Remarks on the Circulation over the Southern Hemisphere in FGGE and on Its Relation to the Phases of the Southern Oscillation

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ABSTRACT

The circulation anomalies over the whole Southern Hemisphere in the First GARP Global Experiment (FGGE) were not those that one would expect in either extreme of the Southern Oscillation; examples of the anomalies in such extremes are given. The zonally averaged pressure gradients between 50 and 65°S in FGGE when compared with those of several other years turned out to be abnormally strong in winter (2.5σ above the mean), and moderately strong in summer (1.4σ above the mean). The 500 mb heights were above normal in middle latitudes and below normal at high latitudes when compared with station data from series 16–29 years long. As the computations are based on operational analyses they are not final, although the conclusions are unlikely to be changed by the use of the complete FGGE data set.

1. Introduction

The First GARP Global Experiment (FGGE) was the latest link in the chain of attempts to observe substantial portions of the global circulation of the atmosphere. In an earlier global experiment, the International Geophysical Year (IGY) 1957/58, Antarctica received special attention and was for the first time covered by a comparatively dense network of observing stations; but the southern oceans were neglected, apart from the additional surface observations which were obtained in the southern summer when whaling was permitted in the previously protected South Pacific Ocean. In contrast, a major achievement of FGGE was the launching of numerous drifting buoys which provided observations of surface pressure over the southern oceans on an areal scale which seemed near-miraculous to veteran analysts of the circulation there. The quality of the operational analyses of sea level pressure thus became comparable to that expected for the Northern Hemisphere, which could not be claimed for the IGY analysis (Taljaard and van Loon, 1964). Although they can be used to describe features of the large scale in space and time, such as we have used them in this paper, the operational upper air analyses in FGGE are not suited to computations of quantities which rely for their accuracy on the correctness of the daily analysis at individual points (van Loon, 1980).

Considering the extent to which the FGGE data from the Southern Hemisphere will be used, particularly as a reference point for the present climate, "it is of course desirable to be able to assess the extent to which this period represents an adequate sample of the current climatic state and to what extent it experienced anomalous conditions in space and/or time" to quote Tucker and Physick (1979).[2] As one approach toward this goal, we shall try in the following to relate FGGE to the sequence of events in the Southern Oscillation as they are experienced on the Southern Hemisphere.

2. Sea level pressure in FGGE

As a picture of the pressure anomalies over the Southern Hemisphere in the extremes of the Southern Oscillation (SO) is beginning to emerge (van Loon and Madden, 1981), it is of interest to see if the anomalies of FGGE belong in either extreme. The SO is commonly measured in terms of the opposing pressure variations over the tropical Pacific and

[1] The National Center for Atmospheric Research is sponsored by the National Science Foundation.

[2] Tucker, G. B., and W. L. Physick, 1980: How anomalous was the FGGE period in the Southern Hemisphere? In: Preprint Volume of Australia–New Zealand GARP Symposium, December 17–19, Melbourne, 80–90.

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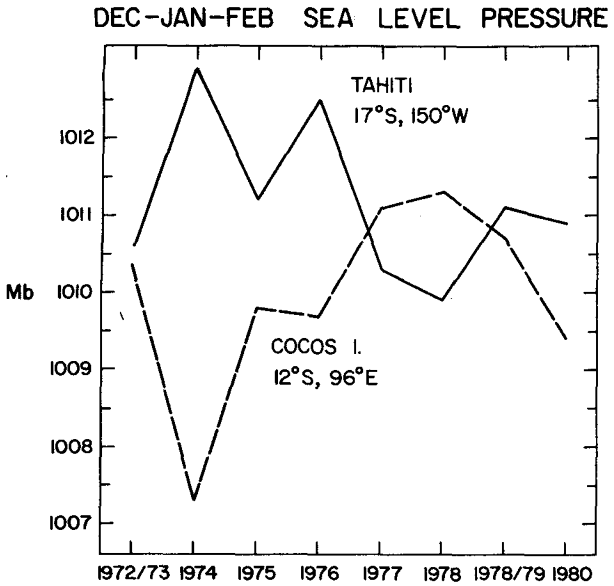

FIG. 1. Sea level pressure at Cocos Island and Tahiti in Dec–Jan–Feb (mb).

Indian Oceans on the Southern Hemisphere. van Loon and Madden used Cocos Island (12°S, 96°E) and Tahiti (17°S, 150°W) as indicators of the Oscillation (Fig. 1) and named its two extremes LOW/WET (L/W) and HIGH/DRY (H/D), where LOW and HIGH refer to pressure in the tropical and subtropical parts of the central South Pacific Ocean, and WET and DRY to rainfall in the equatorial Pacific.

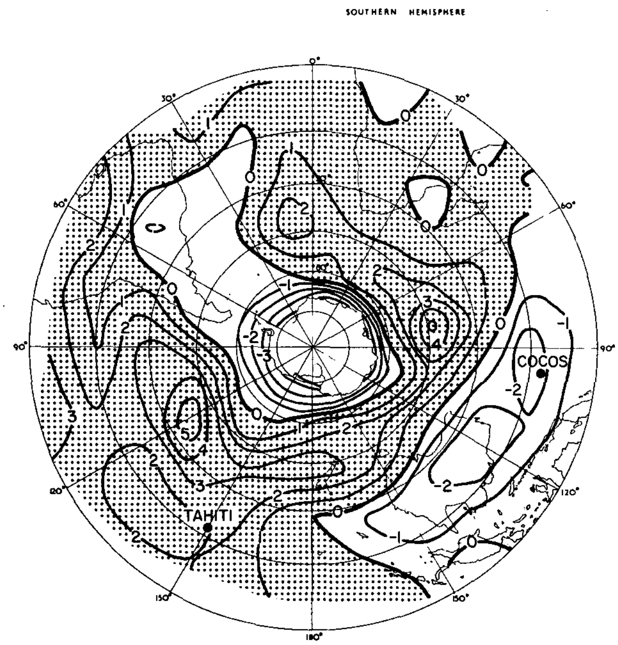

FIG. 3. Sea level pressure anomalies for Dec–Jan–Feb 1973/74 (mb).

The southern summer of 1973/74 (Fig. 1) was thus an instance of H/D and that of 1976/77 was one of L/W; it is also evident from the pressure curves in the illustration that the SO in the FGGE summer of 1978/79 seemed to be on its way out of a L/W extreme.

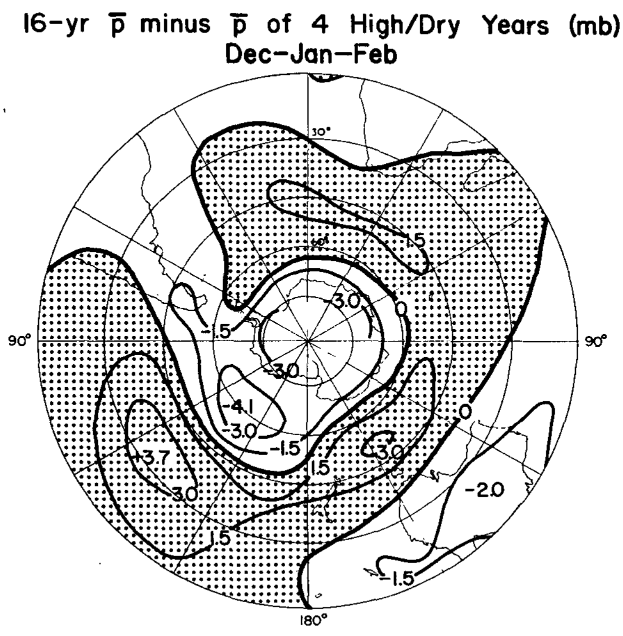

FIG. 2. The difference between a 16-year mean of sea level pressure in Dec–Jan–Feb and a mean of four HIGH/DRY summers (mb).

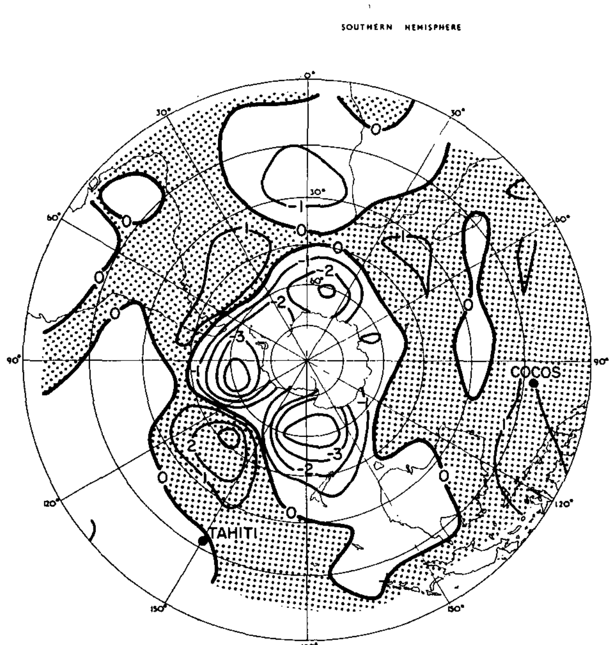

FIG. 4. As Fig. 3 except for 1978/79.

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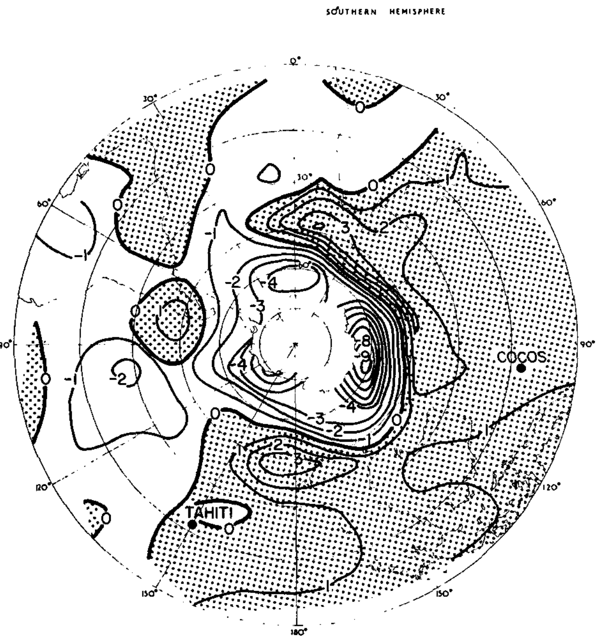

FIG. 5. As Fig. 3 except for June–July–Aug, 1979.

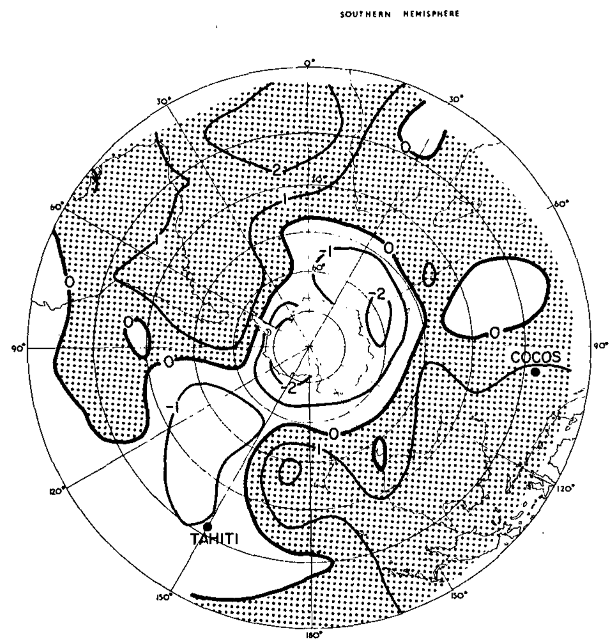

FIG. 7. As Fig. 3 except for 1977/78.

The pressure and wind anomalies on the Southern Hemisphere in the two extremes of the SO are described in van Loon and Madden (1981) and in van Loon and Rogers (1981); in Fig. 2 we show the pressure difference at sea level between a 16-year mean of DJF and the mean of four H/D summers (1954/55, 1955/56, 1973/74, and 1975/76). The pattern is characterized by lower than average pressure over the Antarctic, southernmost Pacific Ocean, and Australia with surroundings, and higher than average pressure over the subtropics and tropics of the Pacific Ocean and in the belt of westerlies over the Atlantic and Indian Oceans. Although the "signal" of an extreme of the SO may be discernible in the mean pressure pattern of an individual season, the pattern does of course contain "noise," such as is evident from the example of the pressure anomalies in one H/D summer (1973/74, Fig. 3). In this and the following illustrations the basis against which the anomalies are measured is the average of seven summers or eight winters analyzed in the Australian Meteorological Office. The H/D summer of 1973/74 in Fig. 3 displays the major features of the 4-summer average anomalies

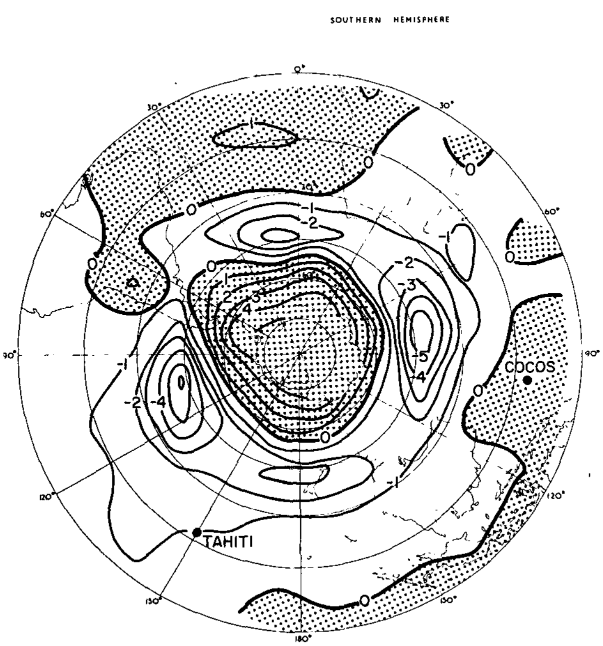

FIG. 6. As Fig. 3 except for 1976–77.

TABLE 1. The zonally averaged sea-level pressure differences 50–65°S in Dec–Jan–Feb, and their deviation from the 11-year mean (14.25 mb) in number of standard deviations (σ = 2.70 mb).

	Pressure difference (mb)	δ/σ
1955/56	13.0	−0.46
1956/57	13.5	−0.28
1957/58	13.5	−0.28
1972/73	13.4	−0.31
1973/74	19.0	1.76
1974/75	13.1	−0.43
1975/76	14.7	0.17
1976/77	8.3	−2.20
1977/78	15.9	0.61
1978/79	18.1	1.43
1979/80	14.3	0.02

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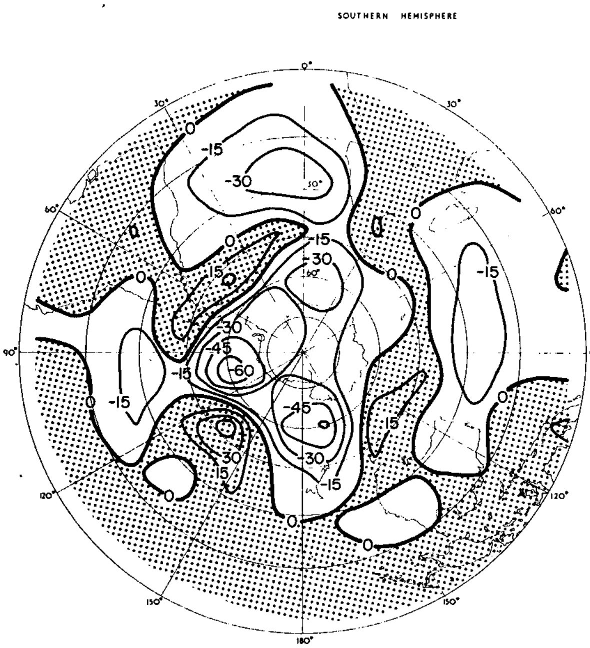

FIG. 8. 500 mb height anomalies in Dec–Jan–Feb, 1978/79 (m).

in Fig. 2, of which it is a part. The FGGE summer, Fig. 4, had traits in common with the H/D "signal" in Fig. 2 over middle and high latitudes, but in low latitudes the signs of the anomalies over Indonesia and the western parts of Australia and over much of the Pacific Ocean were to some extent those of a L/W summer. For the Hemisphere as a whole, the FGGE summer thus did not belong in either extreme of the SO.

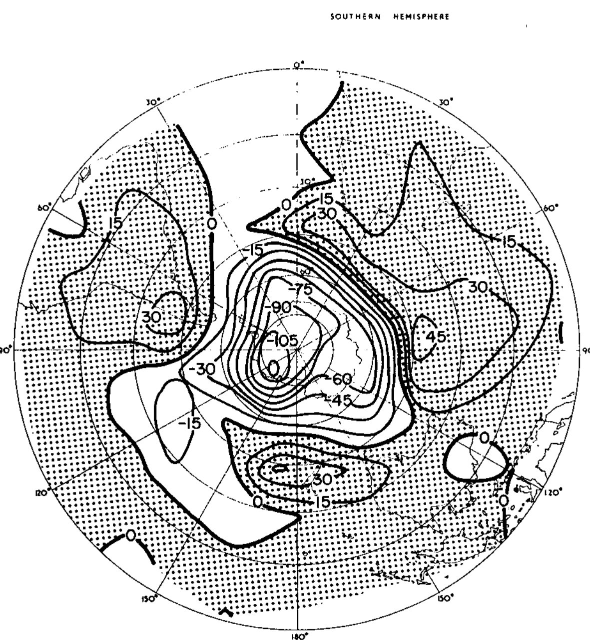

FIG. 9. As Fig. 8, but for June–July–Aug, 1979.

In middle and high latitudes, the pressure anomaly pattern of a H/D summer continued into the winter of 1979 (Fig. 5), whereas at lower latitudes a L/W anomaly pattern was still discernible.

The sea-level pressure anomalies at Cocos Island and Tahiti in the two southern summers before the FGGE summer were clearly those of L/W summers (Fig. 1). In the summer of 1976/77 (Fig. 6) the anomaly pattern was almost the exact opposite of the H/D summer of 1973/74 with positive deviations over Cocos Island–Indonesia and the Antarctic and negative deviations over the Pacific and the westerlies of the Indian and Atlantic Oceans. In 1977/78 (Fig. 7), the tropical pressure anomalies (Cocos, Tahiti) were still those of a L/W summer, but at higher latitudes the sign of the anomalies had changed to negative, which they remained in FGGE.

3. The surface westerlies in FGGE

It is possible to compare the strength of the westerlies at the surface in the southern summer of FGGE with that in a reasonable number of other southern summers. Whaling was permitted in the South Pacific Ocean in the summers of 1955/56, 1956/57, and 1957/58 (IGY) so that there were a number of fairly well-distributed ships south of 50°S at the time when the Antarctic station network was established for the IGY. The zonally averaged pressure difference between 50 and 65°S for each of these summers from the historical maps analyzed in the South African Weather Bureau, is shown in

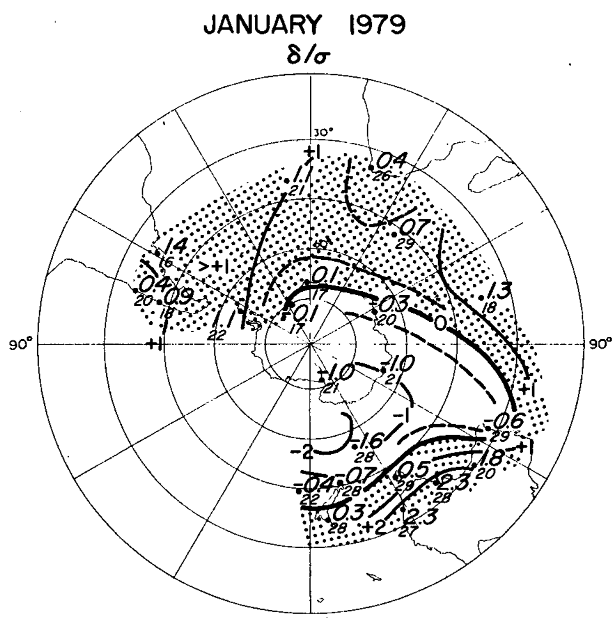

FIG. 10. The 500 mb height anomalies in Fig. 8 expressed in number of standard deviations (upper number). The lower number is the number of years from which the standard deviation was computed.

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Table 1 together with that for eight single summers obtained from the Australian operational analyses. The mean latitudinal pressure difference for the 11 years is 14.25 mb with a standard deviation of 2.70 mb. The deviation of each summer from the mean is given in number of standard deviations in the right-hand column. The pressure difference of the FGGE summer was 1.43σ above the mean which, although large, was not extreme for these years, as it was 1.76σ above the mean in the H/D summer of 1973/74 and 2.20σ below the mean in the L/W summer of 1976/77.

One cannot be so sure of the same statistics for the southern winter when the Antarctic Ocean is devoid of ships and the zonal means at 50°S consequently beset with uncertainty. The following numbers are therefore merely provisional: the mean difference, 50–65°S, for the 10 winters 1957, 1958 and 1972–79 was 15.24 mb with σ = 3.26 mb. In this season the westerlies in FGGE were clearly exceptionally strong in these latitudes in comparison with the other nine years, because the mean for June–July–August 1979 was 2.5σ above the 10-year average. Without FGGE, the mean for the other years, 14.33 mb, was the same as for the summer.

4. 500 mb height in FGGE

The 500 mb height anomalies, Figs. 8 and 9, are consistent with those at sea level and show that the strength of the westerlies in higher latitudes was above the 7–8 year mean while it was below the mean north of about 45°S.

How unusual, then, were the height anomalies in FGGE? That question is answered for January and July in Figs. 10 and 11 which show the anomalies measured in standard deviations. Although the number of years in the means vary between 16 and 29 in January and 19 and 29 in July and the standard deviations thus are not strictly comparable, lines of equal standardized departures have been drawn to outline the pattern (see van Loon and Jenne, 1974, for the pattern of σ_{500}). In January, deviations $\geq$ 1.50 appear only in the Australian sector, and in July only over Antarctica and South America.

For the size of the wind anomalies, however, the pattern of positive and negative height anomalies is decisive, and it is evident that the wind anomalies must have been unusually strong in January over and south of Australia–New Zealand and in July from South America across the South Atlantic and well into the Indian Ocean.

In both months the height anomalies in the parts analyzed were of the same sign: negative to the south and positive to the north of a comparatively narrow zone which stretched eastward from the Antarctic Peninsula to Western Australia and thence to the South Island of New Zealand.

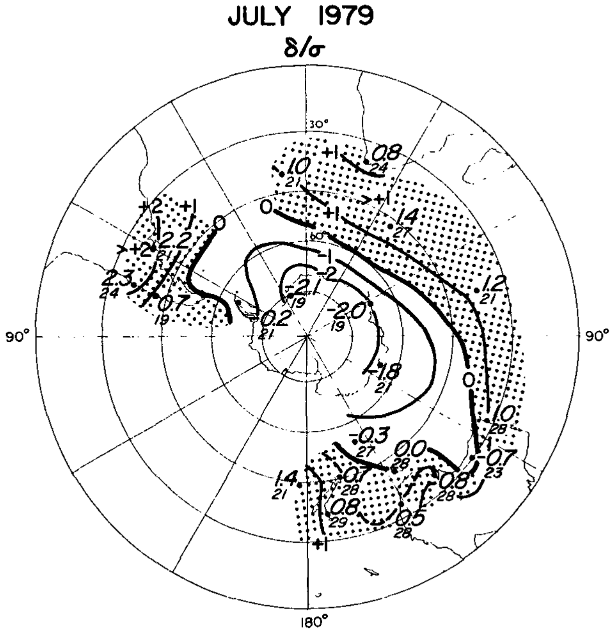

FIG. 11. As Fig. 10 except for the 500 mb height anomalies in July 1979 (Fig. 9).

5. Conclusion

The sea level pressure anomalies on the Southern Hemisphere during FGGE did not fit into those of either extreme of the Southern Oscillation for the Hemisphere as a whole. In middle and high latitudes the anomalies belonged to one extreme, and in low latitudes to the opposite extreme of the Oscillation.

The zonal mean pressure gradients (geostrophic winds) at sea level were moderately above normal in summer (1.4σ) between 50 and 65°S, and 2.5 standard deviations above normal in winter. This was reflected in the anomalies of 500 mb heights which were above the long-term mean in middle latitudes and below at high latitudes.

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