Overview of the Earth's Atmosphere

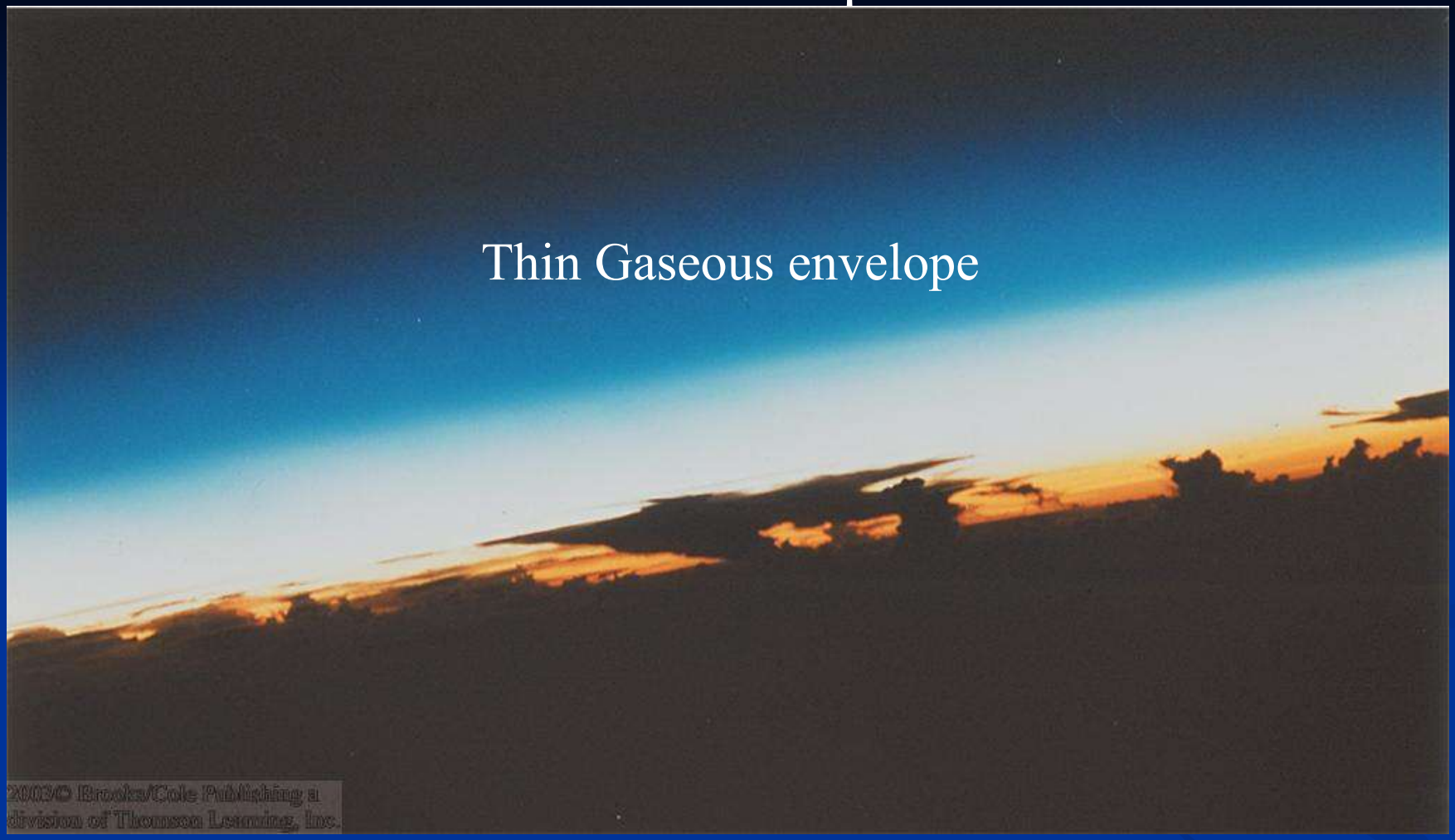
- The atmosphere, when scaled to the size of an apple, is no thicker than the skin on an apple.

- The atmosphere is a gas.

The atmosphere is a fluid.

There is a surface but no "top" – the atmosphere
- gradually thins out with increasing altitude

Earth's Atmosphere



99% of atmospheric gases, including water vapor, extend only 30 kilometer (km) above earth's surface.

Most of our weather, however, occurs within the first 10 to 15

Composition of the Atmosphere

- permanent gases
  - roles of nitrogen, oxygen and argon
- variable gases
  - role of water vapor
- trace gases
  - carbon dioxide, methane, ozone, CFCs, et al.
- aerosols

Composition of the Atmosphere

- The "dry atmosphere": 78% N_2, 21% O_2, 1% Ar
  - N_2 is primordial – it's been part of the atmosphere as long as there's been an atmosphere
  - O_2 has been rising from none at all about 2.2 Gya – comes from photosynthesis
  - Ar^{40}/Ar^{36} tells us that the atmosphere has been outgassed from volcanoes

Composition of the Atmosphere

- Water Vapor: H_2O 0-4%
  - H_20 can exist in all three phases at the surface of the Earth – solid, liquid and gas
  - Liquid or solid H_2O can be suspended by atmospheric winds (clouds) or fall to the surface (precipitation)
  - VERY powerful greenhouse gas (both in vapor form and as clouds)

Composition of the Atmosphere

- The Hydrological Cycle

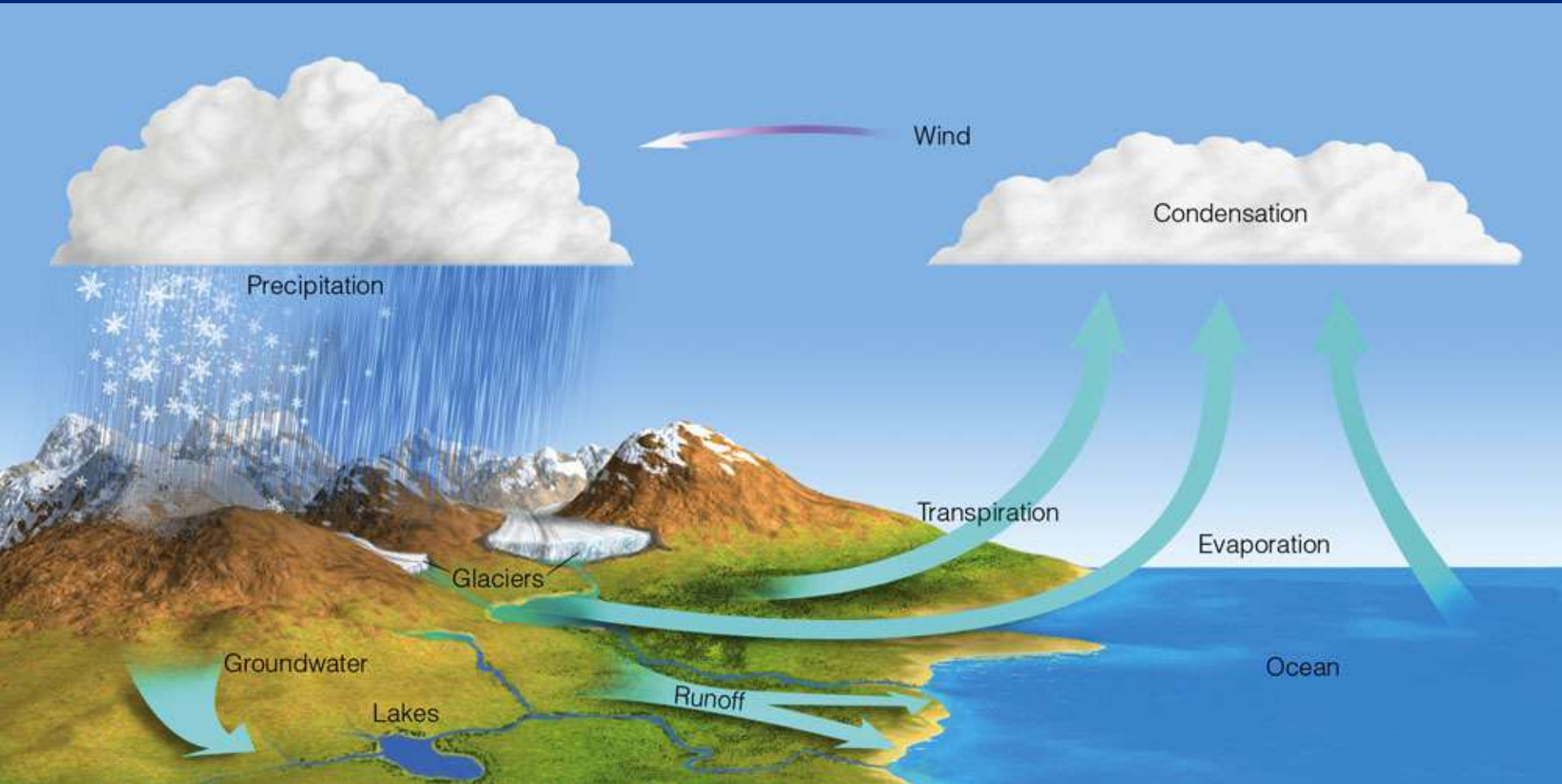


TABLE 1.1 Composition of the Atmosphere Near the Earth's Surface

PERMANENT GASES			VARIABLE GASES			
Gas	*Symbol*	*Percent (by Volume) Dry Air*	*Gas (and Particles)*	*Symbol*	*Percent (by Volume)*	*Parts per Million (ppm)**
Nitrogen	N_2	78.08	Water vapor	H_2O	0 to 4	
Oxygen	O_2	20.95	Carbon dioxide	CO_2	0.038	380*
Argon	Ar	0.93	Methane	CH_4	0.00017	1.7
Neon	Ne	0.0018	Nitrous oxide	N_2O	0.00003	0.3
Helium3	He	0.0005	Ozone	O_3	0.000004	0.04**
Hydrogen	H_2	0.00006	Particles (dust, soot, etc.)		0.000001	0.01–0.15
Xenon	Xe	0.000009	Chlorofluorocarbons (CFCs)		0.00000002	0.0002

*For CO_2, 380 parts per million means that out of every million air molecules, 380 are CO_2 molecules.

**Stratospheric values at altitudes between 11 km and 50 km are about 5 to 12 ppm.

Composition of the Atmosphere

- Carbon dioxide
  - *390 ppm (by mass) and counting…*
  - Natural and anthropogenic sources/sinks
  - Strong greenhouse gas (GHG)

CO_2 is neither the strongest atmospheric GHG pound-for-pound nor molecule-for-molecule…

Why the fuss?

CO_2 is a product of the reaction that allows modern civilization to exist: combustion.

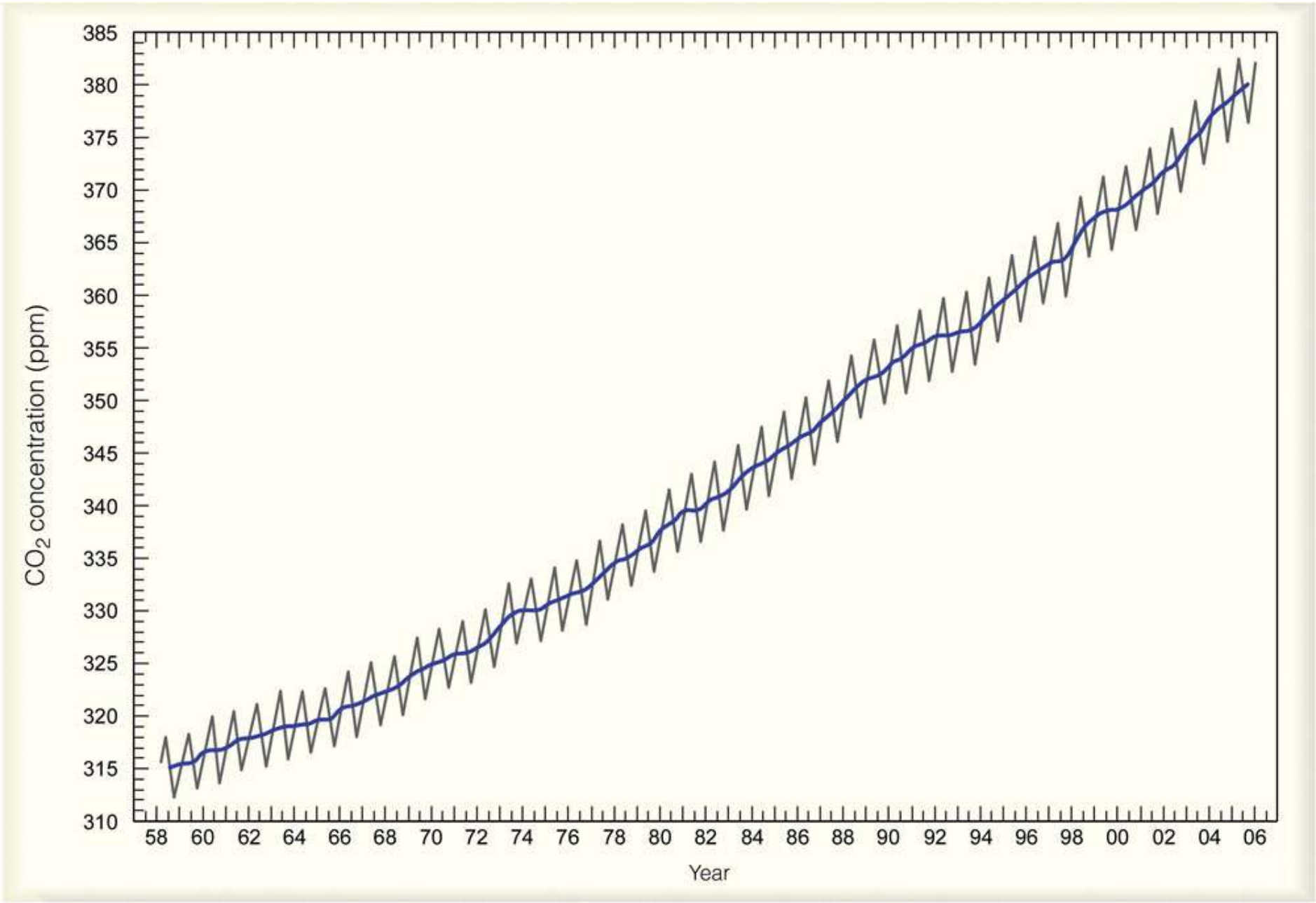
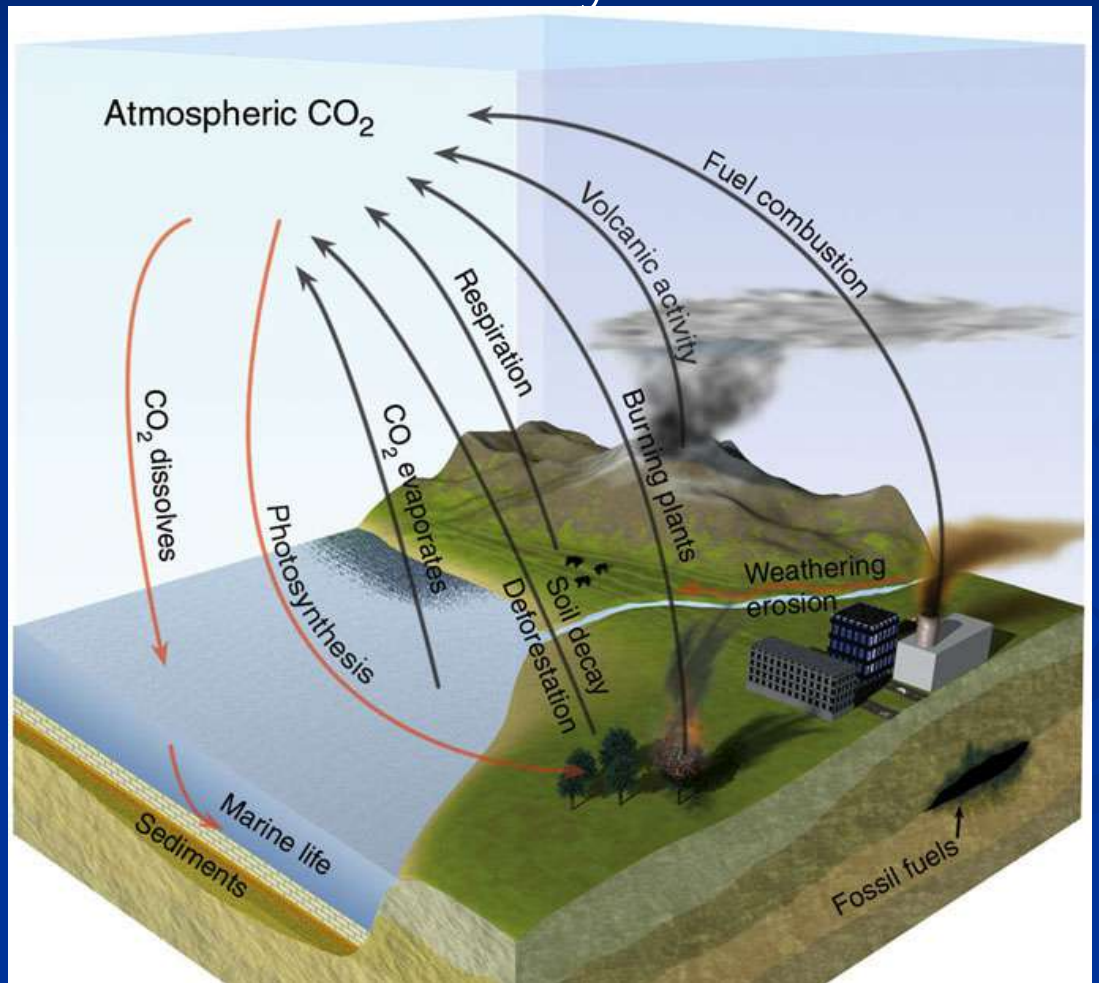


Fig. 1-4, p. 5

Composition of the Atmosphere

- The Global Carbon Cycle



Composition of the Atmosphere

- Methane
  - CH_4 concentration: 1.8 ppmv
  - anthropogenic and natural sources/sinks too
  - powerful greenhouse gas
  - oxidizes rapidly, hence low concentrations
  - Large concentrations proposed to explain greenhouse warming of early Earth

Composition of the Atmosphere

- Ozone, CFCs and NO_x
  - Ozone (O_3)
    - shields the surface from UV rays
    - produced by reaction with NO_x and sunlight near the surface
  - CFC's (Chlorofluorocarbons)
    - destroy stratospheric ozone
    - chlorine is a catalyst: it destroys one O_3 molecule and then is free to find another
      - Ozone at high altitudes (stratosphere) is "good"; ozone at low altitudes (troposphere) is "bad."

Atmospheric Gases

Nitrogen, oxygen, argon, water vapor, carbon dioxide, and most other gases are invisible.

Clouds are not gas, but condensed vapor in the form of liquid droplets.

Ozone – is the primary ingredient of smog!

Ground based smog, which is visible, contains reactants of nitrogen and

Aerosols & Pollutants

Human and natural activities displace tiny soil, salt, and ash particles as suspended aerosols, as well as sulfur and nitrogen oxides, and hydrocarbons as pollutants.

Composition of the Atmosphere

- Aerosols
  - Dust
  - Sea-spray
  - Microbes

  Suspended particles in the atmosphere are responsible for cloud formation: water drops nucleate on them

  Cloud Condensation Nuclei (CCN)

Other Atmospheres

YES	NO
Earth	The Moon
Mars	all the other satellites
Venus	Mercury
Jupiter	asteroids
Saturn	
Uranus	
Neptune	
Pluto	
Triton (Neptune's moon)	
Titan (Saturn's moon)	
The Sun	

Other Atmospheres

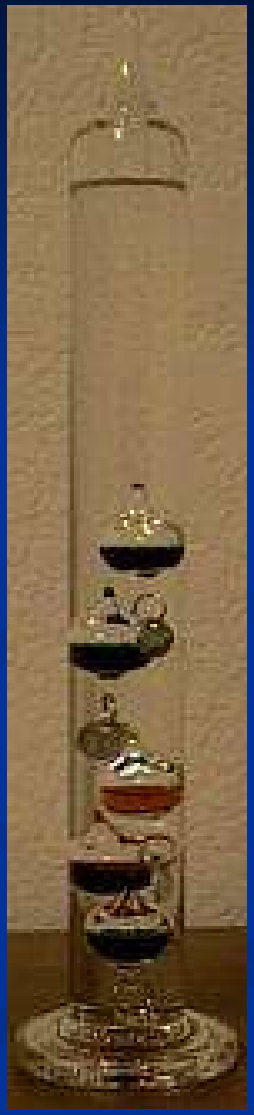
Planet	Composition	Temperature	Pressure
Venus	CO_2 96.5%, N_2 3.5%	750 K	90000 mb
Earth	N_2 78%, O_2 21%, Ar 1%	290K	1000 mb
Mars	CO_2 95%, N_2 2.7%, Ar 1.6%	220K	10 mb

History of Meteorology

- *Meteorology* is the study of the atmosphere and its phenomena
- Aristotle wrote a book on natural philosophy (340 BC) entitled "Meteorologica"
  - Sum knowledge of weather/climate at time
  - Meteors were all things that fell from the sky or were seen in the air
  - "meteoros" : Greek word meaning "high in air"

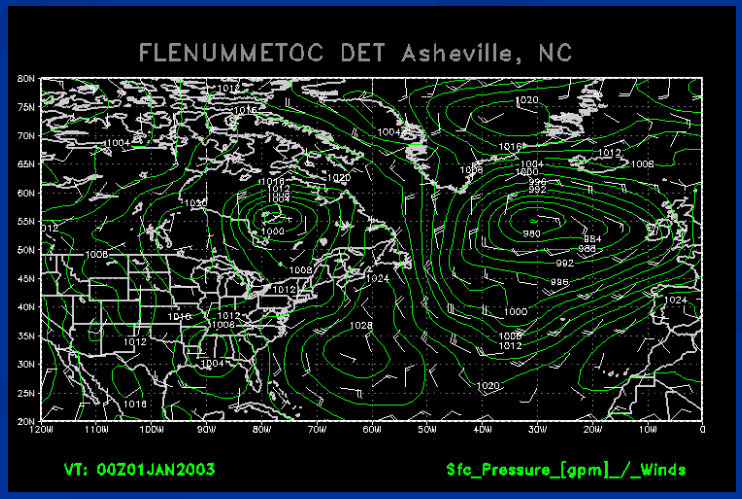
History of Meteorology

- Invention of weather instruments
  - 1500's Galileo invented water thermometer
  - 1643 Torricelli invented mercury barometer
  - 1667 Hooke invented anemometer
  - 1719 Fahrenheit developed temp scale based on boiling/freezing water
  - 1735 Hadley explained how the earth's rotation influences winds in tropics
  - 1742 Celsius developed the centigrade temp scale

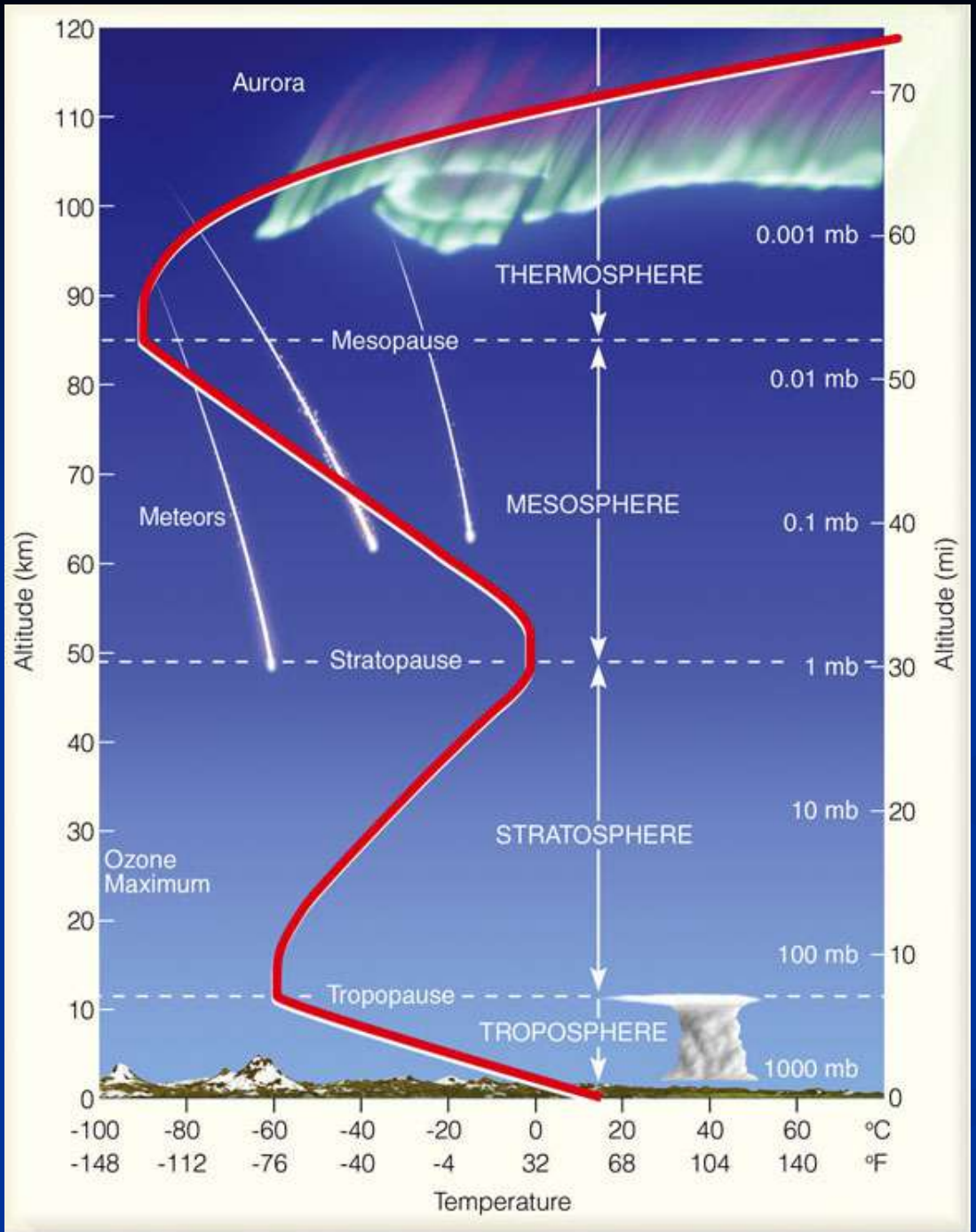


History of Meteorology

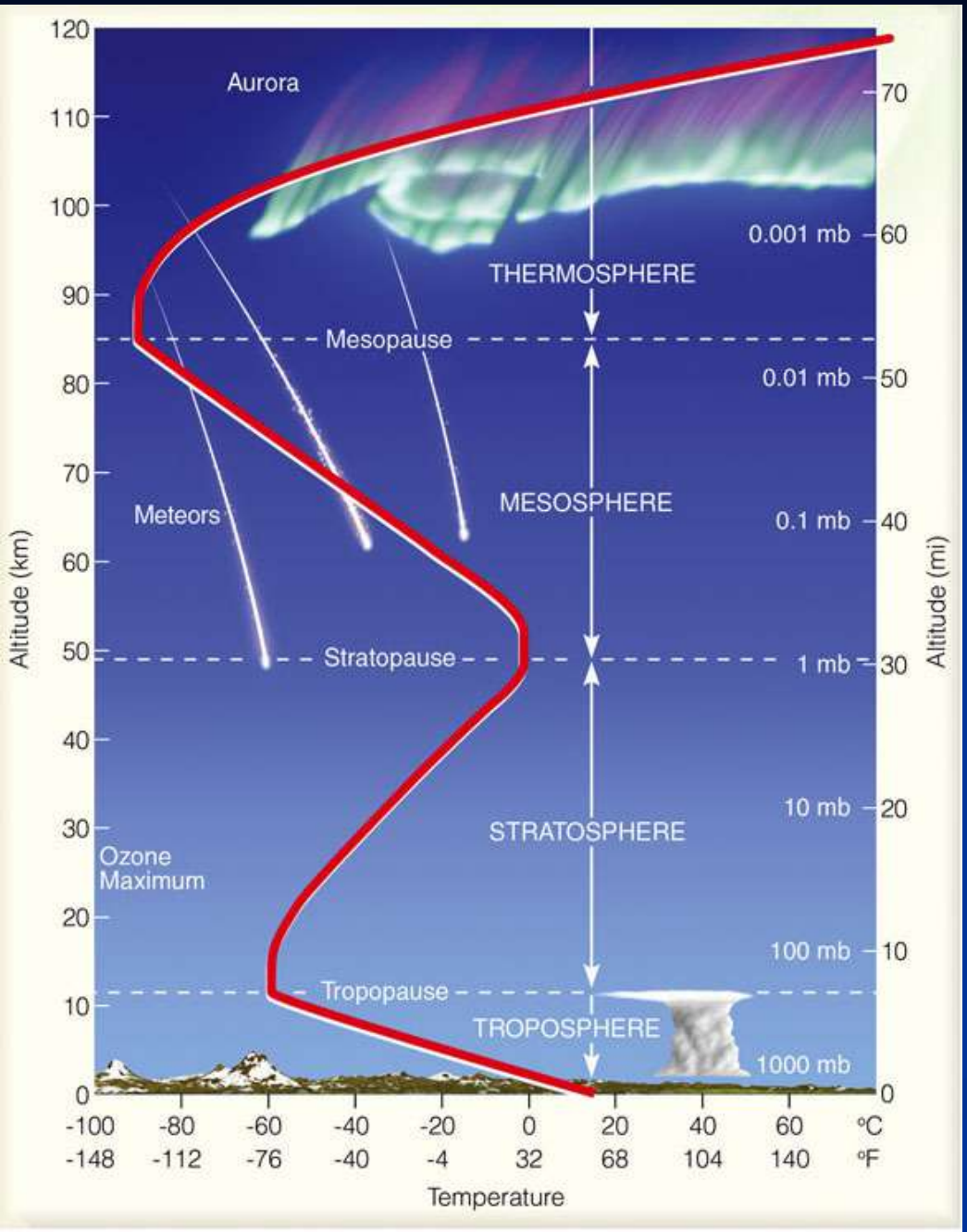
- 1787 Charles discovered relationship between temp and a volume of air
- 1835 Coriolis used math to demonstrate the effect that the earth's rotation has on atmos. Motions
- 1869 first isobars were placed on map
- 1920 concepts of air masses and weather fronts were formulated in Norway
- 1940's upper air ballons/3-D view of atmos
- 1950's high speed computers
- 1960 Tiros 1 first weather satellite



Vertical Structure of the Earth's Atmosphere



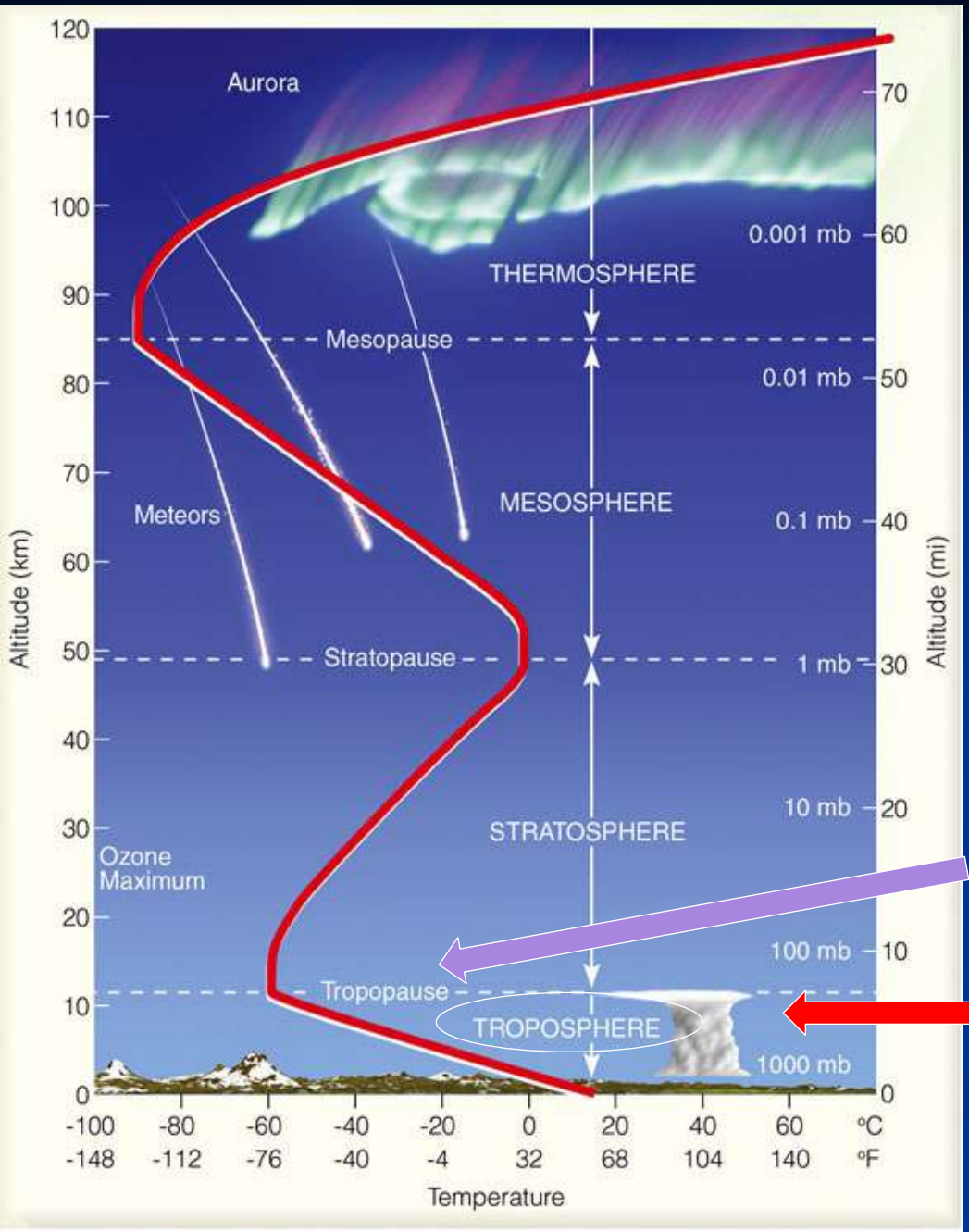
Atmospheric Layers



8 layers are defined by constant trends in average air temperature (which changes with pressure and radiation), where the outer exosphere is not shown.

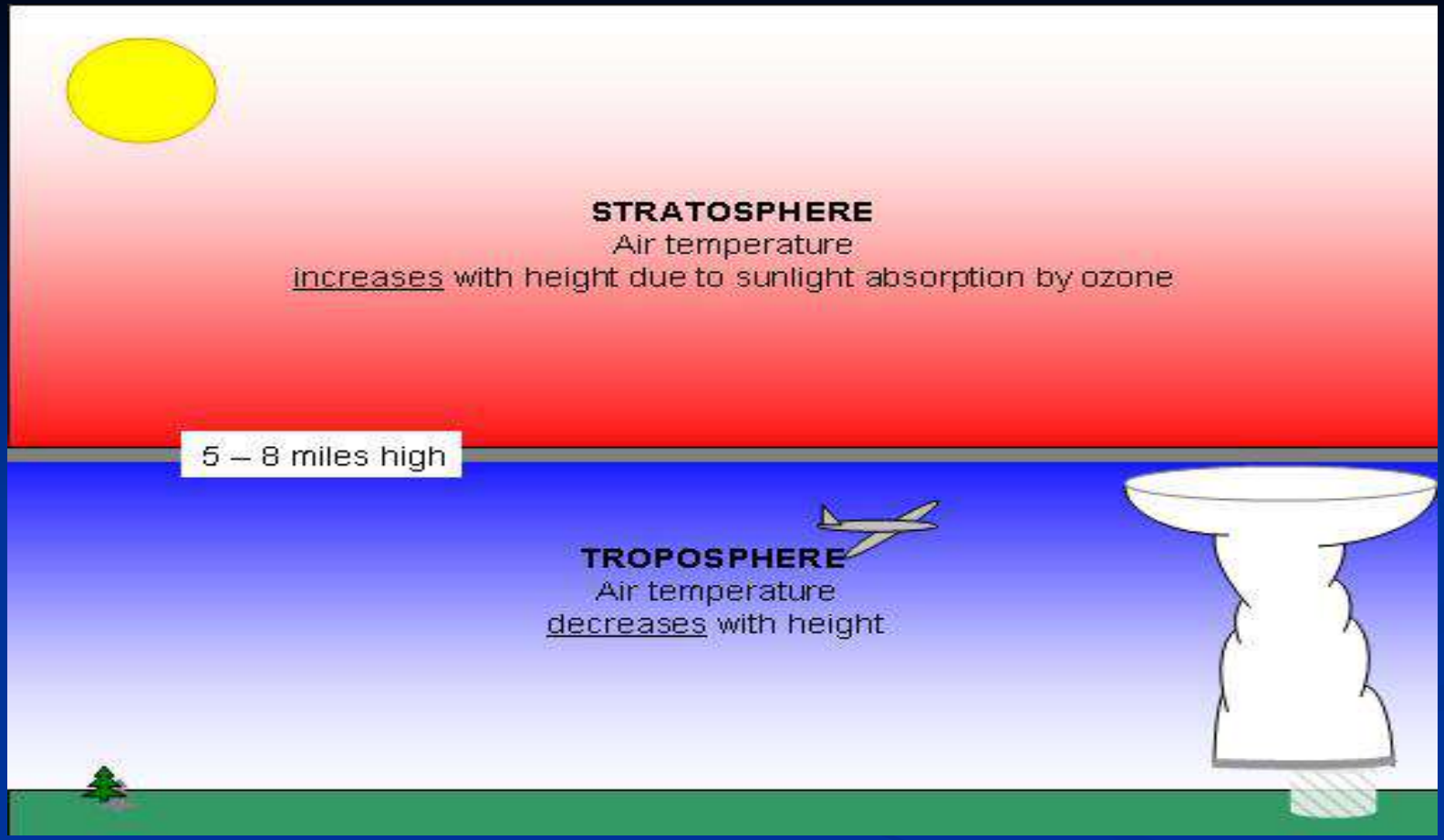
1. Troposphere
2. Tropopause
3. Stratosphere
4. Stratopause
5. Mesosphere
6. Mesopause
7. Thermosphere
8. Exosphere

Atmospheric Layers



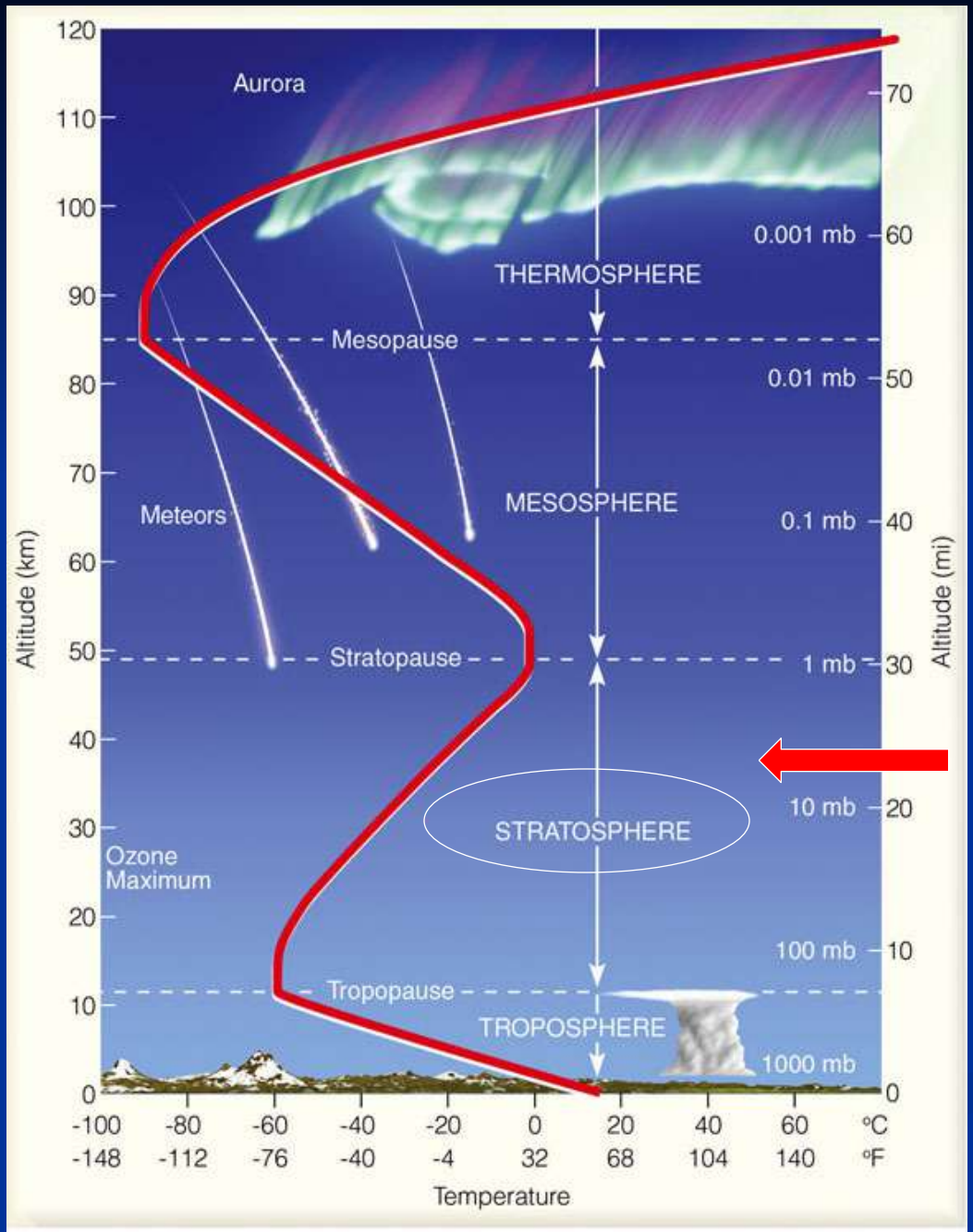
Tropopause separates Troposphere from Stratosphere. Generally higher in summer Lower in winter.

Troposphere – Temp decrease w/ height
Most of our weather occurs in this layer
Varies in height around the globe, but
Averages about 11 km in height.



The troposphere is the lowest major atmospheric layer, and is located from the Earth's surface up to the bottom of the stratosphere. It has decreasing temperature with height (at an average rate of 3.5° F per thousand feet (6.5 ° C per kilometer); whereas the stratosphere has either constant or slowly increasing temperature with height. The troposphere is where all of Earth's weather occurs. The boundary that divides the troposphere from the stratosphere is called the "tropopause", located at an altitude of around 5 miles in the winter, to around 8 miles high in the summer, and as high as 11 or 12 miles in the deep tropics. When you see the top of a thunderstorm flatten out into an anvil cloud, like in the illustration above, it is usually because the updrafts in the storm are "bumping up against" the bottom of the stratosphere

Atmospheric Layers



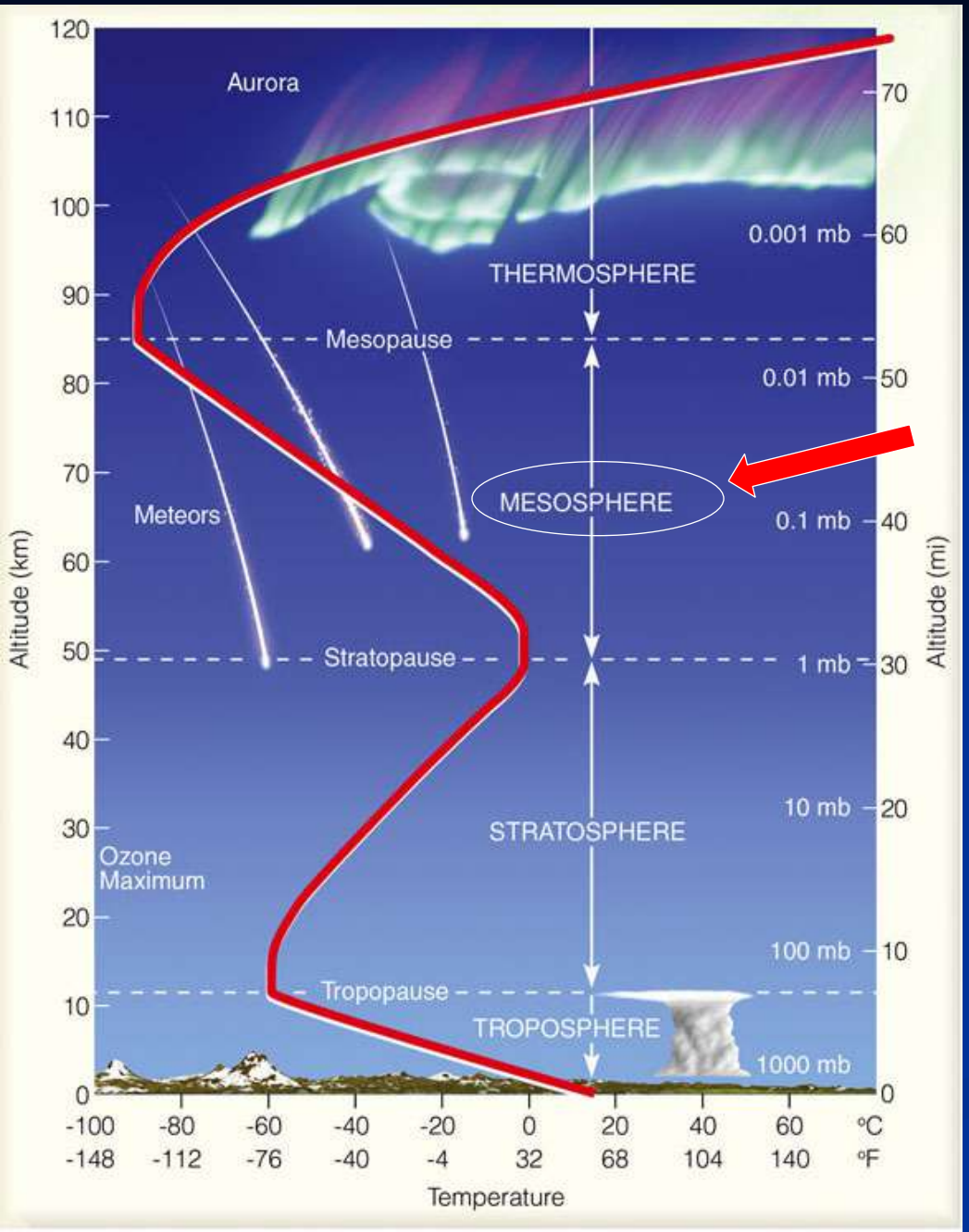
Stratosphere

Temperature inversion in stratosphere

Ozone plays a major part in heating the air

At this altitude

Atmospheric Layers



Mesosphere

Middle atmosphere – Air thin, pressure low, Need oxygen to live in this region.

Air quite Cold -90°C (-130°F) near the top of mesosphere

Atmospheric Layers

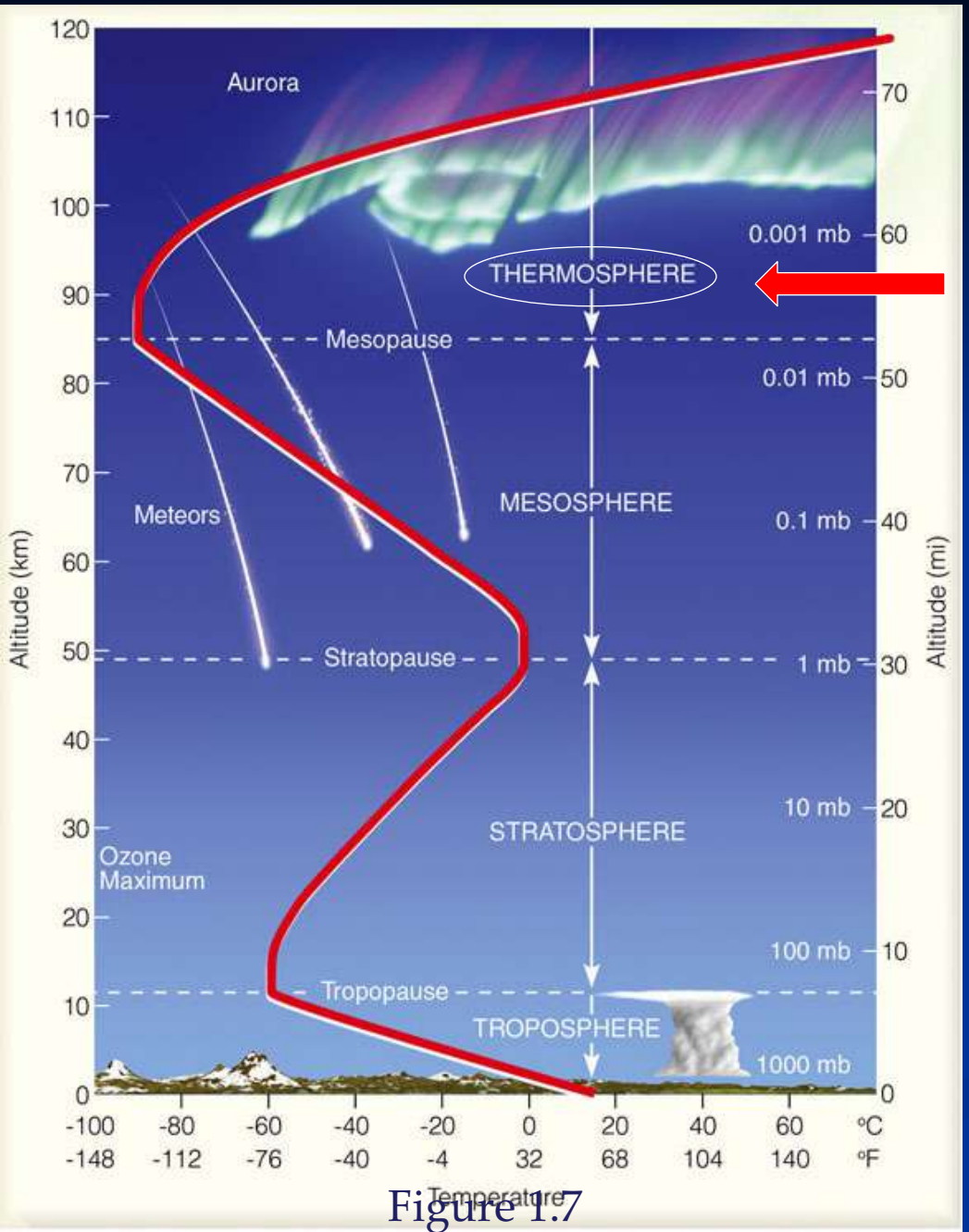
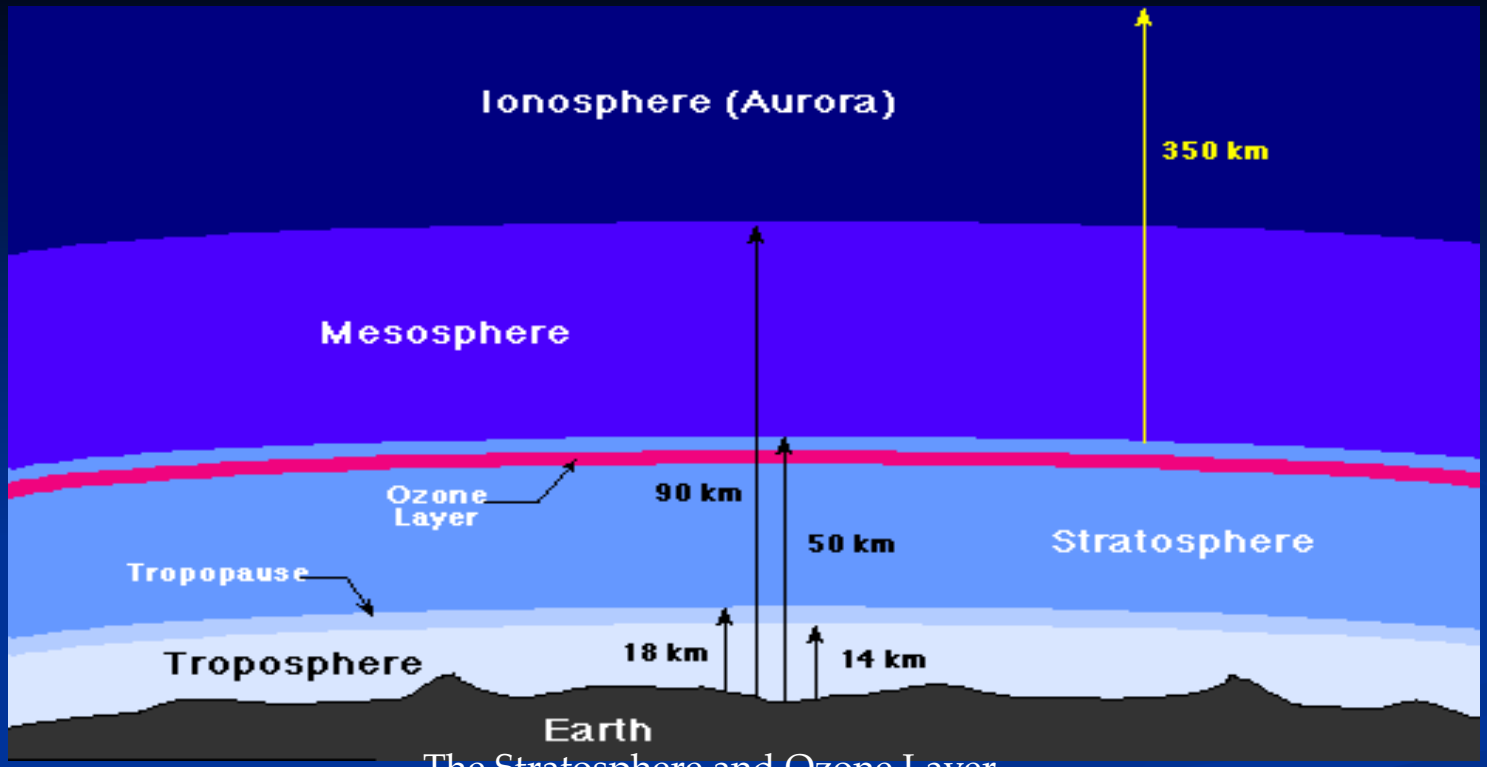


Figure 1.7

Thermosphere

"Hot layer" – oxygen molecules absorb energy from solar Rays warming the air. Very few atoms and molecules in this Region.



The Stratosphere and Ozone Layer

Above the troposphere is the *stratosphere*, where air flow is mostly horizontal. The thin ozone layer in the upper stratosphere has a high concentration of ozone, a particularly reactive form of oxygen. This layer is primarily responsible for absorbing the ultraviolet radiation from the Sun. The formation of this layer is a delicate matter, since only when oxygen is produced in the atmosphere can an ozone layer form and prevent an intense flux of ultraviolet radiation from reaching the surface, where it is quite hazardous to the evolution of life. There is considerable recent concern that manmade flourocarbon compounds may be depleting the ozone layer, with dire future consequences for life on the Earth.

The Mesosphere and Ionosphere

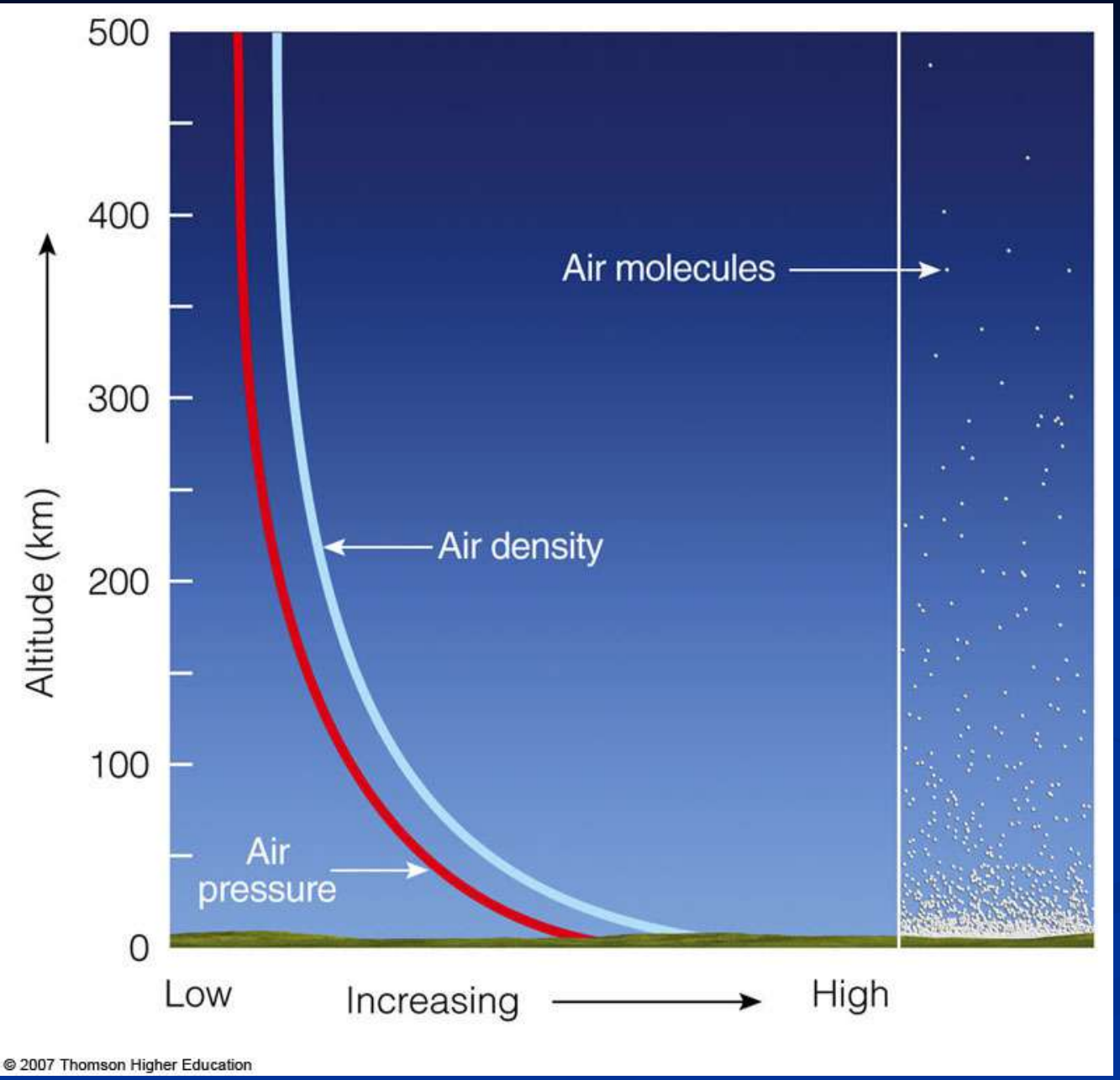
Above the stratosphere is the mesosphere and above that is the ionosphere (or *thermosphere*), where many atoms are ionized (have gained or lost electrons so they have a net electrical charge). The ionosphere is very thin, but it is where aurora take place, and is also responsible for absorbing the most energetic photons from the Sun, and for reflecting radio waves, thereby making long-distance radio communication possible.

A Brief Look at Air Pressure and Air Density

- air density (ϱ pronounced "row")
- air pressure (p)
- sea-level pressure (p_s)

  - Baseballs travel farther in higher-altitude air (Denver) than they do in lower-altitude air.

Pressure & Density



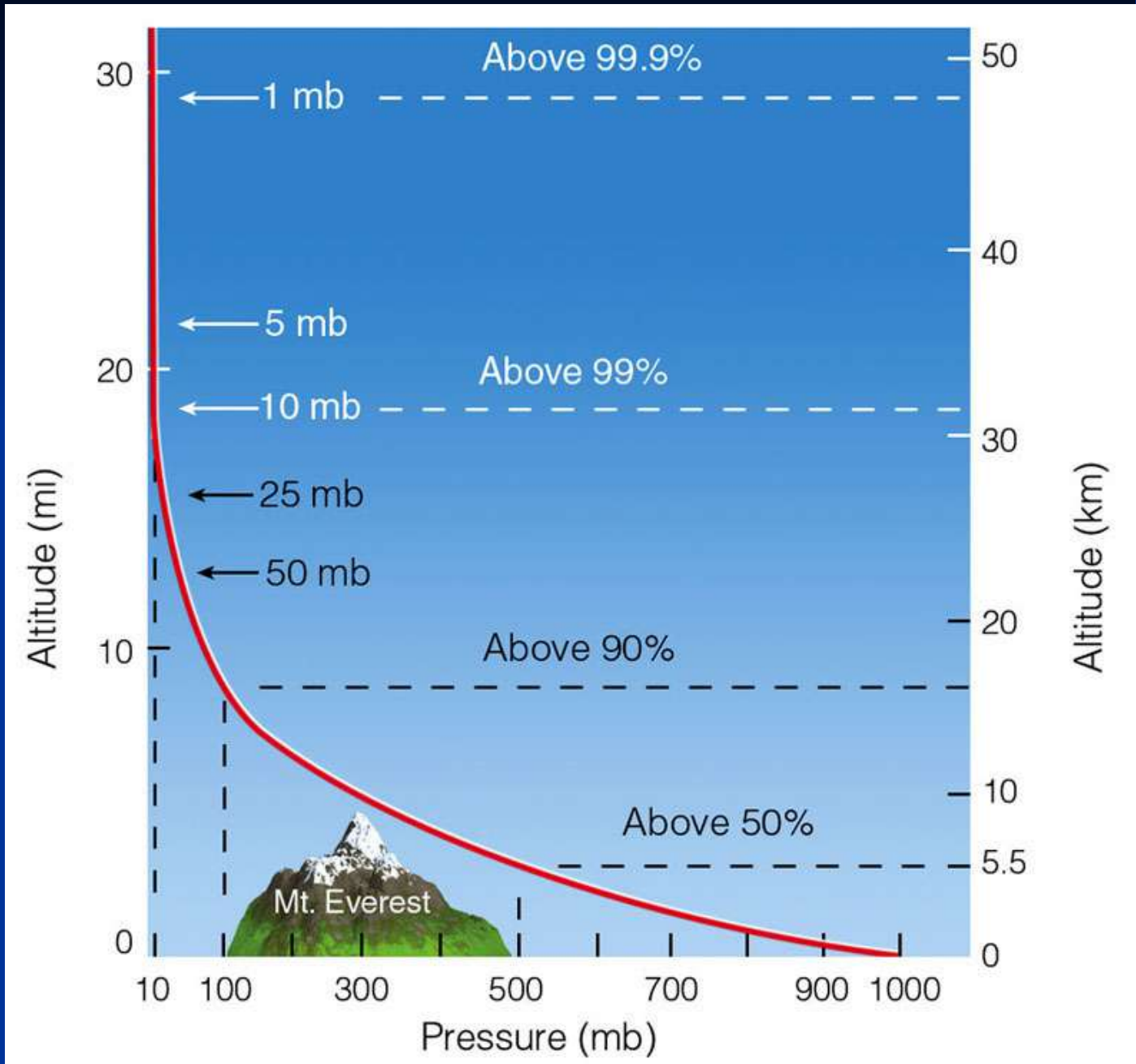
Gravity pulls gases toward earth's surface, and the whole column of gases weighs 14.7 psi at sea level, a pressure of 1013.25 mb or 29.92 in.Hg.

The amount of force exerted Over an area of surface is called Air pressure!

Air Density is The number of air Molecules in a given Space (volume)

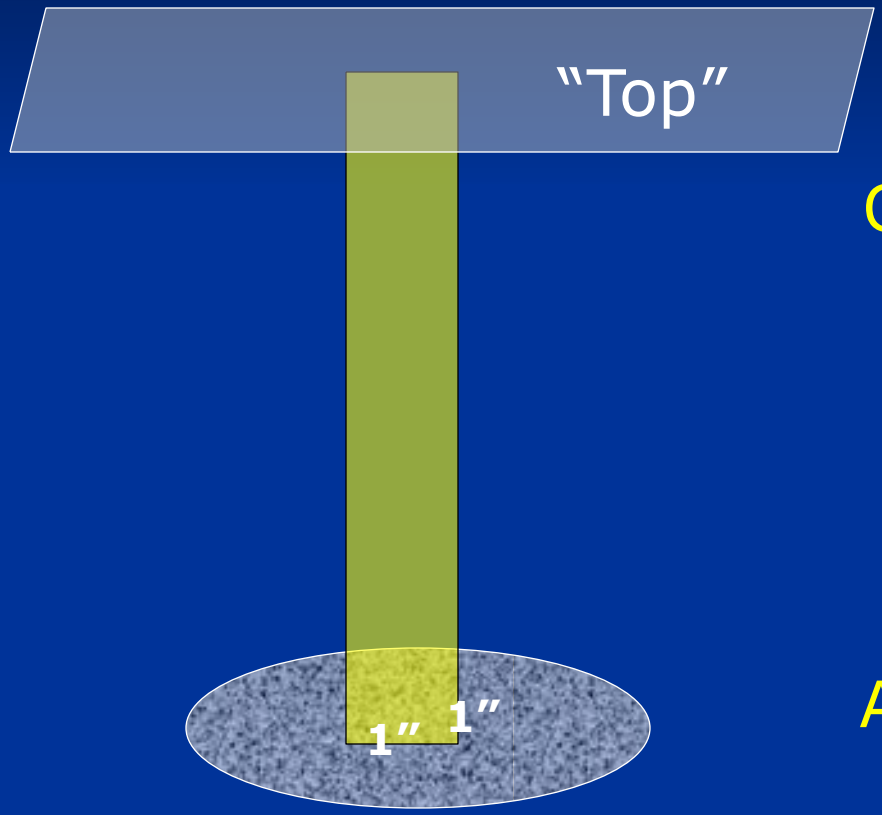
Vertical Pressure Profile

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.



Meteorology 101

Air Pressure



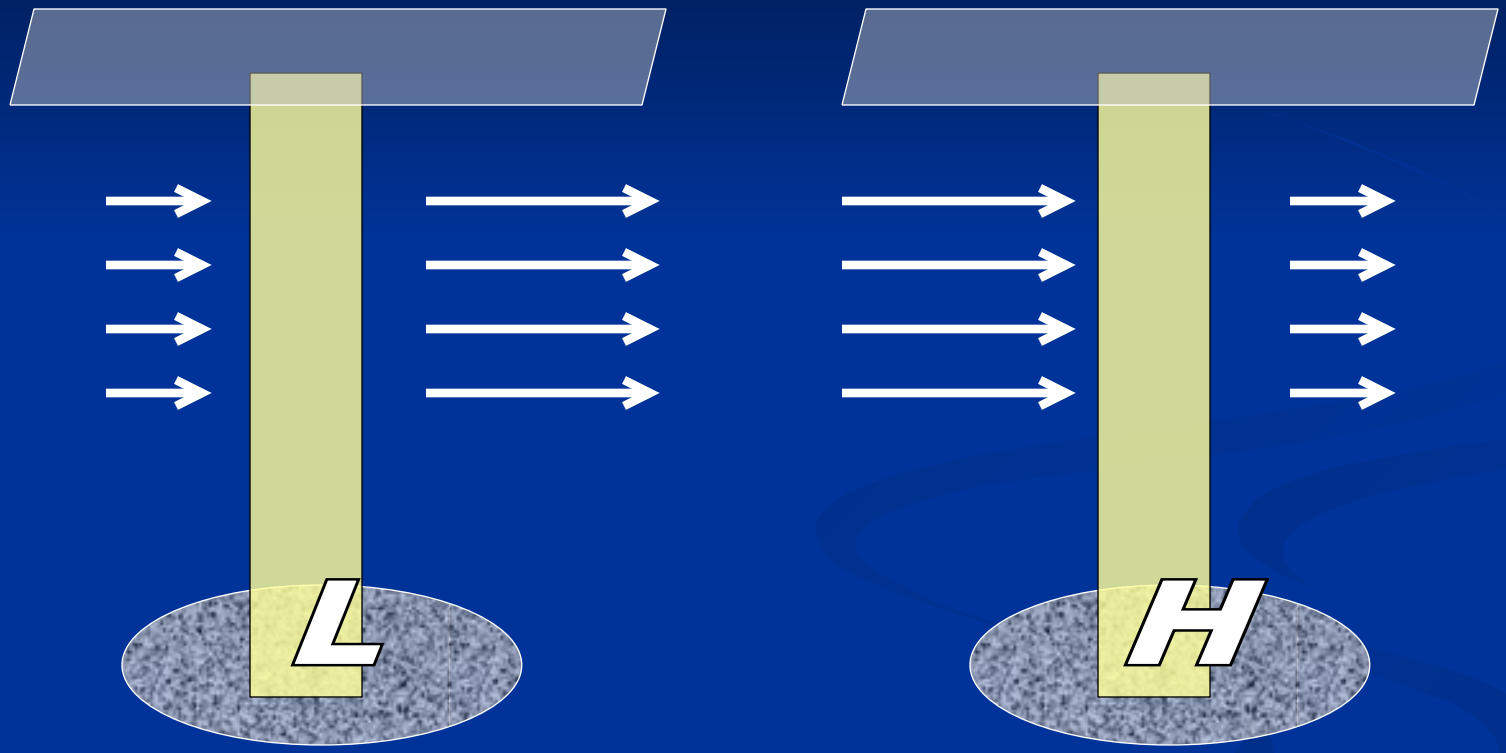
On average, air weighs about 14.7 lb/in^2

14.7 lb/in^2 =29.92 "inches of mercury"

Air Pressure varies over the globe

Meteorology 101

Changing Pressure - Winds



Take more out than put in – decrease pressure

Put more in than take out – increase pressure

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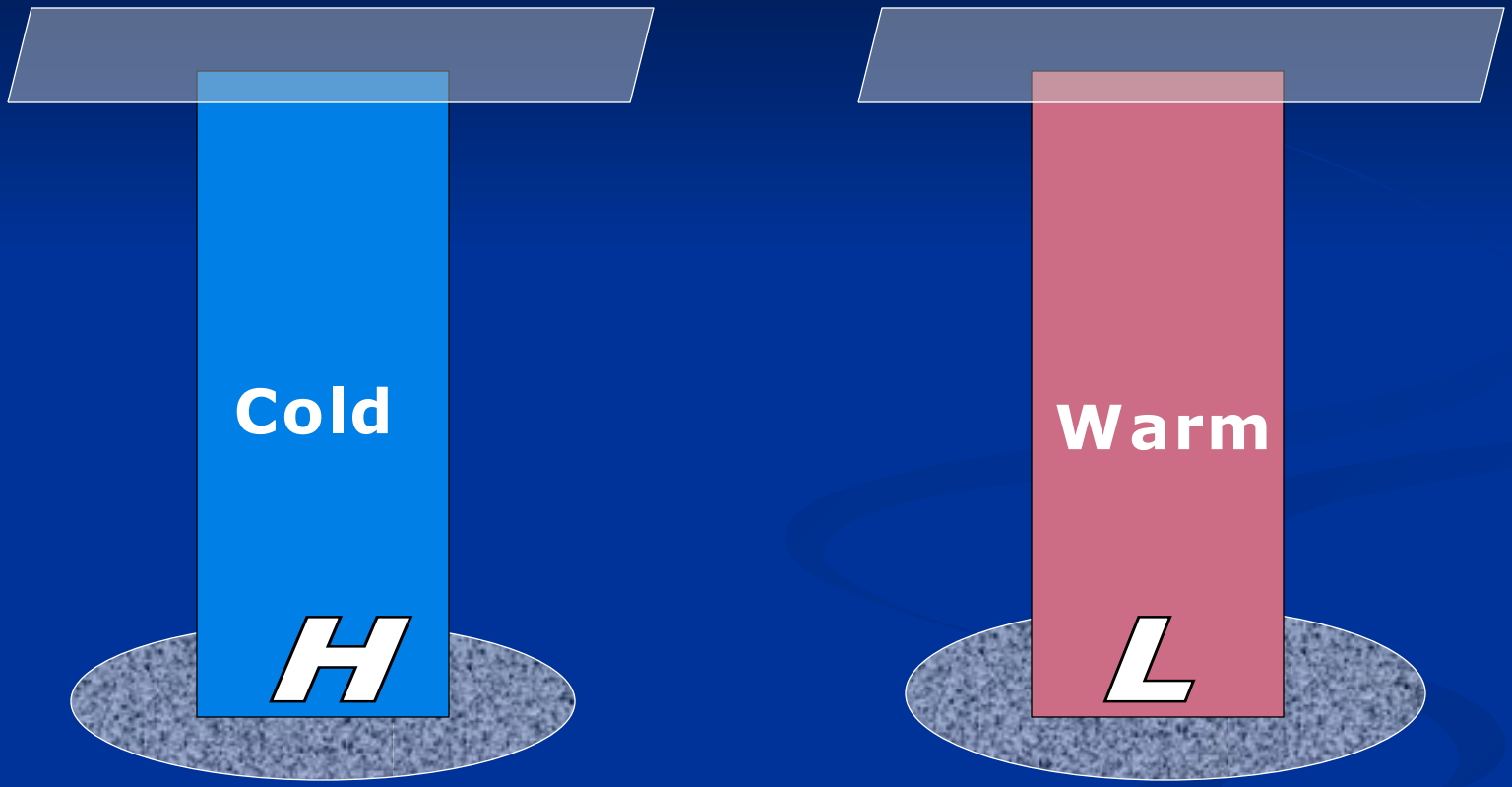
Changing Pressure - Temperature



Coldest column = highest pressure **
Warmest column = lowest pressure **

Meteorology 101

Rising Air near L ows

- Rising air cools; water vapor in the air condenses to form clouds/precipitation
- Lows tend to bring cloudy, wet weather

H

- Sinking air warms and dries out.
- Highs tend to bring fair, dry weather.

Meteorology 101

Some Fundamentals

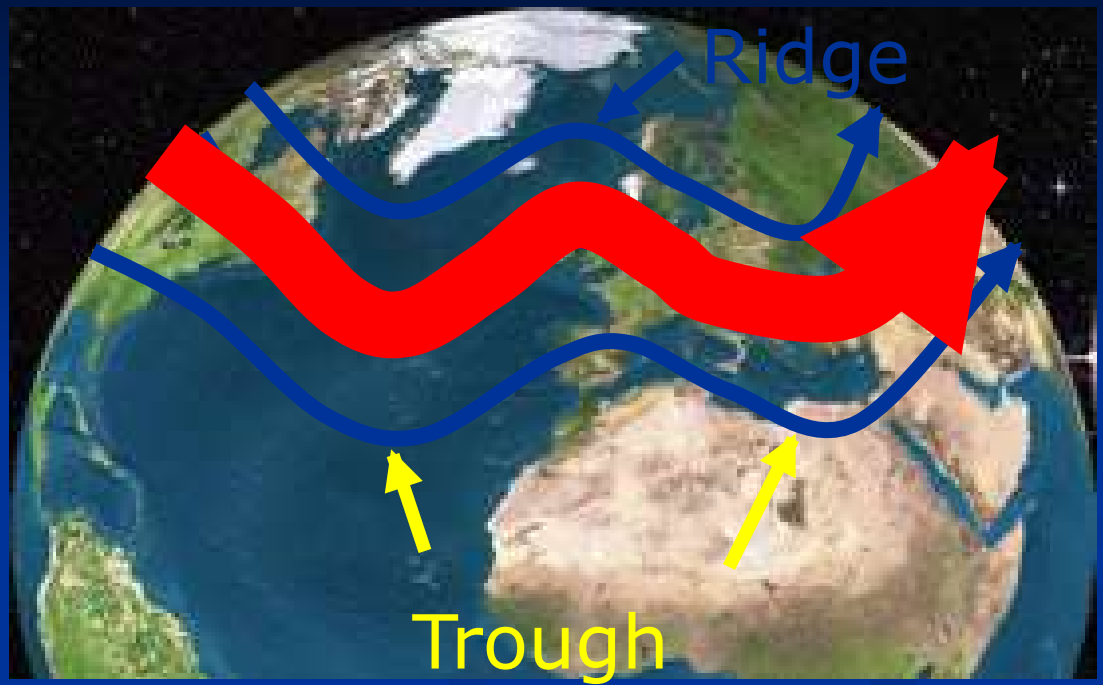
- Earth is heated unevenly: Tropics are warmer than the Polar Regions.

- Nature tries to try to even out temperature differences.

- Uneven heating sets atmosphere in motion and is the fundamental cause of all weather.

Meteorology 101

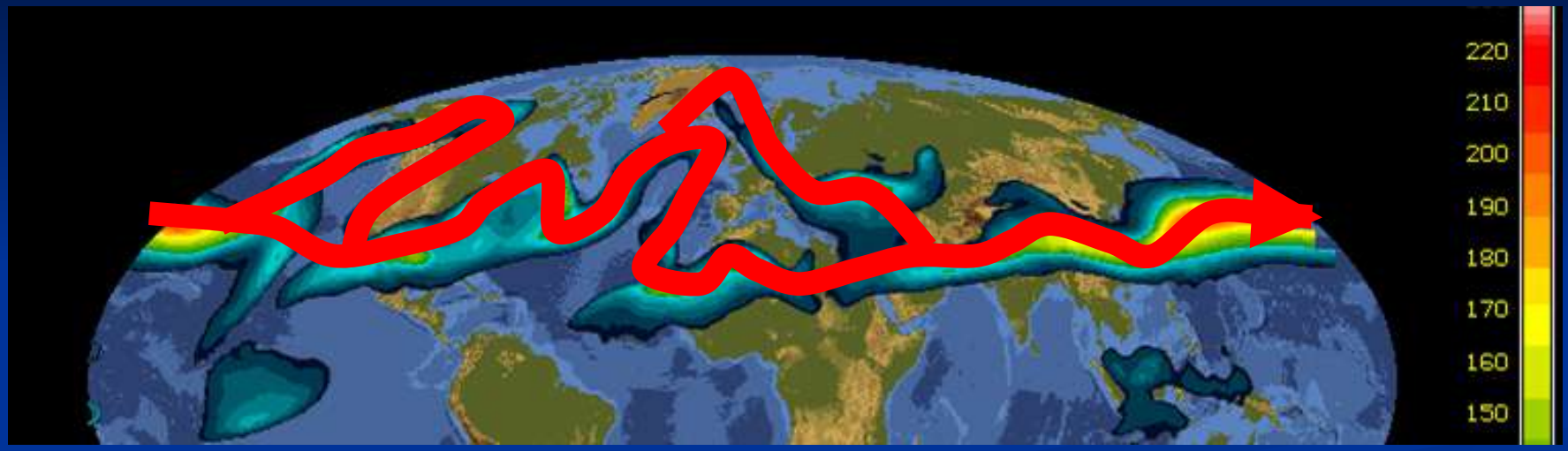
Upper-Level Features



Westerlies - High-Altitude winds blow generally west-to-east 3-6 miles above mid-latitudes.

Jet Stream – River of fastest-moving air within the westerlies.

Meteorology 101



Reality is messier …

Still, highs and Lows move with the westerlies and the jet stream.

Weather *vs.* Climate

Weather is *the dynamical way in which the atmosphere maintains the equilibrium* climate.

Elements of Weather

- air temperature
- air pressure
- humidity
- clouds
- precipitation
- visibility
- wind

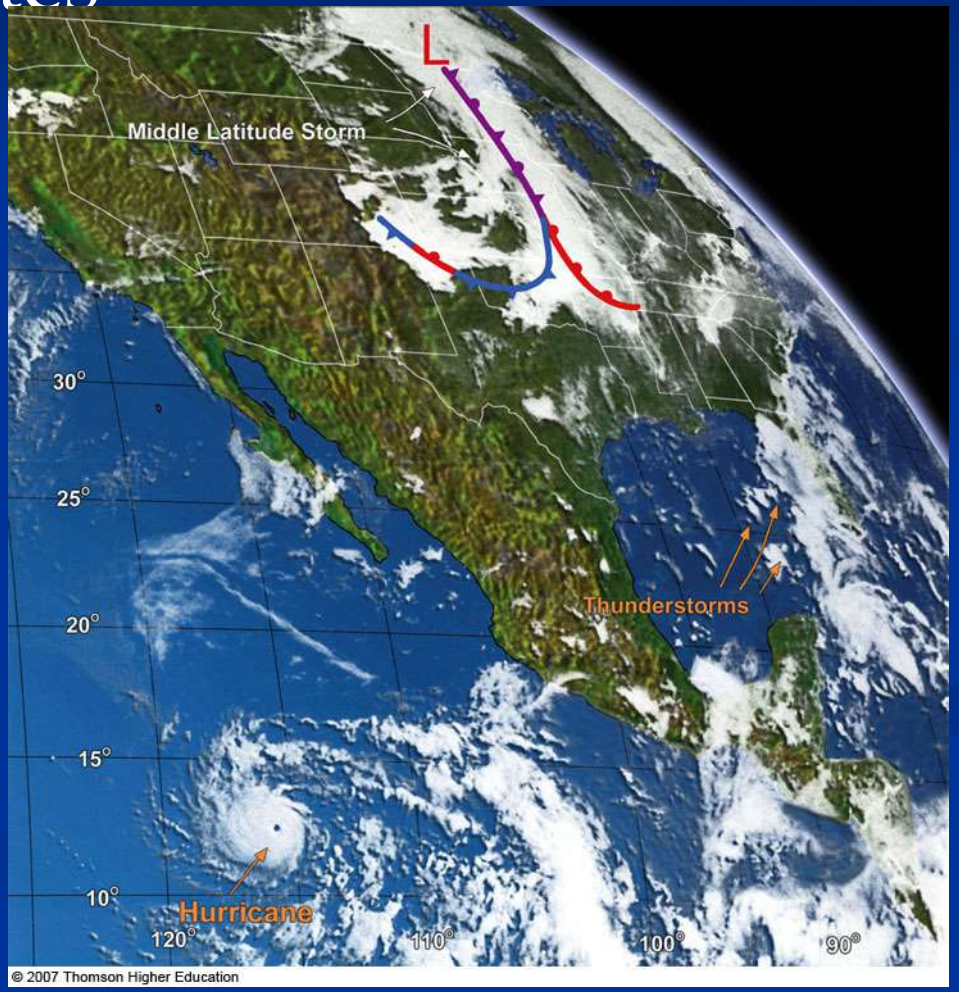
- Certain weather elements, like clouds, visibility and wind, are of particular interest to pilots.

Climate

- Average weather
  - time-average
  - regional (spatial) average
- Extremes
- Trends
- Climate represents long-term (e.g. 30 yr) averages of weather.

A Satellite's View of the Weather

- geostationary satellites
  - Atmospheric observation from satellites was an important technological development in meteorology. Other important developments include computers, internet, and Doppler radar.



Storms of all Sizes

- midlatitude cyclonic storms
- hurricanes and tropical storms
- thunderstorms
- tornadoes

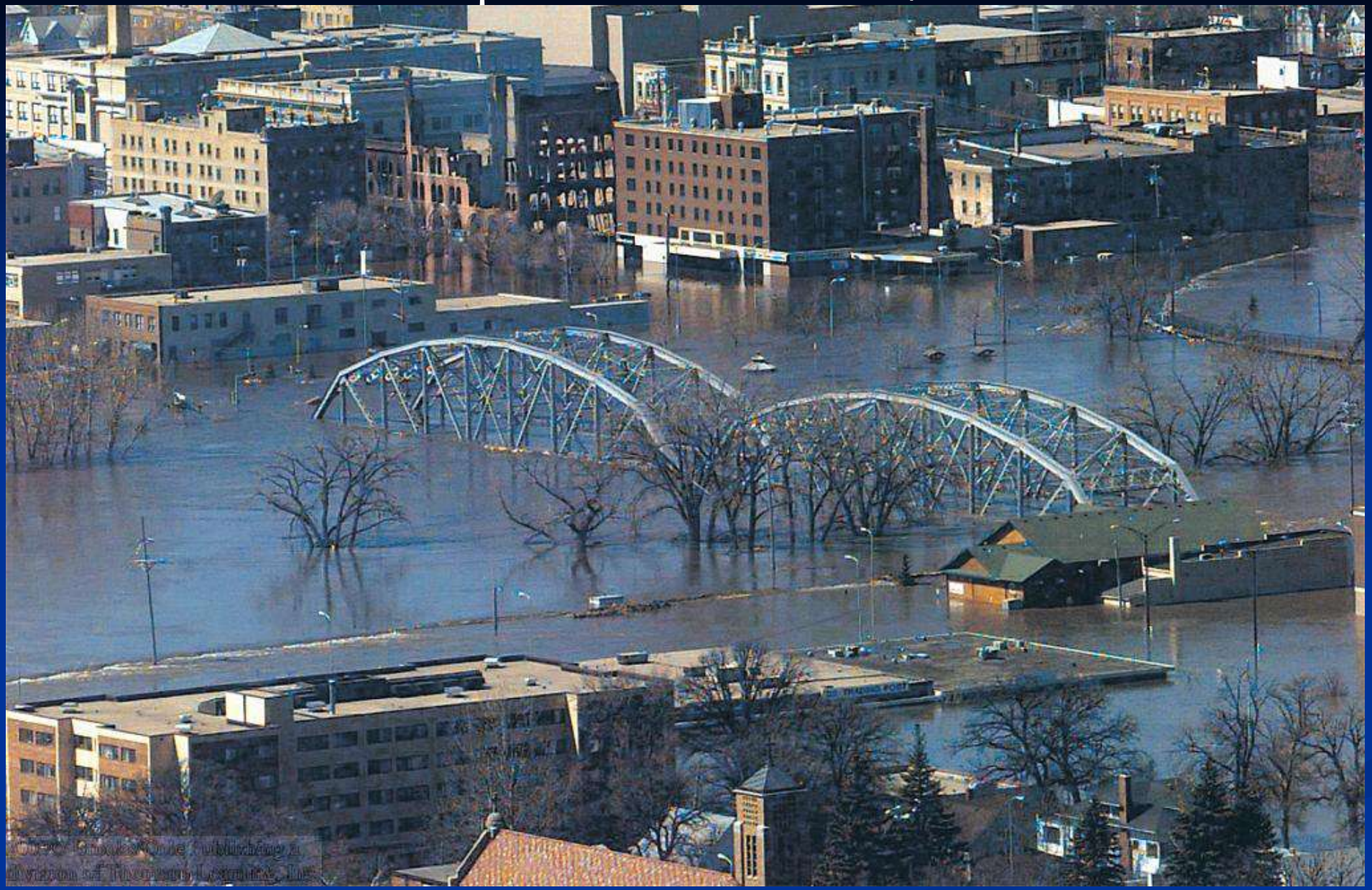
  - Storms are very exciting, but they also play an important role in moving heat and moisture around throughout the atmosphere.

Impacts of Weather 1/5

Impacts of Weather 2/5

Impacts of Weather 3/5

Impacts of Weather 4/5



146 people die each year in US from flash floods

Impacts of Weather 5/5

Lightning strikes earth 100 times every second