PACIFIC CLIMATE IMPACTS CONSORTIUM

PCIC SCIENCE BRIEF: POSSIBLE ARTIFACTS OF DATA BIASES IN THE RECENT GLOBAL SURFACE WARMING HIATUS

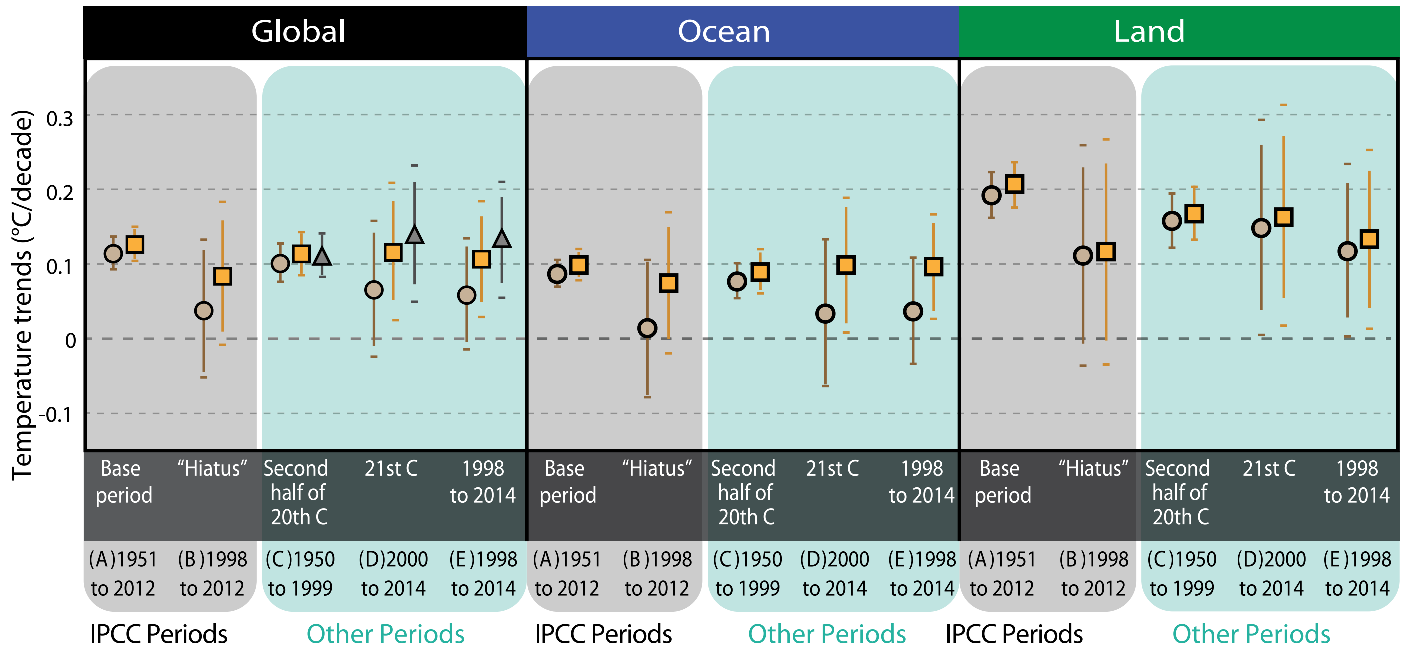

Figure 1: Global surface temperature trends, from Karl et al. (2015).
Plots of global, ocean-only (sea surface) and land-only temperature trends. Squares indicate Karl et al.'s new analysis, circles represent the trend in the older NOAA data set, and triangles indicate Karl et al.'s new analysis with additional polar representation constructed by interpolation (not used in their primary analysis). Time periods, A, B, C, D and E are as marked. Error bars indicate 90% confidence intervals and the additional error range from Karl et al.'s new analysis is shown as horizontal lines that are meant to extend the 90% confidence intervals.

In a recent paper published in *Science*, Karl et al. (2015) revise the National Oceanic and Atmospheric Administration's (NOAA) surface temperature data set and examine temperature trends in the updated data. The authors use a sea surface temperature data set that has been corrected for biases in sea surface data that arise due to the difference in measurements from ships and buoys, and the authors incorporate a much larger amount of data from land-based observations.

They find that the global warming trend in the updated data set over the 1998-2012 period is just over double of that in the old data set, about 0.086 °C per decade, compared to 0.039 °C per decade. This is largely due to the corrections in sea surface temperature measurements. The updated data shows a statistically significant global warming trend over the 1998-2012 period and the authors note that their results "do not support the notion of a 'slowdown' in the increase of global surface temperature."

Global surface temperature trends over the 1998-2012 period have received much attention as of late, in both the peer-reviewed literature and the media. Global temperature trends are of broad interest because, though the effects of climate change are felt at the regional scale, the changes that regional climates will undergo are often tied to changes in global climate. Here, the focus of our discussion will be limited to the peer-reviewed literature.

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For an overview of how these surface temperature trends have been discussed in the media and what role this may have on public perceptions of climate change, see Boykoff (2014).

In order to understand the discussion in the peer-reviewed literature, we should first note that climate science research has generally been concerned with changes to climate on timescales of 30 years or longer (sometimes much longer). Over timescales of 30 years or longer, variations in climate drivers, such as volcanic eruptions, solar cycles and internal variability (e.g. ocean circulation patterns) tend to "average out," making it easier to distinguish climate trend "signals" from the "noise" of short-term variability. The recent shift of focus to the shorter 1998-2012 period has been driven largely by the desire to explain the apparent differences between climate model projections and observations over this period, over which the models tend to predict more warming than observational records show. This recent increase in interest also coincides with the ongoing development of nascent "decadal climate projections," that seek to use cutting-edge global climate models (GCMs) that have their initial states set to match observations and are then run in an attempt to make forecasts of "climate" on the timescale of a decade.

The discrepancy between observations and model projections over the 1998-2012 period that has been dubbed, "the hiatus" was quantified in the peer reviewed literature by Fyfe, Gillet and Zwiers (2013), in an article that appears in *Nature Climate Change*. They find that the observed rate of warming over both the 1998-2012 and 1993-2012 periods is significantly less than climate model projections. The hiatus is also a subject of discussion in the ninth chapter of the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (Flato, et al., 2013).

Subsequent work has focused largely on the role of the Pacific Ocean in the hiatus. Kosaka and Xie (2013) use a climate model that is forced with prescribed sea surface temperatures over parts of the Pacific Ocean find that, when cooling in the tropical Pacific is accounted for, observations and simulations can be made to match. Trenberth and Fasullo (2013) find that a large amount of the heat from the continued warming of the Earth has been drawn down into the deep Pacific. Meehl, Teng and Arblaster (2014) examine a large number of simulations and find that climate model runs that simulate the observed Interdecadal Pacific Oscillation also simulate the hiatus. Schmidt et al. find that if the effects of El Niño and fluctuations in solar radiation and atmospheric aerosol concentrations are accounted for, model output and observations can be almost completely reconciled. In addition, Chen and Tung (2014) find that heat transport into the deep Atlantic and Southern Oceans may also have played a role.

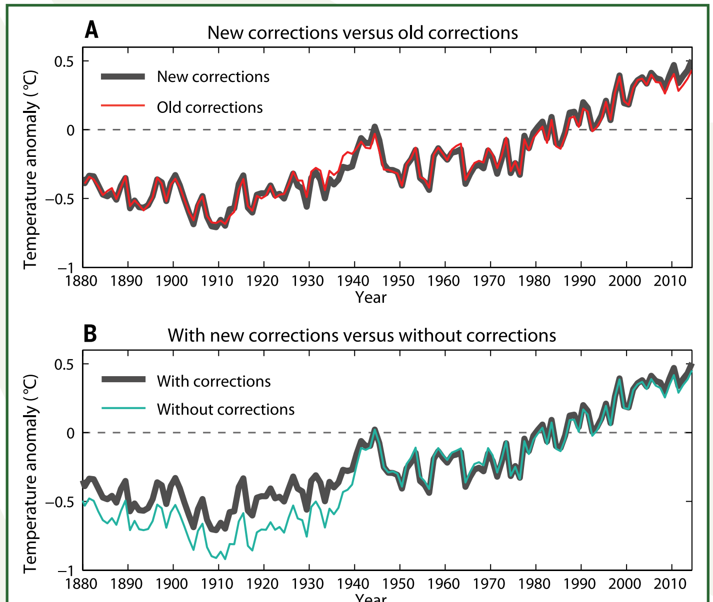

Figure 1: Global surface temperature anomaliess, from Karl et al. (2015).
Plots of global surface temperature anomalies. Panel A shows the new analysis in black compared to the old analysis in red. Panel B shows the new analysis in black versus the temperature data with no corrections for time-dependent biases applied, in blue.

The latest chapter in the ongoing discussion of the hiatus comes by way of a group of researchers who have recently examined global surface temperature trends using the International Surface Temperature Initiative's (ISTI[1]) databank[2] and the latest version of NOAA's Extended Reconstructed Sea Surface Temperature (ERSST[3]) dataset. Publishing in *Science*, Karl et al. report the effect that using this larger land-based surface temperature data set and sea surface temperature data that have been corrected for biases has on observed global temperature trends. The authors find a slight increase to the overall warming trend since 1880, increased warming post-1950 and decreased warming prior to 1950. They also find that the warming trend over the 1998-2012 period in the new data set is 0.086 °C per decade, just over double the value of 0.039 °C per decade found in the previous version of the NOAA

1. For more information on the ISTI, see their website: http://www.surfacetemperatures.org/.
2. For more on the methods used in the construction of the ISTI databank, see Rennie et al., 2014.
3. For information on NOAA's ERSST record, see Karl et al., 2015, Smith et al., 2008 and the references therein, and NOAA's ERSST website: https://www.ncdc.noaa.gov/data-access/marineocean-data/extended-reconstructed-sea-surface-temperature-ersst-v3b.

data set (Figure 1). The new trend is statistically significant at the 0.10 significance level. Using data current to the last year, the trend over 1998-2014 is 0.106 ± 0.058 °C per decade. The choice of start date, 1998 is an El Niño year, in which warm surface waters in the tropical Pacific Ocean increase surface air temperatures. If the year 2000, during which cooler La Niña conditions prevailed over the surface of the tropical Pacific, is chosen as the starting year, the 2000-2014 warming trend is larger, 0.116 ± 0.067 °C per decade. For comparison, the overall 1950-1999 warming trend is 0.113 ± 0.027 °C per decade and the 1951-2012 trend is 0.129 ± 0.020 °C per decade. So, the authors find that, in the new data set the warming trend over the last 15 years or so is roughly similar to the warming trend since the middle of last century, but the overall warming rate since 1880 is lower than in the old data set. As can be seen in Panel A of Figure 2, these adjustments are relatively small.

For their analysis, Karl et al. use a broader set of land surface observations from the ISTI, which subsumes the Global Historical Climate Network[4] (GHCN) that was used in the earlier NOAA data sets, but also includes data from many other stations, including some from regions that were previously data sparse, such as the Arctic. The end effect is that the station data considered for the authors' analysis is more than twice as large. The authors also apply bias corrections and quality control to these data, which correct for things such as changes of station location and equipment, and urban development.

For their ocean data, the authors use an updated version of ERSST that includes data from the new International Comprehensive Ocean-Atmosphere Data Set[5] release 2.5 (ICOADS 2.5), which has more observations than the previous version. The new ERSST also has revised teleconnection[6] data, updated quality control procedures and updated anomaly[7] calculation methods. In addition to these, the sea surface temperature data has been corrected to remove a bias that arises from the recent increase in data from drifting buoys. These buoys display a cold bias relative to shipboard measurements. The buoys have increased in number, and Karl et al. find that the effect of their bias is evident in the ERSST data, accounting for 0.014 °C per decade of the 0.064 °C per decade difference in trends between the old and new data sets for the 2000-2014 period. The new ERSST data has also been adjusted to correct for a cold bias from bucket data taken on ships, which the authors single out for having the greatest single impact on the 2000-2014 temperature trends in the ERSST data. This effect arises from water cooling in buckets in the time between being drawn from the sea and being measured. Though corrections for this bias have been made in earlier versions of ERSST, it was assumed that ship corrections were unnecessary for data collected after World War II. The authors observed that this was problematic, as at least some ships have been taking bucket measurements up to the present, introducing a bias into the data set. Karl et al. correct for this by extending the correction as appropriate. They find that the extension of the correction for this ship bias accounts for nearly half (0.030 °C per decade) of the trend difference over the 2000-2014 period. From these updated data sources the authors compile their new temperature record from which their surface temperature trends are drawn.

Because these constitute a large number of changes from the previous temperature record, the authors analyze the contribution of each to determine the primary causes of the differences in trends between the new and old trends. They report that the main contribution to this difference comes from the updated sea surface temperature data in which the new trend is 0.075 °C per decade over the 1998-2012 period, compared to the trend of 0.014 °C per decade in the old data. The change in land surface temperature trends is smaller, with the new trend being 0.117 °C per decade and the old one being 0.112 °C per decade.

Because the climates of the regions comprising British Columbia and Yukon are affected by changes in large scale climate patterns and global climate, these global trends are ultimately important for stakeholders in the regions PCIC serves. The recent changes to NOAA's data address a number of known problems, but, as with any new set of adjustments, these adjustments will be analyzed by the broader scientific community to determine their strengths and limitations. Even with the new corrections, these global surface temperature observations remain in the lower range of projections from the global climate models participating in the fifth phase of the Coupled Model Intercomparison Project[8] (CMIP5). Current research, part of which has been discussed here, suggests that this has

4. For more information on GHCN, see Menne et al., 2012 and the references therein.
5. For more information on ICOADS data set, see Woodruff et al., 2011 and the ICOADS website: http://icoads.noaa.gov/.
6. A teleconnection is a link between meteorological conditions occurring in regions of the world that are separated from each other by large distances.
7. The use of 'anomaly' here refers to changes in climate relative to a baseline average value. For example, to say that the last 30 years have been warmer than the 20th Century average would be to speak of the temperature anomaly of the last 30 years, relative to the 20th century as a baseline.
8. For more information on CMIP5, see Taylor et al., 2012.

been due to a combination of internal variability, largely in the Pacific Ocean, atmospheric aerosols and solar activity, but that the Earth system has been and will continue to warm, largely as a result of anthropogenic greenhouse gas emissions.

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