The 1.5°C temperature limit in the Paris Agreement and 2016 temperature records

Summary

- Long-term temperature limits are always understood as **annual averages of at least 20 years** to account for natural variability. The 1.5°C limit in the Paris Agreement refers to a global average annual increase in the temperature above pre-industrial average over twenty years.
- Natural variability can lead to **individual years (or months) well above the long term average and, superimposed on the long term warming trend, already has and will continue to lead to warming of individual years or months exceeding 1.5°C.**
- **The extreme 2016 temperature records are, unfortunately, in line with our scientific understanding** of long term warming trends and natural variability that can be expected with the most recent twenty-year average global average of about 0.85°C to date.
- Observed 2016 temperatures thus **do not call into question the feasibility of the 1.5°C warming limit.**
- However, the observed extreme temperatures in 2016 are a very strong warning the likelihood extreme temperatures is increasing very rapidly and will cause large scale damage well before an average annual warming of 1.5°C is reached.

Background

The combination of ongoing anthropogenic warming to about an average 0.85°C increase averaged over last 20 years (including estimated warming for 2016), an extreme 2015-2016 El Niño and temperature anomalies in the Arctic have made **2016 a truly extreme year in terms of climate records**. According to the NASA's Goddard Institute for Space Studies (GISS), **11 of the 12 consecutive months** since October 2015 **have set new monthly high-temperature records.**[i]

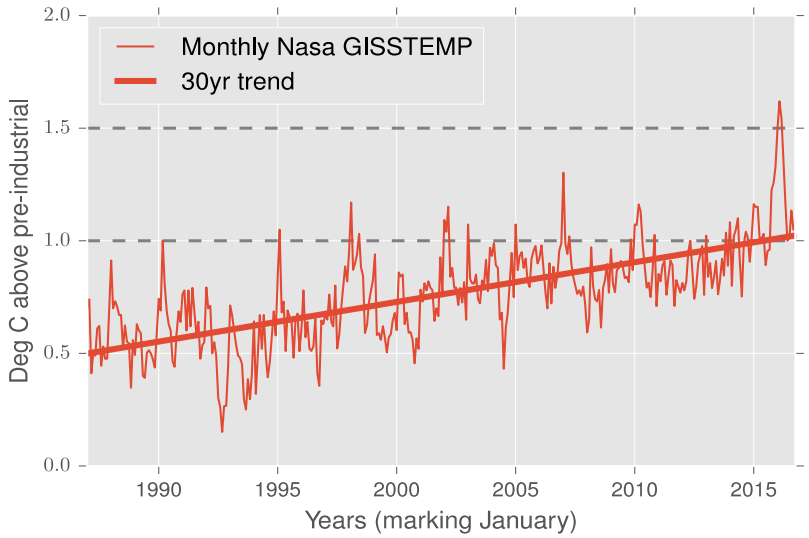

Figure 1 | The effect of natural variability on short time scales vs. long term trends. Monthly temperatures over the last 30 years from NASA GISSTEMP (light red) and a 30-year linear warming trend over the same time frame (bold red).

Large scale earth system damages, including the l**argest and most destructive coral reef bleaching event,** a **severe drought in East Africa** related to El Niño, and devastating tropical cyclones such **as hurricane Matthew** have been recorded in 2016. Observed **2016 extremes have occurred with a twenty-year average warming of only about 0.85°C** above preindustrial levels**, and will be much worse by the time we reach 1.5°C.**

It is **very likely that 2016 will be a new record year,** above the 2015 temperature record of a 1°C increase in global mean surface air temperature above pre-industrial levels.[ii] Individual months in early 2016 have already exceeded 1.5°C above pre-industrial levels, according to NASA (compare Figure 1). This has led to some speculation as to the feasibility of limiting warming to 1.5°C, in line with the long term temperature limit in the Paris Agreement. The purpose of this briefing is to provide clarity on how long term temperature limits are to be understood in the context of short term natural variability.

1. Natural variability vs. long term temperature trends

Natural variability can lead to **individual years (or months) with warming well above the long term average (Figure 1).** For example, **the 2015 attributable anthropogenic warming of 1°C was exceeded in individual months as early as 1995**. Caution must be taken in interpreting monthly or even multi-annual temperature anomalies, such as the slowed-down short-term warming trend in the 2000s, as these anomalies are the result of natural variability on multiple time scales. This is particularly true for the evaluation of climate model projections and the comparison of observed projected warming. In this context, the slowed-warming trend in the 2000s has led to an unfounded debate about the validity of these models.[iii]

As displayed in Figure 2, the 2015 and estimated 2016 warming is well within the range of natural variability projected by IPCC models, in fact just catching up with the median projected warming.

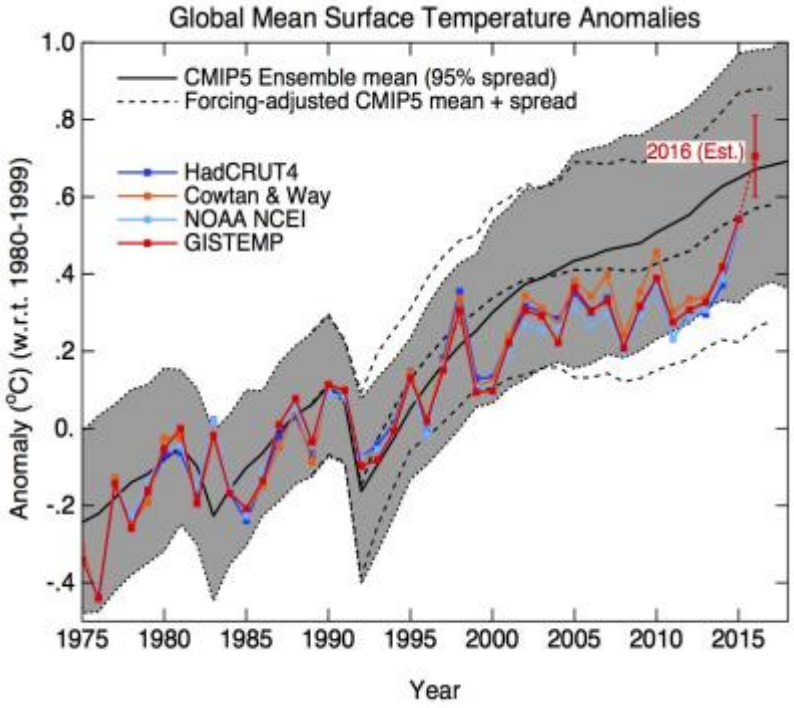

Figure 2 | Observed warming compared to model projections. *Annual global mean temperature estimates based on different data sets versus the projected warming range of the IPCC models (CMIP5) since 1975. The NASA GISTEMP data set includes an estimate for 2016. The grey marked range includes the ensemble spread by the CMIP5 model ensemble and the black line represents the example mean. Source: realclimate.org*

2. The 1.5°C long term temperature limit

To address the issues of natural variability, the IPCC has introduced approaches to identify how much warming can be attributed to human activity,[iv] and has adopted 20-year long-term averages to assess projected warming.[v] The **1.5°C temperature limit adopted in the Paris Agreement** will be assessed against **the average warming over at least 20 years** in order to account for natural variability, consistent with these IPCC methodologies.

This has implications for future warming under stringent emission reduction pathways. Figure 3 displays the warming trajectory of an emissions pathway in line with holding warming below 1.5°C with a 50% chance. For illustrative purposes, this is overlaid with 20th century natural variability, showing that **1.5°C would be exceeded in individual years, even though long-term warming will not exceed this level.**

Long-term temperature limits have been adopted based on the risk assessments of future climate impacts,[vi] thereby **factoring in the effects of natural variability**. If exceedance of global mean warming levels of 1.5°C or 2°C on shorter timescales (years, or even months) should be avoided, the attributable share of warming would need to be substantially lower than these long-term warming levels, as would the respective carbon budget.

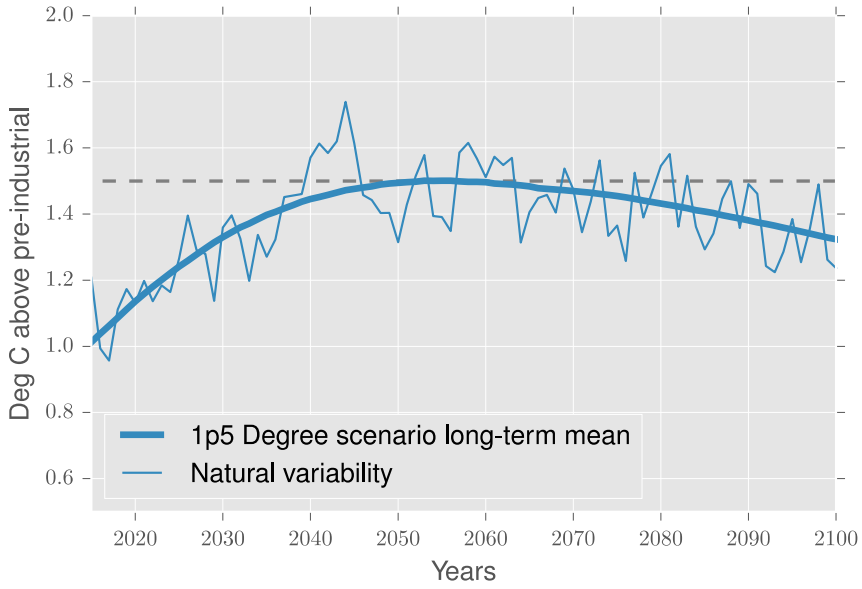

Figure 3 | Illustration of natural variability and long term 1.5°C pathways| Stylised 1.5°C scenario and overlaid 20th century natural variability derived as the annual anomaly from the 20-yr running mean.

[i] http://data.giss.nasa.gov/gistemp/news/20161017/

[ii] http://public.wmo.int/en/media/press-release/2015-hottest-year-record

[iii] Marotzke, J. & Forster, P. M. Forcing, feedback and internal variability in global temperature trends. *Nature* 517, 565–570 (2014).

[iv] Bindoff, N. L. *et al.* in *Climate Change 2013: The Physical Science Basis. (* Cambridge University Press, 2013).

[v] IPCC. *Climate Change 2013: The Physical Science Basis.* (Cambridge University Press, 2013).

[vi] Schleussner, C.-F. *et al.* Science and policy characteristics of the Paris Agreement temperature goal. *Nat. Clim. Chang.* 6, 827–835 (2016).