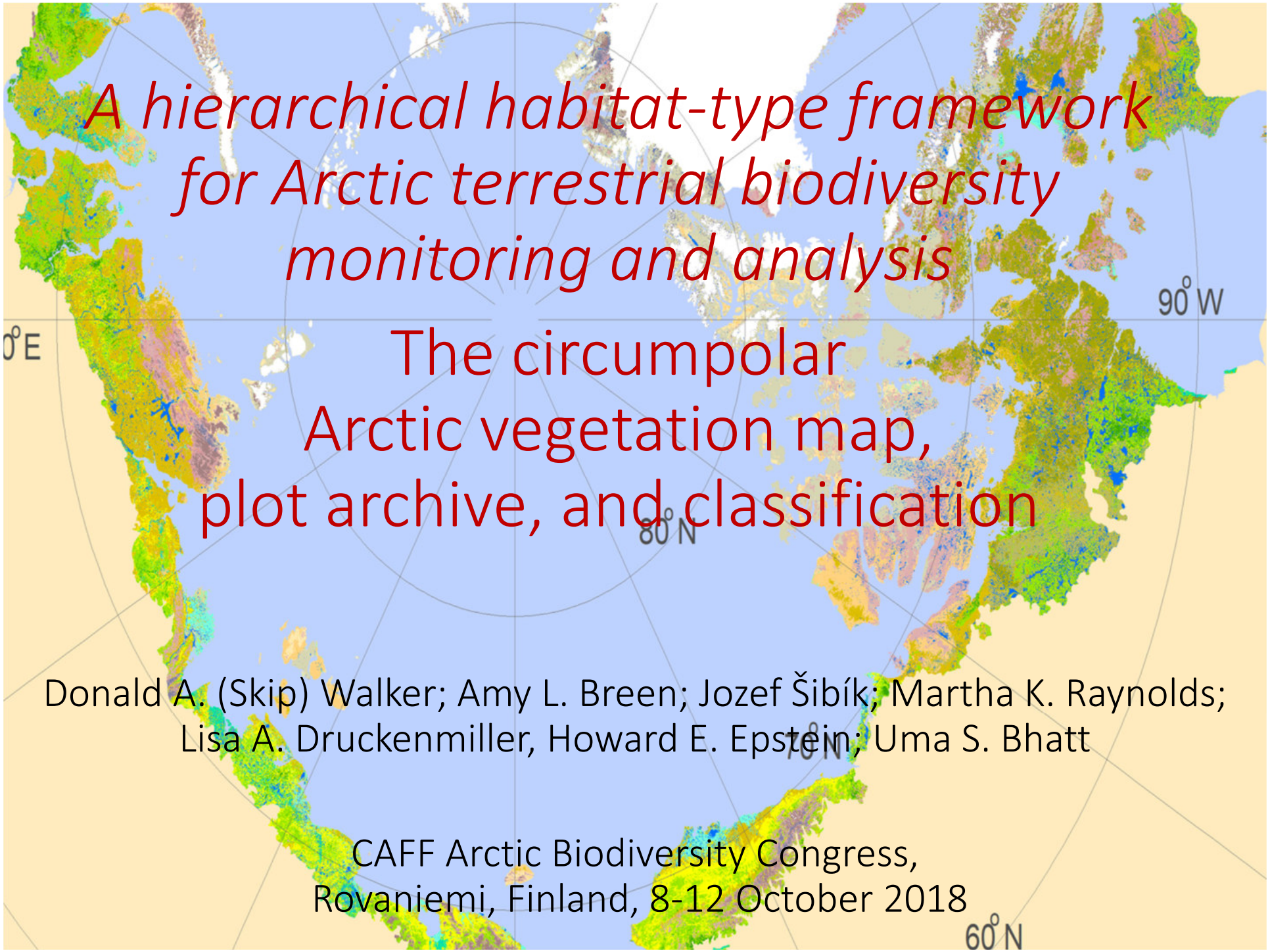
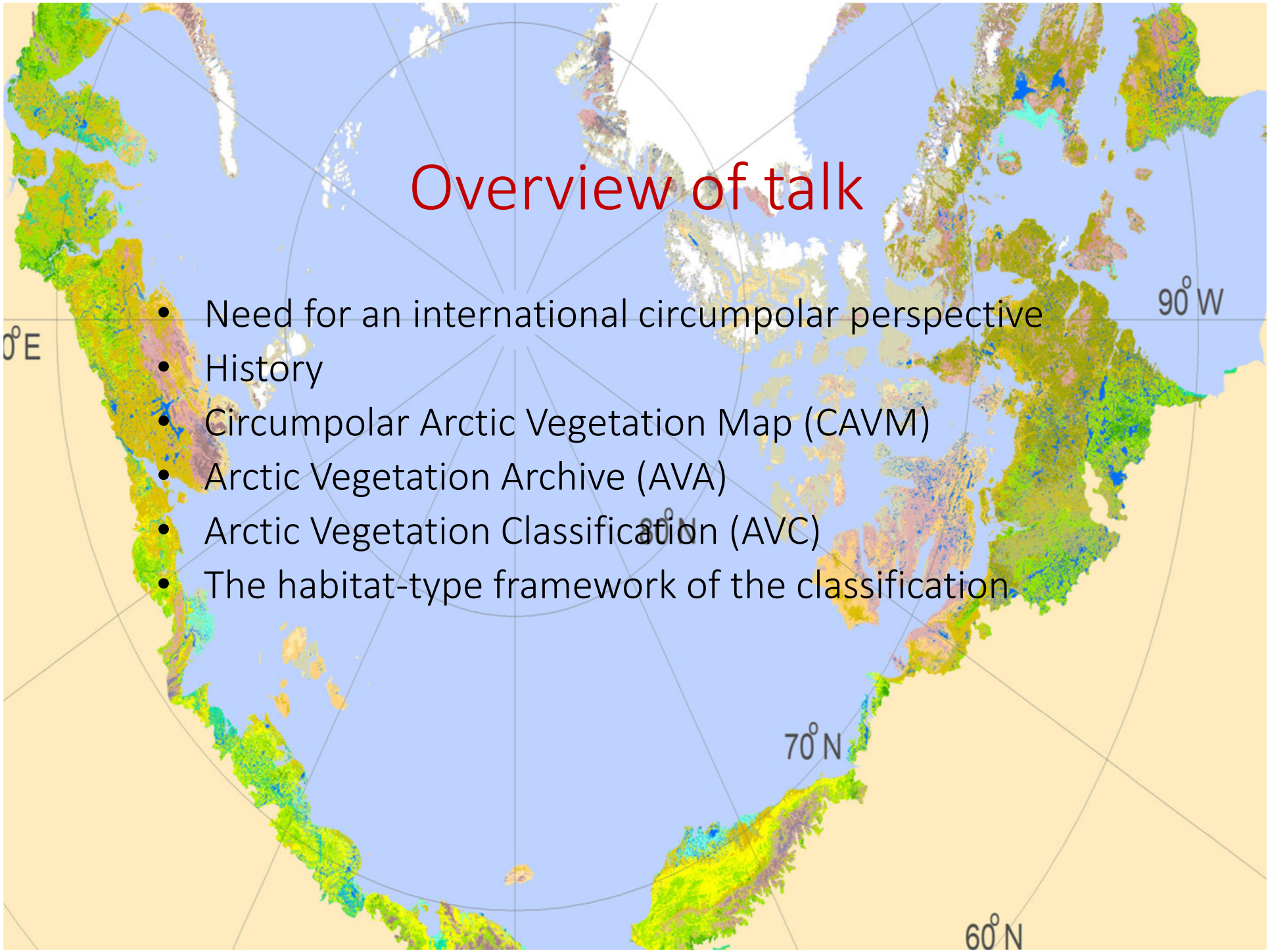


A hierarchical habitat-type framework for Arctic terrestrial biodiversity monitoring and analysis

The circumpolar Arctic vegetation map, plot archive, and classification

Donald A. (Skip) Walker; Amy L. Breen; Jozef Šibík; Martha K. Raynolds; Lisa A. Druckenmiller, Howard E. Epstein; Uma S. Bhatt

CAFF Arctic Biodiversity Congress,
Rovaniemi, Finland, 8-12 October 2018



Overview of talk

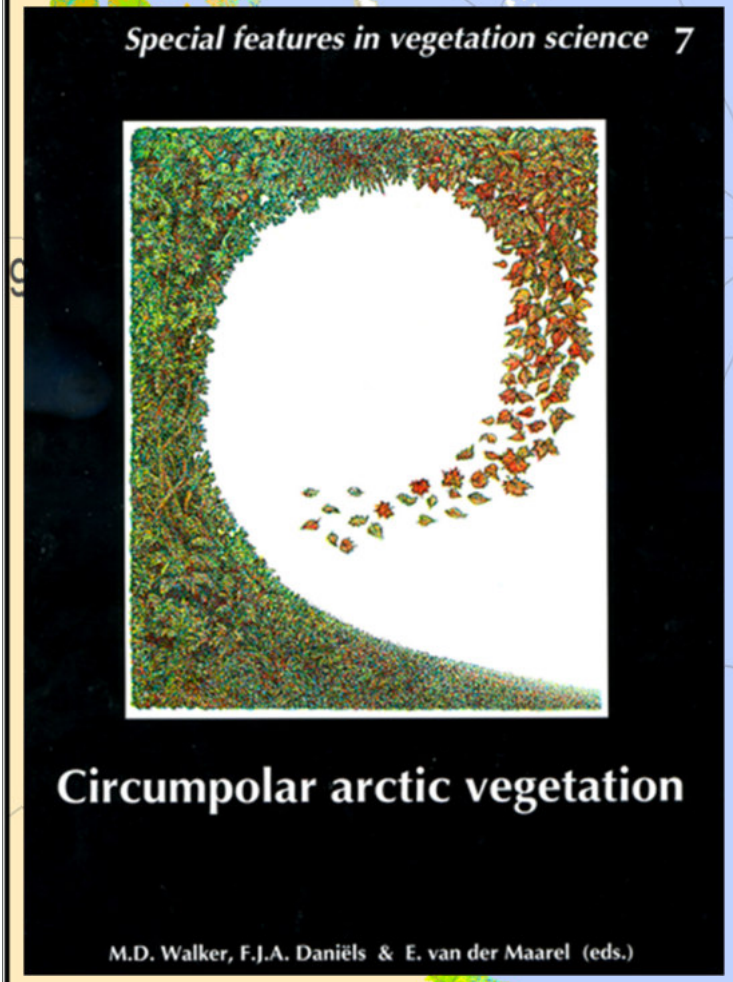
- Need for an international circumpolar perspective
- History
- Circumpolar Arctic Vegetation Map (CAVM)
- Arctic Vegetation Archive (AVA)
- Arctic Vegetation Classification (AVC)
- The habitat-type framework of the classification

Why a circumpolar framework?

- A common international approach is needed for classifying and mapping Arctic vegetation and as a framework for other forms of terrestrial biological diversity across the Arctic as they responds to climate and anthropogenic forces at multiple scales.
- CAFF endorsed the circumpolar vegetation framework through:
  - Pan Arctic Flora (PAF)
  - Circumpolar Arctic Vegetation Map CAVM).
  - Circumboreal Vegetation Map (CBVM),
  - Arctic Vegetation Archive (AVA)
  - Arctic Vegetation Classification (AVC)
- The PAF and CAVM provided a consistent way to analyze plant, fungi, and terrestrial ecosystem biodiversity across the Arctic for the *Arctic Biodiversity Assessment* (Meltof et al. 2013).

History:

Arctic Workshop, Boulder, 1992



First international meeting of arctic vegetation scientists.

Evolved out of the IBP Tundra Biome and MAB.

Began the task of a global synthesis of arctic vegetation with a resolution sufficient to produce:

- Vegetation plot database
- Comprehensive synthesis of phytosociological information
- Circumpolar arctic vegetation map

Walker, M. D., Daniëls, F. J. A., & Van der Maarel, E. (1994). Circumpolar arctic vegetation: Introduction and perspectives. *Special Features in Journal of Vegetation Science*, *5*(6), 757–920.

History:

Important paper by Boris Yurtsev at the Boulder workshop

Journal of Vegetation Science 5: 765-776, 1994
© IAVS; Opulus Press Uppsala. Printed in Sweden

Floristic division of the Arctic

Yurtsev, Boris A.

Department of Vegetation of the Far North, Komarov Botanical Institute, ul. Prof. Popova 2, St. Petersburg 197376, Russia; Fax +7 812 234 4512; E-mail BINRAN@GLAS.APC.ORG ('for Boris A. Yurtsev')

Abstract: The progress in the floristic study of the circumpolar Arctic since the 1940s is summarized and a new floristic division of this region is presented. The treeless areas of the North Atlantic and North Pacific with an oceanic climate, absence of permafrost and a very high proportion of boreal taxa are excluded from the Arctic proper. It is argued that the Arctic deserves the status of a floristic region. The tundra zone and some oceanic areas are divided into subzones according to their flora and vegetation. Two groups of subzones are recognized: the Arctic group (including the Arctic tundras proper and the High Arctic) and the Hypoarctic group.

The Arctic phytochorion is floristically divided into sectors: 6 provinces and 20 subprovinces reflecting the regional features of each sector in connection with flora history, physiography and continentality-oceanity of the climate. Each sector is described and differentiated by a set of differential and co-differential species. The peculiarities of the Arctic flora are manifest in different ways in the various sectors, and endemism is not the universal criterion for subdivision.

Keywords: Chorology; Classification; Flora element; Floristic province; Phytogeography; Polar desert; Syntaxonomy; Tundra vegetation.

posed by Yurtsev et al. 1978 (see also Yurtsev 1978a). Since that time the last four issues of the Arctic Flora of the USSR have been published. Moreover, new floristic monographs in many volumes have been started in the Russian Far East and Siberia, while significant progress has been made in the study of the flora of the Russian Arctic as well as of Alaska and Canada (e.g. Porsild & Cody 1980) and Greenland (Bay 1992).

The present paper is a revision of the publication of 1978 and is based on extensive new data. It is based on two complementary schemes of phytogeographic division of the Arctic, or the tundra zone in its broader sense (Figs. 1 and 2). Fig. 1 deals with the latitudinal phytogeographic zonation of the Arctic and with subzones of the tundra zone, which are essentially circumpolar, except for subzones V and VI. Fig. 2 deals with the floristic division of the Arctic into longitudinal sectors.

A special aim of this paper is to stress the floristic-phytogeographic boundaries in the Arctic for geobotanists concerned with floristical classification of Arctic vegetation and vegetation mapping. The knowledge of

Boris A. Yurtsev (1932-2004)

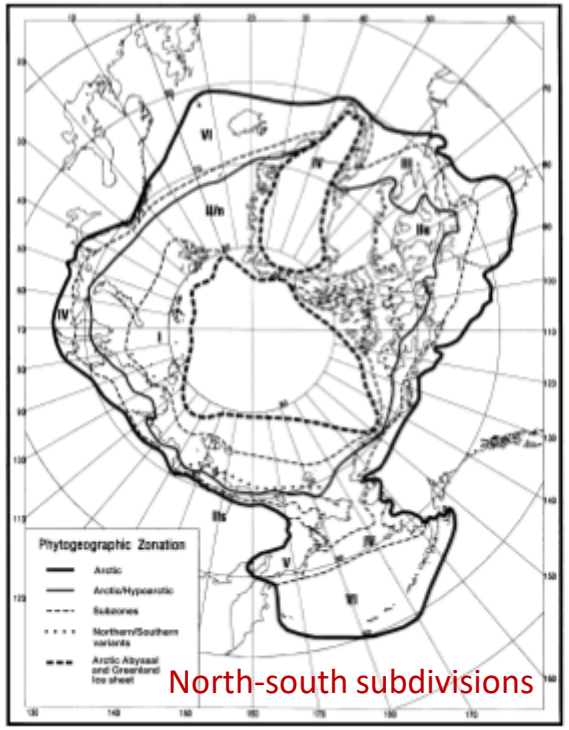
Laid the foundation for the CAVM and AVC.

Yurtsev, B. A. (1994). The floristic division of the Arctic. *Journal of Vegetation Science*, *5*(6), 765–776.

History:

Yurtsev's boundaries for the Arctic Zones

Bioclimate subzones



North-south subdivisions

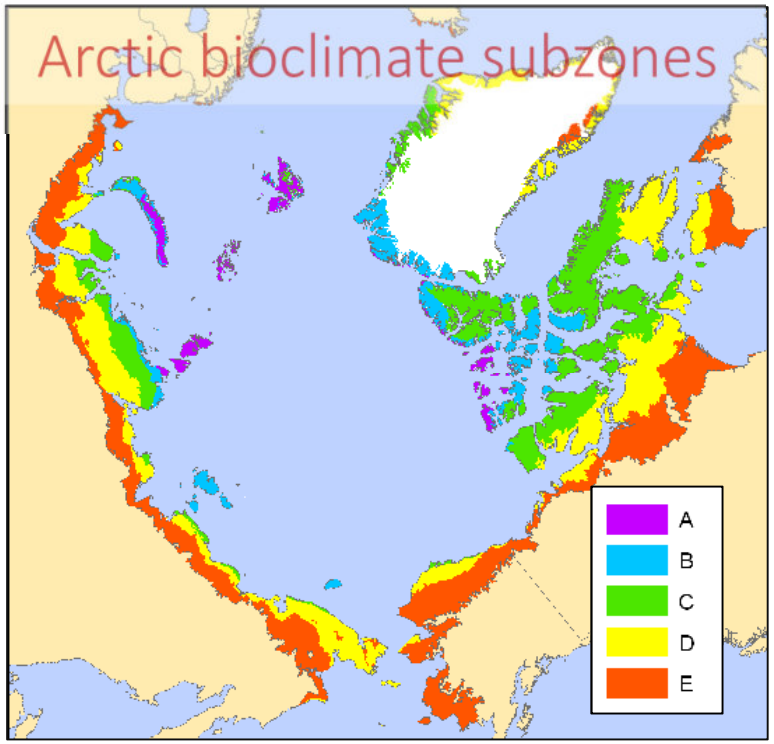
Floristic Subdivisions

East-west subdivisions

- Defined the biogeographic boundaries of bioclimate subzones and major phytogeographic subdivisions of the Arctic tundra biome for the Pan Arctic Flora, the CAVM, and AVA.

Yurtsev, B.A. 1994. *Journal of Vegetation Science.* Floristic division of the Arctic, 5: 765-776.

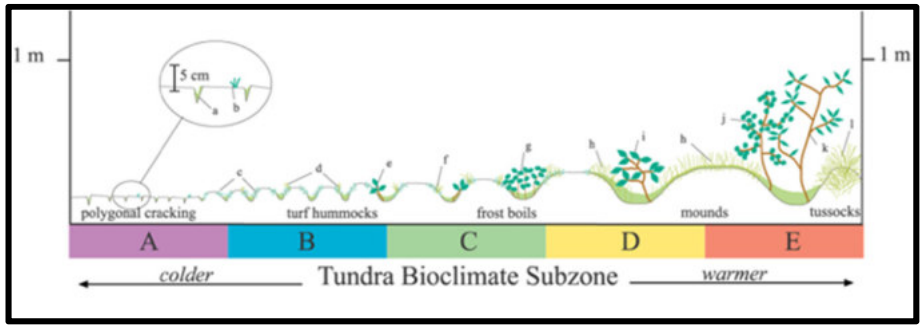
History:



The Arctic Zone

- The tundra region north of the Arctic tree line, characterized by an Arctic climate, Arctic flora, and tundra vegetation.
- Excludes maritime treeless regions with a boreal climate, and boreal flora (e.g. the Aleutian Islands, much of Iceland, maritime Atlantic Islands).

Shrub heights and microtopography along the bioclimate gradient



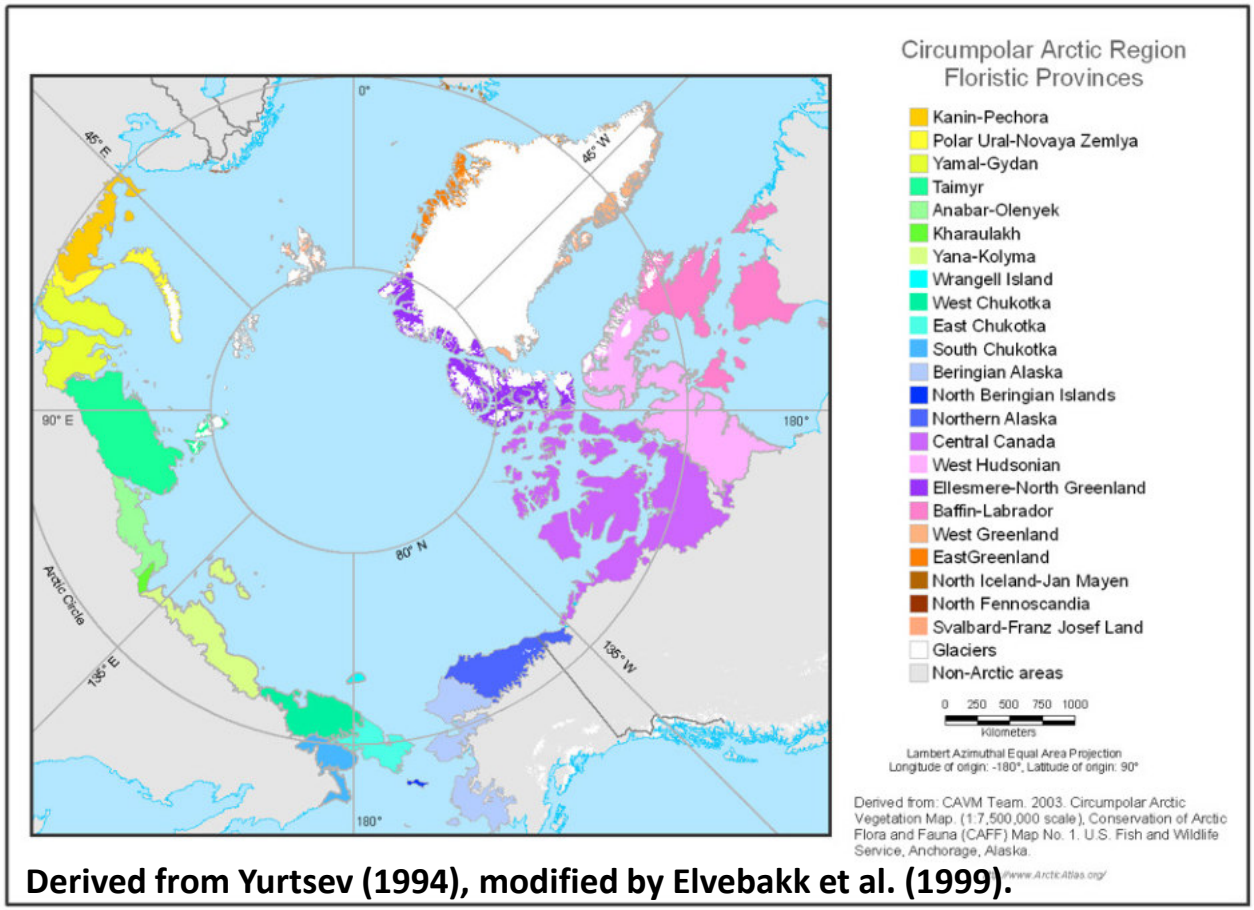
Based on Yurtsev (1994) & Edlund (1990)

Bioclimate Subzones

- Defined mainly by summer temperature and dominant plant growth forms on zonal sites

A – *Papaver* subzone, no shrubs
B – *Dryas* subzone, prostrate dwarf shrubs
C – *Cassiope* subzone, hemiprostrate dwarf shrubs
D – *Betula* subzone, erect dwarf shrubs
E – *Alnus* subzone, low shrubs

History:
Yurtsev's floristic subprovinces

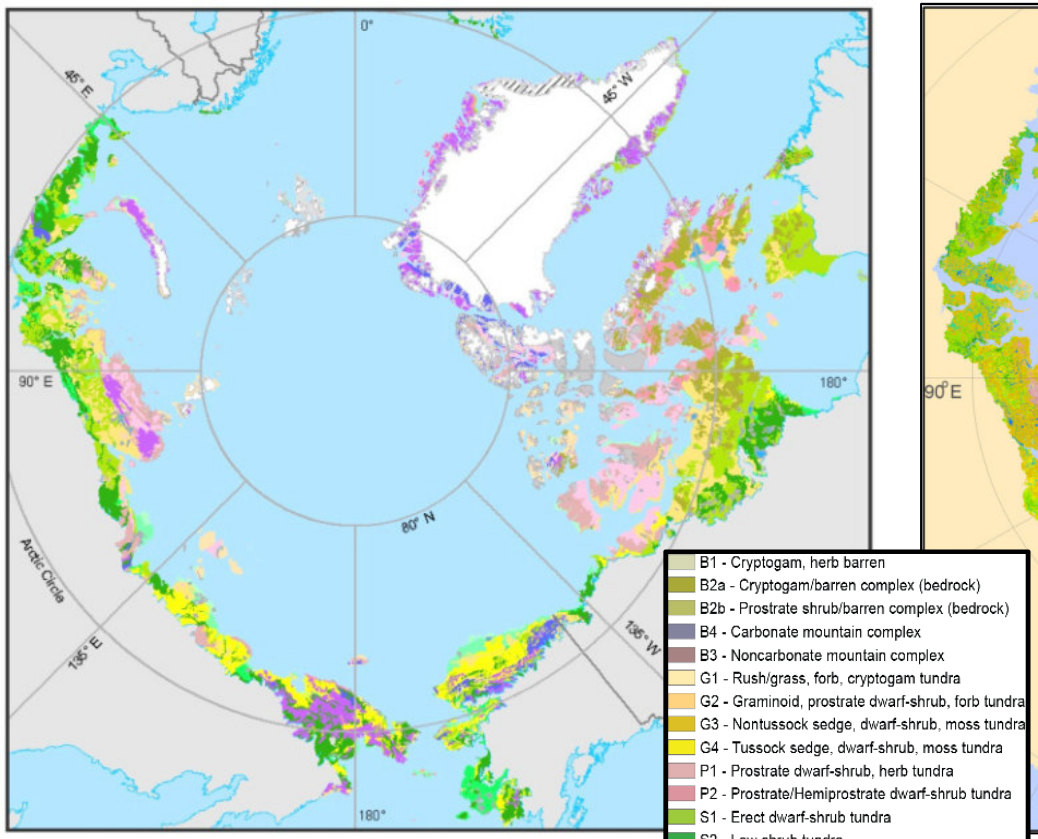


Derived from Yurtsev (1994), modified by Elvebakk et al. (1999).

- Primarily an E-W longitudinal framework.
- Defined distinct floristic regions where geographic and historical influences affected the evolution of the Arctic flora.
- 5 provinces, 22 subprovinces

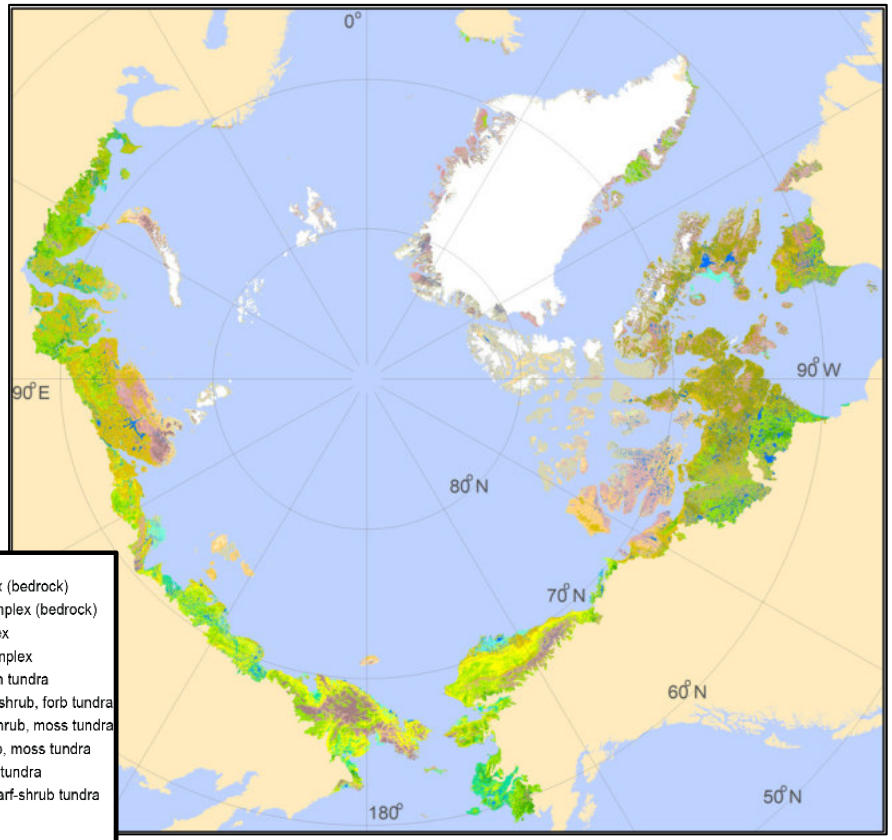
The 1st and 2nd versions of the CAVM

Version 1 (polygon version)



- Hand-drawn boundaries interpreted from AVHRR imagery.
- Useful for broad regional stratification of vegetation.

Version 2 (raster version)

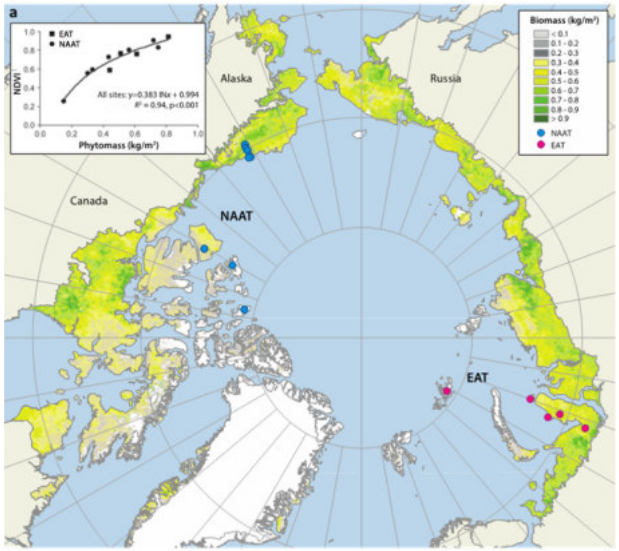


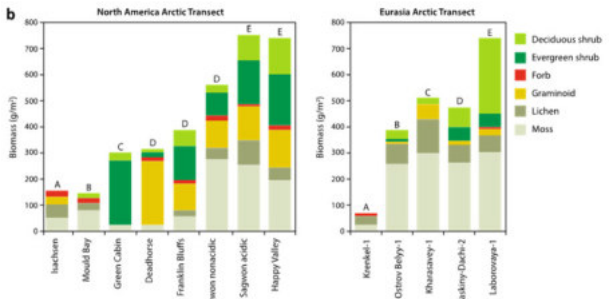
- Derived from MODIS & AVHRR imagery and 7 other data layers.
- 1-km pixel resolution.
- Preserves the map extent, projection and units of the vector version.
- More useful than the vector map for modeling applications.

Raynolds & Walker. 2018. 48th Annual International Arctic Workshop, Boulder, CO. April 4–8, 2018.

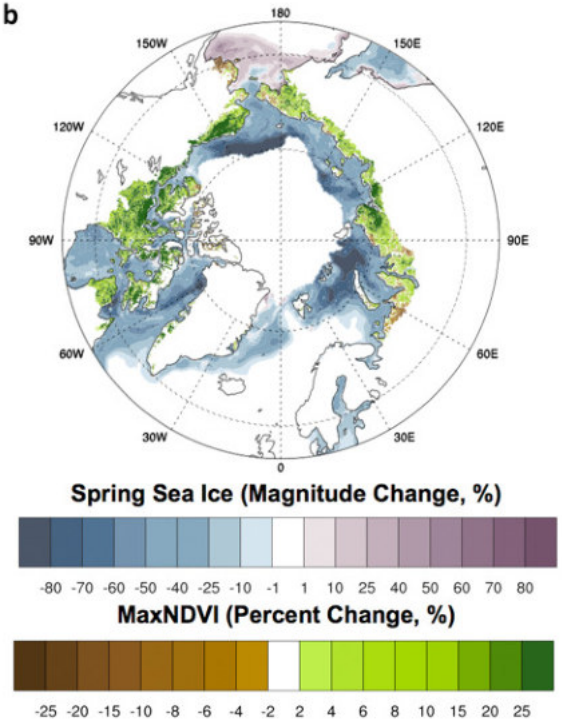
Applications of the CAVM

Circumpolar Phytomass (Raynolds et al. 2008)

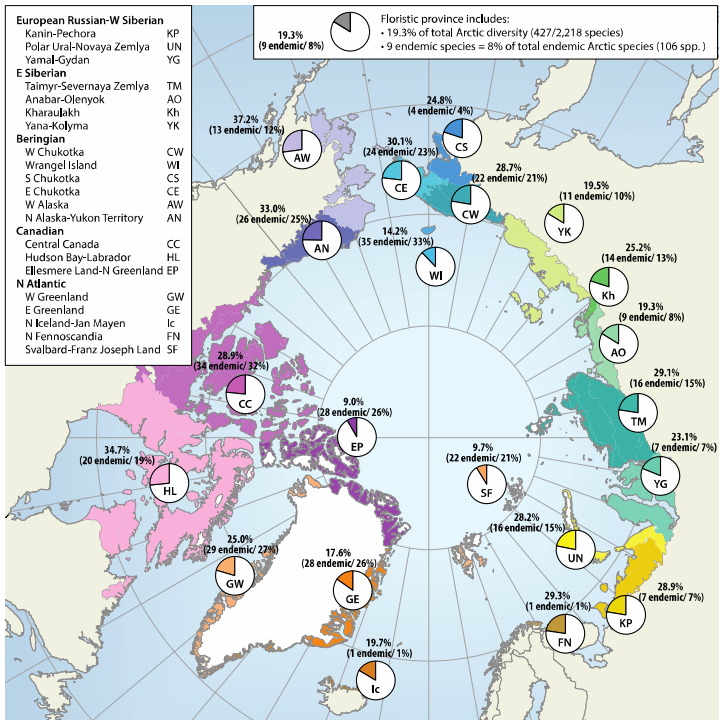




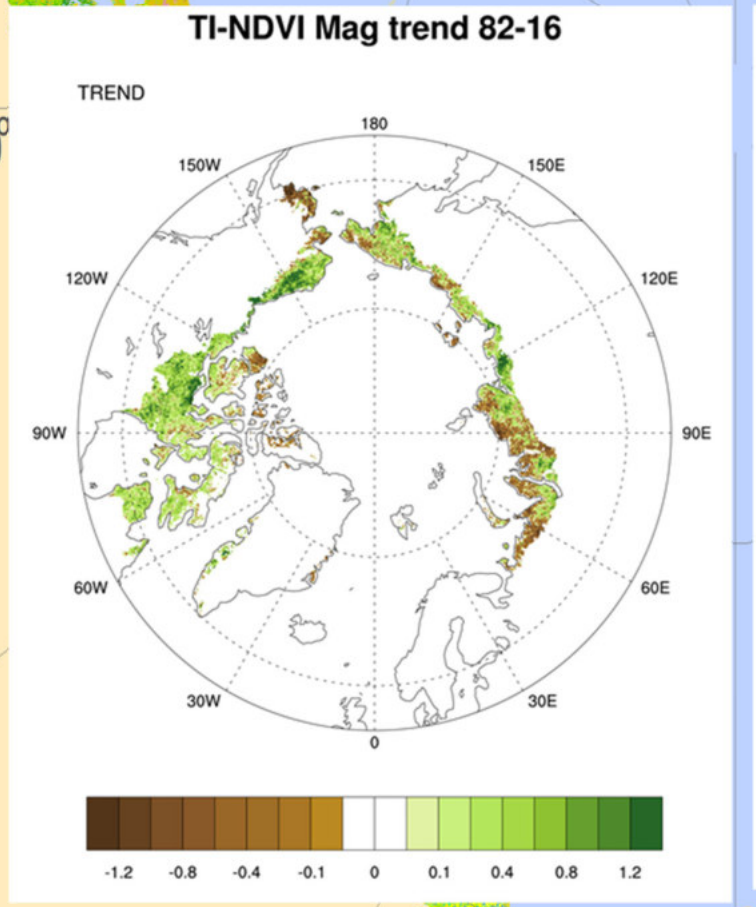
Change in circumpolar greenness patterns in relation to sea ice (Bhatt et al. 2010)

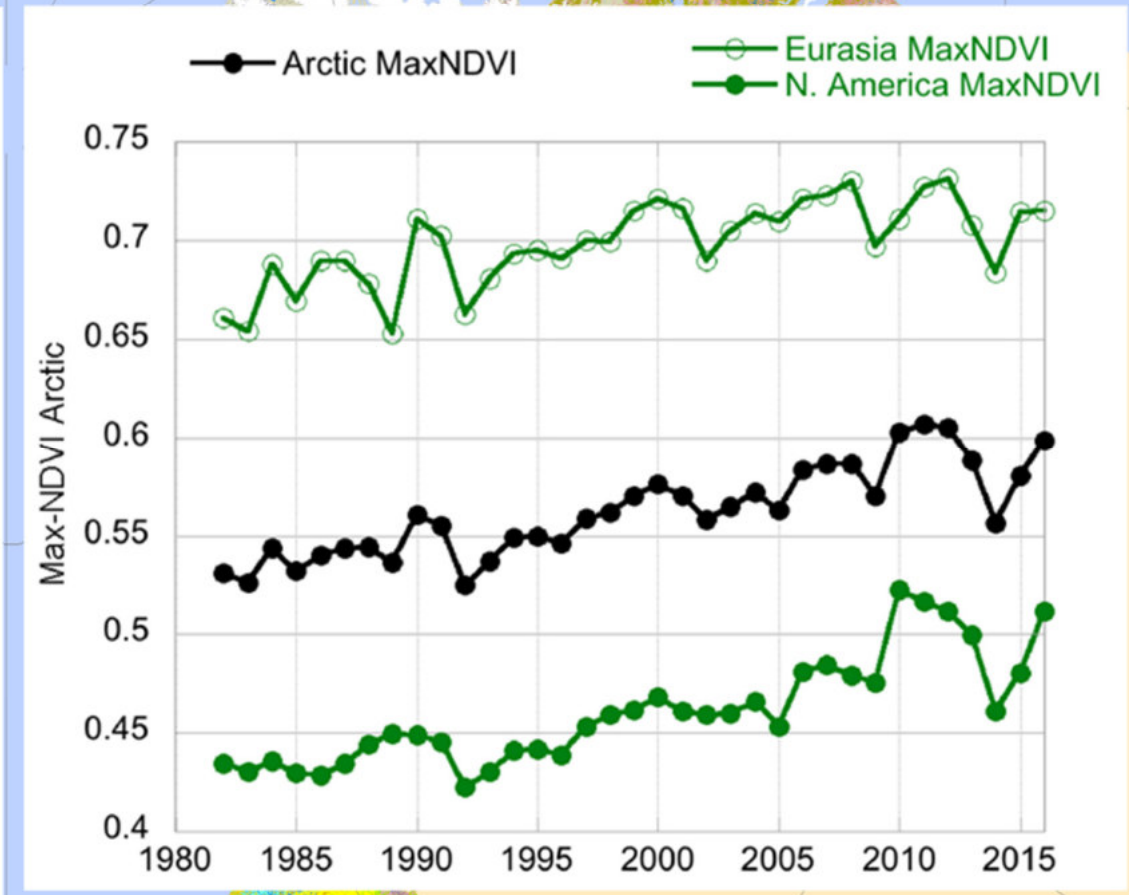


Circumpolar Biodiversity Assessment (Daniëls et al. 2013)



Applications:
Monitoring Arctic Greenness
NOAA Arctic Report Card





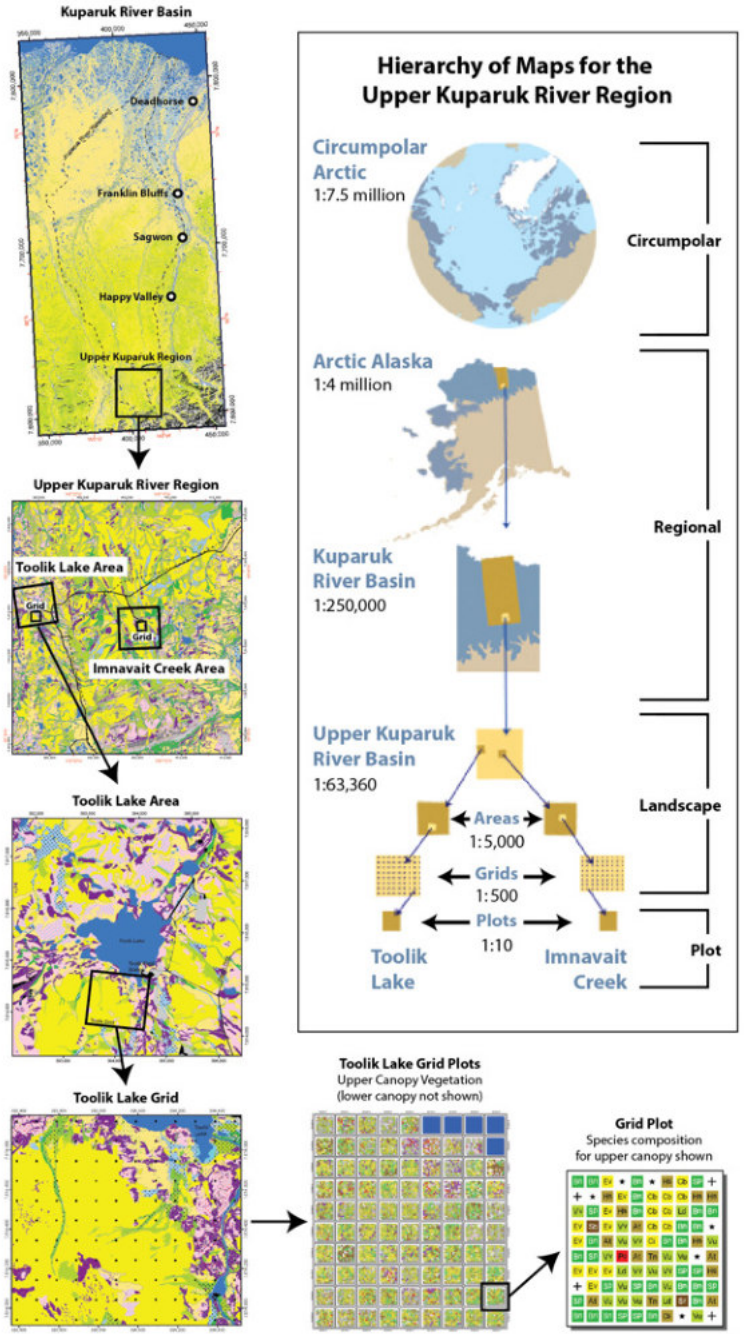
Epstein et al. 2017. NOAA Arctic Report Card

60°N

Applications:

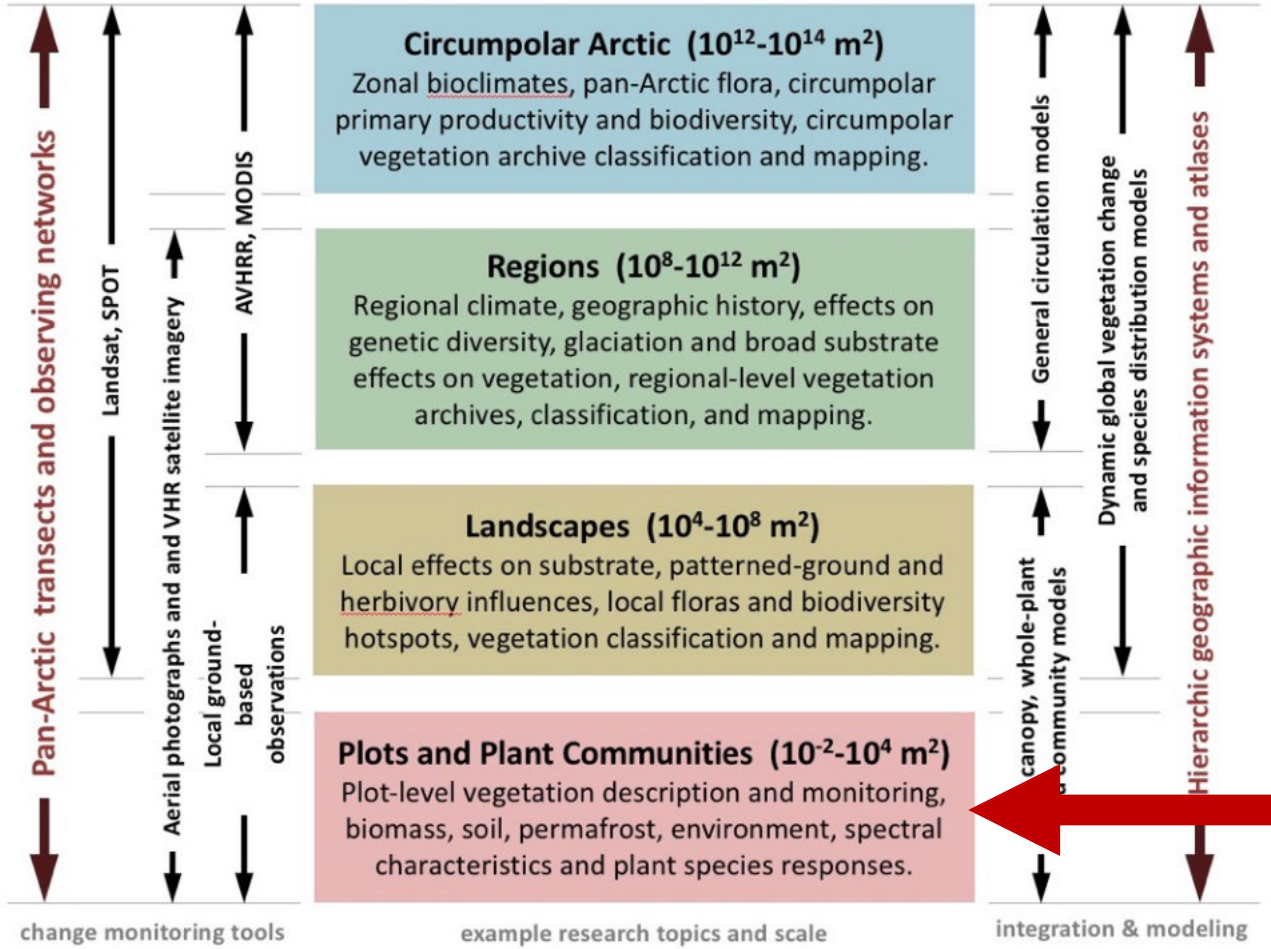
Hierarchy of vegetation maps for the Arctic LTER at Toolik Lake, AK

- The CAVM is the top level of a seven-level hierarchy of geoecological maps centered on the Arctic Long-Term Ecological Research site at Toolik Lake, AK.
- Consistent legends and map colors.



Walker, D. A. et al. (2010). Circumpolar geobotanical mapping: A web-based plant-to-planet approach for vegetation-change analysis in the Arctic. *Viten Fra Skog Og Landscap*, 125–128.

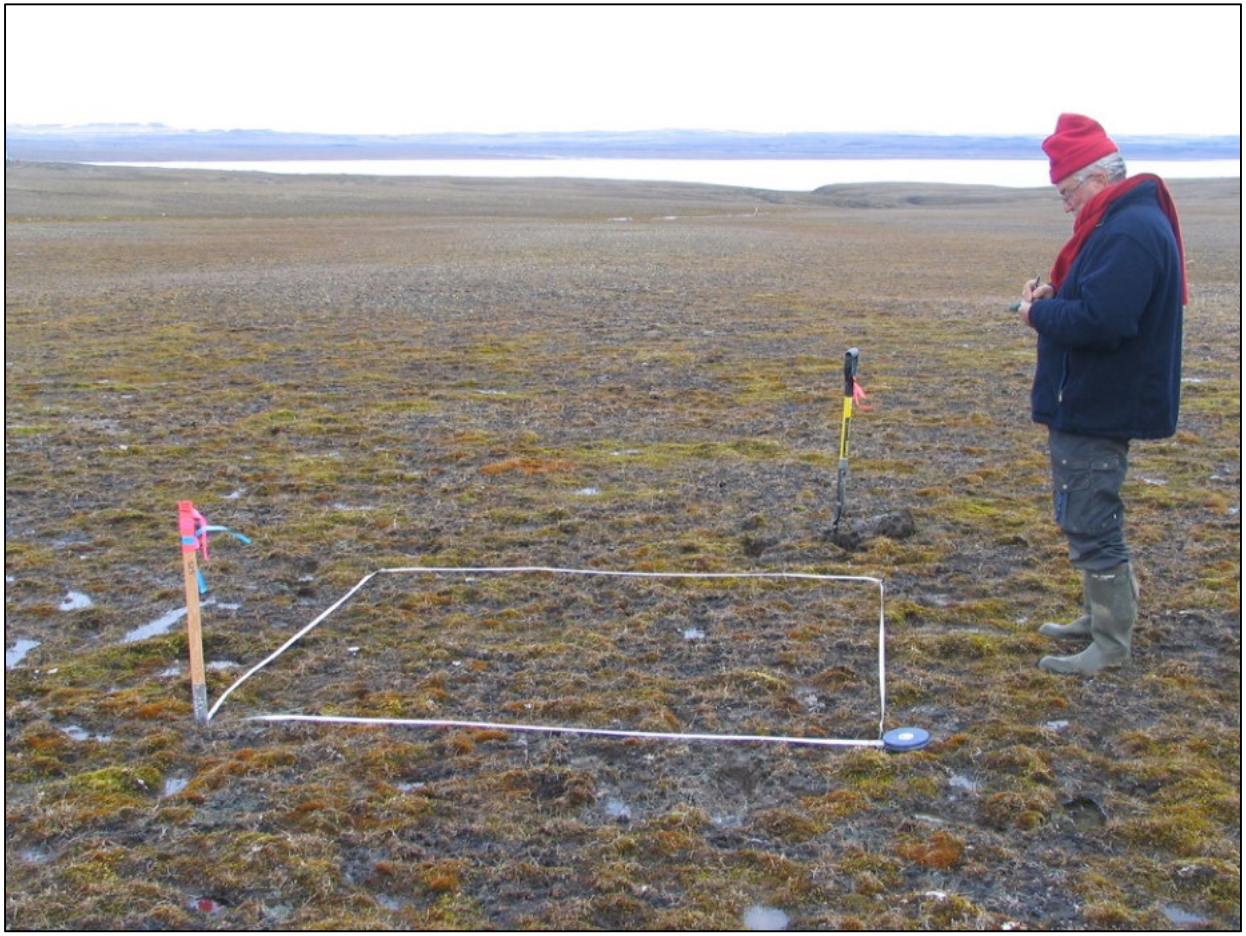
Hierarchy of map scales



The hierarchy of map scales depends on a foundation of plot-level observations

Walker, D. A., et al. (2016). ***Environmental Research Letters*****,** ***11*****(5), 055005.**

Vegetation-plot data

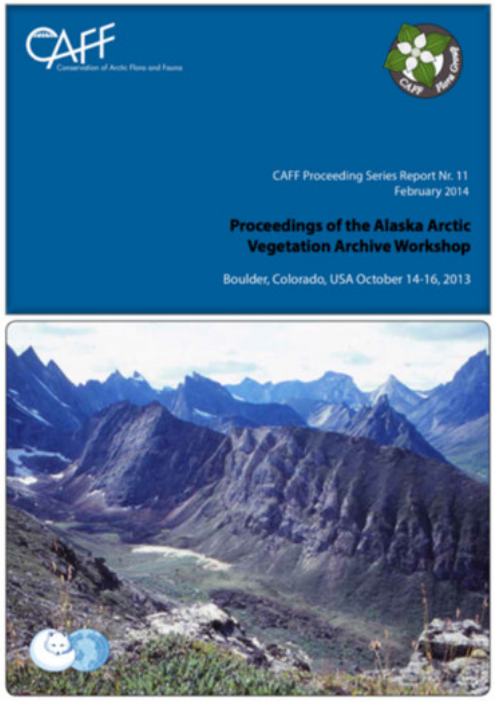


- The fundamental units of vegetation information used for classification and analysis.
- A circumpolar arctic vegetation archive of plot data (AVA) has a habitat-type foundation modelled after the European Vegetation Archive.

Fred Daniëls sampling wet tundra vegetation in subzone A, Isachsen,, Canada.

The Alaska Arctic Vegetation Archive (AVA-AK)

- Prototype arctic archive for Arctic Alaska
- Part of the Global Inventory of Vegetation Databases (GIVD)

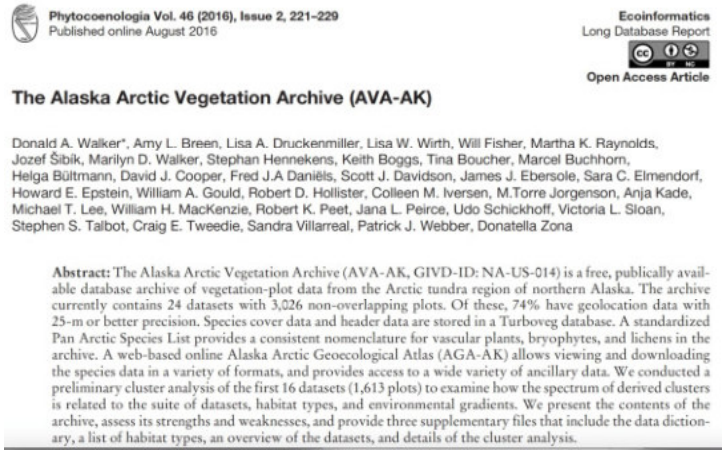


GIVD Database ID: NA-US-014			**Last update:** 2016-05-05
Alaska Arctic Vegetation Archive		**Web address:** http://geobotanical.portal.gina.alaska.edu/plot-archive	
Database manager(s): Amy Breen (albreen@alaska.edu); Lisa Druckenmiller (lddruckenmiller@alaska.edu); Jozef Sibik (jozef.sibik@savba.sk)			
Owner: Donald A. Walker, Amy L. Breen, Jozef Sibik, Lisa Druckenmiller and Martha K. Raynolds			
Scope: The Alaska Arctic Vegetation Archive (AVA-AK) is a regional database that is part of the larger Arctic Vegetation Archive. The database contains vegetation plots from homogeneous plant communities with tables of cover or cover-abundance scores for all species, and accompanying environmental site data. Data are collected using Braun-Blanquet, US National Vegetation Classification protocols, or comparable methods.			
Availability: free online		**Online upload:** yes	**Online search:** no
Database format(s): TURBOVEG		**Export format(s):** TURBOVEG, Excel, CSV file	
Plot type(s): normal plots; time series		**Plot-size range:** 0.16-800 m²	
Non-overlapping plots: 3,026	**Estimate of existing plots:** 4,000	**Completeness:** 76%	**Status:** emerging
Total no. of plot observations: 3,156	**Number of sources (biblioreferences, data collectors):** 24		**Valid taxa:** 1,569
Countries: CA: 5.0%; US: 95.0%			
Formations: Forest: 5% = Terrestrial: 5% // Non Forest: Aquatic: 3% (Fresh water: 3%) , Semi Aquatic: 12% (Fresh water: 12%) , Terrestrial: 80% (Arctic alpine: 80%)			
Guilds: all vascular plants: 100%; bryophytes (terricolous or aquatic): 98%; lichens (terricolous or aquatic): 96%			
Environmental data: altitude: 68%; slope aspect: 84%; slope inclination: 84%; microrelief: 15%; soil depth: 48%; surface cover other than plants (open soil, litter, bare rock etc.): 40%; soil pH: 64%; other soil attributes: 73%			
Performance measure(s): cover: 100%; measurements like diameter or height of trees: 1%; biomass: 13%			
Geographic localisation: GPS coordinates (precision 25 m or less): 74%; point coordinates less precise than GPS, up to 1 km: 7%; political units or only on a coarser scale (> 10 km): 19%			
Sampling periods: 1950–1959: 4.0%; 1960–1969: 5.0%; 1970–1979: 5.0%; 1980–1989: 30.0%; 1990–1999: 30.0%; 2000–2009: 41.0%; 2010–2019: 6.0%			
Information as of 2016-17-05; further details and future updates available from http://www.givd.info/ID/NA-US-014			

Walker, D. A., et al. (2016). *Phytocoenologia*, *46*, 221–229.

Prague Arctic Science Summit Week 2017

- Reviewed the status of the AVA and AVC.
- Circumpolar Vegetation Classification paper published in *Phytocoenologia*



Phytocoenologia Vol. 46 (2016), Issue 2, 221–229
Published online August 2016

Ecoinformatics
Long Database Report

Open Access Article

The Alaska Arctic Vegetation Archive (AVA-AK)

Donald A. Walker*, Amy L. Breen, Lisa A. Druckenmiller, Lisa W. Wirth, Will Fisher, Martha K. Raynolds, Jozef Šibík, Marilyn D. Walker, Stephan Hennekens, Keith Boggs, Tina Boucher, Marcel Buchhorn, Helga Bültmann, David J. Cooper, Fred J.A Daniëls, Scott J. Davidson, James J. Ebersole, Sara C. Elmendorf, Howard E. Epstein, William A. Gould, Robert D. Hollister, Colleen M. Iversen, M.Torre Jorgenson, Anja Kade, Michael T. Lee, William H. MacKenzie, Robert K. Peet, Jana L. Peirce, Udo Schickhoff, Victoria L. Sloan, Stephen S. Talbot, Craig E. Tweedie, Sandra Villarreal, Patrick J. Webber, Donatella Zona

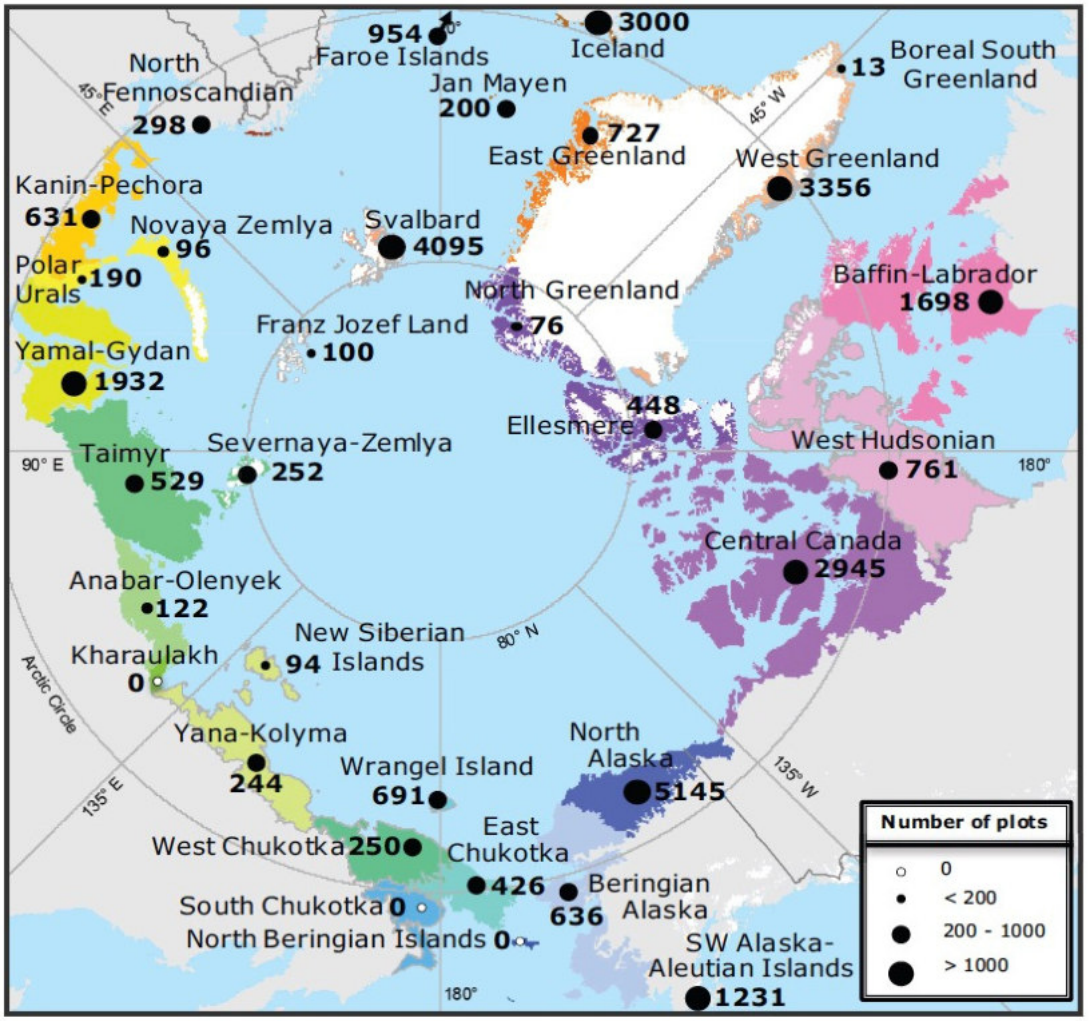
Abstract: The Alaska Arctic Vegetation Archive (AVA-AK, GIVD-ID: NA-US-014) is a free, publically available database archive of vegetation-plot data from the Arctic tundra region of northern Alaska. The archive currently contains 24 datasets with 3,026 non-overlapping plots. Of these, 74% have geolocation data with 25-m or better precision. Species cover data and header data are stored in a Turboveg database. A standardized Pan Arctic Species List provides a consistent nomenclature for vascular plants, bryophytes, and lichens in the archive. A web-based online Alaska Arctic Geoecological Atlas (AGA-AK) allows viewing and downloading the species data in a variety of formats, and provides access to a wide variety of ancillary data. We conducted a preliminary cluster analysis of the first 16 datasets (1,613 plots) to examine how the spectrum of derived clusters is related to the suite of datasets, habitat types, and environmental gradients. We present the contents of the archive, assess its strengths and weaknesses, and provide three supplementary files that include the data dictionary, a list of habitat types, an overview of the datasets, and details of the cluster analysis.

Walker, D. A., Daniëls, F. J. A., Matveyeva, N. V., Šibík, J., Walker, M. D., Breen, A. L., et al. (2018). Circumpolar Arctic Vegetation Classification. *Phytocoenologia*, *48*, 181–201.

Inventory of Arctic plot datasets

Approximately 31,000 vegetation plots were identified for potential inclusion in the AVA.

Good representation of Yurtsev's floristic subprovinces.



Panarctic Flora (PAF)

- A standardized list of accepted names for all arctic vascular plants (Elven et al. 2011).
- The Pan Arctic Species List (PASL) combines the PAF with circumpolar lists of bryophytes, and lichens (Raynolds et al. 2013).

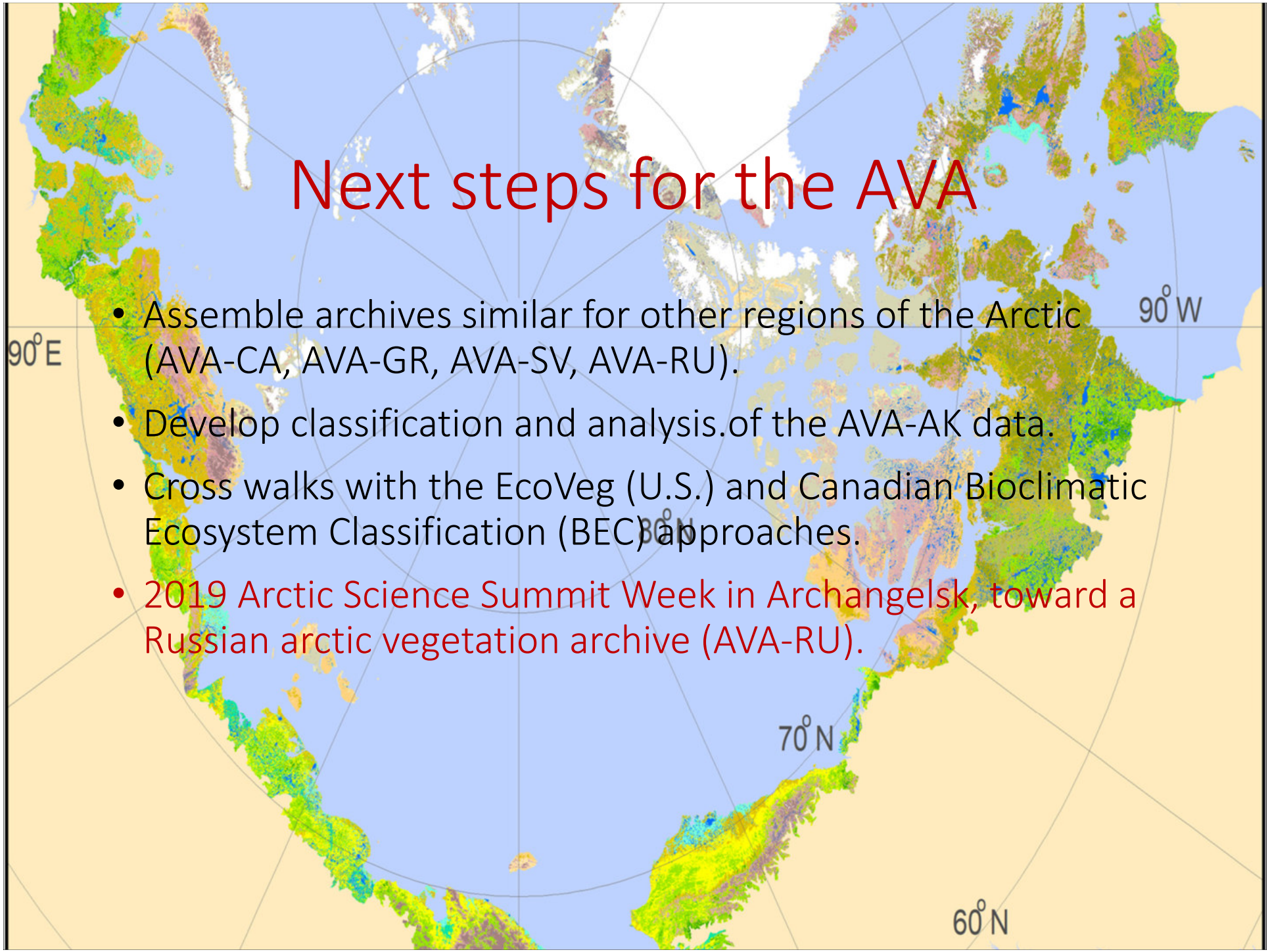
- **Elven, R., Murray, D. F., Razzhivin, V. Y., & Yurtsev, B. A. (2011). Annotated checklist of the panarctic flora (PAF): vascular plants. *Natural History Museum, University of Oslo*.**
- **Raynolds, M. K., et al. (2013). The Pan-Arctic Species List (PASL). *CAFF Proceedings Series Report Nr. 10*, 92–95.**

Habitat-type foundation for the hierarchical maps and the AVA

Partial list of habitat types from Walker et al. 2018

Table 1. List of habitat types with closest equivalent Br.-Bl. units for the Arctic based on information from Greenland (Bültmann & Daniëls 2013), Europe (Mucina et al. 2016), Western North America (Peinado et al. 2005), and Alaska (Walker et al. 2016a) with organization following the Br.-Bl. classes and habitat types of Europe (Mucina et al. 2016).

Habitat type code	Habitat description	Closest equivalent Br.-Bl. unit
1	**ARCTIC ZONAL TUNDRA**	
1.01	**Polar desert vegetation, subzone A**	**PAP: *Drabo corymbosae-Papaveretea dahliani* Daniëls, Elvebakk et Matveyeva in Daniëls et al. 2016**
		PAP-01: *Saxifrago oppositifoliae-Papaveretalia dahliani* Daniëls, Elvebakk et Matveyeva in Daniëls et al. 2016
1.01.1	Polar deserts of the Arctic zone of the Arctic Ocean archipelagos – North America	PAP-01A: *Papaverion dahliani* Hofmann ex Daniëls, Elvebakk et Matveyeva in Daniëls et al. 2016
1.02	**Dry and mesic dwarf-shrub and graminoid zonal vegetation on non-acidic base-rich soils**	**KOB: *Carici rupestris-Kobresietea bellardii* Ohba 1974**
		KOB-01: *Thymo arcticae-Kobresietalia bellardii* Ohba 1974
1.02.1	Dry zonal habitats of graminoid tundra and dwarf-shrub heath vegetation of Scotland, Scandinavia, Iceland and the Arctic Ocean islands on base-rich soils, subzones B and C	KOB-01A: *Kobresio-Dryadion* Nordhagen 1943
1.02.2	Mesic zonal habitats of graminoid tundra and dwarf-shrub heath vegetation of Arctic Western Russia and Siberia on base-rich soils, subzone B, C & D	KOB-01B: *Dryado octopetalae-Caricion arctisibiricae* Koroleva et Kulyugina in Chytrý et al. 2015
1.02.3	Graminoid tundra and dwarf-shrub heath vegetation of Greenland and the Arctic North America, subzones B, C & D, (includes for now early-melting base-rich *Cassiope-Tomentypnum* snowbeds)	KOB-01C: *Dryadion integrifoliae* Ohba ex Daniëls 1982
1.03	**Dry to mesic dwarf-shrub heath on acidic substrates, subzones D and E**	**LOI: *Loiseleurio procumbentis-Vaccinietea* Eggler ex Schubert 1960**

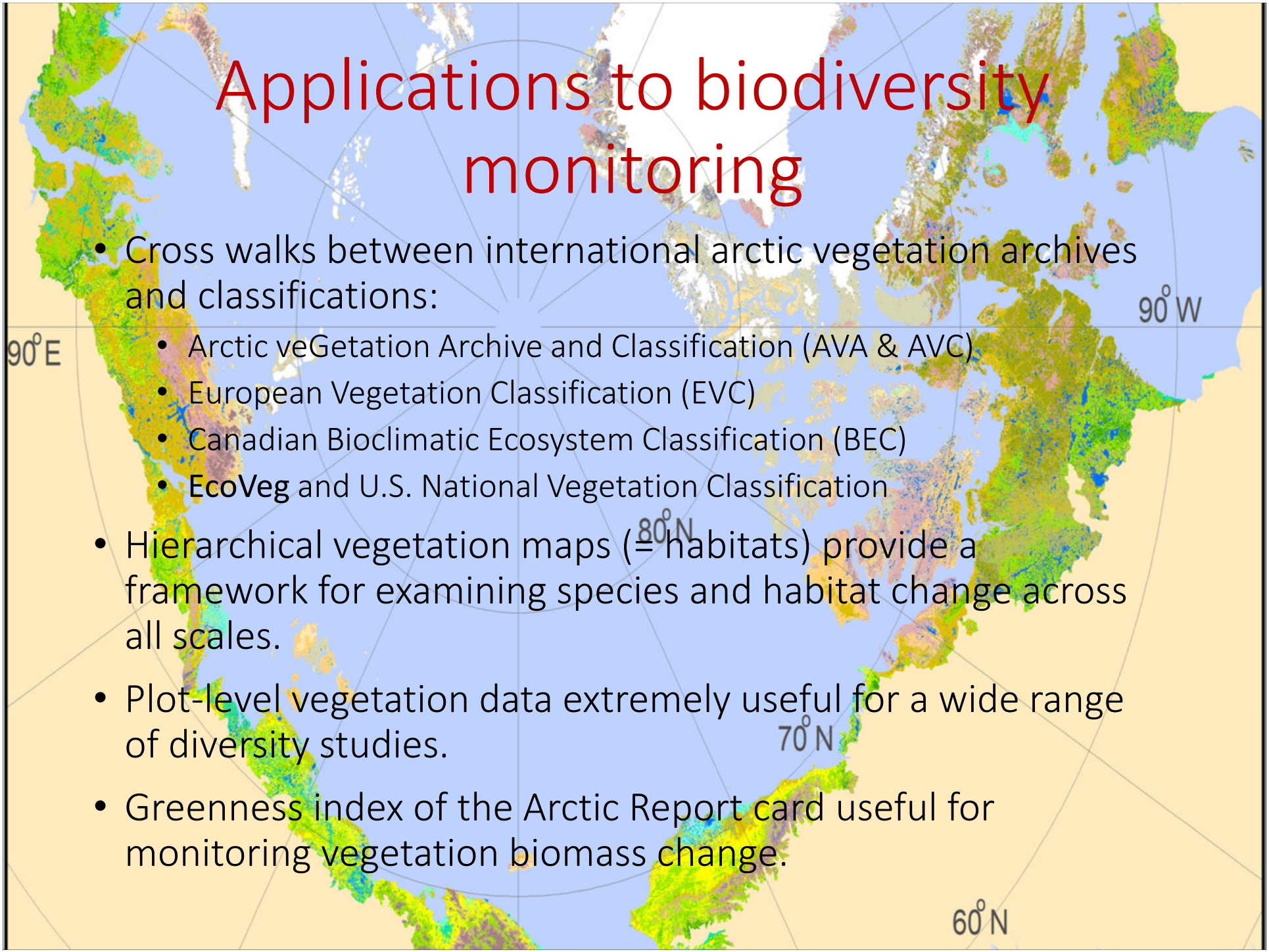


Next steps for the AVA

- Assemble archives similar for other regions of the Arctic (AVA-CA, AVA-GR, AVA-SV, AVA-RU).
- Develop classification and analysis.of the AVA-AK data.
- Cross walks with the EcoVeg (U.S.) and Canadian Bioclimatic Ecosystem Classification (BEC) approaches.
- 2019 Arctic Science Summit Week in Archangelsk, toward a Russian arctic vegetation archive (AVA-RU).

Applications to biodiversity monitoring

- Cross walks between international arctic vegetation archives and classifications:
  - Arctic veGetation Archive and Classification (AVA & AVC)
  - European Vegetation Classification (EVC)
  - Canadian Bioclimatic Ecosystem Classification (BEC)
  - **EcoVeg** and U.S. National Vegetation Classification
- Hierarchical vegetation maps (= habitats) provide a framework for examining species and habitat change across all scales.
- Plot-level vegetation data extremely useful for a wide range of diversity studies.
- Greenness index of the Arctic Report card useful for monitoring vegetation biomass change.



Acknowledgements

Collaborators and coauthors: Uma Bhatt, Amy Breen, Helga Bültmann, David Cooper, Fred Daniëls, Lisa Druckenmiller, Jim Ebersole, Howard Epstein, Ksenia Ermokhina, Bruce Forbes, Anna Marie Fosaa, William Gould, Ingibjörg Jónsdóttir, Starri Heiðmarsson, Stephan Hennekens, Greg Henry, Olga Khitun, Natalia Koroleva, Timo Kumpula, Olga Lavrinenko, Igor Lavrinenko, Esther Lévesque, Marina Leibman, William Mackenzie, Nadya Matveyeva, Natalia Moskokenko, Lennart Nilsen, Robert Peet, Jana Peirce, Martha Raynolds, Volodya Razzhivin, Vladimir Romanovsky, Gabriela Schaepman-Strub, Jozef Šibík, Stephen Talbot, Mikhail Telyatnikov, Dietbert Thannheiser, Ina Timling, Craig Tweedie, Sandra Villarreal, Marilyn Walker, Patrick Webber, and Lisa Wirth.

Funding: United States National Science Foundation, National Atmospheric and Space Administration, Bureau of Ocean Energy Management; Russian Academy of Science; Slovak Academy of Science.