Satellite greenhouse signal

SIR — The temperature of the global atmosphere, particularly the lower troposphere (the lowest 7 km), is expected to rise because concentrations of gases such as carbon dioxide are increasing. Sophisticated yet still relatively idealized ocean–atmosphere models indicate that the temperature of this layer will rise at a rate of 0.3 to 0.4 °C per decade[1,2]. This layer has been monitored since January 1979 by microwave sounding units (MSUs) on polar orbiting satellites, providing perhaps the best measurement of the Earth's air temperature in terms of its global coverage and precision[3]. The length of this satellite record, however, is relatively short for determining climate trends.

The unadjusted 15-year global MSU data (T_{2R}) reveal a trend not significantly different from zero (curve *a* in the figure). Herein lies the issue at hand. In this period, as greenhouse gases have increased rapidly and given that their accumulated effects should be quite apparent by now, why is there no observed warming?

The answer, apparently, is that there were temperature-related events other than enhanced greenhouse warming in the atmosphere during this period. Two large volcanic eruptions, El Chichón in 1982 and Mount Pinatubo in 1991, have caused periods of reduced solar radiation, and therefore cooling[4]. Four El Niño–Southern Oscillation (ENSO) events have also been observed. Our goal is to calculate and then remove these ENSO and volcanic effects from the measurements and to examine what remains.

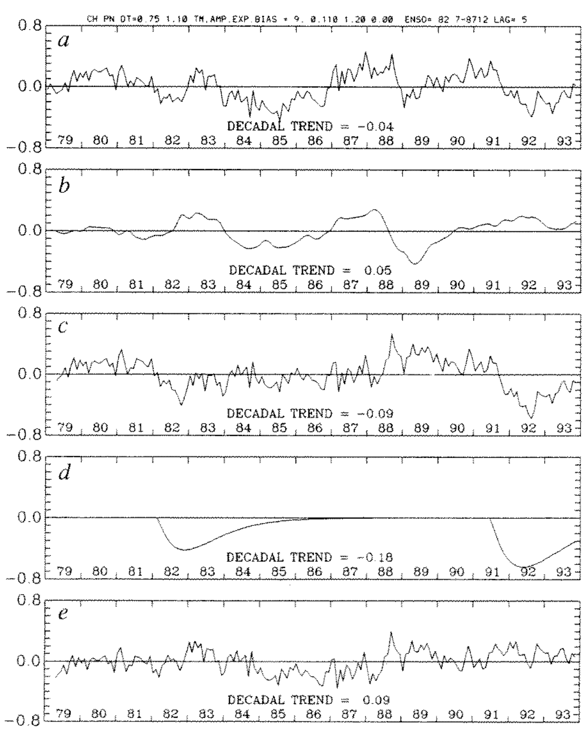
The ENSO signal on T_{2R} is taken from the sea surface temperatures (SSTs) of two tropical Pacific regions, Niño 3 and 4 (refs 5–7). A simple linear regression of the SSTs in these regions against the global T_{2R} explained the most variance (69.7%) when the atmosphere lagged behind the SSTs by 5 months. A 5.5-year period (July 1982 to December 1987) was the best for calibrating the influence of ENSO on T_{2R}; further testing showed no dependence between the effects of El Chichón and the 1982–83 ENSO. This ENSO effect is shown in curve *b*.

Sulphur compounds are often injected into the stratosphere during volcanic eruptions and, when in contact with water, may become aerosol particles of sulphuric acid. These aerosols can scatter sunlight back to space, resulting in less solar energy reaching the lower atmosphere and therefore cooling it[4,8]. These same aerosols also trap thermal energy coming from below, leading to a warming of the stratospheric air. The warming in the MSU stratospheric temperature (MSU 4 or T_4) after the eruptions, then, can represent the magnitude of the volcanic shading effect[9]. We found the temperature increases (ΔT_4) to be 0.75 and 1.10 °C for El Chichón and Mount Pinatubo, respectively. We devised a formula in which the ΔT_4 predicts the magnitude and duration of the T_{2R} cooling

$$T_{2R:VOL} = \alpha\, j^{\gamma} \exp(-j/\tau),$$

where $\alpha = \alpha_0\, (\Delta T_4)^{0.5}$; j is months since eruption; $\gamma = \gamma_0$; and $\tau = \tau_0\, (\Delta T_4)^{0.5}$.

We selected the coefficients α_0, τ_0 and γ_0 (0.11, 9.0 and 1.20, respectively) to fit the observations (curve *c*) of the volcanic impact on T_{2R}. This effect is shown in *d* and the resultant global temperature, once ENSO and volcanoes are removed, is shown in *e*. There was little flexibility in selecting the coefficients because of the fitting requirements. Other simulations for *e* all gave trends within the 0.08–0.09 °C range.



a, Monthly global anomalies of T_{2R} (relative to the base period 1982–91) to November 1993 (°C); *b*, ENSO effect from SSTs; *c*, curve *a* minus *b*; *d*, volcanic effect; *e*, residual time series after ENSO and volcanic effects removed.

Curve *e* reveals an upward trend of +0.09 °C per decade, or about one-quarter of the magnitude of climate model results. Although this residual trend could be greenhouse warming, other factors whose effects are less quantifiable (for example cooling via tropospheric aerosols or fluctuations resulting from solar variations) may also be involved.

Observational detection of the enhanced greenhouse signal is critical in evaluating how the Earth system reacts to increases in infrared-active trace gases, and how well climate models portray the atmosphere. Because of its global coverage, precision and measurement layer (where the global signal should be largest), the MSU temperature record perhaps offers the best opportunity for finding the greenhouse signal in a single variable.

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