Responses to Industry Questions

1. Action DE0601 11/06/14 4 - Met Office to examine the Heathrow data and winter warming trends.

Met Office Response

For the period 2012-2025, the trends from the temperature projection for Q1 and Q3 are given below (in degrees per decade):

Q1	Q3
0.42 +/- 0.07	0.35 +/- 0.09

The overall trend is 0.34 +/- 0.05.

The standard errors mean that the values of the Q1 and Q3 trends overlap. (Met Office have checked the numbers for Coleshill, and get very similar results.) These numbers seem to broadly agree with figures quoted by British Gas during the meeting (0.4 from EP2 and 0.3 from their analysis of the new data).

For the 2012-2018 period (which overlaps with EP2), the numbers are slightly different.

Q1	Q3
0.6 +/-0.19	0.16+/- 0.33

Overall: 0.18 +/- 0.16

Due to the larger standard errors, the gradients for Q1 and Q3 still overlap with each other, and the respective values for the full time series. The larger standard errors arise partly due to the short duration of the time series (only 7 points), but also because there is some variability. In contrast, the standard errors for the full 2012-2025 period are much smaller, indicating a more robust estimation of the trends.

2. By comparing the raw historic data with the adjusted version we find that the adjustment between 1960 and 2012 has been based on a warming of 1.6C between 1960 and 2012. Thus 1.6C has been added to the historic 1960 data on a sliding scale to no addition to the 2011 data to produce the adjusted data set. How did the Met Office estimate that the warming between 1960 and 2012 was 1.6C? Was it for example the difference between a 30yr average centred on 1960 and a 30yr average centred on 2012?

Response:
The calculation of the increments is explained in section 4.1.2 of the Climate Change Methodology (published on the Xoserve secure website – UKLink Documentation – under Folder 18). In summary, a linear regression line was fitted to the annual increments in the Weather Station Methodology dataset. The increments were then taken from the fitted line, rather than from the difference between the actual year and the base year. The regression line is shown diagrammatically in Figure 8 on Page 21 of the report for Coleshill weather station, and is shown below for Heathrow weather station.

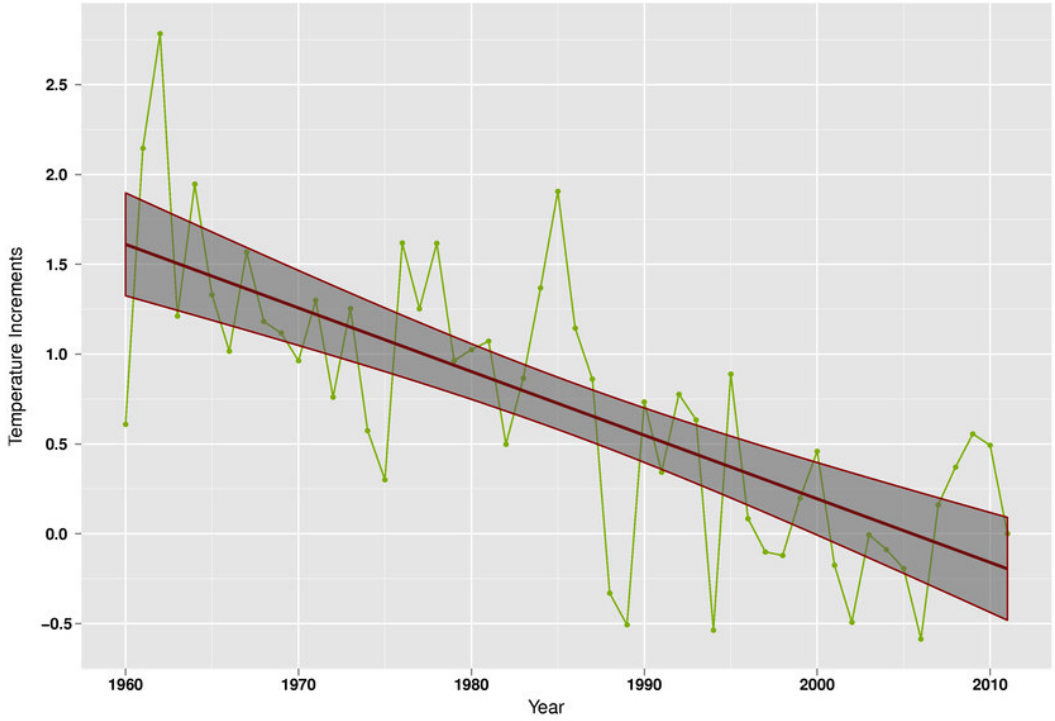

Illustration: Time series for Heathrow weather station of temperature increments (green line) and fitted regression line (dark red line) and associated 95% confidence interval (shaded region). Note the difference between the observed and best-estimate annual mean temperature for 2011/2012: the increment is higher than the fitted line, i.e. the weather was cooler.

3. The output data from the last project (EP2) produced climatologies which warmed year on year between 2008 and 2018. At a monthly granularity it was seen that months August/September/October exhibited the greatest year on year warming, whilst the months December/January/February produced the least warming. The CCM projections also show a warming over the period 2012 – 2025, however the months January/February/March see most warming. Can the Met Office make a qualitative statement describing which months in the projections exhibit the most/least warming. For completeness it would be nice to set this in the context of EP2 i.e. at the time of EP2 our climate models showed warm most pronounced in the months of August/September/October but our current climate models show the greatest warming in the moths of January/February/March.

Met Office Response

There are several aspects to the differences between the current methodology and EP2, and to the differences between winter and summer warming.

Firstly, our analysis of the winter and summer warming trends for Heathrow shows that they are statistically indistinguishable, although the trend is slightly greater in winter than summer.

Secondly, there is higher uncertainty in the model projection in the winter than the summer. Indeed, this is partly what motivated our choice of methodology, as described below. The higher uncertainty in winter is highlighted in Figure 5 of the EP2 report which compares the

root mean square skill scores for each month; it is also evident in Figure 21 of the Methodology, which shows the daily temperatures from the CMIP5 ensemble members for Coleshill. As described in that report, the variance around the ensemble mean is typically greatest in the winter, due to the effect of the North Atlantic Oscillation: "The CMIP5 ensemble explores a wide spread of possible NAO states, giving rise to large variance around the ensemble mean in the winter months". It is for this reason that we developed a methodology which made use of a multi-model ensemble - individual models (or ensembles based on a single model) may have biases in their ability to reproduce the variability of the NAO, leading to either excessively stormy and mild, or excessively cold winters. This can lead to an inaccurate reproduction of the winter climate in some models. However, as mentioned in our previous discussions, multi-model ensemble means tend to outperform any individual model. So, by making use of many different climate models, we are able to make a more unbiased projection.

A related point is that, our larger ensemble ensures that the ensemble mean is less influenced by outliers than the 10-member EP2 ensemble. The new models are also much higher spatial resolution, which allows us to capture local details more accurately.

Results from a review of climate change literuature review:

IPCC AR5 WGII Chapter 23:

"Climate models show significant agreement for all emission scenarios in warming (magnitude and rate) all over
Europe, with strongest warming projected in Southern Europe in summer, and in Northern Europe in winter
(Kjellström et al., 2011)(Goodess et al., 2009)."
http://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-Chap23_FGDall.pdf

See also: http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch11s11-3.html

The regions covered by Northern and Southern Europe can be seen here:
http://www.ipcc.ch/publications_and_data/ar4/wg1/en/figure-11-4.html

The diurnal cycle (diurnal temperature range; DTR) has also been affected by climate change (see Diurnal temperature range as an index of global climate change during
the twentieth century, Karl Braganza et al 2004):

"Observed DTR over land shows a large negative trend of 0.4C over the last 50 years that is very unlikely to have occurred due
to internal variability. This trend is due to larger increases in minimum temperatures (0.9 C) than maximum temperatures (0.6 C) over the same period."
http://journals.ametsoc.org/doi/full/10.1175/2007JCLI1568.1

The same general picture is repeated when looking at extremes:

"The shift in the distribution of night time temperatures appears greater than daytime temperatures although whether distribution changes are simply linked to increases in the mean or other moments is an active area of research (Ballester et al., 2010; Simolo et al., 2011; Donat and Alexander, 2012; Hansen et al., 2012). Indeed, all data sets examined (Duke, GHCNDEX, HadEX, HadEX2 and HadGHCND), indicate a faster increase in minimum temperature extremes than maximum temperature extremes. While DTR declines have only been assessed with medium confidence (Section 2.4.1.2), confidence of accelerated increases in minimum temperature extremes compared to maximum temperature extremes is

high due to the more consistent patterns of warming in minimum temperature extremes globally."

From Too hot, too cold, too wet, too dry: Drivers and impacts of the seasonal weather in the UK, March 2014

"Results from Brown et al (2008) show that the extreme values of the maximum daily temperture and minimum daily temperature in the UK have risen by just over 1 degree Celcius since the 1950s, and there is a suggestion that the warmest daily temperature extremes are rising faster in summer, whereas the coolest daily temperature extremes are rising faster in winter"

Observations for the UK do indicate a slightly higher increase in summer temperatures than in winter, although the values are very close, and confidence intervals overlap:

"when viewed in terms of long-term averages there are many indicators of warming in the UK. For example, Met Office data shows that wintertime temperature has seen a long-term warming of 0.23 (C) per decade since 1960 (slightly lower than the 0.28 (C) per decade in the summer)"
(see http://www.metoffice.gov.uk/media/pdf/t/r/UK.pdf)