

Reply to comment on “Ground vs. surface air temperature trends: Implications for borehole surface temperature reconstructions”

by D. Chapman et al.

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[1] We welcome further investigation of the issues raised in our recently published paper “Ground vs. surface air temperature trends: Implications for borehole surface temperature reconstructions” [Mann and Schmidt, 2003] (hereinafter referred to as MS03). There are many confounding influences on the borehole record of past hemispheric mean temperatures, including (but not limited to) spatial sampling [Huang et al., 2000], land use changes, and calibration to the instrumental record [Mann et al., 2003]. We addressed only one particular issue, that of possible seasonal biases. An insightful followup study using an independent model and a longer-term integration has already yielded both confirmatory and complementary conclusions [Gonzalez-Rouco et al., 2003]. We expect that other modelling groups will make similar analyses in appropriate runs, and that those aspects of our own analysis that are robust will likely be reproduced in these analyses also.

[2] We are however a little disappointed in the tone and content of the comment on our article Chapman et al. [2004] (hereinafter referred to as CBH). We find that they have variously mis-represented the statements and conclusions of MS03 and hence significantly distort the thrust of our paper. This is simply that climate changes in the winter season (particularly due to snow cover changes) are not as well captured in borehole temperature reconstructions as warm season changes. This is a statement for which there is a host of complementary and independent supporting evidence.

[3] CBH begin by listing 3 conclusions from MS03, loosely paraphrased as: i) the correspondence between GST and SAT is stronger in summer than in winter, ii) that changes in snow cover are a possible source of bias, and iii) that snow-cover and pre-conditioning by prior warm season anomalies can in places be as large as the cold

season temperature in determining cold season GST. We stand by all these statements.

[4] CBH appear to miss the key point of MS03 with regard to the interpretation of past temperature trends. Our analysis of this particular climate model, under the particular forcings and for the time-period discussed is not intended to be a demonstration of what actually happened in past centuries. The forcings would be different, and the actual climate change, both in the annual mean, but more relevantly, in different seasons, is unlikely to reflect that seen in the model. However, the modelled relationships of the key variables at the local level are physically consistent. All of the analysis regarding influences on cold season GST are thus based on the sum of these local influences (as shown by MS03’s Figures 2 and 3). Statements regarding relationships at the hemispheric extra-tropical mean are besides the point. Changing the end-points of the analyses does not affect the systematic patterns shown by MS03’s Figures 2 and 3. The hemispheric-mean analysis discussed by CBH is simply incapable of addressing the issue of significant bias locally.

[5] CBH curiously suggest that since snow cover can sometimes warm and sometimes cool the ground, that this need not lead to any bias. If this was an unbiased stochastic effect, then in the mean this might be correct. However, it really implies that the overall bias is likely to be complicated and dependent on the actual climate change that occurred (for example, the extent to which snow cover was insulating in mid-winter, versus the extent to which it may delay spring thaws), and is possibly spatially dependent (as shown by MS03’s Figure 3). Our analysis was an attempt to quantify that, and we found indeed that there is a net bias, i.e., decreases in snow cover lead to relative cooling of GST.

[6] They also state that separation into cold and warm seasons is irrelevant for decadal and longer climate change. We absolutely disagree. Given that there is evidence of changes in the seasonal cycle over the last few hundred years [Jones et al., 2003], we think a separation of cold and warm season impacts are of obvious interest. Gonzalez-Rouco et al. [2003] seemingly agree and show similar results to us, implying that the wintertime correlations are worse than for the summertime and that this is correlated to anomalies in snow cover (J. Gonzalez-Rouco, personal communication). Whether this makes a significant difference in the long-term means depends on what actually

happened, which is not something that is necessarily well captured in any particular GCM simulation. However, to dismiss the possibility out of hand, as CBH appear to do, is rather foolish.

[7] Our analysis looked at two factors that might have an impact on cold season anomalies and explain the increased mismatch during the winter. These two factors, snow cover and prior-warm season SAT explain 9% and 4%, respectively of the variability at all grid points over a 48 year simulation. While this is clearly not dominant globally compared to the 48% explained by cold season SAT anomalies, locally however, these can be significant (as is clearly shown by MS03's Figure 3). There are large areas where the trends in GST are significantly influenced by SNC and to a lesser extent, prior warm season SAT. The mild impact (4% of the variance) of warm season SAT cannot be attributed to seasonal persistence of the SAT anomalies (since that would be removed in the multiple linear regression analysis), but must be related to physical effects such as anomalously warm ground conditions leading to a delay in the snow cover, or anomalies in soil moisture for instance. We note in passing that the GISS GCM is certainly not unique in showing the persistence of seasonal temperature anomalies. Due to the time-scales of ENSO, volcanic forcing etc., all other GCMs and the observations [Hansen *et al.*, 1999] similarly show such persistence.

[8] Our essential points are clearly stated: i) the relationship between GST and SAT is significantly weaker during the cold season than during the warm. This is also supported in a recent model analysis [Gonzalez-Rouco *et al.*, 2003], in independent studies [Zhang *et al.*, 2003; Stieglitz *et al.*, 2003; Beltrami and Kellman, 2003], and even by CBH themselves. ii) In the event that climate changes over the past few centuries have been seasonally different, as indicated for instance by [Jones *et al.*, 2003], there is a potential

for a bias in GST proxies, particularly if snow cover changes are large. These conclusions are not affected by any points raised by CBH.

References

- Beltrami, H., and L. Kellman (2003), An examination of short- and long-term air-ground temperature coupling, *Global Planet. Change*, *38*, 291–303.
- Chapman, D. S., M. G. Bartlett, and R. N. Harris (2004), Comment on “Ground vs. surface air temperature trends: Implications for borehole surface temperature reconstructions” by M. E. Mann and G. Schmidt, *Geophys. Res. Lett.*, *31*, L07205, doi:10.1029/2004GL019054.
- Gonzalez-Rouco, F., H. von Storch, and E. Zorita (2003), Deep soil temperature as proxy for surface air-temperature in a coupled model simulation of the last thousand years, *Geophys. Res. Lett.*, *30*(21), 2116, doi:10.1029/2003GL018264.
- Hansen, J., R. Ruedy, J. Glascoe, and M. Sato (1999), GISS analysis of surface temperature change, *J. Geophys. Res.*, *104*, 30,997–31,022.
- Huang, S., H. N. Pollack, and P.-Y. Shen (2000), Temperature trends over the past five centuries reconstructed from borehole temperature, *Nature*, *403*, 756–758.
- Jones, P. D., K. R. Briffa, and T. J. Osborn (2003), Changes in the Northern Hemisphere annual cycle: Implications for paleoclimatology, *J. Geophys. Res.*, *108*(D18), 4588, doi:10.1029/2003JD003695.
- Mann, M. E., and G. A. Schmidt (2003), Ground vs. surface air temperature trends: Implications for borehole surface temperature reconstructions, *Geophys. Res. Lett.*, *30*(12), 1607, doi:10.1029/2003GL017170.
- Mann, M. E., S. Rutherford, R. S. Bradley, M. K. Hughes, and F. T. Keimig (2003), Optimal surface temperature reconstructions using terrestrial borehole data, *J. Geophys. Res.*, *108*(D7), 4203, doi:10.1029/2002JD002532.
- Stieglitz, M., S. J. Déry, V. E. Romanovsky, and T. E. Osterkamp (2003), The role of snow cover in the warming of the arctic permafrost, *Geophys. Res. Lett.*, *30*(13), 1721, doi:10.1029/2003GL017337.
- Zhang, T., M. Serreze, R. G. Barry, D. Gilichinsky, and A. Etringer (2003), Climate change: Evidence from Russian historical soil temperature measurements, *Geophys. Res. Abstr.*, *5*, 01485.

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