Monitoring global monthly mean surface temperature

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An assessment has been made of how well the monthly mean surface temperatures for the decade of the 1980s are known. The sources of noise in the data, the numbers of observations, and the spatial coverage have been appraised for comparison with the climate signal, and different analyzed results have been compared to see how reproducible they are. A more complete report is given in Trenberth et al. (1992).

A measure of the signal can be seen from the map of standard deviations of monthly mean anomalies from the full surface temperature data set used by the IPCC (1990) (Fig. 1). Over the oceans, sea surface temperatures (SSTs) are used in the surface data set in place of surface air temperature and the Comprehensive Ocean-Atmosphere Data Set (COADS) has been used to show that 80% of the monthly mean air temperature variance is accounted for in regions of good data coverage.

The sources of noise in estimating monthly mean SSTs from ship data can be divided up into (i) errors in making individual observations; (ii) incomplete sampling of the diurnal cycle; (iii) incomplete sampling of within-month variance other than the diurnal and seasonal cycles; (iv) within-month mean variance due to the seasonal cycle; and (v) incomplete sampling of the spatial gradients within a grid square. These problems are all present in COADS.

A detailed analysis of the sources of errors in situ SSTs and an overall estimate of the noise is obtained from the COADS by assessing the variability within 2° longitude by 2° latitude boxes within each month for 1979 (Table 1). In regions of small spatial gradient of mean SST, individual SST measurements axe representative of the monthly mean in a 2° box to within a standard error of 1.0°C in the tropics and 1.2 to 1.4°C in the extratropics. The standard error is larger in the North Pacific than in the North Atlantic and much larger in regions of strong SST gradient, such as within the vicinity of the Gulf Stream, because both within-month temporal variability and within-2° box spatial variability are enhanced. Part of this error is certainly associated with the within-month mean variance due to the seasonal cycle, e.g., see the change in one month given in Fig. 2. The total standard error of the monthly mean in each box is reduced approximately by the square root of the number of observations available (Fig. 3). The overall noise in SSTs ranges from less than 0.1°C over the North Atlantic to over 0.5°C over the oceans south of about 35°S. Greater daily variability in surface marine air temperatures (Table 2) than in SSTs means that two to three times as many observations are needed per month to reduce the noise in the monthly mean air temperature to the same level as for SST.

Tests of the reproducibility of SSTs in analyses from the U.K. Meteorological Office (UKMO) (Bottomley et al., 1990) and the U.S. Climate Analysis Center (CAC) (Reynolds 1988) and from

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COADS (Fig. 4) reveal correlations over 0.9 for most of the northern oceans and in the eastern tropical Pacific. Values drop to less than 0.75 south of about 10°N elsewhere and to much less than 0.5 in the central tropical Pacific and over the southern oceans, all regions where the numbers of months of data drop off. Correlations are also low and rms differences high near the coastal regions, evidently because of the land anomaly influence in the IPCC data set. Elsewhere, the rms differences between the analyses increase from less than 0.2°C over the central North Atlantic to over 0.6°C in the central tropical Pacific, in the eastern Pacific south of 10°S, and generally south of 35°S, except near New Zealand; all areas where the correlation drops to less than ~0.6.

With the marked exception of the eastern tropical Pacific, where the large El Niño signal is easily detected, there are insufficient numbers of SST observations to reliably define SST or surface air temperature monthly mean anomalies over most of the oceans south of about 10°N. The use of seasons rather than months can improve the signal-to-noise ratio if careful treatment of the annual cycle is included. For seasonal means, SST anomalies cannot be reliably defined south of 20°S in the eastern Pacific and south of ~35°S elsewhere except near New Zealand.

The results have implications for how SST data should be processed into means. The COADS SSTs are assembled into 2° boxes and monthly means, and are therefore subject to the significant sampling errors of type (iv) (not allowing for annual cycle variations during the month), and type (v) (not allowing for gradients across a box). The UKMO SSTs reduce but do not eliminate errors from these sources by using a working grid of 1° and 5-day time periods. Nevertheless, these two kinds of errors could be avoided altogether by defining a good background climatological mean field for each month and calculating the anomaly value for each observation relative to the exact interpolated mean value for that location and that day of the year. Errors of type (ii) from the diurnal cycle might be reduced by ensuring, wherever possible, that uniform sampling of the time of day occurs. Other sampling errors (types (i), measurement errors, and type (iii), real within-month variability) can only be reduced by sufficient numbers of observations to beat down the random component.

References

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Table 1. Robust estimates of the within 2° latitude x 2° longitude boxes and within-month SST standard deviations in °C for the areas given and average number of observations per month used to make the estimate, for the year 1979. Boxes were excluded if they contained less than 16 observations per month and if the gradient in SST between any adjacent box was greater than 3°C. Also given is the number of 2° boxes used and the average number of observations per box for those that qualified.

	Area						
	N.Atlantic	Tr. Atlantic	S. Atlantic	N. Pacific	Tr. Pacific	S. Pacific	Indian O.
Year	1.15	0.95	1.03	1.42	1.05	1.23	0.92
Obs/Mo	19180	5513	460	19384	2428	683	3255
No. boxes	353	124	13	435	67	25	73
Obs/box	54	44	35	45	36	27	45

Table 2. Robust estimates of the within 2° latitude x 2° longitude boxes and within-month marine air temperature standard deviations in °C for the areas given and average number of observations per month used to make the estimate, for the year 1979. Boxes were excluded if they contained less than 16 observations per month and if the gradient in SST between any adjacent box was greater than 3°C. Also given is the number of 2° boxes used and the average number of observations per box for those that qualified.

	Area						
	N. Atlantic	Tr. Atlantic	S. Atlantic	N. Pacific	Tr. Pacific	S. Pacific	Indian O.
Year	1.75	1.16	1.27	2.03	1.36	1.58	1.17
Obs/Mo	21284	6289	582	21153	2782	1168	3682
No. boxes	369	136	16	461	74	40	83
Obs/box	58	46	36	46	38	29	44

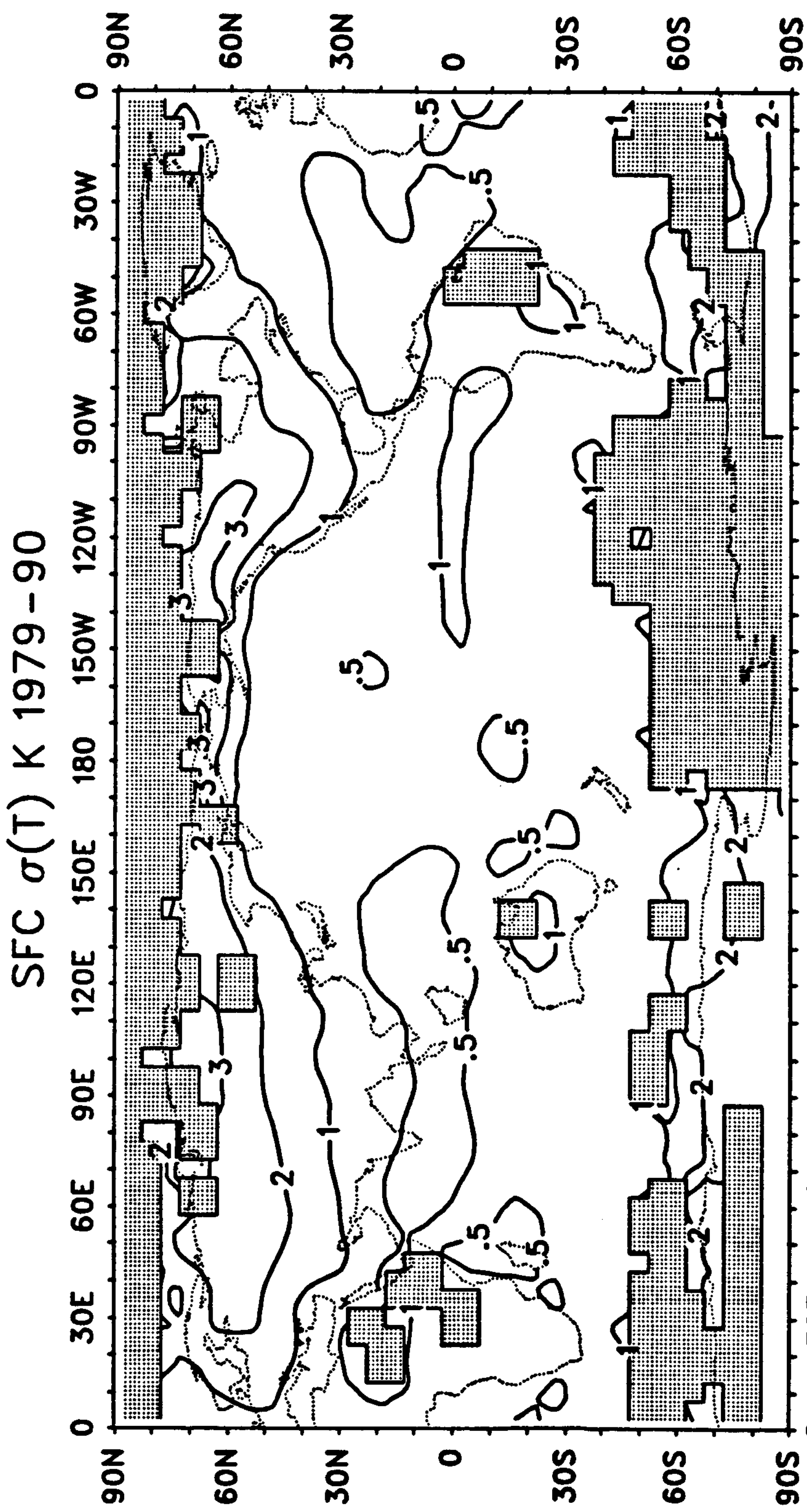

Figure 1. Standard deviation over 144 months from 1979-1990 of surface temperature anomalies. Contours are 0.5, 1.2 and 3 K. Areas of missing data are indicated by stippling.

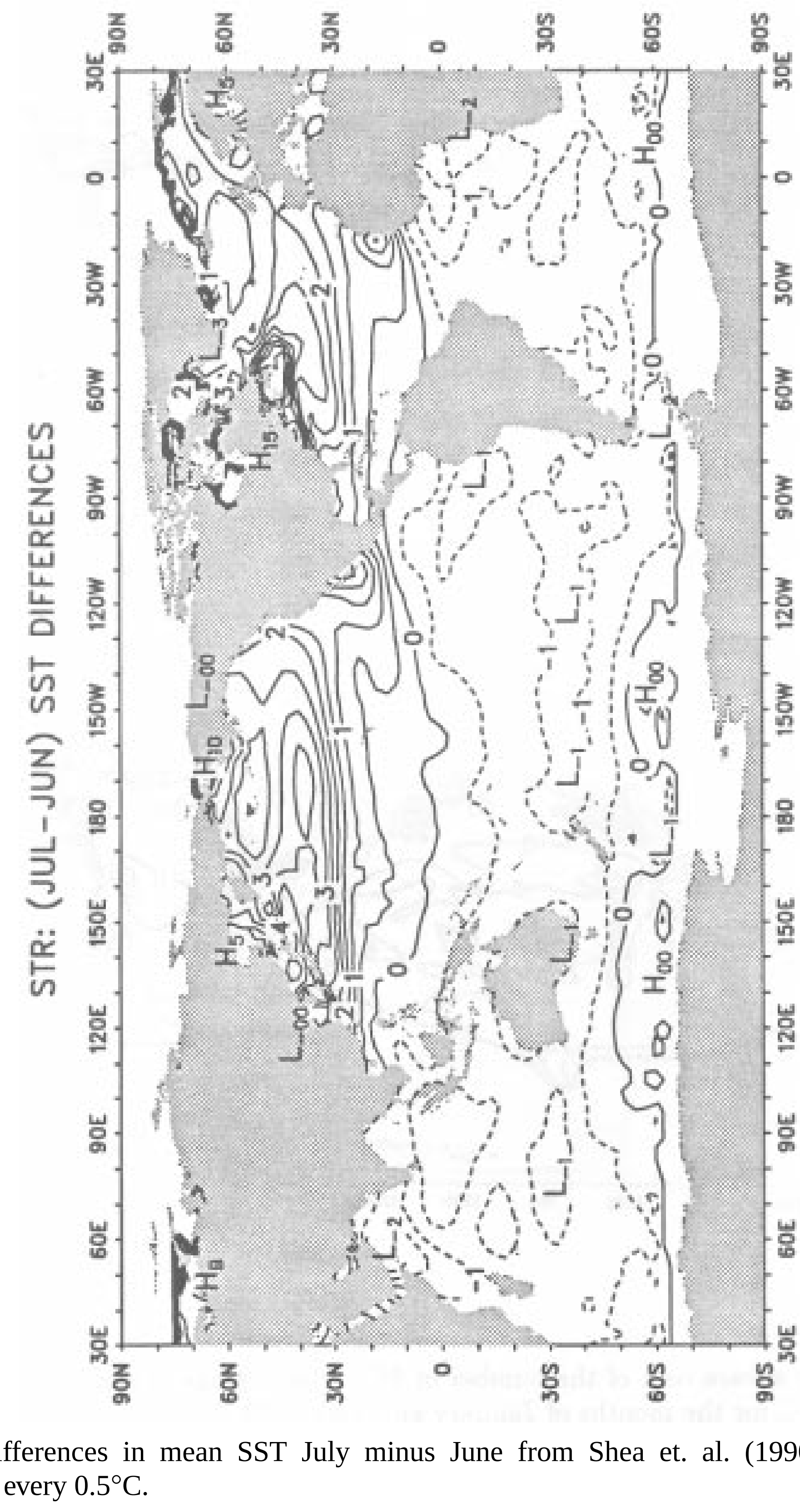

Figure 2. Differences in mean SST July minus June from Shea et. al. (1990) climatology. Contours are every 0.5°C.

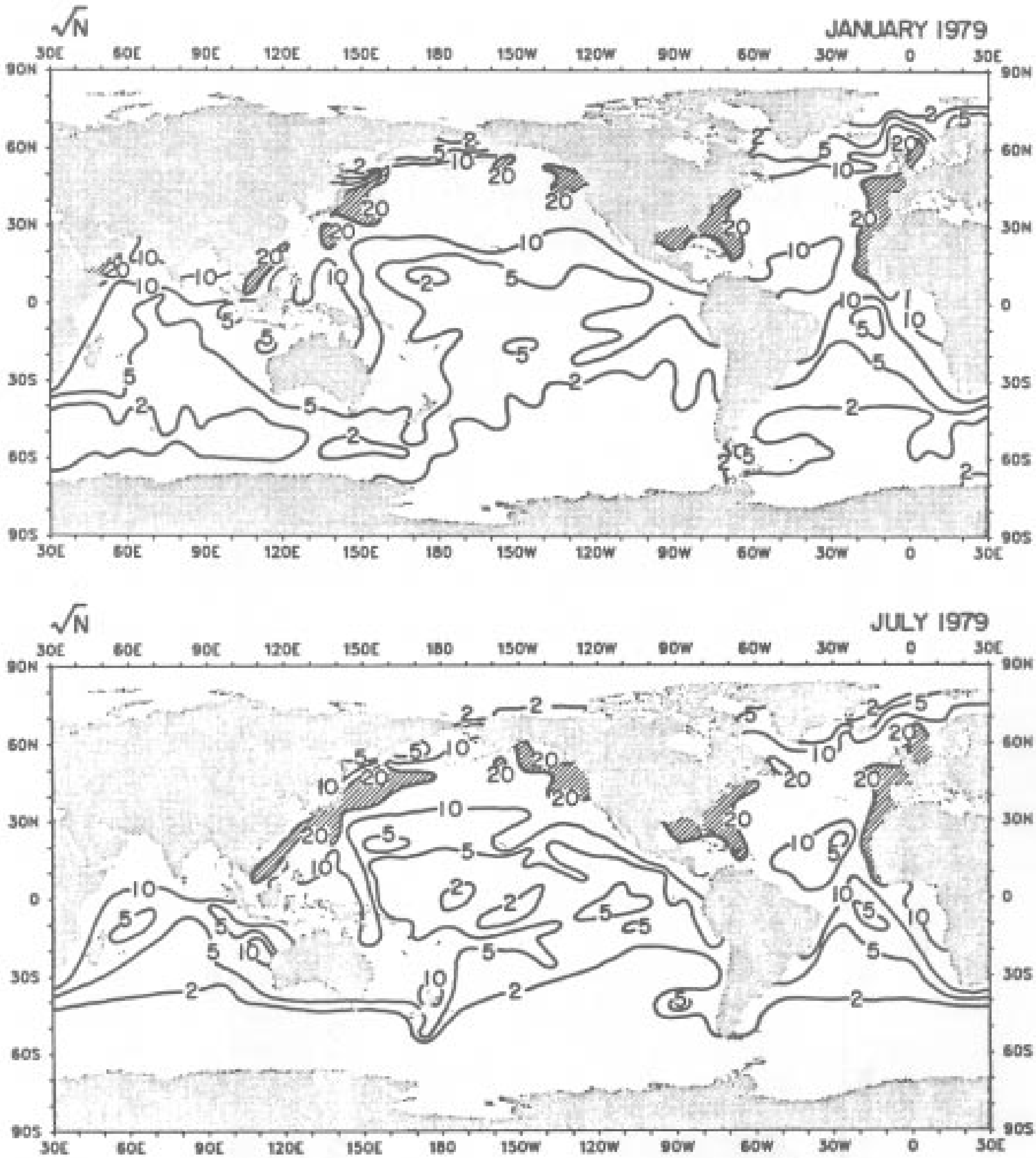

Figure 3. Maps of the square root of the number of SST observations in each 5° by 5° box from COADS for the months of January and July 1979.

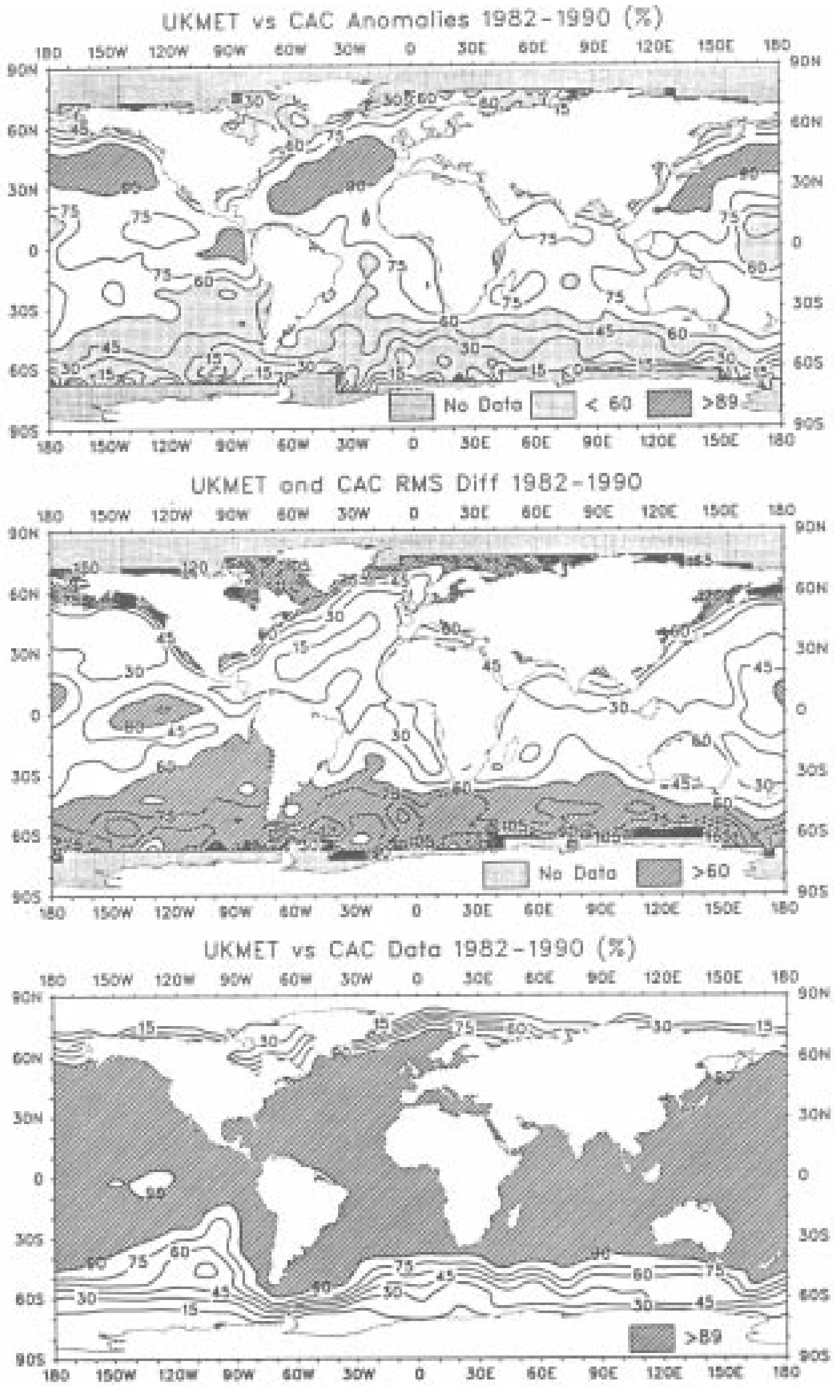

Figure 4. Top: correlation coefficient (x 100) between SST anomalies from the UKMO and CAC analyses for 1982 through 1990 (108 months), values greater than 0.9 are cross hatched, values less than 0.6 are stippled, and area of no data are fine stippled. Middle: Root mean square differences between the monthly anomalies in hundredths °C, values exceeding 0.6°C are cross hatched. Bottom: percentage of months available for the other plots; values greater than 90% are cross hatched.