Earth, the “Goldilocks” Planet

What We Will Learn Today

- What are planet Earth's features?
- Why does our atmosphere have different layers?
- Why is our sky blue?
- What creates wind and weather?
- How will our climate change over the long run?
- How is Earth's Atmosphere unique in the solar system?

Planet Earth Details

Property	Value	
Semi-major axis	149.6 million km (1.00 AU)	
Size (radius)	6,378 km (1.00 R_{Earth})	Largest terrestrial
Mass	5.97 x 10^{24} kg (1.00 M_{Earth})	
Average density	5.52 g/cc	Densest in Solar System
Composition	Rocks, metals	
Average surface temperature	290 K	Liquid water on surface!
Moons	1	Largest moon/planet size
Orbital period	365.242 days (tropical)	
Rotation period (sidereal)	23h, 56m (sidereal)	Fastest terrestrial
Axis tilt	23.5^{o}	
Orbital inclination	0.00^{o}	
Orbital eccentricity	0.007	

Interaction of Sunlight With Atmosphere

- X rays from the Sun *ionize* atoms high in the atmosphere
  - absorbed in the process
- UV photons disassociate loosely bound molecules such as ozone (O_3)
- Visible light is *scattered*
  - Gives us a blue sky
- IR light from the planet is trapped
  - Greenhouse effect

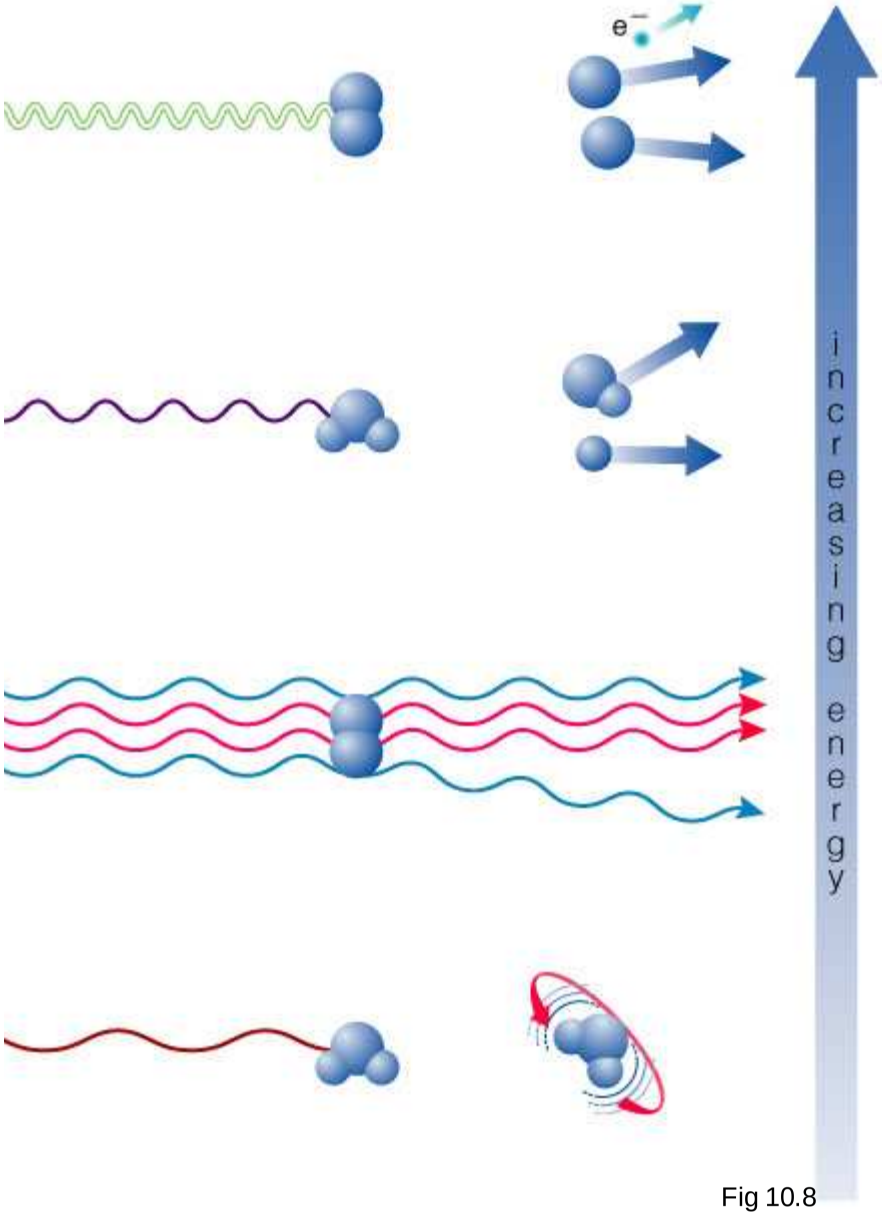


Fig 10.8

Structure of Our Atmosphere

- Troposphere
  - Heated by greenhouse gases
  - Convection is important
    - Tropos = turning
  - Temperature drops with altitude (3.5 ^{o}F per 1000 ft)
- Stratosphere
  - Heated by UV light
  - Temperature rises with altitude, then drops
  - No convection
  - Stratified, stable layers
  - No weather
  - Unique to Earth among terrestrial worlds

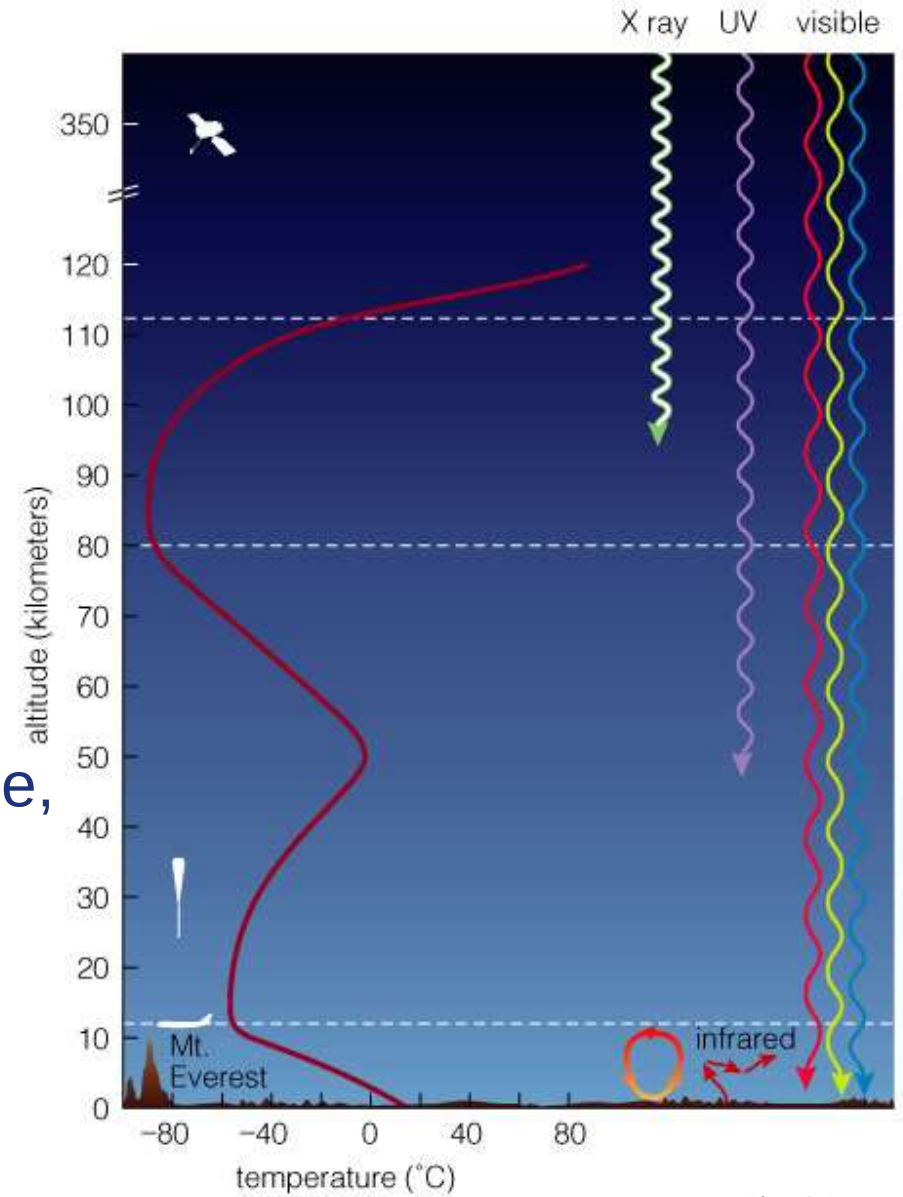


Fig 10.7

Structure of Our Atmosphere

- Thermosphere
  - Heated by X-rays from the Sun
  - Temperature rises with altitude
  - Would not feel hot!
    - Low density
  - Partly ionized (ionosphere)
  - Reflects radio waves back to Earth
- Exosphere
  - Atmosphere fades out
  - Black sky, weightless

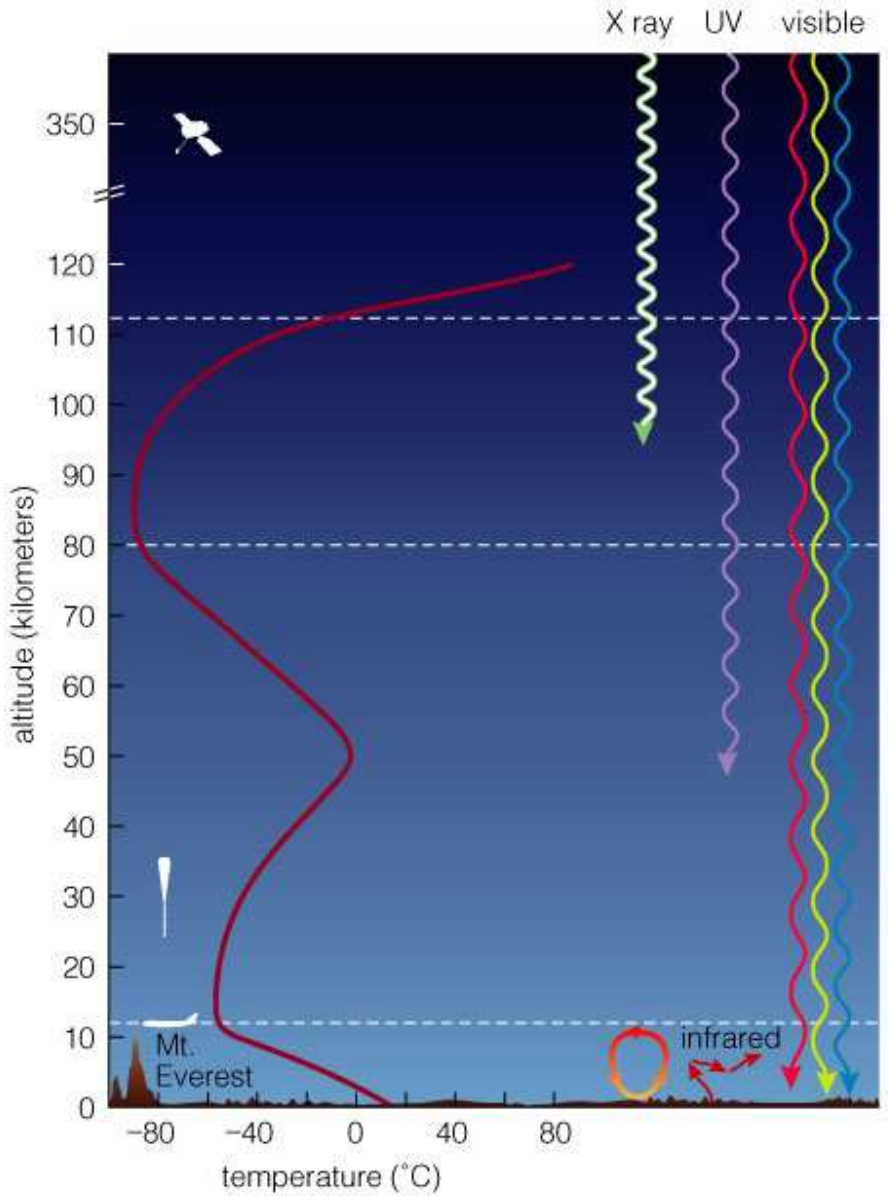


Fig 10.7

Why Is the Sky Blue?

- Sun emits most of its light in visible (ROYGBIV)
- Shorter wavelengths interact more with matter
- Blue light is scatters off air molecules
- Most of the red light reaches the surface
- Results
  - Blue sky
  - Red sun during rise/set
  - Bright sky (no stars during the day)

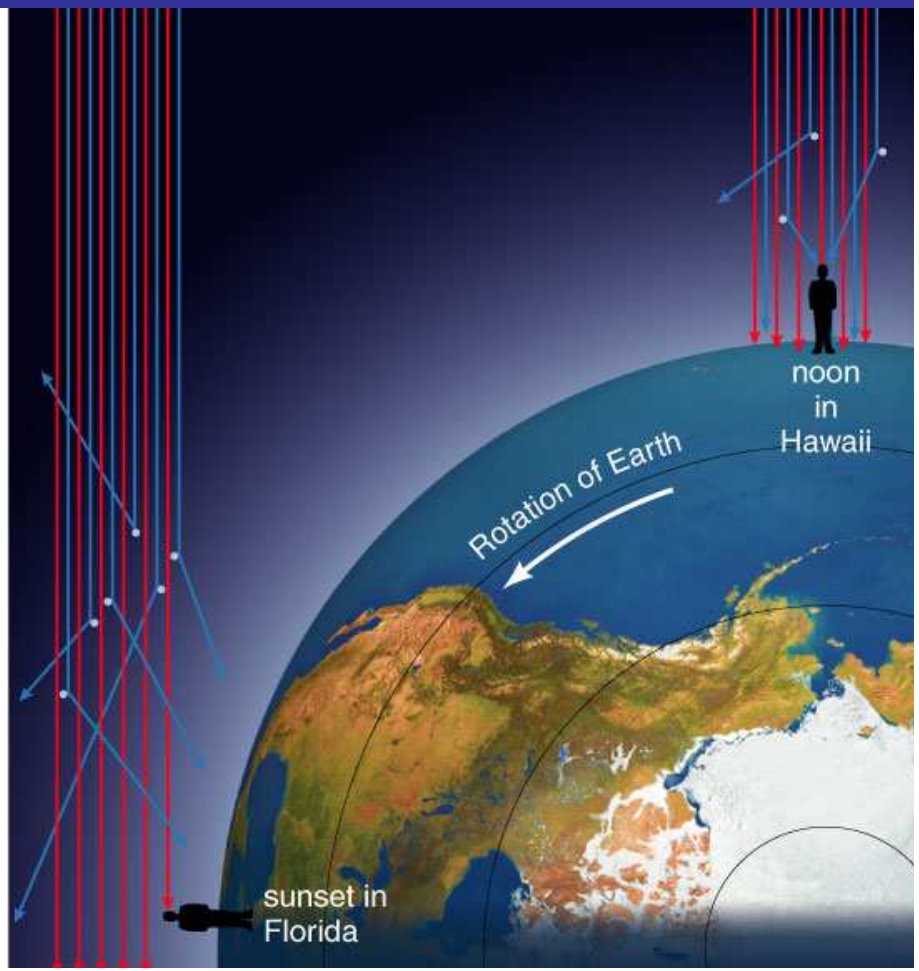


Fig 10.9

Protective Magnetosphere

- Solar wind: High velocity charged particles from the Sun
- Earth's magnetic field protects the planet
- Creates beautiful aurorae
  - Interaction of charged particles with atmosphere
- Van Allen belts
  - Charged particles inside magnetosphere moving along magnetic field lines

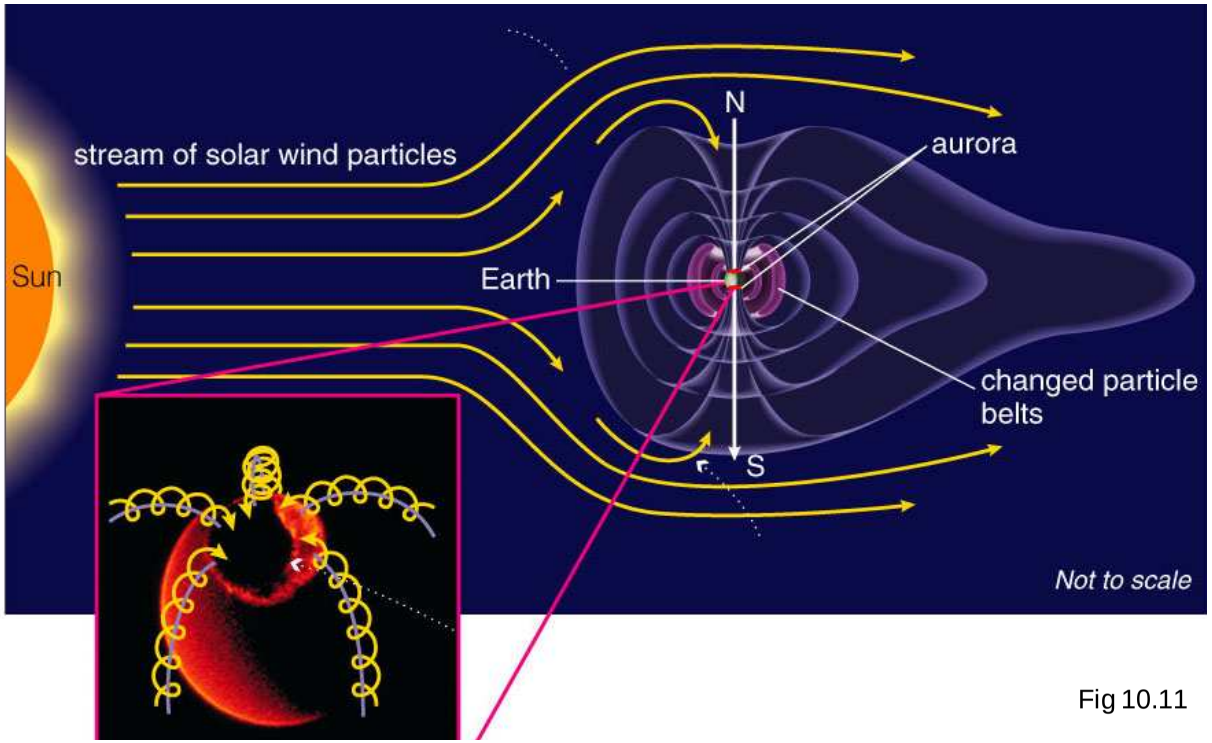


Fig 10.11

Weather Patterns: Wind

- Heating causes circulation cells
  - Warm air rises at the equator
  - Flows towards the pole, where it descends
  - Carries heat from equator to pole
    - Remember, Venus is very efficient at this
- Coriolis Effect
  - Earth's rotation causes circular motion of wind
  - Breaks down the circulation cell into three cells per hemisphere
  - Unique to Earth among terrestrial worlds
- Resulting surface winds
  - East to West near equator and poles
  - West to East in mid latitudes

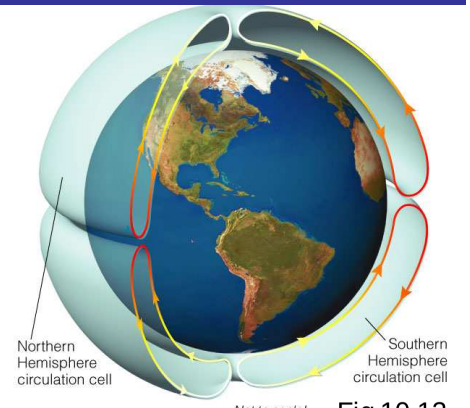


Fig 10.13

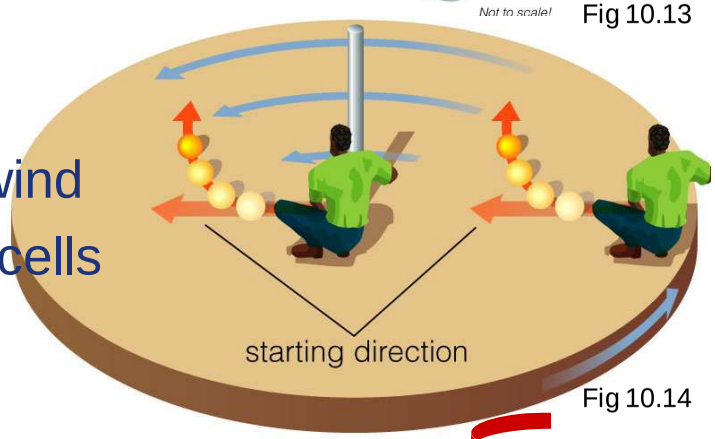


Fig 10.14

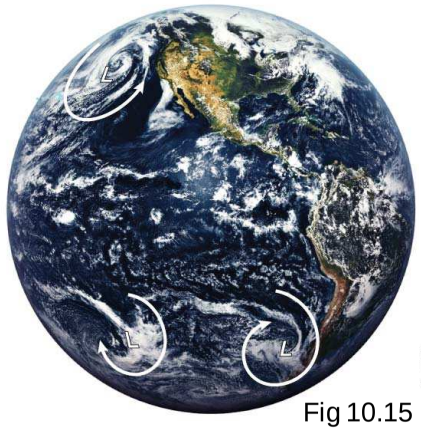


Fig 10.15

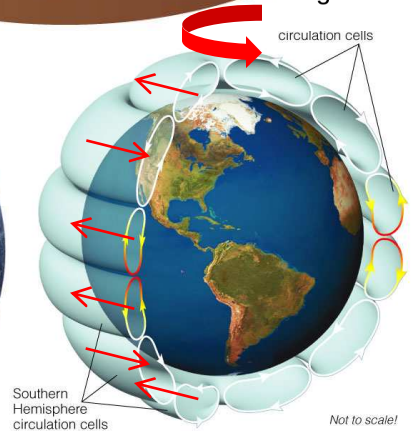


Fig 10.16

Long-term Climate Changes

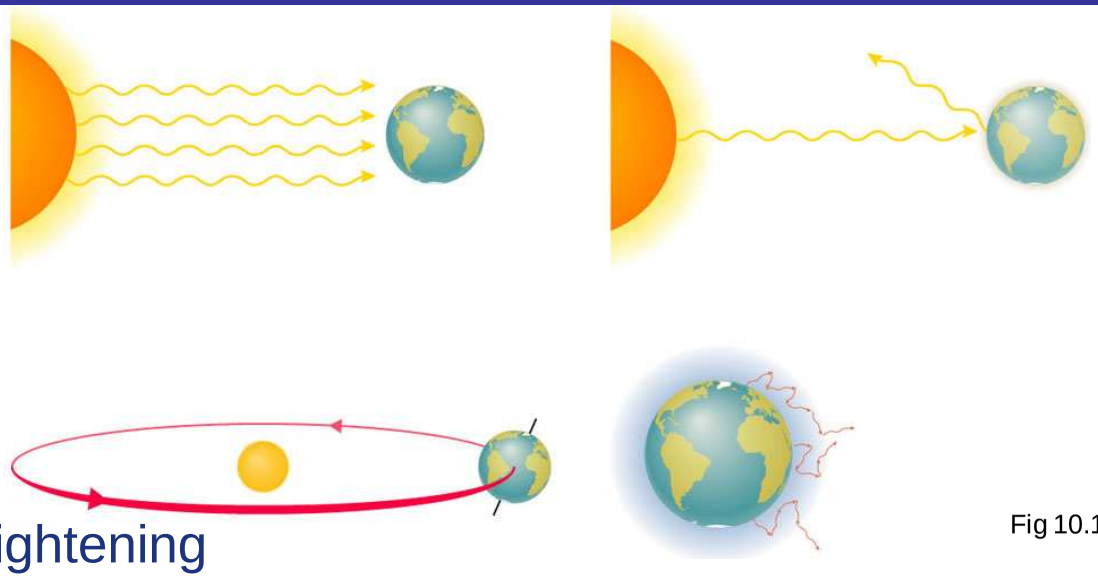
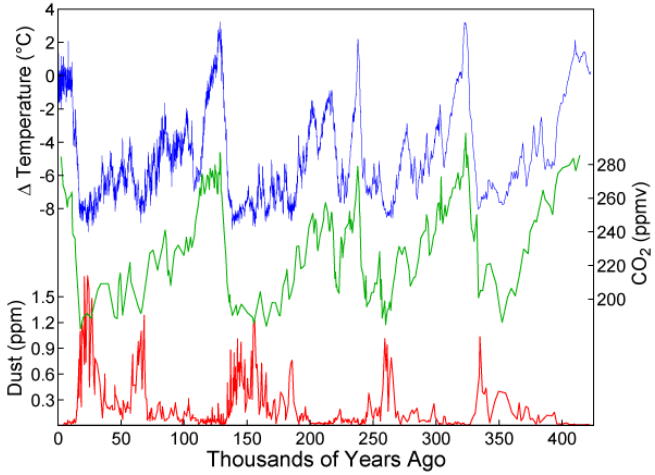


Fig 10.18

- Solar brightening
  - Sun is 30% more luminous now compared to when it was born
  - In a billion years, will be hot enough to evaporate our oceans (runaway greenhouse effect)
  - Earth will become a molten rock ball in a few billion years
- Changes in axial tilt
  - Varies over 22^{o} – 25^{o} over tens of thousands of years
  - Bigger factor for Mars
- Changes in reflectivity
  - Clouds and ice are better reflectors
- Changes in greenhouse gas abundance

Ice Ages on Earth

- CO_2 cycle is 400,000 years long
- Gives room for climate changes such as ice ages
  - 100,000 year cycles
    - ~ 85,000 years of ice age
    - ~ 15,000 years of interglacial periods
- Snowball Earth
  - 750 – 580 million years ago, the entire Earth was frozen over
  - Rescued by plate tectonics and volcanism



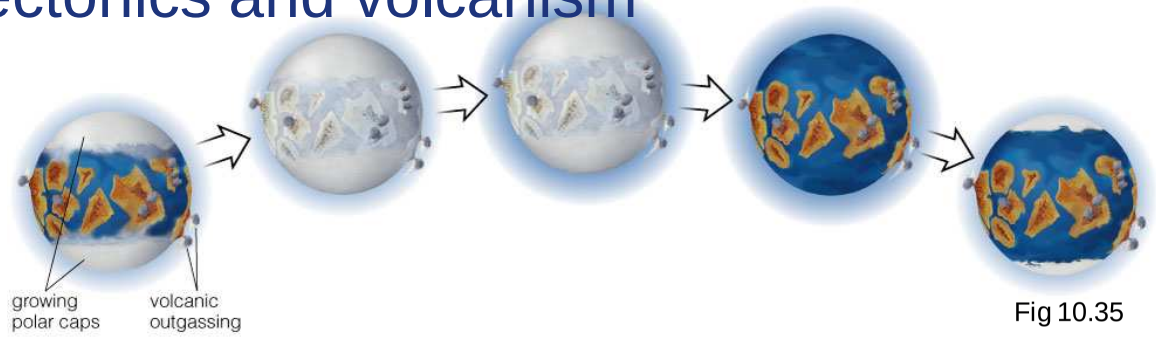


Fig 10.35

Earth's Regulated Greenhouse

- CO_2 and H_2O are efficient greenhouse gases
- CO_2 has a self-regulating effect
  - If volcanoes put excess CO_2 in atmosphere
    - Temperatures rise
    - Convection & rainfall will increase
    - Rain traps more CO_2 from atmosphere into ocean and rocks
    - Earth cools back down
  - Dominant regulator on Earth
- H_2O has a runaway effect
  - If increased heat evaporates more of the oceans
    - Water vapor in atmosphere traps more heat
    - This increases temperature and evaporation
    - Increases greenhouse gas content in atmosphere
    - Runaway greenhouse effect
  - Dominant process in the young Venus

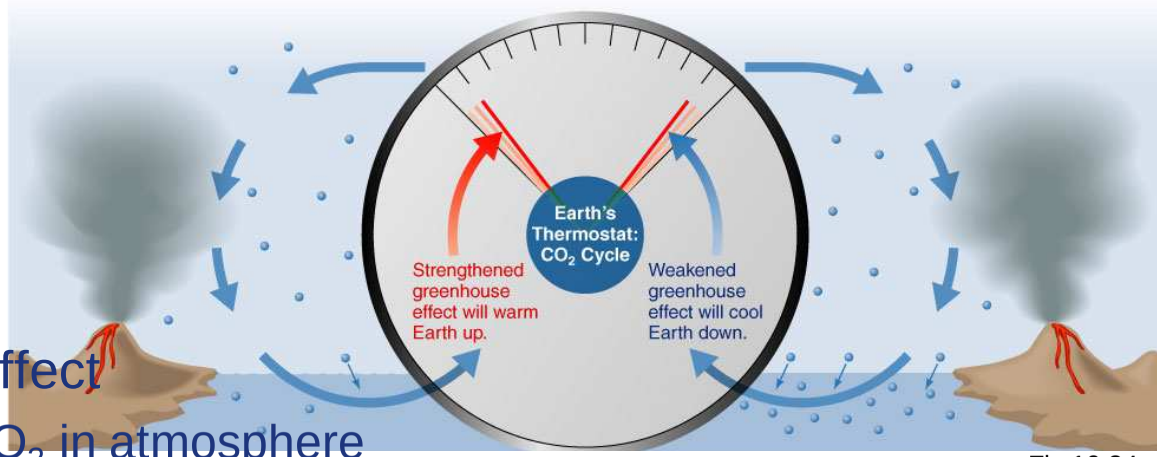


Fig 10.34

Earth's Perfect Environment

- Retained most of the outgassed water
  - Moderate temperatures allowed condensation
  - Create oceans of water o the surface
- Locked away most of the CO_2
  - Dissolved in oceans (60x atmosphere) and locked in carbonate rocks (170,000x atmosphere)
- Nitrogen becomes primary constituent (77%)
  - CO_2 and H_2O locked removed from the air
- Oxygen (21%) level is maintained by life
  - Very reactive, will be lost if not replenished
  - Creates the UV absorbent ozone layer

Human Influence on our Climate

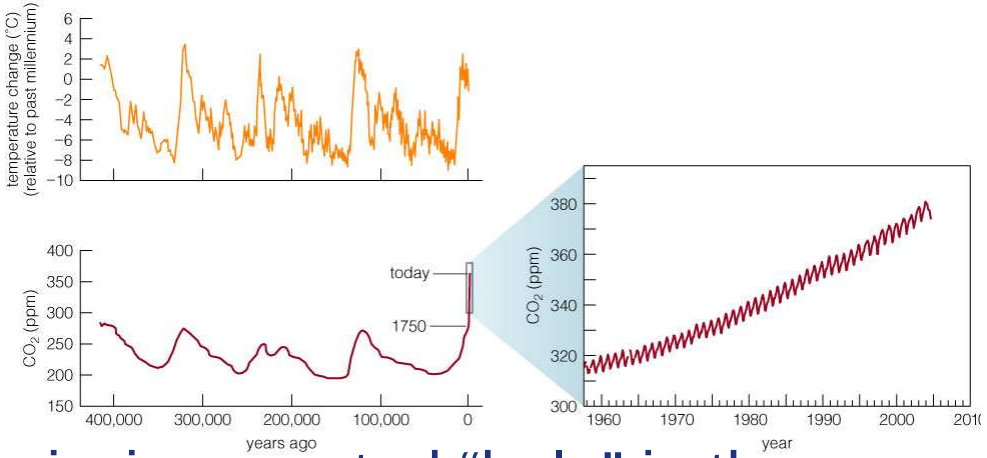


Fig 10.36

- CFC emission created “hole” in the ozone layer
- Extinction rate of other species accelerate due to our dominance
- Global warming
  - A complex process
  - We don’t fully understand it
  - But we are undoubtedly altering the natural process
- Potential consequence of global warming
  - Largely unknown, but could include:
    - Increased storms, rising ocean levels, what else?

Unique Features of Earth's Atmosphere

- Not too hot, not too cold!
  - Liquid water on surface, water vapor in atmosphere
- Oxygen in the atmosphere
  - Maintained by life on Earth
- Stratosphere
  - Efficient UV absorbers in atmosphere
- Strong magnetosphere
  - Protective blanket from solar wind particles
- Weather driven by Coriolis effect
  - Large size + fast rotation
- Self-regulating greenhouse effect
- Artificial effects on atmosphere