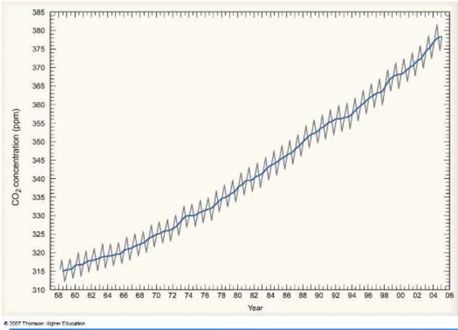
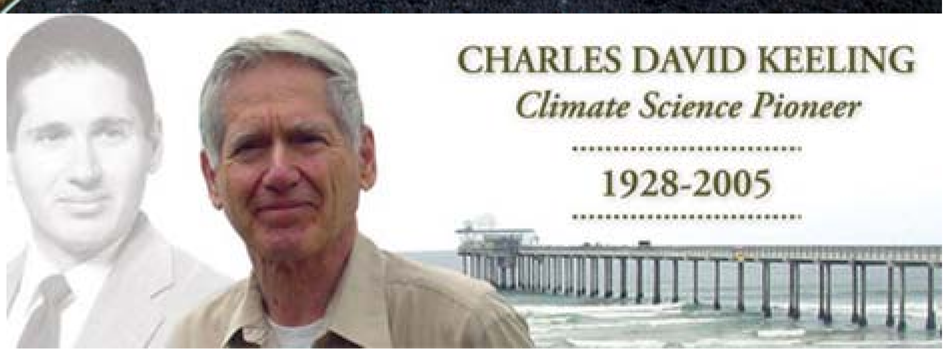
Keeling Curve of CO_2





- Record since 1950s taken at Mauna Loa Observatory (Hawaii)
- Started by Charles David Keeling
- Since, comparable studies started in other locations around the globe

AOSC400-2015

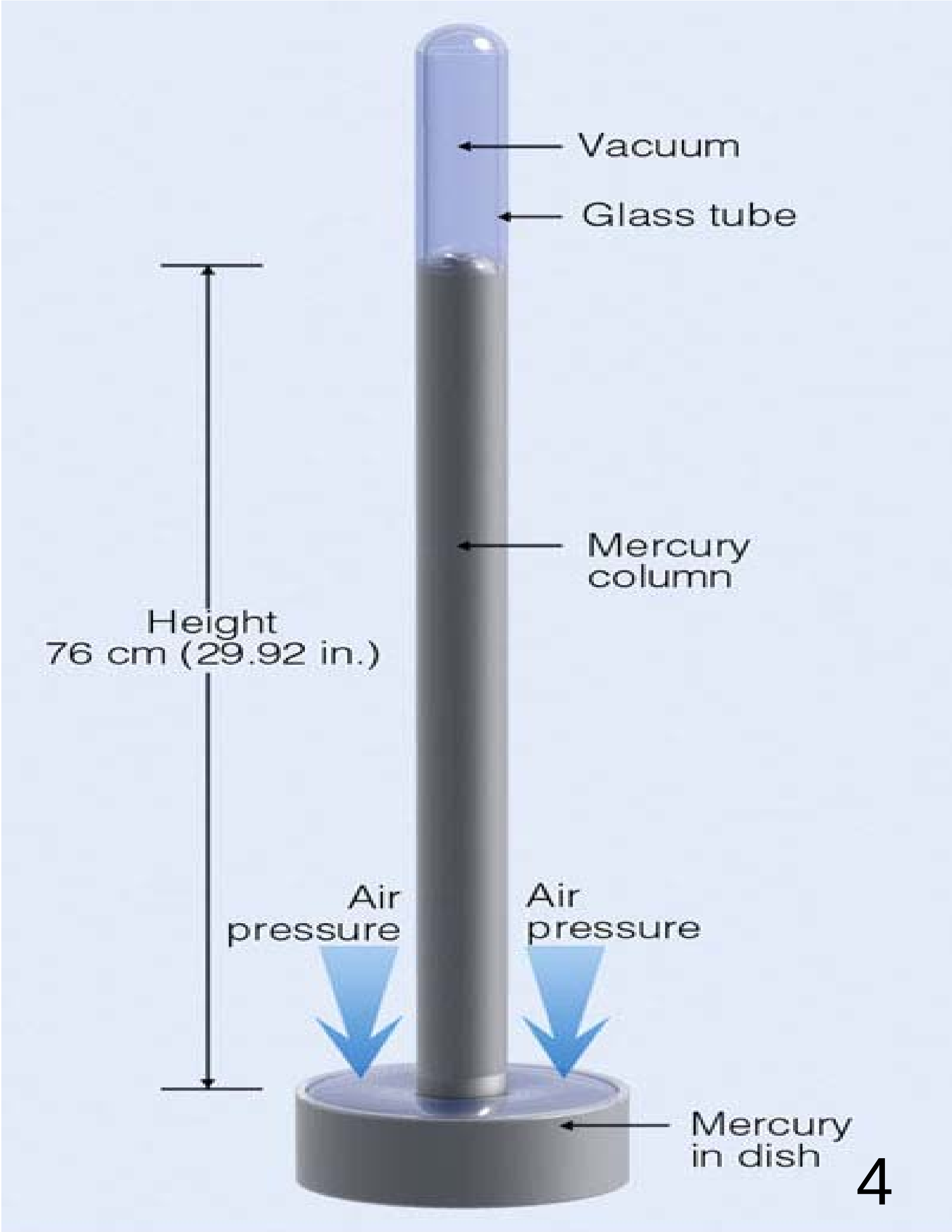
September 08, Lectures # 3

- Probing vertical structure – vertical structure as a function of pressure
- Review of basic concepts: Pressure and Density
- Units of Atmospheric Pressure
- Review: Energy, temperature, heat
- Concept of Latent Heat
- Warming of the Earth and the Atmosphere
- Daily and seasonal temperatures characteristics
- Characteristics of wind structure (*time permitting*)
- Characteristics of rainfall

Review of basic concepts: Pressure and Density

- weight = massxgravity
- density = mass/volume
- Pressure = force/area
- *One newton is the force needed to accelerate one kilogram of mass at the rate of one metre per second squared.*
- F=ma 1N = 1kg. m/s^2
- The **dyne** is a unit of force in the centimetre–gram–second system of units (CGS)
- 1 dyn = 1 $g{\cdot}cm/s^2 = 10^{-5}\ kg{\cdot}m/s^2 = 10^{-5}$ N
- 1 N = 1 $kg{\cdot}m/s^2 = 10^5\ g{\cdot}cm/s^2 = 10^5$ dyn

The mercury barometer.
The height of the mercury column is a measure of atmospheric pressure.



- Most common unit of pressure on weather maps is the *millibar (mb)* or *inches of mercury (in Hg)*

- 1000 dynes/cm^2=1 millibar (mb)

- Standard value of atmospheric pressure = ***1013.25 mb***

Units of Atmospheric Pressure

Pascal (Pa): a SI (Systeme Internationale) unit for air pressure.

1 Pa = a force of 1 newton acting on a surface of one square meter

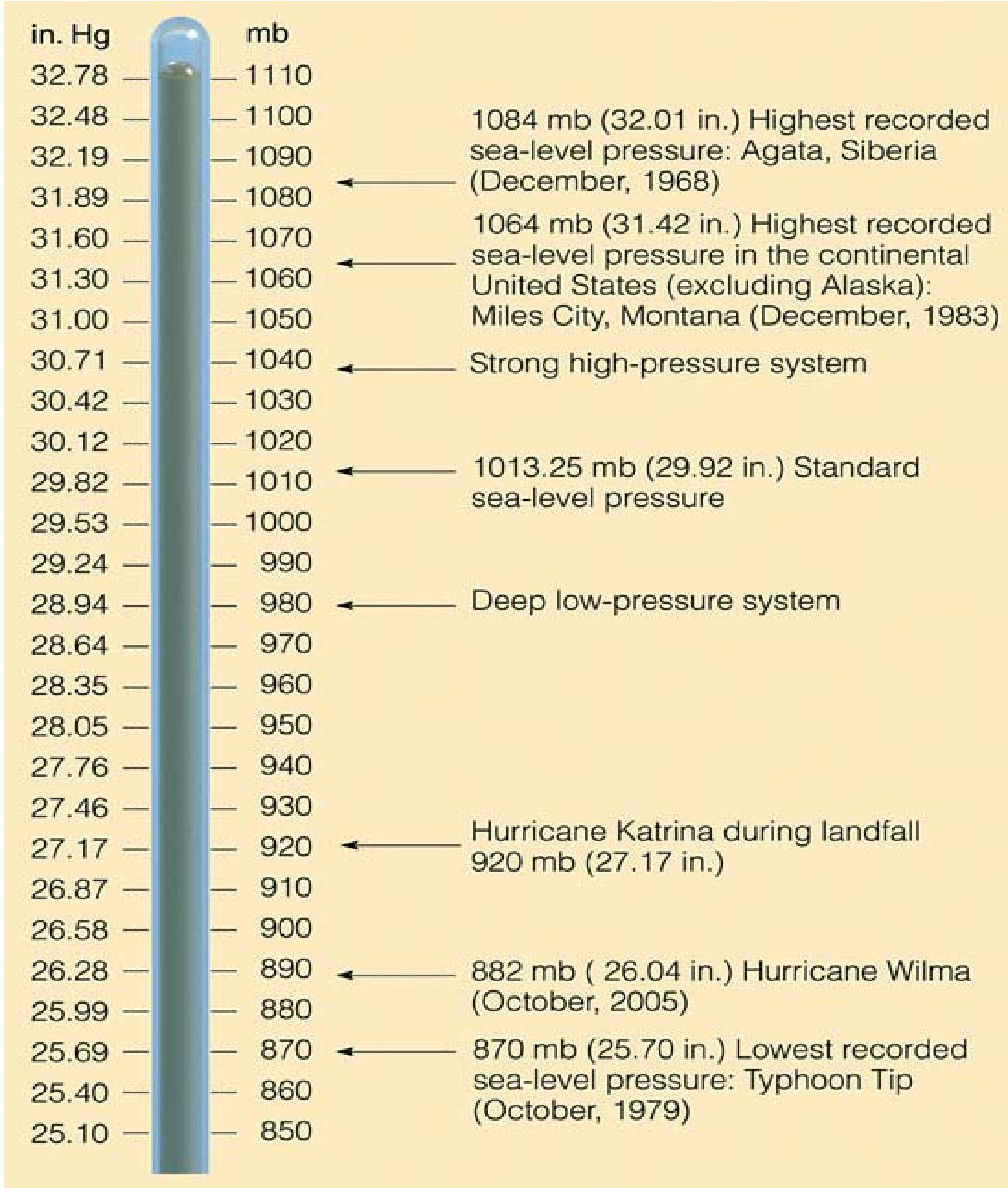
1 hectopascal (hPa) = 1 millibar (mb) (hecto = one hundred =100)

Bar: a more popular unit for air pressure.

1 bar = a force of 100,000 newtons acting on a surface of one square meter= 100,000 Pa = 1000 hPa = 1000 mb

One atmospheric pressure = standard value of atmospheric pressure at lea level = 1013.25 mb = 1013.25 hPa.

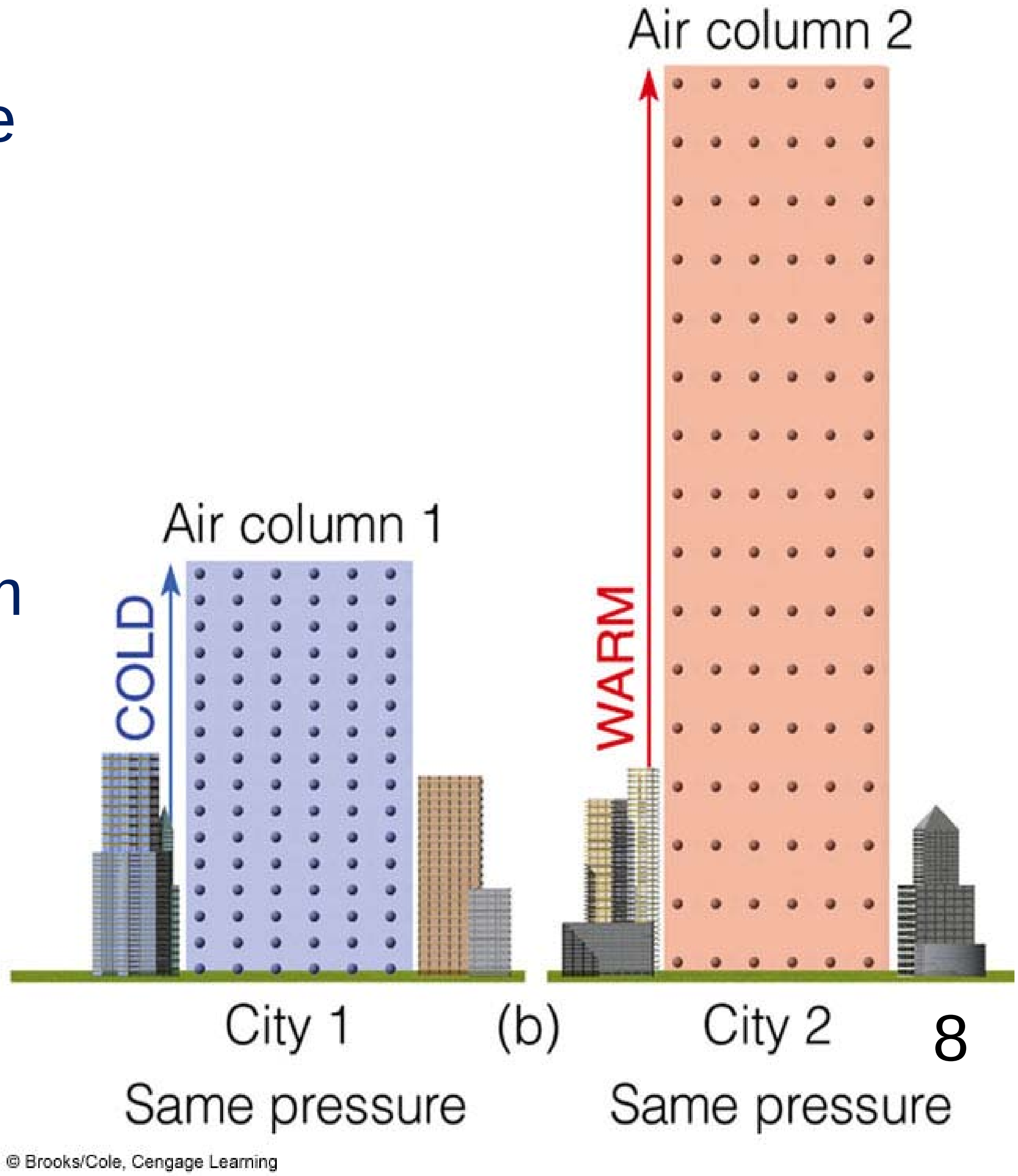
Some "benchmark" values of pressure found in the atmosphere



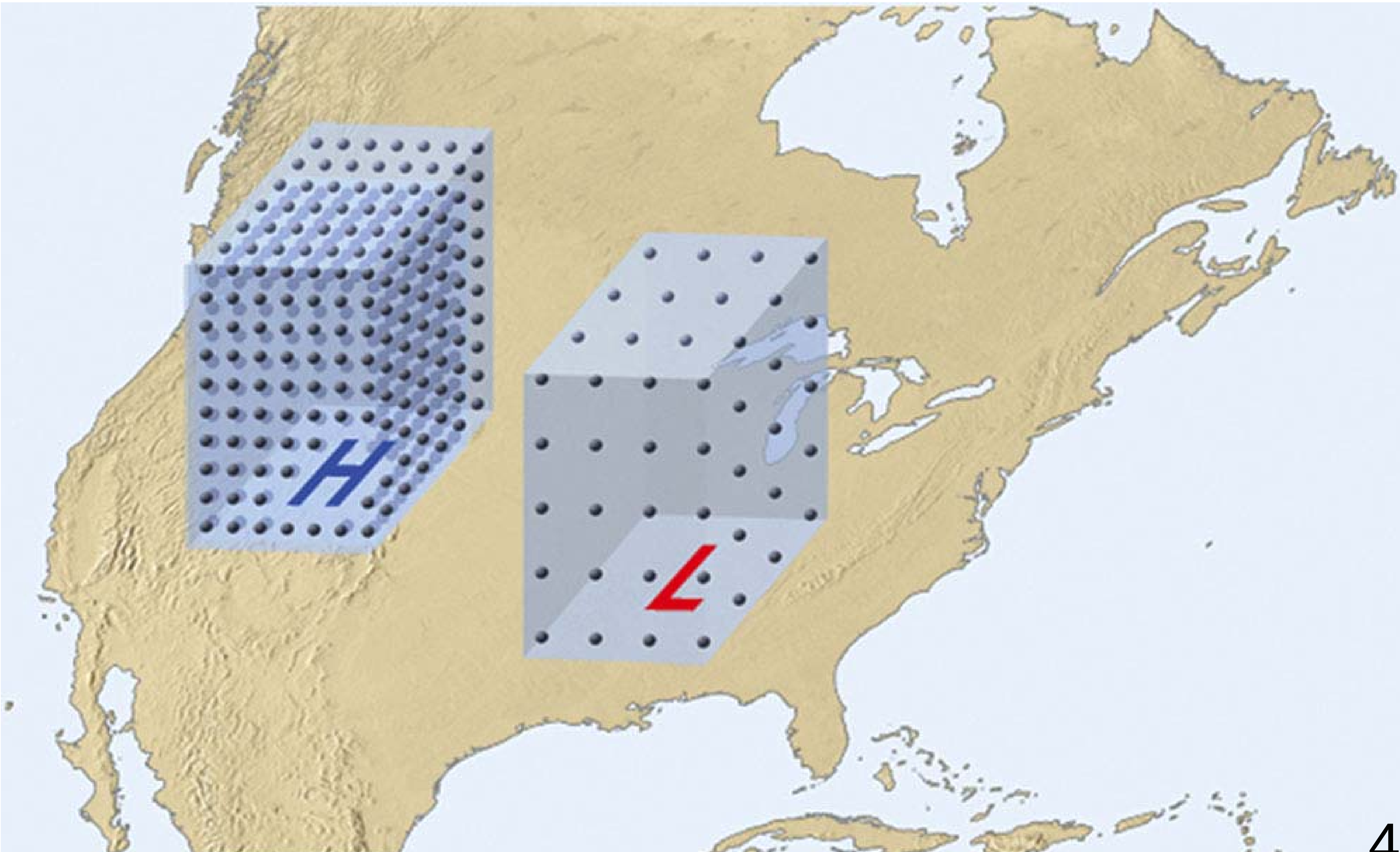
Two air columns of identical mass, will have the same surface air pressure.

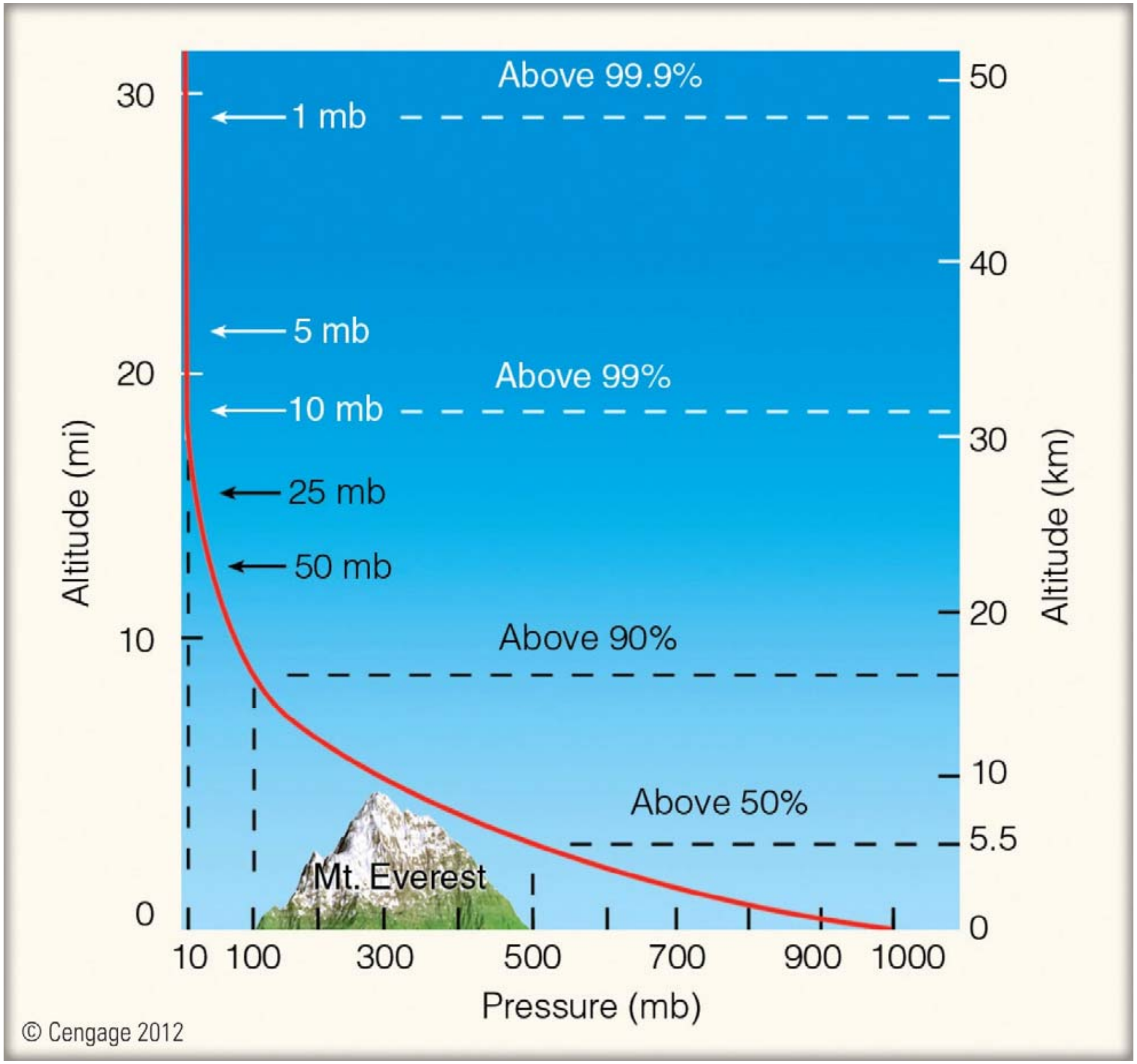
It takes a shorter column of cold air to exert the same pressure as a taller column of warm air.

Why? Has to do with the differences in density of dry and moist air (will be discussed in detail later).



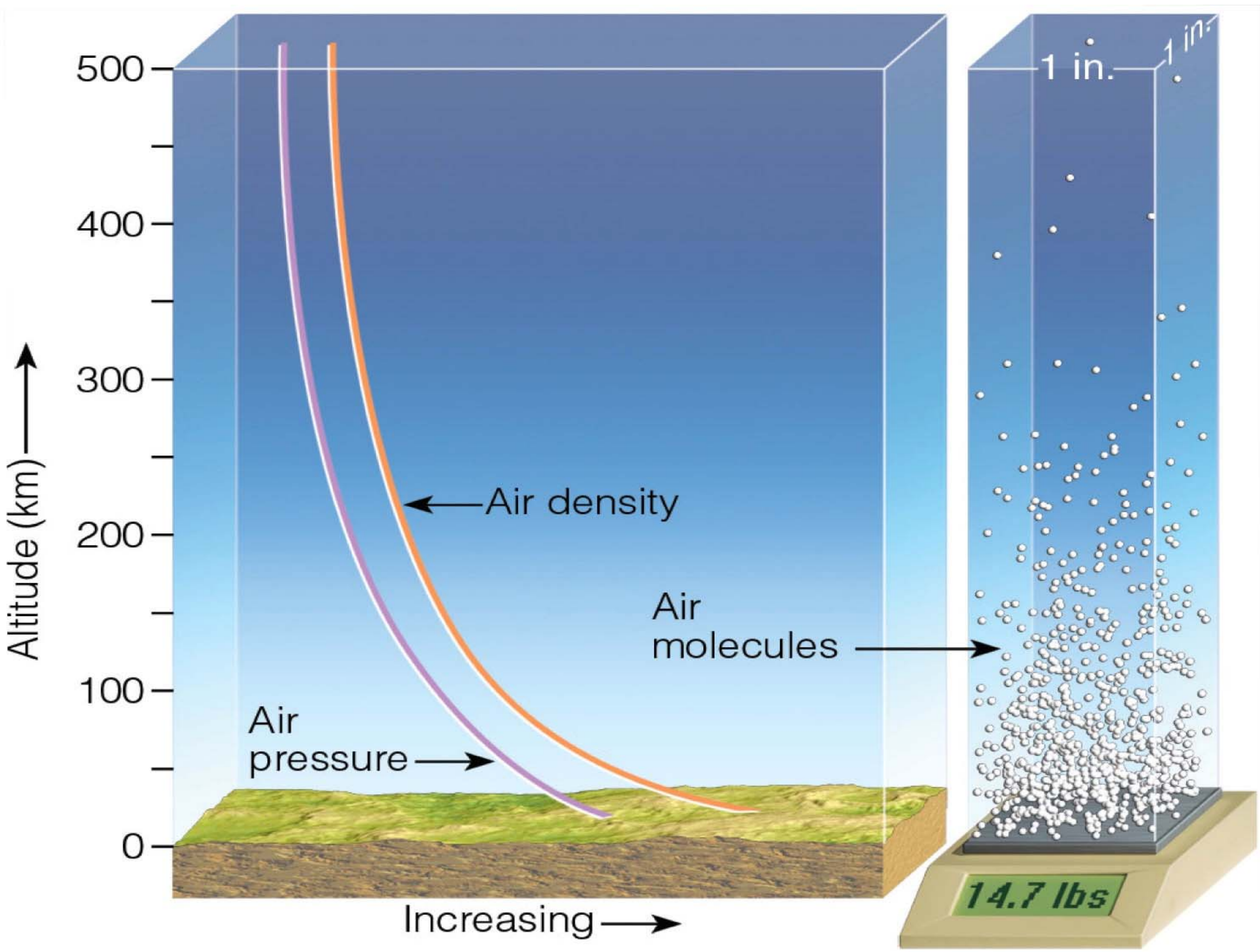
Air above a region of surface high pressure is more dense than air above a region of surface low pressure (at the same temperature).





Atmospheric pressure decreases rapidly with height. Climbing to an altitude of only 5.5 km, where the pressure is 500 mb, would put you above one-half of the atmosphere's molecules.

Both air pressure and air density decrease with increasing altitude.



On the Earth's surface, the atmosphere exerts a downward force due to the Earth's gravitational attraction.

The downward force (the *weight)* of a unit volume of air with density ρ is given by

$$F = \rho g \qquad (1.4)$$

g is the acceleration due to gravity.

Integrating Eq. (1.4) from the Earth's surface to the "top" of the atmosphere, we obtain the atmospheric pressure on the Earth's surface P_s due to the weight (per unit area) of the air in the overlying column:

$$p_s = \int_0^\infty \rho g dz \qquad (1.5)$$

Neglecting the small variation of g with latitude, longitude and height, setting it equal to its mean value of g_o = **9.8 m/s²** we can take it outside the integral, so that Eq. (1.5) can be written as

$$p_s = mg_0 \qquad (1.6)$$

where

is the vertically integrated mass per unit area of overlying air.

$$m = \int_0^\infty \rho dz$$

Exercise ***1.1*** The globally averaged surface pressure is 985 hPa. Estimate the mass of the atmosphere.

Solution: From Eq. (1.6), it follows that

$$\overline{m} = \frac{\overline{p_s}}{g_0}$$

where the overbars denote averages over the surface of the Earth. In applying this relationship the pressure must be expressed in pascals (Pa). Substituting numerical values we obtain

$$\overline{m} = \frac{985 \times 10^2 \text{ Pa/hPa}}{9.807} = 1.004 \times 10^4 \text{ kg m}^{-2}$$

$$
\begin{aligned}
M_{atm} &= 4\pi R_E^2 \times \overline{m} \\
&= 4\pi \times (6.37 \times 10^6)^2\ \mathrm{m}^2 \times 1.004 \times 10^4\ \mathrm{kg\ m}^{-2} \\
&= 5.10 \times 10^{14}\ \mathrm{m}^2 \times 1.004 \times 10^4\ \mathrm{kg\ m}^{-2} \\
&= 5.10 \times 10^{18}\ \mathrm{kg} \qquad \blacksquare
\end{aligned}
$$

Review of Basic Concepts:

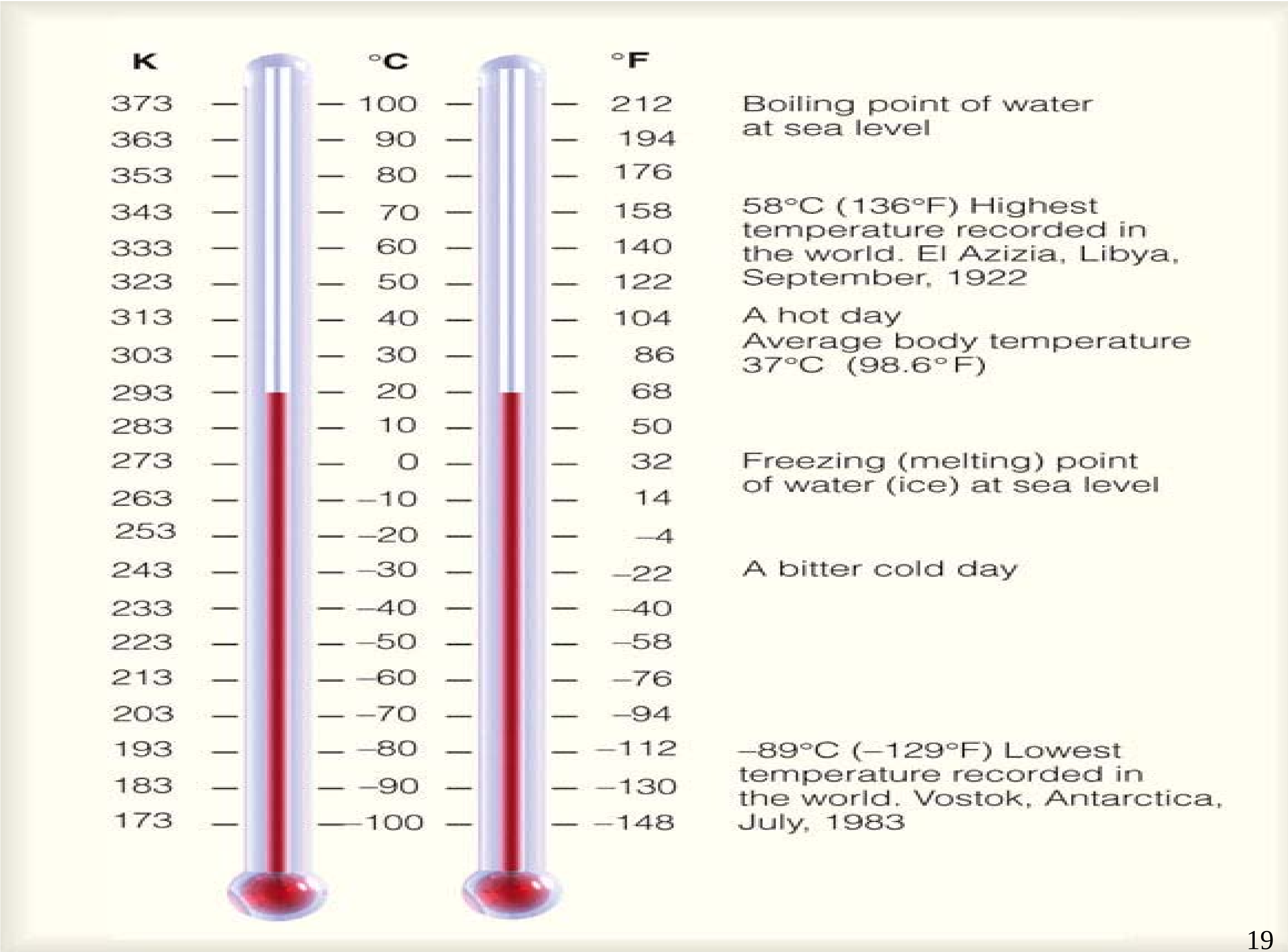
Energy, Temperature, and Heat

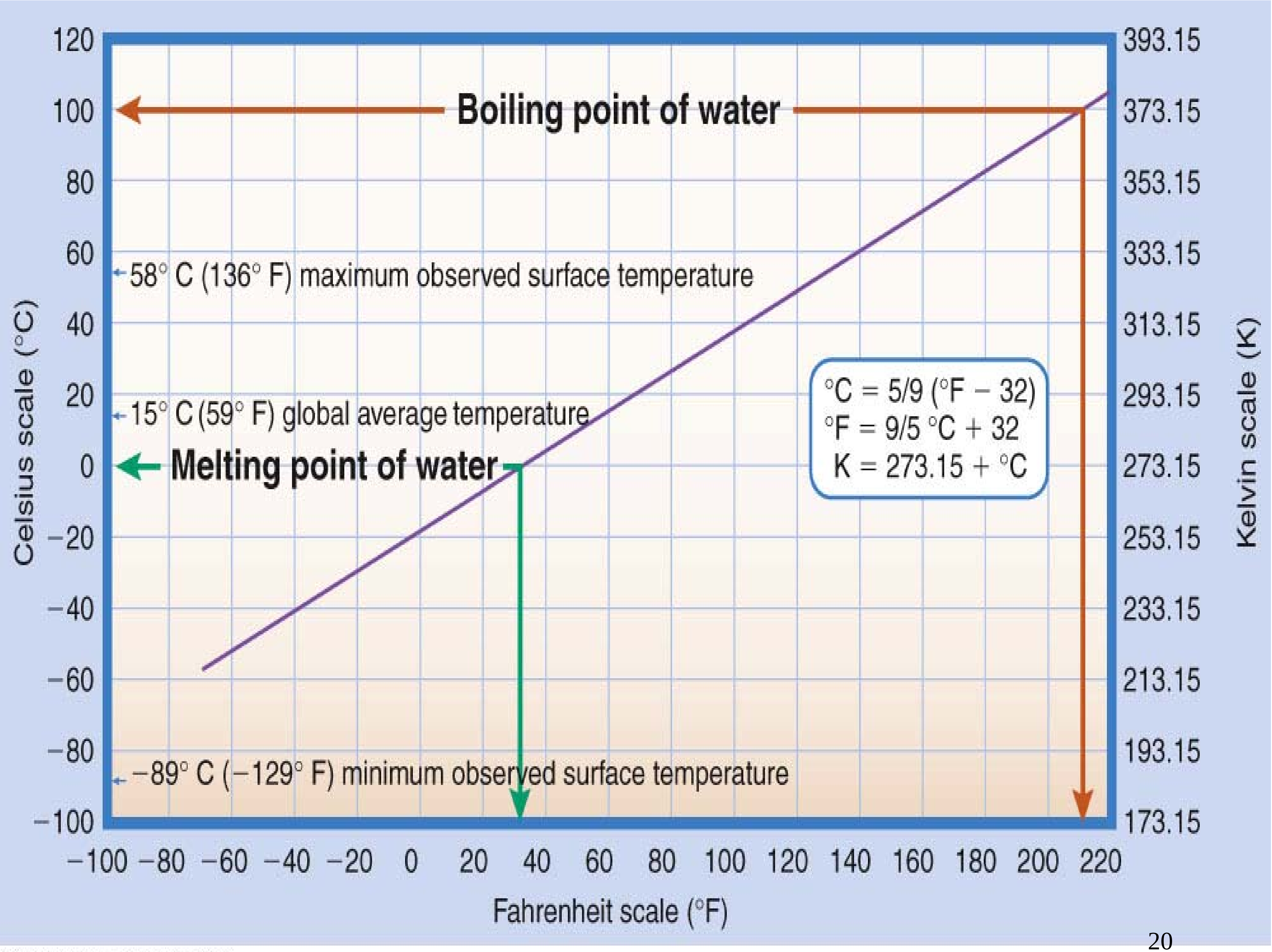
- Energy-capacity to-do work
- Temperature-measure of average kinetic energy, average speed of atoms and molecules
- Heat-energy in the process of being transferred from one object to another because of the temperature difference between them

Energy

- Potential energy -potential to do work
- PE=mgh (mass, gravity, height)
- Kinetic energy
- $KE=1/2mv^2$ (mass, velocity)
- Radiant energy - energy can change from one form to another
- Law of conservation of energy-first law of thermodynamics

Temperature Scales




Celsius scale (°C)
120
100
80
60
40
20
0
−20
−40
−60
−80
−100
Boiling point of water
58° C (136° F) maximum observed surface temperature
15° C (59° F) global average temperature
Melting point of water
−89° C (−129° F) minimum observed surface temperature
°C = 5/9 (°F − 32)
°F = 9/5 °C + 32
K = 273.15 + °C
393.15
373.15
353.15
333.15
313.15
293.15
273.15
253.15
233.15
213.15
193.15
173.15
Kelvin scale (K)
−100 −80 −60 −40 −20 0 20 40 60 80 100 120 140 160 180 200 220
Fahrenheit scale (°F)

“Absolute Zero” Temperature

- The absolute zero temperature is the temperature at which the molecules do not move at all.

- This temperature occurs at –273° C.

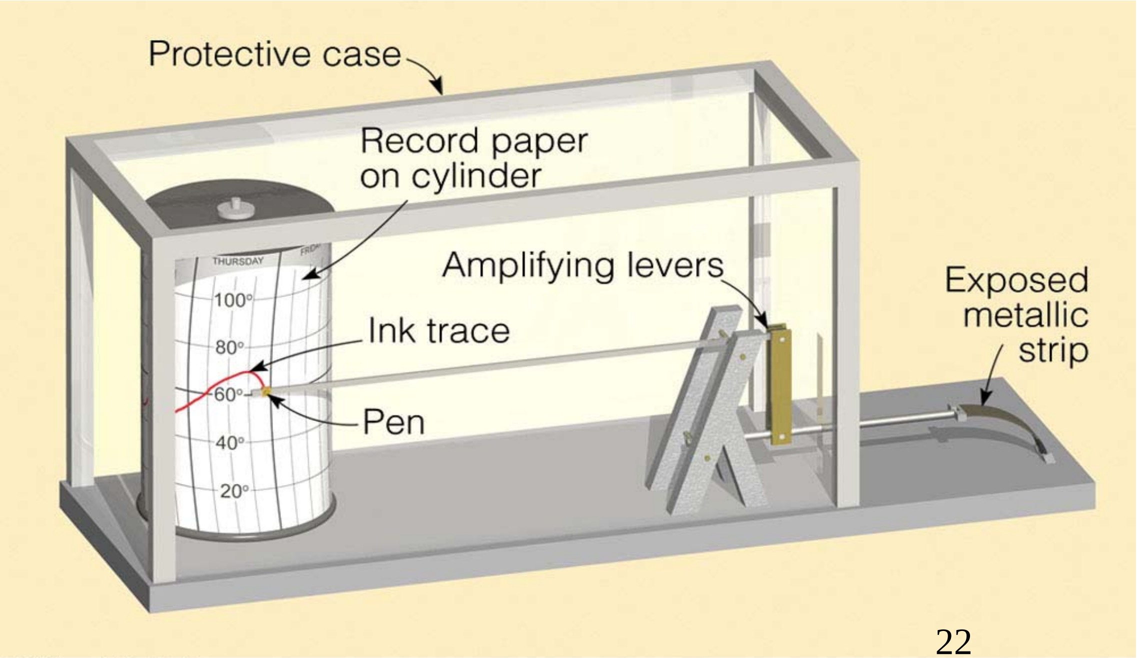
- The Kelvin Scale (K) is a new temperature scale that has its “zero” temperature at this absolute value.

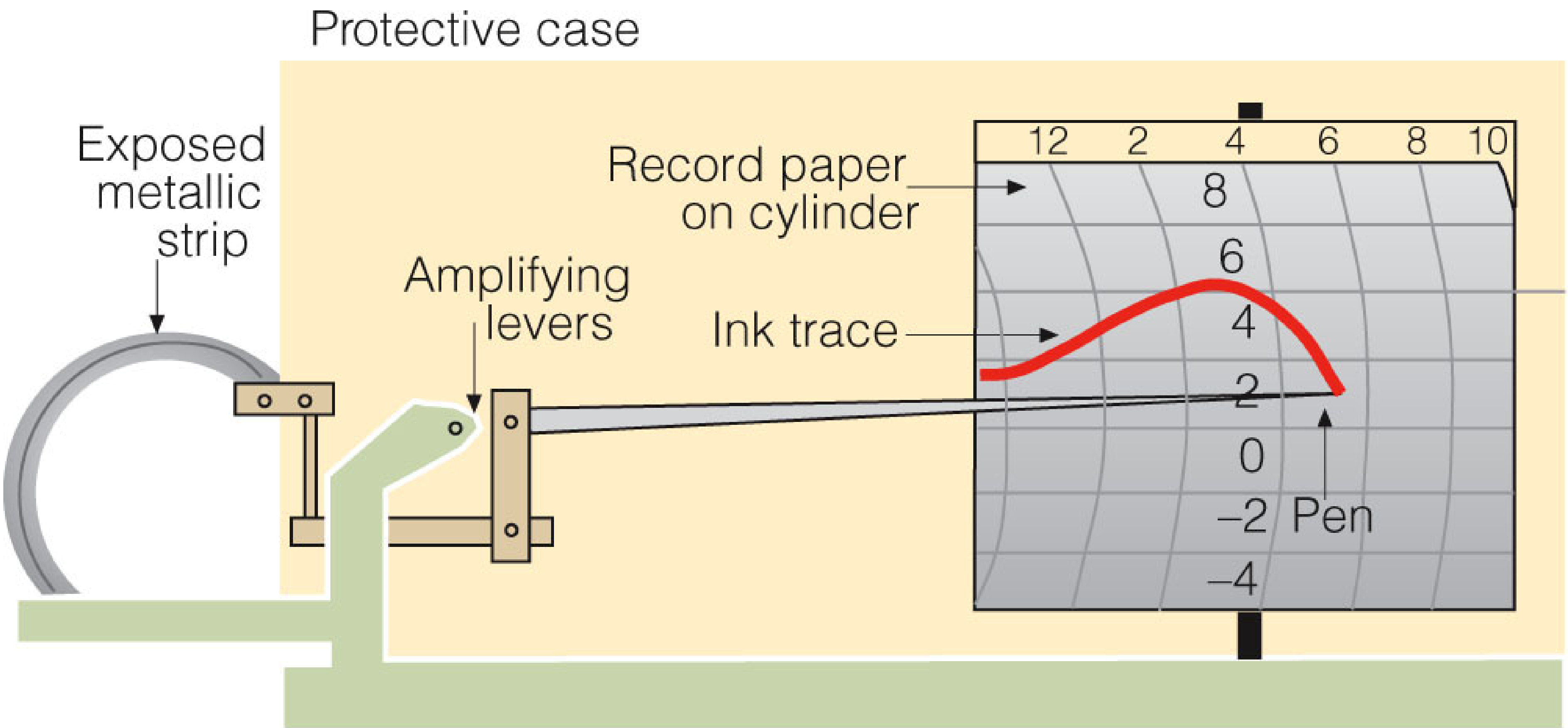
Measuring Air Temperature

- liquid-in-glass thermometers
- maximum and minimum thermometers
- bimetallic thermometers

Where measured: instrument shelters

- Temperatures can also be measured remotely using infrared sensors (radiometers).





The bi-metallic strip bends because the two metals expand differently. The extent of the bending depend on temperature. Bending can be calibrated to ambient temperature. The levers amplify the deformation and allow the arm to record changes in temperature.

Shelters protect from sun and openings provide ventilation.
At 1.5 m level, chance influences from the surface are small.

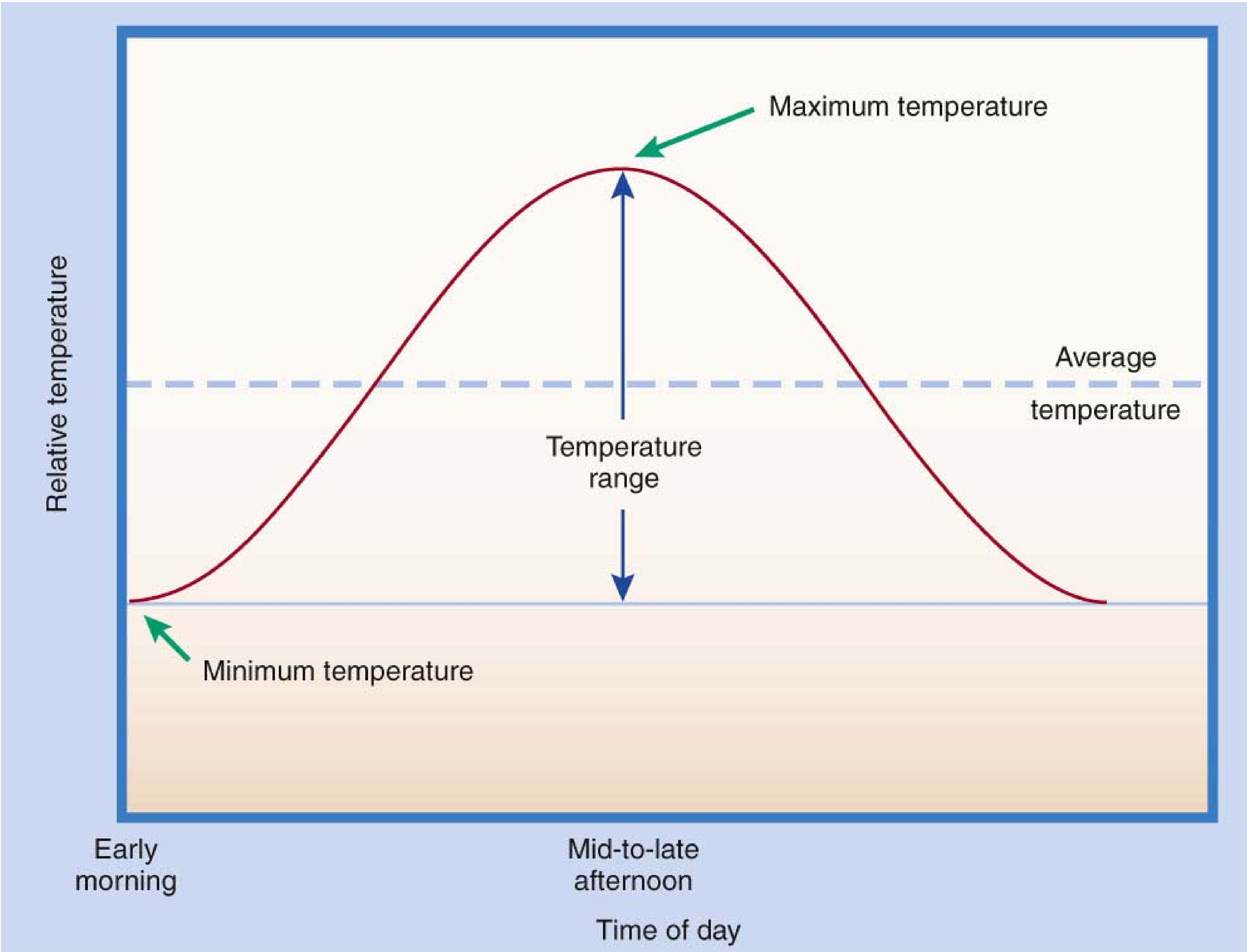
Daily, Monthly and Yearly Temperatures

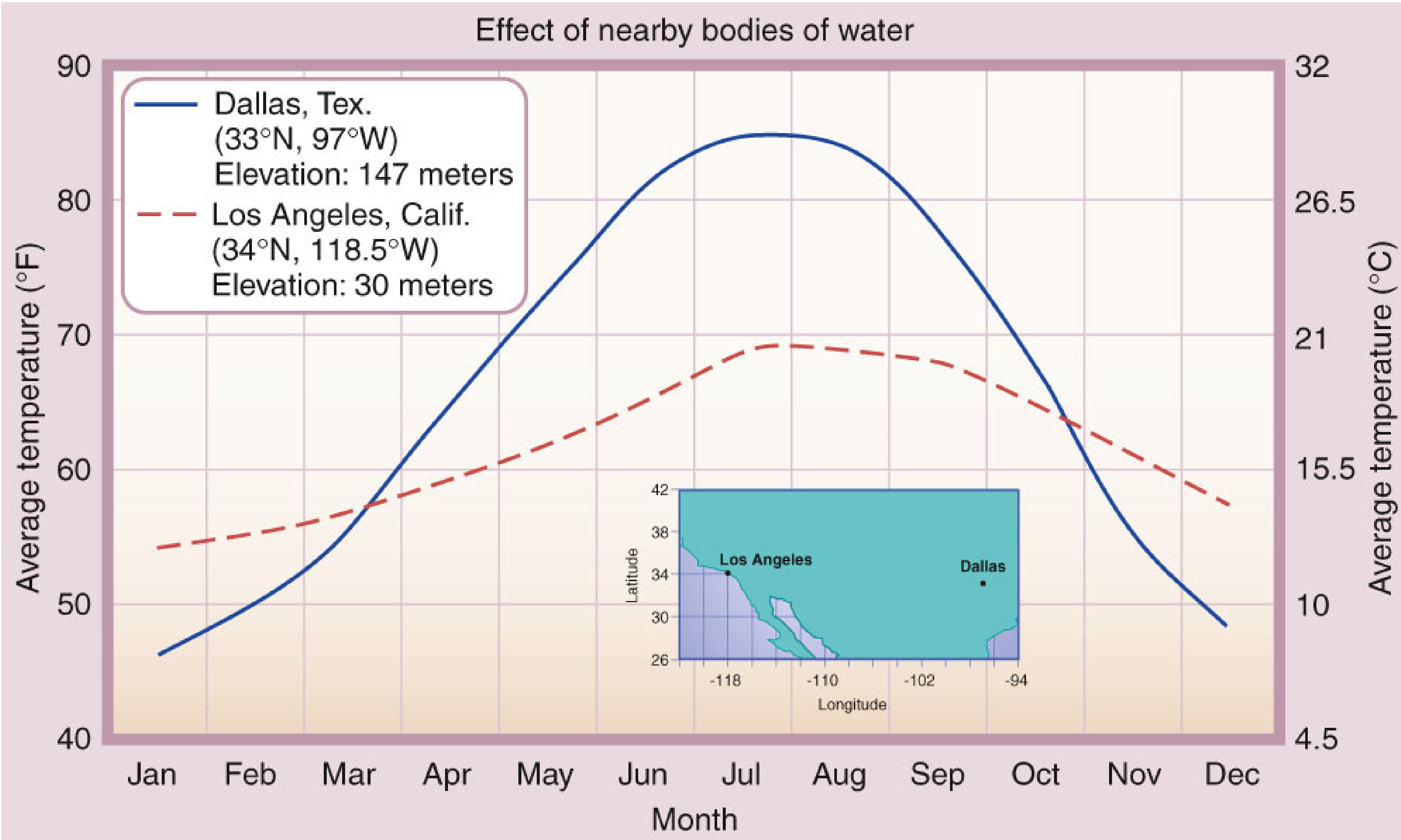
- diurnal temperature range
- annual temperature range

Controls of temperature

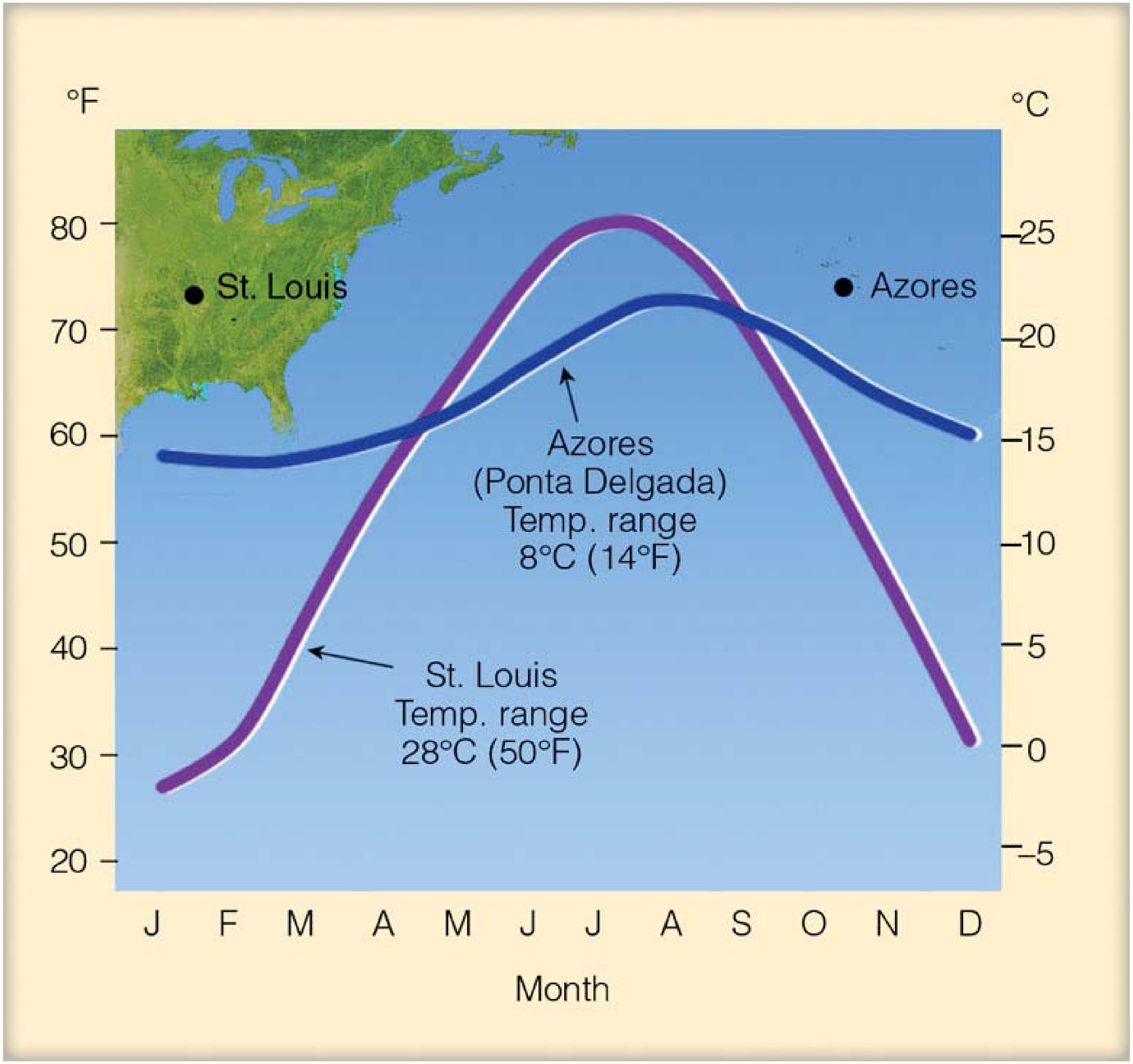
- latitude; land and water distribution; ocean currents; elevation

- clouds and humidity effects

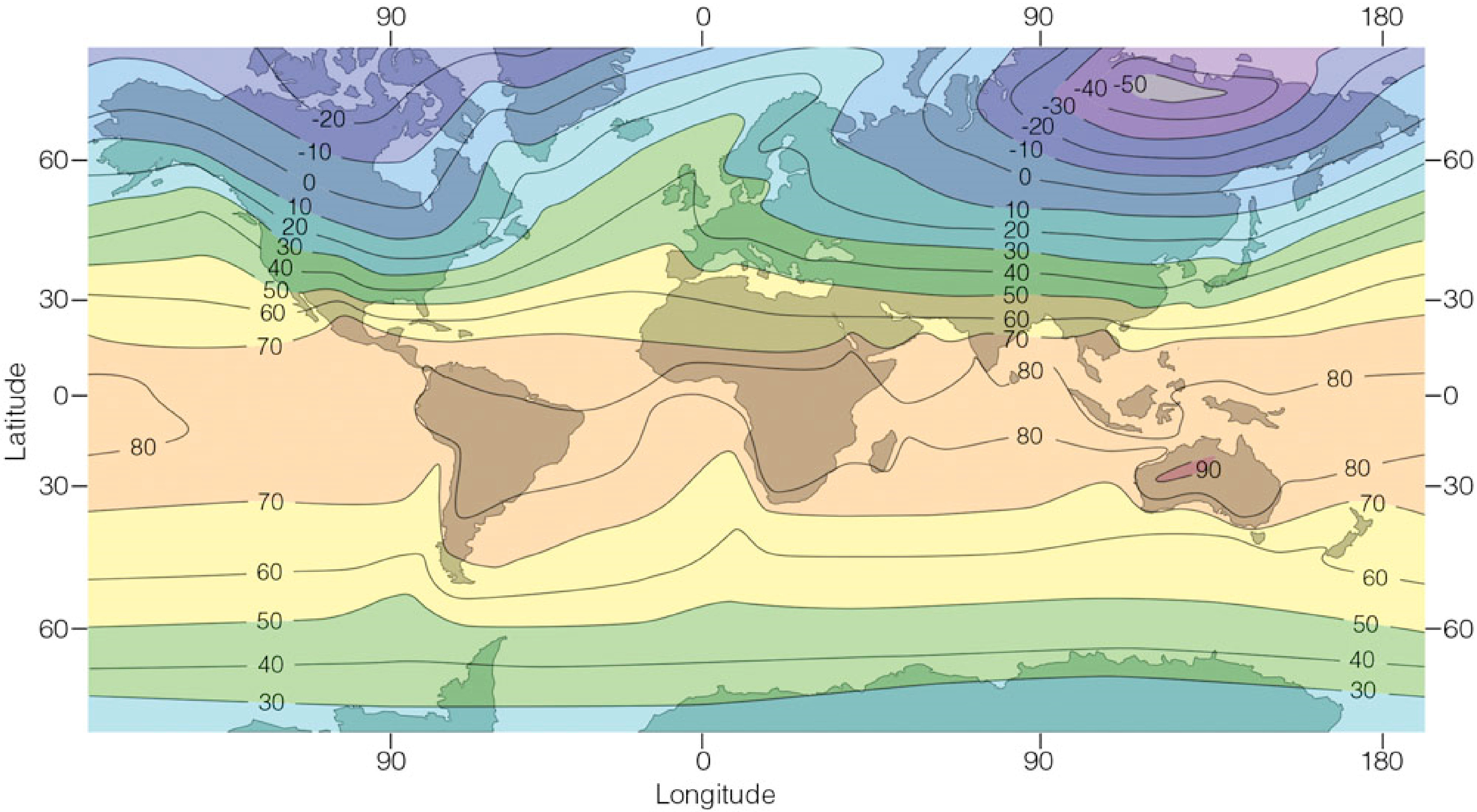

Maximum temperature
Relative temperature
Average
temperature
Temperature
range
Minimum temperature
Early
morning
Mid-to-late
afternoon
Time of day



Effect of nearby bodies of water
Dallas, Tex.
(33°N, 97°W)
Elevation: 147 meters
Los Angeles, Calif.
(34°N, 118.5°W)
Elevation: 30 meters
Average temperature (°F)
90
80
70
60
50
40
Average temperature (°C)
32
26.5
21
15.5
10
4.5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Latitude
42
38
34
30
26
Los Angeles
Dallas
-118
-110
-102
-94
Longitude


°F
°C
80
70
60
50
40
30
20
25
20
15
10
5
0
–5
St. Louis
Azores
Azores
(Ponta Delgada)
Temp. range
8°C (14°F)
St. Louis
Temp. range
28°C (50°F)
J F M A M J J A S O N D
Month

Average air temperature near sea level January (F)



Average air temperature near sea level July (F)

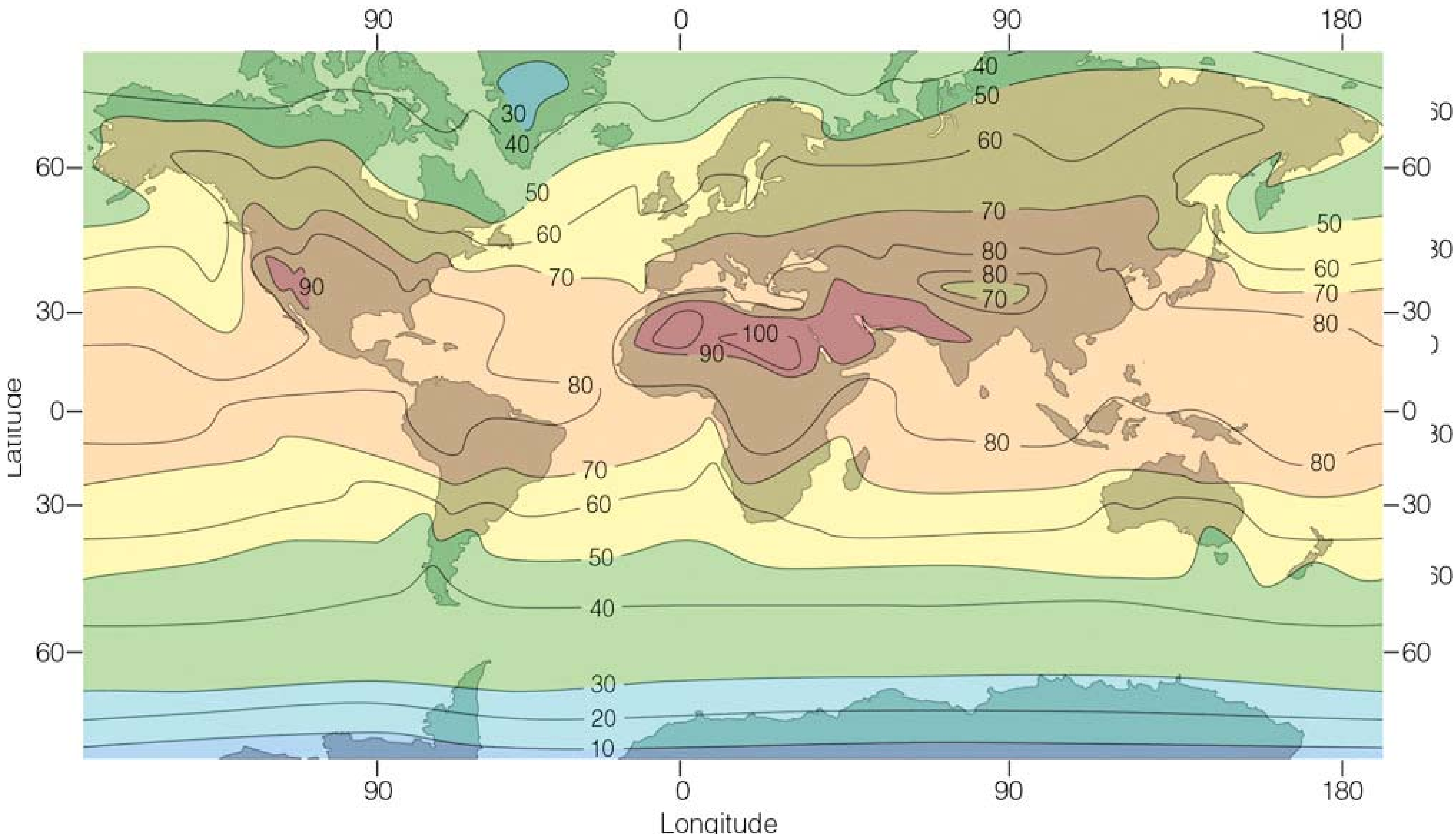


TABLE 2

Some Record Low Temperatures Throughout the World

LOCATION (LATITUDE)	RECORD LOW TEMPERATURE (°C)	(°F)	RECORD FOR:	DATE
Vostok, Antarctica (78°S)	–89	–129	The world	July 21, 1983
Verkhoyansk, Russia (67°N)	–68	–90	Northern Hemisphere	February 7, 1892
Northice, Greenland (72°N)	–66	–87	Greenland	January 9, 1954
Snag, Yukon (62°N)	–63	–81	North America	February 3, 1947
Prospect Creek, Alaska (66°N)	–62	–80	Alaska	January 23, 1971
Rogers Pass, Montana (47°N)	–57	–70	U.S. (excluding Alaska)	January 20, 1954
Sarmiento, Argentina (34°S)	–33	–27	South America	June 1, 1907
Ifrane, Morocco (33°N)	–24	–11	Africa	February 11, 1935
Charlotte Pass, Australia (36°S)	–22	–8	Australia	July 22, 1949
Mt. Haleakala, Hawaii (20°N)	–10	14	Hawaii	January 2, 1961

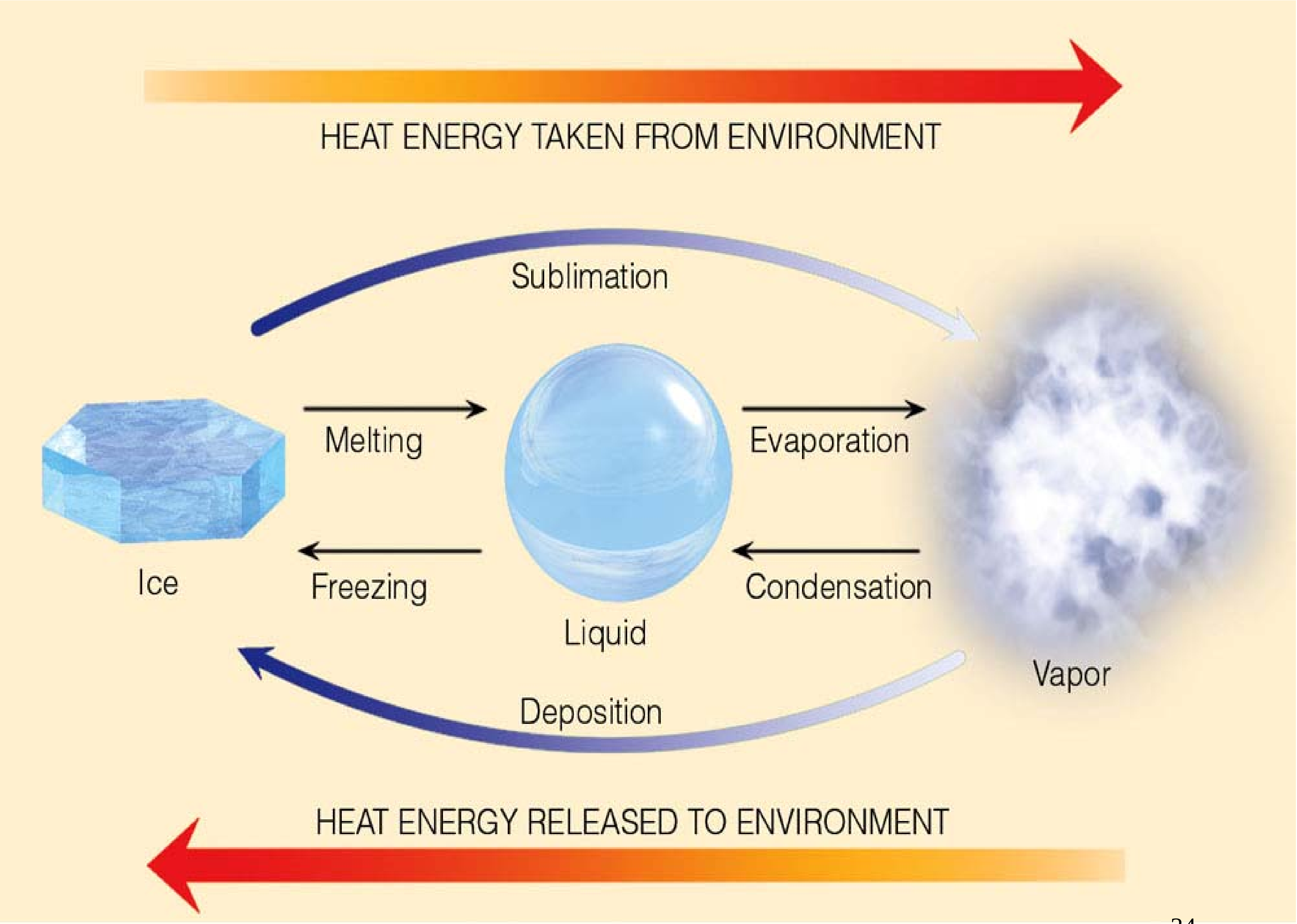
Important concept-Latent Heat
First: What is Specific Heat?

- Heat - Energy in the process of being transferred from one object to another because of the temperature difference between them
- *Heat capacity*-the ratio of heat energy absorbed by a substance to its corresponding temperature rise
- Heat capacity per unit mass-*specific heat*
- Latent Heat-energy required to change a substance from one state to another

• TABLE 2.1

Specific Heat of Various Substances

SUBSTANCE	SPECIFIC HEAT (Cal/g × °C)	J/kg × °C
Water (pure)	1.00	4186
Wet mud	0.60	2512
Ice (0°C)	0.50	2093
Sandy clay	0.33	1381
Dry air (sea level)	0.24	1005
Quartz sand	0.19	795
Granite	0.19	794


HEAT ENERGY TAKEN FROM ENVIRONMENT
Sublimation
Melting
Evaporation
Ice
Freezing
Condensation
Liquid
Vapor
Deposition
HEAT ENERGY RELEASED TO ENVIRONMENT

Important in meteorology:

Latent Heat - The Hidden Warmth

- latent heat of vaporization (or condensation); fusion (from solid to liquid or vice versa); and sublimation (from solid to vapor and vice versa)
- At 0° C :
- L_v = 597.3 cal/gm
- L_f = 79.7 cal/gm
- L_s = 677.0 cal/gm