MET 4300/5355

Lecture 2

Properties of the Atmosphere (textbook CH1)

Atmospheric Properties

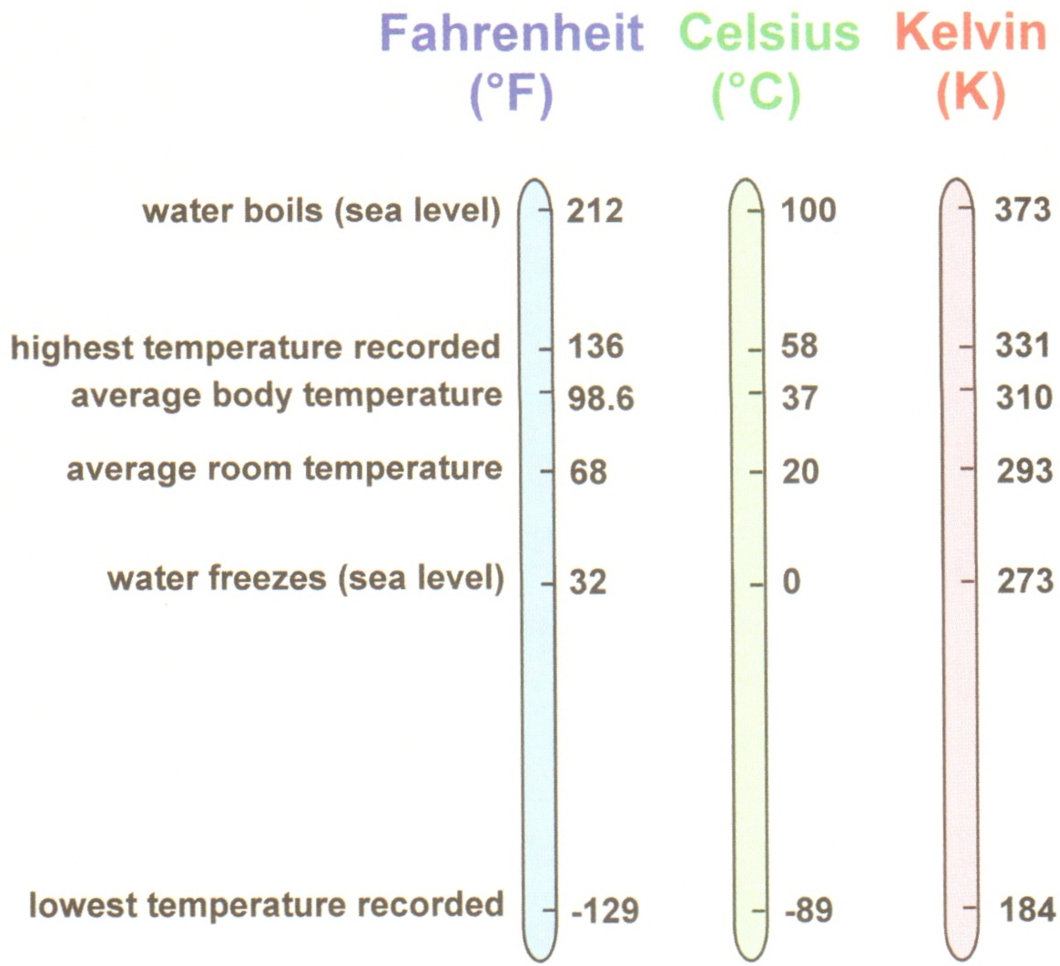
- Temperature (^oC or ^oF)
- Pressure (mb or hPa)
- Moisture
  - Variables (% or hPa or dimensionless)
  - Clouds (Type and dimensions)
  - Hydrometeors (Rain, drizzle, hail, graupel…)
- Wind ($m\ s^{-1}$)
  - Related to pressure in different ways for different scales

Temperature

- Temperature is a measure of the average speed of molecules move in a substance.
- Solid, Liquid, Gas
- Units: Celsius (^oC), Fahrenheit (^oF), Kelvin (K)
- Absolute zero: no more energy can be extracted (-273.15 ^oC)
- In the US, Fahrenheit is used for surface temperatures, Celsius for upper atmospheric temperatures, and Kelvin for scientific applications.

Temperature Scales

°C	°F
-40	-40
-35	-31
-30	-22
-25	-13
-20	-4
-15	5
-10	14
-5	23
0	32
5	41
10	50
15	59
20	68
25	77
30	86
35	95



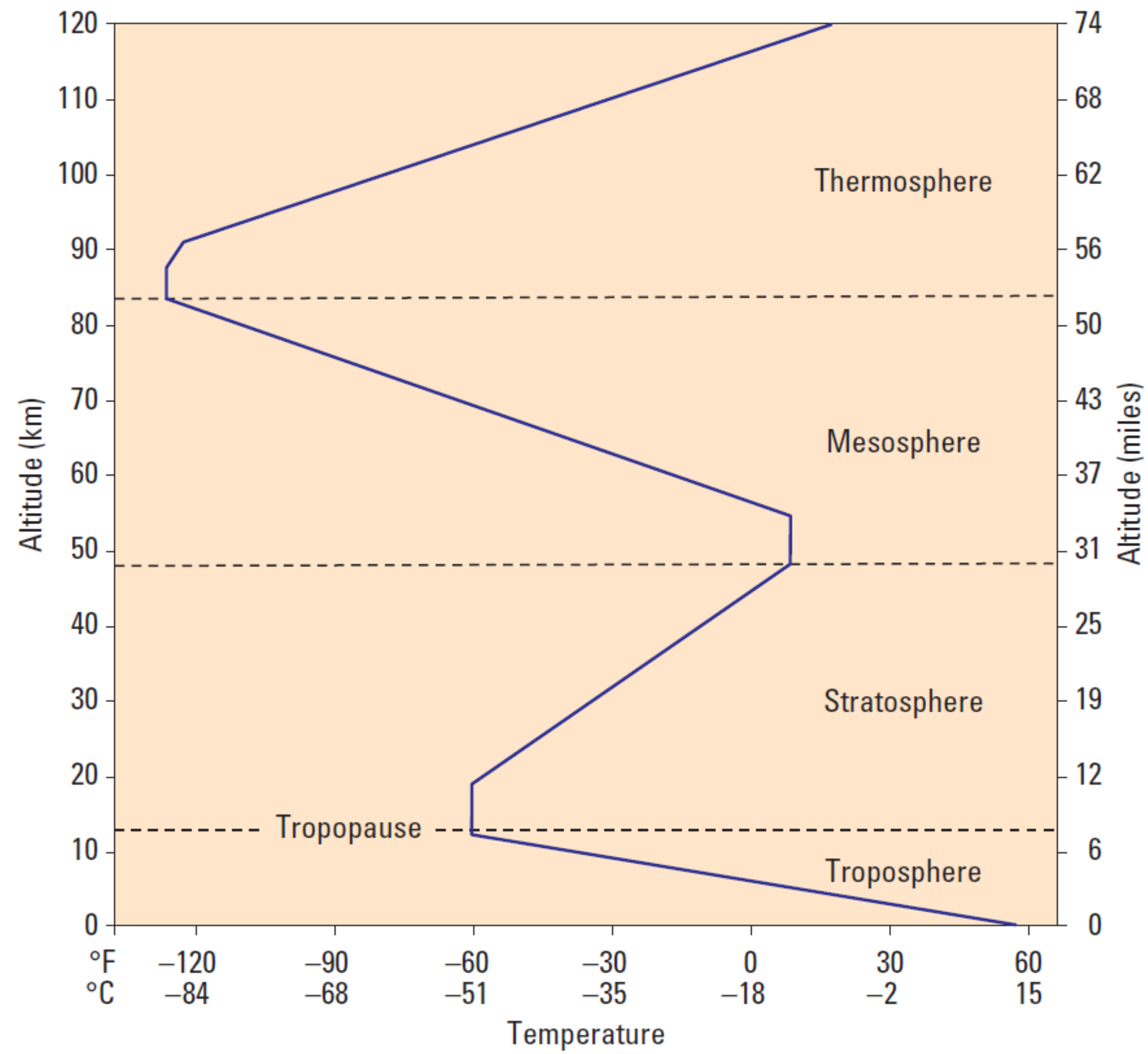
Temperature Conversions

$$°C = (°F - 32)/1.8$$

$$K = °C + 273.15$$

Layers of Atmosphere

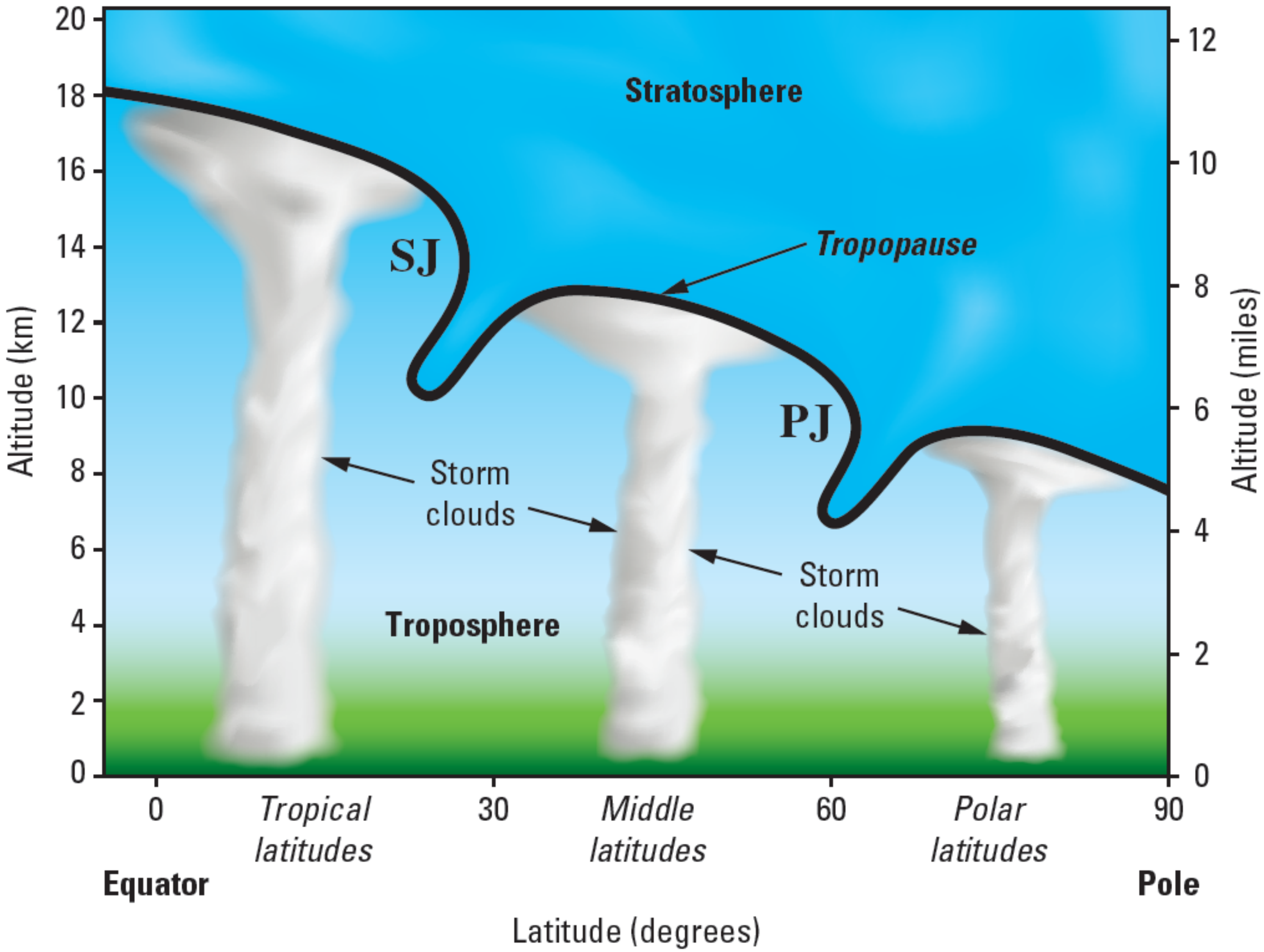
- Troposphere: 0-12 km above surface, T decreases
- Stratosphere: 20-50 km, T increases (Ozone effect)
- Mesosphere: 50-85 km, T decreases
- Thermosphere: >85 km, T increases again



Tropopause

- Definition: The boundary between troposphere and stratosphere. It can be thought of as a lid on Earth's weather.
- Tropopause slopes down from the tropics to the poles:
  - Tropical regions: 16-18 km
  - Mid-latitude: 11-13 km
  - Polar latitudes: 8 km

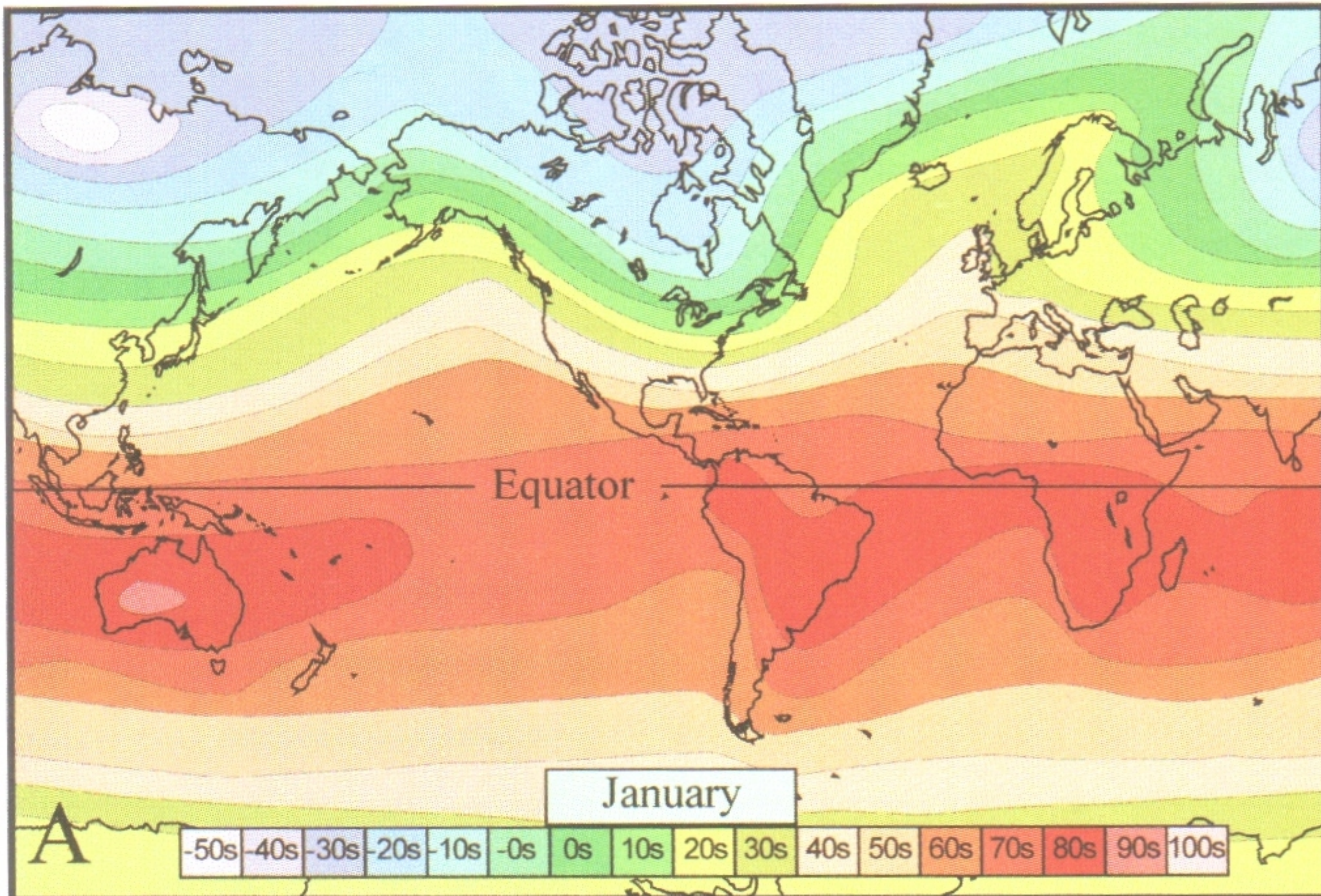
Tropopause Height as a Function of Latitude



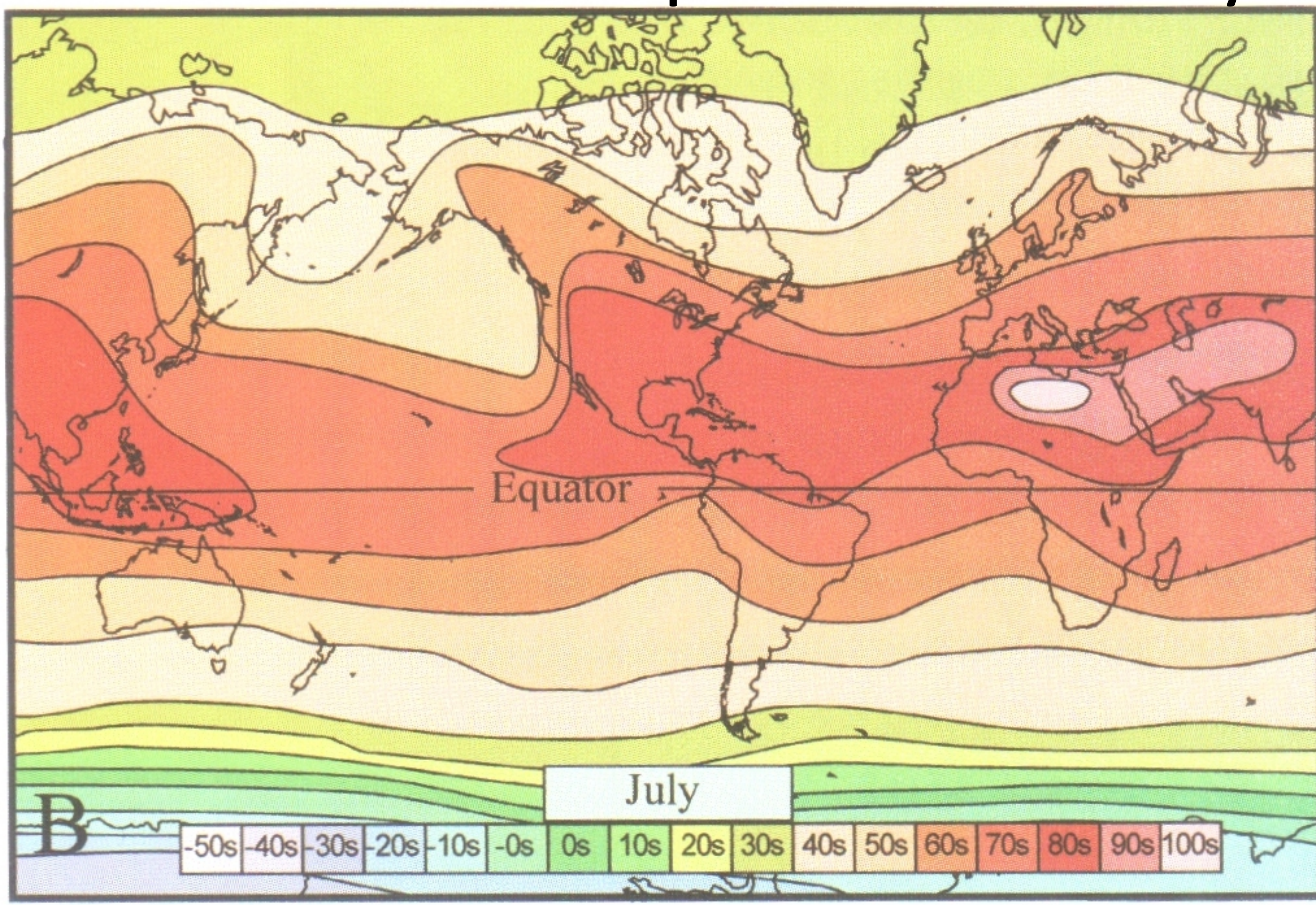
Tropopause folds

- Jet streams: rivers of fast-moving air in the upper tropopause (critical to weather development)
  - Subtropical jetstream: circle the globe at latitudes of about 25°.
  - Polar jetstream: circle the globe at latitudes of about 50°.
- Tropopause folds: just north of each of these jet streams, air from stratosphere often descends in a narrow zone, leading to the folds:
  - It is one way to mix stratophere air with troposphere air.

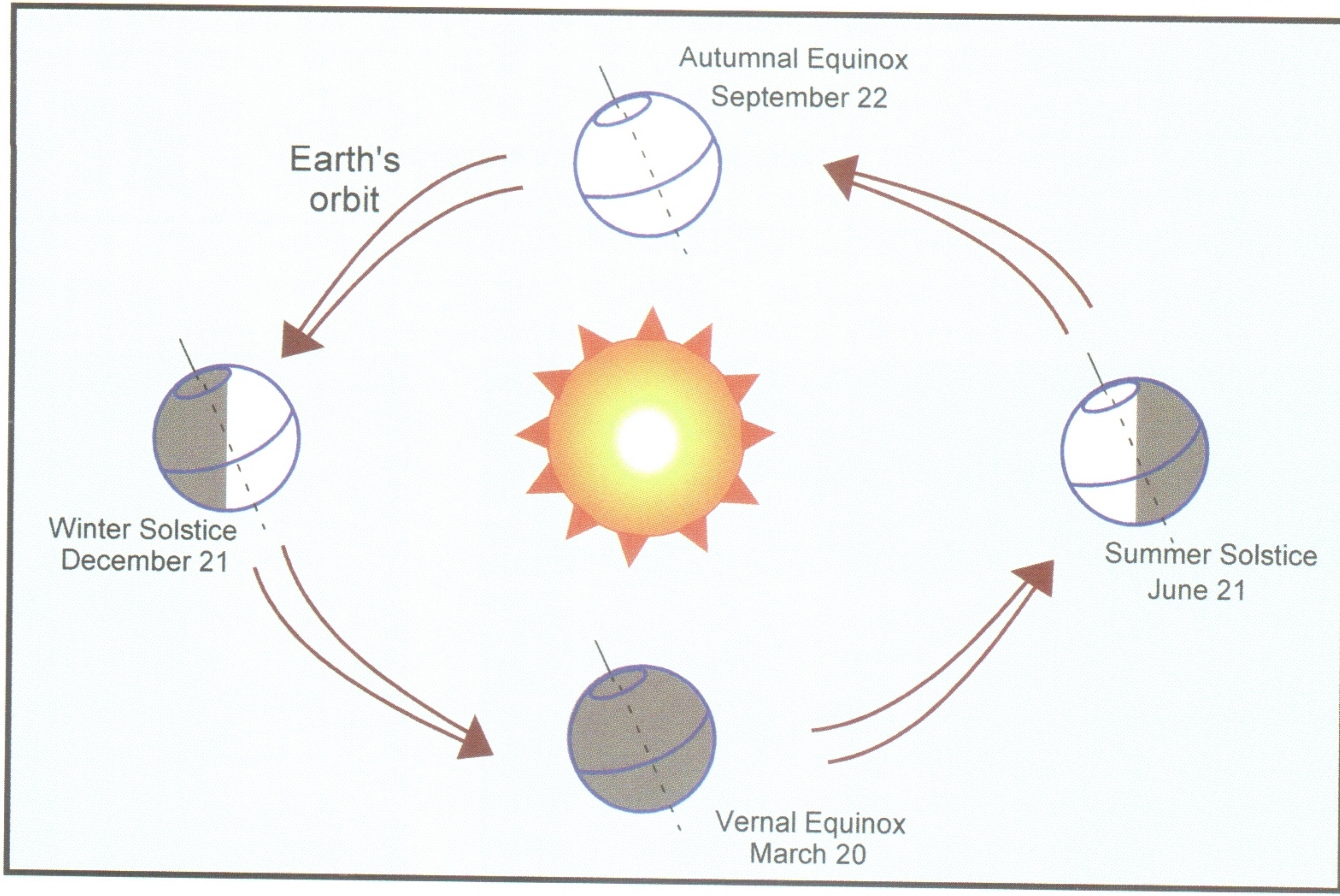
Worldwide Temperatures in January



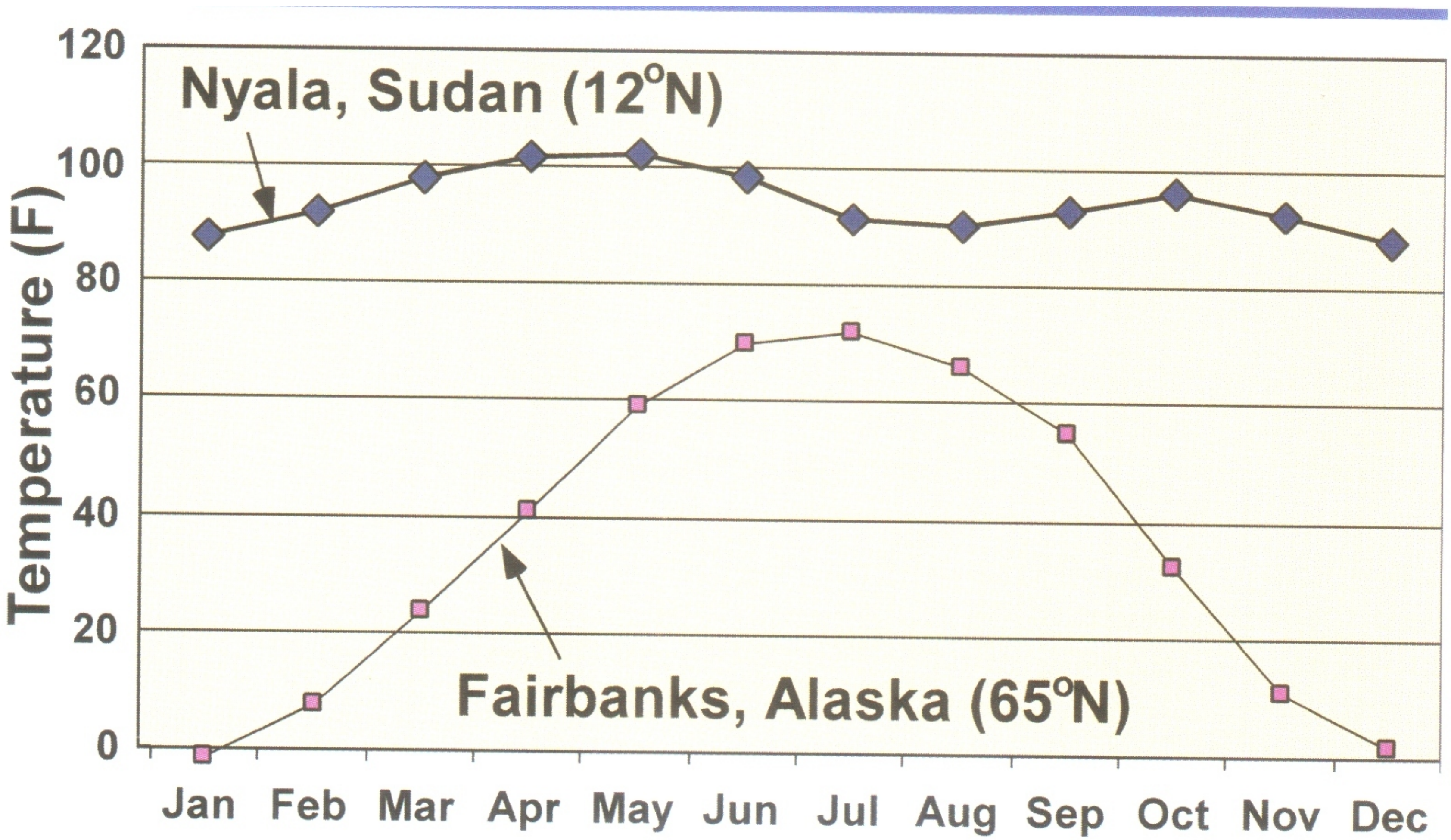
Worldwide Temperatures in July



How the Earth's Orbit Affects Temperature



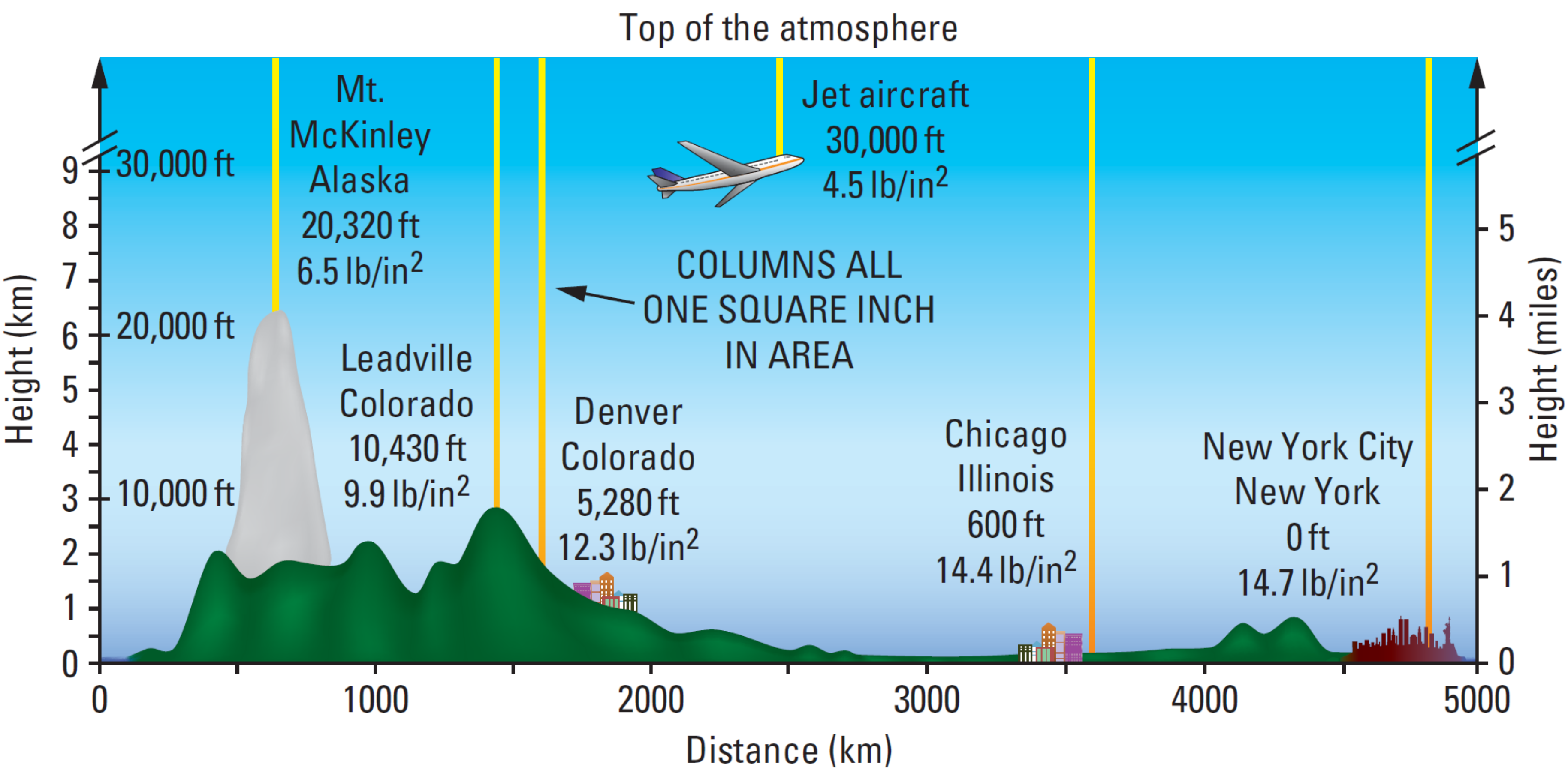
High and Low Latitude Temperature Variations



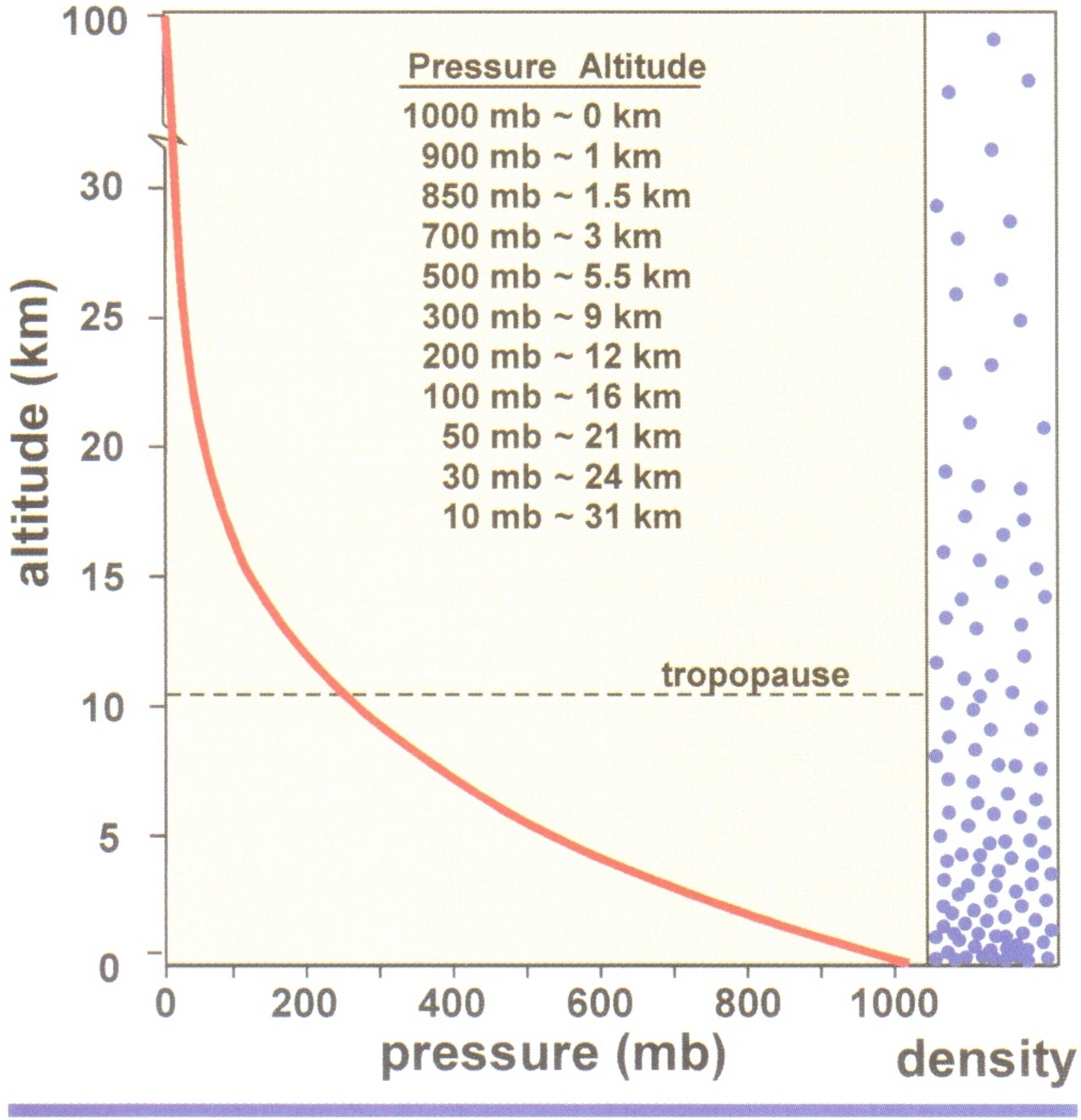
Pressure

- Pressure is the force applied by all of the air molecules that strike over a unit area
- Pressure is equivalent to the weight of a column of air above a unit area (lb/in^2).
- Standard unit: mb or hPa; Pascal=newton/m^2
- Other unit: inches of mercury

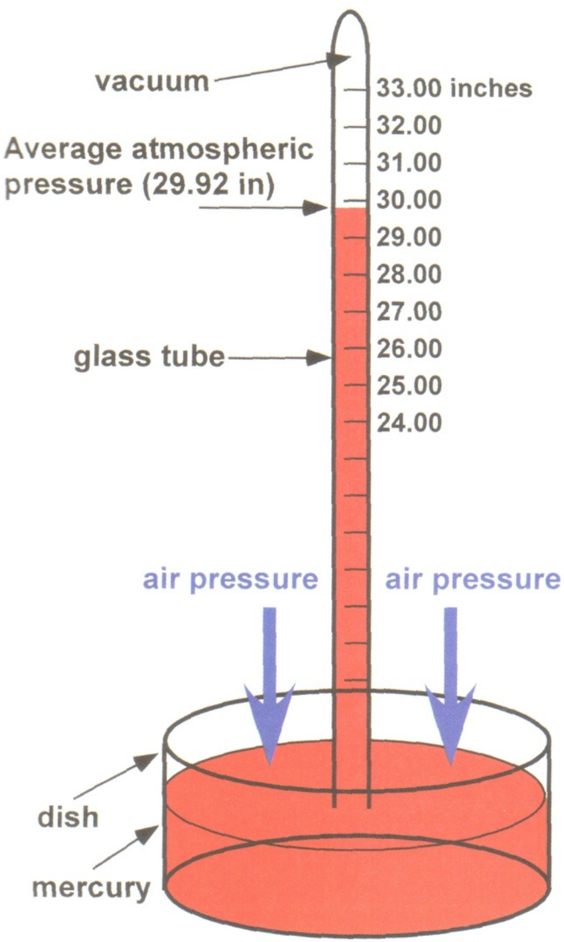
In the Large Scale Atmosphere, Pressure is the Weight of Air Above



Presssure as a Function of Height



How a Mercury Barometer Works



- Air presses on Hg in the dish
- Weight of Hg in column is the same as the weight of the air
- Vacuum at the top of the tube
- Since Torricelli (1644) observers have identified low pressure with bad weather

Table 1.1 Range of Sea-Level Pressures Observed on Earth

	Inches of Mercury (in. HG)	Pounds per Square Inch (lbs/in^2)	Millibars (mb)
Highest recorded sea-level pressure	32.01	15.7	1084
Strong high-pressure system	30.86	15.2	1045
Average sea-level pressure	29.92	14.7	1013
Deep low-pressure system	28.94	14.2	980
Lowest recorded sea-level pressure	25.70	12.5	870

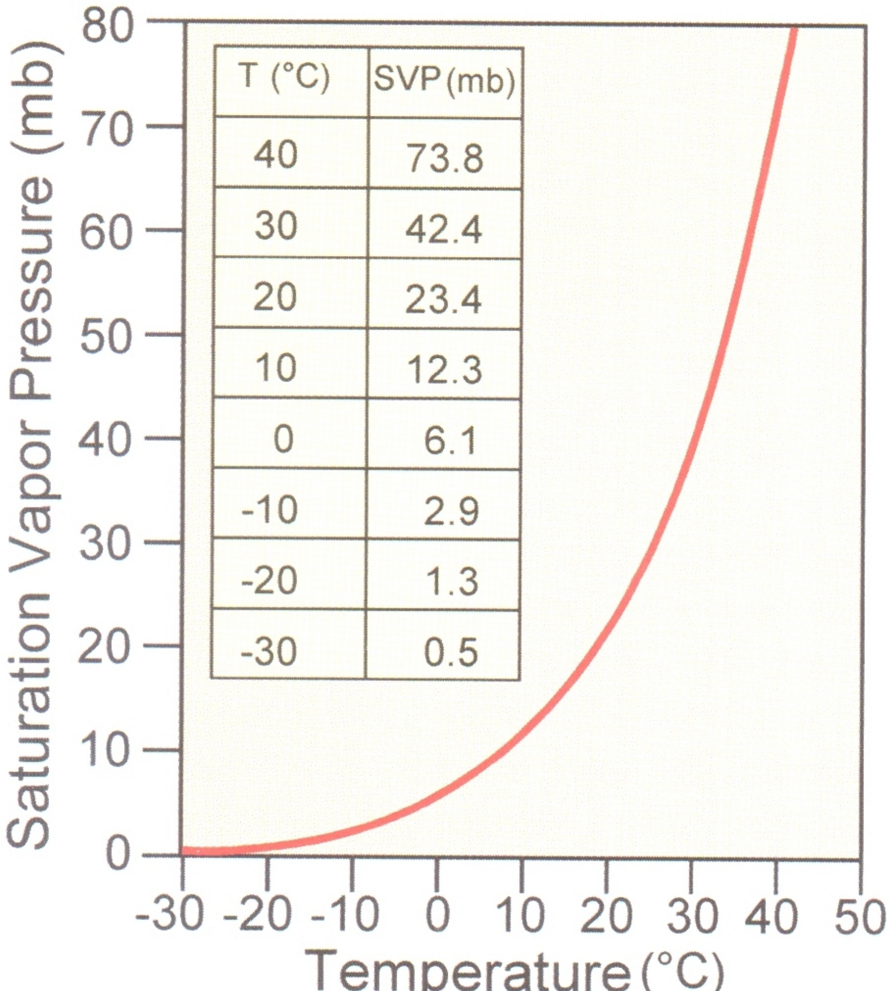
Mean Sea Level Pressure (MSLP)

- Meteorologists have to convert station pressure to a common altitude, which is chosen as mean sea level.
- If no conversion like this is made, a map of station pressure will look much like a map of the topography
- Once the conversion is made, we can see how pressure varies over a region.

Moisture variables (1)

- **Vapor pressure**: the force applied by only the water vapor molecules striking a unit area. It is a measure of **the absolute amount of moisture** in the air (mb).
- The atmosphere cannot hold unlimited amount of moisture. It has a capacity for moisture.
- **Saturation**: When the atmosphere can not contain any more water vapor without condensing into cloud droplets, we say the atmosphere is saturated.
- **Saturation vapor pressure**: The vapor pressure at which the atmosphere becomes saturated. It is **a measure of the atmosphere's capacity for water vapor**, which depends on temperature only!

Saturation Vapor Pressure vs. Temperature



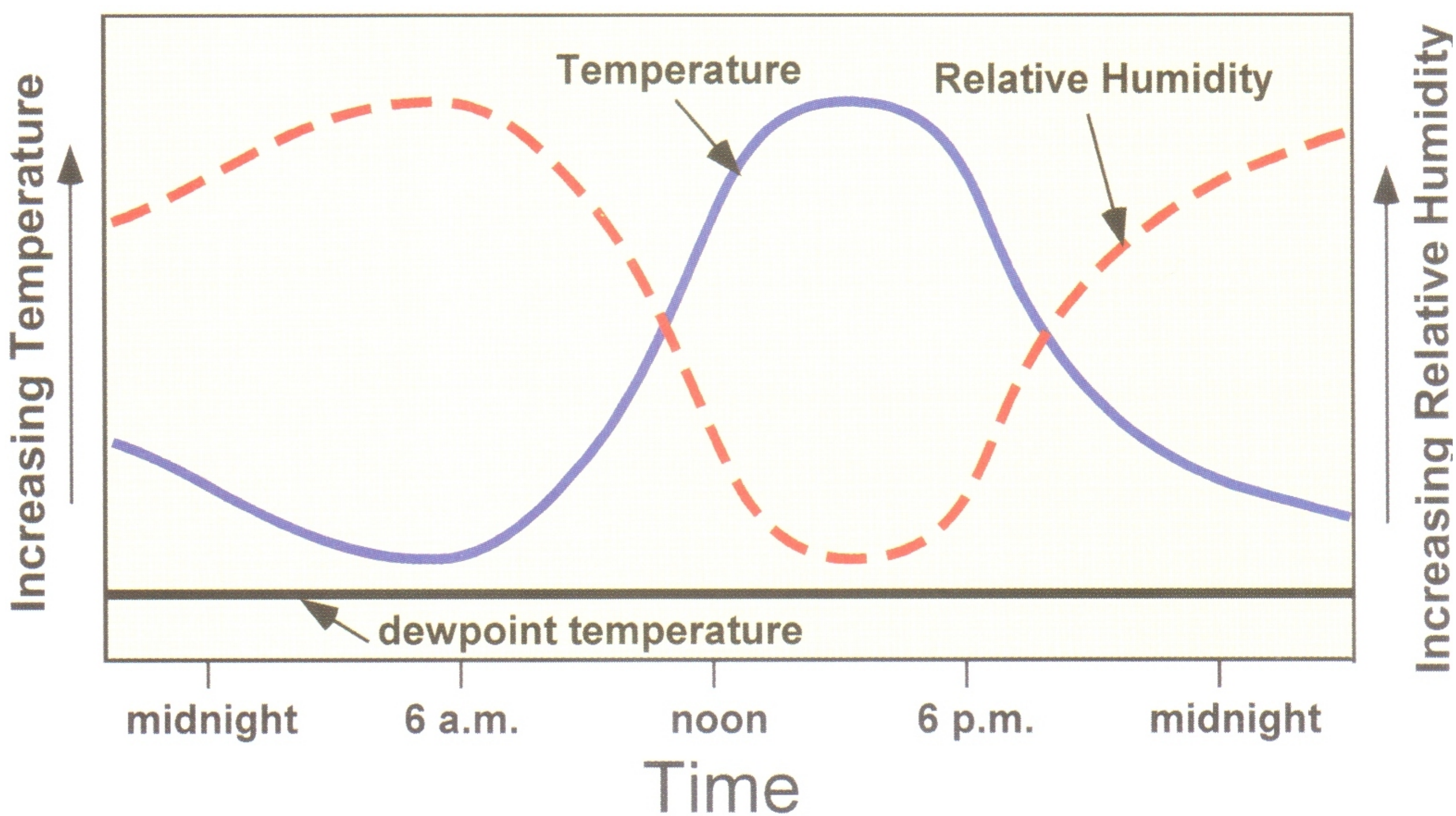
T (°C)	SVP (mb)
40	73.8
30	42.4
20	23.4
10	12.3
0	6.1
-10	2.9
-20	1.3
-30	0.5

- The atmosphere has little capacity to hold water vapor when the temperatures are very cold.
- You can use the same curve on the left for the relationship between **Vapor pressure (y-axis) vs. Dew point temperature (x-axis)**

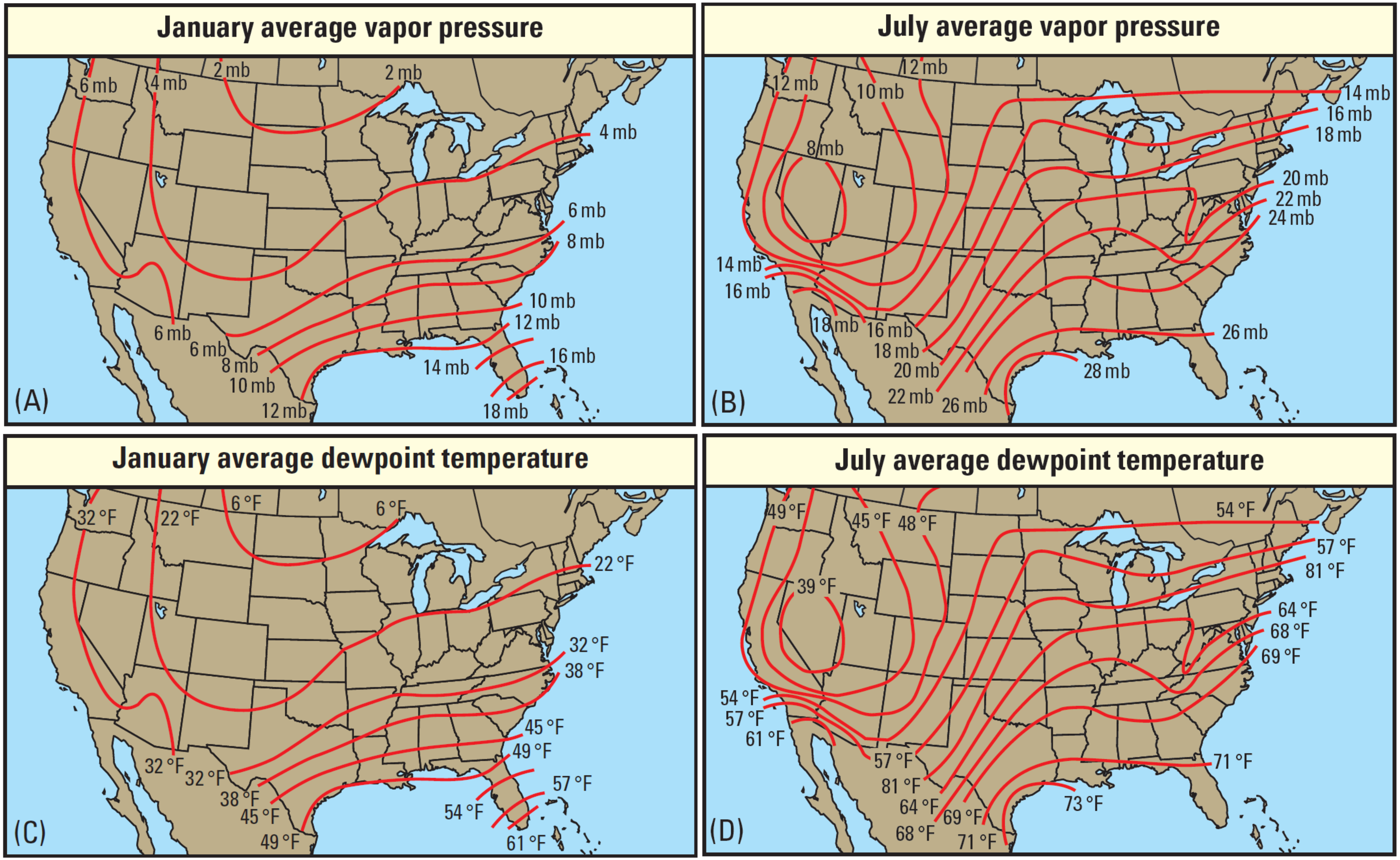
Moisture variables (2)

- Relative humidity= (vapor pressure/saturation vapor pressure) *100%, which is **a measure of the moisture content of the atmosphere relative to its capacity for water vapor**. Humans are sensitive to relative humidity, not the absolute amount of moisture.
- Dewpoint temperature (Td) is the lowest temperature to which air can be cooled at constant pressure before saturation occurs. It is **a measure of absolute moisture content**, just like vapor pressure. Td is easy to measure.
- We can qualitatively calculate the relative humidity if you know Td and T (use Fig. 1.9-the figure in previous slide, use T as the x-axis to get saturation vapor pressure, then use Td as x-axis to get vapor pressure).

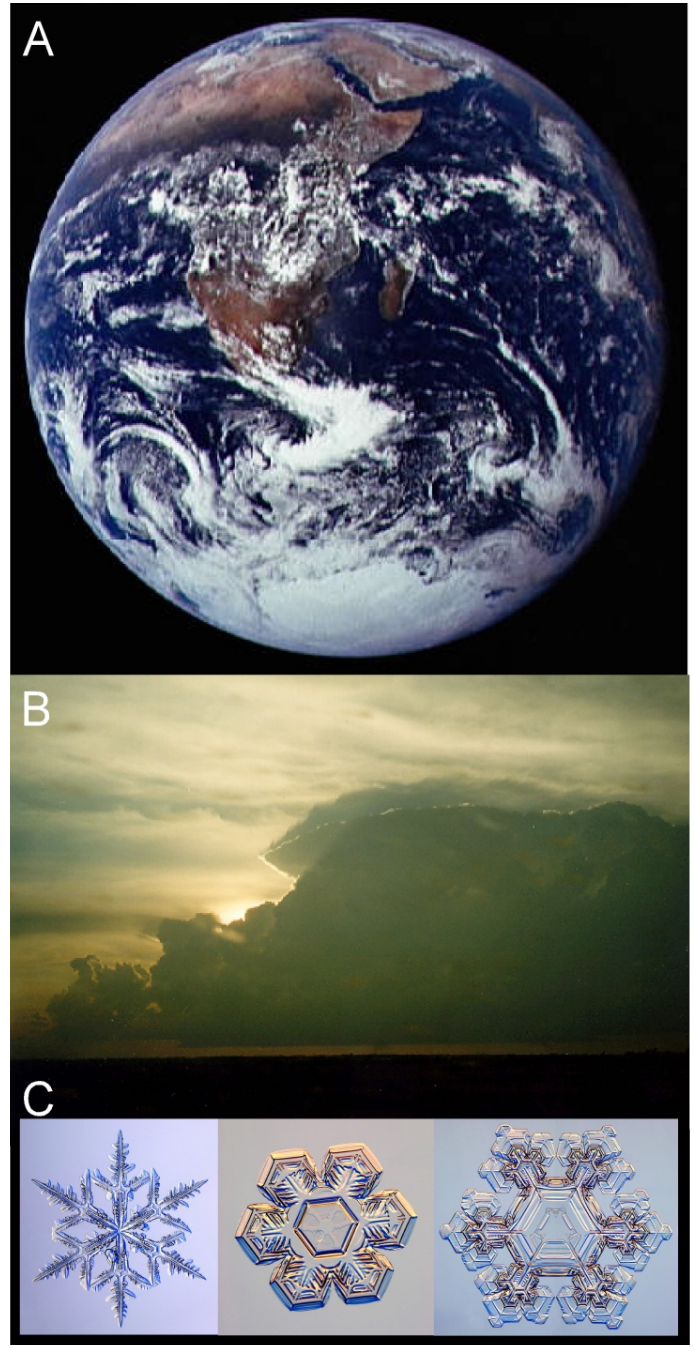
Daily Variation of Relative Humidity with With Temperature when the moisture content (Dew Point) does not vary



Both vapor pressure and dewpoint temperature are measures of absolute amount the moisture content



Clouds

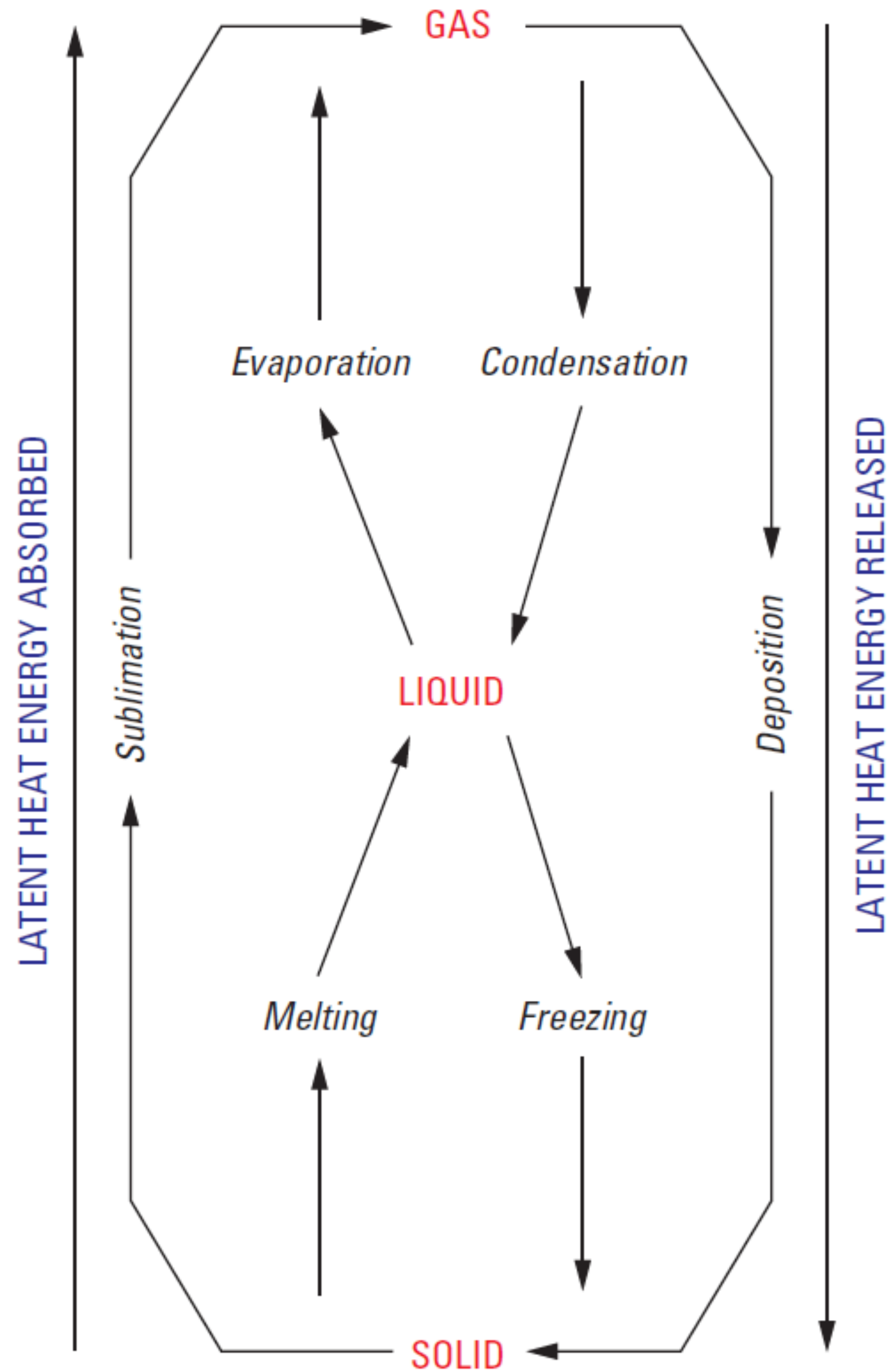


Water Phase Changes and Cloud

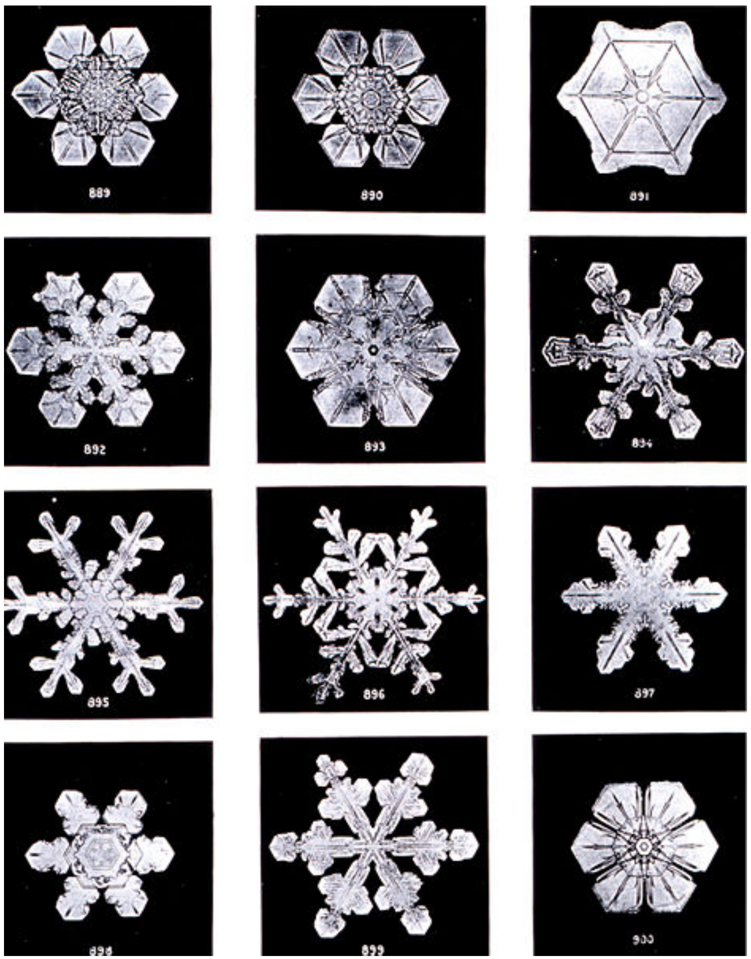
- Solid → Liquid → Gas

  Melting, evaporation, sublimation: absorb latent heat energy

  Freezing, condensation, deposition: release latent heat
- Latent heat: the energy that is required for a phase change. For example, accelerating the molecules to high speeds of vapor and breaking the strong bonds in liquid & ice.
- Supercooled liquid water and ice nuclei (-15 ~ -10 deg C)



Hydrometeors and Precipitation



- Hydrometeor: Any water condensed from the atmosphere
- Precipitation: Water that falls from clouds to the ground
- Liquid: Rain or drizzle (<0.5mm)
- Ice: Hail or graupel (< 5 mm)
- Ice crystals: Snow
- Depth is in mm of liquid water, i.e. melt snow or hail

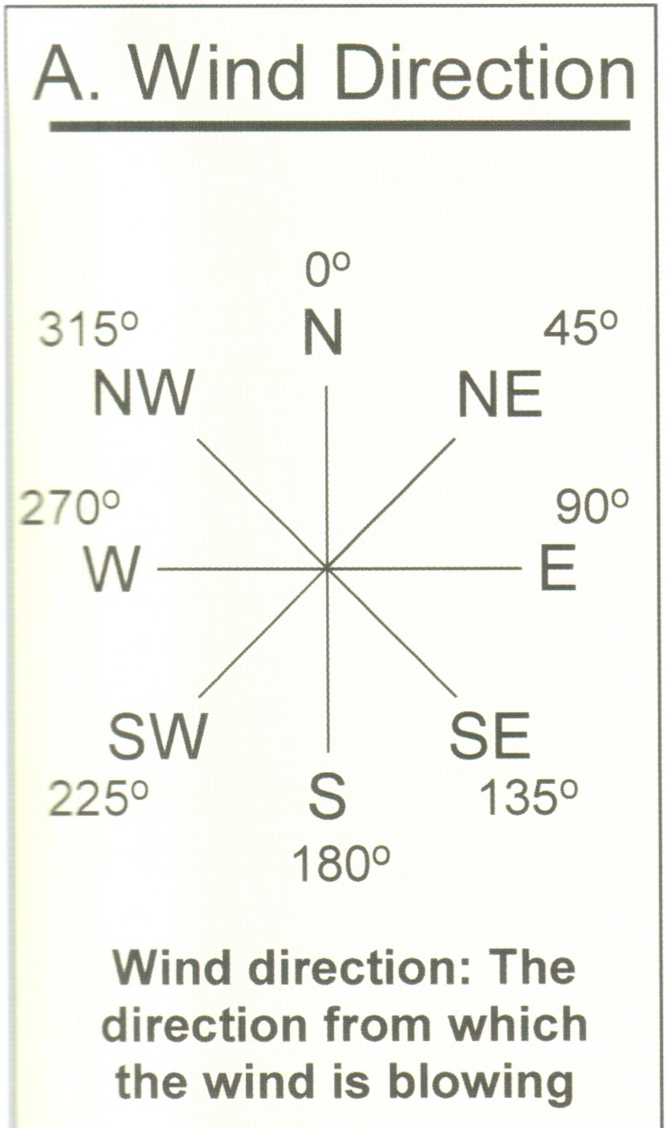
Four Cloud Types

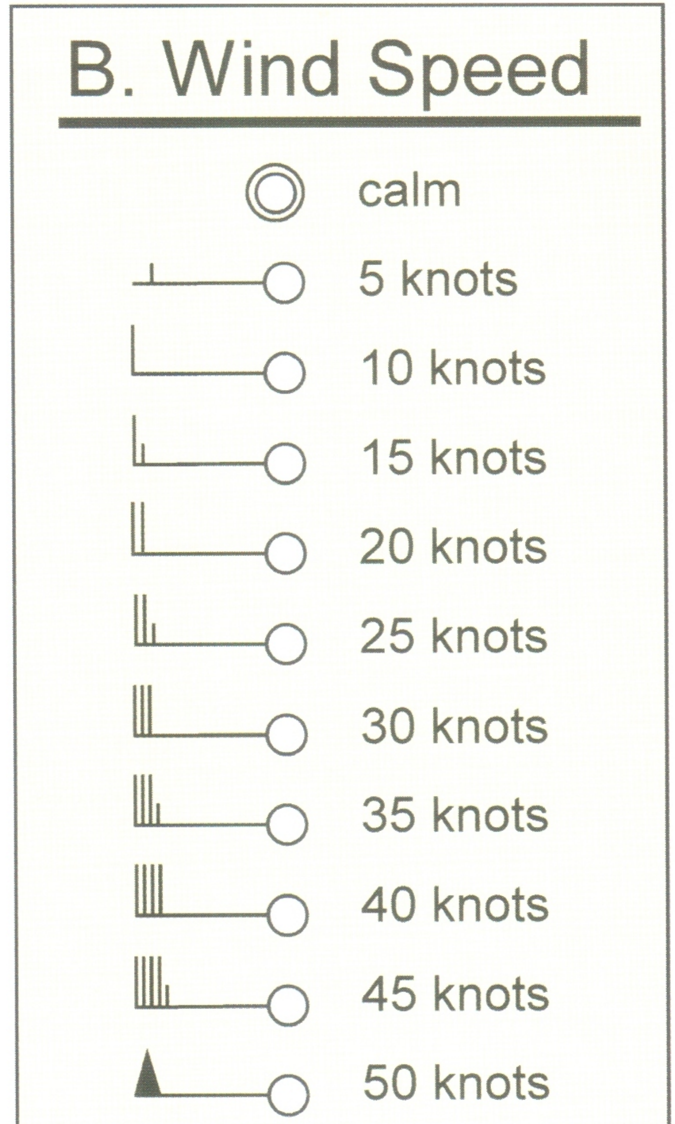
- **Cumulus:** with vertical development, towering, with cauliflower-like lobes
- **Stratus:** layered and widespread
- **Cirrus:** high, wispy, fibrous
- **Nimbus:** raining/precipitating clouds
- These types can be combined to name clouds: High clouds (>6 km): **cirro-??;** middle clouds (2-6 km): **alto-??**

Wind

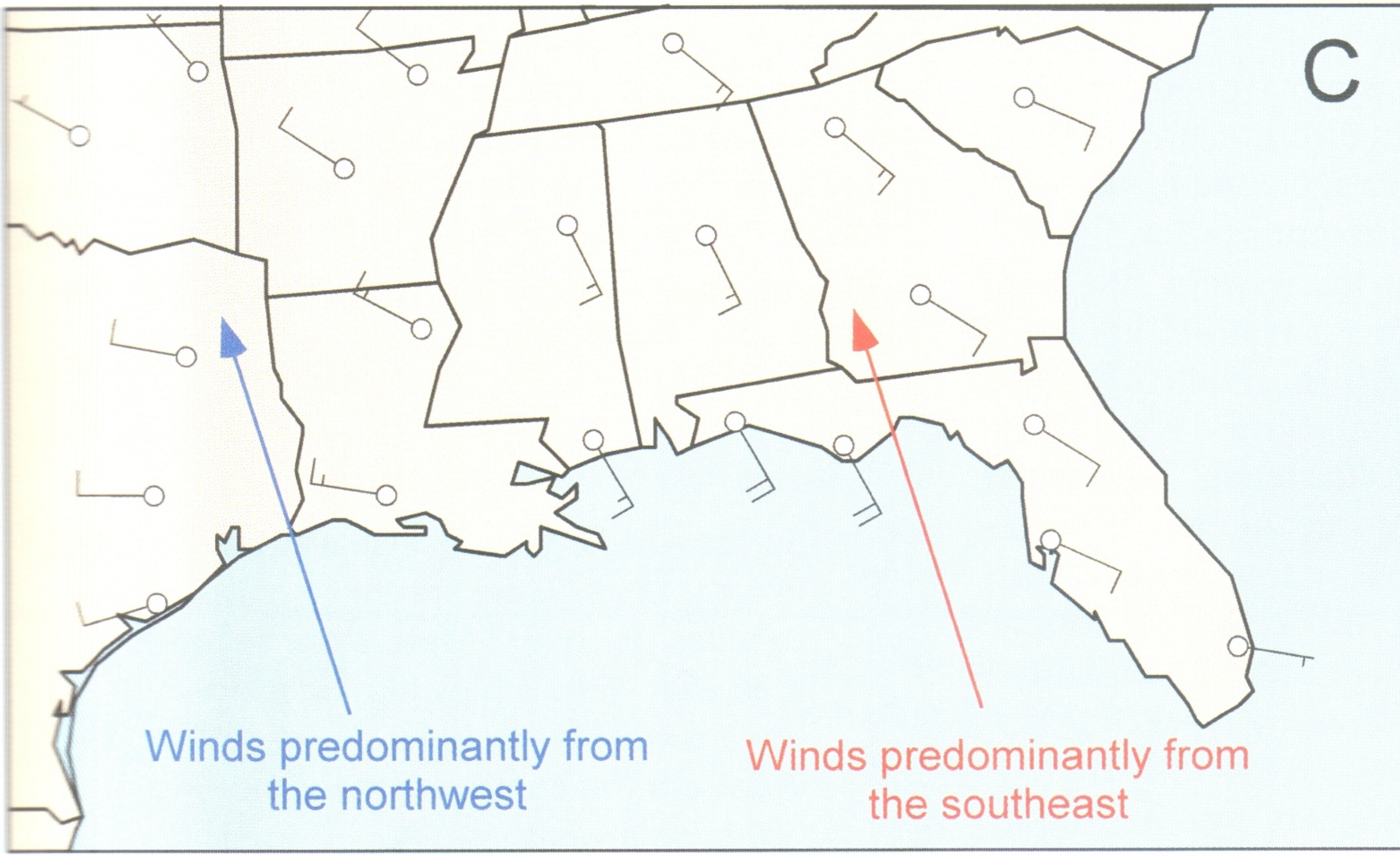
- Wind is simply the movement of air
- Wind is a vector: wind direction & winds peed (measured by anemometer).
- The meteorological wind direction, by convection, is the direction from which the wind is blowing.

Coding of Winds (Review)





An Example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Winds predominantly from the northwest
Winds predominantly from the southeast

Summary

- Temperature
  - Controlled by Sun and Season
  - 6.5^{o}C km^{-1} lapse rate in Troposphere
- Pressure:
  - Weight of air above
  - Decreases upward
- Moisture & Humidity
  - Vapor pressure, dew point, saturation vapor pressure and relative humidity
  - Phase changes of water
  - Latent heat
- Wind: Coded on maps using wind barbs