**HAVE WE REALLY ATTRIBUTED 20TH CENTURY CLIMATE CHANGE TO HUMANS?**

**considering aerosols?**
**Remember their effects are strongest near major cities, in many such regions there was considerable warming in the 20th century.**

## Despite Uncertainties

**IPCC REPORTS FIND**

**1990: "generally consistent"**
**1995: "a discernable influence"**
**2001: "new and stronger evidence that most of the observed warming over the past 50 years is attributable to human activities."**

## IPCC language sounds informal, but it is very precise

**Table 1:** Estimates of confidence in observed and projected changes in extreme weather and climate events.

| Confidence in observed changes (latter half of the 20th century) | Changes in Phenomenon | Confidence in projected changes (during the 21st century) |
|---|---|---|
| Likely[7] | **Higher maximum temperatures and more hot days over nearly all land areas** | Very likely[7] |
| Very likely[7] | **Higher minimum temperatures, fewer cold days and frost days over nearly all land areas** | Very likely[7] |
| Very likely[7] | **Reduced diurnal temperature range over most land areas** | Very likely[7] |
| Likely[7], over many areas | **Increase of heat index[12] over land areas** | Very likely[7], over most areas |
| Likely[7], over many Northern Hemisphere mid- to high latitude land areas | **More intense precipitation events[b]** | Very likely[7], over many areas |
| Likely[7], in a few areas | **Increased summer continental drying and associated risk of drought** | Likely[7], over most mid-latitude continental interiors. (Lack of consistent projections in other areas) |
| Not observed in the few analyses available | **Increase in tropical cyclone peak wind intensities[c]** | Likely[7], over some areas |
| Insufficient data for assessment | **Increase in tropical cyclone mean and peak precipitation intensities[c]** | Likely[7], over some areas |

## Main points of Summary for Policymakers 2001

- Earth warmed in the 20th century by 0.6+/-0.2 C
- the warming can be attributed to humans
- GHGs (cause of warming) are projected to rise substantially
- aerosols (partial offset of warming) are not projected to rise substantially

- Warming projection by year 2100: +1.4 to +5.8 K
- sea-level projection by year 2100: +0.1 to +0.9 m

- Satellites indicate troposphere warming is inconsistent with surface (was a major problem but in 2005, paper by Fu solved it)

- "The projected rate of warming is much larger than the observed changes during the 20th century and is very likely to be without precedent during at least the last 10,000 years based on paleoclimate data."

## 1.4-5.8K Transient Warming projected by 2100

**This range is higher than the equilibrium 2XCO2 range because it includes uncertainty in emissions and ocean heat uptake**

**Why don't aerosols offset future warming?**

**Aerosols don't offset GHG as much in future projection due to human feedback: people won't tolerate deadly pollution**

**Aerosol forcing remains uncertain in the future BUT the forcing from GHG eventually exceeds the aerosol uncertainty**

## The Emission Scenarios of the Special Report on Emission Scenarios (SRES)

A1. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

And you thought climate science had uncertainties!

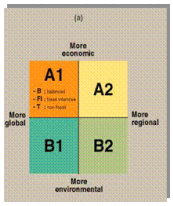
## IPCC Scenarios simplified

**A1: Rapid economic growth followed by rapid introductions of new and more efficient technologies**

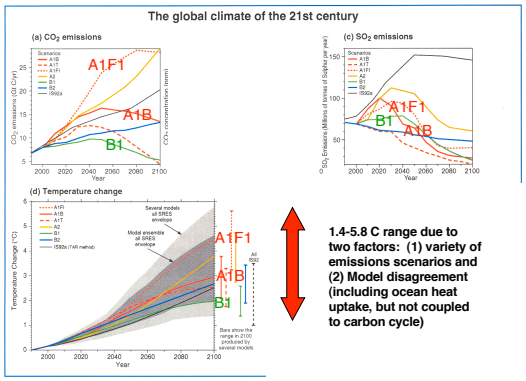
**A2: A very heterogenous world with an emphasis on familiy values and local traditions**

**B1: Introduction of clean technologies**

**B2: Emphasis on local solutions to economic and environmental sustainability**



## A1F1, A1B, B1: Scenarios from IPCC, see SPM



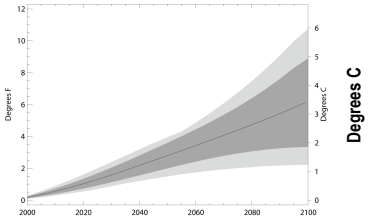

1.4-5.8 C range due to two factors: (1) variety of emissions scenarios and (2) Model disagreement (including ocean heat uptake, but not coupled to carbon cycle)

## Is Global Warming serious? (Impacts)

- depends on the scenario
- It's a local problem: what will happen my backyard?

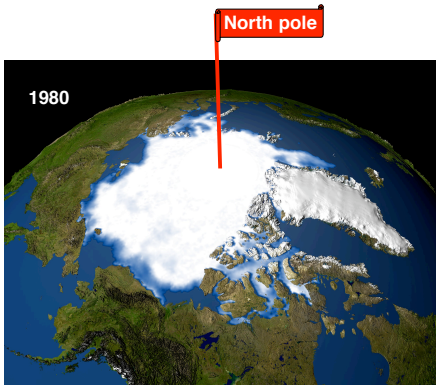
No one lives in the global mean climate
- Climate change at a real location is what we really care about...
- but, regional changes are much harder to predict than global-mean changes

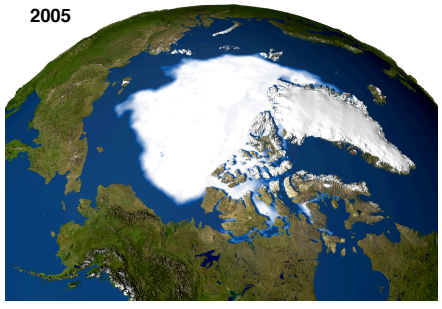
## Average Northwest warming, 2000-2100




Grey shading includes predictions from all 10 models for two scenarios. Why is the range larger locally than globally?

Source: Mote, Salathé and Peacock 2005




## Sea-level projections

- thermal expansion causes rise
- Antarctica is expected to grow (more snowfall than melting)
- Greenland is expected to shrink (more melting than snowfall)
- mountain glaciers are expected to shrink dramatically, but this is a fairly small reservoir
- Ocean circulation can alter sea level regionally

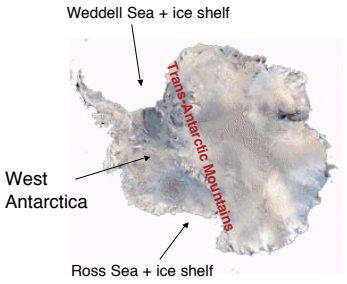
Virtually no contribution from melting Sea ice (its floating anyway)

Melt rate is difficult to predict

## The problem of West Antarctica

**Ice streams into shelves (floating fresh ice). Warming the ocean could cause shelves to destabilize…**

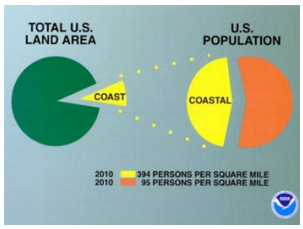
**Potential to raise sea level by many meters**



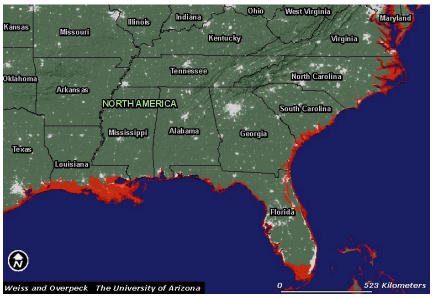

**IPCC on global sea level**

**Range is 20-70 cm from thermal expansion (not from melting land-ice)**

**Range is 10-90 cm includes land-ice but assumes W. Antarctica stays intact**




**Area lost by 1m sea level rise**

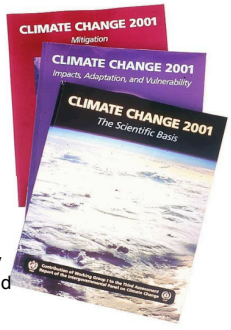




**Area lost by 1m sea level rise**

**(I'm not sure I believe this)**

Summary of Working Group 2 on climate change impacts (some good, most bad)




•Crop yields - Reduction in tropics/increase in high latitudes
•Energy demands - increased in warm climates/decreased in cool climates
•Water availability - increase/decrease regionally
•Increased heat stress mortality/reduced winter mortality
•Increase exposure to malaria and cholera

## Economics of global warming

**Why the problem bugs economics -**

1) **Damages caused by GHG's are not directly related to current rates of emission**

2) **Lag between abatement efforts and decreases in GHG levels**

3) **Multi-century time span**

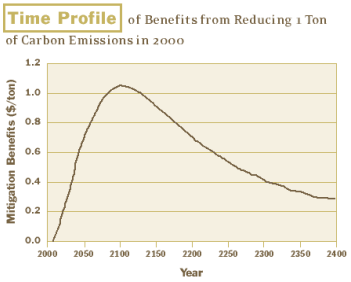
## Basics of economic theory

1. **Resources are limited**
2. **Cost-benefit analysis**
3. **Cost are short-term, benefit are long-term**

**For the GHG problem:**

1. **Benefit is from abating (lessening or avoiding) the damage from climate change.**
2. **The cost is the price of limiting GHG emissions**

Benefit lasts as long as lifetime of GHG molecule, which is 5-200 yrs!




From Pew center report on economic discounting

## Discount rate - 1st factor

**Discount rate = exercise to estimate current value of future benefit**

**First Factor: Growth discounting**

- **Amount earned if cost of abatement was invested instead.**
- **Compare investment earning to damages from climate change**
- **What is really done: future benefit is "discounted" to evaluate present value**
  - **Compounded annually**
  - **Rate is guessed**
  - **Length of time of benefit must be taken into account**

**If discount rate is 3%**
**A $100 benefit 100 years is worth $5.20 today**
**(The formula is $100/(1+0.03)$^{100}$)**

**Hence:**

**We hold little value today for a future benefit**

**AND/OR**

**It is cheap to invest $6.00 today and simply pay for the damages with the profit of investing the money (and pocket the change too)**

**The cost of abatement is enormous afterall**

**But no one knows what the discount rate should be!**

**Some say this uncertainty makes it impossible to use this theory.**

**Others try to include the uncertainty into analysis**

## Discount rate - 2nd factor

**Second Factor: Time preference discounting**

**Most people would rather have the money today, even after adjusting for inflation**

## Estimating the cost of damages

**Usually focuses on sea level rise - ignoring impacts on species or landscape degradation**

**Why?:**

- **Many impacts have both benefits and detriments**
- **Difficult to place a value on the loss of species, landscapes, etc**

## Estimating the cost of reducing emissions

**The forgone economic opportunity from using less fossil fuel**