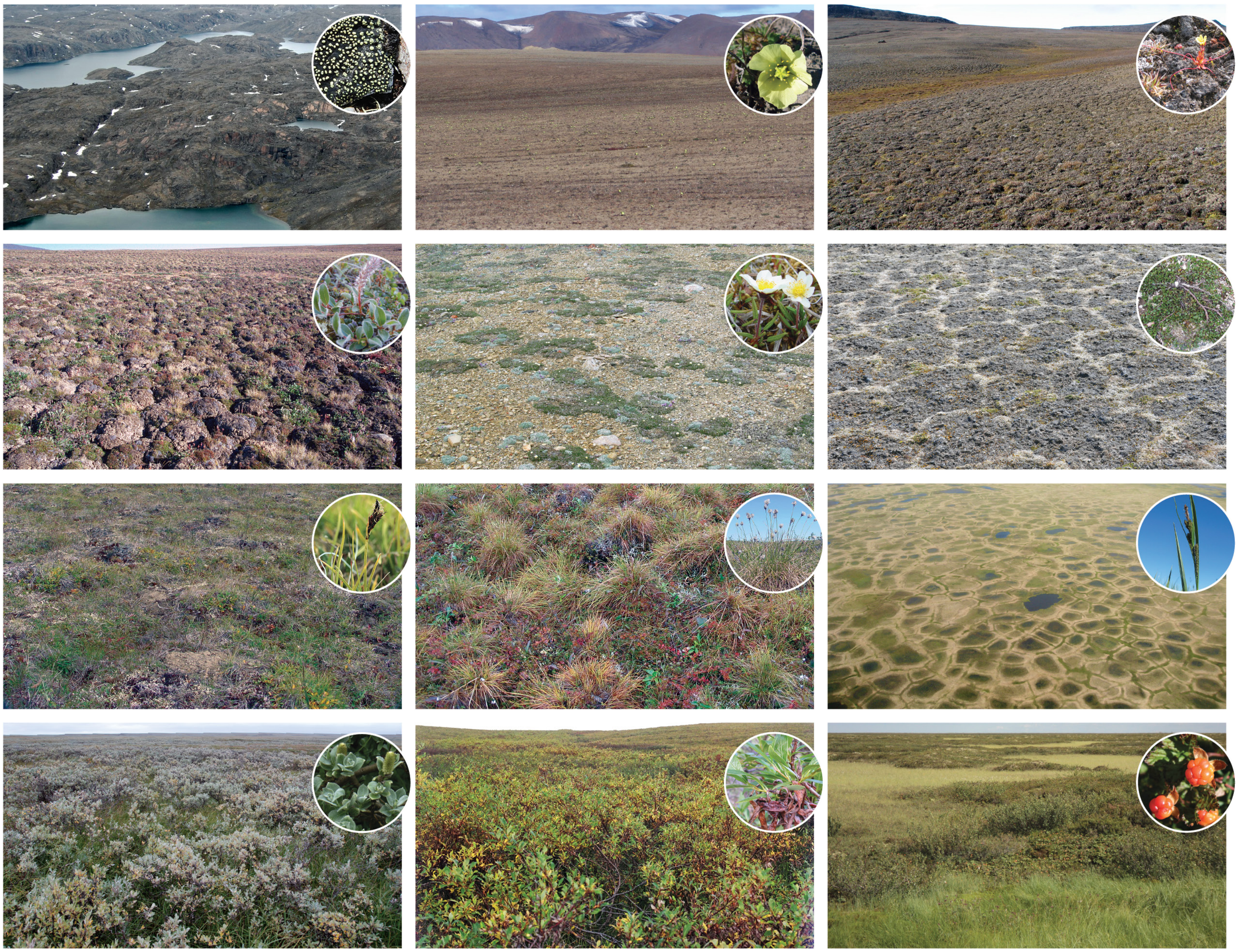
THE CIRCUMPOLAR ARCTIC VEGETATION SCIENCE INITIATIVE (CAVSI)

A FRAMEWORK TO HELP GUIDE THE NEXT DECADE OF ARCTIC VEGETATION RESEARCH

A white paper for consideration in the ICARP IV process



Prepared by the CAVSI Organizing Group

June 30, 2025

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THE CAVSI ORGANIZING GROUP

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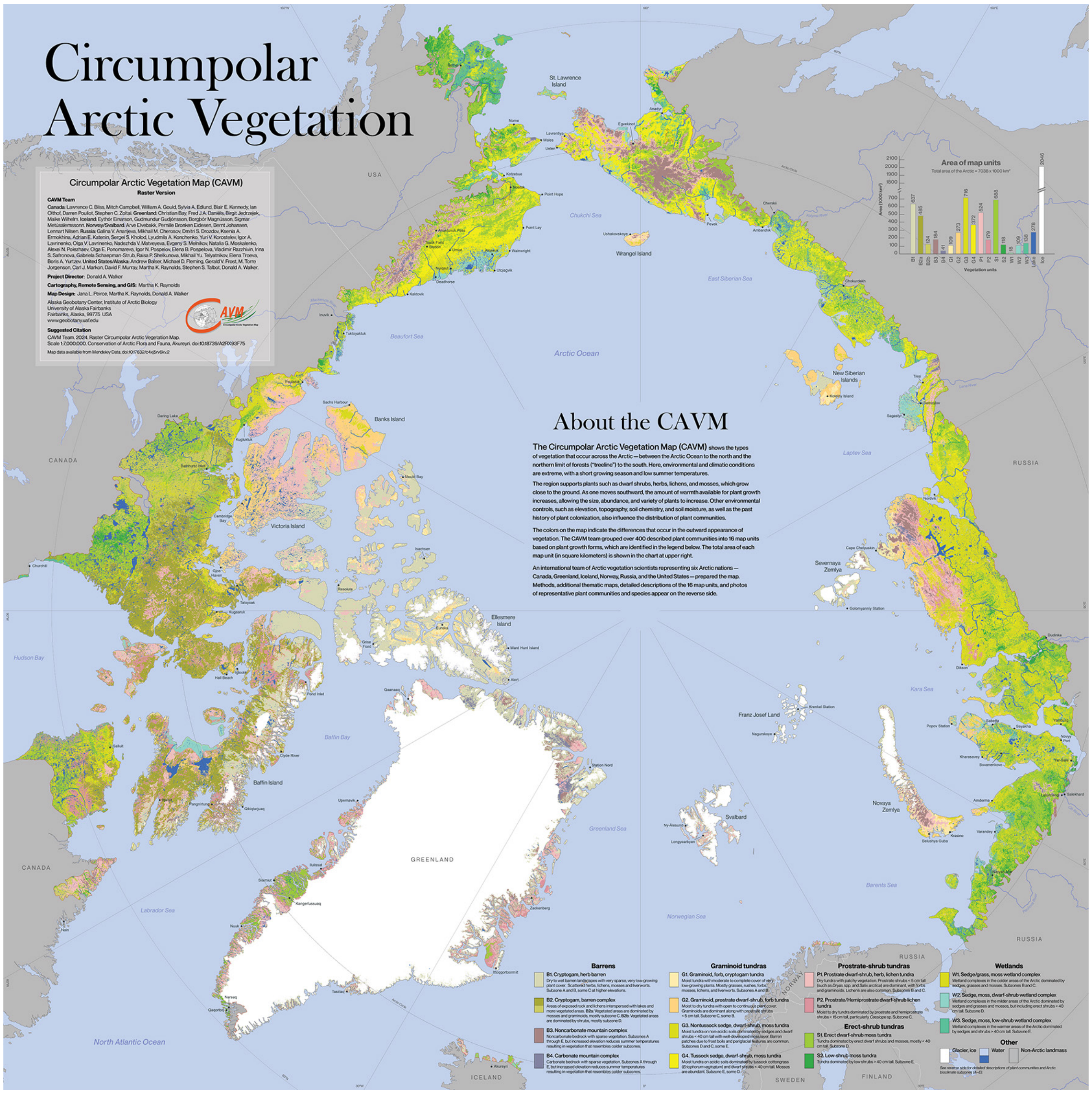

ABOVE: Raster version of the Circumpolar Arctic Vegetation Map (front side of map, published at 1:7 M scale) Derived from MODIS (250-m) data. (CAVM Team 2024)

ON THE COVER: Representative photos of circumpolar Arctic vegetation types shown with diagnostic species. **TOP ROW:** Subzone A and rocky substrates *(from left)*: Cryptogam, barren complex (B2a) on Baffin Island, Nunavut, Canada; Cryptogam, herb barrens (B1) on Ellef Ringnes Island, Nunavut, Canada; Graminoid, forb, cryptogam tundra (G1) on Prince Patrick Island, Northwest Territories, Canada. **UPPER MIDDLE ROW:** Common dry types dominated by prostrate shrubs, herbs, and lichens in bioclimate subzones A, B, and C *(from left):* Graminoid, prostrate dwarf-shrub, forb, moss tundra (G2) on Ellesmere Island, Nunavut, Canada; Prostrate dwarf-shrub, herb, lichen tundra (P1) on Banks Island, NWT, Canada; P1 at a research site in Ostrov Belyy, Yamal Peninsula, Russia. **LOWER MIDDLE ROW:** Common moist and wet types dominated by graminoids, dwarf shrubs, and mosses in subzones C and D *(from left)*: Nontussock sedge, dwarf-shrub, moss tundra (G3) in Ambarchik, Sakha Republic, Russia; Tussock-sedge, dwarf-shrub, moss tundra (G4) at Sagwon in the Brooks Range foothills, Alaska; Sedge, moss, dwarf-shrub wetland complex (W2) near Teshekpuk Lake, Arctic Coastal Plain, Alaska. **BOTTOM ROW:** Common shrub-tundra types in subzones D and E *(from left)*: Low-shrub, moss tundra (S1) in the Polar Urals foothills, Yamal Peninsula, Russia; S2 in the Brooks Range foothills, Alaska; Sedge, moss, low-shrub wetland complex (W3) near Naryan-Mar, Western Siberia, Russia. See the back side of the Circumpolar Arctic Vegetation Map, raster version (CAVM Team 2024) for full descriptions of the vegetation units, diagnostic species, and photo credits.

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ACKNOWLEDGMENTS

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The Conservation of Arctic Flora and Fauna (CAFF) biodiversity working group of the Arctic Council and IASC have endorsed previous Arctic vegetation workshops and activities leading up to the CAVSI Workshop in 2025. A grant from the U.S. National Science Foundation's Office of Polar Programs (Award #2426735) to the University of Alaska Fairbanks provided the majority of the funds for the CAVSI Workshop.

We thank the moderators, panelists, and all workshop participants for their input during the panel and plenary discussions and breakout groups. We also thank the University of Colorado Boulder for the excellent logistics support during the meeting.

SUGGESTED CITATION

CAVSI Organizing Group. 2025. The Circumpolar Arctic Vegetation Science Initiative (CAVSI). University of Alaska, Fairbanks, AK, USA

LIST OF FIGURES & TABLES

LIST OF ACRONYMS

AAGA	Alaska Arctic Geoecological Atlas
ANSEP	Alaska Native Science and Engineering Program
APECS	Association of Polar Early Career Scientists
ASSW	Arctic Science Summit Week
AVA	Arctic Vegetation Archive
AVA-AK	Alaska Arctic Vegetation Archive
AVA-RU	Russia Arctic Vegetation Archive
AVC	Arctic Vegetation Classification
AVON	Arctic Vegetation Observing Network
BIAT	Baffin Island Arctic Transect
BTF	Back to the Future
CAFF	Conservation of Arctic Flora and Fauna
CALM	Circumpolar Active Layer Monitoring
CAVM	Circumpolar Arctic Vegetation Map
CAVSI	Circumpolar Arctic Vegetation Science Initiative
CBMP	Circumpolar Arctic Biodiversity Monitoring Program
CBVM	Circumboreal Vegetation Mapping
CCAT	Central Canada Arctic Transect
CKAN	Comprehensive Knowledge Archive Network
COG	CAVSI Organization Group
DAT	Dalton Arctic Transect
DOE	U.S. Department of Energy
EAT	Eurasia Arctic Transect
ECR	Early Career Researchers
IASC	International Arctic Science Committee
IAVS	International Association for Vegetation Science
ICARP	International Conference on Arctic Research Planning
INTER-ACT	International Network for Terrestrial Research and Monitoring in the Arctic
IPY	International Polar Year
ITEX	International Tundra Experiment
LAI	Leaf area index
LTER	Long Term Ecological Research
ML	Machine Learning
MODIS	Moderate Resolution Imaging Spectro Radiometer
NAAT	North America Arctic Transect
NDVI	Normalized Difference Vegetation Index
NEON	National Ecological Observatory Network
NGEE–Arctic	Next-Generation Ecosystem Experiments—Arctic
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
ORNL-DAAC	Oak Ridge National Laboratory Distributed Active Archive Center
OSTP	Office of Science and Technology Policy
PAF	Pan-Arctic Flora
PASL	Pan-Arctic Species List
RPT	Research Priority Team
SAON	Sustaining Arctic Observing Networks
SDM	Species distribution model
TSP	Thermal State of Permafrost
UAV	Unmanned Aerial Vehicle
UiT	Universitetet i Tromsø
USARC	U.S. Arctic Research Commission
WAAT	Western Arctic Alaska Transect

EXECUTIVE SUMMARY

The Circumpolar Arctic Vegetation Science Initiative (CAVSI) is an international Arctic research effort motivated by widespread and accelerating changes in Arctic vegetation and the need to understand their ecological, climatic, and biodiversity impacts. The goal of the initiative is to coordinate observations, harmonize classifications and mapping, and build an integrated data system—including shared archives - to improve models, support biodiversity assessments, and inform global change research. Moreover, a key component of CAVSI is to support and train the next generation of Arctic vegetation scientists through mentorship, collaboration, and shared research infrastructure. The initiative creates the framework to answer where and why Arctic vegetation is changing—or remaining stable—how these patterns affect ecosystem function and feedbacks, and what scalable observation systems are needed to track and model them.

A vegetation component is needed for U.S. and international Arctic observing networks to coordinate ongoing Arctic vegetation research during the next ten years of Arctic research, including the Fifth International Polar Year (IPY5, 2032–2033). Currently, there is not a cohesive circumpolar framework to observe and monitor changes to Arctic vegetation that includes: (1) a network of sites across the full range of Arctic climates, phytogeographic regions, habitats, and disturbance regimes; (2) standardized methods to describe and monitor local floras, vegetation composition, and key environmental factors; (3) a pan-Arctic vegetation plot archive to store legacy, recent, and future plot data; (4) a consistent hierarchical classification of Arctic vegetation; and (5) an archive of Arctic vegetation maps.

CAVSI is a response to the above needs. The CAVSI Workshop was held March 21-23, in Boulder, Colorado, at Arctic Science Summit Week 2005. Eighty-five participants, including online participants, from 15 countries attended the workshop. In addition, two CAVSI science sessions were held on March 25 and 27. These included 24 oral presentations and 17 posters.

Two CAVSI outcomes are part of the ICARP IV CAVSI activity: (1) This white paper addresses ICARP IV research priorities that focus on the role of the Arctic in the global systems and observing, reconstructing, and predicting future Arctic climate dynamics and ecosystem responses. It outlines a framework for vegetation sampling, data archiving, classification, description, mapping, monitoring, and applications of this framework. The appendices of this document contain details and outcomes of the CAVSI workshop, including: (a) List of CAVSI Workshop participants; (B) CAVSI Workshop agenda; (C) Abstract of keynote address by Prof. Vladislav Mucina; (D) Panel and breakout session summaries and recommendations; and (E) the CAVSI Workshop Resolution.

(2) A separate Proceedings from the CAVSI Science Sessions at Arctic Science Summit Week includes abstracts from 24 oral presentations and 17 posters presented at Science Session 2.6 "Back to the Future II: Linking past and future IPY terrestrial biodiversity efforts, and Science Session 2.8, "Building a time machine out of a Delorean: Observing, reconstructing, and predicting vegetation change in the Arctic".

The CAVSI Organizing Group (COG) is composed of recognized experts for each CAVSI topic and major Arctic-vegetation-related projects, and is responsible for overall program development, organization, and communication. The Early Career Arctic Vegetation Researchers group was formed at the CAVSI Workshop to develop a communications and online platform for the group, foster connections for career development, promote Arctic vegetation-science-related education and training opportunities; and develop cooperative cross-disciplinary and cross-cultural connections with other Arctic-related early-career groups.

The core of CAVSI is an Arctic Vegetation Observation Network (AVON) that will leverage exiting observations within established Arctic observation stations and networks to: (a) Aid in site and project management with development of comparable frameworks for locating and tracking vegetation plot data across the Arctic; (b) Promote long-term sustained observations at well-marked permanent vegetation plots; (c) Coordinate vegetation observations with other geo-ecological surveys; (d) Identify geographic and topical gaps for sampling, archiving, classifying, and mapping Arctic vegetation; and (e) Establish new observatories in understudied vegetation-habitat types and regions.

Arctic vegetation-observing sites will be encouraged to use standardized methods that will be spelled out in methods manuals containing protocols for: species lists and local floras, plot-based vegetation and environmental sampling; archiving and classification of vegetation plot data; and vegetation mapping. Each topic will have a team of researchers and data specialists to develop and harmonize the protocols in methods manuals and databases.

Several prototype products already exist and have been applied to a wide range of circumpolar research activities, most of which will remain relevant for IPY5, including Arctic Research Station management, and a framework for IPY5 Arctic terrestrial research projects. Several ideas for IPY5 initiatives are presented here, including: (1) Back to the Future II; (2) Pan-Arctic Greening; (3) Circumpolar Arctic Species Diversity; (4) Arctic Edges; (5) Arctic-Boreal Transects; and Biomes of the Circumpolar Arctic.

Priority ICARP IV research recommendations include:

1. Establish a Circumpolar Arctic Vegetation Science Initiative (CAVSI) to help address priority vegetation-related science questions across disciplines and a hierarchy of spatial scales in relationship to, for example: landscape dynamics and change, biodiversity monitoring and mapping, climate change and disturbance regimes.

2. Establish an early career vegetation scientists' network to foster career development in Arctic vegetation-related disciplines to promote Arctic vegetation-science-related education and training activities, and develop cross-disciplinary and cross-cultural connections with other Arctic-related early-career groups.

3. Develop an Arctic Vegetation Observation Network (AVON) within existing interdisciplinary observing networks to (1) aid in site and project management and development of comparable frameworks for locating and tracking vegetation plot data and mapped information, (2) promote long-term sustained observations at well-marked permanent vegetation plots and mapped areas; (3) coordinate vegetation observations with other Arctic system observations; (4) identify geographic and topical gaps for sampling, archiving, classifying, and mapping Arctic vegetation, and (4) establish new observatories in understudied vegetation-habitat types and regions.

4. Update, maintain, and publish a Pan Arctic Species List (PASL) and local floras (complete species lists, including vascular plants, bryophytes, and lichens) at Arctic research stations and other research sites.

5. Adopt standardized protocols for vegetation and environmental plot surveys that are widely used by the international vegetation science community, that include traditional plot survey methods, and where feasible, use new transformative methods appropriate for observing, modeling, reconstructing, and predicting Arctic vegetation change.

6. Develop regional Arctic vegetation archives for vegetation plot data and map data and merge the regional archives into a circumpolar Arctic Vegetation Archive (AVA), including methods to harmonize and standardize the data.

7. Develop local, regional, and circumpolar Arctic vegetation classifications (AVCs) and checklists of classified vegetation units based on standardized approaches developed by the international community of vegetation scientists, including crosswalks to equivalent units in other regional and national classification approaches.

8. Revise, edit, and publish a new version of the Circumpolar Arctic Vegetation Map (CAVM v. 3) with increased resolution and a hierarchical legend approach that can be applied to maps at global, regional, landscape, and plot scales.

9. Apply CAVSI products to priority ICARP IV and IPY5 research topics.

INTRODUCTION

Arctic vegetation is the visible surface expression of Arctic terrestrial systems. It is the key to monitoring and modeling changes to most components of the system, such as shrub distribution; greening patterns, plant and animal habitats and biodiversity, hydrological networks, and snow distribution, as well as the less visible aspects, such as permafrost, soil carbon stocks, and greenhouse-gas emissions.

Currently, there are no standardized approaches to sample, describe, map, and analyze circumpolar patterns of Arctic vegetation across a hierarchy of spatial scales and international boundaries. There is a need for a well-distributed Arctic vegetation observatory network and a set of internationally accepted protocols for sampling, data information systems, classifying, and mapping vegetation to aid in addressing priority research topics for ICARP IV and IPY5.

The Circumpolar Arctic Vegetation Science Initiative (CAVSI) is a response to these needs and those expressed by ICARP IV Research Priority Team 1 (RPT 1) (Zhang and Rasouli 2025) and RPT2 (Bret-Harte 2025), which focus on the role of the Arctic in the global system and observing, reconstructing, and predicting future Arctic climate dynamics and ecosystem responses. CAVSI is also a response to the recommendation by the Arctic Council for long-term biodiversity monitoring to address key gaps in Arctic-system knowledge (CAFF 2013, Christiansen et al. 2020, Barry 2023). It aligns with several national and international Arctic research plans and policies that involve observation, monitoring, modeling, and prediction, including those of the United States (OSTP 2022, USARC 2023) and the international Sustaining Arctic Research Network (SAON, Starkweather et al. 2021).

This white paper provides a framework for vegetation description and monitoring. It includes: (1) a network of sites across the full range of Arctic climates, phytogeographic regions, local habitats, and disturbance regimes; (2) standardized methods to describe and monitor local floras, vegetation composition, and key environmental factors; (3) a pan-Arctic vegetation plot archive to store legacy and recent plot data; (4) a consistent hierarchical classification and checklist of Arctic vegetation; (5) an archive of Arctic vegetation and landcover maps; (6) applications and ideas for CAVSI IPY5 initiatives; (7) an 11-year timeline for CAVSI activities leading up to and including synthesis from IPY5 activities; and (8) recommendations for priority activities and research related to ICARP IV RPTs 1 and 2.

CAVSI WORKSHOP | ARCTIC SCIENCE SUMMIT WEEK 2025

Figure 1. CAVSI group photo at ASSW 2025, Boulder, CO. See Appendix A, list of participants.

A three-day CAVSI workshop and two CAVSI science sessions occurred during Arctic Science Summit Week, March 20–28, 2025. Eighty-five participants attended the workshop, including online participants, from 15 countries. The proceedings of the CAVSI Workshop, are in the appendices, including: (A) list of participants, (B) agenda, (C) abstract of the keynote talk by Prof. Ladislav Mucina, (D) results of the panel discussions, and (E) workshop resolution.

PRIORITY VEGETATION SCIENCE QUESTIONS

The workshop participants were asked to identify priority questions related to Arctic vegetation. The resulting approximately 100 questions fell within seven broad categories of research topics:

LANDSCAPE DYNAMICS AND CHANGE

Focus on understanding the processes driving changes in transitional landscapes, including climatic and anthropogenic factors.

Explore the spatial and temporal scales of these changes and their implications for biodiversity and ecosystem health.

BIODIVERSITY MONITORING AND MAPPING

Develop methodologies for effective mapping of vegetation and species at various scales, integrating state-of-the-art technologies like remote sensing and DNA sequencing.

Address the challenges of cataloging historical data and ensuring ongoing documentation of vegetation changes.

CLIMATE CHANGE AND DISTURBANCE REGIMES

Investigate how climate change and human disturbances interact to affect ecosystems, including disturbances such as extreme weather events and their impacts on vegetation dynamics.

Assess the resilience of different species and communities to these changes, focusing on both above- and below-ground interactions.

FUNCTIONAL ECOLOGY AND BIOTIC-ABIOTIC INTERACTIONS

Examine the interactions between vegetation and subsurface biotic and abiotic parameters, studying how these relationships influence ecosystem functions and responses to environmental changes.

Consider the role of functional traits in understanding ecosystem dynamics and responses to disturbances.

COMMUNITY ENGAGEMENT AND INDIGENOUS KNOWLEDGE

Prioritize the inclusion of indigenous communities in research efforts, ensuring that conservation strategies align with local knowledge and values.

Develop frameworks for collaboration that enhance the benefits of research for indigenous communities.

DATA INTEGRATION AND COLLABORATIVE FRAMEWORKS

Foster collaborations across disciplines and organizations to enhance data sharing and integration for more comprehensive understanding of Arctic ecosystems.

Create centralized platforms for sharing research outcomes, methodologies, and datasets to support ongoing studies and conservation efforts related to Arctic ecosystems.

PHENOLOGY AND ECOLOGICAL RESPONSES

Investigate the timing of biological events (phenology) and its implications for ecosystem dynamics, focusing on how changes in phenology affect biodiversity and ecological interactions.

Consider the implications of phenological changes for conservation strategies and ecosystem management.

The questions were also grouped using MindX mind-map software into eleven broader questions and refined further into four CAVSI umbrella questions and strategic approaches that CAVSI could use for answering the questions (Figure 2).

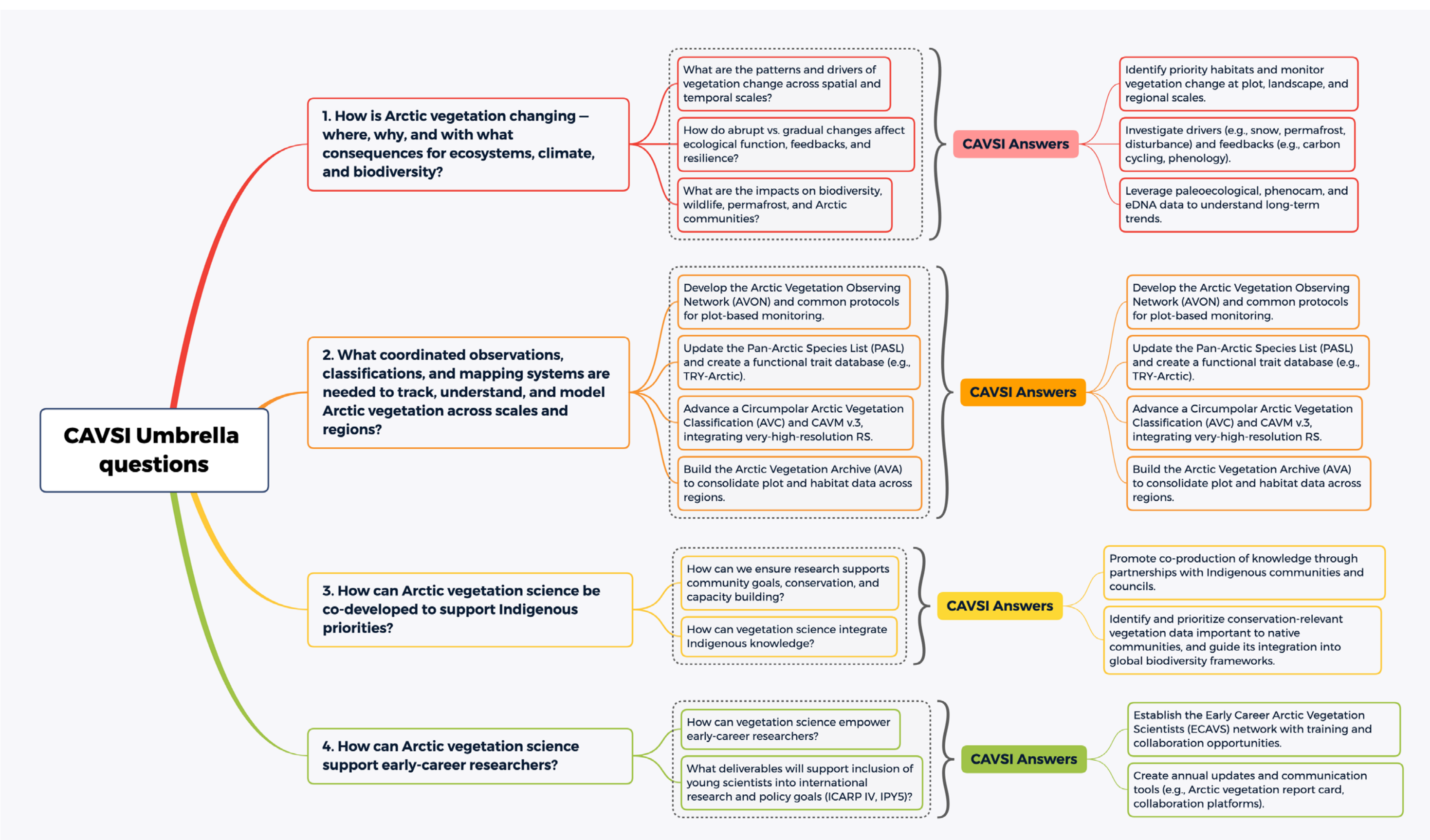

Figure 2. Mind map of the process of grouping approximately 100 research questions from the CAVSI Workshop participants into four broad umbrella questions.

The workshop was organized into sections with panels and breakout groups devoted to: **(a) CAVSI organization, (b) Arctic Vegetation Observing Network (AVON)** including network development and protocols for species lists, plot sampling, plot archiving, vegetation classification, and vegetation mapping, and **(c) Applications** of the CAVSI products including station management, hierarchical framework for Arctic terrestrial research project, and supporting IPY5 (Figure 3). This white paper follows the same structure.

CAVSI ORGANIZATION

CAVSI Organizing Group (COG). This group is responsible for overall program development, organization, and communication. It is composed of recognized experts for each CAVSI topic and major Arctic-vegetation-related projects. The first tasks were to organize the CAVSI Workshop at Arctic Science Summit Week 2025 and develop the CAVSI white paper. Future tasks will include coordinating and aiding in proposal development, building on the existing communication network, developing workshops at future ASSWs and other international meetings such as those of the International Association of Vegetation Science (IAVS), writing of workshop proceedings, and promotion and coordination of international CAVSI activities.

Several prototype products already exist, including the Pan-Arctic Species List (Raynolds et al. 2013); regional classifications (e.g., Table 1, and M. D. Walker et al. 1994a, b); regional plot archives (Figure 5) in Alaska and Russia (Breen 2024, Zemlianski et al. 2023) and, Canada (Mackenzie and Meidinger 2018), and Europe (Šibík 2024); two versions of a Circumpolar Arctic Vegetation Map (CAVM Team 2003, 2024; Figure inside front cover). These products have been applied to wide range of circumpolar activities, most of which will remain relevant for IPY5, including:

Early Career Arctic Vegetation Researchers: This self-organized group of early-career Arctic scientists interested in vegetation-related themes was formed at the CAVSI Workshop. Its chief goals are to: (a) develop a communications and online platform to share information relevant to students and early-career Arctic vegetation scientists and ecologists; (b) foster connections for career development in Arctic vegetation-related disciplines (e.g. IAVS 2025); (c) navigate the multitude of organizations and institutions involved in Arctic vegetation-science research; (d) promote Arctic vegetation-science-related education and training opportunities; and (e) develop cooperative cross-disciplinary and cross-cultural connections with other vegetation and Arctic-related early-career groups (e.g. UiT 2025, ANSEP 2025, Tanski et al. 2019).

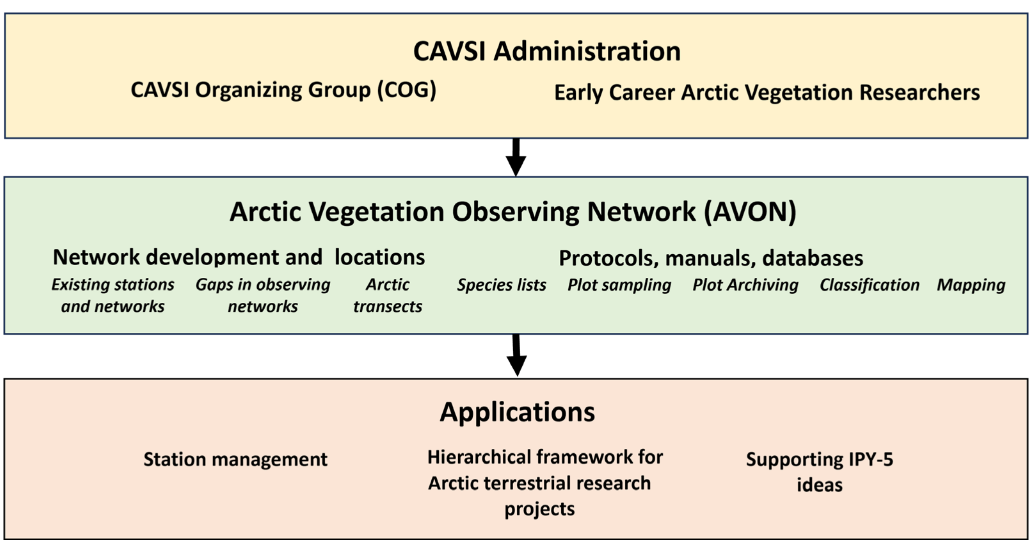

Figure 3. CAVSI organization diagram.

ARCTIC VEGETATION OBSERVATION NETWORK (AVON)

NETWORK DEVELOPMENT

The core of CAVSI will be an Arctic Vegetation Observation Network (AVON) that will be organized mainly within established Arctic observation stations and networks. The goals will be to: (a) aid in site and project management; (b) develop a common framework for locating and tracking vegetation plot data and mapped information; (c) promote long-term sustained observations at well-marked permanent vegetation plots; (d) coordinate vegetation observations with other observation networks; (e) identify geographical and topical gaps; and (f) establish new observatories in understudied vegetation habitats and regions.

Examples of existing programs and networks include the Circumpolar Arctic Biodiversity Monitoring Program (CBMP, Barry et al. 2023), International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT, Johansson and Callaghan 2024), Circumpolar Active Layer Monitoring program (CALM, Nelson et al. 2004), Thermal State of Permafrost (TSP, Romanovsky et al. 2010), U.S. National Ecological Observatory Network (NEON, McKay 2023), Arctic-Boreal Vulnerability Experiment, (ABoVE 2016), International Tundra Experiment (ITEX Henry et al. 2022), Next-Generation Ecosystem Experiments—Arctic (NGEE–Arctic, DOE 2025), and Arctic FLUXNET (Virkkala et al. 2022).

Existing information includes the known existing vegetation plots (Figure 4), existing regional archives of plot data (Figure 5), vegetation maps at plot to circumpolar scales (Figure 6), and a wealth of vegetation and environmental data from previous projects (Figure 7).

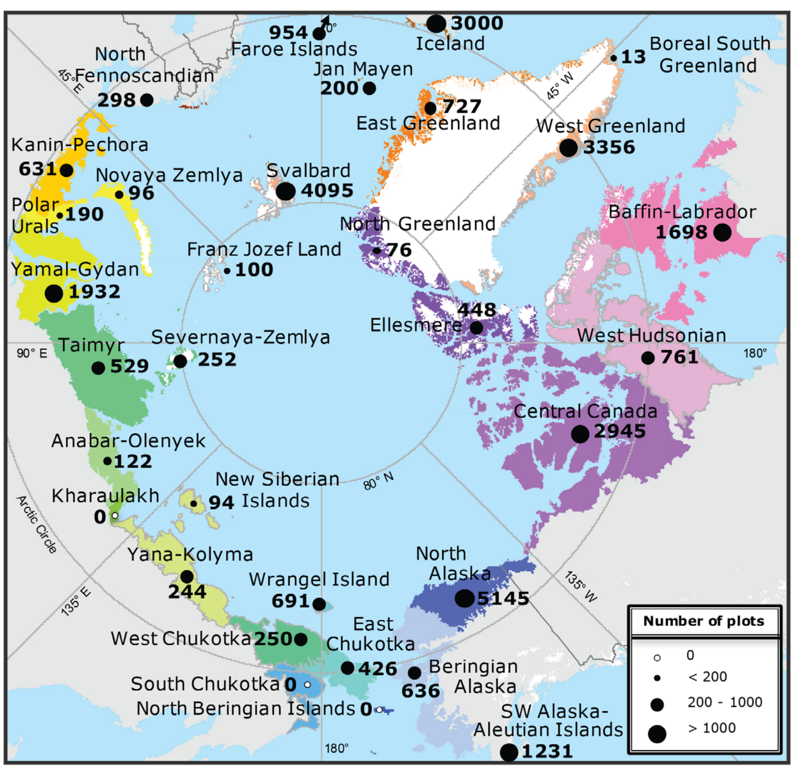

Figure 4. Circumpolar Arctic vegetation plot distribution within 22 Arctic phytogeographic subprovinces containing 31,000 plots that could potentially be archived (Walker et al. 2019a).

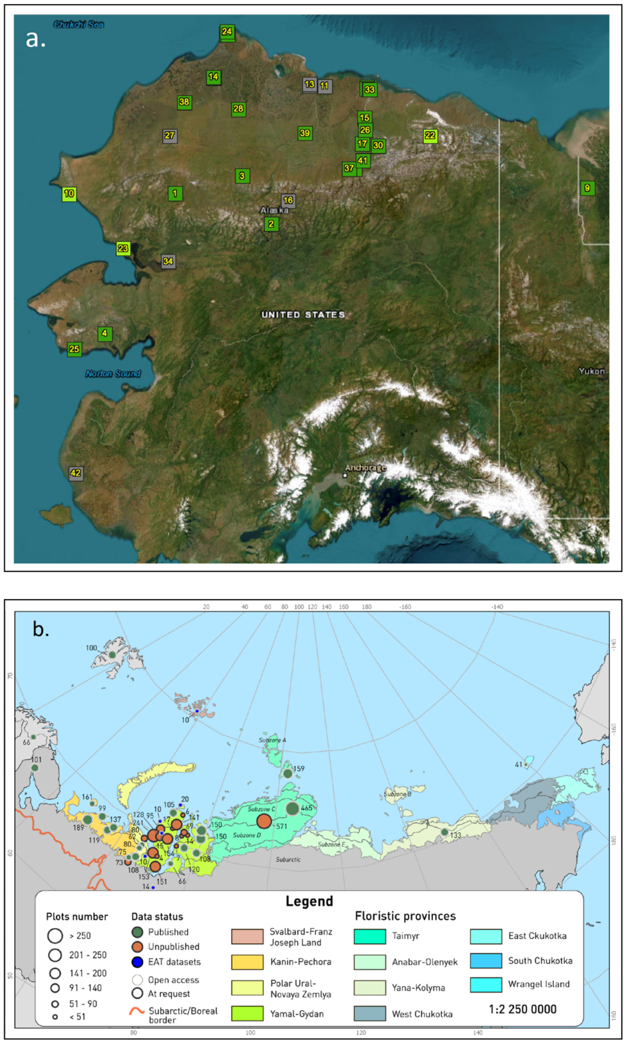

Figure 5. Maps of the datasets in the Alaska and Russian plot archives. **a.** Locations of 43 datasets with 3256 plots in the Alaska Arctic Vegetation Archive (Breen 2024, https://arcticatlas.geobotany.org/catalog). **b.** Russian Arctic Vegetation Archive containing 50 datasets with 4785 plots (Zemlianskii et al. 2023).

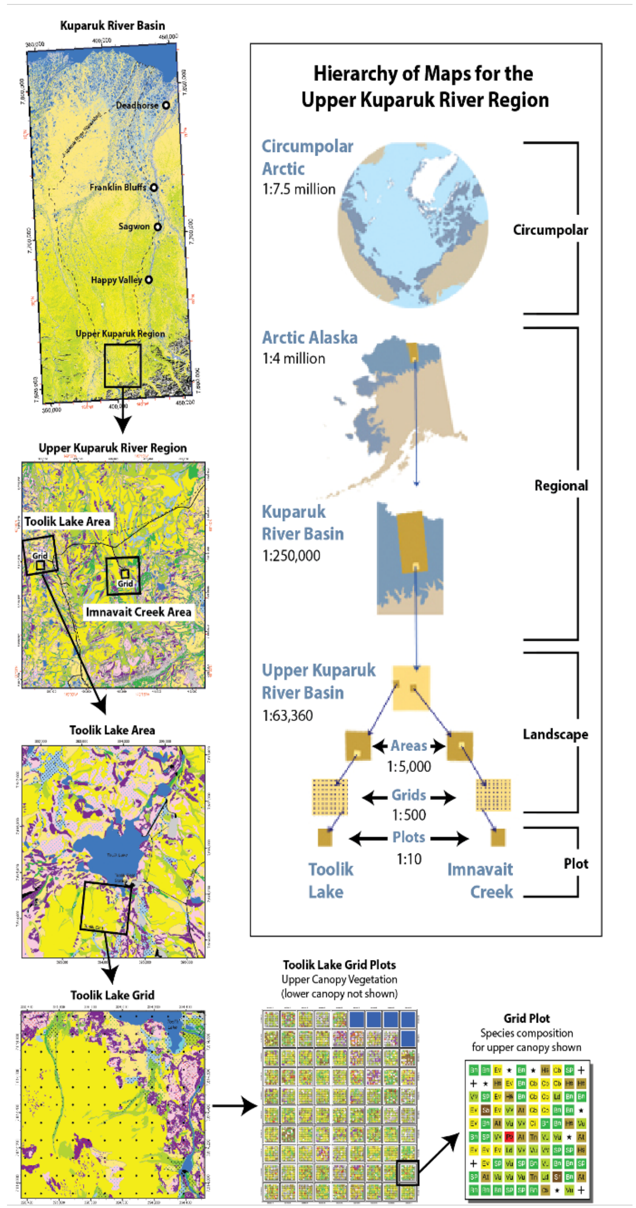

Figure 6. Hierarchy of vegetation maps and GIS databases, developed for the Toolik Research Station. The maps are archived in a CKAN catalog as part of the Alaska Arctic Geobotanical Atlas at the Alaska Geobotany Center, University of Alaska Fairbanks (Walker et al. 2016).

Figure 7. Vegetation plot sampling and coordination with soil floristic, climate and permafrost sampling associated with the North America Arctic Transect (Walker et al. 2008b, 2011a) **a.** Camp at Green Cabin, Banks Island, Nunavut, Canada. **b.** Vegetation survey and mapping grid at Green Cabin. **c.** Students involved in soil and permafrost survey at Green Cabin. **d.** Chien Lu Ping and students describing a pit. **e.** Anja Kade mapping a frost boil. **f.** *Phlox sibirica* in talus slope, near Mould Bay, Prince Patrick Island. **g.** Vlad Romanovsky at climate station, Happy Valley, Alaska. h. Instrument designed to measure frost heave in frost-boil ecosystems at Franklin Bluffs, Alaska. Photos by Alaska Geobotany Center.

PROTOCOLS, MANUALS AND DATABASES

Standardized methods will be encouraged at Arctic vegetation observing sites (Walker and Raynolds 2011, Walker et al. 2016, 2018). Protocols will be spelled out in methods manuals for: **(1) Species lists and local floras**, including (a) a regularly updated Pan-Arctic Species List for vascular plants, bryophytes, and lichens (e.g., Nordal and Rhazzhivin 1999, Murray and Yurtsev 1999; Elven 2012); (b) local floras (complete species lists) for Arctic stations and research sites (Tolmatchev 1931, Yurtsev 1997, Khitun et al. 2016). **(2) Sampling permanent vegetation plots** with standard methods for vegetation composition, vegetation structure, and key site factors (e.g., Westhoff and van der Maarel 1978, Dengler 2008). **(3) Archiving vegetation plot data**, including standardized archives for plot data in each region of the Arctic; and merging the regional archives into a Pan-Arctic vegetation archive (e.g., MacKenzie and Meidinger 2018, Chytrý et al. 2015, Walker et al. 2016, Breen 2024, Zemlianskii et al. 2023, Ermokhina et al. 2023). A goal for the next 10 years is to develop the regional archives (e.g. Figure 5) while simultaneously working to harmonize the plot and map data into a circumpolar archive. **(4) Arctic vegetation classification** that will include an Arctic vegetation habitat-type checklist (prototypes in Table 1, Figure 8) and be compatible with other international classification approaches (e.g. Faber-Langendoen et al. 2014, 2018, Mucina et al. 2016, Walker et al. 2018, MacKenzie and Meidinger 2018). **(5) Vegetation mapping** that includes revision and publication of the Circumpolar Arctic Vegetation Map (CAVM 2003, 2024; Raynolds et al. 2019) to develop a new very-high-resolution raster version (CAVM v. 3), and the development of regional and local vegetation maps in a hierarchy of spatial scales with consistent legends and color schemes (e.g. Figure 6).

Table 1. Tentative list of Arctic vegetation habitats derived from the European Vegetation Classification checklist (Mucina et al. 2016) supplemented with habitats recognized during plot surveys in Arctic Alaska, Greenland, Russia, and Canada. Habitat type is a site-factor variable for plot sampling for the AVA-AK, and could provide an intermediate framework between national vegetation classification approaches.

Code	Habitat type description
1	***ARCTIC ZONAL TUNDRA***
1.01	Polar desert vegetation, subzone A
1.01.1	Polar deserts of the Arctic zone of the Arctic Ocean archipelagos—North America
1.02	Dry and mesic dwarf-shrub and graminoid zonal vegetation on non-acidic base-rich soils
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
1.02.2	Mesic zonal habitats of graminoid tundra and dwarf-shrub heath vegetation of Arctic, Western Russia and Siberia on base-rich soils, subzones B, C & D
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)
1.03	Dry to mesic dwarf-shrub heath on acidic substrates, subzones D and E
1.03.1	Wind-swept dry habitats with prostrate-dwarf-shrub tundra acidic soils, subzones D and E
1.03.2	Zonal habitats with erect-dwarf-shrub tundra acidic soils, subzones D and E (includes for now early-melting acidic *Cassiope-Hylocomium* snowbeds)
1.03.3	Low-shrub tundra, acidic soils, warmest parts of subzone E
1.03.4	Amphiberingian chionophytic heath communities
1.03.5	Achionophytic heath communities (a vicariant alliance to the *Loiseleurio-Arctostaphyllion* that occurs in Northern Europe, Greenland as well as the Eastern part of North America)
2	***BOREAL MARITIME TUNDRA***
2.01	Mesic tall-herb vegetation, boreal maritime tundra
2.01.1	Mesic tall-herb vegetation, boreal maritime tundra
3	***INTRAZONAL VEGETATION OF THE ARCTIC ZONE***
3.01	Cryoxerophytic steppe and associated shrub on base-rich and (sub)saline substrates in continental Greenland and North America
3.01.1	Cryoxerophytic steppe and associated shrub on base-rich soils
3.01.2	Mesic forb-rich, turfy low Arctic (sub)saline steppe vegetation on base-rich soils
3.02	Arctic rush swards on acidic substrates in arctic region
3.02.1	Wind-swept, chionophobous habitats on acidic soils dominated by rushes
3.03	Grass- & rush-rich, zoogenic habitats, subzones A, B & C
3.03.1	Zoogenic, disturbed habitats, subzones, all sub- zones

Code	Habitat type description
4	***EXTRAZONAL BOREAL VEGETATION OCCURRING IN THE ARCTIC ZONE***
4.01	Boreal coniferous forest enclaves within the tundra zone
4.02	Subalpine and subarctic herb-rich alder and willow scrub and krummholz
4.02.1	Moist to dry alder (*Alnus viridis*) communities and alder savannas
4.02.2	Willow shrublands along streams, rivers, and water tracks on hill slopes
4.02.3	Herb-rich willow scrub and krummholz, subzones D and E
5	***AZONAL ARCTIC HABITATS***
5.01	SALT MARSHES, SAND DUNES, SEA CLIFFS
5.01.1	Wet saline coastal marshes
5.01.1.1	Coastal salt-marshes
5.01.2	Tall-grass swards, sand dunes
5.01.2.1	Tall-grass swards, sand dunes (*Leymus arenarius*), and for now other undescribed saline coastal embryonic communities
5.02	***Talus, screes, and boulder fields** (see also habitat codes 5.08.1 to 5.08.4 for epilithic moss- and lichen-dominated communities)*
5.02.1	Rock-crevices, ledges, faces of rocky cliffs & walls
5.02.1.1	Siliceous rock crevices, ledges, faces and walls
5.02.2	Scree habitats and course alluvium
5.02.2.1	Base-rich and neutral screes and moraines
5.02.2.2	Herb-rich snow-beds, stabilized course calcareous soils
5.02.2.3	Herb-rich vegetation, damp coarse gravels, siliceous substrates of Iceland
5.02.2.4	Ruderal riparian floodplain and terrace vegetation (*Epilobium latifolium*)
5.03	***Snowbeds and wet cold frost-active soils***
5.03.1	Late-melting snowbeds and wet cold frost active soils
5.03.1.1	Prostrate dwarf-shrub snowbeds on acidic siliceous substrates
5.03.1.2	Wet late-melting snowbeds and frost boils, cold acidic fine-grained soils
5.03.1.3	Amphiberingian late-melting snowbed communities
5.03.1.4	Early melting snowbed communities of the Alasko-Yukonian phytogeographical sector
5.04	***Springs***
5.04.1	Cold oligotrophic springs in the boreal and arctic zones of northern Europe
5.05	***Fresh water bodies***
5.05.1	Aquatic rooted floating or submerged macrophyte vegetation of meso-eutrophic water
5.05.1.1	Aquatic forb marshes
5.05.2	Pond and lake margins with aquatic grasses
5.05.2.1	Aquatic grass marshes
5.06	***Mires (wetlands)***
5.06.1	Fens, base-rich wetlands
5.06.1.1	Sedge fens on calcareous mineral substrates
5.06.1.2	Sedge-brown-moss fens on peats and peaty mineral soils
5.06.1.3	Moist to wet coastal sedge-grass tundra calcareous slightly saline soils (*Carex stans-Saxifraga cernua, Dupontia fisheri*)
5.06.1.4	Poor fens, slightly acidic organic soils (sedge-dwarf-shrub-*Sphagnum*)
5.06.1.5	Wet acidic sedge forb mires of Aleutian Islands
5.06.1.6	Moist to wet grassy meadows (*Calamagrostis canadensis, Polemonium acutiflorum, Potentilla palustris*)
5.06.2	Bogs, wetlands on acidic ombrotrophic soils
5.06.2.1	Tussock tundra (*Eriophorum vaginatum*)
5.06.2.2	Dwarf-shrub and peat-moss raised bog vegetation in the boreal and Arctic zones
5.07	***Riparian shrublands and gallery forests***
5.07.1	Riparian habitats, willow (*Salix*) shrublands and poplar (*Populus*) forests
5.07.1.1	Floodplains, springs, aufeis deposits and warm south facing slopes with balsam poplar (*Populus balsamifera*)
5.08	***Bryophyte and lichen vegetation***
5.08.1	Bryophyte communities on sunny exposed siliceous rocks, boulders and screes
5.08.2	Bryophyte communities on exposed limestone rocks and screes
5.08.3	Ombryophilous lichen communities of siliceous rock surfaces
5.08.4	Mainly crustose lichen communities on moderately to highly nutrient-rich limestone substrates
5.08.5	Bryophyte and lichen vegetation on dry acid to subneutral, silty-sand and gravelly soils
5.08.6	Bryophyte and lichen vegetation on subneutral and
5.09	***Anthropogenic and ruderal vegetation***
5.09.1	Human-disturbed habitats in the subarctic and Arctic zones of Russia, Siberia and North America
5.09.1.1	Ruderal vegetation of natural disturbances (e.g., lake bluff erosion)

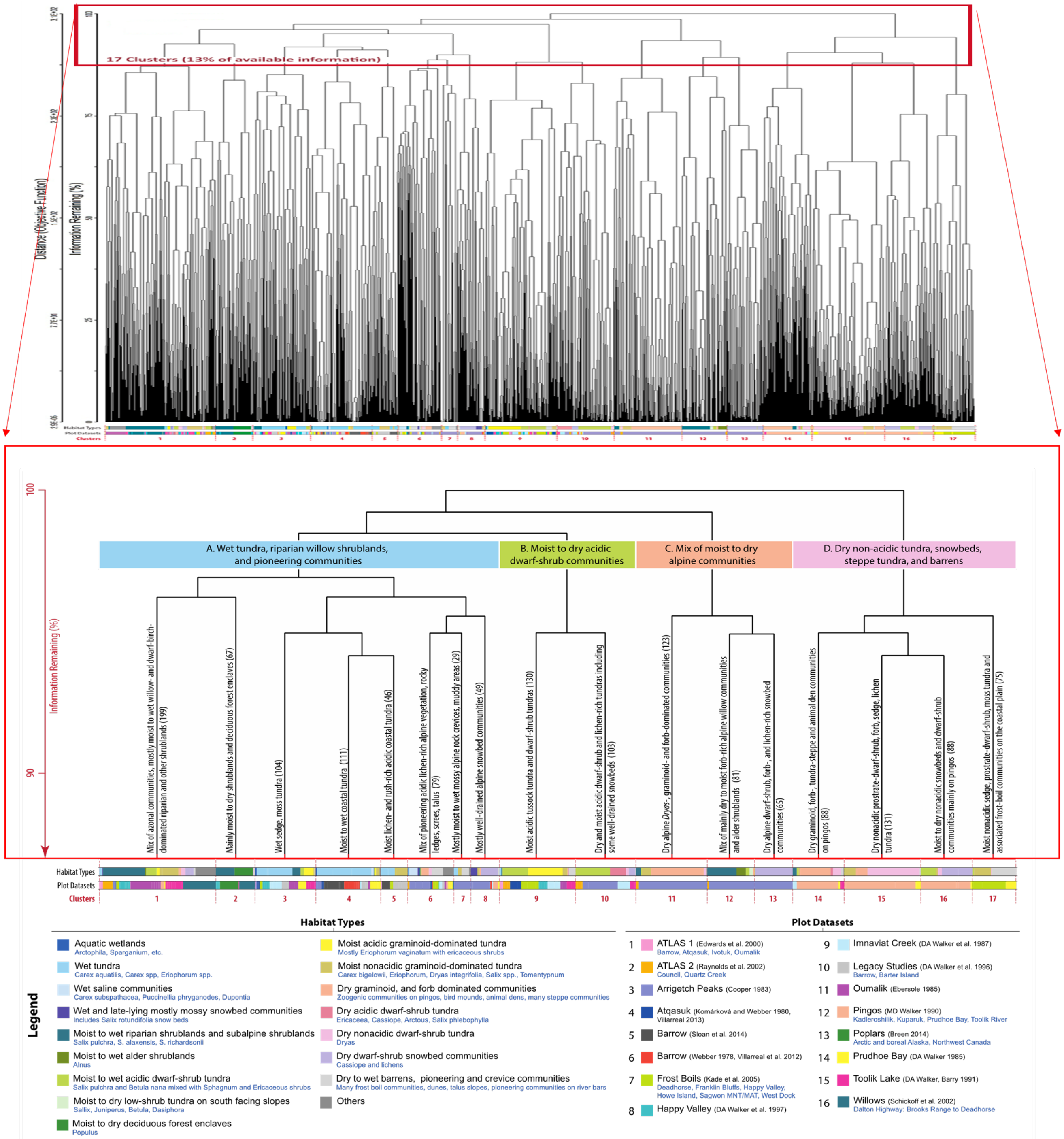

Figure 8. Dendrogram cluster-analysis classification based on species similarity of 1,565 plots from 16 Alaska AVA-AK datasets. The upper part of the figure shows the full dendrogram. The lower part is a color-coded version of the upper portion showing four general habitat groups. Details of the habitat types and datasets in each cluster are shown in the color bars at the bottom of both diagrams. (Modified from Walker et al. 2018).

APPLICATIONS

STATION MANAGEMENT

Arctic research stations require maps of vegetation and other types of landscape information to help site new projects and develop site-compatible experimental designs. Plot data and maps can provide a powerful framework for monitoring and help in sampling across broad environmental gradients. CAVSI would work with station managers and directors of geographic information systems at the various sites to help develop plot and spatial database frameworks that are compatible with intra-site constraints and with other stations.

FRAMEWORK FOR ARCTIC TERRESTRIAL RESEARCH PROJECTS

The Circumpolar Arctic Vegetation Map (CAVM) and its various GIS layers have been used in a wide variety of Arctic analyses (Figure 9).

Topics that will remain important priority research themes for ICARP IV and IPY5. include: (a) circumpolar patterns of phytomass and NDVI (e.g., Raynolds et al. 2008, Orndahl et al. 2022, 2025, Frost et al. 2023, 2025, Greaves et al. 2016,); (b) summer-temperature-vegetation relationships (e.g., Walker et al. 2011, 2019); (c) changes in vegetation greening patterns in relation to changing sea-ice conditions and land-surface temperatures (Bhatt et al. 2010, 2021); (d) diversity of plants, fungi, and terrestrial ecosystems (e.g., Daniëls et al. 2013, Dahlberg and Bültmann 2013, Ims et al. 2013); (e) analysis of vegetation change including changes to dominant growth forms, species diversity and functional traits (e.g., Bjorkman et al. 2018, Elmendorf et al. 2012; Garcia-Criado et al. 2025, Betway-May et al. 2025); (f) large-scale cumulative impact analyses including oil and gas development at Prudhoe Bay and circumpolar assessment of oil and gas development (NRC 2003, Raynolds et al. 2014, AMAP 2010); (g) Arctic species diversity models (e.g., Zemlianskii et al. 2024); (h) vegetation changes in relation to environmental variables (AMAP 2017, Mård et al. 2017, Oehri et al. 2022); (i) evaluation of area-based conservation under climate change (Chacko et al. 2023); (j) prediction of vegeta-

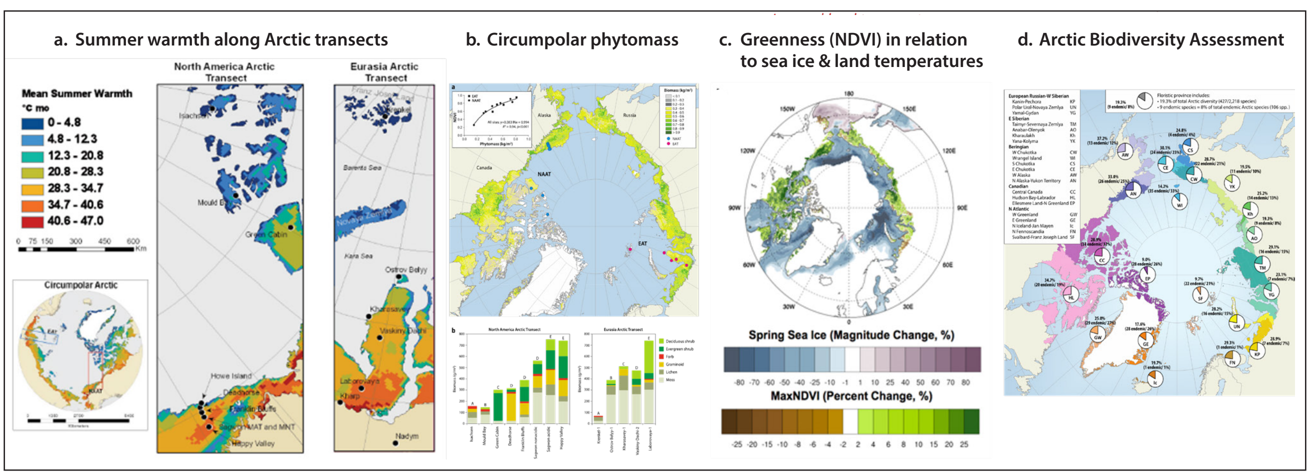

Figure 9. Examples of applications of the CAVM to circumpolar research: **a.** Trends in summer warmth along Arctic transects (Raynolds et al. 2008); **b.** Circumpolar biomass and trends along transects in North America and Eurasia (Walker et al. 2011a, b, 2019b); **c.** Vegetation greenness (NDVI) in relationship to sea-ice cover (Bhatt et al. 2010, 2021); **d.** Arctic plant-species diversity in relationship to phytogeographic and bioclimate subzones (Daniëls et al. 2013, Dahlberg and Bültmann 2013, Ims et al. 2013).

tion shifts under climate change (Pearson et al. 2013); and (k) fire disturbance and ecosystem stable states (Heim et al. 2025).

TOWARD IPY5

While it is still early to formulate well-developed IPY5 projects, several ideas are being developed by a group of collaborative projects that would utilize CAVSI data and maps:

(1) BACK TO THE FUTURE II

Assessment of sensitivity of ecological impacts to key drives, such climate or land-use change, is typically accomplished through repeated observations over either space or both space and time (Cramer et al. 2014). During IPY4, the Back to the Future project (BTF, IPY4 activity #512, Callaghan et al. 2011, Elmendorf et al. 2011, 2012, 2015, Myers-Smith 2015) focused on understanding past changes in polar ecosystems by resampling and monitoring historical research sites and data and to pass this knowledge to a newer generation of researchers to model and predict future changes. BTF and associated projects proved extremely valuable for understanding both the extent and rates of contemporary ecological change throughout the tundra biome as well as the environmental drivers of such change. A key element of the project was the development of databases and methods to harmonize the diversity of information from legacy datasets. BTF II would continue these efforts and apply new methods for sampling vegetation diversity (Yoccoz et al. 2012, Edwards et al. 2018, Collela et al. 2020, Vasar 2023) and observing change that are currently at the frontiers of Arctic Vegetation Science (e.g., Kerby and Myers-Smith 2025, Miller et al. 2025). Nonetheless, the Arctic as a whole remains patchily sampled, with 31% of all studies occurring within 50 km of two high profile research sites, Toolik Lake, AK and Abisko, Sweden (Metcalfe et al. 2018). A BTF II initiative would provide an opportunity to expand the network of resampled sites through fieldwork accomplished during the next IPY, as well as curate and preserve historical datasets which might otherwise be lost to science with the retirement of Arctic vegetation scientists. As the dataset coverage increases, we anticipate BTF II addressing critical questions such as: What is the role of permafrost degradation in Arctic vegetation change? What are the major vegetation components responsible for the "greening of the Arctic observed from space"? Where and when is biodiversity loss occurring across the Arctic biome? How might Arctic vegetation change under different future climate change scenarios?

(2) PAN ARCTIC GREENING

Another successful IPY4 activity was the Greening of the Arctic (GOA, IPY4 activity #139), which examined trends in the Normalized Difference Vegetation Index (NDVI, a measure of tundra greenness, biomass, and productivity) in relationship circumpolar patterns of early-summer Arctic sea-ice cover, and total summer warmth. The project had two main components: (1) a remote-sensing analysis of sea-ice/land temperature/NDVI relationships in all Arctic Ocean basins and adjacent land areas (Bhatt et al. 2010, 2021); and (2) ground-based studies along 1700-km bioclimate gradients in North America and Eurasia to examine trends of summer temperature/NDVI/plant-functional-type biomass (Raynolds et al. 2008a, Walker et al. 2008, 2019, Epstein et al. 2008, 2021). Greenness has become widely used indicator of change an index of Arctic vegetation change is one of the primary variables reported every year as is part of NOAA's annual Arctic Report Card (Frost et al. 2023, 2024a, 2024b, 2025, Phoenix et al. 2025) (e.g., Figure 10). Possibilities of IPY5 would be the inclusion of new transects in understudied regions of the Arctic, and applications of new very-high resolution UAV and satellite data [e.g., F (potentially in conjunction with machine learning (ML) imagery analysis techniques] to examine biomass and greening trends at much finer scales that correspond to the fine-scale of Arctic ecosystem components such as shrub patches and patterned-ground ecosystems (e.g., Witherana et al. 2021, Derkacheva et al. 2025, Kropp et al. 2025, Orndahl et al. 2022, 2025, Miller et al. 2025).

(3) CIRCUMPOLAR ARCTIC SPECIES DIVERSITY

Arctic plant diversity undergoes changes due to both climate warming and increasing industrial activity. Documenting and predicting these changes is increasingly important for conservation and management efforts. With ongoing circumpolar plant diversity inventory efforts (Daniëls et al. 2013, Dahlberg and Bültmann 2013, Walker et al. 2013), the growing body of data enables the development of statistical and process-based models to quantify the impacts of climate change on species diversity (Criado

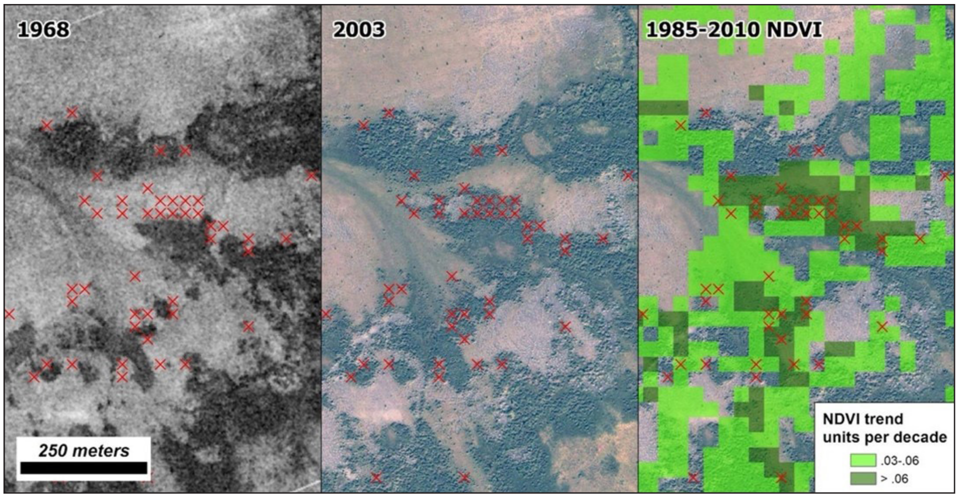

Figure 10. Long-term spaceborne measurements provide unequivocal evidence of Arctic greening, but change tends to be focused in specific landscape settings. For example, Landsat-observed greening (right panel) in was closely linked to upland landscape patches where tall alders (red Xs) have expanded from 1968, left panel to the mid 2000s (center panel). From Frost et al. 2014.

et al. 2025, Chacko et al. 2023). Species distribution models (SDMs), based on vegetation data archives, provide valuable tools for studying the distribution of Arctic plant diversity through several possible applications. For example, investigating the current and future distributions of high Arctic species under different climate scenarios helps document Arctic "squeeze" (Gilg et al. 2012), and supports conservation of the most vulnerable species. SDMs also could support nature conservation prioritization through identification of biodiversity hotspots (Zemlianskii et al. 2024). Additionally, monitoring alien plant species and modeling their future distribution is another prospective application to help mitigate the consequences of climate and ecosystem changes. Furthermore, indigenous Knowledge on new species arriving (e.g., Ksenofontov et al. 2018) could be used to validate model predictions. The predictions on species diversity and distribution can then be used to assess future ecosystem functions, such as energy and carbon fluxes, permafrost insulation, food sources and nesting habitat for animals, and nature's contributions to people.

(4) ARCTIC-BOREAL TRANSECTS

Many of the current data in the prototype plot archive were collected along transects through the five Arctic bioclimate subzones of the CAVM and into the boreal forest in North America and Eurasia (Figures 7 and 11). The first Arctic transect was established on the Taimyr Peninsula during the International Biological Program Tundra Biome (TPAT, Matveyeva 1994 and numerous others in cited in Chernov and Matveyeva 1997). These data are a high priority for incorporation into the AVA-RU. The first Arctic bioclimate transect in North America was established in 1974-75 along the 570-km-long "Haul Road" between the Yukon River and Prudhoe Bay (DAT, Webber et al. 1979). The Central Canada Arctic Transect (CCAT, Gonzalez et al. 1999, Gould et al. 2003) was established to determine if the Arctic bioclimate zonation approach developed in Russia (Yurtsev 1994) could be applied also to the North American Arctic and the CAVM. Studies along the Western Arctic Alaska Transect (WAAT, Walker et al. 2003a, b) and the DAT examined trends in vegetation phytomass, LAI, NDVI, plant functional types along the Alaska summer warmth gradient, on acidic and non-acidic soils in the eastern (drier, nonacidic) and western (wetter, acidic) portions of Arctic Alaska. In 2003–2005, The Dalton Highway transect was extended into High Arctic Canada to form the North America Arctic Transect (NAAT, Epstein et al. 2008, Raynolds et al. 2008b, Ping et al. 2008, Walker et al. 2008b, 2011a) for a study of the complex interactions of climate, permafrost, vegetation, and soil in frost-boil ecosystems. A similar transect was established along the Kolyma River, Russia, in 2002 (KRAT, Raynolds 2004). The Eurasia Arctic Transect (EAT) was established during 2006–2011 as part of the IPY-4 Greening of the Arctic project (Bhatt et al. 2010, Walker et al. 2019b, Epstein

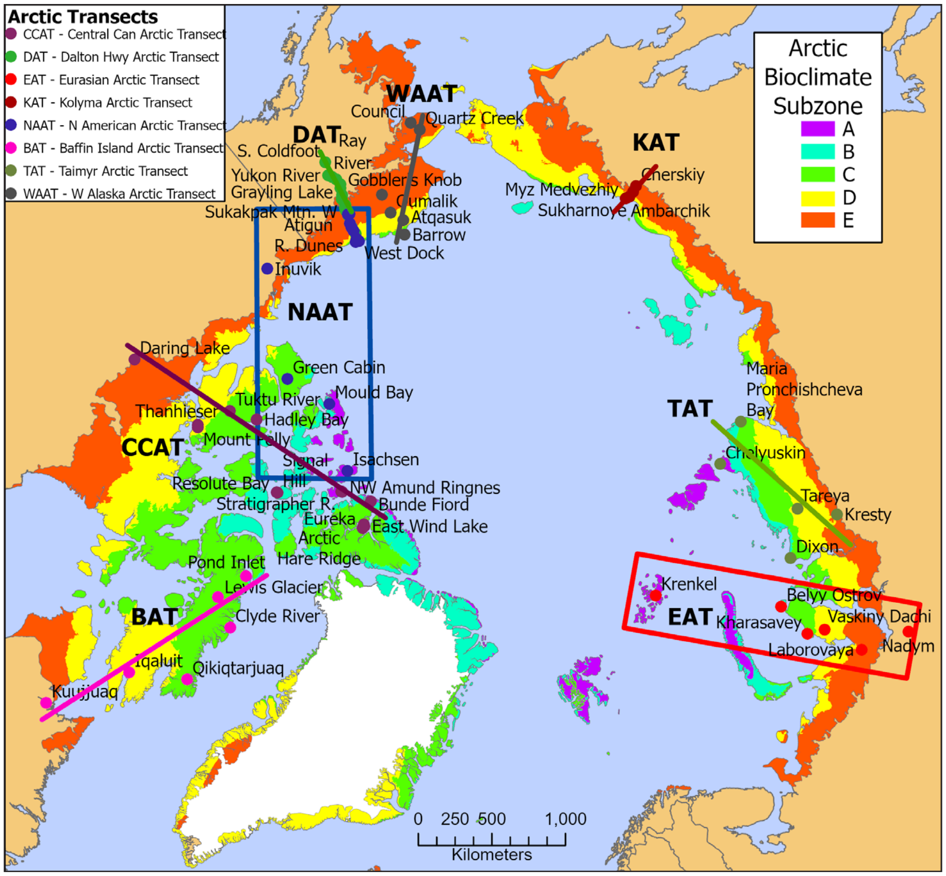

Figure 11. Existing Arctic transects across north-south bioclimate gradients.

et al. 2021, Frost et al. 2013, 2014). The EAT was established to examine trends in plant-functional-type, biomass, LAI, and NDVI through the northern boreal forest and all five bioclimate subzones along the Yamal Peninsula in West Siberia and the Franz Josef Archipelago on sandy and loamy soils. The newest Arctic transect is the Baffin Island Arctic Transect (BIAT, Raynolds et al. 2025), which was established to describe and map contemporary vegetation around targeted lakes spanning a bioclimate gradient from tree line in northern Quebec (58˚N) to polar desert in northernmost Baffin Island (74˚N). Data from these transects were key elements for studies that examined relationships between sea-ice retreat, and changes in terrestrial NDVI patterns and were instrumental in developing NDVI as a key indicator of Arctic tundra variability and change (Box et al. 2019, Bhatt et al. 2021, Frost et al. 2023, 2025).

An IPY5 project would resample and remap existing sites along as many as feasible of the eight existing transects that traverse all or parts of the Arctic Zone and northern portion of Boreal Zone. Special attention would be devoted to the Dalton Arctic Transect (DAT in northern Alaska because of accessibility and long history of studies since the late 1970s (Webber et al. 1979, Brown et al. 1980).

(5) ARCTIC EDGES

Past Arctic vegetation studies and maps have focused on the Arctic Tundra Bioclimate Zone, which includes mainly treeless tundra areas with Arctic climates beyond the northern limit of trees. There is a need to extend the boundaries of current sampling, classification, and maps to include those areas that are intimately connected to the Arctic and experiencing some of the most rapid changes, such as the highly threatened extreme northern Bioclimate Subzone A (Walker et al. 2008a, Zemlianskii 2024), areas emerging from melting ice caps and glaciers (e.g. Kasanke et al 2022, Raynolds et al. 2025); and southern areas near the Arctic treeline, including the Arctic-Boreal ecotone transition (e.g., Timoney et al. 2020), boreal alpine areas connected to the Arctic alpine areas (e.g. Karlsen et al. 2005) and treeless oceanic boreal areas (Talbot 2008,

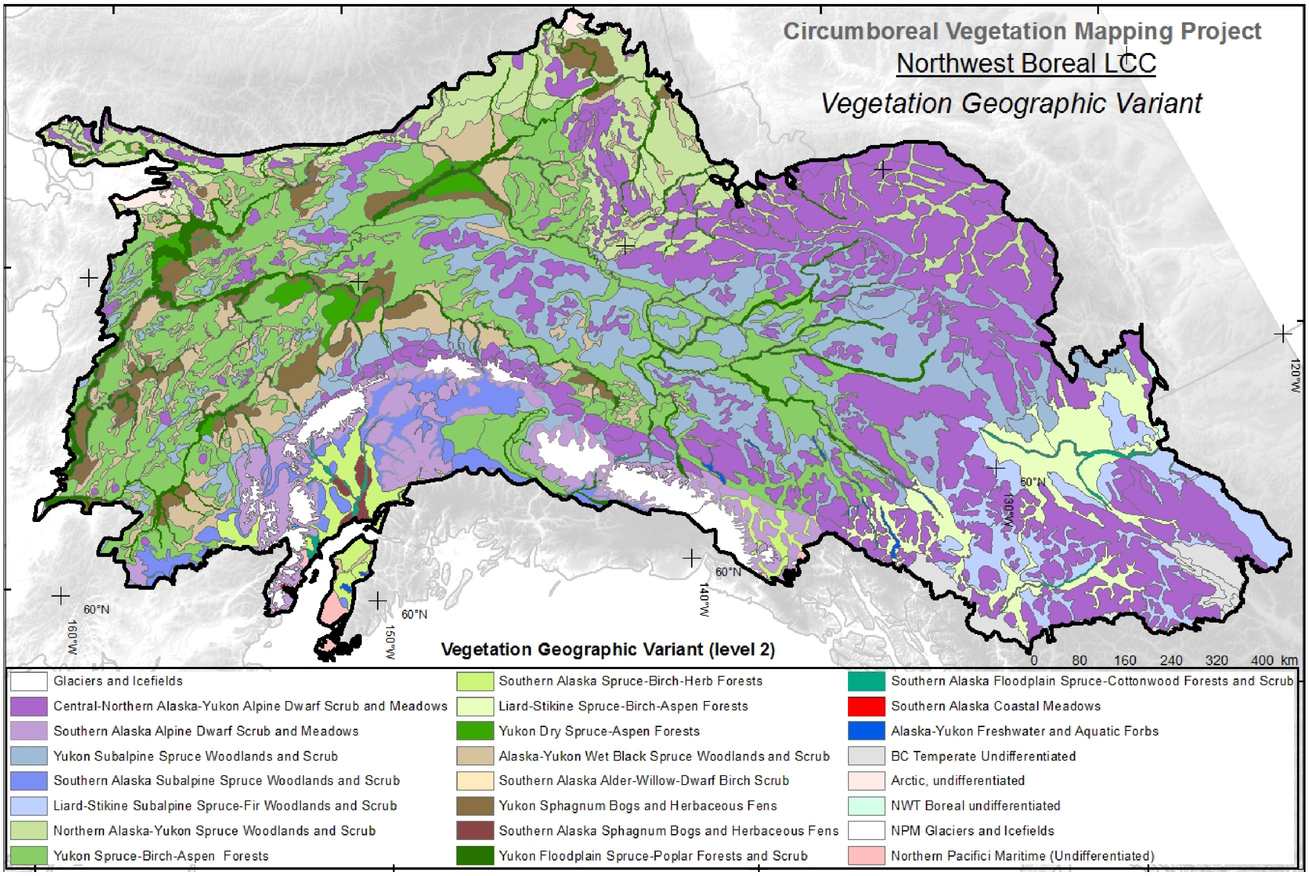

Figure 12. Prototype map of boreal vegetation in the Alaska-NW Yukon region (Jorgenson and Meidinger 2015).

Talbot and Meades 2011, Talbot et al. 2010, 2011, Saucier 2013, Jorgenson and Meidinger 2015) (Figure 12). Some of these, such as the Bioclimate subzone A, high alpine areas in the Arctic, and the treeless boreal areas such as the Aleutian Island (Talbot et al. 2005), and similar habitats in the southern hemisphere are among the most rapidly changing and understudied areas.

(6) BIOMES OF THE CIRCUMPOLAR ARCTIC

This idea builds on the keynote address of Ladislav Mucina. Classification of biomes (functional biotic community units; see Mucina 2019) is a vital tool of large-scale stratification of the Artic biota. This stratification will serve the identification of research needs, design of the AVON, and as the framework for any large-scale survey project, including those addressing the Artic-focused studies of hydrology, nutrient cycling, dynamics of permafrost, climate change, and the like. We shall develop a hierarchy of biomes (following the approach by Mucina 2023, Mucina and Rutherford 2024), using the Circumpolar Vegetation Map (Walker et al. 2005, Raynolds et al. 2019) and the phytogeographic classification by Yurtsev (1994) as the basis. We shall also incorporate data from relevant sources developed in Russia (Ogureeva et al. 2008) and Canada (McLennan et al. 2018).

TOWARDS A CAVSI SCIENCE PLAN

The main goal of the Circumpolar Arctic Vegetation Science Initiative (CAVSI) is to coordinate vegetation observations, harmonize classifications and mapping, and to build an integrated vegetation data framework for a wide variety of interdisciplinary Arctic research needs. Other goals of CAVSI are to improve general knowledge of Arctic vegetation and to support and train the next generation of Arctic vegetation scientists through mentorship, collaboration, and shared research infrastructure.

The 3-day CAVSI Workshop was held during the 26th Arctic Science Summit Week (ASSW), March 21–23, 2025. Eighty-five participants from 15 countries developed a list of current Arctic research topics and focused on key elements of an Arctic Vegetation Observing Network (AVON). Seven panels and breakout sessions during the workshop addressed key elements of the network, including protocols for sampling, archiving, classifying and mapping Arctic vegetation, and application of the products to priority research topics for the Fourth International Conference on Arctic Research Planning (ICARP IV). Furthermore, Prof. Ladislav Mucina, one of the foremost experts on global biome research, presented the keynote address, focusing on Arctic vegetation complexity at disparate spatial scales.

RESOLUTION

At the conclusion of the workshop, the participants developed a CAVSI Workshop Resolution that expressed the need for up-to-date knowledge of the composition and spatial distribution of Arctic flora and vegetation for ICARP IV and the Fifth International Polar Year (IPY5, 2032–2033) and a pledge of their intent to advance the following priorities during ICARP IV and IPY5:

1. Establish a Circumpolar Arctic Vegetation Science Initiative (CAVSI) to help address priority vegetation-related science questions across disciplines and a hierarchy of spatial scales in relationship to, for example: landscape dynamics and change, biodiversity monitoring and mapping, climate change and disturbance regimes.

2. Establish an early career vegetation scientists' network to foster career development in Arctic vegetation-related disciplines to promote Arctic vegetation-science-related education and training activities, and develop cross-disciplinary and cross-cultural connections with other Arctic-related early-career science groups.

3. Develop an Arctic Vegetation Observation Network (AVON) within existing interdisciplinary observing networks to (1) aid in site and project management and development of comparable frameworks for locating and tracking vegetation plot data and mapped information, (2) promote long-term sustained observations at well-marked permanent vegetation plots and mapped areas; (3) coordinate vegetation observations with other Arctic system observations; (4) identify geographic and topical gaps for sampling, archiving, classifying, and mapping Arctic vegetation; and (5) establish new observatories in understudied vegetation-habitat types and regions.

4. Update, maintain, and publish a Pan-Arctic Species List (PASL) and local floras (complete species lists of vascular plants, bryophytes, and lichens) at Arctic research stations and other research sites.

5. Adopt standardized protocols for vegetation and environmental plot surveys that are widely used by the international vegetation science community, that include traditional plot survey methods, and where feasible, use new transformative methods appropriate for observing, modeling, reconstructing, and predicting Arctic vegetation change.

6. Develop regional Arctic vegetation archives for vegetation plot data and map data and merge the regional archives into a circumpolar Arctic Vegetation Archive (AVA), including methods to harmonize and standardize the data.

7. Develop local, regional, and circumpolar Arctic vegetation classifications (AVCs) and checklists of classified vegetation units based on standardized approaches developed by the international community of vegetation scientists, including crosswalks to equivalent units in other regional and national classification approaches.

8. Revise, edit, and publish a new version of the Circumpolar Arctic Vegetation Map (CAVM v. 3) with increased resolution and a hierarchical legend approach that can be applied to maps at global, regional, landscape, and plot scales.

9. Apply the products of CAVSI to priority ICARP IV and IPY5 research topics.

The 2025 CAVSI Workshop Resolution is in Appendix E. Recommendations from the seven panels and breakout groups are included in Appendix D.

TIMELINE

Much of the next decade of Arctic research will be devoted to planning for IPY5. The CAVSI Science Plan will first focus on developing a circumpolar vegetation observing network and protocols discussed above that are needed for the framework datasets, data archives, and maps, while also looking forward to the intensive sampling and data analysis period of IPY and synthesis that will follow. A tentative timeline for the initiative includes the ICARP IV planning period (2025-2026), the IPY5 planning and proposal period (2027-2031), IPY5 (2032-2034), and IPY5 synthesis (2034-35) (Table 2, next page).

Table 2. Timeline for CAVSI activities.

ACTIVITY	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
	ICARP IV		IPY5 planning period					IPY5		IPY5 synthesis	
CAVSI Organization											
Proposals	US-AVON proposal	Other national proposals	IPY proposals								
CAVSI Workshops at ASSWs **Workhop proceedings**	Boulder, CO	Copenhagen	Hakodate, Japan		Stockholm		TBA		TBA	TBA	
IAVS meetings	Greeley, CO	TBA		TBA		TBA		TBA		TBA	TBA
CAVSI Organizing Group (COG) and communication network **Young Vegetation Scientists' Network**	Formation of networks		Planning, proposals, communication, training, summer courses, Indigenous Peoples engagement					IPY activities		CAVSI IPY synthesis	
Arctic Vegetation Observing Network (AVON)											
Network Organization	Mainly online AVON planning meetings			Development of AVON				AVON IPY-5 activities		AVON IPY-5 synthesis activities	
Protocols											
Pan Arctic Species List (PASL)	Organization of PASL group			Development, training, publication, and maintenance of PASL				PASL IPY-5 activities		PASL and local floras synthesis	
Local floras	Local floras manual			Development of local floras for Arctic research stations				Local floras IPY-5 actiities			
Plot-sampling	Plot sampling protocols manual			Plot sampling and resampling at Arctic research stations and other sites				Plot sampling for IPY-5 activities		Synthesis of circumpolar Arctic vegetation sampling, archiving, classification, and checklist	
Vegetation plot archives	Archiving protocols manual			Development and coordination regional plot archives (AK, CA, GR, EUR, RU)				Merging of regional achives into circumplar Arctic plot archve			
Vegetation classification	Classification protocols manual			Development and coordination of regional classifications (AK, CA, GR, EUR, RU)				Merging of regional classifcations into circumpolar Arctic classification an checklist			
Vegetaion mapping	Mapping protocols manuasl			Development of landscape- and regional-scale vegetation and regional biome maps for Arctic stations (AK, CA, GR, EUR, RU)				Development of VHR CAVM v. 3 and circumpolar Arctic Biomes map		Synthesis of local, regional, and circumpolar Arctic vegetation and terrain mapping efforts	
Applications and IPY-5											
Station and site management	Working with local station and site field managers to develop and manage consistent plot netoworks, maps, databasex stations, products										
Supporting on going experimental studies of Arctic change dynamics	Development of collaboration with experimental studies of Arctic change			Planning for IPY5 collaborative studies				IPY5 collaborative activities		Synthesis of collaborative activities	
CAVSI-related IPY projects											
Back to the Future II (BTF II)	Planning, proposals, monitorig for BTF II projects			Continueed BTF monitoring and planning for IPY5				BTF II IPY activities		BTF II synthesis	
Pan-Arctic Greening (PAG)	Plannnibg and proposals for PAG			Contined PAG activities, planning for IPY5				PAG IPY5 activities		PAG sytnthesis	
Arctic Edges (AE)	Organization of AE			Prototype Arctic Edges maps				Application Arctic Edges to IPY5 activities		SE synthesis	
Arctic-boreal transects (ABT)	Planning and proposals for ABT			Resampling old transects where feasible				IPY-5 Arctic-Boreal transects in new underrepresented areas		BAT synthesis	
Arctic Biomes (AB)	Definitions, prototype regional biome maps, and IPY proposals			Development of Circumpolar Arctic Biome Maps and Book				Application of Biome maps to IPY5 activities		AB synthesis	

APPENDIX A | CAVSI WORKSHOP PARTICIPANTS

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Stephan Hennekens, Wageningen Environmental Research, The Netherlands

David Hik, Simon Fraser University, Canada

Olivia Hobgood, University of Alaska Fairbanks, USA

Bob Hollister, Grand Valley State University, Michigan

Steffanie Ickert-Bond, UA Museum of the North, University of Alaska Fairbanks, USA

Marc-Frédéric Indorf, Ministère de l'Environnement, Canada

Shawnee Kasanke, Alaska Biological Research, Inc., USA.

Kelcy Kent, Woodwell Climate Research Center, USA

Jeff Kerby, University of Cambridge, UK

Olga Khitun, Komarov Botanical Institute, RAS, Russia

Simone Lang, The University Centre in Svalbard, Norway

Keith Larson, Arctic Centre at Umeå University, Sweden

Will MacKenzie, Province of British Columbia, Canada

Johanna Malle, University of Zurich, Switzerland

Marc Marias-Fauria, University of Cambridge, UK

Andrew Martin, University of Cambridge, UK

Donald McLennan, Coenosis Consulting, Canada

Briana McNeal, University of Alaska Fairbanks, USA

Courtney Meier, National Ecological Observatory Network (NEON), USA

Dirk Mengedoht, Alfred Wegner Institute, Germany

Oyvind Mikkelsen, Norwegian University of Science and Technology, Norway

Victoria Miles, Nansen Environmental and Remote Sensing Center, Norway

Charles Miller, NASA Jet Propulsion Laboratory, USA

Ladislav Mucina, Murdoch University, Australia

Dave Murray, University of Alaska Fairbanks, USA

Isla Myers-Smith, University of British Columbia, Canada

Dmitry Nicolsky, University of Alaska Fairbanks, USA

Ian Olthof, Environment Climate Change, Canada

Kathleen Orndahl, Northern Arizona University, USA

Jana Peirce, University of Alaska Fairbanks, USA

Gareth Phoenix, University of Sheffield, UK

Darren Pouliot, Environment and Climate Change Canada, Canada

Clay Prater, University of Arkansas, USA

Kabir Rasouli, Desert Research Institute, Nevada, USA

Martha Raynolds, University of Alaska Fairbanks, USA

Christian Rixen, WSL-Institute for Snow and Avalanche Research (SLF), Davos Dorf, Switzerland

Vladimir Romanovsky, University of Alaska Fairbanks, USA

Gabriela Schaepman-Strub, University of Zurich, Switzerland

Jozef Šibík, Slovak Academy of Sciences & Geobotany Research Center, Slovakia

Mária Šibíková, Slovak Academy of Sciences & Geobotany Research Center, Slovakia

Sandy Starkweather, US Arctic Observing Network & University of Colorado Boulder, USA

Scott Sugden, University in Sherbrooke, Canada

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Craig Tweedie, University of Texas at El Paso, USA

Sergio Vargas, University of Texas at El Paso, USA

Natasha de Vere, Natural History Museum of Denmark, University of Copenhagen, Denmark

Marilyn Walker, HOMER Energy, retired, USA

Donald Walker, University of Alaska Fairbanks, USA

Pat Webber, Michigan State University, retired, USA

Aaron Wells, AECOM Technical Services, USA

Kristine Bakke Westergaard, Norwegian University of Science and Technology, Norway

Brandon Whitley, University of Copenhagen, Denmark

Daryl Yang, Oak Ridge National Laboratory, USA

Vitalli Zemlianskii, University of Zurich, Switzerland

APPENDIX B | CAVSI WORKSHOP AGENDA

Arctic Science Summit Week 2025 Community Meeting
Boulder, CO, March 21-23

DAY 1: FRAMEWORK FOR A CAVSI INITIATIVE

ARCTIC VEGETATION OBSERVING NETWORK AND NEXT GENERATION OF ARCTIC VEGETATION SCIENTISTS

8:30–9:00	Coffee meet and greet
9:00–10:00	Goals and overview of the agenda and overview of the Circumpolar Arctic Vegetation Science Initiative (CAVSI) — *Skip Walker and Gabriela Schaepman-Strub*
10:00–10:30	Coffee Break
10:30–11:10	Panel 1: Training the next generation of Arctic vegetation scientists: Curricula, field schools, other resources, and creation of a Vegetation Young Scientist Network *Moderators: Mária Šibíková & Shawnee Kasanke*
11:10-11:50	Panel 2: Learning from large pan-Arctic networks or programs *Moderators: Craig Tweedie and Millicent Harding*
11:50-12:00	Mapping Arctic Science — *Craig Tweedie*
12:00-13:00	Lunch (catered in room)
13:00-13:50	Panel 3: Learning from vegetation-focused Arctic networks or projects *Moderators: Howard Epstein and Cassandra Elphinstone*
13:50–15:30	Breakout/Writing Session: *Group 1: Training the next generation of Arctic vegetation scientists* *Group 2/3: Creation of a new AVON* *Group O: Online breakout*
15:30–16:00	Coffee Break
16:00–17:00	Plenary: Reports from breakout sessions followed by discussion
17:00	Adjourn

DAY 2: MAJOR ELEMENTS OF THE CAVSI INITIATIVE

PROTOCOLS FOR SAMPLING, ARCHIVING, CLASSIFYING, AND MAPPING ARCTIC VEGETATION

8:30–9:00	Coffee meet and greet
9:00–9:15	Welcome & Introduction of keynote speaker — *Skip Walker & Jozef Šibík*
9:15–10:00	Keynote: Vegetation complexity of the Arctic-Alpine realm at disparate spatial scales — *Ladislav Mucina*
10:00–10:30	Coffee Break

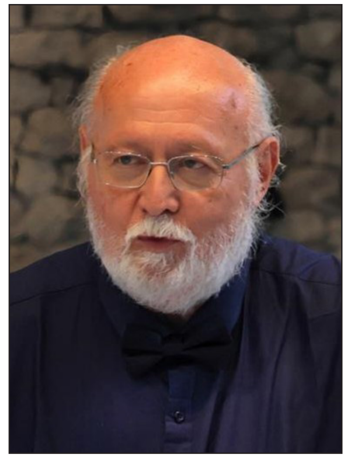
10:30–10:40	Overview of the CAVSI initiative — *Skip Walker*
10:40–11:20	Panel 4: Pan-Arctic Species List and local floras *Moderators: Helga Bültmann and Aaron Wells*
11:20–12:00	Panel 5: Sampling and archiving protocols for Arctic plot data *Moderators: Amy Breen and Maria Dance*
12:00–13:00	Lunch (catered in room)
13:00–13:40	Panel 6: Vegetation Classification *Moderators: Jozef Šibík and Ladislav Mucina*
13:40–14:20	Panel 7: Mapping and Remote Sensing *Moderators: Martha Raynolds and Brianna McNeal*
14:20–16:00	Breakout/Writing Sessions *Group 4: Pan-Arctic Species List and local floras* *Group 5: Sampling and archiving protocols for Arctic plot data* *Group 6: Vegetation Classification* *Group 7: Mapping and Remote Sensing* *Group O: Online breakout*
15:30–16:00	Coffee Break
16:00–16:30	Reports from breakout sessions
16:30–17:30	Plenary: Back to the future: Bridging generations of scientists, from pioneers to young investigators — *Skip Walker*
17:30	Adjourn

DAY 3: APPLICATION OF THE PRODUCTS OF CAVSI
TO PRIORITY ICARP IV RESEARCH TOPICS AND FUTURE DIRECTIONS

8:30–9:00	Coffee meet and greet
9:00-9:20	Welcome and overview of recent applications of circumpolar vegetation-related products — *Gabriela Schaepman-Strub*
9:20-10:00	Lightning Talks: New and future directions for observing, reconstructing, and predicting vegetation change in the Arctic *Moderator: Vitallii Zemlianskii*
10:00-10:30	Coffee Break
10:30-11:15	Plenary: How does CAVSI fit into ICARP IV and IPY *Skip Walker, Gabriela Schaepman-Strub, and Amy Breen*
11:15-12:00	Plenary: Outline 10-year CAVSI Science plan *Skip Walker, Gabriela Schaepman-Strub, and Amy Breen*
12:00-13:00	Lunch (catered in room)
13:00–15:00	Breakout/Writing Session: Outline sections of the science plan and white paper
15:00–15:30	Outcomes Report for Circumpolar Arctic Vegetation Science Initiative
15:30-16:00	Coffee Break
16:00–17:00	CAVSI resolution and additional discussion
17:00	Adjourn

APPENDIX C | KEYNOTE ADDRESS BY PROF. LADISLAV MUCINA

VEGETATION COMPLEXITY OF THE ARCTIC-ALPINE REALM AT DISPARATE SPATIAL SCALES



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ABSTRACT

This paper addresses the need for a standardized methodology of monitoring the status and developmental trends of vegetation of the zonal vegetation of the (or imbedded in) Arctic zonobiome (ZB A1 according to Mucina 2023) and embedded azonal ecosystems within the zonobiome.

The Arctic zonobiome is here defined as the zonal core of the phytogeographic Arctic Zone as defined by Yurtsev (1994) and generally called 'Arctic Tundra', but also including the extrazonal Alpine ecosystems bioclimatically and floro-genetically related to the zonal ecosystems of the North American and Eurasian Arctic. The redefinition of the biome position of the Alpine vegetation follows Mucina (2023). The 'alpine' ecosystems here are understood as those above the timberline, and structured into extrazonal biomes of respective zonobiomes A1 and A4 (Antarctic Zone) and two zonobiomes in their own right: A2 Subtropical Alpine Zone and A4 Tropical Alpine Zone.

The monitoring of the Arctic and Alpine ecosystems is not a new field as several global initiatives contain essential elements of long-term monitoring in the Arctic tundra and Alpine ecosystems. The proposed conceptual monitoring scheme involves all steps across (and including) vegetation sampling and data analyses followed by status reporting. In essence, the framework recognizes the overarching importance of spatial and temporal scales. I argue that it is not feasible and even less so plausible to find a compromise through cross-walking between various, often fundamentally disparate, vegetation classification approaches (and the tools they use) ever used to describe and interpret the vegetation patterns of the Arctic and Alpine realms. Instead, the conceptual scheme focuses on contrasting spatial scales, one involving the scale of biome, the other—the scale of habitat.

At the large spatial scales, a hierarchy of large-scale functional units called 'biomes' has been recognized (see Mucina 2023, in prep.). Here four important tools may assist in forming of a robust biome framework for the Arctic-Alpine realm duo: (1) the bioclimatic zoning of the Arctic (Elvebakk 1999; Walker et al. 2005), (2) phytochorial classification of the Arctic (Yurtsev 1994), global classification of the Alpine regions (Testolin et al. 2020; although in need of revision of the next tool), and finally (4) the global zonobiome classification by Mucina (2023). In this respect, I present a preliminary biome classification scheme at the level of continental biomes for both the Arctic and Alpine realms. The biomes are arenas where large-scale ecological bioclimatic (and at lower tiers of the biome hierarchy also soils) shape the complexes of vegetation units through a plethora of environmental filters. Biomes are arenas offering the space for processes of evolutionary flora and community assembly, operating over deep time scales.

A preliminary attempt using the subzone as defined by Elvebakk (1999) and later by Walker et al.

(2005) and climatic data from WorldClim 2.1 (Fick & Hijmans 2017) to construct climatic diagrams (see Rutherford et al. 2006, Mucina 2023, Tsakalos et al. 2023 for details of the methodology), revealed interesting patterns worth further inquiry.

Firstly, a simple superposition of the mean annual temperature (MAT) and mean annual precipitation (MAP) against latitude (Figure 13) reveals that the subzone F clearly sets off the rest of the subzones by its high precipitation. This suggests that these few patches (as mapped by CAVM Team 2003 embedded within the Arctic Zone proper) are indeed members of another zonobiome. This treeless boreal oceanic ecosystem has been earlier also called 'maritime tundra'. In the Global Biome System (Mucina 2023) it is classified as part of the Oceanic Boreal Zone (B2). Interestingly, the distinction between the subzone A (polar deserts) and B (upper arctic) in the classical Schimperian bioclimatic space (defined by temperature and precipitation) is weak. This possibly goes back to a different bioclimatic index used to define the subzones—the summer warmth index SWI defined as the sum of the mean monthly temperatures above freezing (see also Raynolds et al. 2008). Although the vegetation physiognomic differences between the Subzones A and B are striking, the exploration of other climatic indices is needed to set these two ecosystems bioclimatically apart.

Another preliminary probe into the bioclimatic patterns, this time within the Subzone A (Polar Deserts), using geographic dichotomy North America vs Eurasia (Figure 14) revealed an unexpected large difference between the respective biomes. The North American-Greenland Polar Desert is much drier (MAP) and colder (MAT). This observation, also made by Bhatt et al. (2010) also needs further enquiry in context of defining the position of both biomes in the hierarchy of biomes (see Figure 14).

While the biome scheme addresses the large-scale patterns (and the underlying drivers of its long-term dynamics), the habitat-level vegetation classification scheme shall assist in addressing the fine-scale vegetation patterns and dynamics. Here, undoubtedly in my mind, the floristic-sociological approach (also known as Braun-Blanquet approach) has proved to be most versatile and ecologically informative in describing the vegetation types, characterizing the composition of vegetation along gradients, and assist studies into the processes of plant community assembly along ecological spatial and temporal scales. Using the Braun-Blanquet approach in the Arctic-Alpine context is not only a matter of deep tradition of descriptive vegetation science (the basic tenets of this methodology were partly devised in the alpine

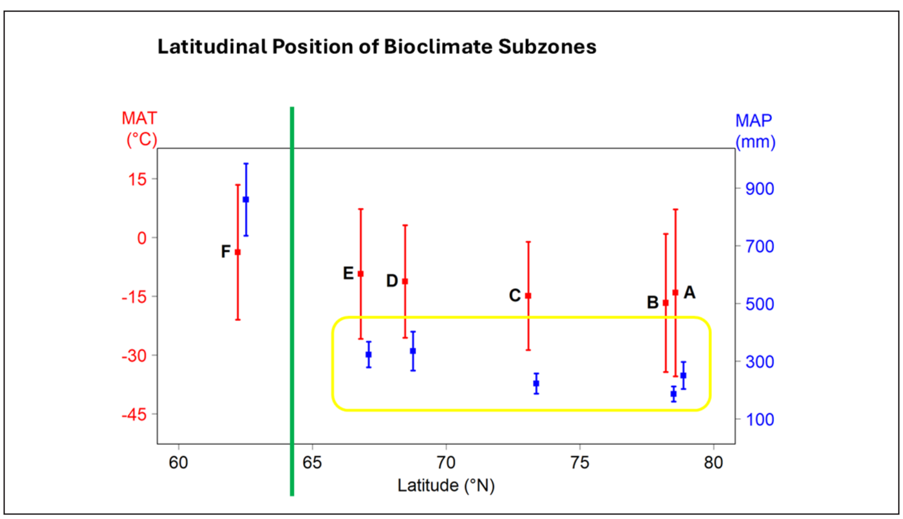

Figure 13. The Mean Annual Temperature (MAT; left vertical axis) and Mean Annual Precipitation (MAP; right vertical axis) of the Bioclimate Subzones (as defined by Walker et al. 2005, F refers to non-Arctic areas) in relation to latitude. The MAT and MAP data were derived from climate diagrams (and the underpinning detailed data; see Mucina 2023 and Tsakalos et al. 2024 for details of the construction of the spatial climate diagrams) of the. The red and blue bars represent the standard deviations of the original climatic data for MAT and MAP, respectively. The green line separates the subzone of the Arctic Zone from those of the Oceanic Boreal Zone (B2; according to Mucina 2023), originally mapped as non-Arctic Areas north of the treeline by the Circumpolar Arctic Vegetation Map.

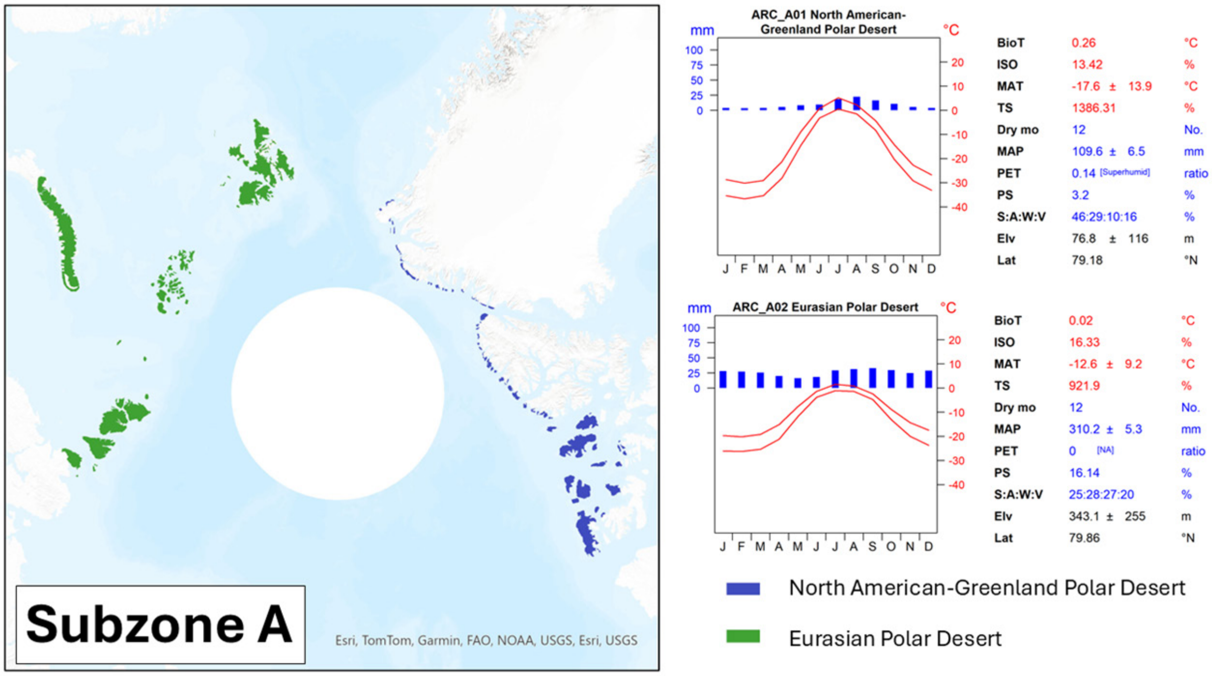

Figure 14. A map of the Subzone A (Polar Desert) classified into two subunits, based on geographic criteria (North American vs Eurasian polar deserts) and accompanied by corresponding spatial climate diagrams. The names of the subunits within the subzone A are preliminary. See Mucina (2023) or Mucina & Rutherford (2024) for detail on the calculation of the elements of the climate diagrams. BioT:biotemperature; ISO: isothermality, MAT: mean annual temperature; TS: temperature seasonality, Dry mo: number of dry months (precipitation less than 50 mm per month); MAP: mean annual precipitation; PET: potential evaporation ratio; PS: precipitation seasonality; S:A:W:V: % of precipitation in 4 yearly periods (S: summer, A: autumn; W: winter; V: springer/vernal); Elv: mean elevation; Lat: mean latitude.

ecosystems of the Swiss Alps!), but also because of its power as international scientific normative. Vegetation-plot databases are being built across the entire planet, incl. the circumpolar Arctic (Walker et al. 2016, Zemlianskii et al. 2023) as well as the alpine ecosystems (Chytrý et al. 2015).

Concise vegetation classification (syntaxonomic) schemes have been defined for Arctic-Alpine realm of Europe (Mucina et al. 2016, 2024), Siberia (e.g., Matveeva & Lavrinenko 2021), and Greenland (Daniëls in Mucina et al. 2016). Although we are not there yet, the wealth of syntaxonomic knowledge of the vegetation of the North American Arctic-Alpine realm, Siberia, Eastern Asia, and the Far East offer solid basis for creation a unified syntaxonomic system for the entire zonobiome A1.

ACKNOWLEDGMENTS

L. Mucina acknowledges the logistic support of the Iluka Chair on Vegetation Science & Biogeography and the support of the University of Alaska Fairbanks. Johan Wasserman received a Murdoch Strategic Scholarship provided by Murdoch.

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APPENDIX D | PANEL AND BREAKOUT GROUP SUMMARIES AND RECOMMENDATIONS

PANEL 1: TRAINING THE NEXT GENERATION OF ARCTIC VEGETATION SCIENTISTS

CURRICULA, FIELD SCHOOLS, OTHER RESOURCES, AND CREATION OF AN EARLY CAREER VEGETATION SCIENTIST NETWORK

MODERATORS

Maria Šibíková, Slovak Academy of Science & Geobotany Research Center, Slovakia
Shawnee Kasanke, Alaska Biological Research, Inc., USA

PANELISTS

Millicent Harding, Durham University, UK
Jozef Šibík, Slovak Academy of Science & Geobotany Research Center, Slovakia
Vitalii Zemlianskii, University of Zurich, Switzerland

The goal of this panel was to identify and discuss resources and opportunities that address the need for education, training, and support of students and early career vegetation scientists working in the Arctic. Questions for the panel and following breakout group included:

- What key topics and skills do you believe should be included in the curriculum for young Arctic vegetation scientists?
- How difficult is it for you to find students who are interested in studying Arctic vegetation science? What factors influence the interest in studying Arctic ecosystems among students? How does the propagation of Arctic studies work in your country or at your institution?
- What are the main obstacles that young students and early-career researchers encounter when working in the Arctic?
- What role do field schools play in training young scientists, and how can we enhance the practical experience offered through these programs? Are there specific locations or ecosystems in the Arctic that should be prioritized for field studies?
- What strategies can be implemented to establish a Vegetation Young Scientist Network? How can this network facilitate collaboration among young scientists working in different Arctic regions?

SUMMARY

Curricula needs. Panelists identified knowledge and skills in five areas that young Arctic vegetation scientists should acquire to ensure a well-rounded skillset: (1) Field geobotanical methods (Braun-Blanquet approach of plot sampling, biomass sampling, etc.); (2) Taxonomic identification and proper collection of vascular plants and cryptogams in field and lab conditions; (3) Geographic information system (GIS) and remote sensing skills; and (4) Methods for data analyses including applied statistics and modeling in R/Python; and (5) Remote field logistical and survival skills.

Recruitment. While finding and motivating undergraduate students has been relatively easy, there is often a shortage of postgraduate researchers. To address this, panelists proposed a range of promotional activities: (1) Promotion of Arctic vegetation science in universities, web platforms, and social media, including sharing photographs from the field and presenting fieldwork as an adventurous, fun activity; (2) Organization of summer schools and field courses, taking into account logistics and visa issues to ensure non-discriminatory access (Hanson, 2025); (3) Preparation of online lessons, seminars, and workshops. For graduate students, it is also important to establish a link between education and research, providing opportunities for students to test their interest through hands-on research.

Obstacles. Young researchers in Arctic vegetation science face many obstacles, including the financial and logistics demands of doing fieldwork in the Arctic. University grants are not often sufficient to cover the costs of organizing Arctic field expeditions. Organizing Arctic field expeditions also requires key field skills such as expedition planning, management, and safety that are not always taught, or not well. Permitting is also challenging, especially where national parks and international travel are involved. There is not always clear guidance on how to obtain permission, and language barriers commonly exist. Finally, many students are lacking essential outdoor skills, making remote expeditions risky.

Early Career Arctic Vegetation Researchers: The formation of an early career researchers working group began shortly after the CAVSI workshop. Twelve early career attendees from the workshop met on 25 March 2025 to discuss the group's goals and methods:

- Create an online platform (e.g., Google Drive) to support network communications and information sharing, including up-to-date lists of upcoming funding opportunities, field schools, and other opportunities and information related to Arctic vegetation science.
- Create a quarterly meeting schedule for business meetings and seminars by ECRs on their research. The first meeting will be held on 7 May 2025 and focus on identifying priority/actionable goals and delegating tasks.
- Start groups on internationally accessible social network platforms (e.g., BlueSky and WhatsApp) to facilitate informal sharing and community building.
- Encourage and facilitate more formal collaboration among vegetation science-related ECRs on research, publication, data collection, and the sharing of expertise.
- Provide opportunities for field and research support, including funding, field courses, field training opportunities, and other related events.
- Integrate this Arctic vegetation science-focused group into other relevant ECR organizations such as the Association of Polar Early Career Scientists (APECS).
- Work towards ensuring that field schools and other vegetation research and training opportunities are available to residents of all countries involved in Arctic research to avoid visa discrimination and encourage pan-Arctic collaboration.
- Recruit and support the involvement of Arctic indigenous youth in Arctic research.

RECOMMENDATIONS

1. To ensure a well-rounded skill set, young Arctic vegetation scientists should receive training in five areas: geobotanical field sampling, taxonomic ID and proper plant collection; GIS and remote sensing; applied statistics and modeling; and remote field logistics and survival.
2. Address the shortage of postdoctoral researchers by promoting Arctic vegetation science in universities, through summer schools, field schools, and workshops, and virtually through online courses, web platforms, and social media.
3. Larger grants are needed to achieve the Arctic vegetation research goals associated with ICARP-IV and IPY 5. Compiling an overview of potential funding sources would be especially useful in helping early career researchers navigate the funding landscape.

PANEL 2: LEARNING FROM LARGE PAN-ARCTIC NETWORKS OR PROGRAMS

MODERATORS

Craig Tweedie, University of Texas at El Paso, USA
Millicent Harding, Durham University, UK

PANELISTS

Kyle Arndt, Woodwell Climate Research Center, USA
David Hik, Simon Fraser University, Canada
Vladimir Romanovsky, University of Alaska Fairbanks, USA
Sandy Starkweather, U.S. Arctic Observing Network & University of Colorado, USA
Elmer Topp-Jorgensen, International Network for Terrestrial Research and Monitoring in the Arctic & Aarhus University, Denmark

The goal of this panel was to learn about the challenges faced in organizing and maintaining a large Arctic network and solicit advice for organizing a new observing network. Questions for the panel and following breakout group included:

- Why was your network/project established, and what was its aim, or what questions was it addressing?
- What are the challenges faced in organizing and maintaining a large Arctic network? Do you have any suggestions or advice for beginning to create a new observing network?

SUMMARY

The sparsity of observing stations and research programs across the Arctic, combined with its vast geographic scope, make partnerships and knowledge-sharing critical to understanding vegetation at a Pan-Arctic scale. This information exchange includes both data and logistical "know-how." For example, obtaining permits, organizing field facilities and equipment, and providing training and safety plans are all challenging due to the remoteness of locations, harsh environmental conditions and the fact that Arctic research often crosses the geopolitical boundaries, each with their own requirements.

Arctic research is largely conducted by academic institutions. This differs from other extensive operational monitoring programs (such as the National Weather Service) in that data sharing structures are not part of the original funding mandate and must instead be constructed after the fact in order to make data accessible for future pan-Arctic work. The distributed funding structures across many nations also mean that Arctic data often require substantial mobilization, collation, and harmonization to be broadly useful.

One key to data integration is identifying select parameters that constitute the essential components of a pan-Arctic monitoring system and can be consistently monitored over space and time. Long-records and repeated sampling are crucial for understanding changes over time—a critical mandate in a rapidly changing Arctic.

Although the variables sampled, spatial scale of sampling, and lengths of record differ among various networks, one objective of all is to assess the spatial patterns and temporal dynamics of vegetation, and hence contribute to the goals of CAVSI.

Successful data integration comes with many challenges in terms of human capacity, cultural norms, organizational structures and technical and infrastructure considerations. Bottom-up organizations often work better than top-down structures in terms of garnering interest and enthusiasm and conducting the relationship-building necessary for collaboration. They, however, lack long-term, centralized funding sources and often rely on individual (frequently unpaid) champions. This model also faces sustainability challenges, as its success depends on key individuals rather than institutions or government entities.

Building governance structures with intentionality will be critical to long-term success. Efforts to build a pan-Arctic observing network must also include meaningful engagement with the broader community (e.g., Indigenous partners).

PANEL 3: LEARNING FROM VEGETATION-FOCUSED ARCTIC NETWORKS OR PROJECTS

MODERATORS

Howard Epstein, University of Virginia, USA
Cassandra Elphinstone, Department of Botany and the Biodiversity Research Centre, University of British Columbia, Canada

PANELISTS

Christopher Baird, National Ecological Observatory Network, USA
Isabel Barrio, Faculty of Environmental and Forest Sciences, Agricultural University of Iceland, Iceland
Syndonia Bret-Harte, Institute of Arctic Biology, University of Alaska Fairbanks, USA
Sarah Elmendorf, Institute of Arctic and Alpine Research, University of Colorado Boulder
Isla Meyers-Smith, University of British Columbia, Vancouver, Canada

The goal of this panel was to learn about the mission, sampling protocols, and other standards used by current vegetation-related networks or projects to better understand the issues and opportunities for collecting or aligning data for use in a circumpolar network of networks. Questions for the panel and following breakout groups included:

- What are the geographic and temporal scopes of your network and what vegetation and ancillary data are collected? What methodologies are used for data collection and how are these data used, shared, and archived?
- Which aspects of your network align best or least with the following CAVSI goals and standards: ongoing field protocols; similarities and differences among networks; completed or proposed synthesis efforts; and data accessibility and potential for integration, both before and after publication?
- What do you think would be the greatest benefit of synthesizing your network data with other networks? Are there any downsides? Essentially, what do you think about the utility of the CAVSI effort?

SUMMARY

Panel 3 was represented by a variety of different vegetation-related networks, including the Long-Term Ecological Research (LTER) network, the National Ecological Observatory Network (NEON), the Herbivory Network, the International Tundra Experiment (ITEX), and the High Latitude Drone Ecology

Network (HILDEN). Both the LTER and NEON are essentially prescribed observation and monitoring networks funded by the NSF, with different variables measured and length of record depending on the network and the individual LTER sites. Vegetation-related variables measured for LTER sites include productivity, biomass, soil nutrients, and disturbances; whereas the NEON locations sample both above- and belowground biomass, plant community composition and diversity, vegetation structure (e.g., woody vegetation), phenology, and foliar traits. The ITEX is a long-running common warming experiment at sites throughout the Arctic, measuring plant community composition and phenological traits. It also acts as a platform for campaign efforts to collect short-term observations across many sites. The Herbivory Network and HILDEN are more project-based at the individual level, with HILDEN specifically collecting remotely sensed vegetation data. Whereas NEON is likely the most "top-down" of these networks with respect to common, prescribed sampling protocols, the LTER and ITEX have elements of both top-down and individualistic "bottom-up" approaches. The Herbivory Network and HILDEN may be mostly bottom-up.

Although the variables sampled, spatial scale of sampling, and lengths of record differ among these networks, they share the common objective of assessing spatial patterns and temporal dynamics of vegetation, and therefore contribute to the goals of CAVSI. Panelists suggested that instead of trying to minimize the differences among networks, focus on the synergies, and work toward open access of the data. Panelists agreed that there are lots of great opportunities for synthesis here, at which point, harmonization of certain data items could occur. Training of early career scientists and their involvement in these networks is crucial for continuity of understanding, skills, and discovery.

RECOMMENDATIONS FOR PANELS 2 AND 3

1. Focus on identifying and leveraging synergies among networks rather than minimizing differences, while advancing open access to data.
2. Pursue opportunities for data synthesis, which will allow for harmonization across networks of key data items.
3. Invest in training early career scientists. Their involvement in these networks is crucial for the continuity of skills and understanding, as well as for sustained scientific discovery.

PANEL 4: PAN-ARCTIC SPECIES LIST AND LOCAL FLORAS

MODERATORS

Helga Bültmann, University of Münster, Germany
Aaron Wells, AECOM Technical Services, Anchorage, AK, USA

PANELISTS

Steffi Ickert-Bond, UA Museum, University of Alaska Fairbanks, USA
Erin Cox, Polar Knowledge Canada, Canada
Stephan Hennekens, Wageningen Environmental Research, The Netherlands
Olga Khitun, Komarov Botanical Institute, RAS, Russia
Natasha de Vere, Natural History Museum of Denmark, University of Copenhagen, Denmark

The goal of this panel was to discuss the best methods and resources to maintain a Pan-Arctic Species List (PASL) that includes vascular plants, bryophytes, and lichens. Questions for the panel and following breakout group included:

- How can we obtain a state-of-the-art list for vascular plants, bryophytes, and lichens, and how do we keep it updated? Do we need a dynamic list for taxonomists and a more stable list for vegetation ecologists?
- How can we obtain new data from fieldwork? How can we work together to ensure a big flow of our data to the species list? Can local floras or mining of open-source data like iNaturalist help?
- What role can new methods such as eDNA play?

SUMMARY

New state-of-the-art list. Ideally, we would have two species lists: one that is dynamic and can be updated at any time, and another for use in vegetation datasets that is more static but can be updated periodically from the dynamic list. The species list would be managed in a publicly available, cloud-based, relational database that would allow for open access by all collaborators as well as programmatic access (e.g., through an API) to allow vegetation species composition datasets to use the list for taxonomic names.

The Conservation of Arctic Flora and Fauna (CAFF), CAFF Flora Group could be a potential host. A dedicated team of people supported by funding is needed to develop, maintain, and update the list, collating data from different countries and watching the literature for published taxonomic changes. Version control and formal archiving of past lists is needed, so anyone using the list can cite the version used (reflecting the accepted names at that time) in a publication. Data cleaning, including managing synonyms, is an important step in the process of integrating species lists across regions in the Arctic. Taxonomic changes that are not one-to-one (e.g., splitting one taxon in two or lumping two or more taxa into one) are a challenge and require special handling.

Distribution and species lists for both bryophytes and lichens can be downloaded from consortia of bryophyte and lichen herbaria. All of the taxa have been digitized by the participating herbaria. Unfortunately, these are not available for the Russian Arctic. While there are large herbaria, less progress has been made on digitization.

A semi-automated workflow has been developed using R to update a checklist of vascular plants in Greenland, comparing names in the digitized herbarium with the Pan-Arctic Flora list and Plants of the World Online database, and flagging discrepancies for manual review. The outputs are a searchable taxon list and meta-collection dataset of occurrence data.

New data from fieldwork and published sources. The days of funding large-scale, multinational field surveys seem to be over. The logistics of Arctic research are expensive and complex. Species data are often collected opportunistically in the course of other funded research. While attempts are sometimes made to reach out before a field expedition to researchers with a known interest in a particular specimen or area, a listserv or other group discussion tool would make such collaboration easier and help researchers prioritize filling regional or organismal knowledge gaps.

Researchers are encouraged to collect herbarium vouchers while in the field to deposit into a relevant herbarium that is able to take new specimens. For bryophytes, it can even be a mass sample if it's difficult to distinguish what you have and you are not a specialist in the area. The most recent specimens in many herbarium collections are from the 1990s or 2000s, so new vouchers provide a valuable addition to collections that may go back to 1800 or earlier and can then be used in timeseries or global change research through DNA analysis.

Russian contributions to Panel 4 and CAVSI. Olga Khitun presented a summary of local flora studies and selected bibliography of recent research on flora and vegetation in the Russian Arctic. In addition, presentations during ASSW science sessions 2.6 and 2.8 by Olga Lavrinenko, Igor Lavrinenko and Vitalii Zemlianskii, along with an abstract by Nadya Matveyeva, provide further details on recent vegetation research in Russia (see Breen et al. 2025, in prep.).

RECOMMENDATIONS

1. Coordinate a multidisciplinary, international working group to tackle the development of the next Pan-Arctic Species List (PASL). Ideally the group would include taxonomists, vegetation scientists, and remote sensing scientists.
2. Compile a list of all taxonomic and herbarium databases (e.g., GBIF) that could be mined to develop a complete checklist of species with accepted names and synonyms.
3. Make progress on curating Arctic plant specimen voucher collections. Put out a call for collections that have not yet been digitized. Identify major geographic gaps in digitized herbarium records and prioritize those for digitization.
4. Ensure that the current PASL list has been properly archived in a human-readable format.
5. Develop DNA barcode library for Arctic vascular plants, bryophytes, and lichens with crosslinks to the new PASL.
6. Create a listserv or other group discussion tool to share information about planned fieldwork to help fill regional or organismal knowledge gaps.
7. Develop and maintain a close collaboration with Russian taxonomists and vegetation scientists to maintain species lists and plot data archives and develop the means to share these data with international vegetation science groups.

PANEL 5: SAMPLING AND ARCHIVING PROTOCOLS FOR ARCTIC PLOT DATA

MODERATORS

Amy Breen, University of Alaska Fairbanks, USA
Maria Dance, University of Cambridge, UK

PANELISTS

Sarah Elmendorf, University of Colorado Boulder, USA
Jeff Kerby, University of Cambridge, UK
Will Mackenzie, Province of British Columbia, Canada
Jozef Šibík, Slovak Academy of Sciences & Geobotany Research Center, Slovakia
Vitalii Zemlianskii, University of Zurich, Switzerland

The panel discussed vegetation sampling and archiving protocols used by panelists' high-profile projects and networks (e.g., Arctic Vegetation Archive (AVA), European Vegetation Archive (EVA), and International Tundra Experiment (ITEX)), with the goal of identifying common international standards for use in regional and pan-Arctic analysis and applications (Barry et al. 2023). Questions included:

- Describe the methodology your networks or projects use for sampling vegetation plots? What are the strengths of this methodology, and how are the plot data formatted, used and archived?
- What are the benefits and drawbacks of adopting common vegetation sampling and archiving protocols?

A variety of vegetation plot sampling methods are in use among panelists. We asked panelists to share not only their field methodology but also to consider other aspects of their project and network protocols including: (1) design—dimension of the study area in space or time); (2) grain (dimension of each sampling unit, e.g. the size of a vegetation plot); and (3) sampling interval (or lag between sampling units). The most common global method for sampling and classifying vegetation is the *Braun-Blanquet (Br-Bl) approach (*Van der Maarel 1974; Ivanova 2024). This approach classifies vegetation based on species composition and cover using an efficient semi-quantitative scale. Plots are grouped into plant communities based on floristic similarity and diagnostic species. Sampling designs typically follow the centralized replicate method, where plots are placed in the most representative part of each vegetation unit to capture its core floristic characteristics. The Br-Bl approach is the methodology adopted by the AVA-AK following the lead of the EVA as an additional strength of the method is its compatibility with historic datasets going back to the early 20th century (Walker et al. 2018)

AVA-Canada (AVA-CA) utilizes an adaptation of the Br-Bl approach for ecosystem classification but puts more focus on environmental variables, including formalized collection of site and soils information (McLennan et al. 2018; MacKenzie 2023). A standardized protocol, used since the 1980s, mirrors Br-Bl in using percent cover instead of classes and in the subjective placement of plots in homogenous zones. Five provinces (excluding Quebec) with Arctic jurisdictions are developing vegetation classifications and sampling protocols.

The International Tundra Experiment (ITEX) has established a long-term global network of tundra plots using a set of common protocols outlined in the ITEX Manual (Molau & Mølgaard 1996). This allows researchers to examine vegetation change over time and across the tundra biome. In this long-term experiment, researchers are limited by the sampling decisions made when the plots were established.

In addition to long-term sites with research-question-driven designs (e.g., warming, herbivory, phenology, and biodiversity), there is also more opportunistic expedition-based sampling where plots are set out to quickly measure variables like species presence, abundance, and diversity, documented with photos.

Data are commonly formatted and stored using the Microsoft Access and TURBOVEG (Hennekens 2015) software programs. While TURBOVEG is proprietary, it forms the basis for the EVA and sPlot archives so there is no need to reformat to share data with these repositories. In addition, species cover and environmental data stored in TURBOVEG can also be made available as open-source, comma-separated values (.csv) files as done by the AVA-Alaska (AVA-AK). All AVA national databases are linked to the CAFF Flora Group website. Some datasets in the AVA-Russia (AVA-RU) are restricted, but requests to data custodians for their use can be made from the AVA-RU website (Zemlianskii et al. 2023). Notable is the AVA-RU is known to be incomplete as to date not all researchers have made their data available for archive.

There is little commonality in where Arctic vegetation plot data are archived. Discussion cited many publicly accessible options that vary based on country (Arctic Data Center, Dryad, Polar Data Catalog, and Zenodo) and network (AVA-AK, AVA-RU, EVA). Panelists agreed data storage should be open access and in a non-proprietary format to ensure compatibility and accessibility. sPlot, the largest repository for plant community data in the world, was mentioned as a common archive as AVA data are also shared with sPlot (Bruelheide et al. 2019). There is agreement databases should be easy to use and provide some quality control and versioning. Dataset versions with DOIs should be released from time to time and include all metadata.

The breakout group discussed the need for harmonized sampling and archiving protocols across the Arctic to support basic vegetation monitoring and provide data for future research projects. A set of common international standards should balance simplicity and flexibility (for broad adoption) and complexity (for scientific rigor).

A tiered protocol system emerged as a preferred solution. Minimum standards for inclusion in shared datasets should include site photos, GPS coordinates, vegetation-habitat type, percent cover of species and plant functional types, as well as a set of basic environmental metrics (e.g., topography, soil moisture). The AVA-AK (Breen et al. 2014) and the Alaska Geospatial Council Vegetation Working group (VTWG 2022) have minimum sampling standards that we could cross-reference.

Recommended or advanced standards would support more detailed data collection and could include point frame sampling, biomass, species-level identification, phenology, and plant/canopy height. Soil moisture is important, but verbal or categorical classes may suffice in place of calibrated probes, and collaboration with hydrologists to establish these measurement standards could be useful.

Common datasheets for the protocols should be distributed, and an app could be developed so people can enter their data digitally in the field. Accurate coordinates and good metadata are needed. Voucher specimens are essential for validation and future reference. The Circumpolar Arctic Vegetation Map (CAVM; Raynolds et al. 2019) classifications are useful because they have been thoroughly vetted and harmonized from different regions. Plots could be positioned along hydrological gradients. What was unresolved was a minimum number of observations per site.

For archiving and data management, there was broad agreement on the need for common metadata standards, searchable fields, digital archiving to enable future syntheses, coordination to maintain consistency, and sustained funding. Open data standards should be adopted from the start. There was also strong support for a metadata portal managed by a CAVSI secretariat. While data may be stored in various repositories depending on funding or other requirements, it could be tagged with a special CAVSI tag for the CAVSI protocols. Voucher specimens should be stored in regional hubs. A definitive list of which institutions are willing to archive samples would be useful.

RECOMMENDATIONS

1. Adopt a standardized sampling protocol with minimum and recommended/advanced standards to balance usability and scientific rigor, and provide common datasheets and digital tools (e.g., a mobile app) to support consistent data collection.
2. Adopt open data standards and establish a CAVSI metadata portal to ensure datasets are findable, searchable, versioned, and interoperable.
3. Identify regional hubs for voucher storage and develop a definitive list of which institutions are willing to archive samples.
4. Clarify contributor roles and incentives, data use policies, and co-authorship expectations.

PANEL 6: VEGETATION CLASSIFICATION

MODERATORS

Jozef Šibík, Slovak Academy of Sciences & Geobotany Research Center, Bratislava
Ladislav Mucina, Murdoch University. Australia

PANELISTS

Helga Bültmann, University of Münster, Germany
Ksusha Ermokhina, A.N. Severtsov Institute of Ecology and Evolution, RAS, Russia
Will Mackenzie, Province of British Columbia, Canada
Aaron Wells, AECOM Technical Services, USA

The goal of this panel is to share insights on existing models for Arctic vegetation classification while exploring the challenges and opportunities of adopting unified methods. Questions included:

- What existing models for Arctic vegetation classification are currently in use, what are their strengths and weaknesses and how do they vary across different regions of the Arctic?
- What are the main challenges to adopting unified Arctic vegetation classification methods, and how can they be addressed to ensure consistency and compatibility across research efforts?
- How can a unified classification system account for regional ecological differences, ensuring local variations are accurately represented and scientifically meaningful?
- How can data sharing and collaboration among researchers, institutions, and regions enhance the accuracy, consistency, and applicability of Arctic vegetation classification systems?
- How can Arctic vegetation classification systems be aligned with global frameworks, and what steps are needed to ensure compatibility and support broader scientific applications?

- What technological advancements are influencing vegetation classification methods, and how can these innovative tools enhance understanding of Arctic vegetation patterns?

SUMMARY

Classification of archived vegetation data is often a first step toward simplifying, summarizing and communicating complex vegetation patterns and changes to those patterns. Classification is often a necessity for making maps that display key aspects of vegetation and for formulating hypotheses about ecological and evolutionary processes (De Caséres et al. 2015).

Diversity of classification approaches. Existing Arctic vegetation classification models include the Braun-Blanquet (BB) approach used for the European Vegetation Classification (Chytrý et al. 2015, Mucina et al. 2016), the EcoVeg approach in the U.S (Faber-Langendoen et al. 2014, 2018; Baldwin et al. 2019, Wells et al. 2022), and the Canadian Arctic and Subarctic Biogeoclimatic Ecosystem Classification (CASBEC) (Krajina 1965, Pojar et al. 1987, Klinka et al. 1996, MacKenzie and Meidinger 2018) These models offer established protocols and comprehensive frameworks that support regional comparisons, but their applicability varies across Arctic ecosystems. Identifying each system's strengths, weaknesses, and application ensures researchers choose suitable methods for mapping, monitoring, and extrapolation. Aligning these approaches enables broader use of Arctic vegetation data in global ecological assessments and promotes consistency, compatibility, and a comprehensive understanding of Arctic vegetation dynamics amid environmental change.

Challenges: The main challenges in adopting unified Arctic vegetation classification methods include the diversity of ecological conditions and existing classification systems. National mandates that require a specific protocol also complicate efforts to implement globally consistent methods. Addressing these challenges requires the development of standardized yet regionally adaptable frameworks, common data protocols, and collaboration among networks to share best practices and promote consistency across research. It also requires understanding the unique ecological characteristics of different Arctic regions, including local environmental factors, species diversity, and traditional ecological knowledge. Engaging regional experts in the classification process can enhance the relevance and accuracy of the system. Key steps include identifying commonalities and discrepancies between existing models, developing guiding principles that integrate local characteristics with global standards, conducting comparative analyses of classification frameworks, and fostering international collaboration to harmonize approaches.

Ecological indicators for species. Developing a consistent ecological indicator value system in the Arctic—with key indicators such as soil moisture, nitrogen, pH, light, temperature, active layer thickness, and permafrost temperature—will help quantify ecological niches and link indicator values to bioclimatic conditions, enabling detection of vegetation shifts over time.

Vegetation habitats in plot surveys. Vegetation classification has evolved toward the use of habitat criteria at the highest "Class" levels of the European Vegetation Classification (Mucina et al. 2016). The list of Mucina's vegetation habitats has been used for vegetation surveys in Greenland, and Alaska (see Table 1 in main white paper). Further development and application as a standard site variable in Arctic plot surveys would be helpful in developing a bridge for crosswalks between different national classification approaches.

Open access repositories. Open-access repositories and cloud computing platforms promote data sharing, which is vital for enhancing vegetation classification efforts, and provide large and diverse datasets that improve the robustness of models. Technological advances such as remote sensing, machine learning, geographic information systems (GIS), and the development of R and Python analytical packages are enhancing our understanding of Arctic vegetation patterns. Remote sensing offers large-scale data on vegetation patterns and changes, while machine learning improves species identification and classification accuracy.

Early Career Researchers. To equip young scientists with the necessary skills in vegetation classification methodologies and data analysis techniques, we should emphasize mentorship programs, provide access to resources such as workshops, online courses, and field training programs, and encourage interdisciplinary collaborations that foster a holistic understanding of Arctic vegetation science.

Future research. Applications of vegetation classifications need to address emerging challenges, such as climate change, by developing adaptive systems

that respond to shifting ecological conditions. Priorities include integrating new technologies, maintaining community engagement, and fostering interdisciplinary collaboration to ensure classification systems remain relevant and effective.

RECOMMENDATIONS

1. Develop meaningful crosswalks between classification systems—clarifying their strengths, weaknesses, and applications—to promote consistency, guide method selection, and enable a broader use of Arctic vegetation data in global ecological assessments.
2. Start by analyzing the data that are already digitalized in existing databases. In parallel, prepare prodomi (checklist of vegetation units) of vegetation units in different regions and compare to see what level of crosswalk can be achieved as the basis for a meaningful classification system.
3. Develop a consistent ecological indicator value system in the Arctic to assess ecosystem health and resilience and the impacts of climate change.
4. Support training and mentorship opportunities and interdisciplinary collaborations to equip young scientists with necessary skills in vegetation classification, taxonomy, and data analysis.
5. Expand on vegetation habitat classification. Encourage its use in developing plot surveys and as a means for helping standardize syntaxonomy across national classification approaches.

PANEL 7: MAPPING AND REMOTE SENSING

MODERATORS

Martha Raynolds, University of Alaska Fairbanks, USA
Briana McNeal, University of Alaska Fairbanks, USA

PANELISTS

Jakob Assman, University of Zurich, Switzerland
Gerald Frost, Alaska Biological Research, Inc., USA
Marc Marias-Fauria, University of Cambridge, UK
Ian Olthof, Environment Climate Change, Canada
Kathleen Orndahl, Northern Arizona University, USA

The goal of this panel is to identify opportunities for Arctic vegetation mapping in the next 10 years. Questions for the panel and following breakout groups included:

- What direction do you see Arctic vegetation mapping moving in the next 10 years?
- What are two major gaps/opportunities for Arctic vegetation mapping that could be addressed in the next 10 years?
- How do you see your specialization(s) related to vegetation mapping best fitting into current and/or future projects in your research group and/or organization?

SUMMARY

The vegetation mapping breakout-session discussed: (1) Approaches for data management of the Arctic Vegetation Map Archive and links to other Arctic map archives such as the ORNL-DAAC and the Arctic Data Center, including reorganization of the map catalog and a GIS-based map index; and (2) inclusion of recent Arctic vegetation maps that are applying multi-dimensional remote-sensing and Artificial Intelligence approaches (e.g., Jones et al. 2021, Witharana et al. 2021, Kattenborn 2021)

To develop stronger assessments, the workshop also weighed advantages and disadvantages of adopting or supplementing the current AVA-AK protocols with newer approaches, such as multi-dimensional remote-sensing approaches to map vegetation change (e.g. Fraser et al. 2018, Abolt and Young 2020, Yang et al. 2020, Eischeid et al. 2021, Orndahl et al. 2022, Pouliot et al. 2022, Bergstedt et al. 2023).

RECOMMENDATIONS

1. Focus on why vegetation of some areas of the Arctic are changing fast and others are changing slowly or not at all.
2. Coordinate and link Arctic map archives such as the Alaska Arctic Geoecological Atlas, the ORNL-DAAC and the Arctic Data Center.
3. Make sure satellite data collection remains effective for vegetation mapping, including inter-compatibility for long-term time series, and affordable access.
4. Incorporate machine learning in vegetation mapping.
5. Develop maps that include newly exposed Arctic areas along glacier boundaries, Arctic-boreal transition areas, and treeless oceanic boreal areas (see Toward IPY5, idea 4, p. 15).
6. Explore methods of mapping that place the Arctic within a global context of zonal and azonal biomes (see Toward IPY5 ideas 5 and 6, p. 16 and 17).

APPENDIX E | RESOLUTION OF THE CAVSI WORKSHOP

PREAMBLE

This resolution expresses the mutual intent of the undersigned participants at the Circumpolar Arctic Vegetation Science Initiative (CAVSI) Workshop, 21-23 March 2025, in Boulder, CO, to address in principle the goals as outlined in the CAVSI White Paper.

RESOLUTION OF THE CIRCUMPOLAR ARCTIC VEGETATION SCIENCE INITIATIVE WORKSHOP, ARCTIC SCIENCE SUMMIT WEEK, BOULDER, COLORADO, MARCH 21–23, 2025

Whereas, up-to-date knowledge of the present distribution, characteristics, and history of Arctic flora and vegetation are of essential importance with regard to the Fourth International Conference on Arctic Research Planning (ICARP IV) efforts to engage the international community on critical topics and priorities for Arctic research in the next 10 years including the 5th International Polar Year (IPY5); and

Whereas, our knowledge of Arctic regions and the environmental constraints on Arctic vegetation has greatly increased, and the existing vegetation data have expanded exponentially since the first Arctic Vegetation Classification workshop at Boulder in 1992; and

Whereas, the methods of sampling, archiving, classifying, and mapping vegetation have also changed and updated protocols are needed for collaborative international Arctic research;

Be it resolved that the international community of Arctic vegetation researchers agrees to:

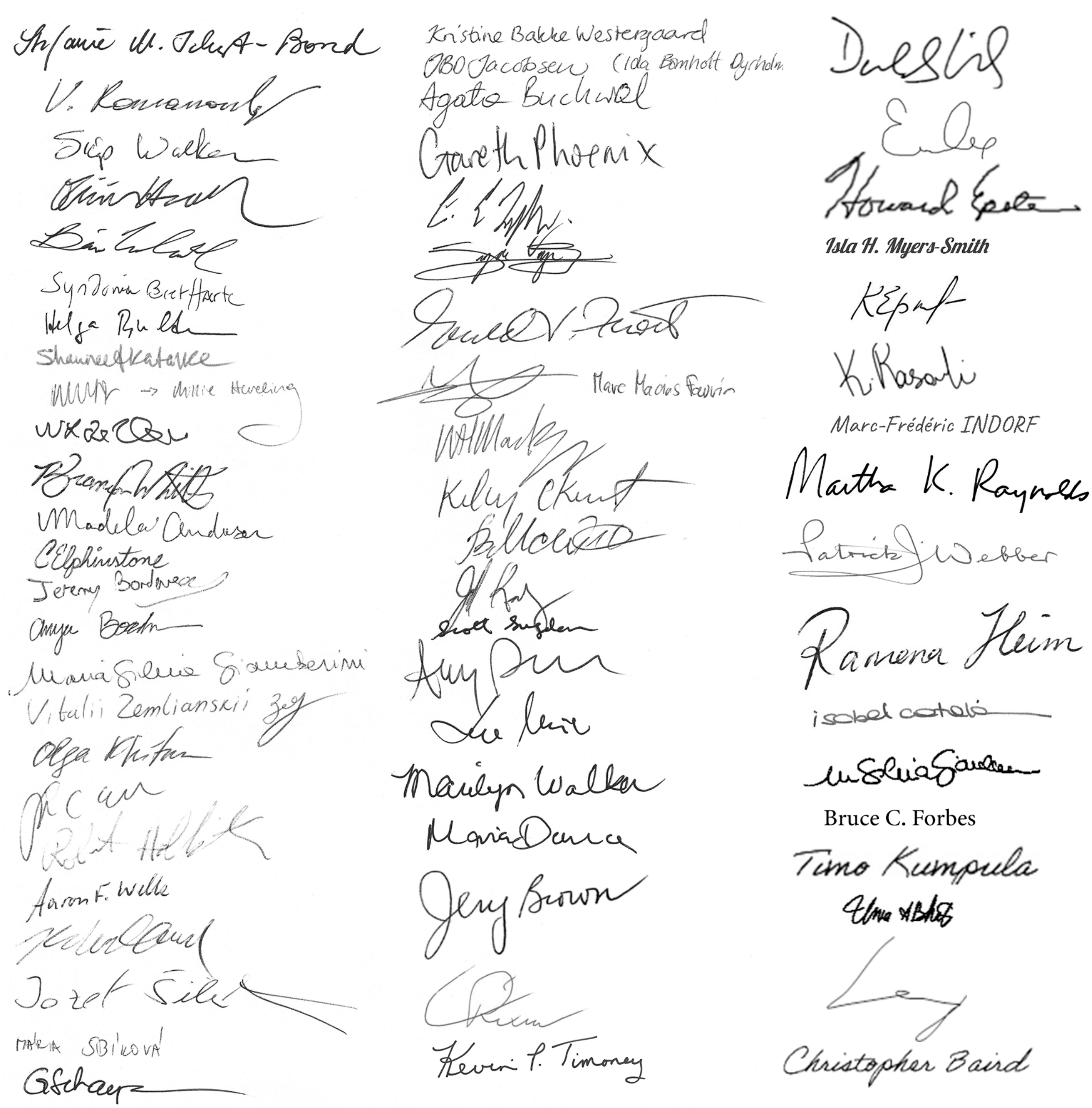
1. **Establish a Circumpolar Arctic Vegetation Science Initiative (CAVSI)** with an administrative organization and an early career Arctic vegetation researchers group;
2. **Develop an Arctic Vegetation Observation Network (AVON)** based on existing interdisciplinary networks, identify gaps in the geographic distribution of observation sites, and fill the gaps where feasible;
3. **Develop international protocols** for:
   - **Species lists and local floras:** Update, maintain, and publish a Pan Arctic Species List (PASL) that includes vascular plants, bryophytes and lichens as a common taxonomical base, and promote the development of local floras (complete species lists) at Arctic research stations;
   - **Vegetation sampling:** Adopt standardized protocols for plot surveys that are widely used by the international vegetation science community, that include traditional plot survey methods, and where feasible, use new transformative methods appropriate for observing, modeling, reconstructing, and predicting Arctic vegetation change;
   - **Vegetation archives:** Develop regional archives for plot data, methods to harmonize and standardize the data, and merge the regional archives into a circumpolar Arctic Vegetation Archive (AVA);
   - **Vegetation classification:** Develop local, regional, and circumpolar Arctic vegetation classifications (AVCs) based on standardized approaches developed by the international community of vegetation scientists, including a circumpolar checklist of vegetation syntaxa (classified vegetation units) and crosswalks to equivalent units in other regional and national classification approaches;
   - **Vegetation mapping:** Revise, edit, and publish a new version of the Circumpolar Arctic Vegetation Map (CAVM v. 3) with increased resolution and a hierarchical legend approach that can be applied to maps at global, regional, landscape, and plot scales.

4. **Collaborate with IASC working groups and other organizations to apply the products of CAVSI to priority ICARP IV and IPY5 research topics**, including for example, applications related to changing climate, sea-ice distribution, permafrost, hydrology, infrastructure, land use, wildlife habitat, biodiversity, and global carbon budgets.

Furthermore, the undersigned scientists agree to develop the organizational mechanisms, science plan, and proposals necessary to complete the above tasks. We will reconvene periodically at international Arctic and vegetation science meetings to continue to advance the initiative.

Signed by the attendees at CAVSI Workshop, March 23, 2025, in Boulder, CO.

2025 CAVSI WORKSHOP RESOLUTION SIGNATORIES



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