Comment on "Climate Science and the Uncertainty Monster" by J. A. Curry and P. J. Webster

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Curry and Webster (2011) discuss the important topic of uncertainty in climate research. While we agree that it is very important that uncertainty is estimated and communicated appropriately, their discussion of the treatment of uncertainty in the IPCC assessment reports regarding attribution is inaccurate in a number of important respects.

IPCC has placed high priority on communicating uncertainty (Moss and Schneider 2000; Mastrandrea et al. 2010, 2011). Since detection of climate change and attribution of causes deals with distinguishing "signals" or "fingerprints" of climate change from climate variability, an approach requiring substantial use of statistics (see Hegerl et al. 2007), this area of research has always placed high priority on estimating uncertainties appropriately. Hence the chapter on attributing causes to climate change of IPCC AR4 (Hegerl et al. 2007) discusses the uncertainty in its findings in detail, including in an overview table where remaining uncertainties are explicitly listed for each finding. In this brief comment we will limit our focus to the four key errors and misunderstandings in Curry and Webster (2011) regarding the treatment of uncertainty in the detection and attribution chapter of IPCC AR4:

1) The authors claim that "The 20th century aerosol forcing used in most of the AR4 model simulations (Section 9.2.1.2) relies on inverse calculations of optical properties to match climate model simulations with observations" and thus claim "apparent circular reasoning." This is incorrect. The inverse estimates of aerosol forcing given in 9.2.1.2 are derived from observationally based analyses of temperature and are compared in Chapter 9 with "forward" estimates calculated directly from understanding of the emissions in order to determine whether the two are consistent. But it is critical to understand that such inverse estimates are an *output* of attribution analyses not an *input*, and thus the claim of "circular reasoning" is wrong. The aerosol forcing used in 20C3M (see http://www-pcmdi.llnl.gov/projects/cmip/ann_20c3m.php) climate model simulations was based on forward calculations using emission data [Boucher and Pham 2002; see references in Randall et al. (2007)]. Further, detection and attribution methods determine whether model-simulated temporal and spatial patterns of change (referred to as fingerprints) that are expected in response to changes in external forcing are present in observations. For example, the aerosol fingerprint shows a spatial and temporal pattern of near-surface temperature changes that varies between hemispheres and over time (see Hegerl et al. 2007, Section 9.4.1.5). The solar fingerprint shows a vertical pattern of free atmosphere temperature changes that has warming throughout the atmosphere unlike the

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observed pattern of warming in the troposphere and cooling in the stratosphere, and also has a distinct temporal pattern, particularly on longer time scales. These patterns make the response to solar and aerosol forcing distinguishable (with uncertainties) from that due to greenhouse gas forcing. The amplitude of those fingerprint patterns is estimated from observations. Therefore, attribution of the dominant role of greenhouse gases in the warming of the past half-century is not sensitive to the uncertainties in the magnitude of aerosol forcing, or of other forcings, such as solar forcing. If the observed response were (at a given significance level) consistent with a smaller aerosol signal, balanced by a smaller greenhouse gas signal than that used in the models, then the results from fingerprint studies would include these possibilities within their statistical uncertainty ranges. Thus, attribution studies sample the range of possible forcings and responses much more completely than climate models do (Kiehl 2007). Also, the IPCC AR4 assessment carefully explores other possible explanations, such as solar forcing alone, and finds that "it is very likely that greenhouse gases caused more global warming over the last 50 years than changes in solar irradiance," based on studies exploring a range of solar forcing estimates and using a range of data (Section 9.4.1.5, Hegerl et al. 2007). Such studies also attribute the warming in the first half of the twentieth century to a combination of external natural and anthropogenic forcing and internal climate variability (Table 9.4) Thus, Curry and Webster misrepresent the role of forcing magnitude uncertainties in attribution and do not appreciate the level of rigor with which physically plausible alternative explanations of the recent climate change are explored.

2) ". . . no traceable account is given in the AR4 of how the likelihood assessment in the attribution statement was reached": Expert open reviews are designed to ensure that the steps taken during the AR4 were clear to attribution experts. An explanation of how the assessment was obtained is given in the introduction to the chapter, and includes a description of how the overall expert assessment is based on technical results and an assessment of their robustness, downgraded to account for remaining uncertainties (Section 9.1.2, second-to-last paragraph). The detailed assessment of the causes of a variety of observed climate changes, including the results from published studies, the remaining uncertainties, and

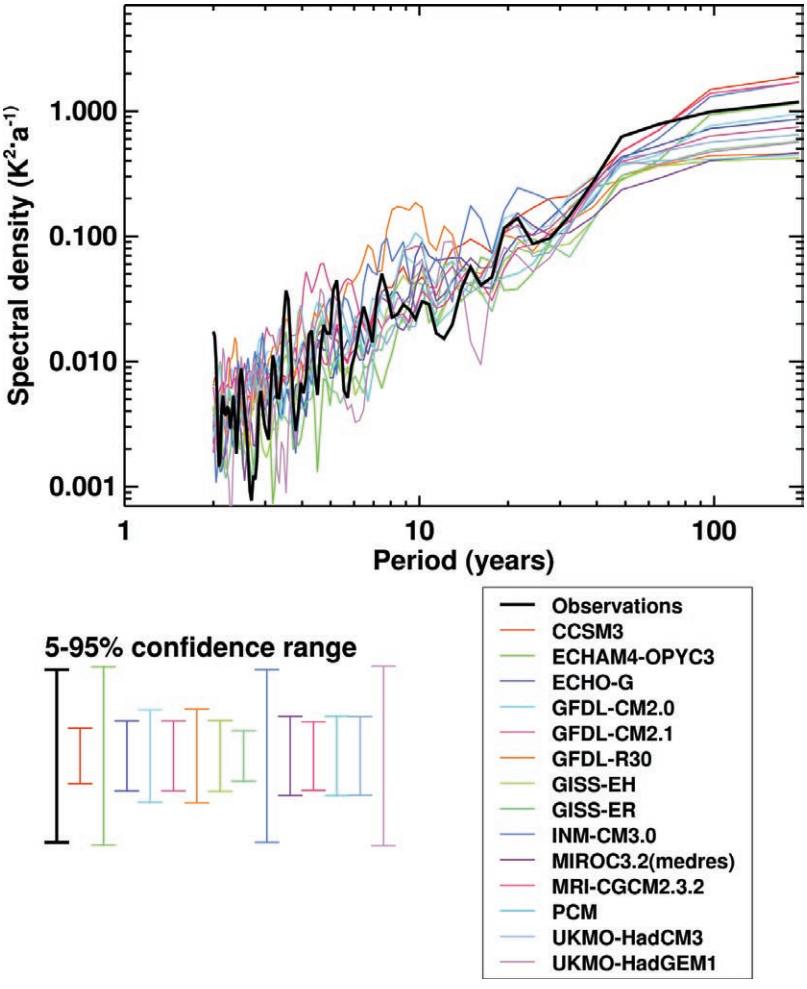

Fig. 1. Comparison of variability as a function of time scale of annual global mean temperature from observations (black) and multiple model simulations of the twentieth century [colors; for details see Fig. 9.7 of Hegerl et al. (2007)]. This figure is used by the authors to claim that "the power spectra of observed and modeled global mean temperatures in figure 9.4 of the IPCC AR4 shows that all models underestimate the amplitude of variability on periods of 40–70 years." Note the uncertainty in the observed and simulated spectral estimates (vertical bars).

the overall assessment is given in Table 9.4, which extends over more than 3 printed pages. However, improving the communication of such material to the broader audience of scientists who are not directly involved in attribution studies is also an important goal, and this exchange shows this can be improved.

3) "The high likelihood of the imprecise "most" seems rather meaningless": We disagree. The likelihood describes the assessed probability that "most" (i.e., more than 50%), of the warming is due to the increase in greenhouse gases. This statement has a clear meaning and an associated uncertainty, although explicitly listing ">50%" in the text to ensure that no misunderstandings are possible could be helpful in future work.
4) The authors claim that "Fig. 9.4 of the IPCC AR4 shows that all models underestimate the amplitude of variability of periods of 40–70 years." This is an incorrect conclusion because Curry and Webster do not appear to have considered the uncertainties that were presented in the chapter. The figure (Fig. 9.7, not Fig. 9.4 of the assessment) clearly shows that the simulated variability of annual global mean temperature on time scales of 40–70 years is consistent with the variability estimated from observations, given uncertainty in spectral estimates. Detection and attribution methods account for the contribution by internal climate variability to observed climate changes. Since the estimates of climate variability that are used for this purpose are generally obtained from climate model data, the chapter also contains a detailed discussion of the reliability of climate model variability for detection and attribution. Section 9.4.1.3 states that detection and attribution methods yield an estimate of the internally generated climate variability in observations and palaeoclimatic reconstructions (see Section 9.3.4) that is not explained by forcing. This "residual" is comparable to the variability generated by climate models, and the patterns of variability in models reproduce modes of climate variability that are observed (see chapter 8). The remaining uncertainty in our estimates of internal climate variability is discussed as one of the reasons the overall assessment has larger uncertainty than individual studies (see, e.g. Table 9.4).

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