A hierarchic approach for examining panarctic vegetation with a focus on the linkages between remote-sensing and plot-based studies: A prototype example from Toolik Lake, Alaska

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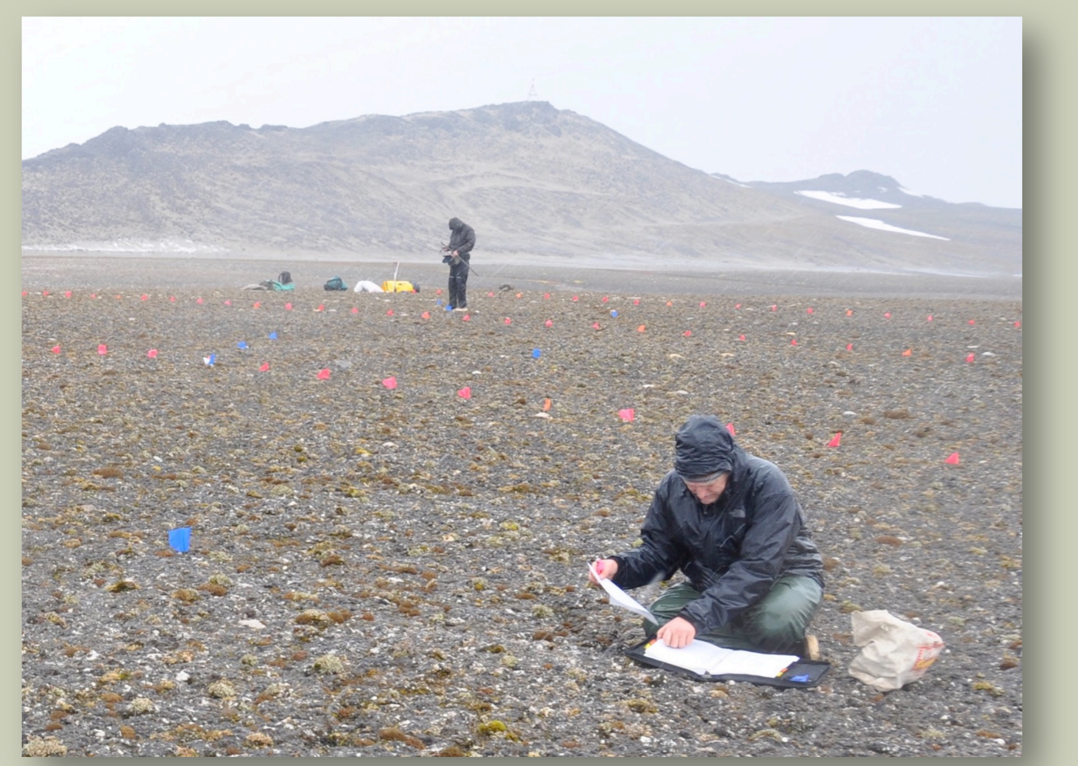
Statement of the problem



Collecting hand-held spectral data and plot-survey data on Hayes Island, Franz Jozef Land, Russia.

- **A hierarchic scaling approach is needed for circumpolar remote-sensing studies, maps, and plot-based studies that are used to understand the causes of Arctic vegetation change (e.g., Bunn & Goetz 2008; Bhatt et al. 2010; Elmendorf et al. 2012; Myers-Smith et al. 2015) (see Box 2).**
- **Studies at all scales rely on information from ground-based plot surveys collected during Arctic expeditions over the past century, but nowhere is this information compiled into a common database for comparative studies and a circumpolar Arctic vegetation classification.**
- **Only a few areas have been intensively sampled and mapped, mainly in the vicinity of permanent Arctic observatories.**
- **Furthermore, although an abundance of plot data have been collected for some areas, much of the information is project specific and is based on sampling protocols that are difficult to compare across sites and scales of study. Many lack complete species lists, accurate taxonomic determinations, and/or supporting photos, soil, environmental, and spectral data, which limits the extrapolation potential of these data.**
- **Here, we provide a hierarchic framework for studying Arctic vegetation, an example of a hierarchic mapping database, a prototype Arctic Vegetation Archive from northern Alaska, and some suggestions for a more standardized approach to plot-based surveys.**

Circumpolar Flora and Fauna (CAFF) initiatives that advance a panarctic understanding of Arctic vegetation:

- Circumpolar Arctic Vegetation Map (CAVM Team 2003).
- PanArctic Flora project (PAF): Elven et al. (2011).
- Arctic Biodiversity Assessment (Meltofte 2013).
- Arctic Vegetation Archive (Walker et al. 2013).

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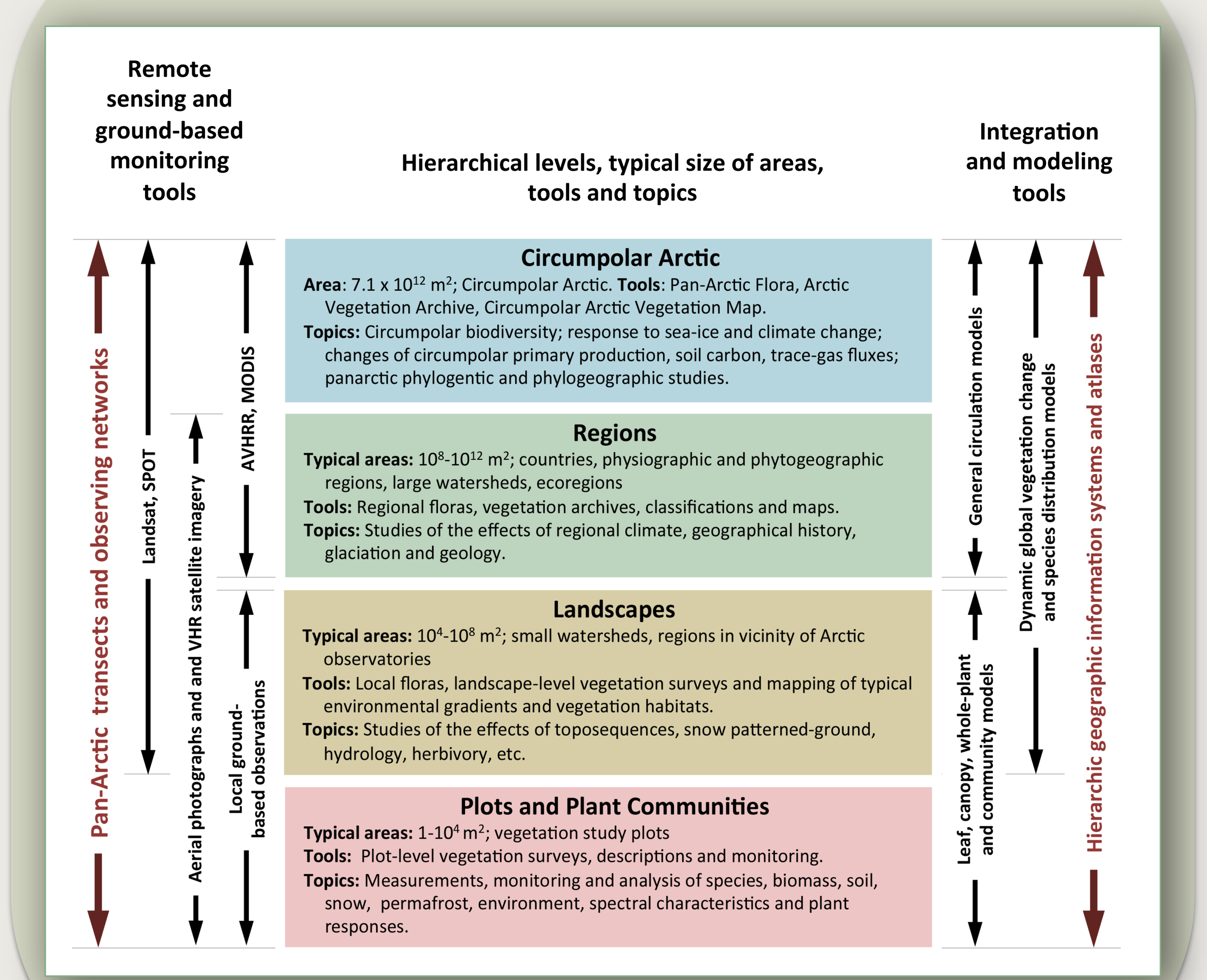
Hierarchic framework for studying Arctic vegetation



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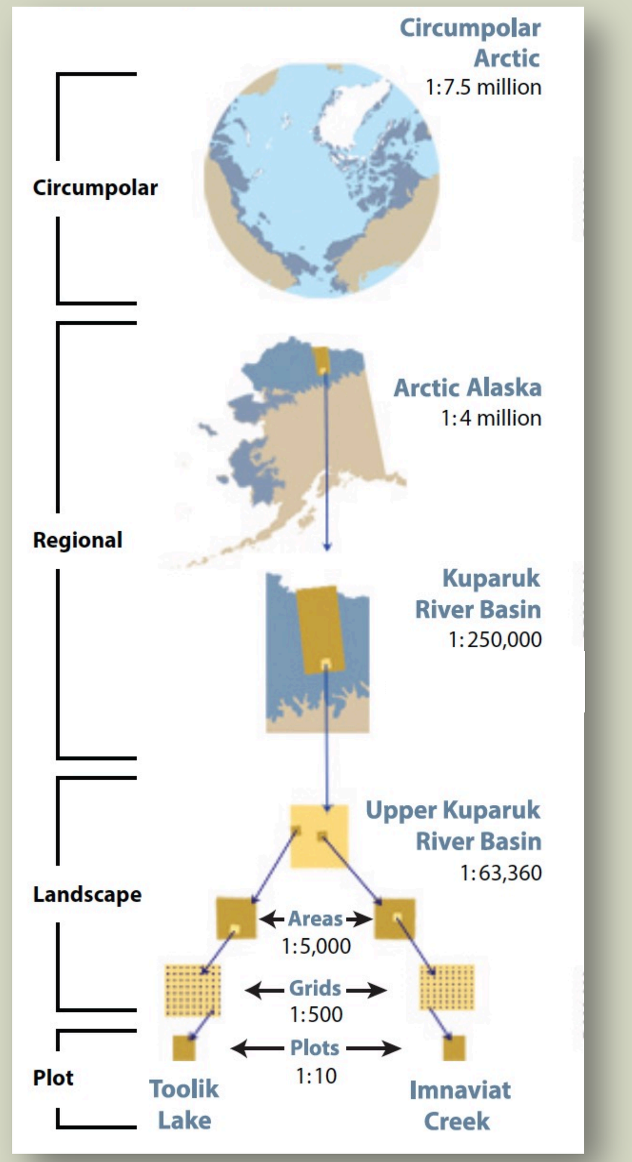
Hierarchy of maps, scales, and research topics for the Toolik Lake research station



Circumpolar

- Circumpolar biodiversity and productivity variation due to global climate, land temperatures, sea-ice distribution.

Regional

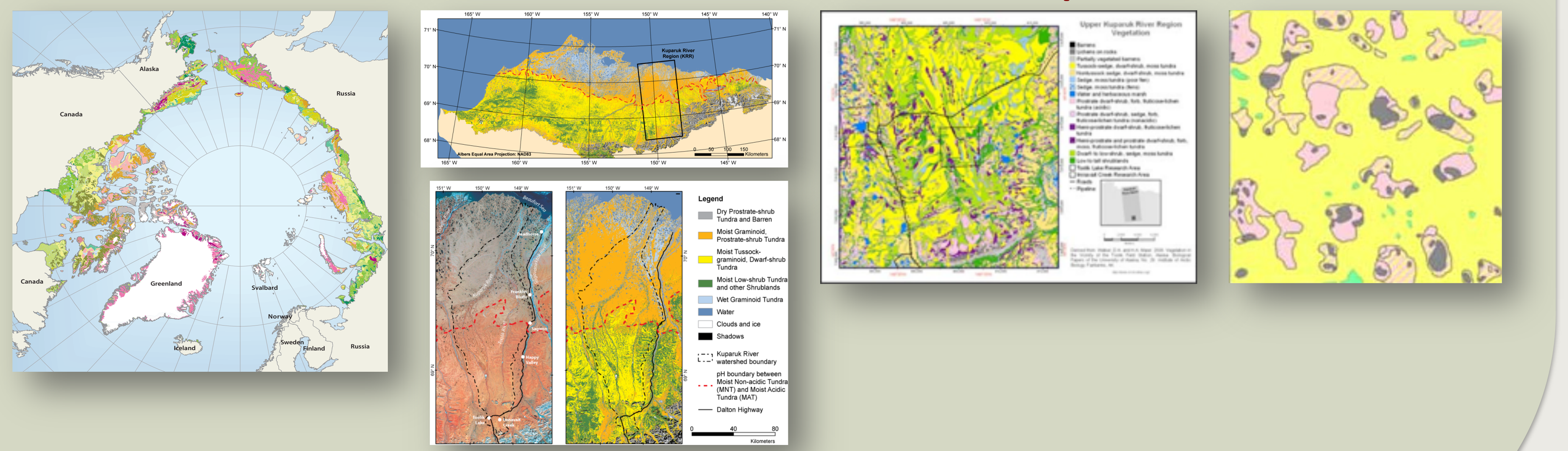
- Variation due to geology, macro-topography, climate, glacial and marine history, parent material, large-scale disturbance regimes.

Landscape

- Variation due to meso-topography, water and snow distribution

Plot

- Variation due to patterned ground, micro-topographic variations, small scale disturbances.



The goal: Consistent hierarchic map units, legends, colors, and terminology for cross-scale comparisons and analyses

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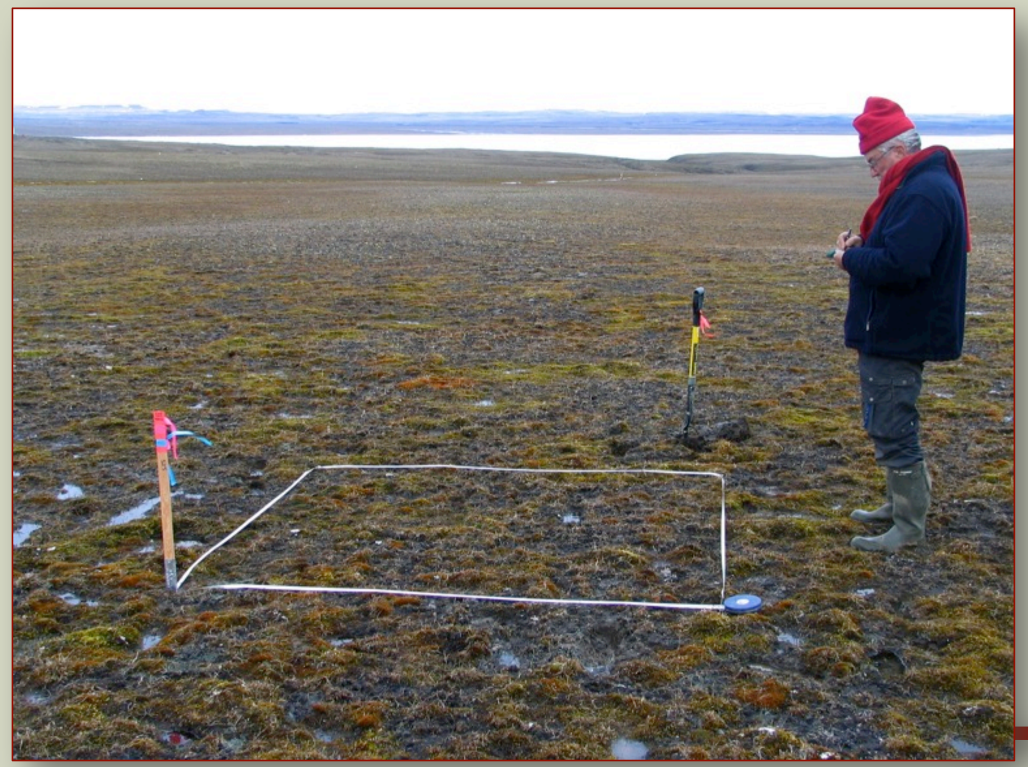
Toward a simple consistent integrated approach for plot-based vegetation surveys



Plot-survey on Ellef-Ringnes Island, Canada.

Ideal plant-community survey data for the AK-AVA (see Box 5):

- **Vegetation-sampling protocols according to the Braun-Blanquet approach or equivalent (e.g. USNVC)**
  - **Centralized replicate sampling:** Numerous observations in common habitat types and plant communities with **homogenous microtopography, vegetation, and soil**
  - **Minimal sample area:** Sufficient to contain >95% of species in the plant community
  - **Plant species-cover estimates**: For all vascular plants, lichens, mosses
  - **Canopy structure:** Height and horizontal cover of vegetation layers, cover of plant functional types
- **Permanently marked corners**
- **Site description:** Coordinates, elevation, photos, slope, aspect, soil moisture regime, snow regime, pH, landform, parent material, geology, surface geomorphology, active-layer thickness, disturbance types and degree, stability
- **Clip harvest for biomass**
- **Soils:** Collection of top mineral horizon for physical and chemical analyses
- **Spectral properties:** Handheld LAI, spectroscopy

As with all floristic-based studies, the surveys require expert taxonomic determination of plant species.

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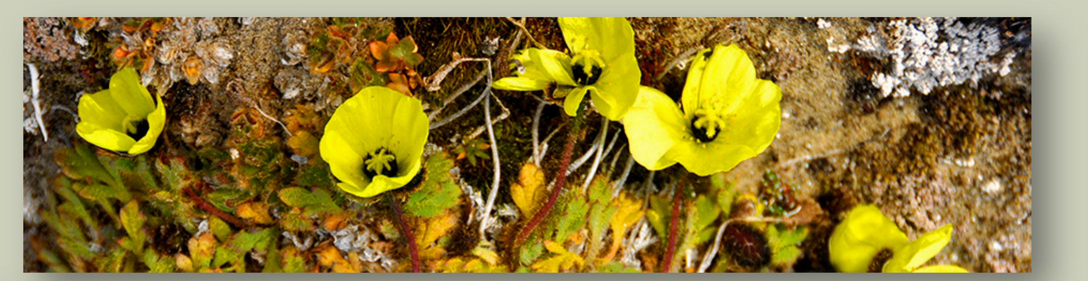
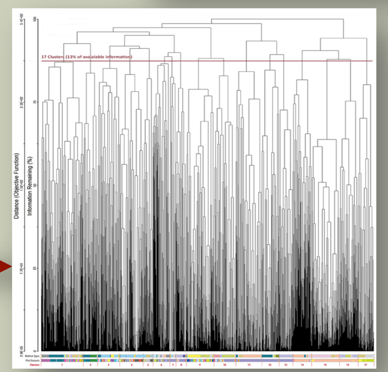
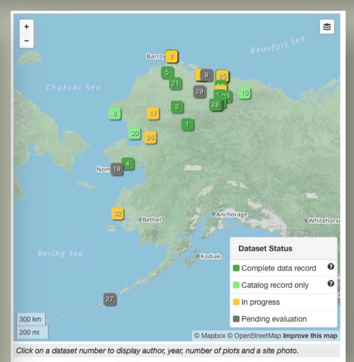
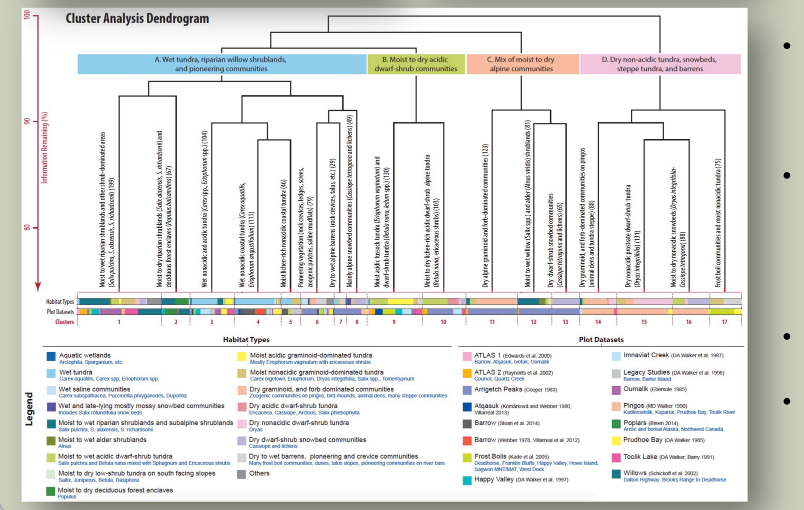
Alaska Arctic Vegetation Archive (AK-AVA)

http://alaskaaga.gina.alaska.edu









Key features

- Currently contains species and ancillary data for ~2000 plots in 21 datasets out of 3500 known Braun-Blanquet plots in Arctic Alaska.
- Species names are standardized according to the Panarctic Species List (PASL) (Elven et al. 2011, Raynolds et al. 2013).
- Links to ancillary data (e.g., soil & environmental, plot photos, publications, biomass, spectral data).
- Data are in .csv and Excel files, and a Turboveg database houses all datasets using consistent terminology and header data (Hennekens & Schaminee 2002).
- Follows database approach of the European Vegetation Archive (Chytrý et al. 2015) and international vegetation database archiving procedures (Dengler et al. 2011).
- A web-based portal provides access to plot and map archives (see link above).
- A preliminary numerical analysis (left) reveals the range of current habitat types, how the current contents fall within described Braun-Blanquet syntaxa and major data gaps.

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Recommendations for improving circumpolar vegetation surveys and monitoring

1. **Arctic Observatories:** Full vegetation surveys at permanent Arctic terrestrial observatories, with permanently marked and replicated vegetation monitoring plots established in the full range of habitat types
2. **Consistent criteria:** Including, methods for marking plots; methods for surveying plants and the environment; full species lists for the vascular plants, bryophytes, and lichens; methods for collecting and analyzing phytomass and ground-based spectral data
3. **Periodic resurveys:** Perhaps every 5-10 years, including species composition, ground-based measurements of biomass, leaf-area index, and NDVI
4. **Link information to a hierarchy of maps at plot, landscape, regional, and circumpolar scales:** Using standardized mapping legends for vegetation classification and mapping
5. **Coordinated observations by other disciplines:** On the same or adjacent plots (e.g., plant taxonomists, vegetation scientists, soil scientists, permafrost scientists, remote-sensing specialists, and animal ecologists)
6. **Include areas of special concern and "hotspots" of productivity or biodiversity**: Need to also survey critical areas not represented at the observatories

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Future directions

Other prototype AVA databases are being developed for Greenland (Bültmann & Daniëls 2013) and the Yamal Peninsula region of northwest Siberia (Ermokhina 2013). Application to the entire circumpolar region will require consensus approval of the approach with appropriate modification by the international group of Arctic vegetation scientists. We anticipate many applications of the database for examining biodiversity, species distribution modeling, vegetation change modeling, land-use planning, resource development, and education.

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