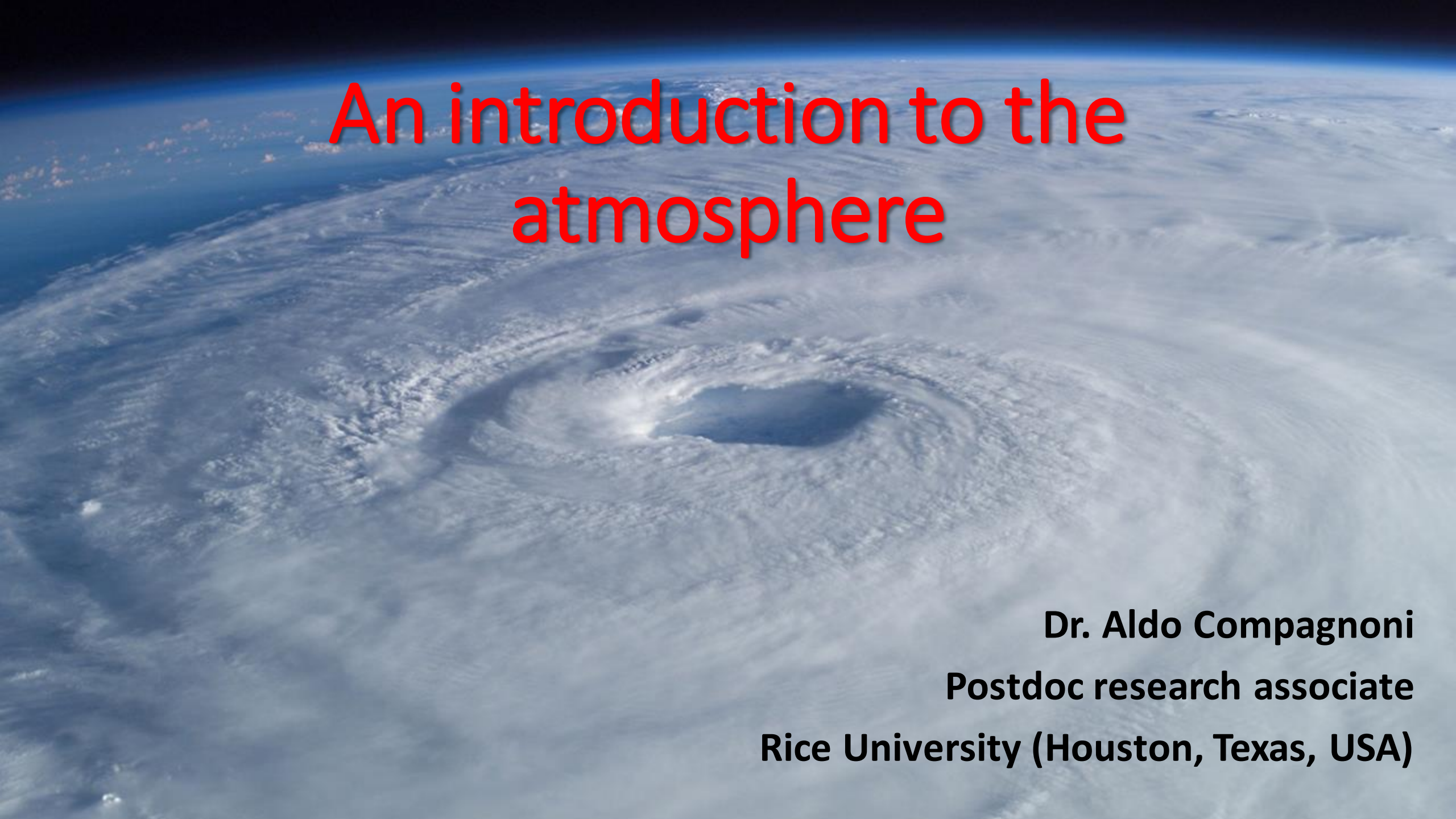


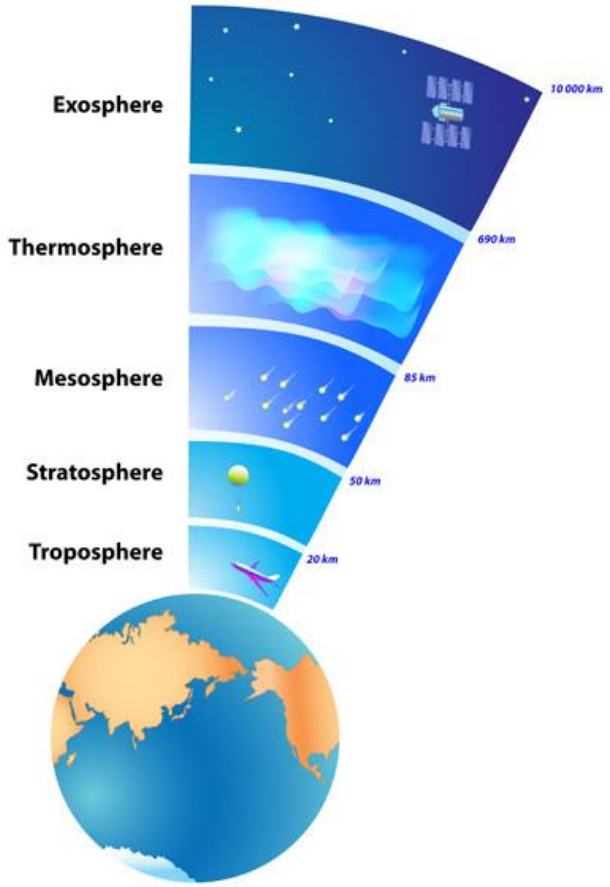
An introduction to the atmosphere

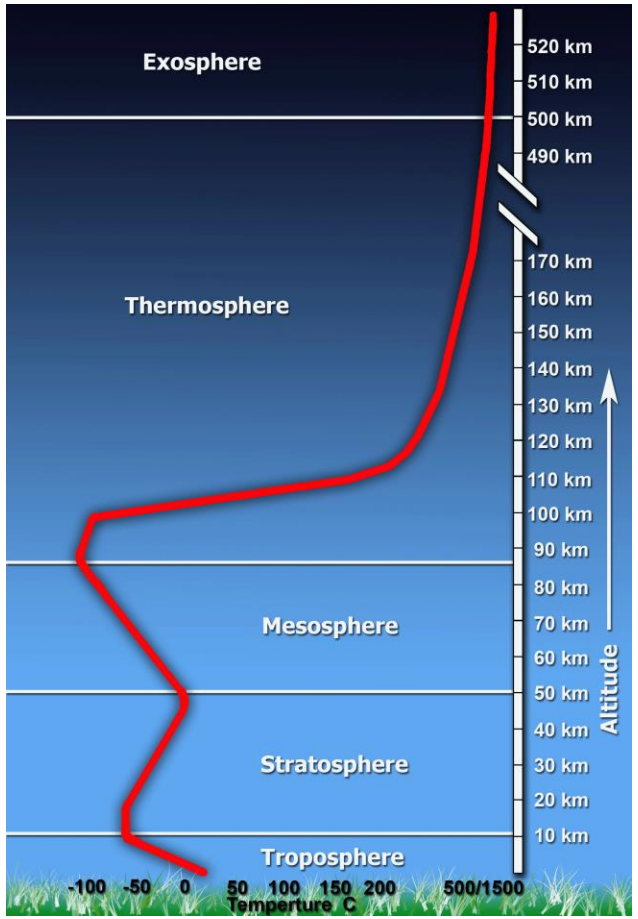
Dr. Aldo Compagnoni

Postdoc research associate

Rice University (Houston, Texas, USA)

Layers of the atmosphere

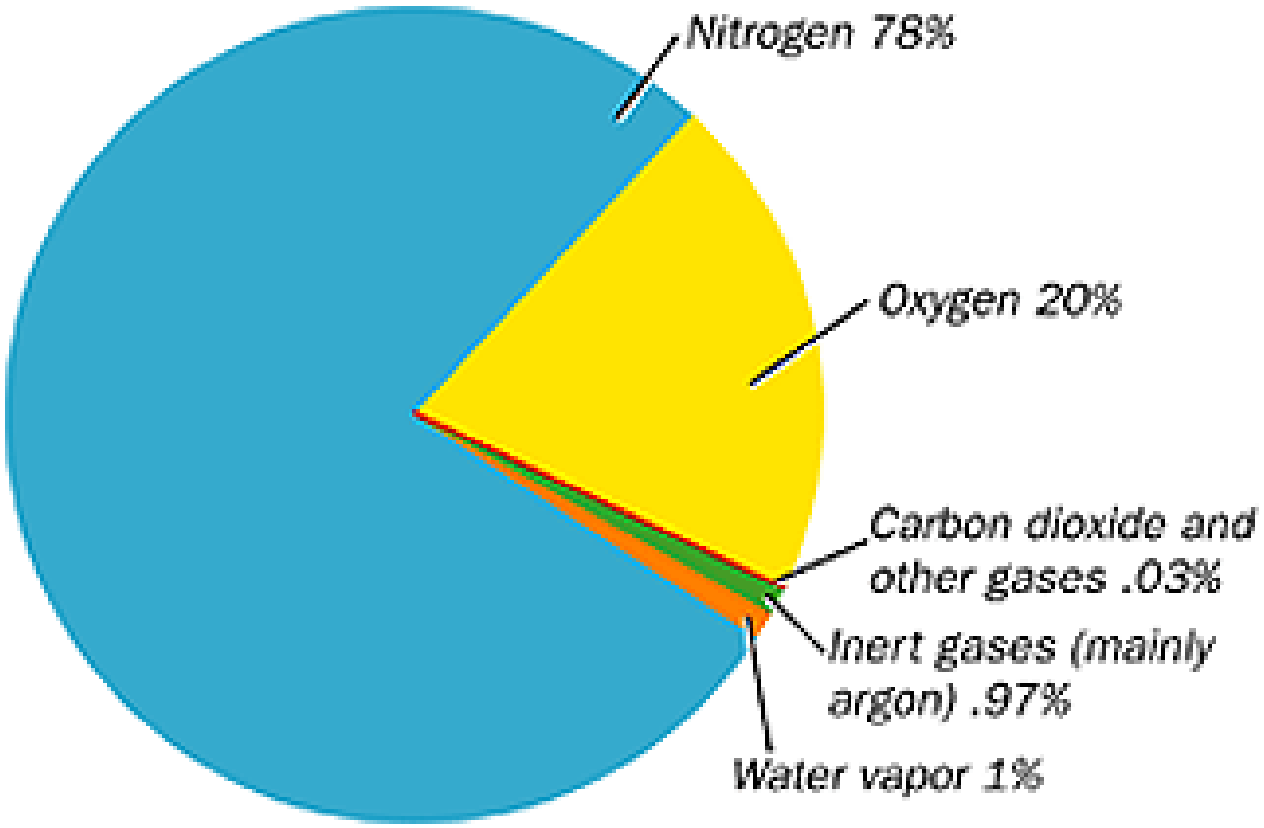




High atmosphere (heterosphere)

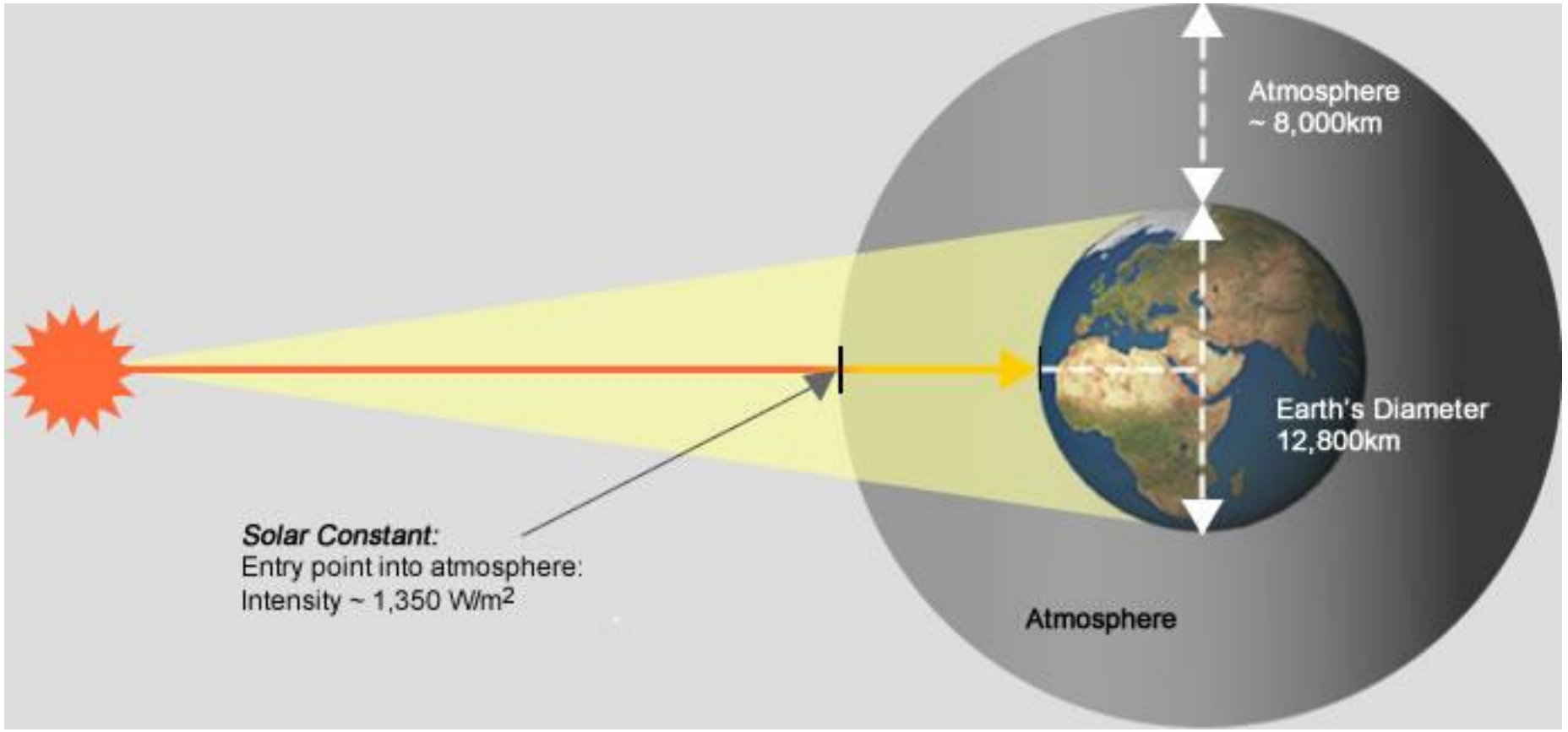
Low atmosphere (homosphere)

Chemical composition of the lower atmosphere



Atmosphere layers

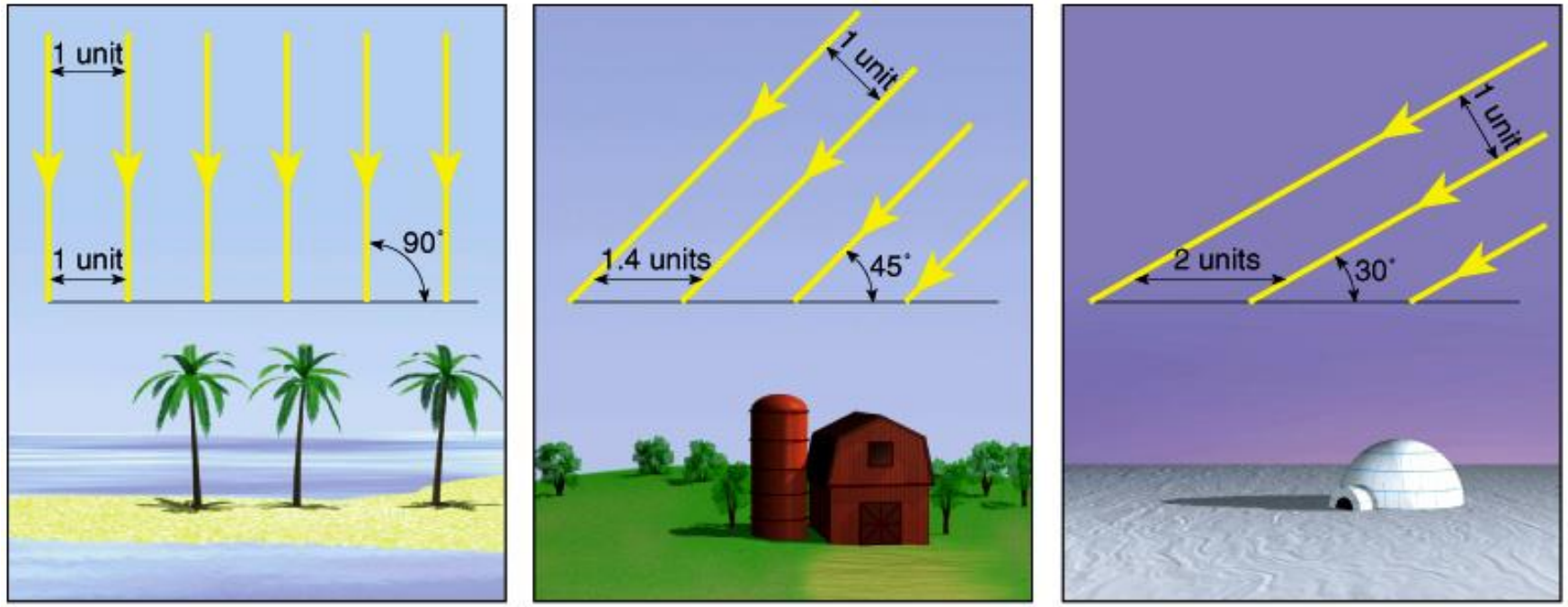
The Earth's energy budget: the Solar Constant



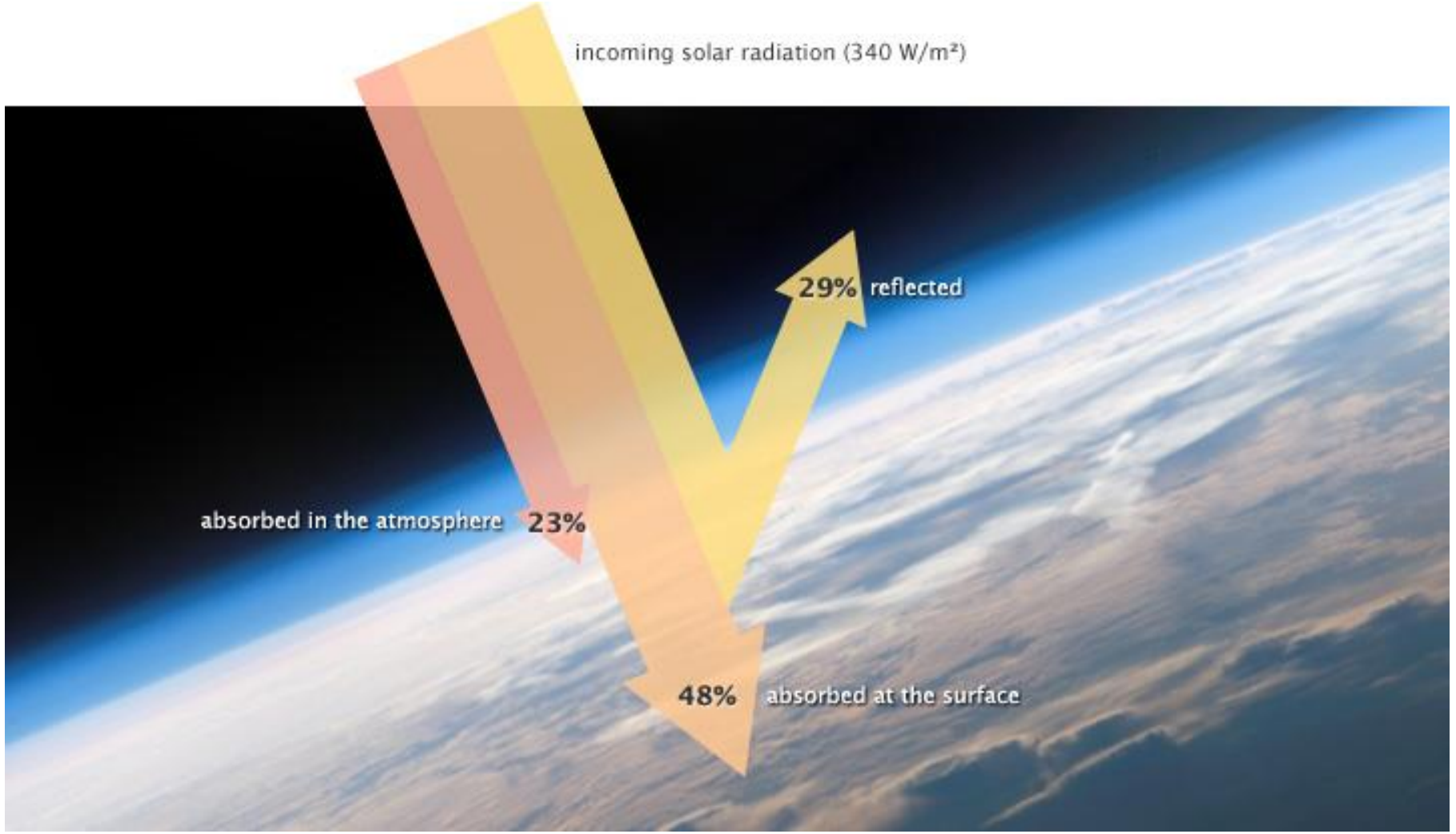
Solar constant: 1,366 W/m^2

Solar heating is uneven

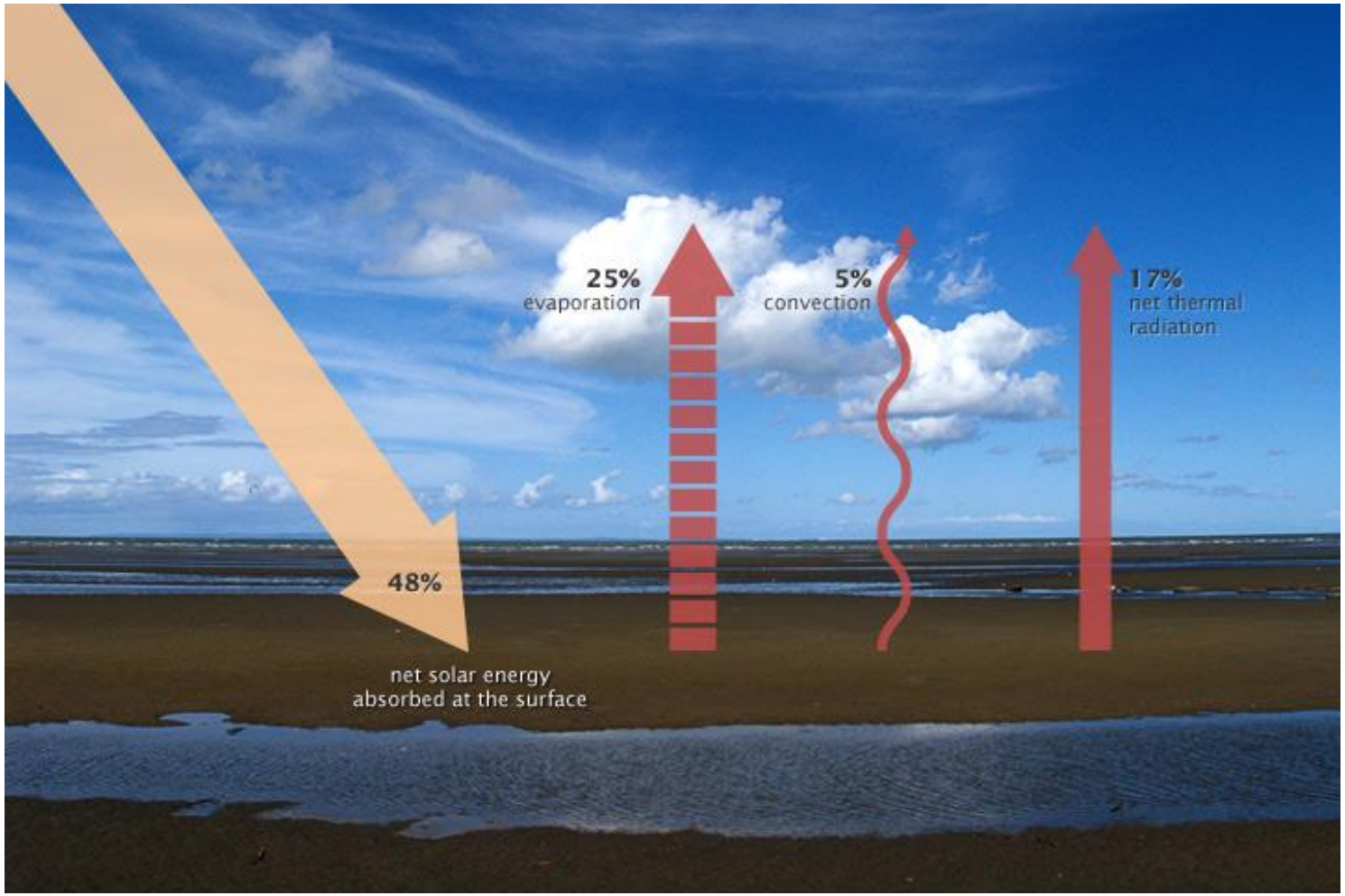
- Different amounts fall on different parts of the earth
- Depends on the angle of the sun



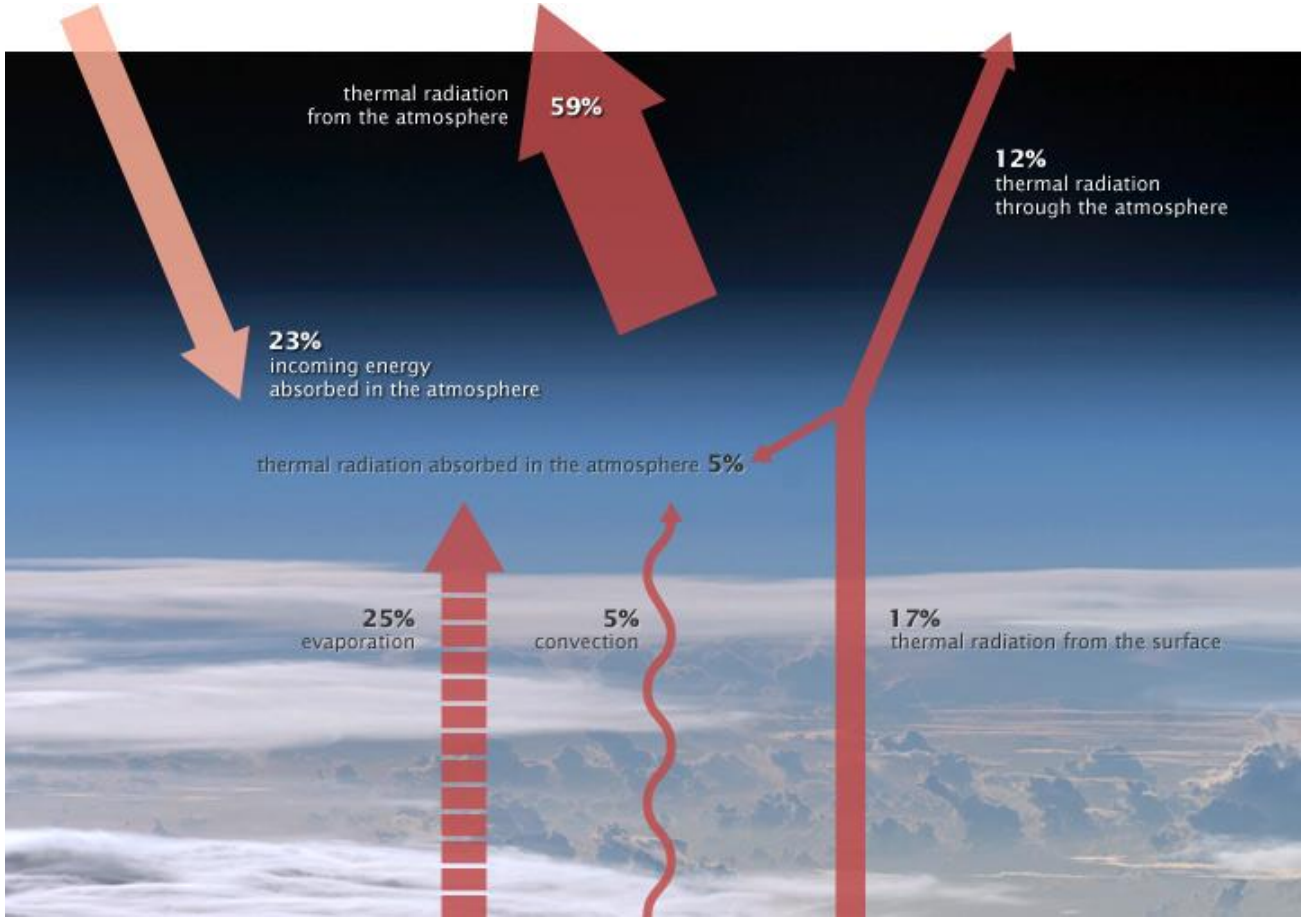
The earth's energy budget



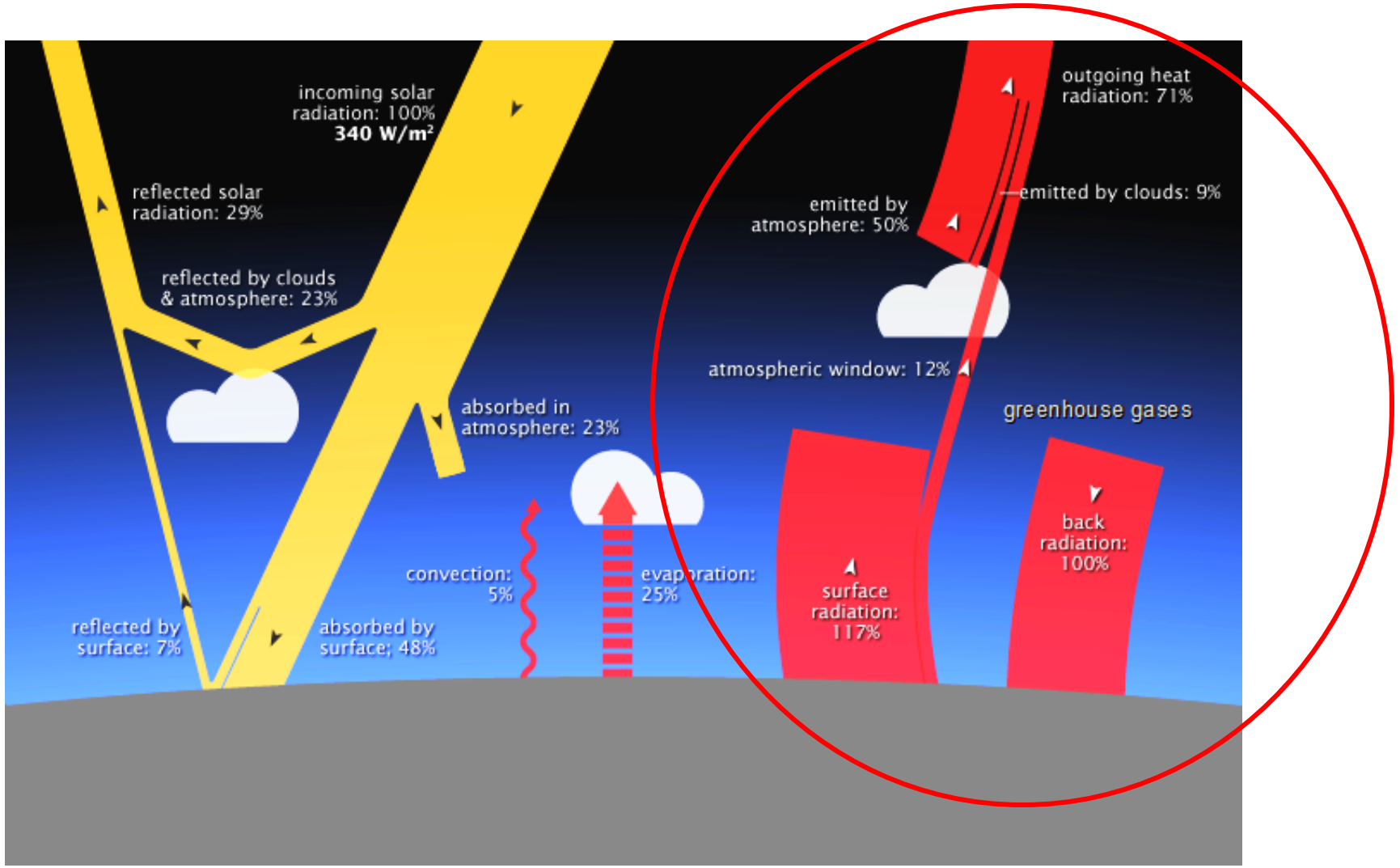
The surface energy budget



The atmosphere energy budget

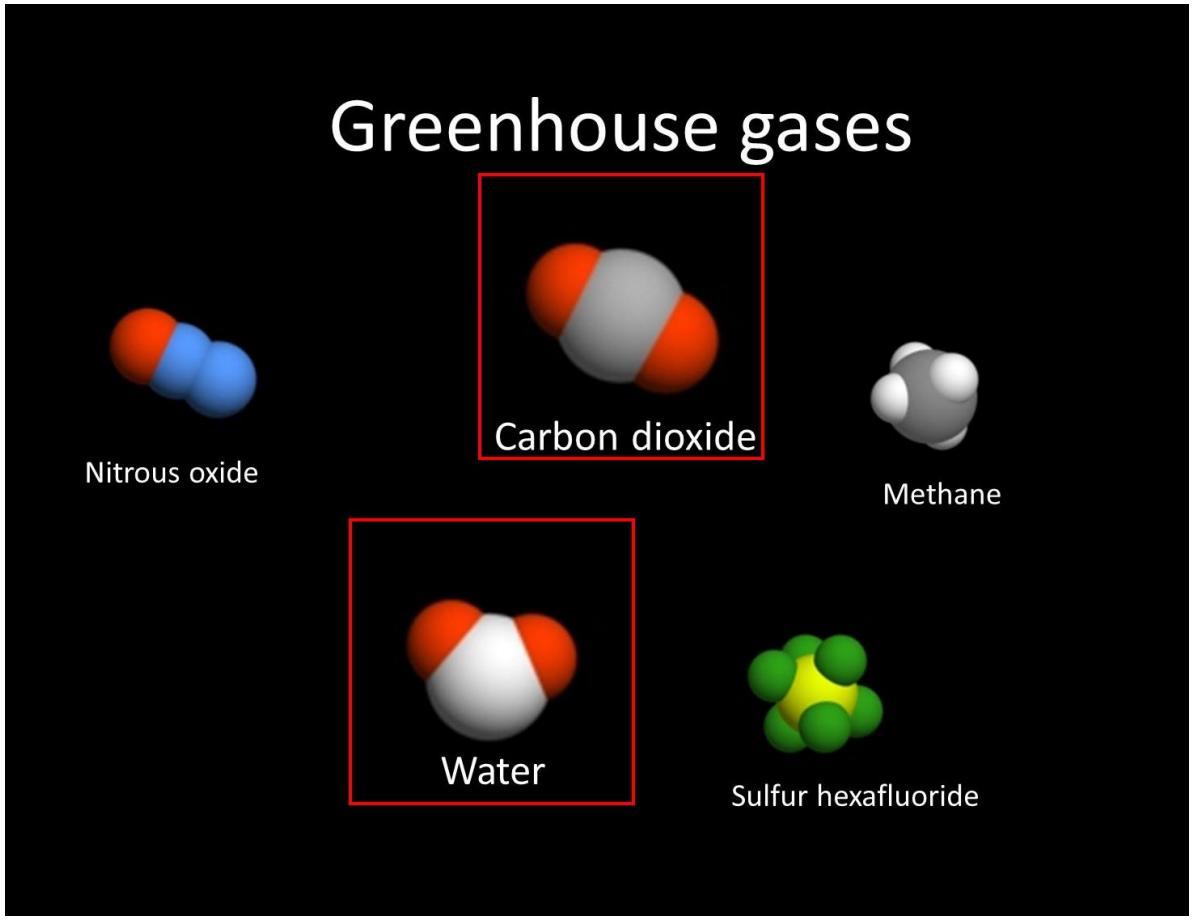


The earth's energy budget



The greenhouse effect

The greenhouse gases



Climate change

Observed changes

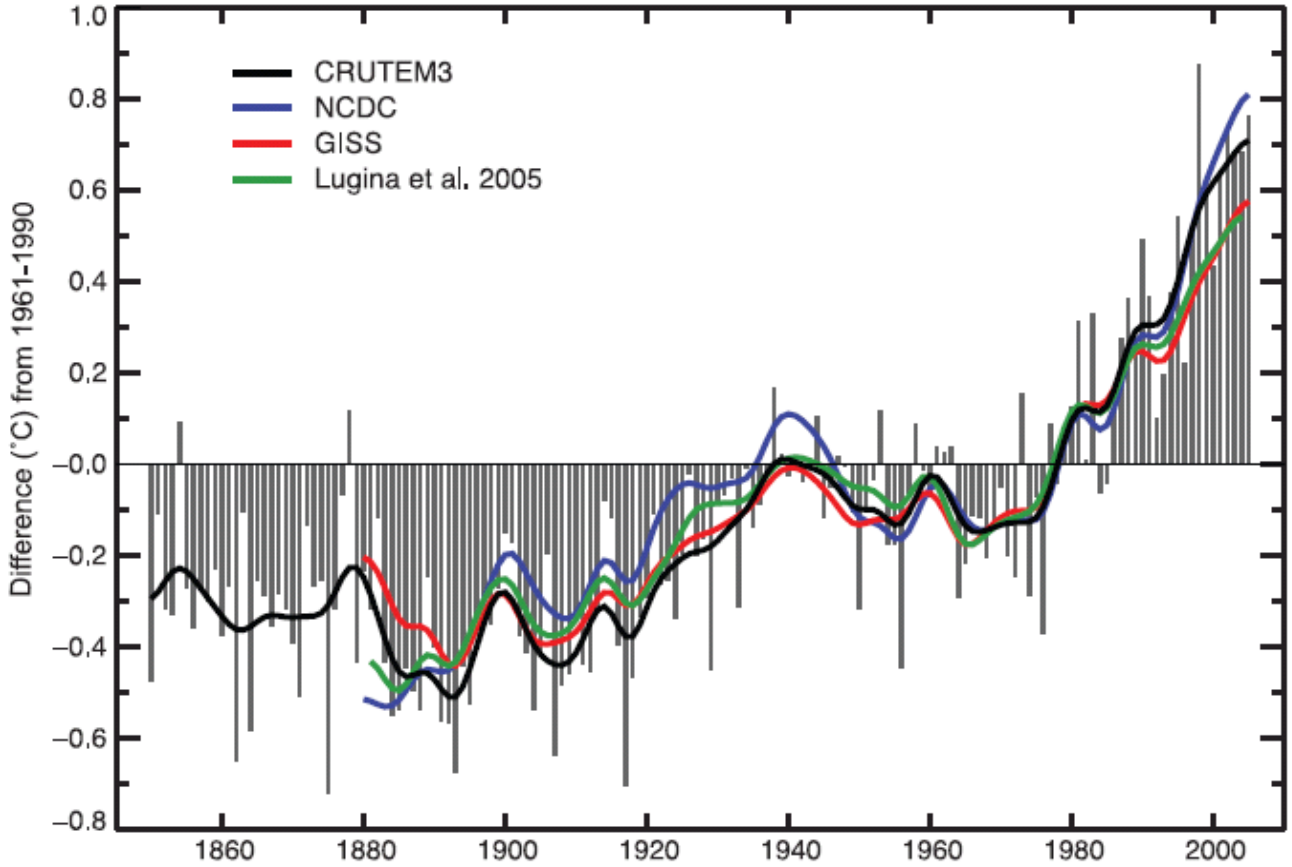
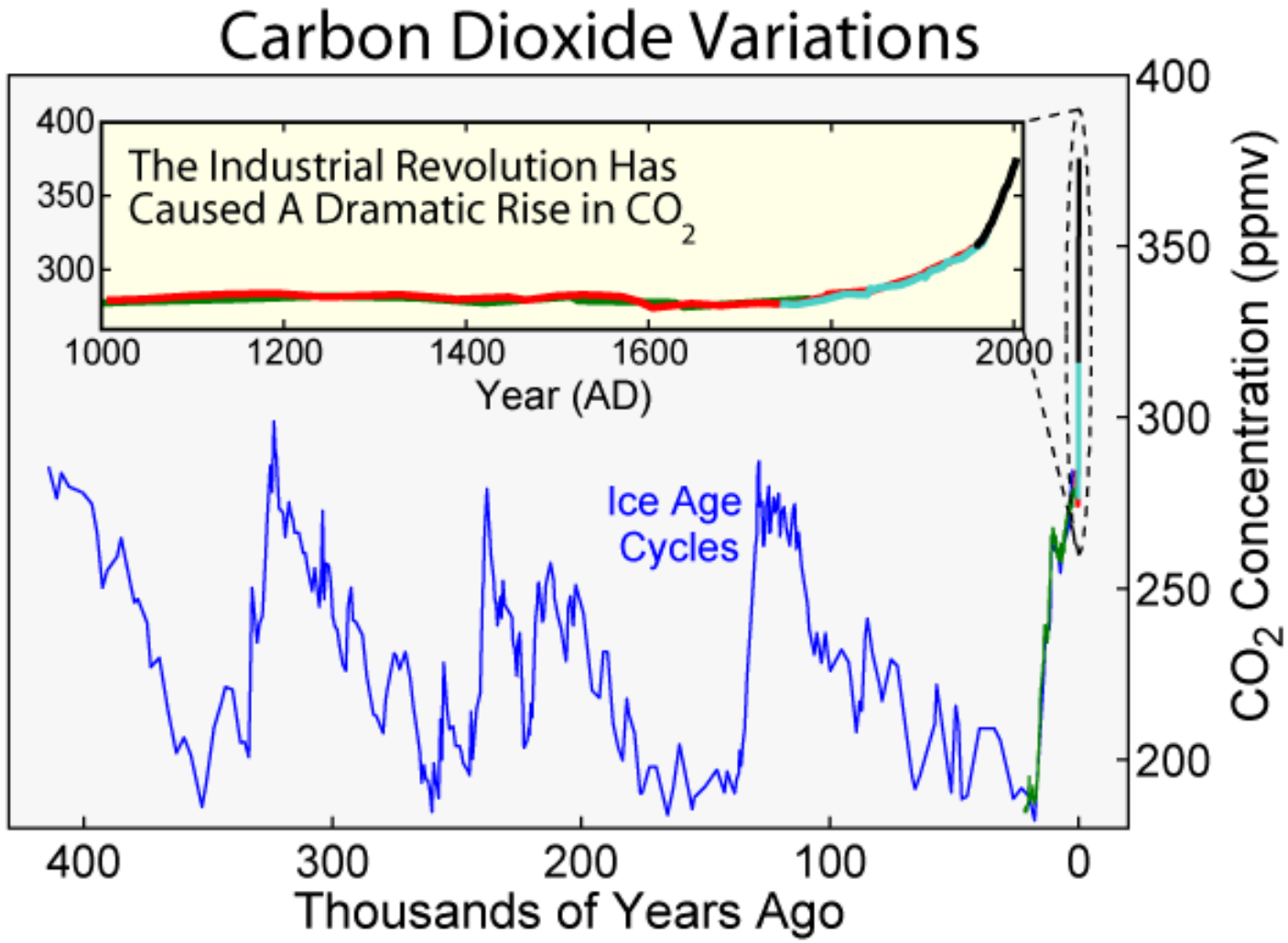


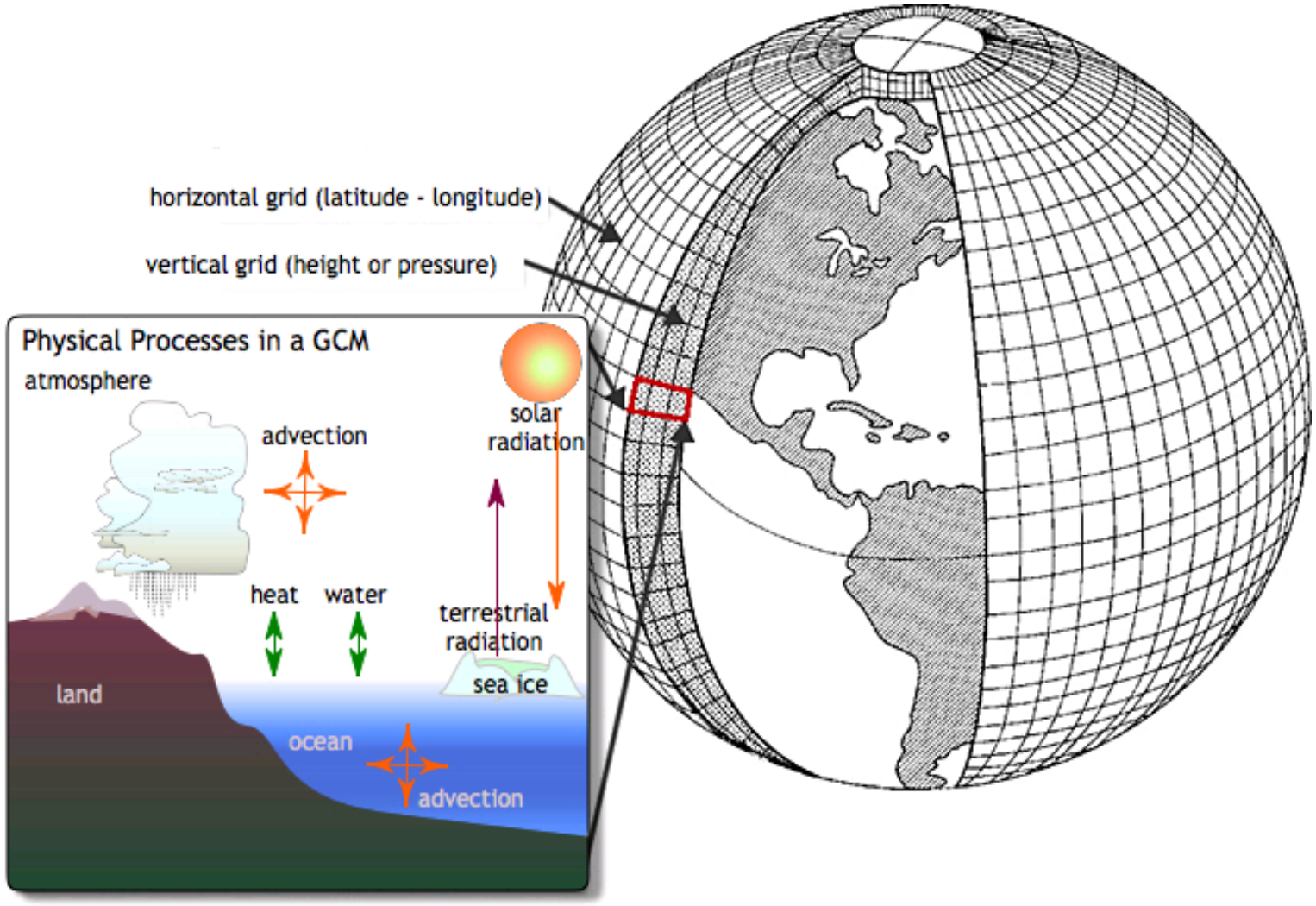
Figure 3.1. *Annual anomalies of global land-surface air temperature (°C), 1850 to 2005, relative to the 1961 to 1990 mean for CRUTEM3 updated from Brohan et al. (2006). The smooth curves show decadal variations (see Appendix 3.A). The black curve from CRUTEM3 is compared with those from NCDC (Smith and Reynolds, 2005; blue), GISS (Hansen et al., 2001; red) and Lugina et al. (2005; green).*

IPCC 2007

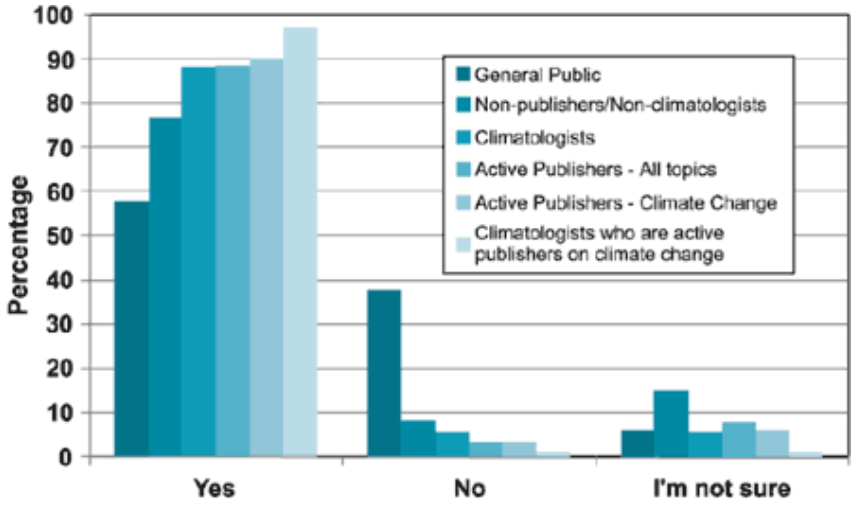
Greenhouse gases are increasing

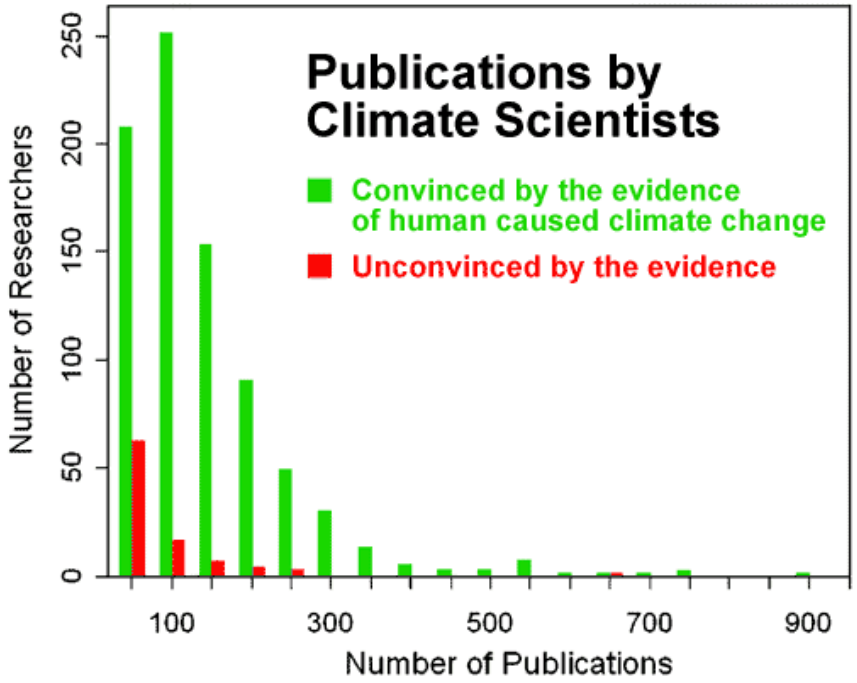


Global circulation models say: it is humans

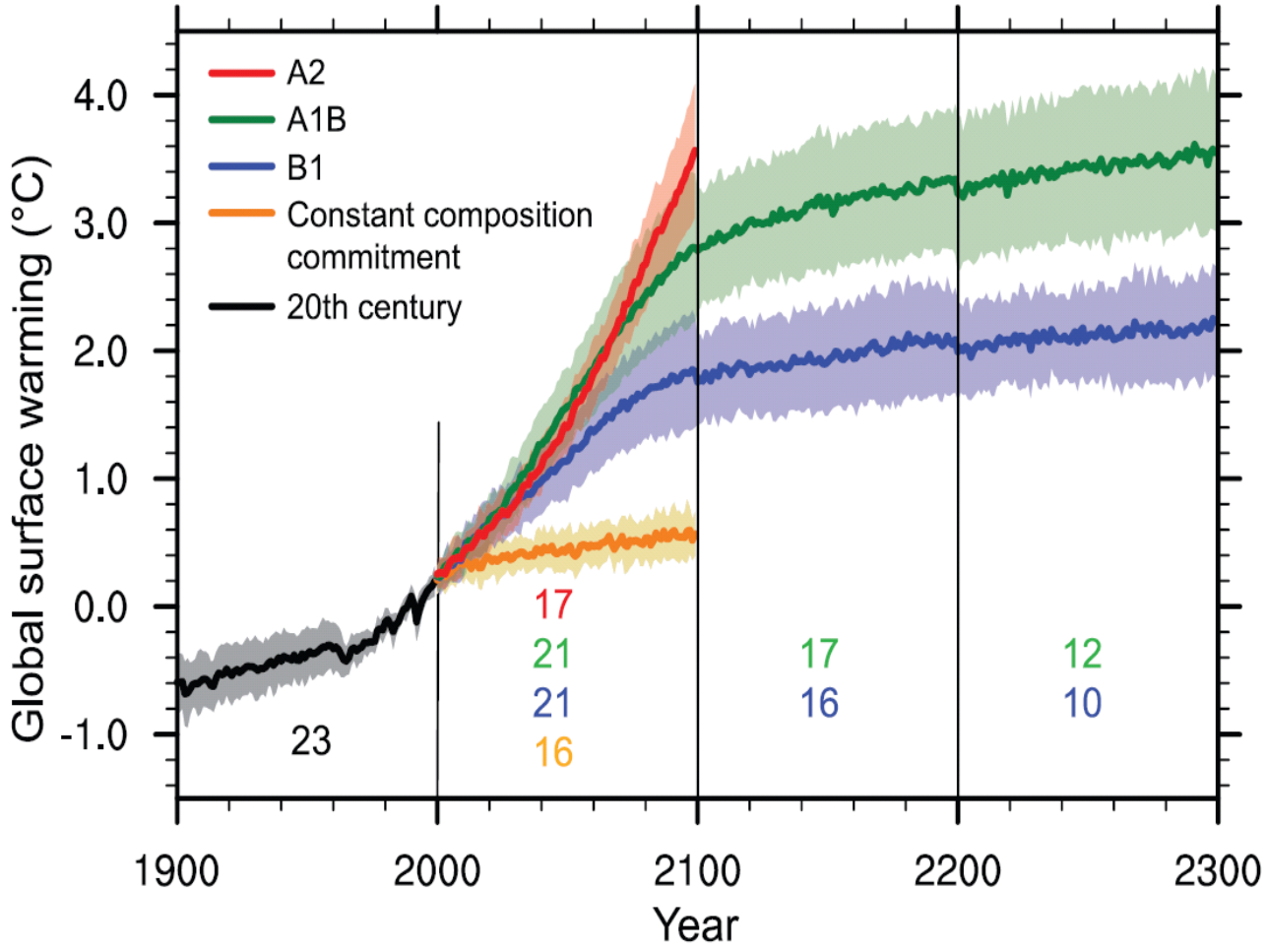


Consensus?


Percentage
100
90
80
70
60
50
40
30
20
10
0
General Public
Non-publishers/Non-climatologists
Climatologists
Active Publishers - All topics
Active Publishers - Climate Change
Climatologists who are active publishers on climate change
Yes
No
I'm not sure


Publications by Climate Scientists
Convinced by the evidence of human caused climate change
Unconvinced by the evidence
Number of Researchers
0
50
100
150
200
250
100
300
500
700
900
Number of Publications

Projections

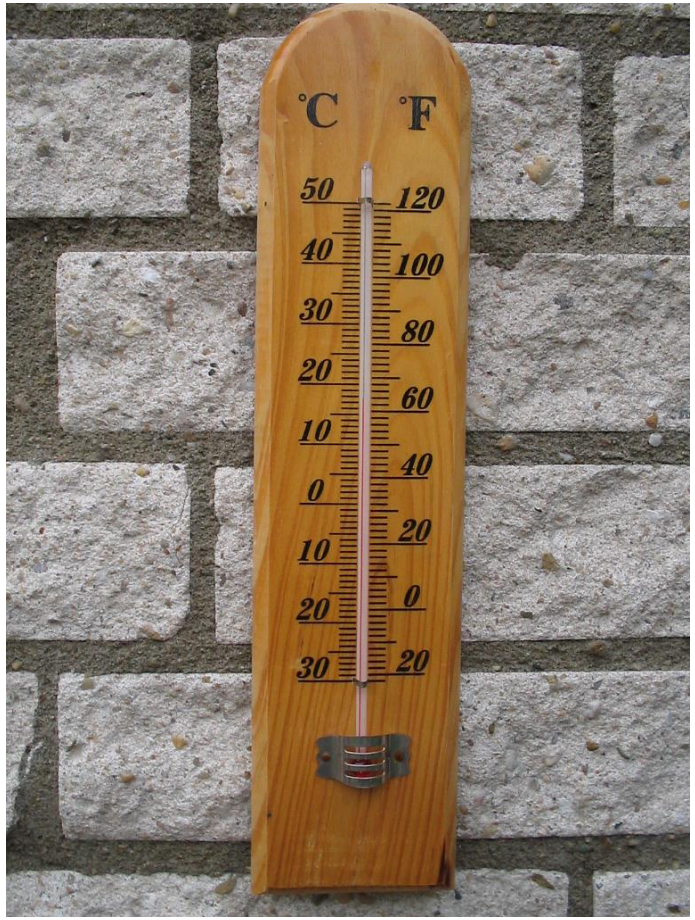


IPCC 2007

The troposphere

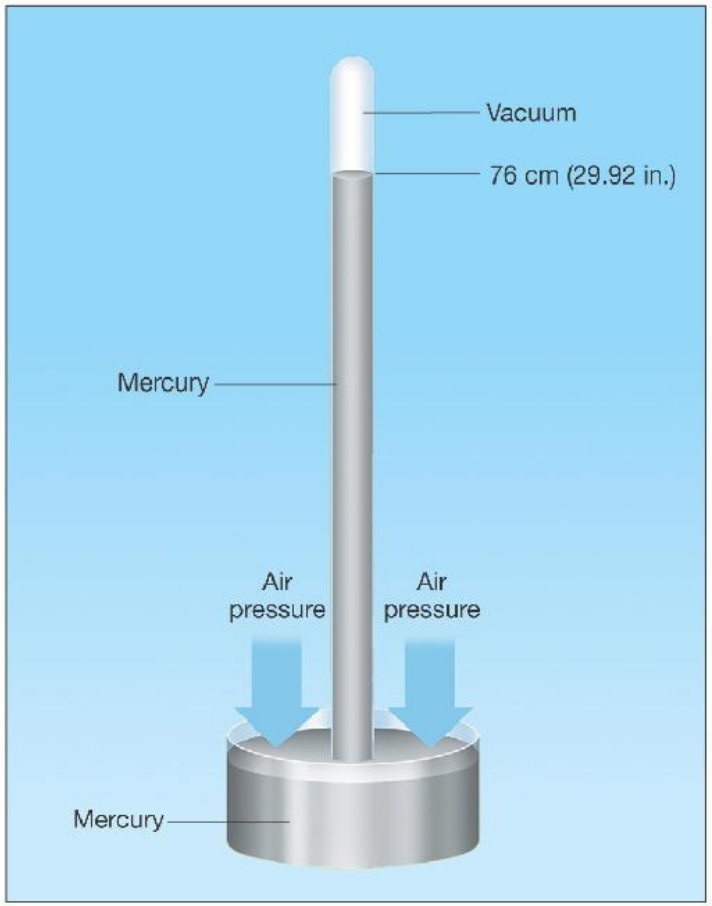
Air temperature

1. Inclination of incoming radiation.
2. Altitude.
3. Presence of large water bodies.
4. Aspect.
5. Type of surface.
6. Clouds and dust.
7. Urbanization.

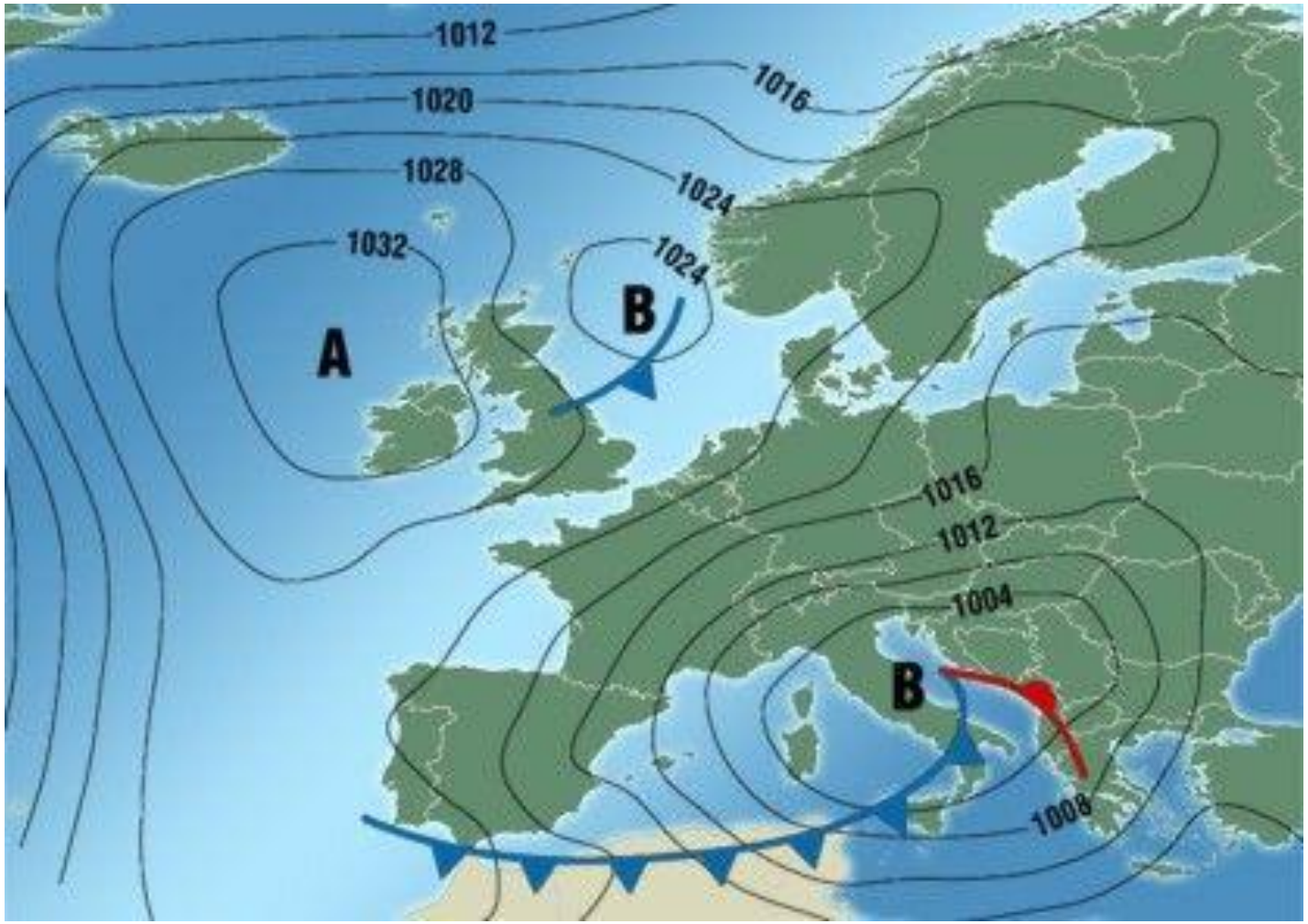


Atmospheric pressure

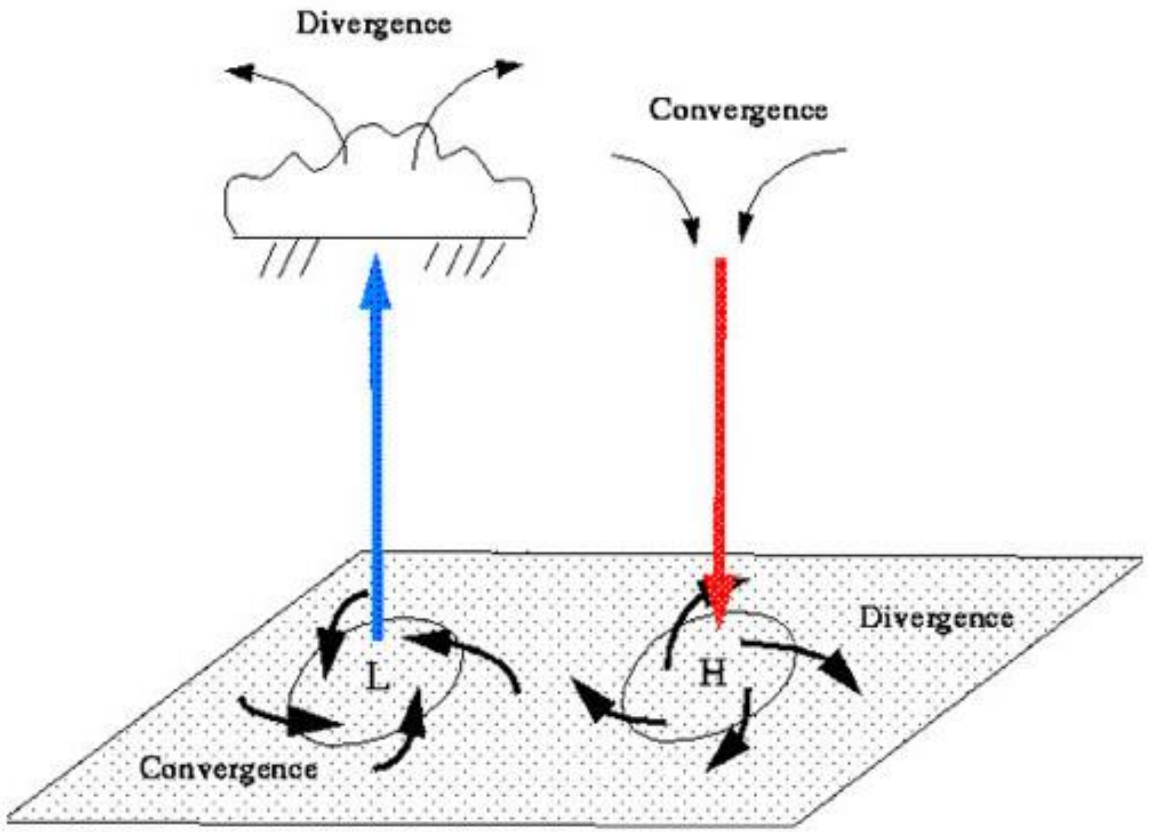
- The force exerted on a unit of surface by the column of air above it.
- Unit of measure: the millibar (mb).
- Average atmospheric pressure: 1013.2 (mb).
- Measured with barometer



Isobaric maps

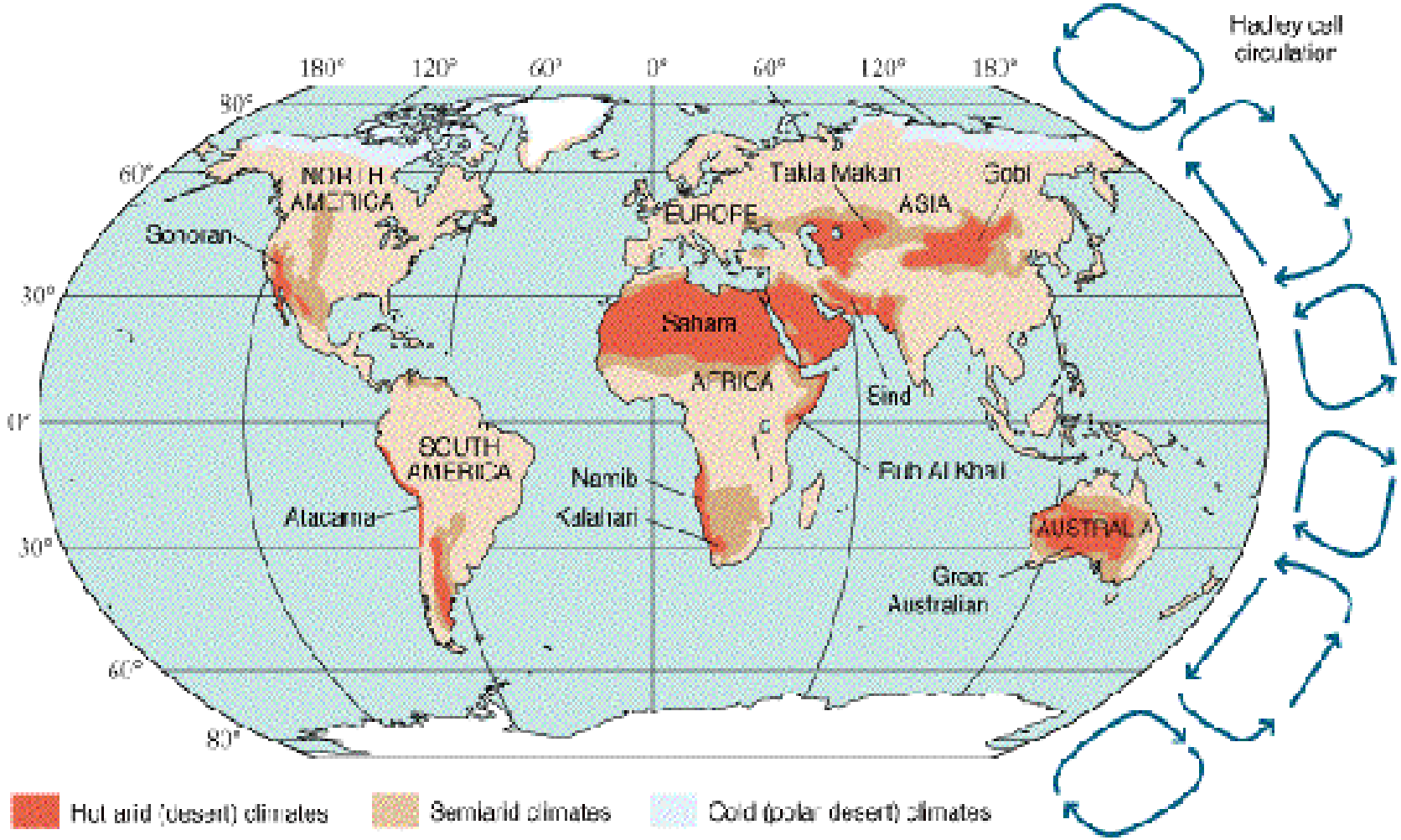


Winds and high/low pressure systems



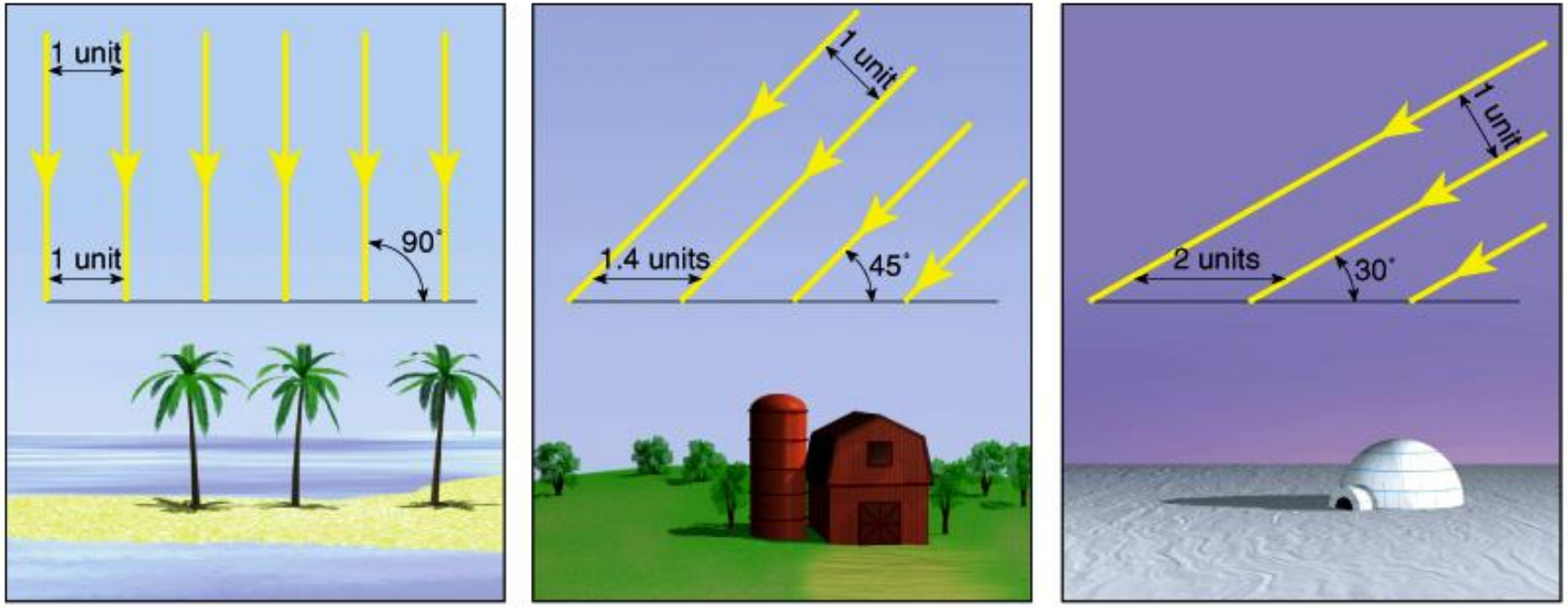
General circulation of the atmosphere

Puzzle: Why are so many deserts found near 30° latitude?



Solar heating is uneven

- Different amounts fall on different parts of the earth
- Depends on the angle of the sun

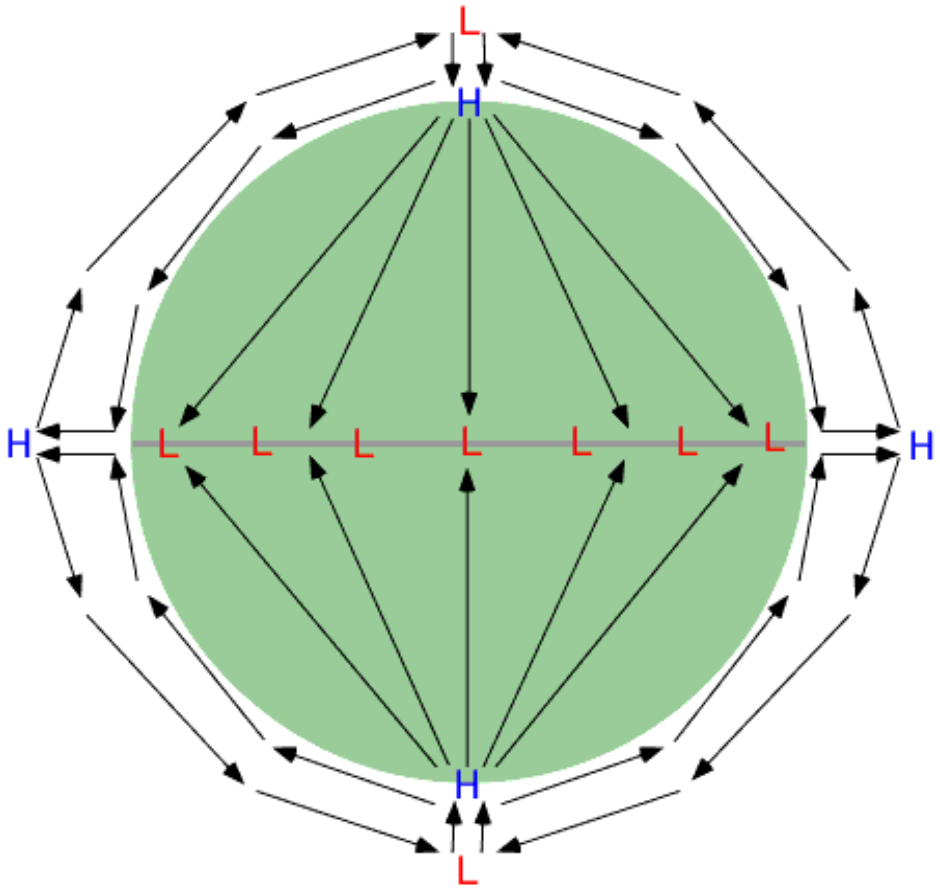


Uneven heating leads to uneven air pressure

Cold air sinks, creating **HIGH** pressure

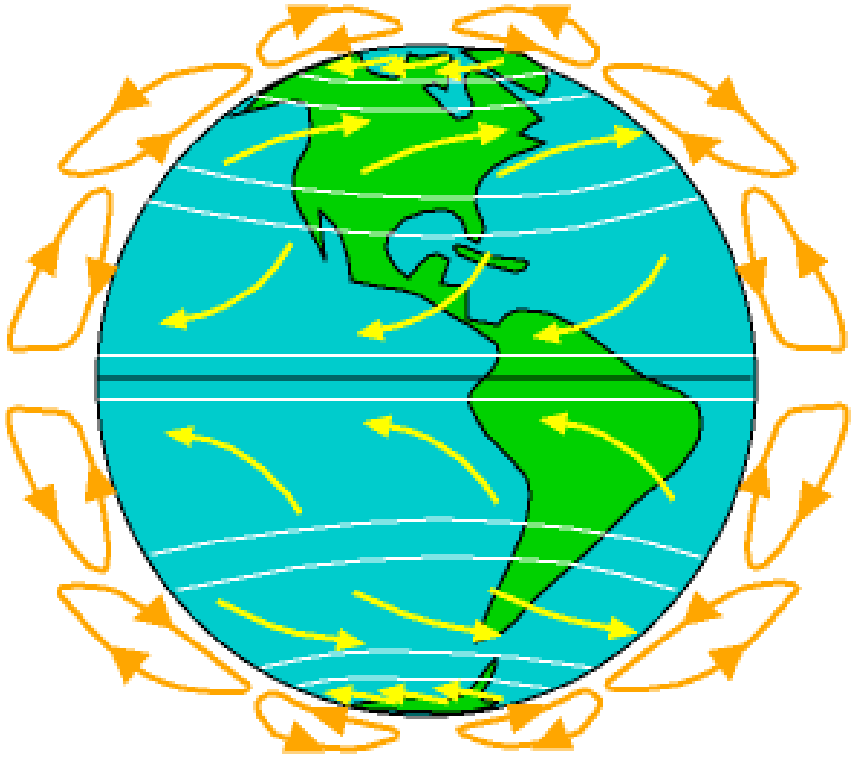
Hot air rises, creating **LOW** pressure

Simplified circulation



But the earth is spinning too...

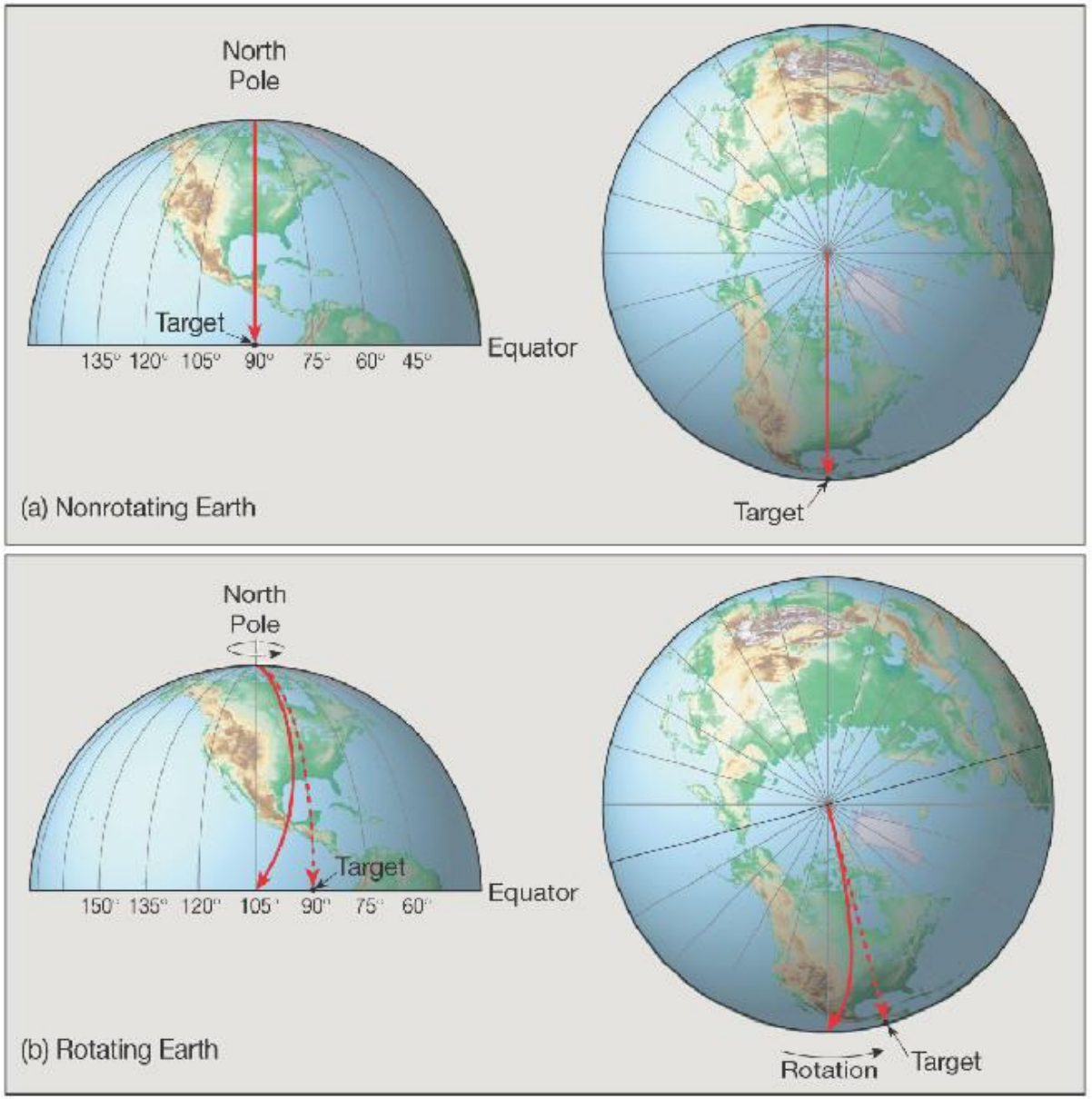
no rotation: no coriolis effect



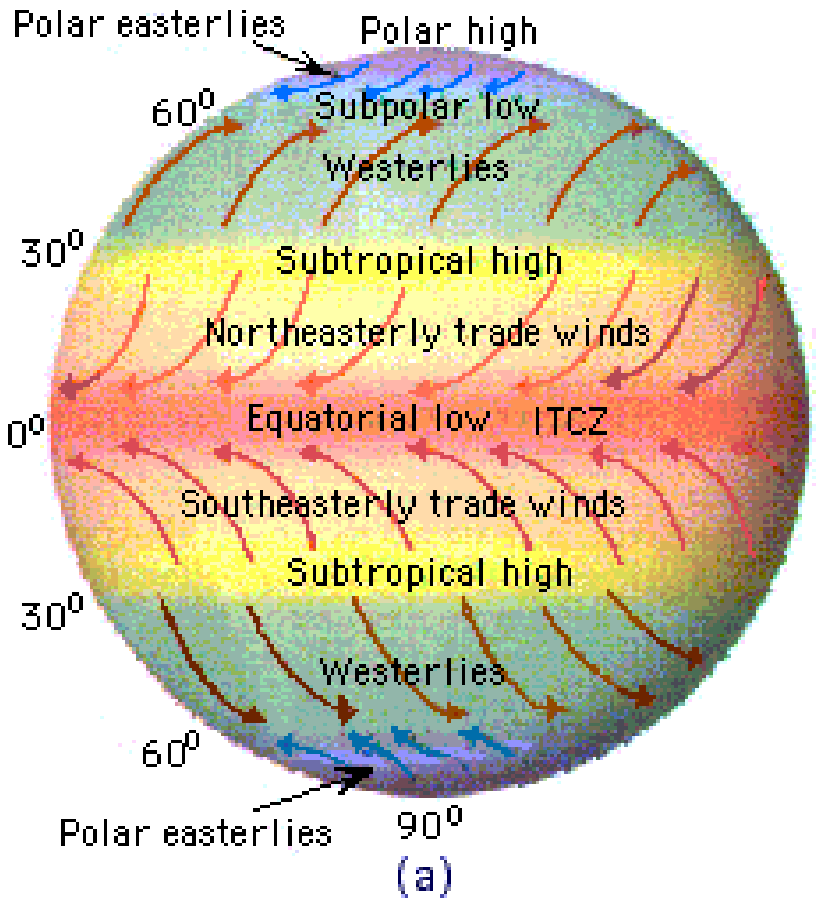
rapid rotation: significant coriolis effect

On a planet with little or no rotation, the global air circulation pattern is very simple. On a planet with rapid rotation, the coriolis effect creates large-scale eddies with belts of wind and belts of calm.

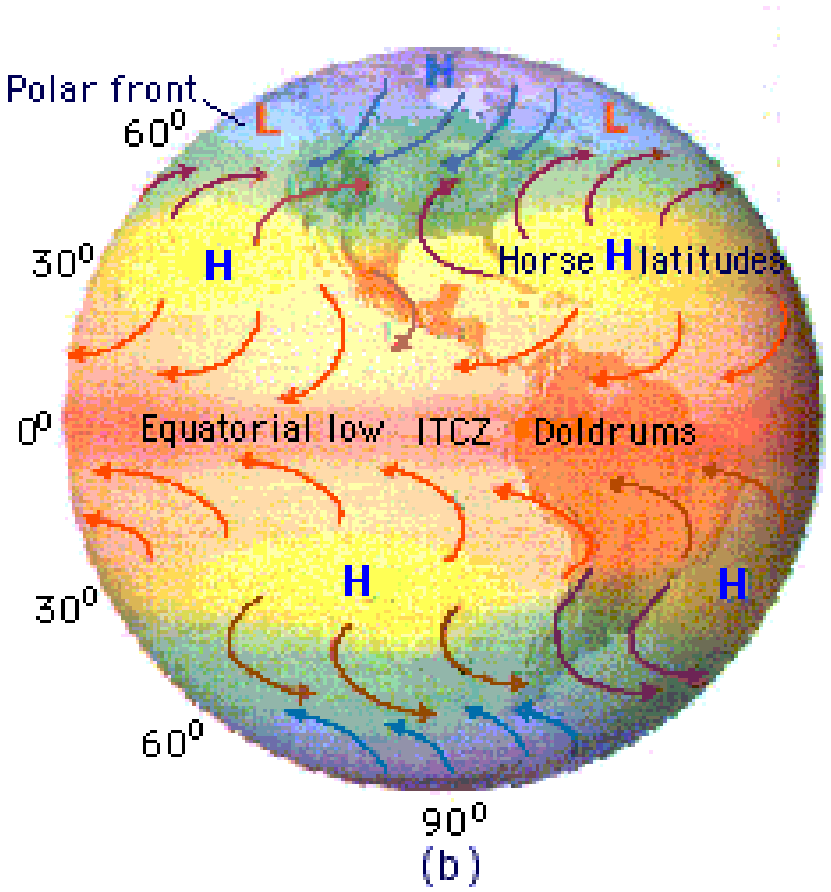
More on Coriolis forces...



Landmasses play a role as well

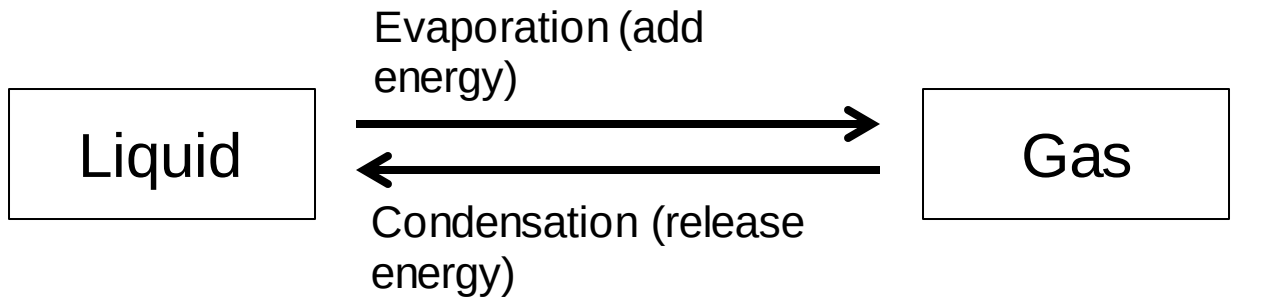


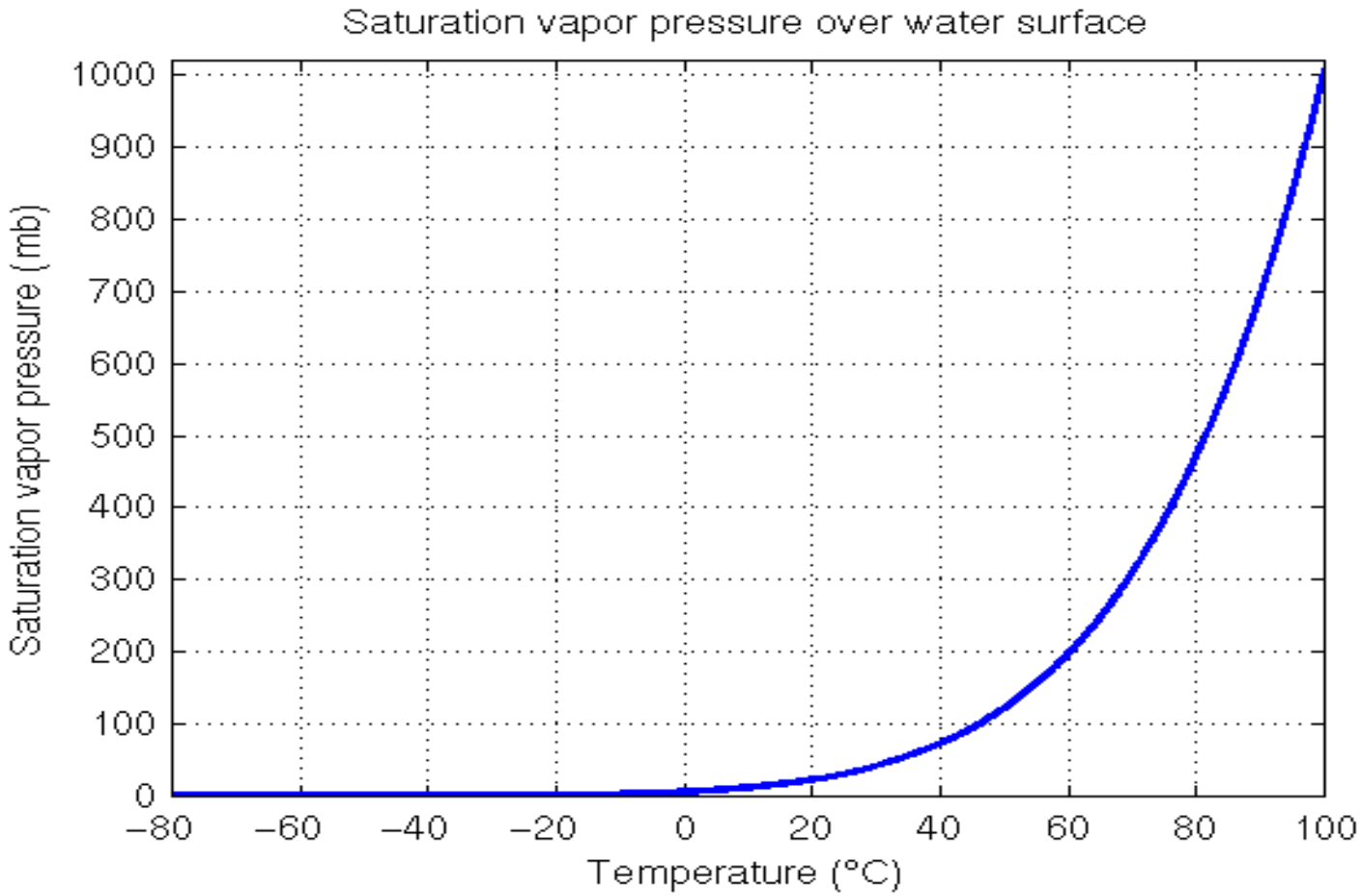
"Ideal" Zonal Pressure Belts
An Imaginary uniform Earth with idealized zonal (continuous) pressure belts.



Actual Zonal Pressure Belts
The real Earth with disruptions of the zonal pattern by large landmasses. These disruptions break up pressure zones into semipermanent high and low pressure belts.

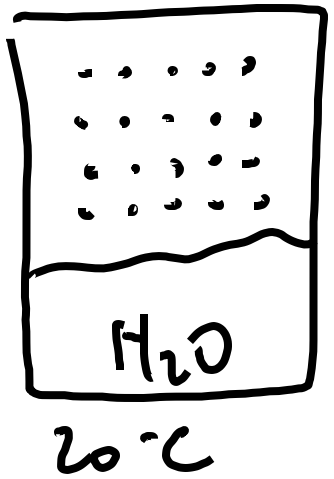
Warm air holds more moisture than cold air

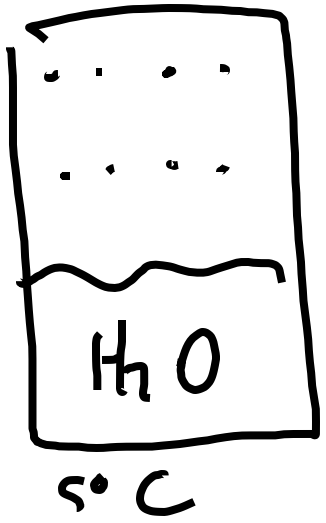


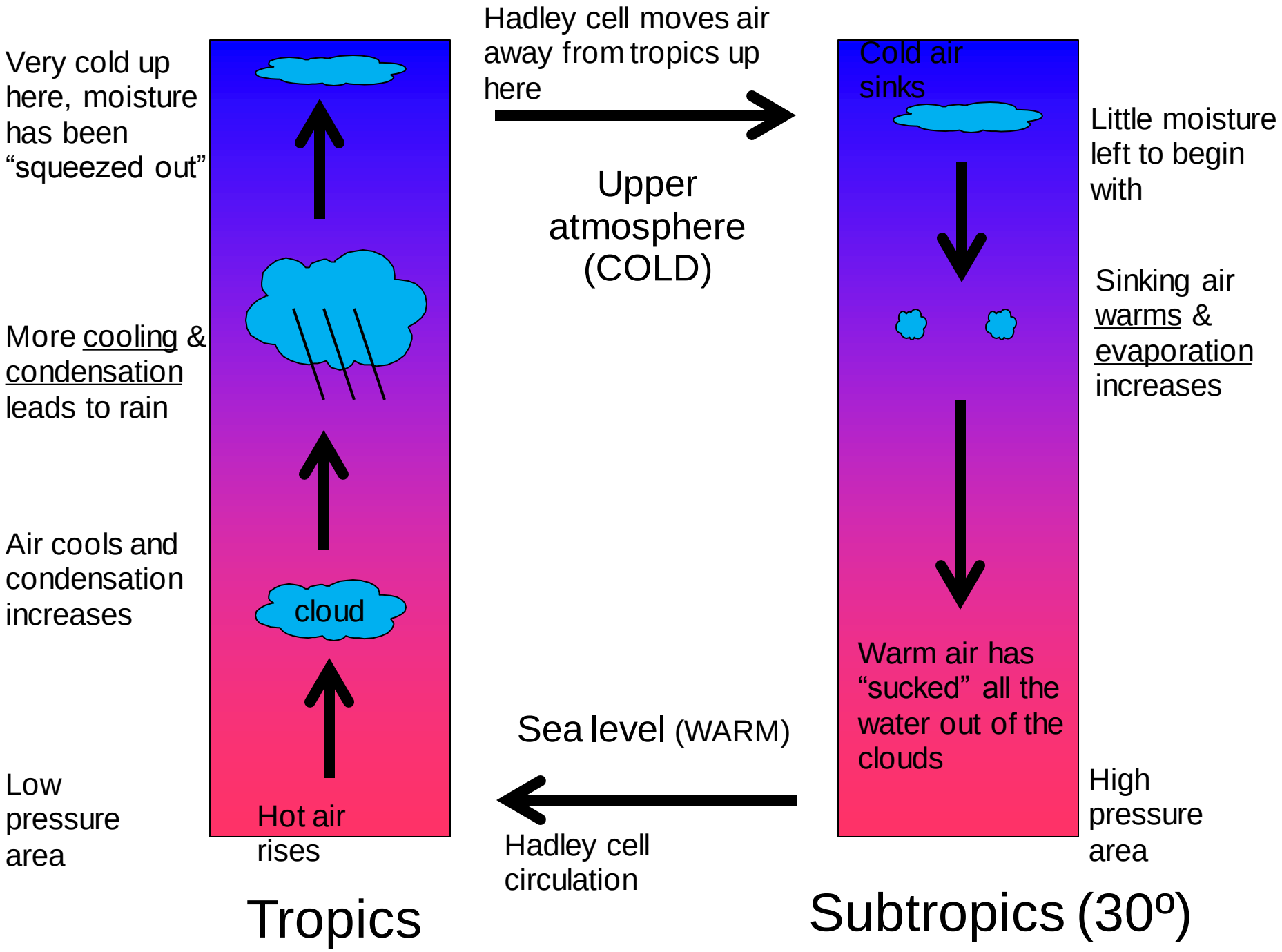


Saturation vapor pressure

- "The saturation vapor pressure is the static pressure of a vapor when the vapor phase of some material is in equilibrium with the liquid phase of that same material." (Wickipedia)
- rate of condensation = rate of evaporation
- often occurs right at the surface of liquid water (or of a water droplet)





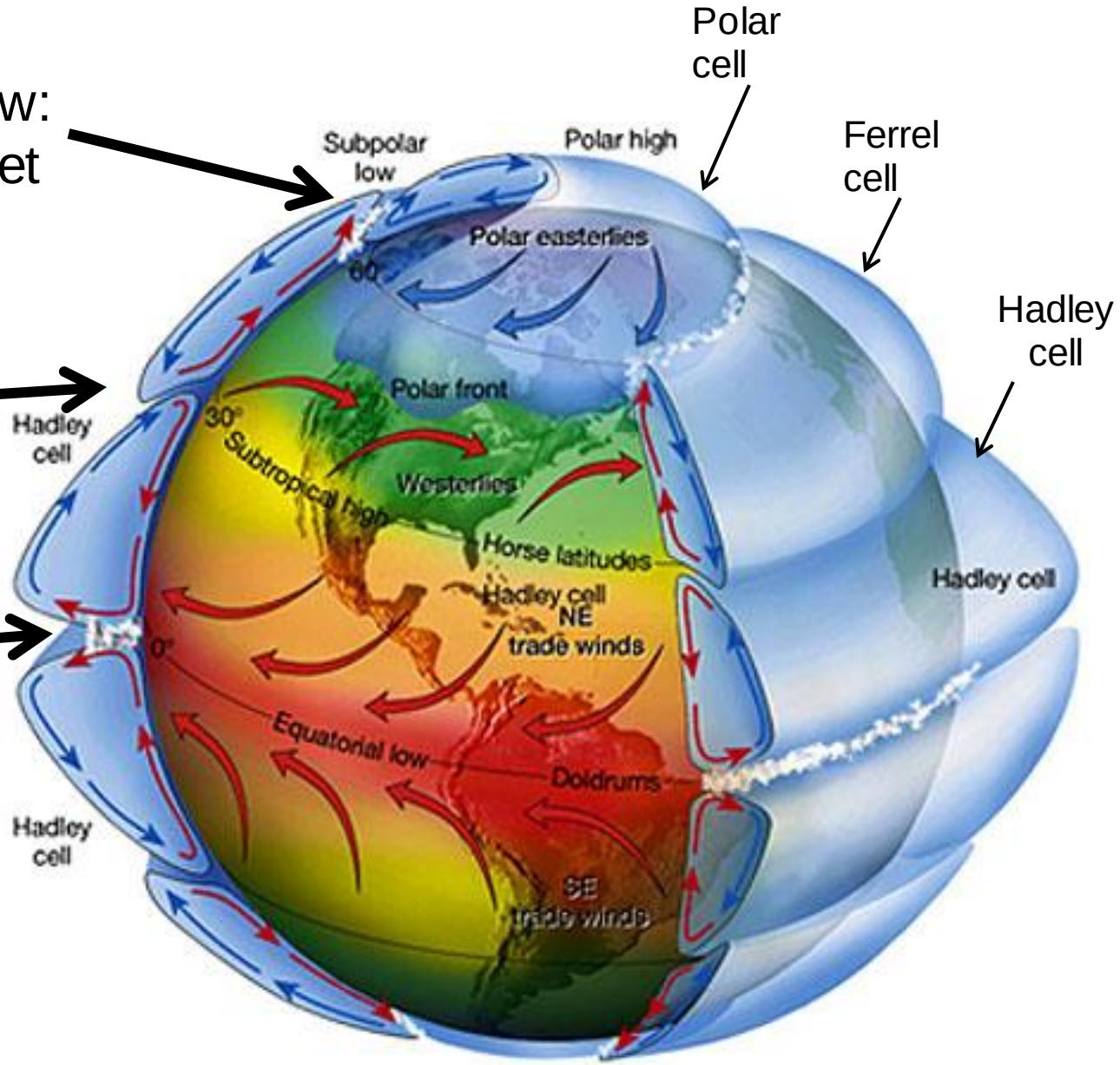

Very cold up here, moisture has been "squeezed out"
More cooling & condensation leads to rain
Air cools and condensation increases
Low pressure area
cloud
Hot air rises
Tropics
Hadley cell moves air away from tropics up here
Upper atmosphere (COLD)
Cold air sinks
Little moisture left to begin with
Sinking air warms & evaporation increases
Warm air has "sucked" all the water out of the clouds
High pressure area
Subtropics (30º)
Sea level (WARM)
Hadley cell circulation

The Big Picture

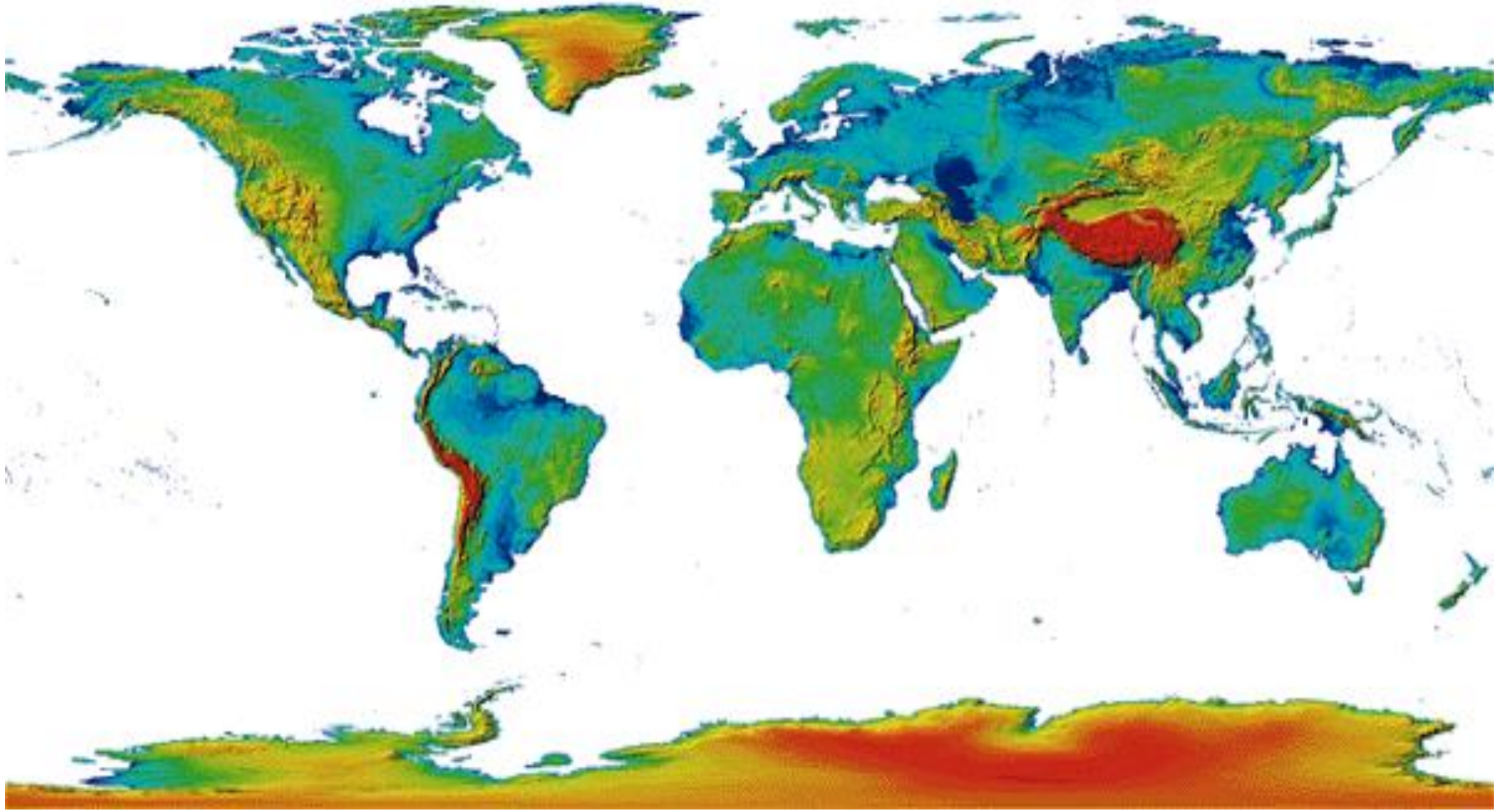
Subpolar low:
Cool and wet

Subtropical high:
Sunny and dry

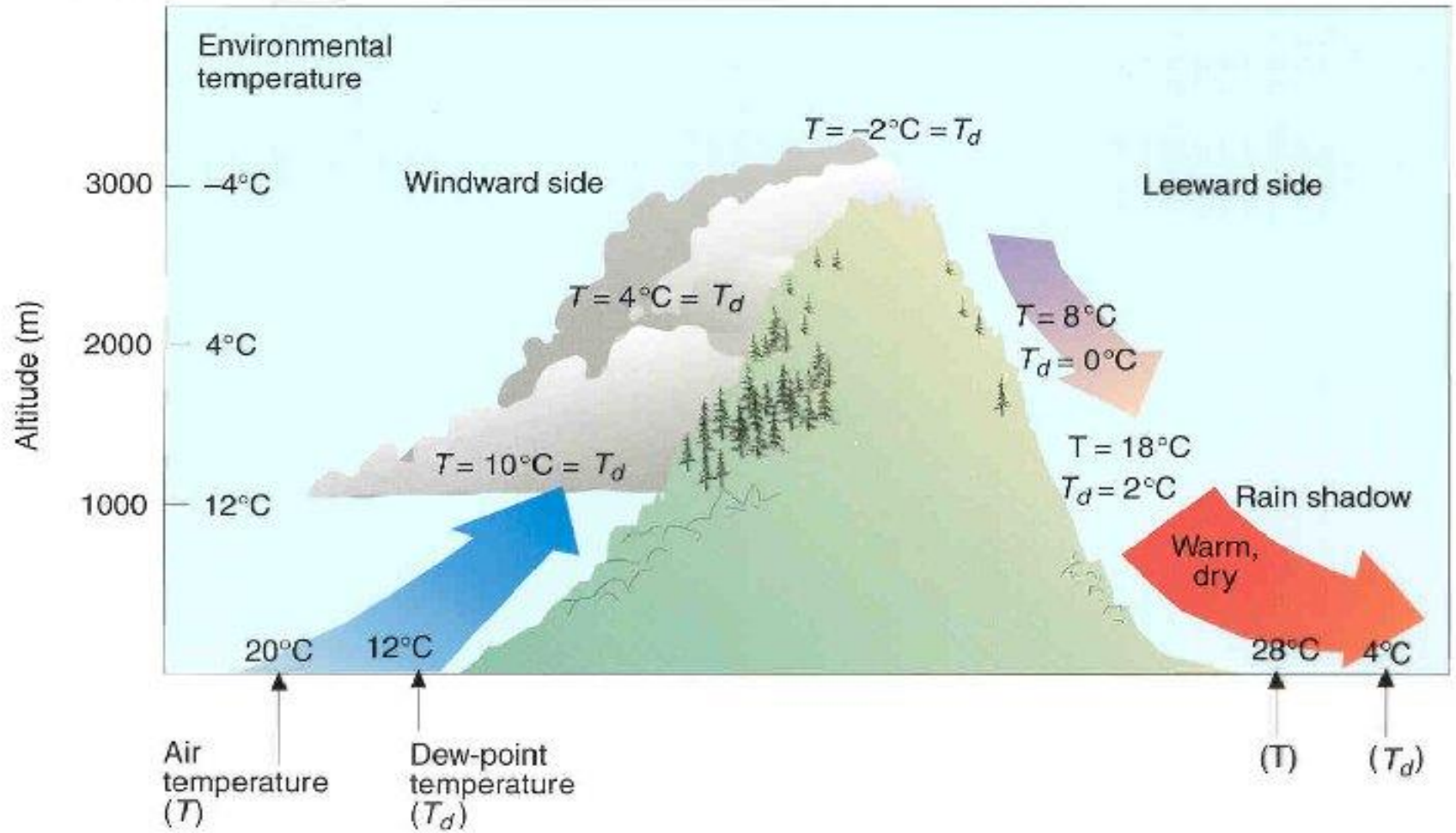
Equatorial low:
Warm, cloudy, rainy



Elevation also influences climate



Orographic effects and rain shadows



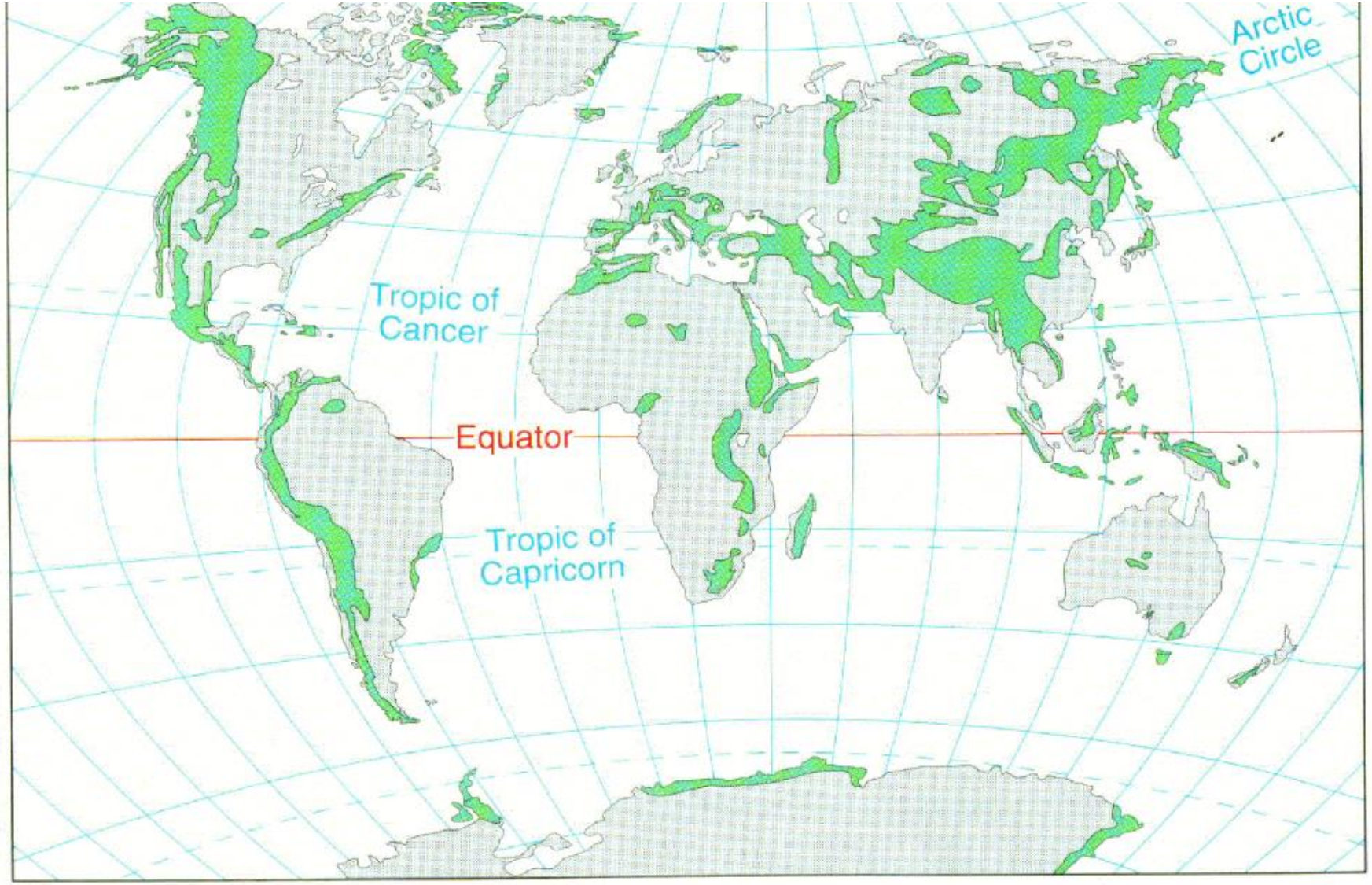
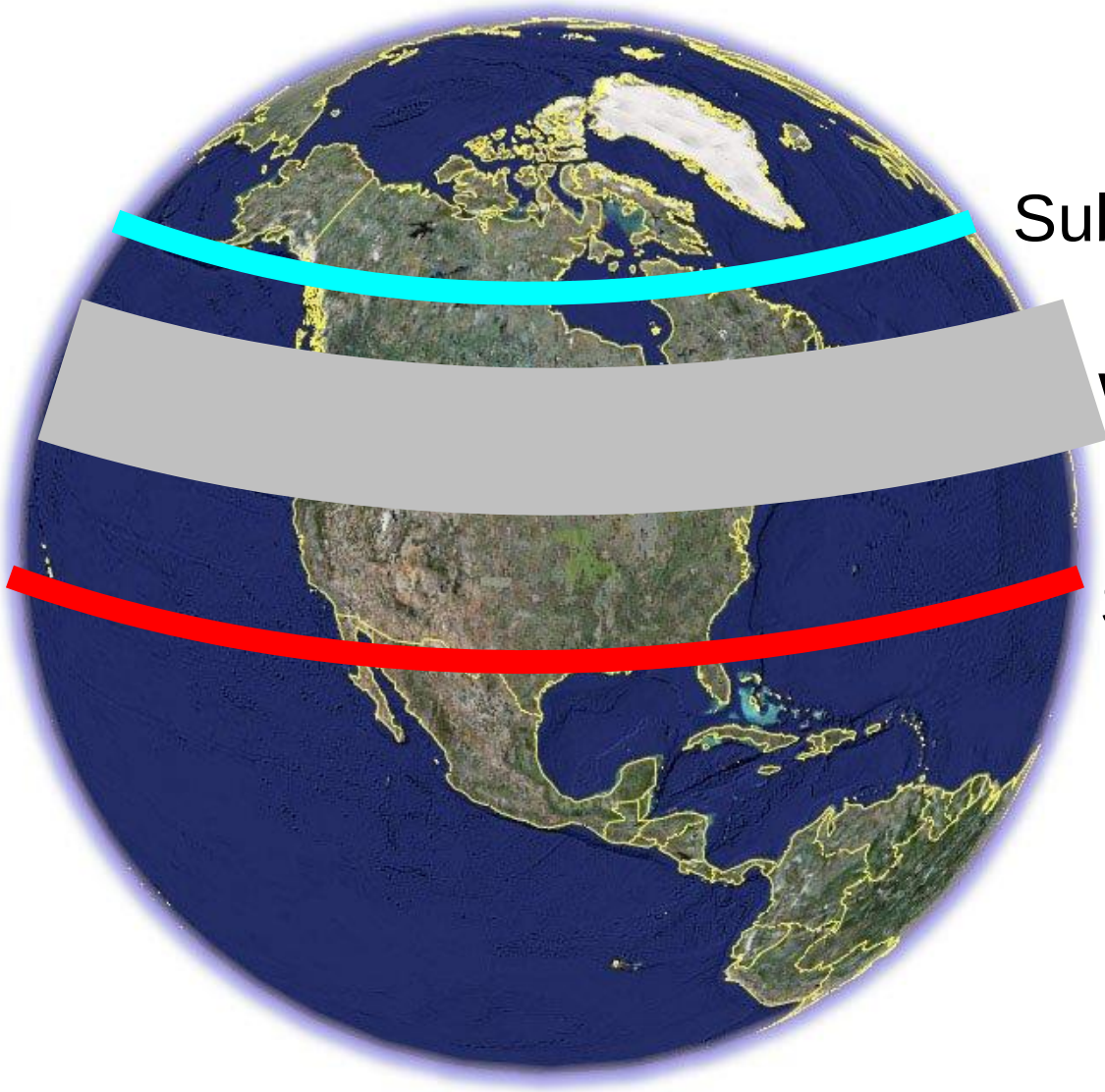


Figure 4.13. The arrangement of orographically modified macroclimates, or highland climates, is distributed as a result of mountain building rather than latitude and therefore cuts across other latitudinally based climates.

Latitude



Subpolar low 60˚N

Westerlies

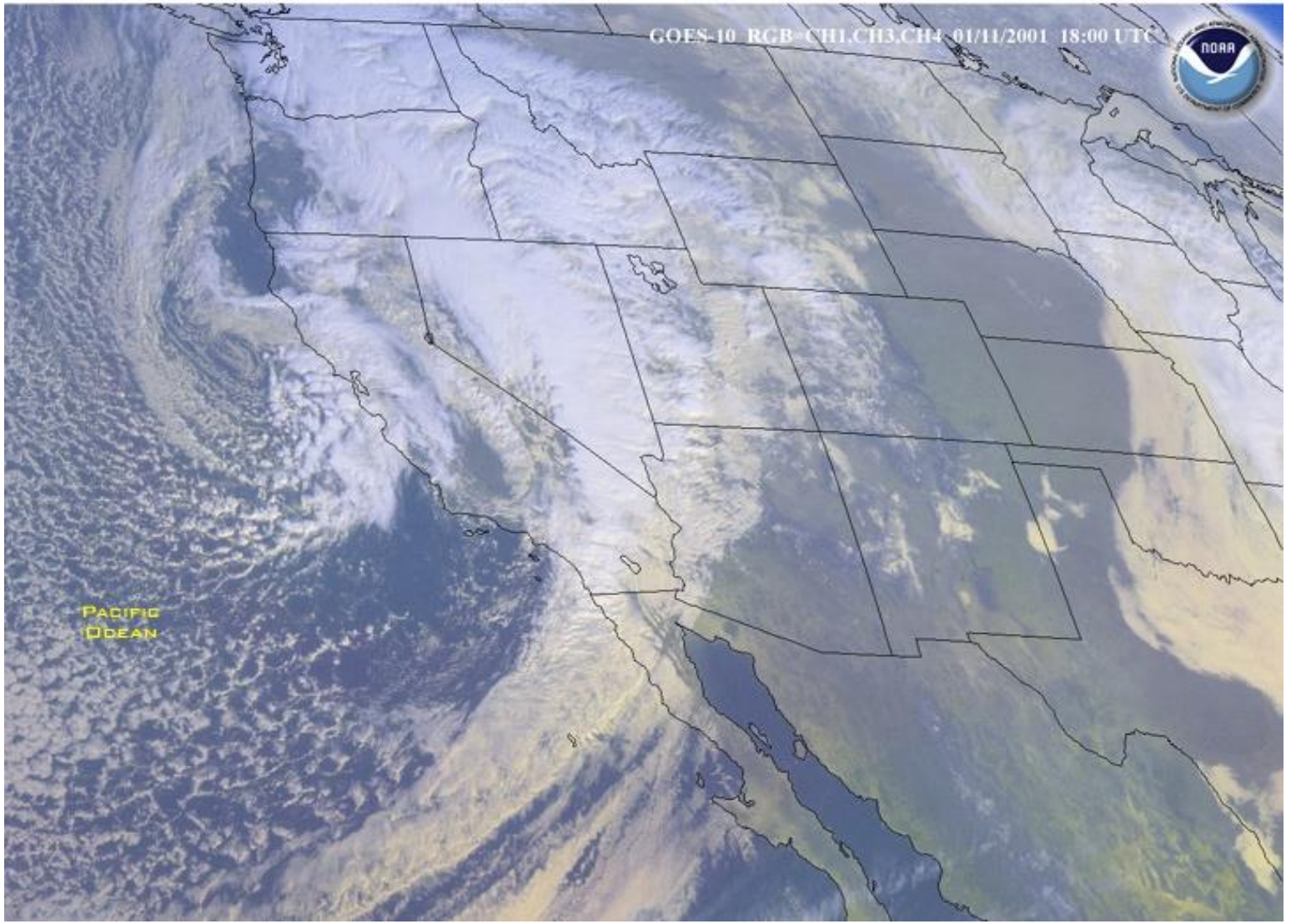
Subtropical high 30˚N

In the winter, the westerly flow dominates all of western and central North America

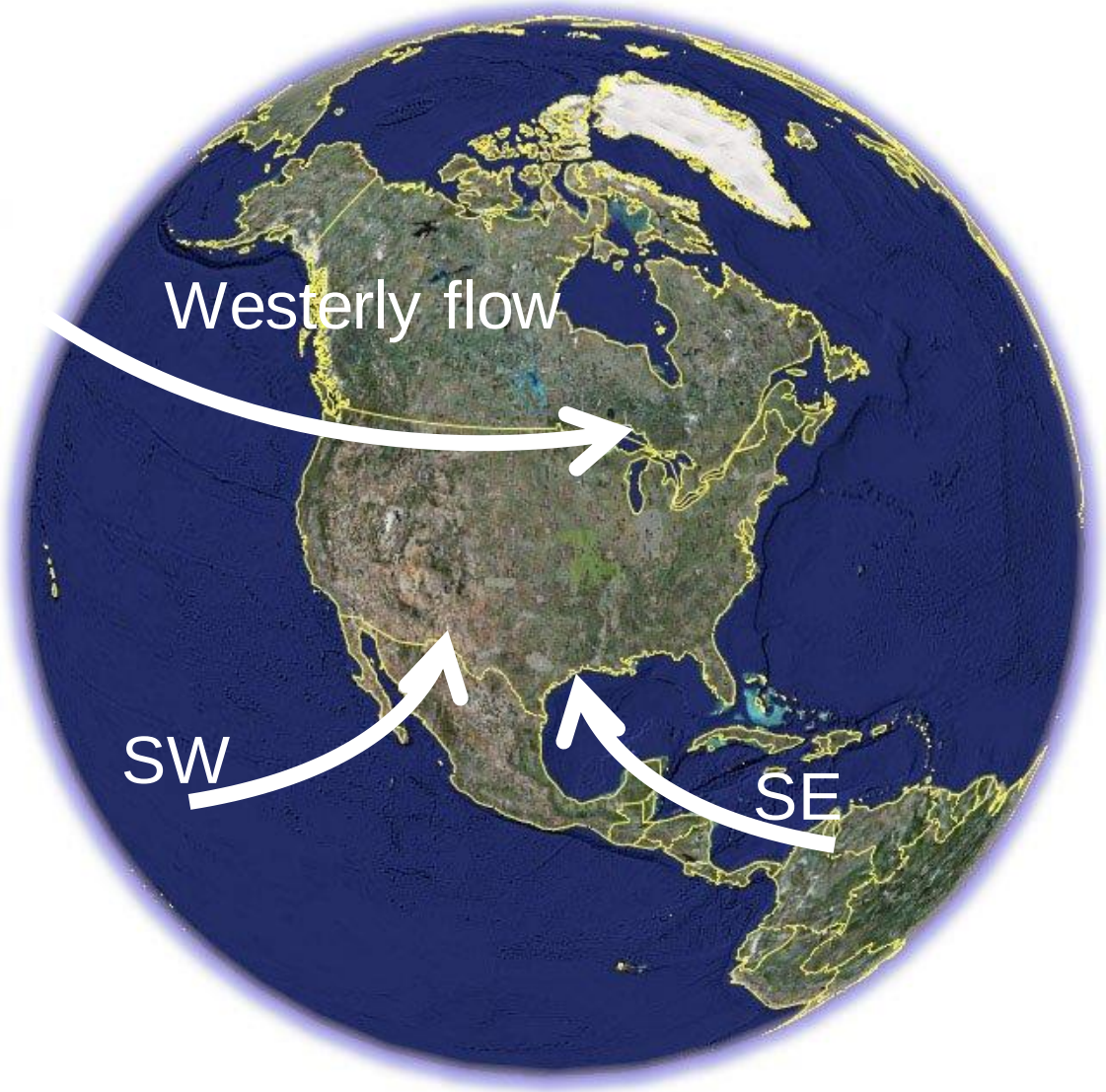
Pacific winter storm

This GOES-10 image shows a low pressure system over California that dumped more than 7 inches of rain on parts of the state on Wednesday and Thursday. The storm has reportedly caused major power outages, dangerous mudslides in the mountains, flash-flooding, and hazardous traveling conditions.

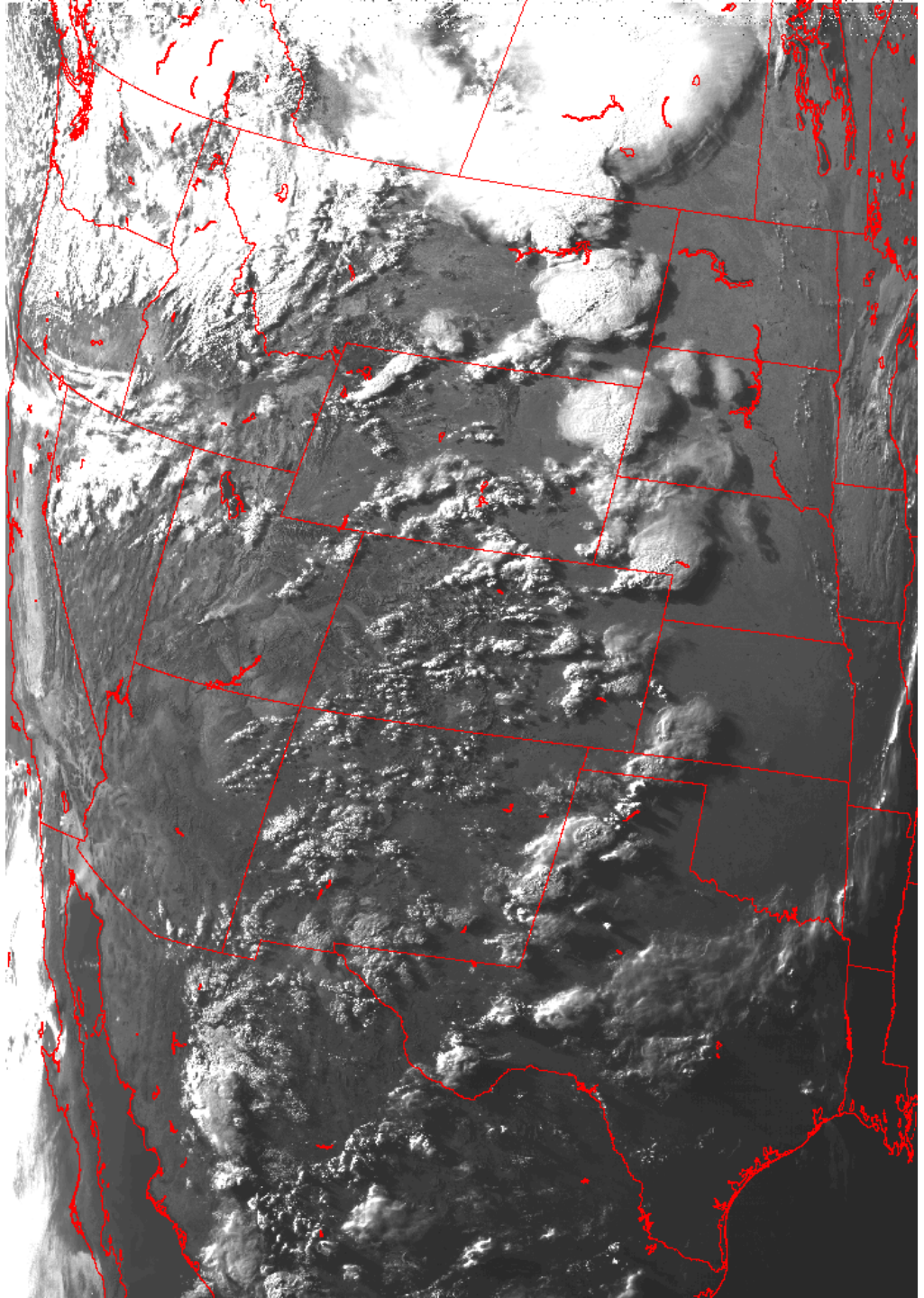
CREDIT: NOAA



In the summer, SW and SE flow become important



Summer thunderstorms in the Great Plains



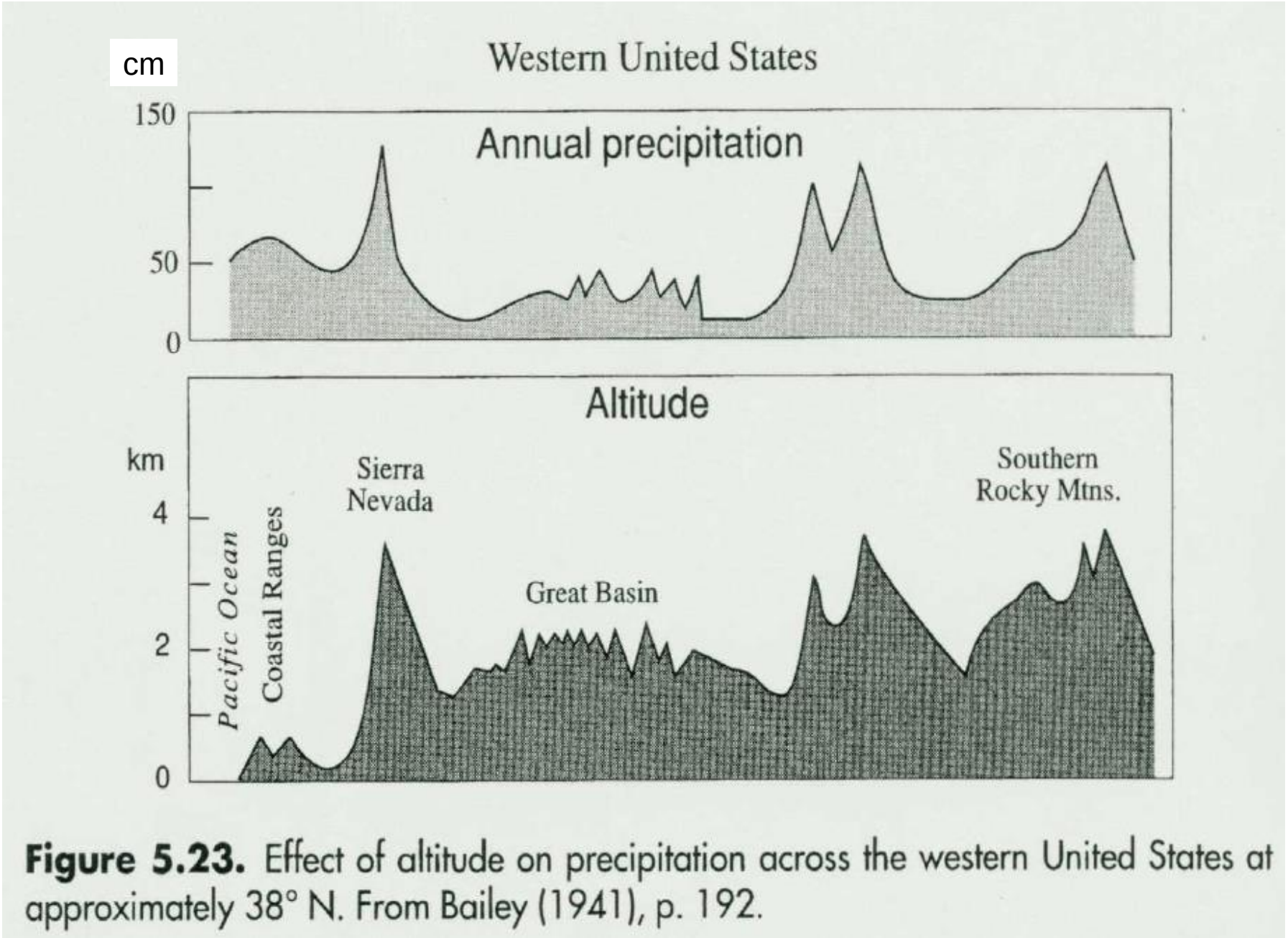
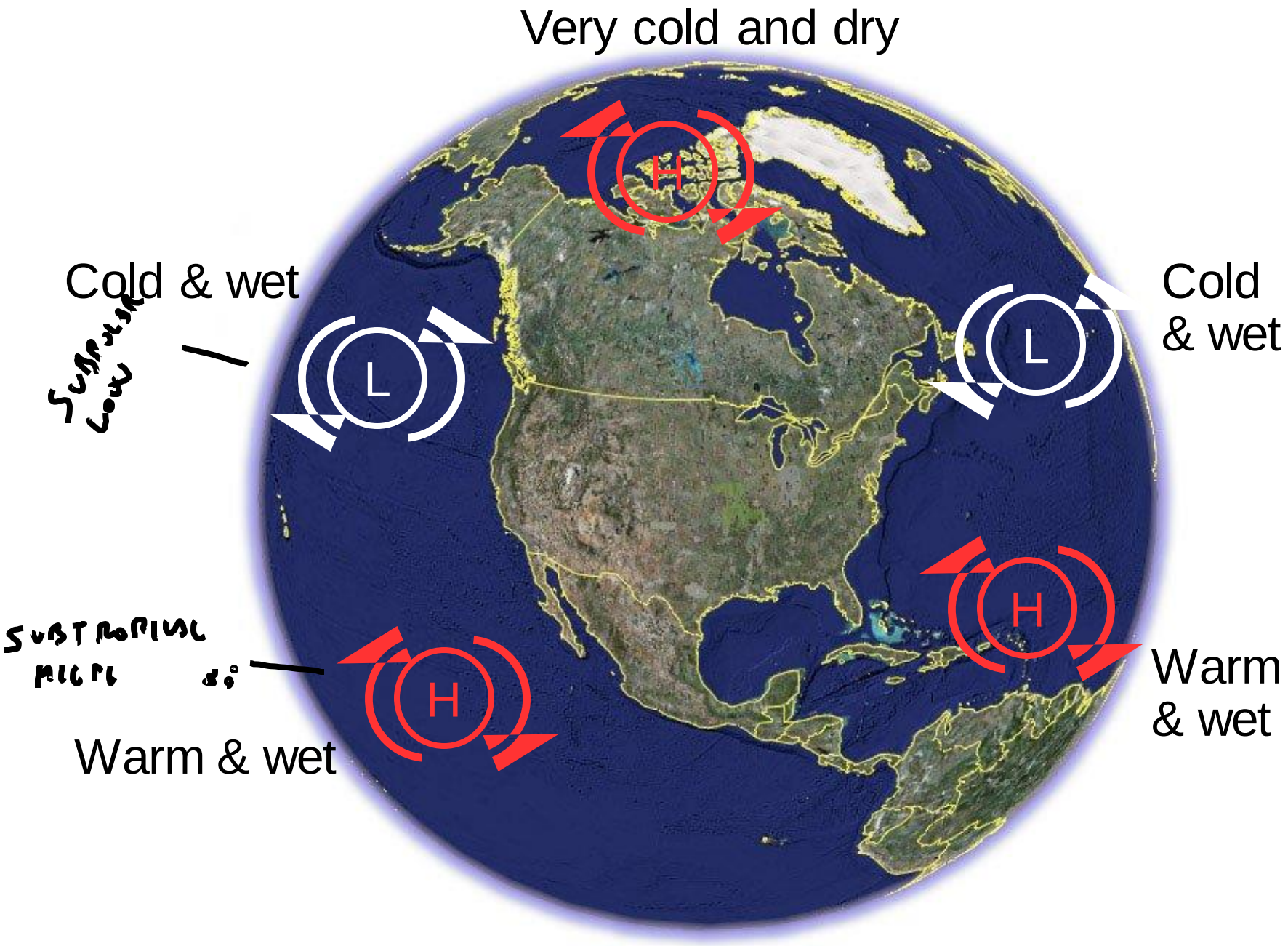
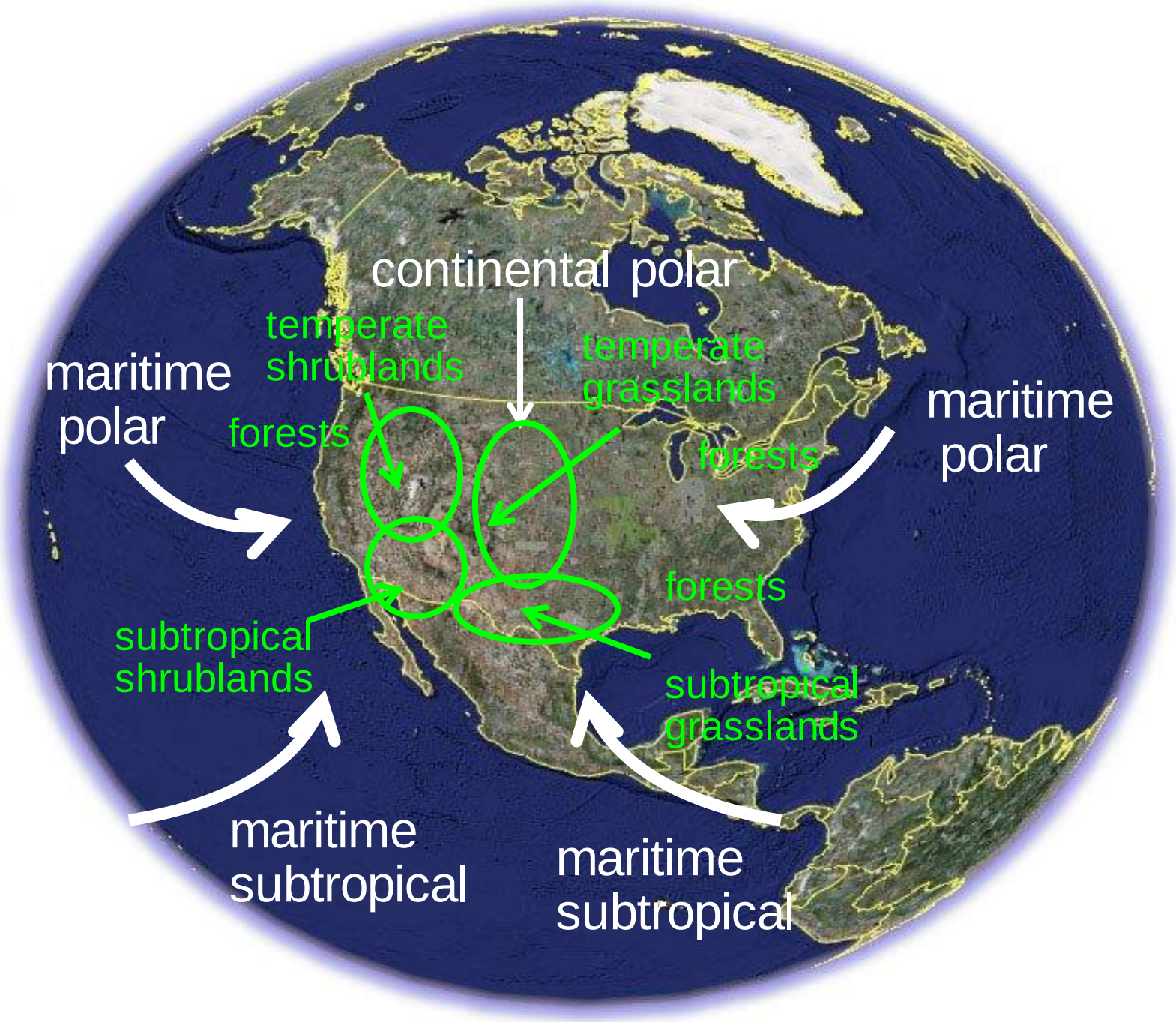
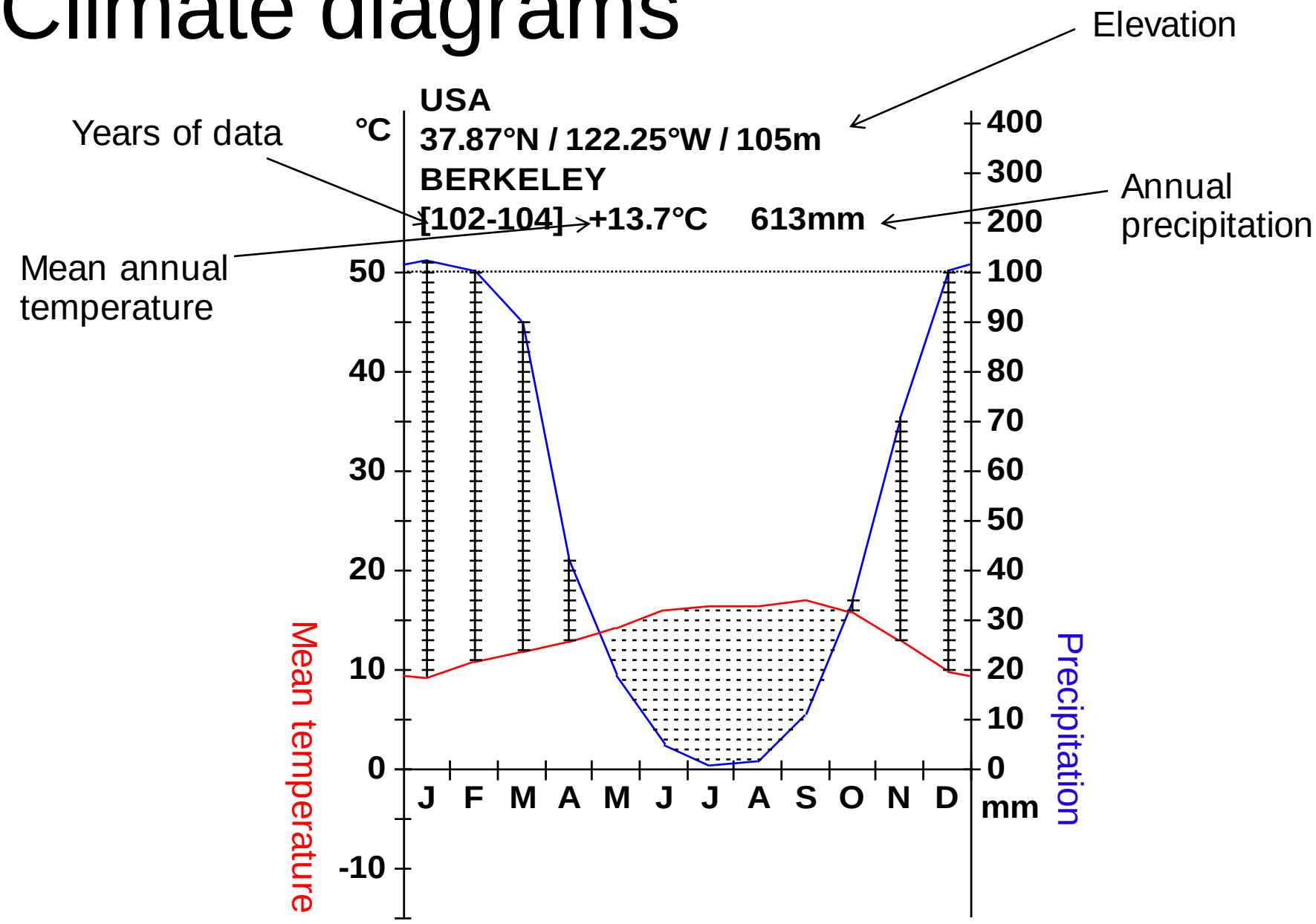


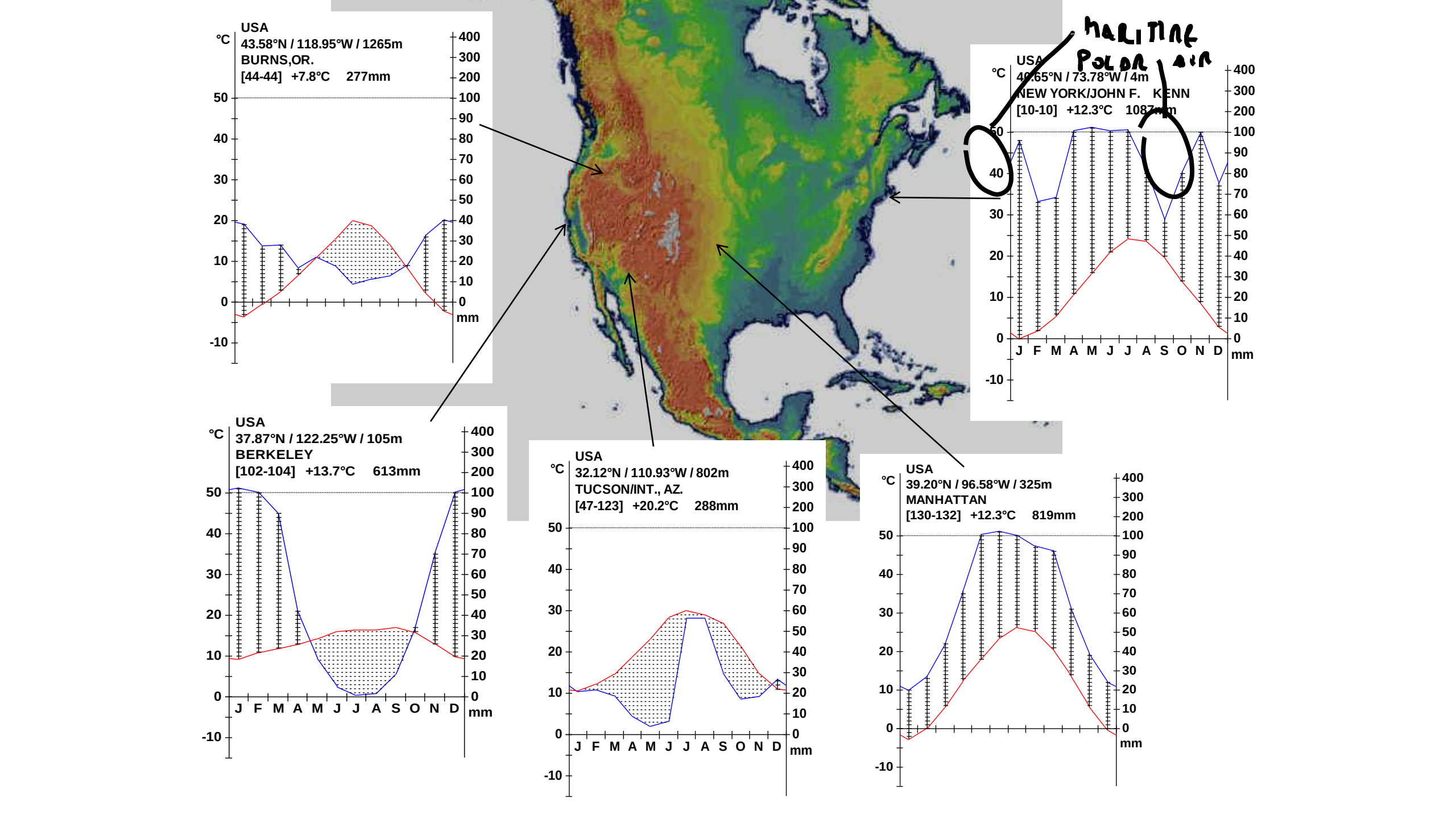
Figure 5.23. Effect of altitude on precipitation across the western United States at approximately 38° N. From Bailey (1941), p. 192.


Very cold and dry
Cold & wet
Cold
& wet
Warm
& wet
Warm & wet
H
L
L
H
H

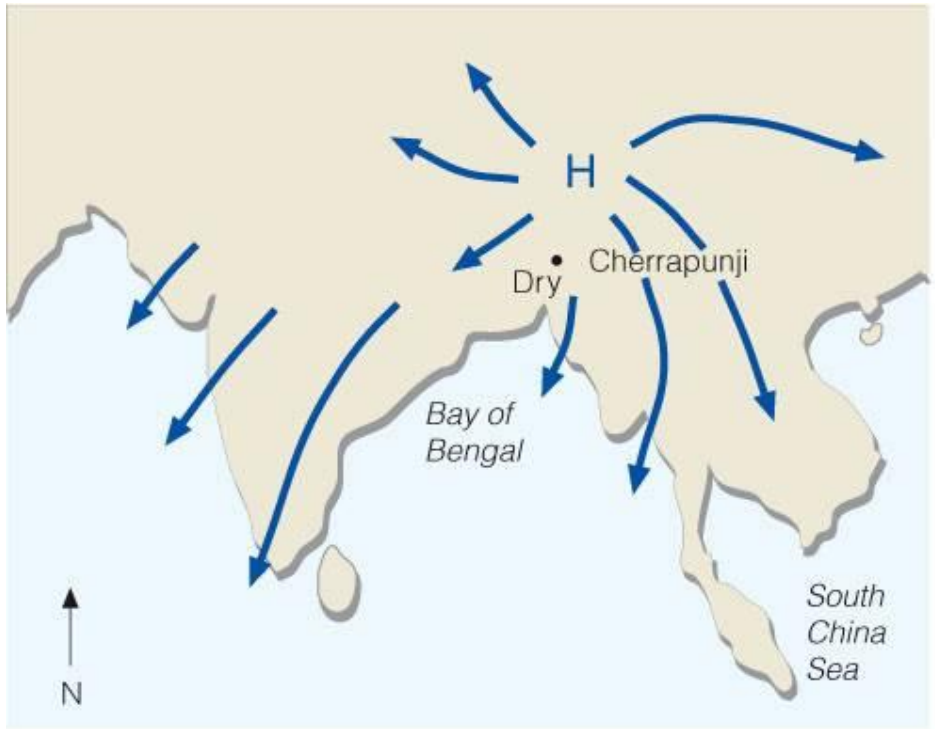

continental polar
temperate shrublands
temperate grasslands
maritime polar
forests
maritime polar
forests
forests
subtropical shrublands
subtropical grasslands
maritime subtropical
maritime subtropical

Climate diagrams

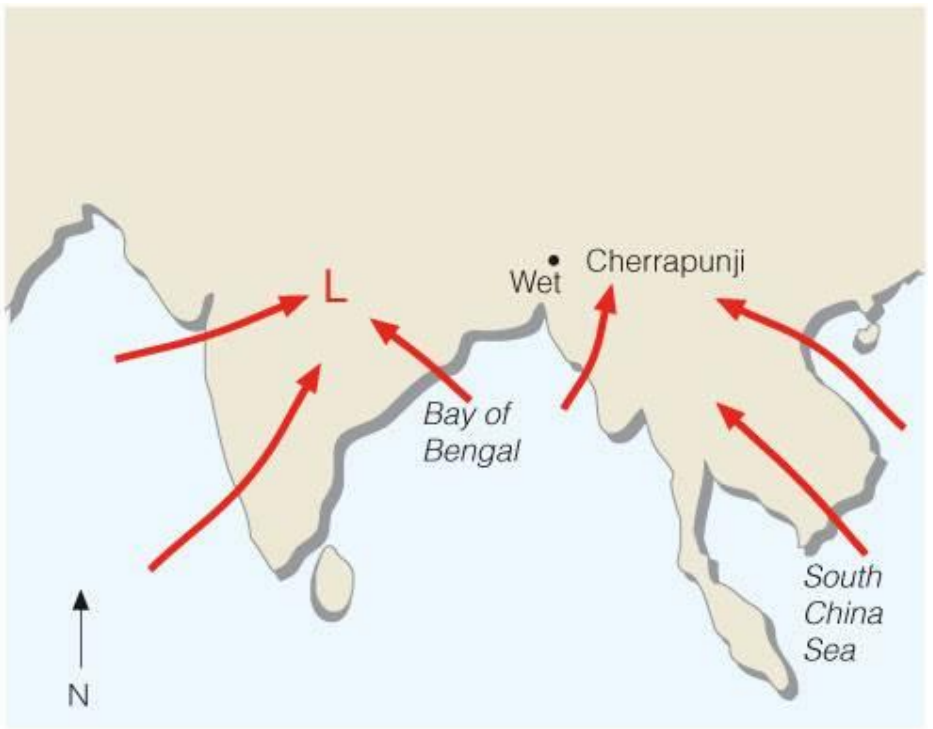



USA
43.58°N / 118.95°W / 1265m
BURNS,OR.
[44-44] +7.8°C 277mm
USA
40.65°N / 73.78°W / 4m
NEW YORK/JOHN F. KENN
[10-10] +12.3°C 1087mm
USA
37.87°N / 122.25°W / 105m
BERKELEY
[102-104] +13.7°C 613mm
USA
32.12°N / 110.93°W / 802m
TUCSON/INT., AZ.
[47-123] +20.2°C 288mm
USA
39.20°N / 96.58°W / 325m
MANHATTAN
[130-132] +12.3°C 819mm
°C
mm
J F M A M J J A S O N D

Periodic winds: monsoons

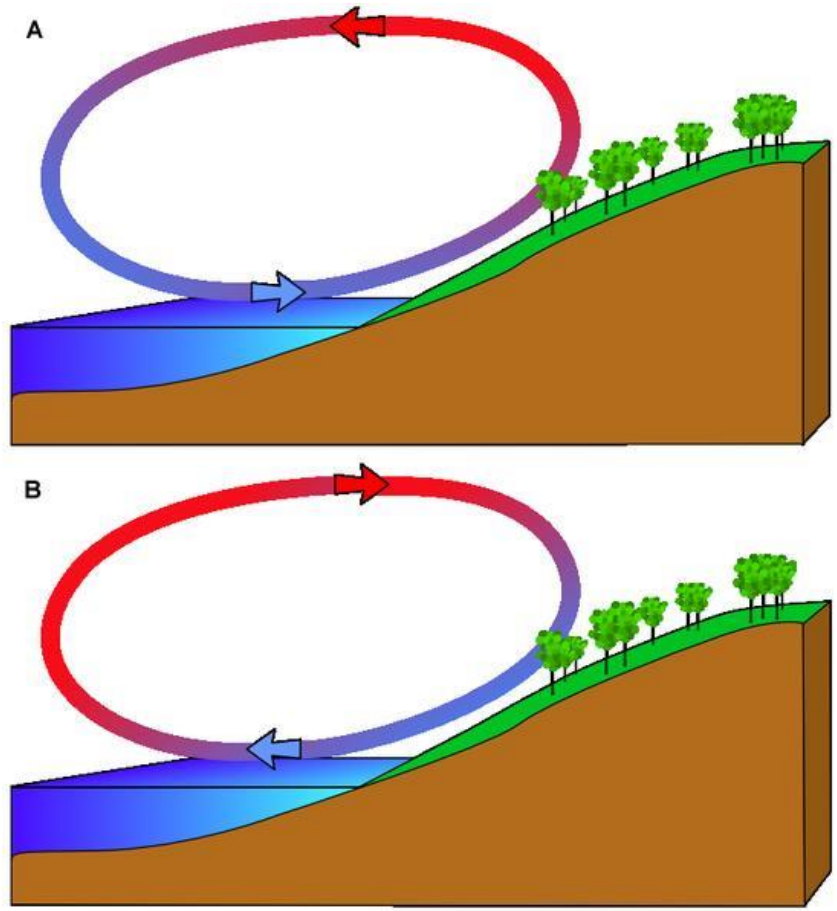


(a) Winter Monsoon

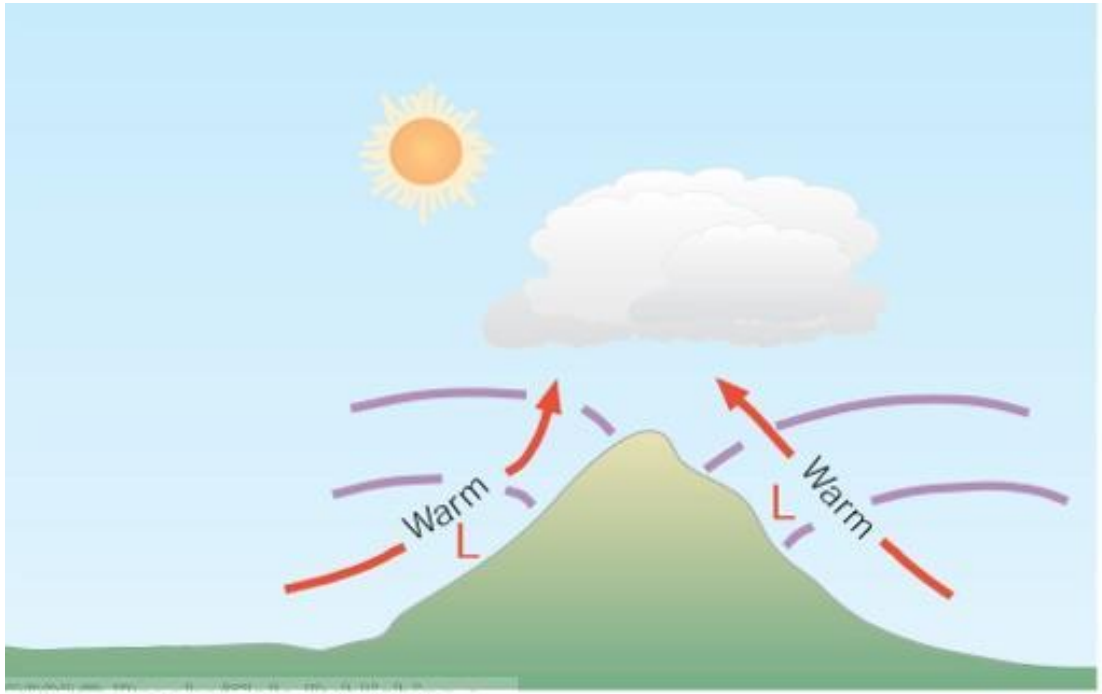


(b) Summer Monsoon

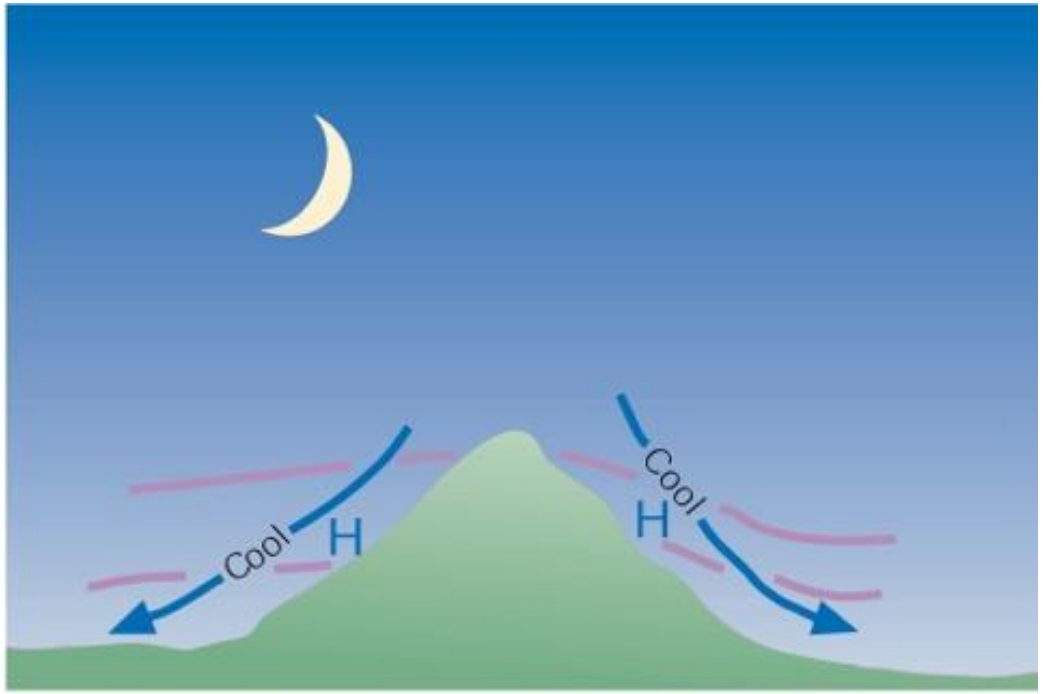
Sea breeze



Mountain breeze



Valley Breeze

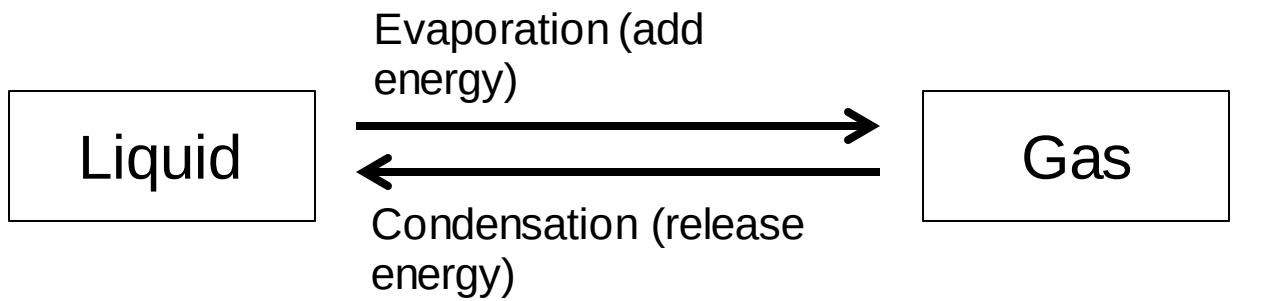


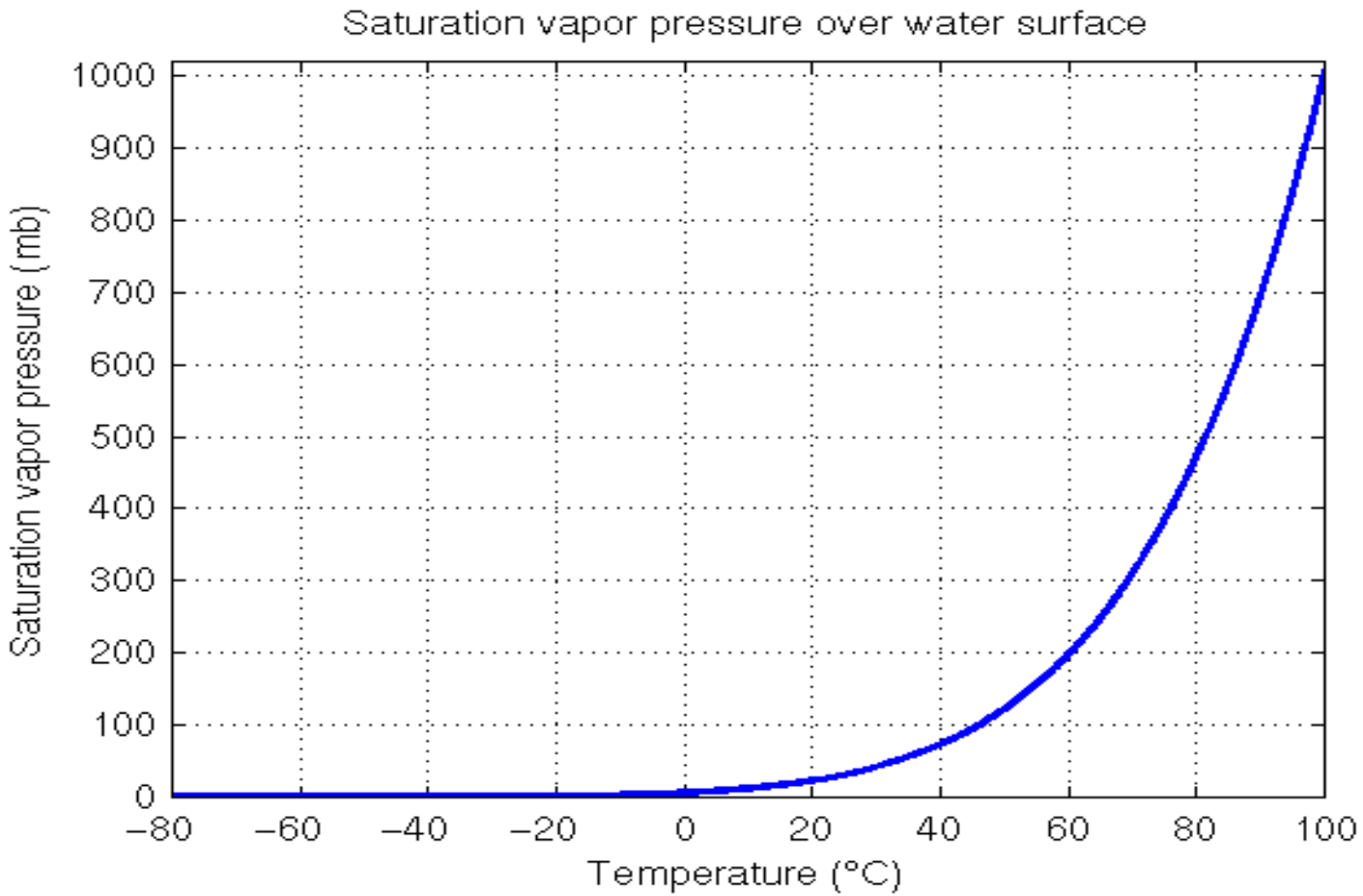
Mountain Breeze

Humidity

1. Absolute humidity
2. Relative humidity
3. Hygrometer
4. Dew point

Absolute versus relative humidity





Condensation and inverse sublimation

Condensation

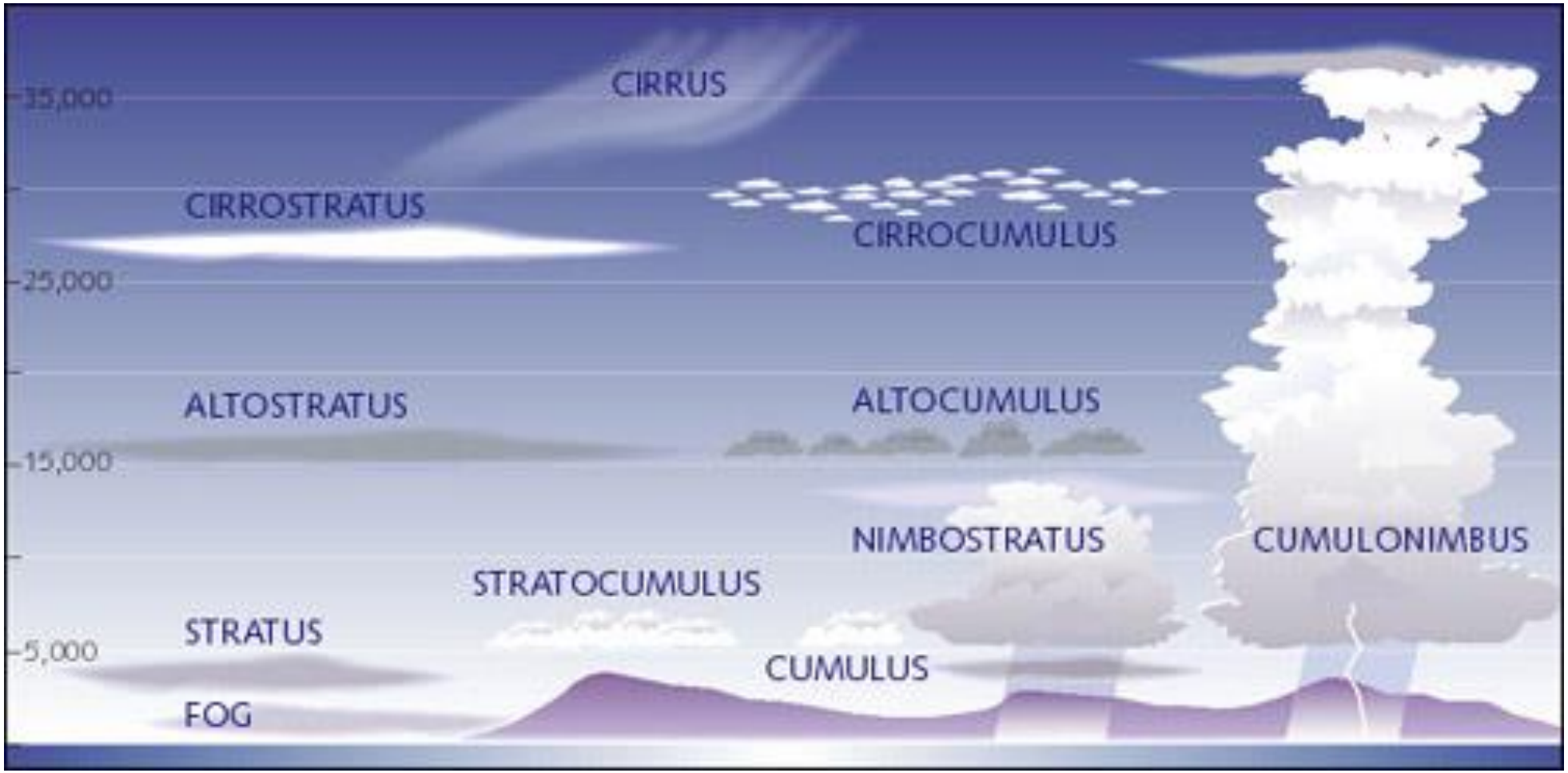
Dew

Fog and clouds

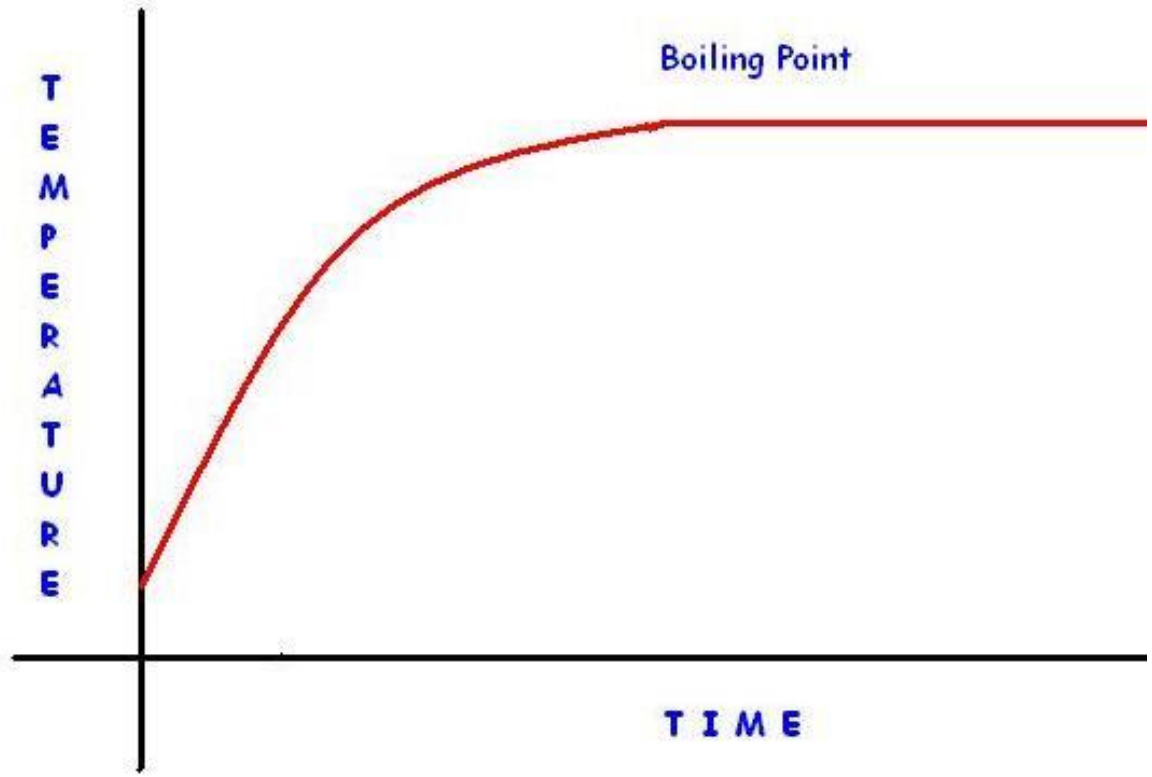
Inverse sublimation

Hoar

Cloud types

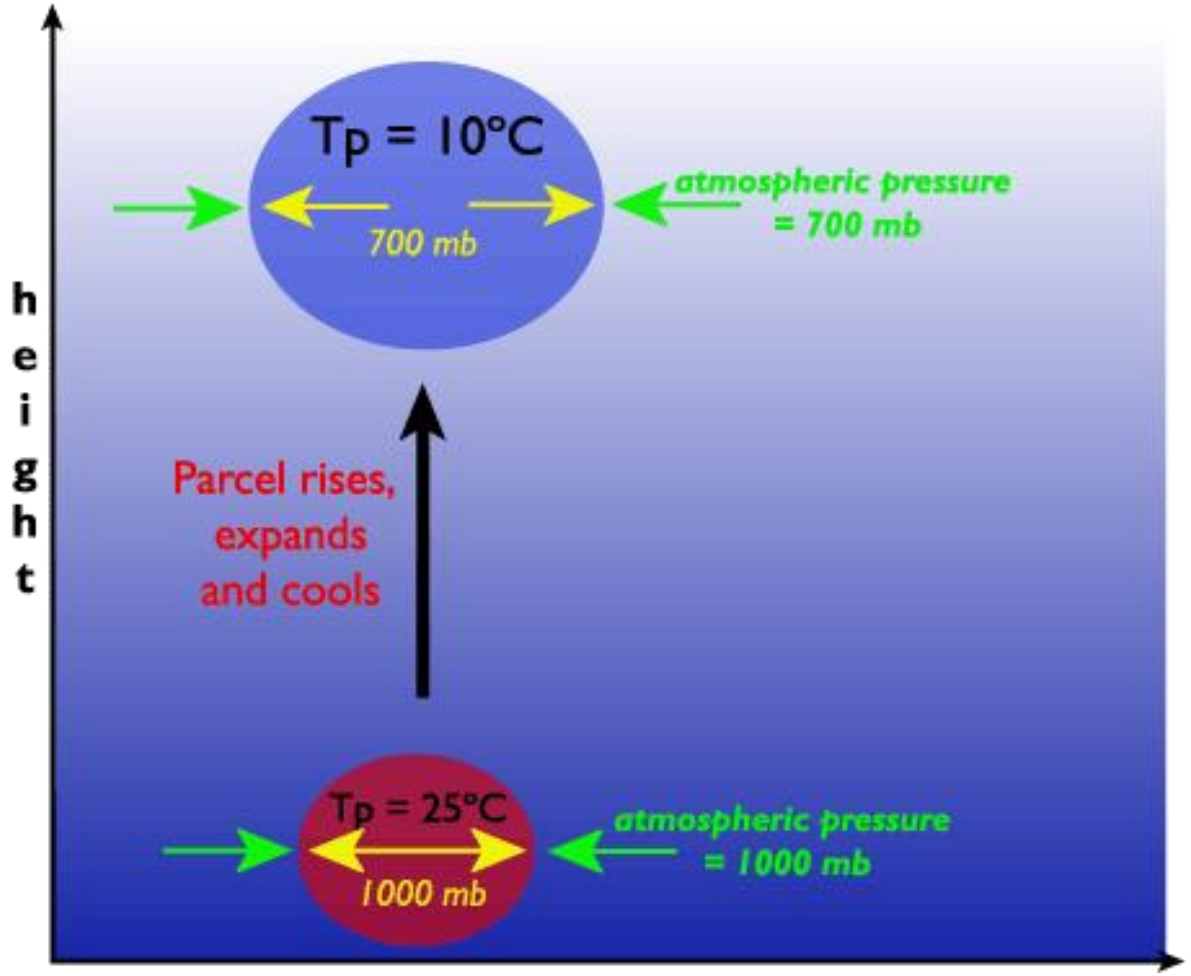

35,000
25,000
15,000
5,000
CIRRUS
CIRROSTRATUS
CIRROCUMULUS
ALTOSTRATUS
ALTOCUMULUS
NIMBOSTRATUS
CUMULONIMBUS
STRATOCUMULUS
STRATUS
CUMULUS
FOG

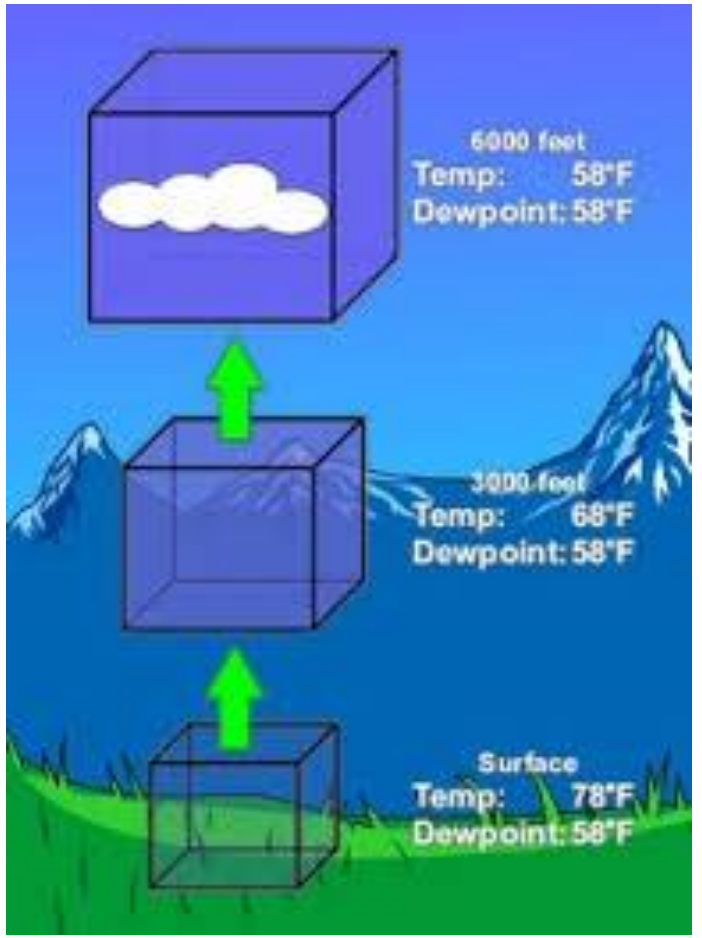
Latent heat



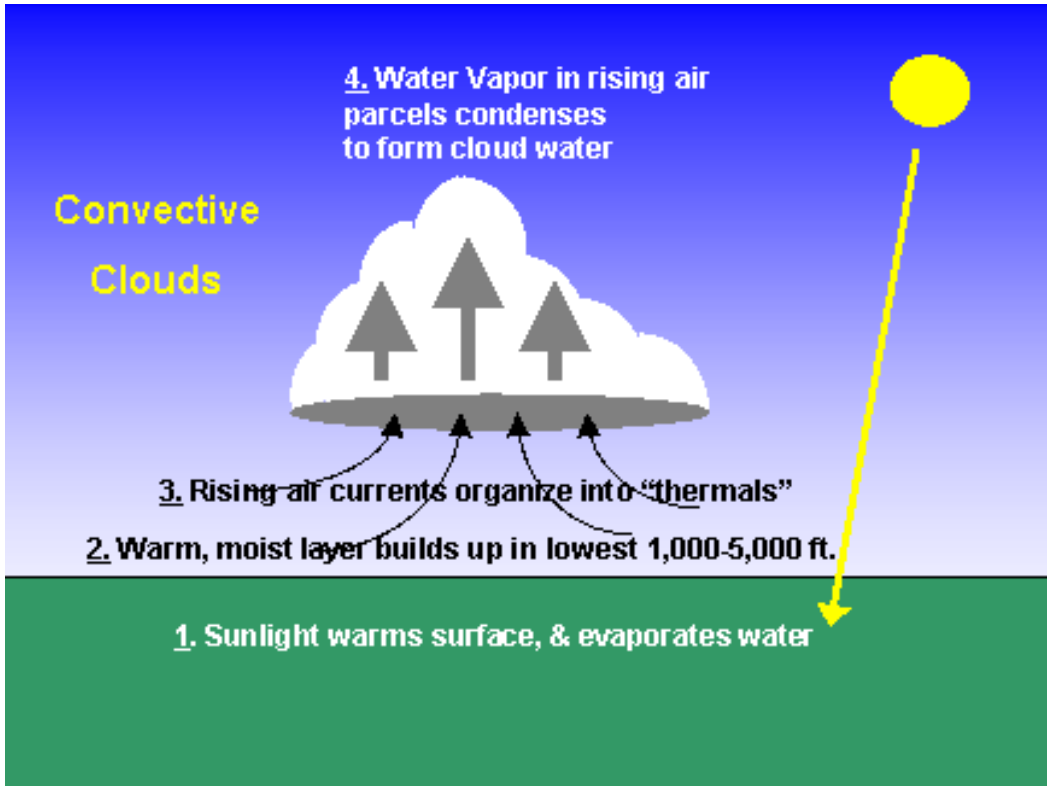
Cloud formation: adiabatic cooling

Adiabatic cooling is cooling *without heat transfer*

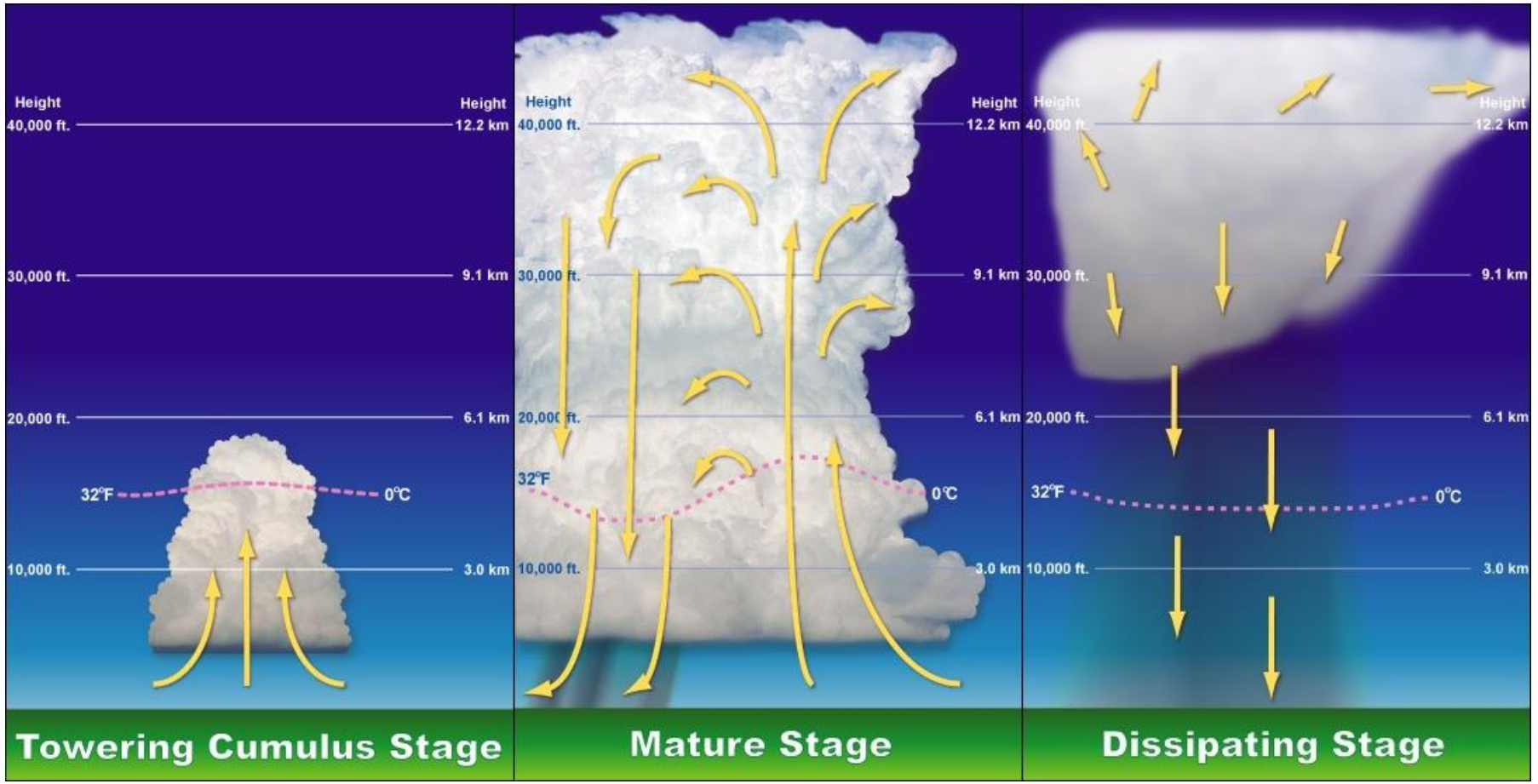




Convective cooling

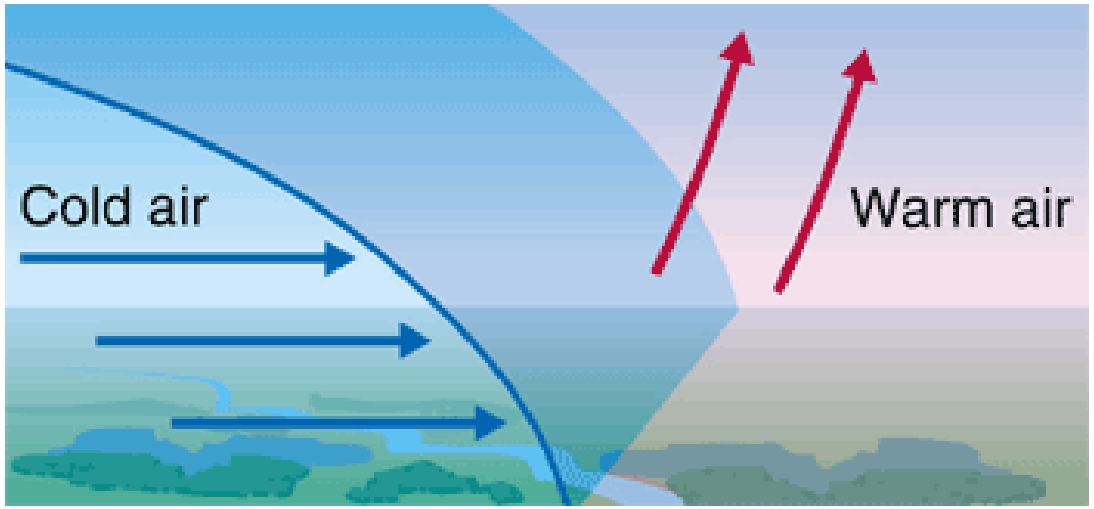


Convective cooling

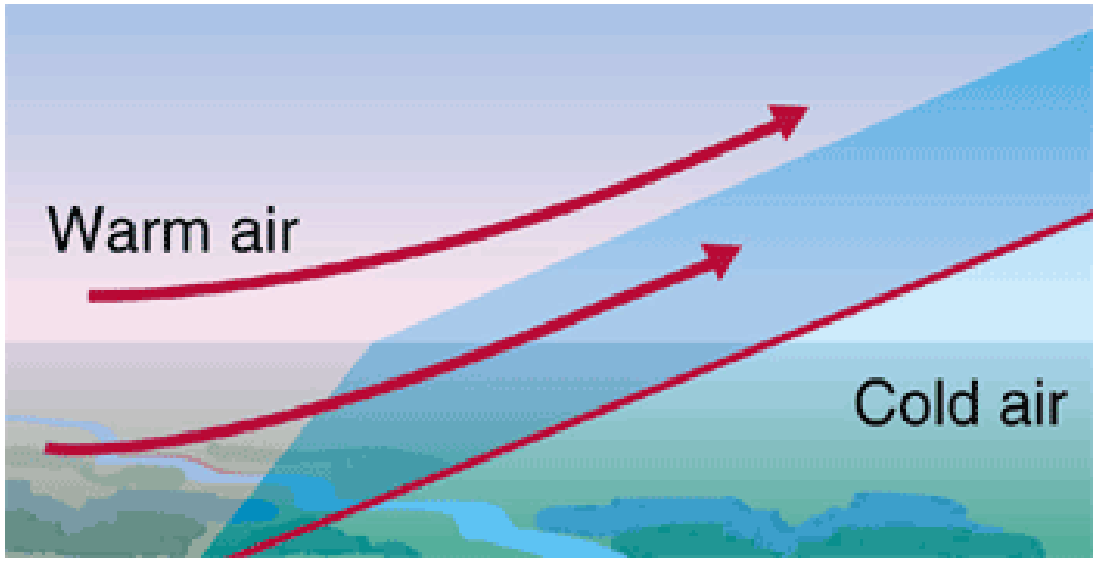


Synoptic cooling

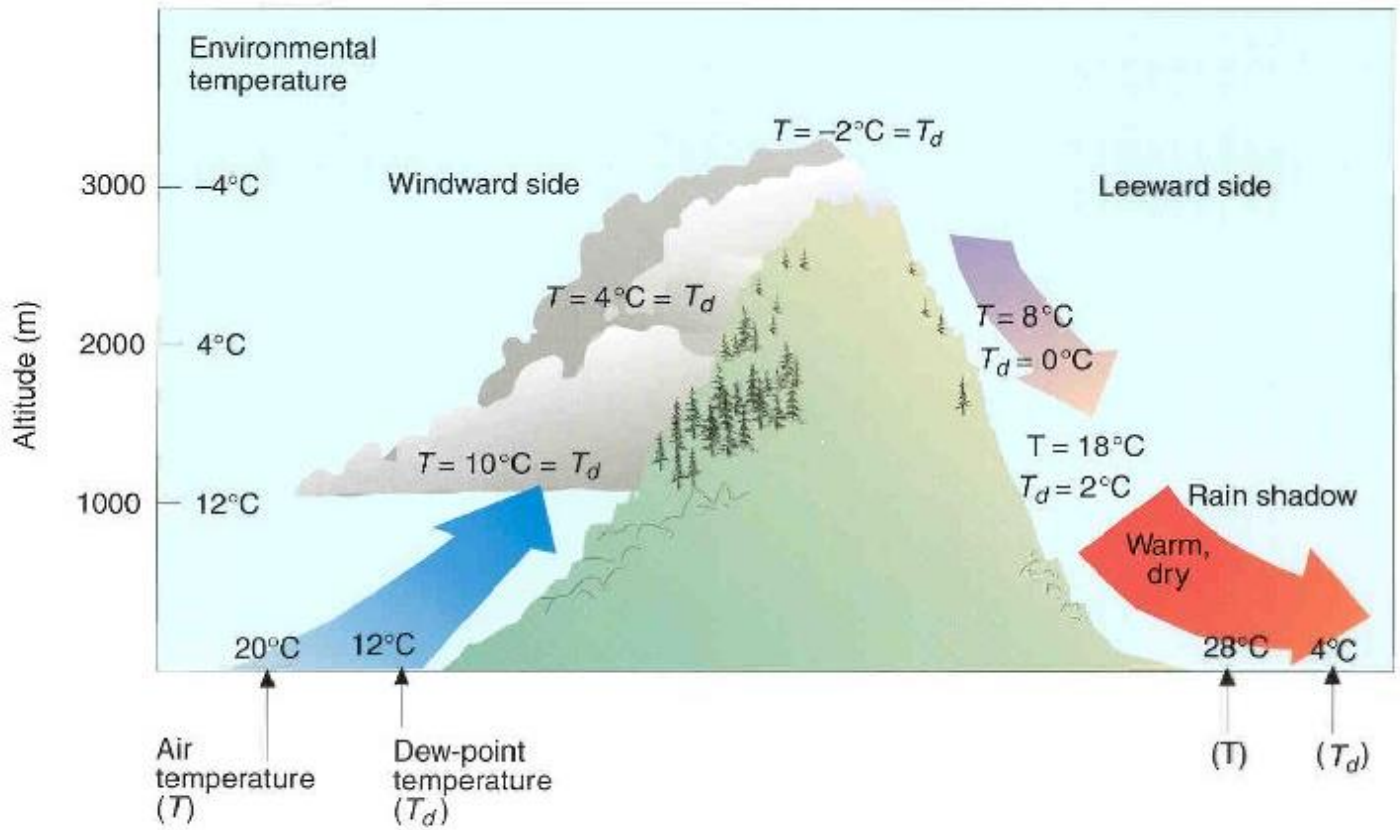
Cold front



Warm front

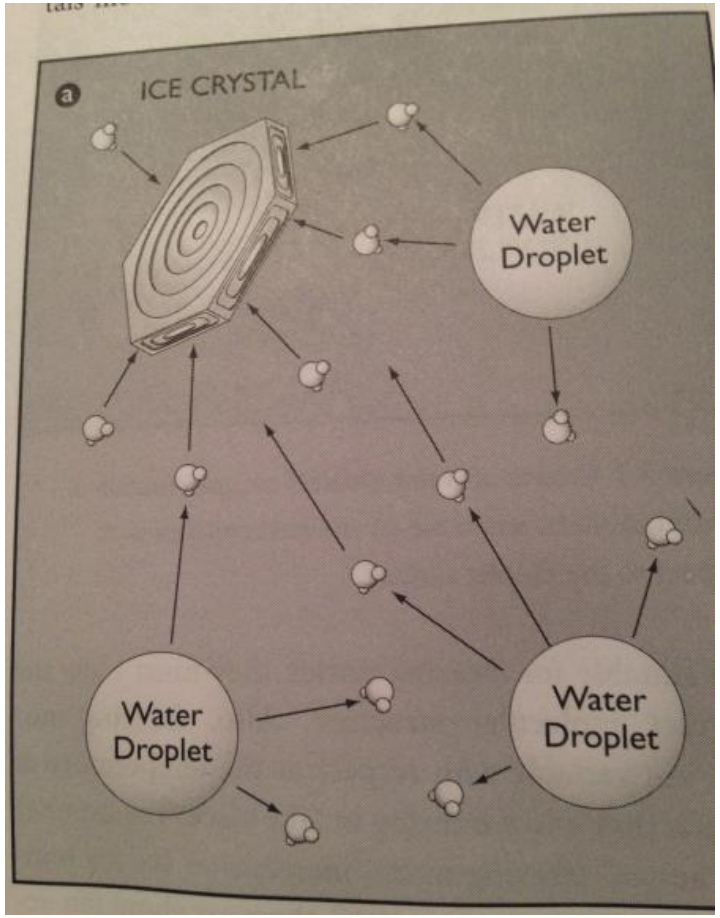


Orographic cooling

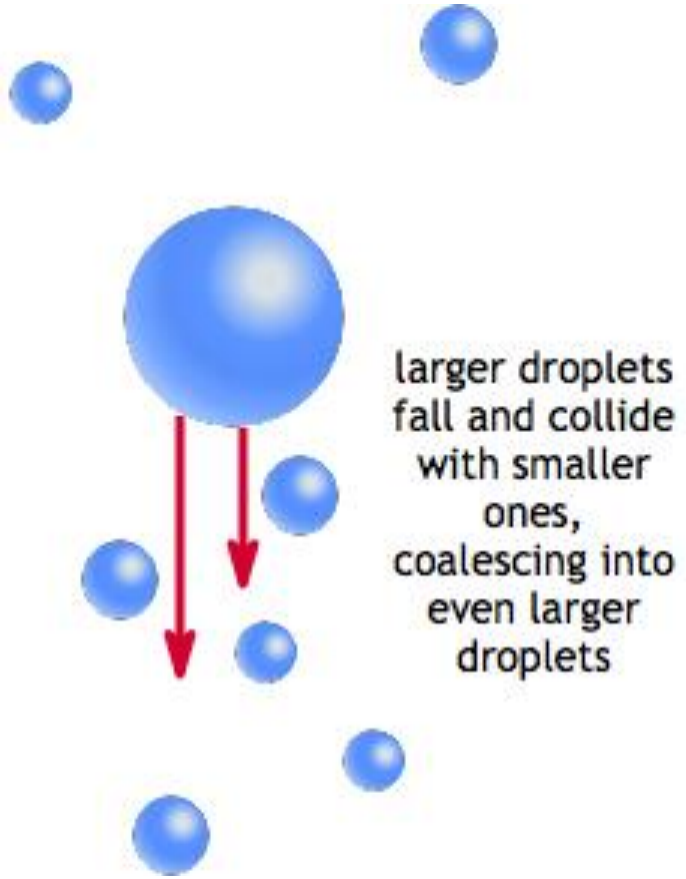


How does rain form?

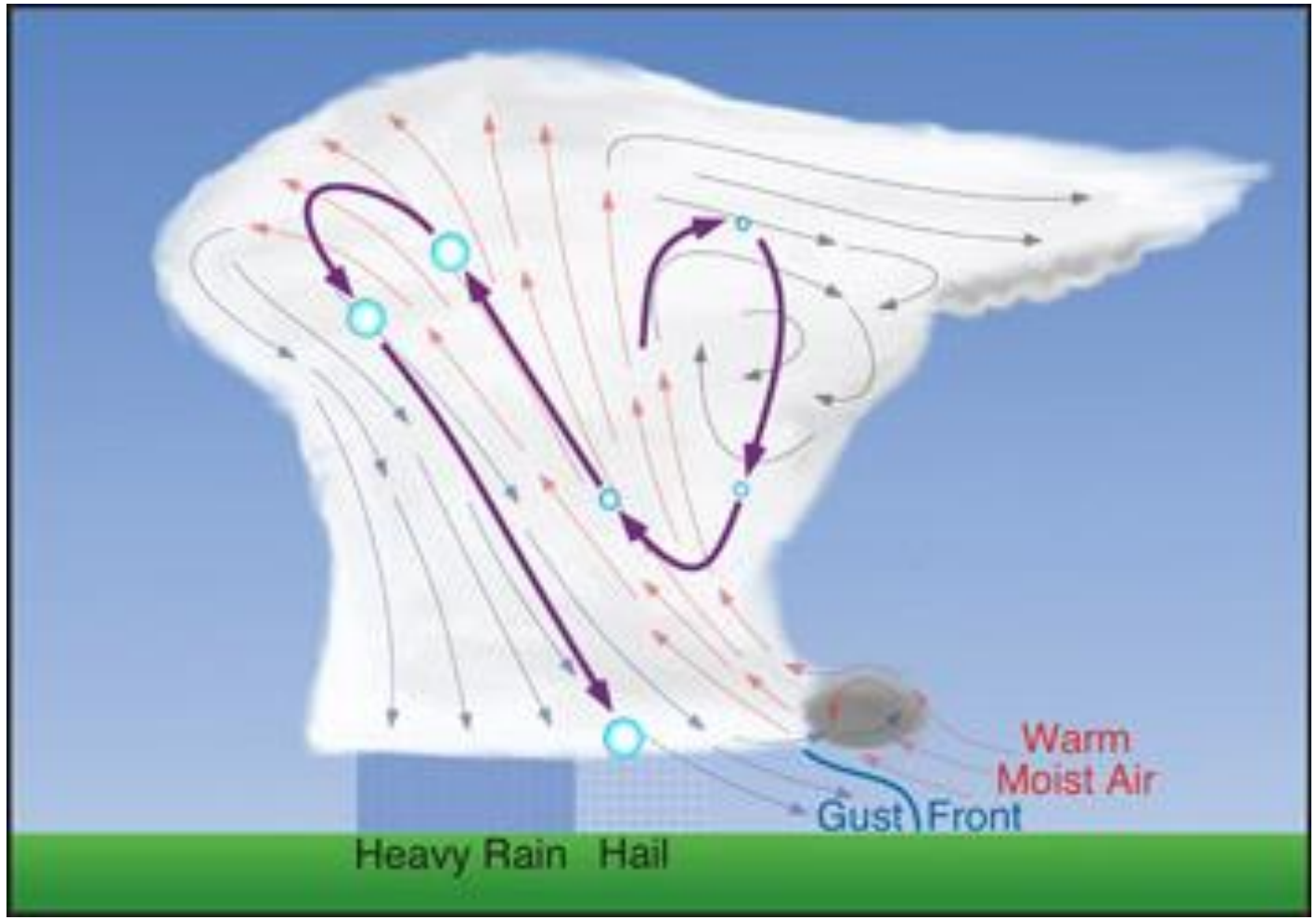
Inverse sublimation



Coalescence

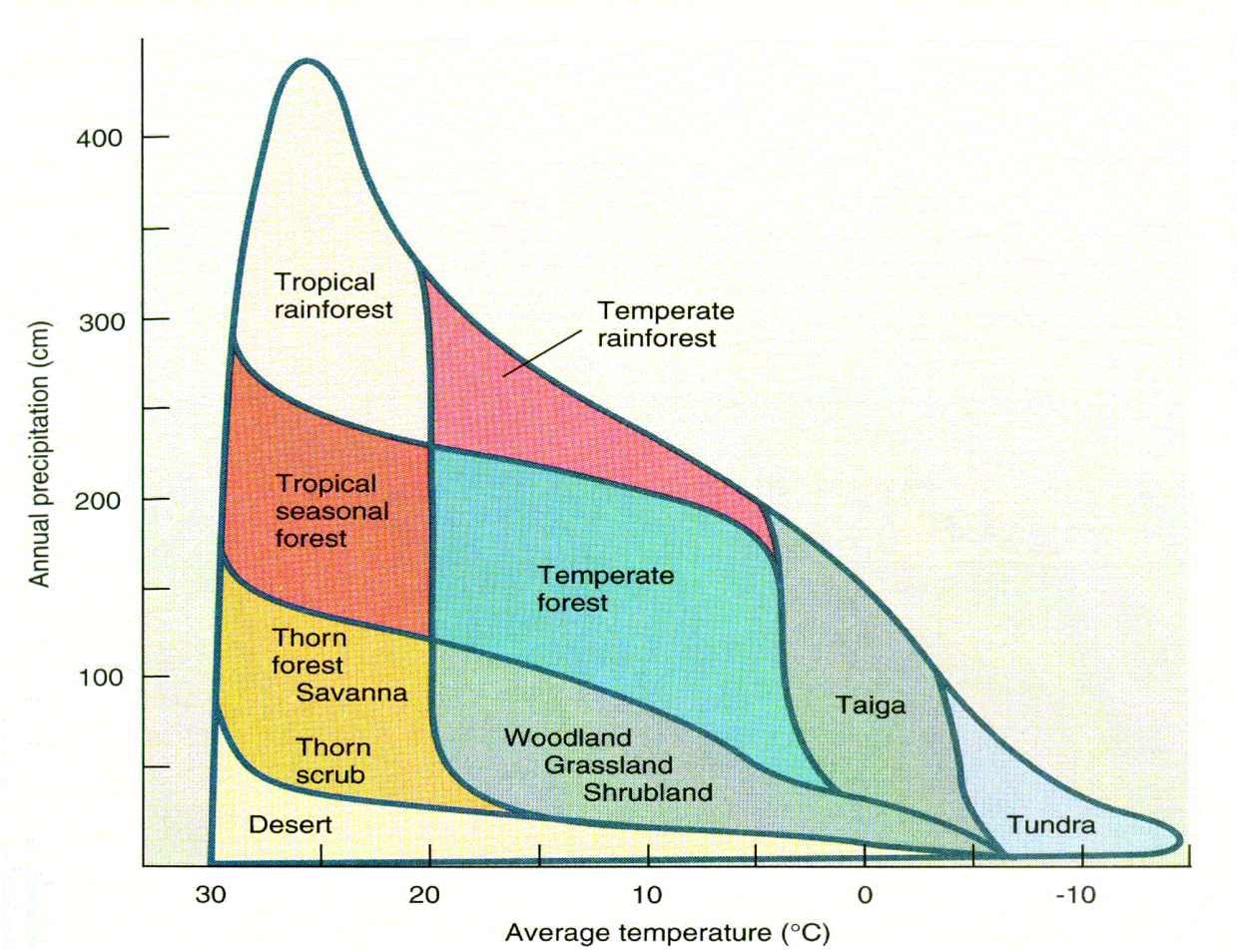


Hail formation

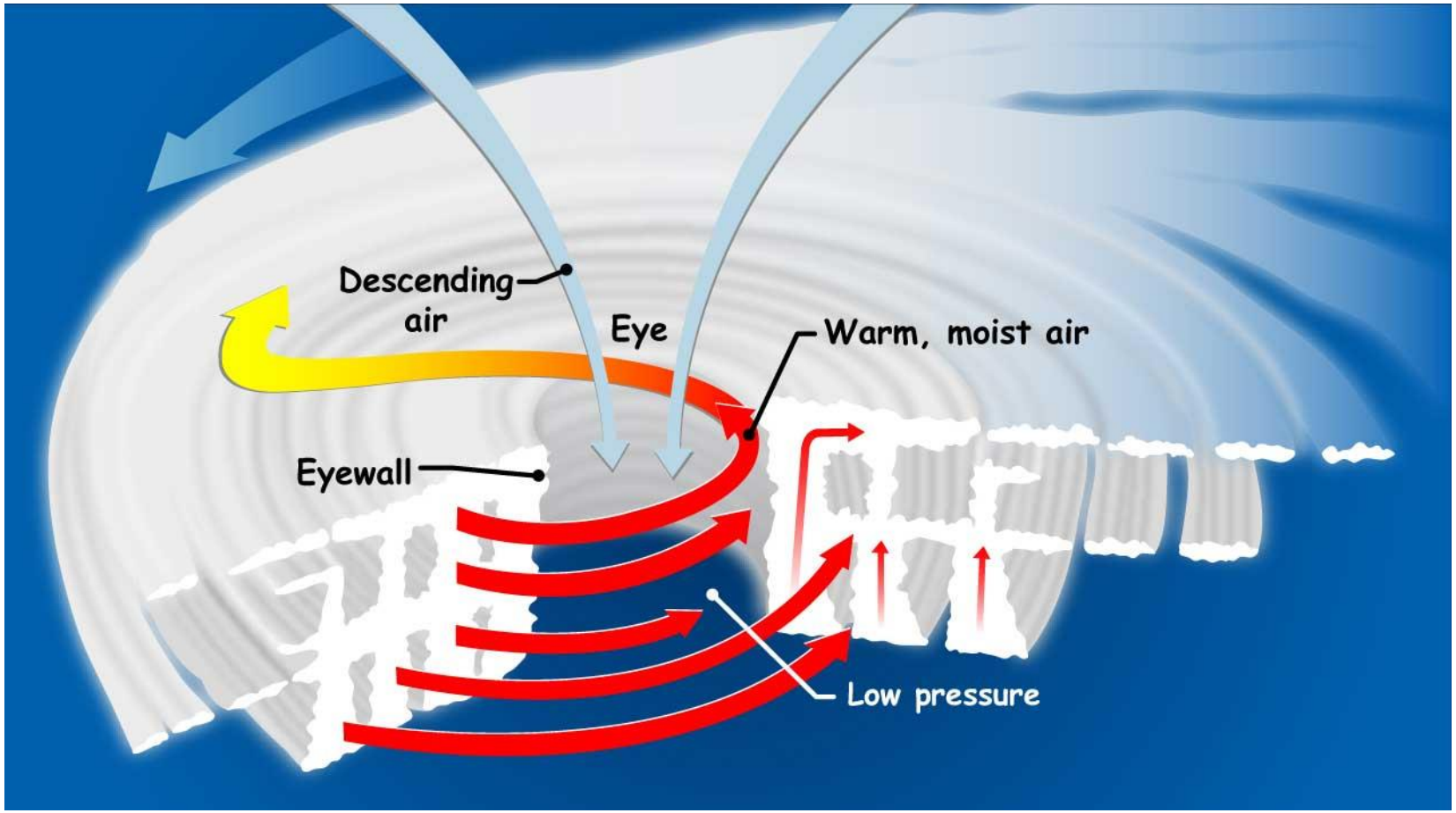


Precipitation regimes

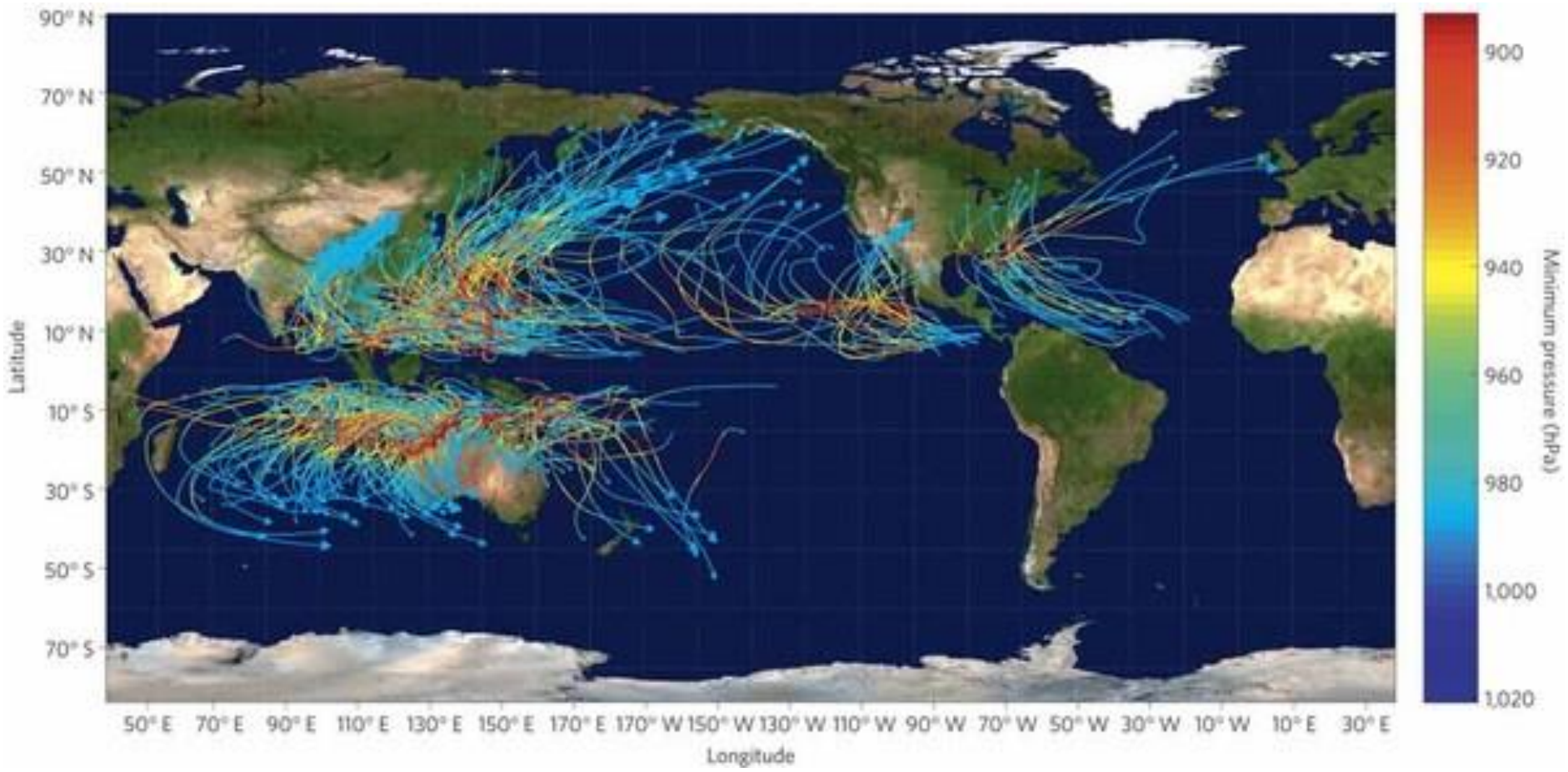
1. Equatorial: high precipitation, uniformly throughout year
2. Tropical: maximum precipitation at summer solstice
3. Temperate: precipitation is not uniform in time and space
4. Polar: low precipitation



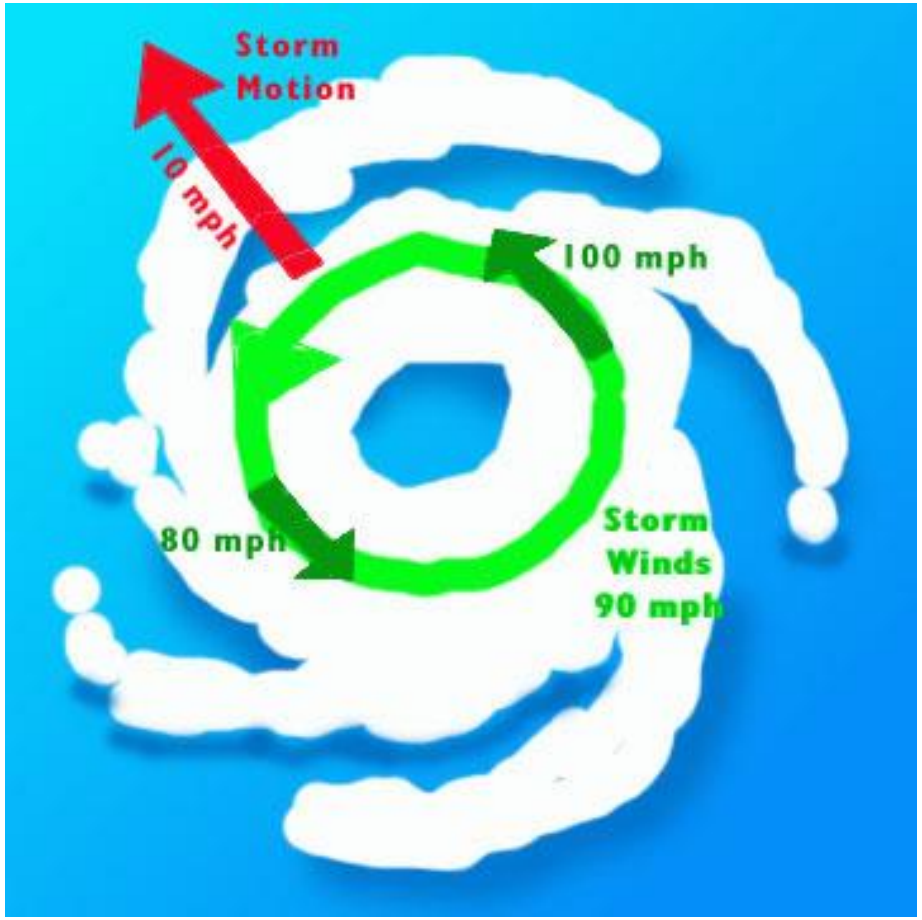
Weather in the tropics: cyclones



Cyclones move from East to West



The “sides” of a cyclone



Mediterranean tropical cyclones