

Topic 7

Tundra Biomes

Plant Ecology in a Changing World

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<http://plantecology.net>

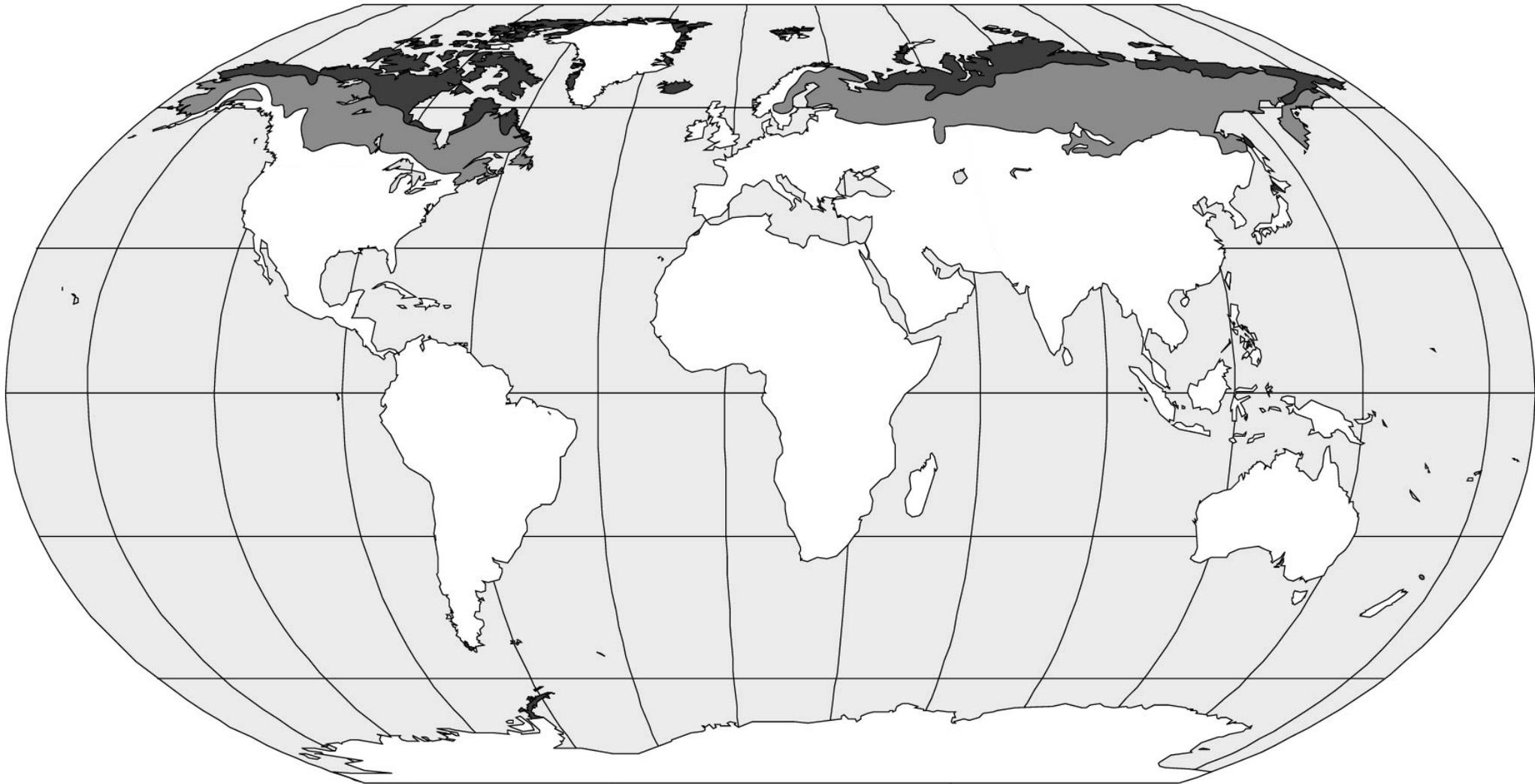


Part 1

Arctic tundra climate and distribution



Arctic tundra and boreal forest biomes



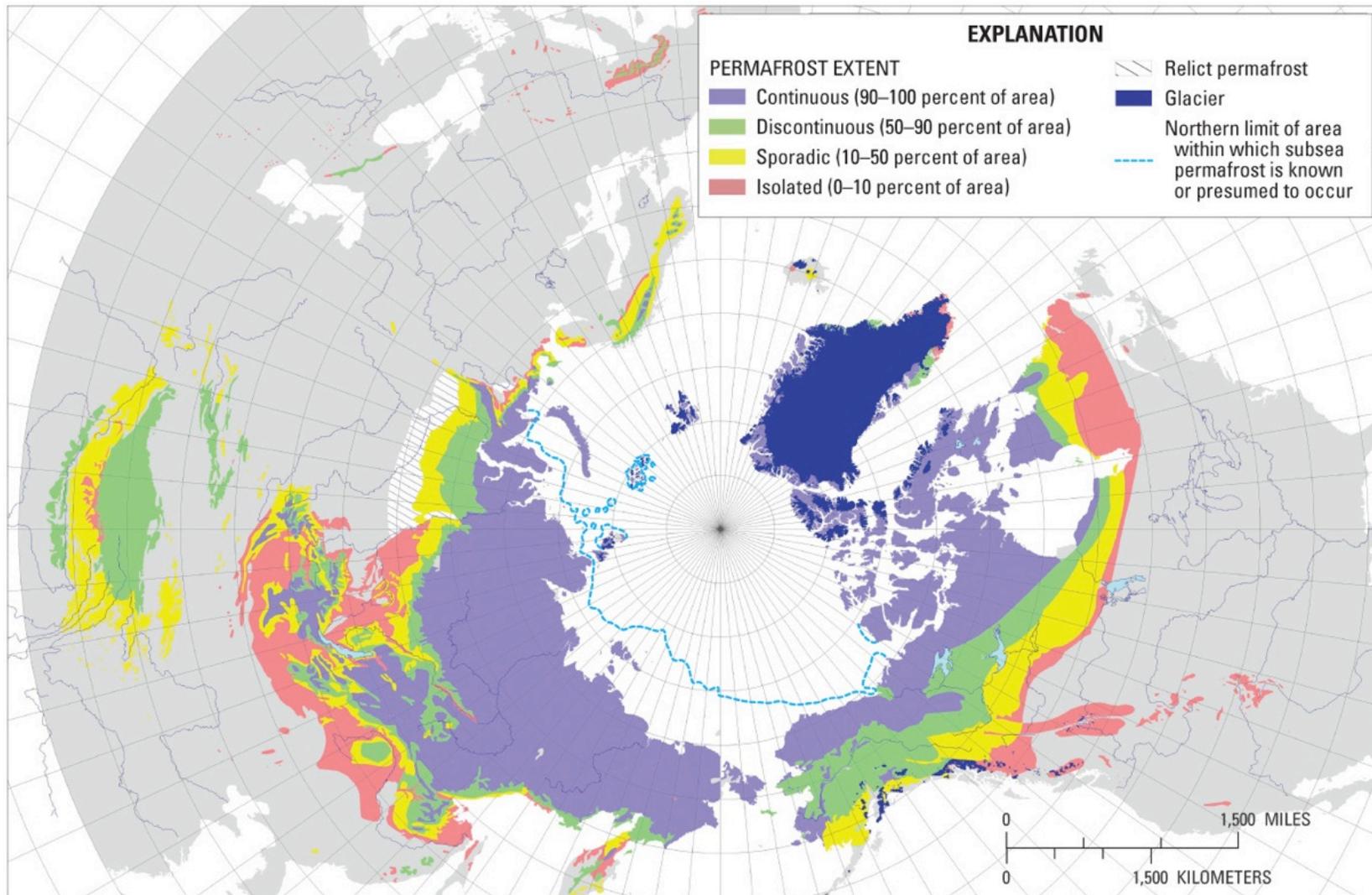
Tundra



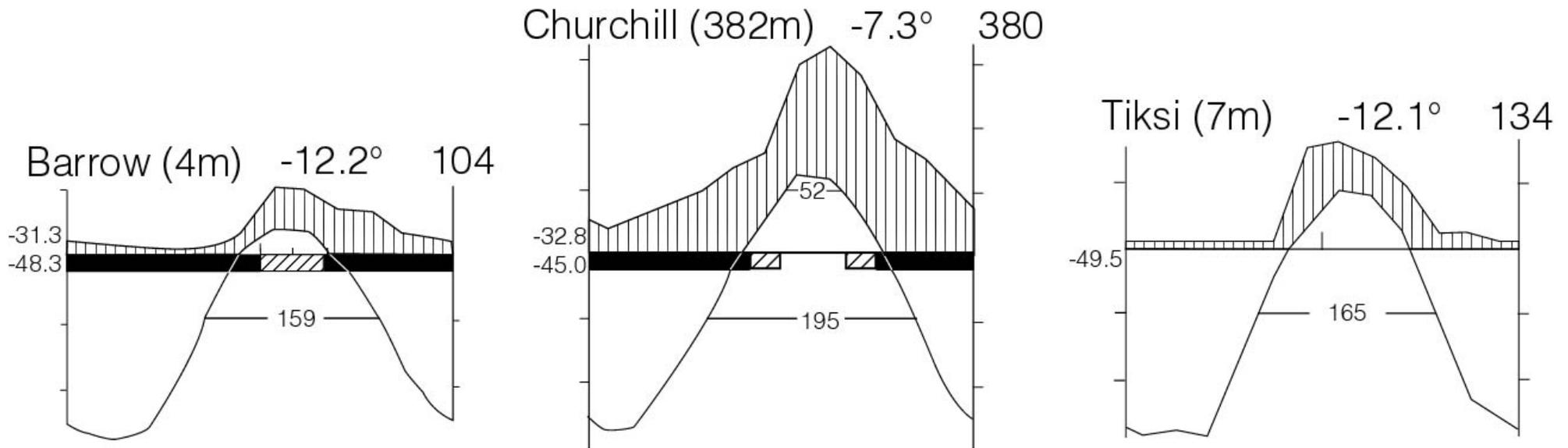
Boreal forest

Arctic tundra

- circumpolar distribution
- southern limits follows the mean summer position of arctic cold fronts
- extends over ~ 5 % of the land surface
- associated with permafrost

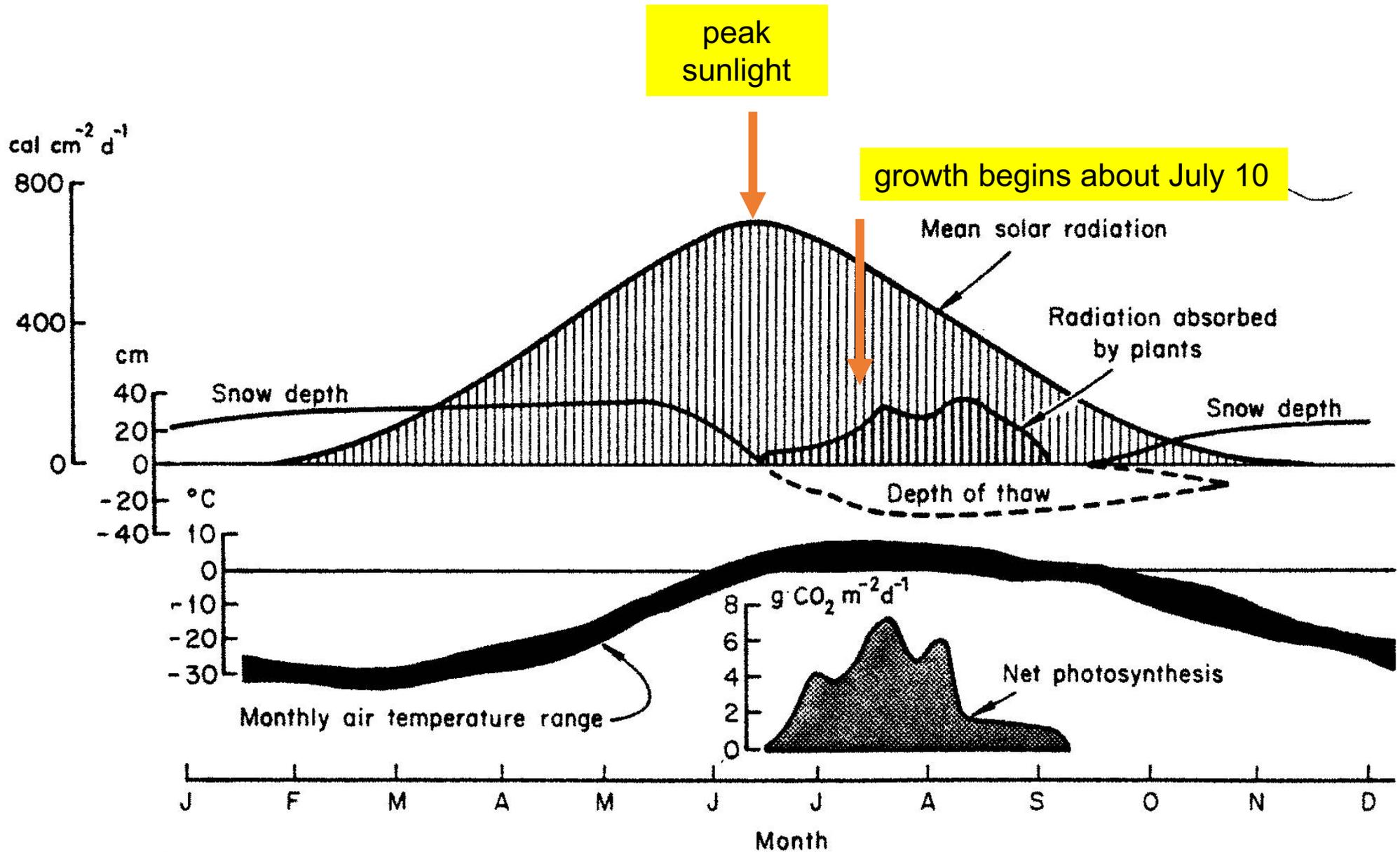


Arctic tundra climate diagrams

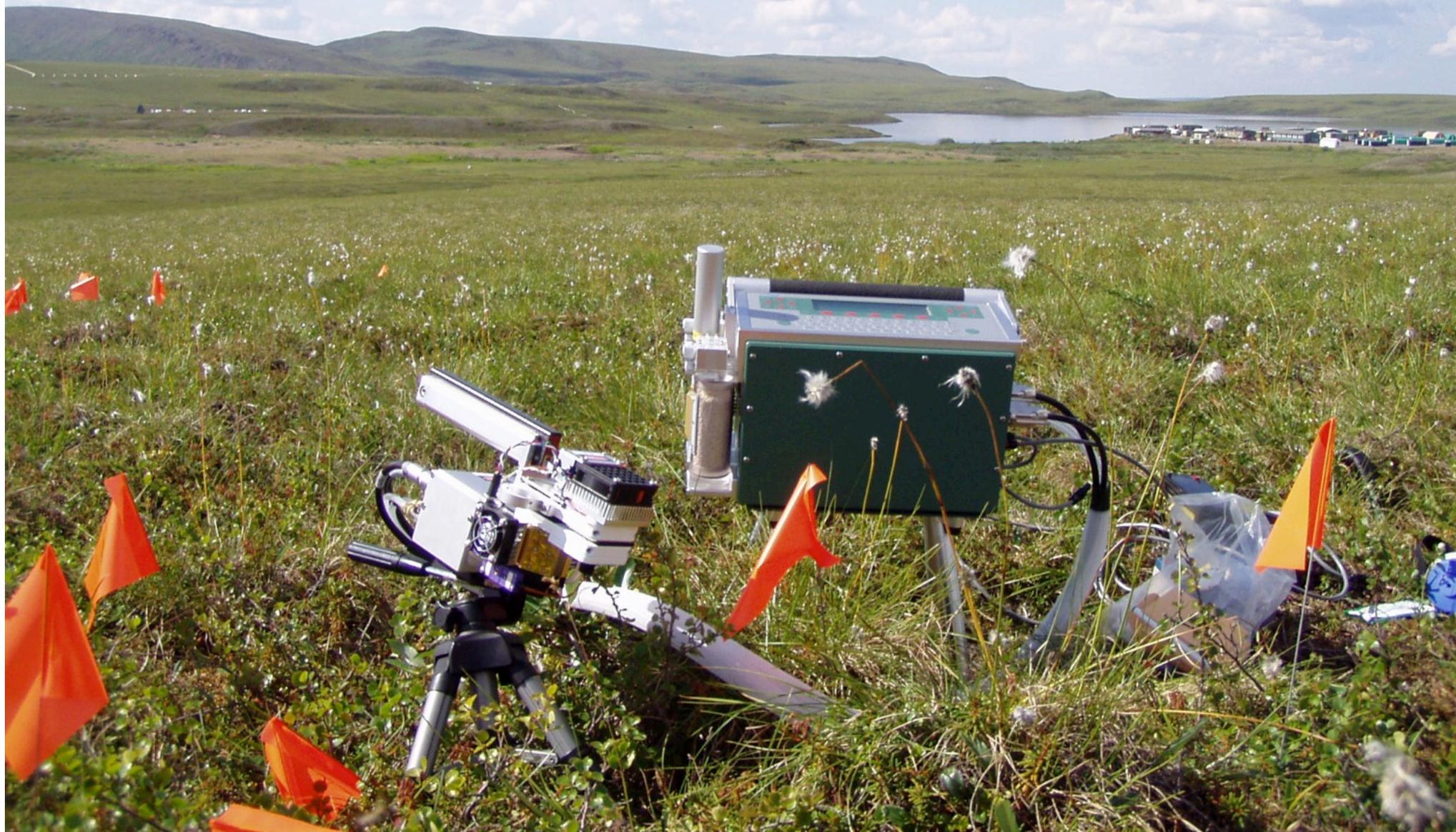


- Very cold winter temperatures (< -20 °C)
- Short growing season with cool temperatures (< 10 °C)
- Relatively low precipitation of 100 - 400 mm, but classified as humid, because precipitation is still greater than potential evapotranspiration
- Cloudy skies, but 24-hour sunlight in summer at latitudes > 66 °

Growth lags daylength because of cold late snowmelt; with climate change advancing snowmelt the start of the growing season is advancing



Toolik Lake, on the northern slopes of Alaska,
an exciting location for arctic research



Frost heaving and permafrost melting result in polygon formation. Inner wet regions melt during summer creating large ponds. The poor drainage results in a vegetation mosaic and anaerobic decomposition within the ponds results in methane production..



Creation of polygon mosaic in the arctic tundra landscape

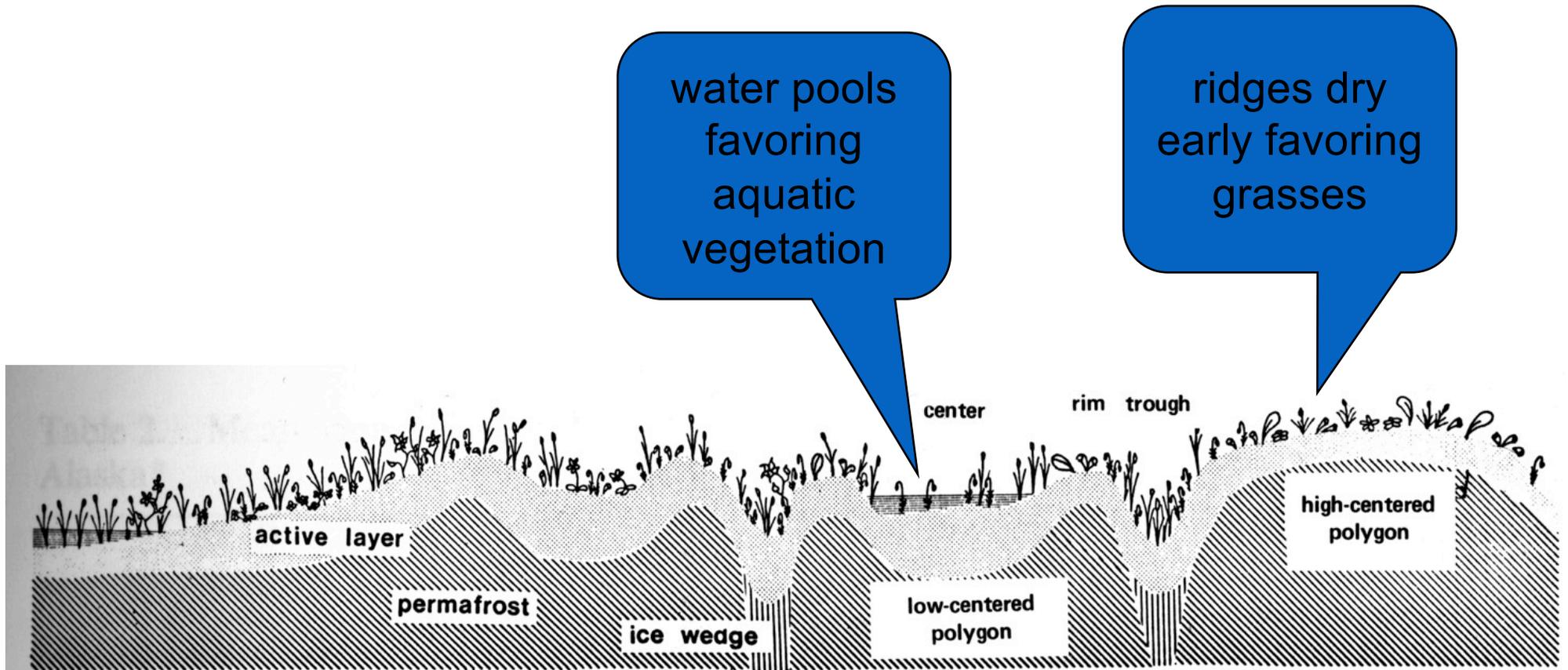


Figure 6. Diagrammatic representation of low-centered and high-centered polygons. Note the position of the ice wedges, rims, and troughs, the active layer, permafrost, and the diagrammatic representation of growth forms. (Provided by P. Bunnell.)

Part 2

Alpine tundra in temperate and tropical regions

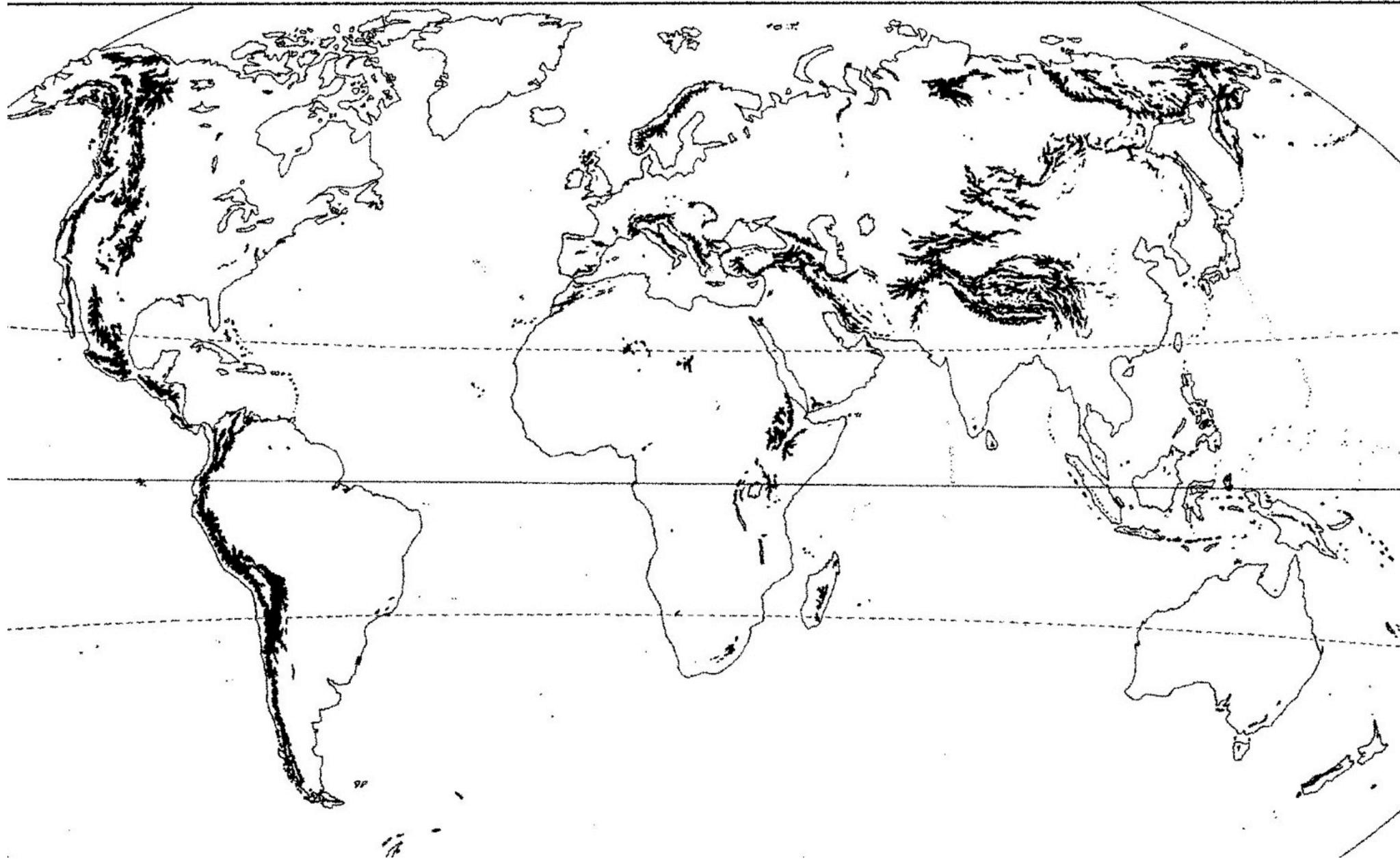


Comparison of arctic and alpine tundra environments

	Arctic tundra	Alpine tundra
permafrost	yes	no
diurnal temperature variation	low	high
solar radiation	low	high

Yet during the summer, the total daily solar radiation and mean daily temperature are quite similar between the two contrasting habitats.

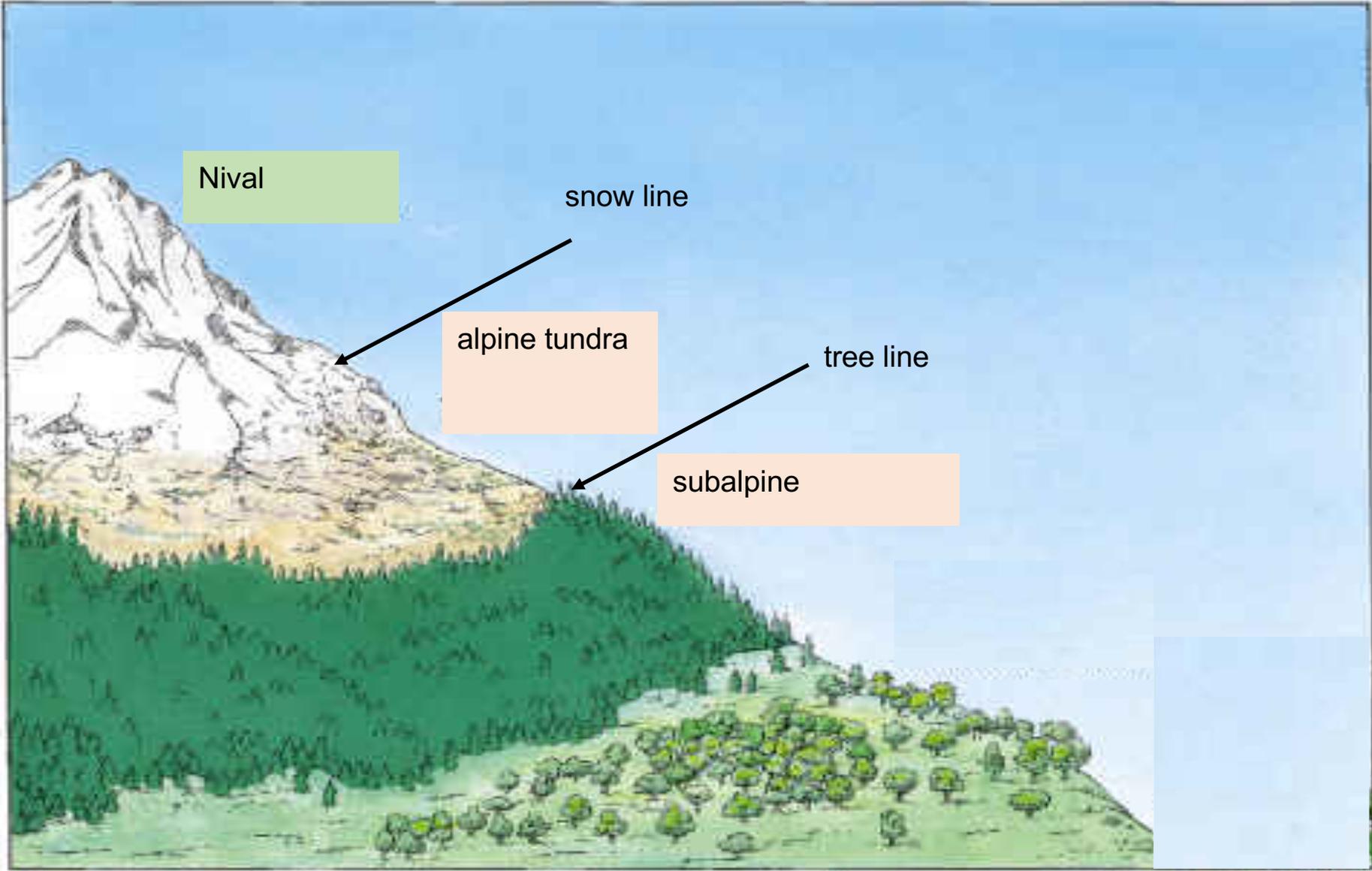
Alpine tundra regions of the world

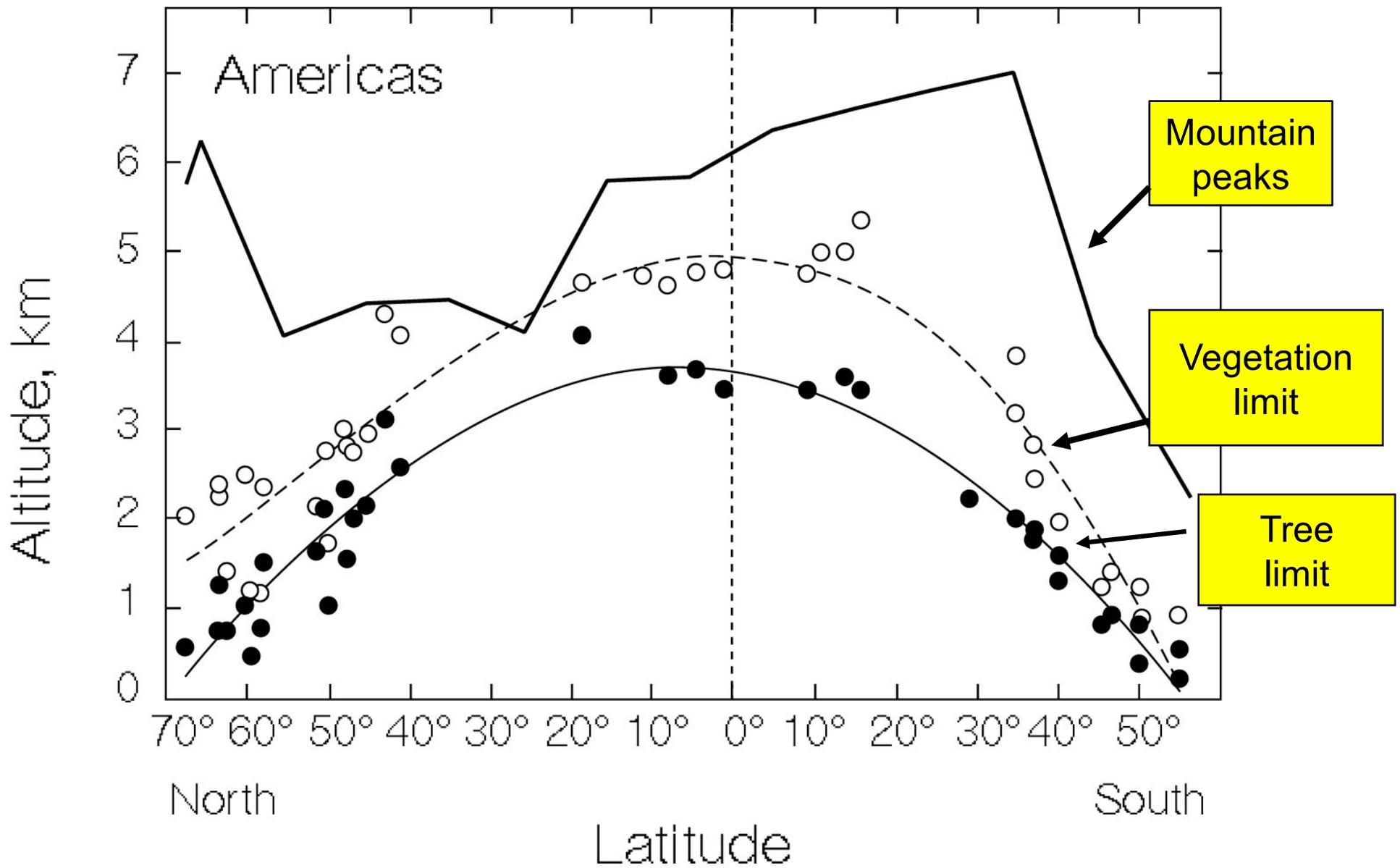


Alpine tundra, Clear Creek, Colorado



Alpine zone





Tree line becomes lower as one moves poleward.



Glacier National Park treeline

Flag trees near tree line in Colorado

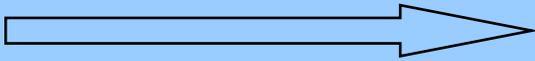


- Fragmented distribution along mountain ranges
- Geographically extensive, ~ 3 % of the land surface
- 80 % in the northern hemisphere



Microsite plays a significant role influencing plant distribution

Prevailing wind



- deep snow pack on leeward versus barren windward
- north- versus south-facing slopes
- drainage versus slope
- soil water drainage can result in ponding

Fellfield

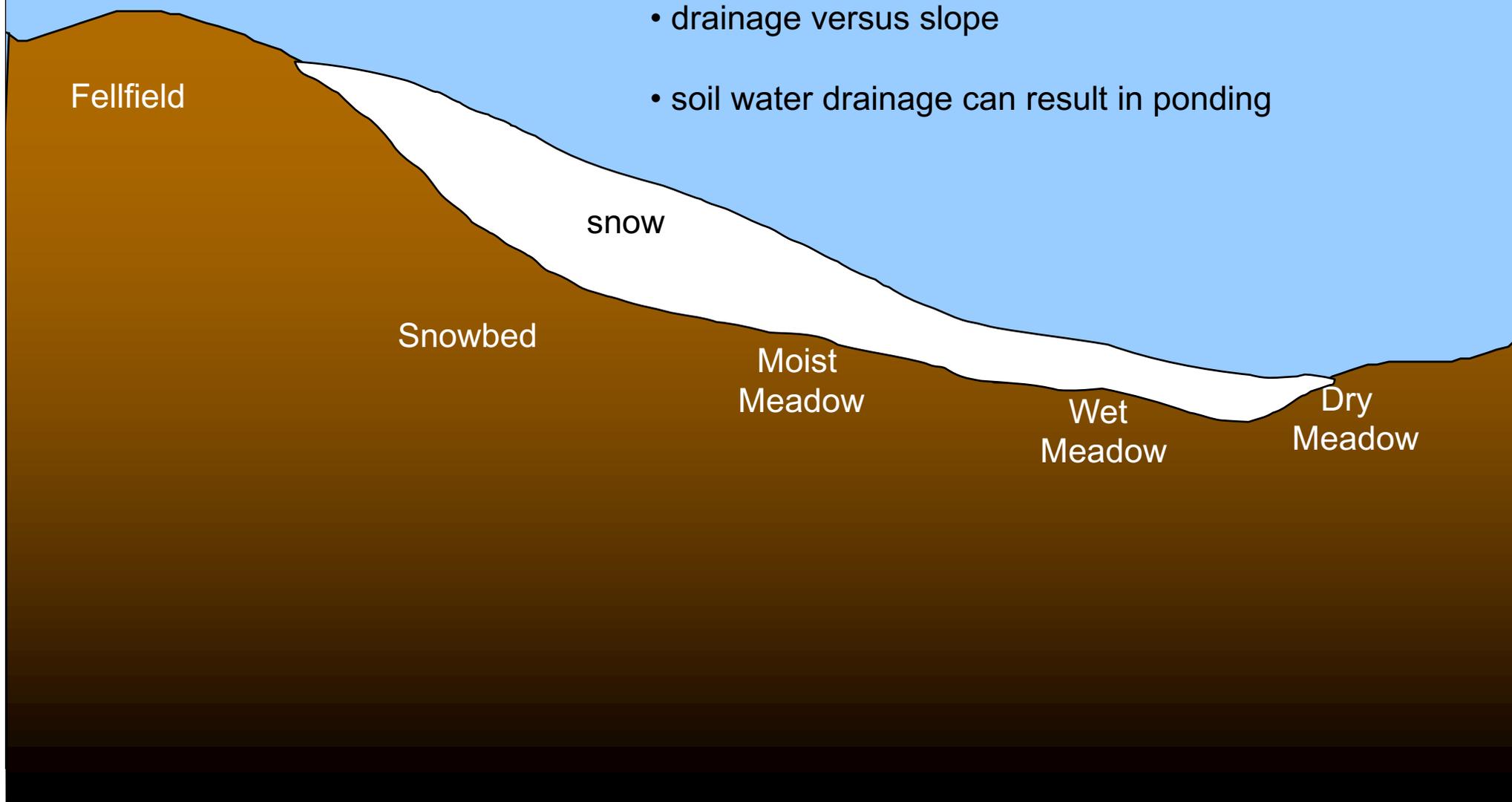
snow

Snowbed

Moist
Meadow

Wet
Meadow

Dry
Meadow



Microhabitat gradients across the alpine tundra



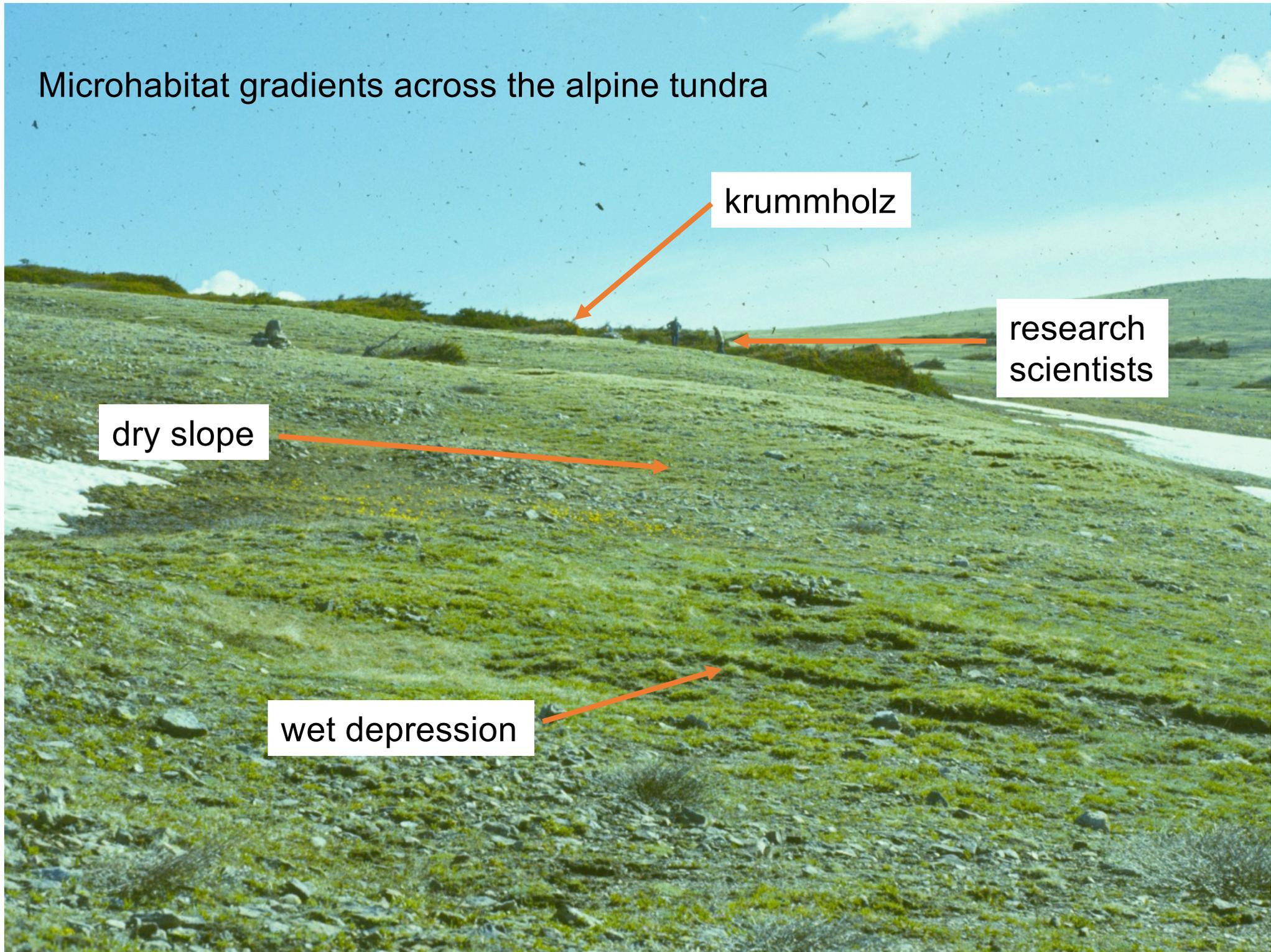
Microhabitat gradients across the alpine tundra

krummholz

research
scientists

dry slope

wet depression



Soil surfaces can be very active

Frost heaving can result in polygon formation in alpine regions as well

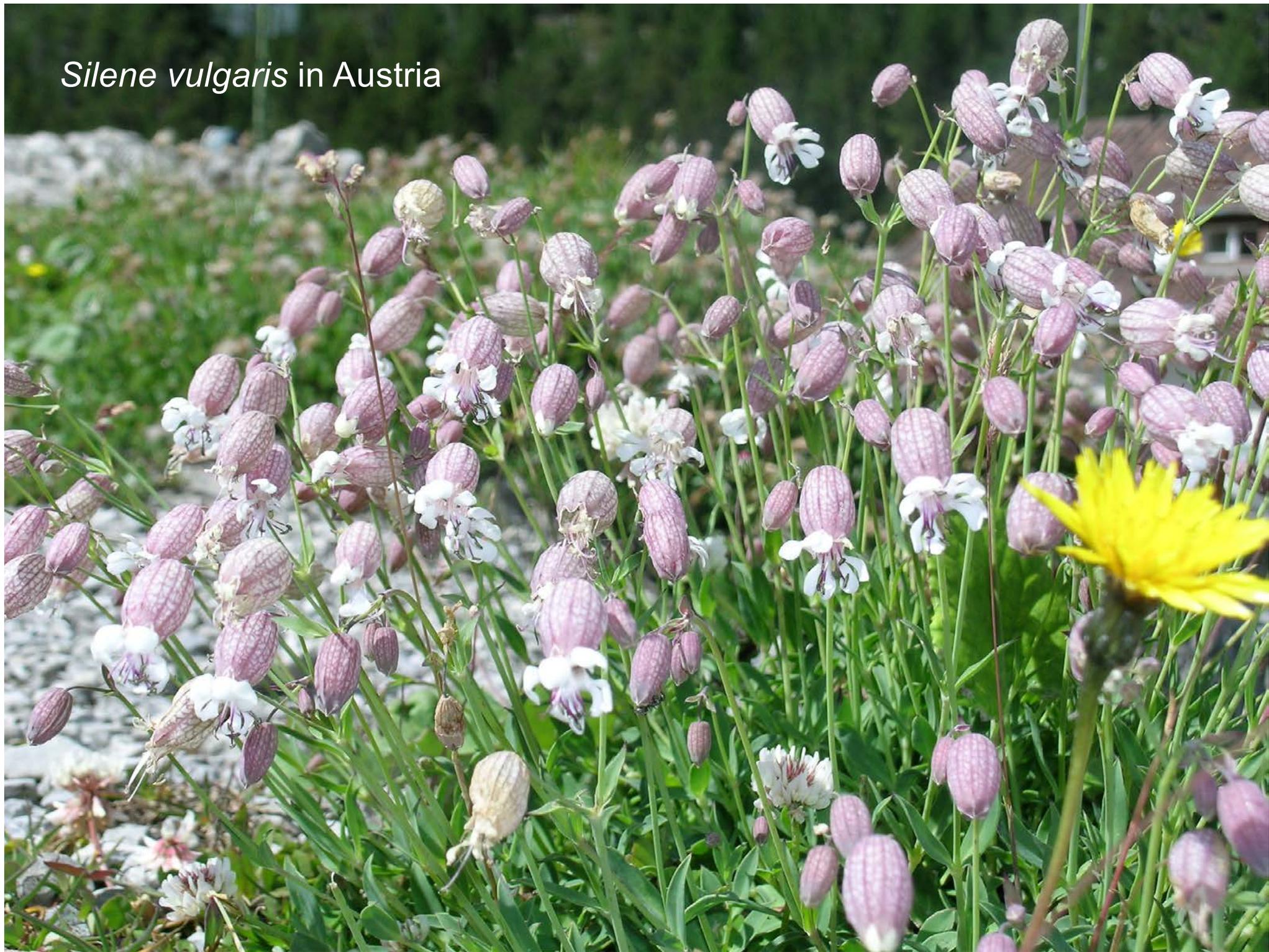


Part 3

Tundra biomes are dominated by hemi-cryptophytes



Silene vulgaris in Austria

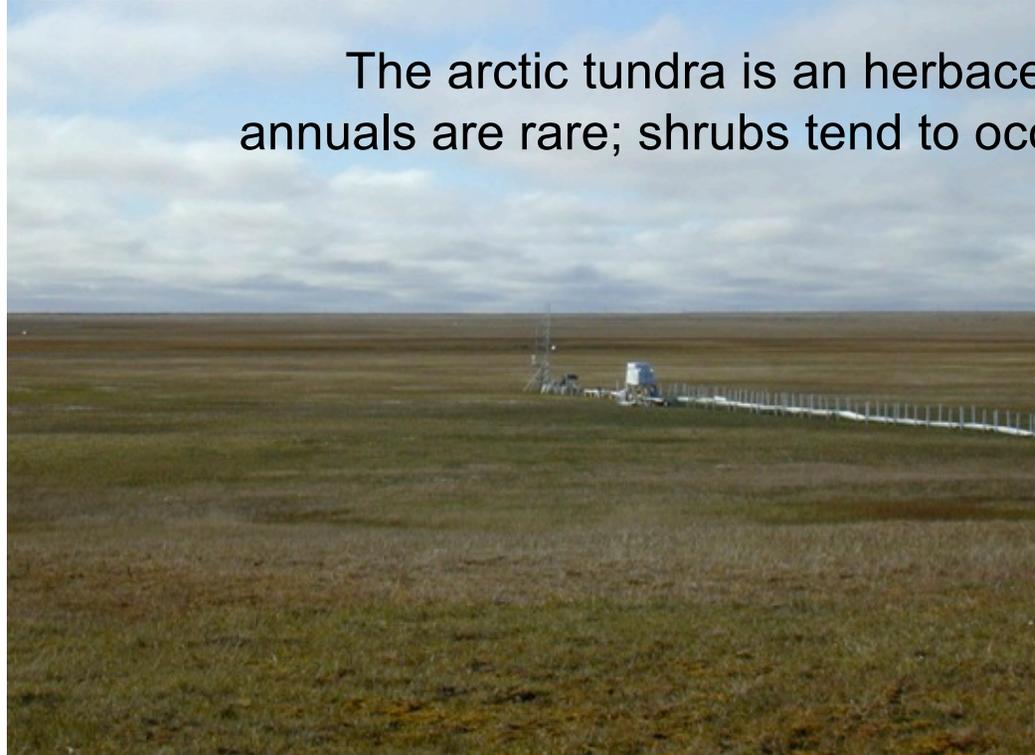


Little Cottonwood Canyon
(note feathering)



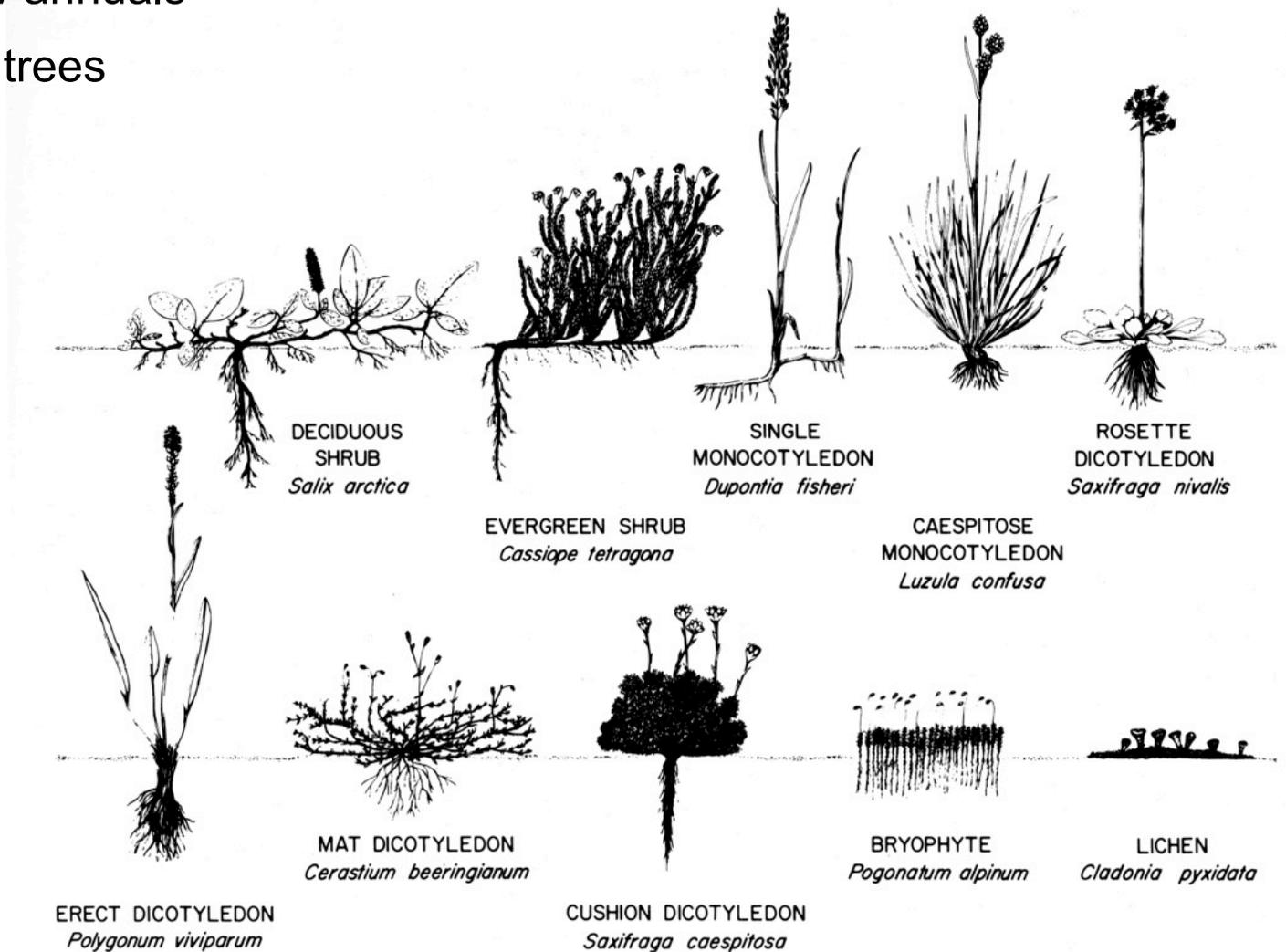


The arctic tundra is an herbaceous vegetation without trees; annuals are rare; shrubs tend to occur only in favorable microhabitats

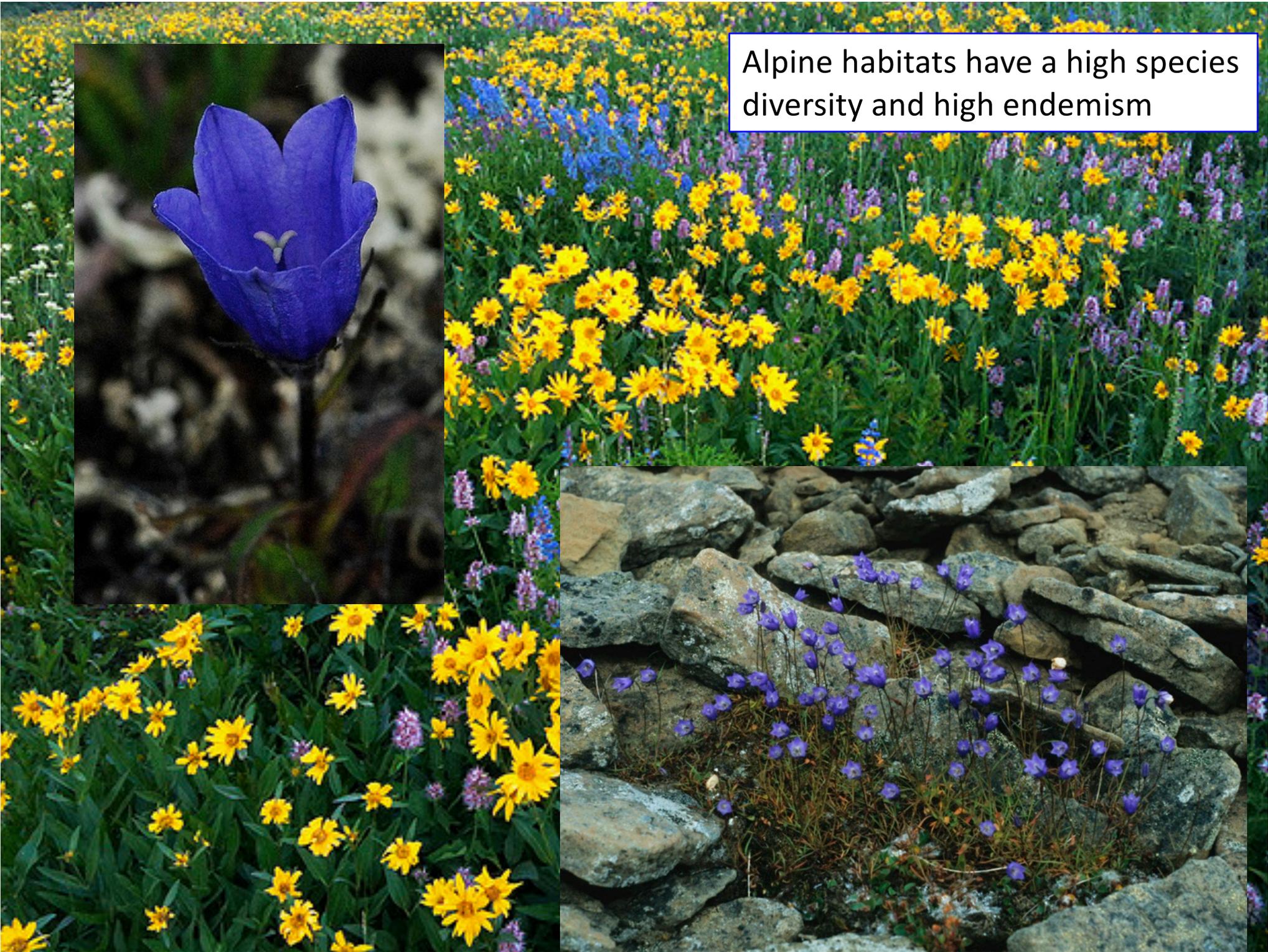


Arctic tundra life forms

- predominantly monocot and dicot herbaceous perennials
- limited shrubs, primarily influenced by winter snow pack conditions
- few annuals
- no trees



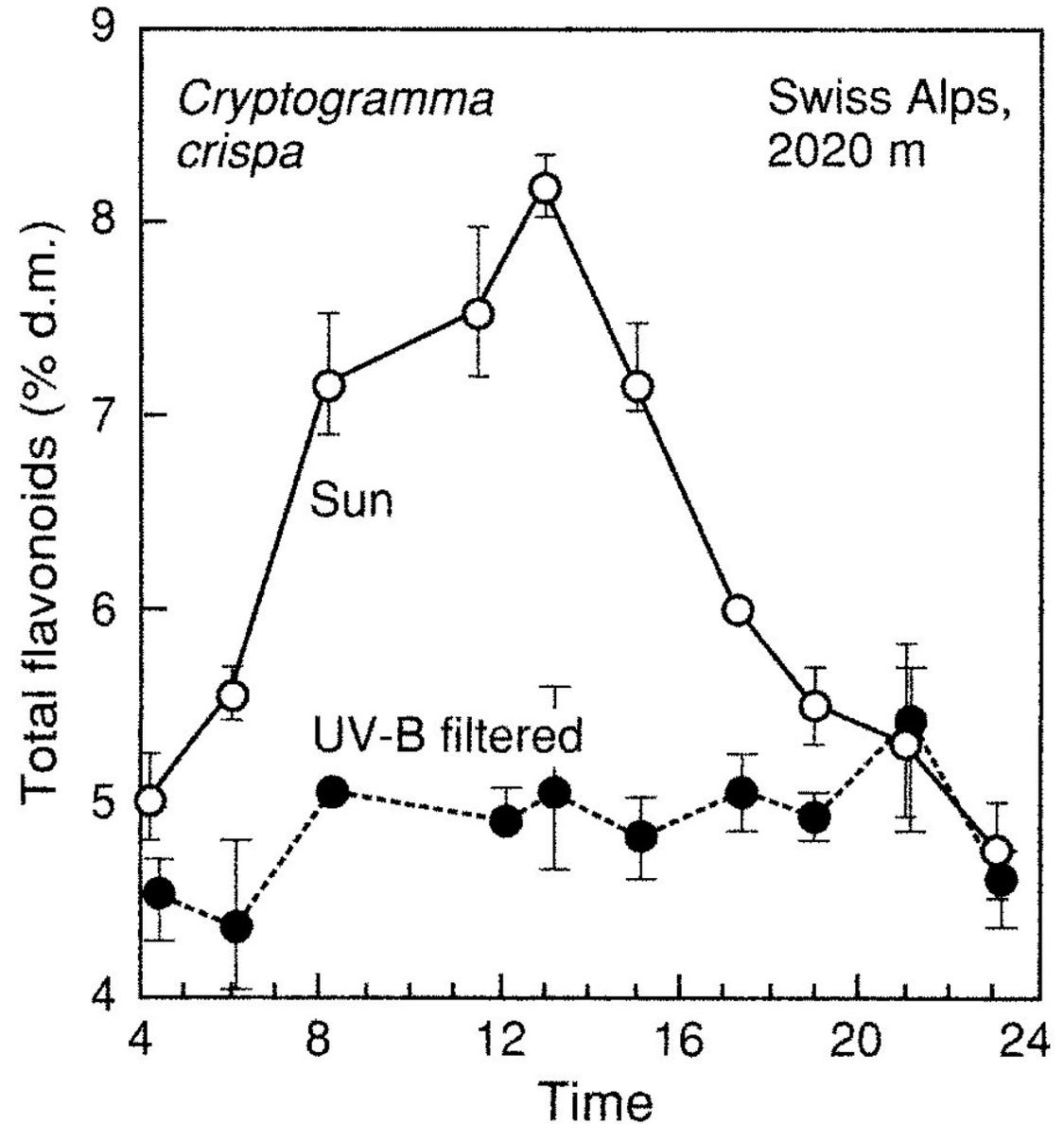
Alpine habitats have a high species diversity and high endemism



cushion plants are a common life form of the alpine tundra from temperate to tropical latitudes



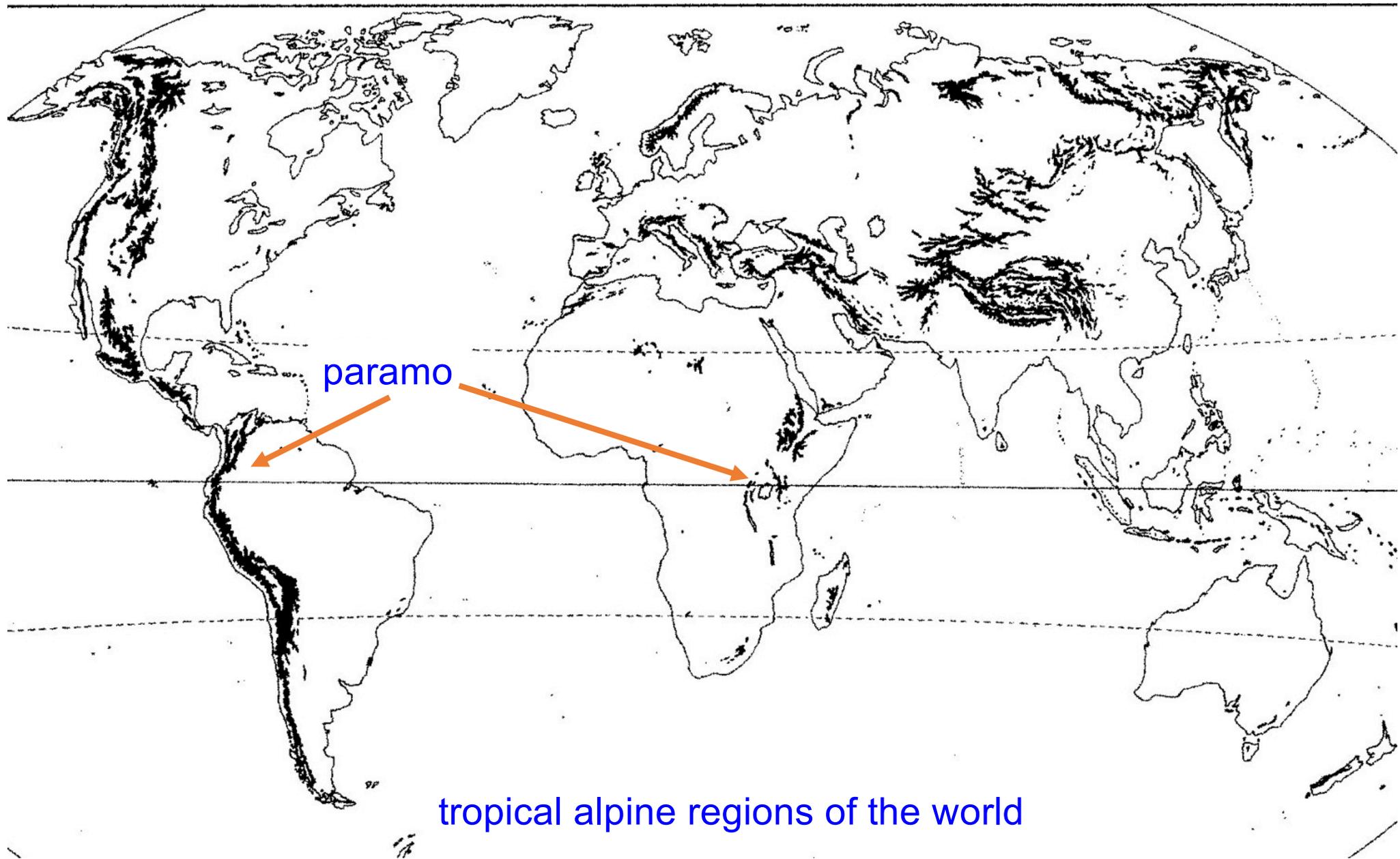
Mechanisms to reduce UV damage are common among alpine plants



Part 4

Convergence in tropical alpine vegetation





paramo

tropical alpine regions of the world

Espeletia, Lobelia, Senecio - arborescent paramo taxa

Predominant tropical alpine tundra life forms

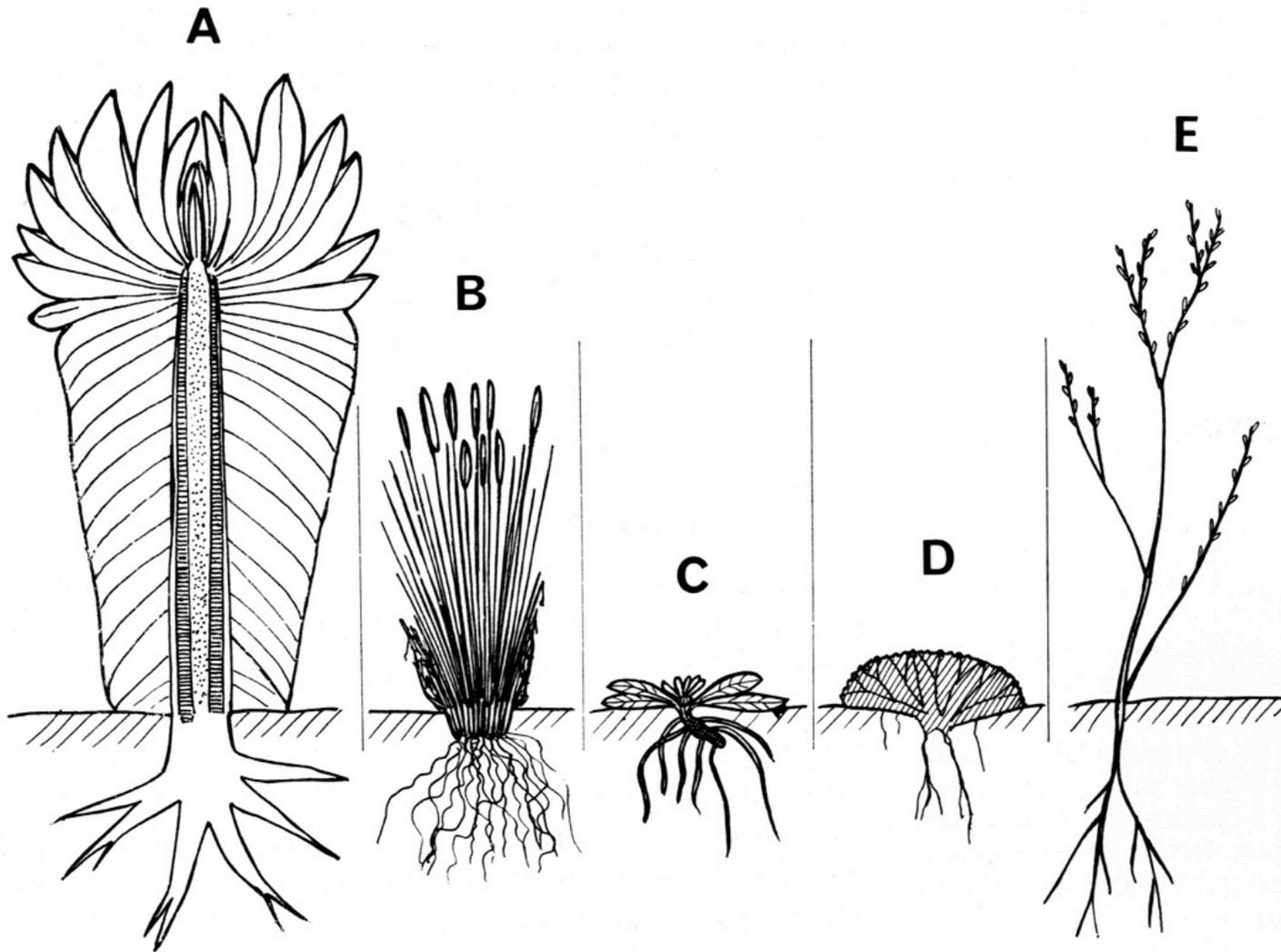


Fig. 1. Diagrammatic sketch illustrating the five most important life-forms of tropical-alpine vascular plants. A = Giant rosette plant, B = Tussock grass, C = Acaulescent rosette plant, D = Cushion plant, E = Sclerophyllous shrub. For further explanation see text. (From Hedberg 1964b).

Senecio brassica (Kenya)



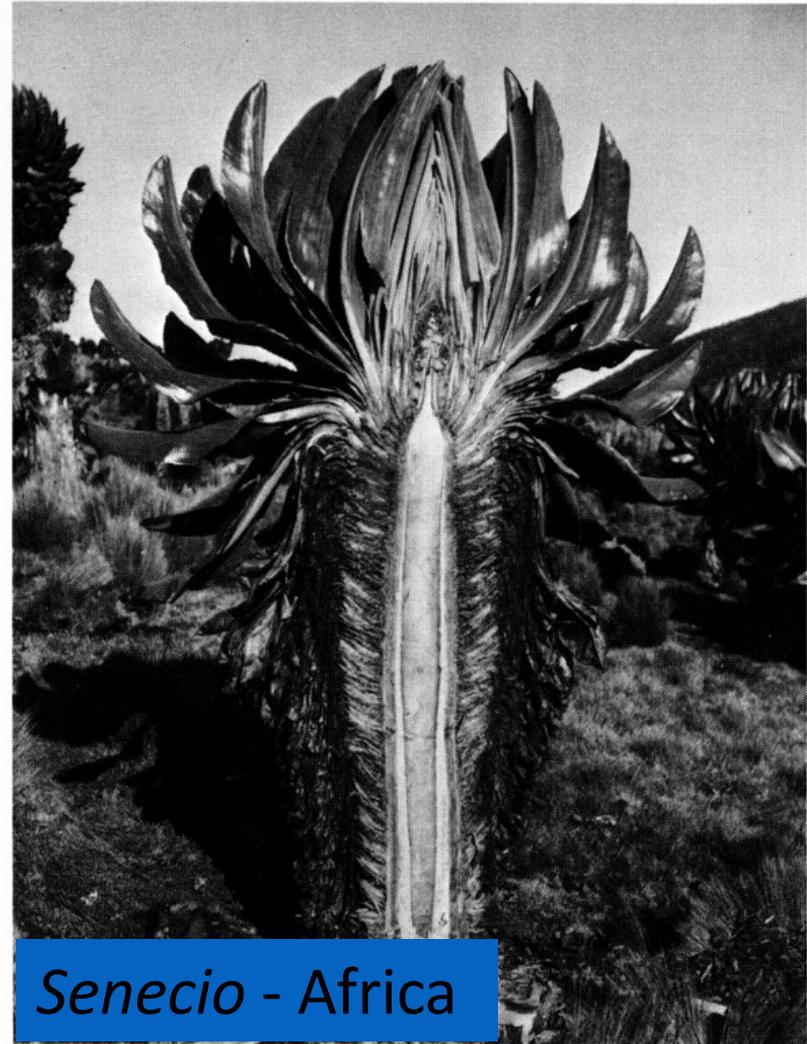
Espeletia
(Venezuela)





Espeletia - South America

Fig. 3. Specimen of *Espeletia schulzii* Wedd., about 0.8 m tall, in longitudinal section. It carries one terminal rosette about 0.5 m wide. The stem contains a thick pith (whitish in the photograph) surrounded by a thin layer of secondary wood (delimited from the pith by a darker line) and a thin cortex (dark grey), carrying on its outside a dense insulating mantle of marcescent dry leaves. The centre of the nyctinastic leaf rosette as well as the water-conducting tissues of the stem are efficiently protected against night frosts. Mucabaji, 3600 m, 15.3.1977. Photo I. Hedberg.



Senecio - Africa

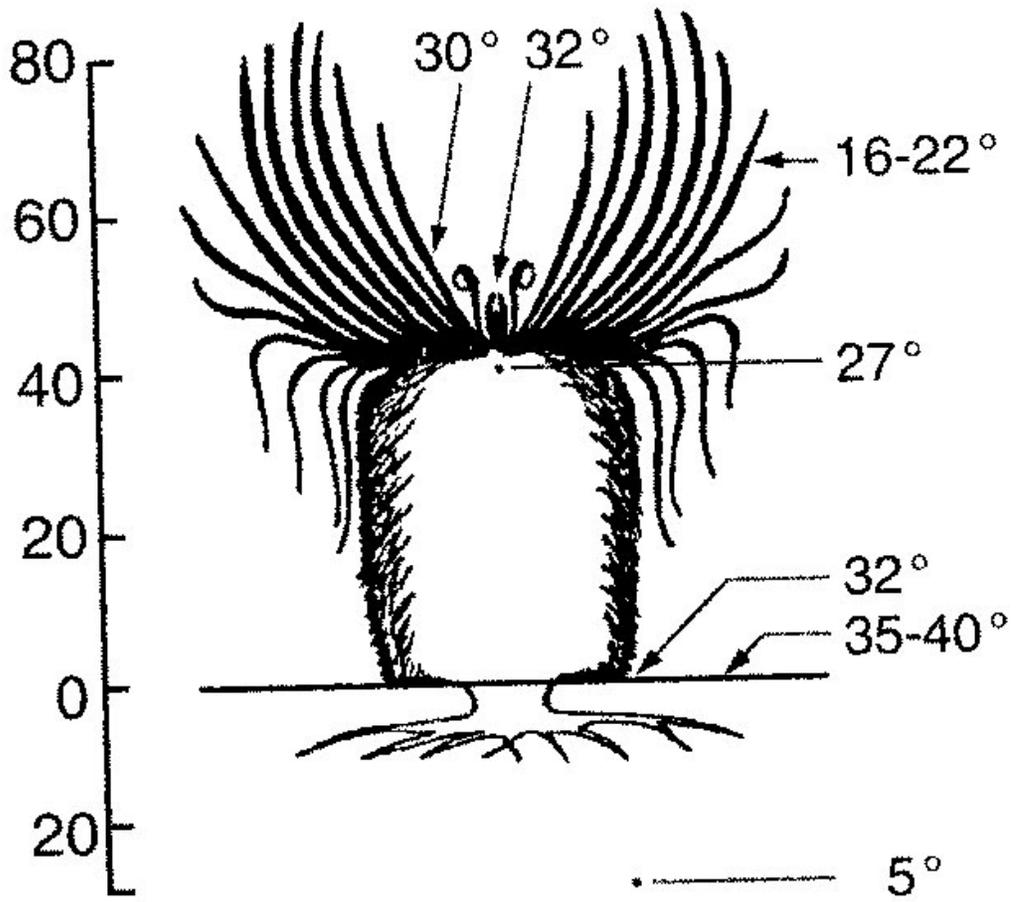
Fig. 4. Specimen of *Senecio keniodendron*, about 1.7 m tall, in longitudinal section. The stem carries a terminal leaf rosette, about 1 m wide, in the centre of which appears a budding inflorescence surrounded by a mass of densely folded young leaves. The meiosis was completed. In the centre of the stem is a thick pith (greyish in the photo) surrounded by a thin layer of secondary wood (white) and a thin cortex (grey), outside which there is a dense insulating mantle of marcescent leaves. The water-conducting tissues of the stem as well as the shoot apex and the young inflorescence are efficiently protected against the recurrent night frosts. Kenya, Mt Kenya, Teleki Valley, 4200 m, 11.8.1948. Photo O. Hedberg.

C

Espeletia schultzii

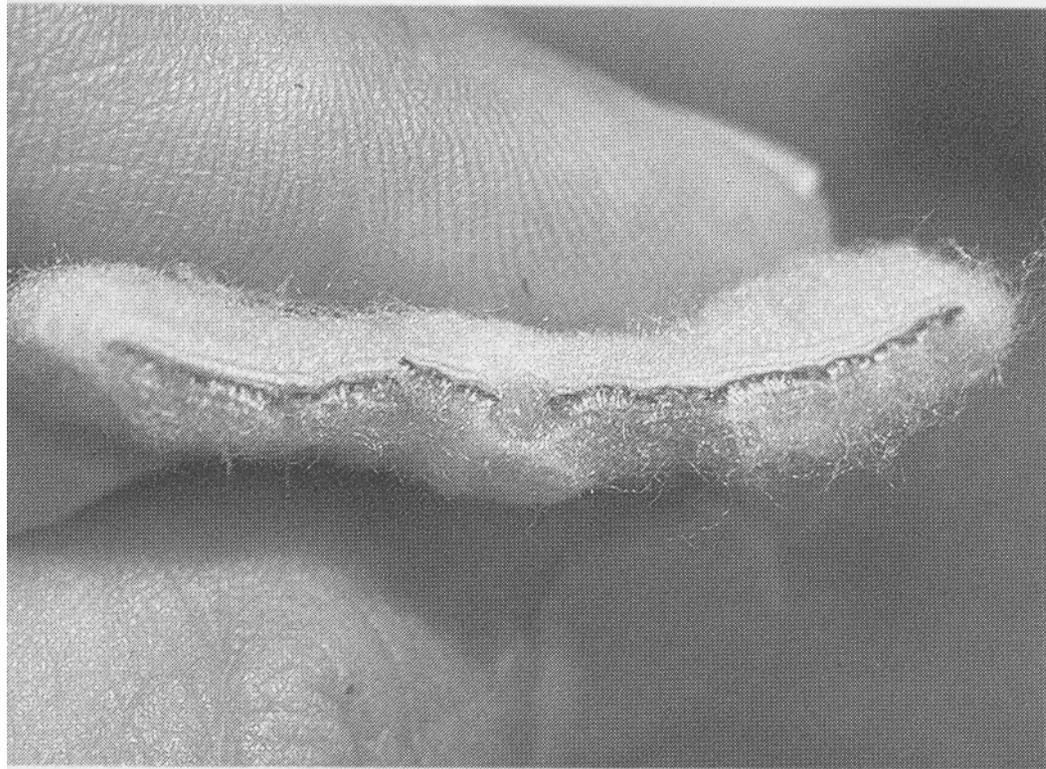
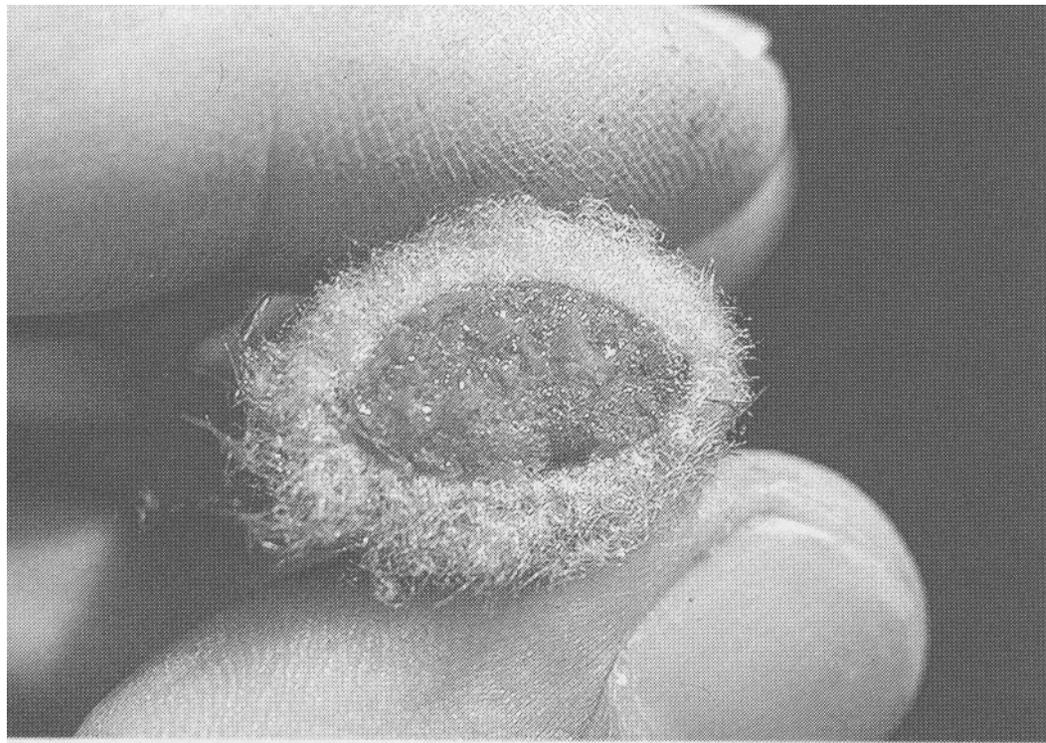
3670 m

14-16 °C



The woolly leaves of *Espeletia* have the effect of providing a boundary layer to trap heat within leaves, raising their temperatures above air during the day and avoiding night frost.





Argyroxiphium sandwicense



Silversword
in Maui



Part 5

Tundra climates are changing rapidly

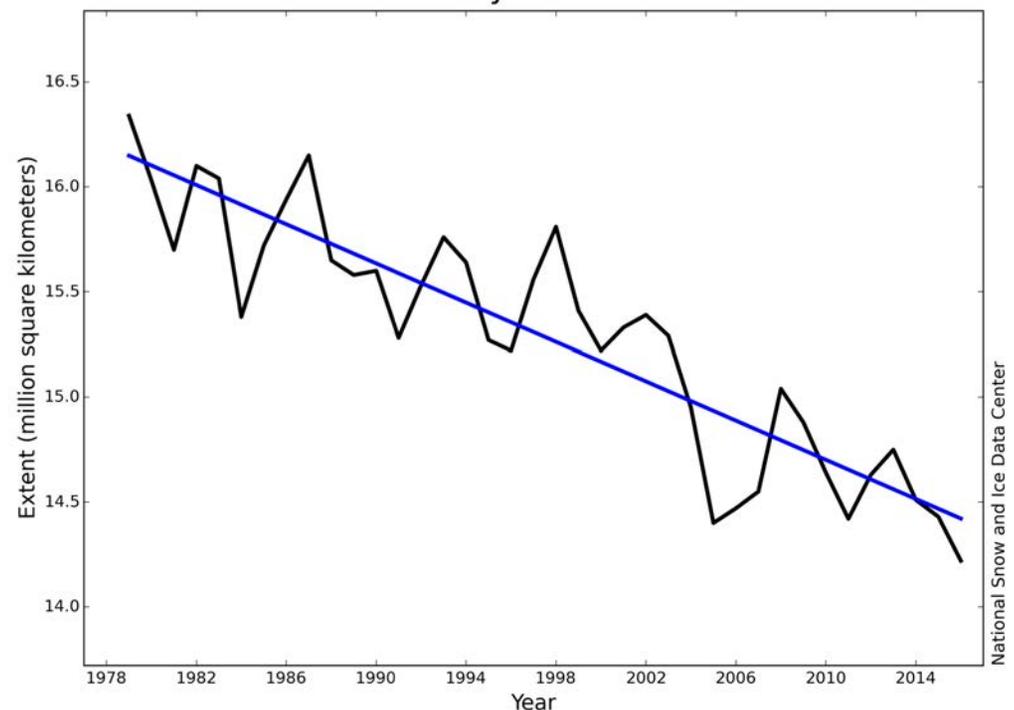




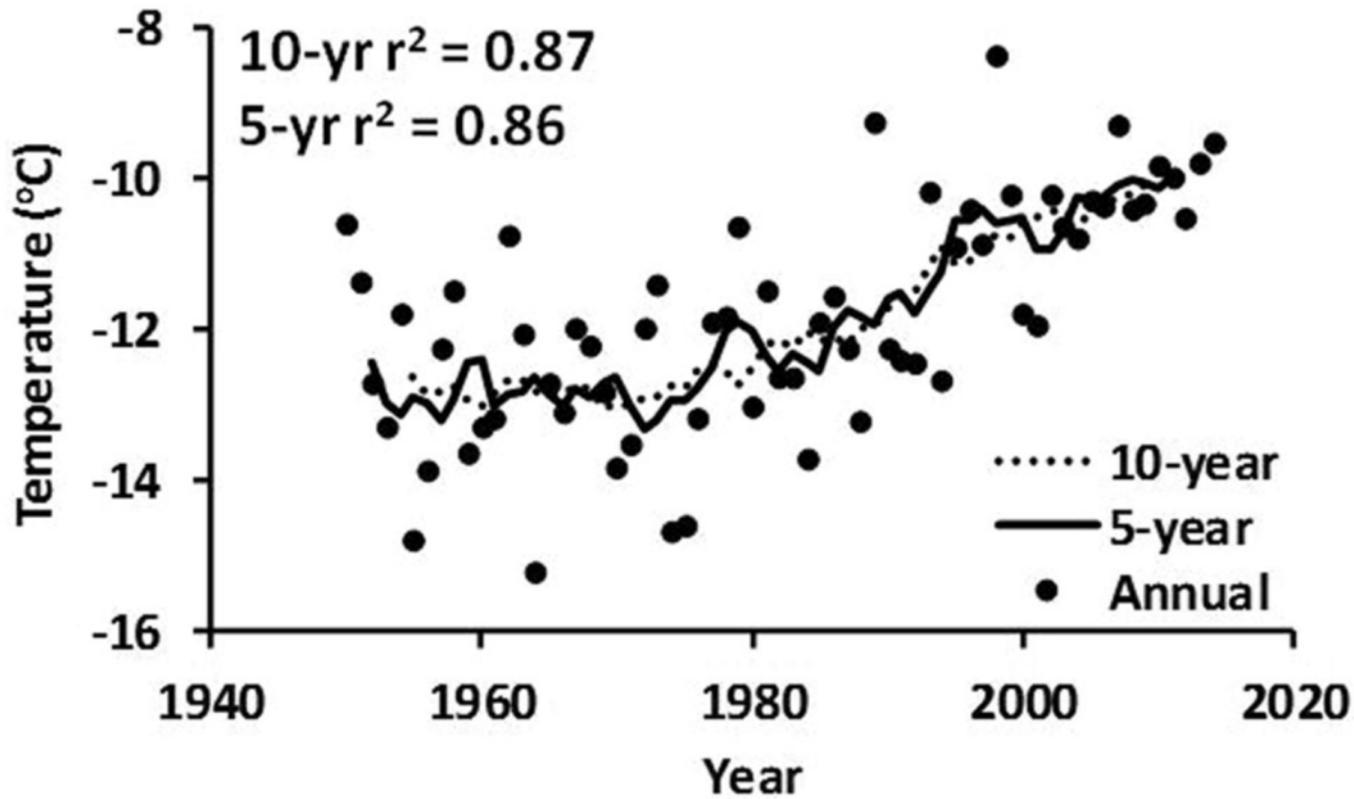
Average Monthly Arctic Sea Ice Extent
February 1979 - 2016

Arctic Sea ice has shown a consistent downward trend, with sea ice forming later in fall of the year and melting early in the summer.

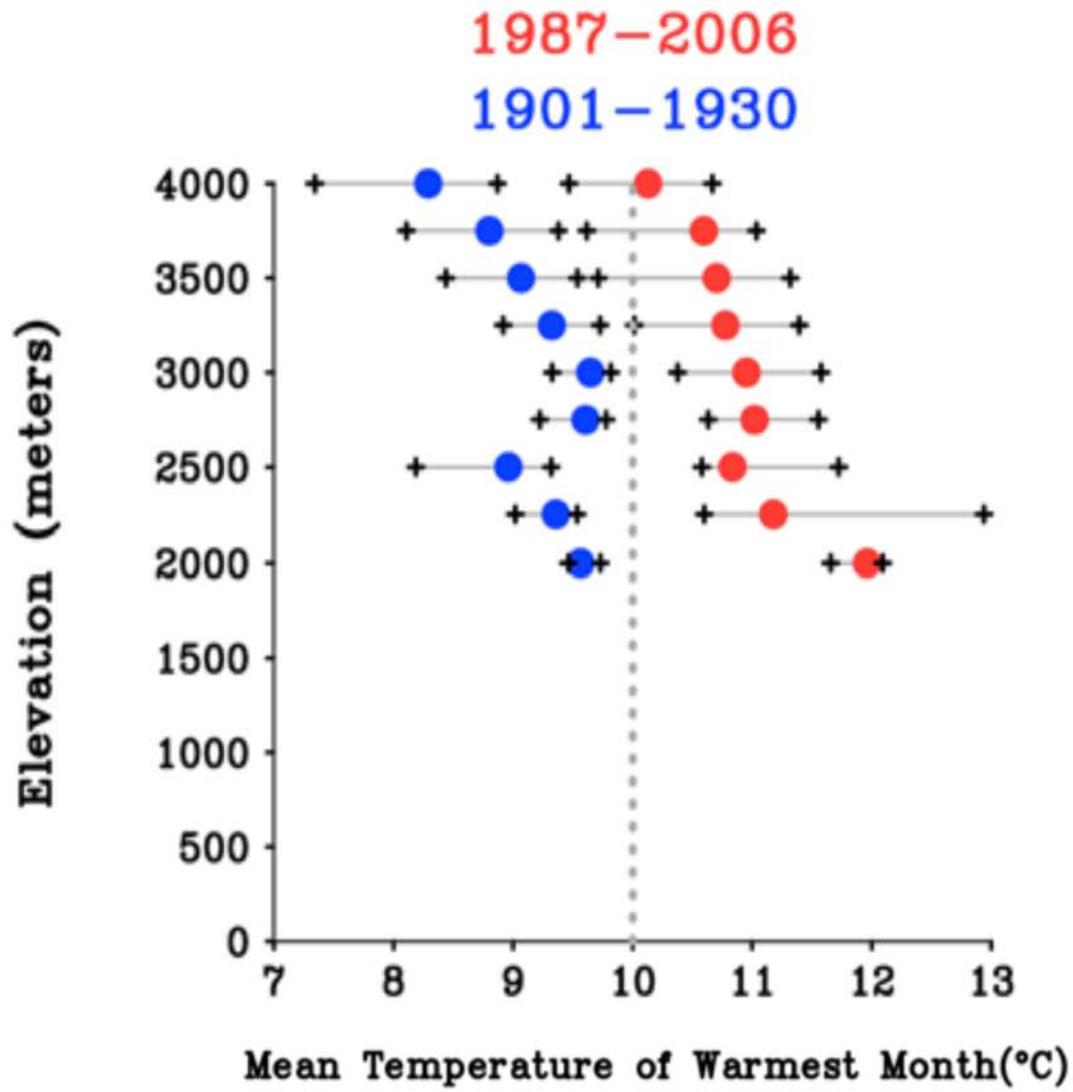
Changes in sea ice influence regional surface albedo (reflectivity), allowing the region to warm faster as solar energy is absorbed and not reflected.



Arctic tundra temperatures
have warmed significantly



Alpine tundra temperatures have warmed significantly in the central USA (Colorado, Utah, and Wyoming)



Permafrost is warming up; upper permafrost layers are melting to greater depths as the region warms up

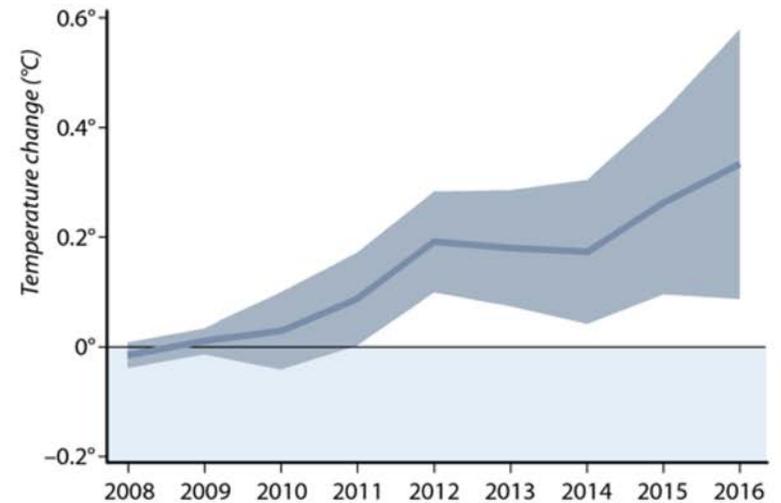


Permafrost Is Warming Up

As global temperatures rise, permafrost zones are also warming quickly. Scientists found that in the past decade, temperatures at dozens of permafrost test sites at least 30 feet deep had risen on average about half a degree Fahrenheit (0.3°C).

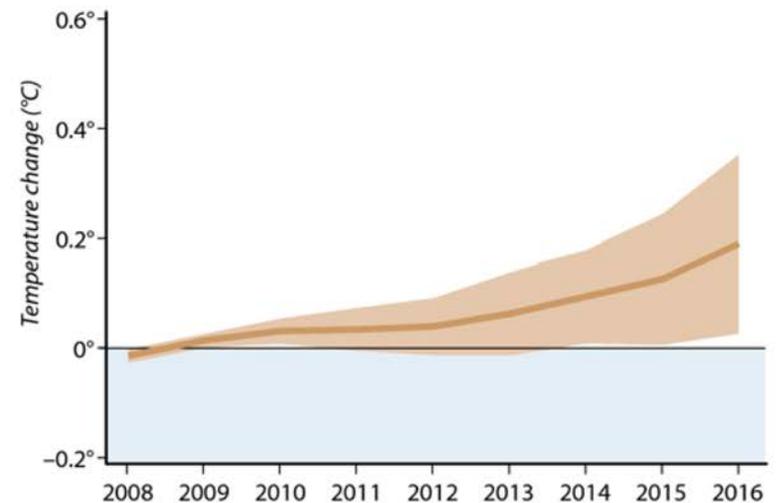
CHANGE IN ANNUAL AVERAGE CONTINUOUS ARCTIC PERMAFROST TEMPERATURE

Relative to 2008-2009 baseline



CHANGE IN ANNUAL AVERAGE HIGH MOUNTAIN PERMAFROST TEMPERATURE

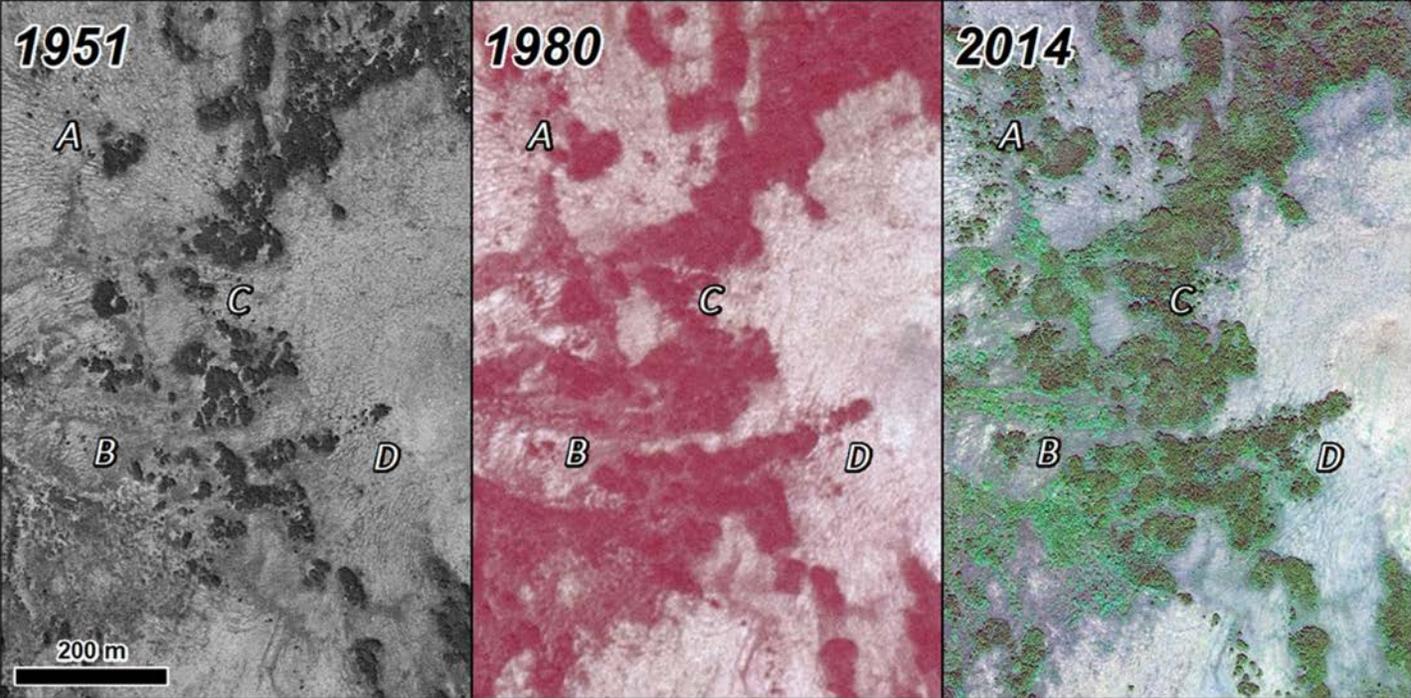
Relative to 2008-2009 baseline



In low lying tundra, lakes form as permafrost melts; decomposing organic matter in these lake is converted to **methane** (greenhouse gas) through anaerobic **methanogenesis**



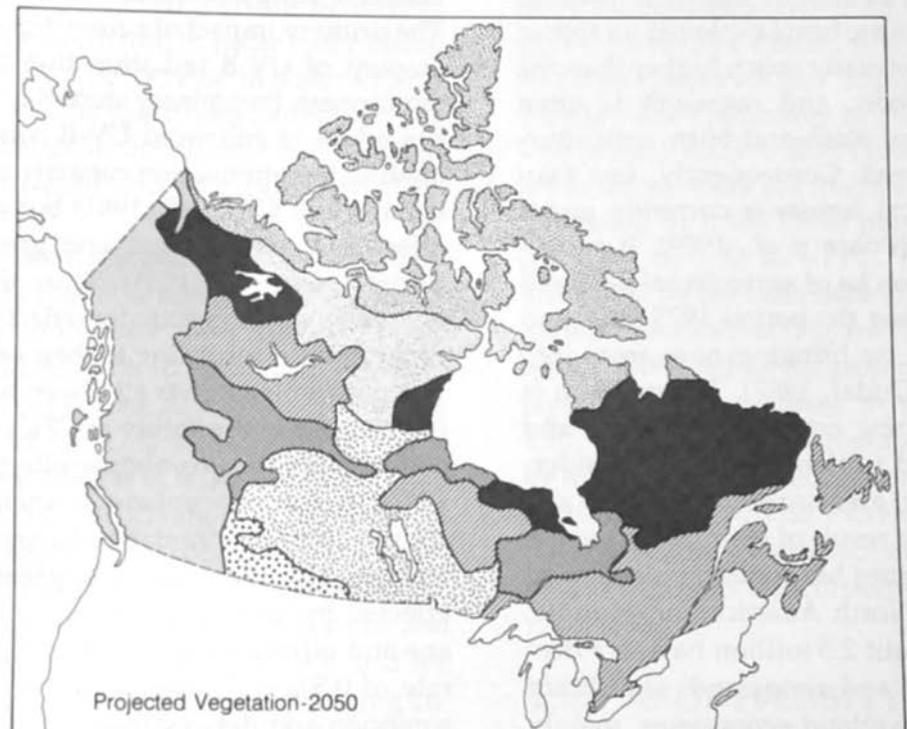
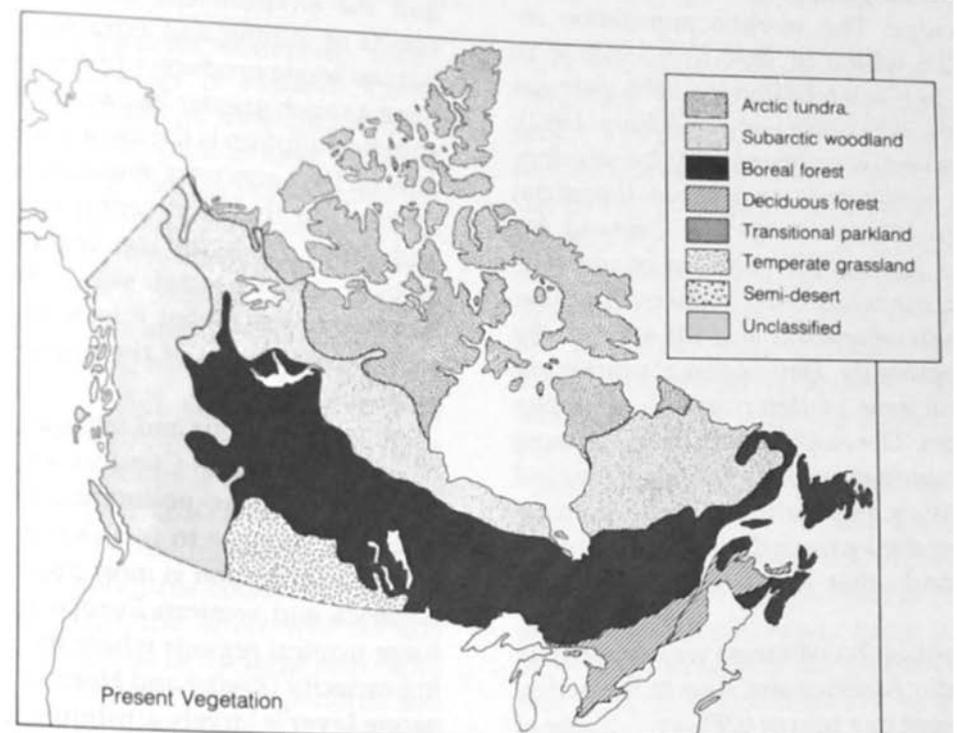
Willow shrubs have expanded their distributions since 1951



Vegetation changes are inevitable as the northern latitudes warm.

The prevalence of boreal forest and tundra are predicted to decrease with **climate change**.

The prevalence of deciduous forest and temperate grassland are predicted to expand northward with **climate change**.



Part 6

How I spent my summer (in 1972)

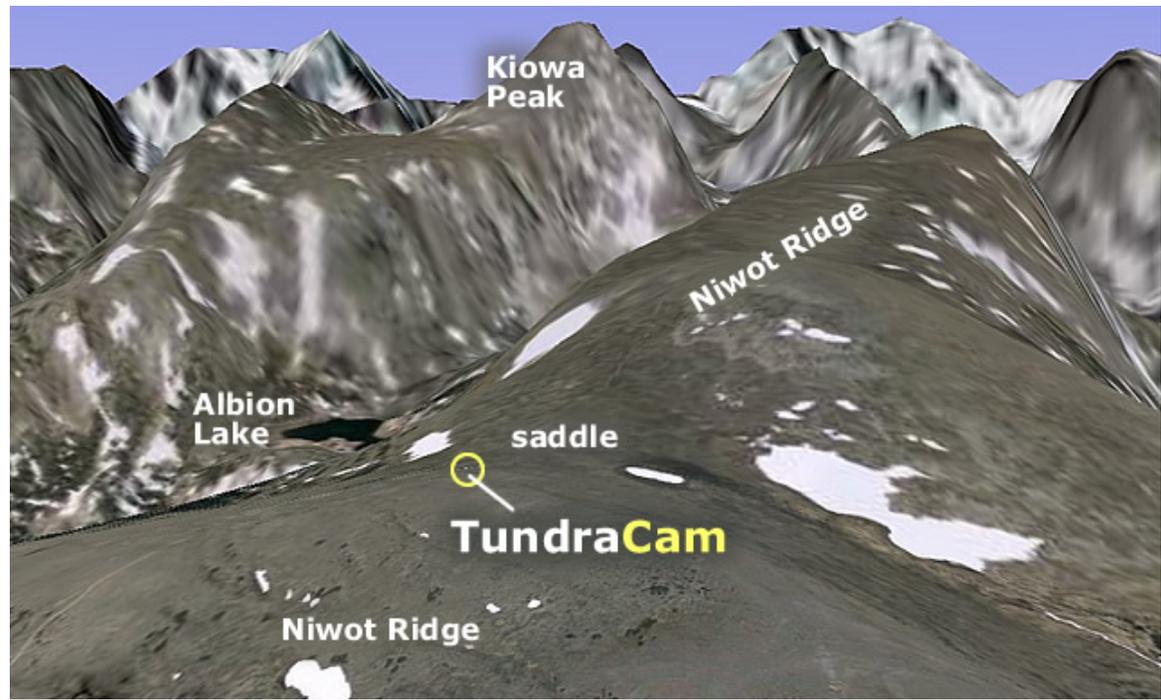


In 1972, I completed Masters Thesis research in the Colorado alpine tundra





Our 1-room home for the summer



Niwot Ridge, Colorado

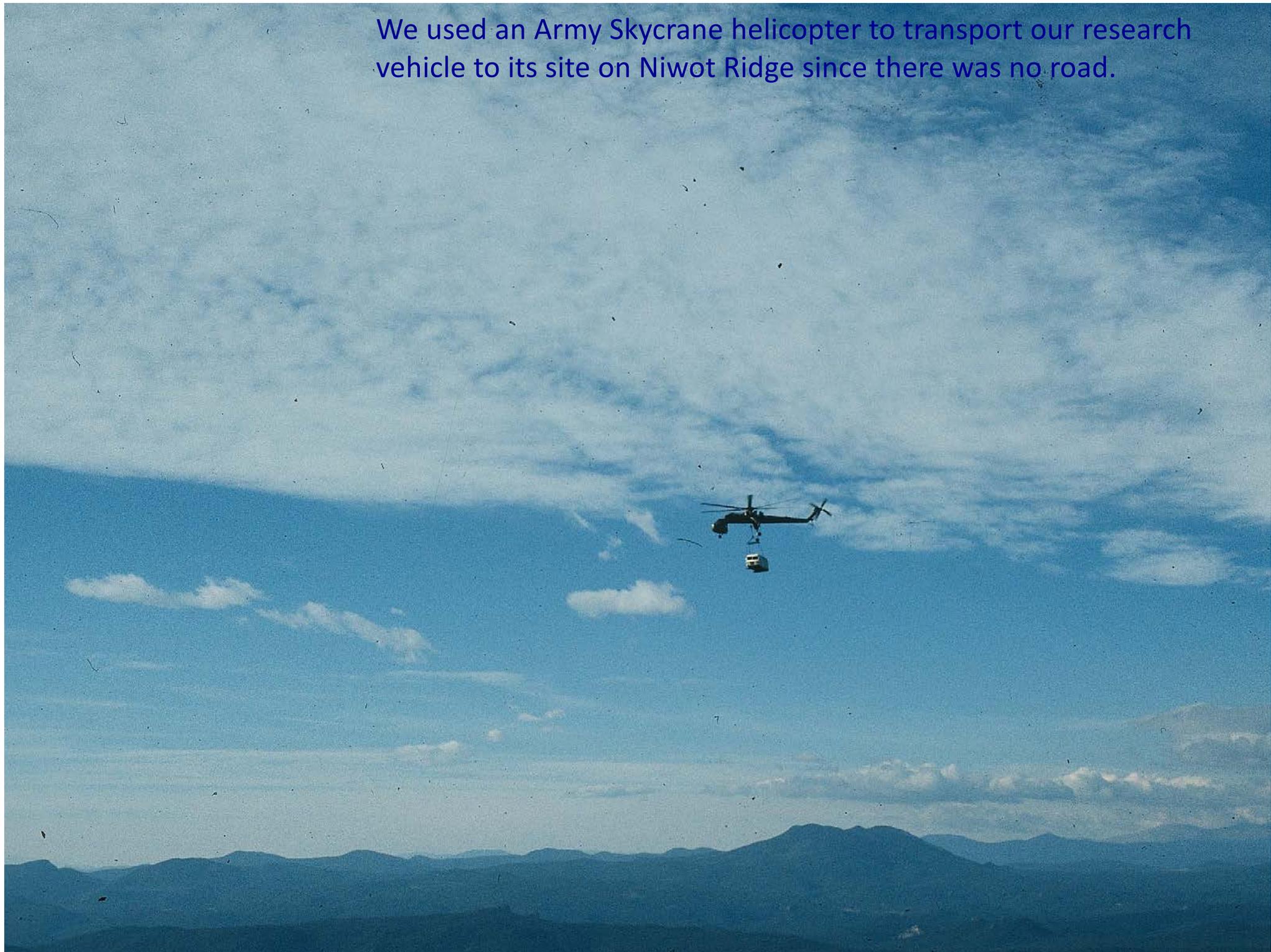
An opportunity to study physiological ecology in the alpine tundra at 10,000 ft



We used an Army Skycrane helicopter to transport our research vehicle to its site on Niwot Ridge since there was no road.



We used an Army Skycrane helicopter to transport our research vehicle to its site on Niwot Ridge since there was no road.



We used an Army Skycrane helicopter to transport our research vehicle to its site on Niwot Ridge since there was no road.





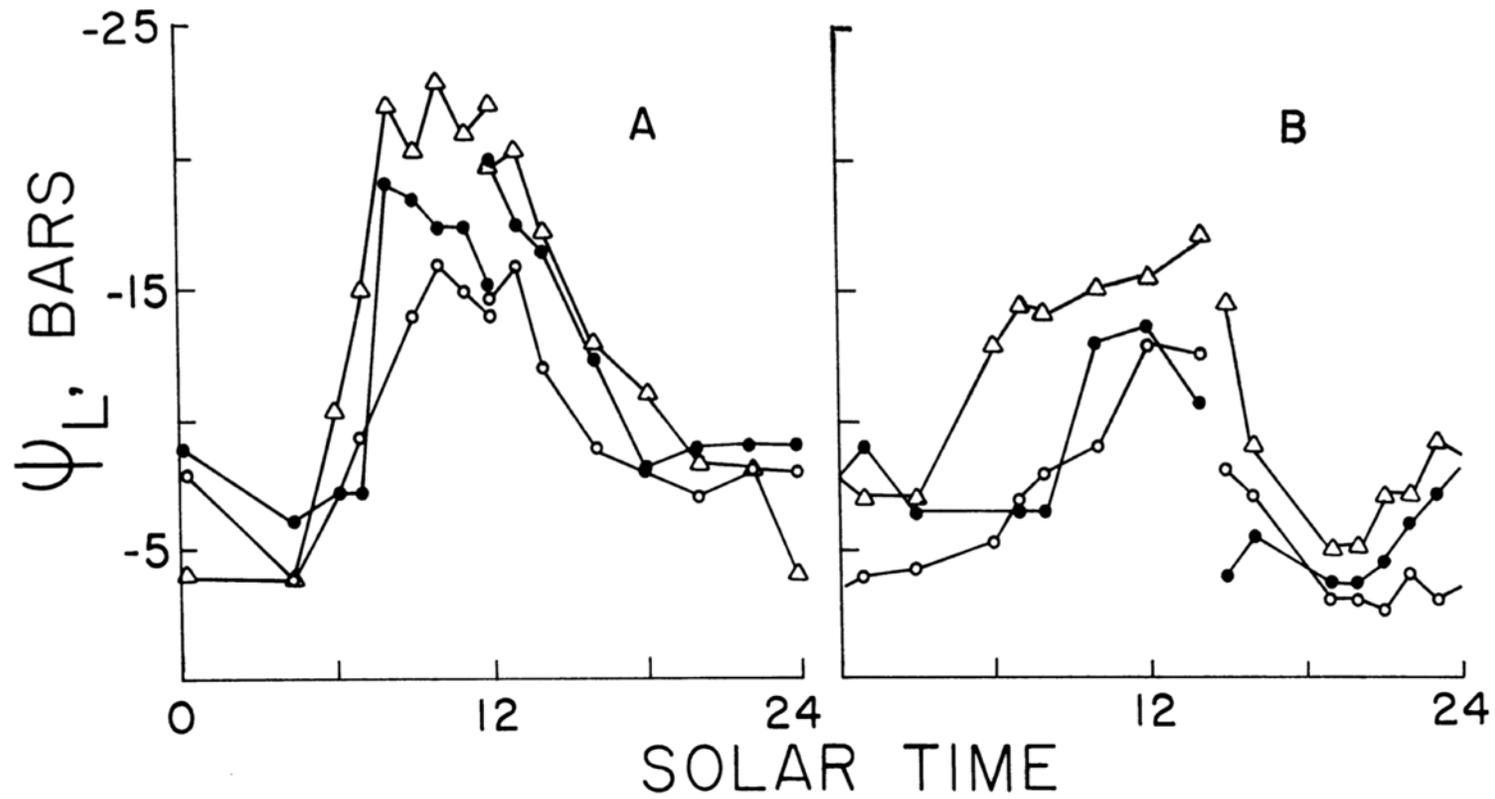


FIG. 4. Daily courses of leaf water potentials (Ψ_L) of *Geum* (●), *Bistorta* (○), and *Deschampsia* (△) on August 10-11 (A) and August 21-22 (B).



Little Cottonwood Canyon
(note krummholz, mine spoils)

