Reconciling multidecadal land-sea global temperature with rising CO2

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Goal

Additional insight into

1. Similarity of the 1860-1880 & 1910-1940 rises to 1970-2000.
2. The recent pause
3. No sign of 3 °C per doubling of CO2.

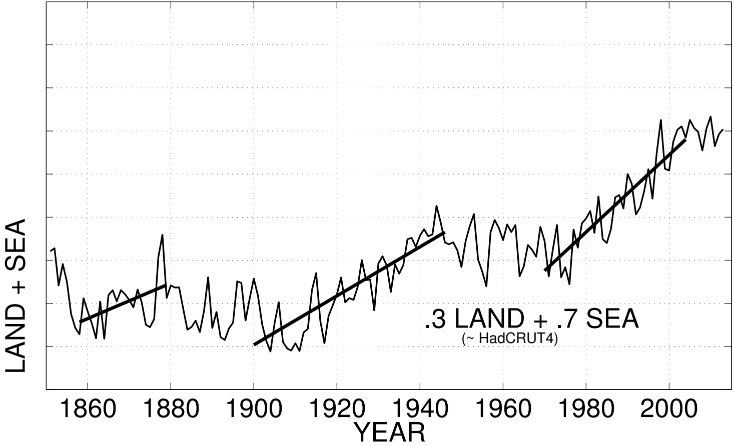
Some applicable audiences:

- Average reader of Scientific American, Discover, etc.
- Decision makers—because any of the above may delay decisions
- Lawyers—because they have to communicate with juries

Part 1: Three Rises

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

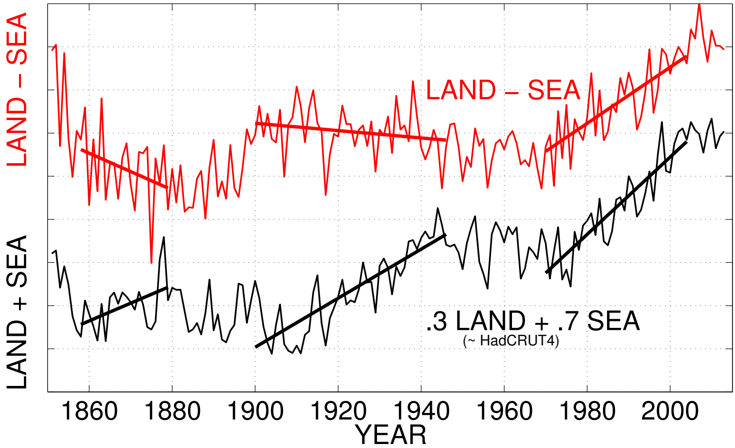
Answer: They can be separated using land-sea difference.



Land-Sea Difference

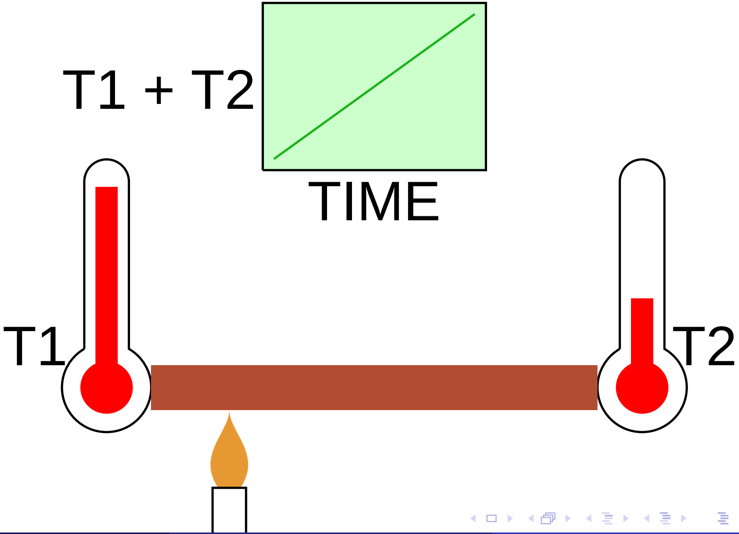
HadCRUT4 $\approx$ 0.3 LAND + 0.7 SEA.

Consider instead LAND − SEA, i.e. CRUTEM4 − HadSST3.



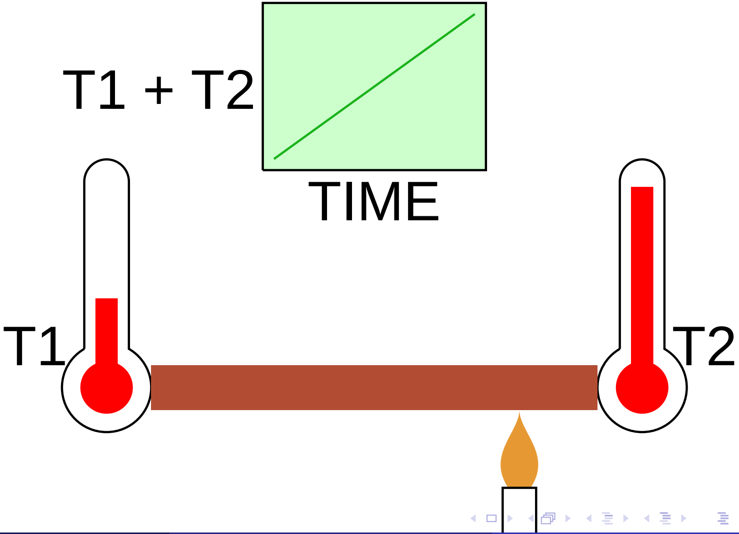
Abstraction: Heating T1

Heating copper bar at left end raises T1 somewhat more than T2



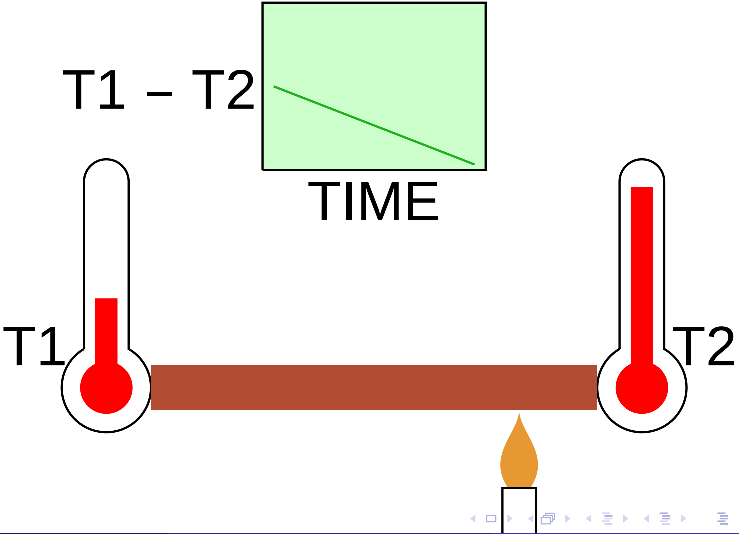
Abstraction: Heating T2

When observing sum, heating T2 end makes no difference



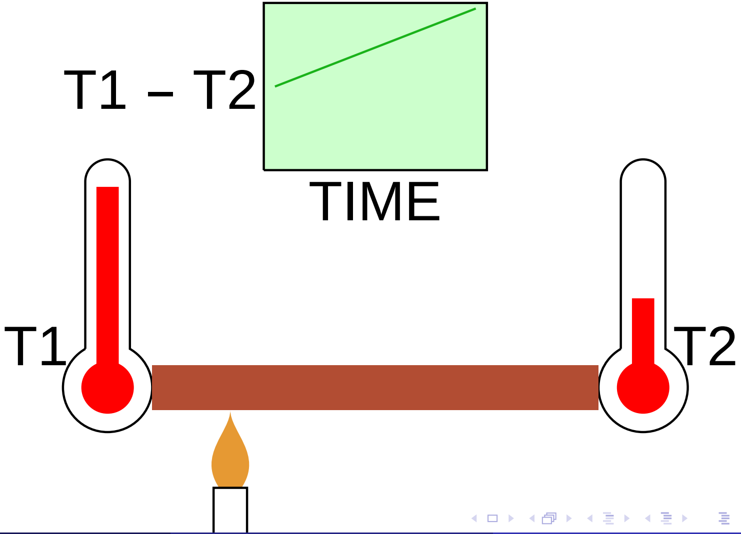
Consider the difference: T2

Observing difference, heating T2 end (SEA) drives difference down



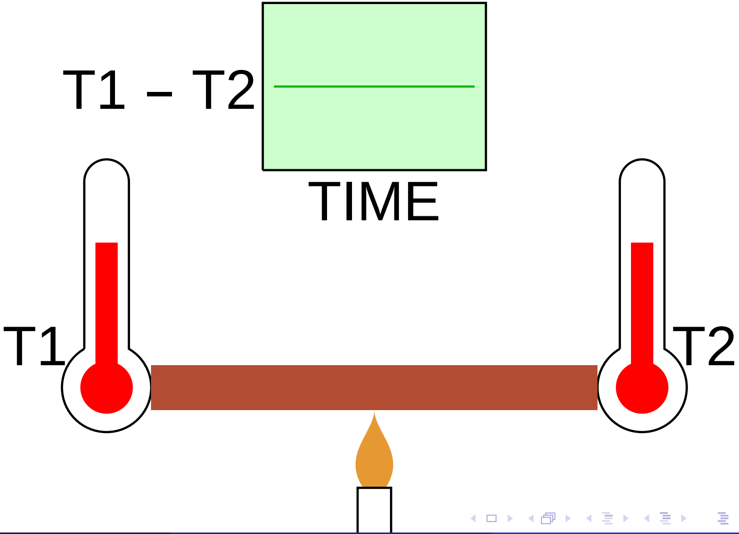
LAND

Heating T1 end (LAND) drives difference up



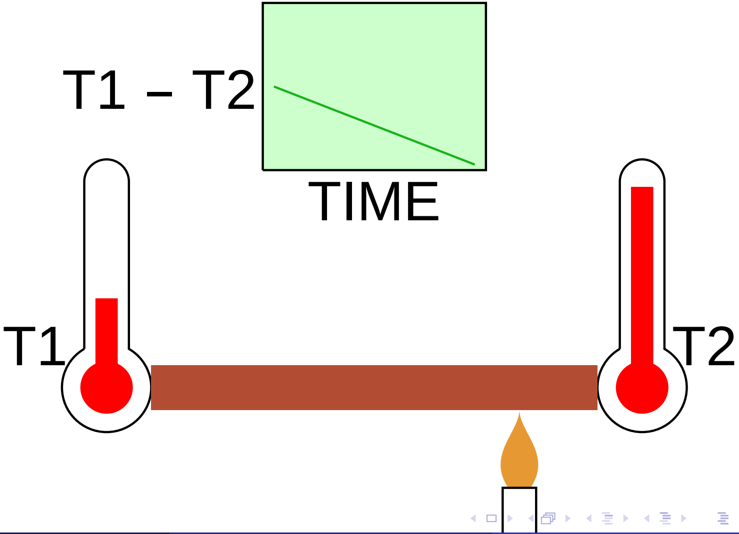
In between

Heating middle drives both up equally, zero difference



SEA

Heating T2 end (SEA) drives difference down

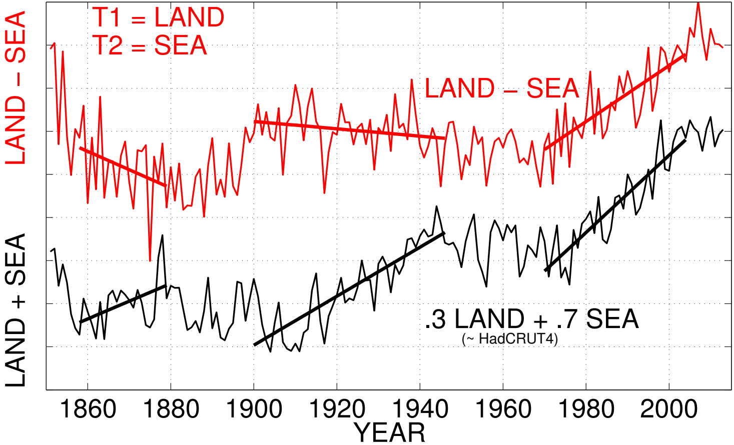


Claims, rise by rise

Rise 1: Heat from below.

Rise 2: Same plus a little heat from above.

Rise 3: A lot of heat from above.

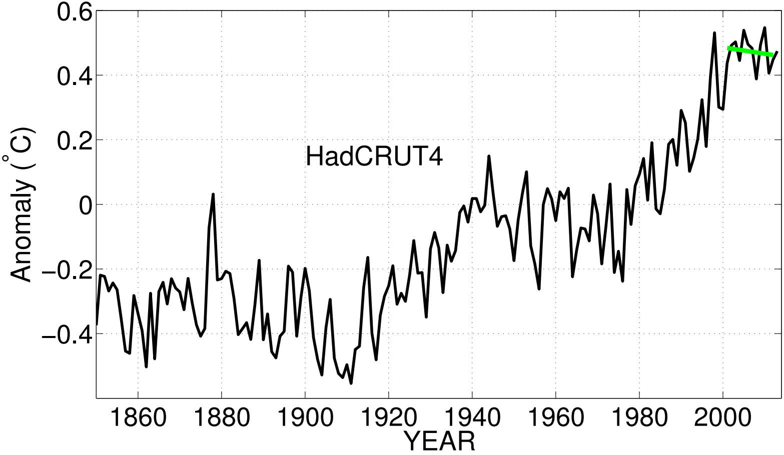


Corollaries

1. The first two rises must result from warming the sea, and the third from warming the land. The third rise is therefore not simply a repeat of the first two rises.
2. The slope of the middle difference, while still negative, is trending towards that of the third rise. This can be interpreted as early signs of whatever is causing the third rise. Continuous adjustment of slope. *A lot of data, therefore a sensitive test.*
3. The first two rises cannot be attributed to atmospheric effects such as volcanic dimming, natural CO2 fluctuations, etc.

Part 2: The pause

The temperature data. Pause at 2001-2013.

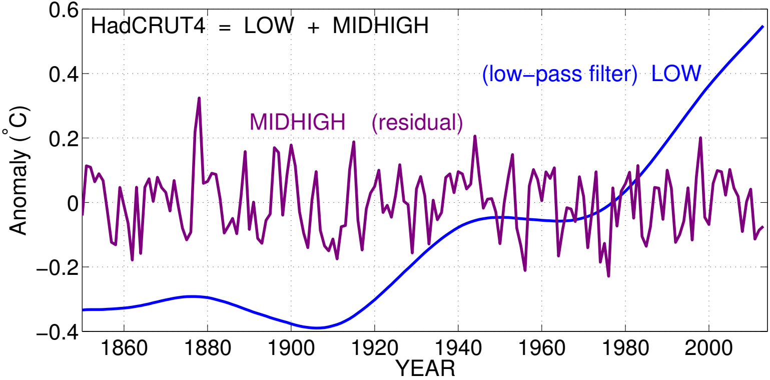


Spectral analysis

We express HadCRUT4 as a sum of frequency bands.

We start by splitting off the lowest frequency, LOW, using a low-pass *Gaussian* or G_0 filter.

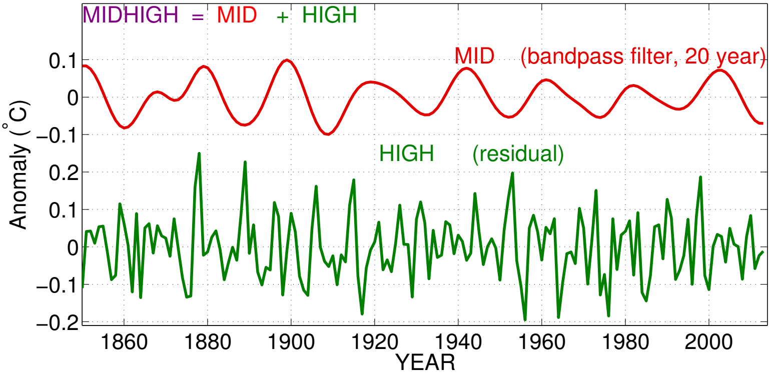
The residual (MIDHIGH, in purple) is everything else.



MID as the 20-year band

We then split off MID from MIDHIGH using a 20-year band-pass *Mexican hat* or G_2 (second derivative of G_0) filter.

This puts the 10-year solar cycle in the residual HIGH, which in HadCRUT4 is less robust (more ragged) than the 20-year cycle.



Refilter LOW

We then remove MID from HadCRUT4.

This leaves a gap at 20 years in the spectrum.

We then increase the cutoff frequency of the low-pass Gaussian to extract LOW again.

This new version of LOW is less distorted because its higher frequencies are less attenuated.

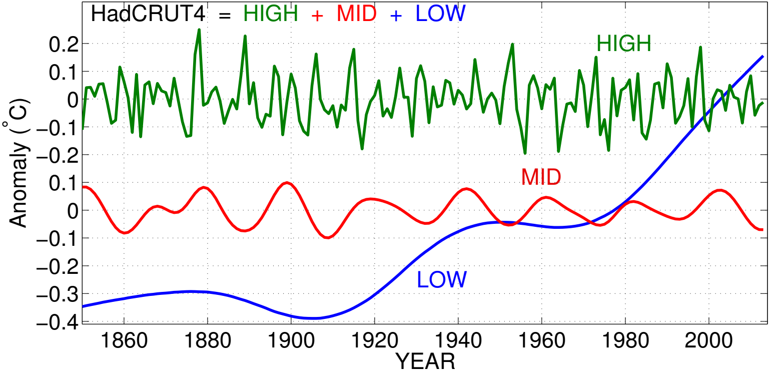
Had we done this earlier we would have inadvertently included some of MID in LOW.

HIGH, MID, LOW

We then obtain HIGH as the residual after refiltering LOW.

This gives the following three-component analysis of HadCRUT4.

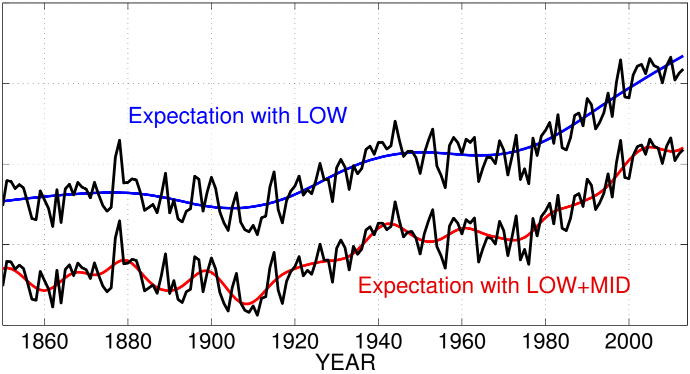
No information is lost in this spectral analysis because HadCRUT4 is recoverable as their sum.



Significance of MID

Lacking the ragged 10-year cycle, MID is sufficiently robust to justify using it for expectations.

Compare HadCRUT4 smoothed without and with MID:
LOW: No pause expected. LOW+MID: Expect a pause.



Corollaries

1. When MID is recognized as ongoing, the hiatus is consistent with our understanding of the CO2-temperature relation.
2. Santer *et al*'s requirement of 17 years on the minimum period needed to detect a reliable trend 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.

Part 3: Finding 3 °C/2xCO2 in the data

Equilibrium Climate Sensitivity, ECS, is *eventual* response to a doubling of CO2.

Hansen et al [1985]: When CO2 rises quickly, the heat sink action of the ocean will reduce the climate response to CO2.

Proposed notion: Transient Climate Response (TCR) as the response *during* a doubling of CO2 rising at 1%/yr.

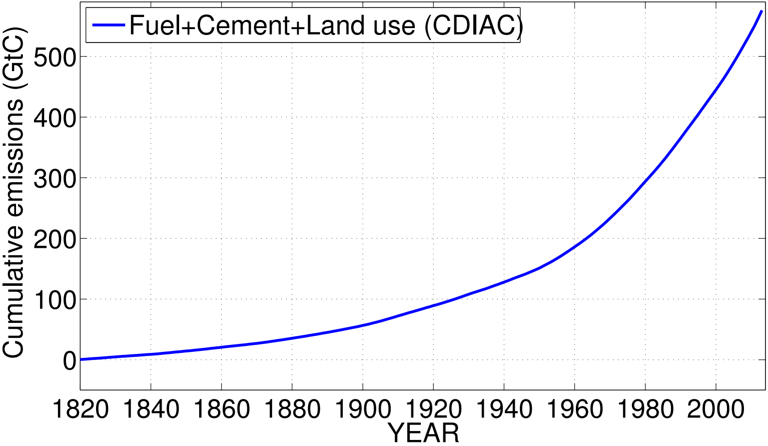
Alternative approach to TCR: Establish a relation between delay and equilibrium climate sensitivity.

Method: Fit CO2 data to temperature assuming a uniform delay of d years.

Impact of Human CO2

Cumulative emissions and land use change. CDIAC data.

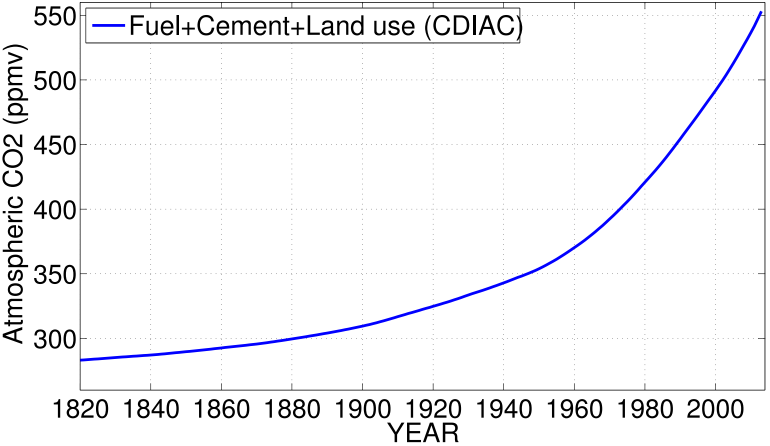
Scaled here in GtC.



Impact of Human CO2

Rescale GtC to ppmv assuming (i) all emissions remain aloft, and

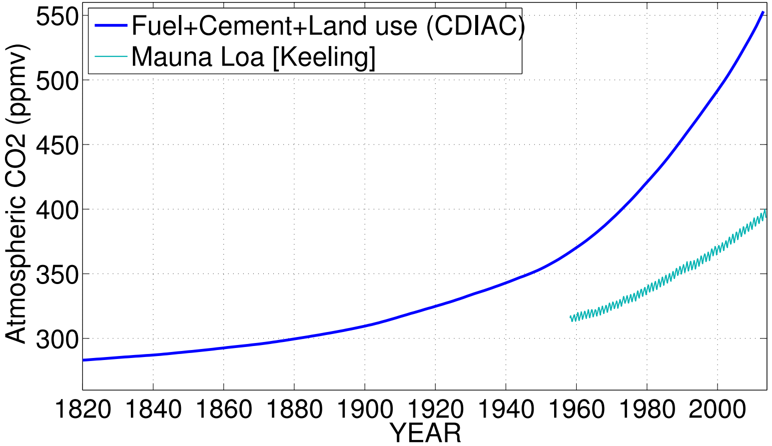
(ii) CO2 was at 283 in 1820.



Impact of Human CO2

Mauna Loa observations since 1958 [Keeling]

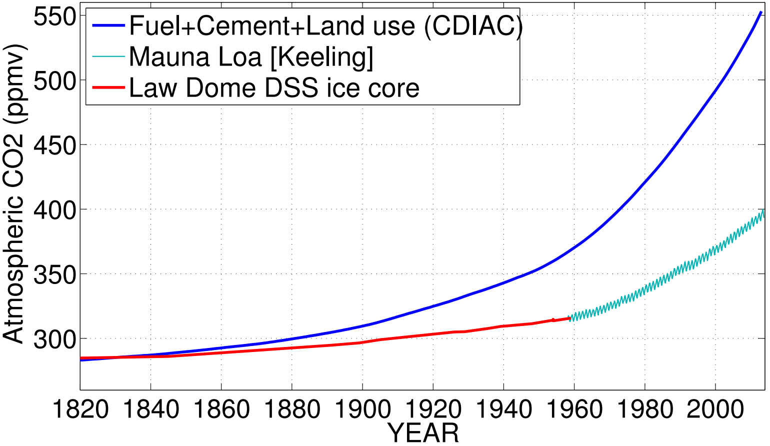
Evidently not all emissions remained aloft.



Impact of Human CO2

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

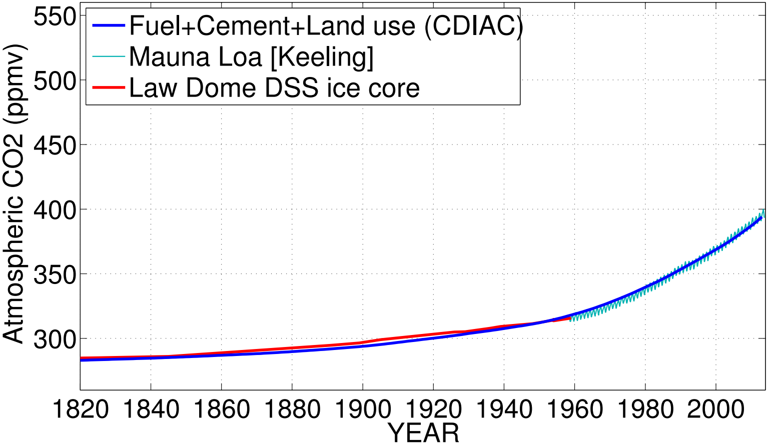
Firn ice is snow packed sufficient to trap but not expel air.



Impact of Human CO2

Assume only 41% of emissions remain aloft.

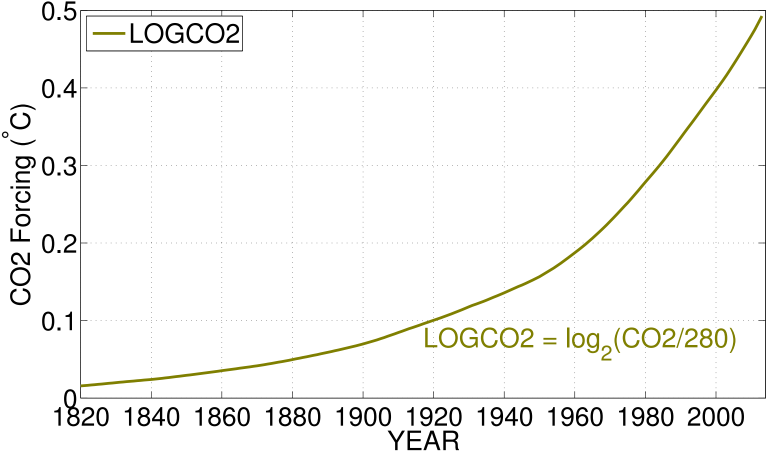
Fits very well to both Law Dome and Mauna Loa.



Impact of Human CO2

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

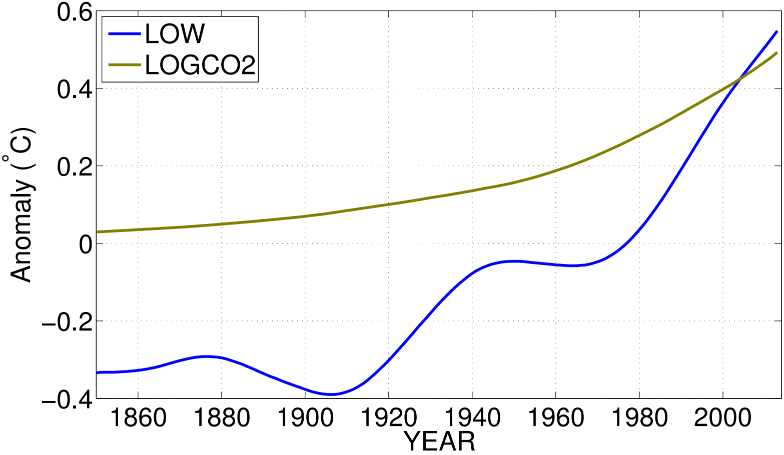
Expected global warming @ climate sensitivity 1°C/CO2 doubling.



Fitting log(CO2) to LOW

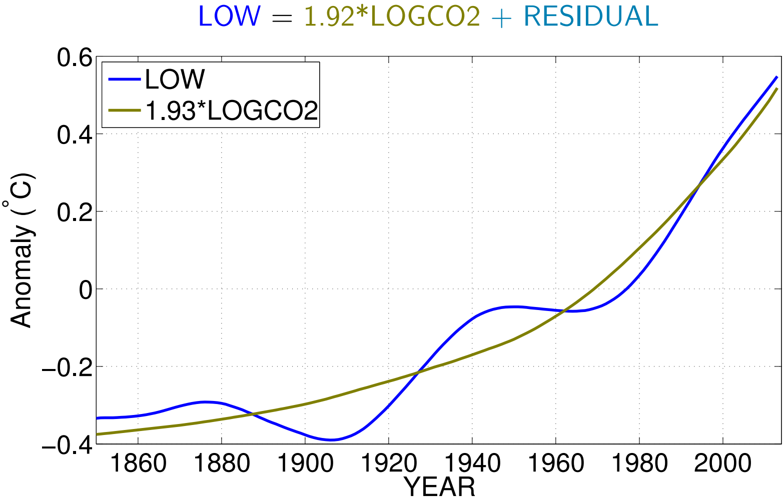
Goal: Split LOW as a sum of CO2-induced warming and a residual.

LOW vs. LOGCO2: Not yet fitted.



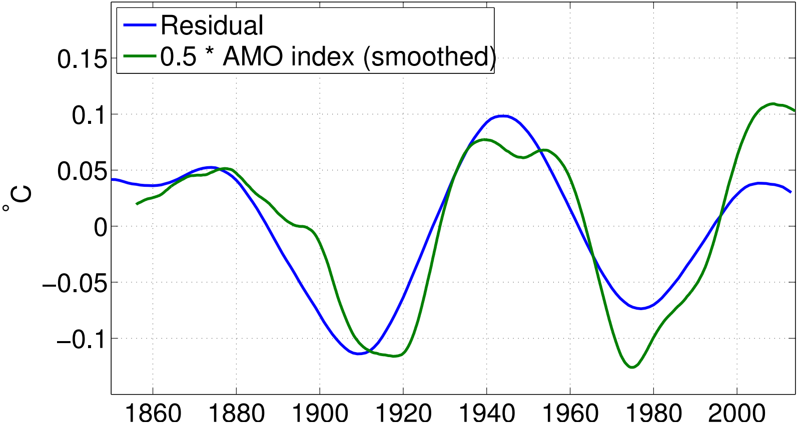
Fitting log(CO2) to LOW

Best fit at 1.92*LOGCO2.



Residual vs. AMO

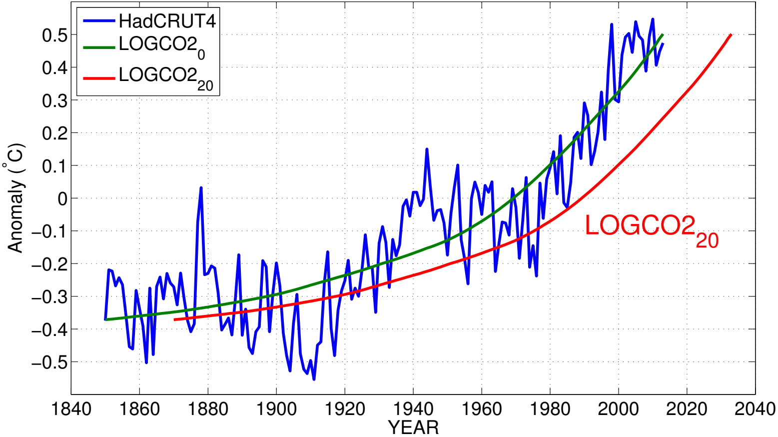
The residual is of independent interest, particularly in relation to the Atlantic Multidecadal Oscillation.



A simple model of delayed response

Definition: $\mathrm{LOGCO2}_d(y) \;=\; \mathrm{LOGCO2}(y-d)$

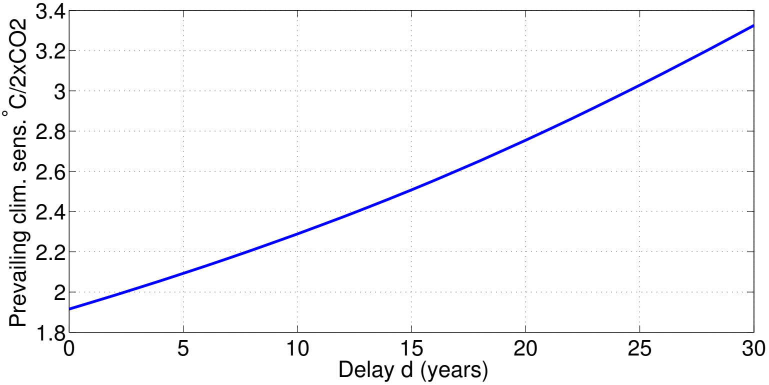
Equivalent to sliding LOGCO2 right d years.



Prevailing climate sensitivity $s(d)$

The graph plots the relation $s(d)$ obtained by fitting LOGCO2_d to LOW to determine s. $s(d) \approx 1.92 + 0.047d$.

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.



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 (seems to be the Sun)
3. ECS of 3 °C/2xCO2 under a 25-year ocean delay.

Further points.

The duration of volcanos and El Nino/La Nina puts them in HIGH. As such they have no evident significance for understanding multidecadal climate.

Other greenhouse gases and aerosols attributable to humans are confounded with CO2, putting them largely in LOW and making them a major source of uncertainty. They could lead to either over- or under-estimates of the impact of CO2.