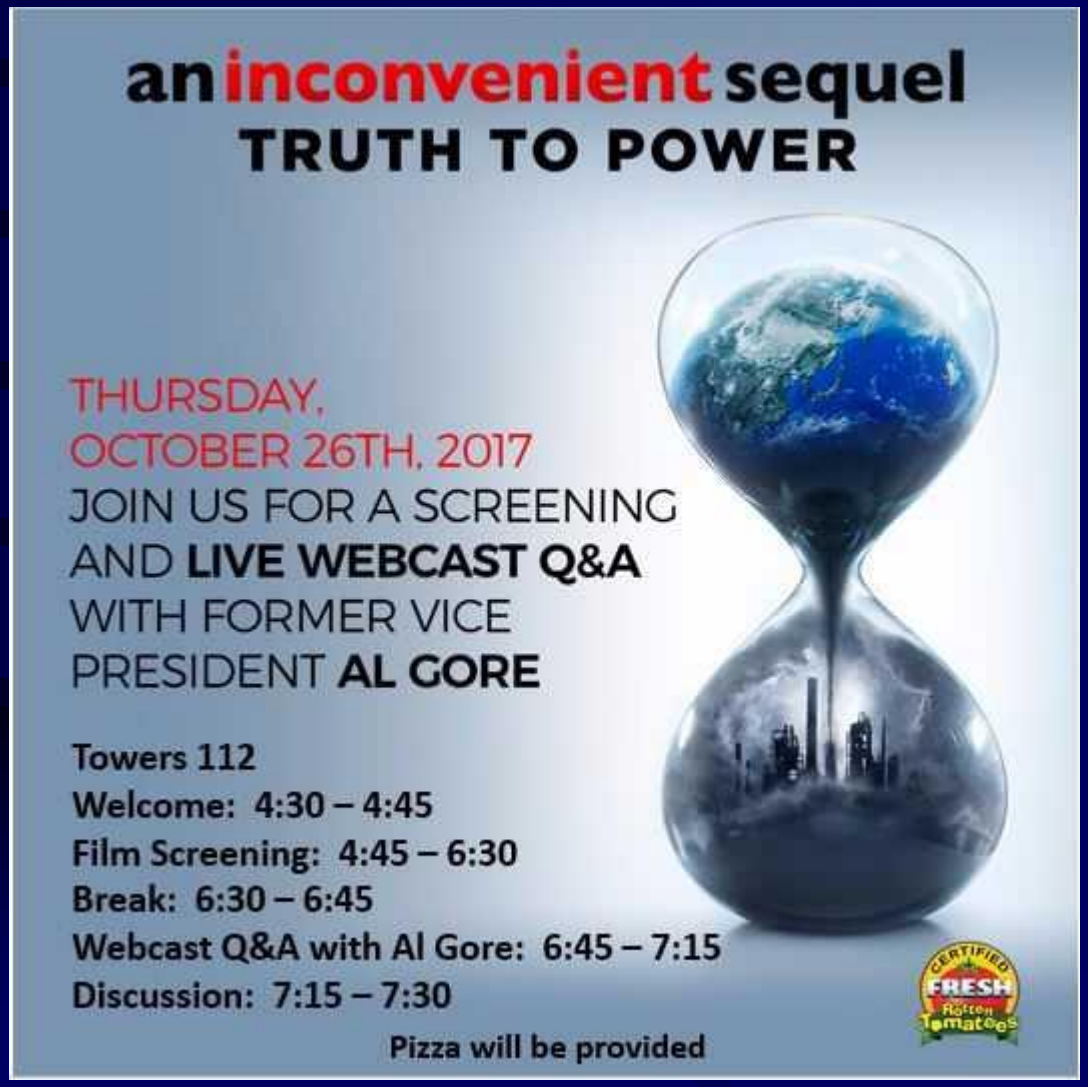
# The Greenhouse Effect

# A timely IS Event on Thursday

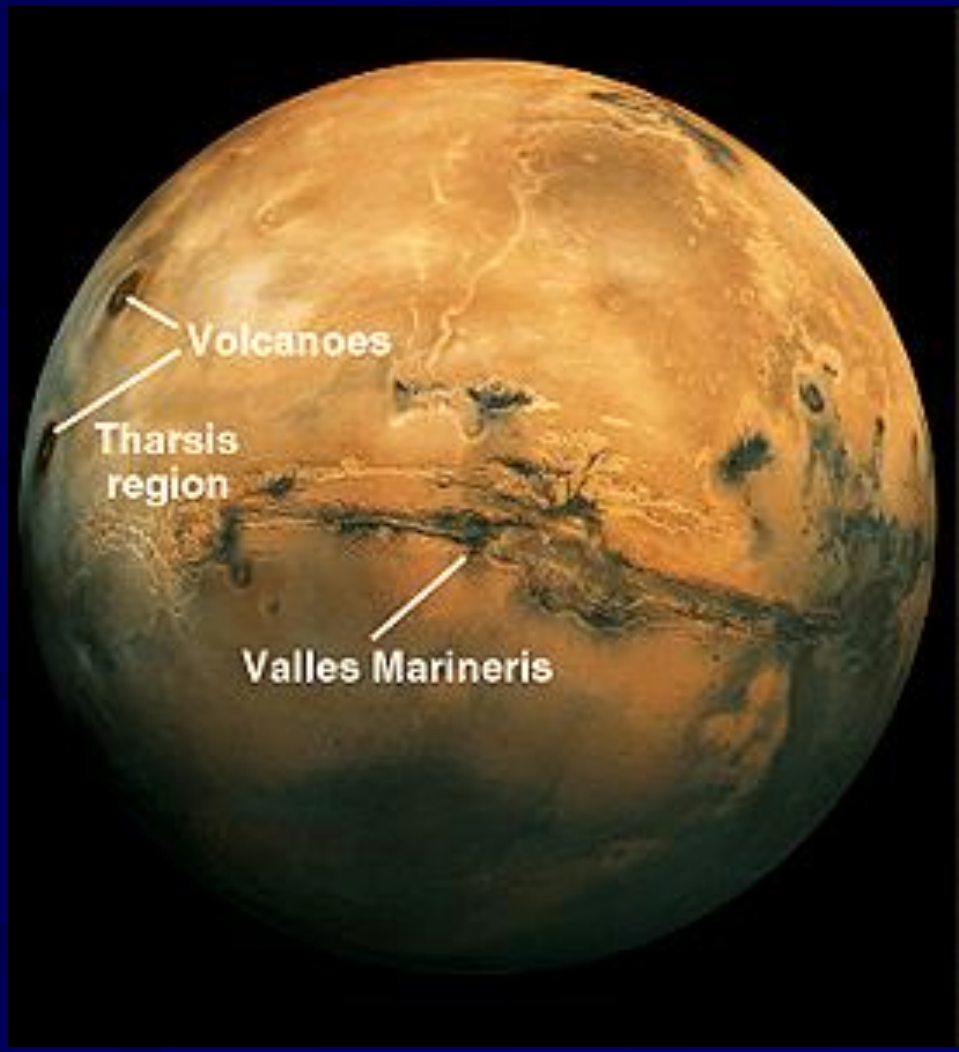


# Mars

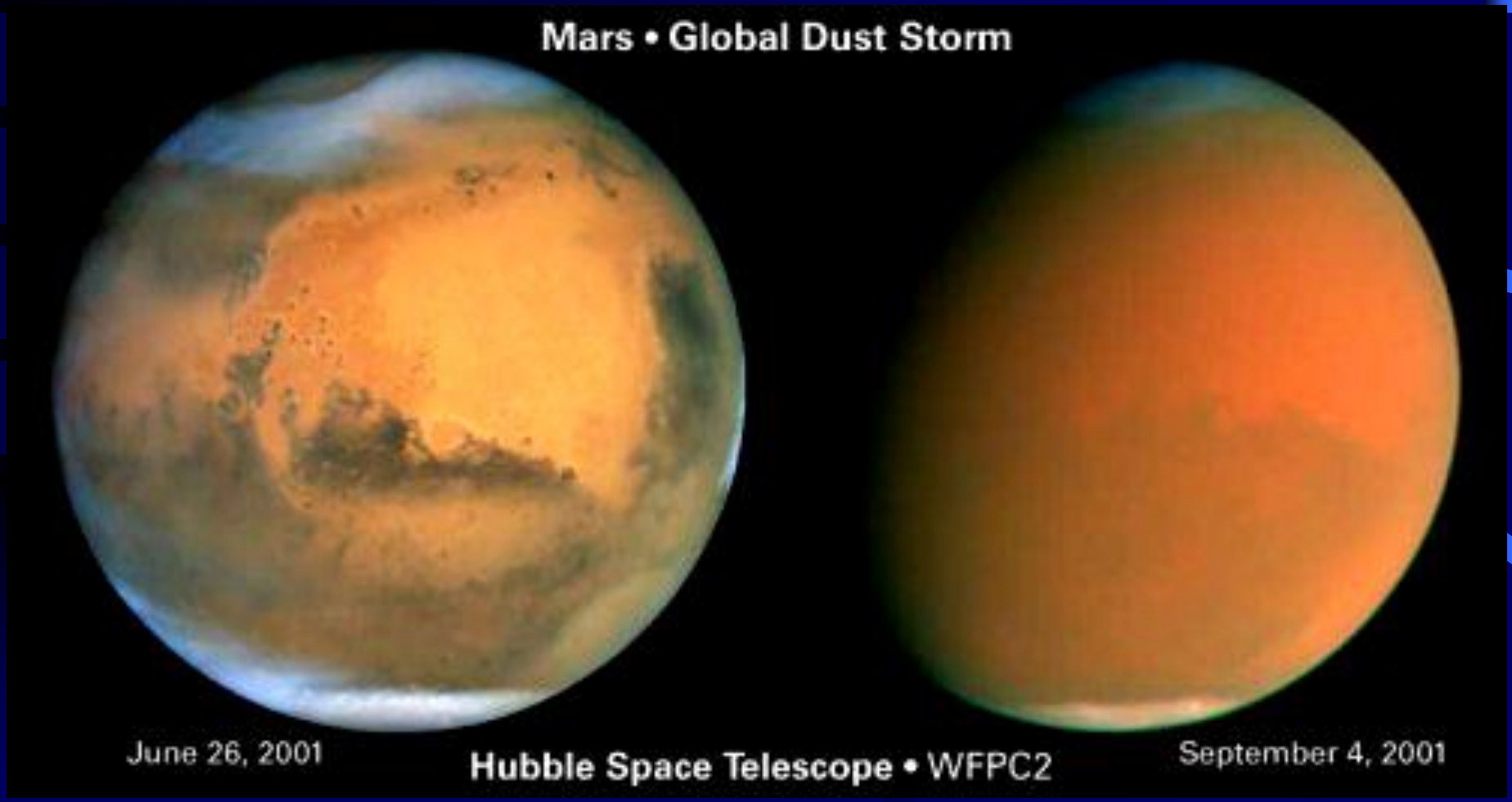
- Fairly bright, generally not too hard to see
- Smaller than Earth
- Density similar to that of the moon
- Surface temperature 150–250 K
- Day ~ 24.6 hours
- Year ~ 2 Earth years
- Thin atmosphere, mostly carbon dioxide
  - 1/150 the pressure of Earth's atmosphere
- Tiny magnetic field, no magnetosphere

# Mars

- Northern Hemisphere basically huge volcanic plains
  - Similar to lunar maria
- Valles Marineris – Martian "Grand Canyon"
  - 4000 km long, up to 120 km across and 7 km deep
  - So large that it can be seen from Earth



# Martian Seasons: Icecaps & Dust Storms



# Martian Surface

Iron gives the characteristic Mars color: **rusty red**!

View of Viking 1

1 m rock

Sojourner

# Martian Panorama

**Note:** the sky is not black as on the moon,

but pale pink of the dust in the **atmosphere**!

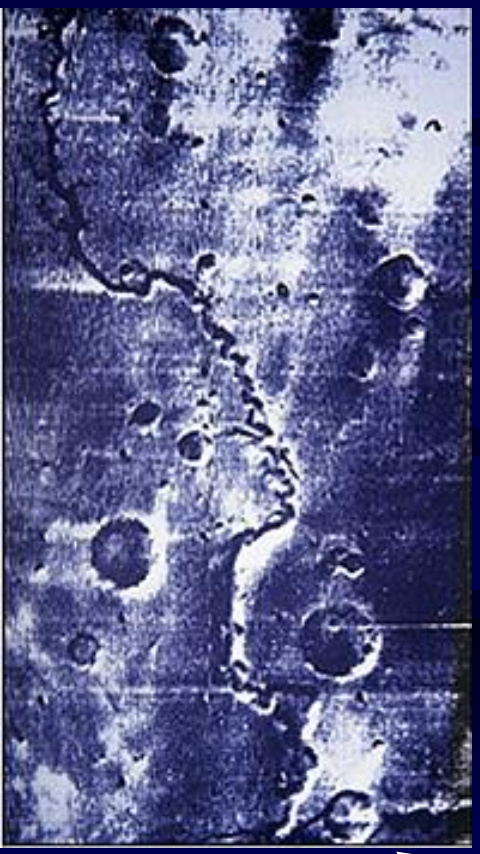
Video: Curiosity Landing

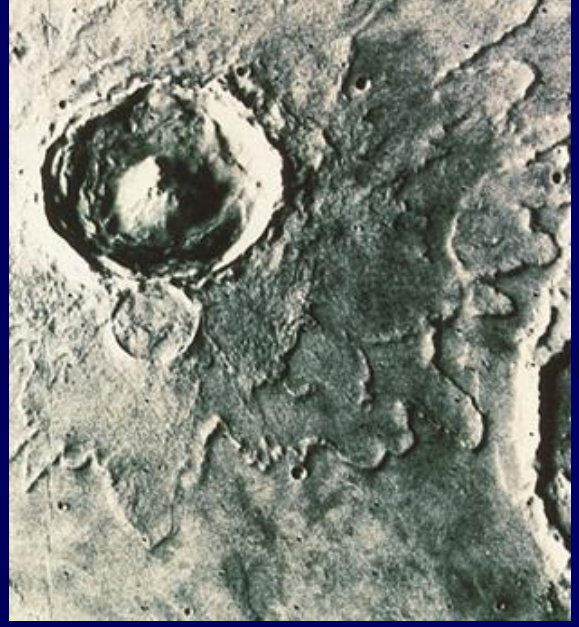
"Twin Peaks" – about 1-2 km away

# Water on Mars?

Mars

Louisiana

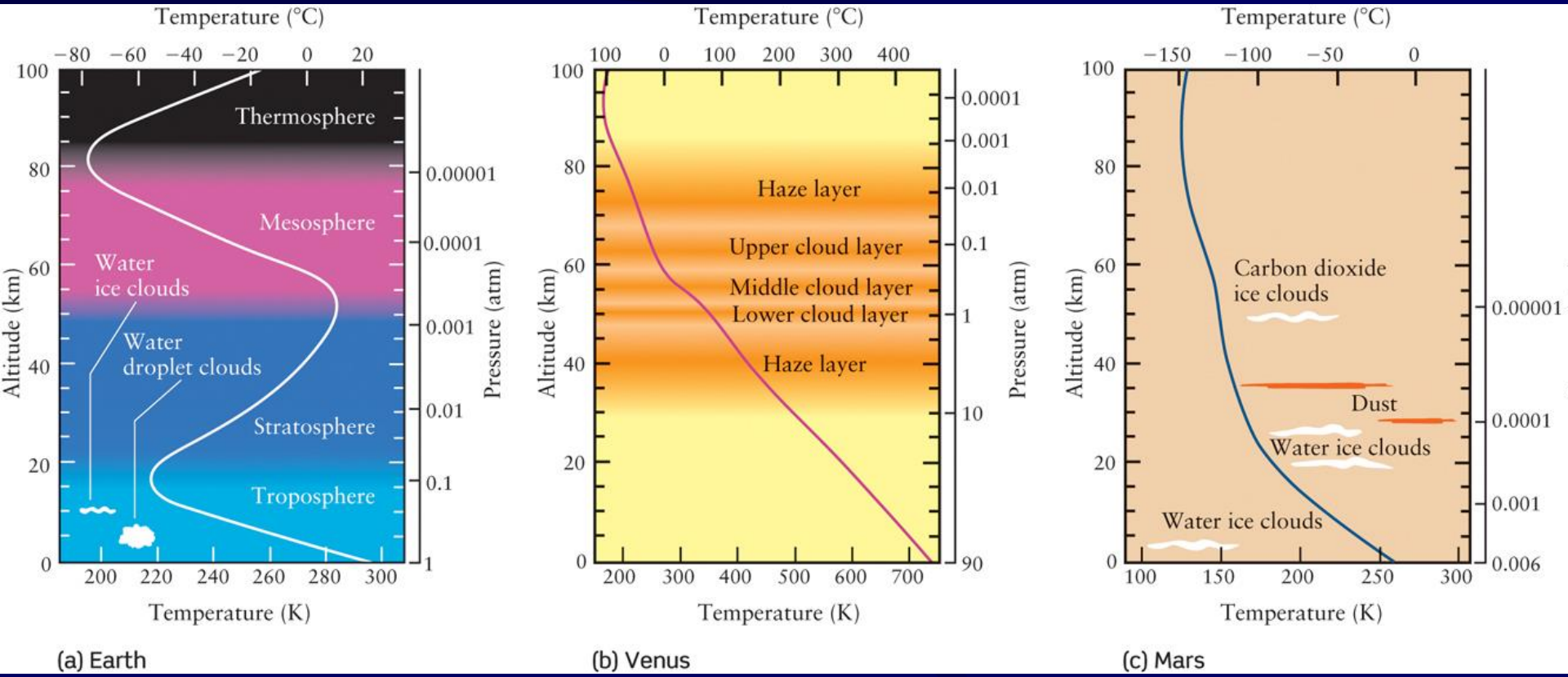




Runoff channels

Outflow Channels

# Terrestrial Atmospheres



# Atmospheric Histories

- Primary atmosphere: hydrogen, helium, methane, ammonia
  - Too light to "stick" to a planet unless it's very big ➔ **Jovian Planets**
- Secondary atmosphere: water, $CO_2$, $SO_2$, …
  - Outgassed from planet interiors, a result of volcanic activity

# Atmospheric Histories - Venus

- Venus is closer to Sun than Earth →hotter surface
- Not a lot of liquid water on surface initially
- $CO_2$ could not be absorbed by water, rocks because of higher temperatures
- → run-away Greenhouse effect: it's hot, the greenhouse gases can't be be stored away, it gets hotter …

# Earth's Atmospheric History

- Volcanic activity spews out water steam
- Temperature range allowed water to liquify
- $CO_2$ dissolves in oceans, damping greenhouse effect
- More water condenses, more $CO_2$ is absorbed
- If too cold, ice forms → less cloud cover → more energy
- No oxygen at this point, since it would have been used up producing "rust"
- Tertiary atmosphere: early life contributes oxygen
  - 1%  800 Myrs ago, 10% 400 Myrs ago

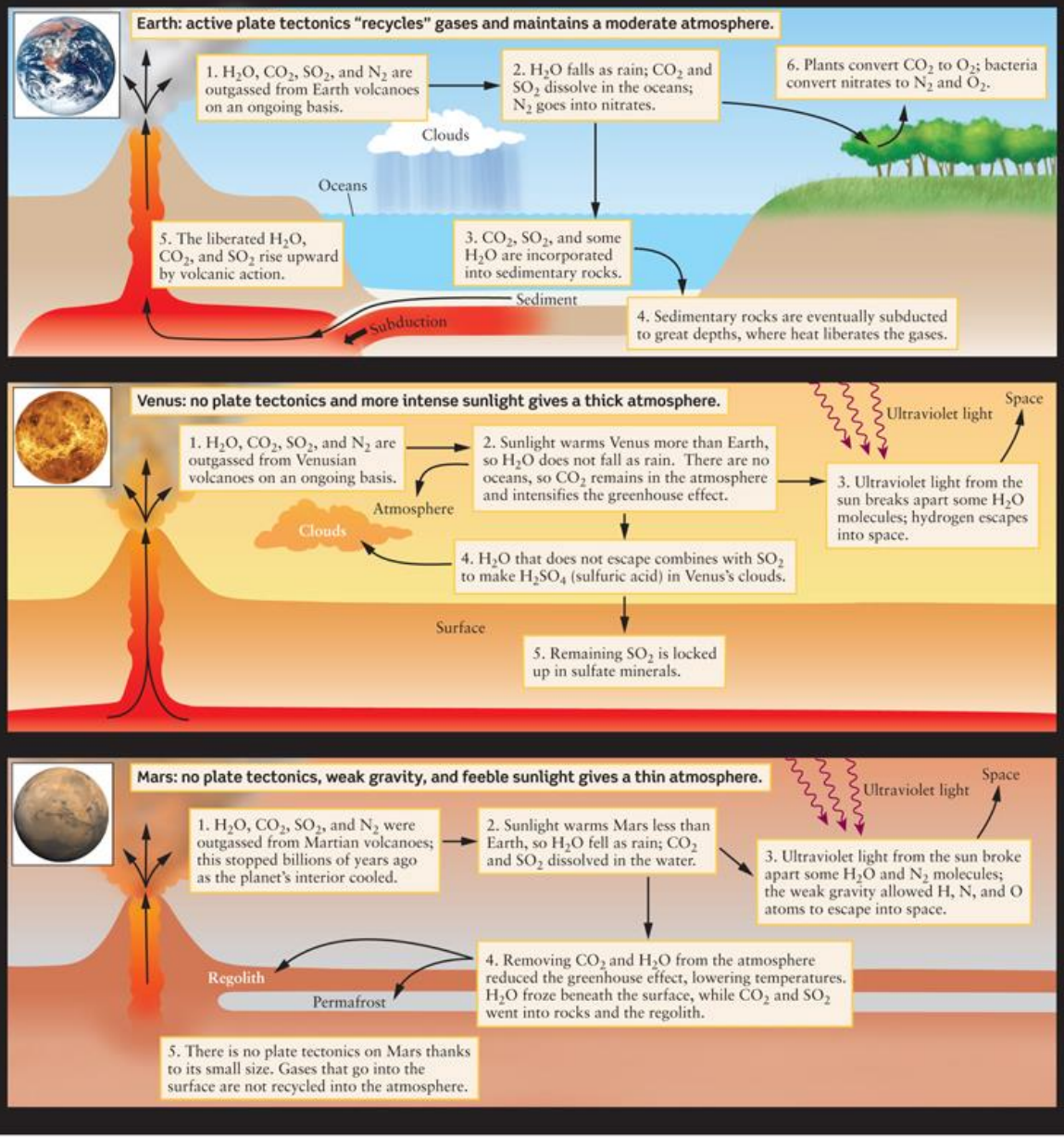
# Mars – Freezing over

- Mars once had a denser atmosphere with liquid water on the surface
- As on Earth, $CO_2$ dissolves in liquid water
- But: Mars is further away from the Sun

  → temperature drops below freezing point → inverse greenhouse effect
- permafrost forms with $CO_2$ locked away
- Mars probably lost its atmosphere because its magnetic field collapsed, because Mars' molten core cooled down

## COSMIC CONNECTIONS Evolution of Terrestrial Atmospheres

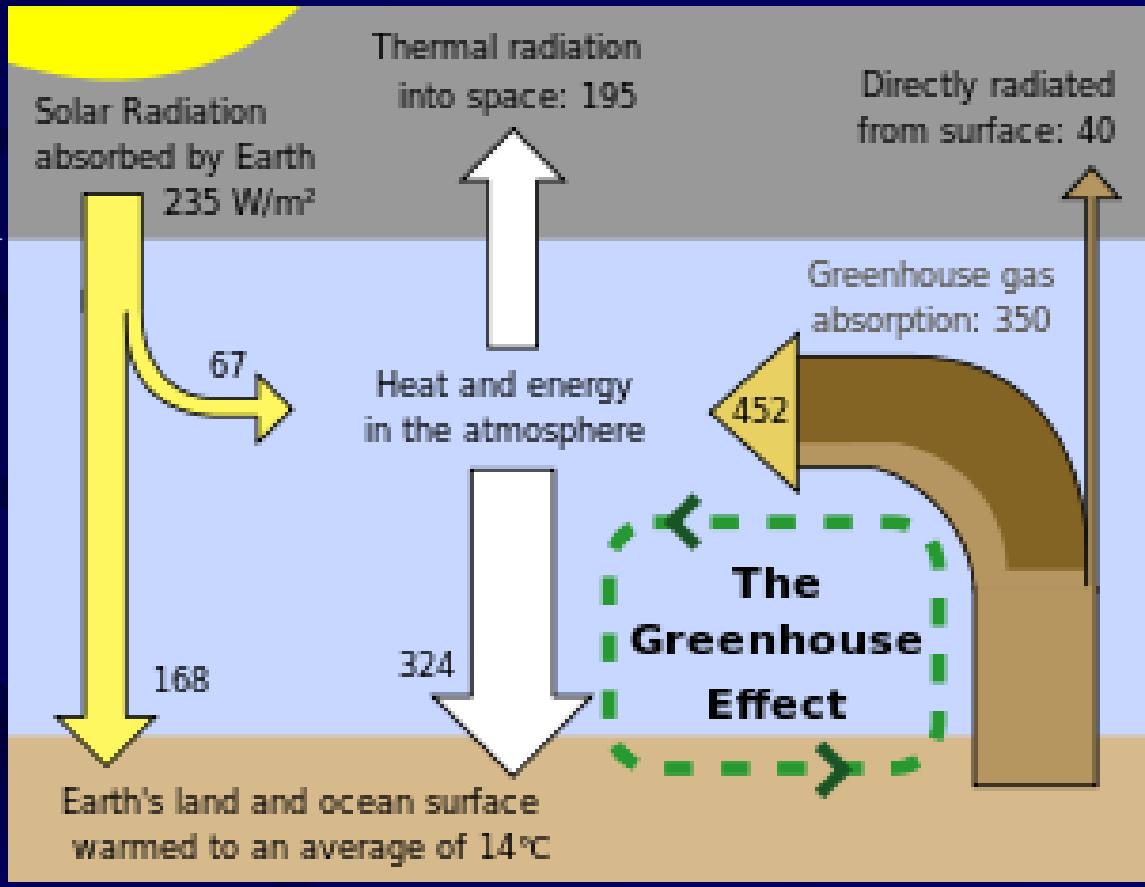
Earth, Venus, and Mars formed with similar original atmospheres. However, these atmospheres changed dramatically over time due to factors such as planetary size and distance from the Sun.




NASA Jet Propulsion Laboratory

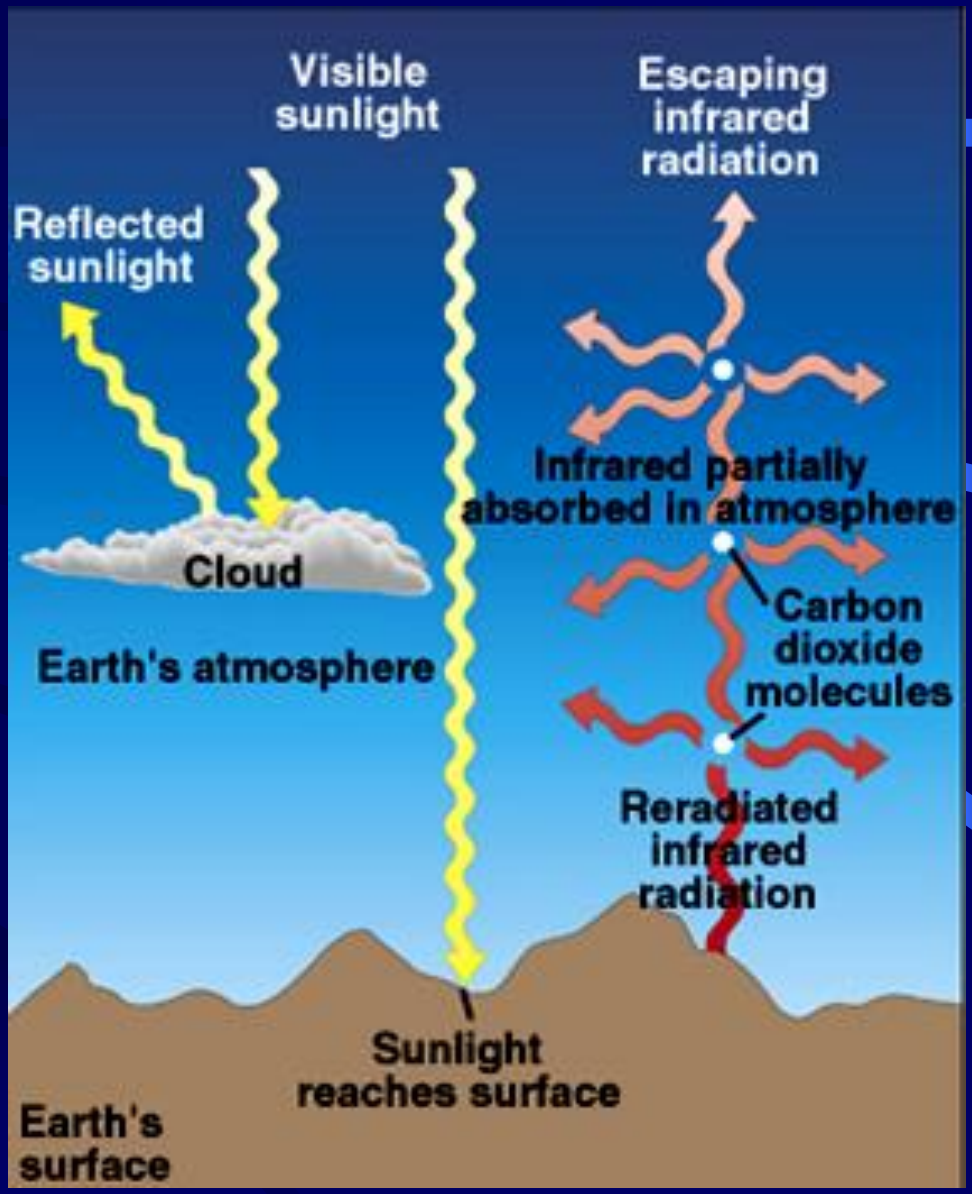
# Greenhouse Effect

- Earth absorbs energy from the Sun and heats up
- Earth re-radiates the absorbed energy in the form of infrared radiation
- The infrared radiation is absorbed by carbon dioxide and water vapor in the atmosphere
- Heats earth by about 40K, up from 250K without greenhouse effect. Significant because it makes surface temp above the freezing point of water

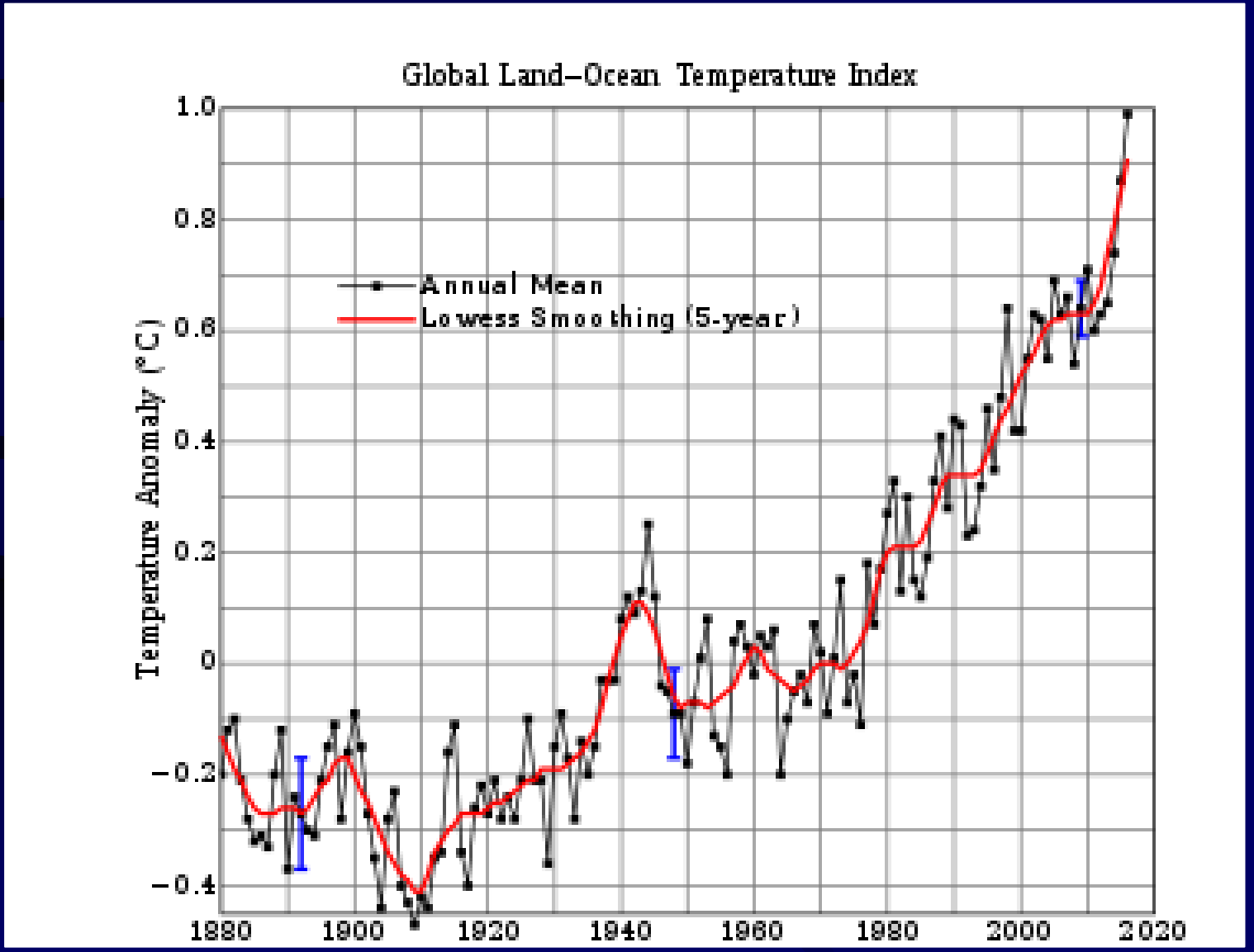


# Global Warming

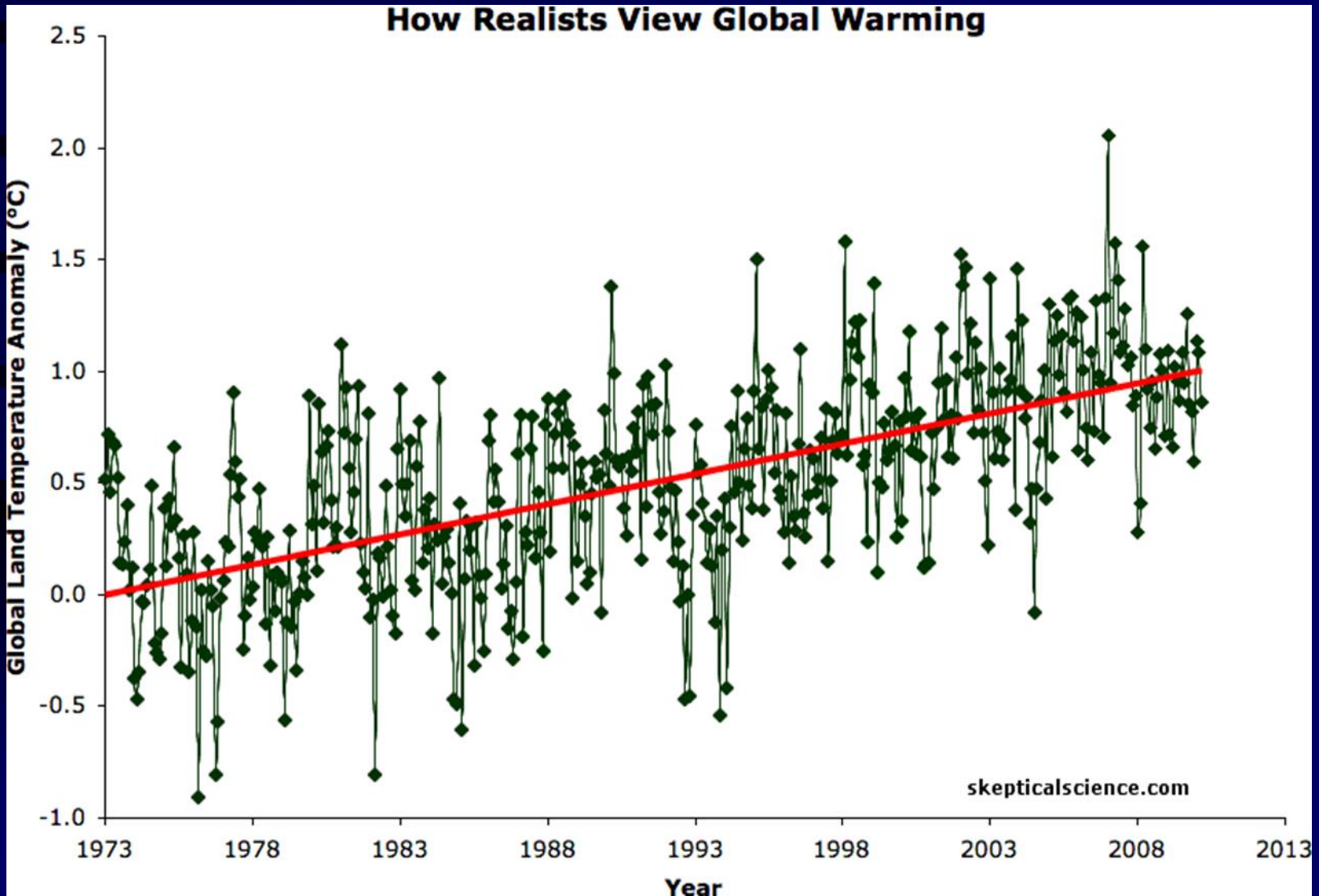
- Excessively "politicized" topic
- Very complex problem scientifically
- Slow changes over long periods of time
- Sources of heating, sources of cooling themselves are temperature dependent



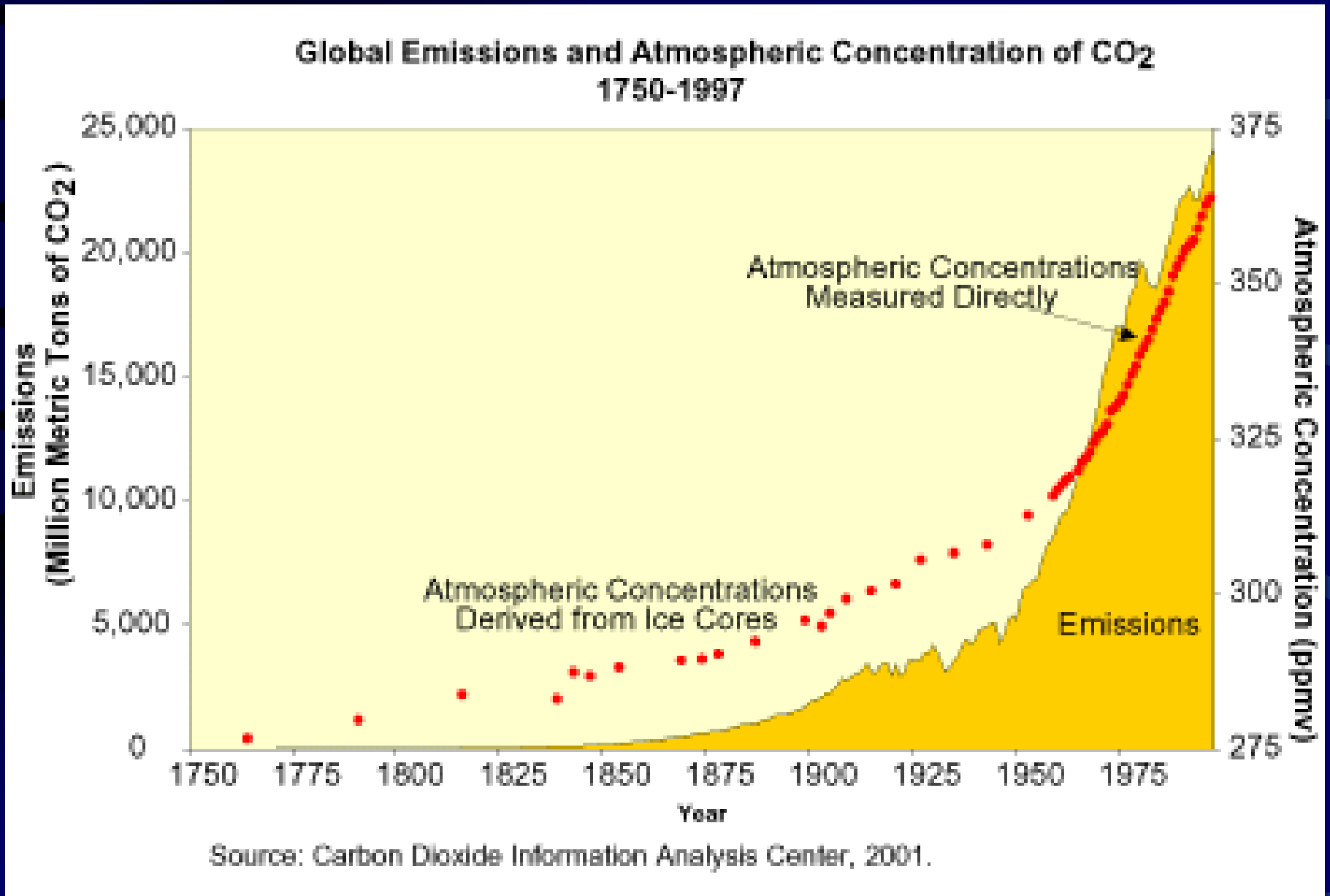
# The Earth is warming up!



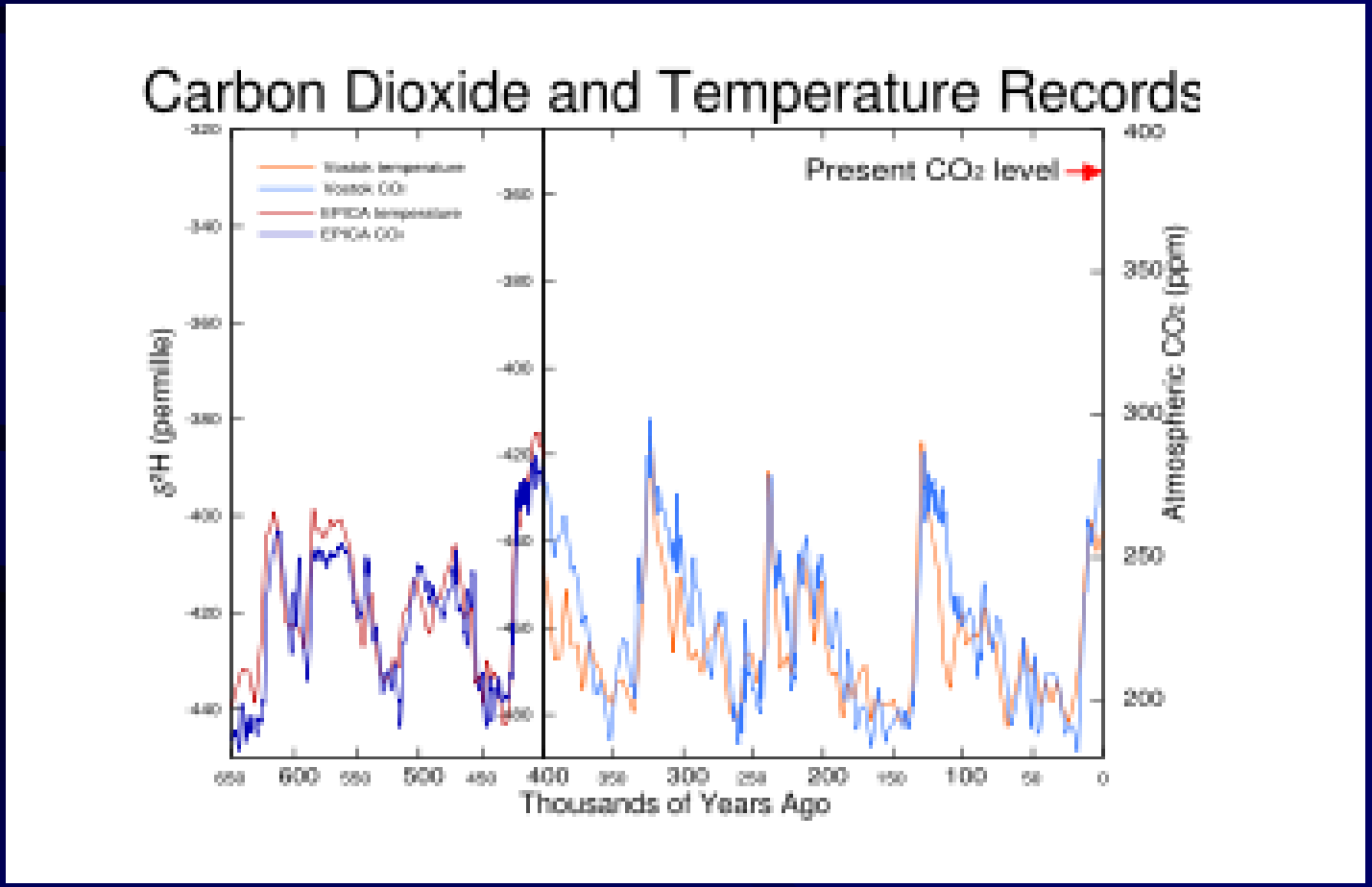
# Noise vs Signal, Long term vs Short term



# Man-made $CO_2$ in the Atmosphere goes up



# Correlation: Temperatures rise when Carbon Dioxide levels rise




- This is true since prehistoric times

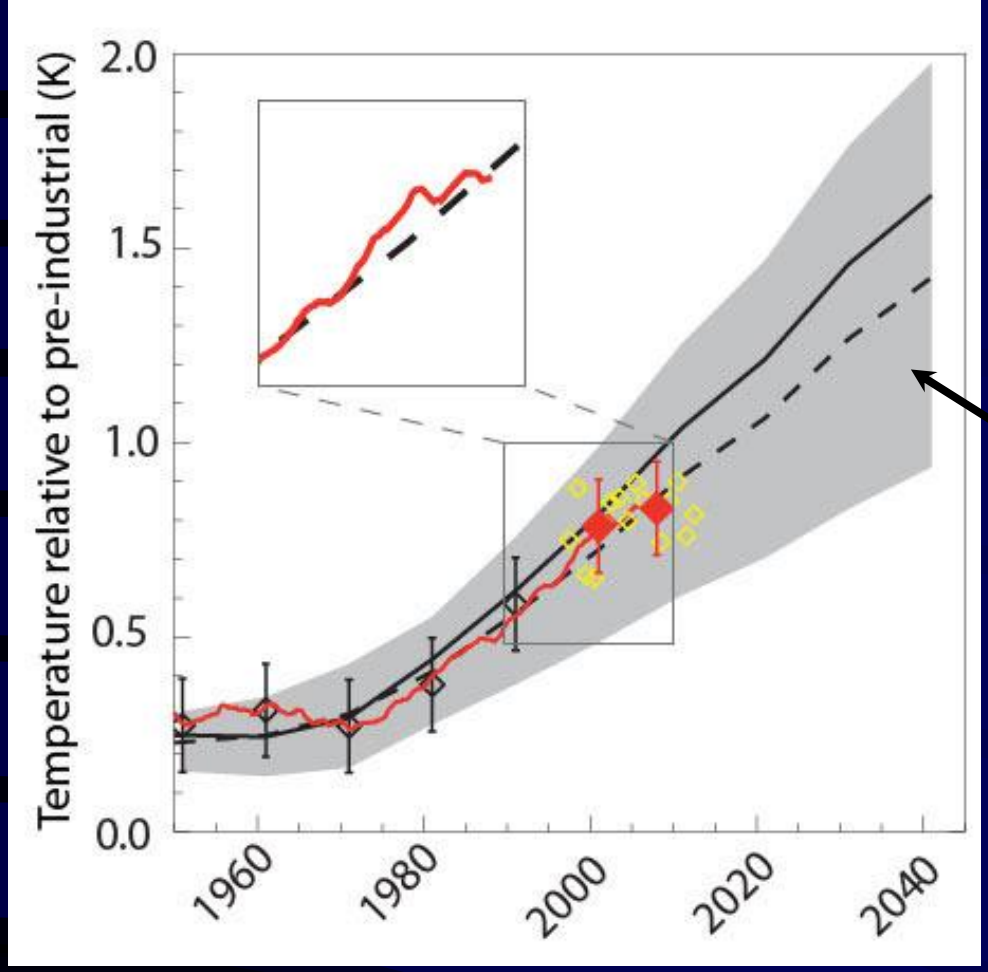
# More evidence of global warming

This is what Whitechuck Glacier in Glacier Peak Wilderness in the U.S. state of Washington looked like in 1973.

In a similar view of Whitechuck as seen in 2006, where this branch of glacier retreated 1.9 km (1.2 mi).

http://en.wikipedia.org/wiki/Retreat_of_glaciers_since_1850


# Boulder Glacier, Washington state




# Predictions are observed to be correct – climate model supported!

prediction in 1999

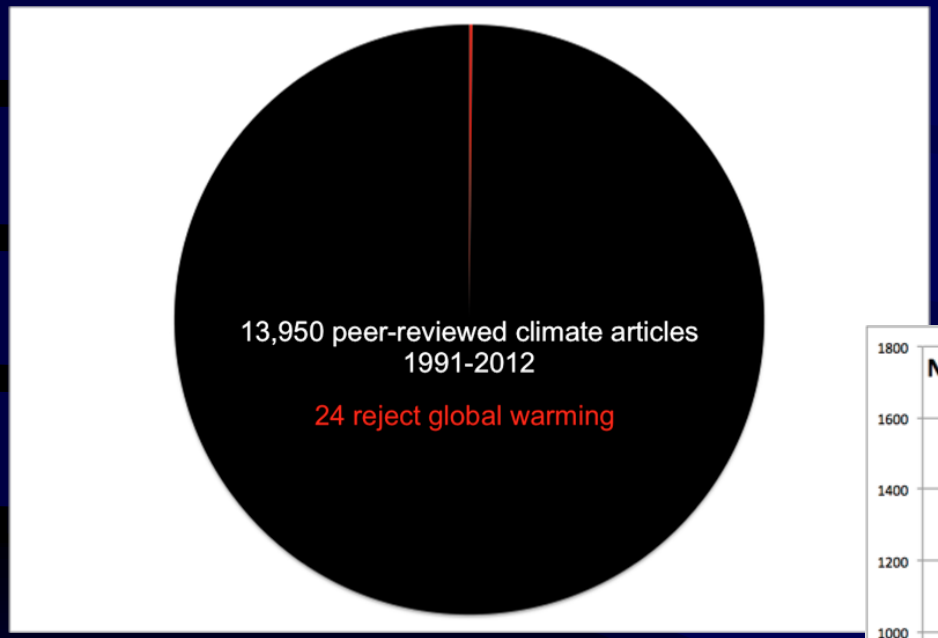
*Nature Geoscience* **6**, 243–244 (2013)

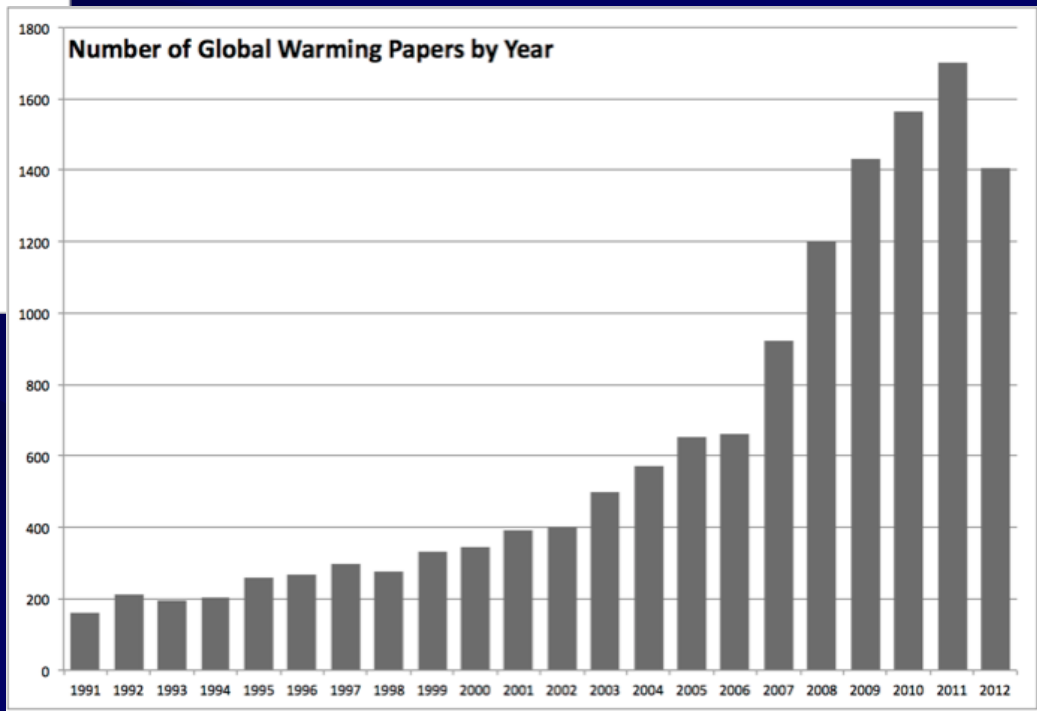
doi:10.1038/ngeo1788

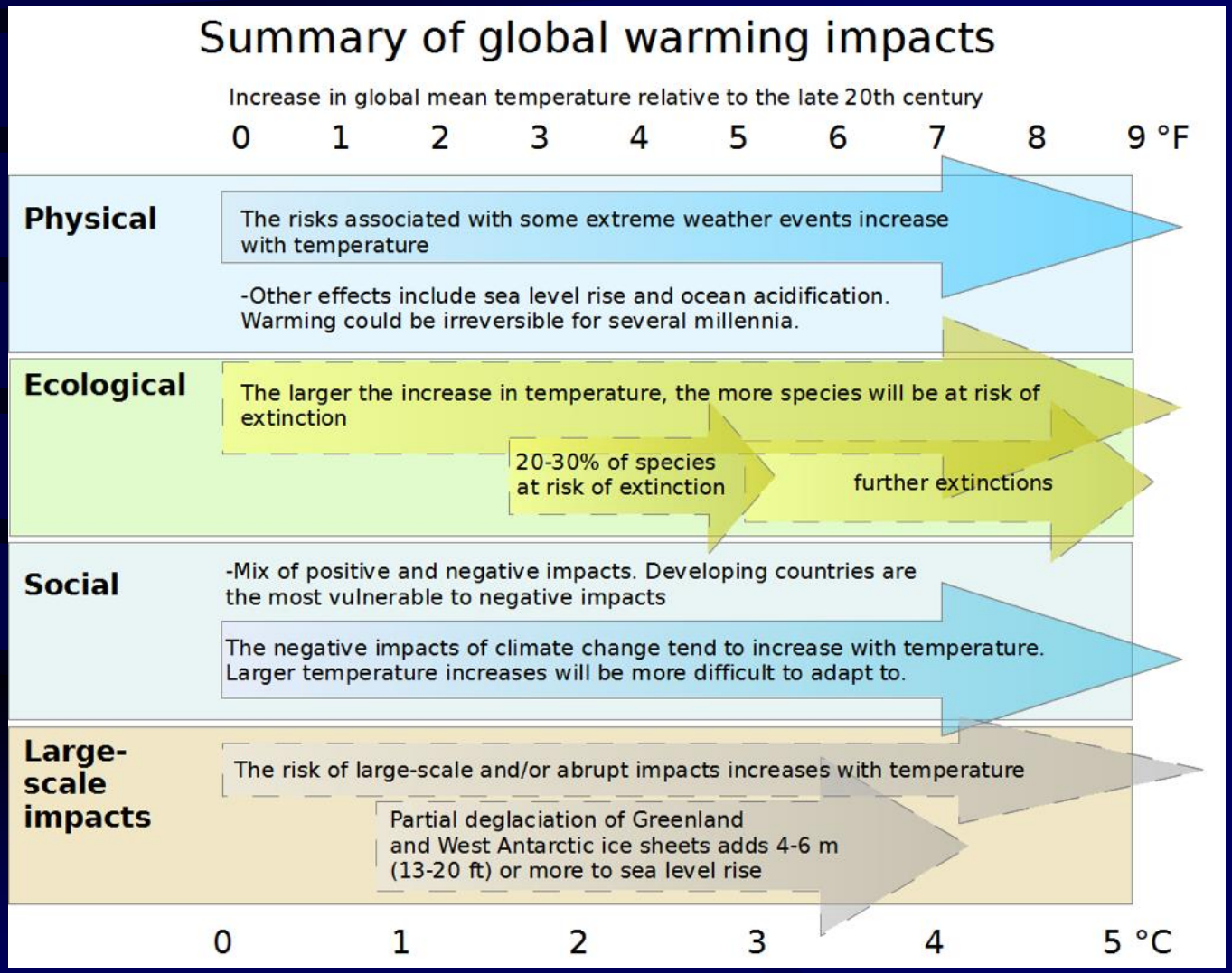
Published online 27 March 2013

The climate forecast published in 1999 is showed by the dashed black line. Actual temperatures are shown by the red line (as a 10-year mean) and yellow diamonds (for individual years). The graph shows that temperatures rose somewhat faster than predicted in the early 2000s before returning to the forecasted trend in the last few years.

# Overwhelmingly, scientists agree that global warming is real

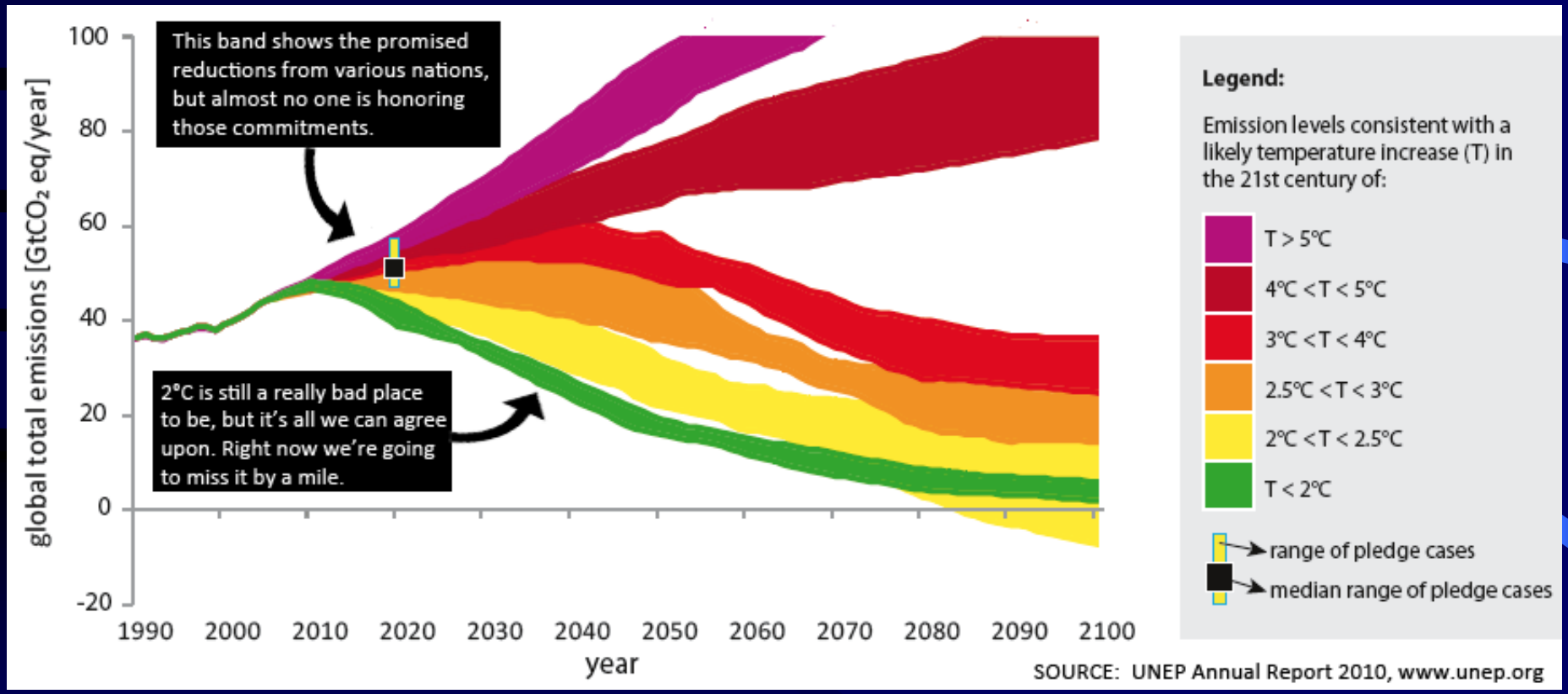


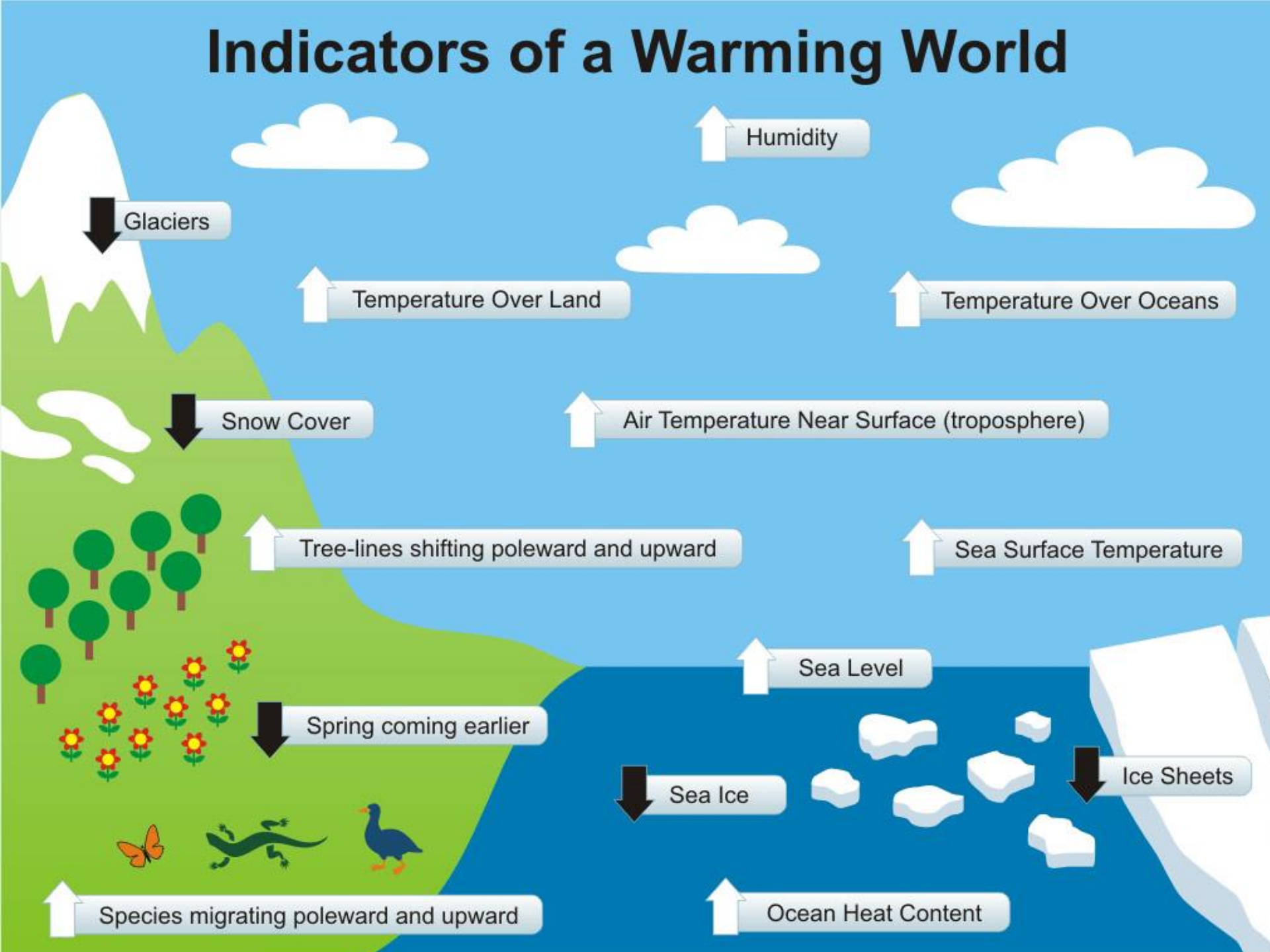

Summary of global warming impacts
Increase in global mean temperature relative to the late 20th century
0 1 2 3 4 5 6 7 8 9 °F
Physical
The risks associated with some extreme weather events increase with temperature
-Other effects include sea level rise and ocean acidification. Warming could be irreversible for several millennia.
Ecological
The larger the increase in temperature, the more species will be at risk of extinction
20-30% of species at risk of extinction
further extinctions
Social
-Mix of positive and negative impacts. Developing countries are the most vulnerable to negative impacts
The negative impacts of climate change tend to increase with temperature. Larger temperature increases will be more difficult to adapt to.
Large-scale impacts
The risk of large-scale and/or abrupt impacts increases with temperature
Partial deglaciation of Greenland and West Antarctic ice sheets adds 4-6 m (13-20 ft) or more to sea level rise
0 1 2 3 4 5 °C

2.5 F

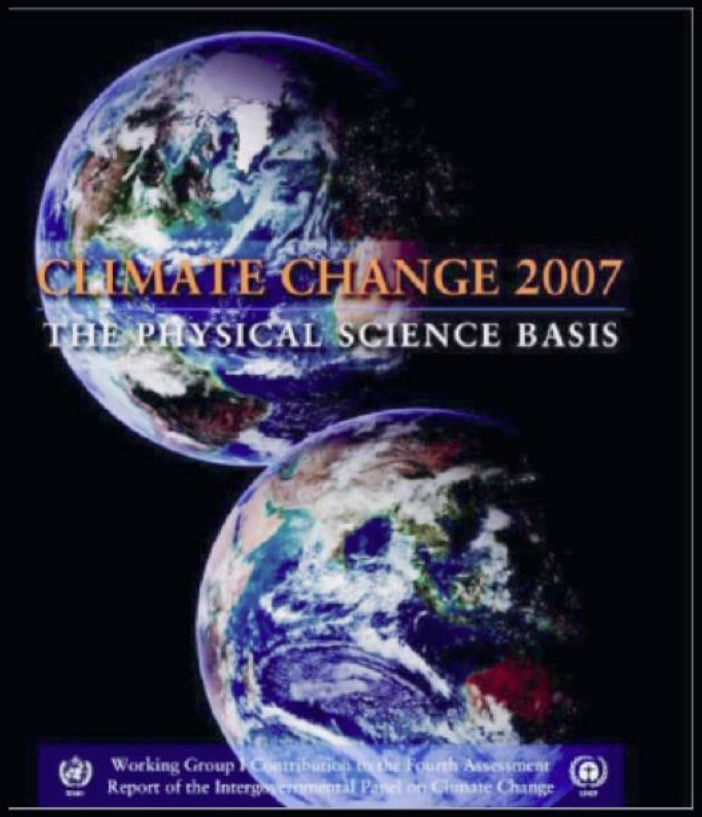
# We're not doing nearly enough!



# Indicators of a Warming World



*THIS* is the consensus:




IPCC 2007

"The observed widespread warming of the atmosphere and ocean, together with ice mass loss, support the conclusion that it is extremely unlikely that global climate change of the past *fifty years* can be explained without external forcing, and very likely [90%] that it is not due to known natural causes alone."