Tundra Ecosystems

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Tundra origin

- Evolved over the last 1.5 million years, since Pleistocene glaciations have depressed global temperatures
  - In Eocene to Miocene (55-20 million yrs ago), Alaska had mixed conifer-hardwood forests (basswood, walnut, hickories, larch, spruce, pine, Metasequoia, etc.)
  - Eurasian ecosystems were similarly temperate up to 80°N
  - Gradual cooling started in Pliocene, 3 mya, with conifers becoming dominant

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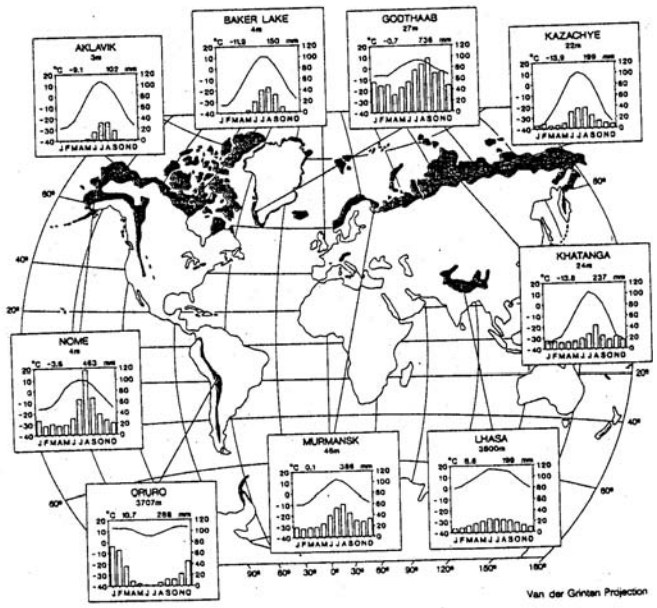
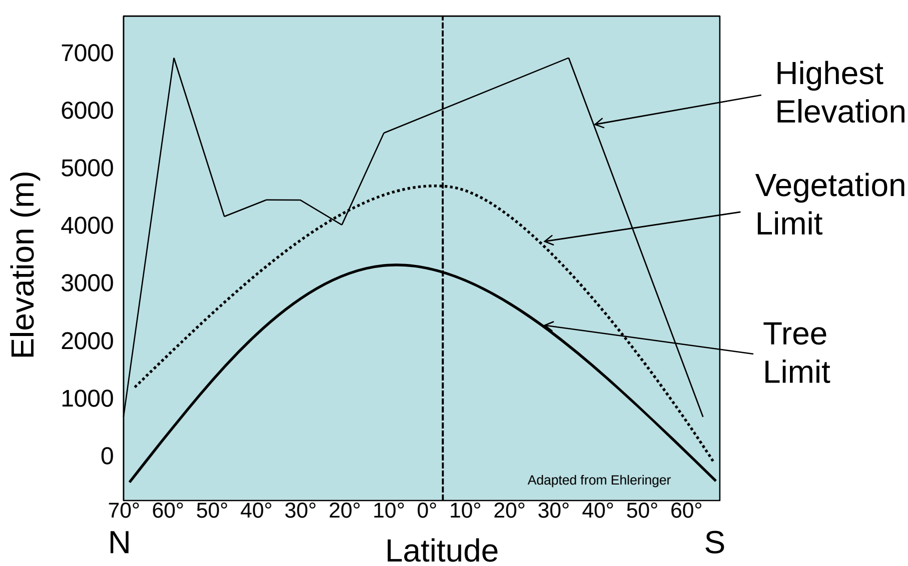
Global distribution of arctic and alpine tundra ecosystems



Elevation-Latitude Tundra Diagram for N. and S. America



Climate in tundra systems

- Growing season only 1-2.5 months
- Low mean annual temperature
  - "low" arctic sites in southern Greenland may have MAT ~0°C
  - "high" arctic sites like Barrow, AK, have MAT –10 to –20°C
  - Alpine sites like Niwot Ridge, CO have MAT of -3.7°C, ranging from -13.2 in January to 8.2 in July.
- Low intensity radiation but long days in arctic
- Strong UV radiation in alpine

Climate (2)

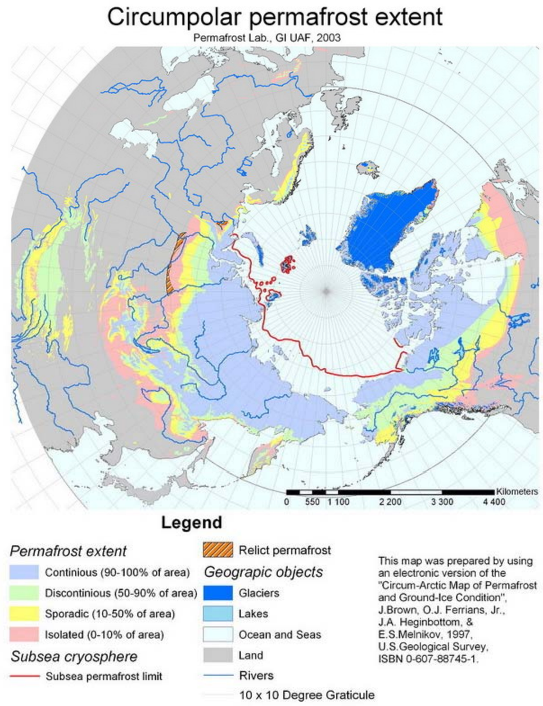
- Polar high pressure system reduces uplift of moist air masses (like subtropical deserts)
  - High arctic ecosystem also known as "polar desert," MAP only100-200 mm
  - Low arctic is more moderate, 100-500 mm MAP
- Most precipitation occurs in summer because polar high is weaker and moves further north, allowing moist storms to penetrate north of boreal forests
- Alpine tundra generally has higher precipitation (e.g. 930 mm at Niwot Ridge) which is dominated by winter snowfall

Tundra soils

- Soils are poorly developed, both because they are young and weathering occurs very slowly in cold, dry climate
- Inceptisols- produced primarily by mechanical weathering caused by freeze-thaw cycles
- Some areas have deep peaty soils due to very slow decomposition
- Tundra soils often display meso-scale patterning, such as solifluction, ice polygons and patterned ground due to freeze-thaw events

Permafrost

- Permafrost consists of soil that is permanently frozen, and may or may not include frozen water
- 40% of Canada has permafrost; 20% of Earth
  - "active layer" is thaw zone, 20-300 cm deep; deeper further south, shallower in north
  - impermeability below active layer creates boggy conditions
  - Permafrost uncommon in alpine tundra



Watch the active layer thaw and freeze:
http://arctic.fws.gov/activel.htm#steps

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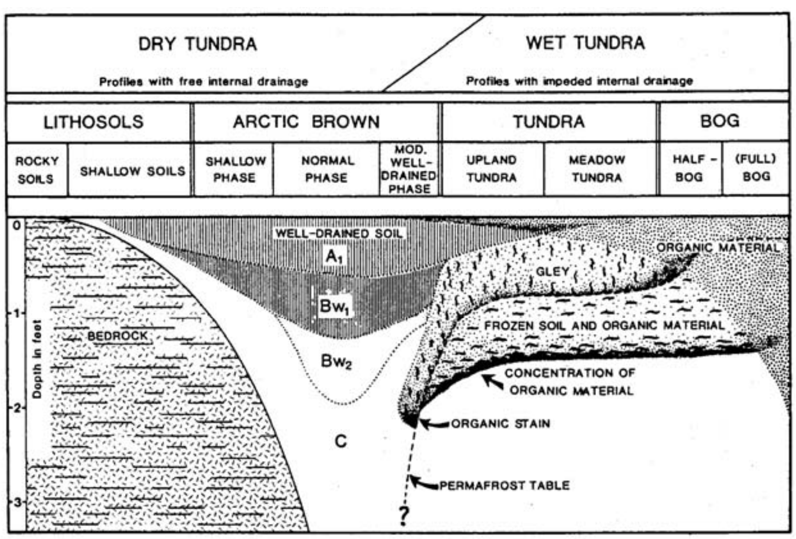
Patterned Ground

- "Dry" tundra: freely drained vs.
- "Wet" tundra: impeded drainage



Arctic tundra vegetation

- Circumpolar Arctic flora ~1000-1100 species, reduced from ~1500 species prior to onset of Pleistocene glaciations
- Most plants are geophytes, hemicryptophytes, or chamaephytes; depends on snow depth

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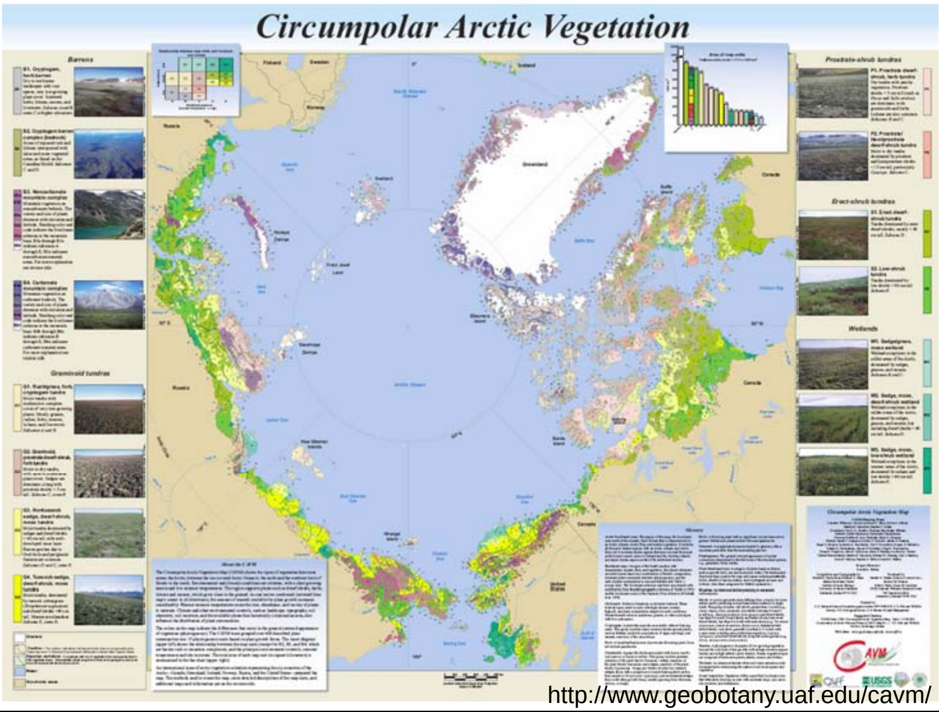

http://www.geobotany.uaf.edu/cavm/

Arctic Tundra vegetation types

- Tall shrub tundra
  - Willow, alder, birch
  - Tufted hairgrass
  - 2-5 m high
  - along river terraces, steep slopes
  - deep active layer
- Low shrub tundra
  - willow, birch, sedges, mosses, lichens
  - 40-60 cm high
  - slopes and uplands
- Dwarf shrub heath tundra
  - Ericaceae genera such as *Vaccinium* & *Arctostaphylos; Rhododendron,* Cottongrass, willow, *Dryas*
  - 5-20 cm high
  - Well drained soils; snow depth 20-30 cm

Arctic Tundra vegetation types (2)

- Tussock tundra
  - Tussock tundra is dominated by cottongrass (a sedge), dwarf shrubs, lichens and mosses
  - Soils of intermediate drainage
- Graminoid-moss tundra
  - Sedges, cottongrass, true grasses, moss
  - Wetlands, saturated soils
  - Drainage gradients (catena)
    - Peat mosses on drier sites
    - Sedges & grasses in wetter sites

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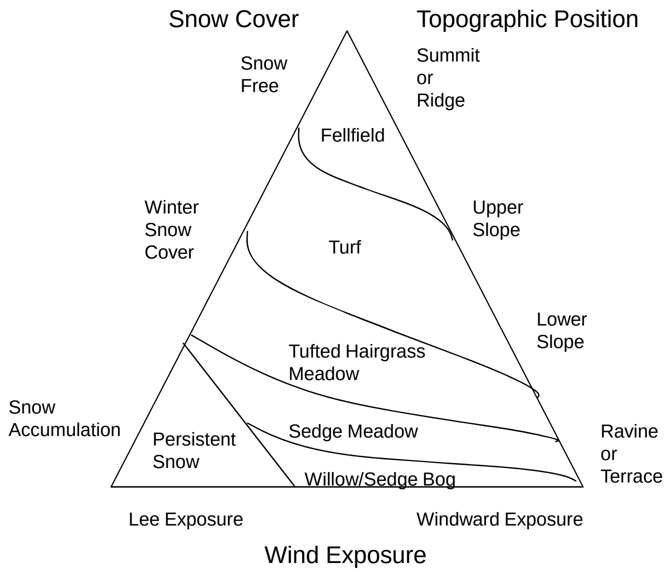
Arctic Tundra vegetation types (4)

- Coastal graminoid tundra
  - Salt marshes support sedges and grasses 1-5 cm high
  - Important for many wildlife species
- Snow geese in Hudson Bay area increase NPP 40-100% by adding Nitrogen

Arctic Tundra vegetation types (5)

- Semi-desert and Polar Desert
  - Cushion plants such as Dryas, with lichens and mosses providing 30-60% of ground cover (cryptogamic crust); vascular plants 5-25% of ground cover
  - Very short growing season, continuous permafrost
  - Further north, “barrens” are found, with >95% bare ground, 2% vascular plants and 3% cryptogamic crust
  - “snowflush” communities are found below large snowbanks, grow on snowmelt
  - many sites in Polar Desert rely on Dryas or N-fixing cyanobacteria in cryptogamic crust

Alpine Tundra Vegetation

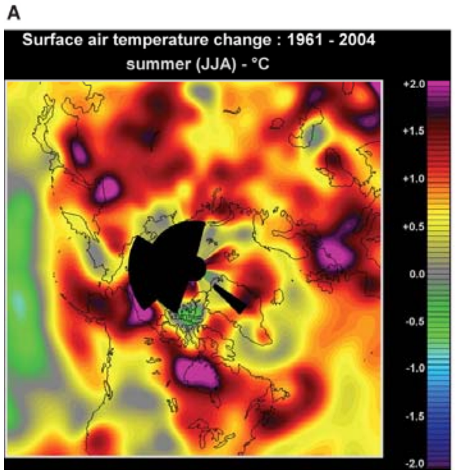


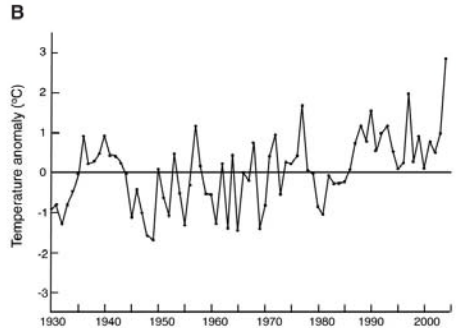
Knight 1994

Climate change and arctic tundra

- Arctic climate is marginal for plant growth; thus, a small increase in temperature may have significant impacts

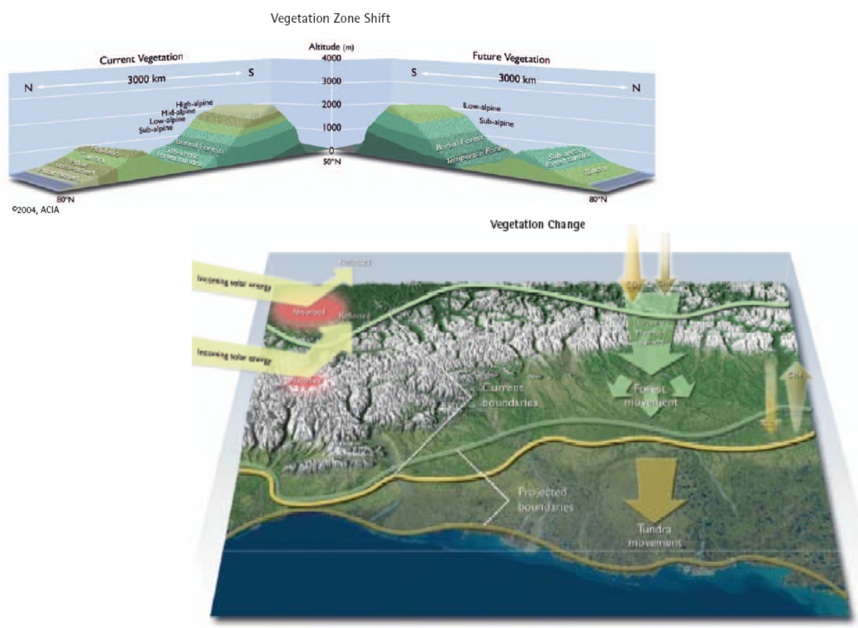
Arctic warming trends

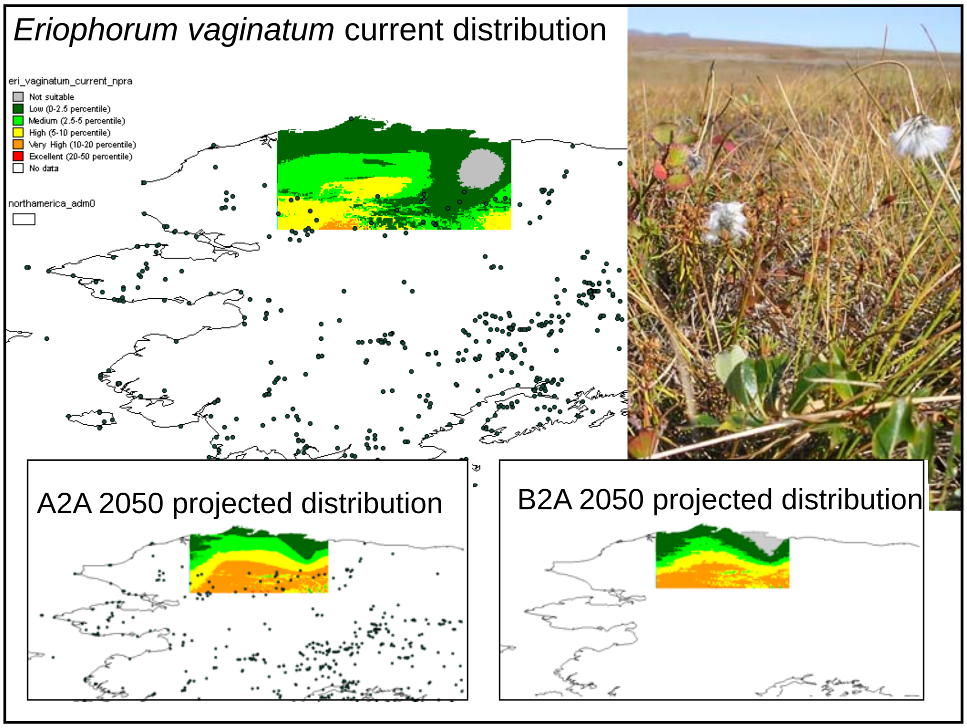


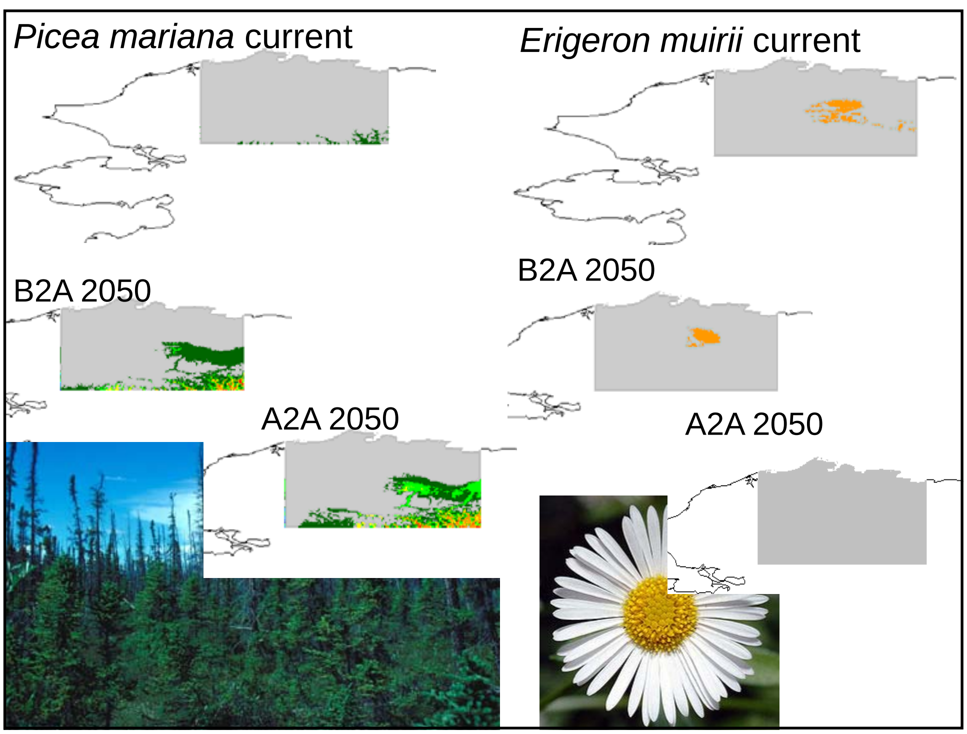


Chapin et al. 2005 Science:
Vol. 310. pp. 657 - 660

Projections of vegetation shifts



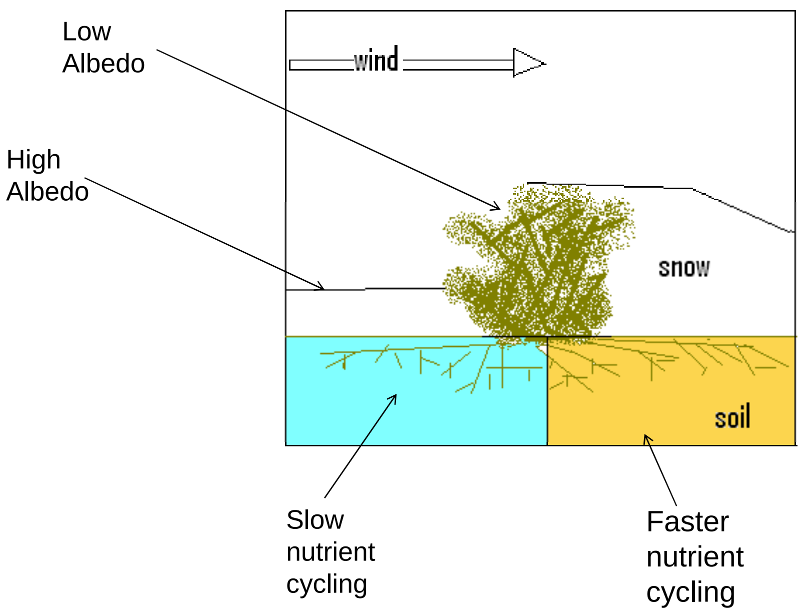

Eriophorum vaginatum current distribution
eri_vaginatum_current_npra
Not suitable
Low (0-2.5 percentile)
Medium (2.5-5 percentile)
High (5-10 percentile)
Very High (10-20 percentile)
Excellent (20-50 percentile)
No data
northamerica_adm0
A2A 2050 projected distribution
B2A 2050 projected distribution


Picea mariana current
Erigeron muirii current
B2A 2050
B2A 2050
A2A 2050
A2A 2050

Shrub Expansion along the Colville River

Figure 1. Increasing abundance of shrubs in arctic Alaska. The photographs were taken in 1948 and 2002 at identical locations on the Colville River (68° 57.9' north. 155° 47.4' west). Dark objects are individual shrubs 1 to 2 meters high and several meters in diameter. Similar changes have been detected at more than 200 other locations across arctic Alaska where comparative photographs are available. Photographs: (1948) US Navy, (2002) Ken Tape.

Increasing MAT and increasing midwinter snowpack have increased soil nutrient availability, and allowed woody shrubs to grow and expand all over the arctic. This expansion has been occuring for the last 100 years or more, and has accelerated in the last 50.



White Spruce Expansion

- White spruce has expanded into tundra in parts of AK (2.3% of tundra, last 50 y)
- Warming promotes forest expansion by creating disturbed soils for seedling establishment in permafrost
- Summer warming mainly caused by longer snow-free season
- Warming increases N availability, which promotes woody plants
- Lower albedo (reflectivity) increases absorption of radiation, which increases warming

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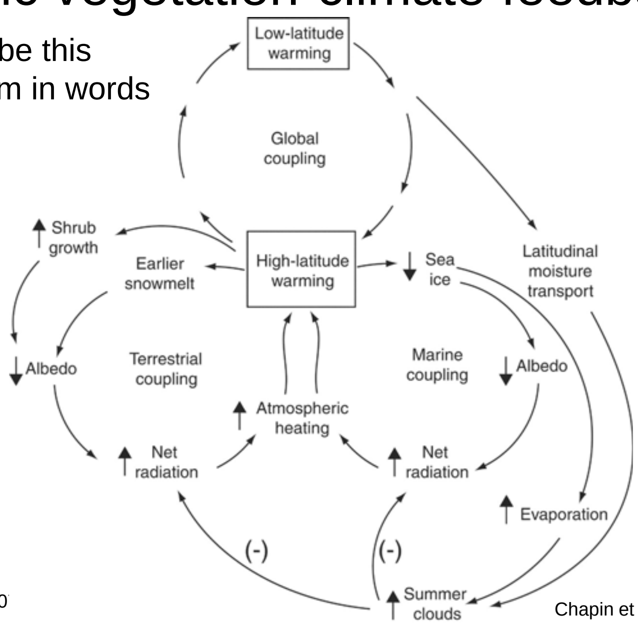
Arctic vegetation-climate feedbacks

Describe this diagram in words



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Chapin et al. 2005

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