SEASONAL CLIMATE SUMMARY

The Global Climate of March–May 1991: Anomalous Low-Frequency Fluctuations Dominate the Midlatitudes; ENSO Becomes Established in the Tropics

GERALD D. BELL AND MICHAEL S. HALPERT

Climate Analysis Center, NWS/NMC/NOAA, Washington, D.C.

1. Introduction

Positive sea surface temperature (SST) anomalies increased and spread throughout the central and eastern equatorial Pacific during April and May, resulting in the largest SST anomalies in the east-central equatorial Pacific since the 1986–87 El Niño–Southern Oscillation (ENSO) event (Kousky and Leetmaa 1989). The increases in SST anomalies were accompanied by sharp decreases in the Southern Oscillation index (SOI) during March–May (MAM) 1991. Atmospheric wind indices indicated a reduced strength of both the easterly trades and the subtropical jet over the east-central equatorial Pacific by May, reflecting a reduced intensity of the Walker circulation. Convective activity, as measured by outgoing longwave radiation (OLR), remained near normal over the east-central equatorial Pacific during MAM 1991 (see also Chelliah 1992). Thus, with the exception of the OLR index, all atmospheric and oceanic indices indicated the initial stages of ENSO by the end of the season.

In the Northern Hemisphere extratropics, persistent circulation anomalies were observed throughout MAM 1991. During March, the primary 500-mb circulation anomalies were found throughout the central North Pacific sector. A major shift of the persistent height anomalies to the Atlantic sector then occurred between March and April. The April mean 500-mb circulation was then dominated by a wave pattern of large-amplitude height anomalies extending eastward from North America to north-central Russia. The mean 500-mb height anomaly field during May primarily reflected an intensification of the April mean pattern.

In the Southern Hemisphere extratropics, the mean 500-mb circulation during MAM 1991 was dominated by a split flow/blocking configuration over the high latitudes of the eastern South Pacific and by negative height anomalies over the lower latitudes of the South Pacific. This persistent anomaly pattern was associated

with an enhanced subtropical jet stream near 30°S and with negative sea level pressure anomalies throughout the central and subtropical South Pacific.

Seasonal mean surface temperatures during MAM 1991 were above normal over many land regions of both the Northern and Southern hemispheres. This continues a trend of warmer than normal MAMs over the globe that began in the early 1980s (Kousky and Halpert 1991). Hemispheric mean temperatures, however, were not as warm as those observed during MAM 1990.

2. Tropics

The development of large negative SOI values during MAM 1991 (Table 1, Fig. 1), coupled with a return to positive SST anomalies throughout the central and eastern equatorial Pacific (Table 1, Figs. 2, 3), indicated a return to warm episode (ENSO) conditions in the equatorial Pacific. Monthly SOI values were consistently less than or equal to -1.0 during MAM 1991, reflecting extensive negative sea level pressure (SLP) anomalies over the central South Pacific and positive SLP anomalies over the western South Pacific (Fig. 4). Positive sea surface temperature anomalies increased markedly during April and May in the Niño 4 region following three consecutive months of positive but decreasing SST anomalies (Table 1, Fig. 2). Similar increases in SST anomalies were noted in both the Niño 3 and the Niño 1–2 regions during May, with positive SST anomalies covering much of the central and eastern equatorial Pacific by the end of the season. The increased SST anomalies reflected a rapid progression of the 28°C isotherm along the equator (Fig. 5) to its most eastward position since the 1986–87 ENSO event (Kousky and Leetmaa 1989). This warming was associated with an increased (decreased) depth of the 20°C isotherm over the eastern (western) equatorial Pacific (Fig. 6) and with the reestablishment of positive upper oceanic heat storage anomalies (integrated temperature) throughout the east-central equatorial Pacific (Fig. 7).

Despite some ambiguity early in the season, all at-

Corresponding author address: Dr. Gerald D. Bell, Climate Analysis Center, W/NMC52, WWB, Rm 605, 5200 Auth Road, Camp Springs, MD 20746.

TABLE 1. Atmospheric and SST index values for the most recent 12 months. Atmospheric indices are standardized by the mean annual standard deviation, except for the Tahiti and Darwin SLP anomalies, which are in millibars. SST indices (anomalies and means) are in degrees Celsius. Note that positive (negative) values of the 200-mb zonal wind index imply westerly (easterly) anomalies; positive (negative) values of the 850-mb zonal wind indices imply easterly (westerly) anomalies.

Date	SLP Anomalies		Tahiti-Darwin SOI	Pacific 850-mb zonal wind indices						Pacific 200-mb zonal wind index	OLR index	Pacific SST					
				5°N-5°S		5°N-5°S		5°N-5°S				Niño 1 + 2		Niño 3		Niño 4	
	Tahiti	Darwin		135°E-180°	175°-140°W	5°N-5°S	135°-120°W	165°-110°W	5°N-5°S			160°E-160°W	0°-10°S	90°-80°W	150°-90°W	5°N-5°S	160°E-150°W
MAY 91	-0.6	1.7	-1.5	-0.5	-0.7	-0.9		-1.2	-0.2	-0.2	0.5	24.6	1.0	27.8	0.9	29.4	
APR 91	-1.1	0.5	-1.0	-0.2	0.3	0.2		-0.6	-0.2	-0.2	-0.3	25.2	0.4	27.6	0.8	29.1	
MAR 91	-0.1	2.1	-1.4	-0.9	0.1	-0.1		0.2	-0.2	-0.2	0.5	26.7	0.3	27.2	0.5	28.6	
FEB 91	0.0	0.1	-0.1	0.4	0.3	0.9		-0.1	-0.6	-0.6	0.5	26.2	0.2	26.5	0.7	28.7	
JAN 91	1.0	0.1	0.6	0.5	0.3	0.1		0.1	-0.3	-0.3	0.0	24.3	0.4	25.8	0.8	28.9	
DEC 90	-0.3	0.4	-0.5	-0.6	-0.6	-0.6		-0.8	-0.3	-0.3	0.0	22.5	0.2	25.3	1.0	29.2	
NOV 90	-0.7	0.4	-0.7	-1.7	-0.3	0.1		0.0	-0.1	-0.1	-0.1	21.4	0.0	25.0	0.8	29.1	
OCT 90	0.4	0.3	0.1	0.5	-0.2	-0.4		-0.4	0.2	0.2	-0.4	20.4	0.2	25.0	0.8	29.2	
SEP 90	0.1	1.4	-0.8	0.0	-0.2	-0.6		0.1	-0.5	-0.5	0.0	20.6	0.2	25.0	0.8	29.0	
AUG 90	-0.1	0.9	-0.6	0.0	0.1	0.2		0.6	-0.6	-0.6	-0.1	20.8	0.1	25.1	0.7	29.1	
JUL 90	0.7	0.0	0.5	-0.1	-0.7	-0.3		0.0	0.1	0.1	-0.6	21.1	0.0	25.6	0.6	29.1	
JUN 90	0.0	0.1	0.0	-0.4	-0.1	-0.8		0.3	0.2	0.2	0.5	23.3	0.3	26.6	0.4	28.9

FIG. 1. The 5-month running mean of the difference between the standardized sea level pressure anomalies at Tahiti and Darwin (Tahiti-Darwin). Values are standardized by the mean annual standard deviation. Crosses are individual monthly means.

FIG. 2. Equatorial Pacific sea surface temperature anomaly indices ($^{\circ}\text{C}$) 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 [see the September 1986 *Climate Diagnostics Bulletin* or Reynolds (1988)].

FIG. 3. Sea surface temperature, (a) mean (blended analysis) and (b) anomalous, for MAM 1991 analyzed on a 2.5° grid. SST contour interval is 2°C . Temperatures greater than 20°C are contoured every degree with odd contours dashed. Anomalies are computed as departures from the COADS/ICE climatology (Reynolds 1988). Anomaly contour interval is 1°C with negative anomalies dashed.

mospheric wind indices indicated the initial stages of ENSO by the end of the season (Table 1). For example, monthly and seasonally averaged indices indicated easterly 200-mb wind anomalies throughout the equatorial Pacific by April (Table 1), indicating ENSO-like conditions in the upper troposphere during the latter part of the season. In the lower troposphere monthly mean 850-mb easterly trade winds were near normal throughout the central and eastern equatorial Pacific during March and April but weakened sharply during May. Thus, a weaker than normal Walker Circulation was clearly evident by the end of the season, consistent with the initial stages of ENSO.

Despite the agreement between oceanic and atmospheric indices in indicating the initial stages of ENSO, enhanced organized convective activity over the equatorial Pacific had not yet become established during the season (Fig. 8). Regions of slightly enhanced con-

vective activity were located between 150°E and 170°W along and north of the equator, and north of the equator east of 170°W . The primary positive OLR anomalies were found over Indonesia and Australia, and along and south of the equator east of 170°W .

3. Extratropics

a. Northern Hemisphere

The mean 500-mb circulation during MAM 1991 was dominated by a zonally elongated dipole of height anomalies over the western and central North Pacific and by a large amplitude wave pattern of anomalies extending eastward from the western United States to north-central Russia (Fig. 9). This anomalous circulation pattern strongly reflected low-frequency height field fluctuations around the hemisphere, with many

FIG. 4. Sea level pressure, (a) mean and (b) anomalous for MAM 1991. Sea level pressure is analyzed on a 2.5° grid and interpolated to a 5° Mercator grid for display. Contour interval is 2 mb, and 1000 mb has been subtracted from contour labels. Anomaly is departure from the August 1982–July 1988 base period monthly means. Anomaly contour interval is 1 mb and negative anomalies are indicated by dashed contours.

circulation anomalies persisting for periods in excess of 1 month (Figs. 10, 11b).

Over the western North Pacific, MAM 1991 began during a major transition to the negative phase of the west Pacific (WP) teleconnection pattern (Wallace and Gutzler 1981). Negative height anomalies developed over the northwestern North Pacific and positive height anomalies developed over the west-central North Pacific (Figs. 10a,b, 12a, 13). This change marked the end of a persistent positive WP pattern that had dominated the western and central North Pacific during January and much of February (Fig. 12a; Chelliah 1992).

Also during March, a major blocking anticyclone developed over the east-central North Pacific (Fig. 14a) within an environment dominated by large positive planetary-scale height anomalies (Fig. 14b). Down-

stream of the mean block position (western United States and eastern North Pacific), negative planetary-scale height anomalies also became established during March. Accompanying this feature was an amplified southwesterly jet over the central North Pacific and an enhanced subtropical jet extending northeastward from the Hawaiian Islands to the southwestern United States within a region of anomalously strong convective activity (Fig. 8). The blocking anticyclone was associated with a complete disruption of transient wave activity (Fig. 14c), such that the mean storm track position over the north-central North Pacific was displaced northward toward the Gulf of Alaska (Fig. 15). Cyclones arriving over the Gulf of Alaska subsequently moved southward toward, and intensified within, the planetary-scale trough centered off the southwest coast of the United States. In effect, the planetary-scale

FIG. 5. Time-longitude section (5°N–5°S) of (a) sea surface temperature and (b) anomaly. Contour interval is 1°C and 0.5°C, respectively. SST values greater than 28°C and anomalies less than -0.5°C are shaded. Stippled areas indicate anomaly values greater than 0.5°C. Anomalies are computed based on the COADS/ICE climatology (see the September 1986 *Climate Diagnostics Bulletin*).

FIG. 6. Anomalous depth of the 20°C isotherm along the equator in the Pacific Ocean. The contour interval is 10 m with dark (light) shading for values greater 10 m (less than -10 m). Anomalies are computed with respect to the 1985–90 base period.

trough provided a focus for subplanetary-scale transient wave intensification within an environment receiving a continuous supply of moisture from the amplified subtropical jet. Each intensifying cyclone consequently brought a moisture surge and heavy precipitation to the western and southwestern United States, providing temporary relief from prolonged drought conditions in that region (Figs. 16c,d).

The primary Northern Hemisphere midlatitude circulation anomalies shifted during late March/early April from the North Pacific to the North Atlantic and Eurasian sectors. Specifically, positive height anomalies became established over the eastern United States, over the east-central North Atlantic, and over north-central

Russia during April (Figs. 10c,d, 17) and persisted during May (Figs. 10e, f, 18). These positive height anomalies represented extremely low-frequency fluctuations occurring primarily on the intermonthly time scale (Figs. 11a,b). For example, the transition to positive 500-mb height anomalies over north-central Russia, in conjunction with persistent negative height anomalies over Scandinavia, reflected a major shift to the positive phase of the Eurasian (EU) teleconnection pattern (Fig. 12e; Wallace and Gutzler 1981) between March and April. This pattern was associated with positive temperature anomalies and drier than normal

FIG. 7. Anomalies of heat storage (integrated temperature) along the equator in the upper 408 m of the Pacific Ocean. The contour interval is $10^3 \text{ cm}^2\text{C}$, with dark (light) shading for anomalies greater $10^3 \text{ cm}^2\text{C}$ (less than $-10^3 \text{ cm}^2\text{C}$). Anomalies are computed with respect to the 1985–90 base period.

FIG. 8. Outgoing longwave radiation, (a) mean and (b) anomalous for MAM 1991 (*NOAA-11* AVHRR IR window channel measurements by NESDIS/SRL). Data are accumulated and averaged over 2.5° areas and interpolated to a 5° Mercator grid for display. Contour interval is 20 W m^{-2} . Contours of 280 W m^{-2} and above are dashed. Anomalies are computed as departures from the 1979–88 base-period mean. Anomaly contour interval is 10 W m^{-2} . Positive anomalies are dashed.

FIG. 9. Northern Hemisphere 500-mb geopotential height, (a) mean and (b) anomalous for MAM 1991 (NMC final analysis). Contour interval is 8 dam and 2 dam for the mean and anomalous heights, respectively. Anomalies are computed as departures from the 1979–88 base-period means. Negative anomalies are indicated by dashed contours.

FIG. 10. Northern Hemisphere—percentage of days during (a), (b) March 1991; (c), (d) April; and (e), (f) May in which 500-mb height anomalies greater than 15 m and less than -15 m were observed, respectively. Values greater than 75% are shaded.

FIG. 11. Northern Hemisphere—standard deviation of the mean 500-mb height anomaly field during MAM 1991 (a) based on the total anomaly field, (b) produced by fluctuations having periods greater than 30 days, (c) produced by fluctuations having periods 10–25 days, and (d) produced by fluctuations having periods 2–6 days. Shading identifies regions in which explained variance exceeds (b)–(c) 40% and (d) 25% (i.e., in which explained standard deviation exceeds 63% and 50%, respectively). Anomalies are computed from the 1979–88 base period. Contour interval is 30 m in (a) and 10 m in (b)–(d).

conditions throughout north-central Russia during the period (e.g., Fig. 21).

The region of positive 500-mb height anomalies over

the eastern North Atlantic and Europe observed during April expanded northward and developed into a major blocking anticyclone over the northeastern North At-

FIG. 12. 700-mb teleconnection indices identified by Wallace and Gutzler (1981). Curves show 25-day running mean values of (a) the west Pacific (WP) index; (b) the Pacific/North American (PNA) index; (c) the west Atlantic (WA) index; (d) the east Atlantic (EA) index; and (e) the Eurasian (EU) index. The running mean is applied to nonoverlapping 5-day averaged index values determined from daily normalized 700-mb height data for the period December 1989–July 1991. Daily height anomalies are normalized using 27-yr (1964–90) daily means and standard deviations. Tick marks along horizontal axes are placed at the beginning of each month. Inset illustrates positive phase of the teleconnection pattern index, with height anomalies over centers of action indicated by (+) and (–) signs.

FIG. 13. Northern Hemisphere 700-mb mean and anomalous geopotential height for March 1991. Mean heights are denoted by solid contours drawn at an interval of 6 dam. Anomalies are departures from the 1961–90 base-period means. Negative (positive) anomalies are indicated by dotted (dashed) contours. Anomaly contour interval is 15 m. The zero anomaly contour has been omitted.

lantic during May (cf. Figs. 10c,e, 17, 18). The simultaneous occurrence of persistent positive height anomalies over the eastern North Atlantic and persistent negative height anomalies over Europe and Scandinavia reflected an intensification of the positive phase of the east Atlantic (EA) teleconnection pattern (Fig. 12d; Wallace and Gutzler 1981). This pattern was associated with below-normal monthly mean temperatures throughout Scandinavia, Europe, the Mediterranean, western North Africa, and the southwestern Soviet Union during May (not shown).

Over North America, the seasonal mean 500-mb circulation was dominated by negative height anomalies over the western United States and Canada and by positive height anomalies over the eastern United States and south-central Canada (Fig. 9). Over the United States, above-normal surface temperatures were observed throughout the central and eastern regions, with below-normal temperatures confined to the west

(Figs. 16a,b, 19a,b, 20a,b, and 21). Overall, MAM 1991 was the third warmest MAM season for the contiguous United States since 1931. The northeastern United States from Pennsylvania to Maine experienced its warmest MAM season since 1931. This anomalous warmth was particularly evident during April and May (Figs. 19a,b, 20a,b), and occurred in conjunction with the intensification of positive height anomalies throughout the region (Figs. 17, 18). Similarly, mean temperatures for MAM were the second warmest on record over the southeastern and Gulf Coast states and over the upper Midwest.

Above-normal precipitation was observed throughout the western United States during MAM 1991 (Figs. 21c,d), with much of this precipitation falling during March (cf. Figs. 16c,d with 19c,d, 20c,d). Above-normal precipitation amounts were also found over the Northern and Central Plains states during April and May and throughout the Gulf Coast states during the

FIG. 14. Daily 500-mb height anomalies for MAM 1991 averaged over 10° latitude bands centered at 40°N . Panel (a) shows the full 500-mb height field anomalies (interval is 120 m); panel (b) shows the planetary-scale (two-dimensional wavenumbers 1–6, zonal mean removed; interval is 120 m) height anomalies; panel (c) shows the subplanetary-scale (two-dimensional wavenumbers 7–12; interval is 120 m) height anomalies. Positive height anomalies are shaded. Anomalies are computed with respect to the 1979–88 base period.

entire season. Rainfall along the Gulf Coast was especially heavy, with precipitation amounts exceeding the 90th percentile throughout much of the region. Many stations recorded in excess of 750 mm of precipitation during the season, with New Orleans, Louisiana, receiving more than 875 mm.

b. Southern Hemisphere

The mean 500-mb circulation during MAM 1991 (Fig. 22) was dominated by two primary circulation anomalies that persisted the entire season (Figs. 23, 24, 25). The first was a split flow/blocking configuration, which shifted from the north-central to the northeastern South Pacific between March and April (Figs. 22a,c). Fluctuations having periods greater than 10 days accounted for the broad maximum of 500-mb height field variability observed throughout this region (Fig. 25). The second reflected negative height anomalies over the central and subtropical South Pacific. This pattern was associated with anomalous westerly subtropical jet speeds in excess of 20 m s^{-1} during May and with seasonally averaged anomalous westerly subtropical jet speeds in excess of 10 m s^{-1} (not shown). Negative sea level pressure anomalies over the central and subtropical South Pacific also reflected the persistent upper-level trough anomaly (Fig. 4).

The pattern of persistent positive height anomalies over Australia, combined with negative height anomalies over New Zealand, was associated with above-normal surface temperatures over southern and eastern Australia (Figs. 26a,b) and with substantial precipi-

tation deficits throughout Australia during the season (Figs. 26c,d). This exceptional dryness is consistent with precipitation patterns often observed during Pacific warm episodes (Ropelewski and Halpert 1987).

FIG. 15. Northern Hemisphere—standard deviation of the 500-mb height field during March 1991 produced by fluctuations having periods 2–6 days. Contour interval is 15 m. Analysis is based on daily 0000 UTC data.

FIG. 16. (a) Mean surface air temperature expressed as percentiles of the normal Gaussian distribution fit to the 1961–90 base period, (b) surface air temperature anomalies ($^{\circ}\text{C}$), contour interval 1°C , (c) total precipitation expressed as percentiles of the Gamma distribution fit to the 1961–90 base period, and (d) total precipitation (mm); contour interval is 25 mm for values up to 100 mm, 50 mm for values between 100 and 200 mm, and 100 for values greater than 200 mm, over the United States for March 1991. Temperature anomalies are computed as departures from the 1961–90 base-period means.

FIG. 17. Northern Hemisphere 700-mb mean and anomalous geopotential height for April 1991. Mean heights are denoted by solid contours drawn at an interval of 6 dam. Anomalies are departures from the 1961–90 base-period means. Negative (positive) anomalies are indicated by dotted (dashed) contours. Anomaly contour interval is 15 m. The zero anomaly contour has been omitted.

FIG. 18. Northern Hemisphere 700-mb mean and anomalous geopotential height for May 1991. Mean heights are denoted by solid contours drawn at an interval of 6 dam. Anomalies are departures from the 1961–90 base-period means. Negative (positive) anomalies are indicated by dotted (dashed) contours. Anomaly contour interval is 15 m. The zero anomaly contour has been omitted.

FIG. 19. (a) Mean surface air temperature expressed as percentiles of the normal Gaussian distribution fit to the 1961–90 base period; (b) surface air temperature anomalies ($^{\circ}\text{C}$), contour interval 1°C ; (c) total precipitation expressed as percentiles of the Gamma distribution fit to the 1961–90 base period; and (d) total precipitation (mm), contour interval 25 mm for values up to 100 mm, 50 mm for values between 100 and 200 mm, and 100 for values greater than 200 mm, over the United States for April 1991. Temperature anomalies are computed as departures from the 1961–90 base-period means.

FIG. 20. (a) Mean surface air temperature expressed as percentiles of the normal Gaussian distribution fit to the 1961–90 base period; (b) surface air temperature anomalies ($^{\circ}\text{C}$), contour interval 1°C ; (c) total precipitation expressed as percentiles of the Gamma distribution fit to the 1961–90 base period; and (d) total precipitation (mm), contour interval 25 mm for values up to 100 mm, 50 mm for values between 100 and 200 mm, and 100 for values greater than 200 mm, over the United States for May 1991. Temperature anomalies are computed as departures from the 1961–90 base-period means.

FIG. 21. Northern Hemisphere (a) surface temperature and (b) precipitation percentiles for MAM 1991. Percentiles are computed based on a fit of a Gaussian (Gamma) distribution to the 1961–90 base-period temperature (precipitation) data. Contours are drawn for the 10th, 30th, 70th, and 90th percentiles. Station locations are denoted by small “+.” Those stations with zero median precipitation are designated by a large “X” in (b). No analysis is done in areas with insufficient data.

FIG. 22. Southern Hemisphere 500-mb geopotential height, (a) mean and (b) anomalous for MAM 1991 (NMC final analysis). Contour interval is 8 dam and 2 dam for the mean and anomalous heights, respectively. Anomalies are computed as departures from the 1979–88 base-period means. Negative anomalies are indicated by dashed contours.

FIG. 23. Southern Hemisphere—percentage of days during (a), (b) March 1991; (c), (d) April; and (e), (f) May in which 500-mb height anomalies greater than 15 m and less than -15 m were observed, respectively. Values greater than 75% are shaded.

FIG. 25. Southern Hemisphere—standard deviation of the mean 500-mb height anomaly field during MAM 1991: (a) based on the total anomaly field, (b) produced by fluctuations having periods greater than 30 days, (c) produced by fluctuations having periods 10–25 days, and (d) produced by fluctuations having periods 2–6 days. Shading identifies regions in which explained variance exceeds (b)–(c) 40% and (d) 25% (i.e., in which explained standard deviation exceeds 63% and 50%, respectively). Anomalies are computed from the 1979–88 base period. Contour interval is 30 m in (a) and 10 m in (b)–(d).

FIG. 26. Southern Hemisphere (a) surface temperature and (b) precipitation percentiles for MAM 1991. Percentiles are computed based on a fit of a Gaussian (Gamma) distribution to the 1961–90 base-period temperature (precipitation) data. Contours are drawn for the 10th, 30th, 70th, and 90th percentiles. Station locations are denoted by small “+.” Those stations with zero median precipitation are designated by a large “X” in (b). No analysis is done in areas with insufficient data.

Acknowledgements. We thank the anonymous reviewers for their critical comments that led to an improved version of the manuscript. We also thank Chet Ropelewski for his critical comments on the manuscript and John Kopman for preparing the figures.

REFERENCES

- Chelliah, M., 1993: The global climate for December 1990–February 1991: Strong temperature and precipitation contrasts over North America and Eurasia, mixed ENSO conditions in the tropics. *J. Climate*, **6**, 1392–1412.
- Kousky, V. E., and A. Leetmaa, 1989: The 1986–87 Pacific warm episode: Evolution of oceanic and atmospheric anomaly fields. *J. Climate*, **2**, 254–267.
- , and M. S. Halpert, 1991: The global climate of March–May 1990: An abnormally warm season in both hemispheres. *J. Climate*, **4**, 80–105.
- Reynolds, R. W., 1988: A real-time global sea surface temperature analysis. *J. Climate*, **1**, 75–86.
- Ropelewski, C. F., and M. S. Halpert, 1987: Global and regional scale precipitation patterns associated with the El Niño–Southern Oscillation. *Mon. Wea. Rev.*, **115**, 1606–1626.
- Wallace, J. M., and D. S. Gutzler, 1981: Teleconnections in the geopotential height field during the Northern Hemisphere winter. *Mon. Wea. Rev.*, **109**, 784–812.