and enhanced upwelling, which contributed to the drop in upper-ocean heat content in the east-central equatorial Pacific in February (Fig. 4.8).

The moderate-strength MJO activity during May through early August resulted in three distinct periods with below-average easterly winds near the date line. An oceanic Kelvin wave was triggered by the MJO during each of these periods (Fig. 4.8). Each wave was weaker than its predecessor, in part because of a gradual decrease in strength of the MJO. This Kelvin wave activity produced considerable intraseasonal variability in the SSTs and heat content across the central and east-central equatorial Pacific. In early June, the downwelling phase of a Kelvin wave eliminated the negative heat content anomalies in these regions. Significant cooling then ensued in late June as the upwelling phase of the wave propagated eastward. Another Kelvin wave produced a similar pattern of warming followed by cooling in late July and early August. This variability most likely delayed the onset of La Niña.

The strongest MJO event of the year began during October and lasted through December. This was the strongest and longest-lived event since March–June 2005. The 2007 event is somewhat unusual, in that MJO activity is typically reduced during La Niña. The resulting increased upwelling, which was linked to periods of enhanced easterly winds and the upwelling phases of oceanic Kelvin waves, acted to periodically reinforce the negative SST anomalies associated with La Niña. The MJO also periodically reinforced the La Niña–related pattern of tropical convection, as was seen in mid-December when exceptionally dry conditions spanned the central equatorial Pacific and exceptionally wet conditions covered Indonesia.

The MJO activity late in the year had two additional noteworthy impacts. It delayed the onset of the northwest Australia monsoon by 1–2 weeks in early December, and then strengthened that monsoon later in the month. The MJO also contributed to periods of intense storminess along the U.S. west coast during December and early January 2008, which produced heavy precipitation in central and Southern California that is not characteristically seen during La Niña.

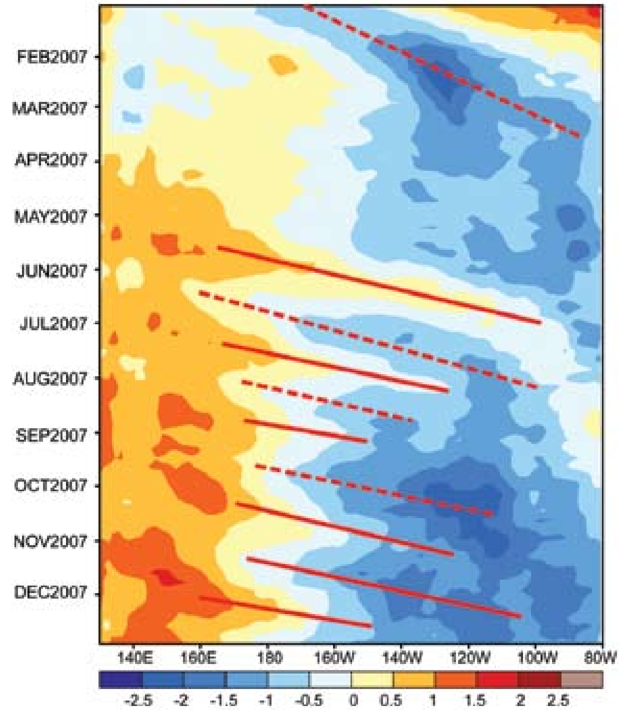

Fig. 4.8. Time–longitude section of anomalous upper ocean (0–300 m) heat content (5°N–5°S) during 2007. Blue (orange) shading indicates below (above) average heat content. The downwelling (solid) and upwelling (dashed) phases of oceanic Kelvin waves are indicated. Anomalies are departures from the 1982–2004 base period weekly means

d. *Tropical cyclones*

1) Overview—H. J. Diamond and D. H. Levinson

Averaged across all basins, the 2007 TC season (2006–07 in the Southern Hemisphere) saw a below normal (1981–2000 base) number of tropical or NS (≥34 kt) and HTC (≥64 kt), and significantly fewer major HTCs (≥96 kt) than average. Globally, 79 NSs developed during 2007 (18 below average), and 44 became HTCs (11 below average). Of these, only 18 (compared with 26 in 2006) attained major/intense status (average is 25.4). The global tallying of total storm numbers is always challenging, and involves more than simply adding up basin totals, as there are a number of storms that cross basin boundaries. Nonetheless, the overall numbers for the 2007 season were clearly below average.

The 2007 season was near normal in one basin (North Atlantic); significantly above average in two basins (NIO and SIO); and below average in the remaining basins (eastern North Pacific, northwest Pacific, southwest Pacific, and Australian). The SIO season saw twice the normal number of major TCs (6); while the NIO season featured two category 5 storms (Fig. 4.35), one of which was the strongest (and possibly first major TC) ever observed in the Arabian Sea. Both TCs caused considerable loss of life and extensive damage to the infrastructure of Oman, Iran, and Bangladesh (see sidebar article).

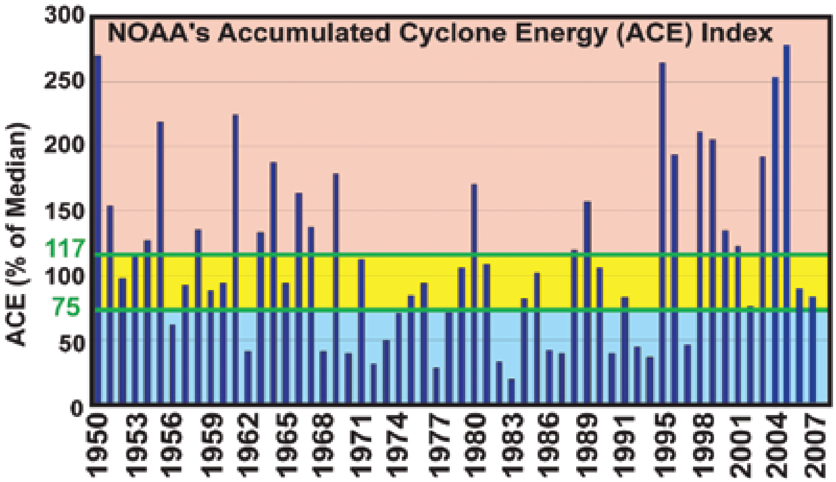

Fig. 4.9. NOAA's ACE index expressed as percent of the 1951–2000 median value (87.5 × 10^4 kt^2). ACE is a wind energy index that measures the combined strength and duration of the NSs. ACE is calculated by summing the squares of the 6-hourly maximum sustained wind speed in kts ($V\max^2$) for all periods while the named storm has at least TS strength. Pink, yellow, and blue shadings indicate NOAA's classifications for above-, near-, and below-normal seasons, respectively.

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

(i) Seasonal activity

The 2007 Atlantic hurricane season produced 15 NSs, 6 Hs and 2 MHs. The 1951–2000 averages are 11 NSs, 6 Hs, and 2 MHs. For 2007 the ACE index (Bell et al. 2000), a measure of the season's overall activity, was 84% of the 1950–2000 median (87.5 × 10^4 kt^2) (Fig. 4.9). This value is in the near-normal range (see www.cpc.noaa.gov/products/outlooks/background_information.shtml) and reflects fewer and generally shorter-lived hurricanes and MHs compared to recent years.

Two hurricanes made landfall in the Atlantic basin during 2007 with category 5 strength. MH Dean struck the Yucatan Peninsula near Costa Maya on 21 August with 150-kt sustained winds. MH Felix then made landfall near Punta Gorda, Nicaragua, on 2 September with 140-kt sustained winds. In addition, several other TSs and Hs struck the region around the Caribbean Sea. The United States was struck by one H, one NS, and three TD. This represented an increase in landfalling storms compared to 2006 (which had NS landfalls), even though both seasons had similar ACE index levels.

(ii) Atmospheric conditions

The peak months (ASO) of the season featured a persistent TUTT (also called the midoceanic trough) over the central North Atlantic and MDR [indicated by the green box spanning the tropical Atlantic and Caribbean Sea between 9.5°–21.5°N and 20.0°–80.0°W (Goldenberg and Shapiro 1996)] (Fig. 4.10). The period also featured a strong and persistent ridge over eastern North America.

During August and September, these conditions produced above-average vertical wind shear (Figs. 4.11a,c) and anomalous midlevel sinking motion (Figs. 4.11b,d) across the western half of the MDR, Gulf of Mexico, and the western and central subtropical North Atlantic. As a result, extensive areas were unfavorable for hurricane development and intensification.

These conditions include below-average vertical wind shear (the difference between the 200- and 850-hPa winds), above-average SSTs, and enhanced convection. However, the pressure pattern in the lower atmosphere was not particularly conducive to hurricane formation. The main area of low pressure was located over the northwestern Caribbean Sea and Central America, with much of the circulation located over land. The pronounced northward shift of this feature, which is normally situated over the southern Caribbean Sea, is likely to have suppressed TC formation in that region.

For the entire ASO period, the primary area of weak vertical wind shear (less than 8 m s^{-1}) was confined mainly to the extreme southern MDR and western Caribbean Sea (shaded regions, Fig. 4.12a).

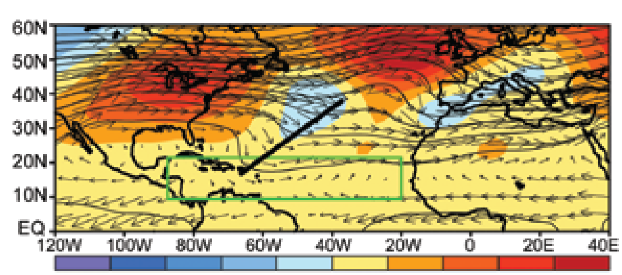

Fig. 4.10. Aug–Oct 2007: 200-hPa heights (contours, m), height anomalies (shaded), and vector winds (m s^{-1}). Thick solid line indicates the upper-level trough axis. Green box denotes the MDR. Anomalies are departures from the 1971–2000 period monthly means.

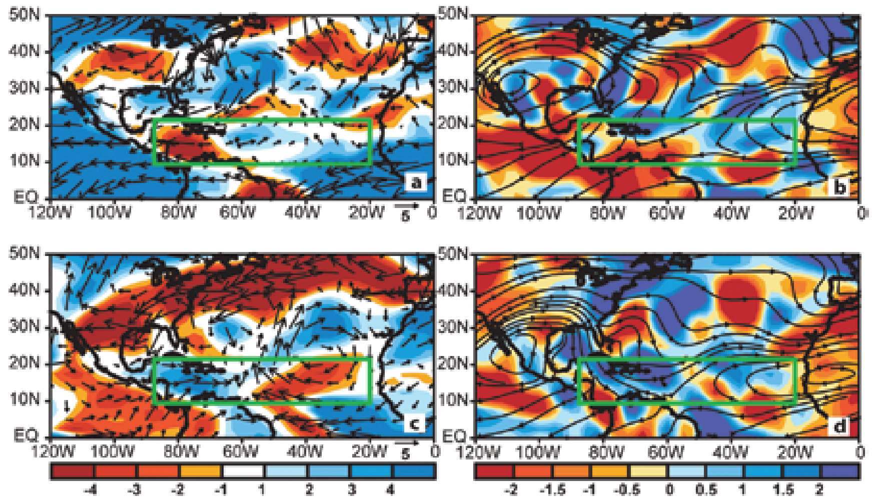

Fig. 4.11. (a),(c) The anomalous 200–850-hPa vertical wind shear strength (m s^{-1}) and vectors during (a) Aug and (c) Sep 2007. Red (blue) shading indicates below-average (above average) strength. (b),(d) The total 200-hPa streamlines and anomalous 500-hPa vertical motion (shaded) during (b) Aug and (d) Sep 2007. Red (blue) indicates anomalous ascent (descent). Green box denotes the MDR. Anomalies are departures from the 1971–2000 period monthly means.

This pattern was especially pronounced in August, when category 5 Hs Dean and Felix developed. Interestingly, the mean ASO vertical wind shear was below average across much of the MDR during ASO, which would normally suggest an above-normal season (Fig. 4.12b). However, for the eastern half of the MDR, most of the contribution to the negative anomalies came from October, a month when the total vertical shear is too strong to support TS formation.

It should be noted that improvements in tools such as QuikSCAT, and the AMSU, cyclone phase space, and the unique use of aircraft observations have likely led to more NSs and subtropical storms being identified now compared to a generation ago (Landsea 2007). For 2007, it is estimated that four NSs, Andrea, Chantal, Jerry, and Melissa, may not have been named a generation ago (Landsea 2007).

(iii) SSTs

SSTs in the MDR were above average (+0.27°C) during ASO 2007 (Fig. 4.13). This ongoing warmth since 1995 is associated with the warm phase of the AMO (Enfield and Mestas-Nuñez 1999) and the active Atlantic phase of the tropical multidecadal signal (Bell and Chelliah 2006). Some of the persistent warmth has also been linked to increasing global temperatures over the last 100 yr (Santer et al. 2006).

The above average SSTs during ASO 2007 were concentrated in the western half of the MDR, where departures averaged +0.47°C. The near-normal hurricane activity in these regions is not consistent with this ongoing warmth. Instead, it reflects the dominant role played by the atmospheric anomalies in controlling Atlantic hurricane activity (Shapiro and Goldenberg 1998). In the eastern MDR, SSTs cooled to near normal during ASO 2007. However, these cooler SSTs cannot account for the strong TUTT and upstream ridge in August and September or for the reduced Caribbean activity in October.

(iv) Prevailing global climate patterns

The occurrence of La Niña during an active hurricane era has been shown to significantly increase the probability of an above-normal Atlantic hurricane season,

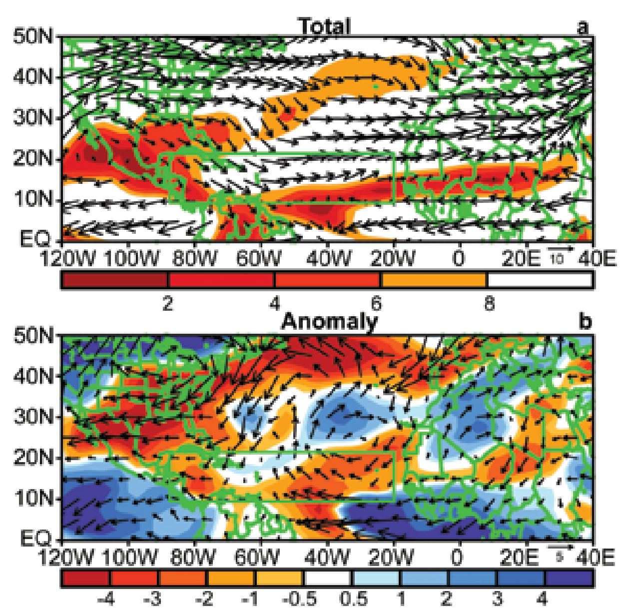

Fig. 4.12. Aug–Oct 2007: 200–850-hPa vertical wind shear magnitude (m s^{-1}) and vectors (a) total and (b) anomalies. In (a), shading indicates vertical wind shear below 8 m s^{-1}. In (b), red (blue) shading indicates below- (above) average magnitude of the vertical shear. Green box denotes the MDR. Vector scale is shown at bottom right of each panel. Anomalies are departures from the 1971–2000 period monthly means.

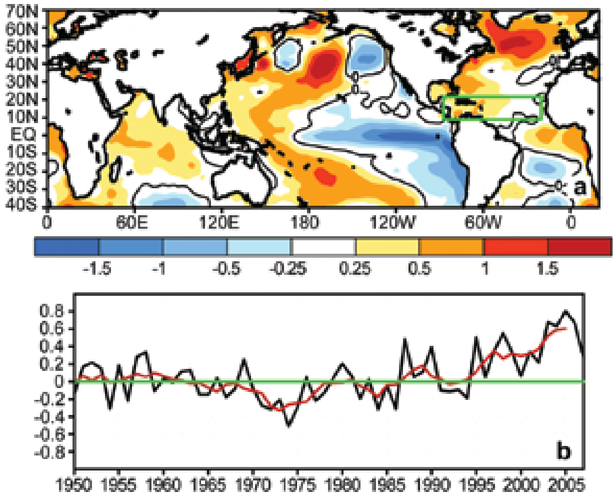

Fig. 4.13. (a) SST anomalies (°C) during Aug–Oct 2007. (b) Consecutive ASO values of SST anomalies in the MDR. Red line shows the corresponding 5-yr running mean. Green box in (a) denotes the MDR. Anomalies are departures from the 1971–2000 period monthly means.

in part because it typically produces a weaker TUTT and reduced vertical wind shear in the MDR (Gray 1984; Bell and Chelliah 2006). La Niña developed during August 2007, and subsequently reached moderate strength during September–November. Also, key atmospheric anomalies known to be associated with the current active hurricane period were in place as expected (section 2ivb).

(a) *La Niña*

Despite the strengthening La Niña during ASO 2007, its typical impacts on the upper-tropospheric circulation across the tropical North Pacific and MDR were notably absent (Fig. 4.14). Over the North Pacific, the 200-hPa streamfunction anomalies were weak, and the typical core of negative anomalies near the date line was absent. Also, there was a lack of persistent positive velocity potential anomalies near the date line, even though convection was suppressed throughout the region (Fig. 4.7). As a result, the downstream TUTT exhibited no connection to La Niña.

One suggested reason for this discrepancy is that convection over Indonesia and the eastern tropical Indian Ocean was also suppressed throughout the period (Fig. 4.15a). Negative streamfunction anomalies (indicating a weaker upper-level ridge) across the western subtropical North Pacific were consistent with this suppressed convection. These conditions are opposite to the typical La Niña signal, and indicate that the total La Niña forcing and resulting 200-hPa circulation anomalies were much weaker than would normally be expected for the observed Pacific cooling.

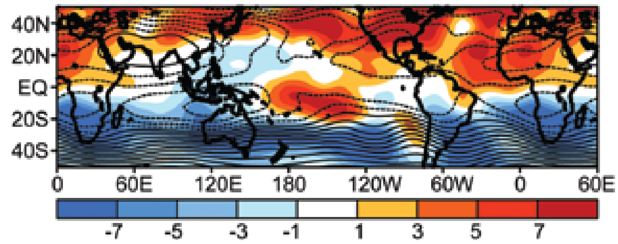

Fig. 4.14. Aug–Oct 2007: 200-hPa streamfunction (contours, interval is 10 x 106 $m^2 s^{-1}$) and anomalies (shaded). Anomalous ridges are indicated by positive values (red) in the NH and negative values (blue) in the SH. Anomalous troughs are indicated by negative values in the NH and positive values in the SH. Anomalies are departures from the 1971–2000 period monthly means.

These conditions were associated with a record-strength pattern (Fig. 4.15b) that also included enhanced convection over the western equatorial Indian Ocean and enhanced convection across India and the Southeast Asian monsoon regions. This entire pattern is more typical of El Niño, as was seen in 2006. This climate signal may have overwhelmed the 200-hPa circulation anomalies normally associated with

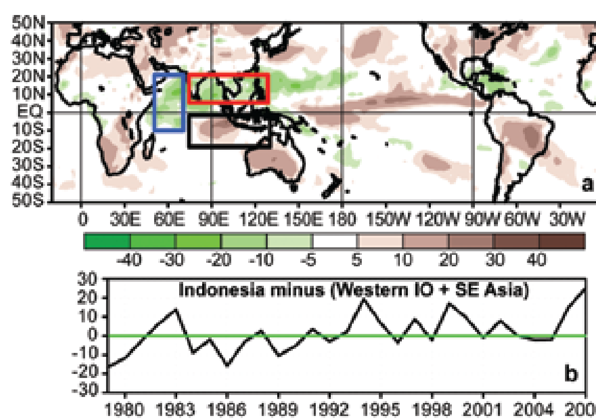

Fig. 4.15. Aug–Oct: (a) anomalous OLR (W m^{-2}), with green shading indicating enhanced convection, and brown shading indicating suppressed convection. (b) OLR time series based on boxed regions shown in (a). The time series is calculated as the area-averaged anomalies over Indonesia (black box) minus area-averaged anomalies over western IO (blue box) minus area-averaged anomalies over southeastern Asia (red box). Anomalies are departures from the 1979–2000 period monthly means.

La Niña, thus negating La Niña's normally enhancing influence on the 2007 Atlantic hurricane season. Conversely, this same pattern may have enhanced El Niño's suppressing influence on the 2006 Atlantic hurricane season (Bell et al. 2007).

(b) Conditions associated with the ongoing active Atlantic hurricane era

Although 2007 had about average activity, it was still more active than most seasons during the below-normal era 1971–94 (Fig. 4.9). A main contributing factor to the current active era is the tropical multidecadal signal, which reflects the leading modes of tropical convective rainfall variability occurring on multidecadal time scales (Bell and Chelliah 2006). A phase change in the tropical multidecadal signal corresponds with the dramatic transition in 1995 to the active era (Bell et al. 2007). Time series of key atmospheric wind parameters highlight the dramatic differences between these above-and below-normal hurricane eras (Fig. 4.16).

One key aspect of the current active hurricane era is an east–west oscillation in anomalous tropical convection between the West African monsoon region and the Amazon basin, signaling an enhanced West African monsoon system (Landsea and Gray 1992; Goldenberg and Shapiro 1996) and suppressed convection in the Amazon basin. A second aspect is ongoing above average SSTs in the North Atlantic, consistent with the warm phase of the Atlantic multidecadal mode (Goldenberg et al. 2001).

As shown by Bell and Chelliah (2006), these conditions are associated with an interrelated set of convectively driven atmospheric anomalies known to favor active hurricane seasons (Fig. 4.16). Most of these anomalies were again in place during 2007, including 1) enhanced ridging at 200 hPa in both hemispheres over the Atlantic Ocean (Fig. 4.14), 2) an enhanced tropical easterly jet and a westward expansion of the area of anomalous easterly winds at 200 hPa, 3) reduced tropical easterlies at 700-hPa across the central and eastern Atlantic (Fig. 4.16, middle), and 4) enhanced cyclonic relative vorticity along the equatorward flank of the African easterly jet (Fig. 4.16, bottom). In light of these ongoing conditions, there is no indication the current active hurricane era has ended.

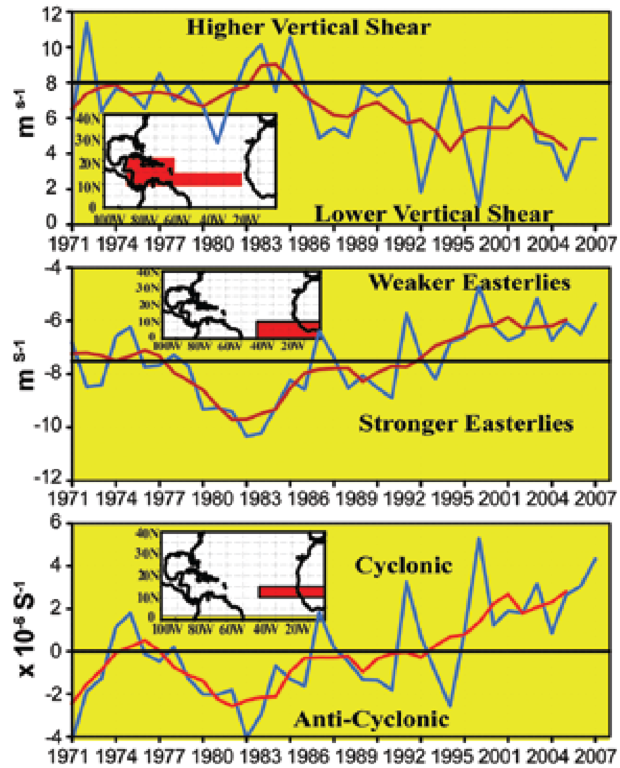

Fig. 4.16. Aug–Oct time series showing area-averaged values of (top) 200–850-hPa vertical shear of the zonal wind (m s^{-1}), (middle) 700-hPa zonal wind (m s^{-1}), and (bottom) 700-hPa relative vorticity (x 10^{-6} s^{-1}). Blue curve shows unsmoothed 3-month values, and red curve shows a 5-point running mean of the time series. Averaging regions are shown in the insets.

3) Eastern North Pacific basin—D. H. Levinson and J. Weyman

(i) Seasonal activity

The ENP basin includes two regions officially designated by NOAA's NWS for issuing NS and H warnings and advisories. The eastern Pacific warning area extends from the west coast of North America to 140°W and is the responsibility of NOAA's NHC in Miami, Florida, while the central Pacific warning area between 140°W and 180° is the responsibility of NOAA's CPHC in Honolulu, Hawaii. The 2007 TC activity in both these warning areas is covered using combined statistics, along with information summarizing activity and impacts in the central North Pacific region.

The ENP hurricane season officially lasts from 15 May to 30 November. The peak activity for the central (eastern) part of the region normally occurs in August (September). The 2007 ENP hurricane season produced 11 NSs, 4 Hs, and 1 MH (Fig. 4.17a). These values are well below the 1971–2005 averages, which are 16.2 NSs, 9.1 Hs, and 4.3 MHs. Four TDs also formed in the ENP during 2007 (03E, 04E, 05E, and 13E).

The 2007 season began quickly with two NSs in May (Alvin and Barbara), which has only happened twice before (1956 and 1984). However, the numbers of NSs and Hs were below normal in all subsequent