Cover & Quality Dictate Caribou Migration

N Boelman, ERL (2018)
Snow Cover & Quality Dictate Caribou Migration

- Timing of spring migration *precedes* snow cover melt
- Animals prefer to migrate over complete snow cover
- Le Corre et al. (2017) suggest they are ‘chasing’ high *quality* snow cover

N Boelman, ERL (2018)
Snow Cover & Quality Dictate Caribou Migration

Elie Gurarie in prep.

N Boelman, ERL (2018)
Snow Cover & Quality Dictate Caribou Migration

High snow cover fraction

100% green

Days ahead of snowline

-10 0 10 20 30

Apr 26 May 06 May 16 May 26 Jun 05

Overwintering  Migrating  On calving grounds

N Boelman, ERL (2018)

Elie Guranie in prep.
SBG Opportunities

- ABoVE (need TIR)
- SnowEx
- IceSat-2 Validation
- NEON
- EnMAP
- PREFIRE

AVIRIS-NG / B-200 (N53W)
Dates: June – August 2017

Number of lines acquired/processed:
- Acquired 437 science runs
- Processed all 437 runs
- >60,000 km2 surveyed

https://avirisng.jpl.nasa.gov/alt_locator/
TIR Characterization of Inundation and Soil Moisture

- Wetness/surface water important to land/atmosphere carbon flux
- Highly spatially variable
- Surface water fraction may be determined by thresholding FLIR observations ~20 cm resolution
- Useful for upscaling analysis
Characterizing Vast Arctic Wetland Systems

AVIRIS-NG imagery acquired near Atqasuk AK 29 July 2018

W Olson-Duvall
Boreal Forest Seasonal Time Series

Line B4 acquired on 24 June/DOY 175 (top) and 6 Aug/DOY 218 (bottom)
The spectral differences will help quantify seasonal changes in the vegetation & land surface
Regional Gradients in Plant Traits: NDVI

F Huemmrich, unpubl
Regional Gradients in Plant Traits: Chlorophyll

F Huemmrich, unpubl
Regional Gradients in Plant Traits: GEP

Area near Barrow

Daily GEP

F Huemmrich, unpubl
SBG Challenges

ISS sensors do not observe > 50N

Persistent cloud cover

Validation, esp Siberia
The Arctic is a critical element in the Earth System

SBG priority Targeted Observables – plant functional traits, biodiversity and snow – will significantly improve our understanding of the Arctic system and its response to climate change

Opportunities for pre-SBG science risk reduction will necessarily focus on airborne data acquisitions since ISS sensors do not observe > 50 N

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• ABoVE (need TIR)
• SnowEx
• IceSat-2 Validation
• PREFIRE

Nearly 60% of the thermal energy exchanged at the Arctic surface via outgoing longwave IR radiation, yet both short-term fluctuations and long-term trends in the atmospheric and surface components of this energy exchange are highly uncertain since the spectral variation of OLIR fluxes have never been systematically observed.

Spatially- and temporally-resolved observations of the longwave emissivity contribution to surface energy balance are imperative for understanding feedback between surface mass balance, the atmosphere, and ice flow dynamics, as well as for projections of sea level.
The Arctic Is a Critical Component of the Earth System

Table 1: Evidence for the presence of all five reasons for concern that characterize dangerous climate change\(^2\) in the Arctic region.

<table>
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<tr>
<th>Reasons for concern with Arctic climate change</th>
<th>Evidence</th>
<th>References</th>
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<tr>
<td>1. Risks to unique and threatened systems (Risk of losing unique ecological and social systems)</td>
<td>Decline of ice-associated biota (polar bears, seals, walruses, ice algae) and Arctic copepods</td>
<td>1, 13</td>
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<td>Rapid changes in landscapes due to permafrost thawing and thermokarst activity</td>
<td>14, 15</td>
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<td>Threats to Inuit cultural practices</td>
<td>2, 16</td>
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<td>2. Risk of extreme weather events (Extreme events with substantial consequences for societies and natural systems)</td>
<td>Severe winter in northern temperate regions</td>
<td>19</td>
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<td>Changes in sea-level rise</td>
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<td>Altered heat budgets</td>
<td>21, 22</td>
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<td>Changes in freshwater discharge and ocean circulation</td>
<td>23, 24</td>
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<td>Greenhouse-gas emissions</td>
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<td>Reduced oceanic carbon dioxide uptake</td>
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<tr>
<td>Impacts to Inuit well being, health, safety and culture</td>
<td>2</td>
<td></td>
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<tr>
<td>3. Distribution of impacts (Spatial scale of impacts)</td>
<td>Risks to security from territorial disputes</td>
<td>27</td>
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<td>Destabilization of the Greenland ice sheet</td>
<td>28, 29</td>
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<td>Poat fires in the subarctic region</td>
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<td>Methane emission from thawing methane hydrates</td>
<td>31, 32</td>
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<td>Slowed global thermohaline circulation</td>
<td>33</td>
<td></td>
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<tr>
<td>Reduced oceanic carbon dioxide uptake</td>
<td>34</td>
<td></td>
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Duarte, NCC (2012)