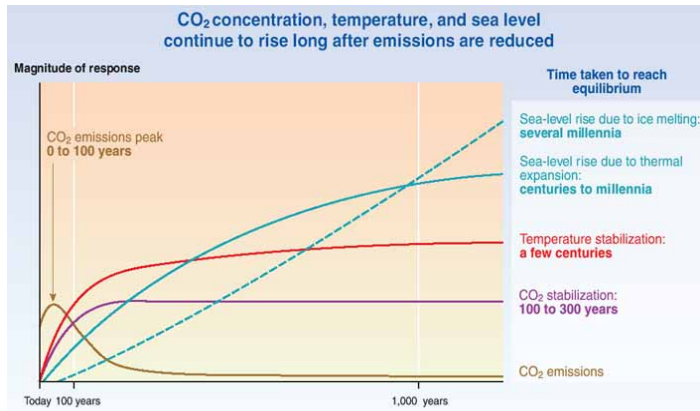


The long term outlook: 2000-3000AD

If -- in the next 200-300yrs or so-- we reduce CO₂ emissions to a small constant rate (<10% of today's emission), the climate will eventually equilibrate. How long will it take to reach the new equilibrium?



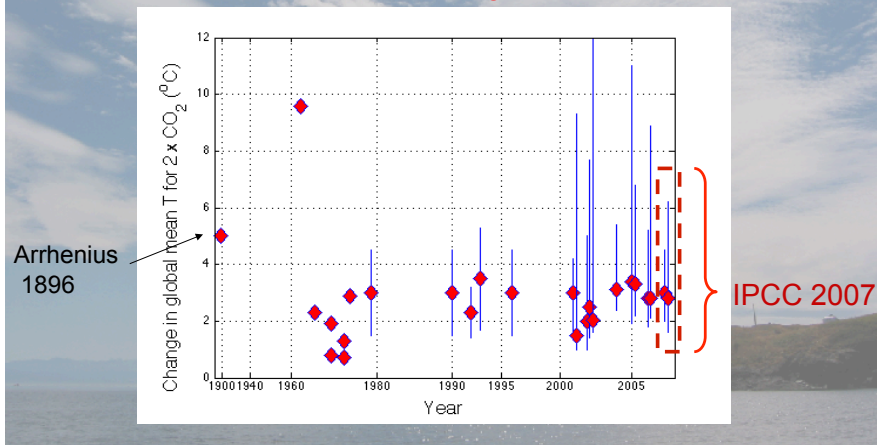
Global Warming: Science, Projections and Uncertainties

An overview of the basic science

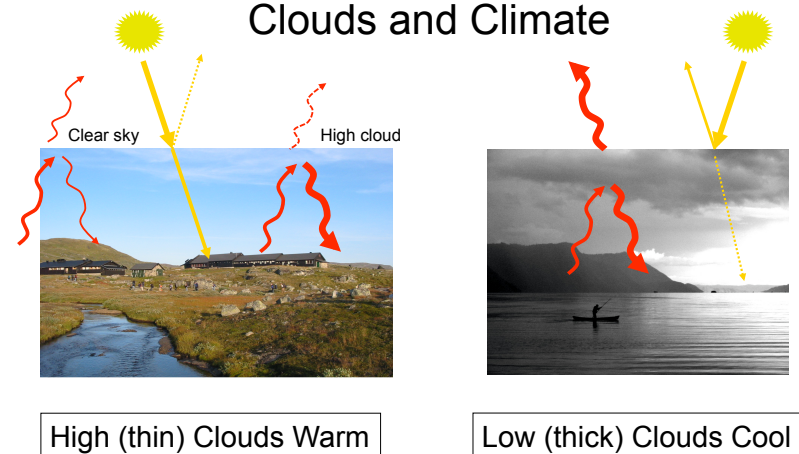
1. A Brief History of "Global Warming"
2. Climate Change: 1850-2007
3. Projections of Climate Change: 2100 and beyond
4. What's new in Climate Science?
5. Conclusions

4. What's new? A better quantification of the spread in the model response and reasons for the spread

Climate Sensitivity: the change in global temperature for a doubling of carbon dioxide



Clouds and Climate



In today's climate, the net effect of clouds is to cool the planet (albedo effect wins over greenhouse effect)

Clouds and Climate



What happens when you double atmos CO₂?

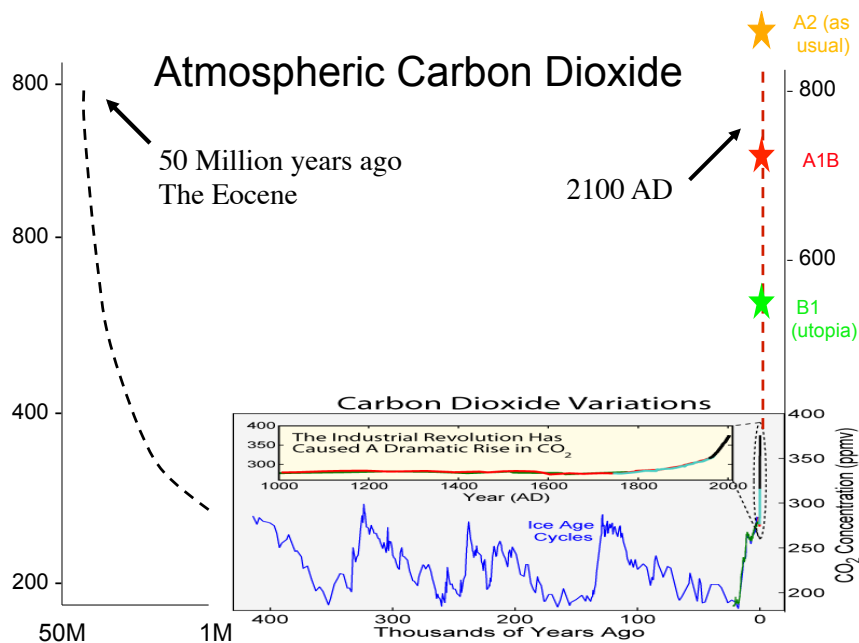
- With no feedbacks: increase temp by 1.2°C
- With all feedbacks (mainly water vapor) *except clouds*: increase by +1.9°C +/- 0.15°C
- With all feedbacks (*incl. clouds*): **+3.2°C +/- 0.7°C**

Clouds are a **major positive feedback** (ie, clouds cool less than today when CO₂ is doubled), but amplitude is uncertain.

More of theseand/or... ... less of these.



Clouds are the major source of the differences between models (i.e., for the uncertainty in the projections of the climate response to increasing CO₂).



In 100 years, the atmospheric CO₂ will reach 500-1000 ppm, which was last experienced during the EOCENE (55 to 36 million years ago)

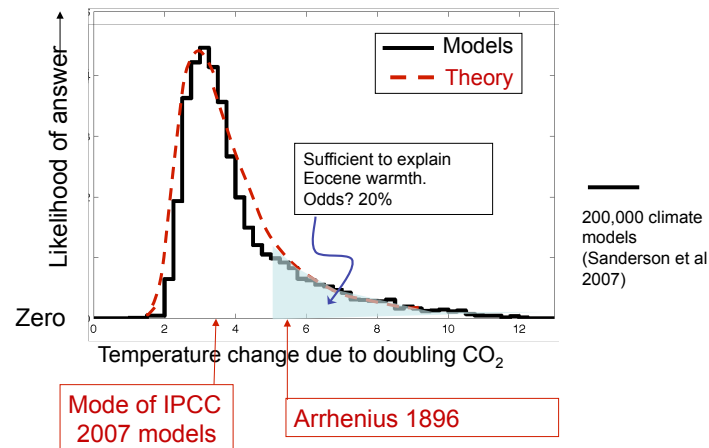


The Eocene climate was warm, even at high latitudes:

- palm trees flourished in Wyoming and Antarctica was a pine forest
- crocodiles lived in the Arctic
- deep ocean temperature was 55°F (today it is ~35°F)
- sea level was at least 300 feet higher than today

* Climate models with mid-range climate sensitivity simulate an Eocene that is much too cold compared to the fossil records

The Expected Distribution of Climate Sensitivity



Roe and Baker (2007) provide a simple theory for estimating the *expected* distribution of model responses due to model uncertainty.

Implication of the fossils: true response is ~1.7x IPCC mean.

Summary: Climate in the 20th Century

- Greenhouse gases have increased over the past 100 years to do human activity, and this has caused the climate to change:
 - Warming -- more over continents than oceans; more in high latitudes than in tropics; more at night than day
 - fewer frost days per year; more extreme warm days, etc.
 - decreased sea ice extent and volume
 - higher sea levels; more acidic ocean
- The warming would have been much greater, if not for the increase in atmospheric aerosols due to burning of coal and atmospheric biomass

From IPCC 2007

Summary: Climate in the 21st Century

- The climate is projected to change over this century because of human-induced changes in greenhouse gases (CO₂, CH₄, SO₂, etc)
- The global, annual averaged temperature will likely increase by ~ +3°C [2.4 to 6.4°C]
 - Only the high-end estimate is consistent with the geological records
- The uncertainty in the climate projections is roughly equally due to
 - Uncertainty in emissions
 - Uncertainty in models

From IPCC 2007

Summary: Climate in the 21st Century (cont)

- Warming will not be uniform in space or time. It is *very likely* that
 - Warming -- more over continents than oceans; more in high latitudes than in tropics; more in winter than summer, more at night than day
 - Fewer frost days per year
 - More extreme warm days and nights
- Other climate changes that are *very likely** over the next 100 years include:
 - the hydrologic cycle will speed up
 - the area covered by snow and sea ice will decrease
 - the subtropics will be drier (less precip/more evaporation)
 - the sea level will rise
 - the ocean will become more acidic.

(* very likely: defined by the IPCC as greater than 90% chance) From IPCC 2007

Summary: Climate in the 21st Century (cont)

- The changes over the next 100 years will be much, much greater than the changes seen over the past 150 years that have been attributed to increased greenhouse gases and aerosols.
- The rate of change is 100 - 1000 times faster than nature
- The changes in climate will have a significant and increasing effect on temperature, precipitation, snow pack, river flows (amount and timing), and soil moisture.
 - > **agriculture**, fisheries, forestry, aquaculture ...
 - > ecosystems and biodiversity
 - > flood control policy, hydropower, vector borne diseases, ...
- We now understand the range in the warming projected for 2100 by the various models, and can better quantify the likelihood of a very large warming (compared to average warming, used by IPCC)

From IPCC 2007