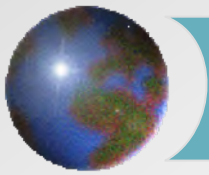


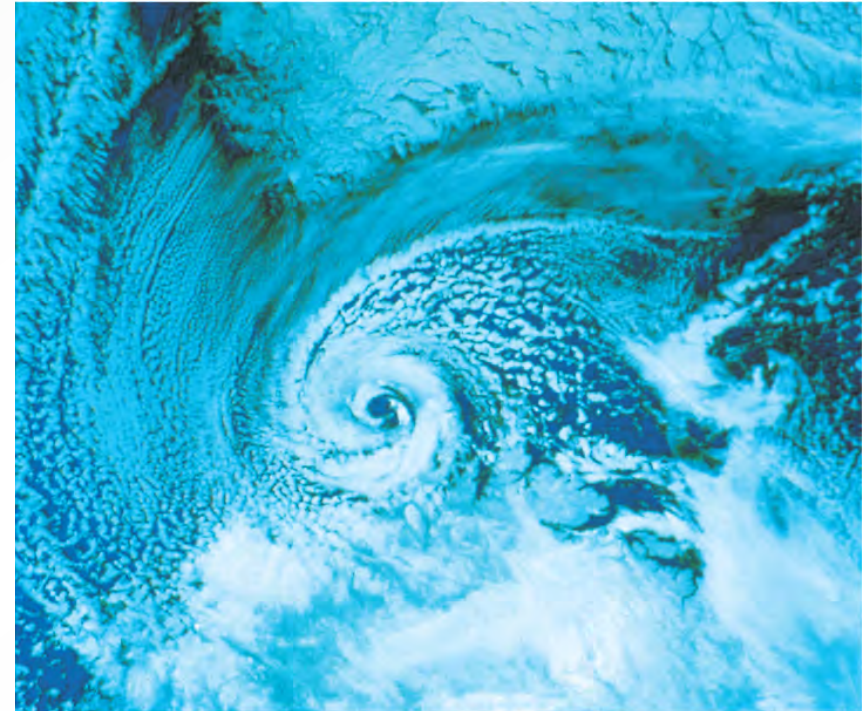
© C. Donald Ahrens

● **FIGURE 19.29** A primary and a secondary rainbow.

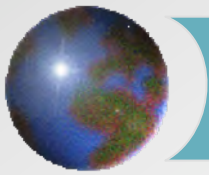


## *Polar Lows*

- ❖ Cyclones forming over the open sea in polar regions
- ❖ Winds must be *gale force*
  - ❑ >60 km/h
- ❖ Several hundred kilometres in diameter
- ❖ Last up to two days

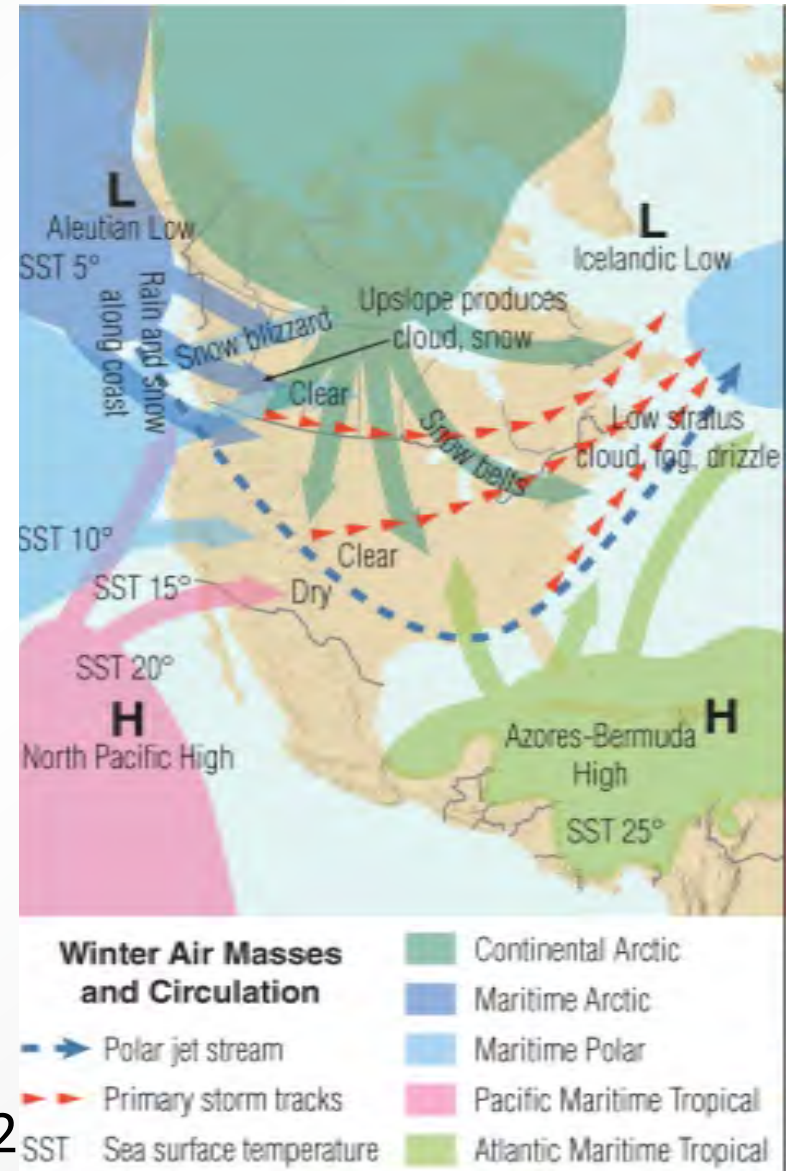


Barents Sea Feb 27 1987  
Ahrens: Fig. 12.28

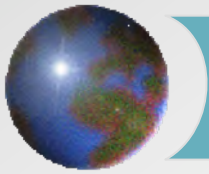


# *Polar low formation*

- ❊ cA air mass moves over open sea water
- ❊ *Arctic front* forms between cA and mP air masses
- ❊ Relative warmth of the open sea fuels the storm

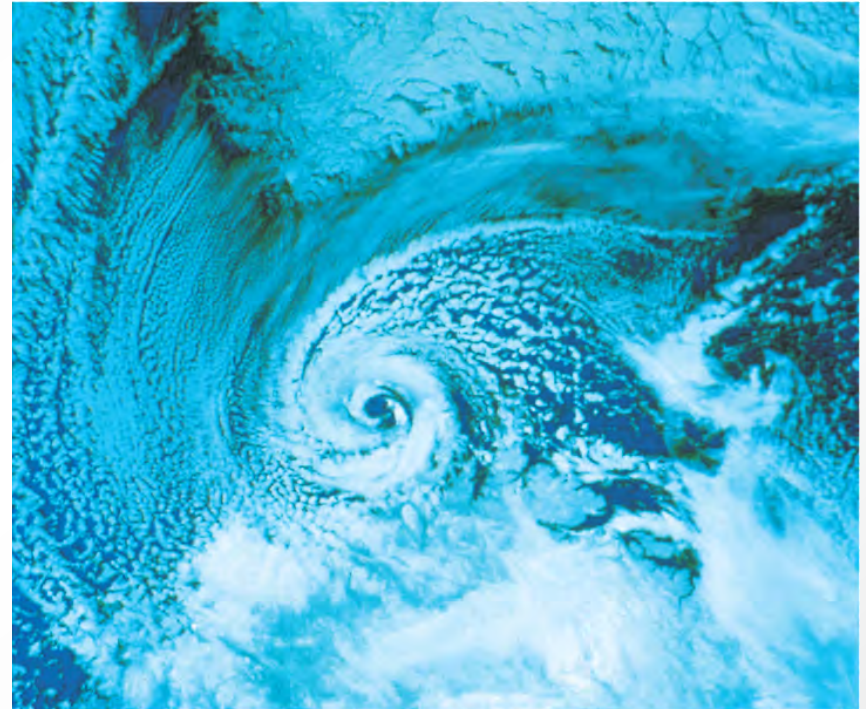


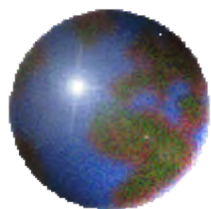
Ahrens: Fig. 11.2



# *Similarity to tropical cyclones*

- ✦ Sea surface temperatures (SSTs) as energy source
- ✦ Eye formation
- ✦ Warm core
- ✦ Dissipate over land (or ice)
  
- ✦ Differences:
  - ❑ Much weaker winds
  - ❑ Heavy snow instead of rain



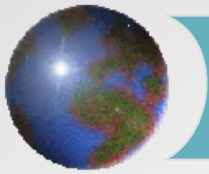


# *Climate Classification*

GEOG/ENST 2331 – Lecture 21

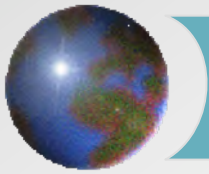
Lab 7

Ahrens: Chapter 17



## *Defining climate*

- ❖ The statistical properties of the atmosphere over the long-term constitute the climate of a particular area
  
- ❖ Certain areas have similar annual and multi-annual ranges in weather properties
  - ❖ Temperature
  - ❖ Precipitation
  - ❖ Air Mass Types
  - ❖ Energy Budget
  - ❖ Seasonal Water Budget

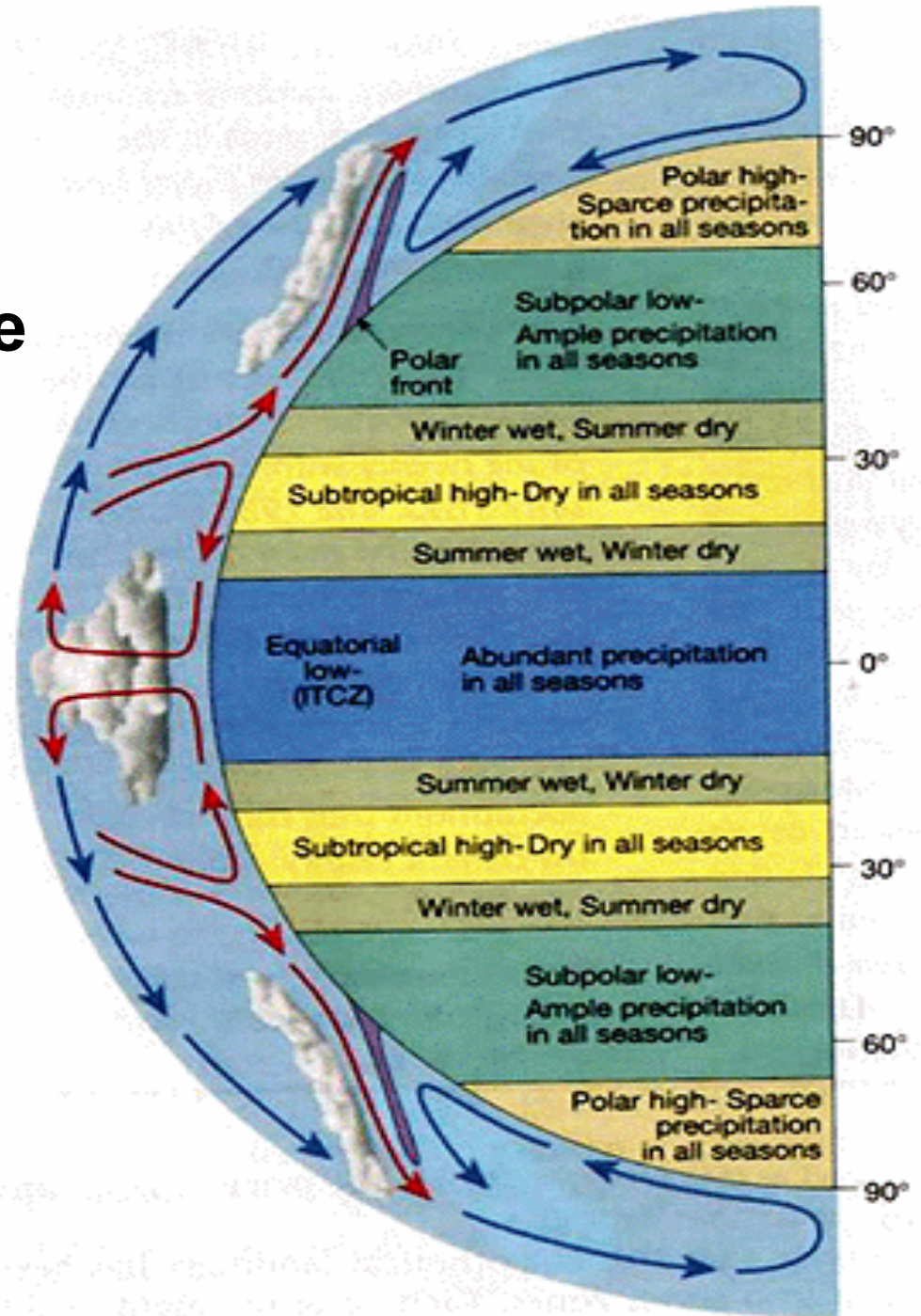


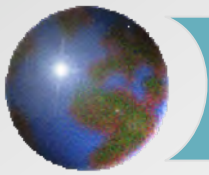
# *Climate classification*

- ✦ Variables are not independent
  - ▣ Similar regions can be grouped together
  - ▣ Generalizations can be useful
  
- ✦ Ancient Greeks
  - ▣ Tropical, temperate and polar
  - ▣ Classification based on latitude



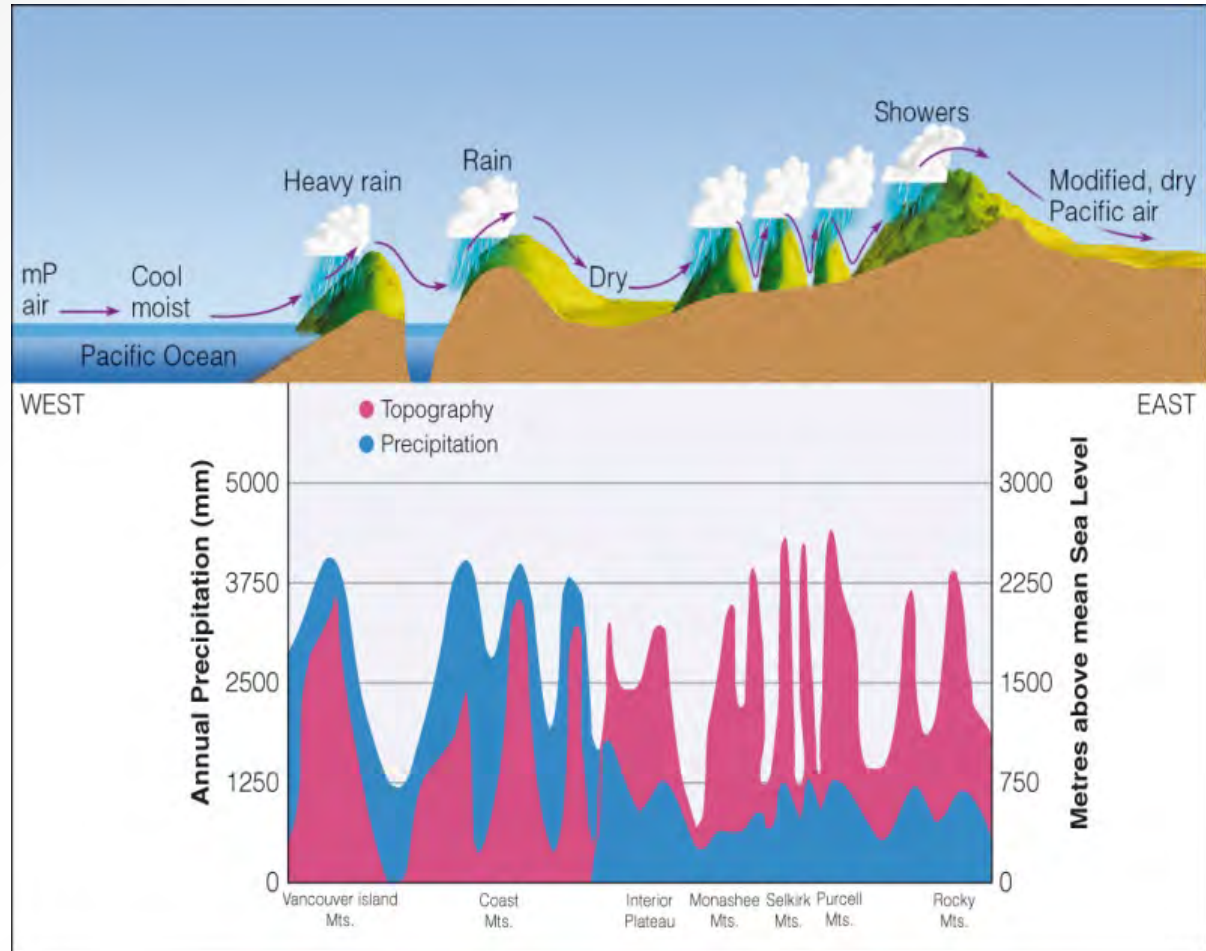
# Global precipitation pattern predicted by the general circulation



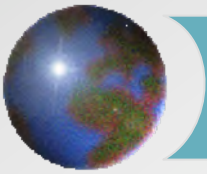


# *Mountains*

- ☉ Temperature decreases with altitude
- ☉ Rain shadows form downwind

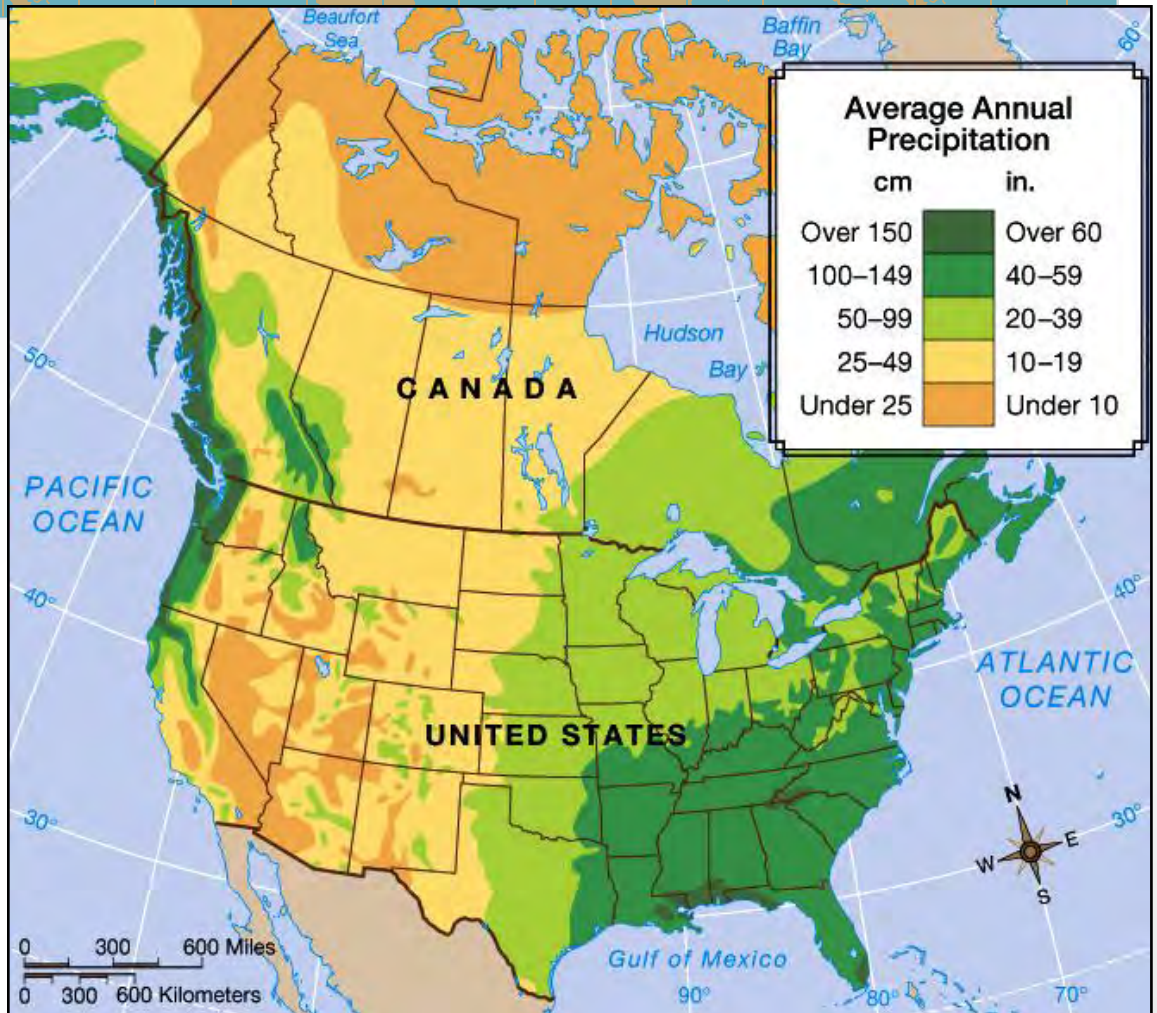


Ahrens: Fig. 17.5

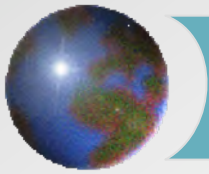


# Oceans

- ⊕ Moderate temperature
- ⊕ Provide moisture



A&B: Figure 7-10



# *Climate classification*

## ✦ Ancient Greeks

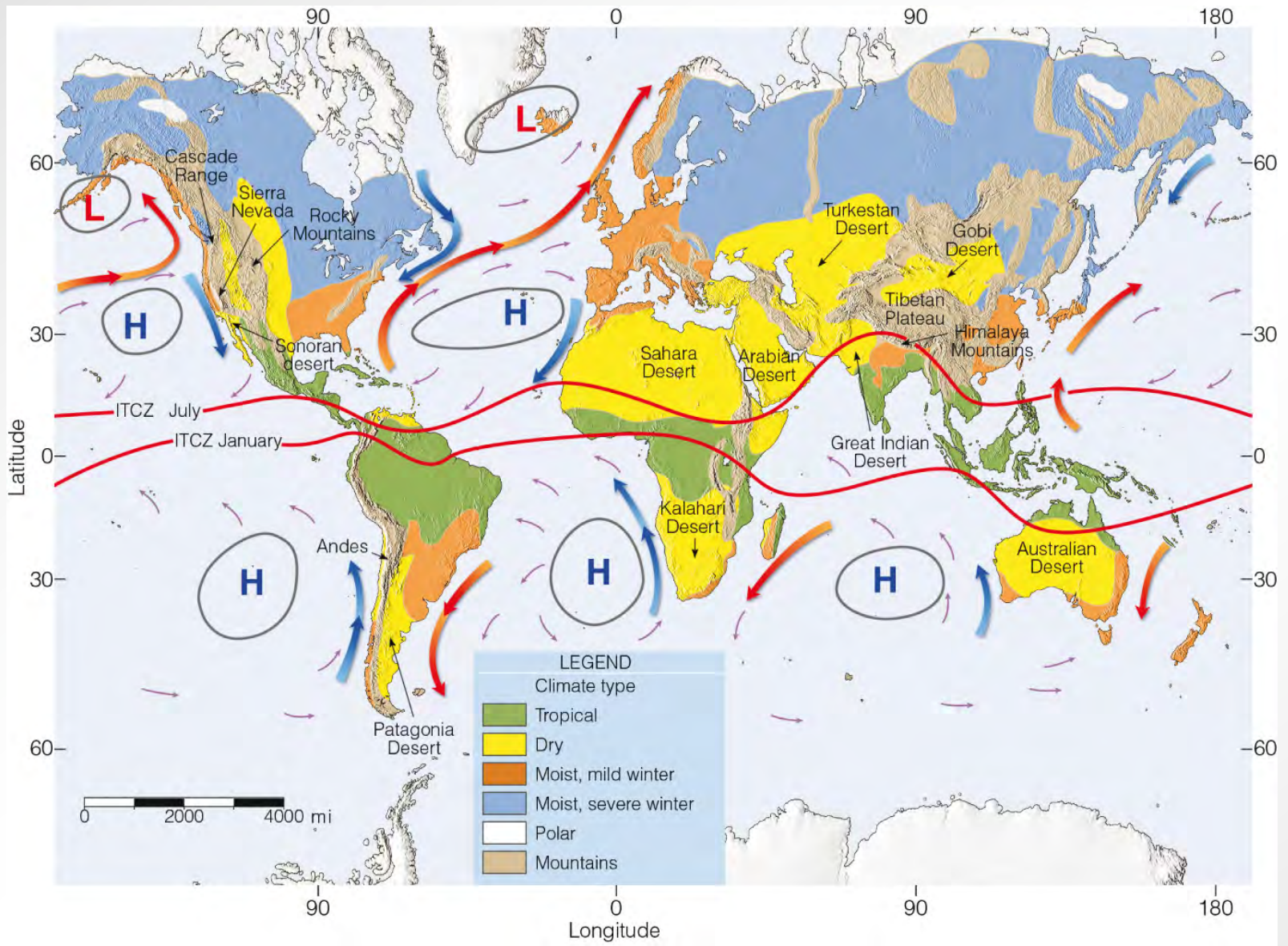
- ▣ Latitude (temperature)

## ✦ The Köppen System (1918)

- ▣ Vegetation used as an indicator because of sparseness of direct observations

## ✦ Thornthwaite's System

- ▣ P/E index (1930)
- ▣ Potential evapotranspiration (1948)

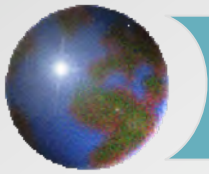


# The Köppen System

Ahrens: Fig. 17.6 See text p. 533

**Table 15-1 Climate Types According to Koeppen**

Type	Subtype	Letter Code	Characteristics
A—Tropical	Tropical wet	Af	No dry season
	Tropical monsoonal	Am	Short dry season
	Tropical wet and dry	Aw	Winter dry season
B—Dry	Subtropical desert	BWh	Low-latitude dry
	Subtropical steppe	BSh	Low-latitude semi-dry
	Mid-latitude desert	BWk	Mid-latitude dry
	Mid-latitude steppe	BSk	Mid-latitude semi-dry
C—Mild Mid-latitude	Mediterranean	Csa	Dry, hot summer
		Csb	Dry, warm summer
	Humid subtropical	Cfa	Hot summer, no dry season
		Cwa	Hot summer, brief winter dry season
	Marine west coast	Cfb	Mild throughout year, no dry season, warm summer
Cfc		Mild throughout year, no dry season, cool summer	
D—Severe Mid-latitude	Humid continental	Dfa	Severe winter, no dry season, hot summer
		Dfb	Severe winter, no dry season, warm summer
		Dwa	Severe winter, winter dry season, hot summer
		Dwb	Severe winter, winter dry season, warm summer
	Subarctic	Dfc	Severe winter, no dry season, cool summer
		Dfd	Extremely severe winter, no dry season, cool summer
		Dwc	Severe winter, winter dry season, cool summer
		Dwd	Extremely severe winter, winter dry season, cool summer
E—Polar	Tundra	ET	No true summer
	Polar ice cap	EF	Perennial ice
H—Highland	Highland	H	Highland



## *Additional codes for A, C and D*

✚ *f* – full year precipitation

✚ *s* – driest in summer

✚ *w* – driest in winter

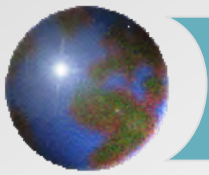
✚ *m* – monsoon

✚ *a* – hottest summers

✚ *b*

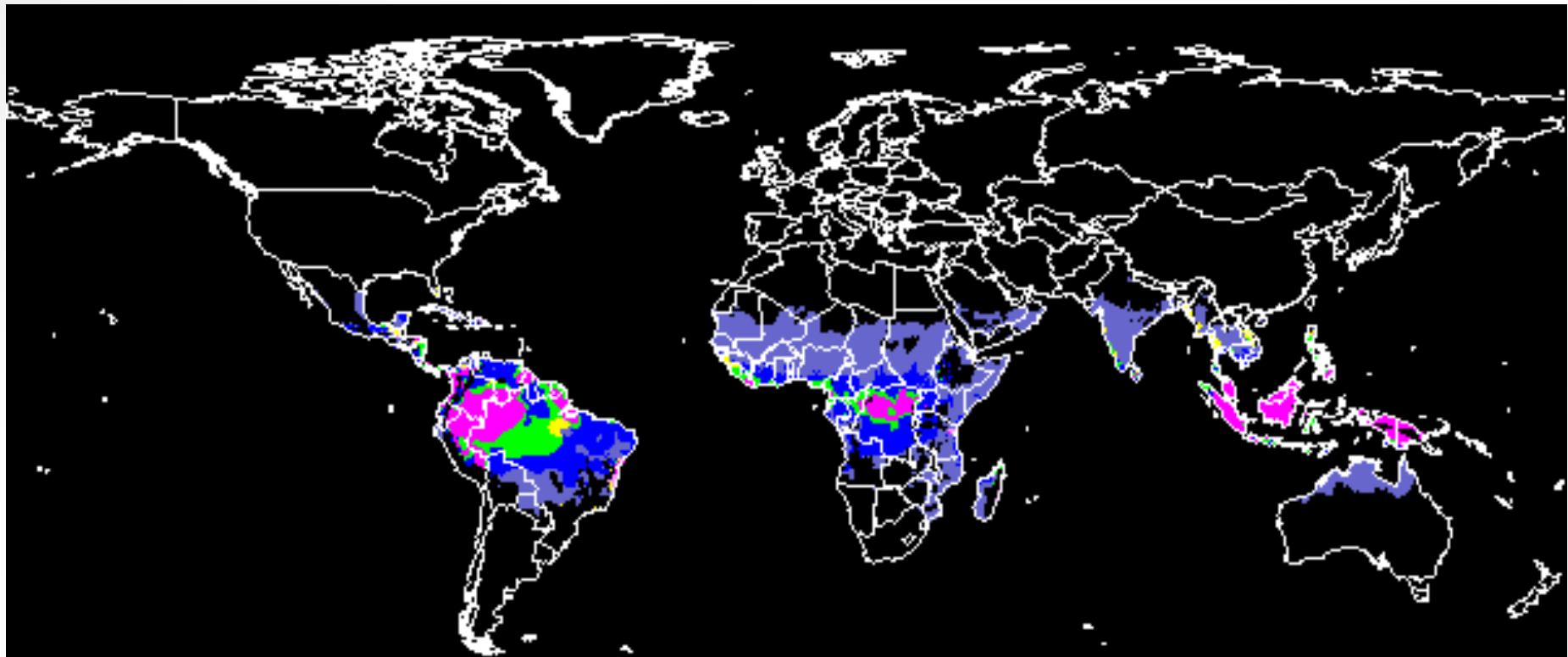
✚ *c*

✚ *d* – coldest summers



## *A - Tropical Climates*

- ⊠ Between the Tropics of Cancer and Capricorn
- ⊠ Exhibit warm temperatures and minimal seasonal temperature



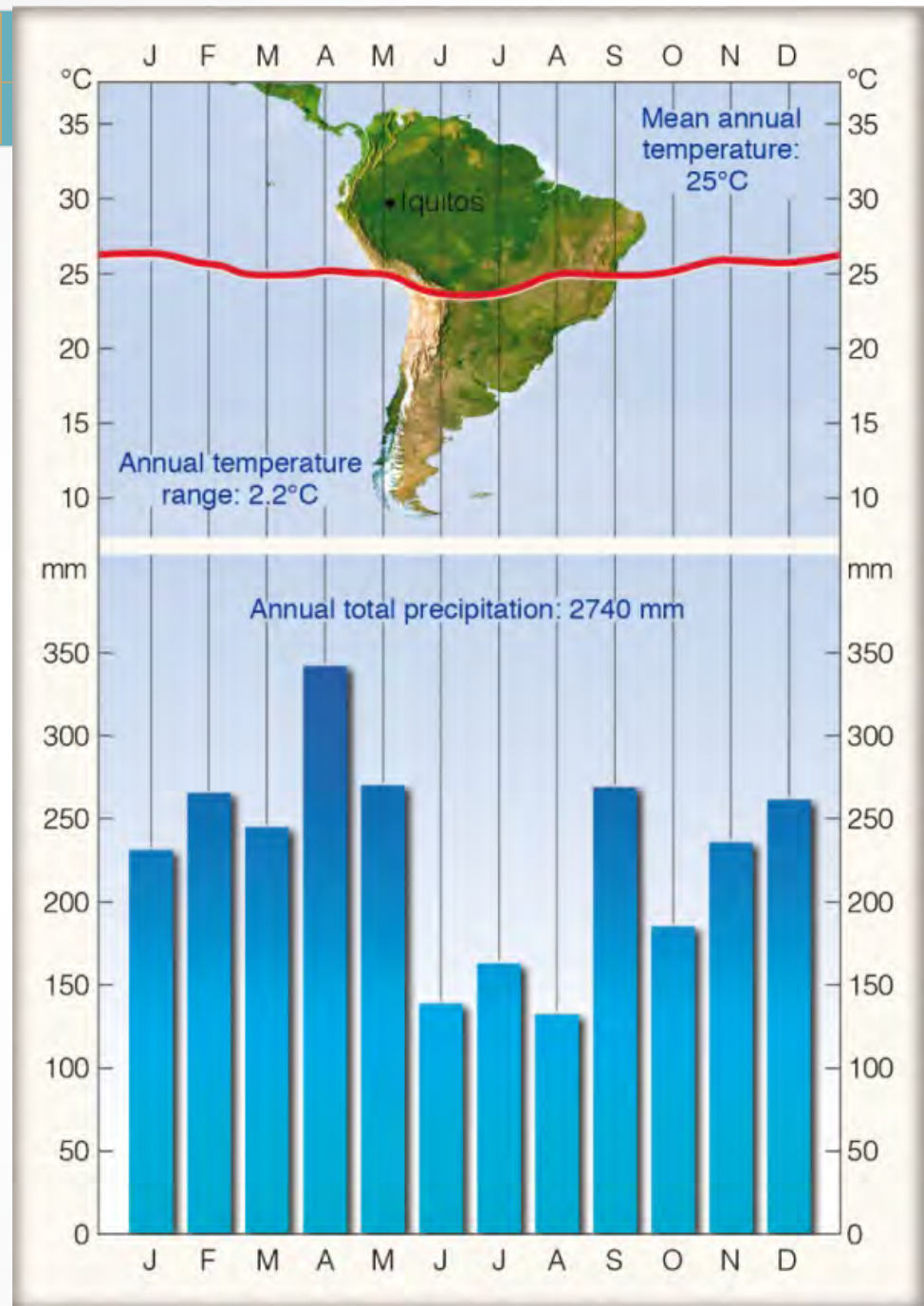
**Koeppen's Climate Classification: Class A: Tropical**

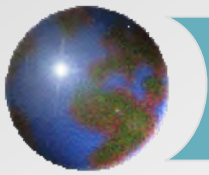
by FAO - SDRN - Agrometeorology Group - 1997



# *Af – Tropical wet climate*

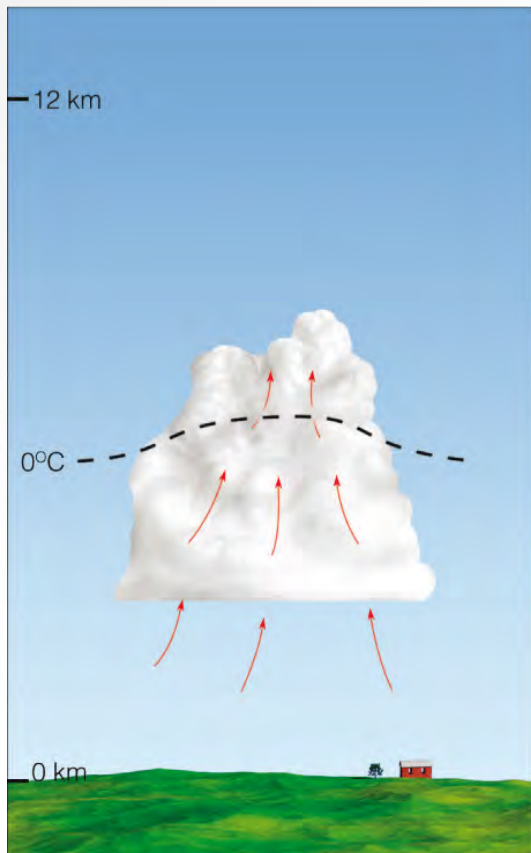
- ✪ ***Climograph*** for Iquitos, Peru
- ✪ 4°S, 73°W
- ✪ 130 m above MSL
- ✪ ITCZ is always close
- ✪ Windward side of Andes



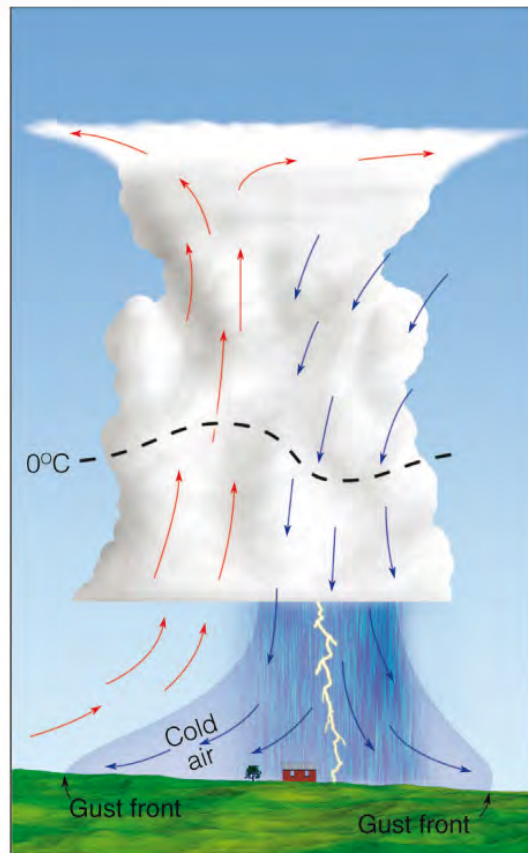


# *Tropical wet climates (Af)*

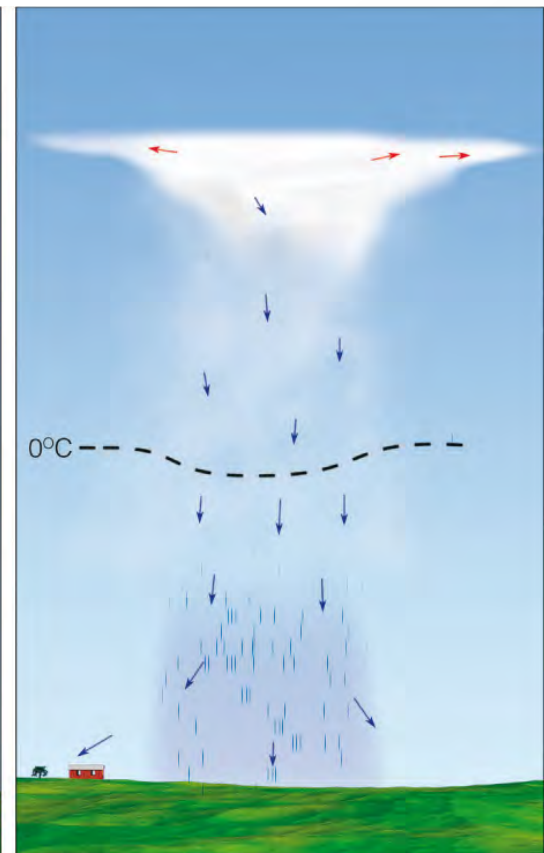
Brief but often heavy afternoon thundershowers



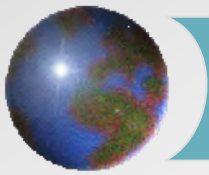
(a) Cumulus



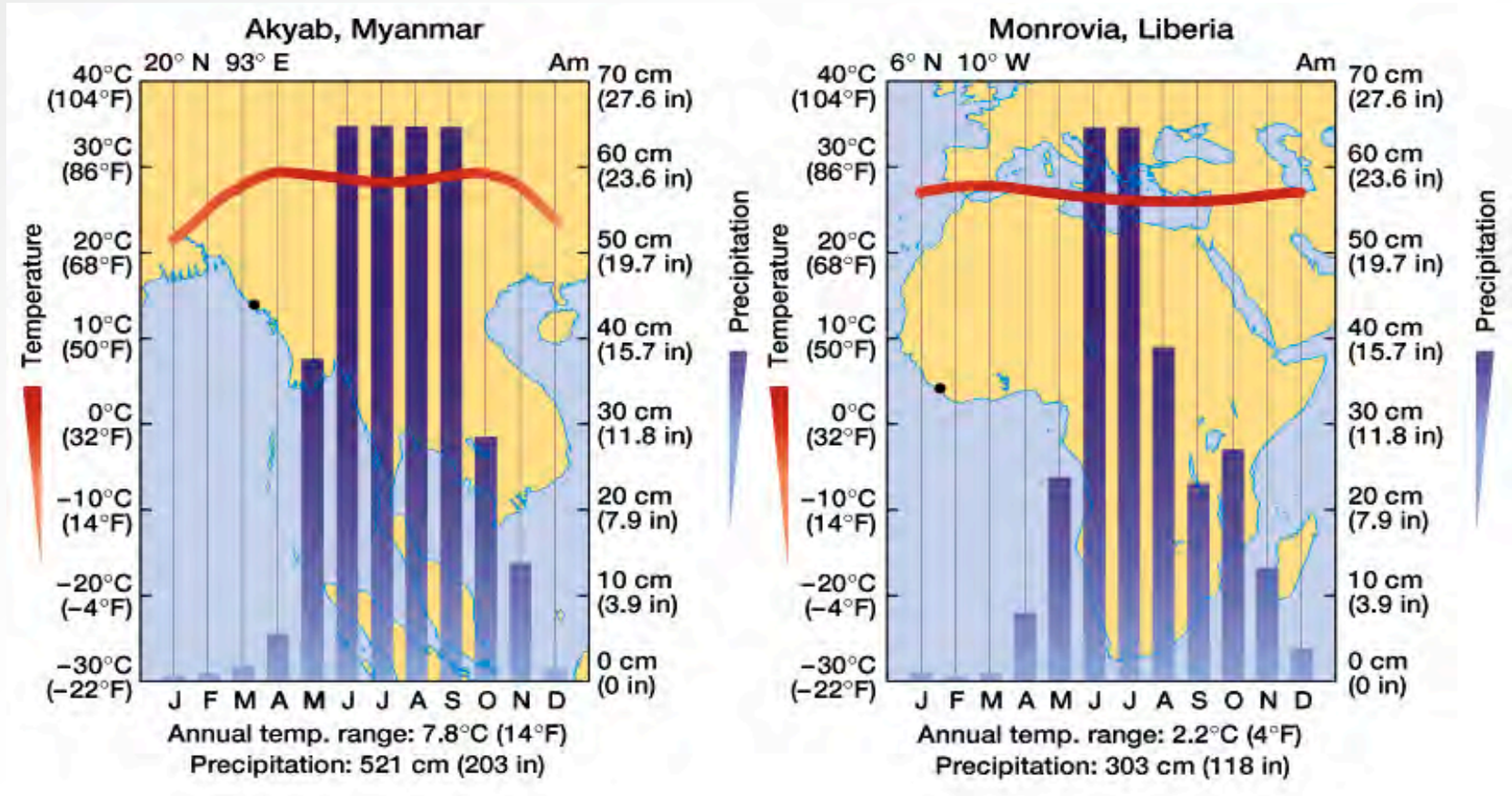
(b) Mature



(c) Dissipating

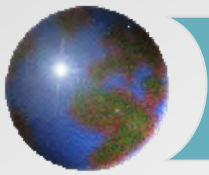


# *Am* climographs – Monsoonal



Occur near tropical coastal areas receiving onshore winds through much of the year

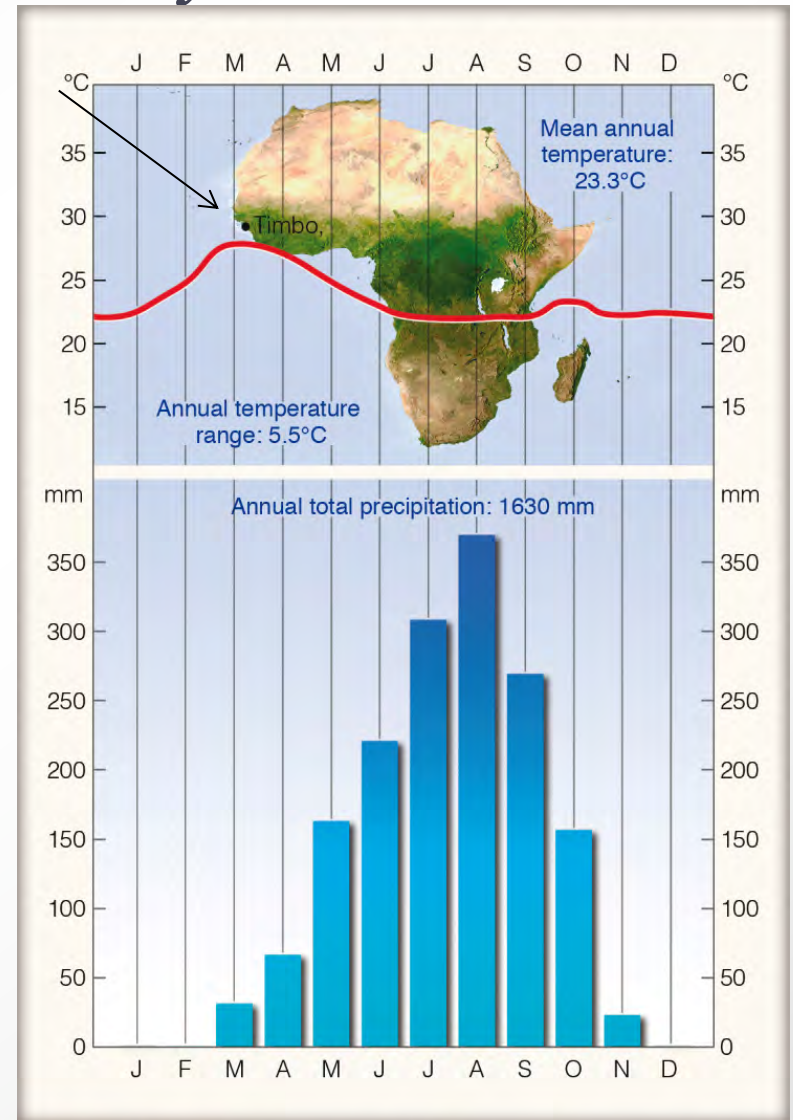
Pronounced seasonal variations of precipitation

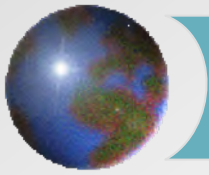


# *Aw – Tropical wet-and-dry climate*

- 📍 Timbo, Guinea
- 📍 10°N, 12°W
- 📍 ITCZ in summer
- 📍 Subtropical high in winter
  - 📍 Higher *T* from sunny skies

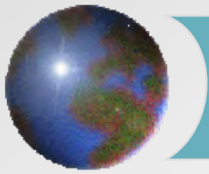
📍 Ahrens: Fig. 17.13





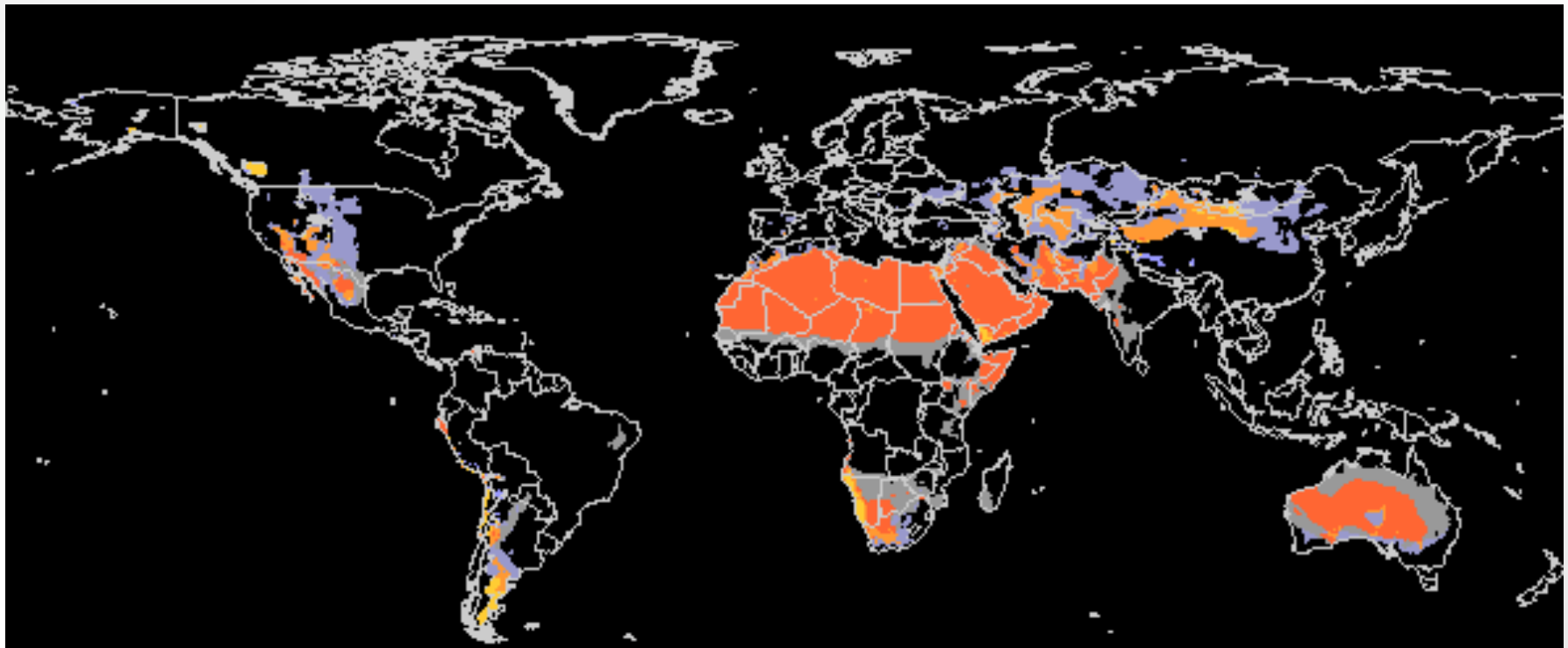
# *Aw climates*

- ✦ Rainfall may be unreliable
  - ✦ E.g. Sahel region
  
- ✦ Savanna vegetation regimes dominate due to a lack of precipitation and frequent fires in the dry months
  
- ✦ Diurnal temperature variations are pronounced in dry season when ranges may be as high as 15 C°
  - ✦ Few clouds
  - ✦ Closer to arid than tropical

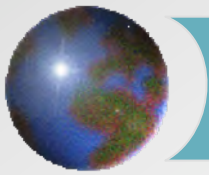


## *B* – *Dry Climates*

- Potential evapotranspiration exceeds precipitation
- Regions sub-classified as either semi-desert (steppe) or desert

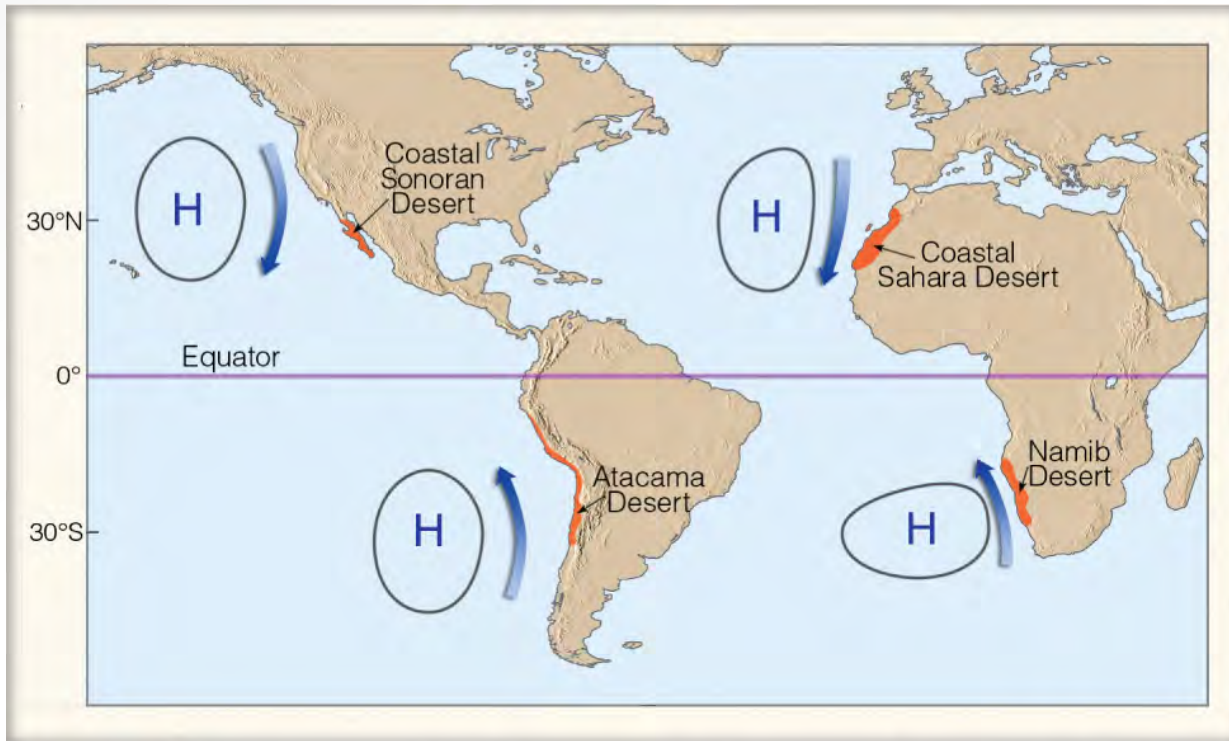


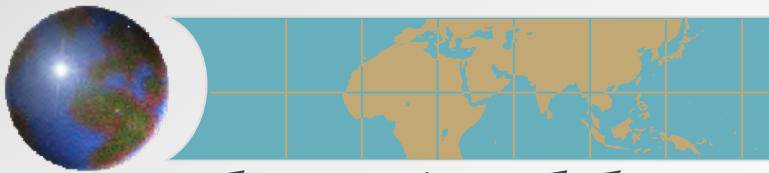
**Koeppen's Climate Classification: Class B: Dry**  
by FAO - SDRN - Agrometeorology Group - 1997



# *Dry climates (B)*

- ✦ Subtropical highs
- ✦ Rain shadows and continentality
- ✦ Cold air
  - ✦ Can bring dry climates even to coastal areas





# *BWh – Arid hot climates*

☉ Phoenix, Arizona

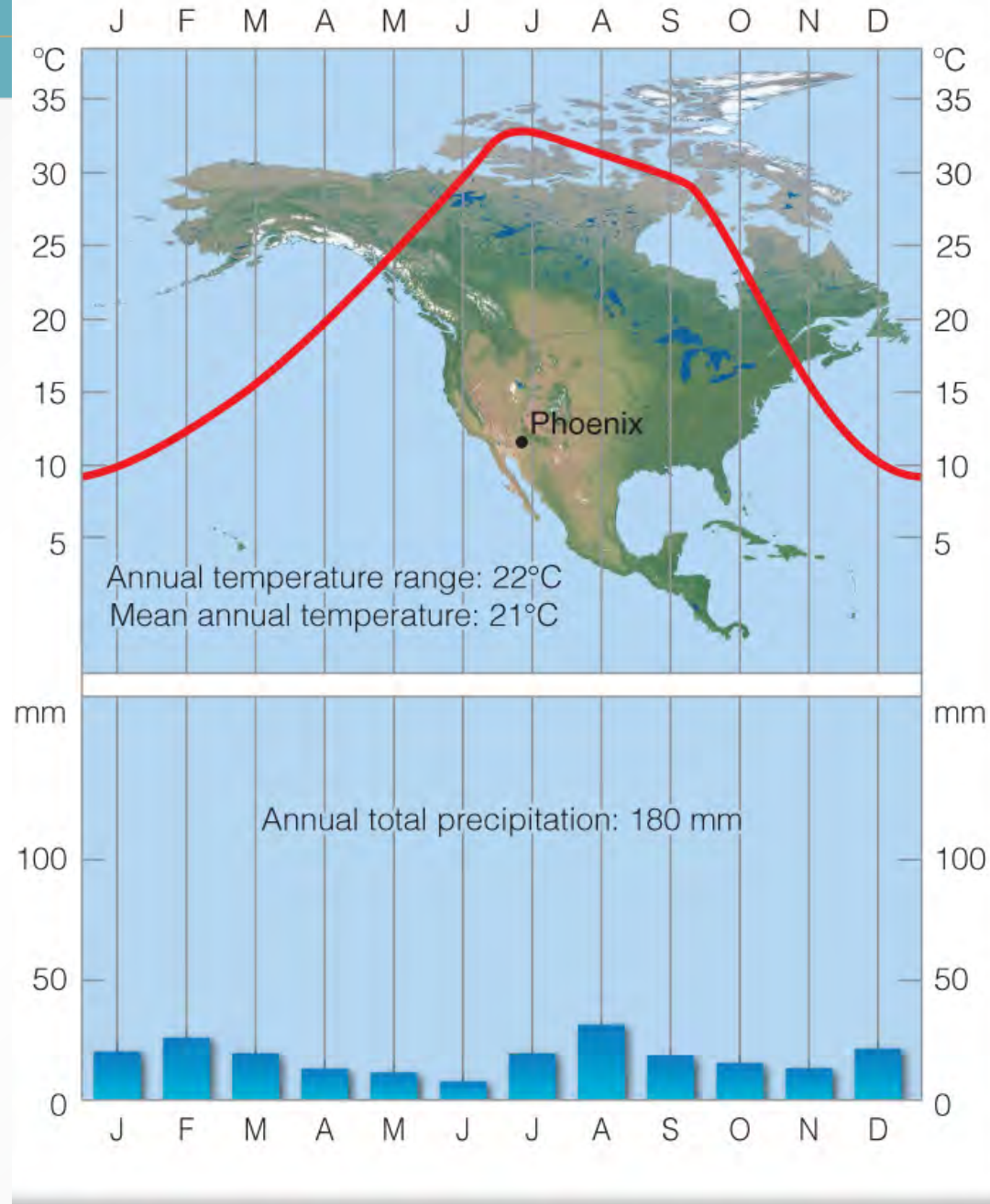
☉ 33°N, 102°W

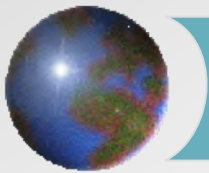
☉ Subtropical highs

☒ Band from 10°-30°

☉ Hot days, cold nights

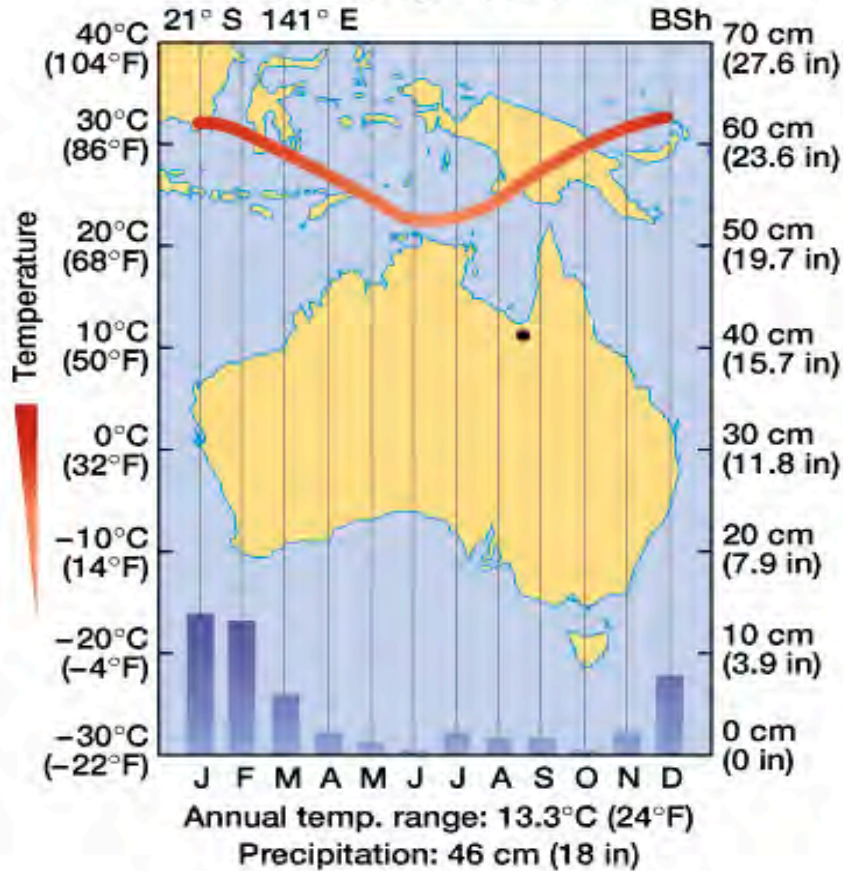
Ahrens: Fig. 17.16



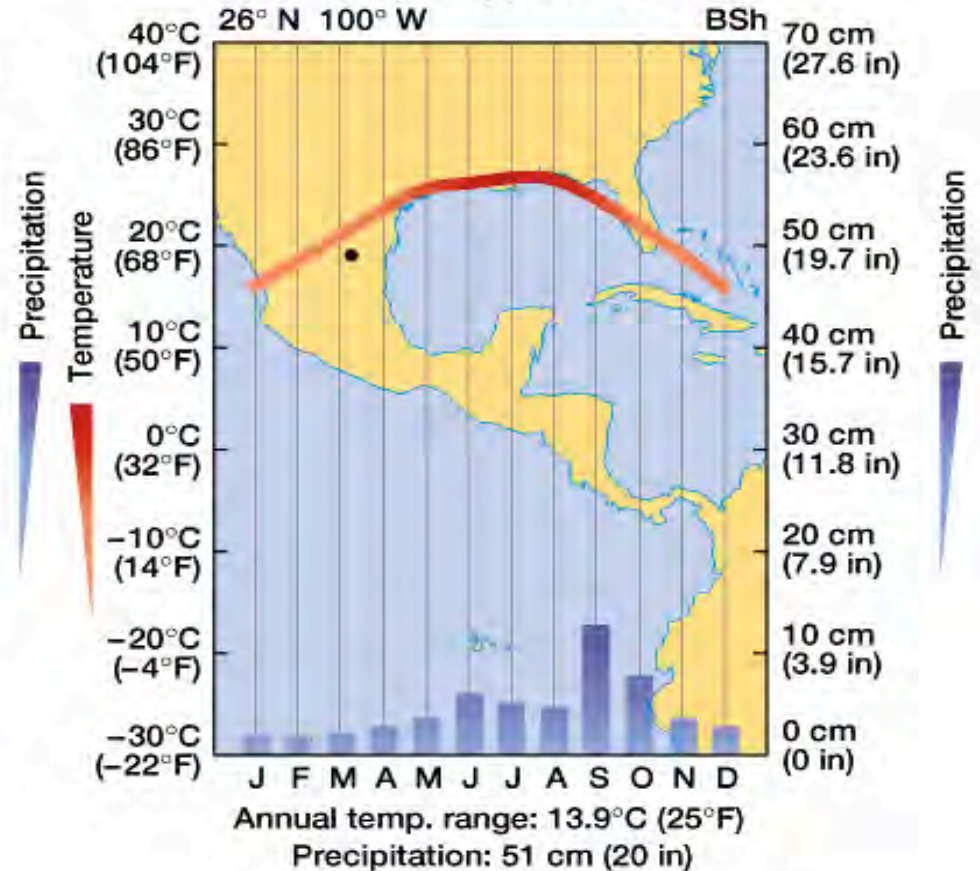


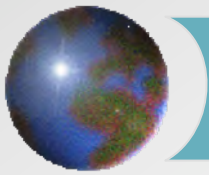
# *BSh – Semi-arid hot climates*

Cloncurry, Australia

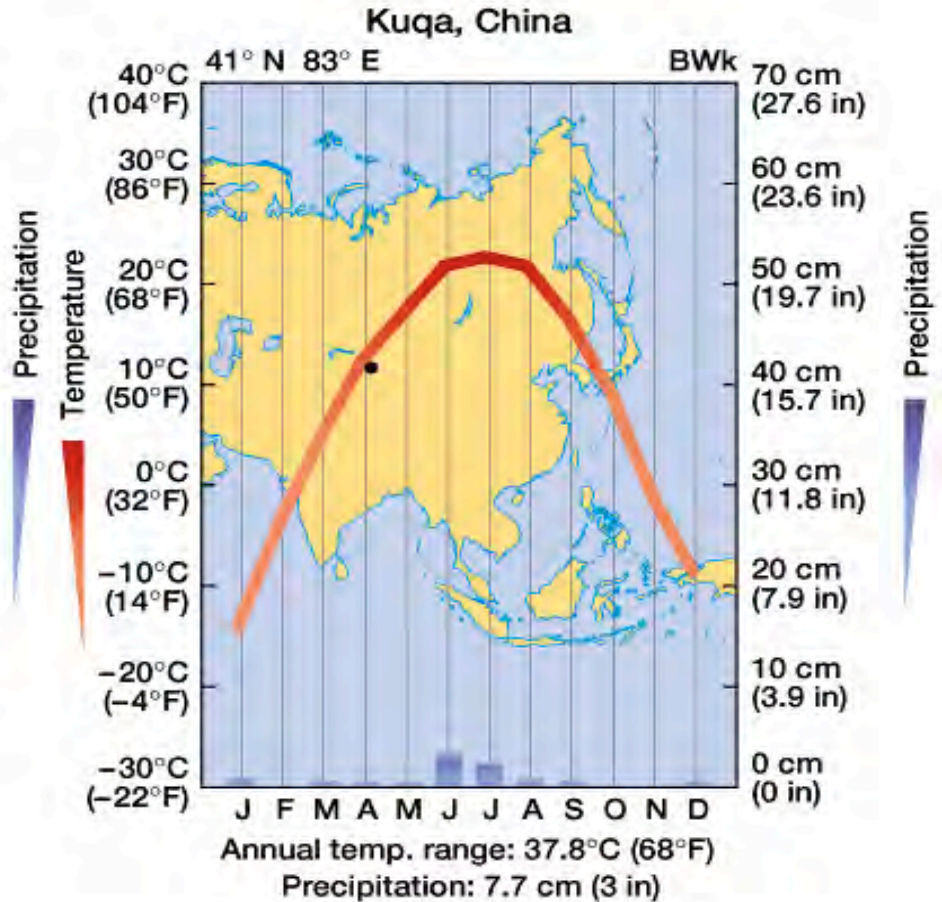
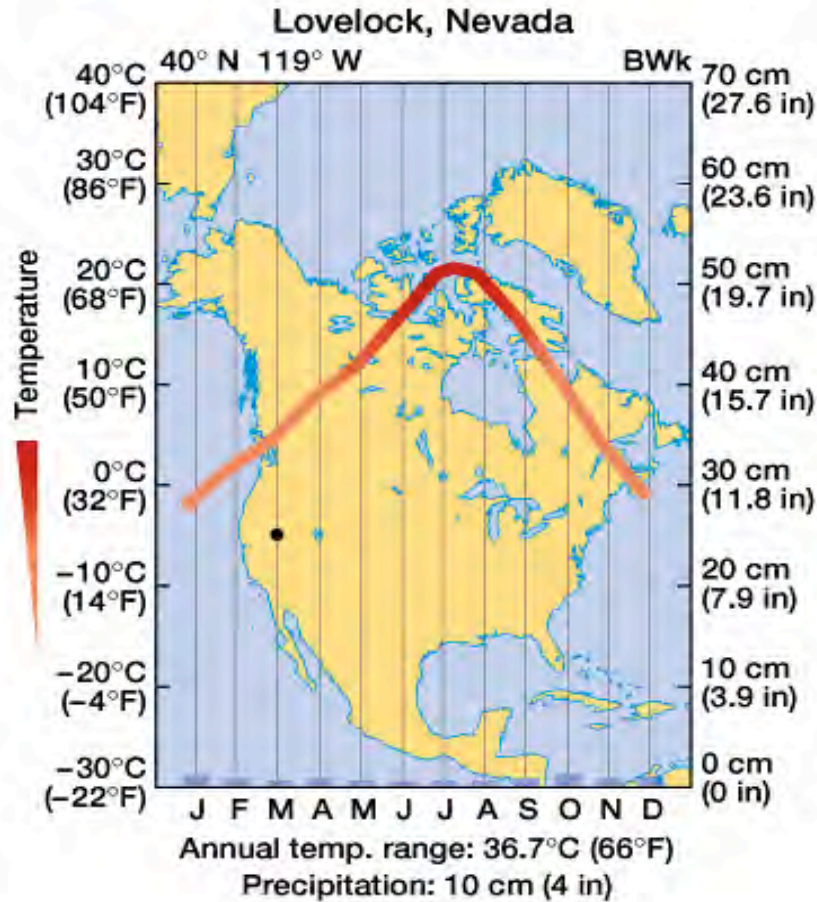


Monterrey, Mexico





# *BWk* – Arid cool climates



Extreme continentality and/or rain shadows

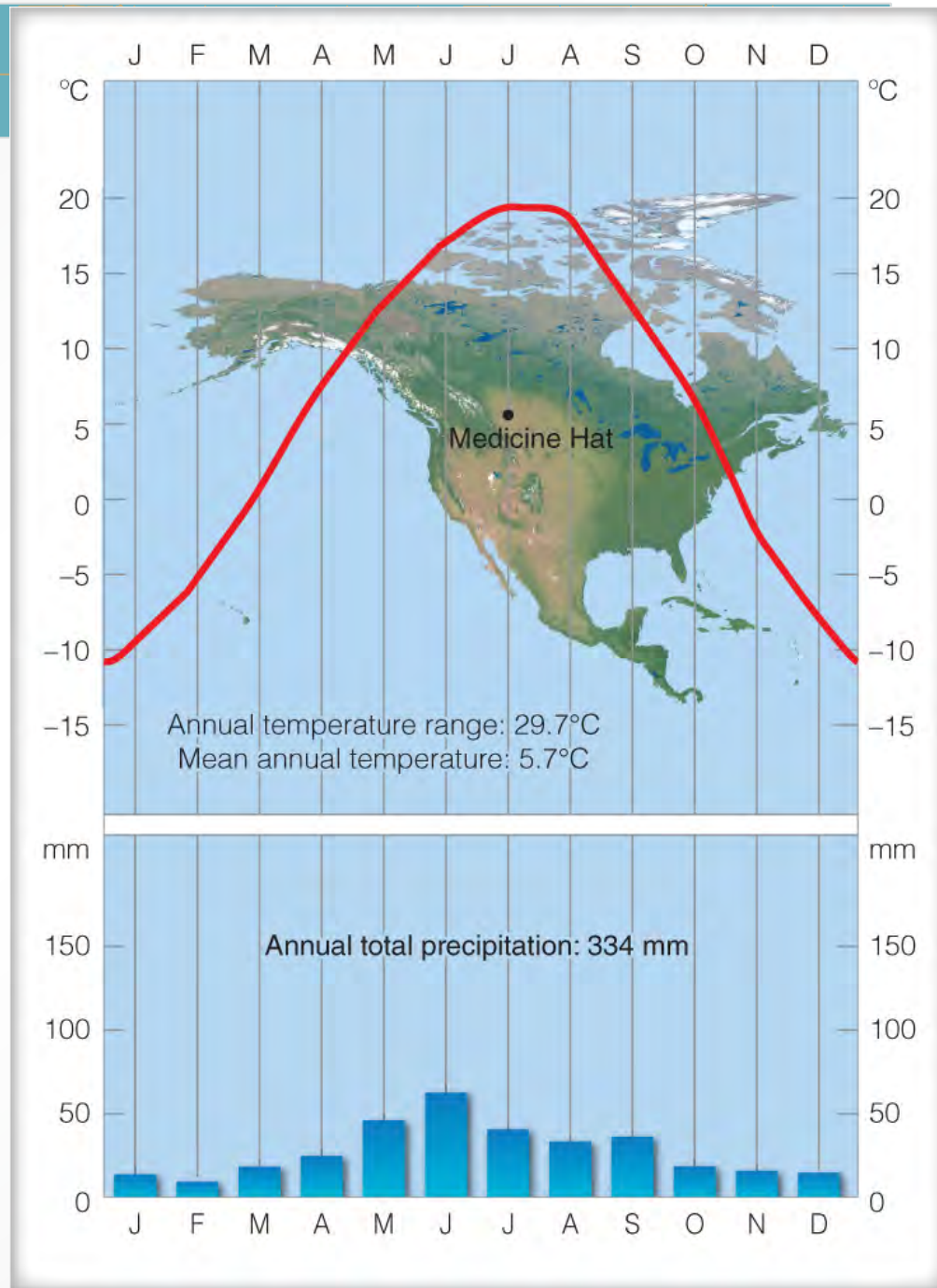
Very cold winter nights

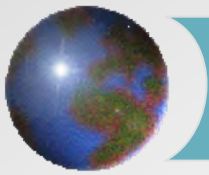


# *BSk – Semi-arid cool climates*

- ✚ Medicine Hat, Alberta
- ✚ 50°N, 140°W
- ✚ Higher annual average precipitation

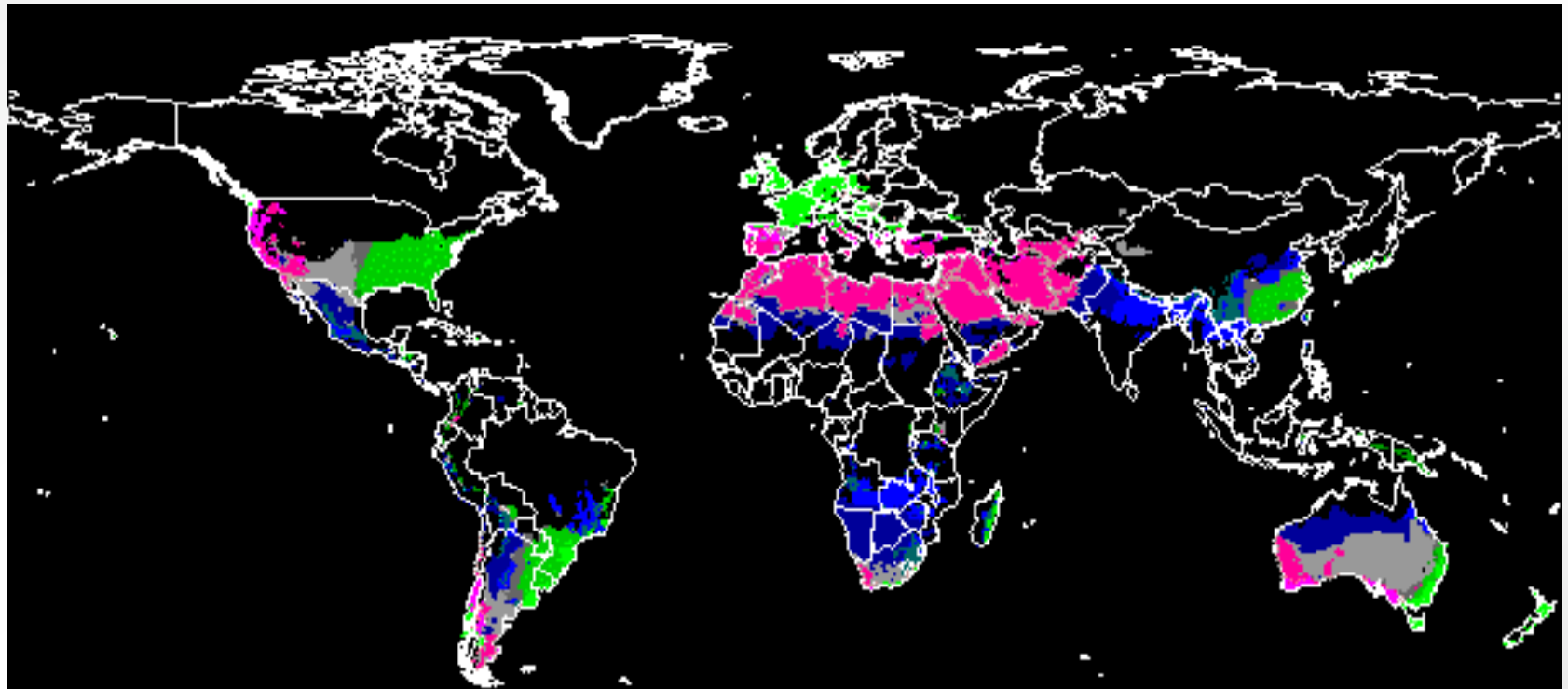
Ahrens: Fig. 17.18





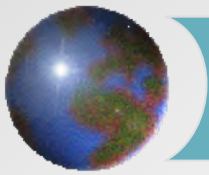
## *C – Temperate Climates*

- Exist between 30° and 60°
- Not cold enough for persistent snow in winter
- Precipitation regimes vary considerably

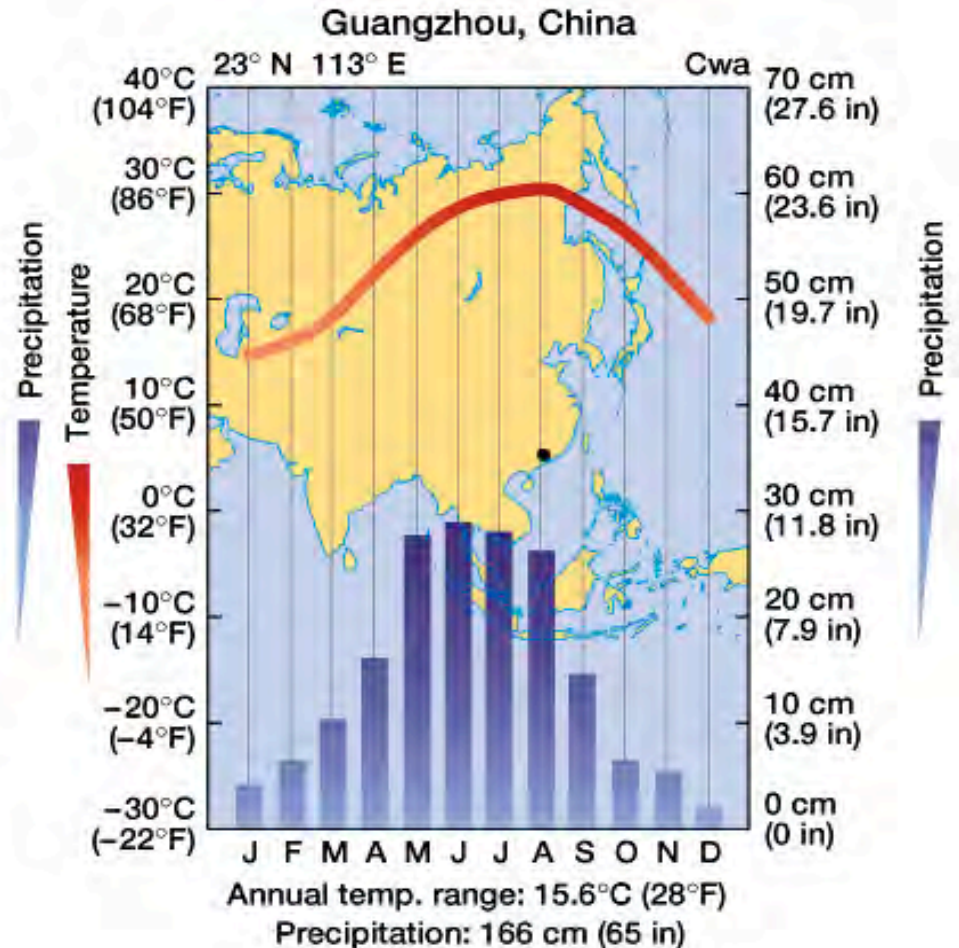
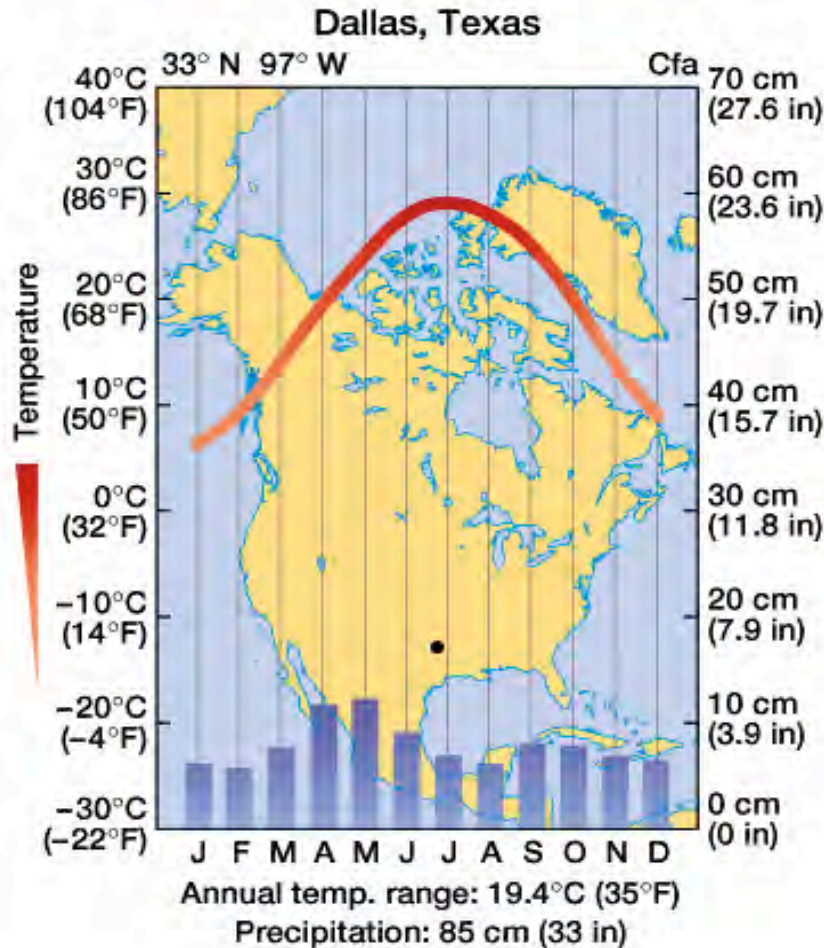


**Koeppen's Climate Classification: Class C: Temperate**

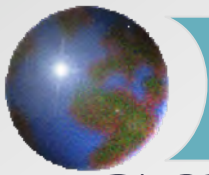
by FAO - SDRN - Agrometeorology Group - 1997



# *Cfa, Cwa – Humid subtropical climates*



Heat and moisture from on-shore advection due to off-shore subtropical highs



# *Cfb, Cfc - Marine west coast climates*

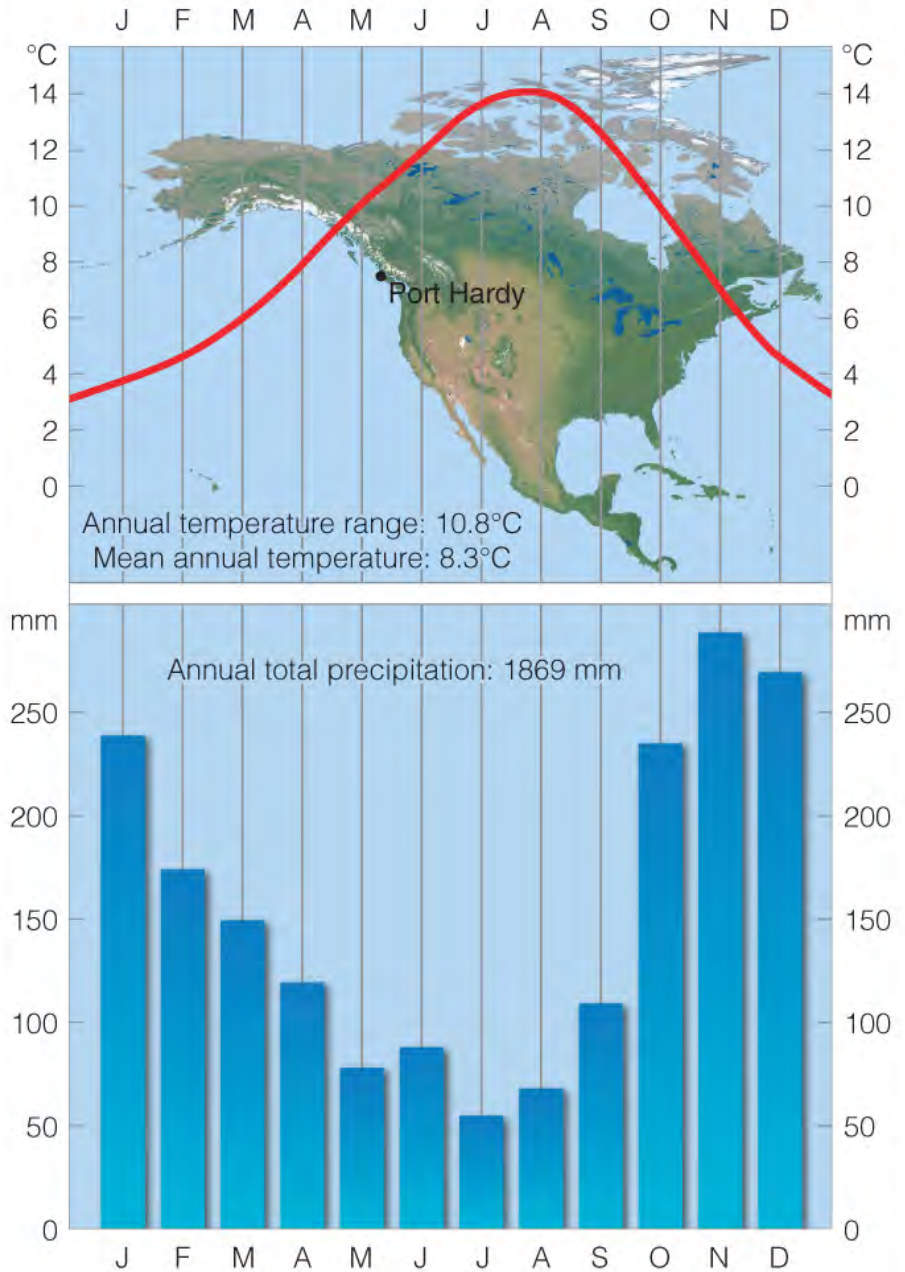
✚ Port Hardy, BC (Cfb)

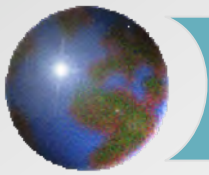
✚ 50°N, 127°W

✚ Sea breeze

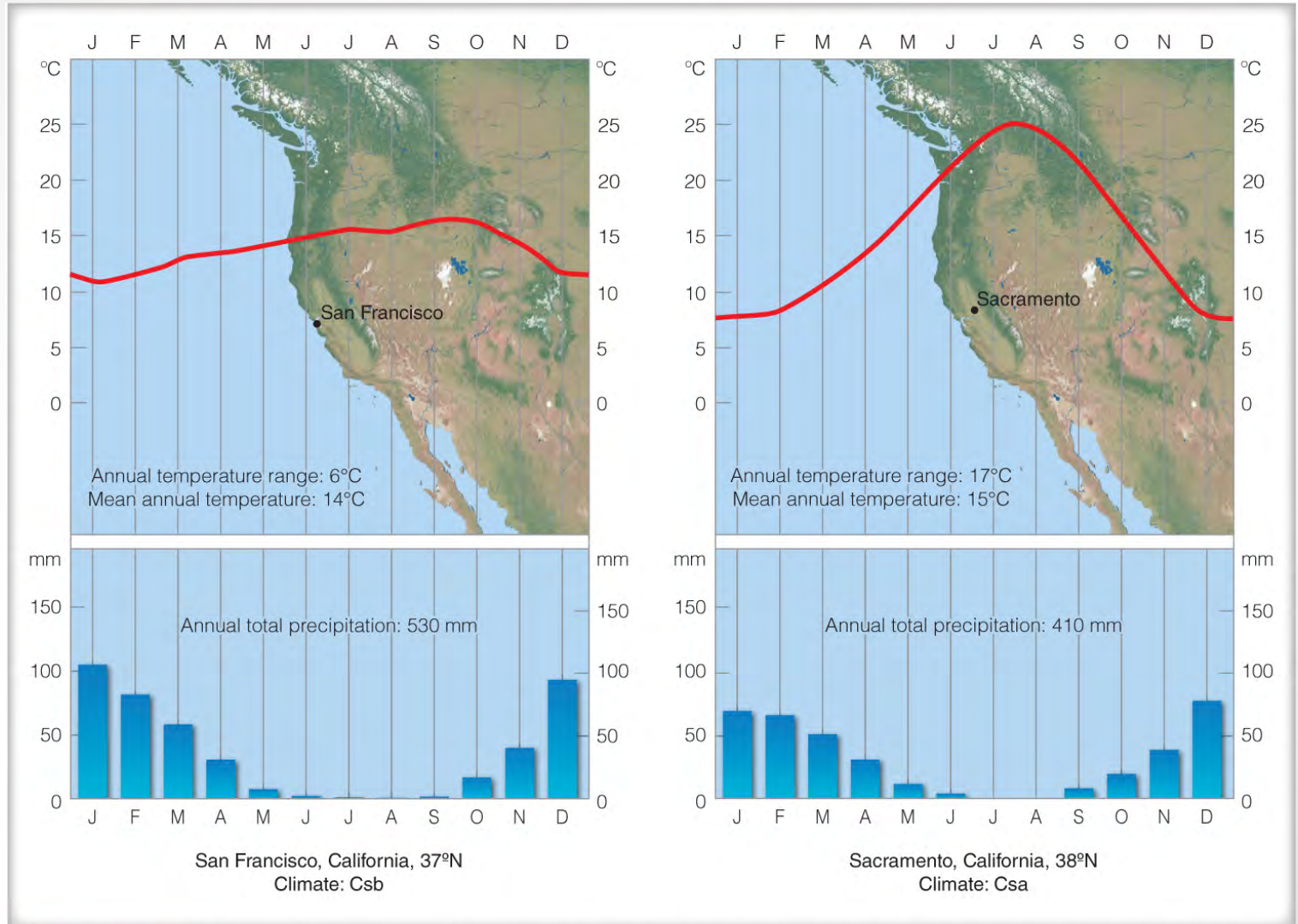
✚ Frequent fog and low clouds

Ahrens: Fig. 17.20

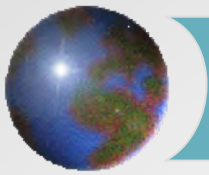




# *Csb, Csa – Mediterranean climates*

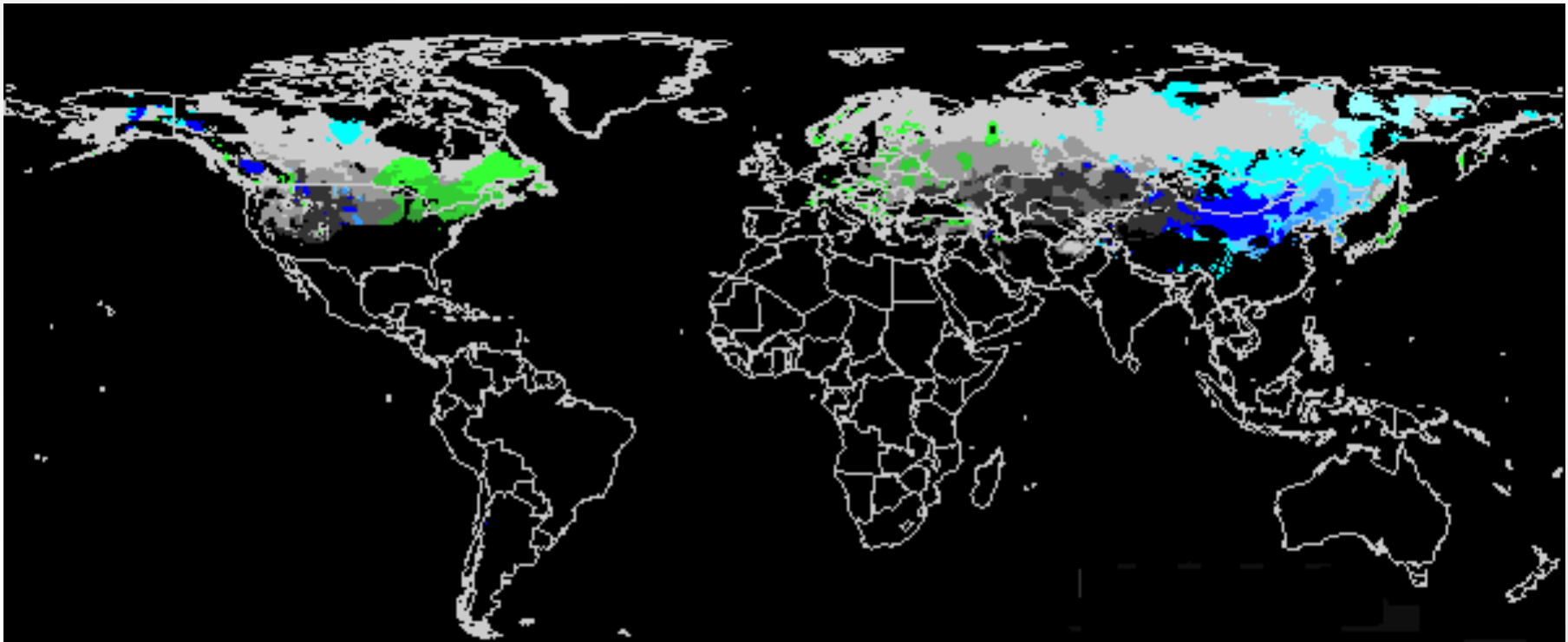


Ahrens:  
Fig. 17.21

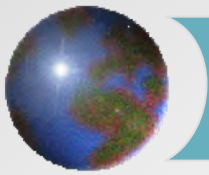


## *D – Cold Climates*

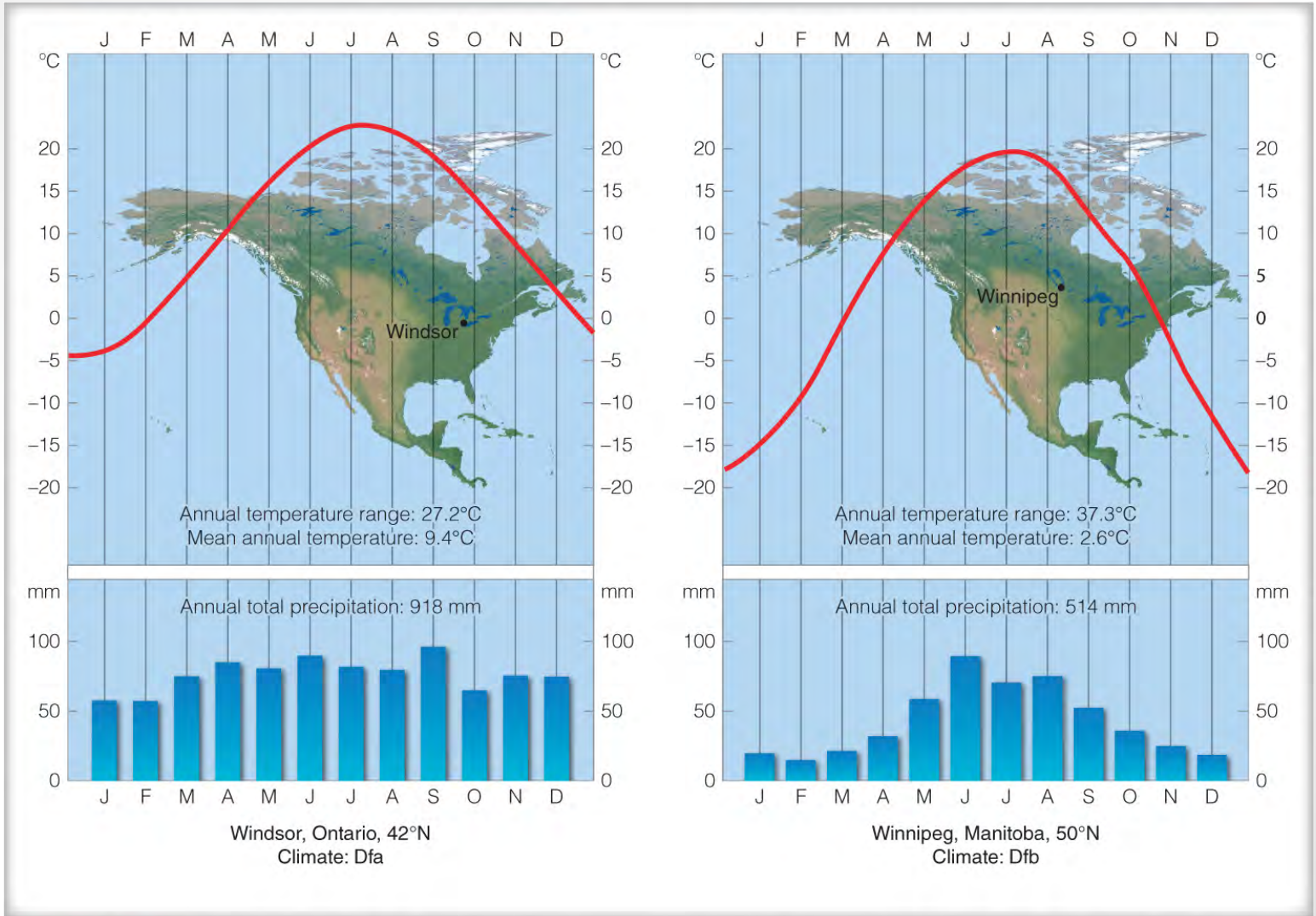
- Common between 40° and 70°
- Cold enough for snow but warm enough for trees



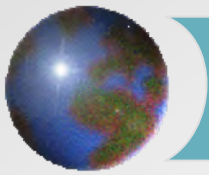
**Koeppen's Climate Classification: Class D: Cold**  
by FAO - SDRN - Agrometeorology Group - 1997



# *Dfa, Dfb, Dwa, Dwb – Humid continental climates*



Ahrens:  
Fig. 17.24



# *Dfc, Dfd, Dwc, Dwd – Subpolar climates*

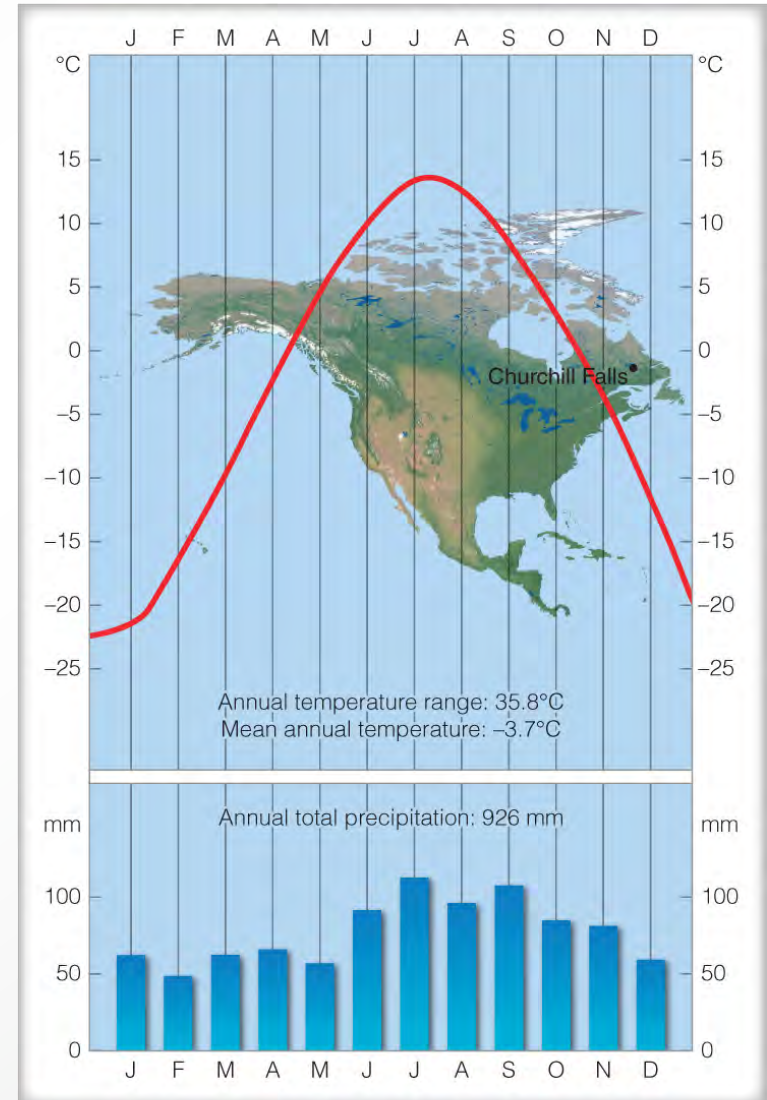
✚ Churchill Falls, NL (Dfc)

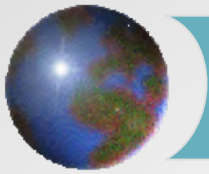
✚ 47°N, 53°W

✚ Poleward of humid continental

✚ Summers warm but short

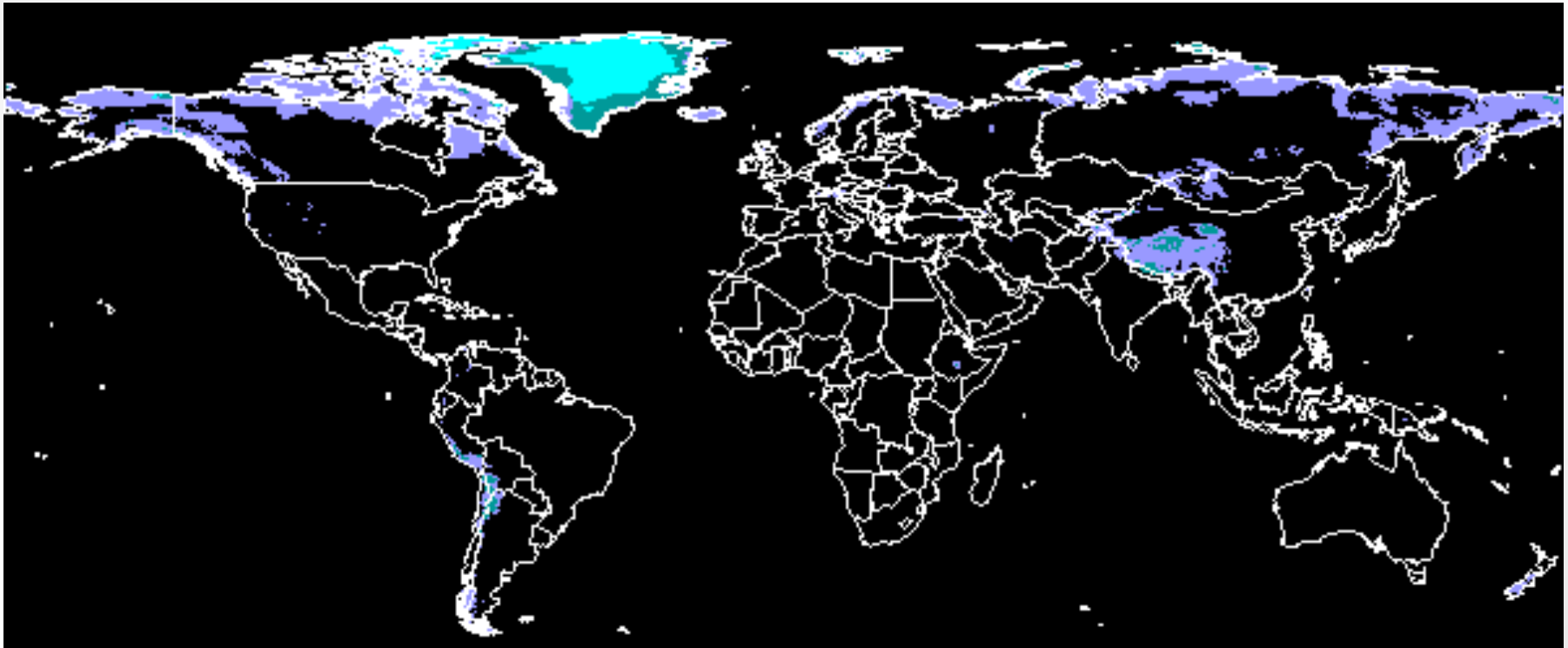
✚ Ahrens: Fig. 17.25





## *E – Polar Climates*

- Typically poleward of 70°
- Treeless terrain and very cold temperatures



**Koeppen's Climate Classification: Class E: Polar**

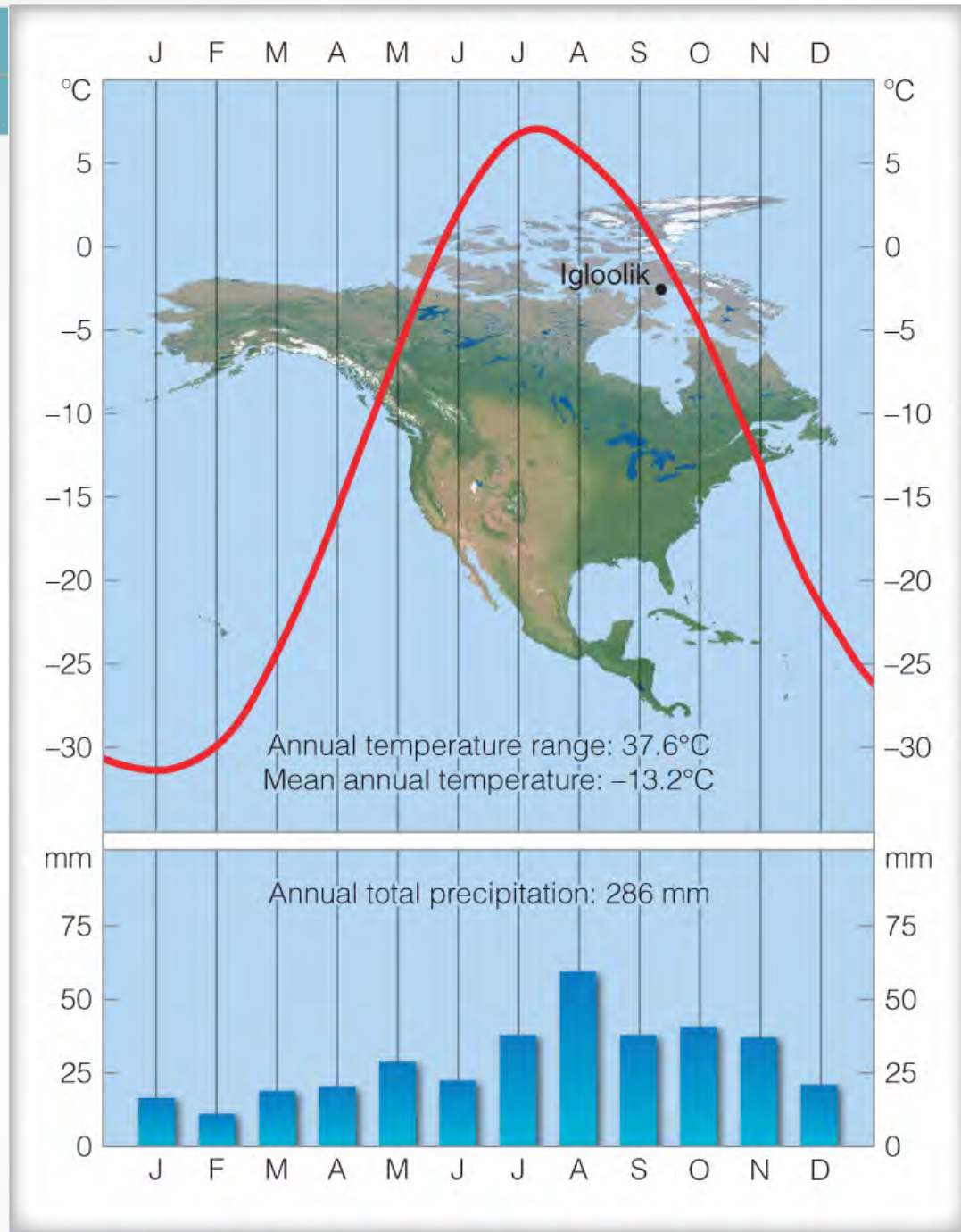
by FAO - SDRN - Agrometeorology Group - 1997

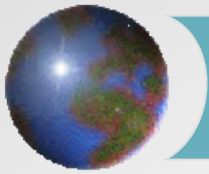


# *ET – Polar tundra climates*

- ✚ Igloolik, Nunavut
- ✚ 69°N, 82°W
- ✚ Harsh winters
- ✚ High annual *T* range
- ✚ Very low precipitation

Ahrens: Fig. 17.27



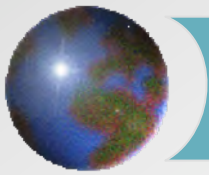


# *Polar tundra climates*

- ✦ Named for tundra  
vegetation: low-growing  
mosses, lichens, shrubs
- ✦ Permafrost is a constant  
feature



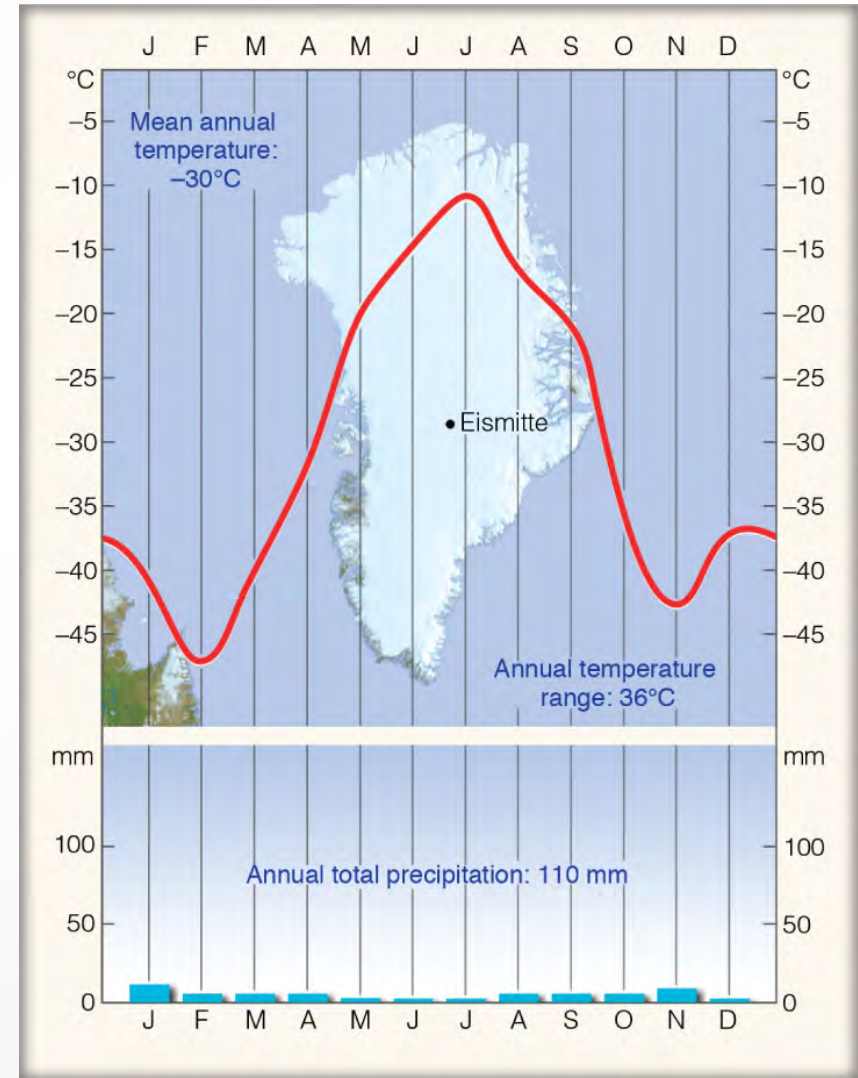
Ahrens: Fig. 17.28

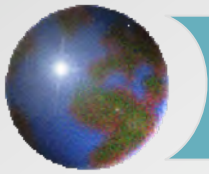


# *EF – Polar ice cap climates*

- ✦ Eismitte, Greenland
- ✦ 71°N, 3000 m above sea level
- ✦ Areas of constant ice cover found in Greenland and Antarctica

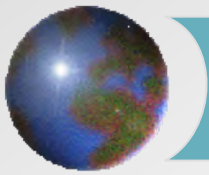
✦ Ahrens: Fig. 17.29



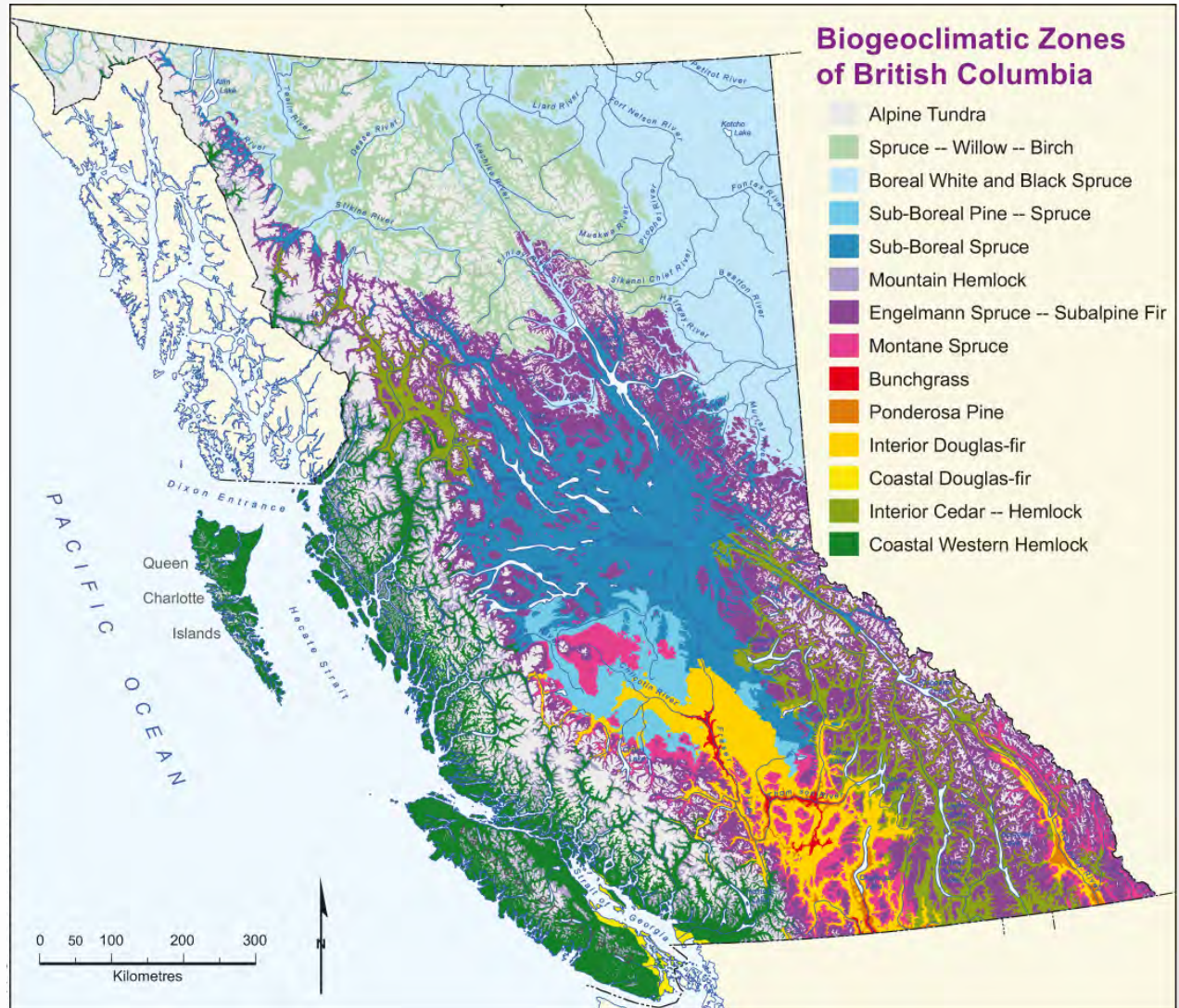


## *H* – Highland Climates

- ❖ Mountainous regions experience rapid temperature variations over short distances as a result of elevation changes
  
- ❖ Slope and aspect play a role in energy and water balances
  - Enhanced precipitation versus rain shadows
  
- ❖ Vertical changes become analogous to latitude changes, eventually leading to ice cap conditions in lofty elevation areas
  
- ❖ This *vertical zonation* leads to highly variable local climates, all classified within H climate designation



# H – British Columbia



Ahrens: Fig. 17.9