Meteorological Centers (RSMC; Knapp et al. 2010). To date, IBTrACS represents the most complete compilation of TC data and offers a unique opportunity to revisit the global climatology of TCs. Using IBTrACS data (Schreck et al. 2012), a 30-year average value for storms (from WMO-based RSMC numbers) is noted for each basin.

The global tallying of total TC numbers is challenging and involves more than simply adding up basin totals because some storms cross basin boundaries, some basins overlap, and multiple agencies are involved in tracking and forecasting TCs. Compiling the activity over all seven TC basins, the 2012 season (2011/12 in the Southern Hemisphere) had 84 named storms (wind speeds ≥34 kts or 18 m s^{-1}), which is below the 1981–2010 average of 89. However, the 2012 total was higher than the previous two seasons, with 2010 having the lowest number of global named storms since the start of the satellite era. The 2012 season also featured 41 hurricanes/typhoons/cyclones (HTC; wind speeds ≥64 kts or 33 m s^{-1}), which is below the 1981–2010 average of 44 HTCs (Knapp et al. 2010). Of these, 19 (which is the global average) reached major HTC status (wind speeds ≥96 kts or 49 m s^{-1}; WMO 2013).

There were only three Category 5 systems during the year [Samba, Bopha (named Pablo in the Philippines region), and Jelawat—all in the western North Pacific], which ties with 2011 as the all-time low number during the satellite era. However, there were there were several Category 3 and 4 intensity-level systems which had major impacts: (1) Sandy in the North Atlantic; (2) Bud and Paul in the Eastern North Pacific; (3) Guchol in the Western North Pacific; (4) Giovanna and Funso in the South Indian Ocean; (5) Jasmine in the Southwest Pacific; and (6) Lua in the Australian region.

The only basin with above-normal activity in 2012 was the North Atlantic, which featured the most well-publicized and destructive storm of the year, Sandy. The nature and climatology of Sandy was unique and Sidebar 4.1 is included to better document this event. Conversely, the South Indian, North Indian, and Southwest Pacific basins experienced well-below-normal TC seasons.

2) Atlantic Basin—G. D. Bell, S. B. Goldenberg, C. W. Landsea, E. S. Blake, T. B. Kimberlain, J. Schemm, and R. J. Pasch

(i) 2012 Seasonal activity

The 2012 Atlantic hurricane season produced 19 tropical storms (TS), of which 10 became hurricanes and 2 became major hurricanes. The 30-year IBTrACS seasonal averages are 11.8 tropical storms, 6.4 hurricanes, and 2.7 major hurricanes. The seasonal accumulated cyclone energy (ACE) value (Bell et al. 2000) was 132.6×10^4 kt^2, which corresponds to 144% of the 1981–2010 median (Fig. 4.9). This value is the 19th highest since 1950, and the 11th highest in the last 30 years. This level of activity, combined with above-average numbers of named storms and hurricanes, satisfies NOAA's criteria for an above-normal season (see http://www.cpc.ncep.noaa.gov/products/outlooks/background_information.shtml). The 1981–2010 seasonal averages are 12 named storms, 6 hurricanes, and 3 major hurricanes.

This year marks the 13th above-normal season since the current high activity era for Atlantic hurricanes began in 1995 (Landsea et al. 1998; Goldenberg et al. 2001). During 1995–2012, 13 (72%) seasons have been classified as above normal with eight (44%) being hyperactive (ACE exceeding 165% of the median), and only two seasons (11%) classified as below normal. These high levels of activity contrast sharply with the recent low-activity era of 1971–94, when 12 (50%) seasons were below normal, and only three (12.5%) were above normal with none being hyperactive.

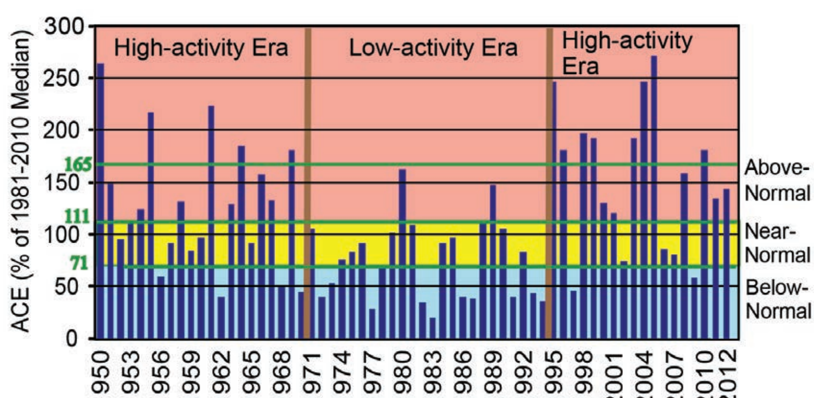

Fig. 4.9. NOAA's ACE index expressed as percent of the 1981–2010 median value. ACE is calculated by summing the squares of the six-hourly maximum sustained wind speed (knots) for all periods while the storm is at least TS strength. Pink, yellow, and blue shadings correspond to NOAA's classifications for above-, near-, and below-normal seasons, respectively. The 165% threshold for a hyperactive season is indicated. Vertical brown lines separate high- and low-activity eras.

(ii) Storm tracks

August–October (ASO) is typically the peak period of the season, and all but four named storms (including one hurricane) during 2012 formed in ASO. During above-normal seasons, much of the ASO activity is linked to storms that first develop in the main development region (MDR, green boxed region in Fig. 4.10, which encompasses the tropical Atlantic Ocean and Caribbean Sea between 9.5°N and 21.5°N; Goldenberg et al. 2001).

During ASO 2012, nine tropical storms formed within the MDR (Fig. 4.10, brown lines), with six becoming hurricanes and one becoming a major hurricane (Sandy; http://www.nhc.noaa.gov/data/tcr/AL182012_Sandy.pdf). These storms accounted for 67% of the seasonal ACE value. Three of these hurricanes made landfall at hurricane strength, including Ernesto (Yucatan Peninsula), Isaac (Louisiana), and Sandy (Jamaica, Cuba as a major hurricane, and New Jersey[3]). This high level of MDR activity was related in part to weak vertical wind shear (Fig. 4.10, green shading) and above-average SSTs (Fig. 4.11a) across much of that region. These conditions are consistent with the ongoing high-activity era for Atlantic hurricanes (Goldenberg et al. 2001; Bell and Chelliah 2006; Bell et al. 2011, 2012).

[3] When Sandy made landfall near Brigantine, NJ, it was a post-tropical cyclone.

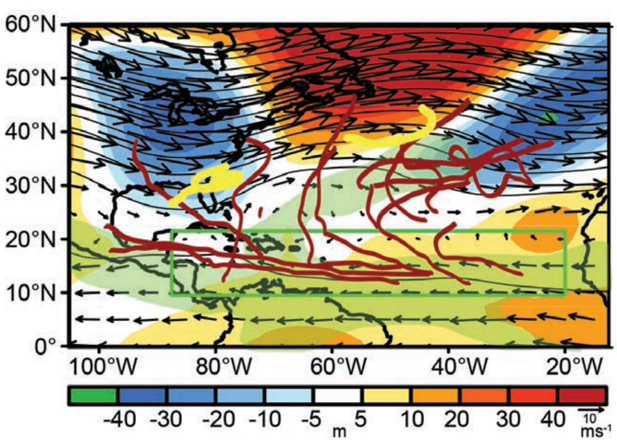

Fig 4.10. Aug–Oct 2012 500-hPa heights (contours, m) and anomalies (shading), mean wind vectors (m s^{-1}) for the 600 hPa–300 hPa layer, and regions where the magnitude of vertical wind shear is less than 8 m s^{-1} (light green shading). Atlantic named storm tracks that formed after 1 Aug are shown in brown, beginning with tropical depression strength. Tracks for storms that formed during May–Jul are shown in yellow. Green box denotes the MDR. Vector scale is below right of color bar. Anomalies are with respect to the 1981–2010 monthly means.

Also during 2012, two named storms formed over the Gulf of Mexico. Debby made landfall in Florida as a tropical storm and Helene made landfall in Mexico as a tropical depression. (Helene actually first developed in the MDR over the central Atlantic, dissipated, and then reformed over the Gulf of Mexico.) Eight named storms (four tropical storms and four hurricanes, with one becoming Major Hurricane Michael) formed north of the MDR over the open North Atlantic, and remained at sea throughout their life cycle. Michael was only the fifth major hurricane in the satellite era to develop from a disturbance of non-tropical origin (http://www.nhc.noaa.gov/data/tcr/AL132012_Michael.pdf).

Sandy became a Category 3 storm with maximum sustained winds of 100 kt (51 m s^{-1}) as it made landfall in eastern Cuba before quickly weakening to a Category 1 hurricane while moving through the central and northwestern Bahamas, only to reach a secondary peak intensity with maximum sustained winds of 85 kt (44 m s^{-1}) while it turned northwestward toward the mid-Atlantic region of the United States. On average, three to four named storms form in the southwestern Caribbean region per season, and roughly two become hurricanes.

The increased 2012 activity north of the MDR reflected a strong mid- and upper-level ridge across the subtropical North Atlantic, along with an extensive region of weak vertical wind shear (Fig. 4.10). These conditions were part of a larger-scale anomalous wave pattern that featured amplified troughs over the eastern US and the eastern North Atlantic. A similar eastern US trough, along with its associated strong southwesterly steering flow over the western North Atlantic, was also evident during ASO 2010 and ASO 2011 (Bell et al. 2011, 2012). In all three years, these conditions contributed to a large number of named storms that stayed well east of North America (Blake et al. 2011).

(iii) Atlantic sea surface temperatures

Sea surface temperatures in the MDR were above average during ASO 2012, with the largest departures (between +0.5°C and +1.0°C) observed across the north-central and northeastern MDR (Fig. 4.11a). The mean SST departure within the MDR was +0.41°C (Fig. 4.11b), which is 0.40°C warmer than the average departure for the entire global tropics (Fig. 4.11c).

This anomalous warmth compared to the remainder of the global tropics has been present since 1995 in association with the warm phase of the Atlantic multidecadal oscillation (AMO; Enfield and Mestas-

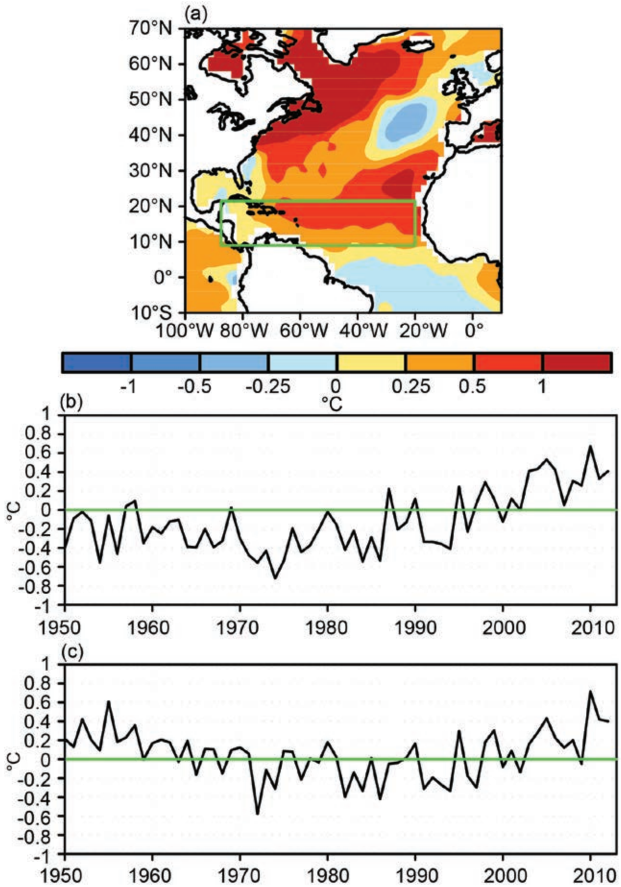

Fig 4.11. (a) Aug–Oct (ASO) 2012 SST anomalies (°C). (b) Time series during 1950–2012 of ASO area-averaged SST anomalies in the MDR [green box in (a)]. (c) Time series showing the difference between ASO area-averaged SST anomalies in the MDR and those for the entire global tropics (30°N–30°S). Anomalies are departures from the ERSST-v3b (Smith et al. 2008) 1981–2010 monthly means.

Nuñez 1999; Goldenberg et al. 2001; Vecchi et al. 2008; Bell et al. 2011, 2012). A similar signal was observed during the previous warm AMO phase of the 1950s and 1960s. Conversely, the MDR was generally cooler than the global tropics during the cold AMO phase (and reduced Atlantic hurricane activity) of the 1970s through the early 1990s.

(iv) Atmospheric circulation

The sharp transition in 1995 to the current high activity era reflects a phase change in the AMO and in the corresponding tropical multidecadal signal (Goldenberg et al. 2001; Bell and Chelliah 2006; Bell et al. 2007). This signal links atmospheric variability across the central and eastern MDR to multidecadal fluctuations in the AMO and the strength of the West African monsoon.

Consistent with this ongoing multidecadal signal, the atmospheric circulation during ASO 2012 again featured an interrelated set of conditions known to be exceptionally conducive for tropical cyclone formation and intensification within the MDR (Landsea et al. 1998; Goldenberg and Shapiro 1996; Goldenberg et al. 2001; Bell and Chelliah 2006; Kossin and Vimont 2007; Bell et al. 2012). Similar ASO conditions have been present throughout the period 1995–2011, and a yearly archive of these conditions is shown in previous *State of the Climate* reports.

In the lower atmosphere, the MDR conditions conducive for cyclogenesis during ASO included weaker trade winds, a deep layer of anomalous cross-equatorial flow, and below-average heights/sea level pressure (Fig. 4.12a). Across the tropical Atlantic and sub-Saharan Africa, the low-level westerly anomalies extended above 700-hPa, the approximate level of the African easterly jet (AEJ; Fig. 4.12b), and were associated with an anomalous northward shift of the AEJ core (thick black arrow).

As a result, the bulk of the African easterly wave energy (Reed et al. 1977) during ASO was often centered well within the MDR. The AEJ also featured increased cyclonic shear along its equatorward flank (red shading), which dynamically favors stronger easterly waves. These conditions have generally prevailed since 1995 and are opposite to those seen during the low activity era of 1971–94 (Figs. 4.12c,d).

Also during ASO 2012, enhanced upper-level ridges spanned the subtropical Atlantic and Africa in both hemispheres (Fig. 4.13a). This interhemispheric symmetry is consistent with an enhanced West African monsoon system (Fig. 4.13b), both of which are prominent features of the current high activity era.

In addition to weaker trade winds, these conditions contributed to anomalous upper-level easterly flow across the MDR. The result was weak vertical wind shear (less than 8 m s^{-1}) across the southern MDR (Fig. 4.10), with the most anomalously weak shear located over the central tropical Atlantic and eastern Caribbean Sea (Fig. 4.14a). These conditions were part of a larger-scale pattern that included increased shear over both the eastern equatorial Atlantic and the eastern tropical North Pacific (blue shading), which is also typical of other above-normal seasons since 1995 (Bell and Chelliah 2006; Bell et al. 2011).

The question then arises as to why there was so little major hurricane activity in 2012. Only two six-hourly periods were observed with storms at major hurricane strength this year, which corresponds to

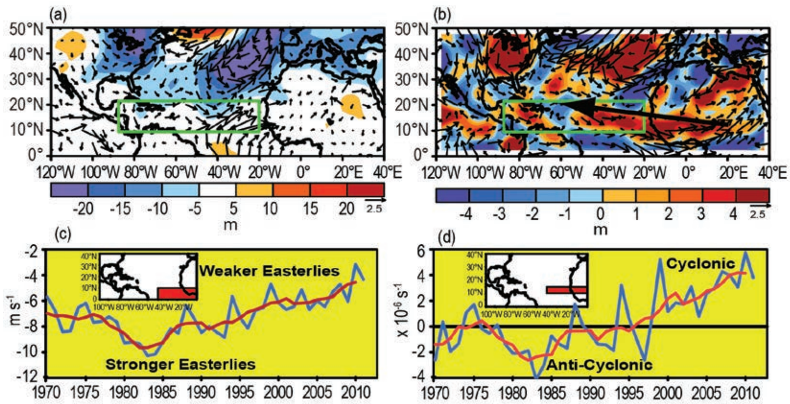

Fig 4.12. (Left) Aug–Oct 2012 anomalies of (a) 1000-hPa heights (shading, m) and wind vectors (m s^{-1}), and (b) 700-hPa relative vorticity (shading, $\times 10^{-6}$ s^{-1}) and wind vectors, with thick black arrow showing the axis of the AEJ. Vector scales are below right of color bars. Green boxes denote the MDR. Anomalies are with respect to the 1981–2010 monthly means. (Right) Historical time series showing yearly ASO values of area-averaged (c) 700-hPa zonal wind (m s^{-1}) and (d) 700-Pa relative vorticity ($\times 10^{-6}$ s^{-1}). Blue curve shows unsmoothed values and red curve shows a five-point running mean. Averaging regions are shown in the insets.

one-half of a major hurricane day[4]. This value is the lowest since 1995, and is even lower than for 79% of the years during the recent low-activity era (1971–94). Some reasons for this low major hurricane activities are evident. First, many storms remained over the central North Atlantic in an area of relatively cool SSTs throughout their life. Second, of the five named storms that moved over the Caribbean Sea, two became hurricanes (Ernesto and Sandy) and both of these made landfall shortly thereafter.

This minimal hurricane and major hurricane activity over the Caribbean Sea was partly related to exceptionally dry air during July–October, which can be linked to anomalous northerly low-level winds (Fig. 4.15a). This observation is consistent with the strong historical relationship between these parameters (Fig. 4.15b). Conditions over the Caribbean Sea were especially non-conducive to major hurricane formation during September, in response to a nearly complete disappearance of the normal ascending motion (Fig. 4.15c, negative values) that led to record anomalies of descending motion throughout the lower and mid-troposphere (not shown; see also Klotzbach and Gray 2012). A time-longitude section of velocity potential (Fig. 4.7) shows that this anomalous sinking motion was related to a quasi-stationary intraseasonal fluctuation characterized by anomalous ascending motion near the date line and anomalous descending motion across the central tropical Atlantic and Caribbean Sea.

The full analysis indicates that all of the key interrelated features of the active Atlantic phase of the tropical multidecadal signal were again present during 2012 (Figs. 4.11–4.14). Therefore, there was neither an apparent weakening of the conditions conducive for cyclogenesis that have prevailed since 1995, nor is there any evidence to suggest that the current high-activity era for Atlantic hurricane activity might be ending soon.

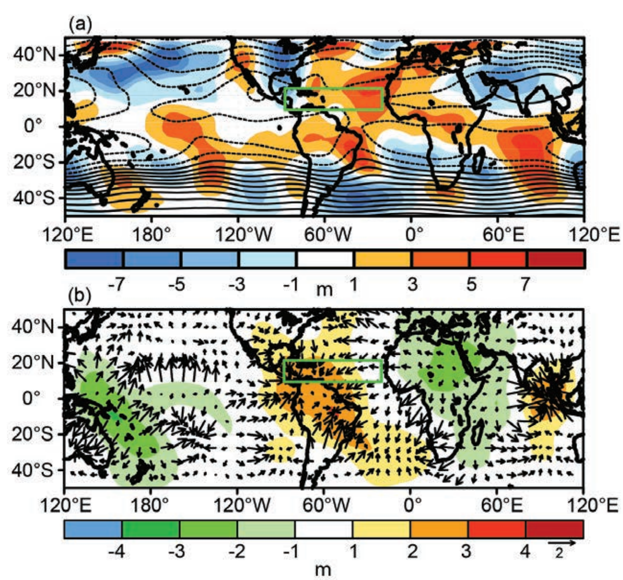

Fig 4.13. Aug–Oct 2012 200-hPa circulation and anomalies: (a) streamfunction (contours, interval is 10×10^6 m^2 s^{-1}) and anomalies (shaded) and (b) anomalous velocity potential (shading, $\times 10^6$ m^2 s^{-1}) and divergent wind vectors (m s^{-1}). In (a) anomalous ridges are indicated by positive values (orange/red) in the NH and negative values (blue) in the SH. Anomalous troughs are indicated by negative values in the NH and positive values in the SH. In (b) vector scale is below right of color bar. Green boxes denote the MDR. All departures are with respect to the 1981–2010 monthly means.

[4] The measure "major hurricane days", also known as "intense hurricane days" (Gray et al. 1993), is the sum of all of the six-hourly periods that storms were at major hurricane status, with each period counting as 0.25 major hurricane days.

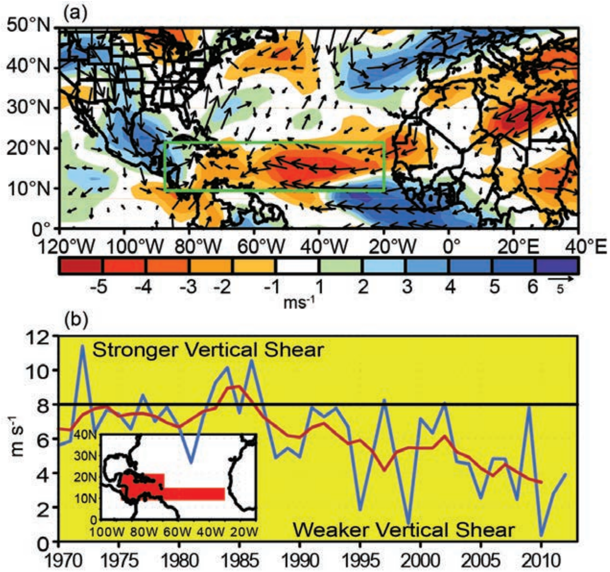

Fig 4.14. (a) Aug–Oct 2012 anomalous vertical wind shear magnitude and vectors (m s^{-1}). Green box denotes the MDR. Vector scale is below right of color bar. Anomalies are with respect to the 1981–2010 monthly means. (b) Historical time series showing yearly ASO values of the area-averaged vertical shear of the zonal wind. Blue curve shows unsmoothed values, and red curve shows a five-point running mean. Averaging region is shown in the inset.

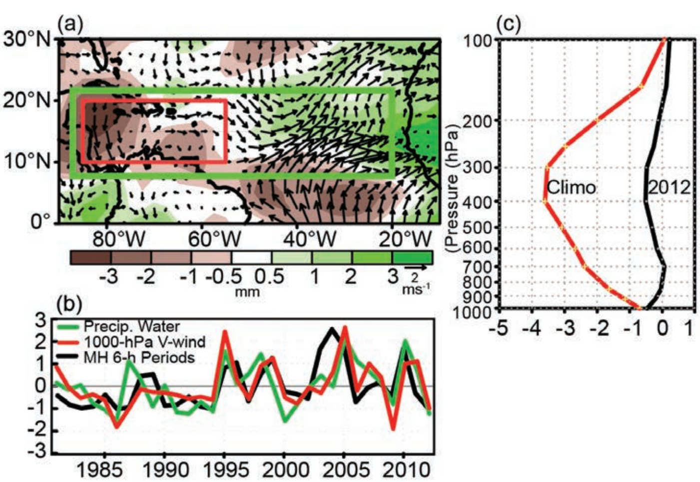

Fig 4.15. (a) Jul–Oct (JASO) 2012 anomalous precipitable water (mm) and 1000-hPa vector winds (m s^{-1}). Green box denotes the MDR and red box denotes averaging region used in (b, c). Vector scale is below right of color bar. (b) Yearly JASO standard deviation of area-averaged precipitable water (green line) and meridional component of 1000-hPa vector wind (red curve), along with yearly std dev of major hurricane days during Jun–Nov. (c) Area-averaged Sep mean vertical profile of vertical velocity (×10^2 hPa s^{-1}) during 2012 (black curve) and climatology (red curve), with negative values indicating ascending motion. Climatology and anomalies are with respect to the 1981–2010 monthly means.

3) Eastern North Pacific Basin—M. C. Kruk, C. J. Schreck, and R. Tanabe

(i) Seasonal activity

The Eastern North Pacific (ENP) Basin is officially split into two separate regions for the issuance of warnings and advisories by NOAA's National Weather Service. NOAA's National Hurricane Center is responsible for issuing warnings in the eastern part of the basin that extends from the Pacific Coast of North America to 140°W, while NOAA's Central Pacific Hurricane Center in Honolulu, Hawaii, is responsible for issuing warnings in the Central North Pacific region between 140°W and the date line. In this section, analysis summarizing the TC activity in both warning areas will be presented using combined statistics, along with information specifically addressing the observed activity and impacts in the Central North Pacific (CNP) region.

The ENP hurricane season officially spans from 15 May to 30 November, although storms can develop outside the official season, especially during El Niño. Hurricane and TC activity in the eastern area of the basin typically peak in September, while in the Central Pacific TC activity normally reaches its seasonal peak in August (Blake et al. 2009).

A near-normal number of 17 tropical cyclones formed in the ENP during 2012, with a distribution of 10 hurricanes and 7 tropical storms. Five of the ten hurricanes were major hurricanes. For the second consecutive year, no storms formed in the CNP (Fig. 4.16). The 1981–2010 IBTrACS seasonal averages for the basin are 16.5 tropical storms, 8.9 hurricanes, and 4.3 major hurricanes. While the 2012 numbers are near or above average, there is a skew to their distribution, with six hurricanes occurring before 15 August, including the strongest storm of the season, Major Hurricane Emilia (7–15 July). Despite the large fraction of strong storms, the ACE index for 2012 indicates the storms were all short-lived, with a seasonal value of only 95.2 × 10^4 kt^2 (Fig. 4.16), which is below the 1981–2010 mean of 137.0 × 10^4 kt^2 (Bell et al. 2000; Bell and Chelliah 2006).

(ii) Environmental influences on the 2012 season

Figure 4.17 illustrates the background conditions for TC activity in the ENP during 2012. Consistent with the marginal El Niño conditions, weak warm SST anomalies were observed near the equator and along the Cen-