Calibrating Climate Feedbacks by the Sun

Are we underestimating the positive feedbacks?

A41M-2848

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AGU Fall Meeting, San Francisco, CA, December 2019

Climate vs. Centennial Climate

"Climate is always changing", making it hard to analyze. For example a footnote in section D.2 of the executive summary of AR5 WG1 states, "No best estimate for equilibrium climate sensitivity can now be given because of a lack of agreement on values across assessed lines of evidence and studies."

Centennial climate however is much simpler. Figure 1 exhibits the difference by taking climate, defined as global mean surface temperature (GMST), to be global HadCRUT4 since 1850 and modeling it as 1.85*log2(CO2) + 1.95*ASI.

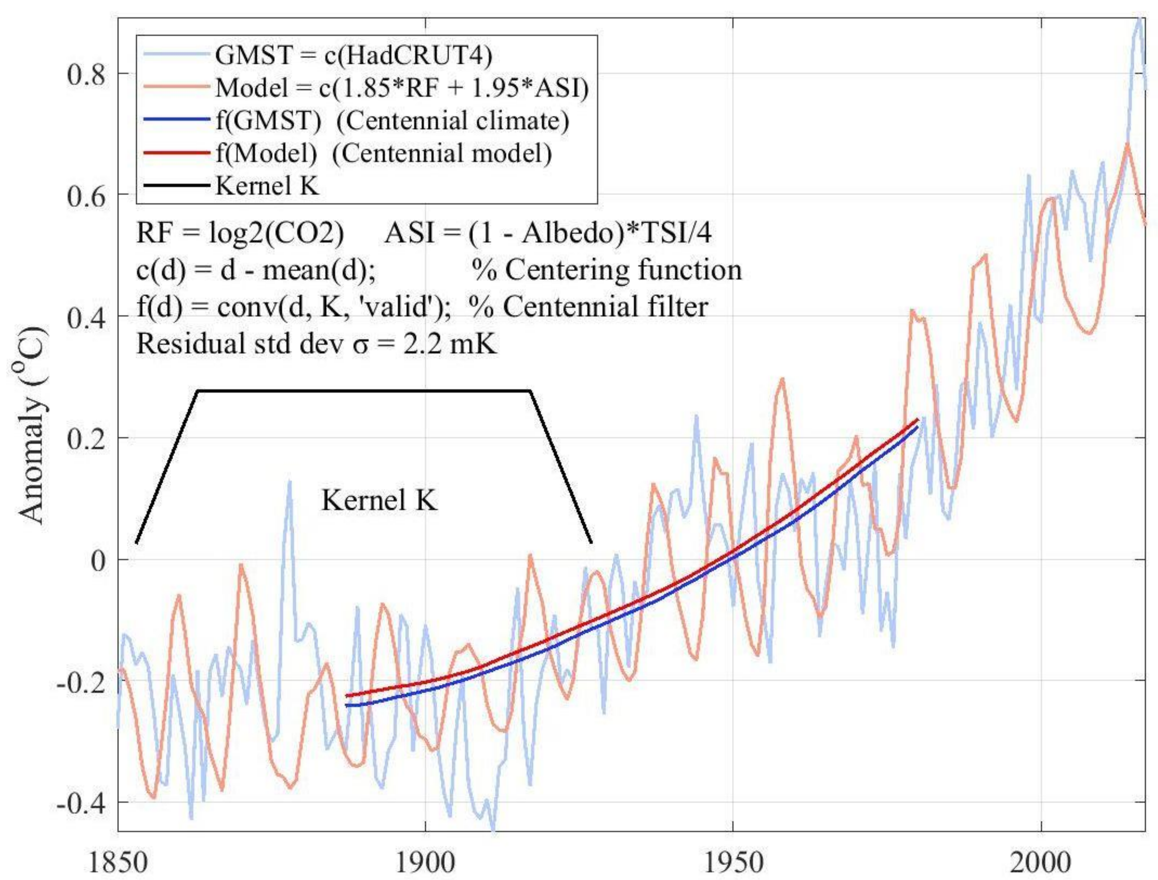

Fig. 1 Climate: observed and modeled; unfiltered & filtered

- log2(CO2) is unit radiative forcing (RF)
- 1.85 °C is transient response to a doubling of climate
- ASI = (1 - Albedo)*TSI/4 is average absorbed SI
- 1.95 is climate response to one more W/m2 of ASI
- CO2 before 1960 is from Law Dome ice cores
- CO2 after 1960 is from measurements on Mauna Loa
- TSI is a reconstruction by L. Svalgaard (col D of https://leif.org/research/Historical-TSI.xls)
- (Figures 3 and 4 repeat this for G. Kopp's TSI.)

At an annual time scale there is a lot of high-frequency chatter in both GMST and its model, thoroughly masking any relation.

But when these high frequency components are tuned out with a suitable filter, what remains of the two are in remarkably good agreement, with a standard deviation of 2.2 millikelvin for the residual (GMST – Model).

Centennial Feedbacks

Our goal at this point is to use the coefficient 1.95 of centennial ASI to estimate climate feedbacks. But if the so-called "solar constant" actually is constant at this time scale, this coefficient would be meaningless.

In fact the standard deviation of ASI is considerably greater than that of the residual in Figure 1. Figure 2 demonstrates this by moving the RF term of the model to the climate side, thereby turning GMST into detrended GMST and leaving just ASI on the model side. This is depicted in Figure 2.

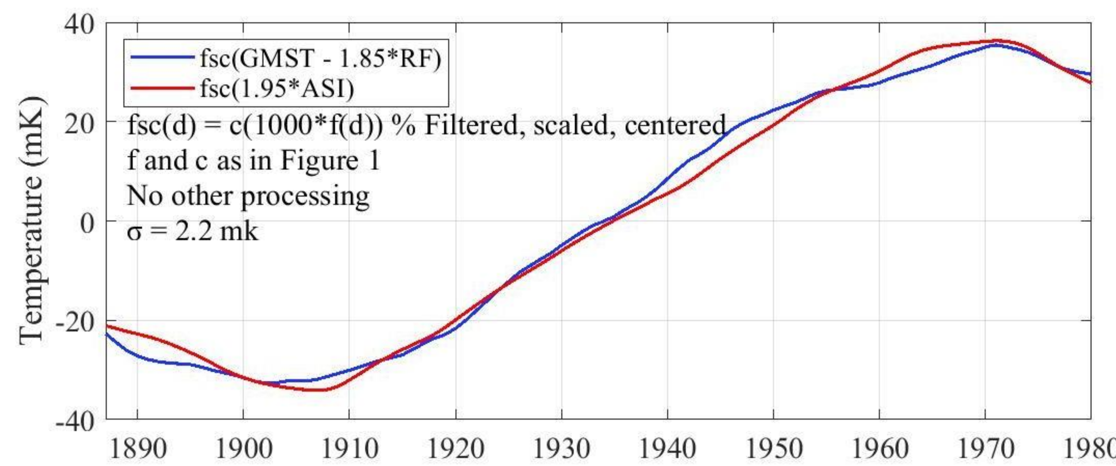

Fig. 2 Compare centennial detrended GMST with centennial ASI (Svalgaard)

Figure 2 shows that detrended centennial climate is well correlated with centennial ASI, with a remarkable R2 (= 1 – var(Resid)/var(ASI)) of 0.996, even though GMST and 1.85*RF are much larger than ASI. We are now in a position to estimate the combined effect of all centennial climate feedbacks.

The derivative of the Stefan-Boltzmann law for a blackbody is $dF/dT = 4\sigma T^3$. Its value at Earth's effective temperature of 254 K is $4\sigma*254^3$ = 3.72 W/m2. Hence in the absence of feedbacks, an increase in ASI of 1 W/m2 should raise the temperature by 1/3.72 ~ 0.27 K.

But the actual rise turned out to be 1.95 K!

Assuming only a negligible loss of insolation through the oceanic mixed layer (OML) into the deep ocean, this rise in temperature is 1.95/(1/3.72) = 1.95*3.72 ~ 7 times what it would have been without feedbacks.

We can infer a no-feedback climate sensitivity of 1.85/7 = 0.26 K per doubling of CO2. This seems remarkably low.

The corresponding gain would therefore be 1 - 1/7 = 6/7.

If say 10% of ASI passed into the deep ocean, an increase in ASI of 1 W/m2 should raise the temperature by 0.9/3.72 ~ 0.24 K. The 1.95 K rise would therefore be 1.95/0.24 ~ 8, with a corresponding gain of 1 - 1/8 = 7/8. So 6/7 is a lower bound on the feedback gain.

Kopp's TSI Reconstruction

Another reconstruction of TSI, due to G. Kopp, can be found at https://spot.colorado.edu/~koppg/TSI/Historical_TSI_Reconstruction.txt Replacing Svalgaard's reconstruction by Kopp's in Figure 2 yields Figure 3.

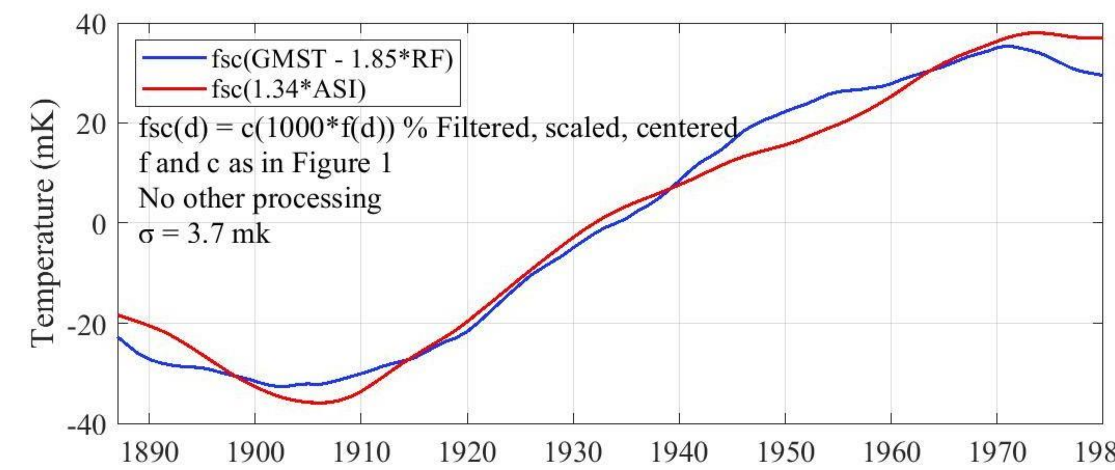

Fig. 3 Compare centennial detrended GMST with centennial ASI (Kopp)

As with Figure 2, the coefficients of RF and ASI have been chosen for best fit to detrended GMST, that is, to minimize the standard deviation σ of the residual. (The absolute best fit is with 1.84 and 1.86 as the respective coefficients of RF but using 1.85 for both does not compromise either value of σ for best fit.) This replaces 1.95 with 1.34. This is only 1.34*3.72 ~ 5 times too high, corresponding to a gain of 4/5.

The corresponding no-feedback climate sensitivity to CO2 would then be 1.85/5 ~ 0.37 K per doubling. This still seems quite low.

So, on the one hand Svalgaard's fit to detrended climate has a residual with roughly half the standard deviation of Kopp's fit. It is hard to get such a good fit by chance.

On the other hand Svalgaard's fit entails a feedback whose amplification is some 1.4 times that of Kopp's.

I feel that there is something worth investigating here, if only to understand where my reasoning is unsound.

This much lower value for the best coefficient of ASI is a consequence of Kopp's TSI climbing rather faster than Svalgaard's during the 20^{th} century, as shown by Figure 4.

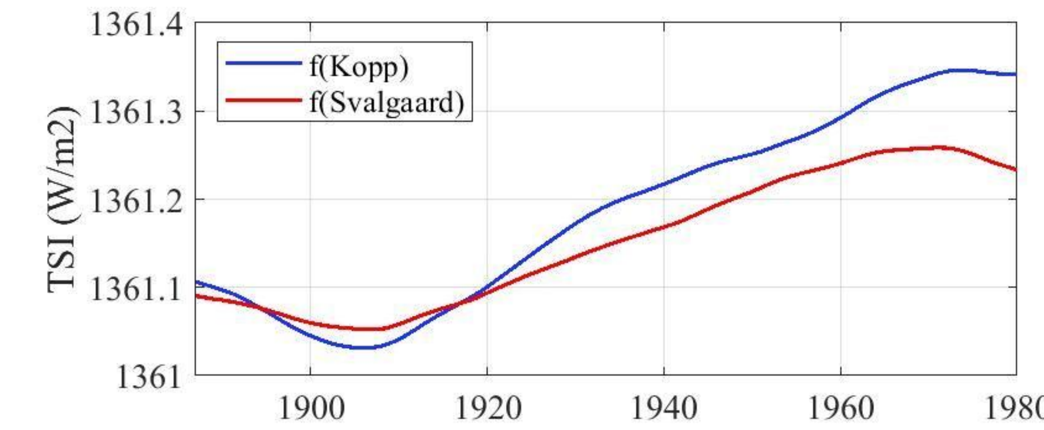

Fig. 4 Centennial TSI: Kopp vs. Svalgaard

Code

The MATLAB code producing Figures 1 and 2 can be downloaded from http://clim8.stanford.edu/MATLAB/AGUFM2019/

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