αβ receptors, and their function is poorly understood. As Zijlstra *et al.* delicately intimate, this calls into question hypotheses that γδ T-cell receptors are thymically selected to interact with CD1 and various non-classical class I MHC antigens, all of which are β2-m associated[13]. As cellular immunologists acknowledge, almost any desired T-cell specificity can be found providing one looks hard enough. So the observed interactions between γδ T-cell receptors and non-classical class I molecules might be fortuitous cross-reactions, such as are occasionally found with monoclonal antibodies. The evidence now accumulating suggests that many non-classical class I molecules are evolutionary remnants of little functional consequence for the contemporary immune system[14]. The same may well be true for the γδ T-cell receptor: time and targeted gene disruption will tell. □

Peter Parham is in the Department of Cell Biology, Stanford University, Stanford, California 94305, USA.

GREENHOUSE EFFECT

Satellite data under scrutiny

P. D. Jones and T. M. L. Wigley

A NEW study, published in *Science*[1], presents the results of ten years of global temperature estimates from satellite-based radiometers. In their analysis, Spencer and Christy say that their estimates show no evidence of warming over this ten-year period. This conclusion, reasonable enough in itself, is unfortunate because taken out of context it is open to the interpetation that the authors have found no evidence for global warming in general — that indeed is the way the study has been widely reported. Yet the data themselves are of considerable value and add another dimension to the analysis of temperature trends.

The radiometers (microwave sounding units or MSUs) were installed on the TIROS-N series of satellites first launched by the National Oceanic and Atmospheric Adminstration (NOAA) in late 1978. They measure the temperature-dependent thermal emission of oxygen at four frequencies near 60 gigahertz; as oxygen concentrations are relatively constant in space and in time, the emissions can be interpreted as indicators of temperatures. The different frequency bands or channels can be combined to give an indication of the average temperature of the lower atmosphere from the surface to around 10 km. These data can than be spatially averaged to estimate global-mean values. Cross calibration of the results of the NOAA-6 and NOAA-7 satellites over the period when they were both in orbit enables the length of the temperature record to be extended to ten years.

In assessing these data, one must be careful to avoid comparing apples and oranges. The MSU data represent an unequally weighted average temperature of the troposphere, with the largest weight on the zone of the atmosphere which lies between the pressure levels of 850 and 500 hectopascals, about 1.5 to 5 km. It would therefore be most appropriate to compare these data with conventional radiosonde data for the free atmosphere. Instead, Spencer and Christy make comparisons with surface data. This is still useful — after all apples and oranges are both round fruits, and surface and free atmosphere data do correlate well[2] — but the comparison fails to do justice either to the satellite data or the surface data. When global annual mean MSU data are correlated with mean temperatures between 850 and 300 hPa (ref. 3), the agreement is excellent (r^2=0.94, n=10), providing mutual support for both types of data (see table). The correlations become less strong on smaller spatial and temporal scales — understandably so, because the MSU data do not fully reflect the 850–300 hPa mean temperature.

Correlations with the land-based[4,5] and land-plus-marine temperature data[6] are, as one would expect, less good. But they are better than the values given by Spencer and Christy, whose correlations are not always based on the full ten-year period. For global annual mean data the r^2 value is 0.86 (see table). The satellite data therefore show that worries about incomplete spatial coverage or data distortion due to urban warming effects in the ground-based data are probably unfounded. Further comparisons are required to assess the full value of the satellite data as an indicator of what is happening near the Earth's surface, and, in turn, to address the question of the coverage and quality of the surface data more fully.

Monthly, seasonal and annual explained variances between the MSU satellite temperatures and surface and 850 and 300 hPa temperature estimates, all calculated over 1979–88.

	NH (%)	SH (%)	GL (%)
Monthly			
Land[4,5]	23	11	32
Land and marine[6]	25	20	38
Seasonal			
Land[4,5]	37	32	47
Land and marine[6]	43	41	58
850–300[3]	58	35	60
Annual			
Land[4,5]	68	73	74
Land and marine[6]	70	60	86
850–300[3]	74	72	94

NH, Northern Hemisphere; SH, Southern Hemisphere; GL, global.

The authors claim that the radiometers should provide the standard for monitoring global temperatures. It would be more prudent, however, to consider them as complementary to the ground-based data, not as a replacement. Spencer and Christy also claim that differences between the various research groups[7,8] who have calculated hemispheric-mean temperature values have led to conflicting reports in the popular press.

This may be true, but the data sets themselves are not in conflict. The two land-data sets[4,5,8] are in excellent agreement (r^2 = 0.93 for global annual means over the 1881–1980 period). Confusion has arisen, however, with regard to the use, or otherwise, of marine data. The Hansen–Lebedeff[8] data are land only whereas the Jones *et al.* data[6,7] include both land and marine observations. Agreement between land-only and land-plus-marine data is also good[2,8], which is a further indication that incomplete coverage is not a serious problem.

The conclusion that there is no evidence of a warming trend over the past ten years contributes little to the debate about global warming in the long-term, in which it is the time series of temperature over the past century that must be considered. The land, marine and upper-air temperature records (see table) agree with the satellite data in showing no statistically significant increase in temperature over the past ten years. But these longer records do show that, relative to the earlier part of the century, the 1980s were unusually warm, being the warmest decade on record and 0.2 °C above the 1950–79 average. □

P. D. Jones and T. M. L. Wigley are in the Climatic Research Unit, University of East Anglia, Norwich NR4 7TJ, UK.

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