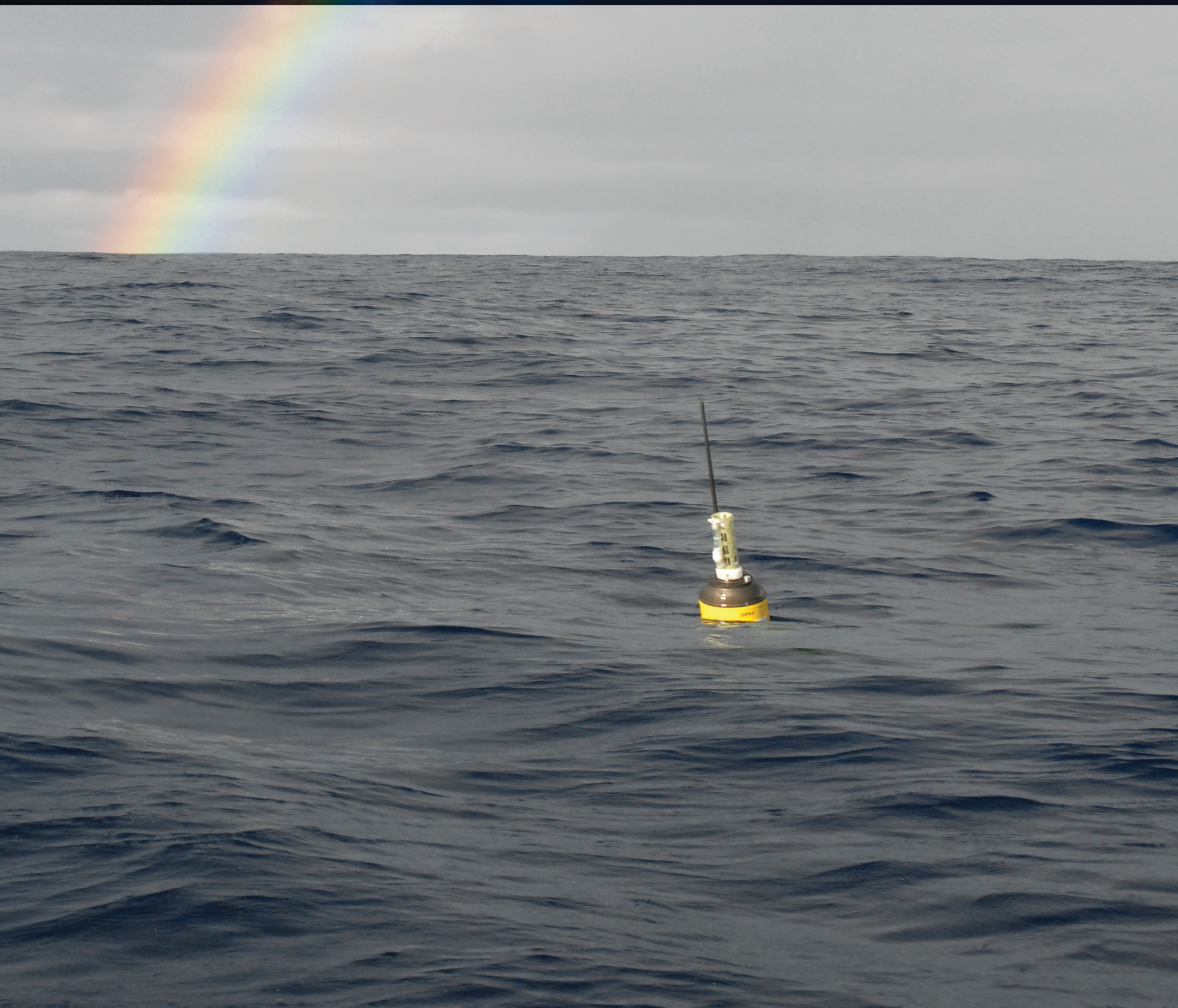
STATE OF THE CLIMATE IN 2014



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

This section summarizes the previously described tropical cyclone (TC) basins from the standpoint of tropical cyclone heat potential (TCHP), by focusing on vertically-integrated upper ocean temperature conditions during the season. The TCHP (Goni and Trinanes 2003), defined as the excess heat content contained in the water column between the sea surface and the depth of the 26°C isotherm, has been linked to TC intensity changes (Shay et al. 2000; Goni and Trinanes 2003; I-I Lin et al. 2008, 2014). In addition, the magnitude of the in situ TCHP impacts the maximum potential intensity (MPI) through modulating the during-TC air–sea coupling and flux supply (Mainelli et al. 2008; I-I Lin et al. 2013). In general, fields of TCHP show high spatial and temporal variability associated with oceanic mesoscale features, interannual variability, or long-term decadal variability that can be detected with satellite altimetry (Goni et al. 1996, 2009; Lin et al. 2008; Pun et al. 2014).

To examine the TCHP interannual variability, anomalies (departures from the 1993–2013 mean values) are computed during the months of TC activity in each hemisphere: June–November in the Northern Hemisphere and November–April in the Southern Hemisphere. In general, these anomalies show large variability within and among the TC basins.

Most basins exhibited positive TCHP anomalies (Fig. 4.35), except for the WNP and the western portion of the South Pacific, which also reported a decrease in the number of tropical cyclones. While the greater Atlantic basin was marginally negative, the TCHP in the Gulf of Mexico was dominated by positive anomalies due to the intrusion of the Loop Current. However, the Gulf of Mexico did not register any hurricanes during this season, similar to the previous year when only one hurricane occurred.

In the ENP basin, the positive TCHP anomalies are consistent with the onset of El Niño conditions, which are characterized by positive sea surface temperature anomalies in that region. Consequently, the TCHP values in this region during the last season were higher than in the previous year (Fig. 4.36).

The WNP basin also usually exhibits anomalies related to ENSO variability. From the 1990s to 2013 it experienced a long-term decadal surface warming associated with La Niña-like conditions (Kosaka and Xie 2013; England et al. 2014; Pun et al. 2013). The TCHP over the WNP main development region (MDR; 5°–20°N, 120°E–180°) was observed to increase considerably until 2013 (Pun et al. 2013; Goni

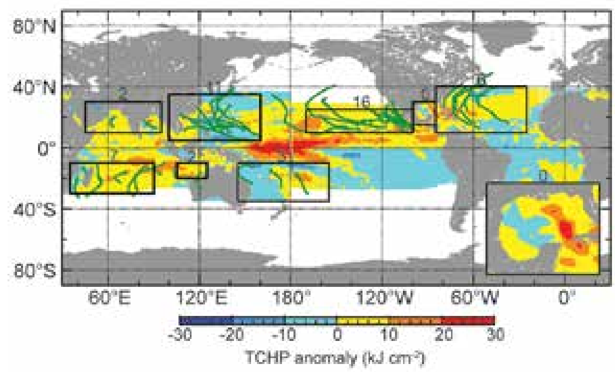

Fig. 4.35. Global anomalies of TCHP (kJ cm^{-2}) corresponding to 2014 computed as described in the text. The boxes indicate the seven regions where TCs occur: from left to right, Southwest Indian, North Indian, West Pacific, Southeast Indian, South Pacific, East Pacific, and North Atlantic (shown as Gulf of Mexico and tropical Atlantic separately). The green lines indicate the trajectories of all tropical cyclones reaching at least 64 kt during Nov 2013–Apr 2014 in the SH and Jun–Nov 2014 in the NH. The numbers above each box correspond to the number of this intensity level of TCs that travel within each box. The Gulf of Mexico conditions during June–Nov 2014 are shown in the inset in the lower right corner.

et al. 2013). Although the TCHP values in the WNP MDR have increased by an average of 15% since 1993, the 2014 values exhibited lower values than in 2013 (Fig. 4.36).

For each basin, the differences in the TCHP values between the most recent cyclone season and the previous season (Fig. 4.36) indicate that the southwest Indian Ocean, the North Atlantic, and the western portion of the ENP basins continue exhibiting an increase in TCHP values (Goni et al. 2014). Tropical cyclone activity in terms of Category 4 and 5 storms was correspondingly elevated in these basins. The largest changes with respect to the previous season were in the ENP and WNP basins, with differences of up to +20 and –20 kJ cm^{-2}, respectively. Although TCHP values over the WNP MDR were, on average, lower in 2014 compared to 2013, they were much higher compared to the 1990s. All four Category 5 super typhoons of 2014 (Halong, Vongfong, Nuri, and Hagupit) intensified over this main development region.

Although the 2014 typhoon season in the WNP [see section 4f(4)] was not as active as in the previous year, it was noteworthy for several reasons:

- Typhoon Halong formed as a tropical storm on 29 July (Fig. 4.37a). The ocean exhibited high values (>75 kJ cm^{-2}) of TCHP, providing favorable condi-

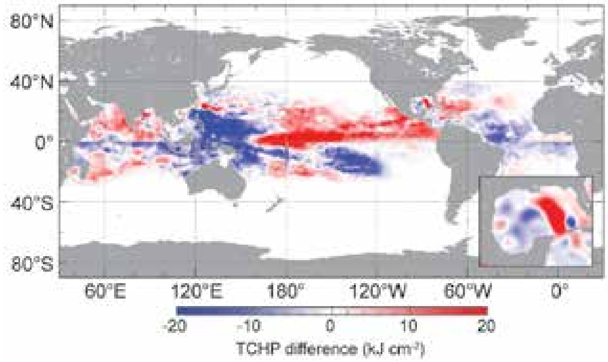

Fig. 4.36. Differences between the TCHP fields in 2014 and 2013 (kJ cm^{-2}).

tions for intensification. Halong reached Category 5 super typhoon status on 2 August while traveling over waters with TCHP >120 kJ cm^{-2}. Cooling under the track of this typhoon was more evident after it attained maximum intensity, reaching values of –50 kJ cm^{-2} and –3°C in TCHP and SST differences, respectively. Halong made landfall over Japan as a tropical storm.

- Vongfong became a typhoon after entering warm waters on 4 October (Fig. 4.37b). Similar to Halong, Vongfong continuously traveled over waters of high TCHP (>75 kJ cm^{-2}) along most of its trajectory. Upper ocean conditions with TCHP values >100 kJ cm^{-2} probably contributed to its rapid intensification from Category 3 to 5 in less than 18 hours on 7 October to become the most intense typhoon of the season. The most intense cooling of –50 kJ cm^{-2} and –3°C in TCHP and SST, respectively, was observed after Vongfong reached maximum intensity. Vongfong made landfall in southern Japan on 13 October as a tropical storm.
- Nuri became a typhoon on 1 November and was one of the strongest on record for this basin in 2014 (Fig. 4.37c). Nuri intensified from Category 1 to 5 in one day, at the high intensification rate of 80 kt day^{-1}. The intensification of this typhoon occurred when it was traveling over waters that had maximum values of TCHP of 75 kJ cm^{-2}. On average, the cooling was not as large as in the previous two cases, reaching values of –25 kJ cm^{-2} and –2°C for TCHP and SST differences, respectively. Nuri did not make landfall.

In the Atlantic Ocean, the 2014 hurricane season was among the weakest in the last 15 years. Hurricane Gonzalo was the most intense Atlantic hurricane of the season. Gonzalo formed east of the Leeward Islands on 12 October and became a Category 4 hurricane, reaching maximum winds of 126 kt (65 m s^{-1}) on 16 October (Fig. 4.37d). During most of its track, Gonzalo moved at an average translation speed of about 20 km h^{-1} and did not create a strong cooling wake until it became a Category 4 hurricane. Underwater glider observations collected in the proximity of the hurricane north of Puerto Rico indicated that there was an average cooling of 0.4°C in the upper 50 m of the water column (Domingues et al. 2015, manuscript submitted to *Geophys. Res. Lett.*). However, by the time Gonzalo reached maximum strength, the cooling of the surface waters was approximately 2°C.

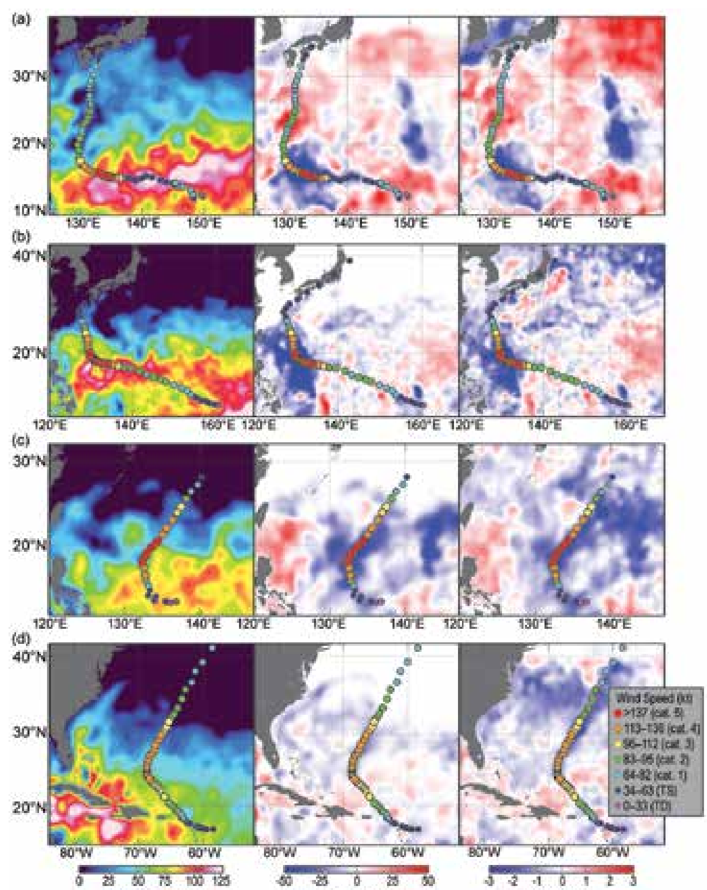

Fig. 4.37. (left) Oceanic TCHP (kJ cm^{-2}), and surface cooling given by the difference between post- and pre-storm values of (center) TCHP and (right) SST (°C) for 2014 TCs (a) Halong, (b) Vonfong, (c) Nuri, and (d) Gonzalo. The TCHP values correspond to two days before each TC reaches its maximum intensity value.