Falling satellites, rising temperatures?

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Satellite-based estimates of trends in atmospheric temperature have disagreed with estimates derived from other measurements. By taking into account declines in the orbital height of satellites, re-examination of those satellite data yields results that are in better accord with independent evidence of global warming.

There is no single, definitive, long-term record of global atmospheric temperatures. So, in their attempt to detect evidence of global warming (or otherwise), climatologists must try to make sense of temperature-trend results from a variety of imperfect measurement systems. In 1995, the Intergovernmental Panel on Climate Change reported[1] agreement among a group of datasets (including weather observations at the surface and from balloons, and data on sea ice, mountain glaciers and underground temperatures) showing that, over the past century, near-surface atmospheric temperatures have risen.

For the past 19 years, temperature measurements have also been made from space. For the lower part of the troposphere (the troposphere is the region of the atmosphere extending from the ground to about 10–15 km), these satellite-derived temperatures have, by contrast, shown slight cooling. This discrepancy has been controversial in the climate research community, and often features in broader discussions about environmental policy. On page 661 of this issue[2], Wentz and Schabel now present a correction to the satellite data that changes the lower-tropospheric trend from cooling to warming.

The main deficiencies of the *in situ* measurements made at surface stations and from balloons are the uneven sampling of the global atmosphere and changes in temperature-measurement systems over time[1]. Polar-orbiting satellites largely overcome the global sampling problem by making measurements over most of the planet. Since 1979, a series of eight different NOAA (National Oceanic and Atmospheric Administration) polar-orbiters have carried microwave sounding units (MSUs) that measure the radiation emitted by atmospheric oxygen near a frequency of 60 GHz. Changes in the strength of this radiation can be attributed to changes in the internal energy of the oxygen molecule, which is directly related to the temperature of the atmosphere itself.

By combining MSU observations from the NOAA satellites, Spencer and Christy[3] developed the first satellite-derived dataset of global atmospheric temperatures. Temperatures in a relatively thick layer, mostly in the mid-troposphere but including part of the lower stratosphere (the atmospheric region above the troposphere), are based on MSU radiation measurements obtained near nadir, when the instrument is looking more or less straight down. Temperatures in a lower layer are derived using MSU data from both near-nadir and off-nadir (near-limb) observations, as shown in Fig. 1. Because the near-limb observations are more sensitive to temperature in the upper troposphere and lower stratosphere, subtracting near-limb observations from near-nadir measurements yields an estimate more representative of the lower troposphere.

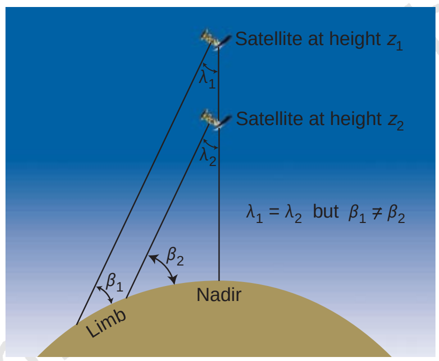

Figure 1 **Angles on temperature trends in Earth's atmosphere (not to scale). A change in the height (*z*) of polar-orbiting satellites has little influence on near-nadir measurements of temperature. But as instruments scan away from a nadir, the interpretation of near-limb measurements (at angle λ) requires knowledge of the angle β, as described by Wentz and Schabel[2]. Incorporating changes in *z* (and thus in β) in data from satellite-borne microwave sounding units, Wentz and Schabel have derived new estimates of temperature trends in the lower troposphere which indicate warming rather than cooling.**

Unexpectedly, Spencer and Christy's analysis revealed different trends in these two layers, with the mid-troposphere showing warming and the lower troposphere showing cooling. Because this result ran counter to expectations about the nature of variations in global climate, and because the other records indicated warming over this period, researchers naturally looked for flaws in the analysis. Among the suggestions offered are that the data from different satellites are inconsistent[4,5] or that they are contaminated by microwave emissions from solid and liquid water in the atmosphere[6,7]. Nonetheless, the proponents of the MSU results have stood by their conclusions[8,9].

Wentz and Schabel[2] have brought to light a neglected aspect of the MSU data that influences the inferred lower-tropospheric temperature trends. The height of a satellite's orbit decreases slightly over time because of the drag of the atmosphere on the satellite. This effect increases during periods of high solar activity, because increased solar ultraviolet radiation warms the upper atmosphere and there are more frequent collisions of air molecules with the satellite (see Figs 1 and 2 on pages 662 and 663, respectively). As the satellite falls, the near-nadir measurements are not much affected. But the near-limb measurements are more seriously influenced because of the change in the MSU's angular view of the surface (Fig. 1). Spencer and Christy used periods of data overlap to merge data from sequential satellites, and this technique may have compounded the effects of orbital decay on data from each successive satellite.

Correction for this 'falling-satellite' effect brings the trends in the lower and mid-troposphere into much closer agreement. In fact, the correction term developed by Wentz and Schabel dominates the new lower-tropospheric trend for 1979–95. Before the correction, the MSU data showed the mid-troposphere to be warming at 0.03 °C per decade and the lower troposphere to be cooling at 0.05 °C per decade. After correction for the orbital decay, the lower troposphere shows warming of 0.07 °C per decade. Although this trend seems small, it is in line with longer-term estimates from surface data[1].

Before making too much of these new indications of warming, we should recognize some limitations in the satellite record. The trends presented cover a period of less than two decades and, given the variability of the global atmosphere and the multiplicity of potential sources of error, we cannot accurately estimate their confidence intervals. Wentz and Schabel estimate the lower tropospheric trend confidence interval as at least ±0.05 °C per decade, at the 80% confidence level, which is much lower than the more commonly used 95% or 99% confidence level, and the trends in question are quite possibly not statistically significant at those higher levels. Viewed in this light, the discrepancy between cooling of 0.05 °C per decade and warming of 0.07 °C per decade may be less notable than it appears.

Furthermore, the mere fact that inclusion of the effects of satellite orbital decay on the trend can completely change its sign makes one wonder what other factors may be influencing the apparent trends. Assiduous analysis of both the satellite and *in situ* datasets has revealed progressively more about the error characteristics of the data and their trends; nevertheless, much remains to be done to resolve differences among them.

The crux of the matter is that climatologists are relying on systems that were never designed for climate monitoring. Various groups have advocated improved observational networks[10,11], but they have yet to be realized. Complementary satellite and *in situ* observations could provide the global coverage and vertical resolution needed for reliable estimation of temperature trends in the troposphere and stratosphere.

Lessons from the analyses of MSU data can be applied to the development of a satellite-based climate monitoring system — obtaining the data needed for credible estimates of temperature trends requires attention to instrument calibration, continuous monitoring of the satellites for potential drift in the observations, sufficient overlap between successive satellites, and a commitment to a long-term programme of observations. *In situ* observations could be obtained from a radiosonde (weather balloon) network dedicated to climate research. Weather services around the world currently launch various types of expendable, and therefore relatively inexpensive, instruments to obtain temperature profiles for weather forecasting, and the types of instruments change frequently. A radiosonde network for climate monitoring could employ a standardized instrument with better accuracy and precision.

In short, we have to decide if we are really interested in monitoring the health of the Earth's atmosphere. If we are, more sophisticated arrangements for tracking the patient's temperature are needed. □

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Cancer

Awakening angels

David Lane

When normal mammalian cells are subjected to stress signals — oxygen deficiency, radiation, DNA damage or chemotherapeutic drugs, for example — the 'guardian of the genome', p53, is woken up. Then, p53-dependent gene transcription is increased and ubiquitin-dependent degradation of the protein is blocked, all of which leads to the p53-mediated induction of programmed cell death and/or cell-cycle arrest. But how do such stress signals awaken p53? One idea is that stress-activated protein kinases modify p53, protecting it from degradation and activating its function as a transcription factor. In support of this theory, many phosphorylated forms of p53 are found in cells. Moreover, p53 can exist in a latent state that cannot bind DNA, and it can be released from this state by phosphorylation.

On page 700 of this issue, Woo *et al.*[1] present striking evidence that the DNA-dependent protein kinase (DNA-PK) is required for the p53 response to occur (Fig. 1a). This enzyme has long been an attractive candidate because it is activated by DNA damage, and p53 was one of its first substrates to be described. Furthermore, DNA-PK modifies the critical amino-terminal region, which controls the interaction of p53 with the transcriptional apparatus and with MDM2 (a protein that regulates p53)[2].

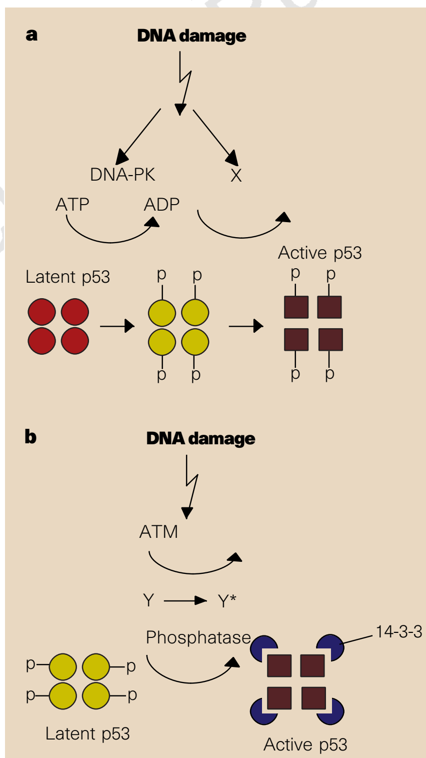

Figure 1 **Possible ways to activate the p53 response.** a, **p53 is made in an inactive latent state. Woo *et al.*[1] have shown that the DNA-dependent protein kinase (DNA-PK) is needed to activate DNA binding and transcription by p53, and another factor (X) from nuclear extracts of irradiated cells is also required.** b, **p53 is made in an inactive latent state. It is phosphorylated but remains inactive until DNA damage activates the ATM kinase. ATM activates a p53-specific phosphatase (Y) that removes phosphate from serine 376, allowing 14-3-3 proteins to bind to the carboxy terminus of p53 and activate DNA binding and transcription.**

Enthusiasm for DNA-PK has, until now, been tempered by the finding that mice with severe combined immunodeficiency (SCID), which have a genetic defect in DNA-PK, can nevertheless respond to DNA damage in a p53-dependent manner[3,4]. Thus, attention shifted to other related protein kinases that can either directly or indirectly affect phosphorylation of p53. These include the ATM protein, which is defective in patients with ataxia telangiectasia (AT)[5,6], and related ATR kinases.

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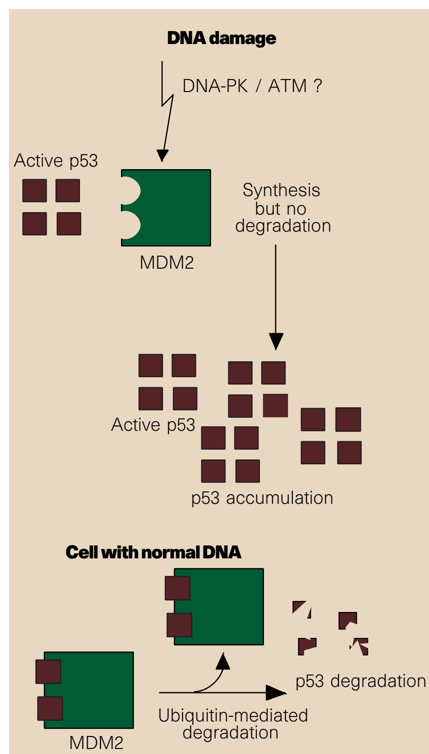

Figure 2 **Another model for activation of p53. p53 is active in normal cells, but at a low level because it is constantly targeted for inactivation and degradation by MDM2. DNA damage blocks MDM2 or other components of the p53-degradation pathway, so that high levels of active p53 can now accumulate and, at this high concentration, may become phosphorylated.**