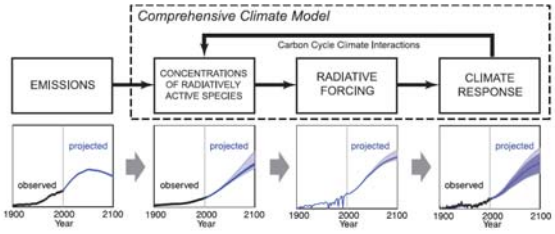
A Climate Change Primer
The IPCC Fourth Assessment Report

Richard McGehee

Seminar on the Mathematics of Climate Change
School of Mathematics
November 7, 2007

The IPCC Fourth Assessment Report

Prediction Methodology



Global Climate Projections, IPCC AR4, p.753
`http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_CH10.pdf`

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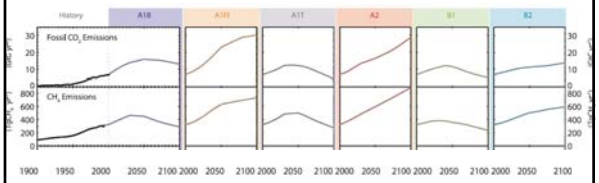
Emission Scenarios



Global Climate Projections, IPCC AR4, p.803
`http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_CH10.pdf`

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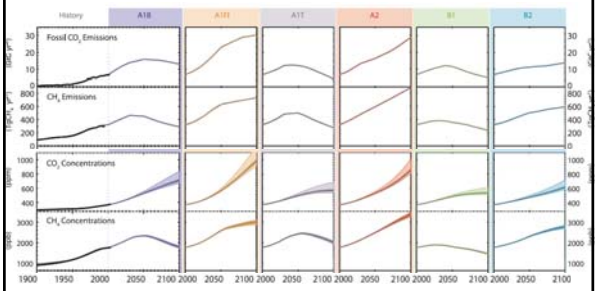
Greenhouse Gas Predictions



Global Climate Projections, IPCC AR4, p.803
`http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_CH10.pdf`

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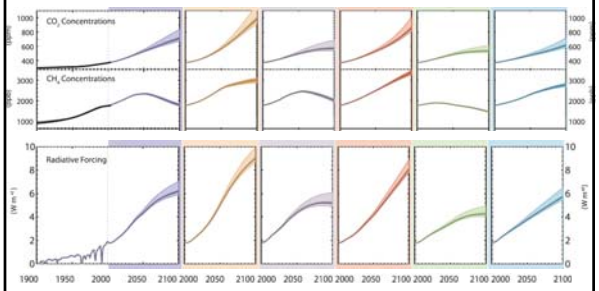
Radiative Forcing Predictions



Global Climate Projections, IPCC AR4, p.803
`http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_CH10.pdf`

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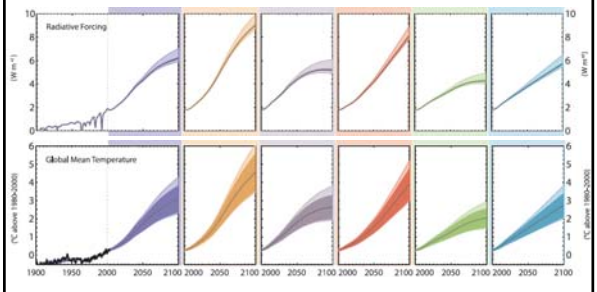
Global Mean Temperature Predictions



Global Climate Projections, IPCC AR4, p.803
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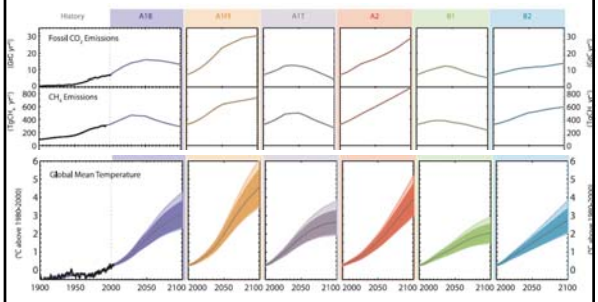

Global Climate Projections, IPCC AR4, p.803
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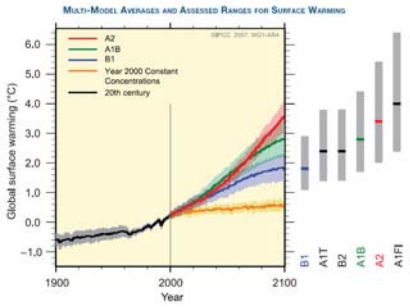

Summary for Policy Makers, IPCC AR4, p. 14
`http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_SPM.pdf`

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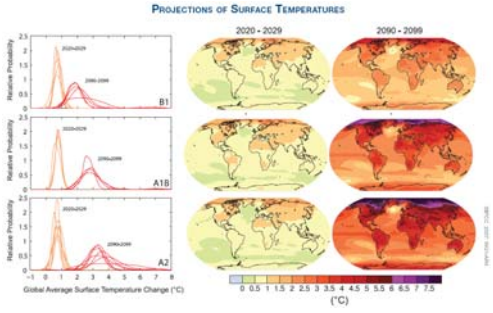
Surface Temperatures



Technical Summary, IPCC AR4, p. 72
`http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_SPM.pdf`

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The Last Interglacial Period

Global average sea level was likely between 4 and 6 m higher during the last interglacial period, about 125,000 years ago, than during the 20th century, mainly due to the retreat of polar ice. Ice core data suggest that the Greenland Summit region was ice-covered during this period, but reductions in the ice sheet extent are indicated in parts of southern Greenland. Ice core data also indicate that average polar temperatures at that time were 3°C to 5°C warmer than the 20th century because of differences in the Earth's orbit. The Greenland Ice Sheet and other arctic ice fields likely contributed no more than 4 m of the observed sea level rise, implying that there may also have been a contribution from Antarctica.

Technical Summary, IPCC AR4, p. 58
`http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_SPM.pdf`

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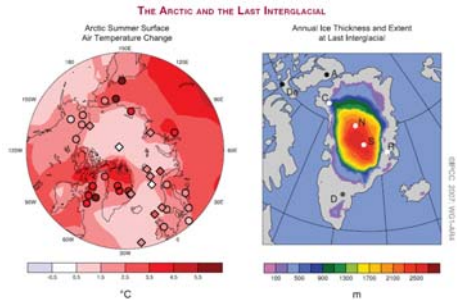
The Last Interglacial Period



Technical Summary, IPCC AR4, p. 57
`http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_SPM.pdf`

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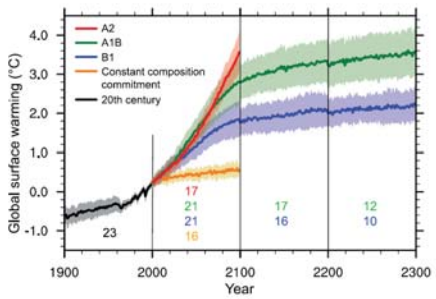
Beyond 2100



Global Climate Projections, IPCC AR4, p.762
`http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_CH10.pdf`

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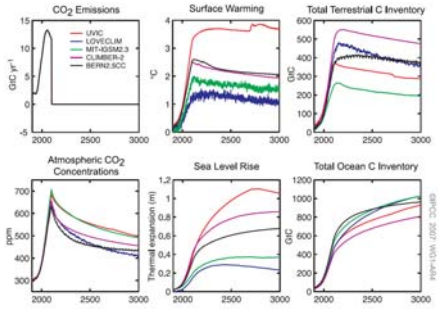
Beyond 2100



Technical Summary, IPCC AR4, p.78
http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_CH10.pdf

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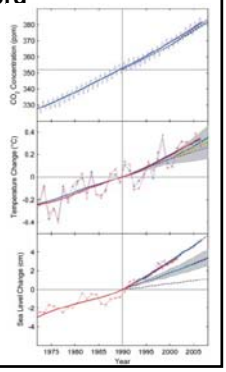
IPCC Track Record

Comparison of IPCC 1990 predictions to actual observations.

Atmospheric CO_2: A-

Global mean temperature: B-

Sea Level: F



Stefan Rahmstorf, et al, Recent Climate Observations Compared to Projections, *Science* **316** (4 May 2007), p.709.
http://www.sciencemag.org/cgi/content/abstract/316/5825/709

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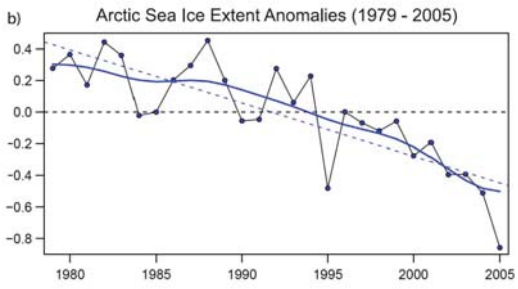
Arctic Sea Ice



Technical Summary, IPCC AR4, p.45
http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_TS.pdf

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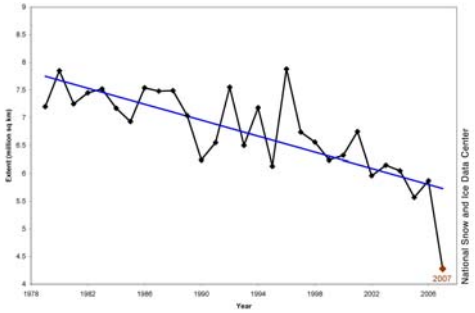
Polar Sea Ice



Press Release, 1 October 2007, National Snow and Ice Data Center
http://nsidc.org/news/press/2007_seaiceminimum/20071001_pressrelease.html

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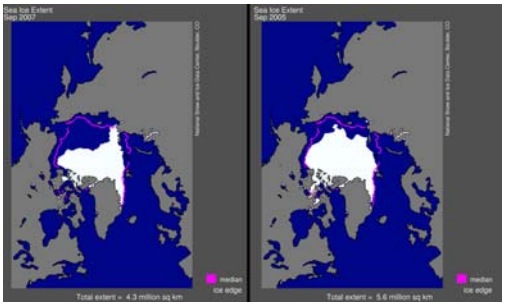
2007 Polar Sea Ice



Press Release, 1 October 2007, National Snow and Ice Data Center
http://nsidc.org/news/press/2007_seaiceminimum/20071001_pressrelease.html

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Global Mean Temperature from Radiative Forcing

Atmosphere-Ocean Global Circulation Models (AOGCMs)

Based on weather prediction models

Highly complex

Take weeks and even months to run

Predict temperature, wind, etc. as a function of latitude and longitude

Predict global mean temperature

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Global Mean Temperature from Radiative Forcing

Policy Question:

Should we build a wind farm in North Dakota?

I.e., will there be enough wind in North Dakota in 20 years?

AOGCMs are the only hope.

Scientific Question:

How does the global mean temperature respond to radiative forcing?

Perhaps there are simple models.

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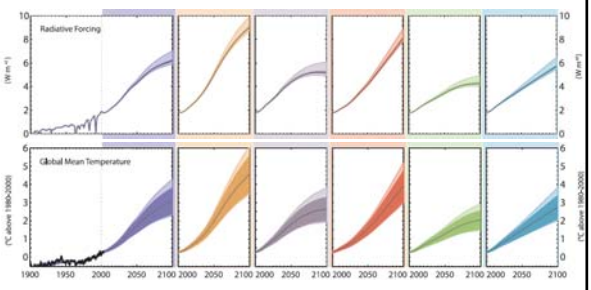
Global Mean Temperature Predictions



Global Climate Projections, IPCC AR4, p.803

`http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_CH10.pdf`

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Global Mean Temperature (GMT) from Radiative Forcing (RF)

Oversimplified Model

$$\frac{dT}{dt} = -\lambda\left(T - T_{eq}\left(F(t)\right)\right)$$

where T = global mean temperature (ºC anomaly)
F = radiative forcing (W/m^2 anomaly)
$T_{eq}(F)$ = equilibrium GMT (function of F)
λ = rate of decay to equilibrium GMT

Assume that T_{eq} is a linear function of F.

$$T_{eq} = \alpha F + \beta$$

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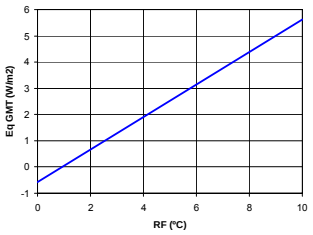
GMT from RF

Reverse engineer the IPCC results

$$\frac{dT}{dt} = -\lambda\left(T - T_{eq}\left(F(t)\right)\right)$$

$$T_{eq} = \alpha F + \beta$$

λ = 0.094
α = 0.62
β = -0.58



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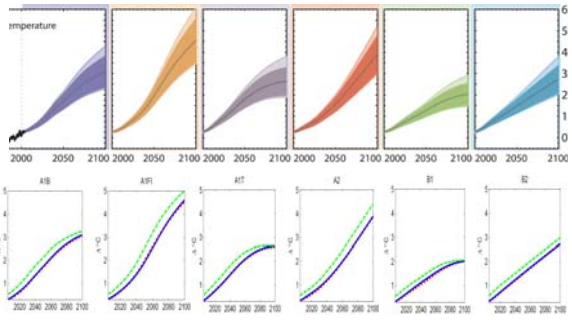
GMT from RF: IPCC vs. Simple Model



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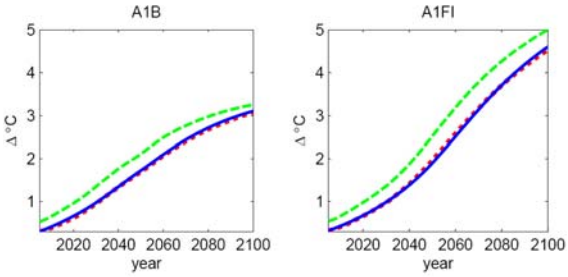
GMT from RF: Simple Model

blue = IPCC mean, red = simple model, green = T_{eq}



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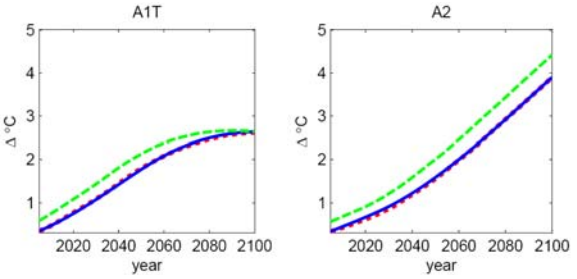

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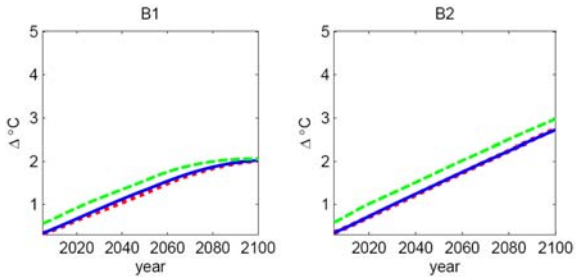

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Radiative Forcing (RF) from Greenhouse Gases (GHG)

"Climate Sensitivity"

The change from pre-industrial level of the equilibrium global mean temperature as a result of doubling the atmospheric CO_2 concentration from the pre-industrial level of 280 ppm to 560 ppm.

This is a computed quantity, not a measured, since the the CO_2 is currently less than 400 ppm.

Generally thought to be a logarithmic function.

Treated in the IPCC report as a random variable.

Likely (66%) range: 2ºC – 4.5ºC

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RF from CO_2

First Approximation

$$RF_C = K_C \log_2 \frac{c}{280}$$

where RF_C = radiative forcing from CO_2 (W/m^2)
c = atmospheric CO2 (ppm)
K_C ≈ 3.7 (my guess)

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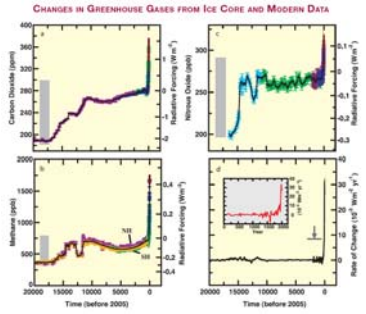
Radiative Forcing by Greenhouse Gases



Technical Summary, IPCC AR4, p.25
`http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_TS.pdf`

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RF from CH_4

First Approximation

$$RF_M = K_M \left(\sqrt{m} - \sqrt{750}\right)$$

where RF_M = radiative forcing from methane (W/m^2)
c = atmospheric methane (ppb)
K_M ≈ 0.032 (my guess)

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RF from GHG

Reverse Engineering

$$RF = a\left(RF_C + RF_M\right) + b$$

where $a \approx 1.33$
$b \approx -0.96$

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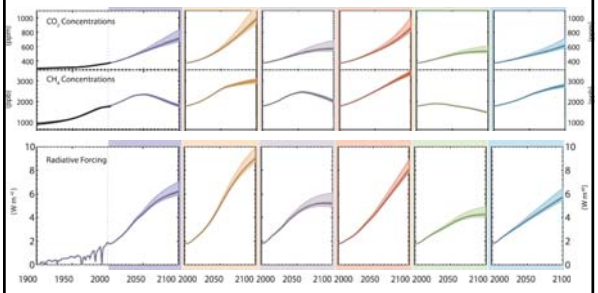
RF from GHG



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RF from GHG

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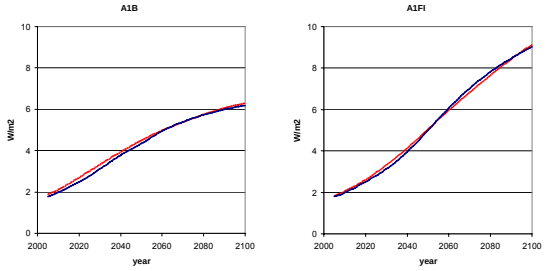

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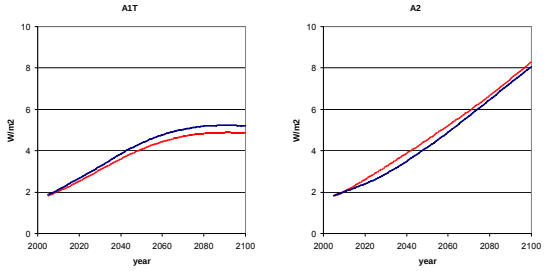

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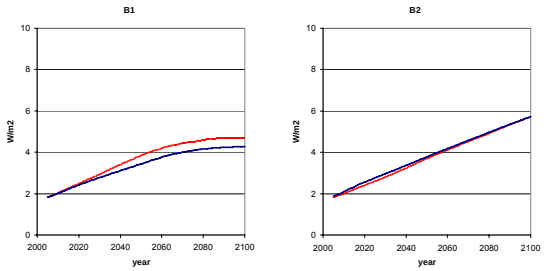

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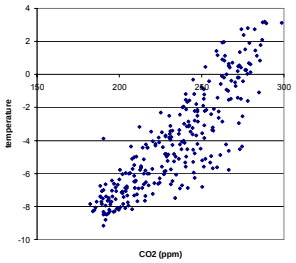
Climate Sensitivity and Vostok Data

temperature vs. CO_2



logarithm?

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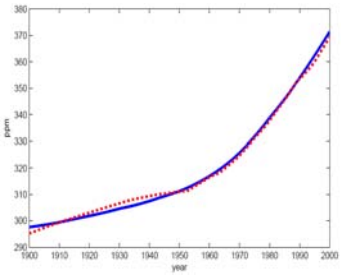
Concentrations from Emissions

Complex Carbon Cycle Models



Really Simple Model

57% of CO2 stays forever

43% disappears immediately

red = IPCC data
blue = simple model