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Climate of the Past Discussions

Interactive comment on "Comment on "Using multiple observationally-based constraints to estimate climate sensitivity" by J. D. Annan and J. C. Hargreaves, Geophys. Res. Lett., 33, L06704, doi:10.1029/2005GL025259, 2006" *by* S. V. Henriksson et al.

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The method used by Annan and Hargreaves in "Using multiple observationally-based constraints to estimate climate sensitivity" is very simple: They multiply three probability density functions corresponding to climate sensitivity estimates produced from different observational data. This would correspond to requiring the same outcome in three independent random events described by those pdfs. The idea to write the

comment article at hand arose because we felt that this kind of multiplication is a very counterintuitive way to combine the evidence from the different sources, and then we formulated as well as we could the shortcomings in the reasoning behind it. As most previous observationally-based studies have resulted in wider distributions for reasons we know, we thought it is very likely that some or most of these reasons are common to all these studies. Thus, simply looking at a larger amount of observations will not eliminate the underlying joint uncertainties. How the argument of AH06 breaks down in the Bayesian framework and the actual circumstance of climate observations is described in our comment article.

While we are convinced that the last glacial maximum constraint contains independent information from the other constraints, we still think that deriving a distribution for climate sensitivity and relating it to present climate requires more careful accounting of uncertainties involved and an argument for independence of radiative forcing from aerosols.

During the interactive discussion, Annan and Hargreaves have avoided commenting on the issue of dependence between ocean heat capacity estimates in the 20th century warming and volcanic cooling cases, and on the issue of the volcanic cooling data used completely ignoring radiative forcing uncertainty. We find using the volcanic cooling data as an independent constraint totally unacceptable.

The later article by Annan and Hargreaves (2009; hereinafter referred to as AH09) achieves even narrower distributions than AH06, but this is achieved by using narrower priors without convincing supporting arguments. In particular, any indications on anticipated economic damages caused by climate change cannot be used as arguments since in this context climate change is causing the economic damages and reasoning cannot therefore be performed the other way around. AH09 does not answer to the concern of dependency between data from different sources.

The recent study achieving a narrower distribution for climate sensitivity based on LGM

evidence referred to by Annan and Hargreaves (Köhler et al., 2010) uses climate model based information from the study by Schneider von Deimling et al. (2006) for the LGM cooling and explicitly states that scientific understanding of the effects of efficacy of forcing and of how feedbacks at the LGM relate to present is low and that uncertainties may be larger than considered in that study. It is well known that climate models span a much narrower range of climate sensitivity values than ranges obtained in most observationally-based studies. The result of Köhler et al. (2009) for the uncertainty of climate sensitivity is totally sound as a partly model-based and partly subjective one, but does not answer to the challenges facing AH06 in combining information from different observationally-based sources. Additionally, when assessing LGM cooling from observational data and estimates of strengths of all feedbacks, a much larger cooling than that used for the climate sensitivity estimate is obtained in the very same article.

We have during the interactive discussion performed sensitivity analyses on some of the assumptions. Ignoring the volcanic cooling constraint increases the upper bound of the 95% confidence interval from 4.9 to 5.6 degrees. We do not consider higher values of climate sensitivity excluded by AH06 either as the remaining distribution is dominated by the LGM distribution and the simplifying assumptions used in deriving it.

The fact repeatedly stated by Annan and Hargreaves that more information is expected to reduce uncertainty is true indeed. However, in the case of dependent datasets the reduction in uncertainty can be very small or zero. The pitfalls in using straight forward Bayesian meta-analysis for combining evidence from different sources are discussed in Jaynes (2009, Section 8.3), for example. The classical example there is the average of the opinion of one billion Chinese about the height of the Emperor. The average has extremely high precision, indeed, but tells us almost nothing about the true height. This is because folklore and beliefs are common for the Chinese people and they create a systematic bias surviving the averaging. In the current context of studying climate sensitivity, Knutti and Hegerl (2008) warn that when estimating climate properties that are not independent, such as climate sensitivity and ocean heat uptake, combining ev-

idence requires combining joint probabilities rather than multiplying marginal posterior pdfs. In AH06, dependency between sources is not taken properly into account by considering joint probabilities and therefore the resulting pdf for climate sensitivity cannot be considered a reliable result.

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