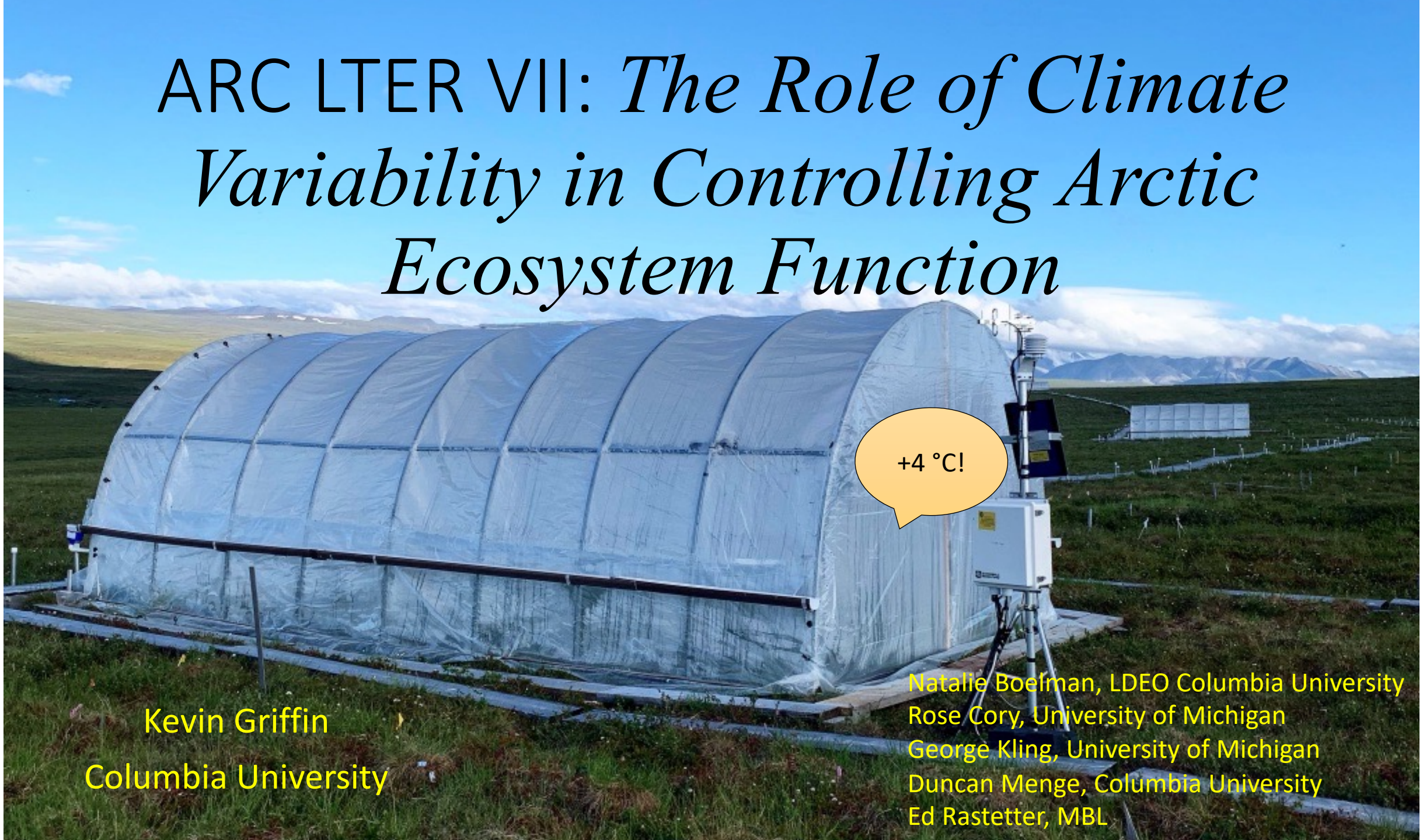
ARC LTER VII: *The Role of Climate Variability in Controlling Arctic Ecosystem Function*



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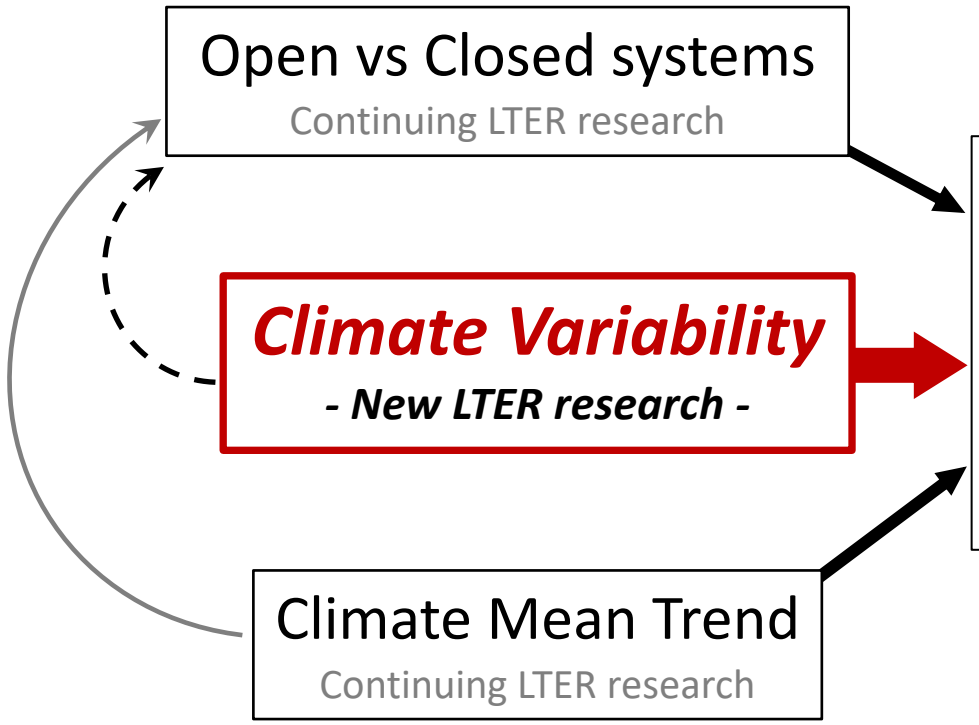
Rose Cory, University of Michigan
George Kling, University of Michigan
Duncan Menge, Columbia University
Ed Rastetter, MBL

Native Land Acknowledgement

The Arctic LTER project is based at Toolik Field Station (TFS) which is operated by the University of Alaska Fairbanks. We acknowledge that TFS and the surrounding areas are located on the ancestral hunting grounds of the Nunamiut, and occasional hunting grounds and routes of the Gwich'in, Koyukuk, and Iñupiaq peoples. We further acknowledge that all of our work, at TFS and elsewhere, occurs on Indigenous land. We acknowledge the legacy of violence and forced removal perpetrated against these lands' first inhabitants, and honor the Indigenous people who have and continue to inhabit and steward the lands where we live and work.



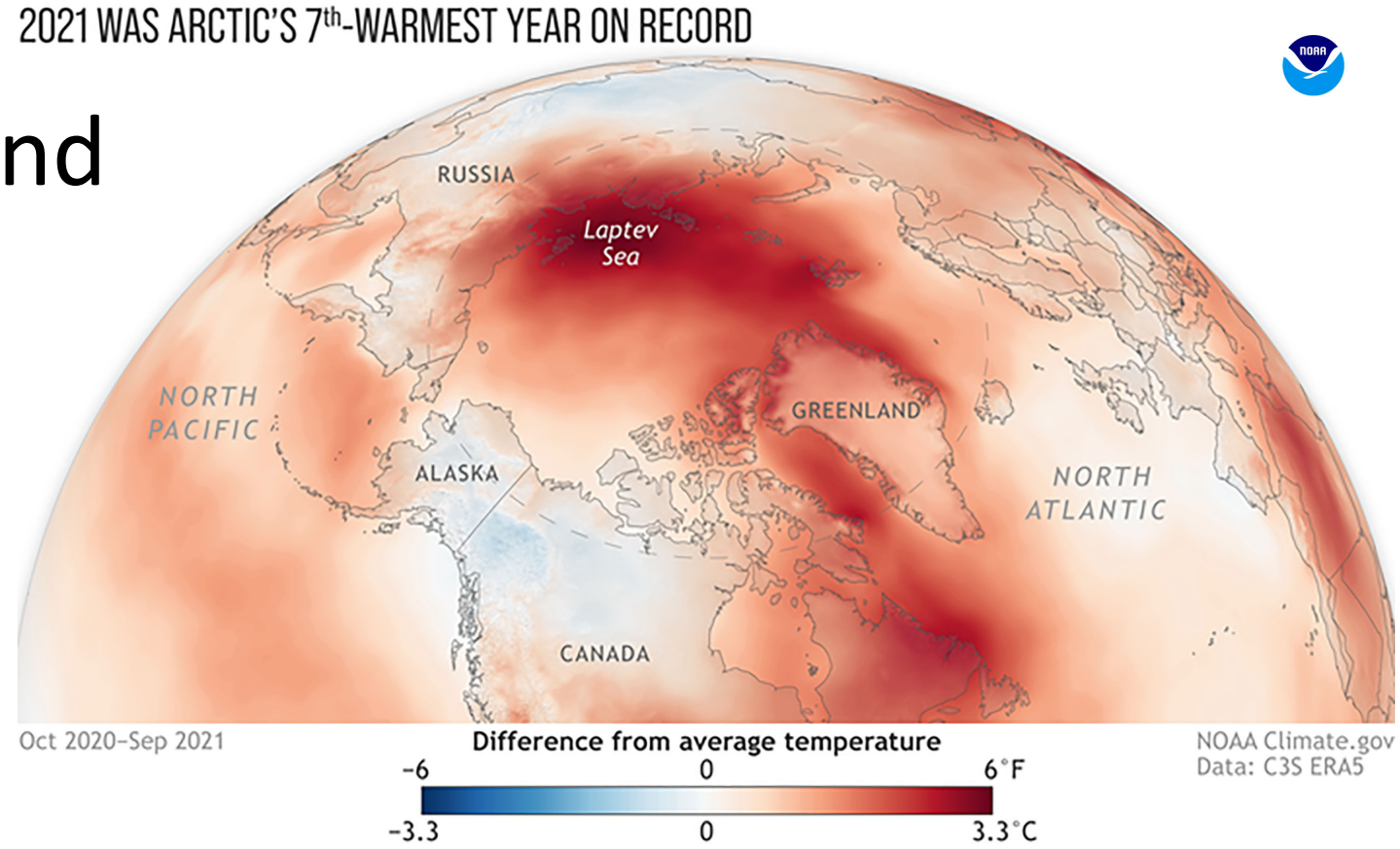
ARC LTER VII Theme:

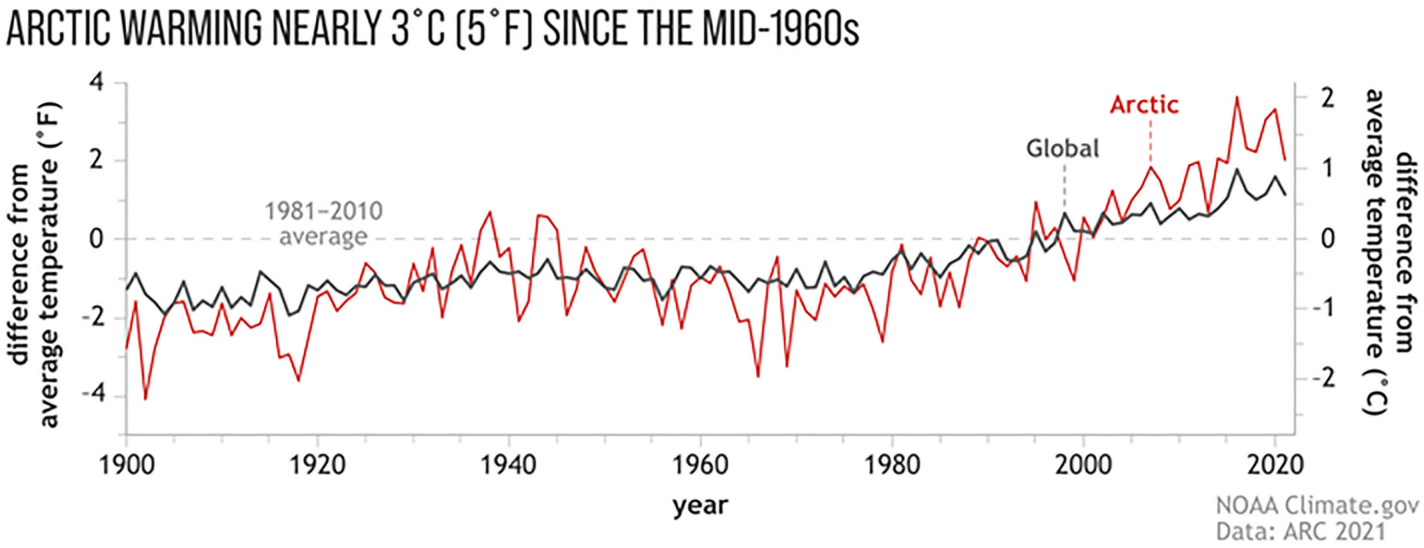
What controls changes in the function of Arctic ecosystems?

Our hypothesis is that climate variability is the strongest control on ecological function

Function includes the 5 core LTER areas: production, populations, nutrients, organic matter, & disturbance

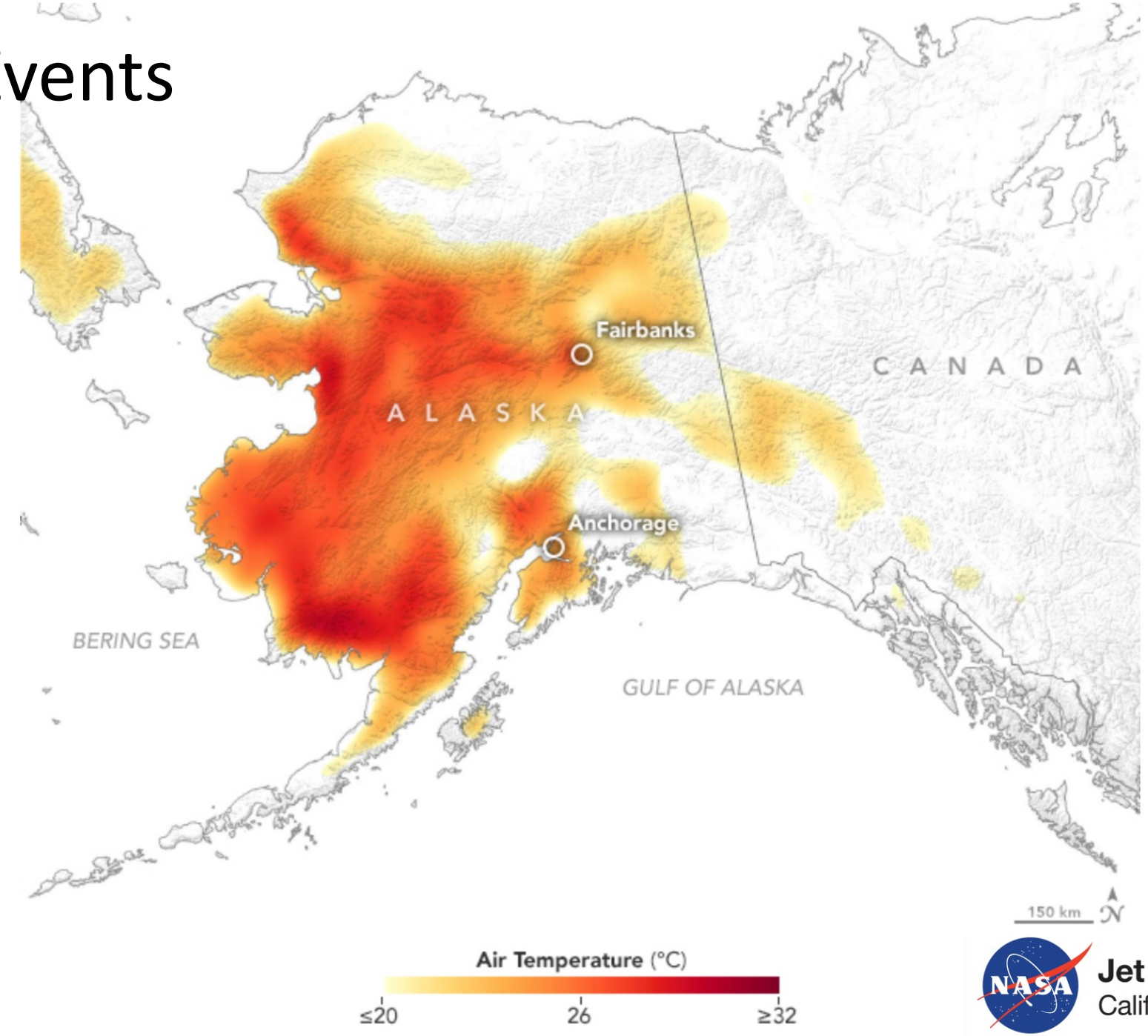
Climate Trend





Extreme Events

July 8, 2019



Jet Propulsion Laboratory
California Institute of Technology

The Ecology of Climate Variability

- Long recognized as an important driver of ecosystem function, but not well studied
- Theoretical foundation has been addressed at several levels
- Recognized by scientists and the public
- Difficult to study with manipulative experiments
- Long-term observations and experiments can provide a way forward

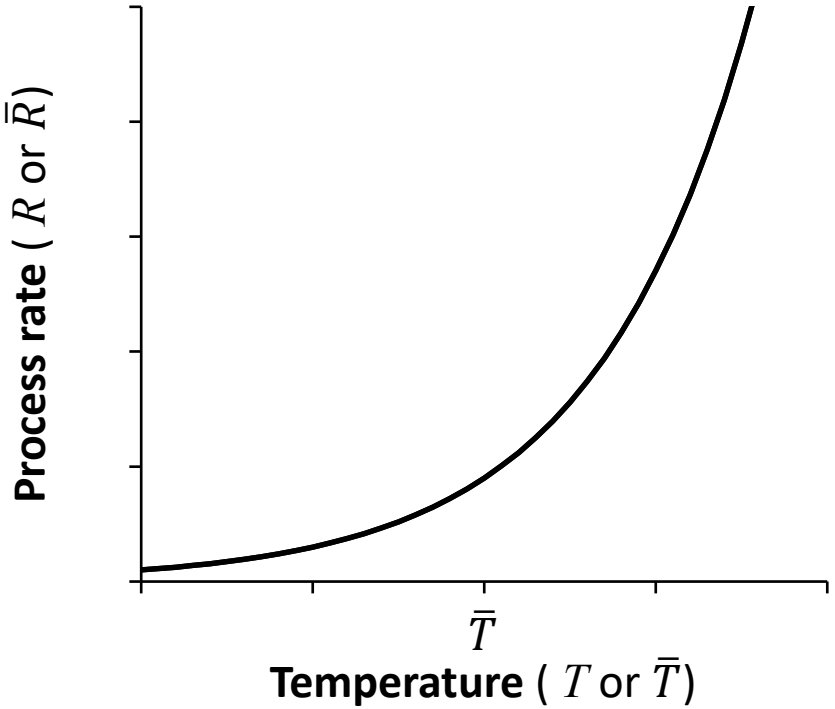
Except under rare circumstances, the response of a system to average conditions is different from the system's average response to variable conditions, a conundrum known as 'Jensen's inequality'

Denny 2017

$$\overline{f(x)} \neq f(\bar{x})$$

'the fallacy of the average'

Why should weather variability make a difference?
Jensen's (1906) Inequality (AKA "The Fallacy of the Averages"):



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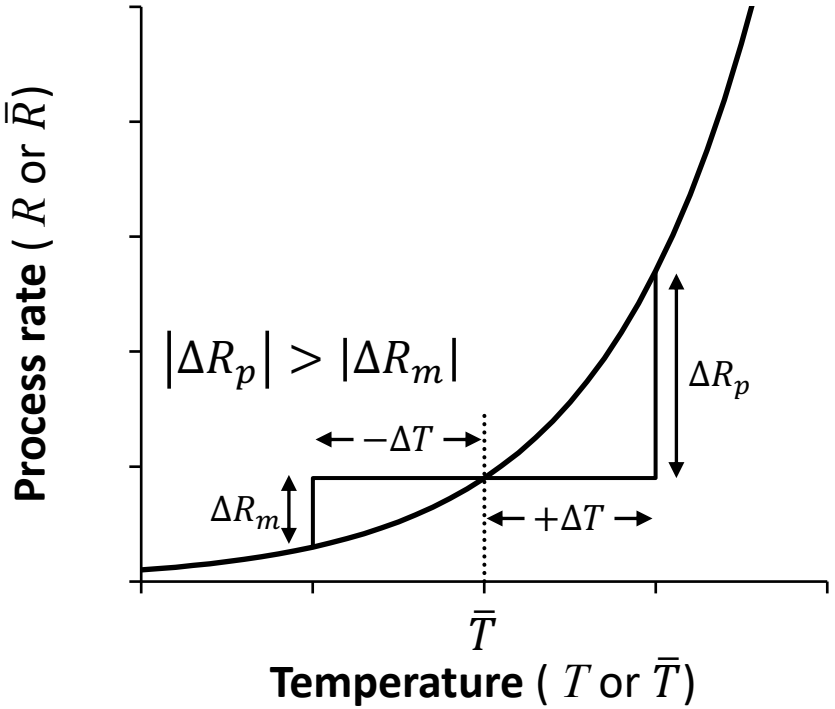

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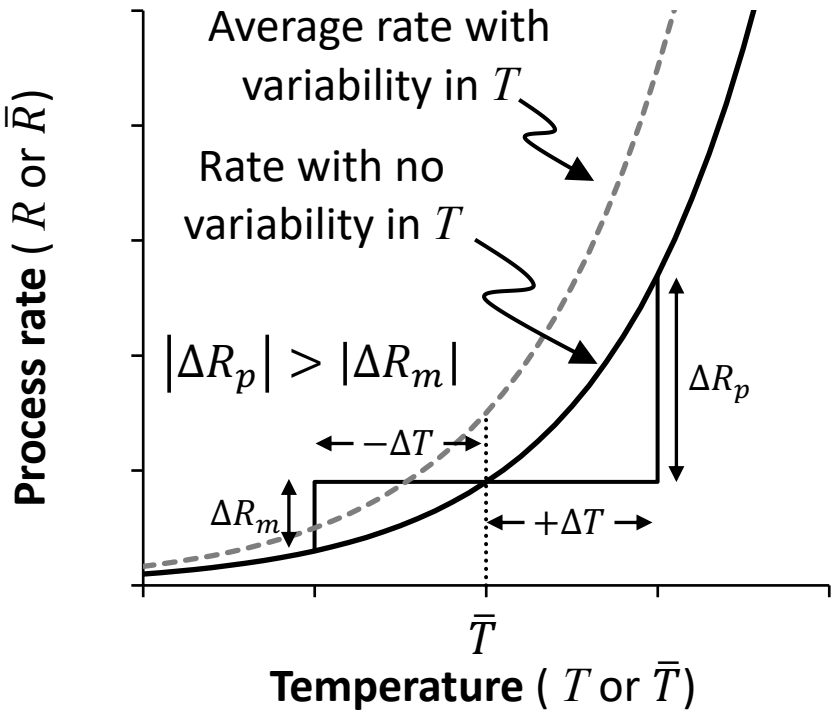
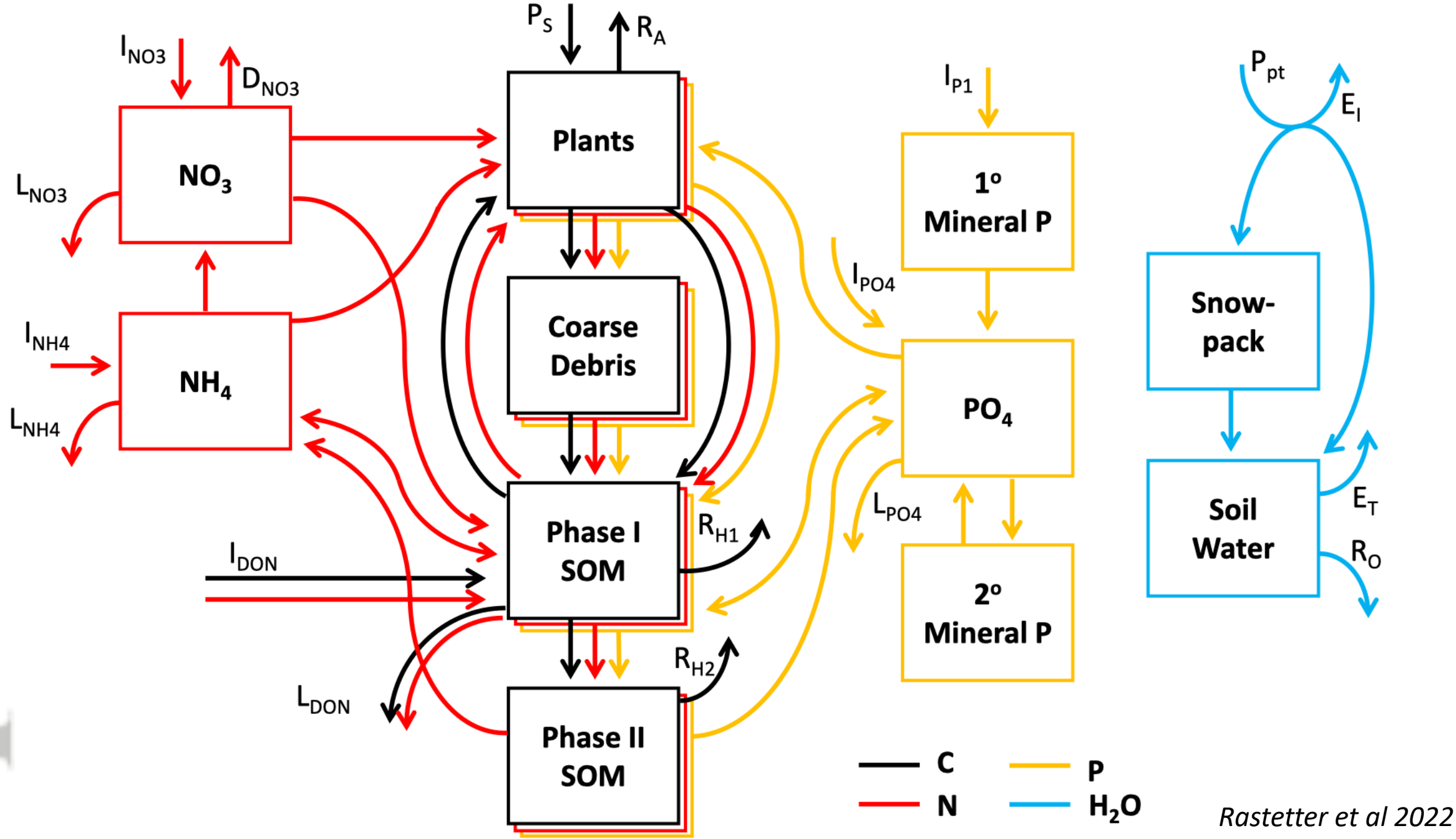


Displacement of rate with variability will always be on the concave side of the graph.

Magnitude of displacement will increase:

1) with variability and
2) with the depth of the concavity (curvature).



Rastetter et al 2022

We address three questions:

- **Do changes in weather variability alter element stocks and cycling rates?**
- **How do responses to changes in the variability of different weather components compare?**
- **How do responses to changes in weather variability compare to responses to climate trends?**

Rastetter, Griffin, Kwiatkowski & Kling, in review

To examine this issue, we ...

- Built a stochastic weather generator based on data from Toolik Lake, AK
- Generated ten 100-year records with control (i.e., Toolik), artificially low, or artificially high variability in precipitation, light levels, and temperature
- Generated additional 100-year records with artificially low or artificially high variability in either precipitation, light levels, or temperature to examine effects of individual weather components
- Used these “data” to drive the Multiple Element Limitation (MEL) model to examine effects on ecosystem C, N, and P stocks and cycles

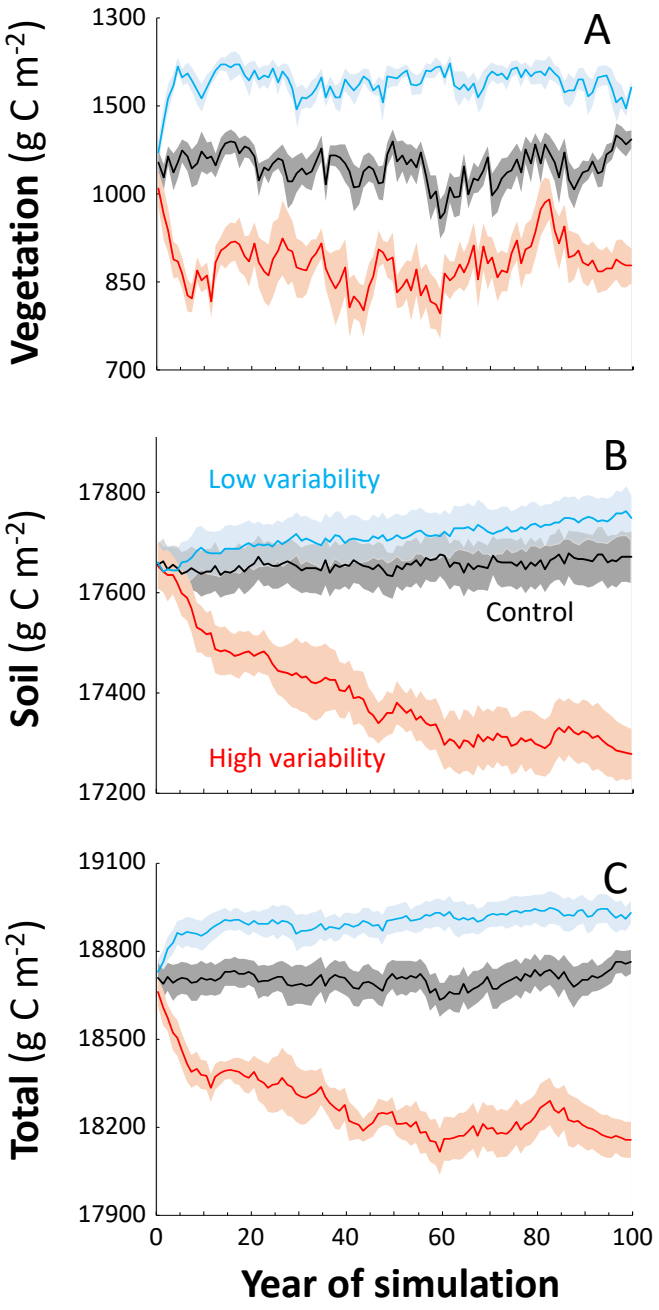
Artificially low variance:

- Same average temperature, light levels, and precipitation
- Temperature variance ~ 3^{o}C lower all year
- Duration of rainy periods 1 day longer, duration of dry periods 1 day shorter
  - (same total precipitation over more days)
- Fewer full-sun days and fewer heavy-cloud days

Artificially high variance:

- Same average temperature, light levels, and precipitation
- Temperature variance ~ 3^{o}C higher all year
- Duration of rainy periods 1 day shorter, duration of dry periods 1 day longer
  - (same total precipitation over fewer days)
- More full sun days and more heavy cloud days

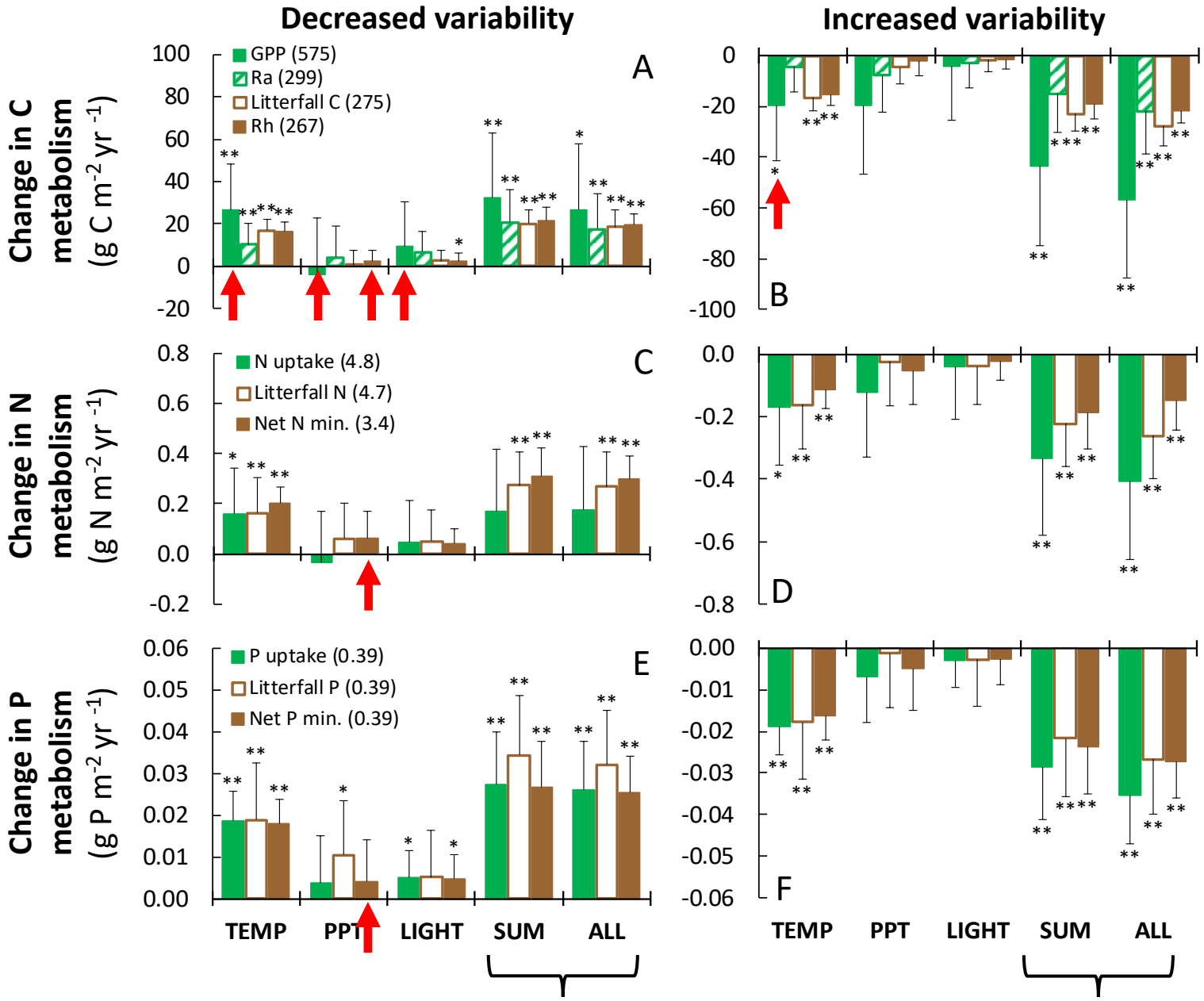
Responses to changes in variability of precipitation, light, and temperature combined



Vegetation C significantly ($p < 0.01$) higher with low variability and significantly ($p < 0.01$) lower with high variability

Soil C unchanged with low variability but significantly ($p < 0.01$) lower with high variability

Ecosystem C significantly ($p < 0.05$) higher with low variability and significantly ($p < 0.01$) lower with high variability



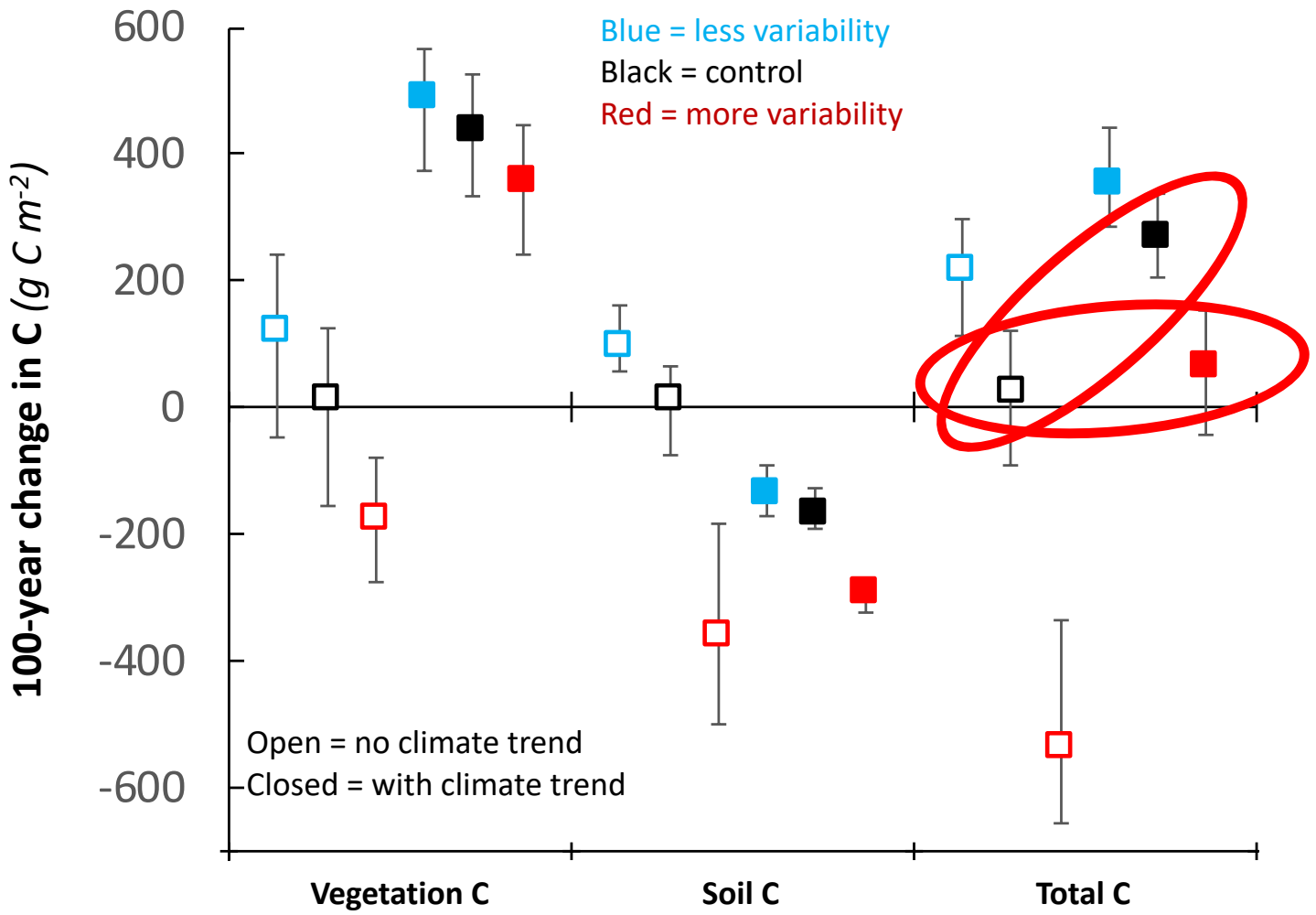
Results that are consistent with expectations from Jensen's Inequality

Numbers in legend are mean values for control simulations

ANOVA & LSD test
** $p < 0.01$
* $p < 0.05$

Elevated CO_2, wet & warming climate trend increased vegetation, decreases soil C (except with high variability), and increased total ecosystem C

Although high variability can almost cancel climate-trend C gain



Bottom Line

1. Changes in day-to-day variability in weather can have important effects on ecosystem C, N, and P stocks and cycling rates
2. Most metabolic responses are opposite to those predicted by Jensen's Inequality because they are embedded in a network of whole-ecosystem interactions and feedbacks (e.g., ↑GPP & ↓N min are incompatible)
3. We need to understand how weather variability might change as the climate changes
4. We need to understand how ecosystems processes will respond to changes in weather variability
5. That understanding needs to include both the direct effects of variability on the individual processes and secondary effects governed by interactions and feedbacks in the context of whole-ecosystem biogeochemistry

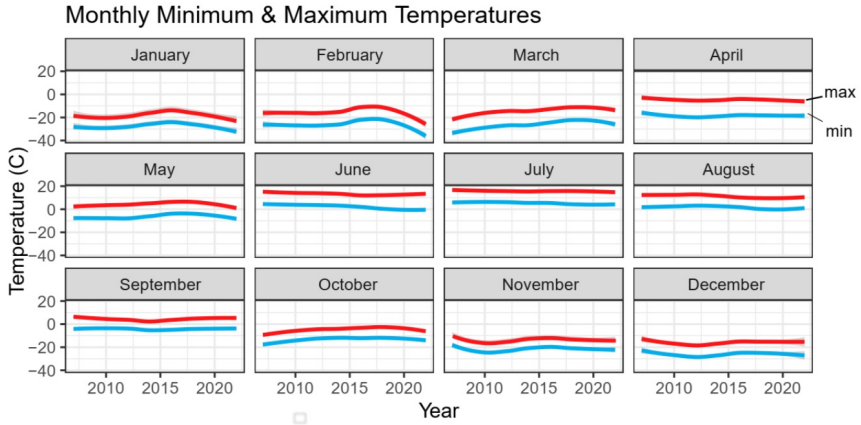
15 Years of Abiotic and Biotic Phenological Change in the Arctic

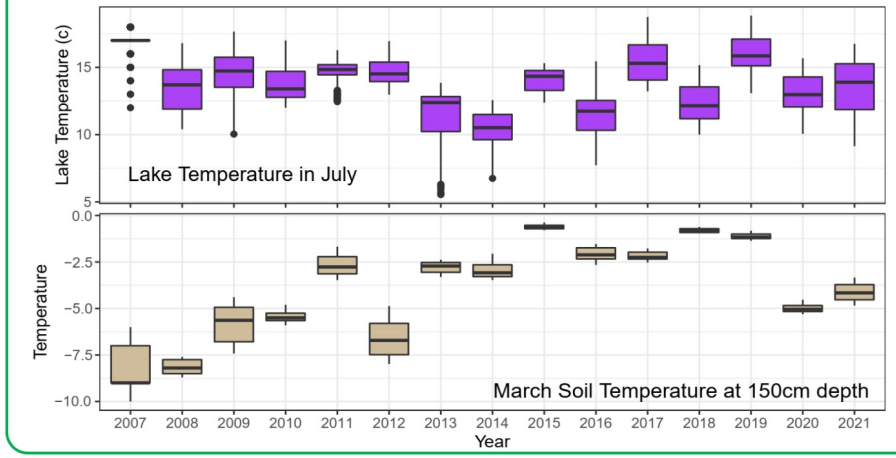
Amanda B. Young*, Marion Syndonia Bret-Harte*, Brie Van Dam*, Anja Kade˚ , Christie Haupert +

*Toolik Field Station, University of Alaska Fairbanks ˚Department of Biology and Wildlife, University of Alaska Fairbanks +Alaska Center for Energy and Power, University of Alaska Fairbanks

Abiotic - Temperature

Temperatures at Toolik vary year by year with few distinguishing trends apparent. Maximum and minimum temperatures have been increasing in March during a time that few researchers are at Toolik.

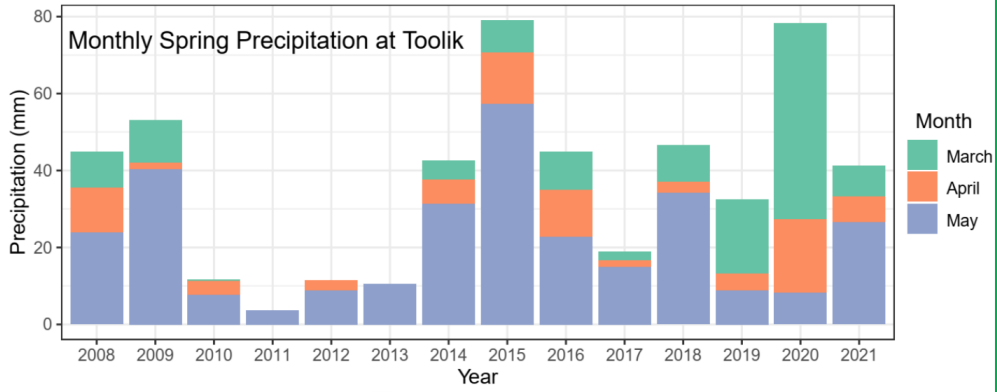


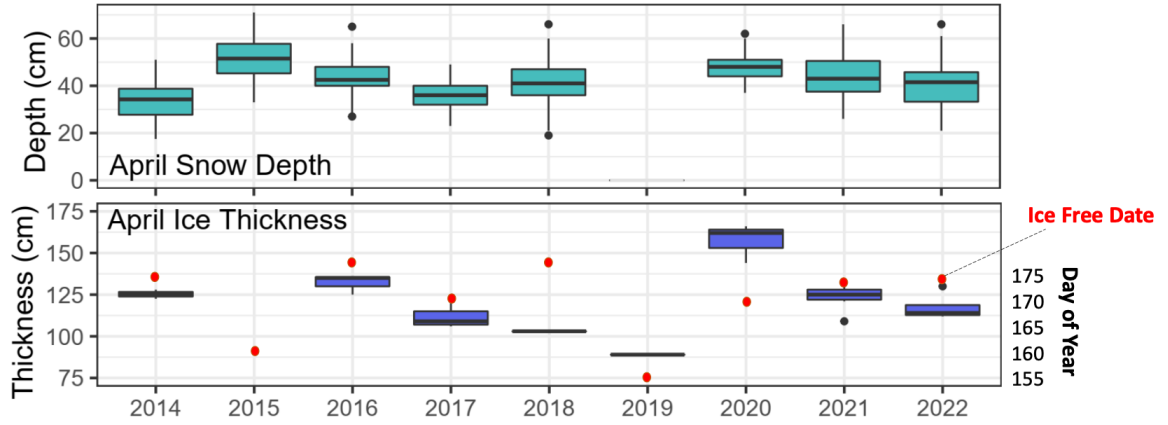


Lake temperatures during the warmest month of the year (July) oscillate between warmer and cooler years, while soil temperatures are generally on the rise. Soil temperatures from 150 cm below ground are rising more dramatically than those near the surface.

Abiotic - Precipitation

Precipitation also varies year to year. Spring snow storms, such as the ones in 2015 and 2020, lead to deep snow packs at the end of the spring.
Ice thickness is influenced by air temperature and snow depth



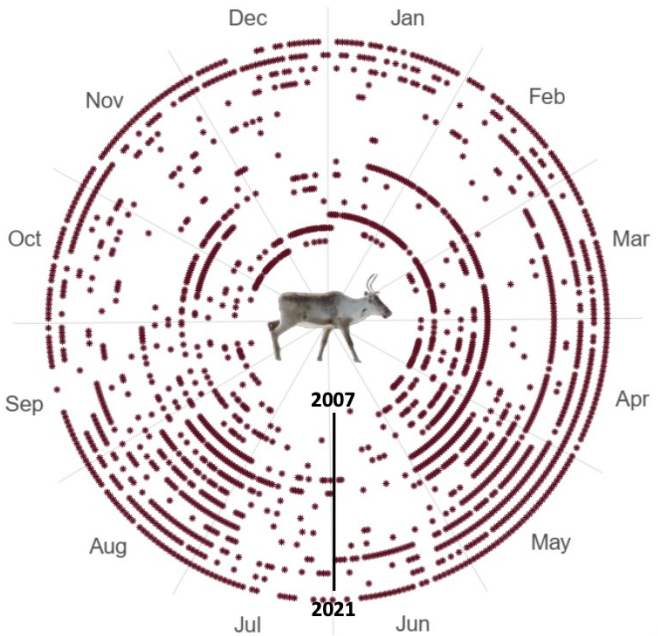


Biotic - Mammals

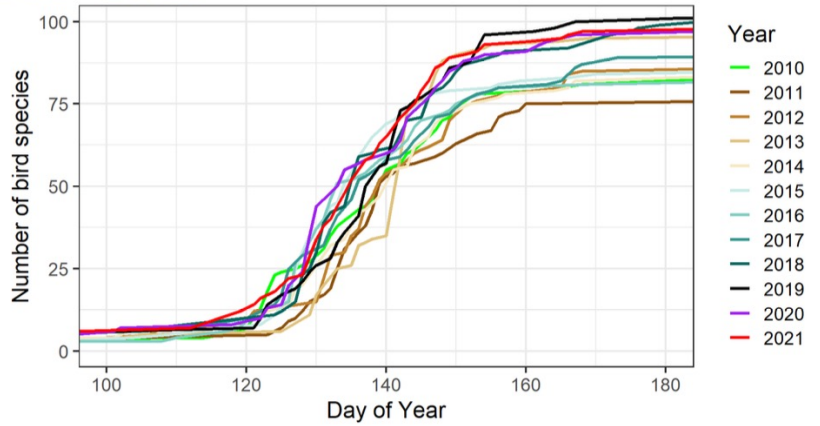
Throughout the year, daily observations are made of mammal sightings in the Toolik Naturalist Journal.

Two species at Toolik the Arctic Ground Squirrel and Grizzly Bear have clear hibernation patterns and are only seen during the warm portion of the year. While the rest of the species stay active throughout the year.

Caribou are the only mammal species to migrate through the region in May on their way to the Costal Plains and again in late July and August on their way back south. Some years the caribou remain in and around Toolik throughout the winter months.

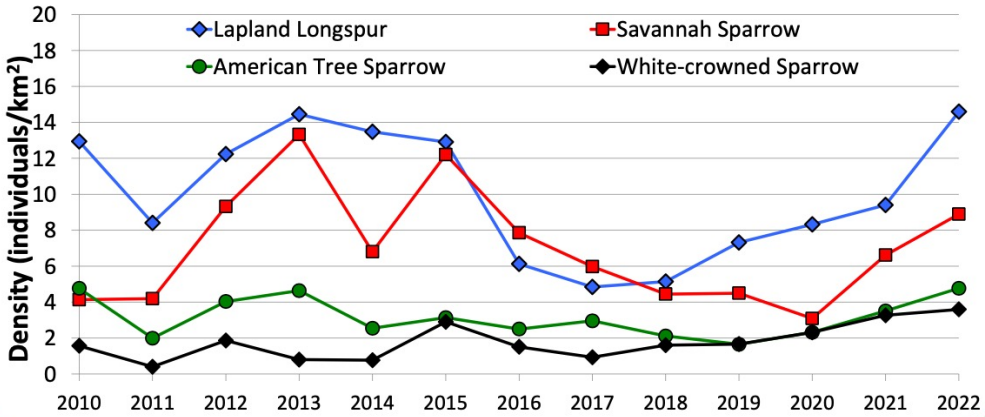


Biotic - Birds



Throughout the year, daily observations are made of bird sightings in the Toolik Naturalist Journal, this captures the spring migration of song birds and waterfowl to the region. Annually, the timing of the migration is fairly consistent, however, the number of birds ranges from year to year with variability up to 25% of the population. Small differences in the arrival of a species may have a large impact reproductive success during such short summers.

Individual species dynamics vary from year to year as well. Lapland longspurs and Savannah sparrow populations dropped in 2016, possibly due to a snowstorm in May 2015. The populations have been making a recovery ever since. American Tree Sparrows and White-crowned Sparrow population remained relatively constant at low levels throughout.



Thanks!