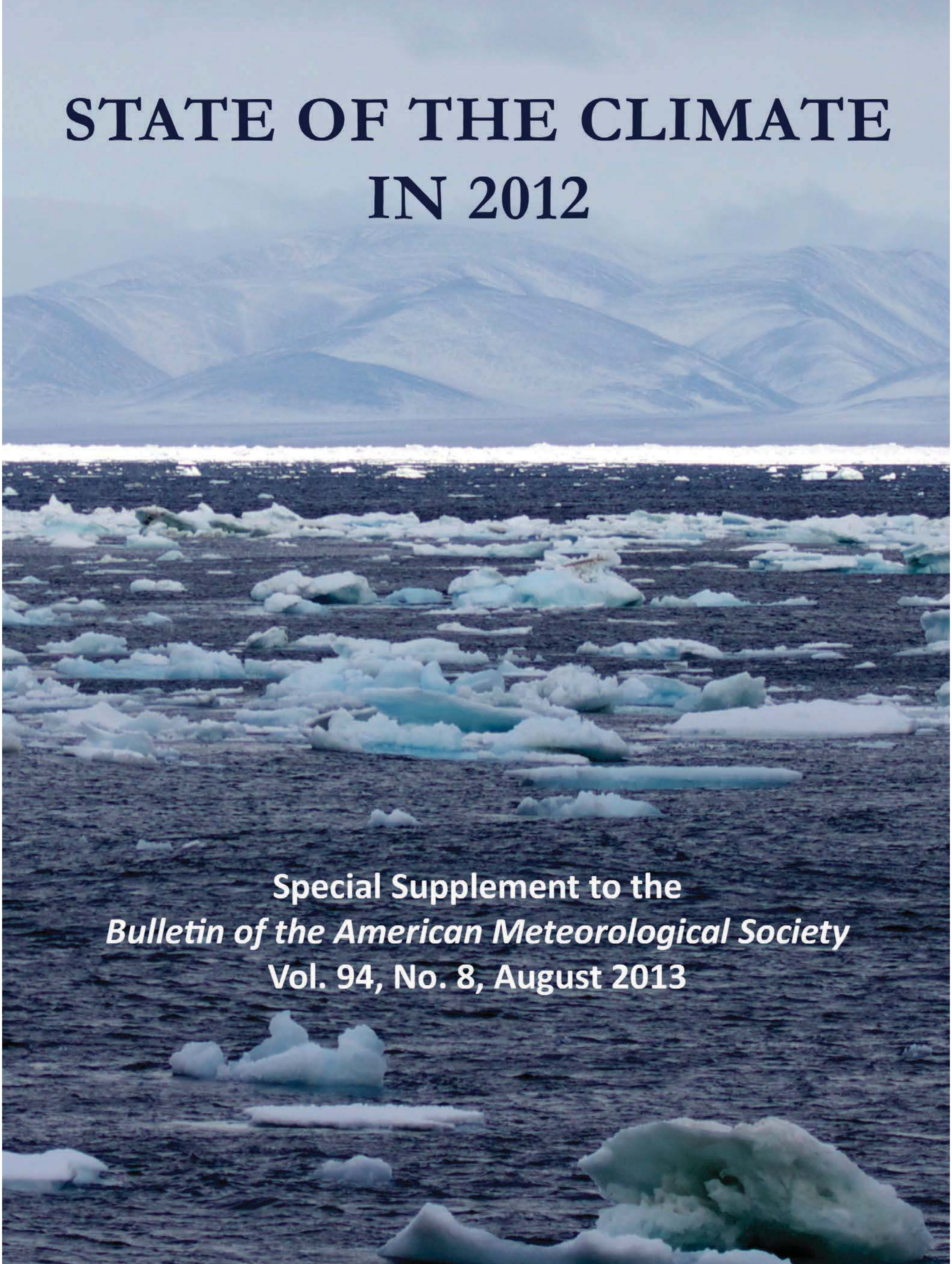
STATE OF THE CLIMATE IN 2012



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The season's last landfalling storm was Tropical Cyclone Iggy, which made landfall as a dissipating system near Jurien Bay, north of Perth, on 2 February. Iggy reached tropical cyclone intensity early on 26 January, about 960 km northwest of Exmouth near 16°S, 108°E. It initially moved southeast towards the Pilbara coast and reached Category 2 intensity, peaking as a 55 kt (28 m s^{-1}) system on 28 January. On 29 January, the storm became near-stationary off the coast near 20°S, 111°E, and weakened before moving southwest and re-intensifying to Category 2 on 30 January. Iggy recurved east and weakened before making landfall. There was moderate rainfall in the landfall area, with Lancelin receiving 73 mm within 24 hours on 2–3 February.

No other tropical cyclones made landfall, or reached Category 3 or higher intensity within the Australian region, although Alenga (December) did so before entering the Australian region from the west, and Jasmine (February) did so after moving into the Southwest Pacific Basin. The circulation associated with the development of Jasmine (discussed in more detail in section d6ii of this chapter) caused some minor wind damage in the Cairns area.

e. *Tropical cyclone heat potential*—G. J. Goni, J. A. Knaff, and I-I Lin

1) Background, overview, and basin highlights for 2012

This section summarizes the seven previously described TC basins from the standpoint of tropical cyclone heat potential (TCHP), by focusing on upper ocean temperature conditions during the season with respect to average values. TCHP (Goni and Trinanes 2003), defined as the ocean heat content contained between the sea surface and the depth of the 26°C isotherm (D26), has been shown to be more closely linked to intensity changes of tropical cyclones than SST alone (Shay et al. 2000; Goni and Trinanes 2003; I-I Lin et al. 2008, 2009a), provided that atmospheric conditions are also favorable. In general, fields of TCHP show high spatial and temporal variability associated with oceanic mesoscale features that can be globally detected with satellite altimetry (Lin et al. 2008; Goni et al. 2009; Goni et al. 1996). Additionally, areas with high TCHP values can be an important factor in the rapid intensification of tropical cyclones (Shay et al. 2000; Mainelli et al. 2008; I-I Lin et al. 2009b). Satellite-derived fields of TCHP are usually validated using Argo and XBT fields (Goni et al. 1996; Pun et al. 2007). It has also been shown that mesoscale features with high values of TCHP can be an important factor for the rapid intensification of TCs (e.g., Shay et al. 2000; Mainelli et al. 2008; I-I Lin et al. 2009b).

Tropical cyclone heat potential is an important seasonal factor since large cooling could affect the intensification for subsequent TCs in the same region and may also influence the upper ocean thermal structure on regional scales within weeks to months after the passage of a TC (Emanuel 2001; Hart et al. 2007; Dare and McBride 2011; Knaff et al. 2013).

To examine TCHP interannual variability, Fig. 4.25 shows anomalies during the months of TC activity in each hemisphere: June through November in the Northern Hemisphere and November through April in the Southern Hemisphere. Anomalies are defined as departures from the mean TCHP calculated during the same months for the period 1993–2012. These anomalies show large variability within and among the TC basins. During the 2012 season, the basins exhibited the following TCHP anomalies:

- The Atlantic Basin displayed generally weak positive anomalies while the Gulf of Mexico (Fig. 4.25, lower right box) showed patterns indicative of variability of the Loop Current. The central region of the Gulf of Mexico, which is typically characterized by high TCHP values, exhibited negative values. In the tropical Atlantic, conditions remained mostly average, but with larger regions exhibiting positive anomaly values (see http://www.aoml.noaa.gov/phod/regsatprod/atln/index.php). It should be noted that there were warm SST anomalies in the Atlantic, and SSTs do not necessarily equate to TCHP values.
- The Western North Pacific (WNP) Basin continues to see an increase in D26 and TCHP by

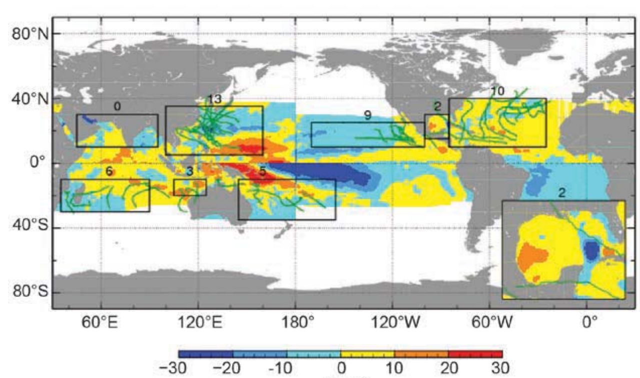

Fig. 4.25. Global anomalies of TCHP corresponding to 2012 computed as described in the text. The numbers above each box correspond to the number of Category 1 and above TCs that traveled within each box. The Gulf of Mexico conditions during Jun–Nov 2012 are shown in the insert shown in the lower right corner.

approximately 10%, as compared to the early 1990s. The sea surface area under very high D26 (>110 m) or very high TCHP (>110 kJ cm^{-2}) has increased by ~13% (Pun et al. 2013). This has been found to be significant, as areas with high D26 and TCHP values are often associated with the development of super typhoons (Lin et al. 2008; Goni et al. 2009; Pun et al. 2013). During 2012, positive anomalies predominated in the WNP MDR in this basin, and TCHP values approached 90 kJ cm^{-2}, making 2012 slightly warmer than average.

- As in 2011, the Southwest Pacific Basin had both positive and negative spatial anomalies (Fig. 4.25), although the basin predominately exhibited high positive anomaly values.
- In contrast with 2011, in the NIO, the Bay of Bengal exhibited a decrease in TCHP values with negative anomalies during 2012, while the Arabian Sea exhibited mostly positive anomaly values.
- Differences in each basin in 2012 with respect to the 2011 conditions (Fig. 4.26) indicate that the east Pacific Ocean and central SIO exhibited larger values (>20 kJ cm^{-2}) of TCHP in most areas in 2012.

2) Examples of TC intensification associated with TCHP

Hurricane Sandy (see Sidebar 4.1) was the most intense storm of the 2012 Atlantic season to make landfall and the largest known Atlantic hurricane in gale wind force diameter on record. Originating as a tropical wave in the Caribbean Sea on 19 October, by 24 October Sandy reached Category 3 strength while crossing over a region north of Cuba with TCHP values above 75 kJ cm^{-2} (Fig. 4.27a). The cooling produced by this storm, even after strengthening,

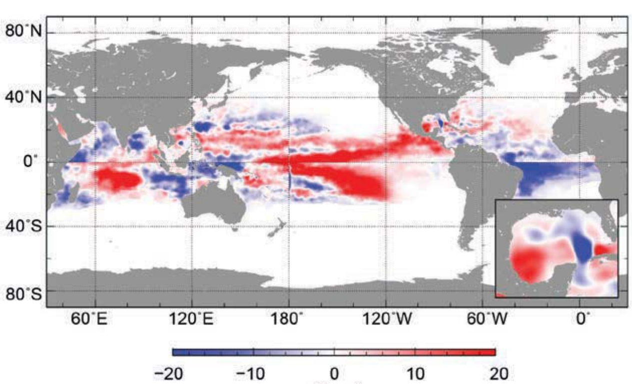

Fig. 4.26. Differences between the TCHP fields in 2012 and 2011.

reached values lower than the typically observed 3C under its track.

In the Mozambique Channel of the Southern Indian Ocean, Tropical Cyclone Funso (Fig. 4.27e) was classified as a tropical depression on 19 January. This is a preferred region for anticyclonic/warm ocean eddies that can interact and influence TCs. The storm initially moved slowly west while rapidly intensifying, reaching an intensity of 100 kt (51 m s^{-1}) on 21 January. At this time the storm was nearly stationary and the eyewall was interacting with the coast of Africa. The upwelling of cooler water, coupled with its interaction with land, caused Funso to weaken slightly as the storm moved slowly eastward and back over the warm Mozambique Channel. Then its steering changed and the storm started moving more steadily, albeit slowly, southward in an environment that was favorable for intensification. During this period of slow southward movement, Funso tracked around the periphery of a warm ocean eddy that had values of TCHP exceeding 75 kJ cm^{-2}. The combination of favorable atmospheric conditions and high TCHP values allowed Funso to intensify to 115 kt (59 m s^{-1}) on 24 January, and it maintained this intensity for 18 hours. As Funso left the influence of this warm eddy, it began the first of two eyewall replacement cycles, resulting in a slight weakening and the formation of a larger eyewall. By this time, Funso was moving more rapidly southward and again re-intensified to 115 kt (59 m s^{-1}) on 26 January after encountering higher TCHP values to the west. After this interaction, Funso began its final eyewall replacement cycle and began to weaken as it moved over the cooler oceanic conditions to the south.

Super Typhoon Sanba was the most intense TC observed in the WNP in 2012. On 13 September, it underwent rapid intensification over a region of high TCHP of >130 kJ cm^{-2} (Fig. 4.27d). Within 18 hours, its intensity increased by 60 kt (31 m s^{-1}) to its peak at maximum sustained winds of 150 kt (77 m s^{-1}). This rapid rate of intensification is more than 2.5 times the rapid intensification threshold value of 30 kt (15 m s^{-1}) in a 24-hour period as described by Kaplan and DeMaria (2003). Sanba was able to maintain this peak intensity for 18 hours while it remained over the high TCHP region that was >130 kJ cm^{-2}. However, as Sanba moved northward away from the higher TCHP region into a southern-eddy-rich zone, it encountered a pre-existing cold ocean eddy. With corresponding significantly lower TCHP values in the range of 60 kJ cm^{-2} –90 kJ cm^{-2}, Sanba's intensity decreased to 110 kt (57 m s^{-1}) within 18 hours.

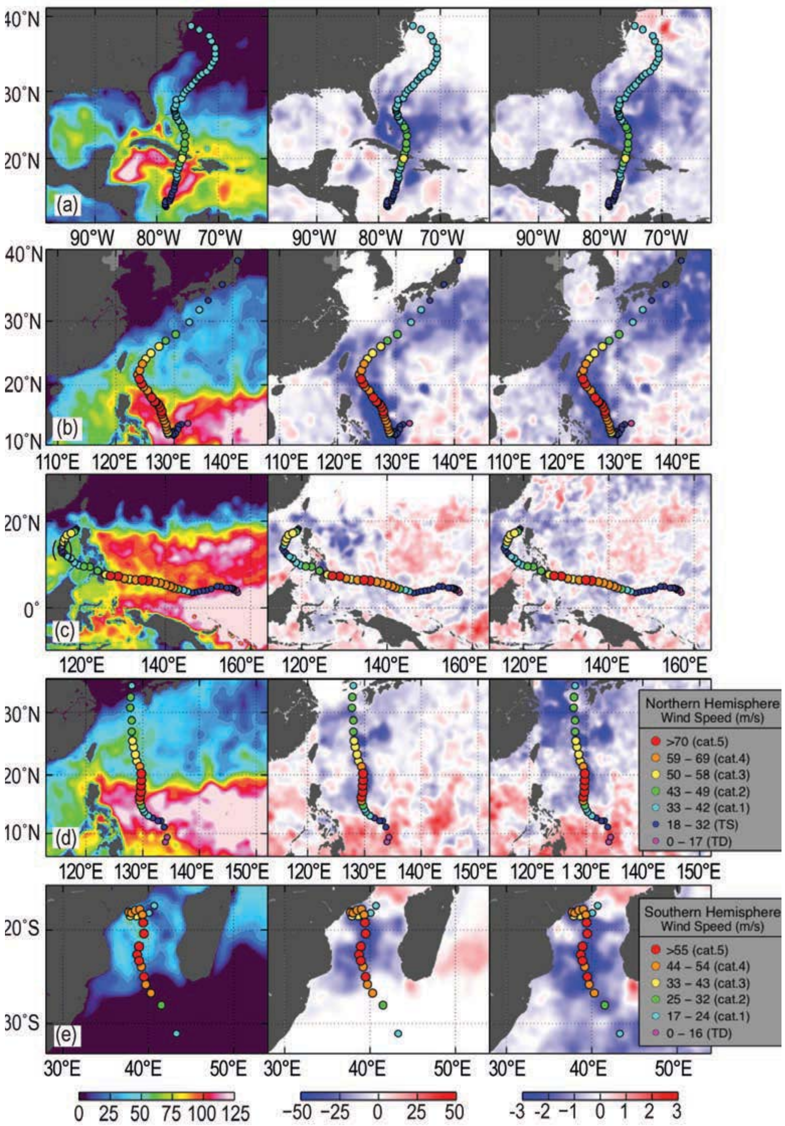

Fig. 4.27. (Left) Oceanic TCHP and surface cooling given by the difference between post- and pre-storm values of (center) TCHP and (right) SST for TCs (a) Sandy, (b) Jelawat, (c) Bopha, (d) Sanba, and (e) Funso. The TCHP values correspond to two days before each TC reaches its maximum intensity value.

On 13 September, Super Typhoon Jelawat (Fig. 4.27b) followed a track similar to Sanba. Jelawat intensified from a Category 1 to a Category 5 storm in only two days and maintained that strength for one day. As it moved away from the high TCHP area and passed over the cold water wake region left by Sanba, its intensity decreased significantly.

Another notable case of intensification was also observed in the WNP with Super Typhoon Bopha, a late boreal fall/early boreal winter storm. Bopha (Fig. 4.27c) was also the only December typhoon to have reached a Category 5 status in the past decade. Bopha had a low-latitude track around 4°N–5°N for much of its existence. Typhoon Bopha formed at a low latitude and in a region where TCHP values are typically above 100 kJ cm^{-2}, and its maximum intensification rates were coincident with a typhoon tracking through a region with TCHP values exceeding 85 kJ cm^{-2}. On 1 December, Bopha had maximum sustained winds of 115 kt (59 m s^{-1}), and by 3 December, it reached its peak intensity of 140 kt (72 m s^{-1}). However, the storm intensified more slowly than Sanba. Bopha made landfall in Mindanao, Philippines, soon after reaching its peak intensity. As noted in section 4d4, Mindanao is not a region that experiences frequent TC landfalls and Bopha was the most devastating typhoon to affect the southern Philippines in the last 20 years.

f. Intertropical convergence zones

1) Pacific—A. B. Mullan

The intertropical convergence zone (ITCZ) lies approximately parallel to the equator with a slight north-easterly tilt, and varies in position from around 5°N–7°N in February–May to 7°N–10°N in August–November. The South Pacific convergence zone (SPCZ) extends diagonally from around Solomon Islands (10°S, 160°E) to near 30°S, 140°W, and is most active during November–April. In the far western Pacific, these two convergence bands merge into the Australian and East Asian monsoon trough.

The Pacific convergence zones are strongly influenced by the status of ENSO; as the year began, a mature La Niña was in place. This event dissipated during April 2012 and warmer-than-normal tropical SSTs developed in the second half of the year, but did not display sufficient amplitude or persistence to qualify as an El Niño. Thus, SST anomalies in the tropical Pacific were not extreme during 2012 nor were the precipitation variations in the convergence zones, other than exceptions as noted below.

Figure 4.28 summarizes the convergence zone behavior for 2012, and relates the seasonal variation to the longer-term climatology. Rainfall transects over 20°N to 30°S are presented for each quarter of the year, averaged across successive 30° longitude bands, starting in the western Pacific at 120°E–150°E. The rainfall data are taken from the Tropical Rainfall Monitoring Mission (TRMM) analysis (Huffman et al. 2007), using the 0.25° resolution 3B43 dataset