Suitability of the 3D radiosonde temperature field for climate change detection and attribution studies.

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Introduction

Previous climate change detection and attribution studies have considered either surface patterns of temperature change (1,2), or zonally averaged vertical profiles of temperature change (3). Here we investigate the potential for using the full field of upper air radiosonde temperatures from the HadRT2.1 dataset (4) in formal detection and attribution studies. These are compared qualitatively with output from ensemble simulations with the HadCM2 (5) climate model under various forcings, provided through the Climate Impacts LINK Project (6).

Method

The HadRT2 dataset is available in various versions, all based upon radiosonde temperatures on standard levels anomalised relative to the 1971-90 mean. The versions used here are 2.1, which has been adjusted for known instrumental heterogeneities (4) using Microwave Sounding Unit (MSU) retrievals as a reference, and 2.1s which has corrections applied in the stratosphere only. This provides us with an estimate of our uncertainty in the observations. Any gridbox values deemed to be sufficiently anomalous in statistical tests (7), were checked with reference to available metadata (8) and discarded if a physically plausible cause existed.

Six forcing combinations (Table 1) were used to force the HadCM2 model, using four-member ensembles in each case (six for GS). Each model run was anomalised relative to 1971-90 climatology using the same seasonally varying data mask as the observations. These seasonal anomalies were then averaged to annual (Dec - Nov) anomalies.

Forcing acronym	Forcings applied.
GSO	Greenhouse gases, Sulphate aerosols, Stratospheric Ozone
GS	Greenhouse gases, Sulphate aerosols
GHG	Greenhouse gases
SOL	Solar forcing (Hoyt and Schatten (9))
LBB	Solar forcing (Lean et al. (10))
VOL	Volcanic forcing (Sato et al. (11))

Table 1. Brief explanation of HadCM2 forced runs

Here we consider the spatial pattern of a tropospheric lapse rate (300hpa minus 850hpa temperature anomalies); we do not lose much information by using a lapse rate because tropospheric annual mean temperatures show quite strong vertical covariance. Patterns of change are diagnosed as the difference between the first and last decades (1958-67 and 1988-97). We use the intra-ensemble variability in this diagnostic to estimate the standard deviation field, and therefore provide an estimate of significance. We choose to use a high (99%) critical threshold to minimise the chances of false rejection of individual grid boxes as showing changes different from those observed. In such an approach the null hypothesis is that not only is the pattern of the ensemble mean correct, but also its magnitude. This analysis is augmented by the use of a root mean squared difference (RMSD) comparison between the entire fields.

Results:

Observations (Figure 1) exhibit distinct spatially coherent changes, with perhaps a few residual errors. We caution that the fields show quite large differences between HadRT2.1s (uncorrected in the troposphere) and HadRT2.1 (corrected in the troposphere): therefore relying on a single observational dataset may yield ambiguous results. Positive values imply a warming of the upper troposphere (300hpa level) relative to the lower troposphere (850hpa level): no information is gleaned from intermediate levels. If the entire troposphere were to warm or cool homogeneously then there would be no signal in the lapse rate. Lapse rate changes are not zonally homogeneous and therefore we expect using the full field will enhance the ability of detection and attribution studies to discriminate between forcings.

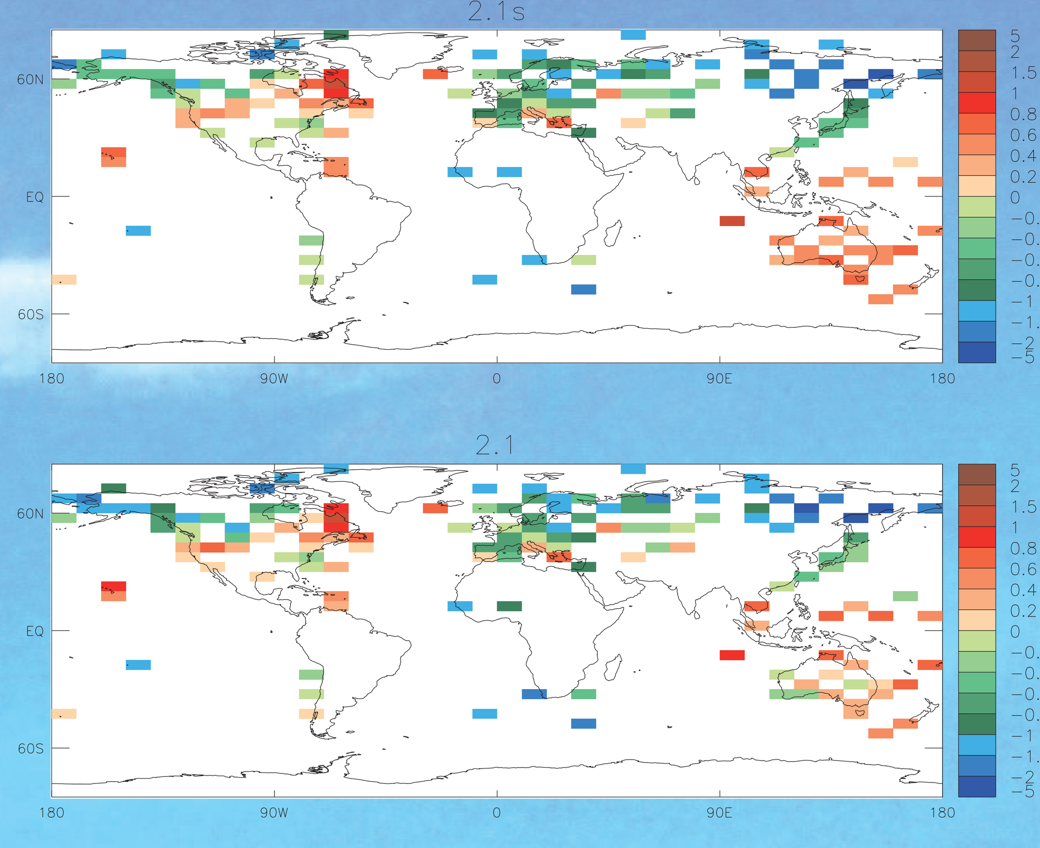

Figure 1. Observational changes in tropospheric lapse rates. Version 2.1s is uncorrected, Version 2.1 has been corrected with reference to MSU data. The differences reflect our uncertainties in the observations.

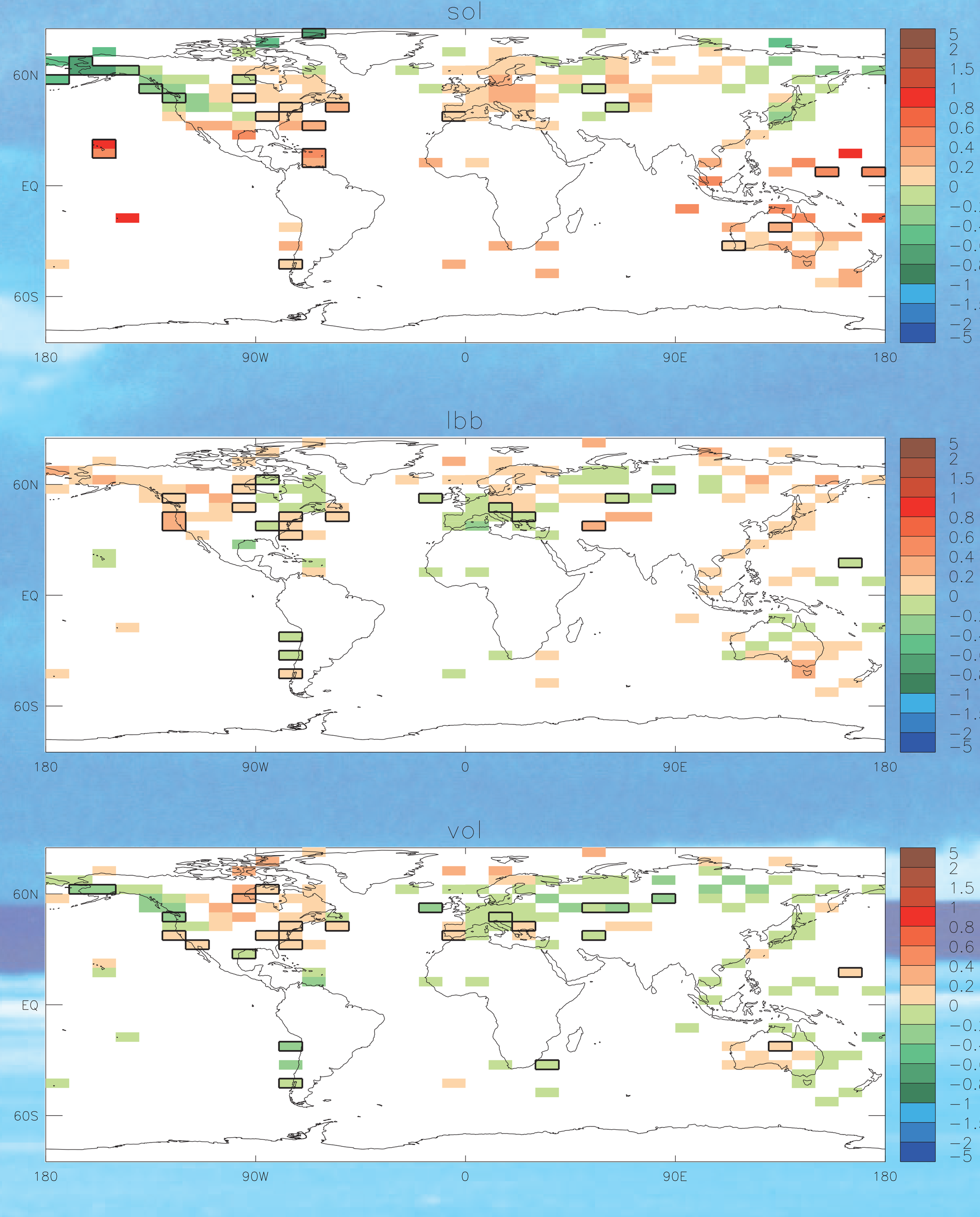

Figure 2. Ensemble mean response to "natural forcings". Areas which are within 3 sigma of the HadRT2.1s observations are highlighted.

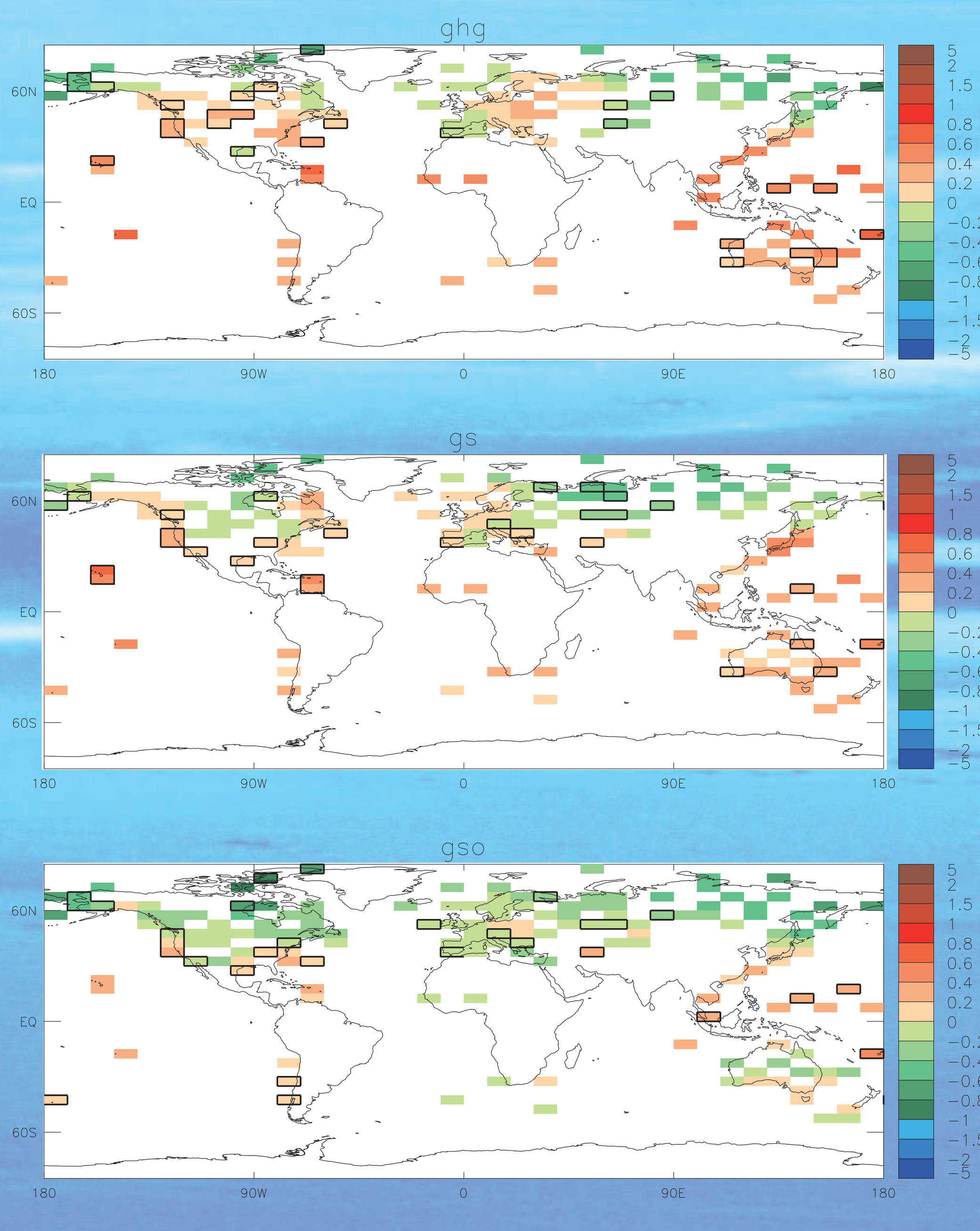

Figure 3. Ensemble mean response to "anthropogenic forcings". Areas which are within 3 sigma of the HadRT2.1s observations are highlighted.

The results from the "natural forcing" simulations are shown in Figure 2. The best explanation arises from a consideration of VOL and SOL in combination, although the magnitude of the simulated changes is low.

Fields for the anthropogenically-forced runs are given in Figure 3. GHG and GS ensembles exhibit similar magnitude changes to those in the observations, although neither is significantly better at explaining individual grid box trends than the natural forcings. Results from GSO significantly degrade the agreement on a grid box basis, exhibiting too great an upper tropospheric cooling, especially over Oceania. However, GSO has the lowest RMSD value (Table 2), suggesting that it best captures some of the large scale changes.

None of the ensembles captures the strength of the large scale lower tropospheric warming over Eurasia and Japan. This may be related to the recent positive phase of the Arctic Oscillation (12), which is not well simulated in HadCM2.

Ensemble	Value
SOl	0.029
LBB	0.031
VOL	0.029
GHG	0.027
GS	0.027
GSO	0.026

Table 2. Table of root mean squared difference values between observed and model predicted fields.

Discussion

We have shown in a purely qualitative manner that observed changes in tropospheric lapse rates over the last 40 years are most likely to be explained by some combination of anthropogenic and natural forcings, and internal variability, rather than a single forcing. We caution against making more conclusive statements pending the results of a rigorous detection and attribution study. It is recognised that lapse rates are not the only available diagnostic; research into finding other suitable diagnostics is ongoing.

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