Scott Goetz

Mapping and Modeling Attributes of an Arctic – Boreal Biome Shift

(Goetz-03)

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Institutional Collaborations

- **Ted Hogg**

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- **Jim Lawler, Maggie MacCluskie, Carl Roland**

  National Park Service, Fairbanks AK
- **Philip Martin**

  US Fish & Wildlife Service, Fairbanks AK (Arctic LCC)
- **Changhui Peng**

  University of Quebec at Montreal (UQAM)
- **Matt Stevens**

  University of Alaska, Fairbanks AK (Extension Service)

And.. But.. therefore (i.e. huz come?)

- Climate change in underway across the North American arctic-boreal region
- We need to understand how ecosystems will respond and what the implications will be – *and* how to plan management responses
- Our project focuses on addressing change in vegetation dynamics across the ABoVE domain
  - boreal mortality & productivity changes ("browning")
  - tundra productivity ("greening")
  - Evidence for related "biome shift"

Expectations / predictions / Hypotheses

- **Warmer temperatures in the arctic region result in increased vegetation productivity**, as it is released from temperature constraints, and more gradual changes in vegetation composition and structure.
- **Warmer and drier air masses in the southern boreal region result in declining forest productivity** as a result of increasing stomatal control and decreased net carbon uptake, **and associated increases in tree mortality**.
- **[Transitions in the presence, abundance, movement and vulnerability of fauna**, e.g. caribou, moose, hares, etc. as vegetation productivity (in the shorter term) and composition and structure (longer term) change]

Science Questions & Objectives

- Overarching ABoVE Science Question:
  - *How vulnerable or resilient are ecosystems and society to environmental change in the Arctic and boreal region of western North America?"*
- Tier 2 Science Questions addressed
  - How are **flora and fauna** responding to changes in biotic and abiotic conditions, and what are the impacts on ecosystem structure and function?
- Tier 2 Science Objectives addressed
  - Determine the causes of greening and browning trends and their impacts on ecosystem form and function.
    - ["Determine how the spatial and temporal dynamics in both faunal abundance and characteristics of fish and wildlife habitat co-vary across gradients of climate and disturbance."]

Our *Project* Objectives

Objective 1: Arctic Vegetation Mapping

Peter Nelson & Matt Macander

Objective 2: Boreal productivity & tree mortality patterns linked with remote sensing

Brendan Rogers & Michelle Mack

Objective 3: Model boreal tree species productivity, mortality and distribution / environmental suitability changes

Jackie Shuman & Hank Shugart

Objective 1: Arctic Vegetation Mapping / Field Data

Mapping extent & density

- **Shrubs**: Low shrub and dwarf shrub zones in Alaska, based on the CAVM

- **Lichens**: northern Alaska and central Canada covering the ranges of the Western Arctic, Teshepek, Central Arctic and Porcupine herd

Field data (see map)

- Vegetation Monitoring Plots in National Park Service Arctic Network: **471 plots**

- BLM National Petroleum Reserve – Alaska (NPRA): **>130 plots**

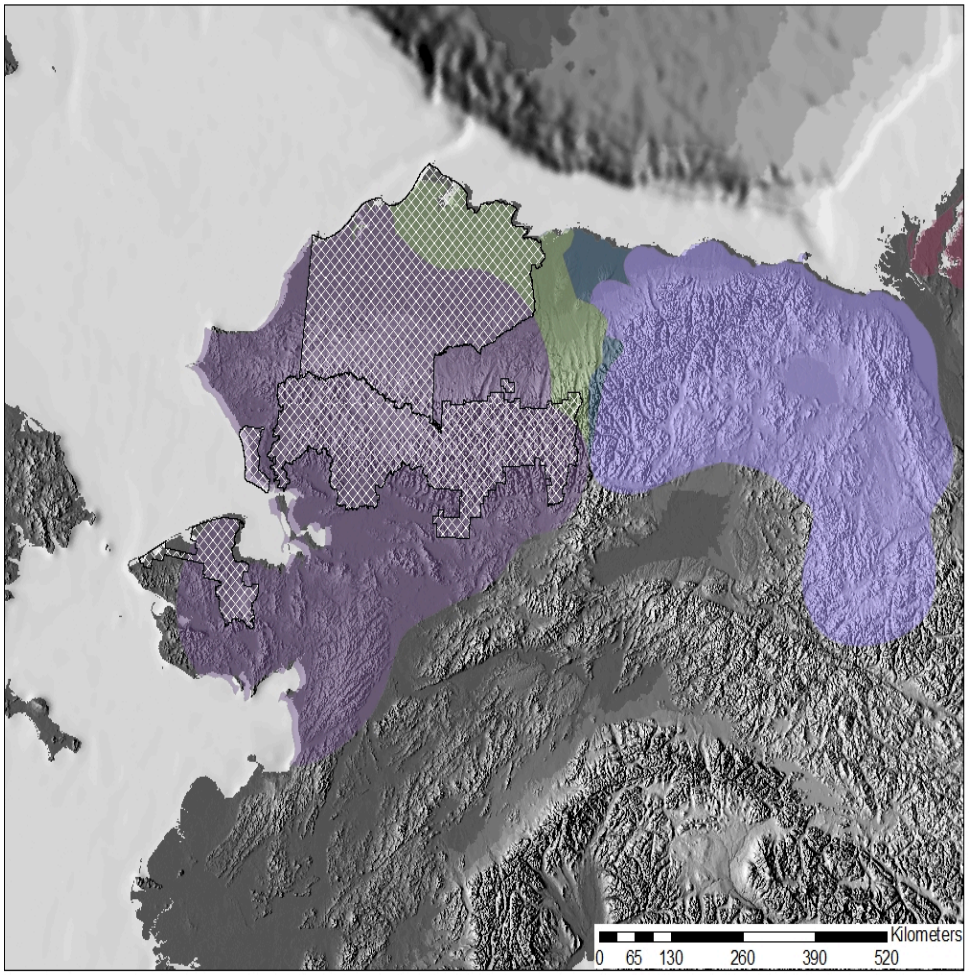


Fig 1: Caribou home ranges (colors) and location of in situ datasets (cross hatching).

Obj. 1 - Arctic Veg Field Studies

- Specifics of ground measurements
  - NPS ARCN long-term vegetation plots with vegetation (incl. lichens) & soil attributes.
    - Each plot w. four 6 m transects within an 8 m radius circle.
    - Vascular plant cover sampled every 25 cm along each transect
  - Plus a 20 km x 20 km grid over the ARCN w. high resolution imagery & aerial photos at each grid point.
    - Designed by NPS to track changes in shrub and tree distribution.
- Planning / timing of field efforts
  - No new mmts planned but a compilation of existing arctic species-level community data (NPS & BLM) is proposed
  - Desire to construct a novel trait-based community data set

Objective 1: Arctic Vegetation Mapping

Remote Sensing Data

(all tentatively available on ASC)

- Landsat composites
  Seasonal (early, middle, late summer) reflectance
- Selected high resolution imagery (DG/NGA)

Approach / Outputs

- Screen high-resolution satellite imagery for quality summer data & with field plot data
- Automate shrub & lichen cover estimation on plots from high-resolution satellite imagery, calibrated by cover estimates from *in situ* plots
- Aggregate high-resolution estimates to 30 m
- Estimate cover using Landsat w/ data mining algorithms (e.g. Random Forests)
- **Generate maps of continuous lichen (Fig. 2) and shrub cover (Fig. 3) at two time epochs (2000 and 2010) for change detection**

Fig. 2: Lichen cover map, Denali

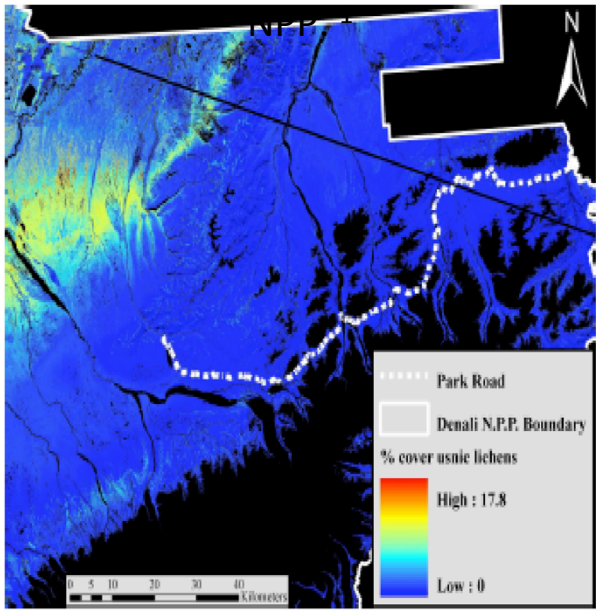
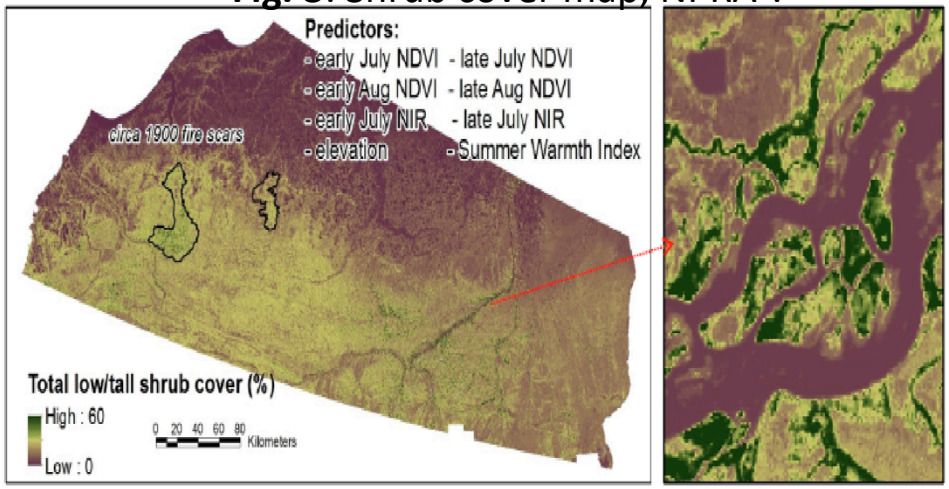
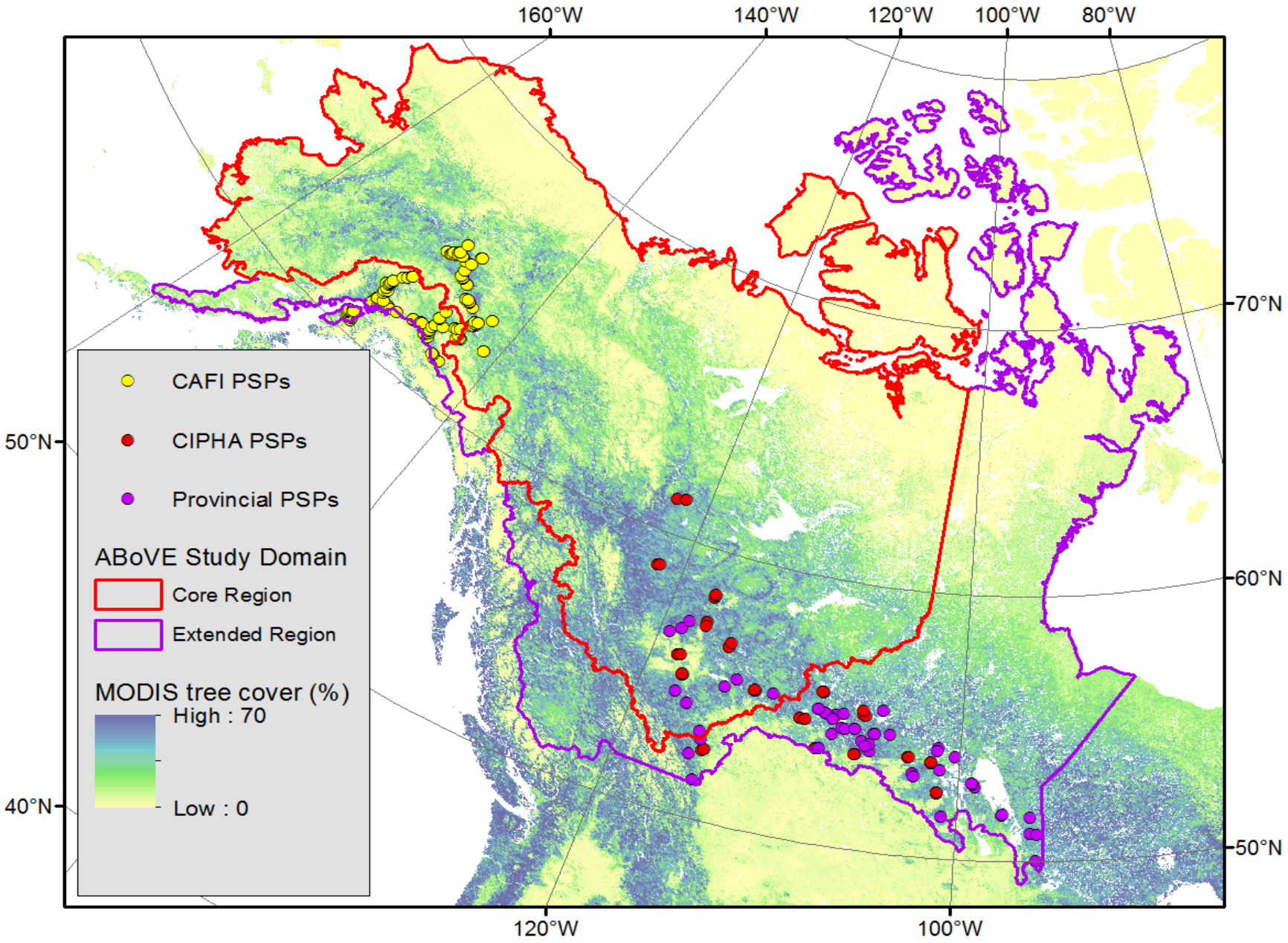


Fig. 3: Shrub cover map, NPRA[2].



Obj. 2 – Boreal Veg Field Studies

- Existing ground measurements
  - CAFI (Cooperative Alaska Forest Inventory)
    - Matt Stevens
  - CIPHA (Climate Impacts on Productivity and Health of Aspen)
    - Ted Hogg
  - Canadian Provincial permanent sample plots
    - Changhui Peng


160°W
140°W
120°W
100°W
80°W
70°N
60°N
50°N
40°N
120°W
100°W
CAFI PSPs
CIPHA PSPs
Provincial PSPs
ABoVE Study Domain
Core Region
Extended Region
MODIS tree cover (%)
High : 70
Low : 0

CAFI (Cooperative Alaska Forest Inventory)

- 612 PSPs (permanent sample plots)
- 409 of the PSPs are contained in the ABoVE domain.
- each covering 405 m^2, arranged at three per site and spaced at 30 – 63 m apart.
- Plots established in 1994 and later in interior and south-central Alaska and the Kenai Peninsula
- sampled every five years.
- As of 2014, 77% of the plots have been sampled at least three times.

CIPHA (Climate Impacts on Productivity and Health of Aspen)

- 144 aspen PSPs in 24 study areas across the western Canadian interior
- 114 of the PSPs are in the ABoVE domain.
- established in 2000
- Each study area contains 3 sites spaced at a distance of 30 km or less, each of which contains two PSPs covering 150 - 350 m^2, spaced 100 m apart.
- Half of these reside in the aspen parkland, and the other half in the intact boreal forest.
- Most CIPHA plots continue to be measured annually
- many have been harvested for tree-ring analysis.

Canadian Provincial PSPs (via Peng)

- 96 plots, 49 of which are located in the ABoVE domain (Alberta, Manitoba, and Saskatchewan)
- measured approximately every 5 – 12 years going back to the 1950s and 1960s
- dominated by black spruce (36%), white spruce (15%), lodgepole pine (13%), aspen (12%), and jack pine (9%).
- Will be analyzed for mortality by stand characteristics, number of inventories, disturbance history and stand age.
- We will explore the effect of selecting additional PSPs that were only measured twice for analyzing mortality events.
- We will select only unmanaged mature sites that are free from recent human and fire disturbance.

Obj. 2 – Boreal Field Studies

New field data collection efforts

- **We will build stand-level chronologies for 45 forest sites stratified across 3 regions of Interior Alaska**: Fairbanks, Delta Junction and Tok.
- All white spruce, aspen and birch stands & 3 of the black spruce stands are part of the CAFI study.
- **Augment the study design with black spruce plots in each region from the Bonanza Creek LTER Extended Site Network** or from Boby et al. (2010).
- Build stand-level ring width chronologies for replicate stands of each species comprised of samples from live and dead individuals.
- **On a subset of our stands, measure the ^{13}C signature of rings** on dead trees that precede mortality.
- On live trees, measure the **^{13}C** signature in rings that are precedent and antecedent in time to stand-level mortality events.
  - *This will allow us to examine differential moisture stress as a driver of mortality.*

- Chronologies will be used along with those at the CIPHA sites to examine stand-level covariance between climate, growth and mortality

Obj. 2 – Boreal Field Studies

Planning / timing of field efforts

- We plan to be in the field each summer 2016, 2017, 2018
- Focus on tree ring chronologies at CAFI sites & BNZ LTER
- Also **^{13}C** isotope analysis from cores & samples

Obj. 2 – Boreal remote sensing

We will use NDVI products from the latest GIMMS3g (AVHRR) and MODIS series.

- **GIMMS3g** is a well documented product for long-term vegetation dynamics, with a multi-decadal time series (1982 – present)
- **MODIS 250m** (~232m) NDVI 16-day products from Terra (MOD13Q1) and Aqua (MYD13Q1) for 2000 & 2002 - present, respectively.
  - Explore nadir BRDF corrected MODIS data at 250m from MCD43A1
- We will also take advantage of any finer-resolution (e.g., **Landsat** 30 m) NDVI products that become available

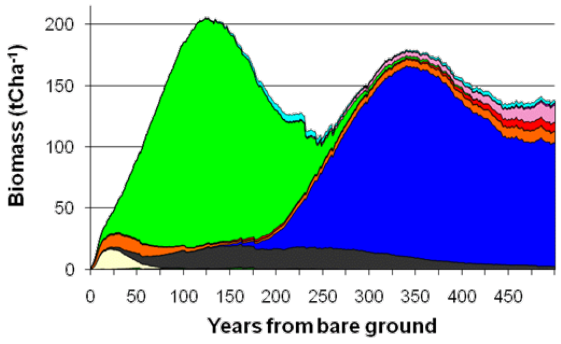
Airborne Remote Sensing

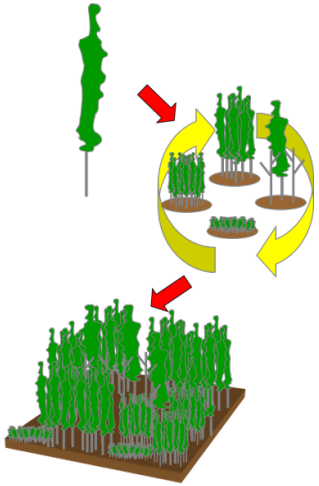
- Existing airborne remote assets to be used
  - Not certain of current data availability
    - lidar data would be of interest
    - Wulder's; GLiHT; LVIS; others?
- Potential uses for new airborne data
  - Lidar, Lidar and Lidar for canopy structure
  - These data would provide us unique information
    - which trees are experiencing greater mortality? taller / larger trees?
    - Can we map densification of arctic shrubs?
    - Lots of other stuff beyond our project (e.g. surface deformation, thermokarst progression, etc)

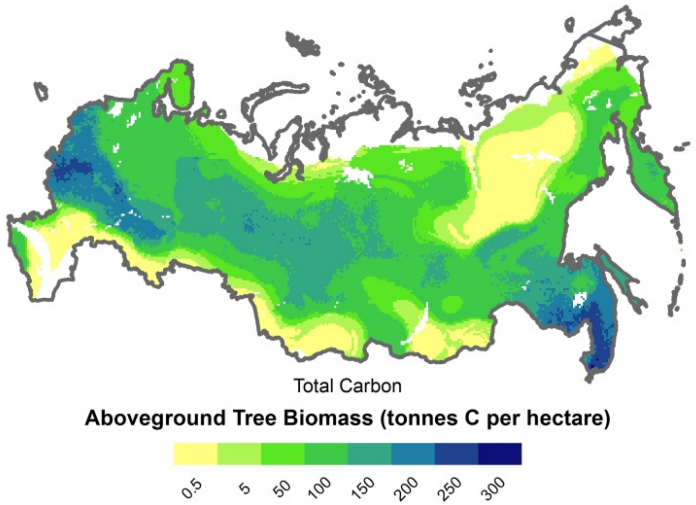
Objective 3: ***Modeling*** boreal tree species productivity, mortality & distribution

University of Virginia Forest Model Enhanced (UVFME)

Composition change through time







- Individual tree / species model of forest ecosystem
- Tree growth modulated by soil nutrients and water, climate, and canopy shading
- Species niche parameters drive competition (growth rates, regeneration needs, sizes, longevities)
- Forest community and species response to climate and disturbance regimes using ensemble approach
- Site simulation at continental scale

Input Data UVAFME

Minimum requirements:

- Avg monthly climate data from at least 30 years data (tmax tmin, total precip, radiation)
- Soil carbon and nitrogen in organic & mineral soils (tons per hectare)
- Soil water holding characteristics
  - (for soil: best source and scale across Alaskan study domain?)
- Species parameters (update per inventory where possible, otherwise literature)
  - Historical range distribution, Age Max, DBH max, Height max, Growth curves, Seed dispersal and survival, Tolerance for climate, shade, drought, and nutrients

Input Wish List:

- Slope, aspect, climate gridded for historical and future projections
- Species mortality details (markers: drought, insects, fire)
- Stand age OR time since disturbance with percent cleared, stand details
- Stem density by species and DBH size class

Geospatial Data Products to be produced

- **Objective 1 – Arctic veg mapping**
  - Proportional (0-100%) shrub cover maps of North Slope
  - Proportional lichen cover maps of North Slope
  - Both of these for 2000 & 2010 (later?) for change
- **Objective 2 – Boreal veg mapping & analysis of drivers**
  - Probability maps of boreal tree mortality
    - Press and Pulse NDVI changes included in statistical "machine learning" approach
- **Objective 3 – Boreal modeling of distribution / NPP change**
  - Species productivity & range suitability map outputs
    - Cal/val'd maps (site inventory-like predictions)
  - Probability maps of species-specific boreal tree mortality & northern range expansion