EC313 Lecture #1
Introduction
and
How to measure Climate and CO_2

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Introduction – content of the course.

The object of this course is to pose the problem of global warming as a version of the 'consumer's problem' you studied in intermediate micro-economics and to use this model to think about policy responses to global warming.

That is, it if we let

- $c_1, c_2 =$ per capita consumption now and in 100 years
- $W =$ per capita wealth/income today
- $s =$ savings today
- $M =$ expenditure on mitigation today
- $E_1 = F(s, M) =$ Emission of CO_2 today, F increases in s and decreases in M
- $P =$ Atmospheric concentration of CO_2 today
- $T_1, T_2 =$ climate now and in 100 years

then we can pose the 'global warming problem' as

$$\max_{s,M} u(c_1,c_2) \tag{1}$$

$$\text{s.t. } W = c_1 + s + M \tag{2}$$

$$c_2 = (1+r)s - \gamma(T_2 - T_1)s \tag{3}$$

$$E = F(s,M) \tag{4}$$

$$P = \rho_0 E \tag{5}$$

$$T_2 = \rho_1 P + T_1 \tag{6}$$

for the choice of savings and mitigation maximizes welfare u.

This is, obviously, an almost silly simplification. The object is to organize ideas. What we're going to do in this course is to work towards an understanding of the different pieces of this problem.

Topics to cover(preliminary)

- the link between emissions and climate
- cost of climate change
- cost of mitigation (reduction of emissions)
- what should u look like (the problems of discounting and uncertainty)
- how regulation of emissions should work (carbon taxes and cousins)
- discussion of common policy proposals, e.g. Stern, Kyoto

Things to think about that aren't in the model

- Population growth
- Economic growth
- Dynamics – this is a dynamic problem, so c, T are consumption paths and climate paths. A wise regulatory program will reflect the fact that investments in climate and economic growth have different returns at different times. This will turn out to suggest a 'ramping up' of mitigation expenditures.
- There is LOTS of uncertainty. This makes everything more difficult.

Outline for today

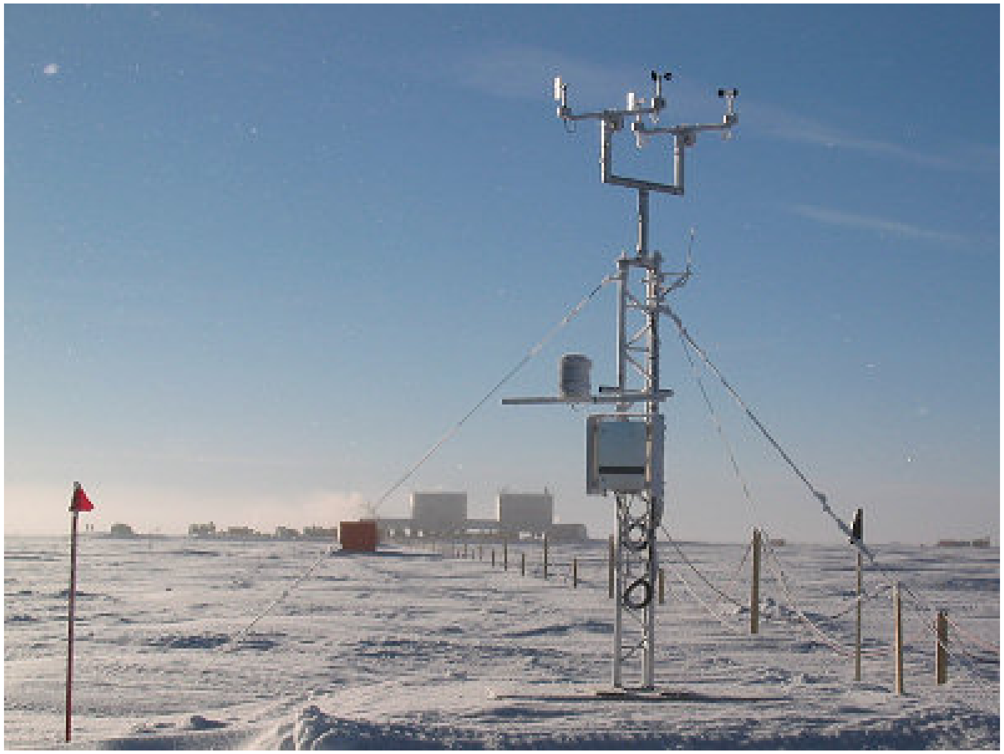
To start (loosely) we want to try to understand our endowment of climate.

1. Measured temperature, and the problem of measuring temperature.
2. Icecores and oxygen isotope ratios, other climate proxies.
3. Basic atmospheric chemistry
4. Time series for CO_2 and other greenhouse gases: Mauna Loa and icecores

Measured Temperature

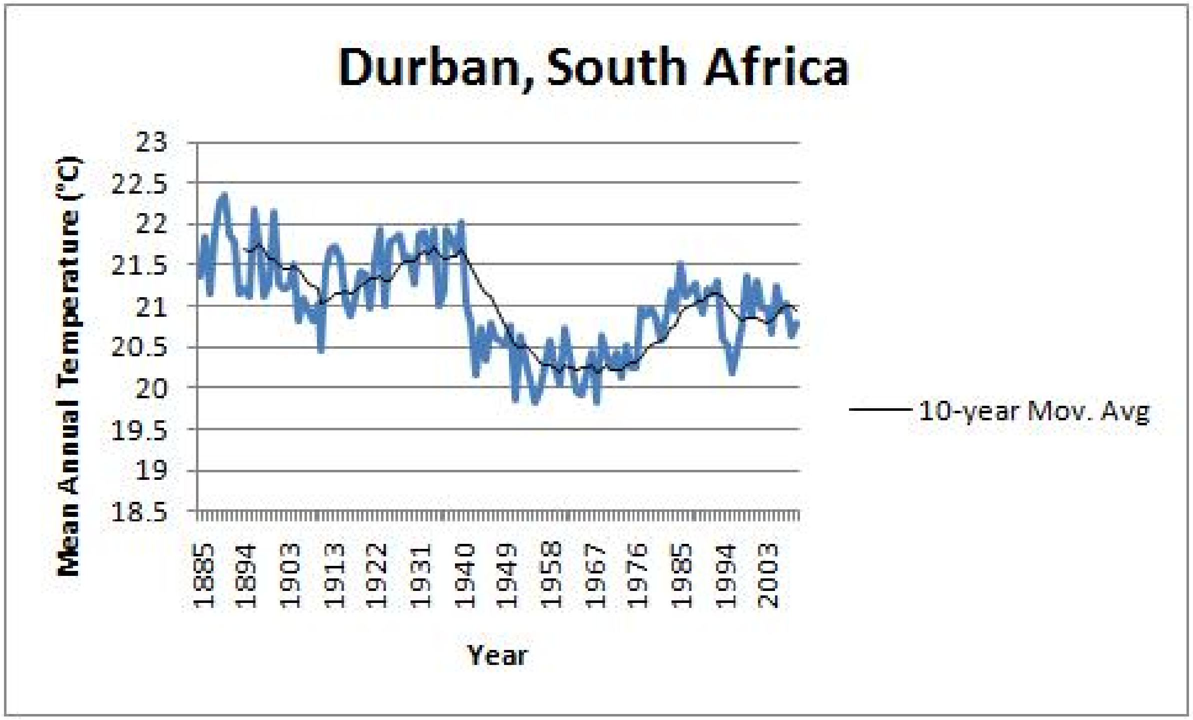
This is what modern weather stations look like:

(JFK airport in NY) http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~StnPhoto~20019418~a~000

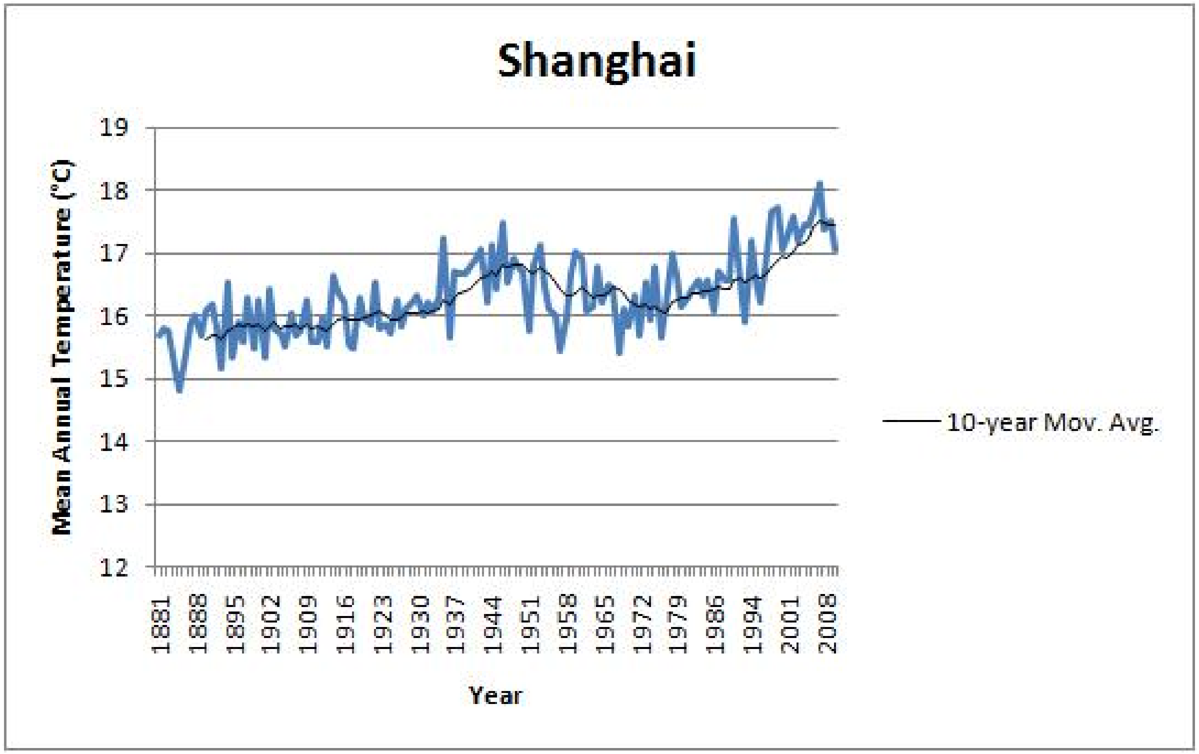


(Antarctic weather station)
http://www.gdargaud.net/Antarctica/DC2005/20050406_10_WeatherStation.jpg

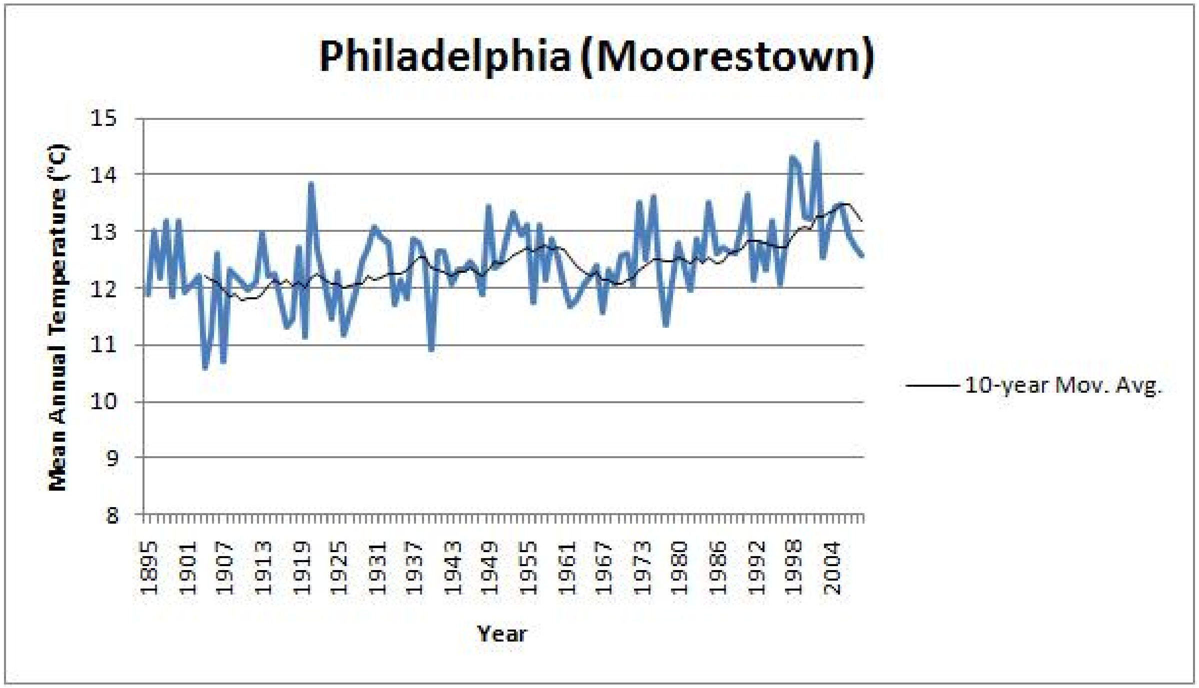
- We have measured temperature data going back about 100 years.
- There are about 935 Automated Surface Observing Systems (ASOS) just in the US, and over almost 11,000 cooperative stations, which are operated by local observers.



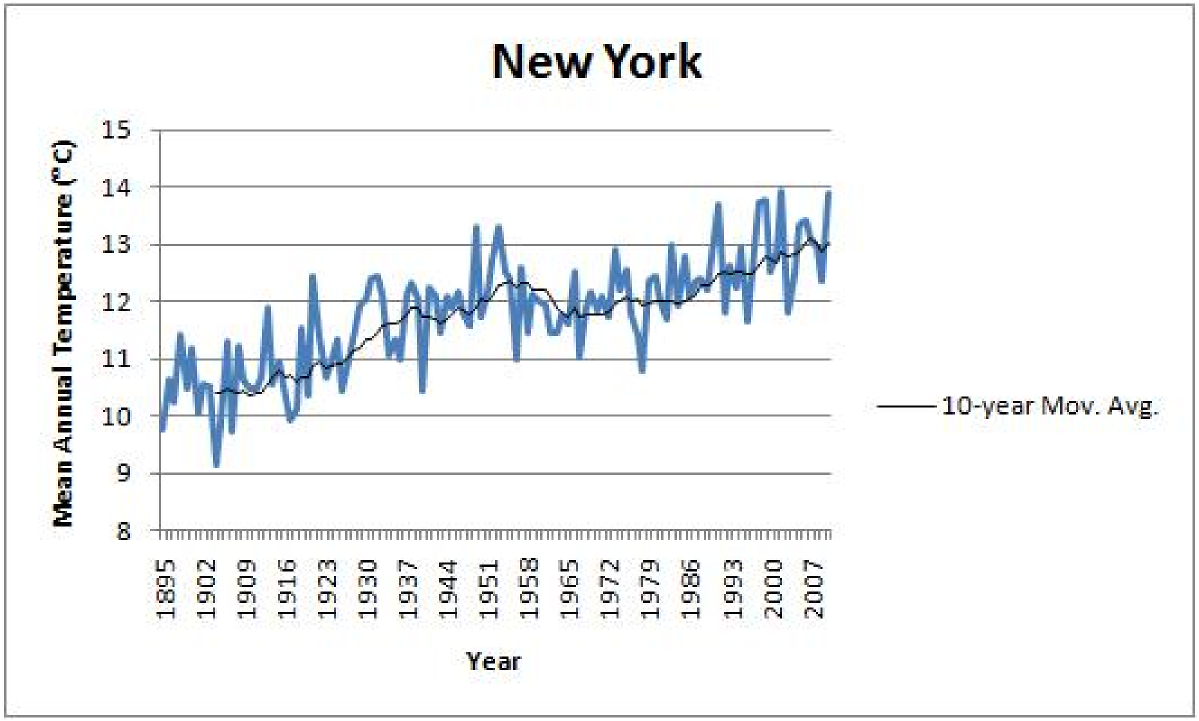
Measured temperature in Durban. Black line is 10 year moving average, i.e. in each year plot
$T_{10,t} = 0.1 \times (T_{t-9} + T_{t-8} + ... + T_{t-0})$.



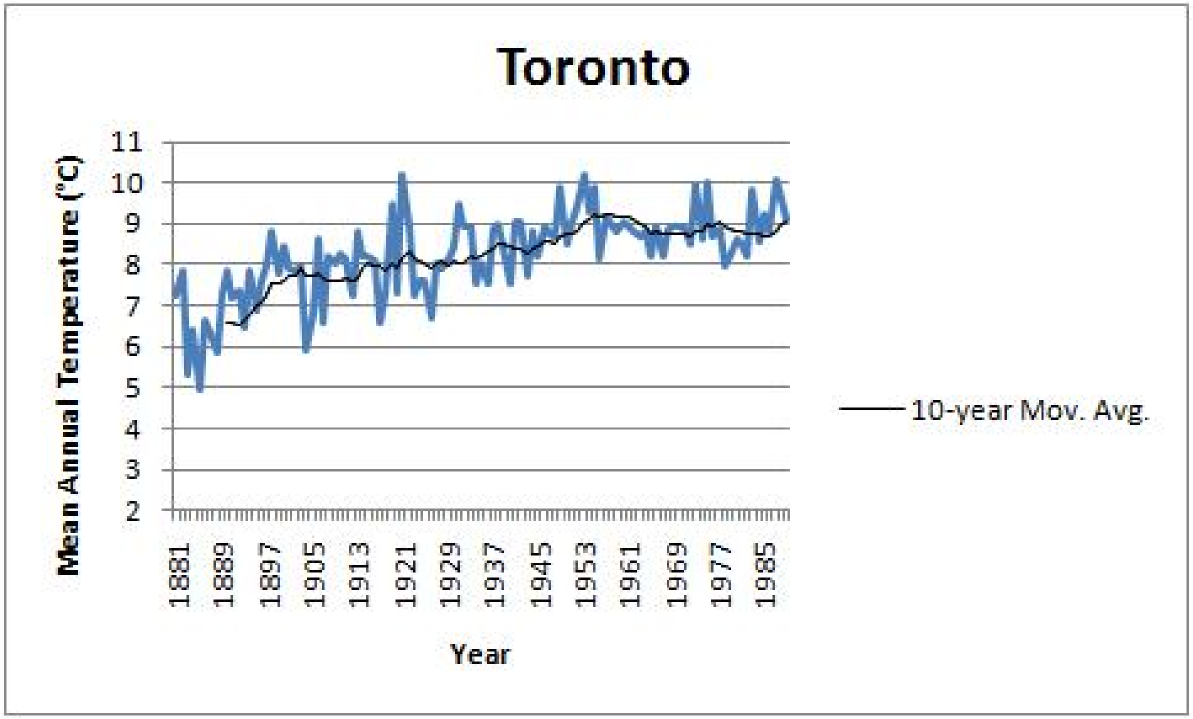
Measured temperature in Shanghai



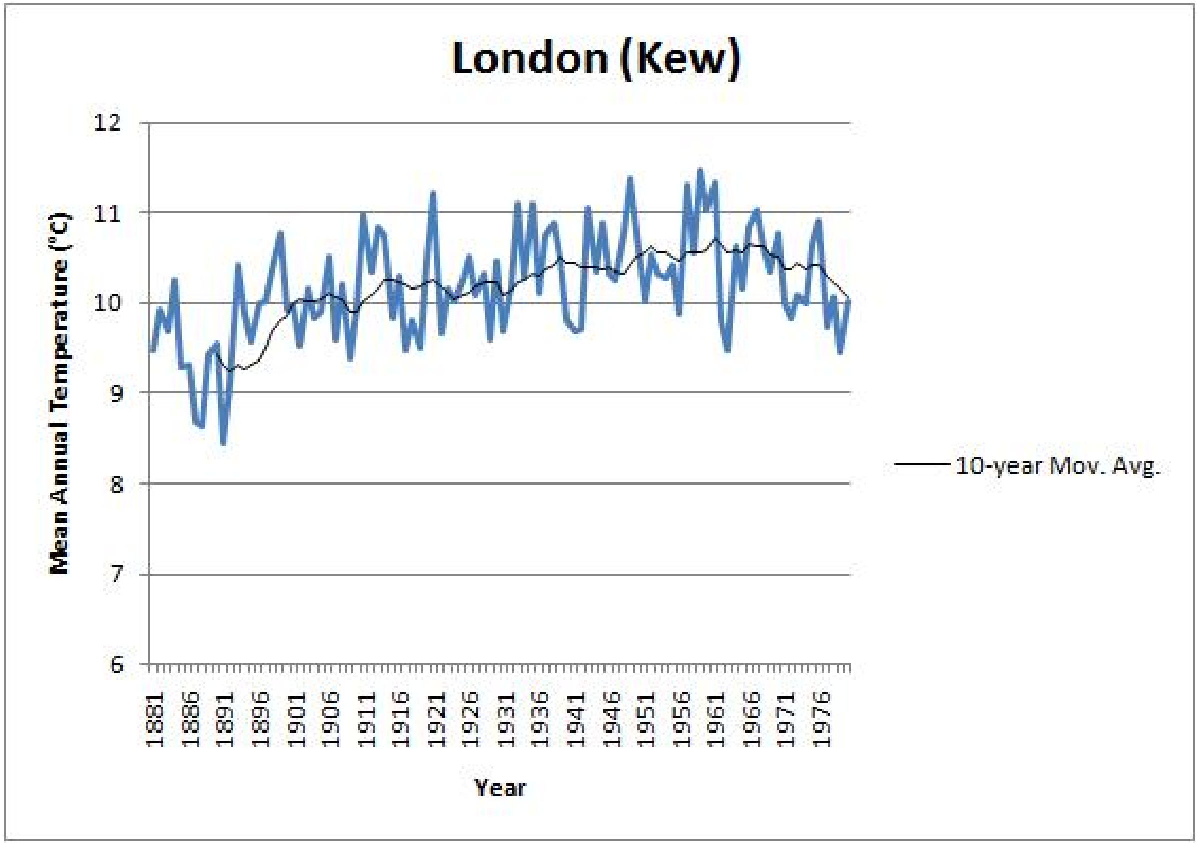
Measured temperature in Philadeliphia



Measured temperature in New York



Measured temperature in Toronto

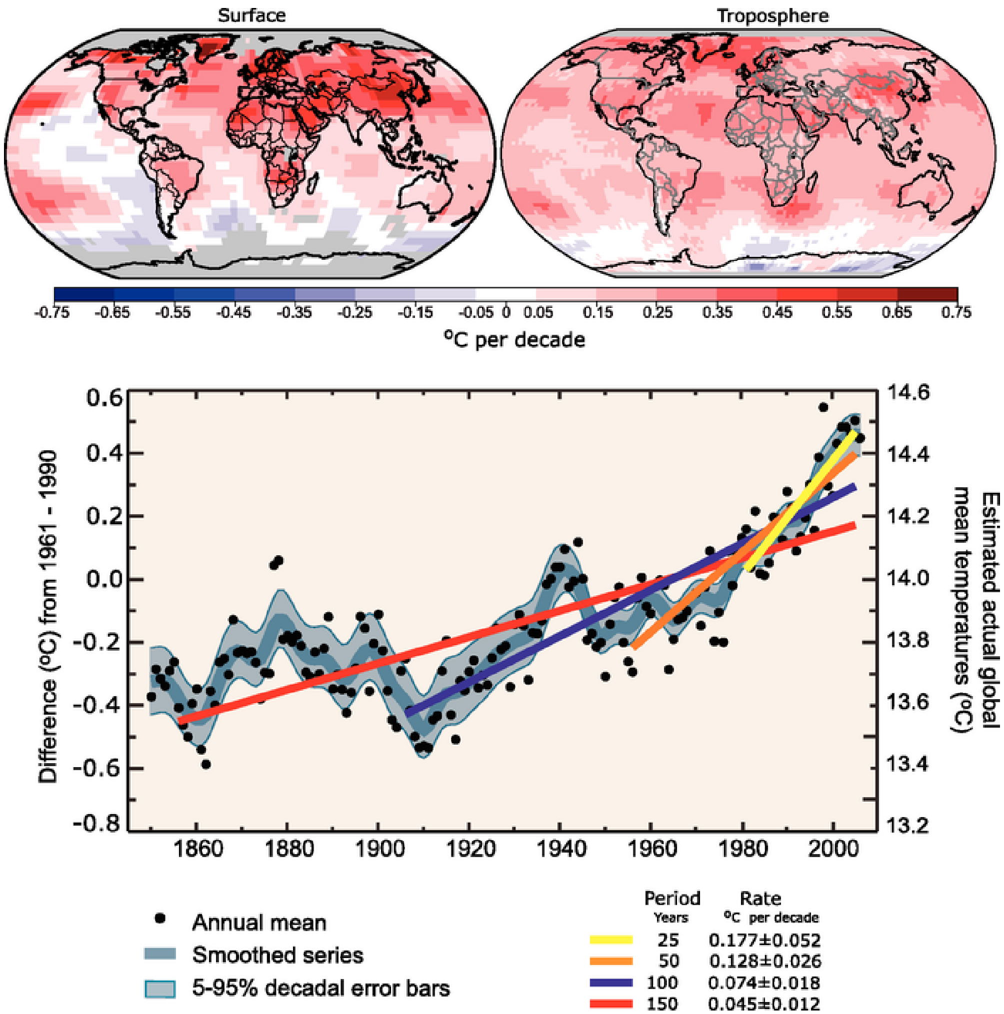


Measured temperature in London

Issues with measured temperature:

- Measurement error.
- Urban heat Islands.
- Different types of instruments.
- Sample of stations varies over time.
- Very little coverage of the ocean.
- What does ‘world average temperature’ mean? What about upper atmosphere?

Many of these issues can be resolved with statistics. Some cannot.



(Top) Patterns of linear global temperature trends over the period 1979 to 2005 estimated at the surface (left), and for the troposphere from satellite records (right). (Bottom) Annual global mean temperatures (black dots) with linear fits to the data. IPCC 2007 figure TS.6

Long run climate

It is possible that the recent rise in global measured temperature is part of normal climate fluctuations. To assess this, we need longer time series. Since no longer series of measured temperatures exist, we use proxies. There are many sorts of proxy data that can give us information about historical temperature. Among these ice cores are of particular interest.

(Extracting an ice core)

http://kaira.sgo.fi/2011/05/ice-cores-part-1.html

(Extracting an ice core)

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(sections of an icecore)

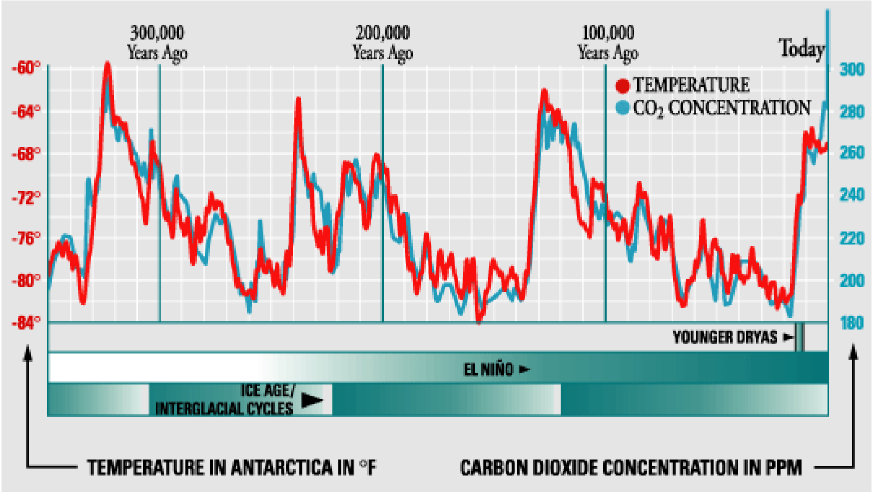
http://www.gdargaud.net/Antarctica/DC2005/20050406_10_WeatherStation.jpg

youtube video on icecores

http://www.youtube.com/watch?v=Kr02VF3ralc&feature=view_all&list=PL852A1CC5DA995E7C&index=0

Icecores are records of the water deposited on the site over many years. Water consists of several isotopes. In particular, some water molecules contain oxygen atoms with 8 neutrons, while other contain 10. The ratio of these isotopes in polar snow varies systematically with temperature. Thus, icecores allow us to track temperature back into the very distant past, about 800,000 years in some cases.

CO_2 from Vostok Antarctica ice core



Blue is CO_2 . This core goes back about 400,000 years, others go back 800,000 and show the same thing.

http://www.koshland-science-museum.org/exhibitgcc/historical02.jsp

Do climate proxies tell us about climate? (Homework)

- Plot of Ice core Oxygen isotope data against nearest measured temperature station

Other climate proxies

- Boreholes.
- Tree rings.
- Glacial extent.
- Species range.

All are reviewed in IPCC reading. Generally, all point toward warming.

Atmospheric Carbon

Basic atmospheric chemistry:

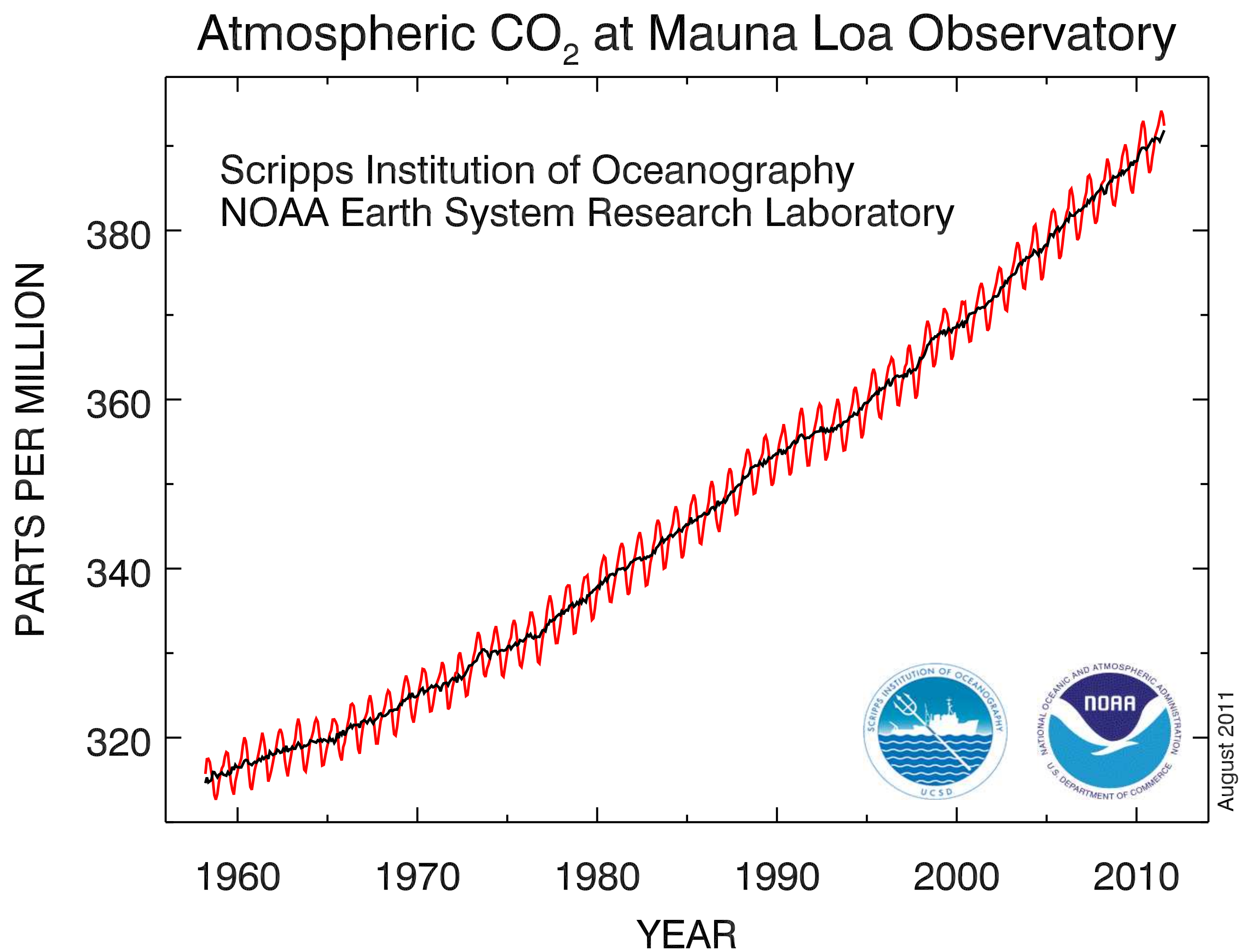
- Nitrogen 78%, 780,000 ppm
- Oxygen 21%, 210,000 ppm
- Argon 0.93% 930 ppm
- CO_2 0.0365% , 365 ppm
- Methane (CH_4) 1.7 ppm

and lots of other trace gases. From: Introduction to Atmospheric Chemistry, D. J. Jacob, Princeton University press, 1999.

Actually, CO_2 is at about 390ppm in 2010.

Atmospheric Carbon Measurements

Since 1959, atmospheric concentration on CO_2 has been measured daily at the Mauna Loa observatory in Hawaii. Since CO_2 disperses rapidly through the atmosphere, a single observatory gives a good description of what is going on in the whole world (I think).



http://www.esrl.noaa.gov/gmd/webdata/ccgg/trends/co2_data_mlo.pdf

Icecore Carbon Measurements

Small air bubbles are trapped in icecores. By checking the CO_2 concentration in this air, it is possible to create much longer series of atmospheric CO_2 , though with somewhat lower frequency (we can't reconstruct daily CO_2 concentrations from icecores). Similarly for other trace gases.

Trends in other CO_2 and other trace gases

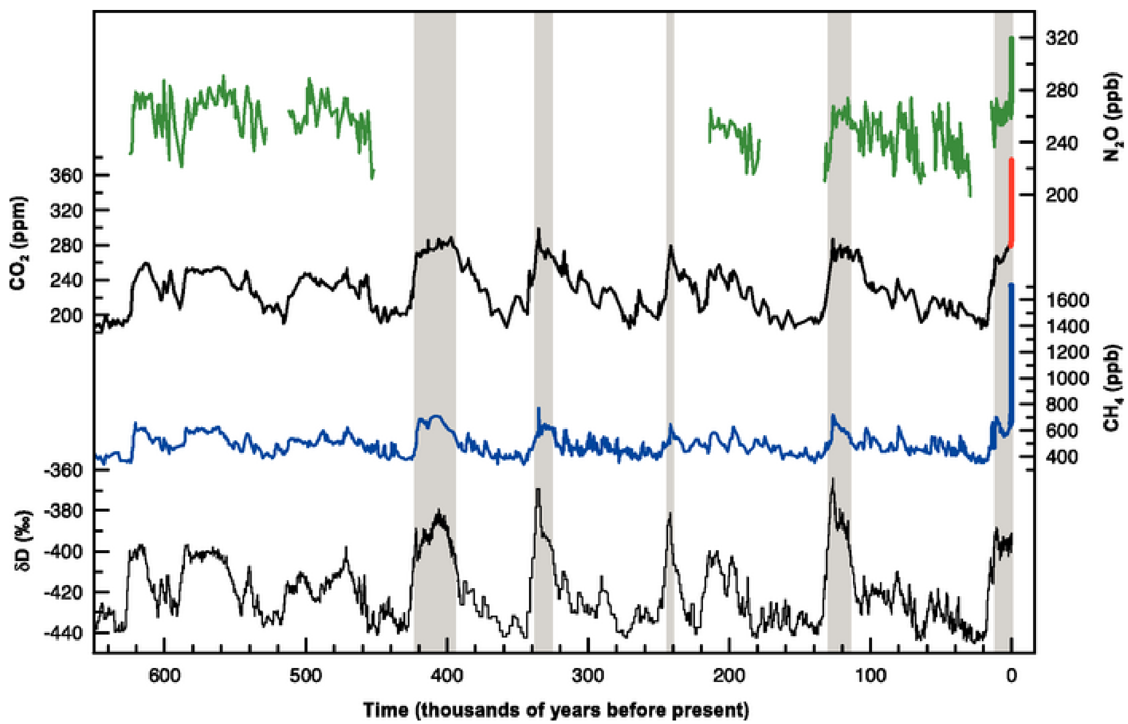


Figure TS.1. Variations of deuterium in Antarctic ice, which is a proxy for local temperature, and the atmospheric concentrations of the greenhouse gases carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) in air trapped within the ice cores and from recent atmospheric measurements. Data cover 650,000 years and the shaded bands indicate current and previous interglacial warm periods. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/figure-ts-1.html

Conclusion – measuring T and atmospheric CO_2

We've tried to measure T with instrumental measurements and proxies

- Measured temperature data, though subject to some problems, suggests dramatic warming.
- Other short run proxies, glacial extent and species range, confirm measured temperature data.
- Ice core data data shows that the last 200 years are warmer than the preceding 650,000+. Other long run proxies (tree rings, boreholes) are broadly consistent, though (I think) less reliable.

We don't actually care about atmospheric CO_2 . It's really just an intermediary between consumption and climate, but we need to understand how the process works in order to understand the consumption price of climate.

We've measured CO_2 directly with instruments and with icecore bubbles

- Mauna Loa measured CO_2 shows steady increase since 1959.
- Icecore record of CO_2 and other trace gases show that the levels of last 200 years are without precedent in the preceding 650,000+ years.

Next step is to look at how atmospheric CO_2 affects temperature.