of storms were the eastern/central Pacific and south Indian Ocean basins.

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

(i) 2014 Seasonal activity

The 2014 Atlantic hurricane season produced eight named storms (NS), of which six became hurricanes and two became major hurricanes. The HURDAT2 1981–2010 seasonal averages are 11.8 tropical storms, 6.4 hurricanes, and 2.7 major hurricanes (Landsea and Franklin 2013).

The 2014 seasonal accumulated cyclone energy (ACE) value (Bell at al. 2000) was 72.2% of the 1981–2010 median (Fig. 4.18), which barely exceeds NOAA's lower threshold (71.4% of the median) for a near-normal season (see www.cpc.ncep.noaa.gov/products/ outlooks/background_information.shtml). Based on this ACE value, combined with approximately near-average numbers of hurricanes and major hurricanes, NOAA officially classified the 2014 Atlantic hurricane season as near-normal.

The levels of activity during 2014 are well below those typical of the recent active period (1995–2014), which had averages of 15 named storms, 7.6 hurricanes, and 3.5 major hurricanes; as well as having a seasonal ACE that was 141.6% of the median (Goldenberg et al. 2001; Bell and Chelliah 2006; Bell et al. 2014). Since 1995, 13 of the 20 seasons (65%) have been above normal, 4 seasons (20%) including 2014 have been near-normal, and only 3 seasons (15%) have been below normal. (A yearly archive of conditions during these seasons can be found in previous *State of the Climate* reports; see www.ncdc.noaa.gov/bams-state-of-the-climate). In contrast, during the 1971–94 low-activity era for Atlantic hurricanes, twelve (50%) of the seasons were below normal and only three (12.5%) were above normal.

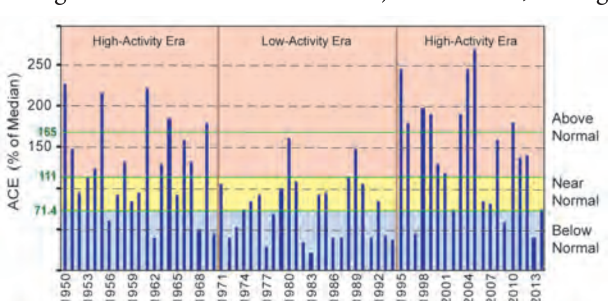

Fig. 4.18. NOAA's ACE index expressed as percent of the 1981–2010 median value. ACE is calculated by summing the squares of the 6-hourly maximum sustained surface wind speed (knots) for all periods while the storm is at least tropical storm strength. Red, yellow, and blue shadings correspond to NOAA's 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.

The reduced activity during 2014 follows a below-normal season the previous year (Bell et al. 2014). In fact, almost 30% of the 2014 seasonal ACE was produced during a 10-day period in October by Hurricane Fay and Major Hurricane Gonzalo. Only one other period since 1995 (2006–07) has featured two consecutive hurricane seasons that were not above normal.

A main delineator between active and less-active seasons is the number of hurricanes and major hurricanes that originate as named storms within the main development region (MDR; green boxed region in Fig. 4.19a, which encompasses the tropical Atlantic Ocean and Caribbean Sea between 9.5° and 21.5°N; Goldenberg and Shapiro 1996; Goldenberg et al. 2001; Bell and Chelliah 2006). Only four named storms

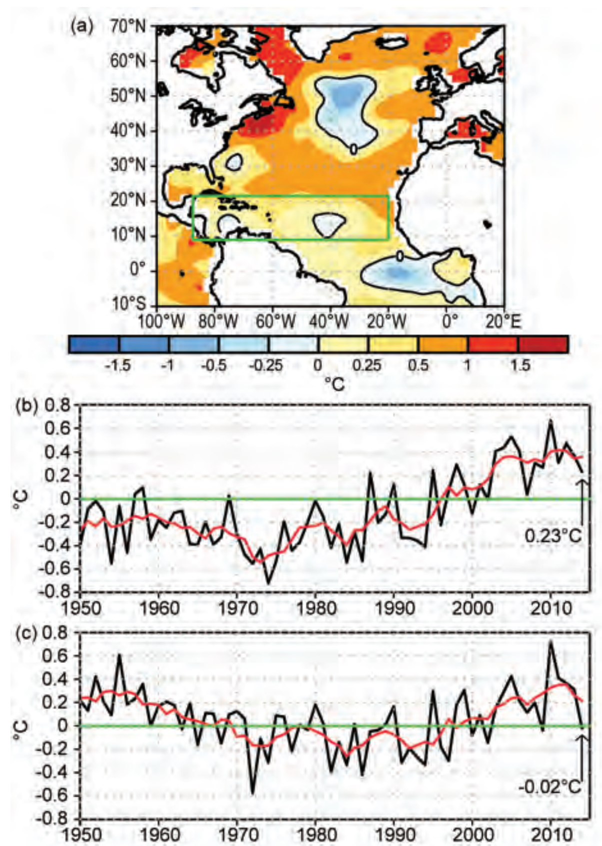

Fig. 4.19. (a) ASO 2014 SST anomalies (°C). (b) Time series during 1950–2014 of ASO area-averaged SST anomalies (°C) in the MDR [green box in (a)]. (c) Time series showing the difference between ASO area-averaged SST anomalies (°C) in the MDR and those for the entire global tropics (20°N–20°S). Red lines show a 5-pt. running mean of each time series. Anomalies are departures from the ERSST-v3b (Smith et al. 2008) 1981–2010 monthly means.

formed in the MDR during 2014, three of which eventually became hurricanes and two of those became major hurricanes.

The resulting ACE value from the four MDR storms was 42.8% of the median. Overall, these MDR statistics are comparable to 1981–2010 averages for the MDR during near-normal seasons of 5 named storms, 3 hurricanes, 1.5 major hurricanes, and 51.8% of the median ACE. They are far below the MDR averages for above-normal seasons (9 named storms, 6.5 hurricanes, 4 major hurricanes, and 151.1% of the median ACE).

(ii) Storm tracks

The 2014 Atlantic hurricane season featured one main set of storm tracks, comprising five of the eight named storms. These tracks originated over the central MDR and western subtropical North Atlantic (see Fig. 4.20a, thick lines). Two of these storms (Hurricane Fay and Major Hurricane Gonzalo) made landfall in Bermuda, striking as Category 1 and 2 hurricanes, respectively (see section 7c for more details).

One storm that formed outside of the main set of tracks was Hurricane Arthur, the first storm of the season, which made landfall in the U.S. state of North Carolina as a Category 2 hurricane in July. The other two storms that formed outside of the main set of tracks were Tropical Storms Dolly and Hanna, with Dolly primarily affecting eastern Mexico and Hanna primarily affecting Nicaragua.

For the second consecutive year, no hurricanes tracked through the Caribbean Sea. This dearth of activity is linked to an anomalous circulation pattern that not only produced strong vertical wind shear and anomalous sinking motion across the region, but also steered the MDR-related storms to the north before they could reach the Caribbean Sea.

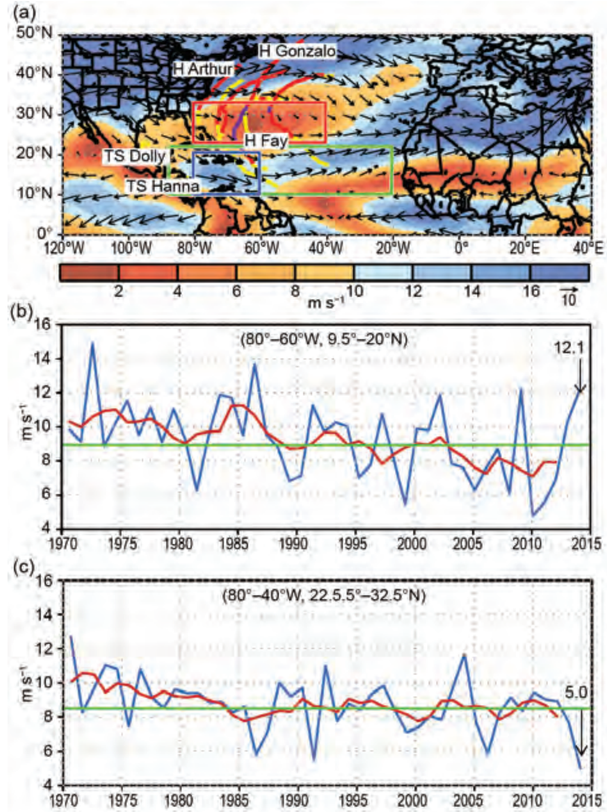

Fig. 4.20. (a) ASO 2014: 200–850-hPa vertical wind shear magnitude and vectors (m s^{-1}). (b), (c) Area-averaged magnitude of the ASO 200–850-hPa vertical wind shear vector from 1970 to 2014 for the red and blue boxes, respectively, shown in (a). In (a), orange-red shading indicates areas where vertical wind shear magnitude is ≤8 m s^{-1}. Thick lines indicate observed named storm tracks, with yellow, red, and purple indicating tropical storm, hurricane, and major hurricane strength, respectively. Storm names are only shown for the storms mentioned in the text. Green box denotes the MDR. Vector scale is below right of plot. In (b) and (c), red lines show a 5-pt. running mean of the time series and green line shows the ASO 1981–2010 mean.

(iii) Atlantic sea surface temperatures

Sea surface temperatures (SST) were generally above average across the MDR during the peak months (August–October, ASO) of the Atlantic hurricane season (Fig. 4.19a), with the mean SST departure (+0.23°C) being the 11th warmest in the 1950–2014 record (Fig. 4.19b). Consistent with this ongoing warmth, objective measures of the Atlantic multidecadal oscillation (AMO; Enfield and Mestas-Nuñez 1999), such as NOAA's operational AMO index, indicate a continuance (but at a weaker strength compared to a few years ago) of the AMO warm phase (www.esrl.noaa.gov/psd/data/correlation/amon.us.long.data).

For the first ASO season since 2009, the mean SST departure within the MDR was comparable to the average departure for the entire global tropics (Fig. 4.19c). This occurrence is not typical of the warm AMO phase (Goldenberg et al. 2001; Bell et al. 2011, 2012), which has been the primary climate factor associated with the recent high-activity era for Atlantic hurricanes. The warm AMO phase is generally associated with anomalously warm SSTs in the MDR compared to the remainder of the global tropics (see also the 1950–70 high-activity period as shown in Fig. 4.18), while the cool AMO phase is associated with anomalously cool SSTs in the MDR compared to the global tropics (for example, 1971–94).

(iv) Atmospheric conditions

(1) Atlantic Basin

A main feature of the 2014 Atlantic hurricane season was a northward shift of the main storm intensification region from the MDR (i.e., tropics) to the western subtropical North Atlantic. This shift occurred mainly during ASO in response to a corresponding northward shift in the area of conducive atmospheric conditions.

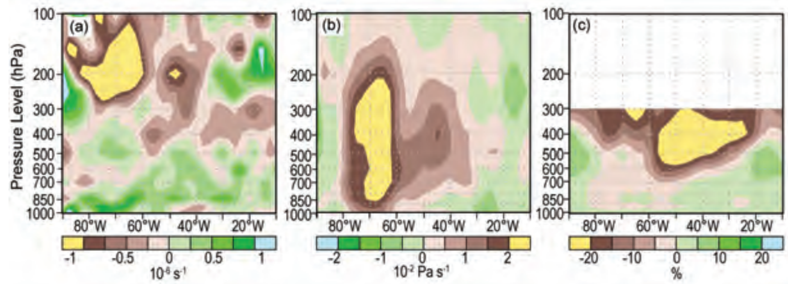

Fig. 4.22. ASO 2014: Atmospheric height-longitude sections averaged in the MDR (9.5°–21.5°N) of (a) anomalous divergence (× 10^{-6} s^{-1}), (b) anomalous vertical velocity (× 10^{-2} Pa s^{-1}), and (c) % of normal specific humidity up to 300 hPa. Green shading indicates anomalous divergence, anomalous rising motion, and increased moisture, respectively. Brown shading indicates anomalous convergence, anomalous sinking motion, and decreased moisture, respectively. Departures are with respect to the 1981–2010 monthly means.

Such inverse conditions between the MDR and the subtropical North Atlantic have been identified previously (Goldenberg and Shapiro 1996) as a common interannual characteristic. During years when atmospheric conditions are less conducive for tropical cyclone development in the MDR, they are often more conducive over subtropical North Atlantic, and vice versa. Although ENSO can produce such conditions, it is difficult to ascribe the cause of these conditions during ASO 2014 to a weak Pacific warming (see section 4b). Instead, the observations show that these conditions are linked primarily to a rare and exceptionally strong upper-level circulation pattern that seems to have no consistent link to ENSO or the AMO. As discussed below, a similar pattern was also observed during the below-normal 2013 Atlantic hurricane season (Bell et al. 2014).

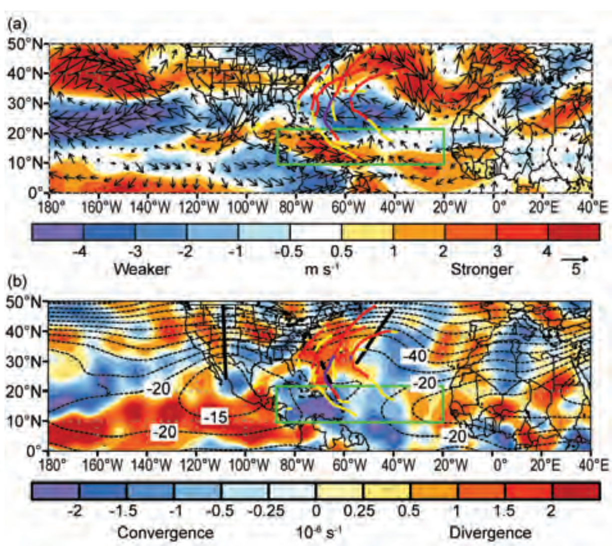

Fig. 4.21. ASO 2014: (a) Anomalous magnitude of the vertical wind shear vector and anomalous shear vector (m s^{-1}). (b) Total 200-hPa streamfunction (contours, interval is 5 × 10^{6} m^{2} s^{-1}) and anomalous divergence (shaded, × 10^{-6} s^{-1}). Vector scale in (a) is below right of plot. In (b), thick solid (dashed) lines identify ridge (trough) axes of persistent wave pattern discussed in text. Green boxes indicate the MDR. Thick lines indicate observed named storm tracks, with yellow, red, and purple indicating tropical storm, hurricane, and major hurricane strength, respectively. Anomalies are based on the 1981–2010 climatology.

MDR conditions that were associated with this pattern during ASO 2014 included strong vertical wind shear (Figs. 4.20a,b and 4.21a), anomalous upper-level (200-hPa) convergence (Fig. 4.21b), anomalous low-level (850-hPa) divergence (Fig. 4.22a), anomalous mid- and low-level sinking motion (Fig. 4.22b), and drier air (Fig. 4.22c).

The vertical wind shear across the Caribbean Sea (blue box region in Fig. 4.20a) was the fourth strongest (12.1 m s^{-1}) in the ASO 1970–2014 record (Fig. 4.20b). The three ASO seasons with larger shear values over the Caribbean Sea were the El Niño years of 1972, 1986, and 2009. On monthly time scales, shear values greater than 8 m s^{-1} are generally considered to be inhibiting to hurricane formation (DeMaria 1996).

In contrast, more conducive conditions over the western subtropical North Atlantic (i.e., north of the MDR) included a combination of exceptionally weak vertical wind shear (Figs. 4.20a, 4.21a) and anomalous upper-level divergence (Fig. 4.21b). The area-averaged vertical wind shear over this region (between 22.5° and 32.5°N, red box in Fig. 4.20a) was 5.0 m s^{-1}, the lowest in the ASO 1970–2014 record (Fig. 4.20c).

These conducive conditions contributed to the intensification of many tropical cyclones outside of the MDR. Four of the six named storms that either formed either over or tracked across the western subtropical North Atlantic intensified into hurricanes and the other two became major hurricanes. As a result, the season was more active than might otherwise have been expected given the nonconducive conditions within the MDR.

(2) Continental

The 200-hPa circulation during ASO 2014 featured a strong and persistent anomalous wave pattern that extended from the central North Pacific to the eastern North Atlantic Ocean (Fig. 4.23a). This pattern was associated with anomalously weak vertical wind shear and anomalous upper-level divergence across the central and eastern Pacific hurricane basins, which contributed to increased hurricane activity in those regions. In the Atlantic hurricane basin, the pattern contributed to the previously noted combination of suppressive conditions within the MDR and conducive conditions in the subtropics.

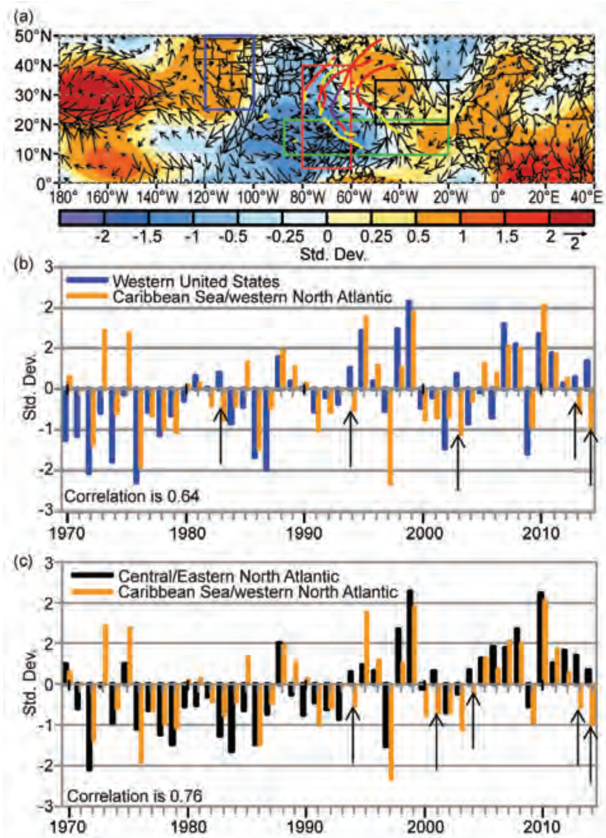

Fig. 4.23. (a) ASO 2014: standardized 200-hPa streamfunction anomalies and vector winds (std. dev.), with boxes indicating the averaging regions of the western United States. (blue box), the Caribbean Sea/western North Atlantic (orange box), and the central/eastern subtropical North Atlantic (black box). Thick lines indicate observed named storm tracks, with yellow, red, and purple indicating tropical storm, hurricane, and major hurricane strength, respectively. (b), (c) Time series during ASO 1970–2014 of 200-hPa standardized streamfunction indices for the boxed regions in (a). Both panels show the same index for the Caribbean Sea/western North Atlantic region (orange bars), with (b) also showing the time series for the western U.S. region (blue bars) and (c) showing the time series for the central/eastern subtropical North Atlantic region (black bars). The indices are calculated by first standardizing the ASO streamfunction anomalies at each grid point, then standardizing the area-averaged value of the standardized grid-point anomalies. All standardizations are based on the 1981–2010 climatology.

Over North America and the Atlantic hurricane basin, key features of this circulation pattern (indicated by thick black lines in Fig. 4.21b) included (1) an amplified ridge over the western United States.; (2) a downstream amplified trough over the western North Atlantic and Caribbean Sea (called the tropical upper-tropospheric trough, TUTT); and (3) an amplified ridge over the central North Atlantic.

An examination of the standardized streamfunction and vector wind anomalies associated with this wave pattern shows three ways in which it was a primary contributor to the observed north–south dipole patterns of vertical wind shear and upper-level divergence in the Atlantic basin. First, the 200-hPa wind vector anomalies closely match the vertical wind shear vector anomalies (Fig. 4.21a), indicating that these anomalies were the primary contributors to both the increased shear within the western MDR and the decreased shear farther north. Although the 850-hPa winds also contributed to the anomalous vertical shear, their contribution was much less than that of the upper-level winds (not shown).

Secondly, the wave pattern was likely a primary contributor to the anomalous upper-level convergence and sinking motion across the western and central MDR (Fig. 4.21b). These regions were situated upstream of and within the mean TUTT axis, which is an area within a midlatitude wave pattern known for upper-level convergence and descending motion. Thirdly, the wave pattern was a primary contributor to the large area of anomalous upper-level divergence and ascending motion between the mean trough and downstream ridge axis, which is an area within midlatitude wave patterns known for upper-level divergence and ascending motion.

Given these relationships between the larger-scale circulation and the regional set of conditions within the MDR that ultimately suppressed the 2014 hurricane season, it is of interest to quantify the relative strength of the observed 200-hPa wave pattern across North America and the Atlantic basin and to assess its relationship to the historical record.

The analysis is based on 200-hPa streamfunction indices for the ASO season during the 45-year period 1970–2014. The indices were computed from the area average of the standardized streamfunction anomalies for the three boxed regions shown in Fig. 4.23a: the western United States (blue box), the Caribbean

Sea/western North Atlantic (orange box), and the central/eastern subtropical North Atlantic (black box).

The index time series show that streamfunction anomalies within the Caribbean Sea/western North Atlantic region (orange bars, Fig. 4.23b,c) often have the same sign as those in both the western United States (blue bars, Fig. 4.23b) and the central/eastern subtropical North Atlantic (black bars, Fig. 4.23c) regions. These relationships are reflected in their index correlations of 0.64 and 0.69, respectively. Similarly, the streamfunction anomalies in both the western United States and central/eastern subtropical North Atlantic regions tend to have the same sign, and their index correlation is 0.76.

The ASO 2014 pattern contrasts with this general result, in that the large negative anomalies throughout the Caribbean Sea/western North Atlantic region were of opposite sign to the other two regions. To assess the historical frequency of occurrence of this specific pattern, all ASO seasons were identified in which the index amplitudes for each region exceeded 0.25 standard deviations (thereby removing seasons with small anomalies in any region). Only 5 seasons (1983, 1984, 2003, 2013, and 2014) out of the 45 (or 11%) were found in which the index for the Caribbean Sea/western North Atlantic region was negative while that for the western United States region was positive. Similarly, only five seasons (1994, 2001, 2004, 2013, and 2014) were found in which the index for the Caribbean Sea/western North Atlantic region was negative while that for the central/eastern subtropical North Atlantic region was positive. There are only three common seasons (1994, 2013, and 2014) between these two sets of five, indicating that the ASO 2014 pattern has occurred only three times in the last 45 years. Each of these years had low hurricane activity.

While it is beyond the scope of this observational study to assess the origins of the anomalous circulation pattern during ASO 2014, its rarity suggests no consistent relationship to known climate factors such as the AMO or ENSO. Also, its presence during consecutive ASO 2013 and ASO 2014 periods, despite notably different conditions across the tropical Pacific between these two seasons, suggests that the pattern may not have a strong link to the tropics.

Although multidecadal fluctuations in Atlantic hurricane activity are a prominent part of the historical record, the seasonal activity during any given year or set of years can be influenced by many other factors such as ENSO or persistent and large amplitude circulation patterns. The above analysis shows that this situation describes well both the 2013 and 2014 seasons; additional analysis is presented in Sidebar 4.1.

3) Eastern North Pacific and Central North Pacific Basins—M. C. Kruk, C. J. Schreck, and T. Evans

(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 (CNP) region between 140°W and the dateline. This section summarizes the TC activity in both warning areas using combined statistics, along with information specifically addressing the observed activity and impacts in the CNP region.

The ENP/CNP hurricane season officially spans from 15 May to 30 November. Hurricane and tropical storm activity in the eastern area of the basin typically peaks in September, while in the central Pacific TC activity normally reaches its seasonal peak in August (Blake et al. 2009). During the 2014 season, a total of 22 named storms formed in the combined ENP/CNP basin, with just one of these forming in the CNP. This total included 16 hurricanes, 8 of which were major hurricanes. The 1981–2010 IBTrACS seasonal averages for the basin are 16.5 named storms, 8.5 hurricanes, and 4.0 major hurricanes (Schreck et al. 2014). The 2014 season's 22 named storms is the highest storm count since the 1992 season.

A near-normal number of five tropical cyclones developed in, or entered into, the CNP during 2014 (Fig. 4.24). The long-term 1981–2010 IBTrACS mean for the CNP basin is 4.7 storms per season. Given that 72% of the ENP/CP TCs that formed in 2014 reached hurricane intensity, it is no surprise that the ACE index for 2014 was high as well, with a seasonal value of 158.1×10^4 kt^2 (Fig. 4.24), which is above the 1981–2010 mean of 132.0×10^4 kt^2 (Bell et al. 2000; Bell and Chelliah 2006; Schreck et al. 2014).

(ii) Environmental influences on the 2014 season

Figure 4.25 illustrates the background conditions for TC activity in the ENP and CNP during 2014. Consistent with the near-El Niño conditions, the equatorial Pacific was dominated by warm SST anomalies (Fig. 4.25a). SSTs were particularly warm along the Baja California coast, where many of tropical cyclones in 2014 tracked. The SSTs were closer to nor-