Global warming and its implications for conservation.

1. Overview.

The IPCC (Intergovernmental Panel on Climate Change) consensus forecast for climate is an increase in global temperature by 2 - 5^{o}C (3.8 - 9.5 ^{o}F) by 2100.

This is for 'business as usual' models of human population growth, economic development and energy production. IPCC is the UN-coordinated international scientific advisory group for the Framework Convention on Climate Change. FCCC is the international group that implements the Kyoto Protocol, which originated at the Earth Summit in 1992, in Rio de Janeiro. The Kyoto Protocol aims to reduce CO_2 emissions, but its targets are much too limited to have much effect on eminent changes.

Ohead: business as usual projections from NCAR, Hadley, CSIRO.

There is good evidence that current climate change is due to anthropogenic release of CO2 into the atmosphere. (Much more on the carbon cycle and atmospheric CO_2 later.) Based on 15 well-tested models considered by the Intergovernmental Panel on Climate Change, a doubling of atmospheric CO2 would yield an increase in global ***mean*** temperature of ΔT_{2X} = 3.5^{o}C (6.7 ^{o}F, with 95% confidence limits of 1.9^{o}C – 4.1^{o}C, or 3.6 – 7.8^{o}F).

IPCC considers only peer-reviewed science, and these models do well at:

(1) predicting past climates (***hindcasting***) for data not used to develop the model, and
(2) predicting changes in climate for the period since they were developed (Mean global temperature has already risen 0.8 ^{o}C in just over a century, with recent increases tracking the predictions of the models).
(3) accounting for known ***climate forcings***, which are factors that by logic should alter temperatures, such as solar intensity or volcanic activity

Ohead: global climate anomaly time series (Mears & Wentz 2005 Science 309:1548)
Ohead: Archer Fig 11.8
Ohead: IPCC climate change attribution

Much more on the models and the ways of assessing their reliability later. Basically, models that incorporate all known non-anthropogenic effects (variations in the orbit, sunspots, volcanos, etc.) do not predict recent climate patterns, but models that also incorporate anthropogenic greenhouse gas emission do predict recent climate patterns.

Detection and ***attribution*** of climate signals have specific meanings within the field of climate change. From the IPCC's third assessment report

Detection of a signal requires demonstrating that an observed change is statistically significantly different from that which can be explained by natural internal variability.

Attribution requires demonstrating that a signal is:

- unlikely to be due entirely to internal variability;
- consistent with the estimated responses to the given combination of anthropogenic and natural forcing
- not consistent with alternative, physically plausible explanations of recent climate change that exclude important elements of the given combination of forcings.

Detection does not imply attribution, and is easier than attribution. Unequivocal attribution would require controlled experiments with multiple copies of the climate system, which is not possible... as the saying goes, there is no planet B.

The models that predict climate require enormous computer resources. The essentially break the world into a grid, and within each grid have a stack of layers (up into the atmosphere and down into the ocean). Tracking many parameters across this volume is a computational problem, even with supercomputers. ClimatePrediction.net is a parallel processing effort (www.climateprediction.net) that allows the models to be run many times. Across multiple model runs, the mode of the distribution of ΔT_{2X} is near the mean, predicting a 3.4^{o}C increase in temperature.

Archer Fig 12.1a

Note that the distribution of predictions does not overlap zero… that is, there is essentially no uncertainty that global temperatures will continue to rise.

But, there is a fair amount of uncertainty about the ***magnitude*** and ***rate*** of the increase. We'll return to this later, but the main uncertainties fall into three groups:

(1) How much does ***equilibrium temperature change*** in response to a given change in atmospheric conditions?
(2) ***How long*** does it take temperature to equilibrate? (The oceans can cause long lags, because they are enormous and water has a high heat capacity. The uncertainty arises because patterns of circulation from deep oceans to surface waters have a big effect on the volume of water involved… and ocean currents themselves are affected by climate. This sort of relationship is a feedback loop. Negative feedbacks slow change and promote stability in a system. Positive feedbacks speed changes and allow runaway destabilization of a system.
(3) How will ***emissions*** change?

Weather vs Climate

So what? An increase of 3.4^{o}C doesn't seem like a big deal. That's a lot less than the day to day variation in weather at any given location. Bozeman can swing more than 20^{o}C in a day.

Several important and perhaps counterintuitive points here:

1. ***Weather*** is short term changes in local conditions (temperature and precipitation). ***Climate*** is long term changes in spatially broader conditions.

2. A long term change in mean temperature can have large effects, even if the change in the mean is small relative to short term variation. For example:

- The 'Medieval Optimum' (in Europe) was only 0.5^{o}C warmer than typical, but caused drought in the SW US longer and deeper than any in recent history. (temperature and precipitation are linked)
- 20,000 years ago at the end of the last Glacial Maximum, ice covered huge portions of N.America at depths comparable to parts of the Greenland Ice Sheet. It was only 5-6 ^{o}C colder than now.

3. Over the past 10,000 years, mean surface temperature for the entire earth has been about 57^{o}F or ***13^{o}C***. A change of 0.8^{o}C (as already measured since the industrial revolution) is a change of ***6.1%***. The earth's temperature is an equilibrium system maintained by feedbacks, just as your body is. If your body was this far out of equilibrium, your temperature would be 104.6. A change of 3.4^{o}C is 26%, which represents a major shift in abiotic conditions. A shift of this magnitude and speed is unprecedented… smaller and slower shifts caused major extinction events.

4. Weather is chaotic and difficult to predict more than a short span into the future. Climate is much less chaotic and therefore can be predicted more accurately. You intuitively know this, if you stop to think about it. I cannot tell you if December 10th or December 20th will be colder, but the mean for December will be colder than the mean for August.

Implications for Conservation

1. Rapid, large scale changes in temperature and precipitation are known drivers of past major extinction events.

Ohead: Flannery p.47

Cretaceous- Tertiary extinction 65 MYA with asteroids injecting particulates into atmosphere.   Lost the dinsosaurs and every other living thing that weighed more than 77 lbs.

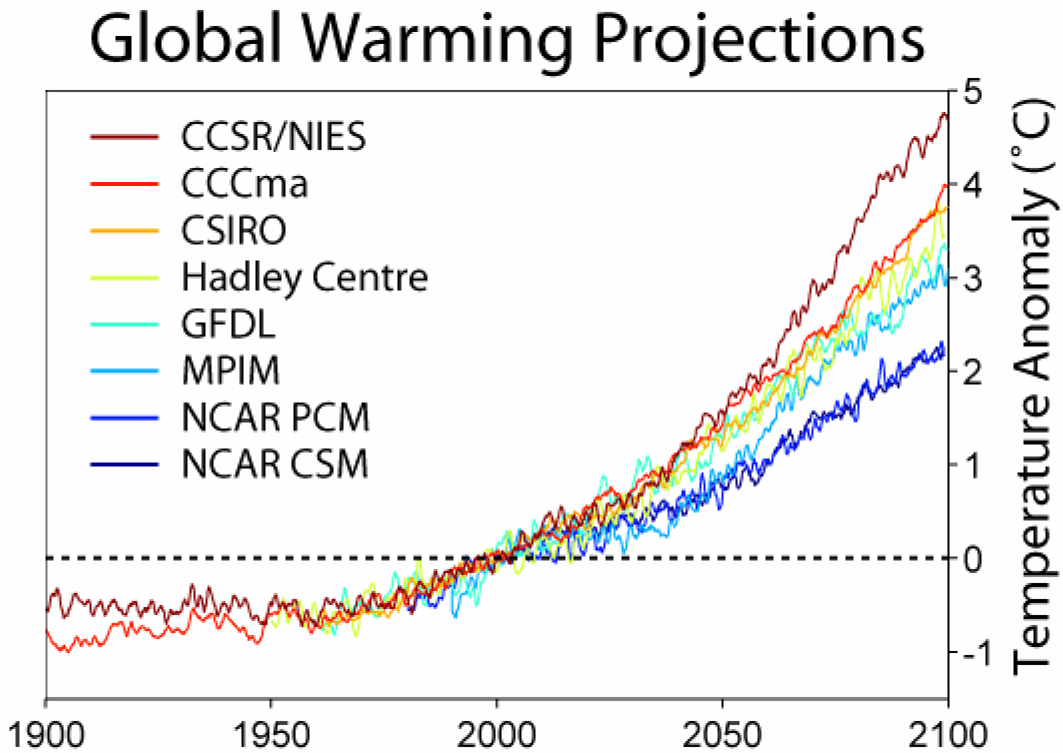
Oheads: Some illustrations of rapid changes in abiotic conditions: Alaskan glaciers, Larsen B Ice Shelf, coral bleaching.

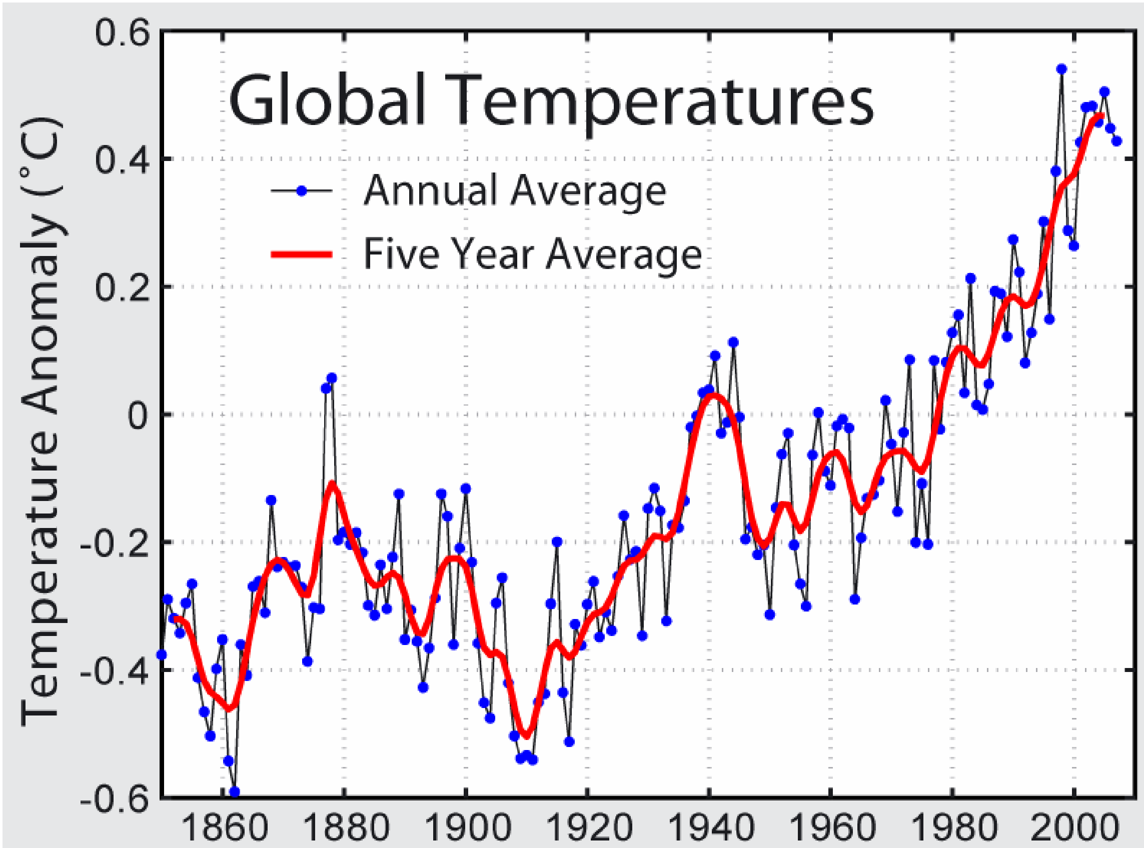
2. Changes in ranges, compounded by fragmentation.

Oheads: range figures, Paremsan & Yohe, Pounds et al, Root et al.

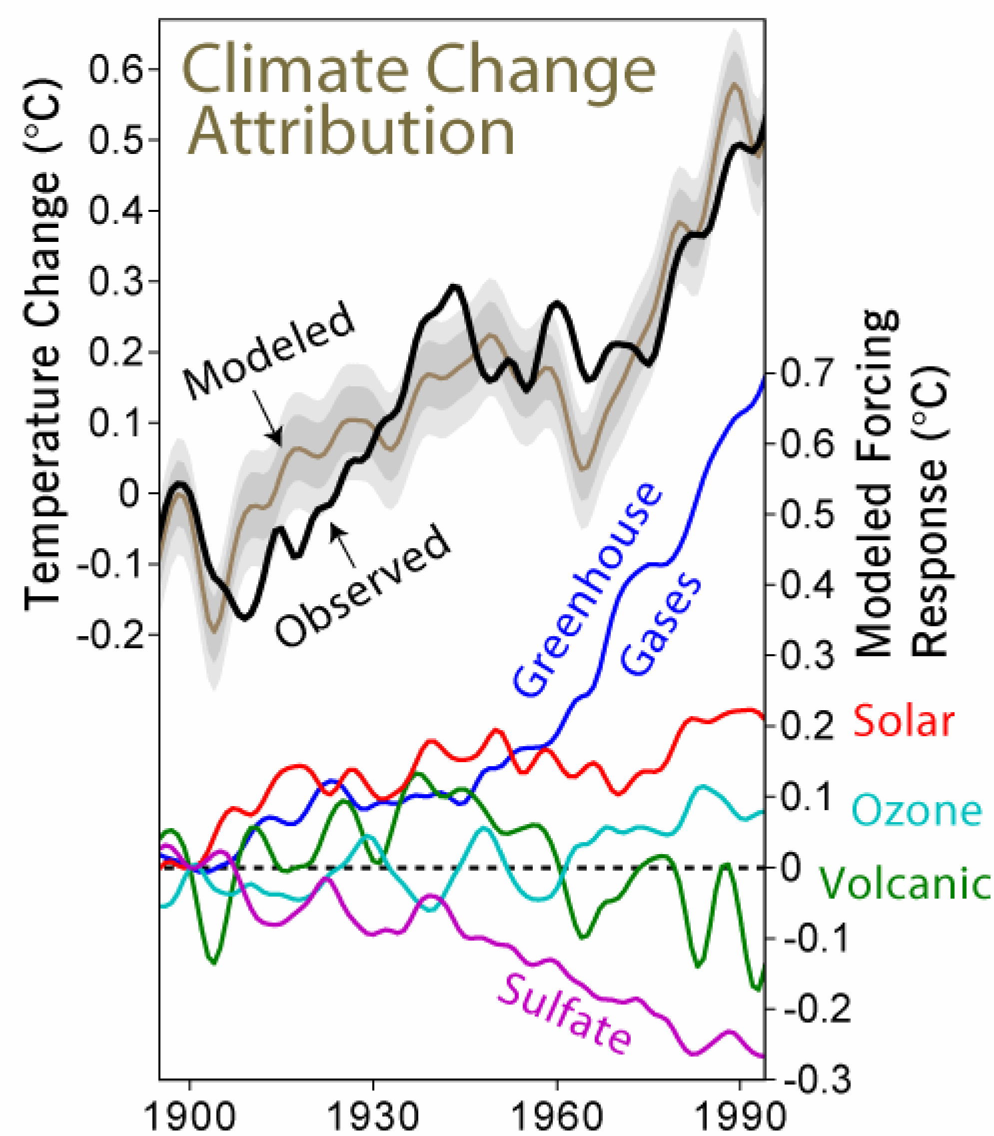
3. Changes in timing (effects on interspecific interactions, e.g. timing of migrations and resources, or timing of breeding and resources).
4. Changes in community structure (again, effects on interspecific interactions, e.g. lose prey, lose its predator).

2-3-4 all expected to increase extinction rates.


Global Warming Projections
CCSR/NIES
CCCma
CSIRO
Hadley Centre
GFDL
MPIM
NCAR PCM
NCAR CSM
Temperature Anomaly (°C)
5
4
3
2
1
0
-1
1900
1950
2000
2050
2100

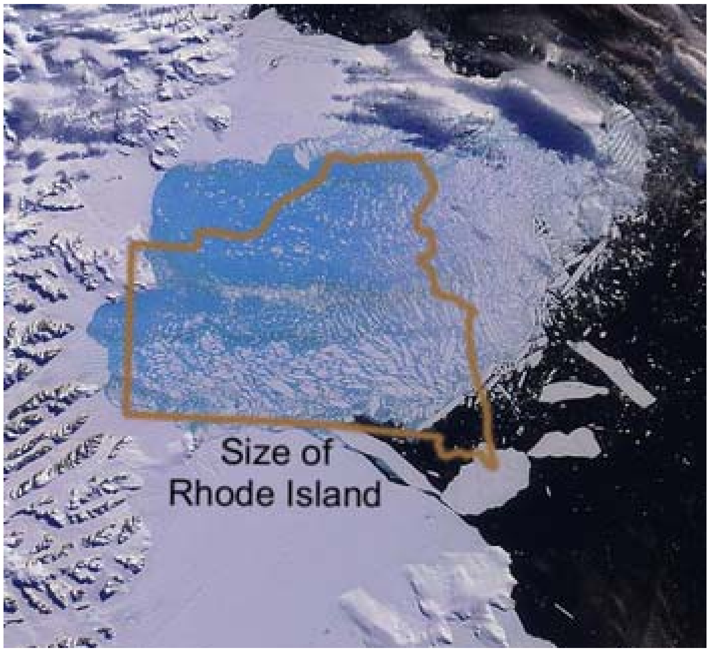


Global Temperatures
Annual Average
Five Year Average
Temperature Anomaly (°C)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
1860
1880
1900
1920
1940
1960
1980
2000



Climate Change Attribution
Temperature Change (°C)
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
Modeled
Observed
Greenhouse Gases
Modeled Forcing Response (°C)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
Solar
Ozone
Volcanic
Sulfate
1900
1930
1960
1990

Muir and Riggs Glaciers



Larsen Ice Shelf