Opportunities and Challenges for SBG in the Arctic System

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SBG Kickoff Meeting

Carnegie Institute, Washington DC

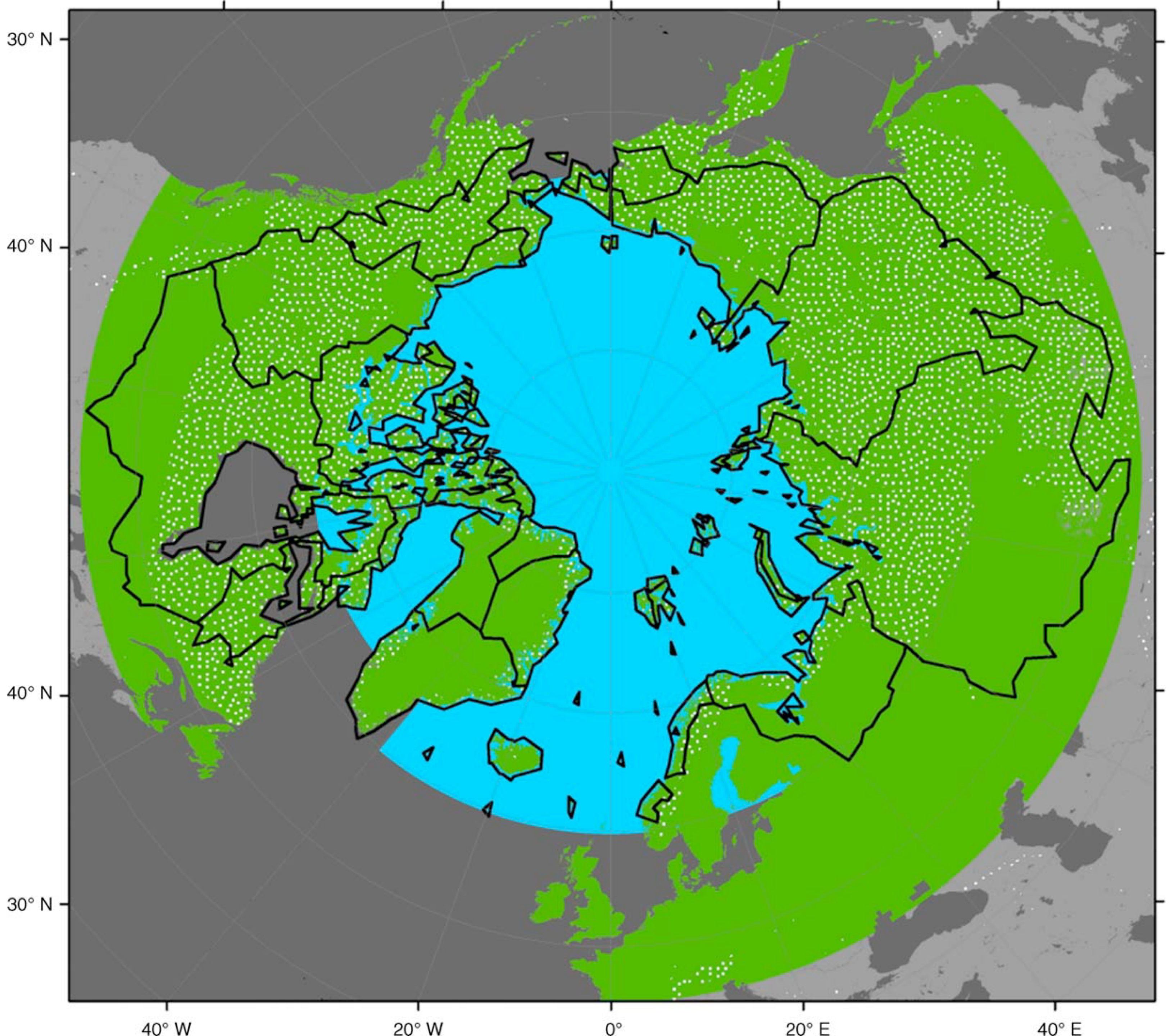
15-17 August 2018

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)



McGuire, Ecol Mon (2009)

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

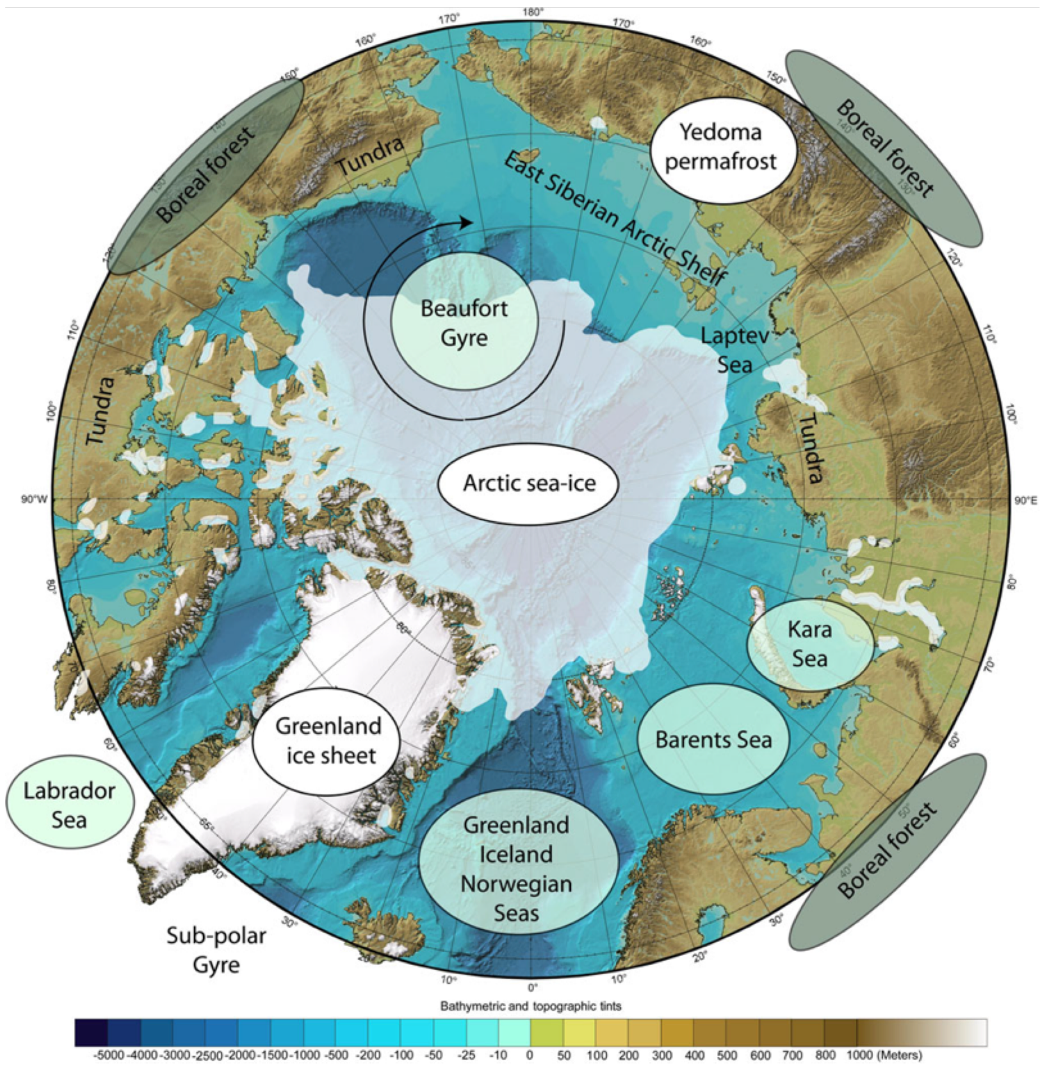
The Arctic has the greatest concentration of potential tipping elements in the Earth system

- Tightly linked, non-separable system

The Arctic provides a test of our ability to respond to abrupt climate change

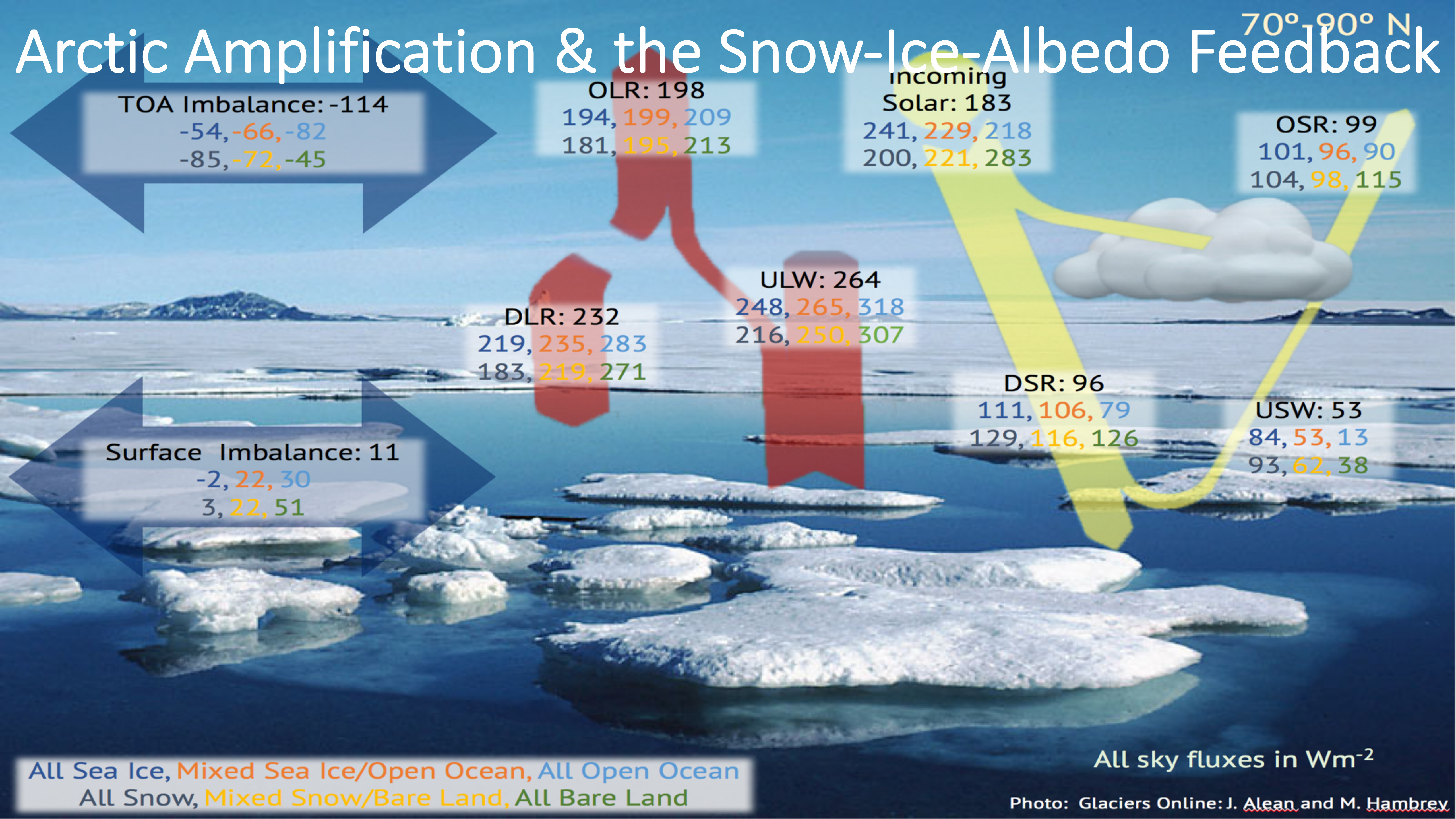
- Develop early warning indicators of abrupt climate change

Arctic System Tipping Elements



Duarte, Nature Climate Change (2012)

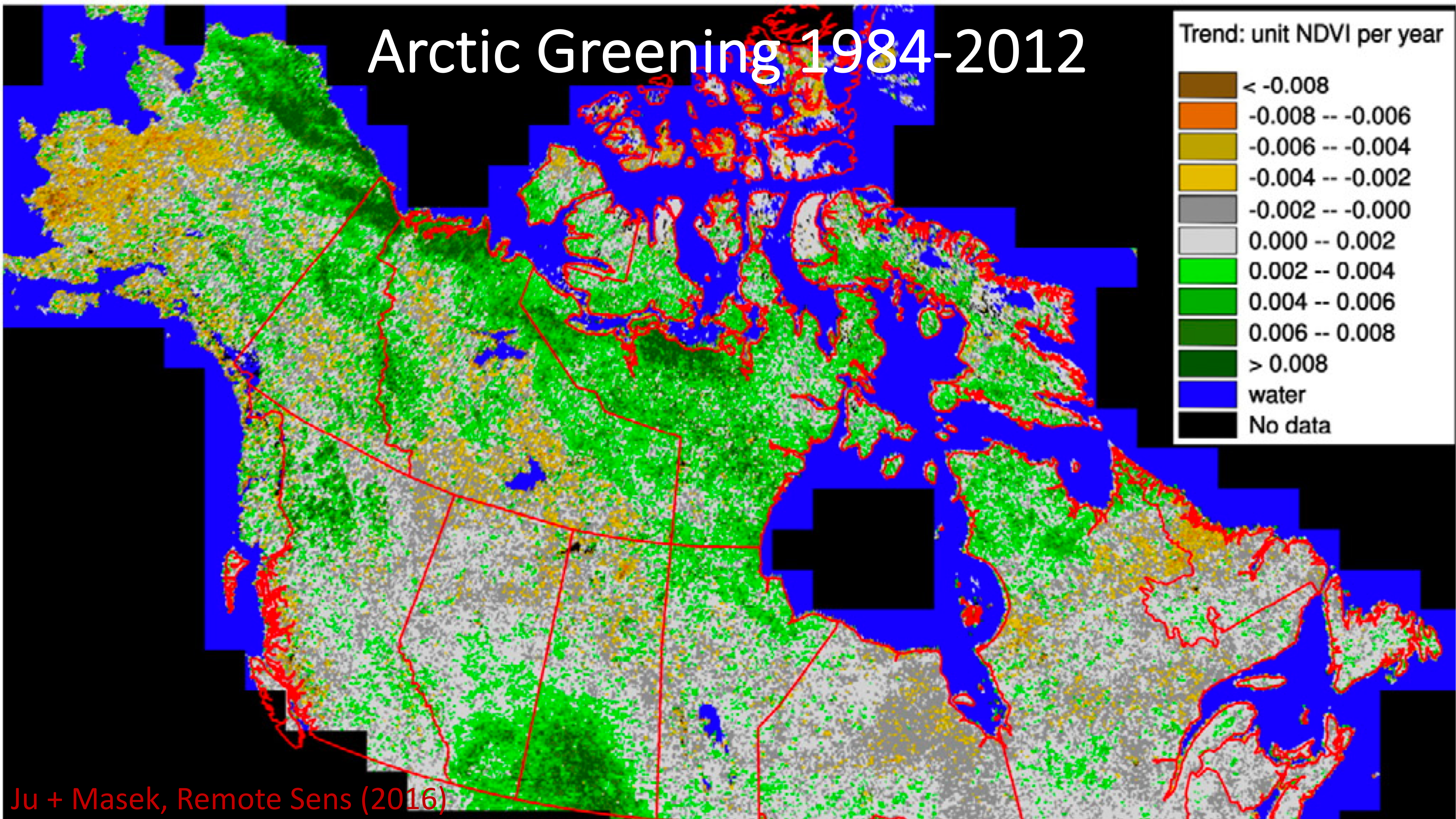
Arctic Amplification & the Snow-Ice-Albedo Feedback



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



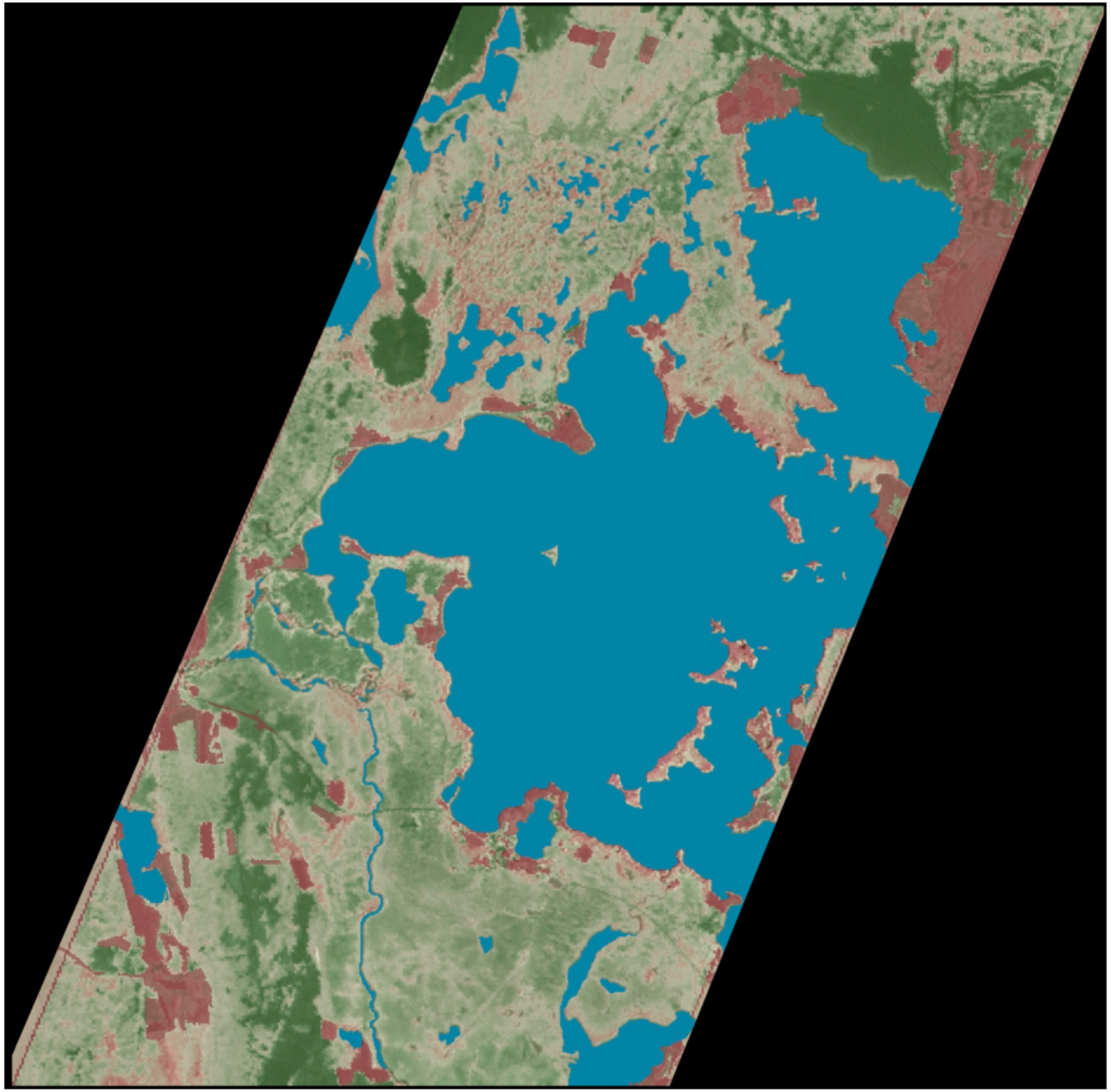
Ju + Masek, Remote Sens (2016)

Trait Diversity

Foliar %N variation derived from 2009 Hyperion data

High variability despite low species diversity

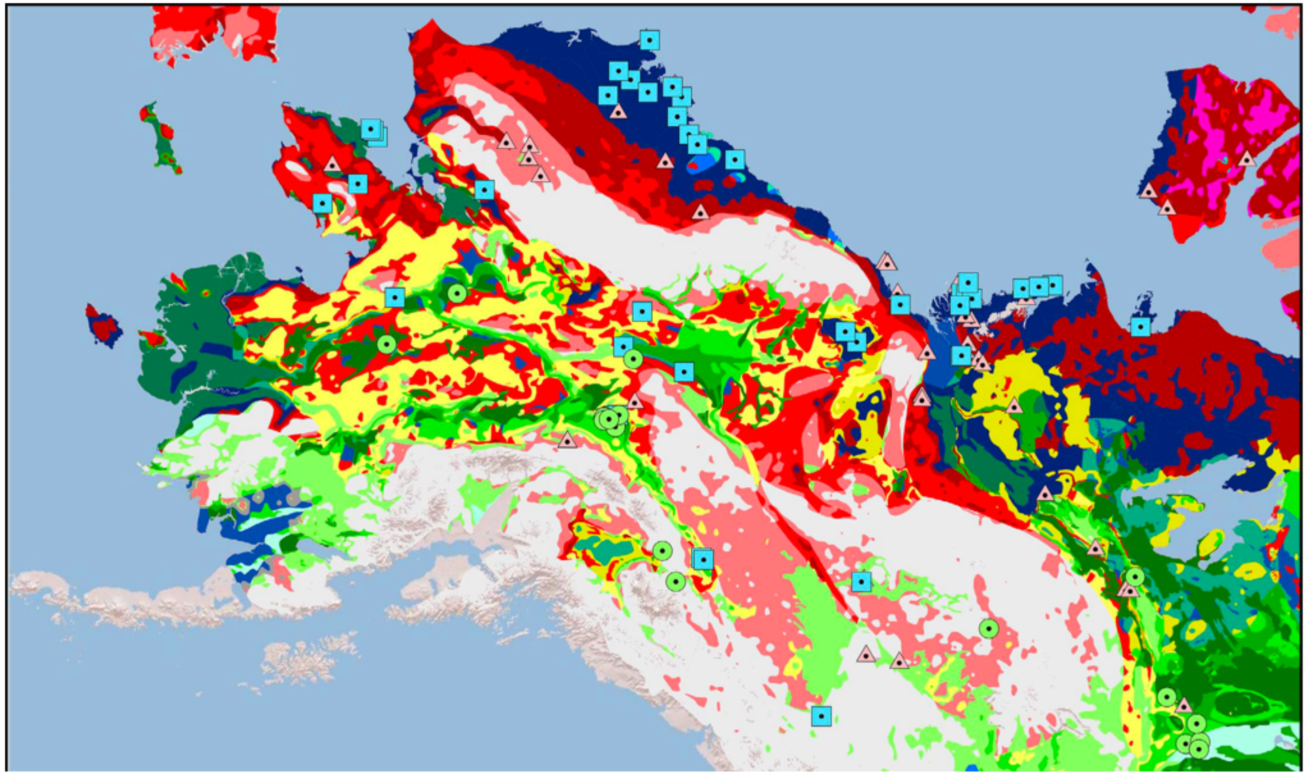
Lake Myvatn, Iceland



Dreyer, Townsend et al. (2015, *Ecology*)

Thermokarst & Fire Reshape the Landscape Annually

Thermokarst Collapse



Dominant thermokarst landscapes in Alaska

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**
- **Hardness**
- **Wetness**

- **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

N Boelman, ERL (2018)

Snow Cover & Quality Dictate Caribou Migration

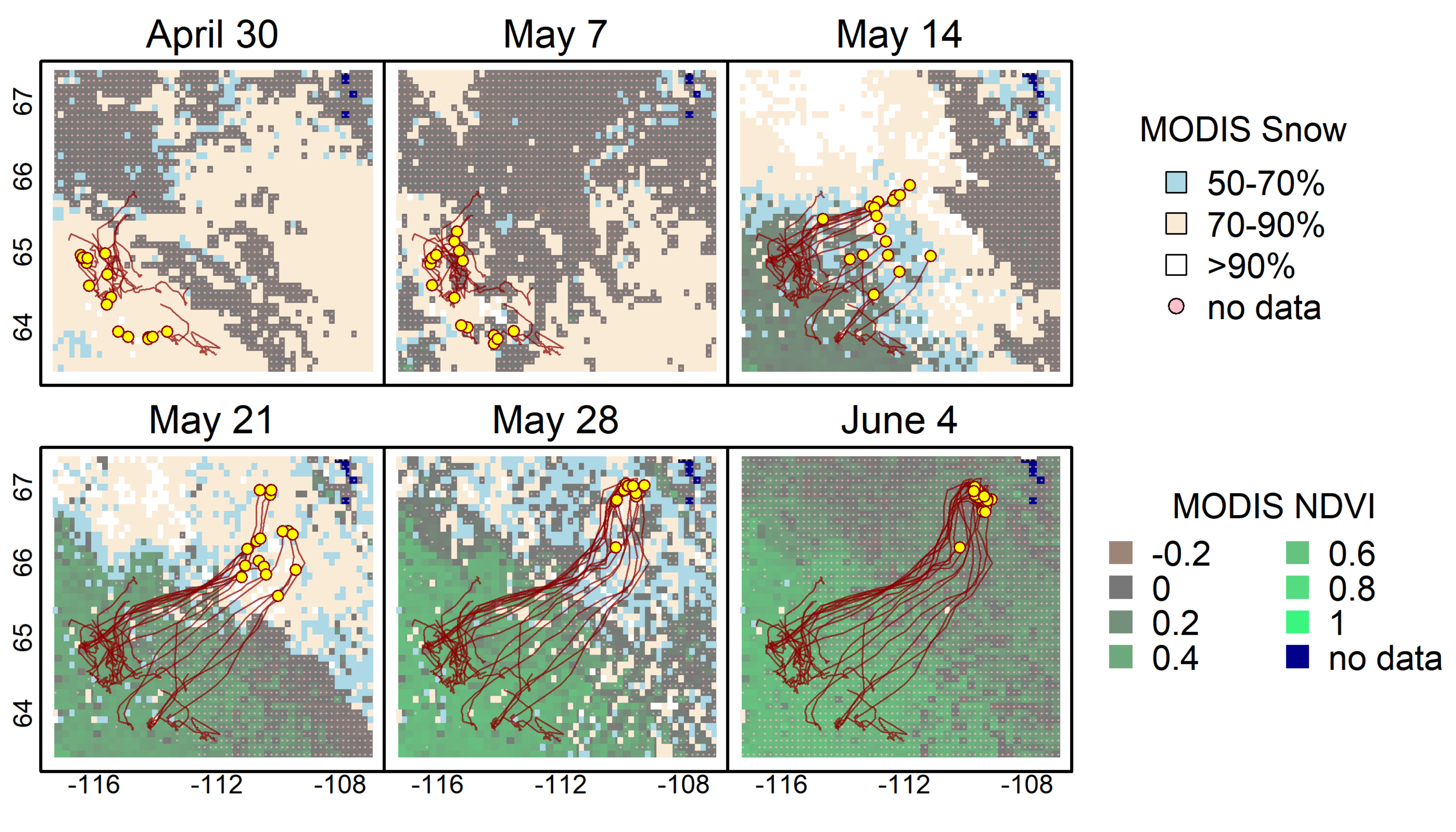
N Boelman, ERL (2018)

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)

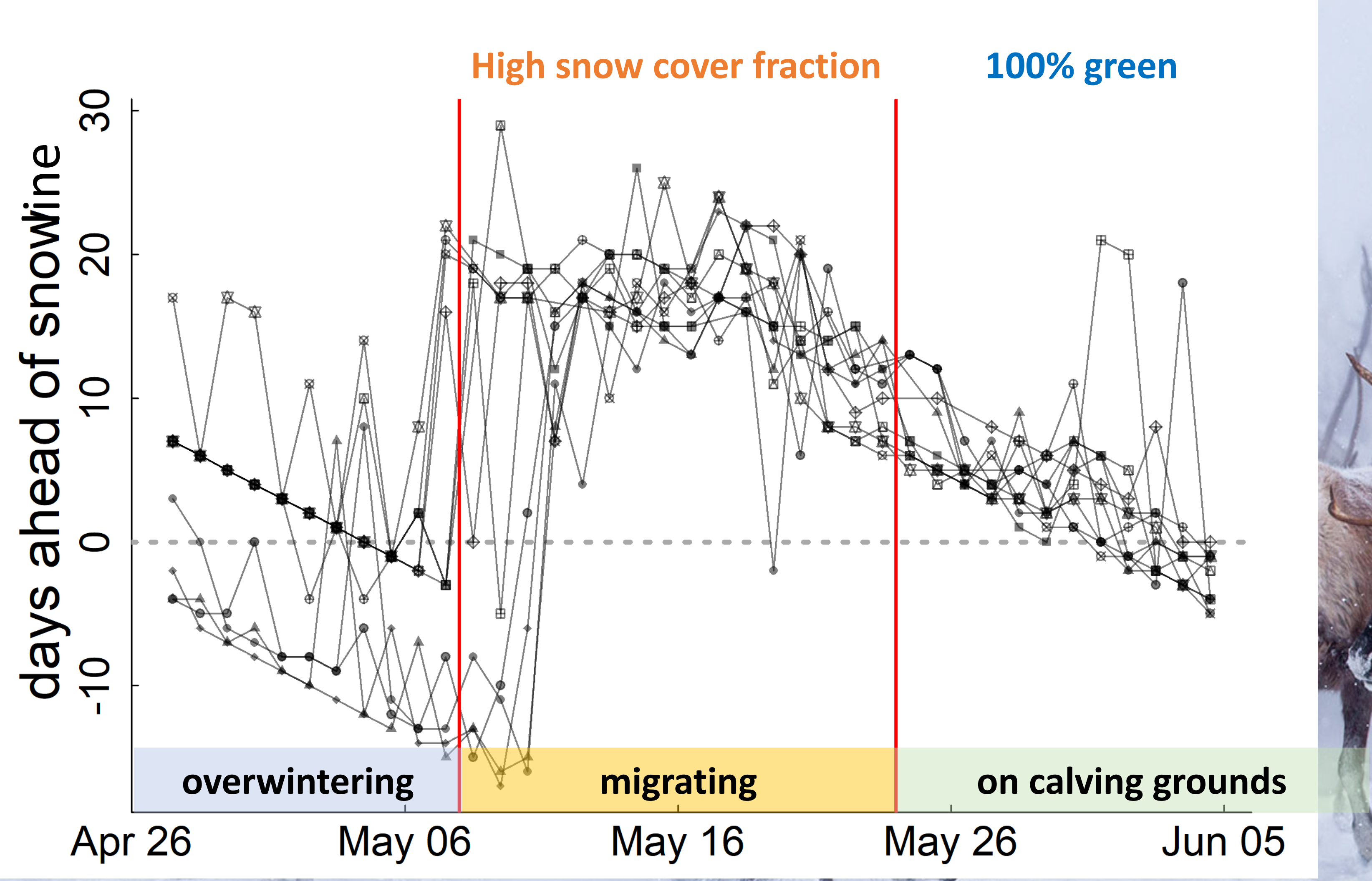
Snow Cover & Quality Dictate Caribou Migration



N Boelman, ERL (2018)

Elie Gurarie *in prep.*

Snow Cover & Quality Dictate Caribou Migration

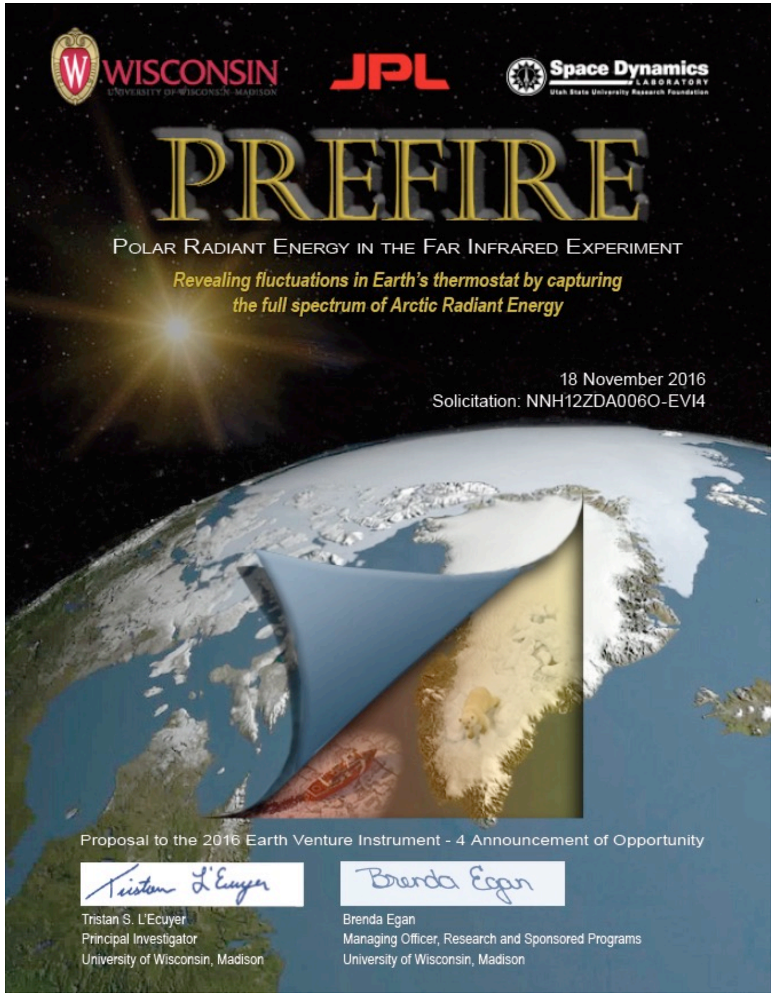


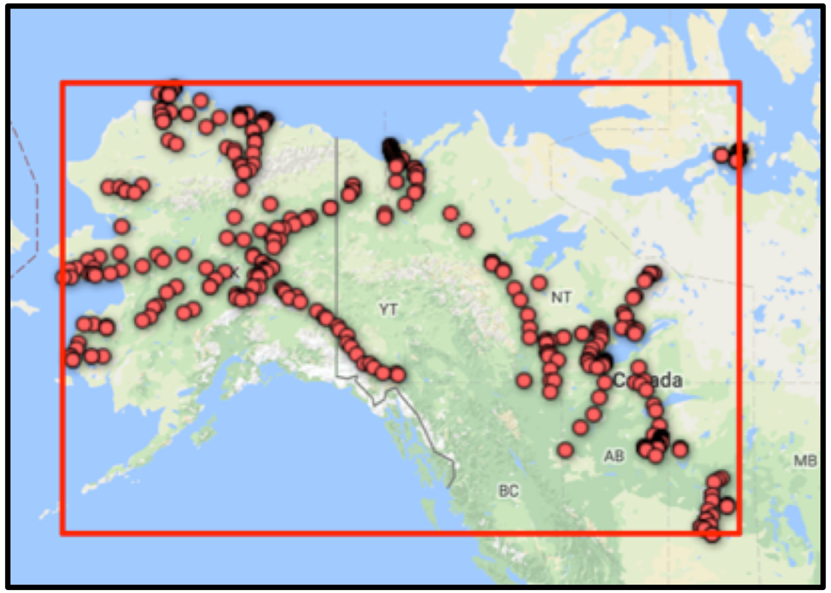
N Boelman, ERL (2018)

Elie Gurarie *in prep.*

SBG Opportunities

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





https://avirisng.jpl.nasa.gov/alt_locator/

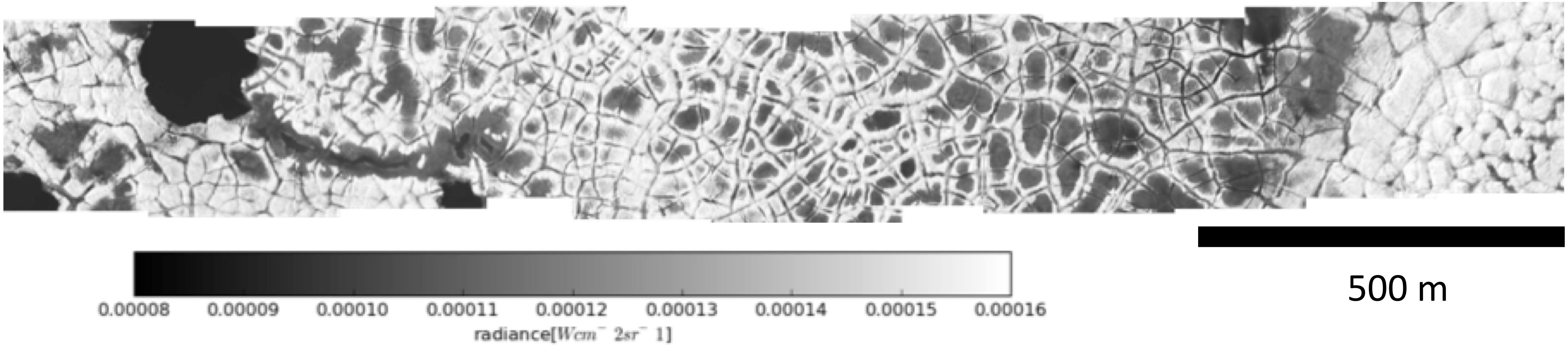
AVIRIS-NG / B-200 (N53W)

Dates: June – August 2017

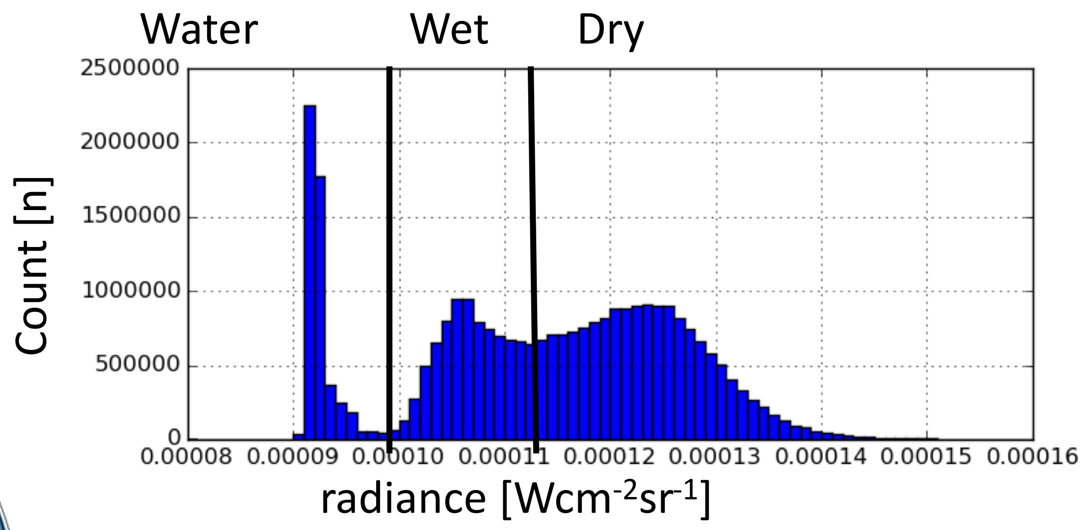
Number of lines acquired/processed:

- Acquired 437 science runs
- Processed all 437 runs
- >60,000 km2 surveyed

TIR Characterization of Inundation and Soil Moisture

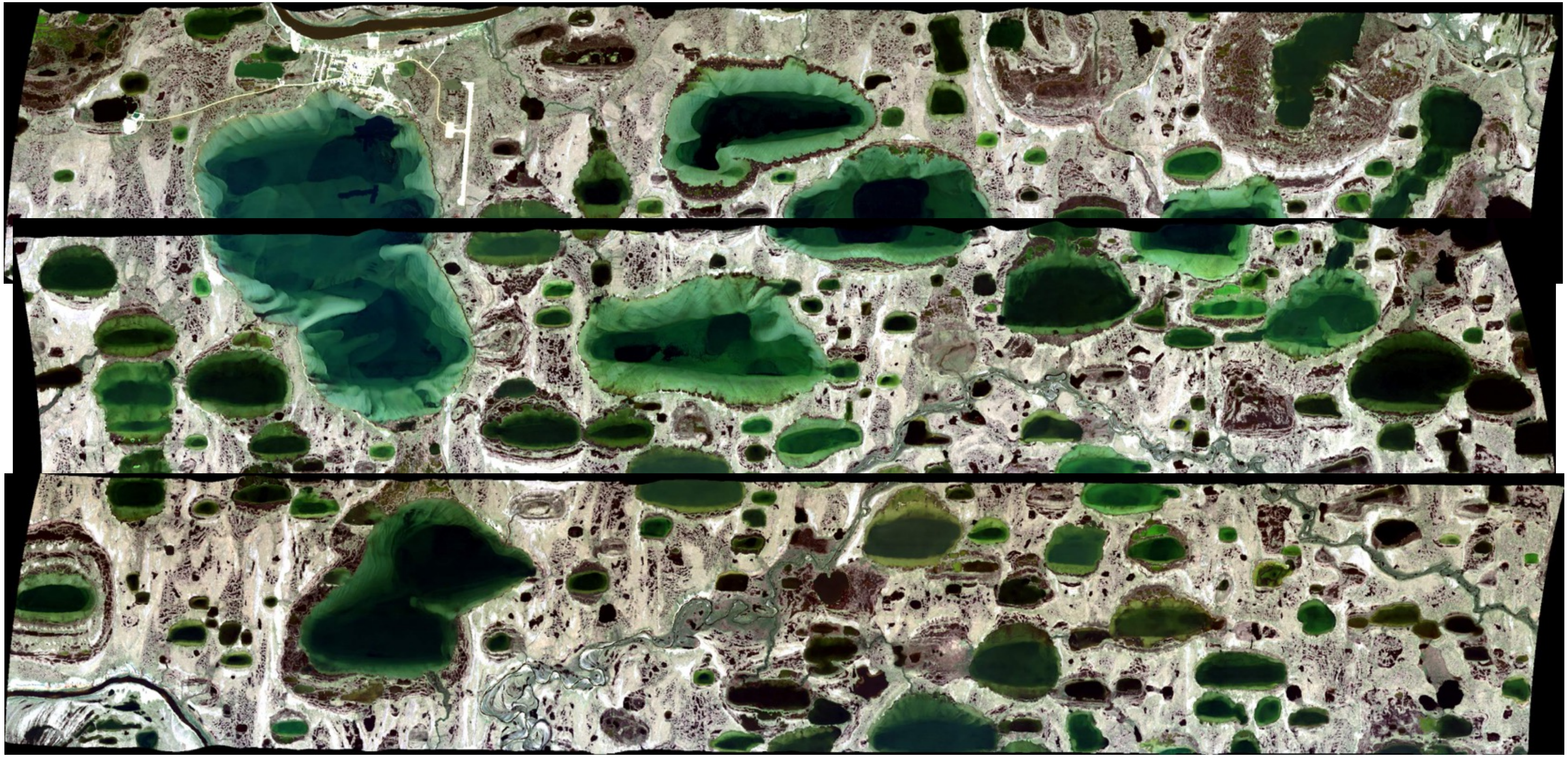


- Wetness/surface water important to land/atmosphere carbon flux
- Highly spatially variable
- Surface water fraction may be determined by thresholding FLIR observations
  ~20 cm resolution
- Useful for upscaling analysis



N Steiner, AGU (2015)

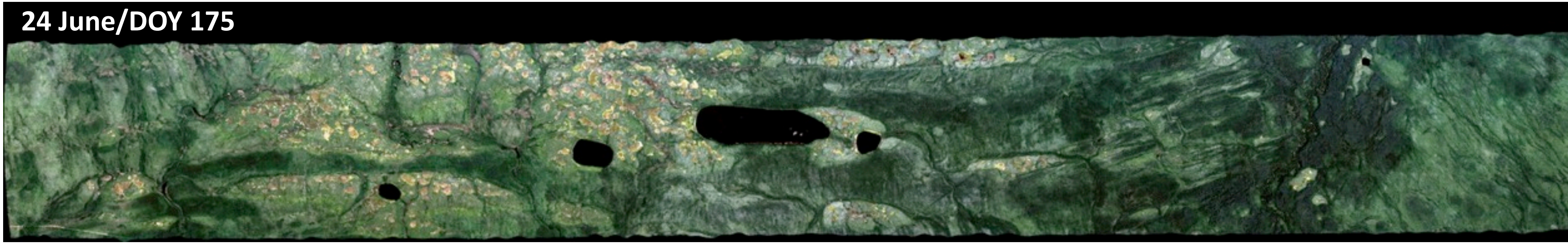
Characterizing Vast Arctic Wetland Systems

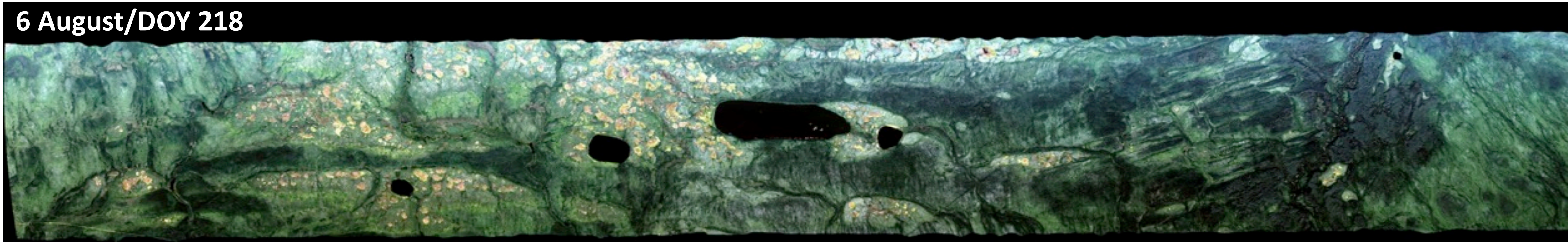


AVIRIS-NG imagery acquired near Atqasuk AK 29 July 2018

W Olson-Duvall

Boreal Forest Seasonal Time Series

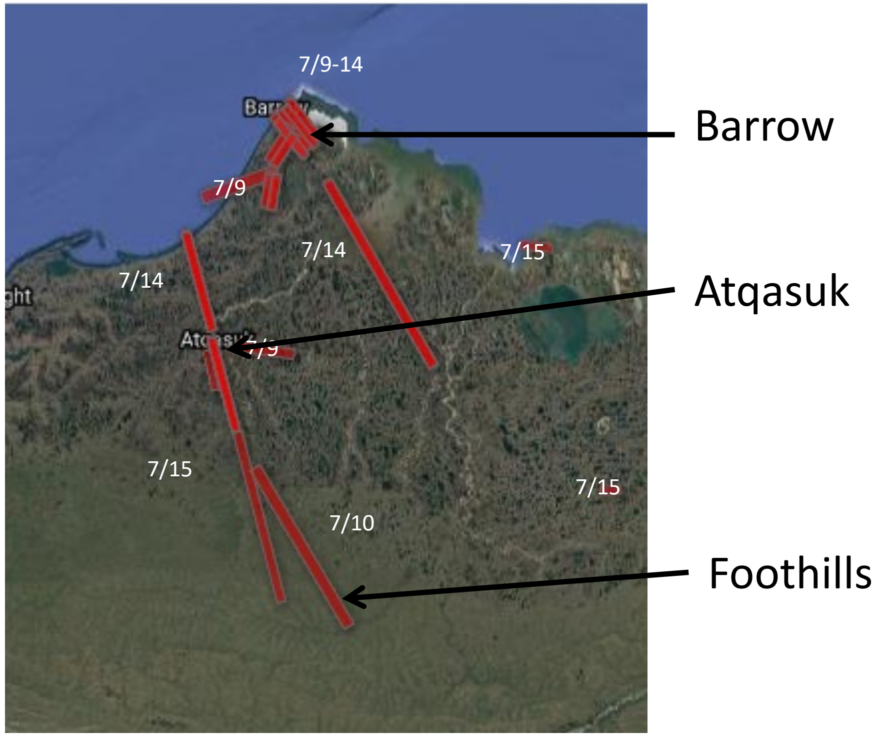


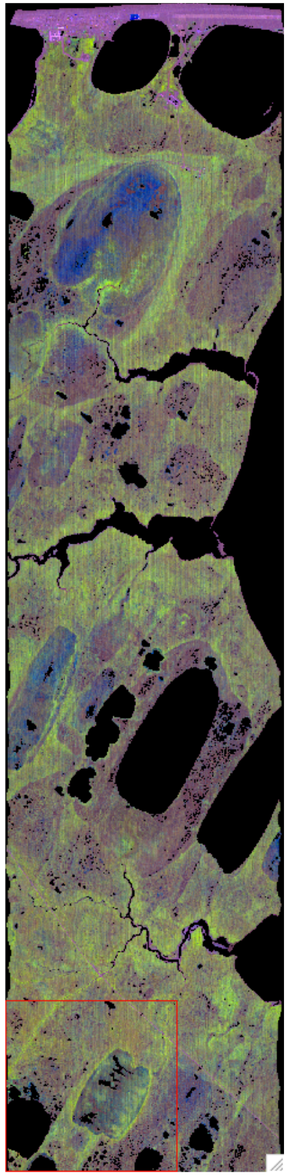


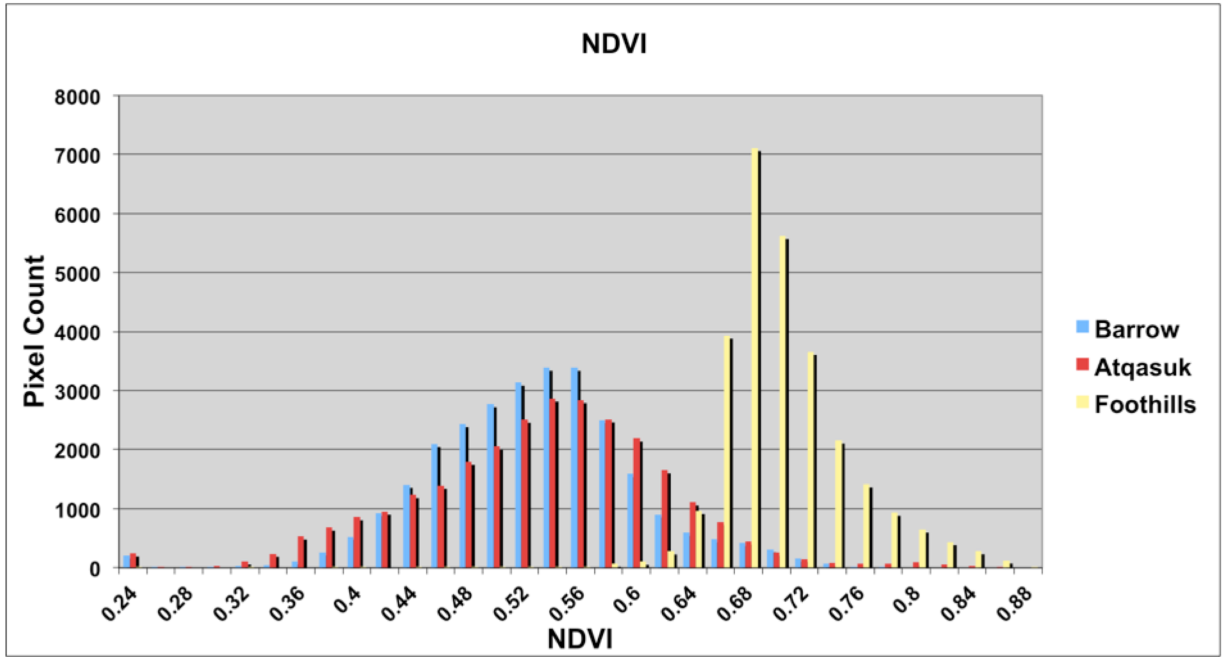
Line B4 acquired on 24 June/DOY 175 (top) and 6 Aug/DOY 218 (bottom)
The spectral differences will help quantify seasonal changes in the vegetation & land surface

ABoVE
ARCTIC – BOREAL VULNERABILITY EXPERIMENT

Regional Gradients in Plant Traits: NDVI



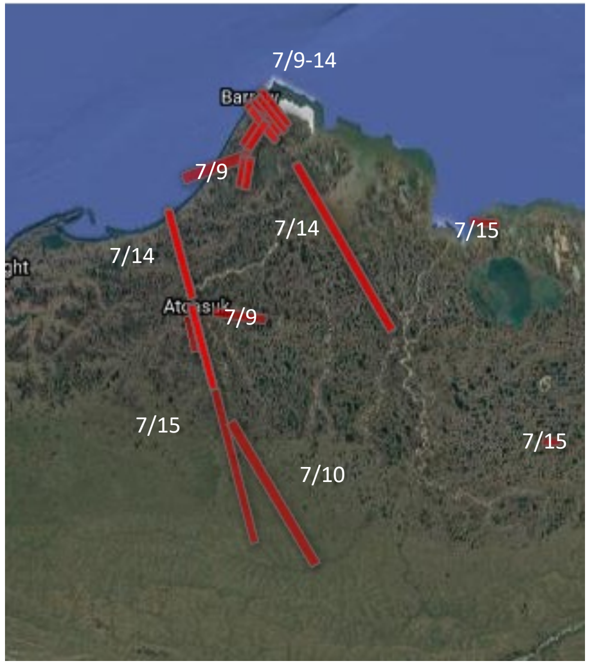




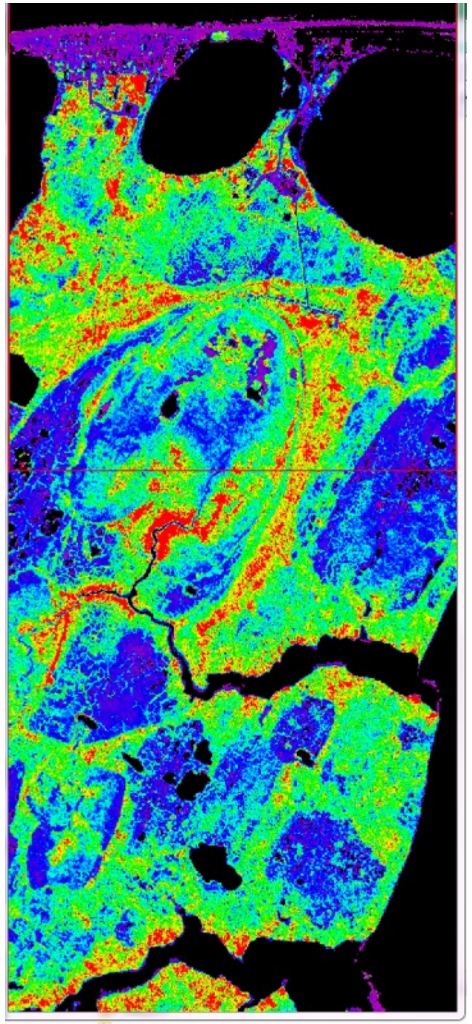
ARCTIC - BOREAL VULNERABILITY EXPERIMENT

F Huemmrich, unpubl

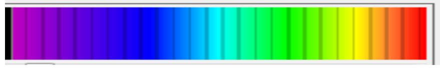
Regional Gradients in Plant Traits: Chlorophyll

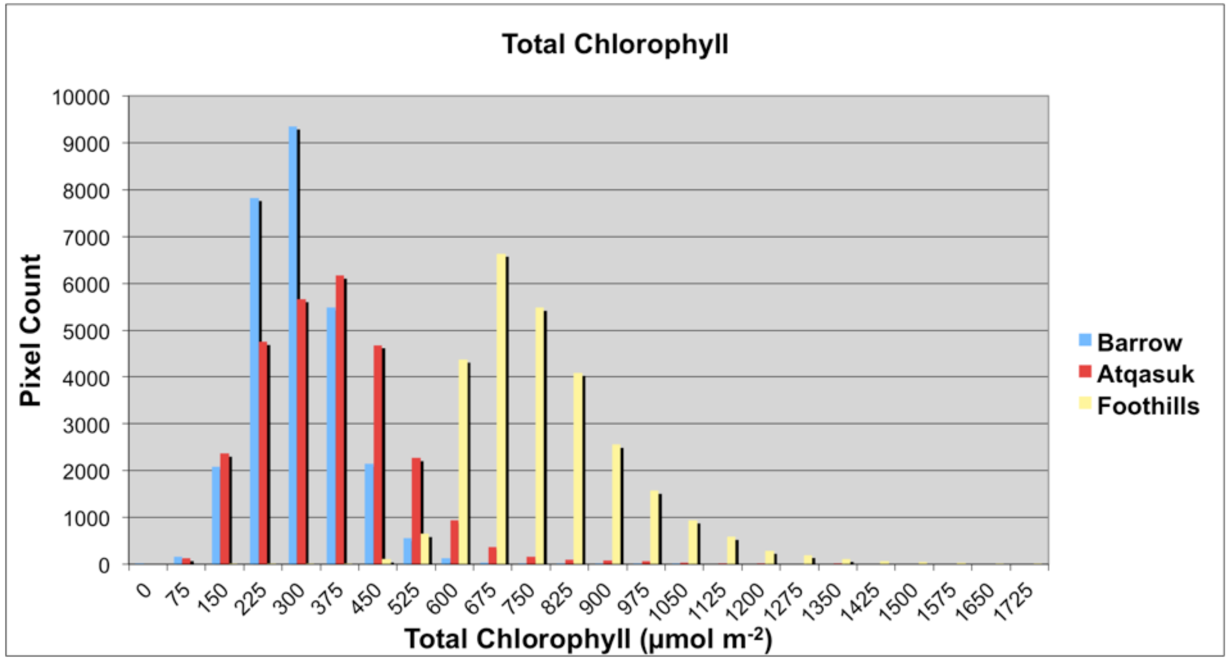


Area near Barrow



Chlorophyll content (µmol m^{-2})

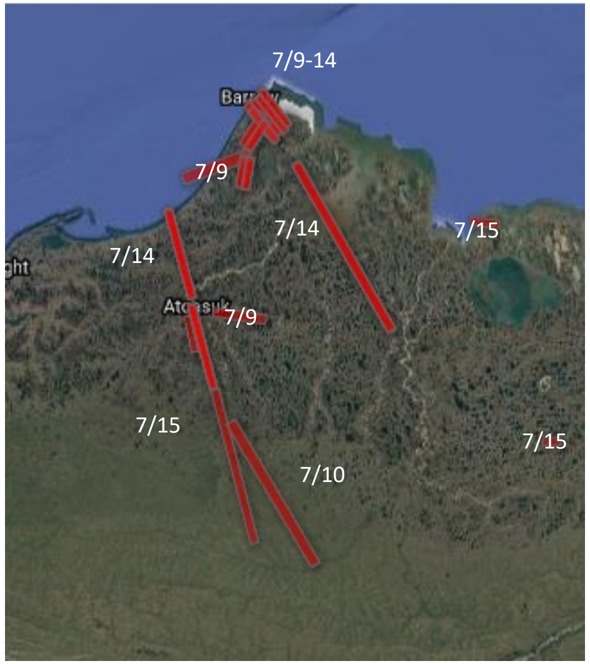




ARCTIC – BOREAL VULNERABILITY EXPERIMENT

F Huemmrich, unpubl

Regional Gradients in Plant Traits: GEP



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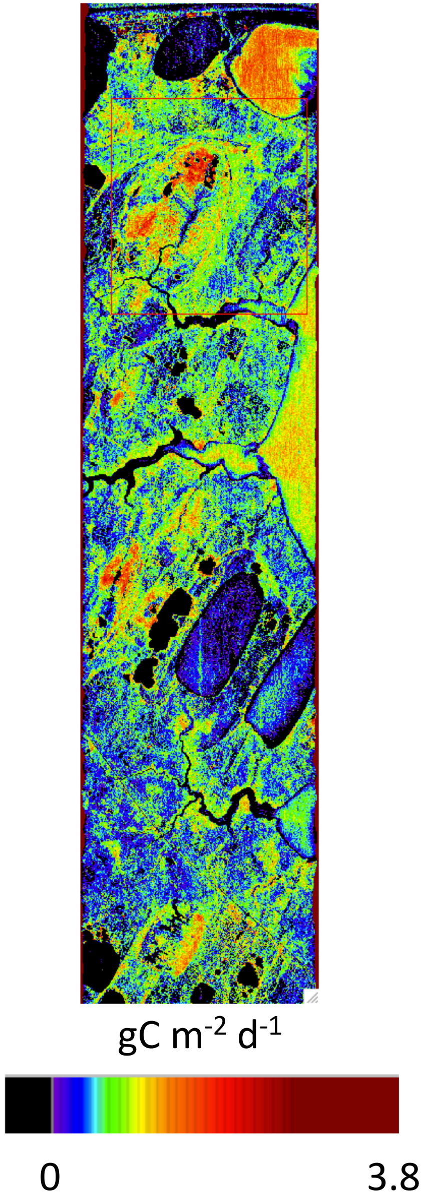
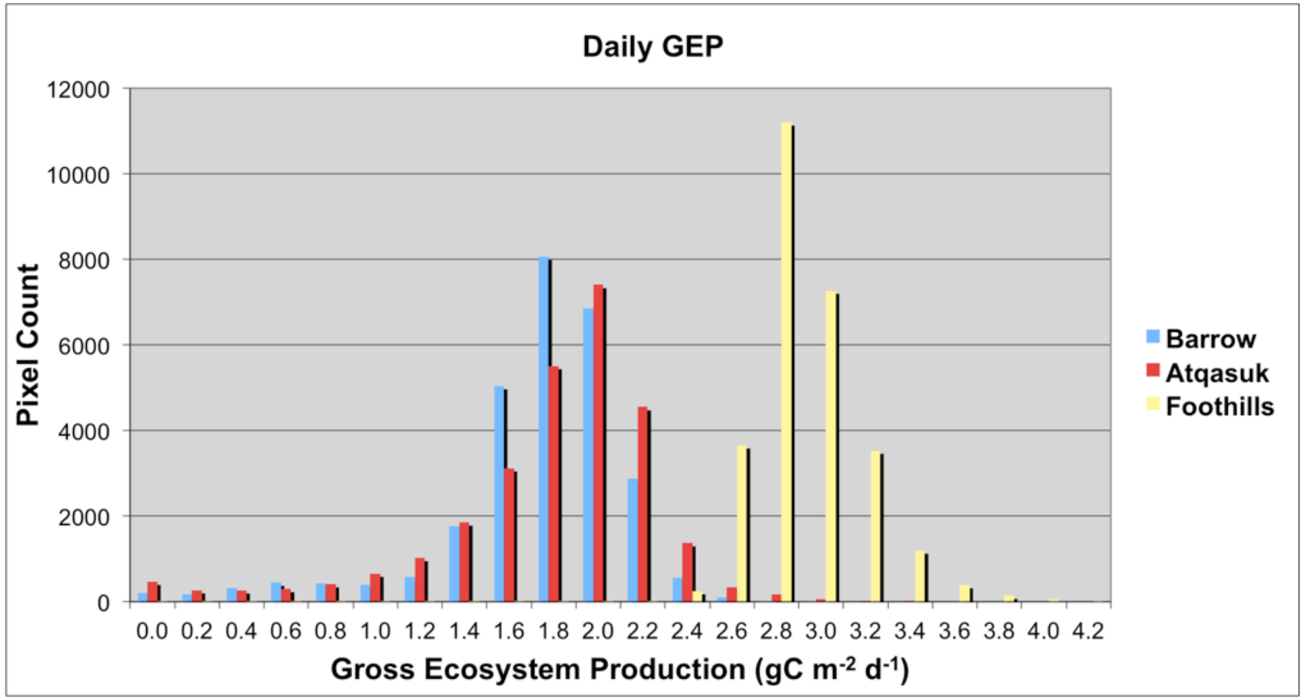




ARCTIC – BOREAL VULNERABILITY EXPERIMENT

F Huemmrich, unpubl

Characterizing Arctic Coastal Environments

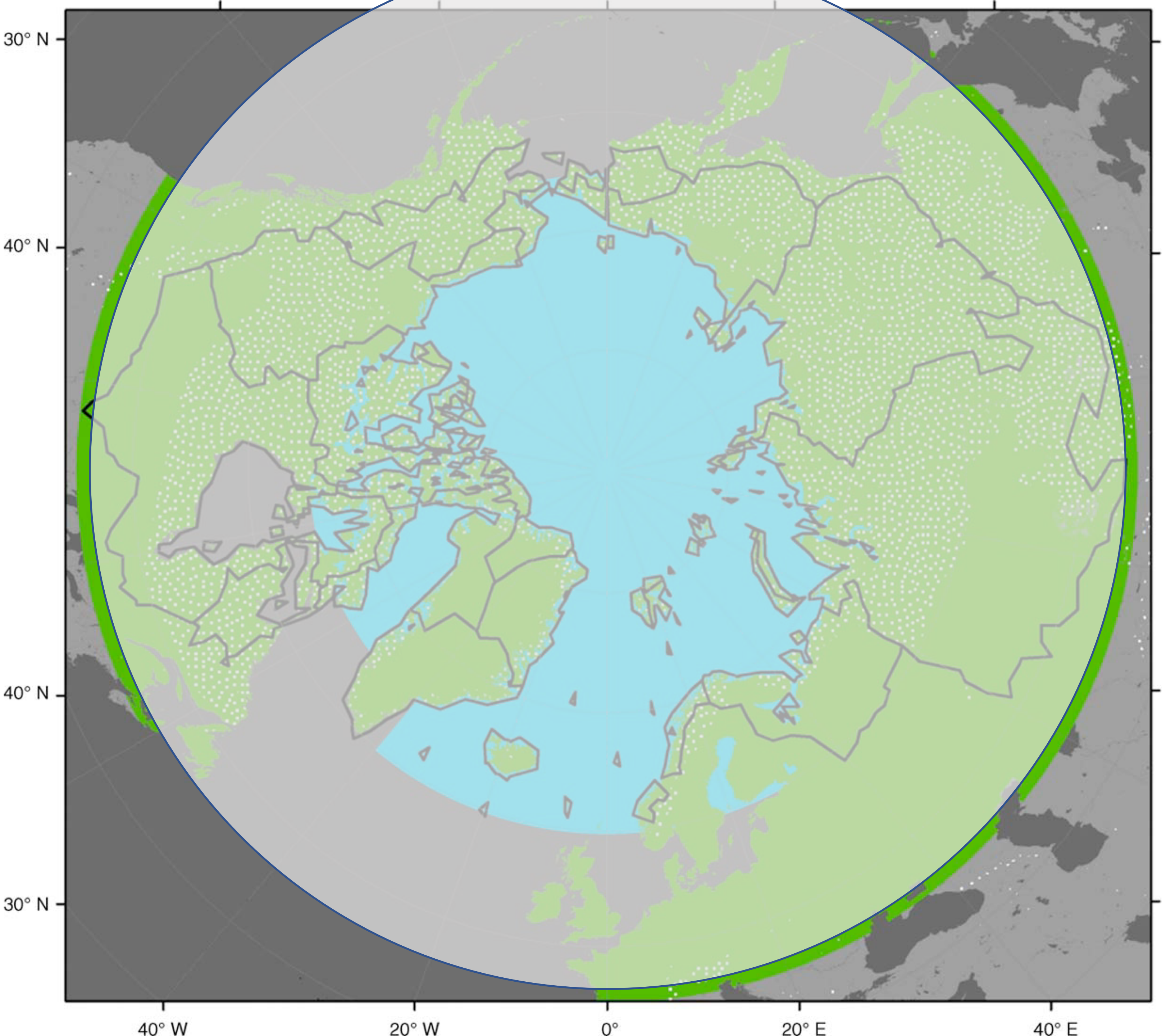
W Olson-Duvall

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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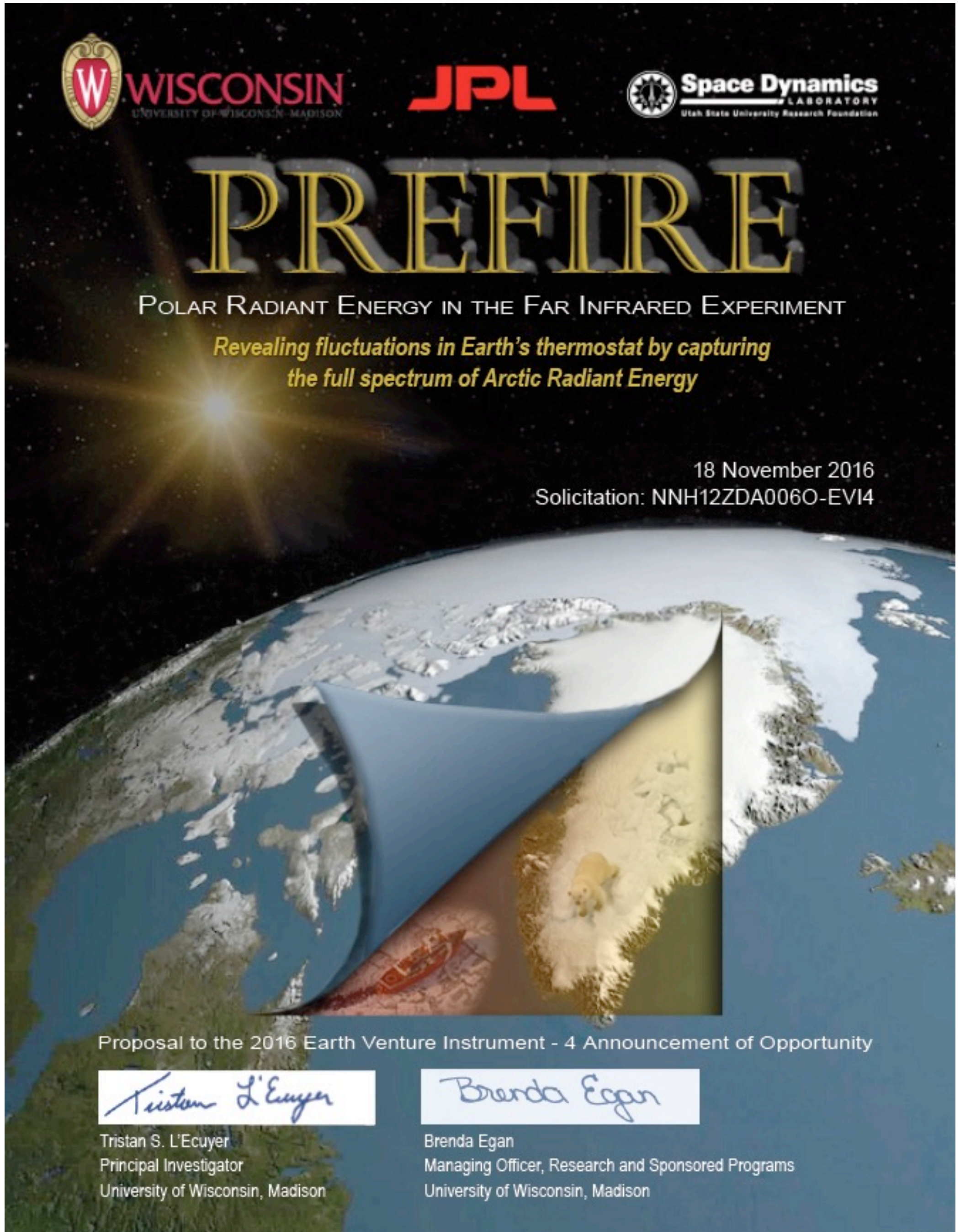
SBG Opportunities

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

- PREFIRE



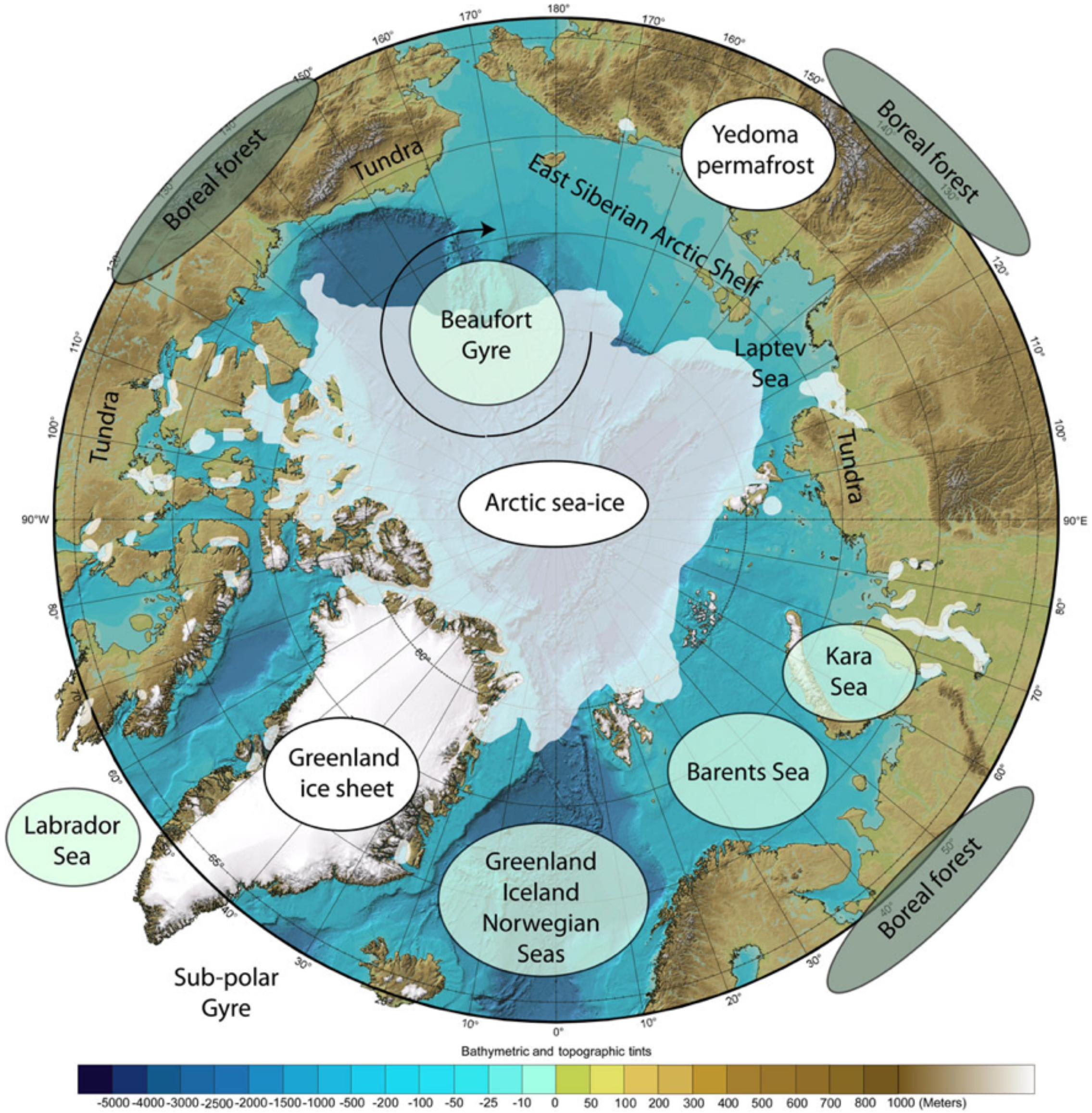
- Nearly 60% of the thermal energy exchanged at the Arctic surface via outgoing longwave IR radiation, yet both *short-term fluctuations and long-term trends in the atmospheric and surface components of this energy exchange are highly uncertain* since the spectral variation of **OLIR fluxes have never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

T L'Ecuyer, B Drouin

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[12] in the Arctic region.

Reasons for concern with Arctic climate change	Evidence	References
1. Risks to unique and threatened systems (Risk of losing unique ecological and social systems)	Decline of ice-associated biota (polar bears, seals, walruses, ice algae) and Arctic copepods	1, 13
	Rapid changes in landscapes due to permafrost thawing and thermokarst activity	14, 15
	Threats to Inuit cultural practices	2, 16
2. Risk of extreme weather events (Extreme events with substantial consequences for societies and natural systems)	Peat fires in the subarctic regions	17, 18
	Severe winter in northern temperate regions	19
3. Distribution of impacts (Spatial scale of impacts)	Changes in sea-level rise	20
	Altered heat budgets	21, 22
	Changes in freshwater discharge and ocean circulation	23, 24
	Greenhouse-gas emissions	25
	Reduced oceanic carbon dioxide uptake	26
4. Aggregate damages (Monetary damages or monetary losses, and lives affected or lives lost)	Impacts to Inuit well being, health, safety and culture	2
	Risks to security from territorial disputes	27
5. Risks of large-scale discontinuities (Likelihood of reaching tipping points)	Destabilization of the Greenland ice sheet	28, 29
	Peat fires in the subarctic region	30
	Methane emission from thawing methane hydrates	31, 32
	Slowed global thermohaline circulation	33
	Reduced oceanic carbon dioxide uptake	34



Duarte, NCC (2012)