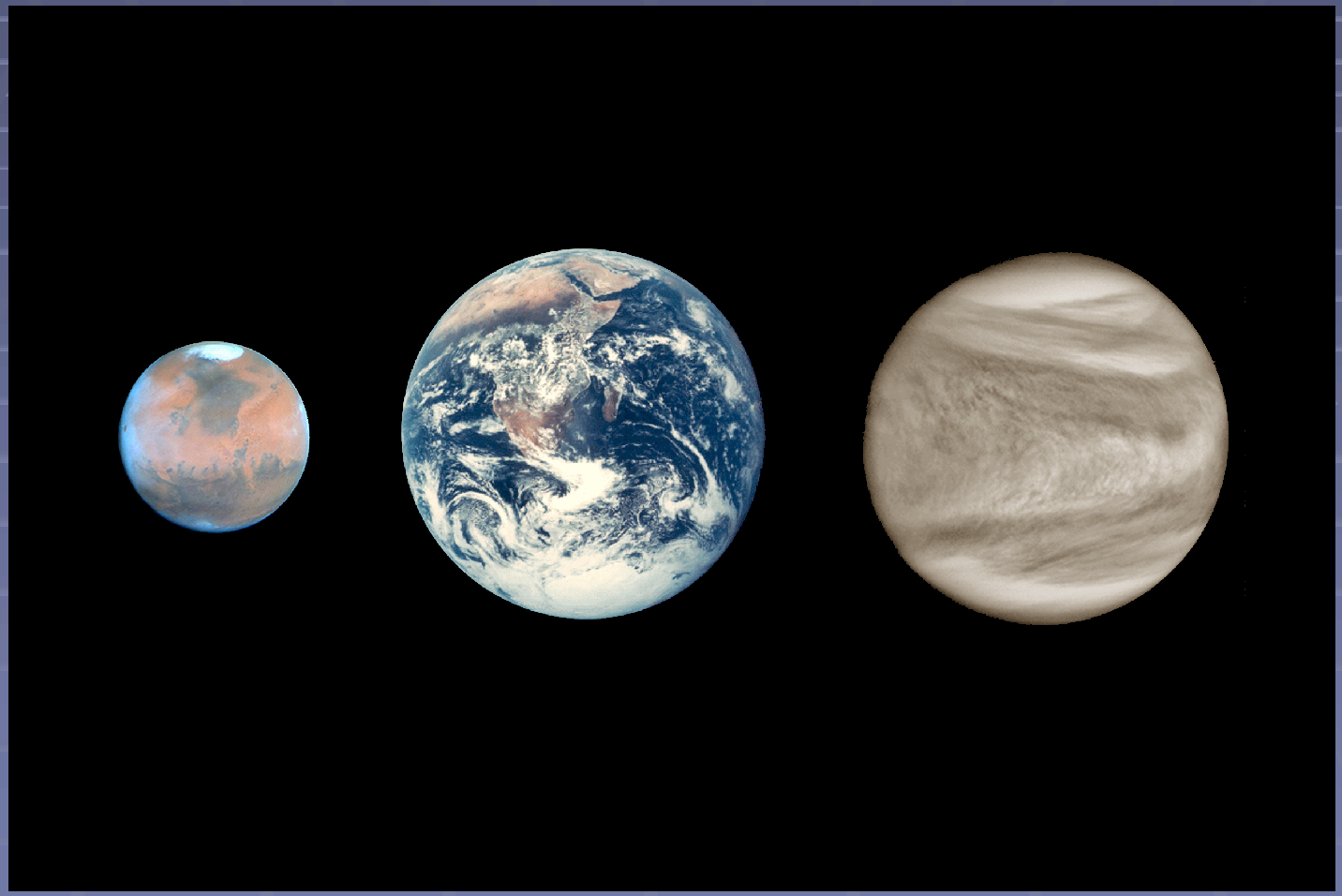
Earth & Earthlike Planets



Course Logistics

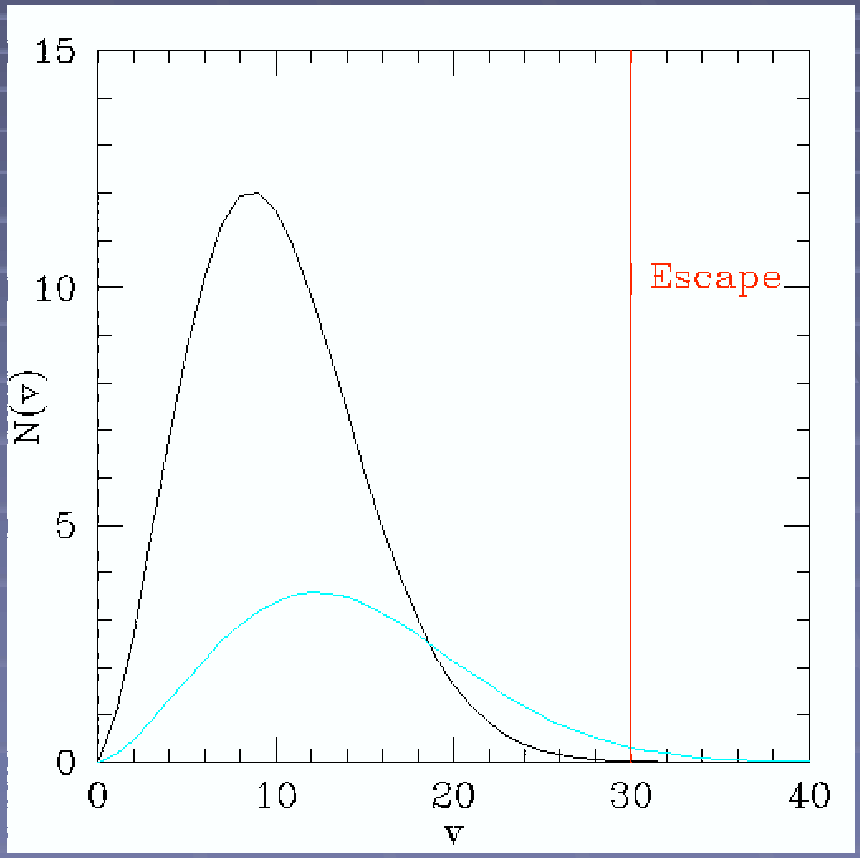
- Life Everywhere and Rare Earths are now in the U-Store
- Each precept will be divided into two teams (at this week's precept). Debate topic: Are Earthlike planets in habitable zones common? Come prepared with 1 page brief
- Final: You will get a long list of questions in advance and will have to answer a select list of questions

Evolution of Earth's Atmosphere

- Earth lost its early atmosphere in major collisions (first 10-100 Myr)
- Subsequent infall of comets brought in material from outer solar system and replenished N_2, H_20.
- Volcanic source of CO_2
- 3.8 Gyr ago: 10 bar of CO_2 85 C

Losing Our Air

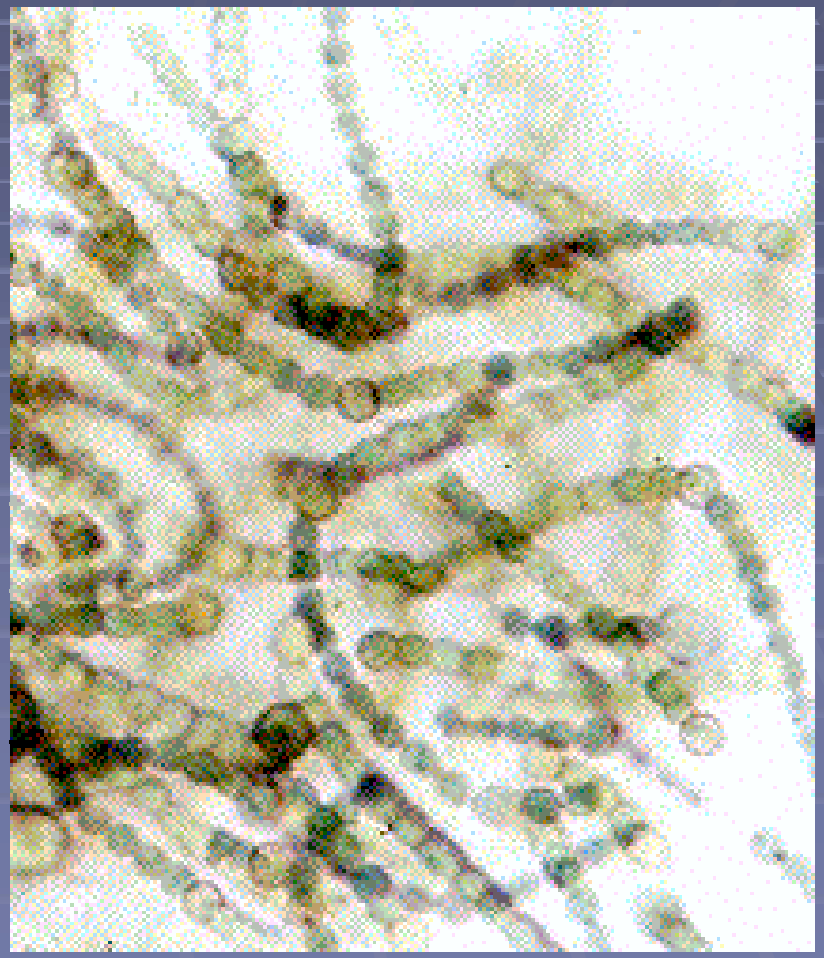
- Catastrophic Atmospheric Loss
- Thermal Escape
  - Velocity depends on mass of molecule
  - Predicts that all light elements are lost
  - Does not fit abundance
- Driven Wind
  - Solar EUV radiations hits H which drives wind.
  - Wind preferentially removes light elements that are no embedded in heavy molecules



Thermal distribution

Oxygen

- During pre-Cambrian period (90% of age of Earth), Oxygen levels were > 2% of current levels
- Biogenic production of Oxygen
  - Oxygen is highly reactive. In the absence of biogenic production, would disappear. Free oxygen appears about 2 Gyr ago (first pollution crisis)
  - Fe abundances in rock traces Oxygen abundances
  - Appearance of ozone in troposphere allows burst of marine productivity. Increases rate of carbon fixing in carbonates

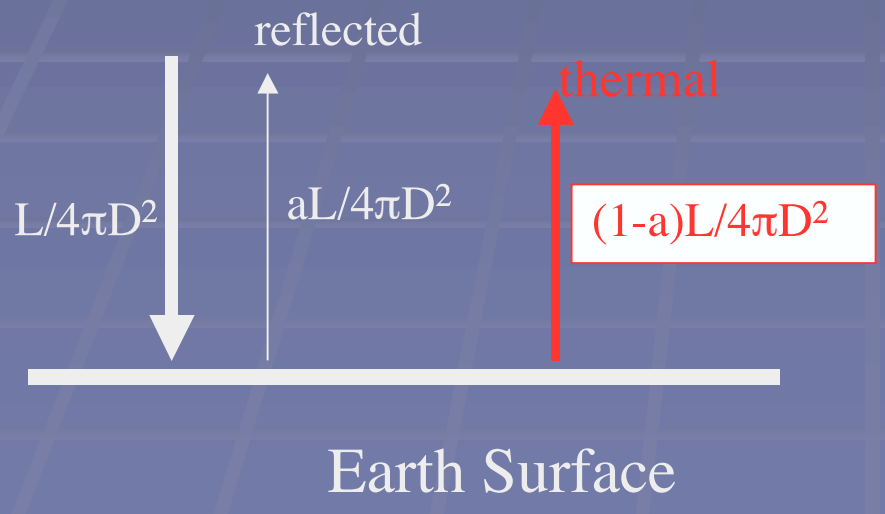


cynobacteria

Energy Balance

Energy In/ (from Sun) = Energy Emitted by Earth

a = albedo

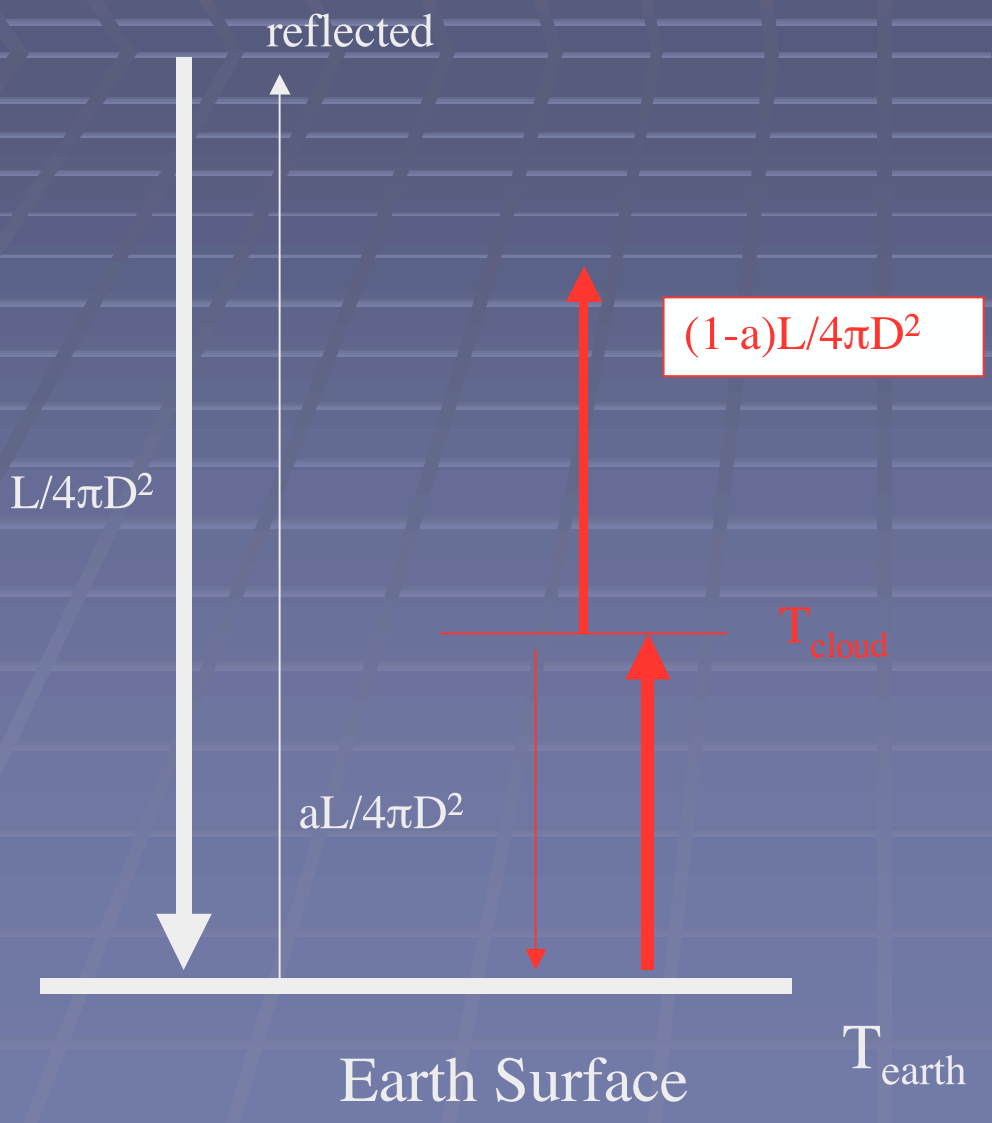


$$\dot{E}_{in} = (1-a)L_{\odot}/(4\pi D^2)(\pi R^2_{Earth})$$

$$\dot{E}_{out} = \sigma_B T^4_{Earth}(4piR^2_{Earth})$$

$$T_{Earth} = [(1-a)L_{\odot}/(4\sigma_B \pi D^2)]^{1/4}$$

Greenhouse Effect

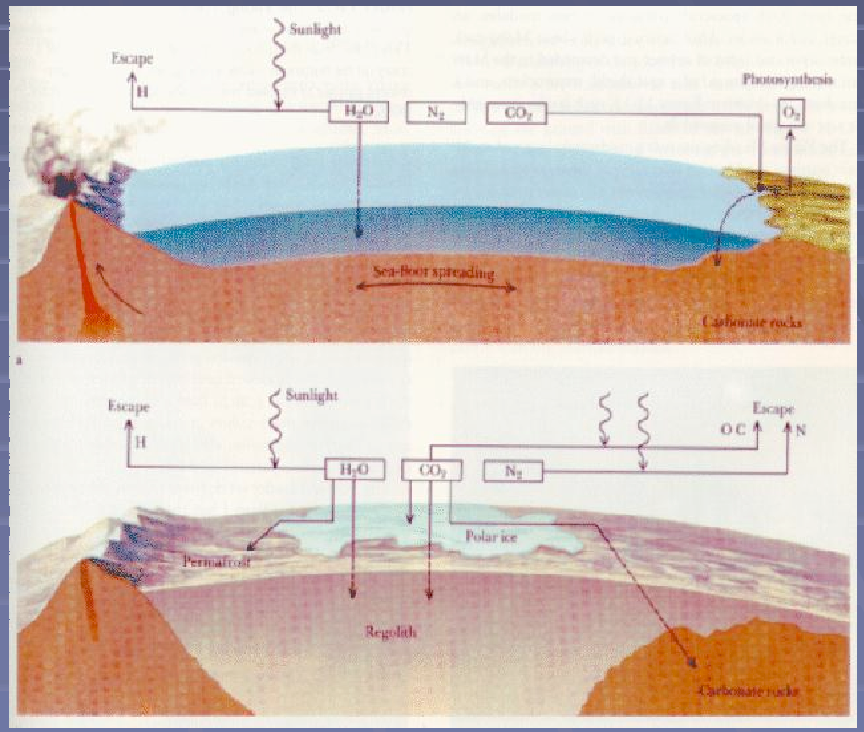


Greenhouse gases

- CO_2, CH_4

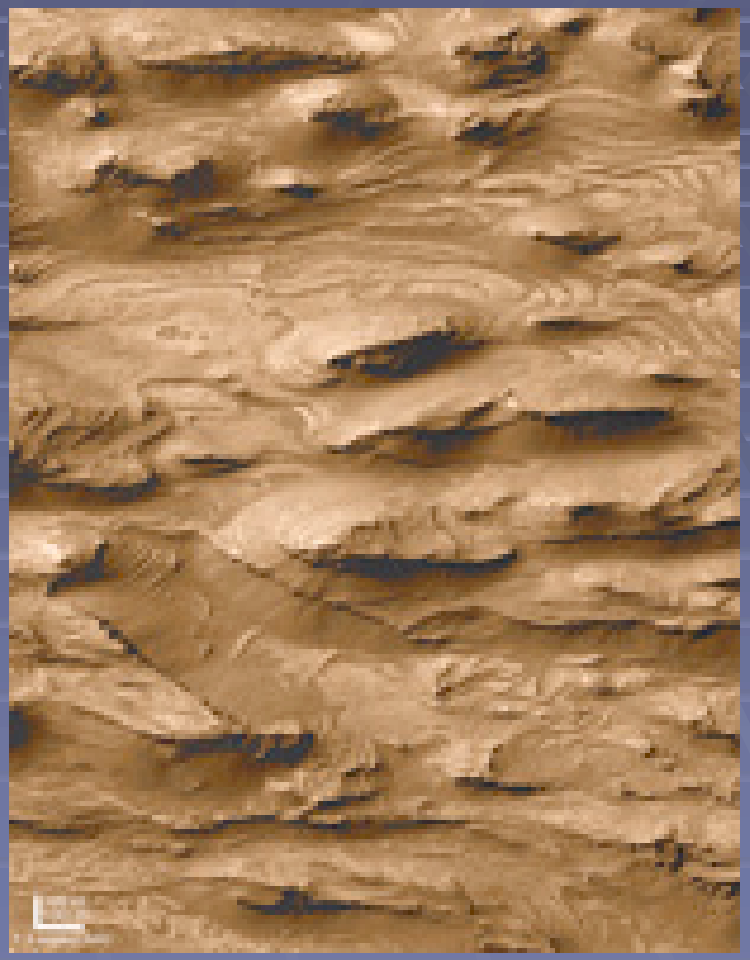
Were Terrestial Planets Once Similar?

- Earth, Mars, Venus have similar masses and composition
- Carbon cycle
  - On Earth, CO2 in oceans settle into rocks
  - Venus is too hot for oceans. Water lost during early very hot phase
  - Mars: No plate tectonics-- no source for CO2



Mars: Too Cold

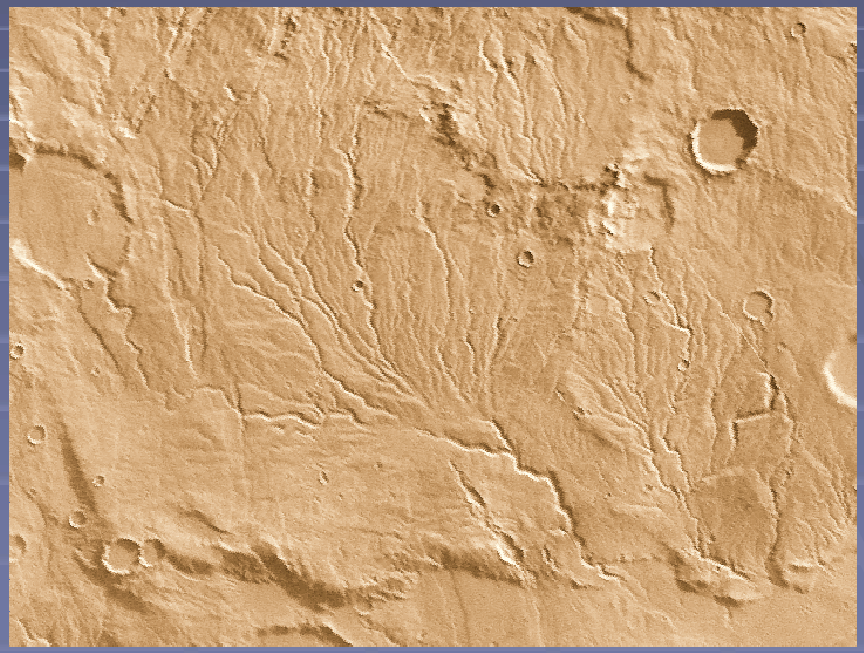
- Early Mars was warmer
  - CO_2 now incorporated in carbonate rocks
- Evidence of running water
- Has Mars had recent episodes of high pressure and liquid water



Dry lake beds on Mars?

Mars & Water

- Evidence of running water on Mars
- Is there still running water?
- Is there life?
- Focus of upcoming NASA missions
- Are we Martians?

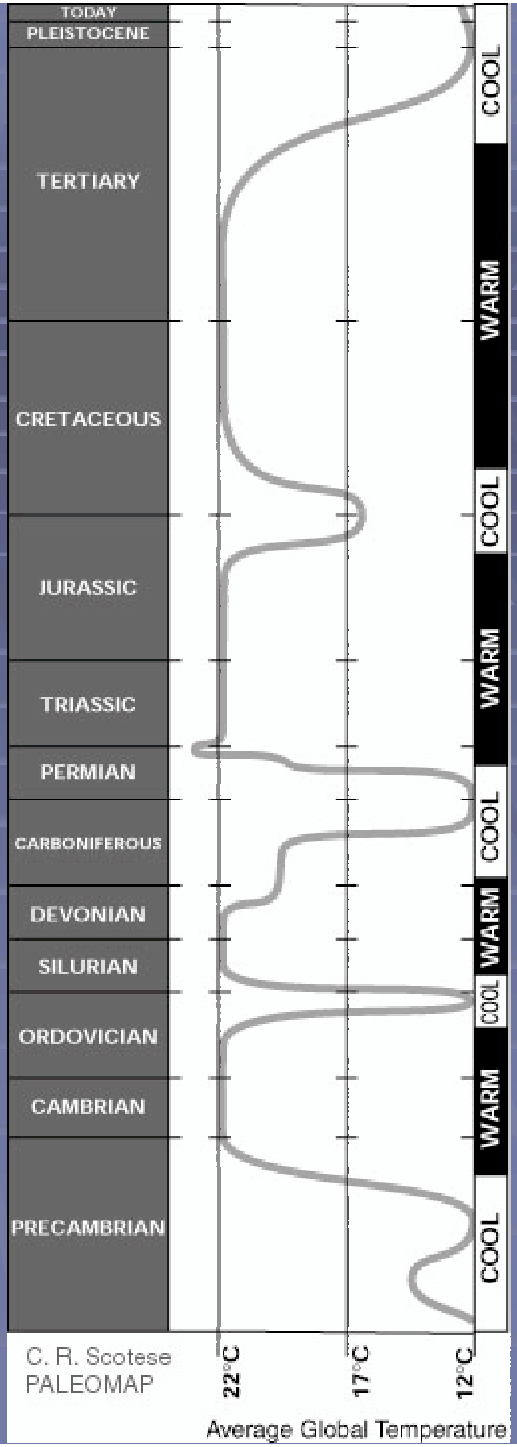


Venus: Too Hot

- Nearly Earthlike: almost the same mass and heated at similar rates
- Surface temperature ~700 K
- Runaway greenhouse effect
- How was Venus' water lost?
  - Blowoff of H?
  - Early super-greenhouse

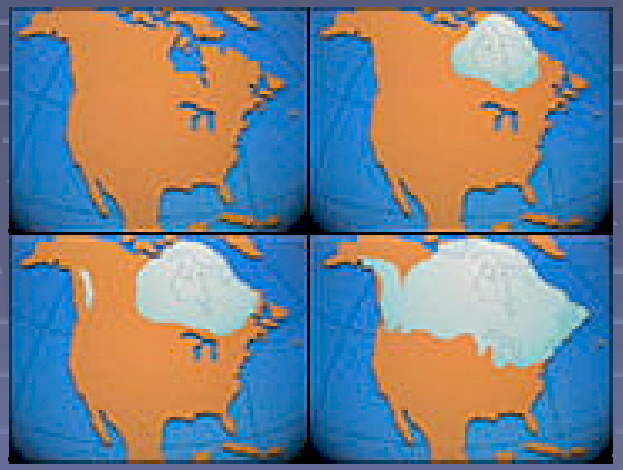
Earth: Just Right?

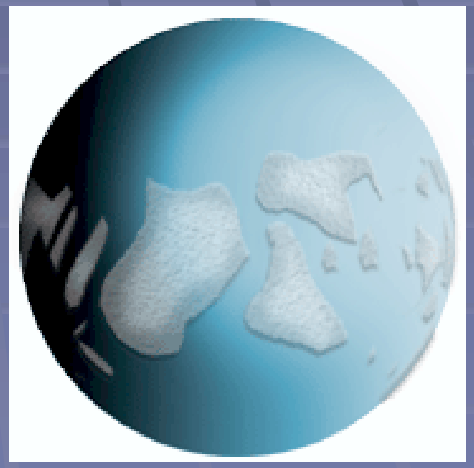
- Sun's temperature is slowly increasing. Temperature was 30% lower in past
- Earth's temperature has been remarkably constant
- Higher concentration of greenhouse gases
- CO2 trapped in carbonates today



Snowball Earth

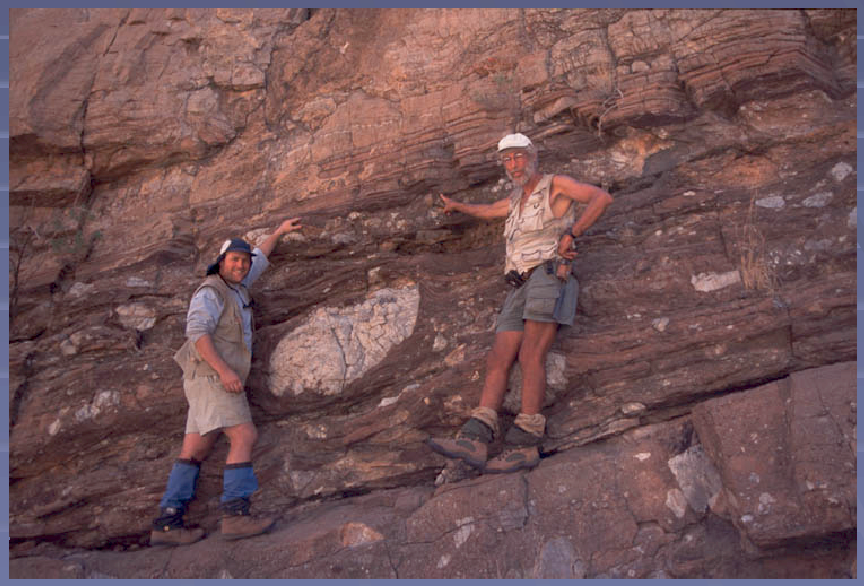
- Snow/ice instability
  - Albedo of ice = 0.8
  - Albedo of sea water=0.1
- Over past several million years, multiple glaciations. Last one ended only 10,000 years ago
- About 1 Gyr ago, continents were all near equator. Ice near completely covered Earth
  - Ice without end?
  - Seems to persist for millions of years



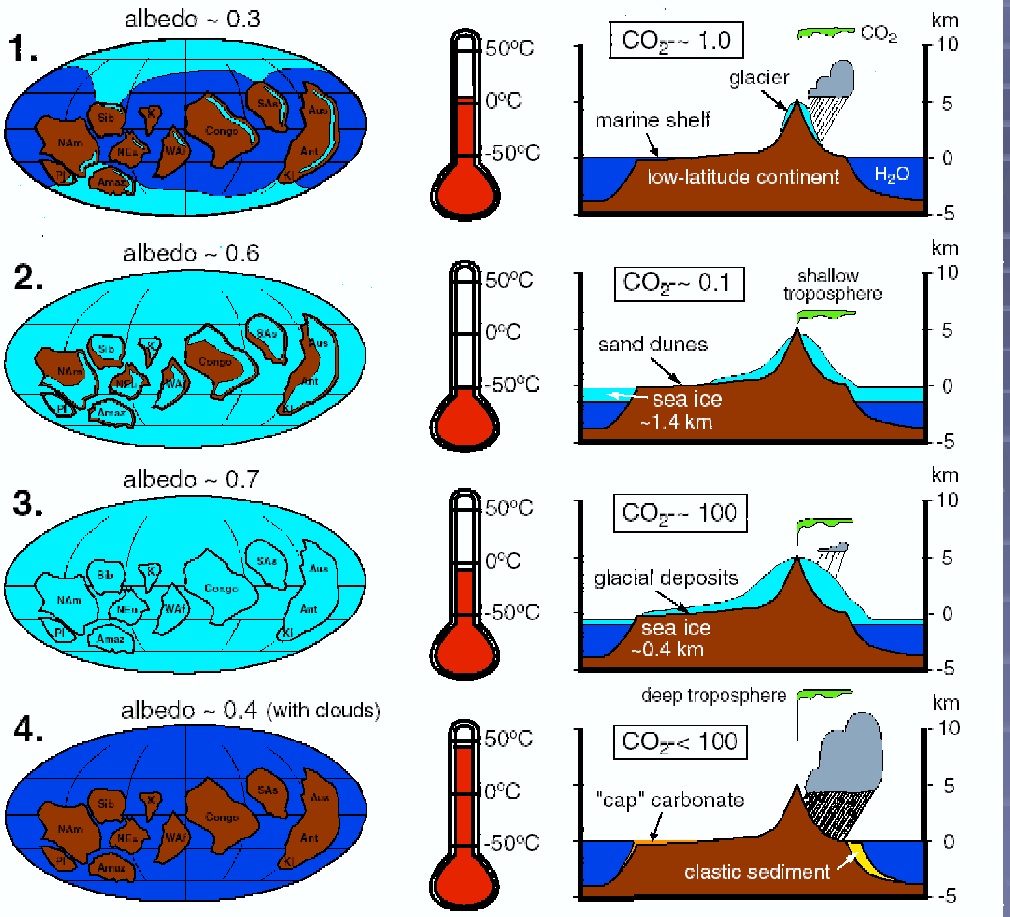


Snowball Earth II

- Volcano outgassing increases CO_2 to 300x current levels
  - Limited plant life -> no CO_2 sink
    - Signature seen in $^{13}C/^{12}C$ ratio
  - Earth's temperature increases to 50 C
    - Cap carbonates
  - Multiple cycles?
- Survival of life near volcanic vents? Unfrozen regions of ocean?
- Extinctions lead to emergence of multicellular life?



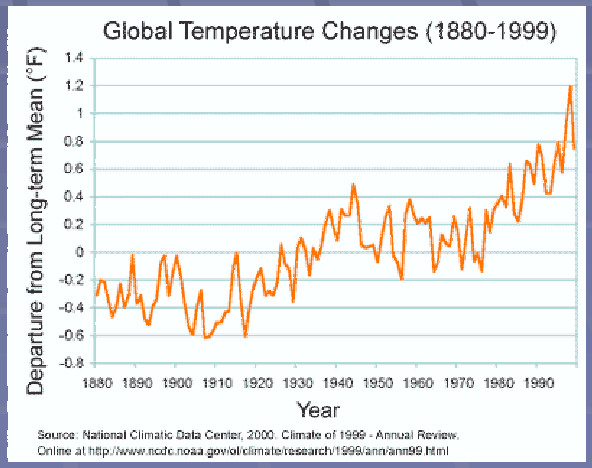
SNOWBALL FREEZE-FRY SCENARIO

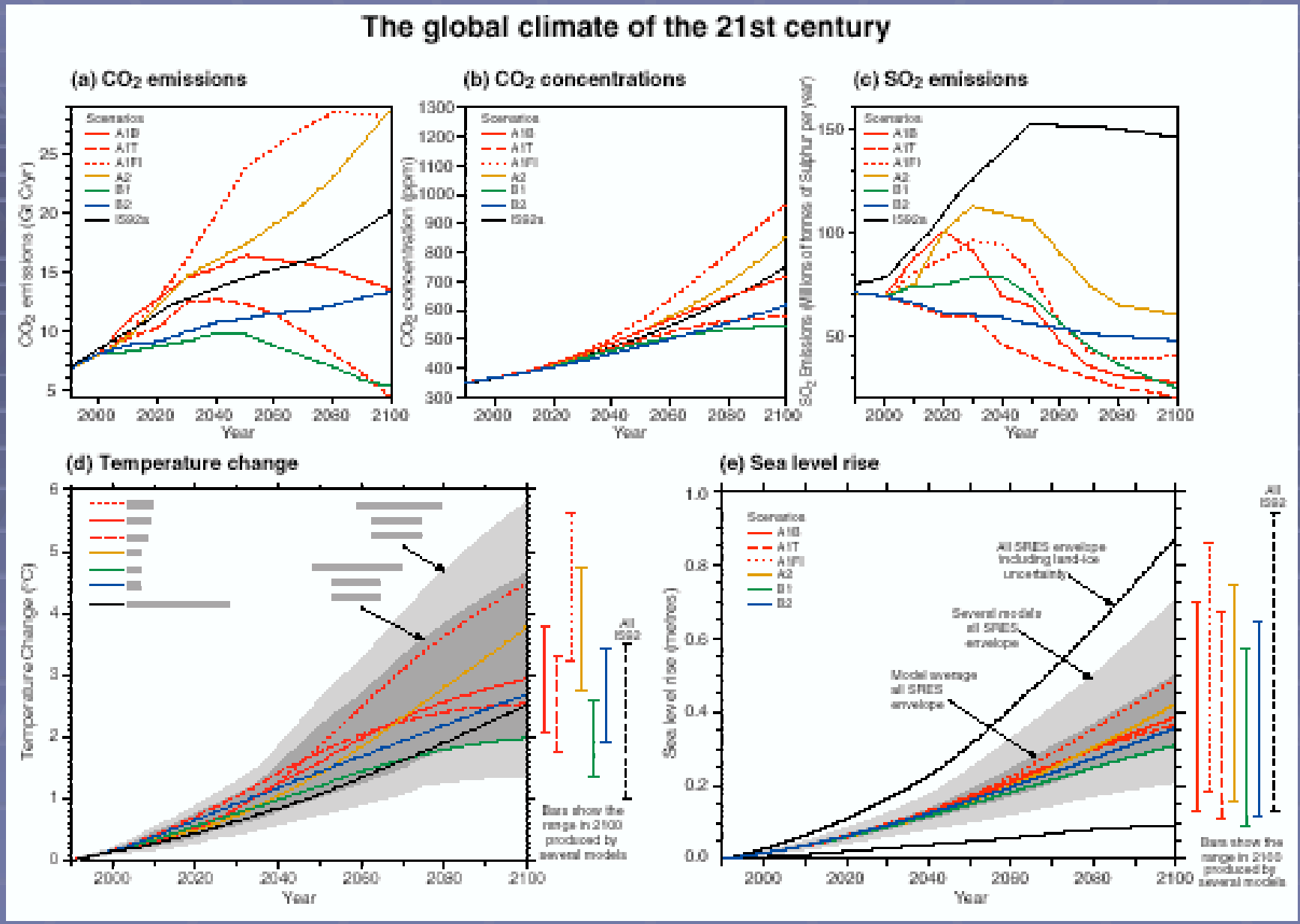


Cartoon of one complete 'snowball' episode, showing variations in planetary albedo, atmospheric carbon dioxide, surface temperature, tropospheric depth, precipitation, glacial extent, and sea ice thickness. Stage 1. incipient glaciation; 2. runaway ice-albedo (onset of 'snowball'); 3. end of 'snowball'; 4. transient 'hothouse' aftermath.

21st Century Greenhouse Experiment

- Burning fossil fuels: we've seen that CO2 plays important role in thermal balance
- Global effects
  - Ice caps melting
  - Flooding of coastal regions
  - Destruction of habitats
  - 2 -10 K mean warming of Earth's surface
- Comparable to major climatic events

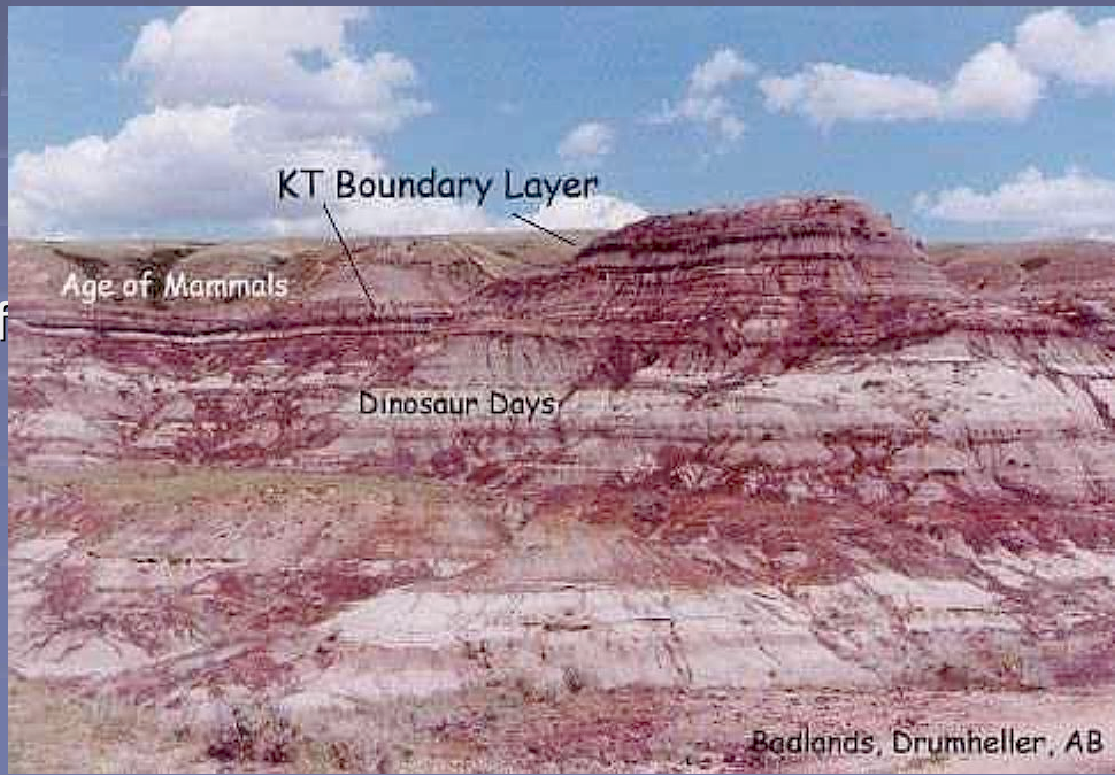



The global climate of the 21st century
(a) CO_2 emissions
(b) CO_2 concentrations
(c) SO_2 emissions
(d) Temperature change
(e) Sea level rise
Scenarios
A1B
A1T
A1FI
A2
B1
B2
IS92a
Year
Bars show the range in 2100 produced by several models
All SRES envelope including land-ice uncertainty
Several models all SRES envelope
Model average all SRES envelope

IGPP report

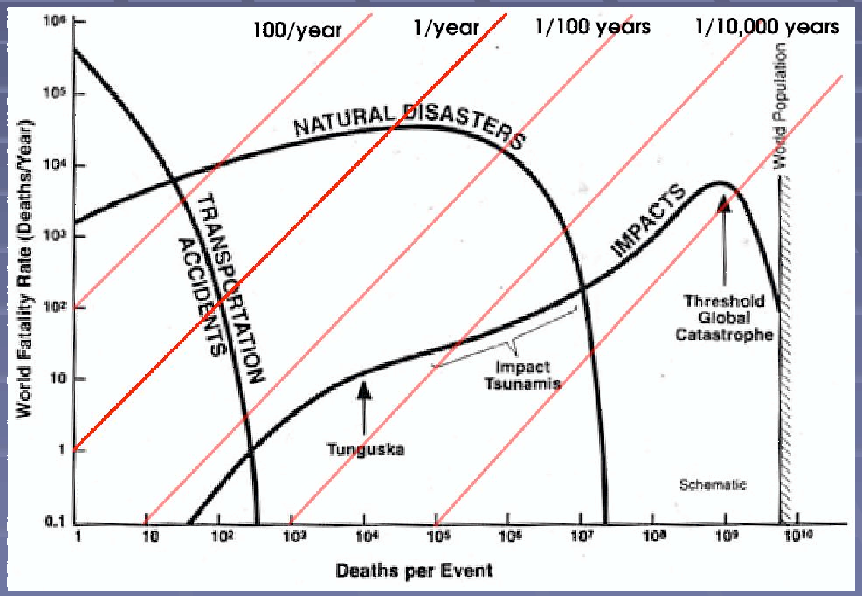
Mass Extinction

- Bombardment continues to today
- Comet hits Yucatan penisula 65 million years ago
  - Collision kicks up dust layer that covers Earth's surface
  - Nuclear winter
  - Sudden disappearance of much of life on planet (including dinosaurs)
  - Iridium layer
  - Evidence of global fires
  - Nuclear winter



Another Thing to Worry About…

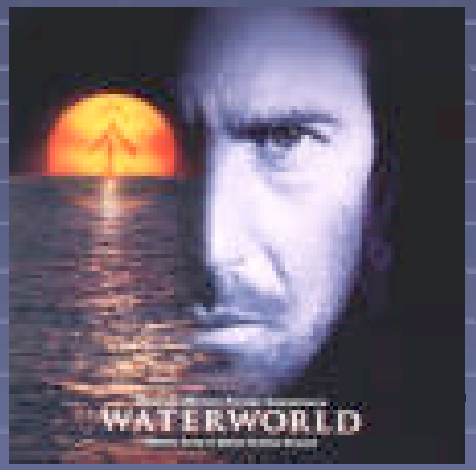
- Tunguska impact
- Evidence for episodic extinctions
- Proposals for large scale astronomical surveys
- Bad Hollywood movies
- Role of Jupiter as Planetary Protector



Other Earth-Like Planets

- Ocean Planets
  - 1-8 Earth mass planets that form in outer solar system disk and migrate in (smaller version of Uranus and Neptune)
    - Too small to retain H and He, but able to retain water
    - Moves inwards (like Jupiter-like planets)
  - Deep Oceans (60 km?)
  - Oxygen atmosphere (without life)
  - Cloud layer allows comfortable conditions close to star
- Earth looks very different at different stages
- Mars, Venus: small differences lead to significant variation in planet properties


alien
alien


WATERWORLD


Disney
MY FAVORITE MARTIAN


DEEPIMPACT
the movie
n.e.o. database
impact survival network