13 May 2014

Dear Prof. Ghan,

Following your suggestion, Figure 1 and Figure 2 below show emulations of the published GISS October 2011 and UKMet/CRU February 2011, respectively, centennial land plus SST surface air temperature records.

The emulations were made using the generalized form of manuscript equation 6 and the method described in the revised Auxiliary Material document.

For your convenience, generalized eqn. 6 is reproduced here:

$$\Delta T = f_{CO_2} \times 33C \times [(F_0 + \sum_{i=1}^{n} F_i) \big/ F_0] + a \qquad\qquad 1$$

f_{CO_2} is the fractional greenhouse forcing of GHG in CO_2 equivalents, 33 C is the unperturbed greenhouse temperature, F_0 is the base-year GHG forcing (Wm^{-2}), F_i is the annual change in forcing (Wm^{-2}), and a is an offset (Celsius) that accounts for use in the denominator of the total base-year greenhouse gas forcing.
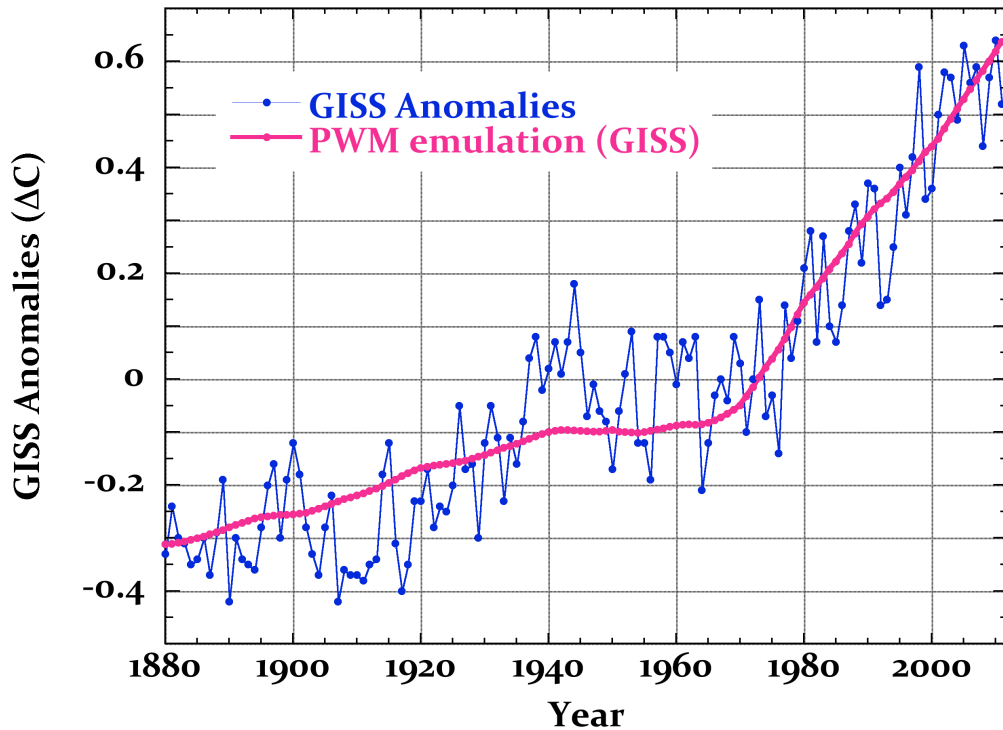

Figure 1: (-•-), GISS land+SST global average air temperature anomalies, 2012 data set, and; (—), PWM emulation. PWM coefficients were: $f_{CO2} = 0.513$, $F_0 = 33.00$ Wm^{-2}, $a = 17.27$ C.
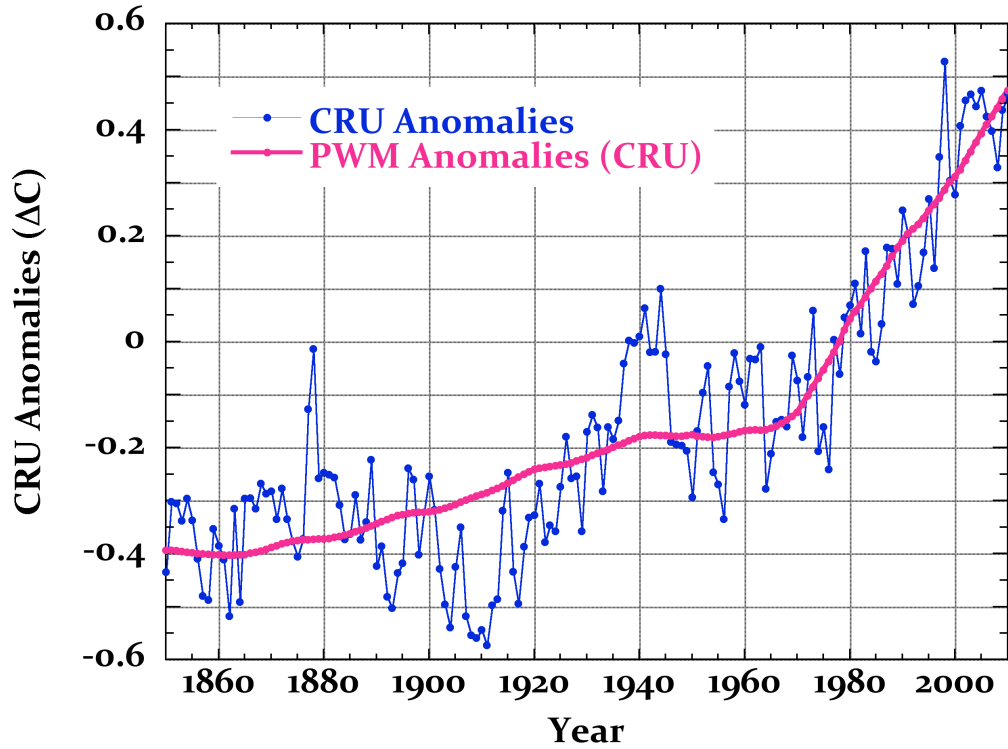
Figure 2: (-•-), UKMet/CRU land+SST global average air temperature anomalies, 2010 data set, and; (—), PWM emulation. PWM coefficients were: f_{CO_2} = 0.466, F_0 = 32.95 Wm^{-2}, a = 15.78 C.

For these emulations, the forcing changes, F_i, were the combined annual "CO_2" plus "GHG Other" plus "Aerosol (Total)" forcings of AR5 WG1 Annex II Table AlI.1.2, over the full historical period.

The variation of f_{CO_2} between the GISS and UKMet/CRU emulations no more invalidates the PWM than do the adjustments of climate sensitivity and aerosol forcing, made to attain their hindcasts, invalidate CMIP3 or CMIP5 climate models.

Figure 3 below is Figure TS 9 (a) of the AR5 WG1 Technical Summary, showing CMIP3 and CMIP5 simulations of the centennial global average annual surface air temperature anomaly record, compared to GISS, UKMet/CRU and MLOST data sets. For Figure TS 9(a) these records were re-normalized over 1880-1919.

Inspection shows the PWM does well emulating the observational records, and is faithful to the averages of the CMIP3 and CMIP5 simulations.

This results meets your requirement that the PWM should pass one of the, "*most important tests of climate models [which] is their ability to predictively simulate the warming since 1850.*"
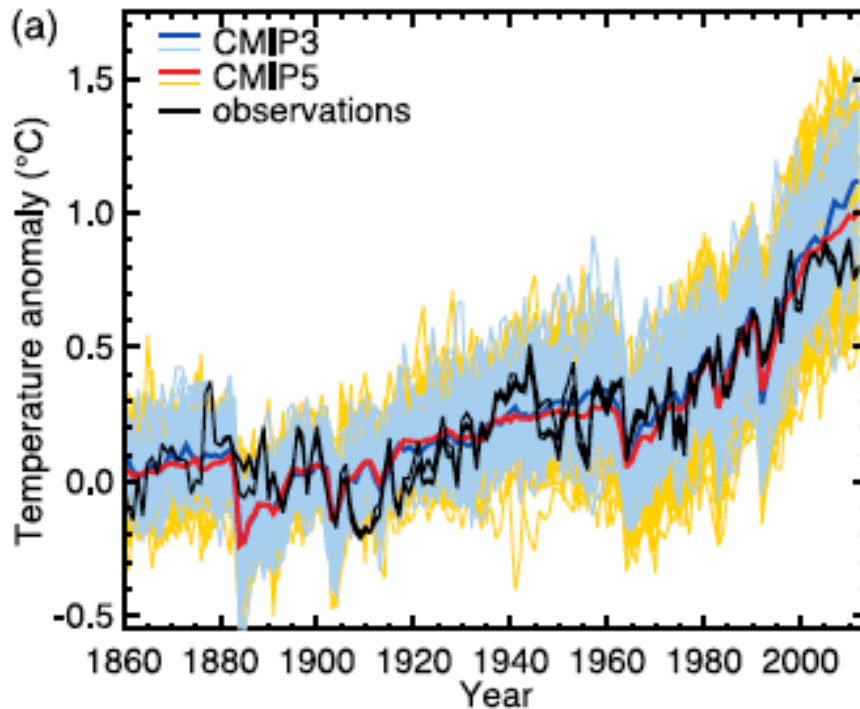

Figure 3: Figure TS 9(a) of the AR5 WG1 Technical Summary. Original Legend (partial): "*Three observational estimates of global mean surface temperature (black lines) from the Hadley Centre/Climatic Research Unit gridded surface temperature data set 4 (HadCRUT4), Goddard Institute for Space Studies Surface Temperature Analysis (GISTEMP), and Merged Land–Ocean Surface Temperature Analysis (MLOST), compared to model simulations (CMIP3 models – thin blue lines and CMIP5 models – thin yellow lines) with anthropogenic and natural forcings (a), ... Thick red and blue lines are averages across all available CMIP5 and CMIP3 simulations respectively.*"

These results will be migrated into the Auxiliary Material.

However, these exercises are not meant to imply the PWM is a climate model. It is not. The PWM is a linear equation. The PWM linearly extrapolates GHG forcing. The output of the PWM very faithfully emulates the temperature projections of advanced climate models. The conclusion is obvious.

The success of the PWM with the air temperature record shows that CMIP3 and CMIP5 models hindcast past surface air temperatures by linear extrapolation of total forcing.

The congruence of PWM and CMIP3/5 air temperature projections in the manuscript and in the Auxiliary Material Figures shows just as clearly that advanced climate models project future air temperatures by linear extrapolation of GHG forcing.

Prof. Ghan, you wrote that, *"Models that cannot reproduce the observed record of climate change are not considered credible for projections of future climate change. If a model has incorrect physics it would fail this test. I therefore will not consider another manuscript from you on this subject."*

The PWM has now fully passed your tests.

However, I do not claim at all that the PWM has the correct physics to simulate climate. The claim only is that the PWM has the correct functional and physical form to closely emulate the air temperature projections of advanced climate models. It has demonstrated that capacity with flying colors.

It is now established, beyond doubt, that advanced climate models project future global average surface air temperature by linear extrapolation of GHG forcing.

It follows directly that linear propagation of climate model error yields the uncertainty in climate model air temperature projections.

As the PWM successfully reproduces CMIP3 and CMIP5 air temperature projections, it is a valid propagator of model error.

The manuscript analysis still stands on its merits, and all reviewer concerns have now been resolved.

Thank-you very much for your consideration,

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