Atmospheric Processes

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Synopsis: Leading to Exploring Other worlds

Applications: Two Physical Effects
- Ozone Hole
  - UV creates and destroys O₂ in atm
  - Natural balance disturbed by man-made chemicals
- Green House Effect
  - Energy has to get to Earth’s surface
  - Heat (IR) is blocked by atm → causes an increase in T

Earth is a Complex System
- Interdisciplinary approach needed
- Don’t understand all feedback systems
- Models only as good as data

What are Implications for our “space ship”?

Endogenic Processes
- Clues to interior processes
- Heat loss mechanism
- Volcanos & tectonics
- Interaction with surface
- Recycling of materials

Surface Features
- Mountains / peaks / ridges
- Cracks, trenches
- Plains
- Causes: plate motion, volcanos, planetary shrinking, expansion . . .

What can we tell about a world & its potential for life just from its surface features?

Atmospheres Outline

- Purpose
  - Understand what effect an atmosphere has on a planet
  - Understand how to recognize that there is an atmosphere (now and in the past)
  - Understand the typical atmospheric structure
  - Understand that atmospheres change with time (physically and chemically – and why)

- Content
  - History and comparison of Terrestrial Planet Atmospheres
  - Atmospheric Structure & Composition
  - Aeolian (Wind Driven) Processes
    - Of or pertaining to an atmosphere (winds and liquids)
  - Some Examples

Mercury

- Pre-spacecraft data
  - 0.4 AU from sun
  - 28° max solar elongation
  - 19th century images “features” not real
  - Radar images
    - Early – not much detail (size of planet)
    - New – ice (!) at polar cap

- Space Era
  - Images: craters/tectonics
  - Magnetosphere
  - Thin atmosphere

Mercury Surface Features from Earth

- 1991 & 1994 Earth Radar data
  - Bright reflections
  - Coincide with Mariner 10 dark craters
  - Hints at ice

Mercury Moon Phobos

Mars Moon Phobos

Mars Surface (art)

Jupiter’s moon Europa Surface

Mars Surface (art)
1932 CO$_2$ discovered (spectra). H$_2$O had been assumed
1941 Greenhouse effect? $\rightarrow$ hot surface
1955 Early H$_2$O oceans + liquid hydrocarbons; UV photodissociation $\rightarrow$ oceans of crude oil
1955 Surface cool; oceans of H$_2$O & carbonic acid (H$_2$CO$_3$)
1961 Large 600K global desert w/strong winds (frictional heating)
1962 Sagan revives Greenhouse effect
1964 Planet accreted hot & dry – never had water

**Mars**
- Early Earth Observations
  - Schiaparelli (1877) & Antoniadi (early 1900s)
  - Observations of “channels” $\rightarrow$ canals
  - Distinct albedo changes
  - Vegetation?
- Lowell Observatory
  - For “Astrobiology”!

**Basic Atmospheric Structure**
- Extent of Atmosphere
  - There is no “edge” to an atm
  - Scale Height (H)
    - Distance over which atm density decreases by 1/3 (1/e)
  - Earth’s H = 8.4 km
- $H = \frac{kT}{(\mu m_H)g}$
  - $k$ = a constant (bolzmann)
  - $T$ = Temperature [K]
  - $\mu$ = avg atomic weight of molecules
    - (relative to mass of Hydrogen)
  - $m_H$ = mass of Hydrogen
  - $g$ = planet’s gravity
Weather

- **Mercury**
  
  - “Atm” too thin for weather

- **Venus**
  
  - At surface probably not much – mild winds

- **Mars**
  
  - Southern hem winter: CO$_2$ condenses → 25% P drop → winds
  
  - Summer
    
    - warmed regolith → sublimating CO$_2$
  
    - Strong winds → Mars dust storms

  - Polar Caps record seasonal changes

Comparative Planetology

- Atlantic storm: 2/26/00

- Mars: N polar dust storm

- Mars: N hemisphere

- Sahara: 6/22/98

Gradational Processes

- **Saltation**

  - Wind lifts sand; bounces

  - Erosion 1 m from surface

  - Need higher winds on Mars: lower atm density

- **Large scale features**

  - Dunes
  
  - Yardangs

Comparisons – Aeolian: Mars

- **Victoria Crater** (MRO)

  - 800 m diameter

  - Sedimentary rocks inner wall

  - Sand dune fields

  - Wind blown dust

Moles Chasma (MRO)

Dunes in Valles Marineris-Meles Chasma (Mars)

Comparisons – Dunes in the SS

Earth

Titan
**Water Erosion – Mars**

- **Channels & Valley Networks**
  - Gradual flow?
  - Similar to riverbeds
  - Appear old (3.5 Gy) from cratering
- **Chaotic Terrain**
  - Large “flood channels”
  - Melting subsurface ice
  - Discharge $10^7$-$10^9$ m$^3$/s (Amazon $10^5$ m$^3$/s, Lake Missoula $10^8$ m$^3$/s)

**Mars Chaos Regions**

- Aram Chaos: E of Valles Marineris

**Lake Missoula Flood**

- Pleistocene lake (12,000 BC) blocked by glacier
- Water volume = Lake Erie + Ontario
- Ice dam burst: emptied in 48 hrs
  - “tidal wave” 2000 ft high @ 65 mph
  - Removed 200 ft of topsoil
  - Carved out “scablands”

**Jokulsargljufur Canyon, Iceland**

- Vatnajokull catastrophic flood

**Other Atmospheres – Titan**

- $N_2$ atmosphere
- Rich organics
- Near triple point of CH$_4$
- Organic “soup”
  - Life precursor chem?

**Jupiter’s Large Moons**

- Ganymede
  - Magnetosphere & thin atmosphere
  - Oxygen
  - Water ice sputtering
- Callisto
  - CO$_2$ exosphere
  - Outgassing
- Io
  - SO$_2$
  - Volcanic eruptions
  - Io plasma torus
**Triton & Pluto**

- **Triton**
  - N₂/CH₄ atmosphere
  - Frost in vapor pressure equilibrium with surface
  - P = 1.5 x 10⁻⁵ bar
  - Haze rises 13 km above surface
- **Pluto**
  - N₂/CH₄ atmosphere
  - Large seasonal variations

**Atmospheric Processes**

**Consequences of an Atmosphere**
- Protects planet from hazards
- Regulates surface heat
- Alters chemistry of planet
- Interacts with interior, alters geological

**Atmospheric Structure**
- Scale Height
- Distance to sun, gravity, composition

**Atmospheres change in time**
- Interacts with interior, alters geological

**Evolutionary Paths**

- Early sun less L?
- Liquid H₂O?
- Plate tectonics?
- T ins H₂O evap
- UV+H₂O → H₂+O
- H escapes
- O combines w/rock
- Volcanism → CO₂
- Runaway greenhouse
- Cooler initially
- Needed greenhouse to keep from freezing
- Plate tectonics
  - CO₂ dissolves in rain
  - CO₂ → carbonates
  - Falls to ocean floor
  - Subduction → melting
  - Volcanism resupplies
- Early sun less L
- Needed greenhouse
- 1 bar atm may have formed
- No plate tectonics
- Cooler core
  - CO₂ dissolves in rain
  - CO₂ → carbonates
  - No CO₂ recycling