Reading this week: Chap. 8, Sec. 8.3-8.4; Chapt 10, Sect. 10.3, Chap. 11
Homework 7: due this Friday / Monday

Brief review of last time: **Venus & Mars**

- Venus: impact craters, volcanism, tectonics?
- Mars: craters, volcanism, erosion, tectonics
  - Hemisphere dichotomy, weathering, impacts
  - Tharsis Bulge features, volcanos and tectonics
  - evidence of liquid water in the past and present

Today: **Planetary Atmospheres**

- Survey of Planetary Atmospheres
- Primary Atmosphere, Secondary Atmosphere alteration
- Atmospheric Pressure and Temperature
  - Pressure vs. height: Hydrostatic Equilibrium; T vs. height: thermal equilibrium
- Earth's Atmosphere
- The Greenhouse Effect

Overview of Planetary Atmospheres

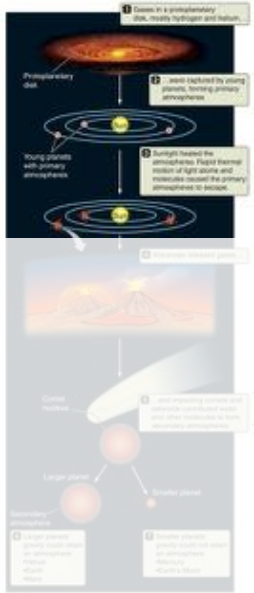
Terrestrial

	Venus	Earth	Mars
Surf. Pressure	92	1	0.007
%CO_2	96	trace	95
%N_2	4	77	3
% O_2	0	21	0
avg. T [C]	470	15	-50
Clouds	H_2SO_4	H_2O	CO_2 , H_2O

Jovians

	Jupiter	Saturn	Uranus
% H	75	85	74
% He	24	14	24
%CH_4	< 0.1	< 0.1	< 1
% NH_3	< 0.1	< 0.1	< 0.1
avg. T [C]	-150	-185	-210
Clouds	NH_3, H_2O, ?	NH_3, NH_4 SH	NH_3, CH_4

Planetary Atmospheres: gas, vapor, ice



Primordial Atmosphere composition:

- mostly H_2, He
- trace elements tied up in molecules
  CO_2, CH_4, N_2, H_2O, NH_3

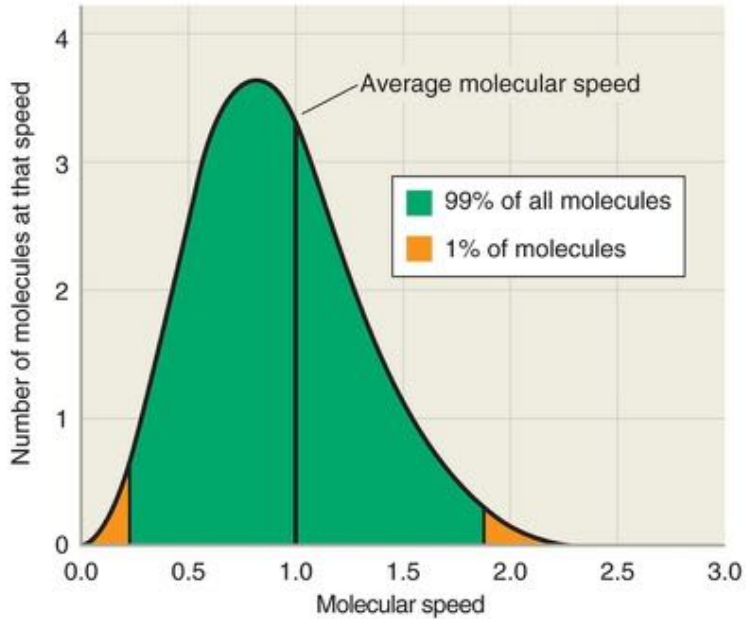
Hydrogen lost from inner planets very early:

$$\text{av.mol.speed} = 2.1\ \text{km/s} \times \sqrt{\frac{T}{273K} \times \frac{m_h}{m_{\text{mol}}}}$$

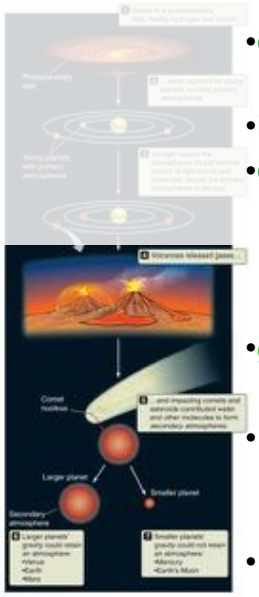
gas will escape if this is greater than 1/6 v_{esc}:

$$1/6\ v_{\text{esc}} = 1.9\ \text{km/s} \times \sqrt{\frac{M_{\text{planet}}}{M_{\text{Earth}}} \times \frac{R_{\text{Earth}}}{R}}$$

molecular speed at a fixed temperature

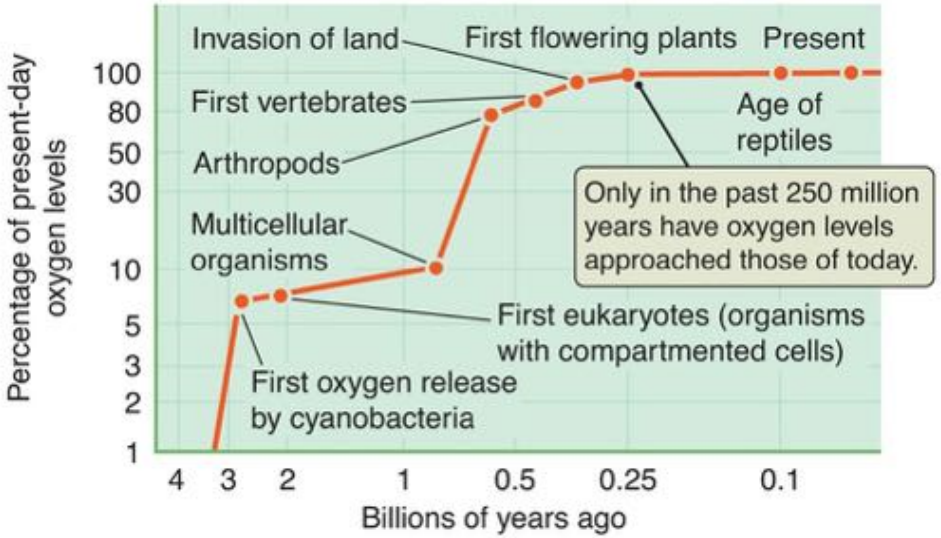


Secondary Atmosphere alteration



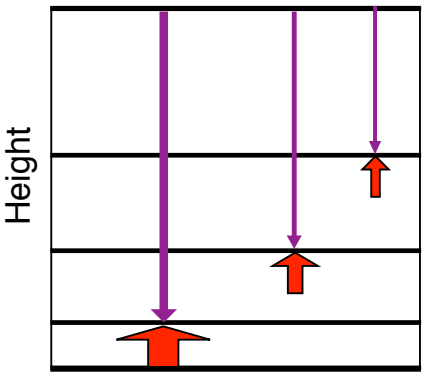
- outgassing (volcanism): release of gas from interior
  CO_2, N_2, H_2O, CH_4, SO_2
- impacts of icy bodies brings: H_2O, CH_4, CO_2
- chemistry
  - O_2 bound up in oxides (very fast)
  - CO_2 bound up in carbonate rocks, surface H_2O
  - H_2O bound up in rock
- geology
  - H_2O trapped beneath surface (permafrost)
- BIOLOGICAL ACTIVITY:
  - photosynthesis: CO_2 –> O_2; methane from cows
- Human Activity
  - CO_2, complex organics, CFCs, ozone depletion

Earth biology and our atmosphere



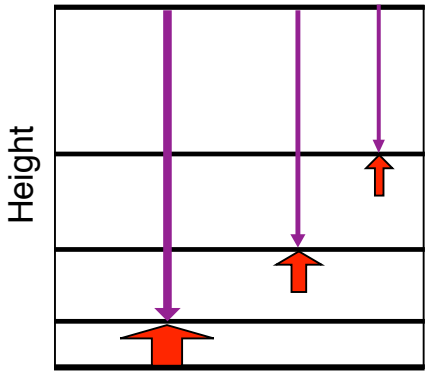
Atmospheric Pressure and Temperature

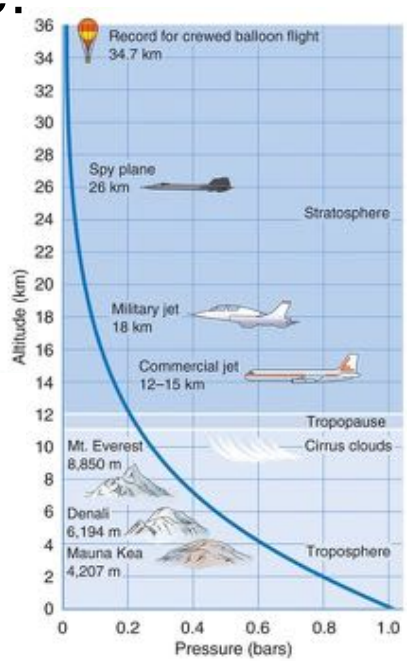
- **Pressure** vs. height: Hydrostatic Equilibrium:
  - gas pressure upwards
    balances
  - gravity (weight) downwards
    - pressure highest at surface, drops with altitude
    - density also highest at surface, drops with altitude



Earth's Atmosphere:

pressure vs. height

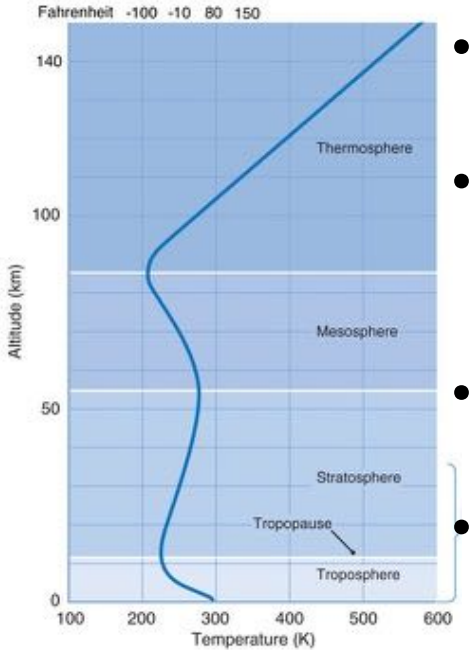




Atmospheric Pressure and Temperature

- **Pressure** vs. height: Hydrostatic Equilibrium:
  - gas pressure upwards
    balances
  - gravity (weight) downwards
    - pressure highest at surface, drops with altitude
    - density also highest at surface, drops with altitude
- Temperature vs. height: thermal equilibrium:
  - warm if layer absorbs solar energy
  - cool if layer is transparent to solar radiation
- temperature depends on composition of atmospheric layers as well as pressure & density:
  - IR absorbers: CO_2, H_2O
  - UV absorbers: N_2, O_2, O_3

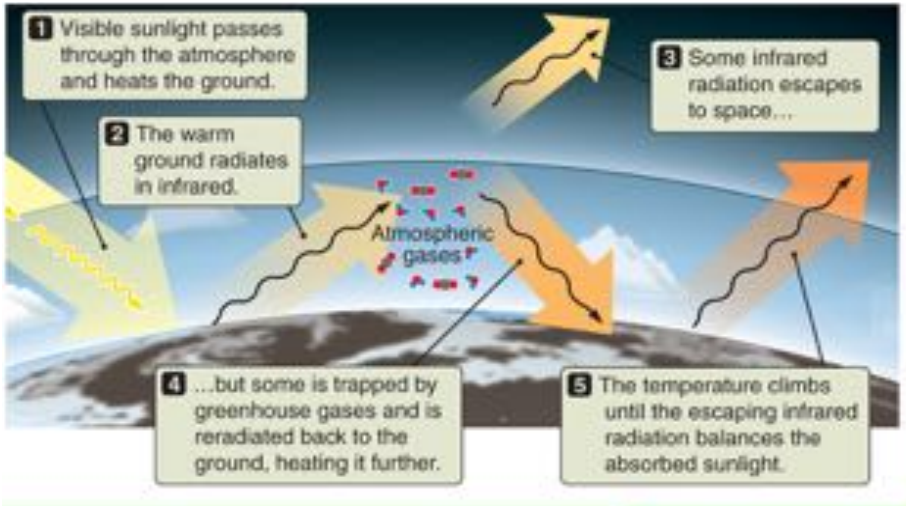
Earth's Atmosphere: temperature vs. height



- 85-110+ km: thermosphere
  - UV absorption by N_2, O_2
- 55-85 km: mesosphere
  - O_2+UV –> O
  - O + O_2 + UV –> O_3
  - O_3 great absorber of UV
- 12-55 km: stratosphere
  - cold
- 0-12 km: troposphere
  - ground heating

The Greenhouse Effect

The Greenhouse Effect



The Greenhouse Effect:

some gasses are transparent in visible/UV wavelengths
but
are opaque (absorbers) in the Infrared

MAIN GREENHOUSE GASSES: CO_2, H_2O

- solar energy arrives at Earth, heats up ground
- ground radiates energy in far–IR
- far–IR trapped by Greenhouse gasses
- ground heats up more, radiates in near–IR
- greenhouse gasses allow near–IR to escape
  sets up a balance with incoming energy

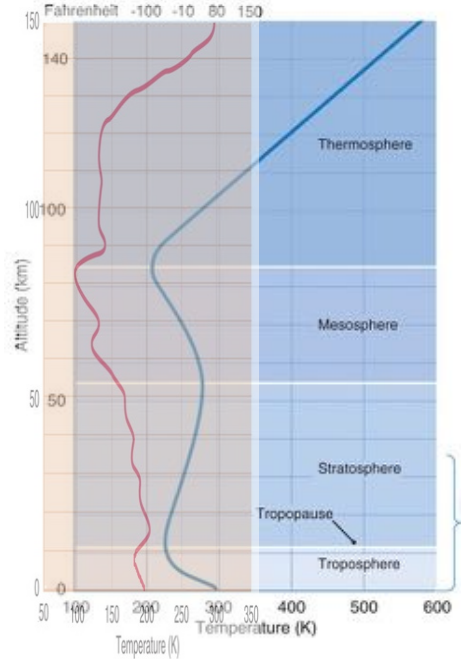
	w/o atmosphere	with atmosphere
Mercury	160 C	160 C
Venus	40 C	470 C
Earth	0 to -15 C	15 C
Mars	-55 C	-50 C

Methane leak
Aliso Canyon (Porter Ranch) California

- Oct. 23, 2015 - Feb.11, 2016
- ~100,000 tons of methane escaped
  - equivalent to CO_2 release from burning 1 billion gallons of gasoline
- **Methane is transparent to visible light, so leak is "invisible"**
- But methane blocks Infrared light, so IR photography reveals escaping gas

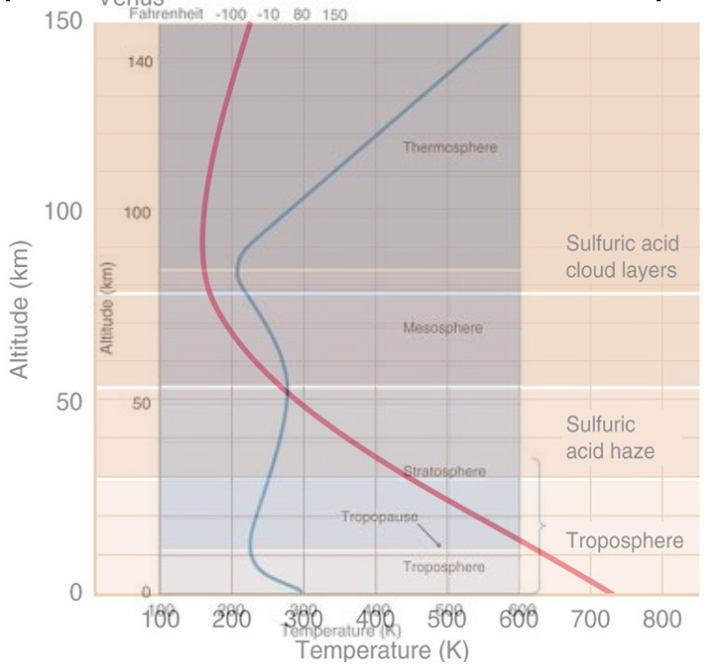
Infrared view

Temperature Structures in terrestrial planets



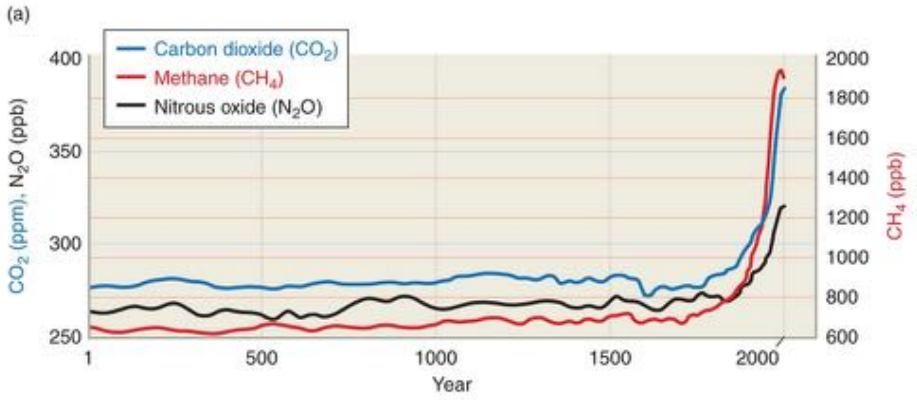
Earth
Mars

Temperature Structures in terrestrial planets

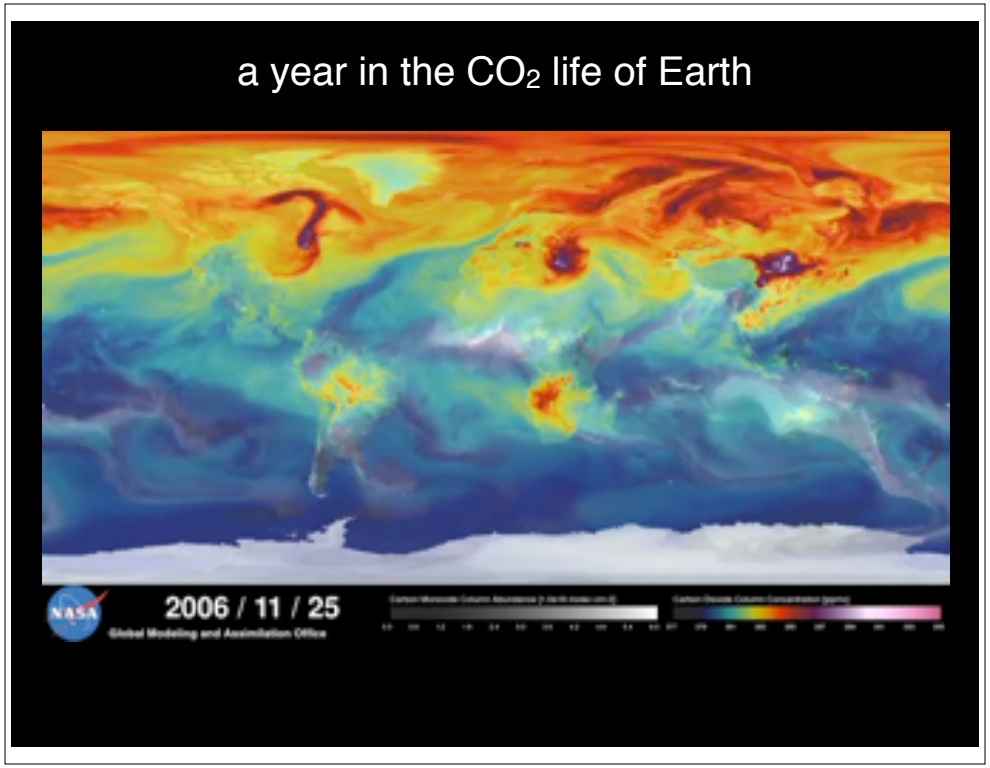


Earth
Venus

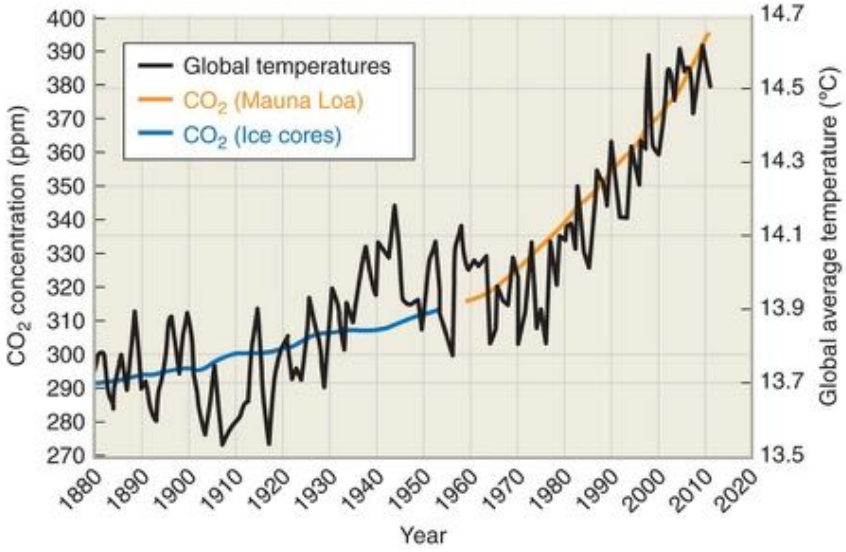
Earth's changing greenhouse effect: Greenhouse gasses



a year in the CO_2 life of Earth



Earth's changing greenhouse effect: CO_2 and global temperature



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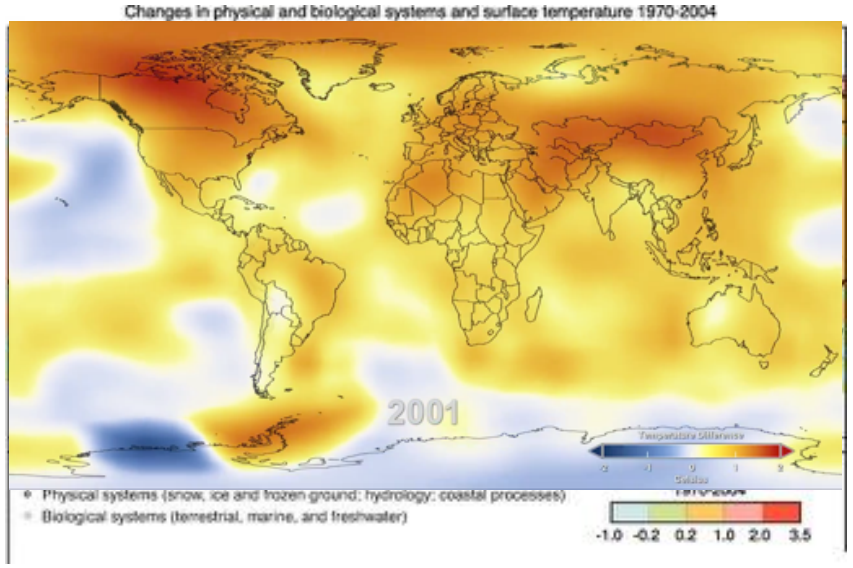
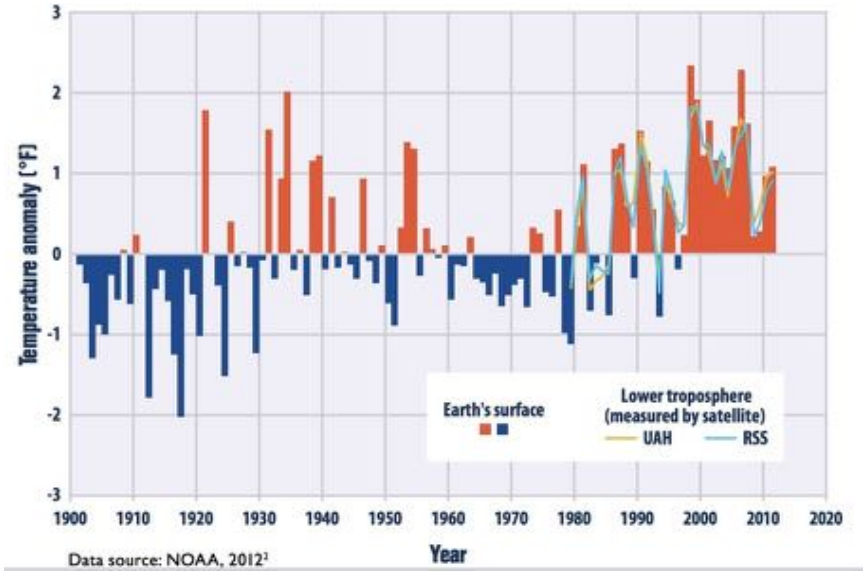
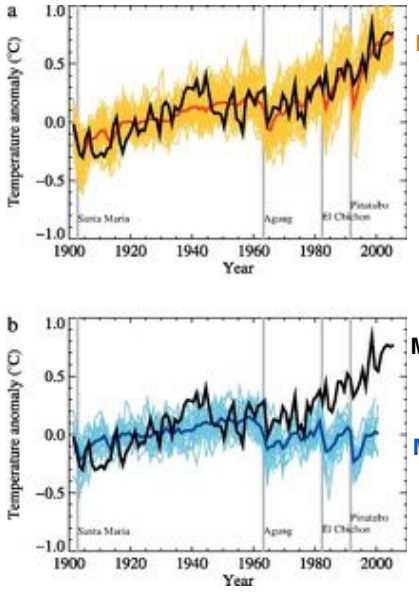


Earth's changing greenhouse effect: US surface temperature



Is it all natural? No.



Model with human activity

Measurements

Model with natural forcing only

Global Warming and Ozone Depletion

effects of mankind on our atmosphere

- CO_2 is up 15% this past century
  - from burning fossil fuels
  - increased greenhouse effect
  - excess global warming?
  - complicating factors:
    - warmer = more clouds
    - = blocked sun
    - = less energy input
  - consequences (possible)
    - global warming
    - reduction in polar ice caps
    - raised sea level

      or
    - massive cloud cover
      - global cooling
      - next ice age?

Global Warming and Ozone Depletion

effects of mankind on our atmosphere

- Ozone (O_3) critical for life
  - shields land from bad UV
  - is very fragile:
  - destroyed by trace chlorofluorcarbons (CFCs)
- complicating factors:
  - complex chemistry
  - CFCs live a long time
  - seasonal effects
- consequences:
  - increased UV exposure
  - skin cancer in humans
  - mutations etc.