ATMOSPHERIC SCIENCE

The answer is blowing in the wind

Uncertainty over tropical tropospheric temperature change has loomed large over the last two decades. Use of wind data to infer temperature change offers a new avenue of investigation.

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In 1990, a paper boldly entitled "Precise monitoring of global temperature trends from satellites"[1] suggested that according to satellite measurements there had been no net global warming in the troposphere (the part of the atmosphere stretching from the surface of the Earth up to 12–16 km in altitude). The radiosonde (balloon-based) temperature measurements that were available at the time supported this conclusion. These findings, however, cast doubt upon the reliability of climate models, which suggest that these regions should be warming at least as quickly as the surface (and quicker in the tropics). The discrepancy has fuelled nearly 20 years of intensive research, along with several multi-expert assessments[2,3]. Yet despite all this work, we remain in the dark as to whether temperatures in the tropical upper troposphere really are increasing, as expected, as the Earth's surface warms. On the *Nature Geoscience* website today, Allen and Sherwood[4] use radiosonde-derived wind data to reveal that temperatures in the tropical upper troposphere are very likely to be increasing as global surface temperatures rise.

Historically, atmospheric observations have primarily been made to help weather forecasters initiate their models. Because of an ever-evolving awareness of the limitations of data accuracy, ubiquitous improvements have been made to all observational systems, but particularly to those from radiosondes and satellites, which together form the backbone of our upper-air observing system. Now we are relying on these very same data to confirm climate model behaviour — a necessary pre-requisite for confidently predicting the climate for the coming century. However, the improvements in network density and instrumentation that seemed beneficial have introduced spurious trends, making it difficult, or potentially impossible, to assess true long-term changes to the degree of accuracy required.

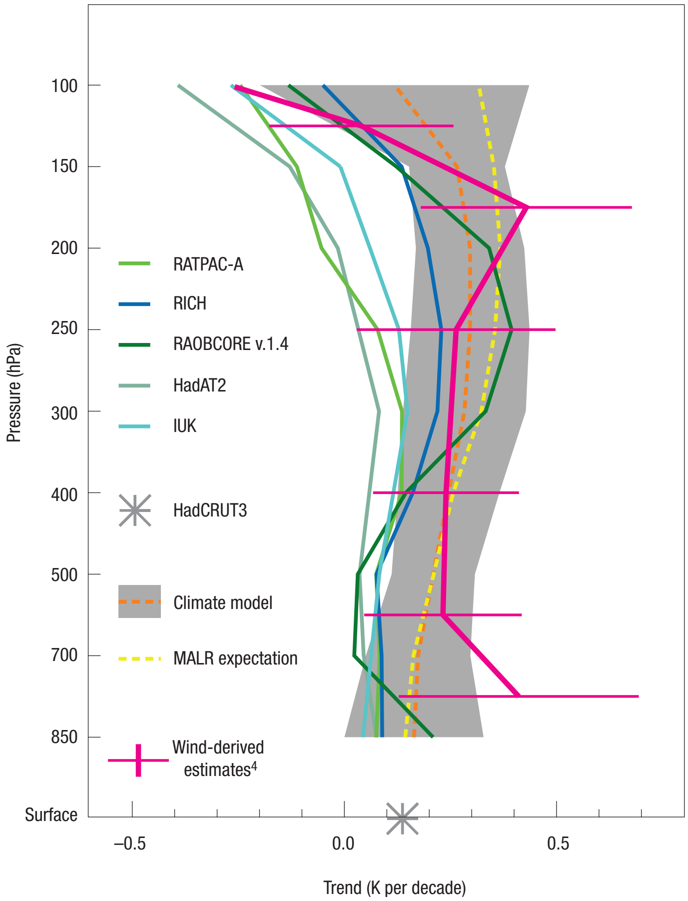

Figure 1 Vertical profile of tropical mean temperature trends. Trends reflect the mean change in temperature (in K per decade) between 20° N and 20° S for the period 1979–2005, obtained from radiosonde temperature measurements[5] (blue and green colours), climate models[8] (dashed orange, with grey shading indicating 2-sigma range) and the new reconstructions from radiosonde winds[4] (pink, with error bars indicating 2-sigma range). The surface temperature change[11] from 1979–2005 (grey asterisk) and the vertical profile inferred from the moist adiabatic lapse rate (dashed yellow) are also shown. The model range was derived by scaling the model vertical trend behaviour (which has been shown to be tightly constrained[8]) and its uncertainties[8] by the surface trend. Prior to 2007, only the HadAT and RATPAC estimates existed, and a case could be made for a fundamental discrepancy between modelled and radiosonde observed behaviour.

The uncertainty with respect to upper air temperature estimates in the tropics is so substantial that we can draw no meaningful conclusions as to whether or not there is a discrepancy between long-term trends in the real world and our expectations from climate models[3,5] (Fig. 1). This is not simply an interesting academic aside — not knowing where observational problems begin and modelling limitations end undermines our ability to understand and predict global climate change.

In order to gauge upper air temperature change in the tropics in a fundamentally different way, Allen and Sherwood[4] exploit the thermal wind relationship, in which vertical gradients in wind are linked to horizontal gradients in temperature. At first glance this seems a rather convoluted way of measuring temperature change, but on closer inspection this methodology may have some compelling advantages. In particular, whereas temperature measurements have relied on an ever-evolving technology, wind measurements are supported by ground-tracking and, more recently, global positioning satellites. The up shot? There are approximately ten times fewer discontinuities in the wind records than the temperature records[6], making wind measurements a potentially more reliable indicator of long-term trends than temperature measurements.

There are, of course, potential limitations in our ability to exploit the wind records in this way. In particular, on weather timescales (days) the relationship between wind and temperature breaks down near the equator. However, this doesn't seem to be a problem on multi-decadal climate timescales, where the pattern of wind-derived temperature change matches satellite estimates that we believe to be reasonably accurate, at least in their portrayal of spatial trends[7]. Given the diverse characteristics of the radiosonde stations in the equatorial region, these results are unlikely to arise from chance alone. In addition, Allen and Sherwood[4] show that climate model simulations obey the thermal wind relationship on climate timescales. A more significant limitation, perhaps, is that winds do not inform us of absolute temperature trends — they can only tell us how one location's temperature is changing relative to another location's temperature. Thus, to retrieve absolute trends requires a specification of 'truth' at some well-defined place. Given our poor knowledge of the true temperature trends anywhere in the tropics, this leads to a potentially large uncertainty. Integrating from increasingly distant but accurately known temperature trends in the northern mid-latitudes, where the network sampling is denser and the observations have been made with greater fidelity, can mitigate, but not remove, this effect.

So are we any closer to resolving the riddle of tropospheric temperature change? It seems we're getting there. Allen and Sherwood[4] give evidence for a strong warming in the tropical upper troposphere, providing long-awaited experimental verification of model predictions. Furthermore, the warming they observe reaches its maximum just below the tropical tropopause. Such amplification of surface warming is expected on theoretical grounds, and is indeed found on monthly to inter-annual timescales by both models and observational estimates[8]. However, it has been absent in almost all observational estimates on decadal timescales — upon which non-climatic artefacts project most strongly. The new analysis[4] adds to the growing body of evidence suggesting that these discrepancies are most likely the result of inaccuracies in the observed temperature record[3,5,8] rather than fundamental model errors (Fig. 1).

Of course, the long-term homogeneity of the wind data, that is, the absence of spurious trends through changes in observational methods, requires further assessment. We also need to understand the sources of error inherent in direct temperature measurements and the datasets derived from these before we can confidently reject them in favour of this new analysis. Undoubtedly the wind data is a powerful tool, but alone it is not the golden bullet.

Finally, this story of tropical tropospheric warming highlights the fact that monitoring climate change requires a fundamentally different observational approach to that used in weather forecasting. For this reason, it is imperative that we whole-heartedly pursue activities that lead to robust, highly accurate and inter-calibrated ground-based[9] and space-based[10] data sets.

Published online: 25 May 2008.

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