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PCIC SCIENCE BRIEF: CLIMATE MODEL SIMULATIONS OF THE OBSERVED EARLY-2000S HIATUS OF GLOBAL WARMING

In a recent paper in the journal *Nature Climate Change*, Meehl, Teng and Arblaster (2014) examine individual global climate model runs from models participating in the fifth phase of the Coupled Model Intercomparison Project (CMIP5) to see if any runs replicated the observed early-2000s hiatus in surface temperature warming. They found that those individual model runs that have Interdecadal Pacific Oscillation (IPO) values that matched with observed values successfully simulate the early 2000s hiatus. Using data available in the mid-1990s, they also apply a recently-developed climate prediction technique that uses modern global climate models (GCM), initialized with observations, to make so-called “decadal climate predictions” and find that both the negative phase of the IPO and the surface temperature hiatus could be predicted with this method, using only data that was available prior to the hiatus.

Over the longer timescales typically associated with climate projections—generally 30 years and longer—variations in climate drivers, such as volcanic aerosol emissions, the amount of solar radiation that the Earth receives from the sun and internal variability tend to “average out,” to some degree. The same is true of the internal variability of individual climate model runs, because ensembles of these runs are averaged together to form projections. However, this is not the case for shorter periods and there has been much interest as of late, both in the observed difference in surface temperature trends between GCM projections and observations over the last 15-to-20 years, and in decadal-scale climate information more generally.

The decadal scale sits between the relatively short seasonal-to-interannual timescale where rapid adaptation to extreme weather and climate change impacts is often necessary, and the longer-terms associated with large-scale infrastructure projects and government planning. The comparatively short decadal timescale has also received less attention from the climate science community, though the recently established difference between decadal temperature trends in climate models and observations has brought it into the spotlight, as has the development of decadal climate prediction methods.

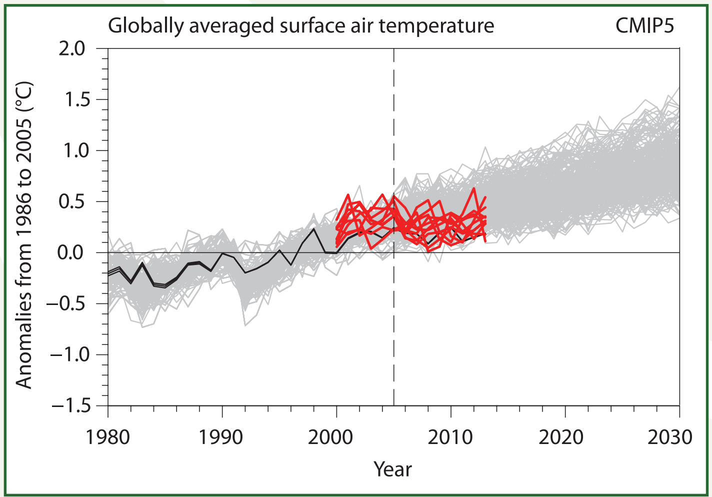

Figure 1: Global surface temperature anomalies. Global average surface temperature anomalies relative to the 1986-2005 average, from observations (HadCRUT4, black), 262 simulations from CMIP5 (grey) and those simulations in CMIP5 that simulate an early-2000s hiatus (red), from Meehl et al. (2014).

The first article to rigorously quantify the discrepancy in global surface temperature trends between models and observations, is by Fyfe, Gillett and Zwiers (2013), published in *Nature Climate Change*. They find that, while observations and modelled rates of warming over the 1900-2012 period are very similar, over both the 1998-2012 and 1993-2012 periods the observed rate of warming is significantly less than the trend found in climate model simulations. Fyfe and colleagues also consider the effects of El Niño, stratospheric aerosols and a potential link to the North Atlantic, and find that none of these individually can explain all of the discrepancy.

This so-called “hiatus” in surface warming has been the focus of much subsequent research, with Kosaka and Xie (2013) examining in detail the role that the tropical Pacific Ocean (where El Niño occurs) might have played and finding that, once cooling in that region is accounted for, observations and simulations can be made to match. A recent paper by Chen and Tung (2014) suggests that heat transport into the deep Atlantic might also have played a role. In addition to ocean influences, future solar output and atmospheric aerosol concentrations cannot, as yet, be predicted in detail ahead of time, so the values for both of these that have been used to drive climate model projections for the future generally differ from the observed amounts of solar output and aerosols, to an extent that appears to be significant over decadal timescales. Recent work by Schmidt et al. (2014) examines if, in addition to El Niño's influence, these differences might have contributed to the hiatus. They find that, once the combined influence of aerosols, El Niño and solar output are properly adjusted for, the model output can be almost completely reconciled with observations.

The hiatus and the difference between models and observations over decadal timescales raises several questions that have been pursued by Meehl and colleagues. First, do any climate model simulations replicate the observed hiatus? Second, if any runs do replicate the hiatus, do they exhibit the changes to sea surface temperatures that earlier research has suggested as a factor for the hiatus? Third and finally, could current decadal climate prediction methods predict such a hiatus, using only data that was available prior to its occurrence?

The authors first examine all of the simulations from the models that participated in CMIP5. They find that, among all of these runs, 21 simulations include a hiatus from 2000-2012 and that ten members show a surface warming trend of less than 0.04 °C per decade (Figure 1). Further, and of particular interest, these simulations show a negative phase of the Interdecadal Pacific Oscillation (IPO), a naturally-occurring pattern of climate variability in Pacific Ocean surface temperatures and pressures that cycles through positive and negative phases with a period ranging from about 15 to 30 years.

The question remaining is, could current decadal climate prediction methods predict such a hiatus? To see if this would be possible, Meehl and colleagues use a set of 16 models from those participating in CMIP5 that have their internal climates initially set to match observations over various time periods and are then allowed to run freely. They are then used to make "predictions" of how the future "climate" (here meaning the five-year average over three-to-seven years in the future) will vary from the previous 15 years. These are compared against the assumption that the climate averaged three-to-seven years in the future will be the same as the average of the previous five years (i.e. assuming that prior conditions would simply persist).

Meehl et al. first test the ability of the models to beat the persistence condition for surface air temperatures, as checked against observations. Using starting years from 1960 to 1987 they find that the models beat persistence 64% of the time, in that they are often much closer to the observed temperatures (Figure 2) and show statistically significant skill for 25 out of 28 of the prediction periods. The initialized models also successfully simulate transitions in the IPO. To check that the models are simulating ocean temperatures for the right physical reasons, the authors verify that the models produce the correct trade winds and transfer of heat between the ocean and atmosphere.

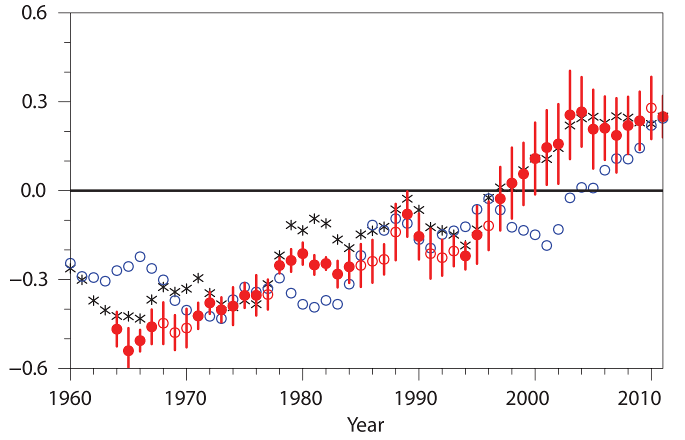

Figure 2: Global surface temperature anomalies. Surface air temperature anomalies relative to the 1986-2005 from Meehl et al. (2014). Stars represent observations, blue circles represent persistence "predictions" and red circles represent initialized model "predictions" (these are filled if they beat persistence) and red bar "whiskers" represent an one standard deviation of predictions (i.e. ~67% of predictions fall within the bar).

With this done, Meehl and colleagues see how well the models fare in making predictions for the 1990s, the early 2000s and up to the present day. They find that the models that are initialized to observations outperform either the persistence assumption or uninitialized models, and that they also simulate the North Atlantic warming observed in the late 1990s. Crucially, using only information available in the mid-1990s, the initialized models do predict the transition in the IPO and the reduced warming seen in the early 2000s.

The findings of Meehl et al. are consistent with earlier research by Schmidt et al. and Xie and Kosaka, and further suggest that Pacific Ocean temperatures played an important role in the hiatus. These findings also implicitly account for the Fyfe et al. concern regarding forcings such as stratospheric aerosols because Meehl et al. used models initialized with observations, and this provides the models with information about the climate system's response to those forcings, up until the time of initialization.

The authors also note that limitations remain for the decadal prediction methods that they use. For example, the models show a reduced skill for the six initial years

(1986-1991) of the third part of their experiment that examines model predictions from the 1990s to the present day. Meehl et al. speculate that the lack of skill that the models exhibit over this period may be due to processes occurring as a result of Mt. Pinatubo's eruption that the models have difficulty simulating.

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Fyfe, J.C., N.P. Gillett and F.W. Zwiers, 2013: Overestimated global warming over the past 20 years. *Nature Climate Change* **3**, 767–769, doi:10.1038/nclimate1972.

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