Reconciling multidecadal land-sea global temperature with rising CO2

Vaughan Pratt
Stanford University

Goal

Additional insight into

1. Similarity of the 1860-1880 & 1910-1940 rises to 1970-2000.
2. The recent pause (2001-2013).
3. No sign of 3 °C per doubling of CO_2.

Simple reasoning (no opaque models or sophisticated statistics).

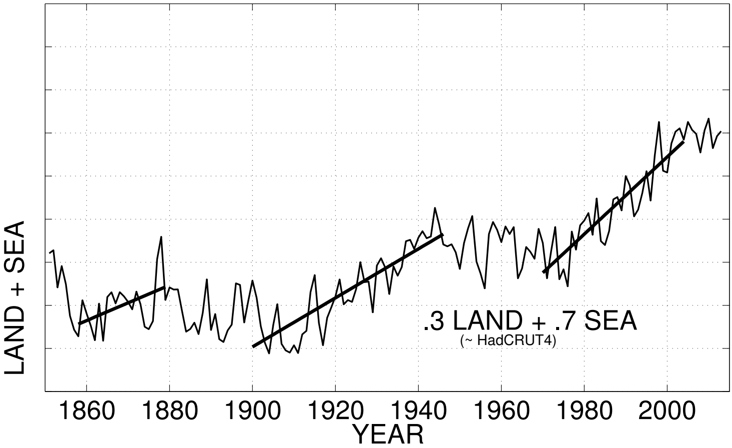
Some applicable audiences:

- Average reader of Scientific American, Discover, etc.
- Decision makers—because complex reasoning may delay decisions.
- Lawyers—because they have to talk to judges and juries.

Part 1: Three Rises

Question: If the first two rises below are natural, why not the third?

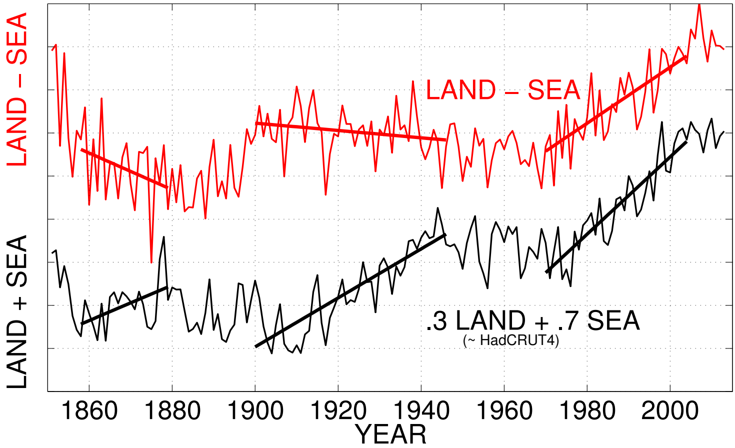
Answer: They can be separated using land-sea difference.



Land-Sea Difference

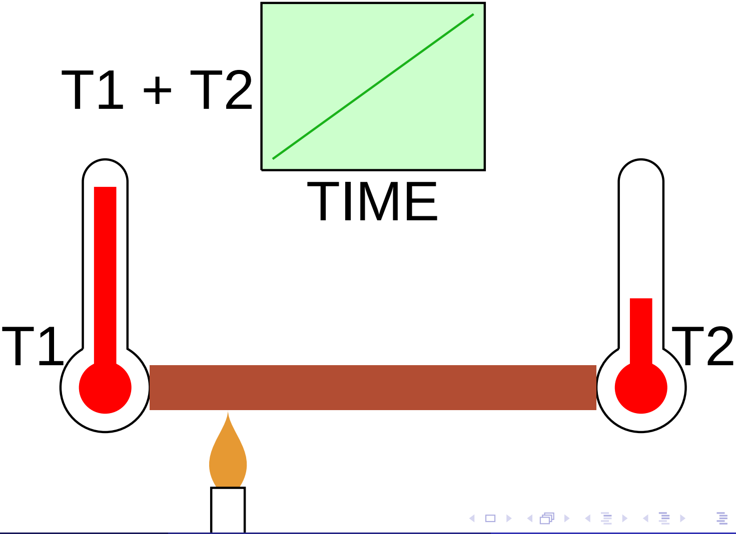
HadCRUT4 ≈ 0.3 LAND + 0.7 SEA (geographical weighting).

Consider instead LAND − SEA, specifically CRUTEM4 − HadSST3.



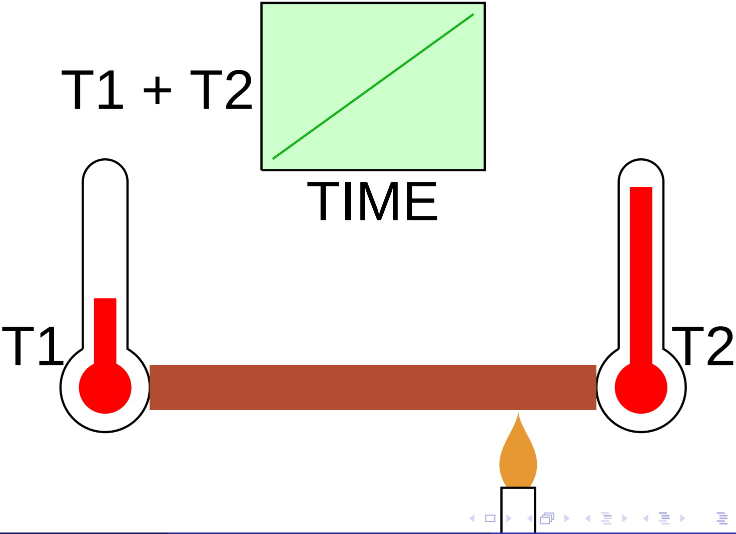
Heat flow direction: The Copper Bar Gedankenexperiment

Heating copper bar at T1 end raises SUM(T1,T2) over time.



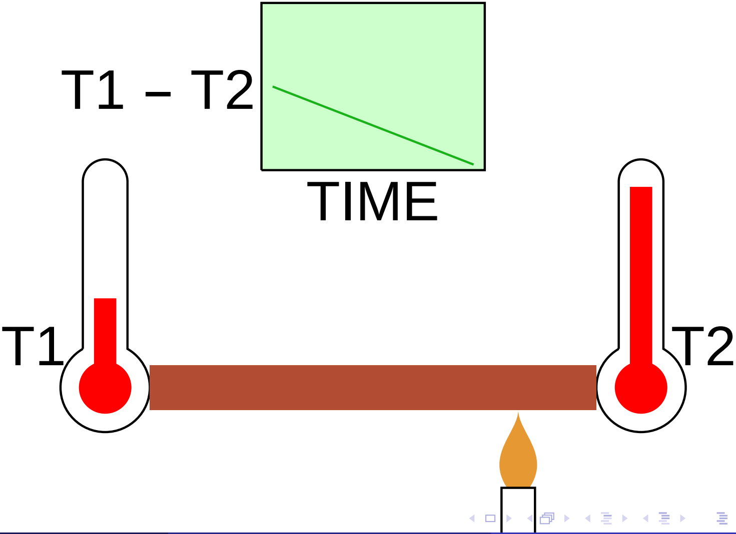
Heat flow direction: The Copper Bar Gedankenexperiment

SUM is not a diagnostic of direction, witness heating other end.

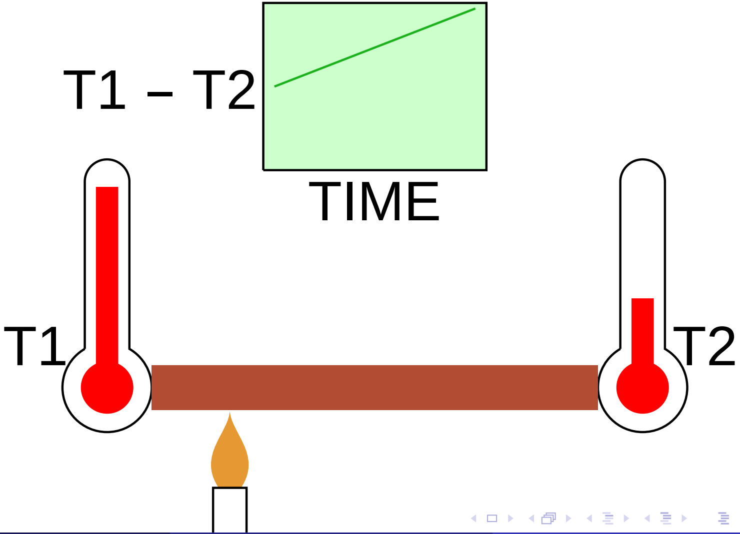


Heat flow direction: The Copper Bar Gedankenexperiment

By Fourier's law, flow T2 → T1 *lowers* DIFF(T1,T2).

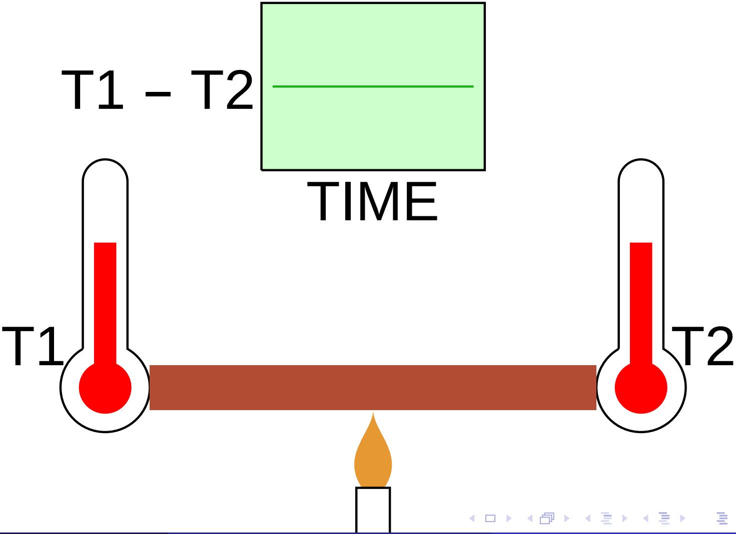


Dually, flow T1 → T2 *raises* DIFF. So DIFF indicates direction.



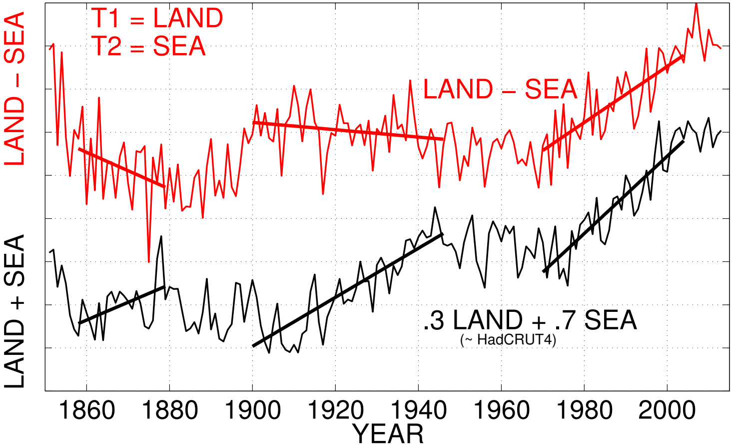
Heat flow direction: The Copper Bar Gedankenexperiment

Heating middle (or both ends) balances the flow. DIFF unchanged.



Claims, rise by rise

Rise 1: Heat flow largely from sea to land.
Rise 2: Same, perhaps attenuated by a reverse flux (see Part 3).
Rise 3: Heat flow largely from land to sea (Part 3).



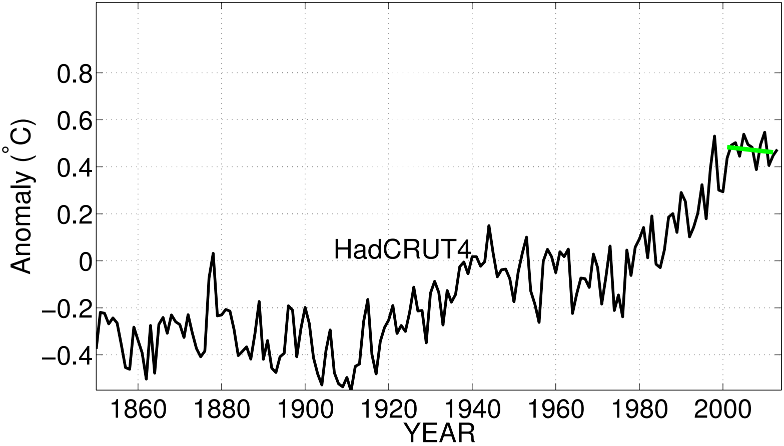
Corollaries

1. At successive rises of land-sea sum, the corresponding trends of land-sea difference shift gradually from strongly negative to strongly positive.
2. The first two rises of the sum cannot be attributed to atmospheric effects such as volcanic dimming, natural CO2 fluctuations, etc.

Part 2: The pause

The "pause" at 2001-2013.

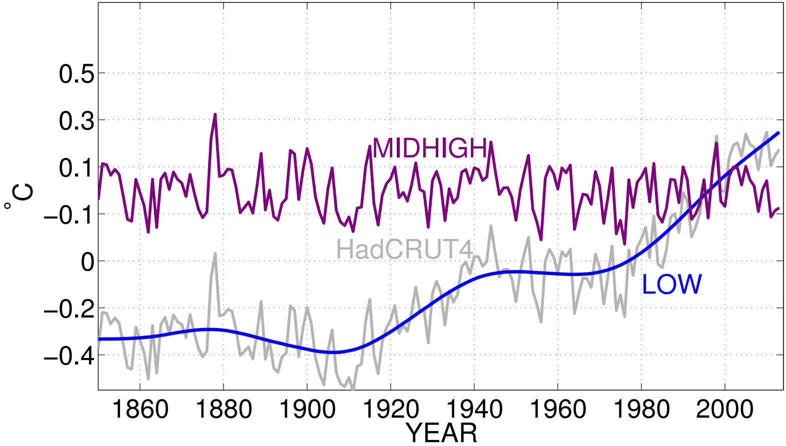
Downward trend of $-0.2\ ^\circ C/century$.



Spectral analysis

First stage: HadCRUT4 = LOW + MIDHIGH.

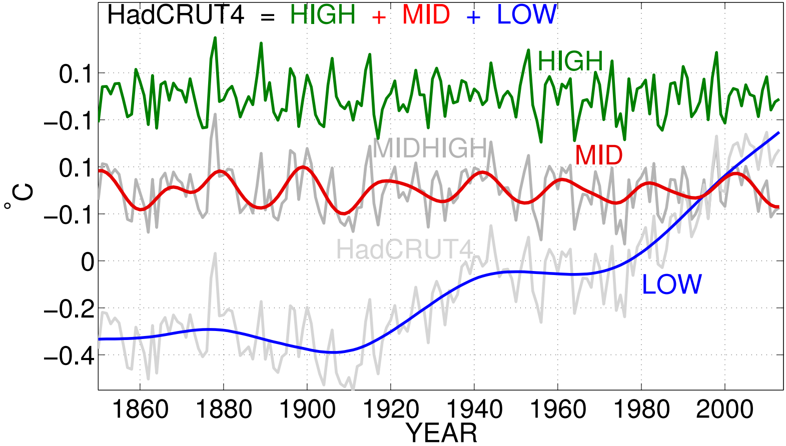
Filter: Low-pass *Gaussian* (G_0) cutting off at 20 years (3σ).



MID as the 20-year band

Second stage: MIDHIGH = MID + HIGH.

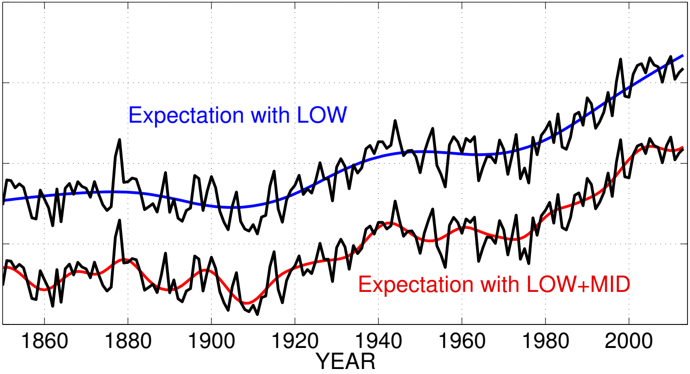
Filter: Band-pass *Mexican hat* (Ricker, G_2) centered on 20 years.



Significance of MID

MID is (a) robust and (b) phase-locked with the 20-year solar Hale cycle.

LOW: No pause expected. LOW+MID: Expect a pause.



Corollaries

1. When MID is recognized as ongoing, the hiatus is consistent with the steady recent rise of LOW (whatever its cause).
2. Santer *et al*'s requirement of 17 years on the minimum period needed to detect a trend reliably is too high.
   - Santer treated MID as part of the unpredictable noise.
   - Treating it as a predictable signal
     permits reducing the 17 year figure to the order of a decade.
3. Puzzle: Why no pause in 1980-1990?
   This needs Part 3.

Part 3. The missing climate sensitivity

Doubling CO_2 will *eventually* raise the temperature 3 °C
(or whatever the Equilibrium Climate Sensitivity (ECS) actually is).

But what if the CO_2 keeps rising?

Transient Climate Response, TCR, is the rise in temperature

- *during* a doubling of CO_2
- while it is rising at 1%/yr (so 70 years to double).

Can we relate the two?

Proposal: ECS as delayed TCR.

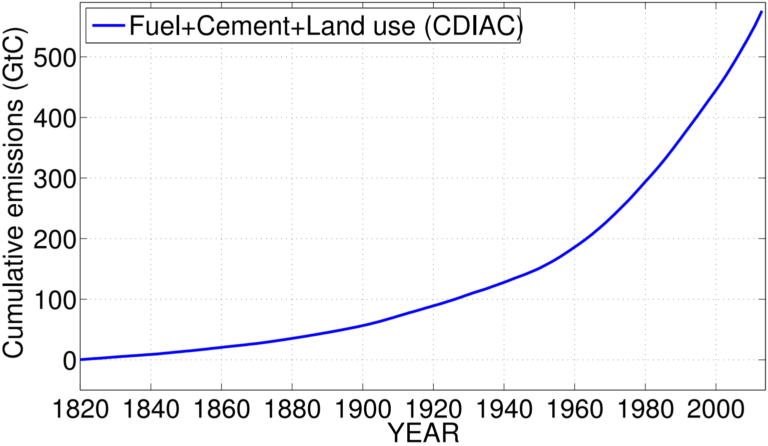
Basis: The ocean as heat sink [Hansen et al 1985]

Quantify this as follows (several steps).

Impact of Human CO2

Cumulative emissions and land use change since 1820.

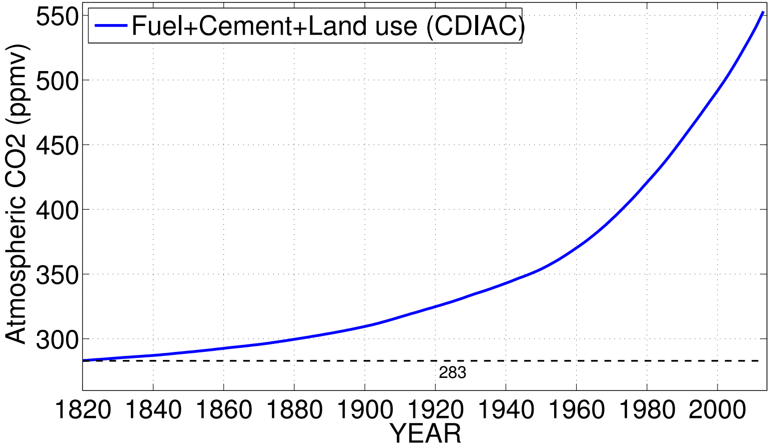
CDIAC data, in units of GtC.



Impact of Human CO2

Rescale GtC to ppmv: divide by 5.148*12/28.97 (m_{atm}, AW_C, MW_{air}).

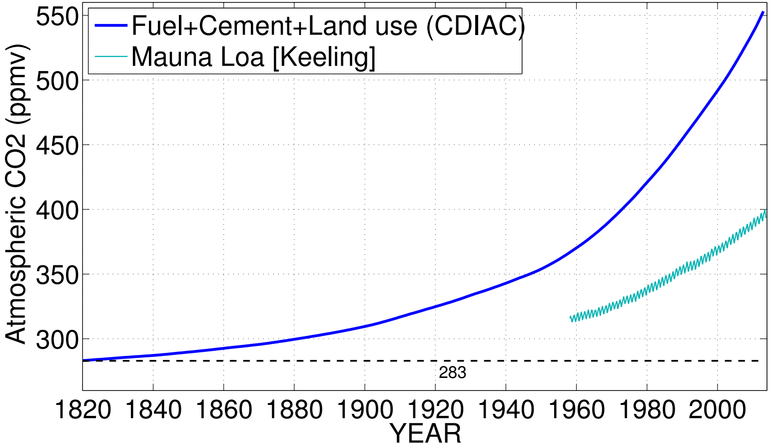
Then add 283 as estimate of pre-1820 atmospheric CO2.



Impact of Human CO_2

Mauna Loa observations since 1958 [Keeling]

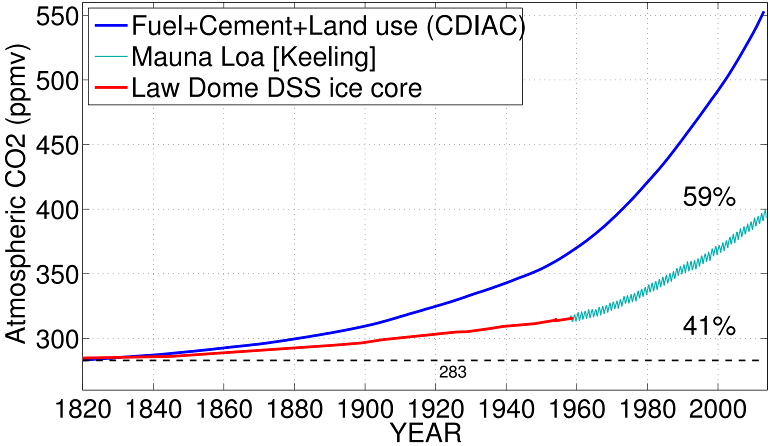
Evidently not all emissions remained aloft.



Impact of Human CO2

Firn air from Law Dome DSS ice core data (Australian)

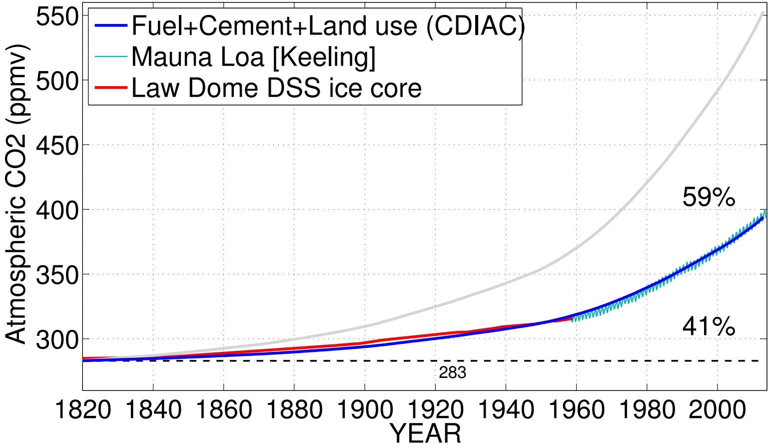
Firn is preglacial ice packed sufficiently to trap air.



Impact of Human CO2

Assume only 41% of emissions remain aloft.

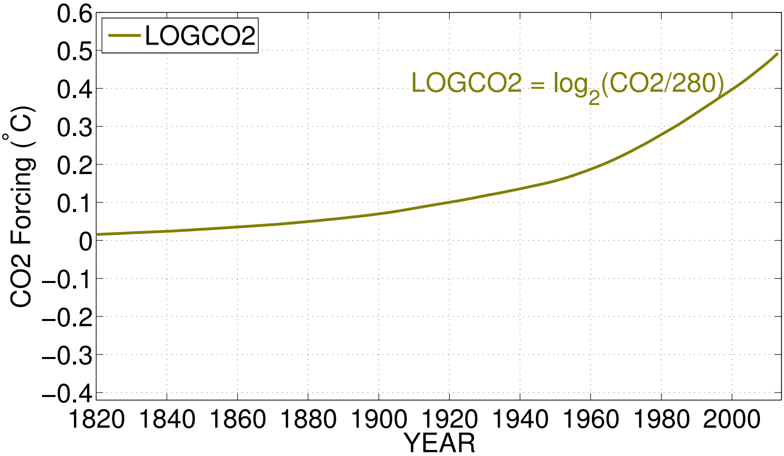
Fits Mauna Loa well, Law Dome reasonably (19th C: 50%?).



Impact of Human CO2

Arrhenius Law: LOGCO2 = $\log_2$(CO2/280). (Use CDIAC for CO2.)

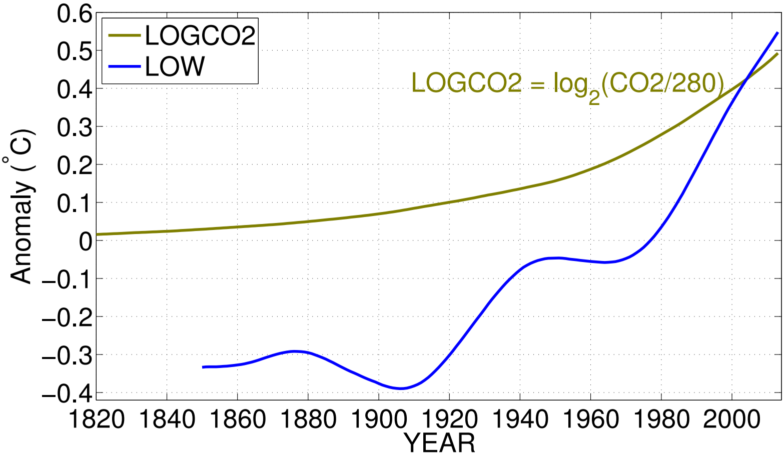
Expected global warming @ climate sensitivity 1°C/CO2 doubling.



Fitting LOGCO2 to LOW

Introduce LOW as below. Coming up: fit LOGCO2 to it...

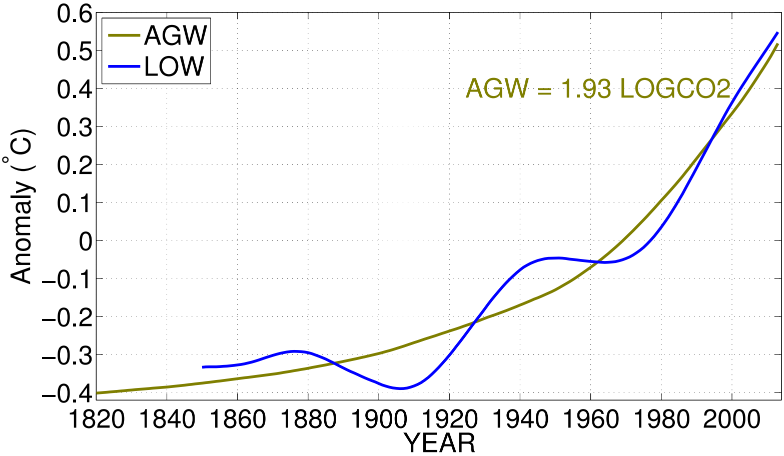
...in order to analyze LOW = AGW + RESIDUAL.



Fitting LOGCO2 to LOW

Best fit at 1.93*LOGCO2.

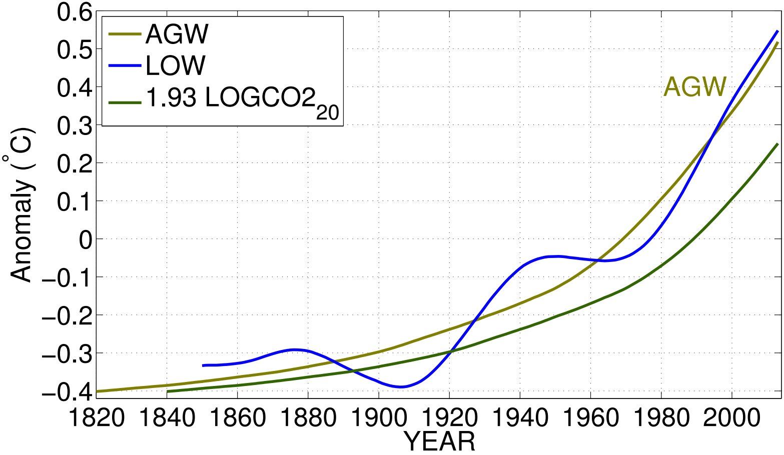
LOW = 1.93 LOGCO2 + RESIDUAL



A simple model of delayed response

Let $\text{LOGCO2}_d(y) = \text{LOGCO2}(y - d)$ (slide LOGCO2 right d years).

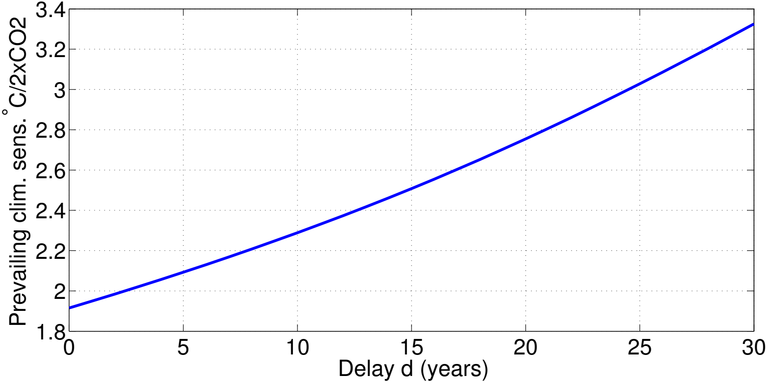
1.93 LOGCO2_{20} fits LOW badly. Best fit is 2.77 LOGCO2_{20}.



Prevailing climate sensitivity $s(d)$

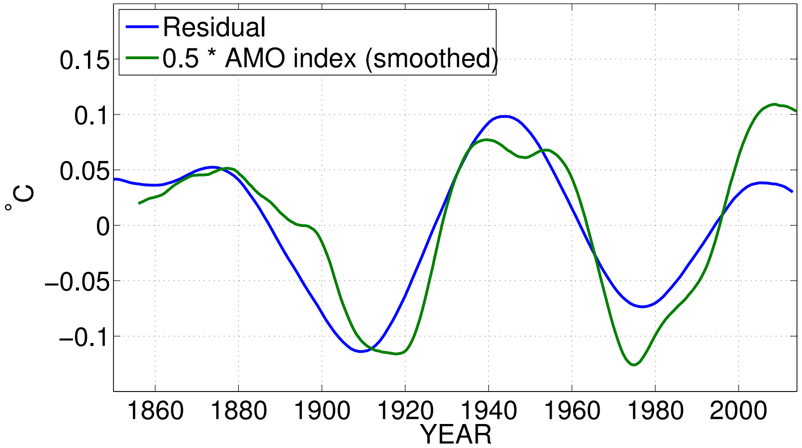
The graph plots the relation $s(d)$ obtained by fitting $\mathrm{LOGCO2}_d$ to LOW to determine s. $s(d) \approx 1.93 + 0.047d$.

In particular $s(25) \approx 3$. That is, a delay of 25 years entails a prevailing climate sensitivity of about 3 °C per doubling of CO2.



Identifying RESIDUAL with AMO

1. Part 1 shows AMO originates below sea surface (not volcanism).
2. Part 2 needs AMO to explain no pause in 1980-90.



Conclusions

Our understanding of the CO2 control knob is consistent with

1. The natural rises up to 1940 (seems to be the ocean)
2. The hiatus (the Sun and the AMO together)
3. ECS of 3 °C/2xCO2 under a 25-year ocean delay.

Further points

Volcanos and El Nino/La Nina not necessary in this account.
By Occam's Razor they should not be part of the explanation.
(Contrapositive: If they should be, that refutes Occam's Razor.)

The more stable human influences besides CO2 are in LOW.
This confounds them with CO2, hence a major source of uncertainty.
For this reason they have been closely studied for decades.