The CAVM integrated terrain unit mapping approach as developed for northern Alaska

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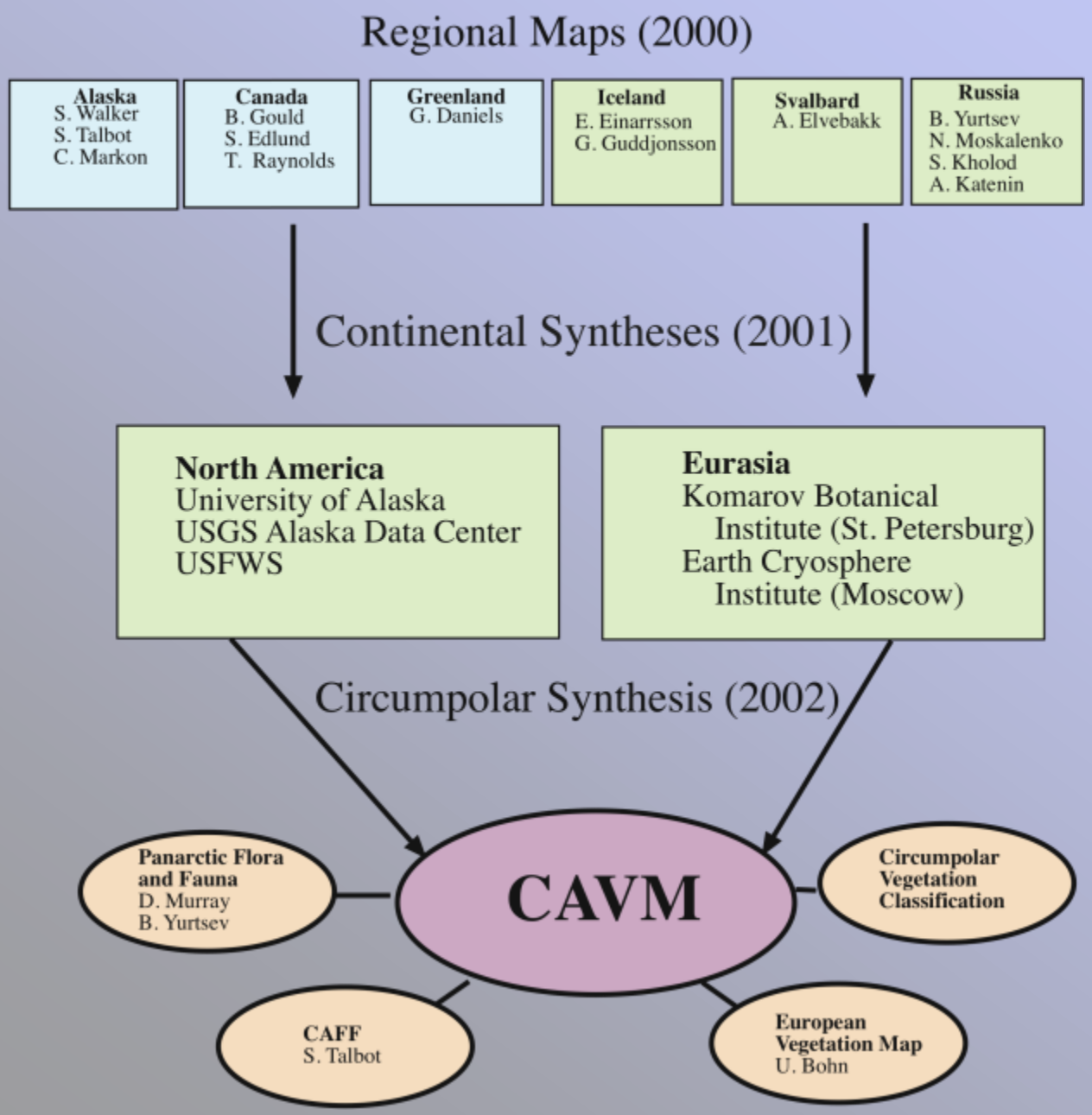
Introduction

- *The mapping methodology is distinct from development of the mapping legend. It refers to the process of delineation of the map polygons.*
- *Existing maps of the boreal region have a multitude of scales, legends, projections, languages and mapping approaches. Many areas have no good existing vegetation maps.*
- *The CBVM editorial board should consider developing a specific mapping methodology that could be applied consistently across the boreal forest domain by all participating countries.*
- *Here I summarize the 6-step integrated mapping method that was used for making the Circumpolar Arctic Vegetation Map with specific reference to the Alaska North Slope, where the method was first applied.*

Initial plan for CAVM synthesis



Equivalent subzones

	Russia			North America					Fennoscandia	
CAVM subzone	**Alexandrova (1980)**	**Yurtsev (1994)**	**Matveyeva (1998)**	**Polunin (1951)**	**Edlund (1990) Edlund & Alt (1989)**	**Bliss (1997)**	**Daniels et al. (2000)**	**Walker et al. (2002)**	**Tuhkanen (1986)**	**Elvebakk (1999)**
A	Northern polar desert Southern polar desert	High Arctic tundra	Polar desert	High Arctic	Herbaceous and cryptogam	High Arctic	Arctic herb	Cushion forb	Inner polar Outer polar	Arctic polar desert
B	Northern Arctic tundra	Arctic tundra: northern variant	Arctic tundra	Middle Arctic	Herb-prostrate shrub transition Prostrate shrub		Northern Arctic dwarf shrub	Prostrate dwarf shrub	Northern Arctic	Northern Arctic tundra
C	Middle Arctic tundra Southern Arctic tundra	Arctic tundra: southern variant	Typical tundra		Dwarf and prostrate shrub		Middle Arctic dwarf shrub	Hemi-prostrate dwarf shrub	Middle Arctic	Middle Arctic tundra
D	Northern sub-Arctic tundra Middle sub-Arctic tundra	Northern hypo-Arctic tundra		Low Arctic	Low erect shrub	Low Arctic	Southern Arctic dwarf shrub	Erect dwarf shrub	Southern Arctic	Southern Arctic tundra
E	Southern sub-Arctic tundra	Southern hypo-Arctic tundra	Southern tundra				Arctic shrub	Low shrub		Arctic shrub-tundra

Vegetation properties in each subzone

Subzone	Mean July Temp[1] (ūC)	Summer warmth index[2] (ūC)	Vertical structure of plant cover[3]	Horizontal structure of plant cover[3]	Major plant growth forms[4]	Dominant vegetation unit (see Detailed Vegetation Descriptions for species)	Total phyto-mass[5] (t ha^{-1})	Net annual production[6] (t ha^{-1} yr^{-1})	Number of vascular plant species in local floras[7]
A	0-3	<6	Mostly barren. In favorable microsites, 1 lichen or moss layer <2 cm tall, very scattered vascular plants hardly exceeding the moss layer	<5% cover of vascular plants, up to 40% cover by mosses and lichens	b, g, r, cf, of, ol, c	B1, G1	<3	<0.3	<50
B	3-5	6-9	2 layers, moss layer 1-3 cm thick and herbaceous layer, 5-10 cm tall, prostrate dwarf shrubs <5 cm tall	5-25% cover of vascular plants, up to 60% cover of cryptogams	npds, dpds, b, r, ns, cf, of, ol	P1, G1	5-20	0.2-1.9	50-100
C	5-7	9-12	2 layers, moss layer 3-5 cm thick and herbaceous layer 5-10 cm tall, prostrate and hemi-prostrate dwarf shrubs <15 cm tall	5-50% cover of vascular plants, open patchy vegetation	npds, dpds, b, ns, cf, of, ol, ehds* * in acidic areas	G2, P2	10-30	1.7-2.9	75-150
D	7-9	12-20	2 layers, moss layer 5-10 cm thick and herbaceous and dwarf-shrub layer 10-40 cm tall	50-80% cover of vascular plants, interrupted closed vegetation	ns, nb, npds, dpds, deds, neds, cf, of, ol, b	G3, S1	30-60	2.7-3.9	125-250
E	9-12	20-35	2-3 layers, moss layer 5-10 cm thick, herbaceous/ dwarf-shrub layer 20-50 cm tall, sometimes with low-shrub layer to 80 cm	80-100% cover of vascular plants, closed canopy	dls, ts*, ns, deds, neds, sb, nb, rl, ol *in Beringia	G4, S1, S2	50-100	3.3-4.3	200 to 500

[1] based on Edlund (1996) and Matveyeva (1998).
[2] Sum of mean monthly temperatures greater than 0ūC, modified from Young (1971).
[3] Chernov and Matveyeva (1997).
[4] b - barren; c - cryptogam; cf - cushion or rosette forb; deds - deciduous erect dwarf shrub; dls - deciduous low shrub; dpds - deciduous prostrate dwarf shrub; g - grass; ehds - evergreen hemiprostrate dwarf shrub; nb - nonsphagnoid bryophyte; neds - nondeciduous erect dwarf shrub; npds - nondeciduous prostrate dwarf shrub; ns - nontussock sedge; of - other forb; ol - other lichen; r - rush; rl - reindeer lichen; sb - sphagnoid bryophyte; ts - tussock sedge. Underlined codes are dominant.
[5] Based on Bazilevich, Tishkov and Vilcheck (1997), aboveground + belowground, live + dead.
[6] Based on Bazilevich, Tishkov and Vilcheck (1997), aboveground + belowground.
[7] Number of vascular species in local floras based mainly on Young (1971).

Division of the mapping effort by geographic regions

Alaska:

- **Northern Alaska**, Skip Walker.
- **Seward Peninsula,** Martha Raynolds.
- **Southwest Alaska**, Carl Markon and Steve Talbot.

Canada:

- **Northern Arctic Canada**, Bill Gould and Larry Bliss.
- **Southern Arctic Canada**, Bill Gould, Dietbert Thannheiser, Steve Zoltai, and Helmut Epp.

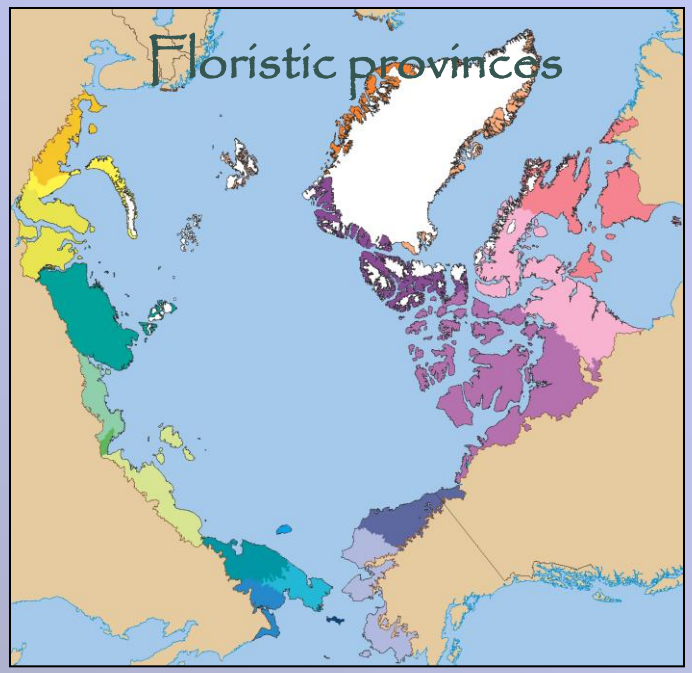
Greenland: Fred Daniels and Christian Bay.

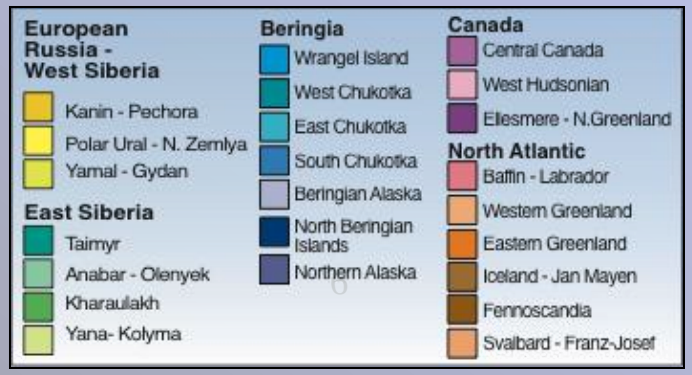
Svalbard and Scandinavia: Arve Elvebakk, Bernt Johanasson.

Iceland: Eythor Einnarsson, Gudmundur Gudjonsson.

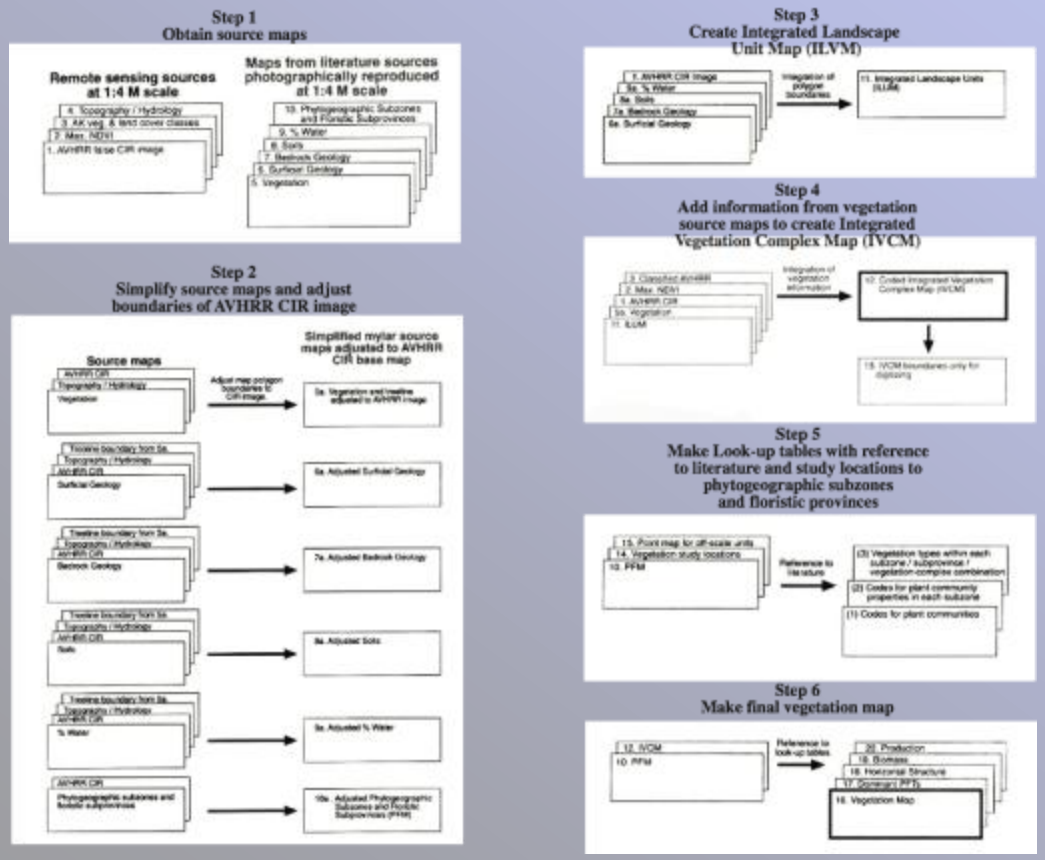
Russia:

- **European Russian**, Sergei Kholod, I.S. Iljina, T.K. Yurkovskaya;
- **West Siberia**, Sergei Kholod, Natasha Moskolenko, Liya Meltzer
- **Taimyr Peninsula**, Sergei Kholod, Nadya Matveyeva, Raisa Schelkunova,
- **Franz Josef Land**, Sergei Kholod
- **Yakutia**, Alexei Polezhaev, Valentina Perfilieva,
- **Chukotka**, Alexei Polezhaev, Adrian Katenin.





The 6-Step Integrated Vegetation Mapping Method



- *Consolidation of information from many source maps onto a single map.*
- *Map polygons are coded with many attributes in a GIS database.*
- *In areas where the vegetation is poorly known, terrain attributes help determine the dominant vegetation.*

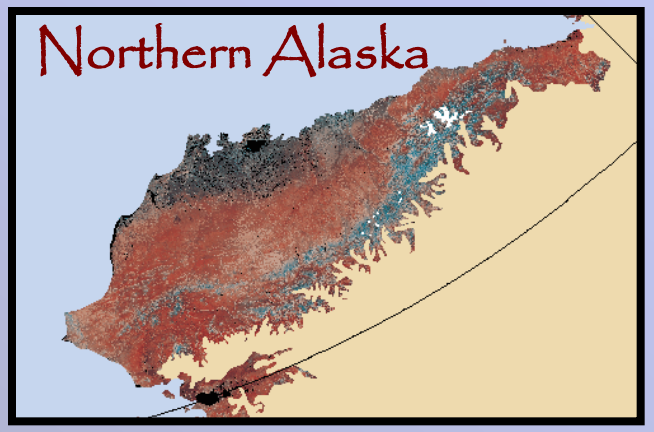
Similar approaches

- *Landscape units of the "Landschaft" approach in Russia (Minkin et al. 2002).*
- *The landscape guided approach used in Europe (Zonnelveld 1980).*
- *The geobotanical mapping method developed for northern Alaska (Walker et al. 1980).*
- *Integrated terrain unit mapping approach (ITUM) used by ESRI in the U.S. (Dangermond and Harding 1992).*

From Walker et al. 1999. Int. J. Remote Sens. 21: 4551-4570.

6-step integrated vegetation mapping method first applied to northern Alaska (Walker et al. 1999)

- *The approach was used in Arctic areas where little vegetation-map information was available at the required scale or with appropriate legends (Canada, Alaska, Greenland).*
- *Much of Russia was mapped combining existing small scale vegetation maps with the Russia "Landschaft approach" developed at the Earth Cryosphere Laboratory in Moscow (Minkin et al. 2001).*
- *Svalbard and Iceland were mapped based on existing maps.*

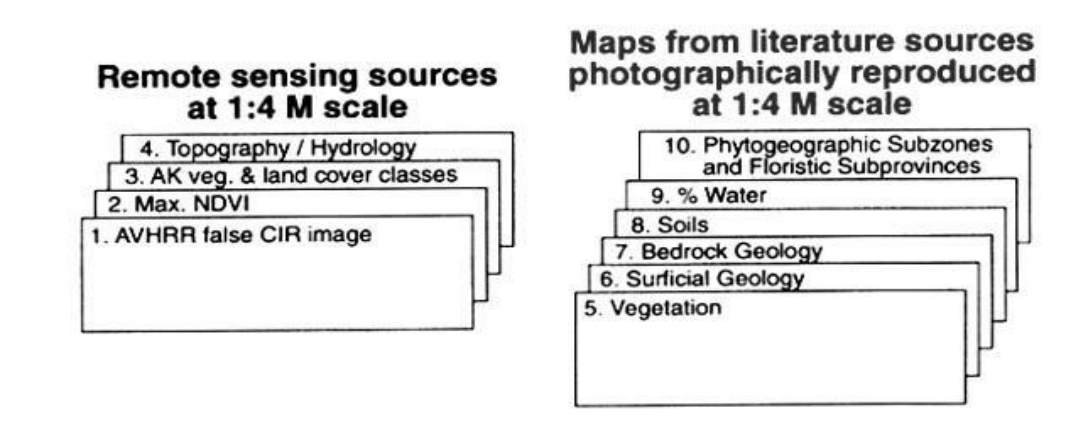


Not all of the Arctic was mapped using the this method.

The most critical factor was to adjust the map boundaries from various sources to a standard base map, the mosaic of AVHRR satellite images.

Method applied to Northern Alaska

Step 1: Obtain source maps



Remote sensing products:

1. *AVHRR false color infrared image (USGS, Fleming 1997)*
2. *Max NDVI (USGS, Fleming 1997)*
3. *AK vegetation land-cover classes (Fleming 1997)*
4. *Topography, hydrology, and coastal boundaries (GTOPO30 global DEM, Gesch et al. 1999)*

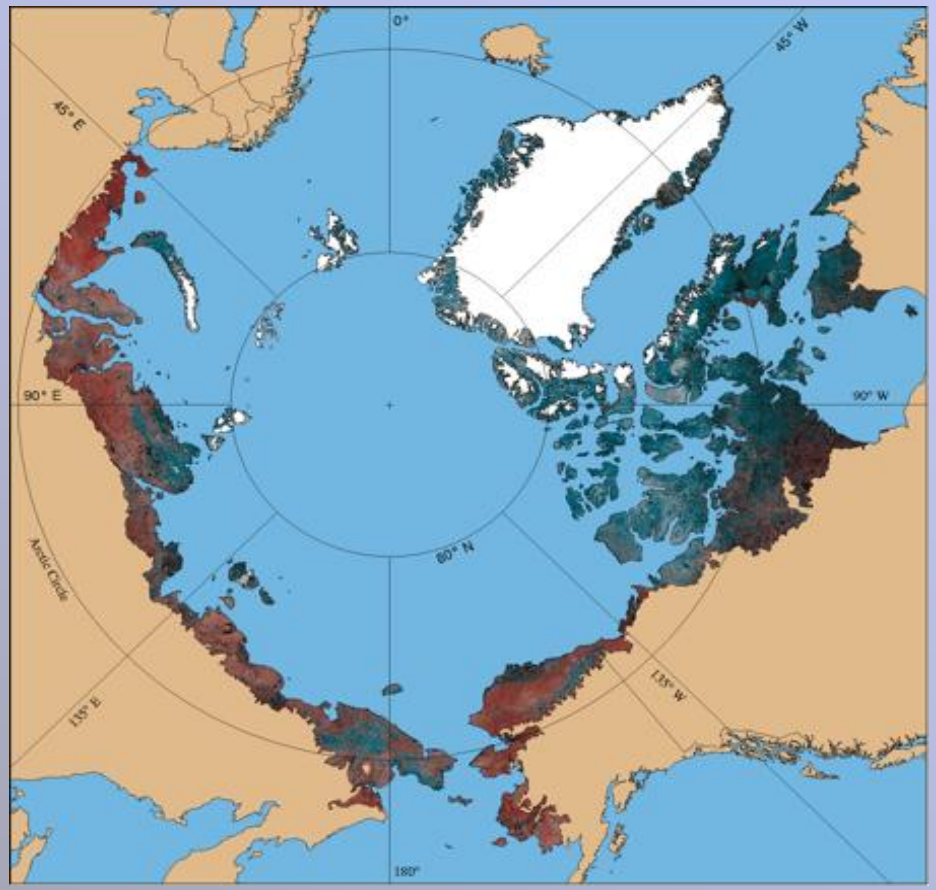
Maps from literature sources:

5. *Vegetation (Spetzman 1959, Ecosystems of Alaska, Joint Federal State Land-Use Planning Commission 1973)*
6. *Surficial geology (Karlstrom 1964 and Willims 1977)*
7. *Bedrock geology (Beikman 1980 and Moore et al. 1994)*
8. *Soils (Reiger et al. 1979)*
9. *Percent water (Sellman et al. 1975)*
10. *Phytogeographic subzones and Floristic subprovinces (Yurtsev 1994, Elvebakk 1999)*

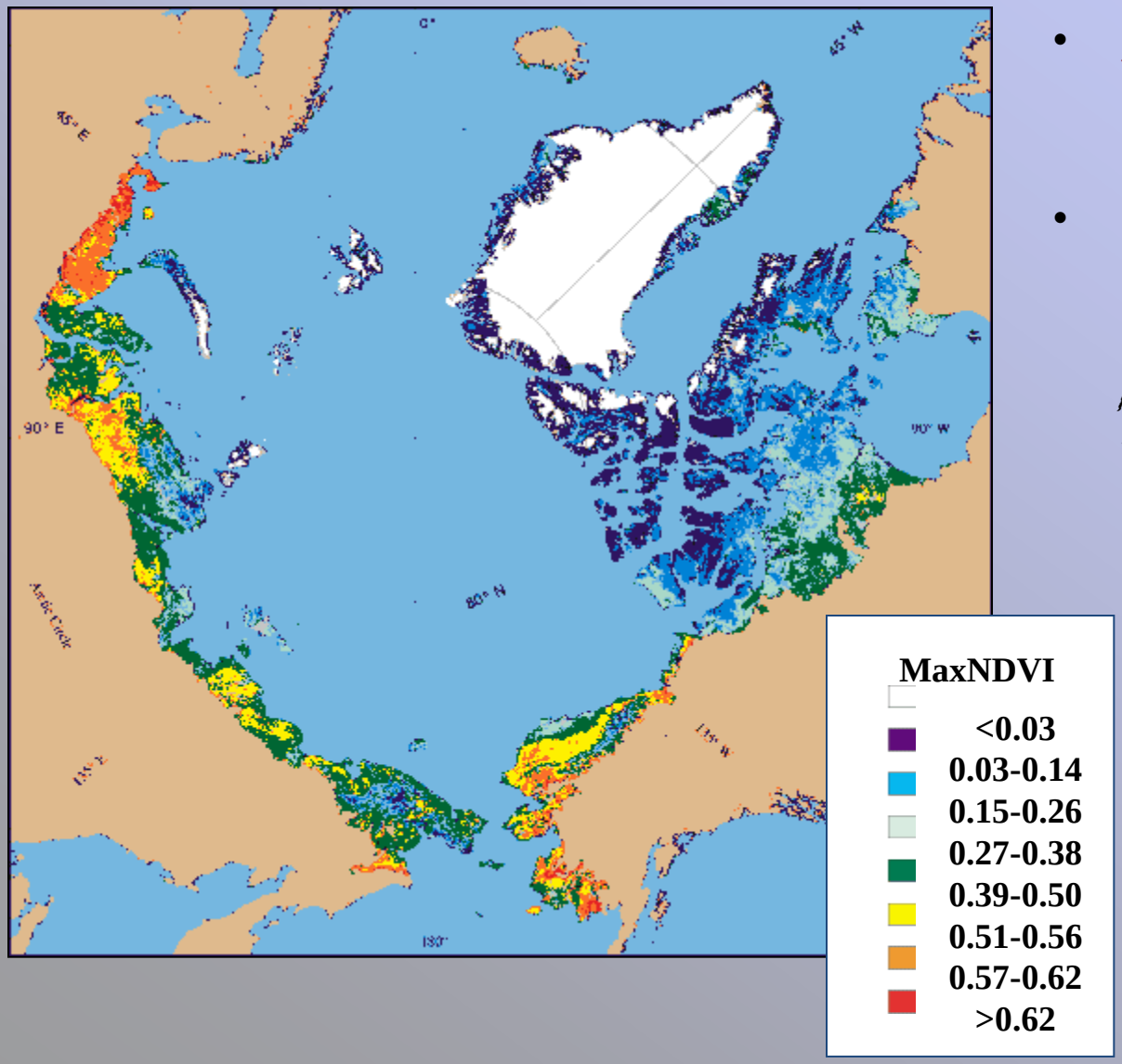
- All maps were photographically reproduced to 1:4M scale.

Circumpolar Map sources the best

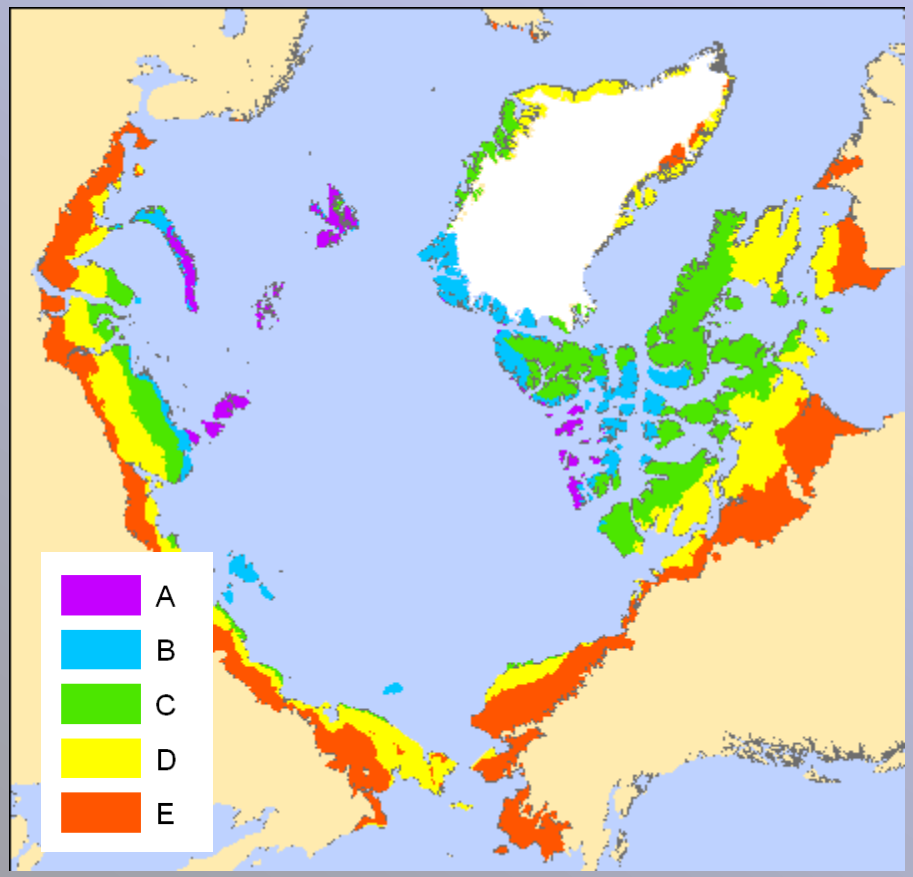
- ***The base image was a key first step because it provided a common base and scale on which all countries could do the mapping.***
- *Defined the domain of the map ("Arctic Tundra Zone" = "Arctic Bioclimate Zone").*



MaxNDVI map of the circumpolar Arctic

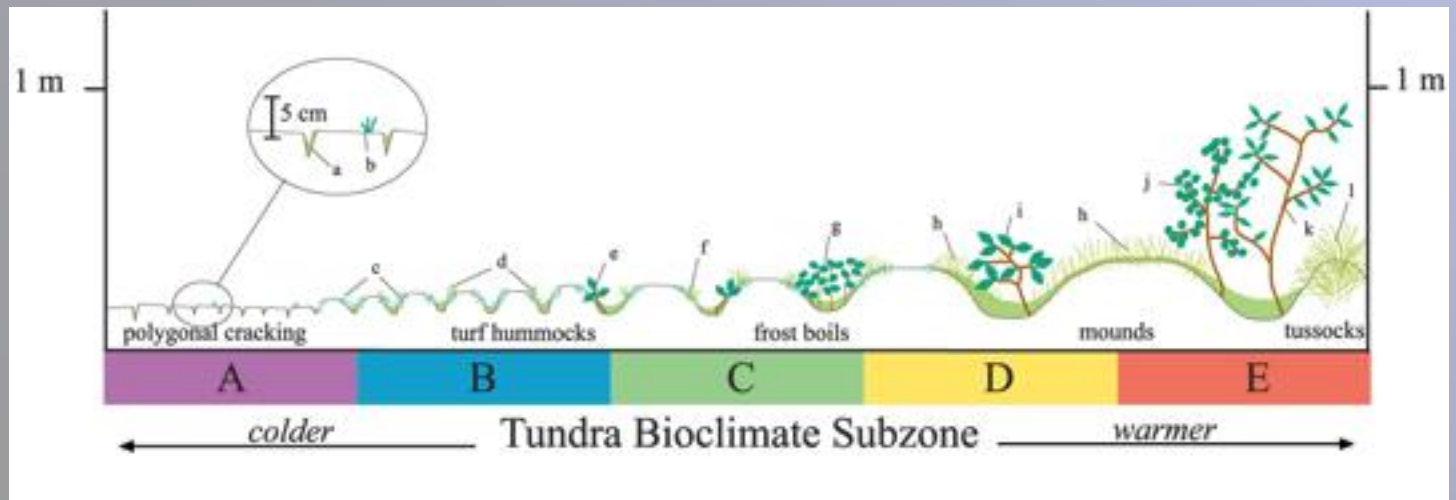


- NDVI derived from the AVHRR base data
- Very useful for delineating many vegetation boundaries, particularly shrublands.



Arctic bioclimate subzones

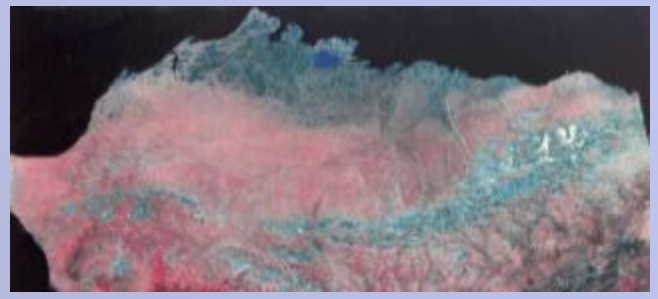
- Defined on basis of climate and dominant plant growth forms in each subzone
- Adopted primarily from Russian subzones (Yurtsev 1994) as modified by Elvebakk (1999).
- General agreement on boundaries, but not on terminology, so letters were assigned to each subzone.



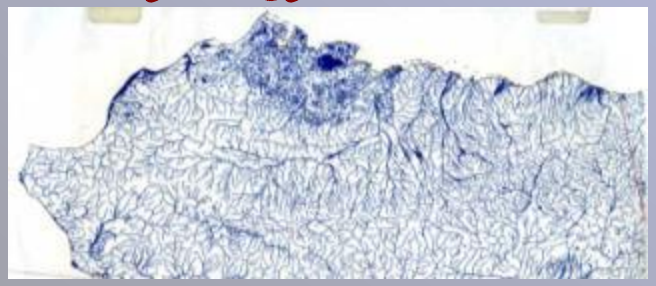
DEM and remote sensing products

Map domain

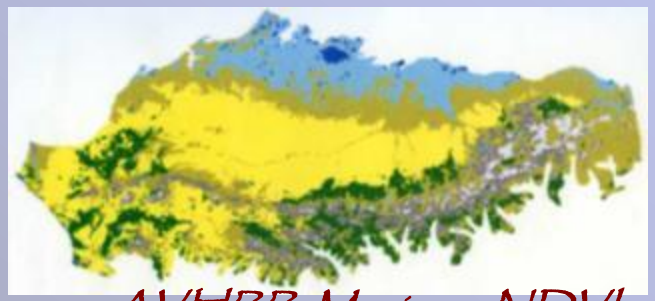
AVHRR False-CIR image (Fleming 1997)



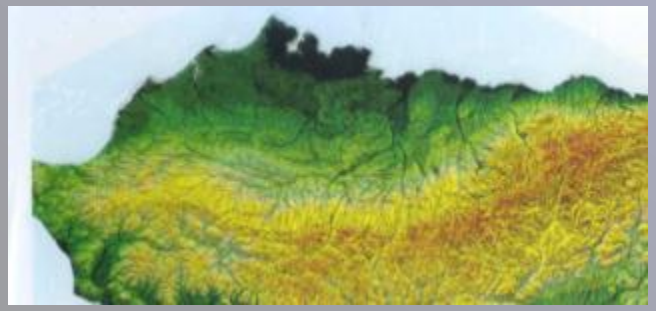
Hydrology and coastlines



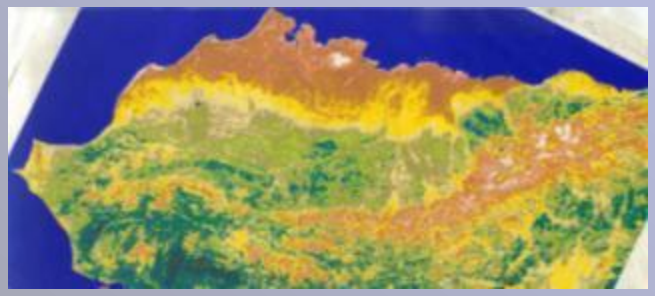
AVHRR Landcover Classification



Topography



AVHRR Maximum NDVI

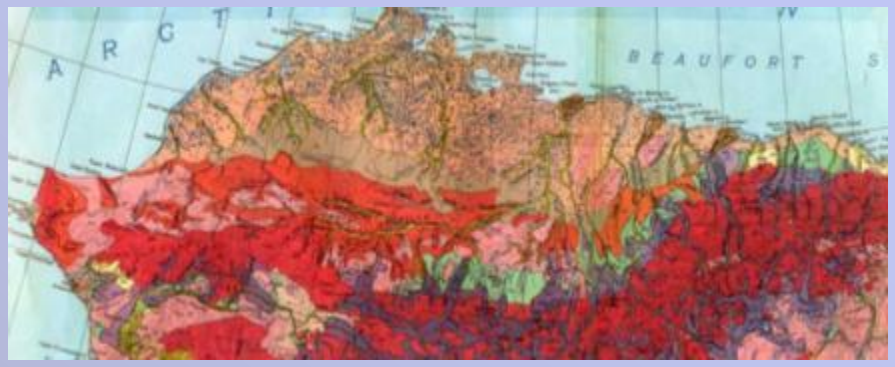


All maps registered to map domain and AVHRR False-CIR.

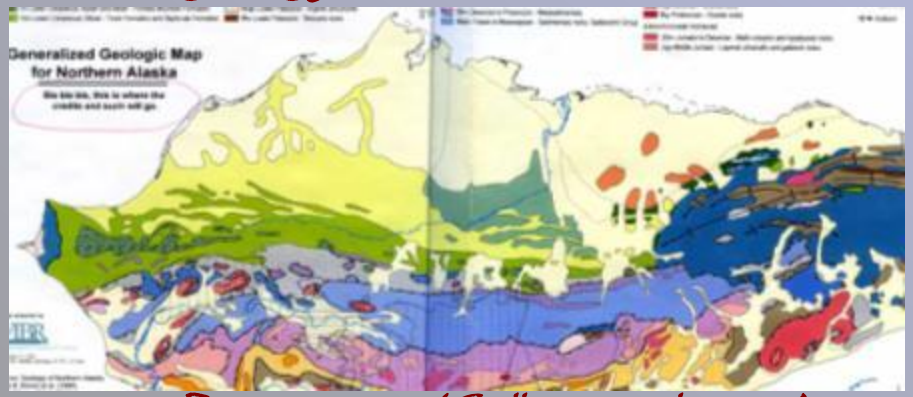
Published and derived maps

Landscape units

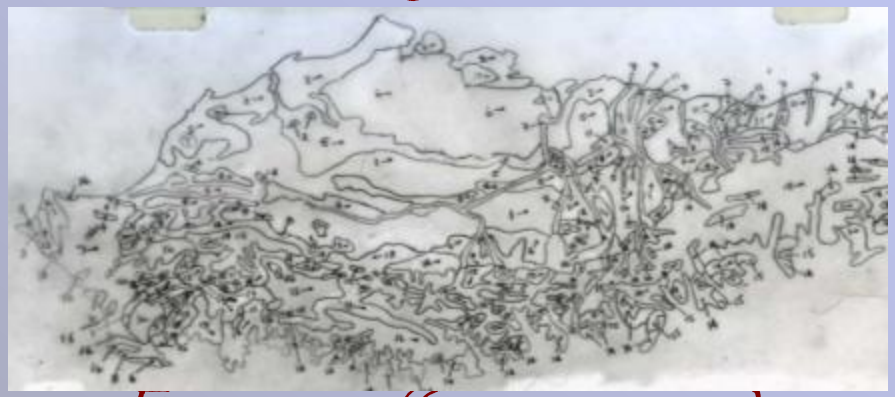
Surficial geomorphology (Karlstrom et al 1964)



Bedrock geology (Beikman 1974, Moore 1980)

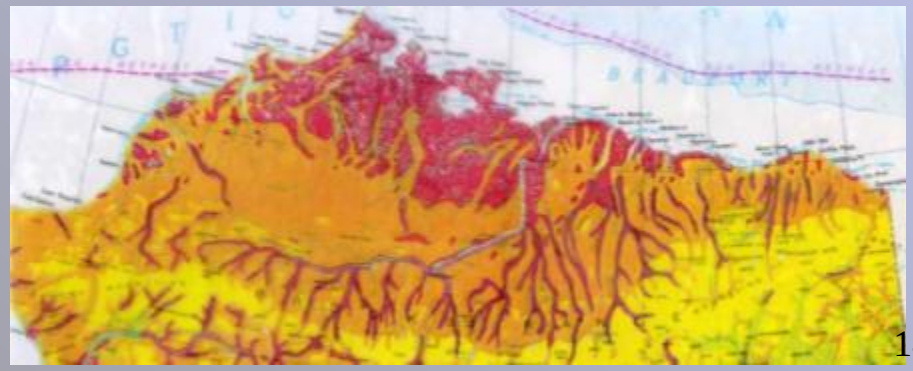


Soils (Rieger et al 1964)



Percent water(Sellman et al. 1975)

Ecosystems (Spetzman 1959)



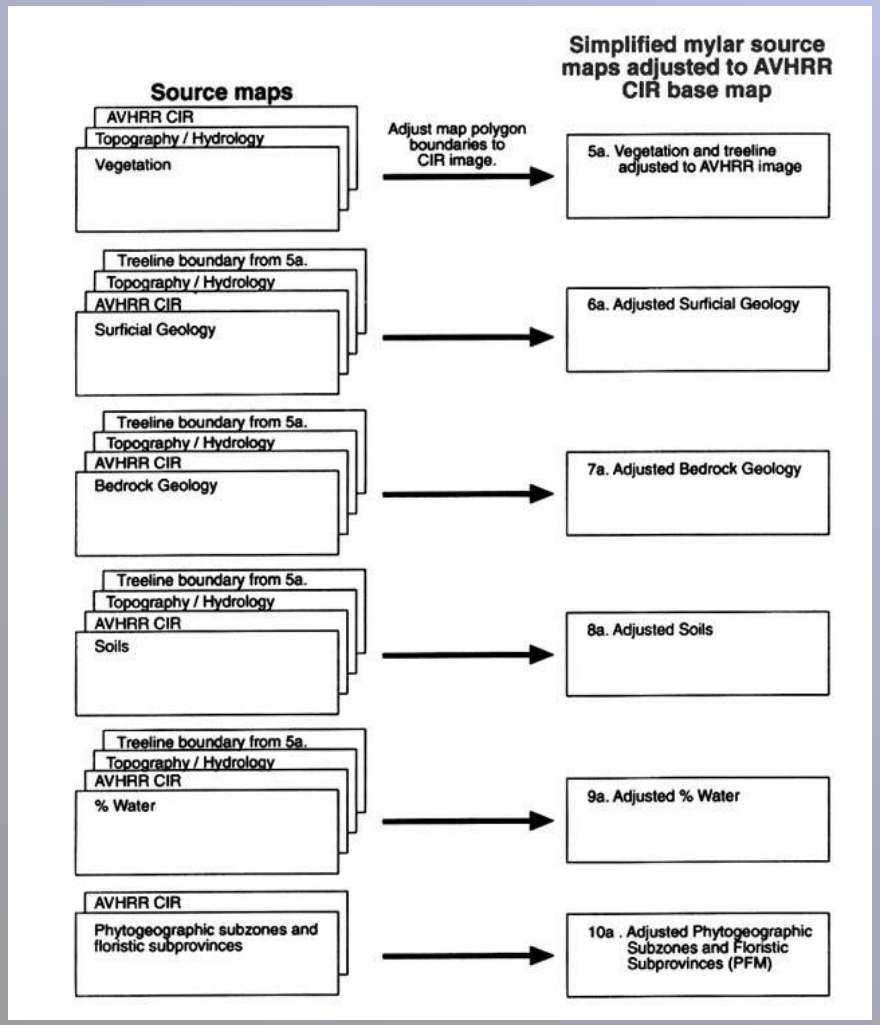
Landscape Unit map

- *Missing from the description in Walker et al. 1999.*
- Photo-interpreted from the AVHRR CIR image.
- Shows the major landscape units (mountains, hills, plains, floodplains.
- The landscape units are based on the the Russian "Landschaft" approach (Minkin et al. 2001).
- The most important terrain map of the lot because it fixed many of the boundaries for vegetation and other units.

Landscape units

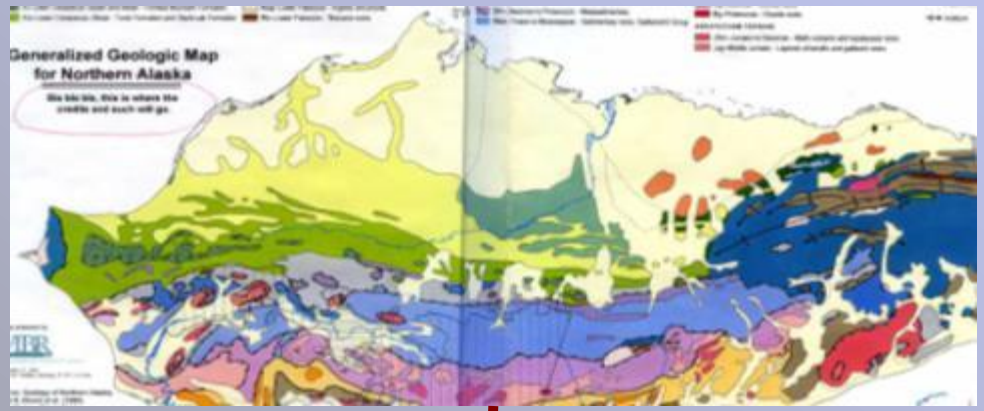
1. Lakes
2. Ocean
3. Plains
4. Plateaus
5. Hills and low mountains without altitudinal belts.
6. Mountains with altitudinal belts.
7. Floodplains and deltas

Step 2: Simplify source maps



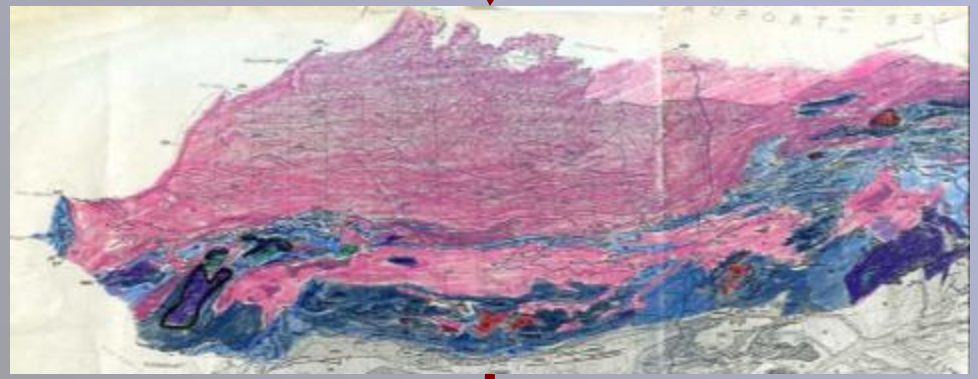
- *Polygon boundaries drawn on mylar overlays of the source maps at 1: 4M scale.*
- *Legends and detail simplified to contain only information of known relevance to the vegetation.*
- *All boundaries are adjusted to conform with the AVHRR base map.*
- *Minimum polygon size 3.5 mm except for linear features (2 mm).*

Example of simplified map



Bedrock geology Map, 1:3M scale (Moore 1980 generalized by ABR)

- Many units, mostly unimportant to vegetation



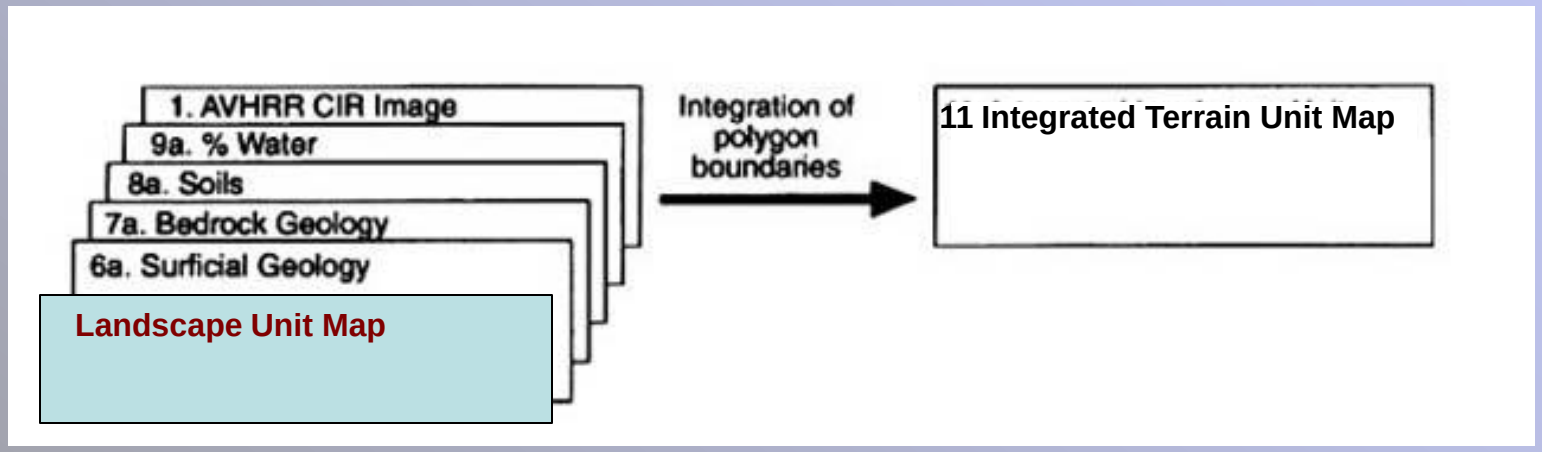
Retain geology important to vegetation:

1. Acidic sedimentary rocks (sandstones, conglomerates, shales, etc.)
2. Acidic felsic rocks, primarily intrusives
3. Nonacidic sedimentary rocks or mixtures with nonacidic sources (mainly limestones, dolomites, etc.)
4. Ultramafic rocks, primarily basic intrusives.
5. Volcanic rocks.

Adjusted and simplified bedrock geology map, 1:4M scale

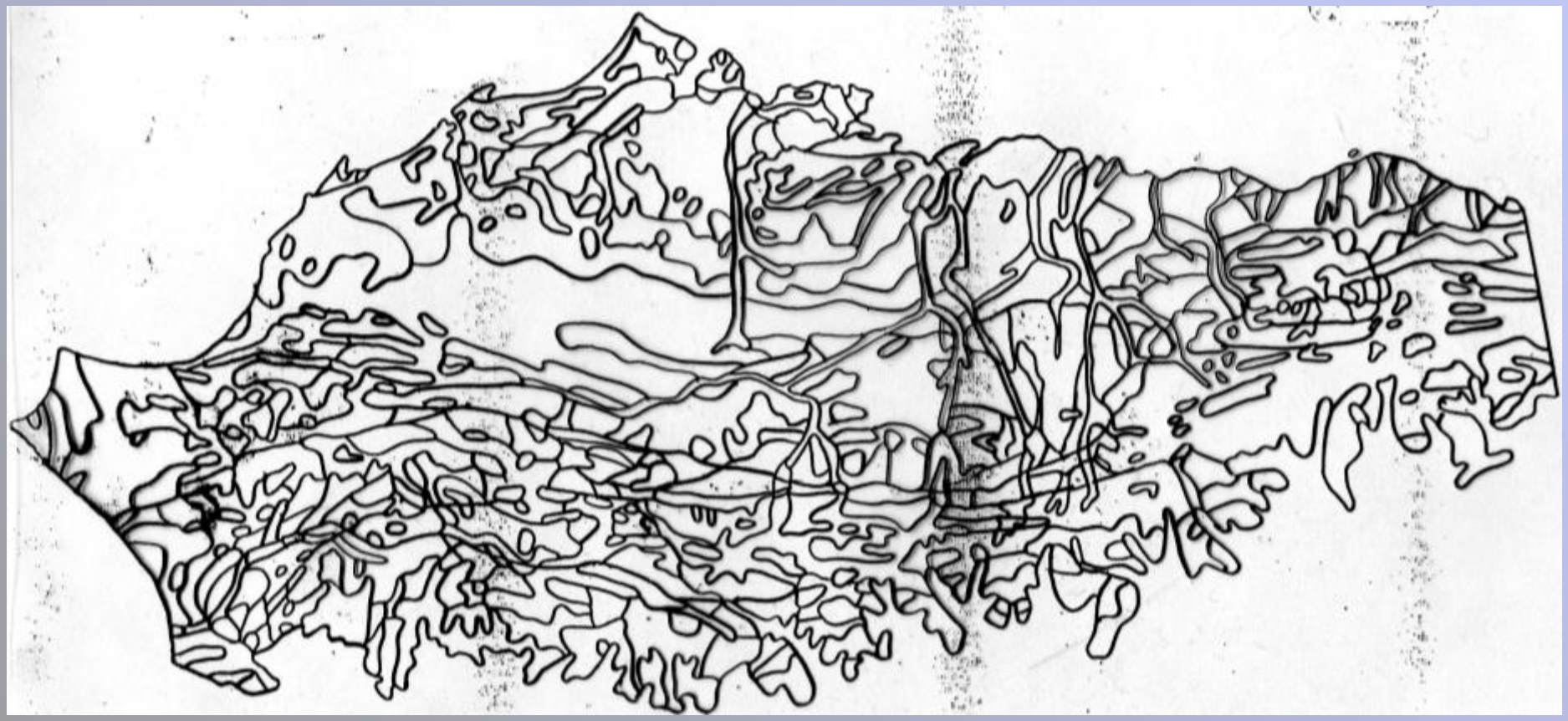
- Boundaries adjusted to terrain on AVHRR image.
- Units grouped in units important to vegetation.

Step 3: Create Integrated Terrain Unit Map (ITUM)



- *All maps were photographically reproduced at 1: 4M scale.*
- *Boundaries were all adjusted to the AVHRR CIR image and DEM coastlines, lakes and rivers <u>and landscape unit boundaries</u>.*
- *(In Walker et al. 1999, The Landscape Unit map is missing from the left side of this diagram! And the right side should be labeled <u>Integrated Terrain Unit Map</u> (ITUM).*

ITUM polygon map



Simplified Legend for North Slope Integrated Terrain Units

Mountains

1. Acidic mountain complex with coarse deposits, extensive bedrock
2. Nonacidic mountain complex with coarse deposits, extensive bedrock
3. Acidic plateau, basin, or plain complex
4. Nonacidic plateau, basin, or plain complex
5. Glaciated valley and moraine complex

Hills

6. Acidic hill complex with rare bedrock outcrops
7. Acidic hill complex with occasional bedrock outcrops
8. Nonacidic hill complex with rare bedrock outcrops
9. Nonacidic hill complex with occasional bedrock outcrops,

Plains

10. Acidic plains, <25% lakes
11. Acidic plains, 25-75% lakes
12. Nonacidic plains, <25% lakes
13. Nonacidic plains 25-75% lakes
14. Deltas and coastal wetlands (saline)

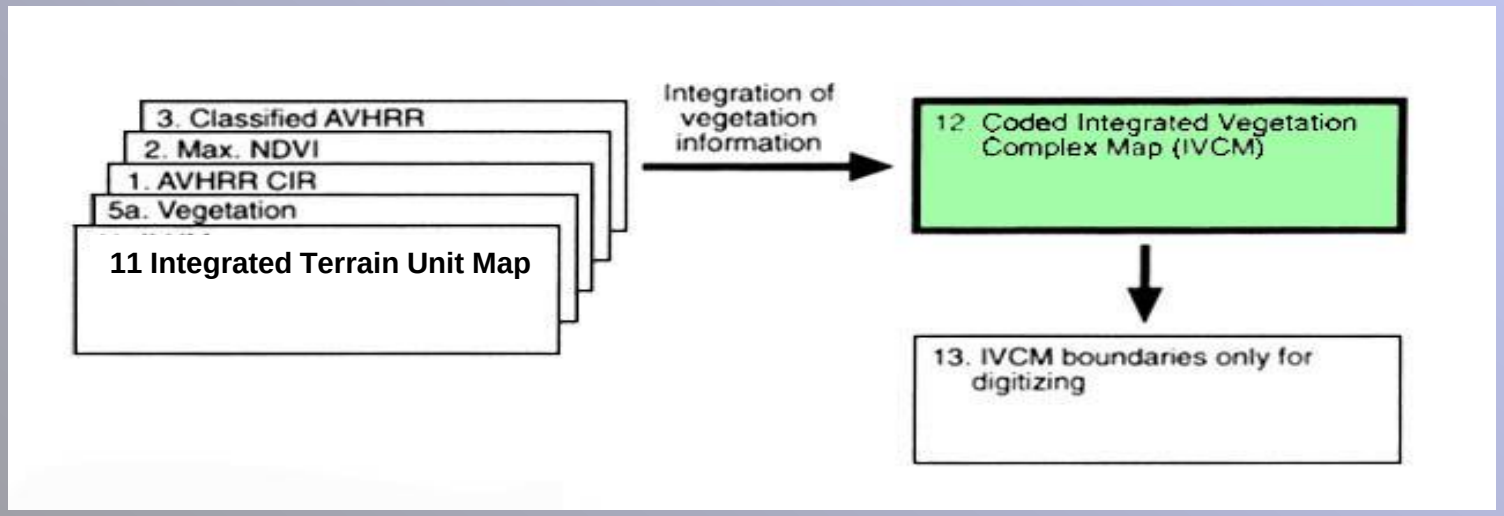
Riparian areas

15. River floodplain complex

Water and glaciers

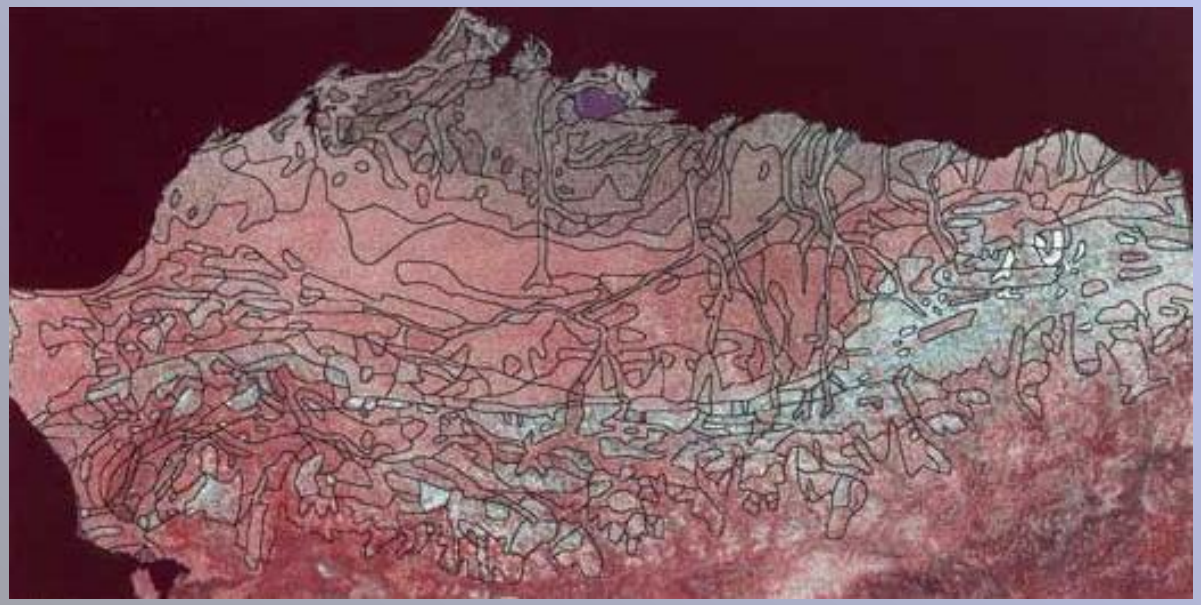
16. Water or lake complex (>75% water cover)
17. Glacier complex (>75% glacier cover)

Step 4: Create Integrated Vegetation-Complex Map (IVCM)



- ***Vegetation map units are derived from information on the ITUM plus information from the various vegetation map sources (landcover classification, NDVI, vegetation maps).***

IVCM boundaries



IVCM overlaid on the AVHRR image

Clean IVCM polygon map ready for digitizing

- Each polygon assigned a unique polygon ID number.
- Attribute file created containing string of geobotanical attributes for each polygon.

Vegetation Complex legend

Mountains

1. Acidic mountain vegetation complex with coarse rubbly deposits, extensive bedrock, and vertical zonation
2. Nonacidic mountain vegetation complex with coarse rubbly deposits, extensive bedrock, and vertical zonation
3. Acidic plateau, basin, or plain vegetation complex
4. Nonacidic plateau, basin, or plain vegetation complex
5. Glaciated valley and moraine vegetation complex

Hills

6. Acidic hill vegetation complex with rare bedrock outcrops, no vertical zonation
7. Acidic hill vegetation complex with occasional bedrock outcrops, no vertical zonation
8. Nonacidic hill vegetation complex with rare bedrock outcrops, no vertical zonation
9. Nonacidic hill vegetation complex with occasional bedrock outcrops, no vertical zonation
10. Low- to high-shrub vegetation tundra complex on uplands
11. Subalpine shrubland vegetation complex
12. Mixed evergreen and deciduous forest complex on uplands (border area with Canada)

Wetlands

13. Acidic mire vegetation complex, <25% lakes
14. Acidic mire vegetation complex, 25-75% lakes
15. Nonacidic mire vegetation complex, <25% lakes
16. Nonacidic mire vegetation complex 25-75% lakes
17. Coastal mire vegetation complex (saline)

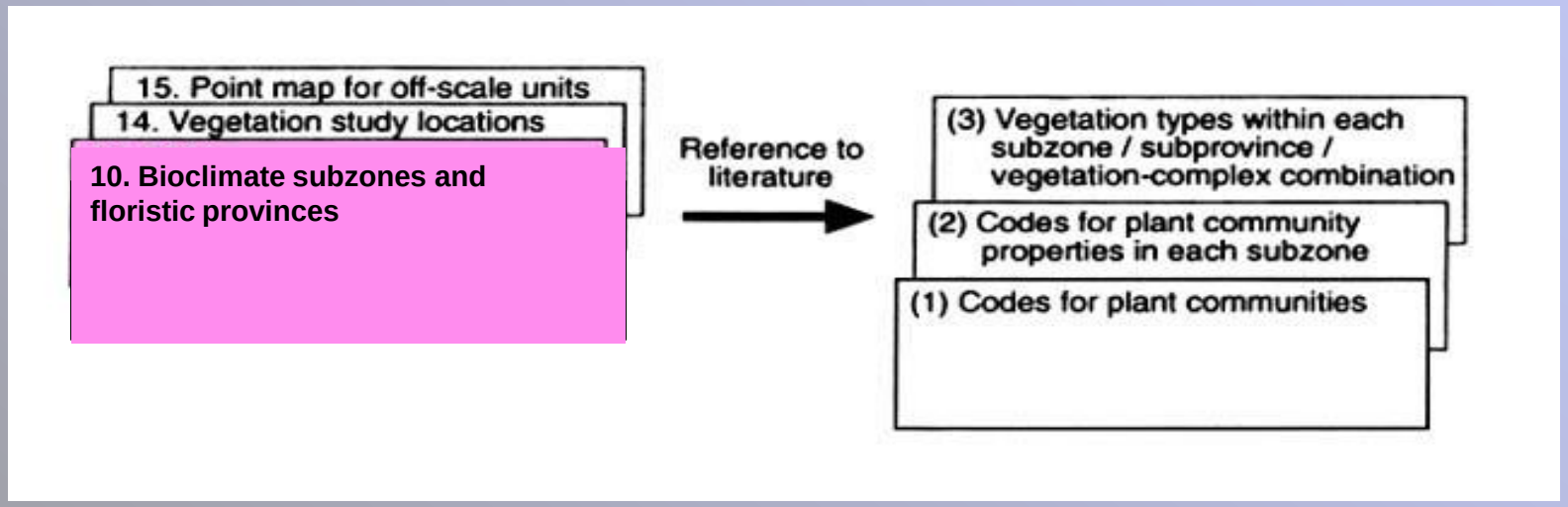
Riparian areas

18. River floodplain vegetation complex
19. Bottomland evergreen forest vegetation complex
20. Bottomland deciduous forest vegetation complex

Water and glaciers

21. Water or lake vegetation complex (>75% water cover)
22. Glacier complex (>75% glacier cover)

Step 5: Derivation of plant-community look-up tables



- *These tables relate the IVCM map to published information regarding the plant communities.*
- *A map showing locations of all known vegetation-study locations was overlaid on the the PFM to find the relevant literature sources. This information is used to construct a table showing the vegetation within each combination of floristic province, bioclimate subzone, substrate type, and position on the mesotopographic gradient.*
- *Codes are given to the major described plant communities, and another look-up table is constructed giving the various properties of the plant communities (e.g. biomass, productivity, horizontal structure) derived from the literature or estimated.*

Maps for creating look up tables

Modified boundaries of bioclimate subzones and floristic subprovinces

Locations of good plant community information

Vegetation Tables (Walker 1999)

Plant communities from literature

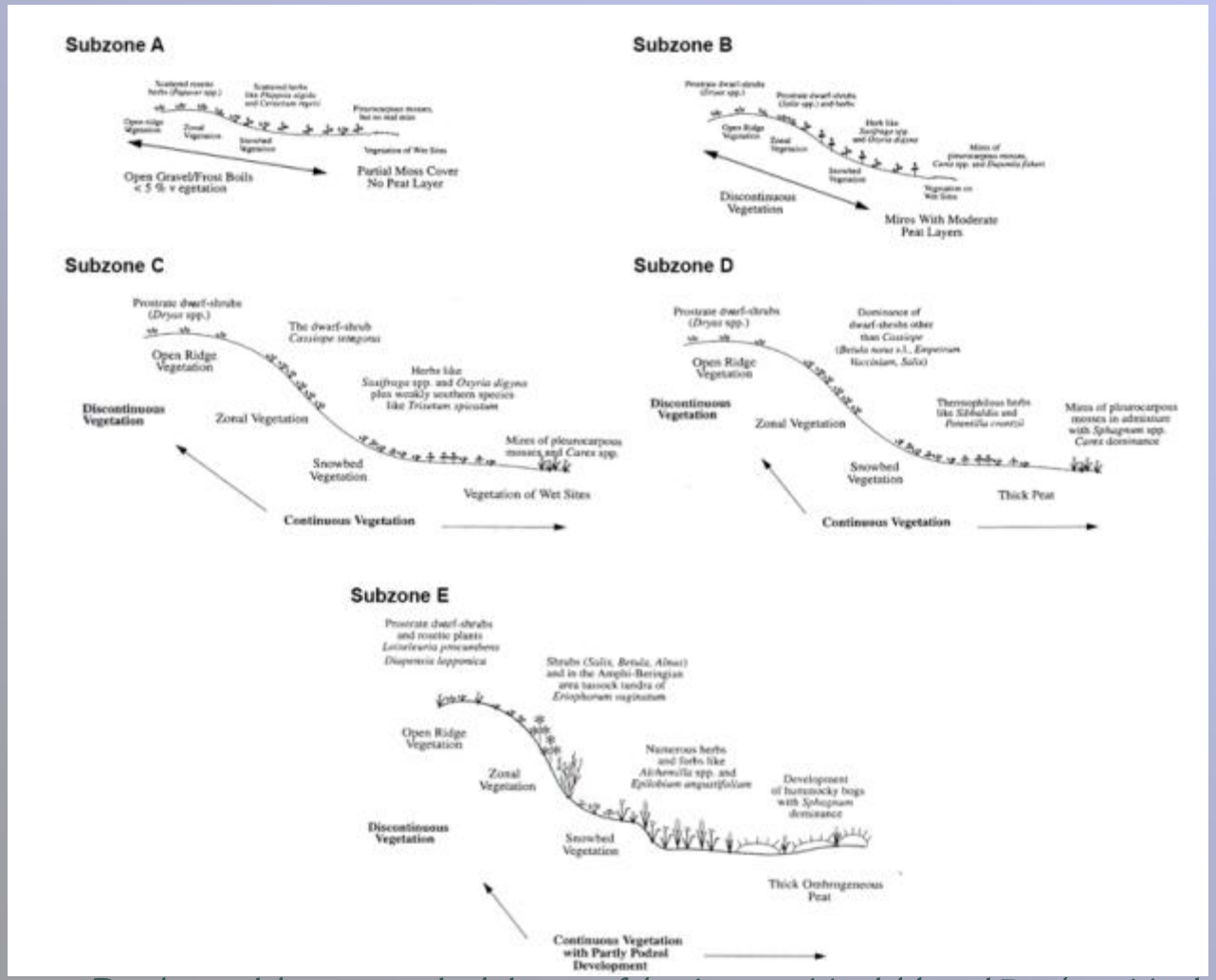
Primary, secondary, tertiary plant communities in each combination of subzone, vegetation complex

Look-up table 1. Partial list of plant communities, habitats and literature sources.

Veg code	B–B class and plant community	Habitat	Source
01000	***Rhizocarpetea geographici***	**Acidic rock lichen communities**	
01010	*Cetraria nigricans-Rhizocarpon geographicum* comm.	Xeric, acidic, sandstone and conglomerate rocks	Walker *et al.* 1994
02000	***Carici rupestris-Kobresietea bellardii***	**Dry, often calcareous, tundra swards**	
02010	*Selaginello sibiricae-Dryadetum octopetalae*	Xeric, exposed, acidic, rocky slopes, mountains, foothills	Walker *et al.* 1994
02011	*Oxytropis bryophila* ssp. *pygmaeus-Dryas octopetala* comm.	Xeric, exposed, acidic, rocky slopes, Cape Thompson	Johnson *et al.* 1966
02012	*Dryas integrifolia-Oxytropis nigrescens* comm.	Xeric, exposed, calcareous sites, coastal plain	Walker and Everett 1991
02020	*Dryas integrifolia-Cassiope tetragona* comm.	Subxeric, well-drained, nonacidic, shallow snowbeds	Walker *et al.* 1994
03000	***Cetrario-Loiseleurietea***	**Dry acidic tundra**	
03010	*Salici phlebophyllae-Arctoetum alpinae*	Subxeric, moderately exposed, acidic, rocky sites, glacial till, foothills, sandstone	Walker *et al.* 1994
03020	*Hierochloë alpina-Betula nana* comm.	Subxeric, somewhat protected, acidic sites	Walker *et al.* 1994
03030	*Carici microchaetae-Cassiopetum tetragonae*	Subxeric, well drained, acidic shallow snowbeds	Walker *et al.* 1994
04000	**Salicetea herbaceae**	**Snow patch communities**	
04010	*Salix rotundifolia* comm.	Mesic, nonacidic, deep snowbeds	Walker *et al.* 1994
05000	***Oxycocco-Sphagnetea***	**Raised bogs, acidic tussock tundra**	
05010	*Sphagno-Eriophoretum vaginati* typicum	Mesic to subhygric, acidic, uplands, moderate snow	Walker *et al.* 1994, Churchhill 1955, Bliss 1956, Johnson *et al.* 1966
05011	*Eriophorum vaginatum-Cassiope tetragona* comm.	Coastal plain tussock tundra with short tussocks and few shrubs	Walker unpub.
05020	*Sphagno-Eriophoretum vaginati betuletosum nanae* subass. prov.	Dwarf-birch dominated, mesic margins of water tracks, high-centred polygons	Walker *et al.* 1994
05030	*Sphagnum lenense-Salix fuscescens* comm.	Subhygric, acidic fens	Walker *et al.* 1994
06000	***Scheuchzerio-Caricetea nigrae***	**Small sedge nonacidic mires and moist tundra**	
06010	*Dryado integrifoliae-Caricetum bigelowii*	Mesic to subhygric, nonacidic, uplands foothills	Walker *et al.* 1994
06011	*Eriophorum triste-Dryas integrifolia* comm.	Mesic to subhygric, nonacidic, uplands coastal plain	Walker 1985

Subzone	Subprovince	Veg. Complex	Veg1	Veg2	Veg3
1	1	1	na	na	na
1	1	2	na	na	na
1	1	3	na	na	na
1	1	4	na	na	na
1	1	5	na	na	na
1	1	6	05011	10010	
1	1	7	na	na	na
1	1	8	06011	10020	
1	1	9	na	na	na
1	1	10	na	na	na
1	1	11	na	na	na
1	1	12	na	na	na
1	1	13	09011	06011	11000
1	1	14	na	na	na
1	1	15	na	na	na
1	1	16	06032	06031	

Toposequences for each subzone (Elvebakk 1999)



From Elvebakk, A., 1999, Bioclimatic delimitation and subdivision of the Arctic, in Nordal, I., and Razzhivin, V. eds., The Species Concept in the High North - A Panarctic Flora Initiative: Oslo, The Norwegian Academy of Science and Letters, p. 81-112.

Framework for table of plant communities for CAVM

Bioclimate subzones

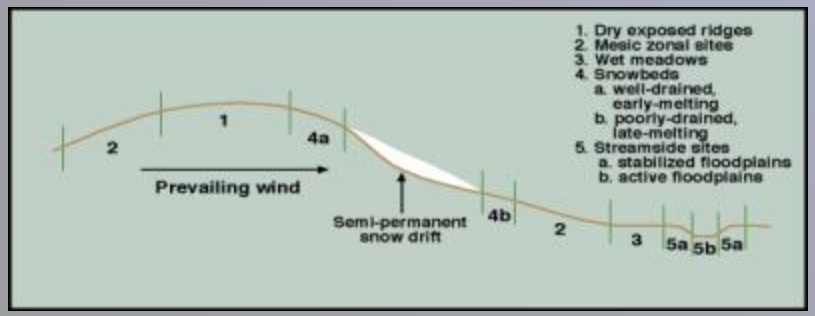
Floristic subprovince

Substrate pH

For northern Alaska:

- 3 subzones
- 2 subprovinces
- 3 pH classes
- 7 mesotopographic microsites

Generalized mesotopographic gradient



Locations of good plant community information

Plant community information summarized in tables on Alaska tundra vegetation map

Dominant arctic Alaska plant communities

Numbered units within the table are plant community types
Braun-Blanquet descriptions, dominant plant functional types and species are listed where data were available. Literature citations (in small font) include unit names, habitat, citation and location.

Major table sections are Tundra Bioclimate Subzones (see inset map on front side)

Subzone C | Subzone D | Subzone E

Table columns within the subzone sections separate acidic and non-acidic communities (see inset map on front side)

Blocks of rows are positions along a mesotopographic gradient (see figure to right)

Colored text outlines denote Floristic Provinces (see inset map on front side)

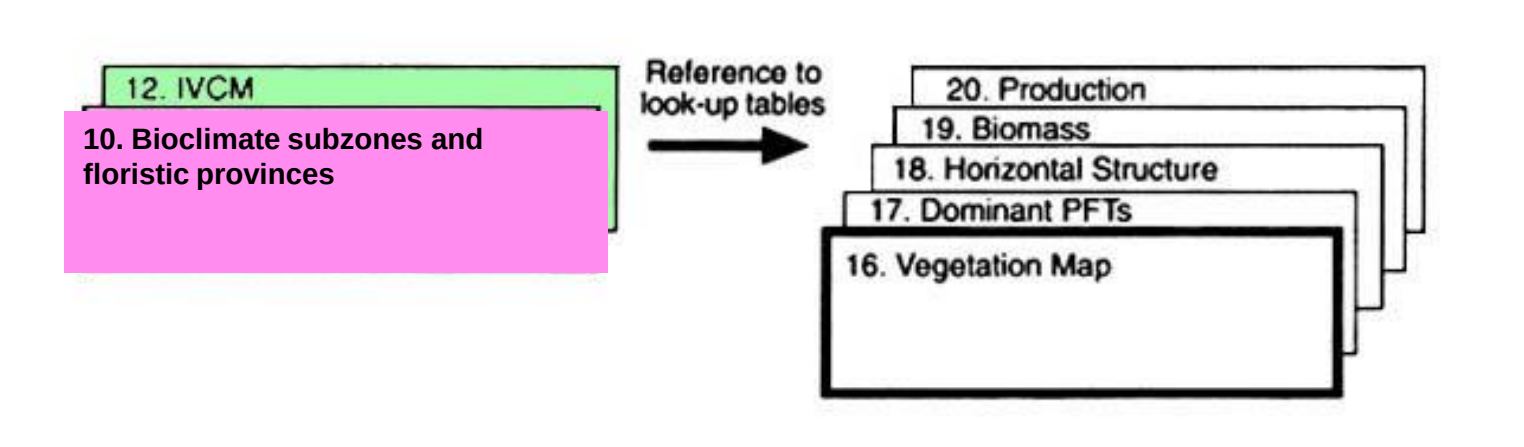
Northern Alaska | Beringian Alaska | Northern Beringian Islands

Subzone C
Northern part of Arctic Coastal Plain

Habitat along the meso-topographic gradient	Acidic substrates (community # 1-7)	Non-acidic substrates (community # 8-12)
Dry exposed sites	**1.** Prostrate dwarf shrub (*Salix rotundifolia*), lichen (*Alectoria nigricans, Bryocaulon divergens, Dactylina arctica*), rush (*Luzula confusa, L. arctica*), grass (*Arctagrostis latifolia*), forb (*Potentilla hyparctica, Pedicularis lanata*), bryophyte (*Polytrichum strictum, Dicranum elongatum, Gymnomitrion corallioides*). Nodum 11 (Webber 1978); *Sphaerophorus globosus-Luzula confusa* comm. subtype *Salix rotundifolia*, dry beach and river terraces (Elias et al. 1996) (Barrow).	**8.** Prostrate dwarf shrub (*Dryas integrifolia*), sedge (*Carex rupestris*), (*Lecanora epibryon, Thamnolia subuliformis*). Type B12, coastal dry nonacidic gravelly sites (Walker 1985)(Prudhoe Bay).
Moist sites	**2.** Sedge (*Carex aquatilis, Eriophorum angustifolium*), grass (*Poa arctica, Dupontia fisheri*), rush (*Luzula arctica*), prostrate dwarf- shrub (*Salix rotundifolia*), forb (*Saxifraga cernua, S. hieraciifolia, S. hirculus, Cardamine pratensis, Petasites frigidus, Ranunculus nivalis*), moss (*Oncophorus wahlenbergii, Sarmenthypnum sarmentosum, Aulacomnium turgidum*). Nodum IV (Webber 1978); Type 6 and 7, moist, fine-grained soils (Walker et al. 1977); *Saxifraga cernua-Carex aquatilis* comm. (Elias et al. 1996) (Barrow). **3.** Rush (*Luzula confusa, L. arctica*), grass (*Poa arctica*), forb (*Potentilla hyparctica, Pedicularis lanata*), lichen (*Alectoria nigricans,*	**9.** Sedge (*Carex aquatilis*), prostrate dwarf shrub (*Salix pulchra, S. reticulata, Dryas integrifolia*), moss (*Tomentypnum nitens, Oncophorus wahlenbergii, Campylium stellatum, Distichium capillaceum*). Type U12, moist calcareous coastal meadows (Walker 1985) (Prudhoe Bay).

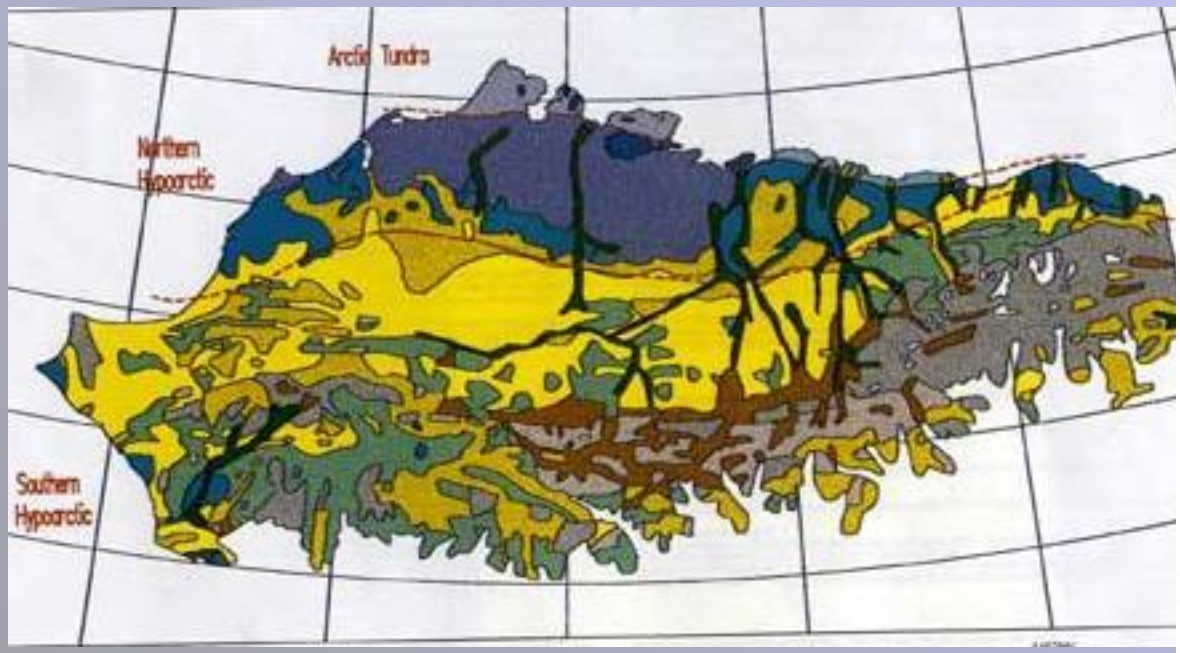
Raynolds et al. 2005. *Phytocoenologia 35: 821-848.*
Raynolds et al. 2006. Alaska Arctic Tundra Vegetation (1:4 000 000), CAFF Map No. 2.

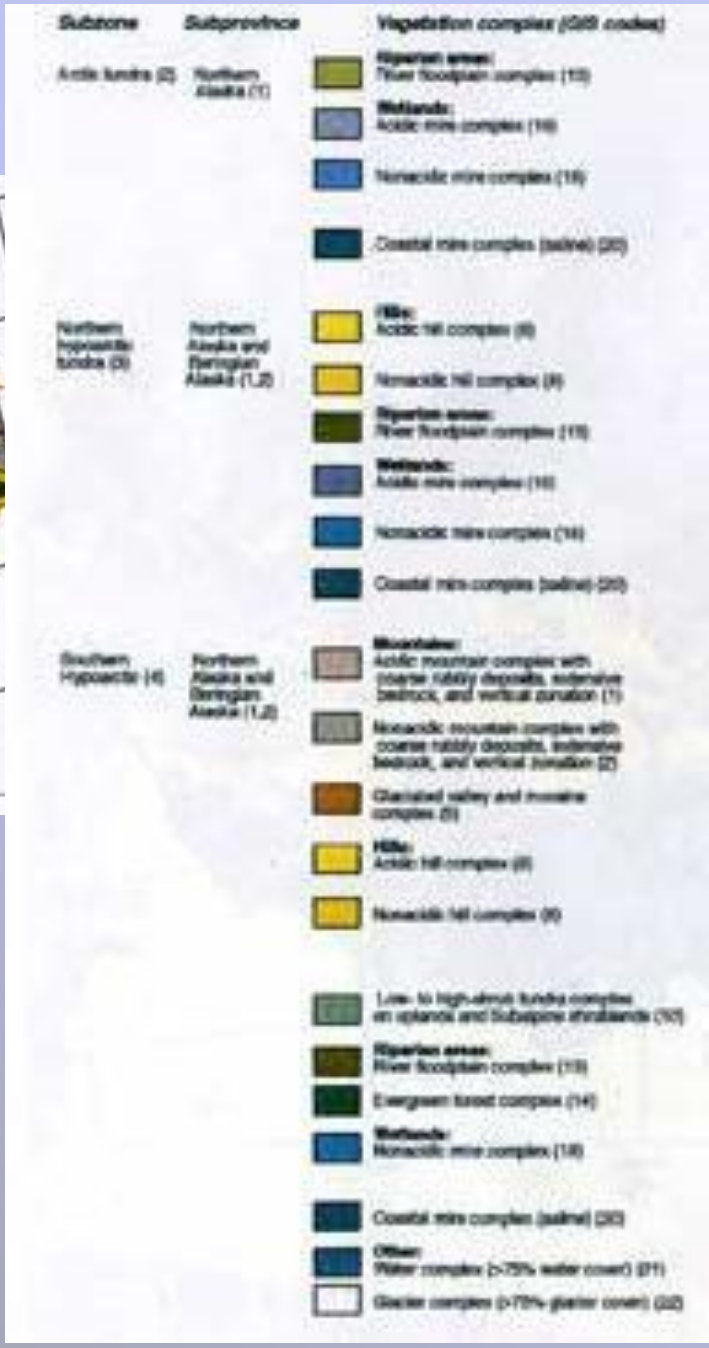
Step 6: Final vegetation map and other derived maps



- *The draft vegetation maps was produced with reference to look-up tables.*
- *Legends and colors for the map can be modified considerably based on look-up tables.*
- *Separate maps can also be derived showing dominant plant growth forms, biomass, horizontal structure also based on information in look-up tables.*
- *Or any of the other geobotanical attributes that went into making the IVCM.*

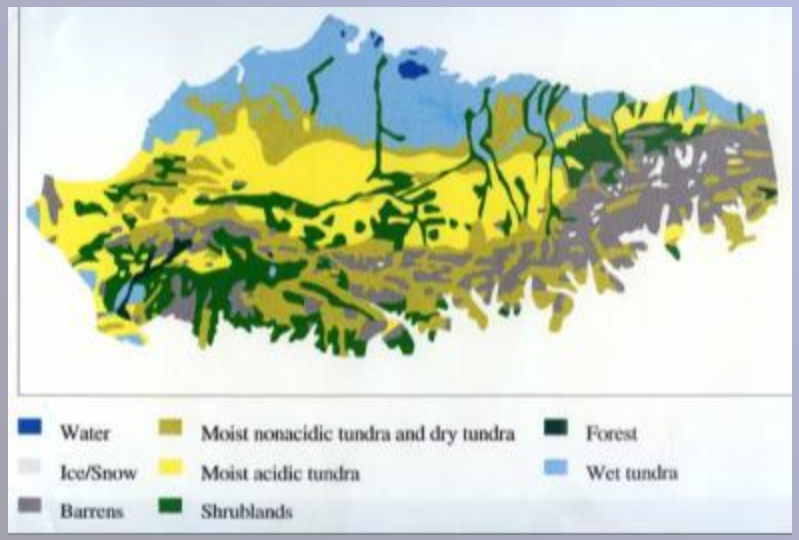
Draft Vegetation Complex Map



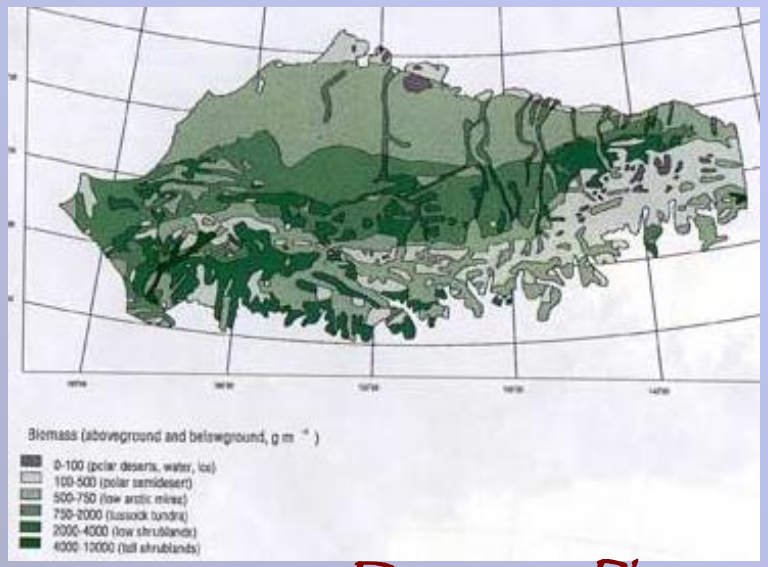


Other types of vegetation maps derived from the look-up tables

Simple Vegetation Map (same classes as Landsat-derived map)

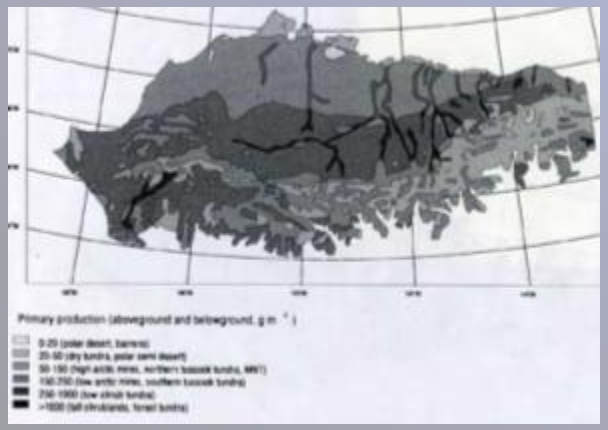


Biomass



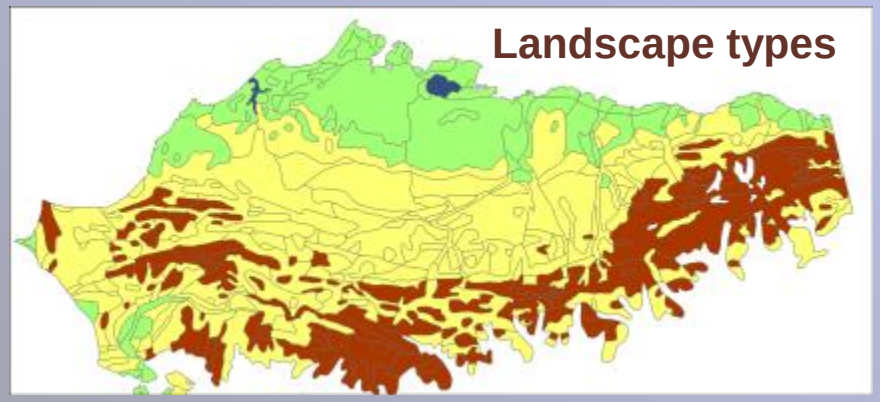
Horizontal Structure

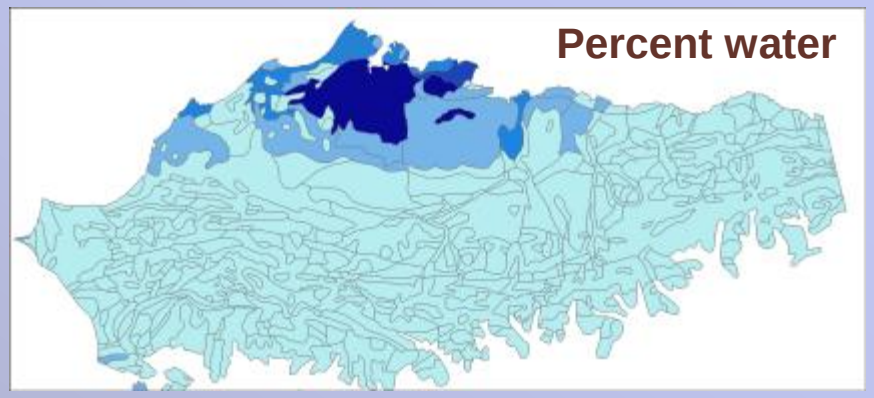
Primary Production

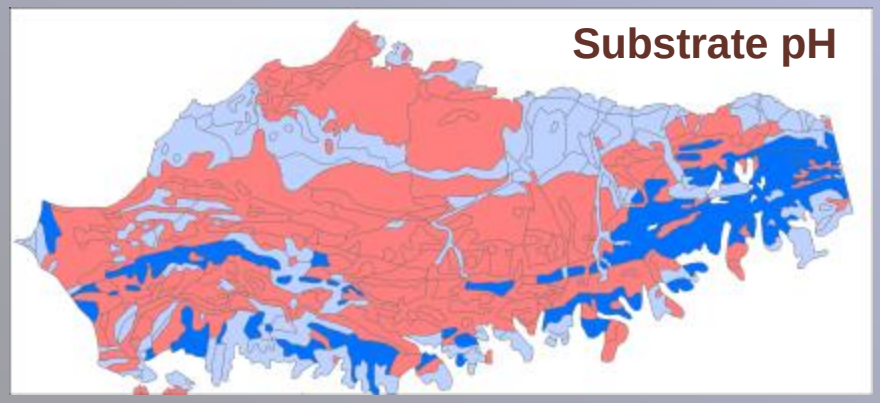


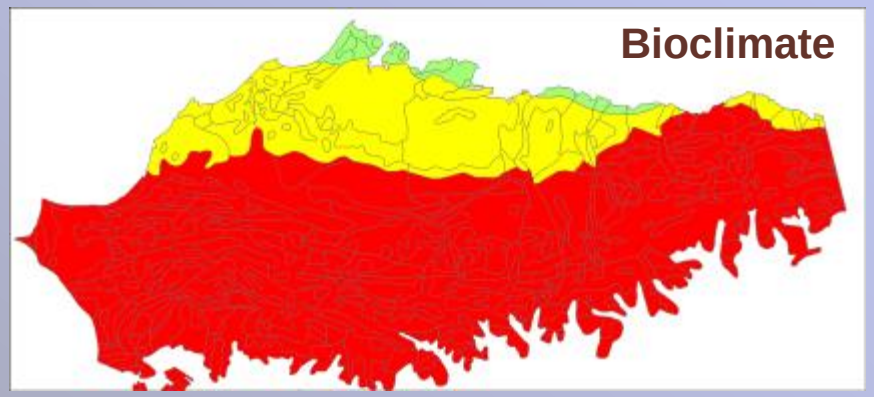
Dominant Plant Functional Types

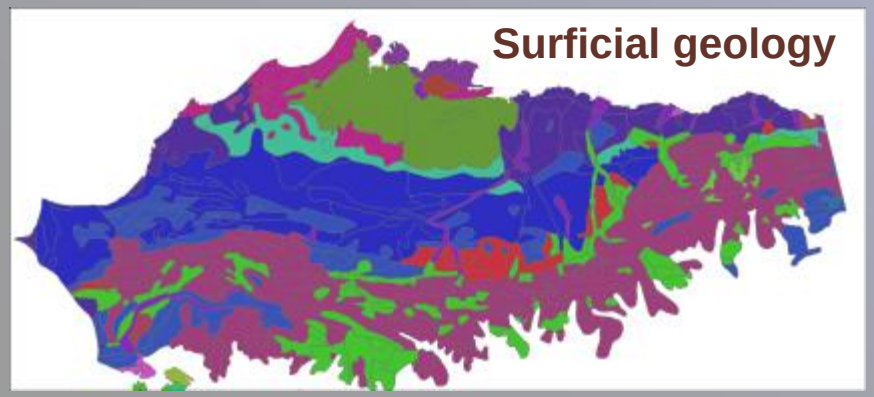
Other types of maps derived from the geobotanical GIS database

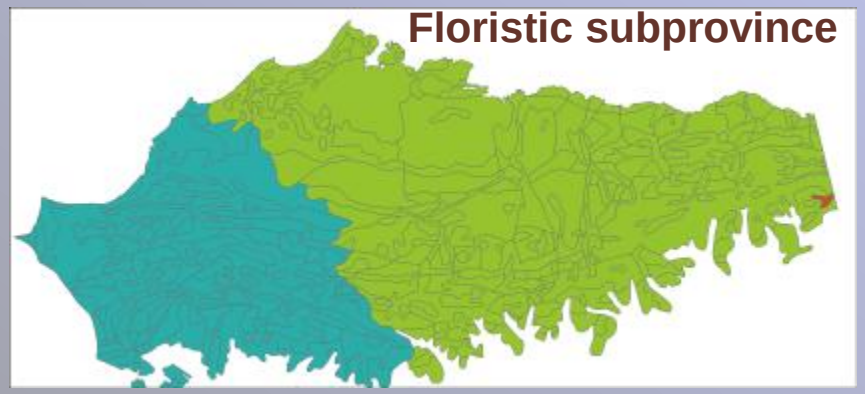




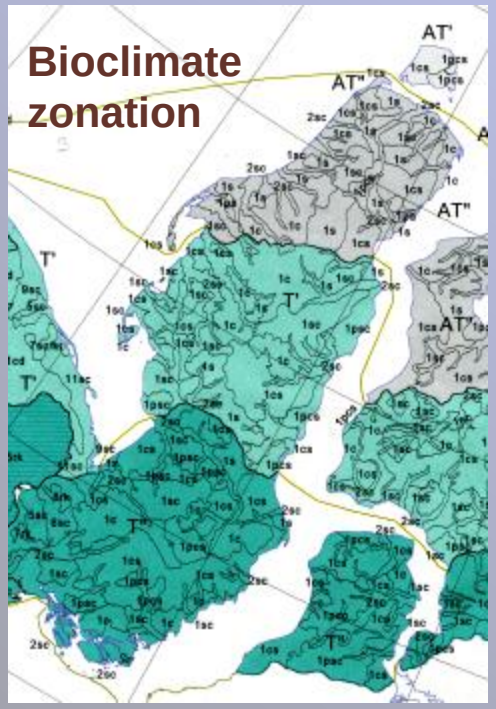


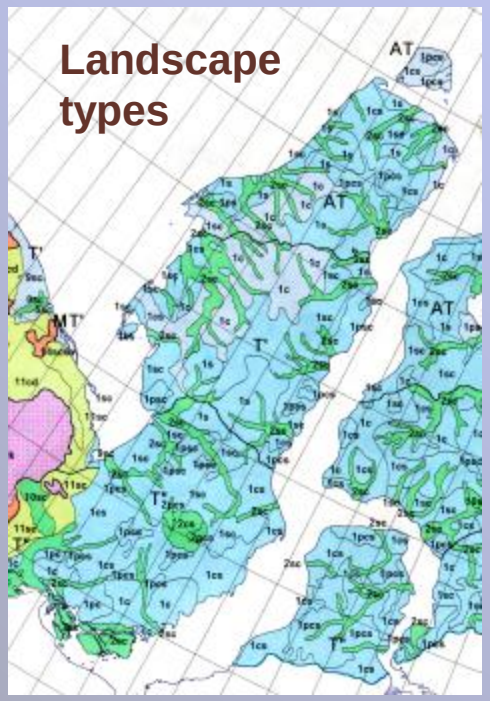


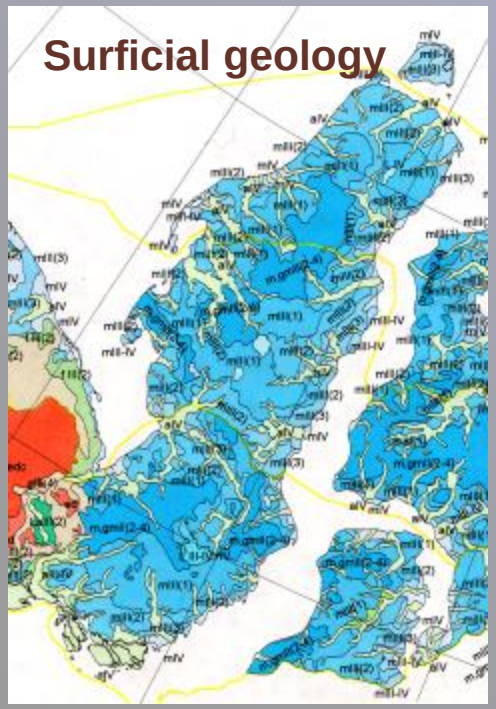


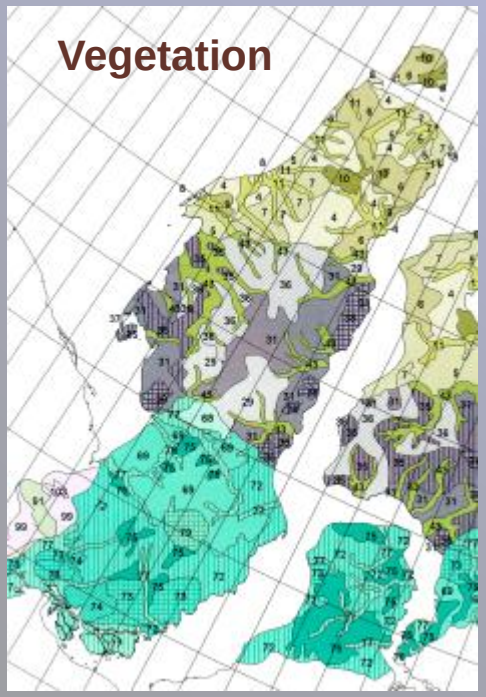


Russian Landschaft maps



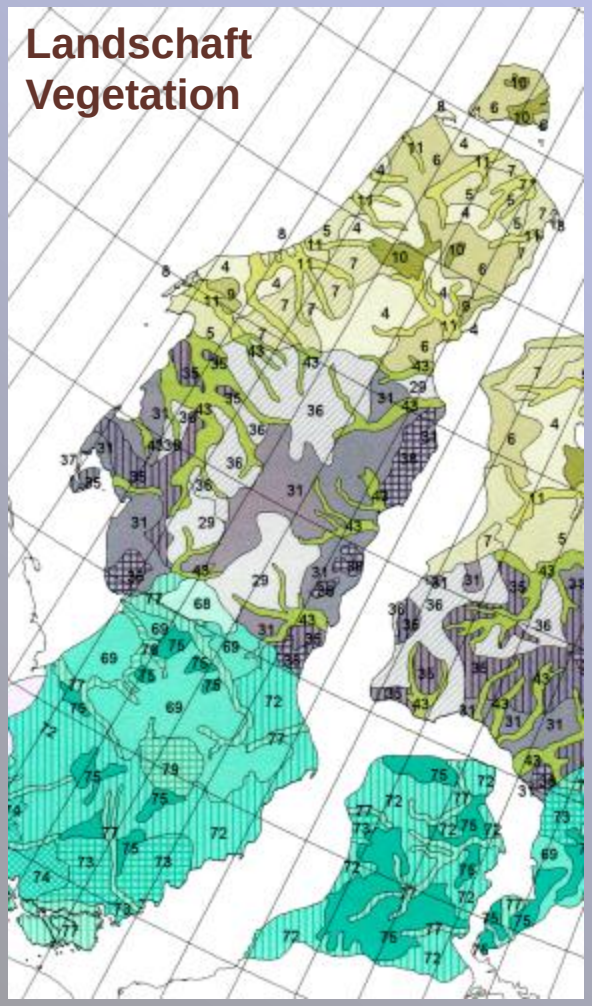


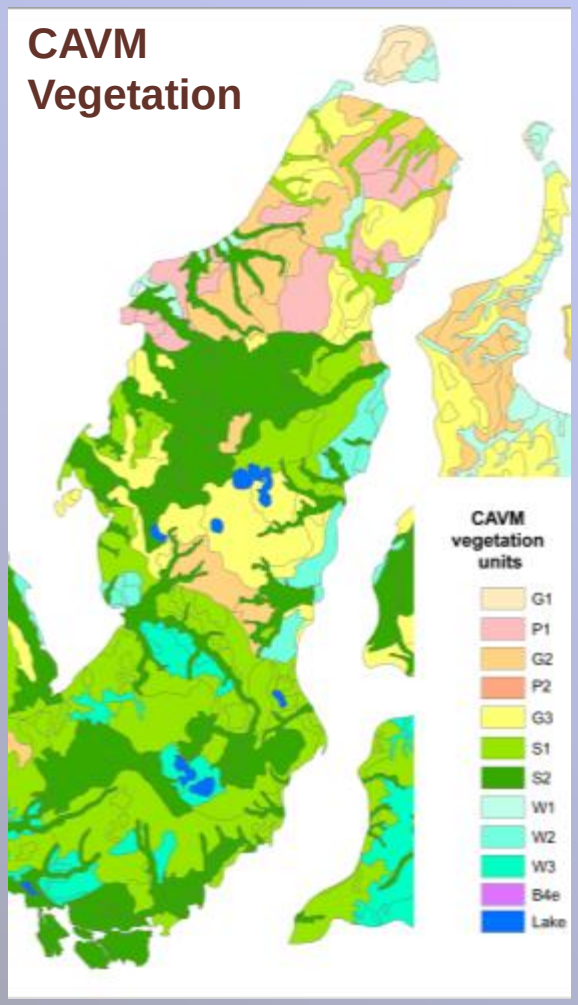




1. Zonal, subzonal altitudinal, longitudinal units.
2. Landscape types (hills, mountains, plains, etc.).
3. Types of lithogenic base of landscapes (mainly soil texture).
4. Vegetation map boundaries were adapted and integrated from 1:4M scale maps of Russian vegetation.

Russian vegetation map units converted to CAVM units.





- **121 vegetation units for Russia.**
- **Zonation dominates color scheme**

- **Reduced to 15 units.**
- **Plant physiognomy dominates color scheme.**

- ***Descriptions of plant communities in Russia followed the same approach used in Alaska (plant communities described for each subzone, floristic province, substrate, mesotopographic position).***
- ***First Russian map followed traditional Russia hierarchical legend with subzones at the highest level.***
- ***Final CAVM legend had only 15 map units, but detail of original communities is in the look-up tables (87 communities in Alaska, about 150 in Russia).***

Summary of integrated mapping method

Landscape Unit map
(interpreted from AVHRR imagery and DEM)

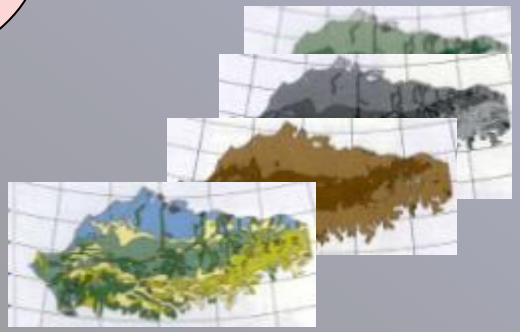
Additional terrain boundaries from soil, geology, geomorpholgy, and wetland maps

Integrated Terrain Unit Map (ITUM)

Additional vegetation boundaries from NDVI and vegetation maps

Integrated Vegetation-Complex Map (IVCM)

Information from lookup tables



Vegetation maps derived from GIS database

Other points

- The boundaries of the map polygons at 1:7.5M scale are based mainly on landscape variables (mountains, plains, hills, wetlands, very large river systems, and large areas with distinctive soils such as sands vs. loams, and acidic vs. nonacidic soils) and not the vegetation per se.

- It is also essential to keep the scale in mind when considering what vegetation can be portrayed at such a small scale. Nearly all river valleys, south and north-facing slopes, and successional details in forested regions will not be large enough to be explicitly represented. At this scale, only the dominant vegetation type, usually the zonal type in most areas, or dominant type within large azonal complexes (e.g. mountains and wetland complexes), can be portrayed. More detail regarding the vegetation mosaic within the polygons can be contained in accompanying tables and charts.

- Mappers should avoid the temptation to add too many polygons to the map, such as in river systems or the mountains, or to make lines overly crenulated because this will unduly increase the size of the data base and will be invisible at the scale of the map. (Use a Sharpie to draw boundaries!)

- Ecological land units can be derived from the data base if desired. but it is essential during the mapping to keep the dominant vegetation distinct and independent from the other landscape variables and not merged into ecological land units as primary mapping units.

- Countries with already existing vegetation maps at similar scale, such as Europe and Russia, should conform existing map boundaries to the base imagery. But I would encourage them to also code other landscape attributes into each map polygon, so the GIS data base is consistent across the full mapping domain. This will require agreement on legend systems for the other attributes of the GIS database (geological units, landscape units, soil units, etc.). These legends should be kept as simple as possible and contain only information relevant to the vegetation at the scale of the map.

Conclusions:

An explicit consistent mapping approach that is used by all participants will require the least amount of reconciliation during the synthesis and joining phases of the mapping.

If the method described here or a similar integrated mapping method is applied consistently, it would result in a GIS data base whereby each map polygon is coded with numerous landscape attributes in addition to the vegetation. These attributes are essential anyway to help in defining the vegetation within polygons and should be captured in the mapping process.

The mapping methodology is quite distinct from the vegetation legend. The final vegetation legend could come much later after the polygons are attributed with terrain and preliminary vegetation designations and the full range of vegetation complexity is realized.

Suggestions for the CBVM map legend and making the Arctic Tundra compatible with the CBVM legend:

1. Consider the plant functional types used by Cramer and/or Elgin Box. These are used in the most widely accepted international global vegetation change models.

Option for including tundras in the boreal forest legend

I. Forest
- A. Needleleaf Forest
  - 1. Evergreen needleleaf forest
    - a. Dark evergreen needleleaf forest (*Abies, Picea*)
    - b. Light evergreen needleleaf forest (*Pinus,* include *Pinus pumila* here)
  - 2. Deciduous needleleaf forest (*Larix*)
- B. Broadleaf Forest
  - 1. Small broadleaf forest (*Betula, Populus, Chosenia*)
  - 2. Large broadleaf forest (*Quercus, Acer,* etc.)
- C. Mixed needleleaf and broadleaf forest

II. Shrublands
- A. Tall and medium height shrublands
- B. Dwarf shrublands
  - 1. Erect dwarf-shrublands
    - a. Arctic erect dwarf-shrub tundras (mainly *Betula nana, S. planifolia*, *Cassiope*)
    - b. Alpine dwarf-shrub tundras
    - c. Oceanic dwarf-shrub heaths (*Empetrum* and others)
  - 2. Prostrate dwarf-shrub tundras (*Dryas, Salix arctica, S. nummularia, S. polaris*)

III. Herbaceous vegetation (sedges, rushes, grasses *Carex, Eriophorum, Luzula,* Poaceae, and forbs)
- A. Grasslands
- B. Graminioid-dominated tundras
  - 1. Tussock-sedge, dwarf-shrub tundra (*Eriophorum vaginatum*)
  - 2. Sedge, dwarf-shrub tundras
  - 2. Sedge and grass dominated “steppe tundras” (Kobresia, and Poaceae)
  - 3. Rush dominated tundras (*Luxula* communities of the High Arctic)

IV. Wetlands
- (include the wet graminoid tundras here?)

V. Barrens

Include cushion-forb, graminoid, cryptogam tundras (polar deserts, *Saxifraga, Minuartia, Papaver, Cerastium, Luzula, Gymnomitrion, Thamnolia, Racomitrium, etc.*)

Option 2 for including tundras in the boreal forest legend

I. Forest (same as previous slide)
and broadleaf forest

II. Shrublands
- A. Tall and medium height shrublands
  - 1. Low-shrub tundra (Betula, Alnus)
  - 2. Other shrublands
  - 3. Riparian shrubland?
- B. Dwarf shrublands
  - 1. Dwarf shrublands

III. Tundra and heaths
- A. Arctic tundras
  - 1. Tussock-sedge, dwarf shrub tundra (*Eriophorum vaginatum*)
  - 2. Sedge, dwarf-shrub tundras
  - 3. Sedge dominated "steppe tundras" (Kobresia, and Poaceae)
  - 4. Rush dominated tundras (*Luxula* communities of the High Arctic)
  - 5. Cushion-forb, graminoid, cryptogam tundras (polar deserts, *Saxifraga, Minuartia, Papaver, Cerastium, Luzula, Gymnomitrion, Thamnolia, Racomitrium, etc.*)
- B. Alpine tundras
- C. Oceanic dwarf-shrub heaths (*Empetrum* and others)

III. Graminoid-dominated vegetation vegetation (sedges, rushes, grasses *Carex, Eriophorum, Luzula*, Poaceae)
- A. Grasslands (south of treeline)
- B.

IV. Wetlands
(include the wet graminoid tundras here?)

V. Barrens
(include the cryptogam barrens (polar deserts and high elevation barrens) here?).