SEASONAL CLIMATE SUMMARY

The Global Climate for June–August 1987: Mature Phase of an ENSO Warm Episode Persists

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1. Introduction

The current El Niño/Southern Oscillation (ENSO) warm episode, which began nearly one year ago (Bergman, 1987), continued in a mature phase during June–August (JJA) 1987. Indices of sea surface temperature (SST), sea level pressure (SLP), tropospheric circulation and convection in the equatorial Pacific remained near the values reached during the preceding season (Wagner, 1987), although substantial intraseasonal variability was present. The pattern of global climate anomalies during the season was, in general, consistent with that observed during previous episodes (Ropelewski and Halpert, 1987).

Section 2 will discuss the seasonal characteristics of the global tropics, emphasizing the oceanic and atmospheric manifestations of the warm episode. Southern Hemispheric circulation and climate anomalies are described in section 3, followed by a discussion of Northern Hemisphere features in section 4. The progression of monthly climatic features in the United States is described in section 5.

2. The tropics

a. Equatorial Pacific indices

Table 1 contains the values of indices used to monitor oceanic and atmospheric conditions in the equatorial Pacific over the past year. They all reflect the complex of anomalies which typifies ENSO warm episodes (Rasmusson and Carpenter, 1982), with above normal SSTs in the central and eastern equatorial Pacific, a weaker than normal zonal sea level pressure gradient and more westerly than normal low level winds between the western and central Pacific, an eastward displacement of convection to near the dateline and easterly anomalies in the upper troposphere. Most of the indices appear to have approached their extreme values during the April–June period, and have varied near those values since.

Inspection of time series plots of these indices does not yield a clear indication that the peak of the current event is past. The Southern Oscillation index (SOI—Fig. 1) had a 5-month running mean value below −2.0 from April–June and has been above −2.0 since. However, one can see in the series that multiple minima in the smoothed series were found in two of the most recent four warm episodes (1969 and 1976–77). Indices of SST (Fig. 2) have declined in the extreme eastern equatorial Pacific in recent months, but have remained near constant or have increased in the central part of the basin. Except in the central Pacific, anomalies during the current episode are about half of those observed during the 1982–83 warm episode. Indices based on the 850 mb zonal wind from 5°N–5°S (Fig. 3) continue to show that a pronounced decline in the strength of the equatorial easterlies has occurred in the past two years. However, no sharp minimum such as that found during late 1982 and/or early 1983 appears to have occurred. Winds at 200 mb in the eastern equatorial Pacific have been more easterly than normal since mid-1986 (Fig. 4a), although the 5-month running mean has not reached values below −1.0. An index based on the degree of opposition between zonal winds at 200 mb in the central equatorial Pacific and the equatorial Atlantic (Fig. 4b) shows a slightly different relationship between extrema and warm episodes in the past 20 years; in this index the current episode is relatively well defined. Outgoing longwave radiation (OLR) is used as an indicator of variations in deep convective cloudiness in the tropics. An index derived from equatorial OLR variations near the dateline (Fig. 5) shows that the intensity of convection in this region during the current episode has been comparable to that observed during the 1982–83 event. This is somewhat deceiving illustration of the relative amplitudes of the two episodes, since the area of anomalous convection observed during 1982–83 continued to move eastward and was

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actually centered well east of the index area during the peak of the event (Arkin et al., 1983).

b. Sea surface temperatures

As in the past three seasons (Bergman, 1987; Kousky, 1987; Wagner, 1987), the equatorial maximum in SST was located in the central Pacific near the dateline (Fig. 6a), in contrast to its normal position farther west. Areas with SST warmer than 29°C were observed in the western Pacific north of the equator, in the central Pacific, south of Central America and in the Gulf of Mexico, and in parts of the Indian Ocean. The area of positive SST anomalies in the central and eastern Pacific was expanded somewhat from the previous seasons, with anomalies of 1°C or more extending from the dateline to South America and reaching 2°C near 130°W (Fig. 6b). Positive SST anomalies thoroughly dominated the tropics during the season, with negative anomalies found only in a small area southeast of Java and in a region near and southeastward of New Guinea. This pattern is characteristic of the late stages of a warm episode (Rasmusson and Arkin, 1985). An area of negative anomalies has persisted in the north central Pacific since JJA 1986 (Halpert and Ropelewski, 1987), with anomalies in JJA 1987 reaching −2°C in parts of the region. Positive anomalies essentially covered the central and eastern equatorial Pacific by October 1986 (Fig. 7) and have persisted since. Two areas of positive anomalies were seen in earlier months; the region in the eastern Pacific was that which led Arkin and Janowiak (1987) to speculate about the possibility of an El Niño at that time, while the area which progressed eastward from about 150°E bears an intriguing resemblance to a feature found in the SST composite of Rasmusson and Carpenter (1982—their Fig. 22).

c. Tropical convective activity

The mean OLR for JJA 1987 (Fig. 8a) had minima, indicating maxima in convective activity, over the Bay of Bengal, Panama and equatorial Africa, with pronounced zonal elongations across the Atlantic and Pacific Oceans. The only region with large negative anomalies (Fig. 8b) was centered just south of the equator on the dateline, with extensions east- and westward along the equator and southeastward towards Chile. Positive anomalies, indicative of relative drought, were observed over Indonesia and New Guinea (extending toward the southeast), and in the Arabian Sea and over northwestern India. The last region was associated with a markedly poorer than normal monsoon season in large parts of India, while flooding occurred in Bangladesh near the negative anomaly area in the Bay of Bengal. Negative anomalies have been observed near the equator across most of the Pacific from 140°E eastward since December 1986 (Fig. 9), with the largest departures found near 170°W.
Fig. 1. Five-month running mean of the difference between the standardized sea level pressure anomalies of Tahiti and Darwin (Tahiti – Darwin). Values are standardized by the standard deviation of the appropriate monthly mean. Crosses denote individual monthly means.

Fig. 2. Equatorial Pacific sea surface temperature anomaly indices (°C) for the areas indicated at the bottom of the figure. Niño 1 + 2 is the average over the Niño 1 and Niño 2 areas. Anomalies are computed with respect to the COADS/ICE climatology (Reynolds, 1987).
Fig. 3. Five-month running mean of the standardized 850 mb easterly wind anomaly in the latitude belt 5°N–5°S for (a) 135°E–180°, (b) 175°–140°W and (c) 135°–120°W. Crosses are the monthly anomalies; "O" indicates that the mean wind was westerly during the month.
Fig. 4. Five-month running mean of the standardized monthly 200 mb westerly wind anomaly averaged over the area 5°N–5°S for the longitudes (a) 165°–110°W and (b) the difference between 160°E–100°W and 20°E–80°W. Values are standardized by the standard deviation of the appropriate monthly mean; crosses are individual monthly means.

Fig. 5. As in Fig. 4, except for the standardized monthly anomaly in outgoing longwave radiation over the area 5°N–5°S, 160°E–160°W.
Fig. 6. (a) Mean sea surface temperature, JJA 1987 (blended analysis) on a 2.5° grid. Contour interval 2°C. Temperatures > 20°C are contoured every degree with odd contours dashed. (b) Sea surface temperature anomalies, JJA 1987. Anomalies are computed as departures from the COADS/ICE climatology (Reynolds, 1987). Contour interval is 1°C, with negative anomalies dashed.

Fig. 7. Time–longitude section of monthly sea surface temperature anomalies for 5°N–5°S. A 1-2-1 smoothing filter in time is used on all internal points of the diagram. Contours in °C at an interval of 0.5°C. Dashed lines indicate negative anomalies.
Fig. 8. (a) Outgoing longwave radiation, JJA 1987 (NOAA AVHRR IR window channel measurements by NESDIS/ESL). Data are accumulated and averaged over 2.5° areas and interpolated to a 5° Mercator grid for display. Contour interval 20 W m⁻², with contours of 280 W m⁻² and above dashed. (b) Outgoing longwave radiation anomaly, JJA 1987. Anomalies are computed as departures from the 1974–83 base period mean (1978 missing). Contour interval 10 W m⁻², with positive anomalies dashed.

Fig. 9. Time–longitude section of monthly outgoing longwave radiation anomalies for 5°N–5°S. Contour interval is 10 W m⁻² with dashed contours indicating negative anomalies. A 1–2–1 smoothing filter in time is used on all internal points of the diagram. Anomalies are computed as departures from a 1974–83 base period mean (1978 missing).
Fig. 10. (a) Mean 850 mb vector wind, JJA 1987, (NMC final analysis). Winds are analyzed on a 2.5° grid and interpolated to a 5° Mercator grid for display. Vector length of 5° longitude represents wind speed of 6.25 m s⁻¹. Contour interval for isotachs is 5 m s⁻¹. (b) As in (a) except for wind anomalies. Vector length of 5° longitude represents anomalous wind speed of 3.125 m s⁻¹, and anomalies are computed as departures from 1980-83 base period monthly means.

Fig. 11. Time-longitude section of monthly 850 mb zonal wind anomalies for 5°N–5°S. A 1-2-1 smoothing filter in time is used on all internal points of the diagram. Contour interval is 1 m s⁻¹, and dashed contours indicate easterly anomalies. Anomaly is departure from monthly mean averages calculated from a Mar 80-Feb 84 base period.
d. Tropical circulation

1) THE 850 MB CIRCULATION

Easterly low level (850 mb) winds were found in a belt centered near 10°S in all ocean regions during the season (Fig. 10a). Except for a small region in the central Pacific, these winds were more easterly than normal (Fig. 10b). Areas of westerly anomaly were observed in the Indian Ocean, across the Philippines and near the equator in the central Pacific. The area of westerly anomalies at 850 mb which has dominated the central Pacific since about May 1986 remains (Fig. 11), but shows signs of being past its peak. The continued eastward progression of the westerly anomalies which was noted during 1982–83 (Arkin et al., 1983) has not been evident during the current episode.

2) THE 200 MB CIRCULATION

Easterly winds with a northerly component were continuous along the equator at 200 mb during the season (Fig. 12a), with northerly anomalies found in most regions (Fig. 12b). This anomalous flow from the summer to the winter hemisphere is in the sense of an anomalously enhanced Hadley circulation. Some part of this anomaly is likely an artifact resulting from the May 1986 changes in the NMC Global Data Assimilation System (Janowiak et al., 1988) and the subsequent inconsistency between the current analysis and the climatology used to compute the anomalous winds, but it seems probable that a portion is real.

An anticyclonic anomaly couplet was found in the eastern Pacific, with the strongest subtropical westerly

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Fig. 12. (a) Mean 200 mb vector wind, JJA 1987, and (b) anomalies. Anomaly is departure from 1968–83 mean. Contour interval for mean (anomalies) is 10 m s⁻¹ (5 m s⁻¹). Vector length of 5° longitude represents wind speed of 20 m s⁻¹ (6.25 m s⁻¹) for mean (anomalies).
anomalies near 28°S, 120°W. This feature has been present in varying degrees for more than one year, and has been shown to be characteristic of warm episodes (Arkin, 1982). The interannual change in the strength of the tropical easterly jet across the Indian Ocean is probably best illustrated by the change from the same season in 1986 (Halpert and Ropelewski, 1987). No 20 m s⁻¹ contour was present during 1987 (Fig. 12a), while nearly the entire Indian Ocean from the equator to 15°N was covered by 200 mb winds of greater than 20 m s⁻¹ during the previous year. The Southern Hemisphere subtropical jet, which had a 50 m s⁻¹ core extending from about 75°E–150°W during 1986, only exceeded 50 m s⁻¹ between 160°E–130°W in 1987.

3. The Southern Hemisphere extratropics

a. Seasonal atmospheric circulation

As is generally the case, the mean 500 mb geopotential height field during the season (Fig. 13a) was quite zonal in character. The anomaly field (Fig. 13b) shows that above normal heights were found in a belt from about 20°–50°S in the Eastern Hemisphere, with a narrow belt of negative anomalies to the south. An area of negative anomalies covered the majority of the eastern and central South Pacific from 20°–50°S, while a strong positive anomaly was located between 50°S and Antarctica in the same longitudes.

b. Seasonal climate anomalies

Only a few stations in a small region northeast of New Zealand experienced temperatures in the lowest 30% of the Gaussian distribution fit to the historical data during JJA 1987 (Fig. 14); probably in association with the negative SST anomalies observed there (Fig. 6b). On the other hand, large parts of each of the continents were covered by temperatures in the upper 30%, and Indonesia and South America had substantial regions where temperatures were in the warmest 10%. Precipitation anomalies were not as extensive (Fig. 15), with southern South America having several areas in the wettest 30% of the Gamma distribution fit to the historical record at the individual stations, and a region extending north from the North Island of New Zealand experiencing rainfall in the lowest 30%.

4. The Northern Hemisphere extratropics

a. Seasonal atmospheric circulation

The 700 mb geopotential height anomalies (Fig. 16) were modest in amplitude and without notable continuity from the previous season (Wagner, 1987). Positive anomalies were observed north of the Bering Strait, across Greenland and south into the Atlantic, northeast of the Aral Sea, and in many parts of the subtropics. Significant negative anomalies were found in the North Pacific, northern Canada extending into the Atlantic southeast of Newfoundland and from England across Scandanavia to Novaya Zemlya.

b. Seasonal climate anomalies

Negative temperature anomalies were also small in extent in the Northern Hemisphere during the season (Fig. 17), with only an area centered on the Baltic Sea exhibiting temperatures in the lowest 10%. Much of northern Europe was in the lowest 30%, in association with the negative height anomaly over Scandinavia, while smaller areas of negative departure were found in a few locations in Asia near 55°N, Greece and Cyprus and parts of the southwestern United States. Positive anomalies dominated large parts of the hemisphere, particularly in the subtropics. Much of Central America, the Caribbean and the eastern United States were in the warmest 30%, along with much of northern Africa and the western Mediterranean, India, Indochina, the Philippines and Indonesia. Substantial portions of all these regions were in the warmest 10%. A tendency for general warmth in the tropical troposphere to occur during the late stages of ENSO warm episodes was noted by Horel and Wallace (1981).

Precipitation anomalies during the season were less coherent (Fig. 18), and, in general, of lower amplitude. No substantial positive anomalies were found in the subtropics, while drier than normal conditions were observed in many of the regions where temperatures were above normal. Areas in the highest or lowest 10% were scarce, with only the dry anomalies in the Sahel and the western Indian subcontinent of significant extent.

5. Seasonal and monthly circulation and climate anomalies in the United States

a. Summer season means

A more detailed look at the anomalies for the season as a whole over the United States shows that much of the eastern United States was well above normal in temperature (Fig. 19a), with substantial areas in the highest 10%. It was the third hottest summer of the past 57 years in the South Atlantic states. The Midwest and South Atlantic coastal regions and much of Florida were not only warm but dry as well, with much of the area in the lowest 30% and a few pockets in the lowest 10% (Fig. 19b). Below normal temperatures were found in New Mexico and western Texas, as well as in a few other small regions in the West. The only substantial area of drier than normal conditions, aside from those associated with the heat in the East, was found in western and central Washington, where the region around Puget Sound was in the lowest 10%. Regions of greater than normal precipitation were found in the Rocky Mountains and near the Great Lakes, although few stations had rainfall in the highest 10%.
FIG. 3. (a) Mean Southern Hemisphere 500 mb height for JJA, 1997. Contour interval is 8 dam. (b) Height anomaly (departure from the 1976–83 mean), contour interval 2 dam, with negative anomalies dashed.
Fig. 14. Mean Southern Hemisphere surface air temperature for JJA 1987 expressed as percentiles of the normal (Gaussian) distribution fit to the 1951–80 base period data, contoured at the 10th, 30th, 70th and 90th percentiles. Hatched area, <30 percentile; stippled area, >70 percentile. Station locations are denoted by small "+"; no analysis done in areas with insufficient data.

Fig. 15. Southern Hemisphere precipitation percentiles for JJA 1987 based on a Gamma distribution fit to the 1951–80 base period data, displayed as in Fig. 14.
b. June 1987

Above normal 700 mb geopotential heights covered the entire country during June (Fig. 20), with centers in Montana and off the southeast coast. The anomalous trough centered north of Hudson Bay during May (Wagner, 1987) persisted during June but was much weaker. Temperatures across the United States were generally above normal (Fig. 21), except for a region centered in western Texas. Rainfall was in the upper 30% over much of the Gulf Coast (Fig. 22), with few stations in the upper 10%. An area of the Northeast along the Canadian border from northeastern Indiana to Maine was moderately wet as well. The northern tier from Michigan to the Pacific was relatively dry, consistent with the higher than normal geopotential heights across the region.

c. July 1987

The anomalous ridging across the country during June was replaced in July by a rather deep trough in the west and a weaker ridge across the east, centered over the Mid-Atlantic states (Fig. 23). Temperature anomalies during the month reflected the circulation pattern, with negative anomalies west of the Rockies and positive anomalies in an area from the North Central states across the Great Lakes and down the East Coast to Florida (Fig. 24). Stations in a large part of the Great Basin had temperatures in the lowest 10%, while an area across Lake Michigan and from Lake Erie down the Mid-Atlantic Coast to North Carolina was in the warmest 10%. Precipitation was relatively high in the Northwest, with areas in the wettest 10% in western Oregon and centered over the northern
Continental Divide, while many stations in the Southeast were relatively dry (Fig. 25).

**d. August 1987**

During August, a weak trough was found in the Northern Plains, with weak ridging to the east and west (Fig. 26). The anomalous ridging off the West Coast was an extension of a strong anticyclonic anomaly that was centered over the Bering Strait. Positive anomalies covered much of the Northern Hemisphere during the month, extending across the Pole in the North Atlantic and covering much of Asia and the Mediterranean. The negative anomaly in the central United States was the southernmost extension of a cyclonic anomaly centered north of Hudson Bay. Temperatures were below normal in the region of this trough (Fig. 27), with many stations in the Rockies and the Northern Plains experiencing monthly means in the coldest 30% and a few in northern Montana in the coldest 10%. An area on either side of the Hudson River Valley also had temperatures in the lowest 30%. Above normal temperatures were found in small areas of the Pacific Northwest and in most of the Southeast. A substantial number of stations in Florida and an area extending northward from the southern Atlantic Coast into West Virginia had August temperatures in the warmest 10%. Precipitation anomalies were scattered (Fig. 28), with drier than normal conditions predominating in Washington and discontinuously along a belt from eastern Texas to New England. Much of the Midwest and
Rocky Mountain states had stations with rainfall in the heaviest 30%, including small areas in Wyoming, New Mexico and from Iowa across Lake Michigan in the wettest 10%.

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REFERENCES


