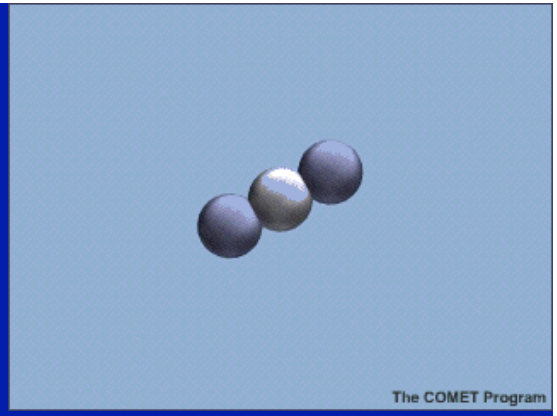

Our Climate: A Global Challenge

Academy of Lifelong Learning
Denver, CO

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JFOrmes@comcast.net

Human Causation

Can we find a “smoking gun”

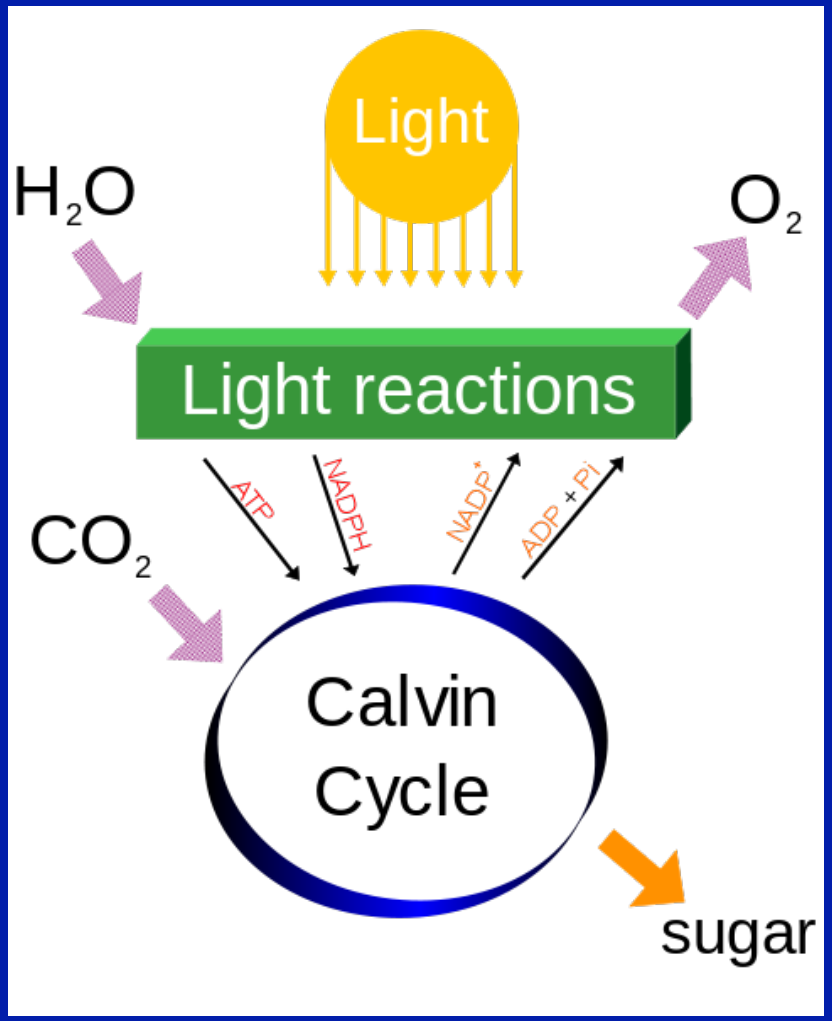
Reduced $^{13}C/^{12}C$ in plants and fossil fuels.

- Plants find it easier to use the lighter isotopes (^{12}C) when they convert sunlight and CO_2 into food.

Young plants

150Myr old plants

Photosynthesis



$6CO_2 + 12H_2O + light \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$

This explains why you have to water plants (12 in 6 out).

The plant uses the sugar to make fiber and grow.

Light provides the energy to drive the process. It takes less energy to use the lighter carbon, ^{12}C.

Different plants use different photosynthetic processes (C3 and C4), but both processes deplete ^{13}C.

What happens when we burn fossil fuels?

- Plants use ^{12}C slightly more easily than they use ^{13}C.
- Plants die and end up as fossil fuels.
- We burn them releasing the carbon to the atmosphere.
- When we burn these ancient hydrocarbons, the CO_2 released has a slightly lower value of $\delta^{13}C$ than the current atmosphere.
- We observe a slowly decreasing $\delta^{13}C$ in the CO_2 in the atmosphere.
- To distinguish against CO_2 from decaying plants, compare $\delta^{13}C$ & $\delta^{14}C$.

$$\delta^{13}C = \frac{\left[\left(\frac{^{13}C}{^{12}C}\right)_{\text{sample}} - \left(\frac{^{13}C}{^{12}C}\right)_{\text{standard}}\right]}{\left(\frac{^{13}C}{^{12}C}\right)_{\text{standard}}} * 1000\%$$

The $^{13}CO_2/^{12}CO_2$ story

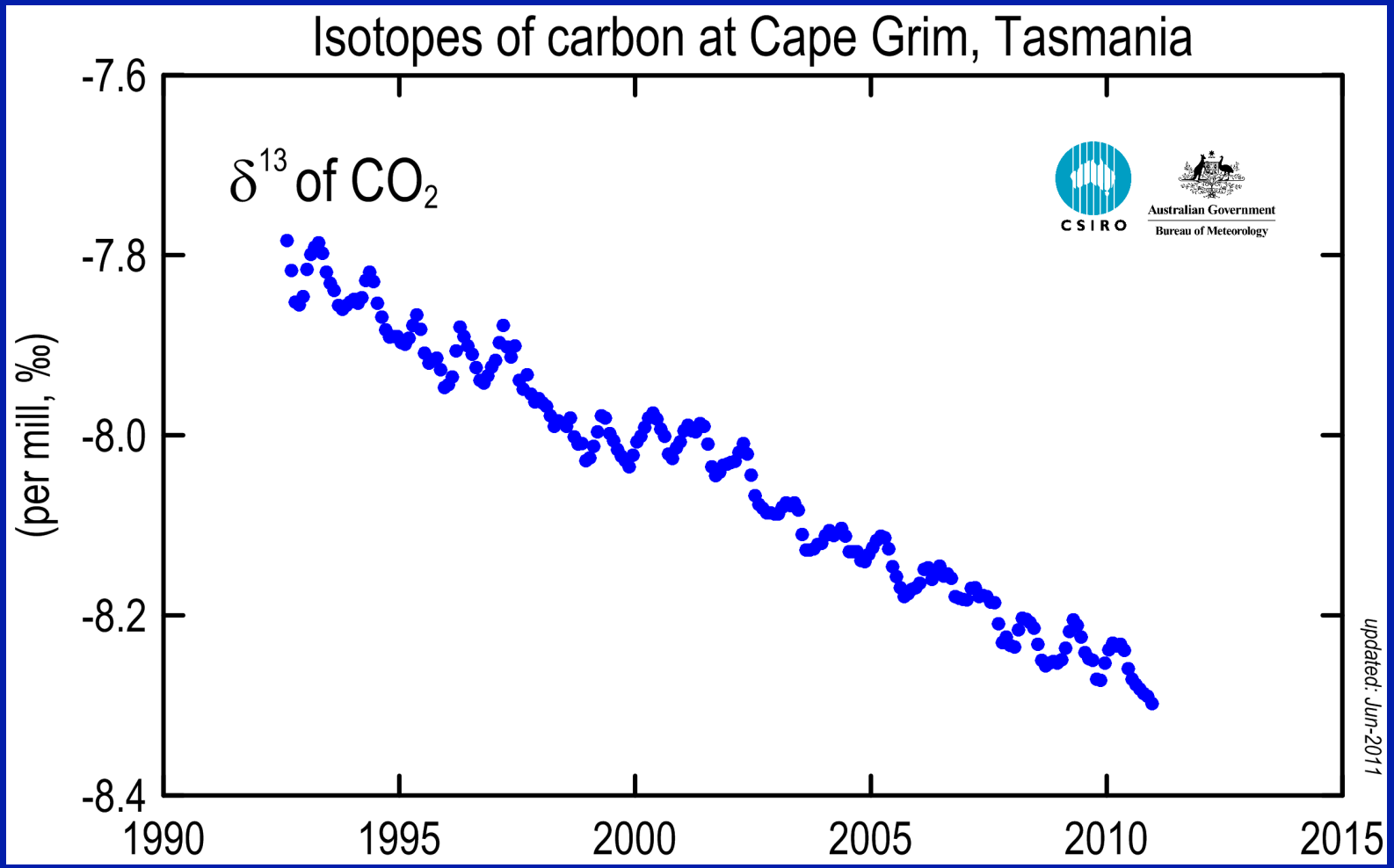
Hypothesis: Burning fossil fuels is responsible for the increase in atmospheric CO_2

- Carbon has 2 stable isotopes ^{13}C and ^{12}C (note ^{14}C is unstable – half-life 5730 years - and is used to date tree rings, etc.)
- There were 280 ppm of CO_2 [$^{13}CO_2$ + $^{12}CO_2$] in the atmosphere before the contamination by the burning of fossil fuels became significant.

The $^{13}CO_2/^{12}CO_2$ story

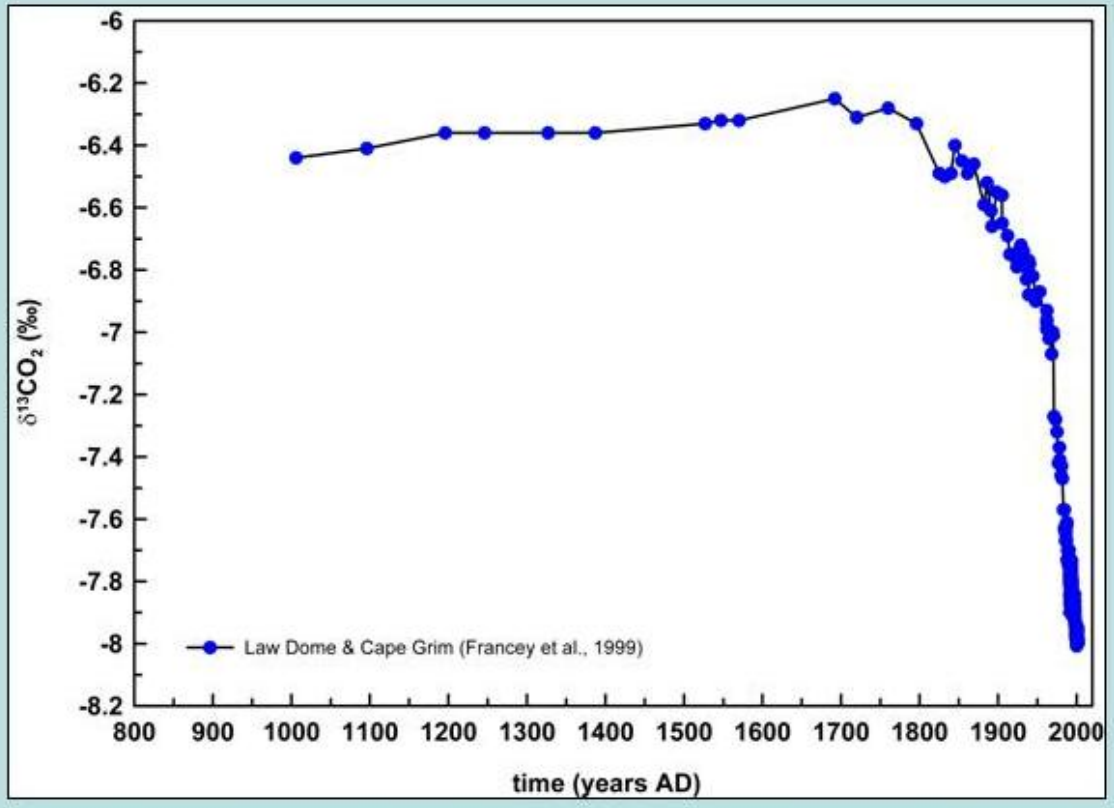
- Outgassing of C from volcanoes has the "natural" or universal abundance.
  - Ratio of $^{13}CO_2/^{12}CO_2$ in the air was the "natural" abundance when coal & oil were formed.
  - Varies slightly with the kind of plant (or microbes) from which the ancient hydrocarbon was formed.
- There is now 400 ppm of CO_2 [$^{12+13+14}CO_2$] in the atmosphere (after contamination by the burning of fossil fuels became significant – our hypothesis, 280 ppm).
- So (400-280)/400 = **30%** of the CO_2 (in air) comes from burning fossil fuels.

Hypothesis is tested in air



http://www.cmar.csiro.au/research/capegrim_graphs.html

Hypothesis is tested in ice cores

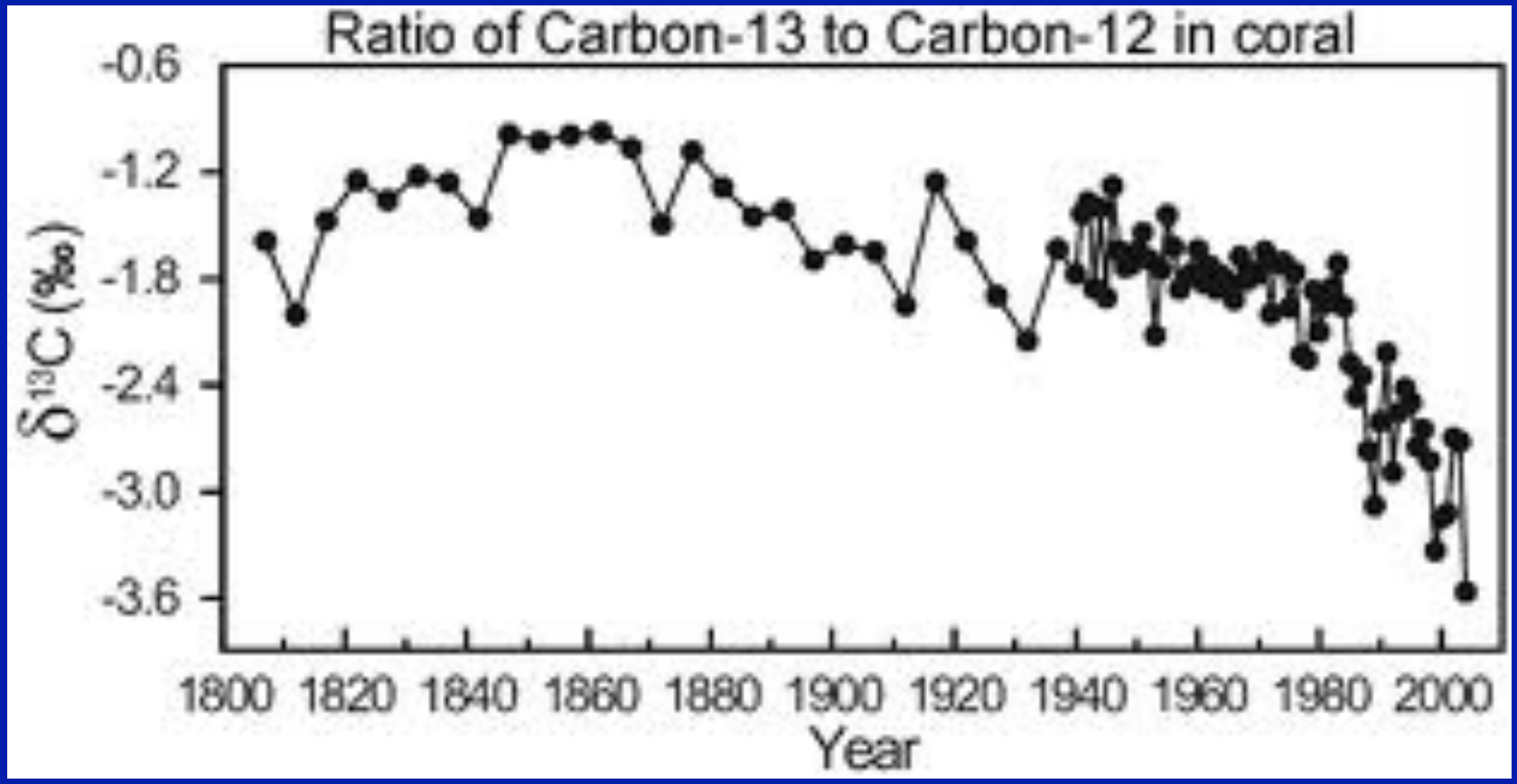


Reconstruction of the carbon isotope (C-13) of atmospheric CO2 from the Law Dome ice core (Francey et al., 1999) and the Cape Grim ambient air measurements (Allison et al., 2003).

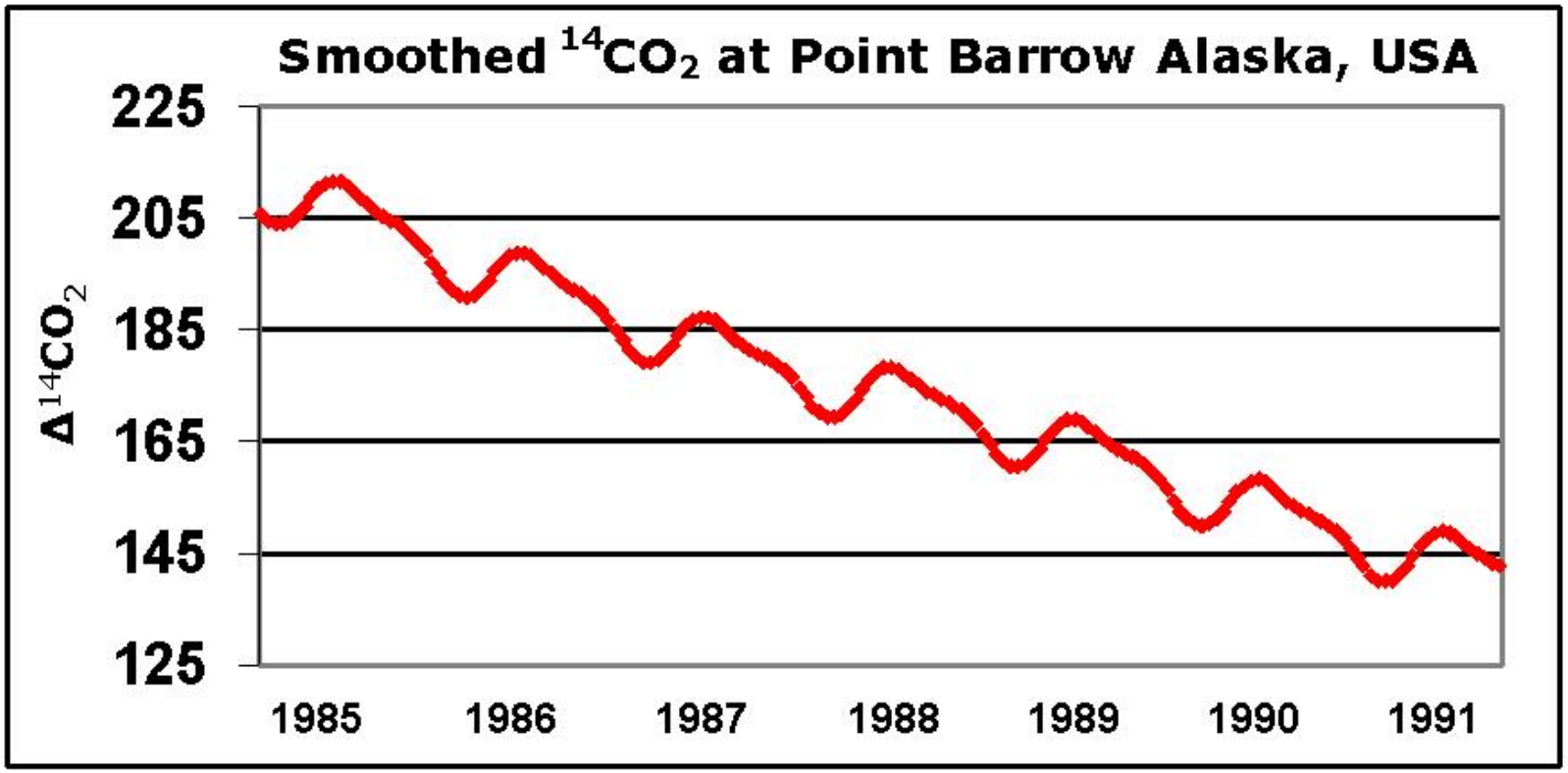
pre-industrial value -6.4

http://www.bridge.bris.ac.uk/projects/pcmip/experiments.html

Hypothesis is tested in corals



"Evidence for ocean acidification in the Great Barrier Reef of Australia", G. Wei et al. 2009, Geochimica et Cosmochimica Acta Volume 73, Issue 8, 15 April 2009, Pages 2332–2346



Fossil fuels have no ^{14}C (half-life 5739 yrs). Declining $^{14}CO_2$ indicates the recently added atmospheric CO_2 is from ancient material, not from plants that grew and died recently.

http://cdiac.ornl.gov/trends/co2/meijer/Meijer_14C.html

Alternative explanations??

I know of no other explanation for the simultaneous decreases in the ratios of $^{13}CO_2/^{12}CO_2$ in the atmosphere and in corals (and ^{14}C and O_2).

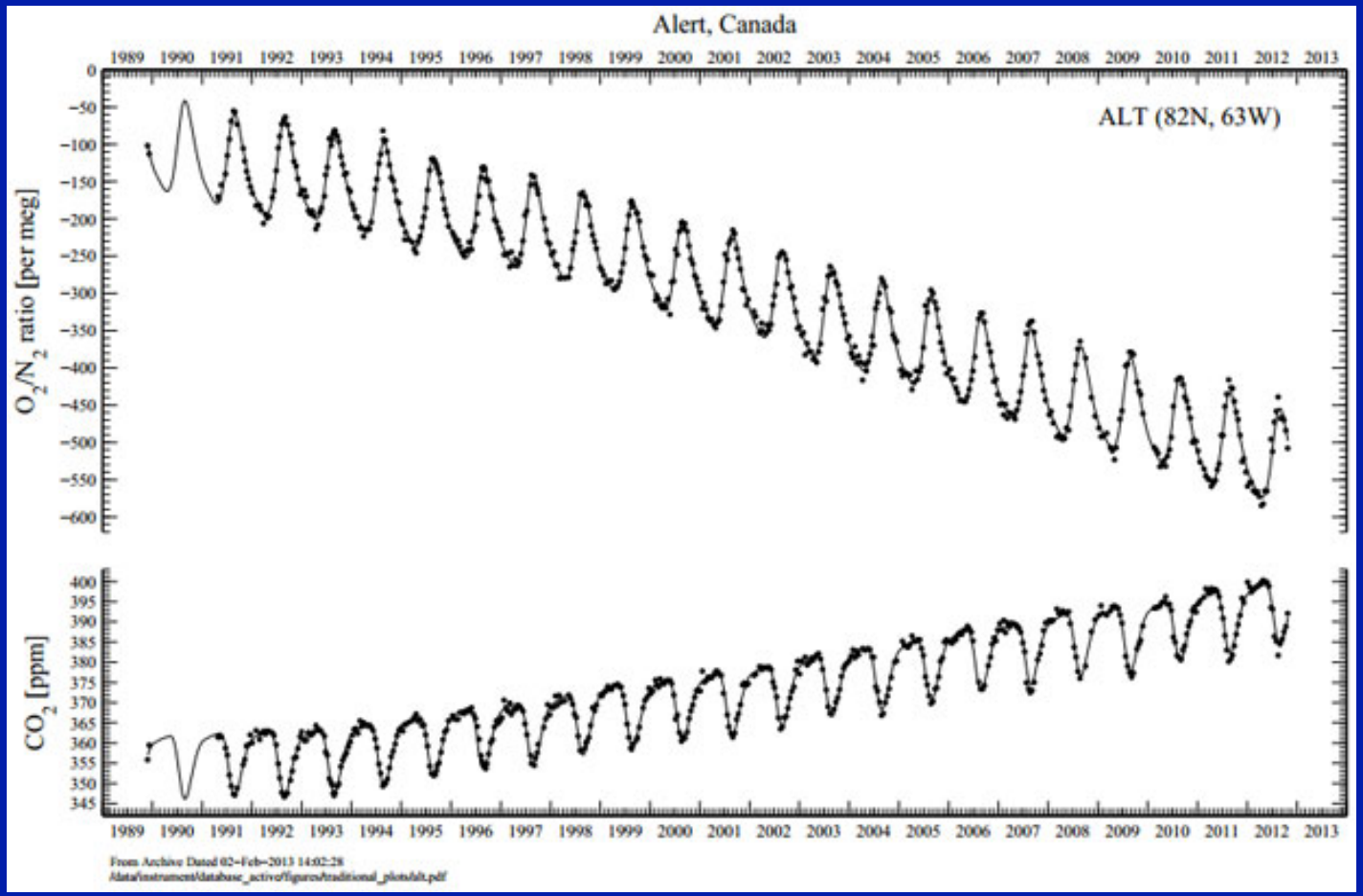
If you know of one, please inform the instructor.

Corroborating Evidence for Anthropomorphic changes

Just from measurements, not model dependent

- Changes in the infrared spectrum from the sky (as seen from Earth) and from the Earth (as seen from space)
- Nights warming faster than days and
- Winters warming faster than summers (not the sun)

Oxygen used by burning



The observed downward trend is 19 'per meg' per year. This corresponds to losing 19 O_2 molecules out of every 1 million O_2 molecules in the air/year.
http://scrippso2.ucsd.edu

10 Indicators of a Human Fingerprint on Climate Change

Less heat escaping to space

Shrinking thermosphere

Cooling stratosphere

Rising tropopause

Less oxygen in the air

More fossil fuel carbon in the air

30 billion tonnes of CO_2 per year

More heat returning to Earth

Nights warming faster than days

More fossil fuel carbon in coral

Summary

- Anthropomorphic CO_2 (and other GHG) are causing global warming
  - science is sound and has long history
  - focus action here!!
- Other contributors to climate change are much less well understood
  - aerosols, clouds, ocean-atmosphere interactions and flow patterns of energy