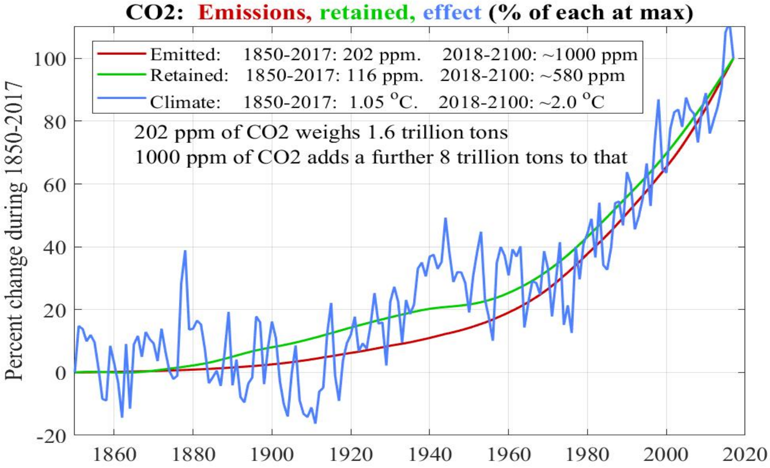
The Four Horsemen of Modern Multidecadal Climate

Vaughan Pratt
Stanford University

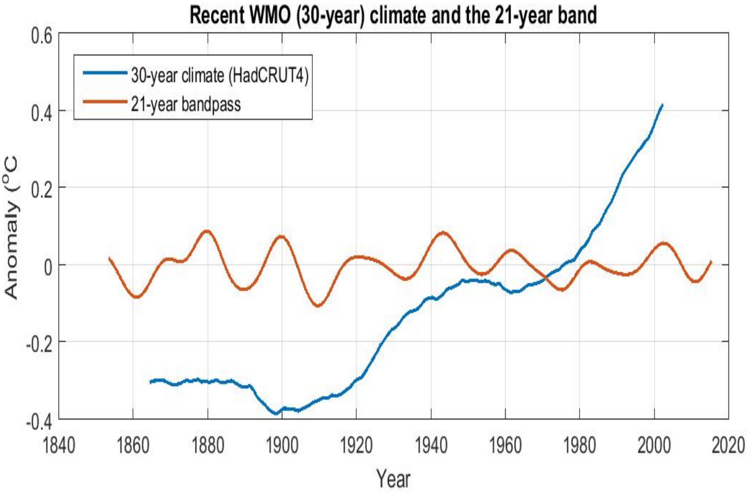
Earth and Ocean Science Center
SFSU

October 31, 2018

1. Causal Chain



2. The Two Fastest Horsemen



3. The Two Fastest Horsemen

The 21-year bandpass filter reveals a 21-year oscillation well correlated with the polarity reversals of the heliomagnetic field (HMF).

The 30-year moving average filter defines global climate according to the WMo. It reveals a 65-year fluctuation superimposed on global warming due to CO2.

This accounts for three of the four horsemen. The fourth, a slow component of total solar insolation, is not visible in this plot.

4. CLIMATE CHANGE 101 (CC1010)

Greenhouse Effect (GHE): Greenhouse gases as thermal insulation

Main GHGs: Water vapor and CO2

Climate Warmth CW: Lapse rate + water vapor. Both essentially fixed in time.

Climate Change CC: changing CO2

Richard Alley 2009: CO2 as the biggest control knob in paleoclimate

Venus: CW but with CO2 in place of water vapor. No CC.

5. THE GEOPHYSICISTS

Horace de Saussure 1780 Identified greenhouse effect but not lapse rate

Joseph Fourier 1810 Supported de Saussure

John Tyndall 1850 Heat trapping by triatomic and larger molecules

Svante Arrhenius 1896, 1906 Invented and estimated climate sensitivity

Guy Callendar 1938-1964 Rising CO2 causing rising temperature

Charles Keating 1958 Built CO2 observatory, on Mauna Loa

6. NUMERICAL WEATHER PREDICTION (NWP)

(Taken from Peter Lynch, history of NWP, J. Comp. Phys. 2007)

Cleveland Abbe 1901: mathematical basis

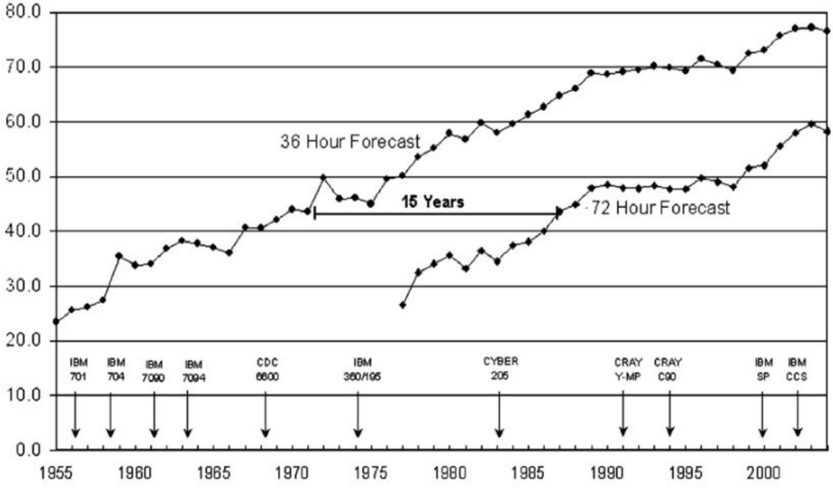
Vilhelm Bjerknes 1904: specific equations (theory)

Lewis Richardson 1922: invented NWP as an application of Bjerknes equations, proposed parallel computation: one computer per cell

John von Neumann 1946-1952: Electronic Computer Project (Princeton)

Jule Charney 1948-1956: Meteorology component of project

7. NUMERICAL WEATHER PREDICTION (NWP)



8. CLIMATE MODELS

Elaboration of NWP:

Manabe & Wetherald 1967: First atmosphere-ocean coupled model, 1974: Application of model to influence of GHE: CS, greater lapse rate and hydrological cycle

Coupled Model Intercomparison Project (CMIP), phases 1-6 ... major role in recent IPCC assessment reports

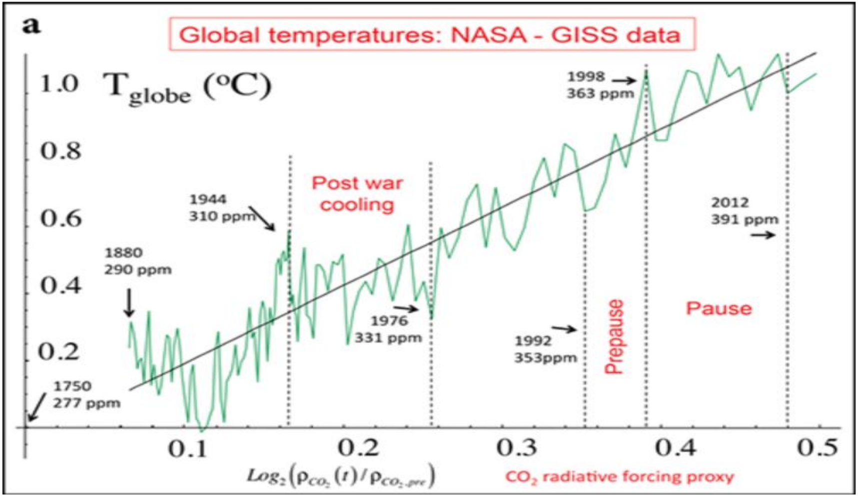
9. LONG RANGE CLIMATE PROJECTION

Alternative to elaboration of NWP

Claim: Far more accurate and easier than NWP because

1. Climate: Sparseness of centennial band: only Sun and CO2
2. CO2: Predictable via Hofmann's law of exponentially growing ACO2
3. Based on prevailing CS (PCS) instead of ECS or TCR

10. Lovejoy's really simple method, 2014



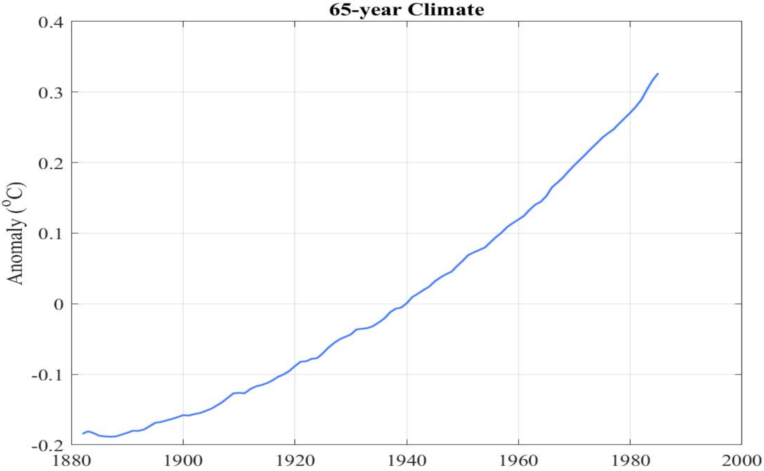
11. Lovejoy's really simple method, 2014

Slope gives climate sensitivity as 2.33 C/dbl

Compare this with the more usual approach of fitting unit radiative forcing (URF = log2(CO2)) to climate using linear regression (best fit via least squares).

12. CENTENNIAL BAND

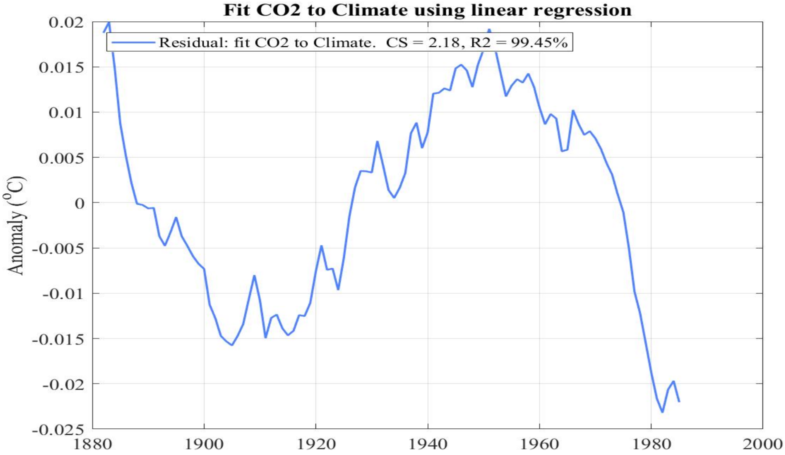
Tune into the band using a 65-year moving average filter.



Use linear regression to fit URF

13. Residual

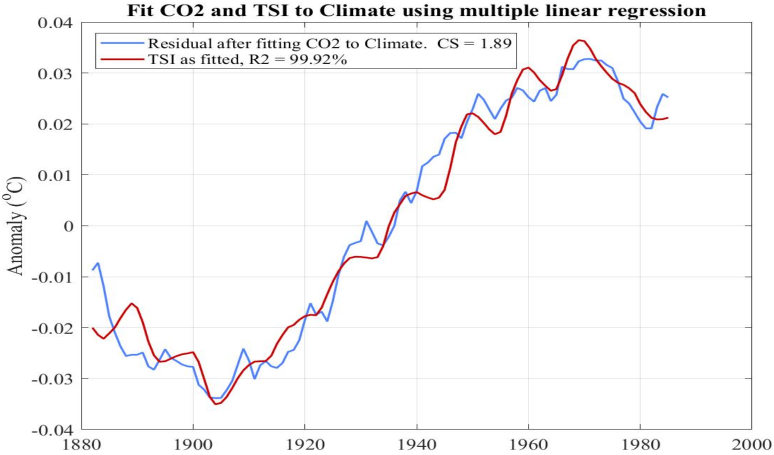
But examine residual.



It is suspiciously regular!

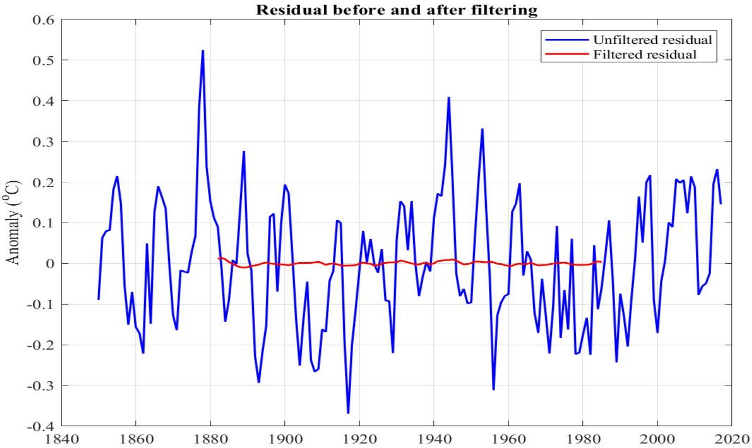
14. Residual

Compare with TSI: amazing match



Two parameters: PCS = 1.8 C/dbl, R2 way up.

15. Residual



Difficulty: Confounding of parameters Uncertainty is 1.7-1.9 C/dbl Could be fixed if we had an independent way of estimating the solar parameter.

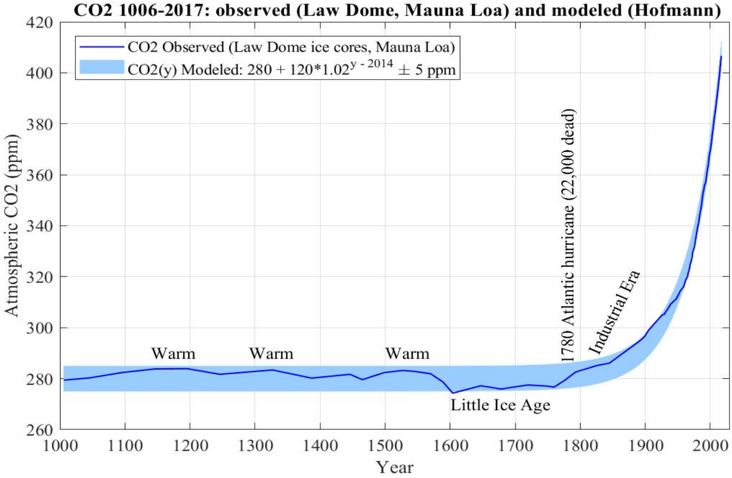
16. Reconciling Lovejoy’s 2.33 C/dbl

Lovejoy’s method of estimating climate sensitivity gives CS 2.1 C/dbl when when the curve is resampled uniformly.

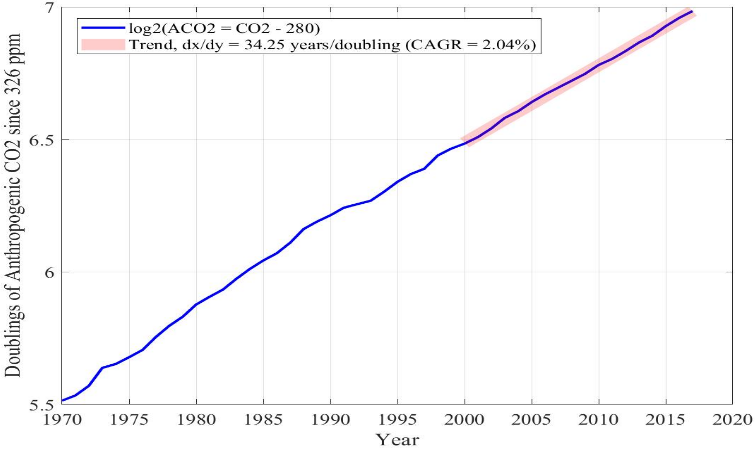
This is because taking the log concentrates the samples on the left.

Detrending climate by TSI further reduces it to 1.9 C/dbl.

17. ANALYTICITY OF CO2, big picture



18. ANALYTICITY OF CO2, close up



Doublings of Anthropogenic CO2 since 326 ppm (1970)

19. HOFMANN's FORMULA

ACO2 = CO2 - 280

Hofmann: To within 5 ppm, ACO2 is at 120 ppm in 2014 and grows exponentiallys with a compound annual growth rate (CAGR) of 2%

Extreme straightness implies high confidence in forecasting CO2.

(No evidence yet that we can bend this curve downwards.)

20. IMPLICATION FOR 2100

Based on two principles: uncertainty principle, and analyticity principle

Uncertainty principle: if we can predict 65-year climate accurately then we know that half of the 65 years will be hotter than predicted.

21. Analyticity principle

A hidden (unknown) passive (RLC) network responds analytically to an analytic input. Hence if the historical input and output were both analytic, and if the input remains analytic, so will the output, making it predictable.

Application: In this case input is CO2 and output is climate (temperature).

Benefit: Obviates the need to model the coupled ocean-atmosphere.

22. uncertainty principle

Heisenberg-like uncertainty principle: give up precision in time for precision in temperature.

Accurate projection for 65-year climate

Half the time colder, half the time hotter.

The hotter half is worse than average

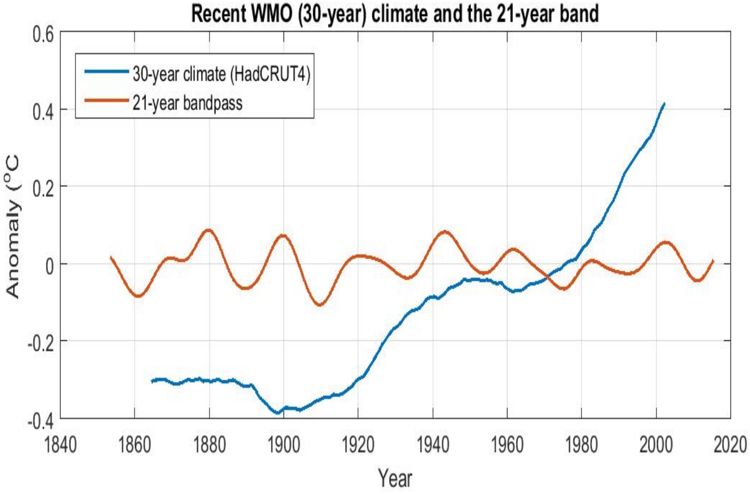
The uncertainty is that we can't predict which half is hotter.

Not quite right because of upward trend

But we can at least try.

23. THE TWO FASTEST HORSEMEN [reprise]

Plot of 65 and 21 year climate:



24. THE TWO FASTEST HORSEMEN [reprise]

Problem: can’t predict their phase precisely enough.

65-year cycle may decay, 21-year will not

Low amplitude –¿ colder and hotter parts not that far apart

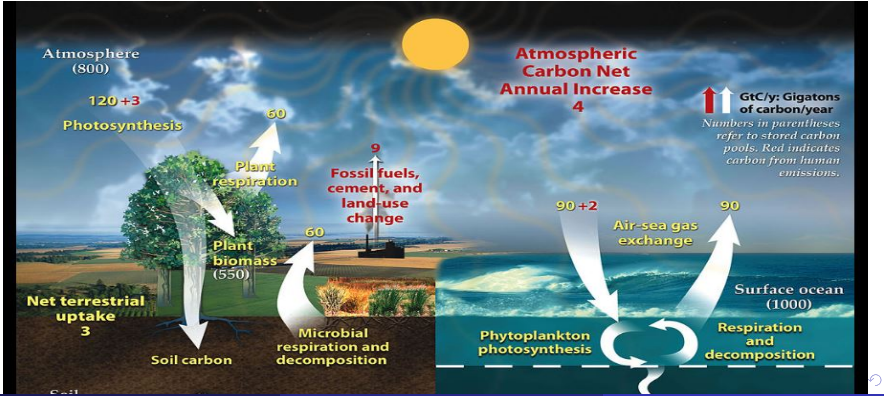
25. FAILURE OF ANALYTICITY

The two sides of CO2 mitigation

Good because it restores climate to an earlier condition

Bad because how it does so is less predictable than if not done.

The wild card: Annual plant drawdown at 280 ppm is 120 GtC, grew by 3 GtC at 400 ppm.



THANK YOU