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Estimate of the Global Change in Temperature, Surface to 100 mb, Between 1958 and 1975

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ABSTRACT

The global variation in temperature during the period 1958–75 is investigated using a sample of 63 radiosonde stations. The surface temperature as well as the mean temperature in 850–300 mb and 300–100 mb layers is examined, the latter based on thickness analysis. Between 1958 and 1965 there was a significant cooling averaging about 0.3°C over much of the globe, but since 1965 the temperature variations have been small. During the past few years there has been a slight warming in most latitudes. The meridional temperature gradient between the tropics and temperate latitudes has continuously increased, but since 1965 the temperature gradient between temperate and polar latitudes has decreased, with an especially large surface warming indicated for Antarctica. In the tropical troposphere, a temperature oscillation of about 3-year period and 0.3°C amplitude has been dominant since 1965. The eruption of Mt. Agung in 1963 may have decreased the surface temperature by as much as 0.2°C in the tropics, 0.4°C in the south extratropics and 0.6°C in the north extratropics. In the south extratropics there was also a 0.7°C warming and cooling in the 300–100 mb and 850–300 mb layers, respectively, in the year of the eruption. Also shown is the variation with longitude of the temperature changes and the tendency for increased spatial variability of temperature.

1. Introduction

A previous article (Angell and Korshover, 1975) provided an estimate of tropospheric temperature changes during the period 1958–73, based on an analysis of thickness changes between 700 and 300 mb at 45 radiosonde stations fairly evenly distributed about the world. It was shown that the temperature changes deduced thereby agreed reasonably well with the changes obtained by Starr and Oort (1973) and by Dronia (1974) using analyzed maps. In view of the ever-increasing interest in climatic variations, as expressed, for example, by the recent works of van Loon and Williams (1976a,b) and Brinkmann (1976), the latter involving an update of the temperature trends of Mitchell (1961), it was decided to expand this previous effort both with regard to the number of radiosonde stations used and the levels for which data were obtained, with the primary purpose of setting up a crude data base for global temperature monitoring. Consequently, in addition to the stations in polar, temperate and subtropical regions previously analyzed, an effort was made to establish an equatorial network and to expand the data in the vertical to the surface and the 100 mb level. It might be noted here that stations were selected not only to provide nearly equal longitudinal spacing of observations, but also with the hope that the stations would remain in operation for years to come, a ticklish choice in some areas.

Fig. 1 shows the location of the 63 radiosonde stations chosen to represent the seven climatic zones, i.e., north and south polar, north and south temperate, north and south subtropical and equatorial. Table 1 indicates the number of stations within each zone. The mean observational latitudes were about 70°N, 50°N, 20°N, 0°, 20°S, 40°S and 70°S, and for purposes of later synthesis it has been assumed that the equatorial zone extends from 10°S to 10°N, the subtropical zones from 10° to 30°, the temperate zones from 30° to 60°, and the polar zones from 60° to the Poles. Originally the attempt was made to obtain data approximately every 30° of longitude, feeling that such a spacing would provide adequate sampling. However, this turned out to be possible only in the north temperate and north subtropical zones (Table 1). Radiosonde data were particularly sparse in south temperate latitudes, the equal-spacing criterion limiting us to only six stations there.

The numbers in parentheses following some of the stations in Fig. 1 indicate the year data were first obtained (e.g., 67 signifies 1967) if the data record did not start in 1958. Note that only two of the equatorial stations have temperature records extending back to 1958, and this is the reason an equatorial network was not established for the previous paper. However, since we expect to monitor the temperature in the future using these same stations, it was thought desirable to

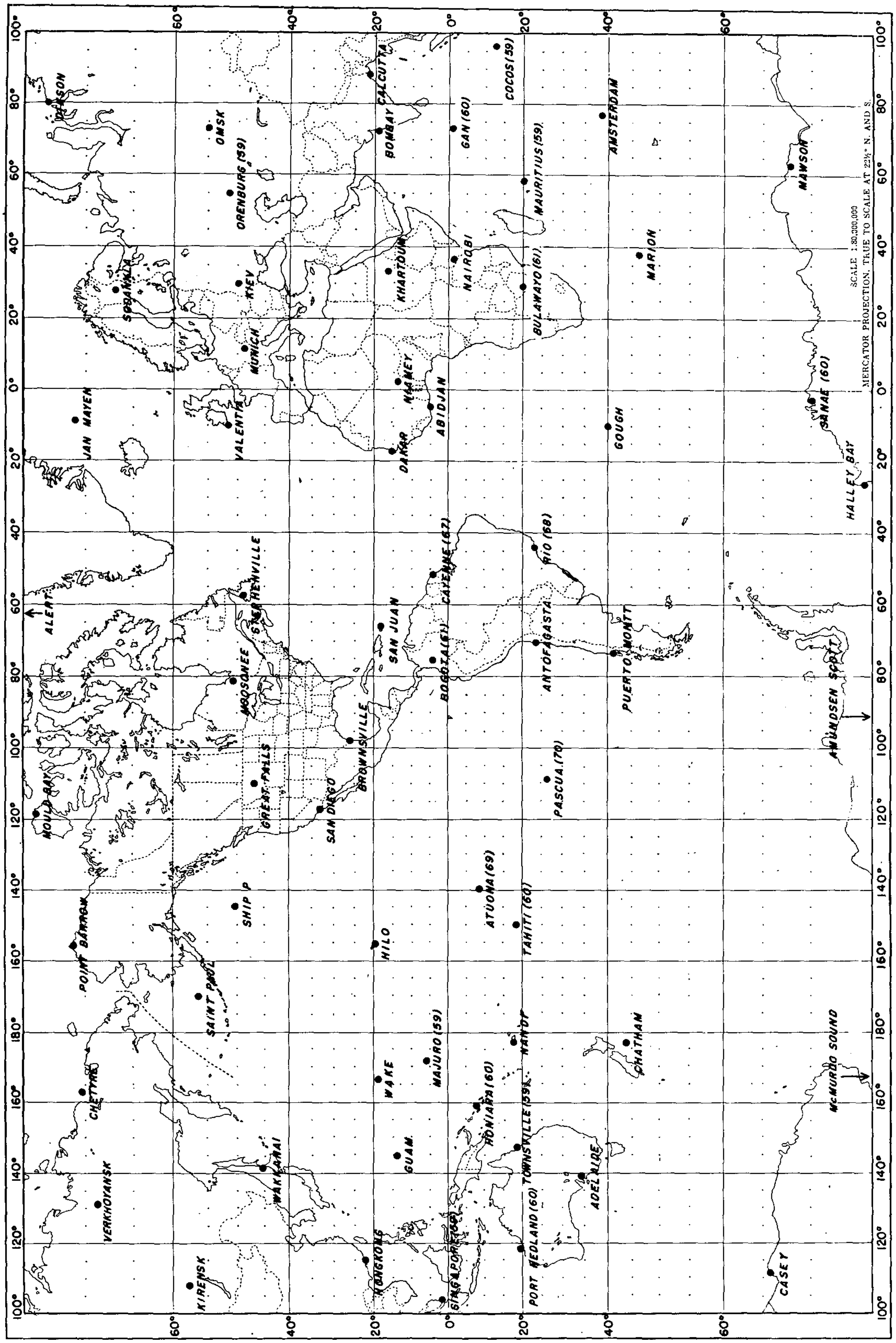

FIG. 1. Radiosonde stations used in the analysis. The numbers in parentheses indicate the first year for which data were available (e.g., 67 signifies 1967) for those stations whose data record did not begin in 1958.

TABLE 1. Smoothed temperature changes (°C) at the surface and within 850–300 mb and 300–100 mb layers for given time intervals and regions.

	Number of stations	1959–65			1965–71			1971–74		
		Surface	850–300 mb	300–100 mb	Surface	850–300 mb	300–100 mb	Surface	850–300 mb	300–100 mb
North polar	8	−0.53	−0.51	−0.58	0.25	0.08	−0.05	0.10	0	0.20
North temperate	12	−0.30	−0.22	−0.39	−0.12	−0.35	−0.18	0.02	−0.07	0.04
North subtropics	12	−0.09	−0.45	−0.32	0.06	−0.04	−0.32	−0.05	0.06	0.10
Equator	9	−0.06	0.02	−0.16	−0.01	0.10	0.20	0.06	0.05	0.11
South subtropics	10	−0.36	−0.37	0.05	0.01	0.17	0.14	0.06	0	0
South-temperate	6	−0.49	−0.53	0.11	−0.57	0.22	−0.51	−0.04	0.10	−0.15
South polar	6	0.32	0.17	0.14	0.25	0.30	−0.09	0.42	0.05	−0.10
North extratropics	20	−0.36	−0.30	−0.43	−0.02	−0.23	−0.15	0.04	−0.05	0.08
Tropics	31	−0.18	−0.27	−0.15	0.02	0.08	0.01	0.03	0.03	0.07
South extratropics	12	−0.29	−0.34	0.11	−0.36	0.25	−0.39	0.08	0.08	−0.14
Northern Hemisphere	37	−0.22	−0.29	−0.36	0.01	−0.11	−0.15	0.01	0	0.10
Southern Hemisphere	26	−0.27	−0.29	0.05	−0.17	0.21	−0.11	0.07	0.04	−0.06
World	63	−0.25	−0.29	−0.15	−0.08	0.05	−0.13	0.04	0.02	0.02

establish such a network even if the early data are somewhat unrepresentative.

While every possible effort was made to use the same stations in this analysis as in the previous one, some changes had to be made. Most important, the relocation of weather ships in the Atlantic (due to the withdrawal of United States support) made it impossible to use the radiosonde data from these ships for climatic purposes, and consequently Stephenville and Valentia were selected in order to minimize the Atlantic gap. Byrd station had to be dropped because it is now only a summer station, leaving a considerable gap also in the Antarctic coverage. Pretoria was replaced by Bulawayo because of a change in time of observation at Pretoria, a problem considered further in the next section. These and other considerations led to the sampling of radiosonde stations used and illustrated in Fig. 1.

Finally, in any analysis of this sort the problem of data accuracy and representativeness arises. It has been suggested, for example,[1] that the indicated temperature decrease in the early 1960's was at least partly due to the introduction of a correction for the radiative heating of the radiosonde, as well as a change in surface thermometer exposure. We believe it unlikely that such factors dominated the temperature trends during this period, but others may wish to comment on this matter.

2. Procedures

Mean-monthly values of the height of the 850, 300 and 100 mb pressure surfaces, as well as surface temperature, were obtained from the publication *Monthly Climatic Data for the World*, issued by the Environmental Data Service of the U. S. Department of Commerce, Asheville, N. C. In the case of missing data, the station-average value for that month from the entire period of record was inserted, yielding a conservative estimate for any trend. The mean-monthly data have then been averaged to yield year-average data. Based on the mean annual height values, yearly values of the "thickness" between 850 and 300 mb, and between 300 and 100 mb, were determined and transformed into mean annual temperatures. Because of the station altitude, at Bogota and Nairobi it was necessary to use the 700–300 mb thickness and at Amundsen Scott (South Pole) the 500-300 mb thickness. The Indian stations of Bombay and Calcutta did not report 100 mb heights until 1963, so the 300-100 mb thickness is missing from these two stations until that time.

Every effort has been made to ensure that the observation time at any given station remained the same during the period of record, but because of the uncertainty in this time in some cases, there may still be an occasional problem along this line. However, the data sample is sufficiently large that any discrepancy of this nature should have only a minor effect on the results presented.

In order to integrate the results obtained for the previously defined seven climatic zones, the temperature data (as well as the error estimates) have been weighted by the area of the earth's surface these zones represent in order to obtain a tropical average (30°N–30°S) and two extratropical averages (30°N–90°N and 30°S–90°S). The mean of the tropical and the two extropical values yields, of course, the global average temperature value. Finally, a vertically averaged (by mass) value of the temperature has been obtained by weighting the temperature by the pressure interval of the layers used (550 and 200 mb, respectively) and

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[1] Sid Teweles, personal communication.

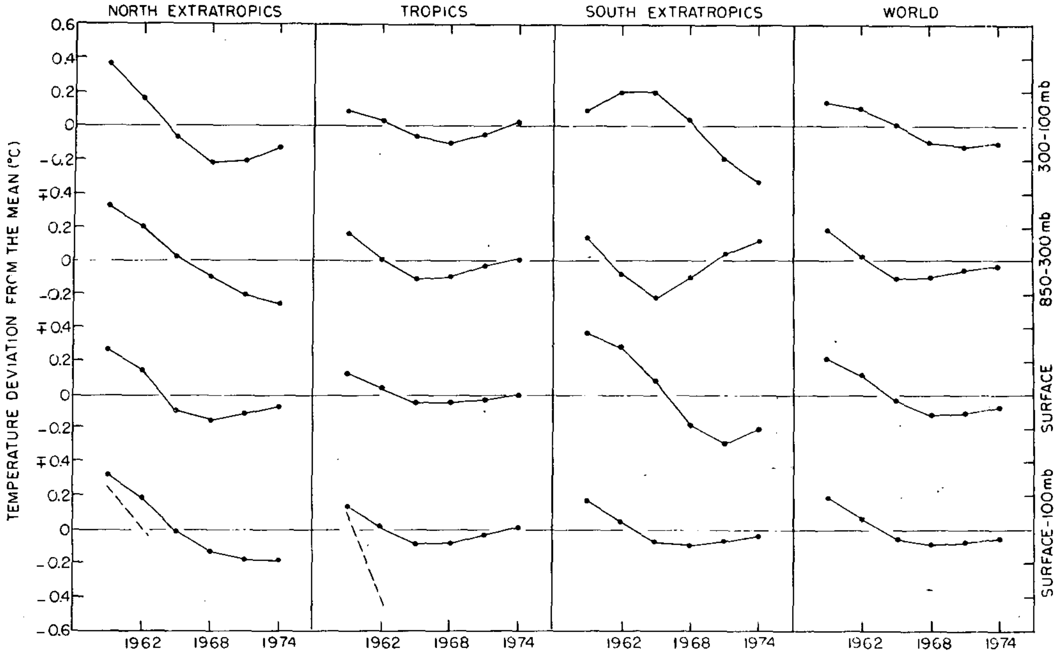

FIG. 2. Temperature trend as a function of climatic region and height, as determined from a 1-2-1 smoothing (divided by 4) of successive 3-year block-average values of the temperature deviation from the record mean. The bottom traces represent the vertically averaged (by mass) temperature trends, with the dashed regression lines indicating the vertically averaged (surface to 50 mb) temperature variations obtained by Starr and Oort (1973) for the north extratropics and north tropics.

assuming that the surface temperature applies to the layer 1000–850 mb (150 mb weighting).

3. Temperature trends

Fig. 2 shows the temperature trends in the tropics and extratropics obtained by applying a 1-2-1 smoothing (divided by 4) to successive 3-year block-average values of the temperature deviation from the record mean (2-1 and 1-2 smoothing at beginning and end of record). Obviously, this is a very severe smoothing since it involves, in effect, averaging over 9 years, but was necessary in order to obtain a smooth variation suitable for an overall impression. The results are as follows:

1) In the north extratropics the cooling was fairly uniform in the 850–300 mb layer between 1959 and 1974, but at the surface and in the 300–100 mb layer a slight warming began in 1968, implying subtle lapse rate changes. The vertically averaged (by mass) temperature shows a continually declining rate of temperature decrease, with essentially no temperature change between 1971 and 1974. The vertically averaged temperature decrease between about 1959 and 1963 agrees well with that deduced by Starr and Oort (1973), as shown by the dashed regression line.

2) In the tropics the temperature trends are similar at all three tropospheric levels, i.e., there was a cooling from 1959 to 1965–68 and a slight warming thereafter. Between about 1959 and 1963 the vertically averaged temperature change is considerably less than that deduced by Starr and Oort, reflecting the sparsity and uncertainty in tropical radiosonde data during these early years.

3) The temperature trends in the south extratropics are indicated to vary greatly from level to level, with the cooling at the surface continuing until 1971, but in the 850–300 mb layer only until 1965. The nearly out-of-phase relation in temperature trend between the 850–300 mb and 300–100 mb layers is anomalous in the context of this diagram, and while it will be discussed further in connection with Fig. 5, the possibility must be considered that the relation is partly fictitious and due to the sparsity of stations and/or measurement difficulties.

4) In the global average there was about a 0.3°C cooling from 1959 to 1965–68, and less than a 0.1°C warming thereafter.

The question arises as to the significance of these temperature trends. In Fig. 3 are plotted the temperature changes in the tropics, extratropics and the world for the period intervals 1959–65, 1965–71 and 1971–74, as determined from Fig. 2. The dots represent surface temperature changes, the small circles the temperature changes in the 850–300 mb layer, and the crosses the changes in the 300–100 mb layer. For each region, and for the world as a whole, the standard deviation of the

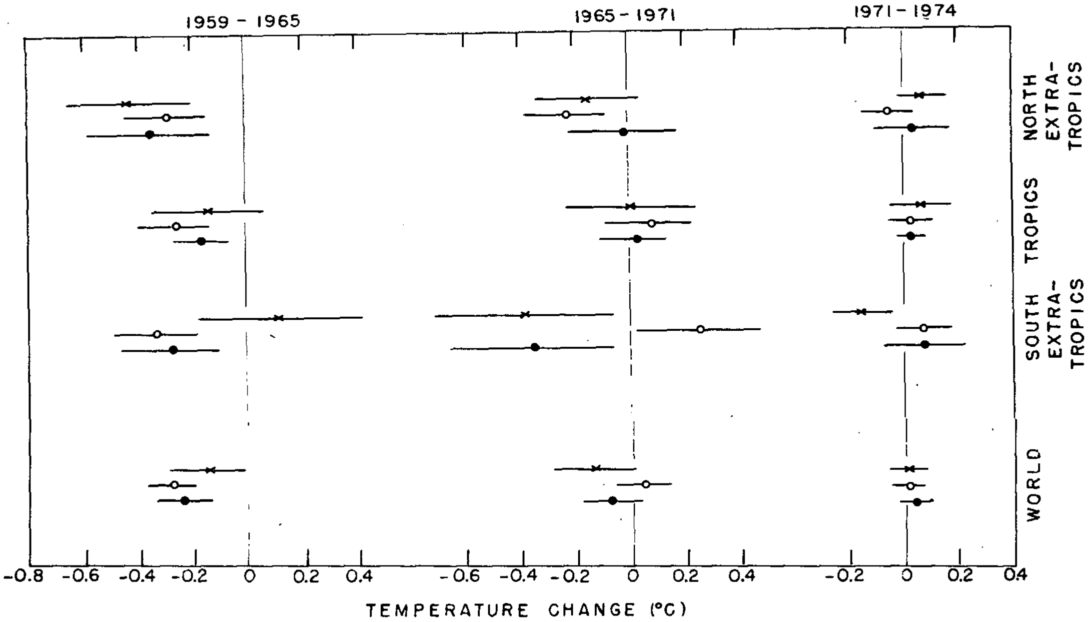

Fig. 3. Smoothed temperature changes (°C) at the surface (dots) and within the 850–300 mb layer (circles) and 300–100 mb layer (crosses) for the given climate regions and time intervals. The horizontal bars extend two standard deviations of the mean (two standard errors of estimate) either side of the mean, based on smoothed values at individual stations.

temperature change was determined based on the individual (smoothed) station values of temperature deviation from the mean, using the same "area of the earth's surface" weighting as was used to estimate the changes themselves. The standard deviation of the mean (the standard deviation divided by the square root of the

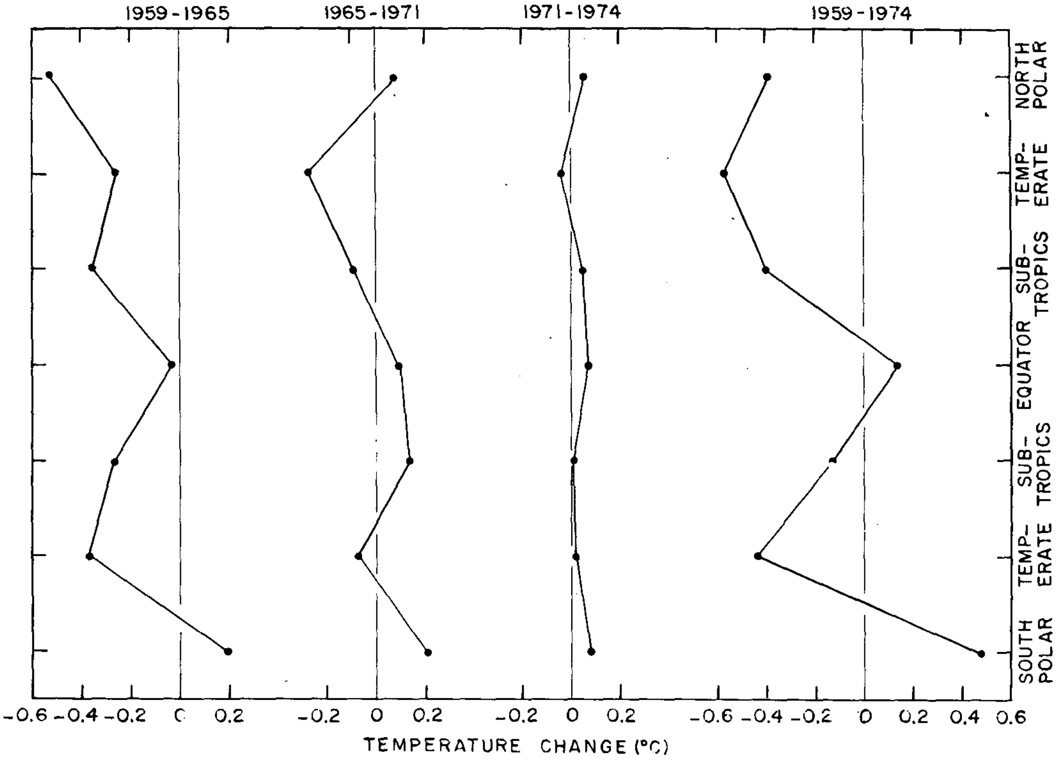

Fig. 4. Variation with latitude of the vertically averaged surface to 100 mb temperature change for given time intervals.

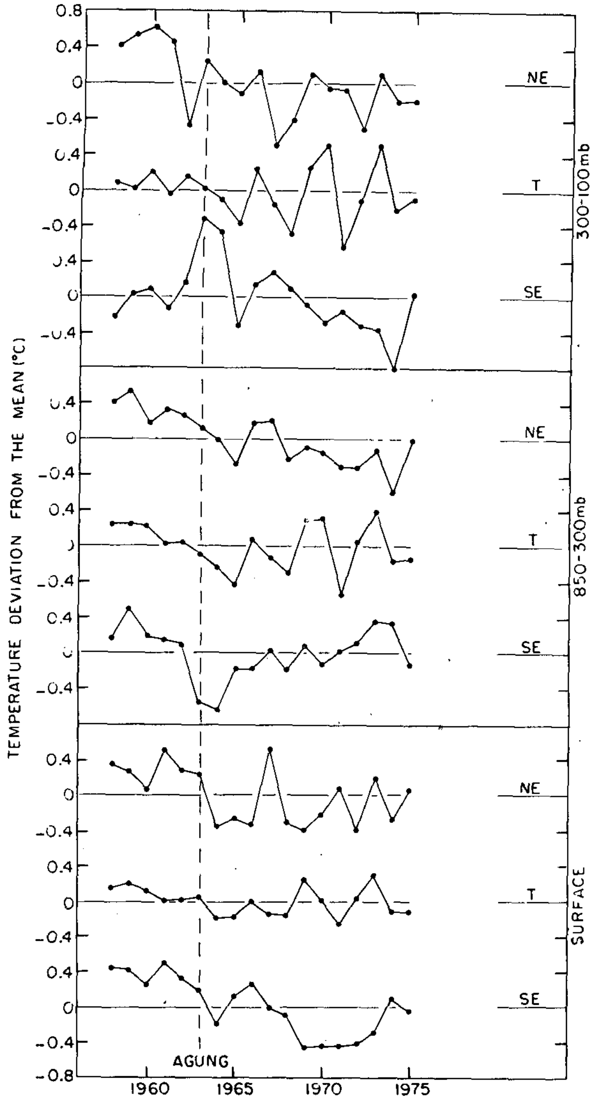

FIG. 5. Time variation of the unsmoothed yearly temperature in the north extratropics (NE), tropics (T) and south extratropics (SE) at the three heights. The dashed line denotes the year of the Mt. Agung eruption (8°S).

number of cases) was then determined using 20, 31, 12 and 63 for the number of cases or stations. In Fig. 3 the horizontal bars extend two standard deviations of the mean (two standard errors of estimate) either side of the mean. If the horizontal bars do not intersect the zero line, the cooling or warming is assumed significant at the 5% level. The results are as follows:

1) Between 1959 and 1965 the cooling was significant everywhere except in the 300–100 mb layer in the tropics and south extratropics.

2) Between 1965 and 1971 the cooling was significant in the north extratropics in the 850–300 mb layer, and in the south extratropics at the surface and in the 300–100 mb layer.

3) Between 1971 and 1974 the cooling was significant only in the 300–100 mb layer in the south extratropics.

4) Temperature changes at the three levels are significantly different only in the south extratropics during 1965–71, implying for this region and period a significant decrease in lapse rate in the troposphere and increase in lapse rate in the low stratosphere.

Fig. 4 presents the latitudinal variation in vertically averaged (by mass) temperature change for the period intervals 1959–65, 1965–71, 1971–74, and for the total period of record 1959–74. The results are as follows:

1) Between 1959 and 1965 there was cooling in all regions except the south polar region, whereas between 1971 and 1974 there was a slight warming in all regions except the north temperate region.

2) In general the cooling has been greatest, or the warming least, in the temperate regions of both hemispheres, i.e., there has been an increase in the meridional temperature gradient between tropical and temperate latitudes.

3) Contrariwise, the meridional temperature gradient between temperate and polar latitudes has generally been decreasing, with the warming indicated to be particularly large in the south polar region (Antarctica). It is hoped that the latter warming is real and not partly due to a station heat-island effect.

4) Over the period of record there has been approximately a 0.5°C cooling in temperate latitudes and nearly a 0.2°C warming in equatorial latitudes, and it will be shown in Section 6 that this long-term increase in meridional temperature gradient is associated with an increase in temperature variability.

For the benefit of those interested in the quantitative data, Tables 1 and 2 provide a listing, respectively, of the smoothed layer and vertically averaged temperature changes for the above time intervals for the tropics, extratropics and the world, as well as for the seven climatic regions and both hemispheres.

TABLE 2. Vertically averaged (by mass) temperature change (°C), surface to 100 mb, for given time intervals and regions.

	1959–65	1965–71	1971–74	1959–74
North polar	−0.53	0.08	0.06	−0.39
North temperate	−0.27	−0.27	−0.03	−0.57
North subtropics	−0.26	−0.09	0.05	−0.40
Equator	−0.03	0.10	0.07	0.14
South subtropics	−0.28	0.14	0.01	−0.13
South temperate	−0.38	−0.07	0.02	−0.43
South polar	0.19	0.21	0.08	0.48
North extratropics	−0.34	−0.18	−0.01	−0.53
Tropics	−0.23	0.05	0.04	−0.14
South extratropics	−0.23	0.01	0.03	−0.19
Northern Hemisphere	−0.29	−0.10	0.02	−0.37
Southern Hemisphere	−0.21	0.08	0.02	−0.11
World	−0.25	−0.01	0.02	−0.24

4. Year-to-year temperature variations

Fig. 5 shows the unsmoothed year-to-year temperature variations in north extratropics, tropics and south extratropics at the three levels. The dashed line denotes the eruption of Mt. Agung in the spring of 1963. The results are as follows:

1) Between 1963 and 1964 the surface temperature decreased by 0.6°C in the north extratropics, 0.2°C in the tropics and 0.4°C in the south extratropics. The respective standard errors of estimate were 0.24°, 0.13° and 0.17°C, so that the decrease is significant at the 5% level in north and south extratropics but not quite significant at this level in the tropics. At least some of this temperature decrease presumably is due to the eruption of Mt. Agung, although in none of the three regions individually is the decrease unusual (the similarity in sign and magnitude of the change among the three regions is unusual, however). The greater temperature decrease in the north extratropics than in the tropics and south extratropics may reflect the moderating effect of the oceans on temperature changes so induced.

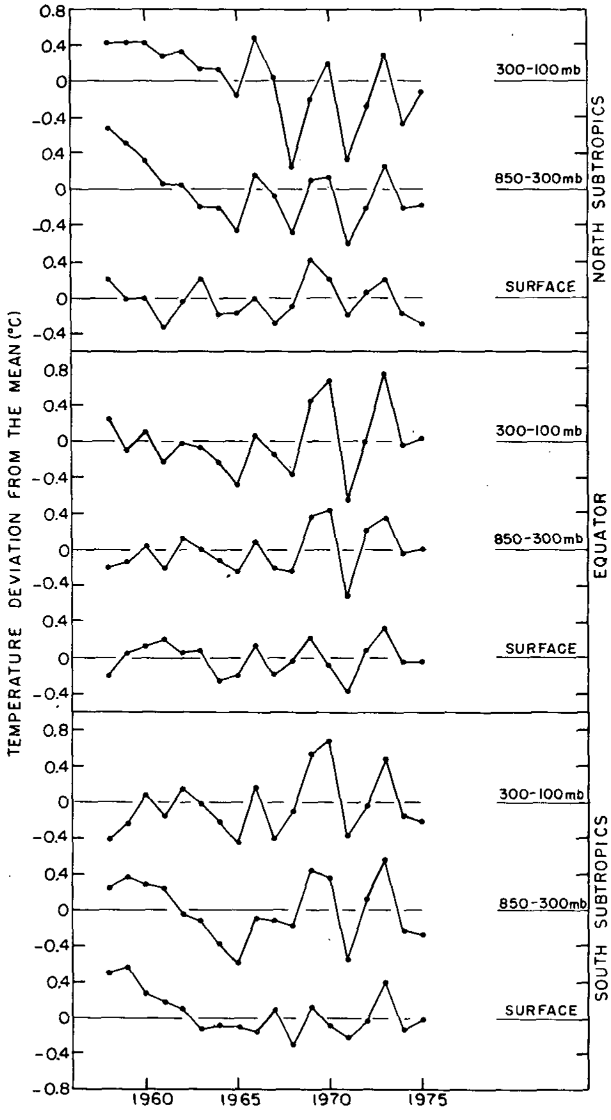

Fig. 6. Time variation of the unsmoothed temperature in the tropics at the three heights.

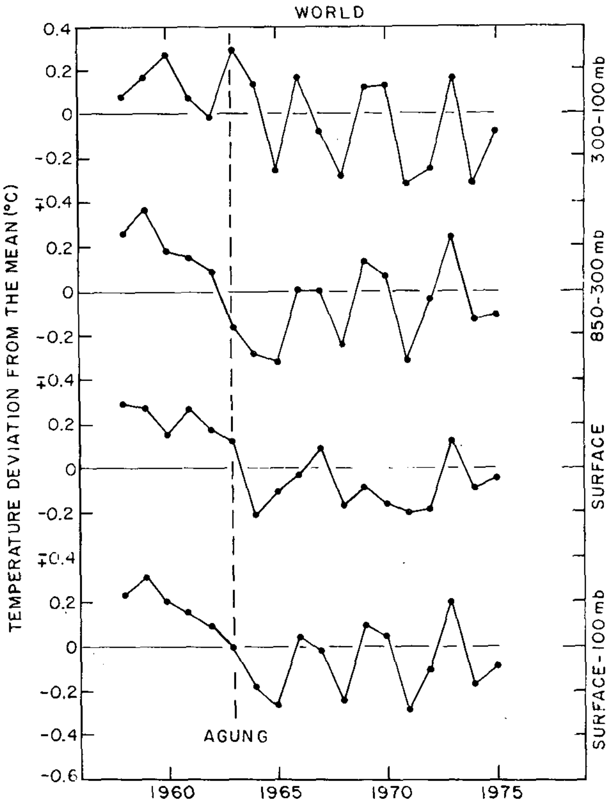

Fig. 7. Time variation in unsmoothed global temperature at the three heights, and in the vertically averaged value. The dashed line denotes the year of the Mt. Agung eruption.

2) Between 1962 and 1963 in the south extratropics there was a 0.7°C rise in temperature in the 300–100 mb layer and a corresponding fall in temperature in the 850–300 mb layer, suggesting a rapid response of these layers to the Agung eruption. The respective standard errors of estimate were 0.35° and 0.44°C, so that the rise in temperature in the 300-100 mb layer is just significant at the 5% level but the fall in temperature in the 850–300 mb layer is not quite significant at this level. Accordingly, there is an indication that the warming in the low tropical stratosphere due to the eruption (Newell, 1970) also propagated into the south extratropical stratosphere, and perhaps into the north extratropical stratosphere on the basis of the temperature rise of 0.7°C (because of the large temperature decrease between 1961 and 1962, the latter rise is not so convincingly related to the eruption). It is not clear why the tropospheric cooling in the year of the erup-

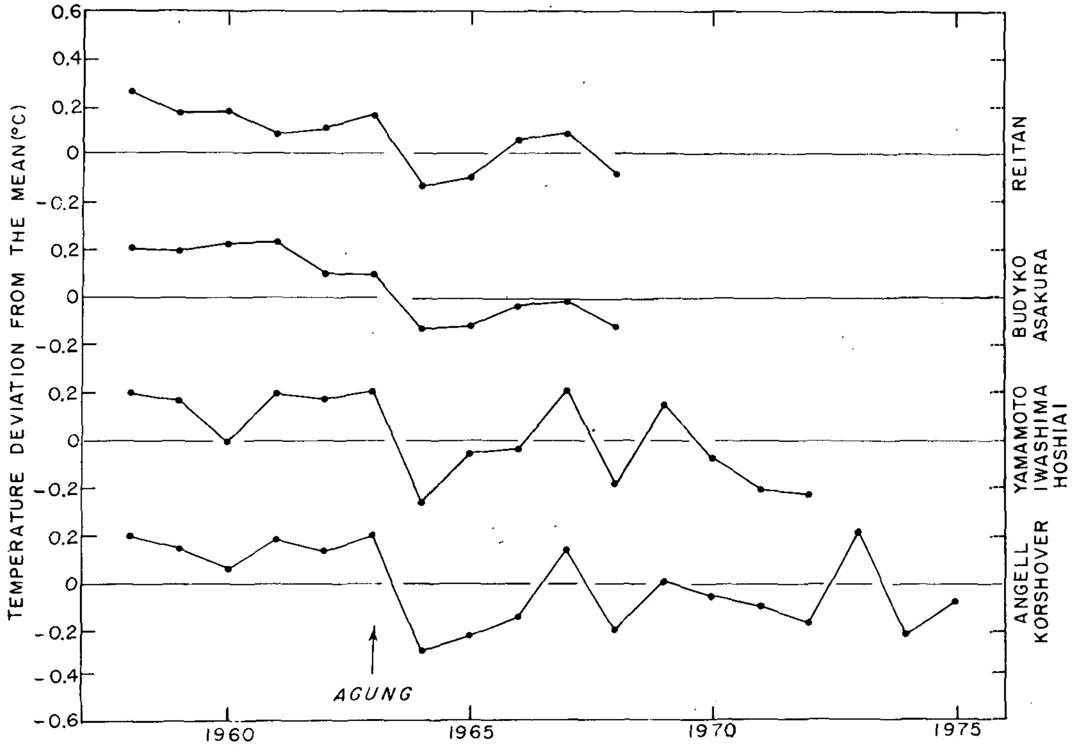

FIG. 8. Comparison of Northern Hemisphere surface temperature variations reported in the literature. The year of the Mt. Agung eruption is shown at bottom.

tion should be larger, or indicated to be larger, than the surface cooling in the year following the eruption.

3) In the tropics a tropospheric temperature oscillation of 3–4 year period is evident at all levels after about 1965. There is evidence of a similar oscillation in the 300–100 mb layer in the north extratropics. Because of its interest, this tropical oscillation will be considered in some detail.

Fig. 6 shows the unsmoothed temperature traces for the north subtropics, equator and south subtropics. The 3–4 year temperature oscillation shows up clearly in all three regions at all three levels after about 1965. Since that data for the three regions are completely independent, the reality of the temperature oscillation in the tropical troposphere at this time can hardly be questioned. The significant features of the oscillation are as follows:

1) The period of temperature oscillation is more often 3 years than 4 years, or on the average about $3\frac{1}{4}$ years, too long to be associated with the stratospheric quasibiennial oscillation, but of a period compatible with the "Southern Oscillation."

2) The oscillation increases in amplitude with height, averaging 0.2°C at the surfaces, 0.3°C in the 850–300 mb layer and 0.4°C in the 300–100 mb layer. Since the respective standard errors of estimate average 0.09°, 0.10° and 0.15°C during this period, the oscillations at all heights are significant at the 5% level.

3) In general, the temperature minimum in 1964–65 provides the first real evidence of the oscillation, although at the surface in the north subtropics the oscillation can possibly be traced back to 1960.

Monitoring of this oscillation will be of interest in order to see to what extent it is ephemeral and how well it fits in with other parameters of the "Southern Oscillation."

Fig. 7 presents the (unsmoothed) variation in global mean temperature, as obtained by averaging the tropical and extratropical values. Inasmuch as the tropics embrace half the earth's surface, the $3\frac{1}{4}$ year tropical oscillation tends to dominate the global average temperature pattern. The eruption of Mt. Agung is indicated to have induced an approximate 0.3°C global temperature decrease at the surface and perhaps a 0.4°C decrease in the 850–300 mb layer, but in the 300–100 mb layer the $3\frac{1}{4}$-year oscillation appears to persist back to 1958 and there is little evidence that the Agung eruption affected this layer globally. In the vertical average the eruption is shown as occurring in the middle of a period of declining temperature, with some acceleration in the rate of temperature decreaes following the eruption. The $3\frac{1}{4}$ oscillation commences as the temperature begins slowly to increase again.

The question arises as to how well the surface temperature variations derived from the limited number of radiosonde stations used here agree with the results obtained by others using hundreds of surface stations. Fig. 8 shows a comparison of our Northern Hemisphere surface temperature variations and those obtained by Reitan (1971), Budyko (1969, updated by Asakura), Yamamoto *et al.* (1975). In general the agreement is surprisingly good, particularly between Yamamoto *et al.* (1975) and our work, suggesting that the essence of the surface temperature fluctuations may indeed be obtained from a limited sample of representative stations. It is emphasized that in all four traces there is a more or less anomalous temperature decrease just after the eruption of Mt. Agung in 1963. The Northern Hemisphere temperature decrease of 0.5°C at this time observed in our data is significant at the 1% level based on the standard error of estimate of 0.14°C.

5. Variation with longitude

With the relatively small sampling of stations it is not possible to obtain a detailed picture of the longitudinal variation in temperature change. Consequently, our modest efforts along this line involved only a 1-2-1 smoothing of the temperature changes at 60° longitude intervals in the tropics and extratropics, pretty well confining the analysis to wavenumber 1. Fig. 9 shows the results for the surface (solid line), 850–300 mb layer (dashed line) and 300–100 mb layer (dotted line). The significant features are as follows:

1) The cooling between 1959 and 1965 was a maximum in the Western Hemisphere and a minimum in the Eastern Hemisphere in both the north and south extratropics, but in the tropics the cooling was a maximum near the Greenwich meridian. Thus, the relation between the tropics and extratropics during this period was neither an in-phase nor an out-of-phase one.

2) Between 1965 and 1974 (the results for 1965–71) and 1971–74 were so similar as to make a separate analysis unnecessary) there was almost a complete reversal in the longitudinal variation of temperature change in the tropics, the maximum warming during this period being found near the Greenwich meridian. In the south extratropics, however, the maximum cooling occurred near the Greenwich meridian (about 60° of longitude east of the maximum cooling during the earlier period), so that basically there was an out-of-

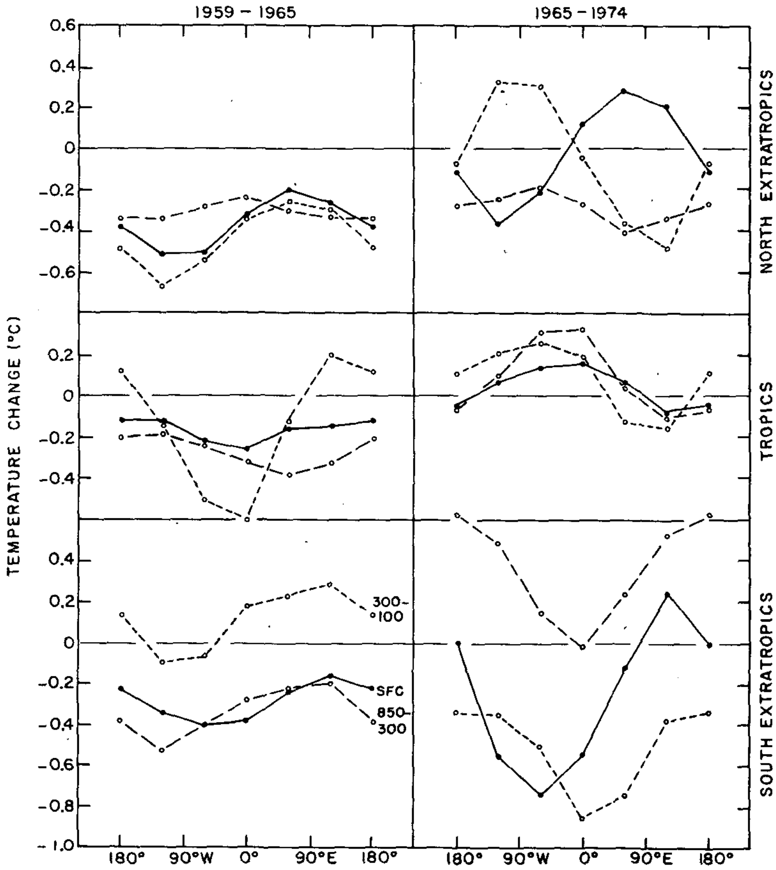

Fig. 9. Variation with longitude of the temperature change (°C) at the surface (solid lines) and within the 850–300 mb layer (dashed lines) and 300–100 mb layer (dotted lines) in the tropics and extratropics for given time periods.

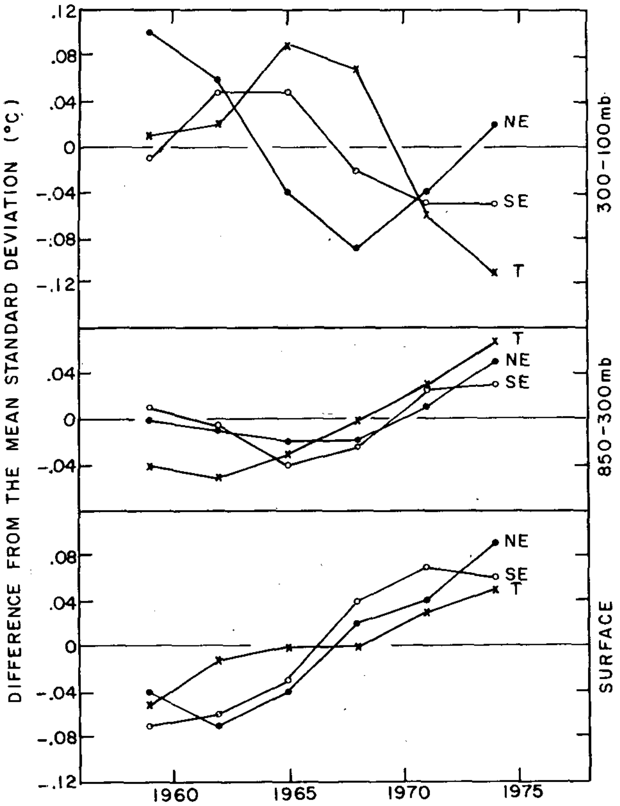

FIG. 10. Time trend of the spatial variability of temperature in the north extratropics (NE), tropics (T) and south extratropics (SE) at the three heights, based on standard deviations of the individual station values within the climatic regions.

phase relation between the tropics and south extratropics.

3) Between 1965 and 1974 in the north extratropics the temperature changes at the surface and in the 300–100 mb layer were indicated to be almost exactly out of phase, the surface warming being a maximum in the Eastern Hemisphere (as during 1959–1965) and the 300–100 mb warming a maximum in the Western Hemisphere. The 850–300 mb layer is in agreement with the higher layer, but with reduced amplitude. There is the implication here of an overall increase in lapse rate in the Eastern Hemisphere and decrease in lapse rate in the Western Hemisphere between 1965 and 1974.

4) During the entire period (1959–74) the warming was greatest, or the cooling least, near the longitude of Australia–New Zealand. The recent warming in this region has also been documented by Salinger and Gunn (1975).

6. Spatial variability

Claims have been made recently to the effect that the weather is becoming more variable or "extreme." Figs. 5 and 7 show the tendency for an increase in the temporal or year-to-year variability of temperature, particularly in the tropics. It is also of interest to investigate the trend in spatial variability, as expressed by the standard deviation of the individual station values. Fig. 10 shows that at the surface in the tropics and extratropics there has been a consistent increase in this standard deviation since 1959, certainly suggesting that the spatial temperature variability has indeed been increasing. In the 850–300 mb layer the standard deviation decreased between 1959 and 1965 but increased thereafter. We suggest that the early decrease was due to improved measurement techniques and does not reflect an actual decrease in the temperature variability. Similarly, it is likely that the indicated overall decrease in the standard deviation in the 300–100 mb layer is due to improved measurement techniques. Thus, the evidence in general is that the increase in meridional temperature gradient between the tropics and temperate latitudes (Fig. 4) has been associated with an increase (amounting to about 15%) in the spatial temperature variability, and accordingly that weather extremes *are* more likely now than 10–15 years ago.

7. Conclusions

The following are the main points of interest from this study of the temperature variation at the surface and within 850–300 mb and 300–100 mb layers during the period 1958–75.

1) Between about 1959 and 1965 there was a significant temperature decrease of about 0.3°C over most of the world.

2) Since 1965 there has been no significant change in global temperature, although a slight warming appears to have begun about 1971.

3) The atmosphere has cooled the most, or warmed the least, in temperate latitudes, indicating an overall increase in meridional temperature gradient between the tropics and mid-latitudes. However, the meridional temperature gradient has generally decreased between temperate and polar latitudes, particularly in the Southern Hemisphere.

4) Since 1965 there has been a 3-year temperature oscillation in the tropical troposphere of about 0.3°C amplitude, the oscillation increasing in amplitude with height.

5) We estimate that the eruption of Mt. Agung in 1963 may have caused a surface temperature decrease of as much as 0.6°C in the north extratropics, 0.2°C in the tropics, and 0.4°C in the south extratropics.

6) In 1963 in the south extratropics there was a 0.7°C decrease in temperature in the 850–300 mb layer and a corresponding increase in temperature in the 300–100 mb layer, presumably also associated with the eruption of Mt. Agung.

7) At the surface and in the 850–300 mb layer the temperature variability among stations has increased

by about 15% during the period of record, suggesting that weather may indeed be becoming more "extreme."

8) Over the period of record there has been considerably more warming, or less cooling, in the Australia–New Zealand sector of the south extratropics than in the other sectors, so that this sector cannot be assumed to be typical of the entire south extratropics.

Climate foreshadowing is a notoriously dangerous occupation because at this time all one can really do is assume some sort of persistence and extrapolate recent trends into the future. On this basis, the available evidence suggests that a warming trend may now be starting following the considerable cooling of the early 1960's (partly but certainly not entirely due to the eruption of Mt. Agung). On the other hand, there seems little doubt that the meridional temperature gradient and the temperature variability have been increasing over the last 10–15 years, and if this continues, superimposed on this warming trend would be more weather extremes in general. We have set up our data base so that it is very easy to update each year, and we plan to do so, thus providing a crude temperature monitoring system which should be capable of delineating significant temperature variations on a global scale.

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