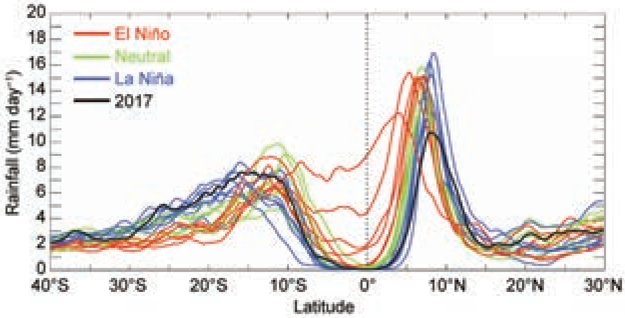

Fig. 4.12. CMORPH rainfall rate (mm day^{-1}) for Oct–Dec, for each year 1998 to 2017, averaged over the longitude sector 180°–150°W. The cross-sections are color-coded according to NOAA's ONI, except for 2017 (a La Niña period) shown in black.

rainfall over large parts of Indonesia, indicative of a La Niña pattern. In general, the ITCZ and SPCZ were near their climatological positions and intensities during this 6-month period, although the SPCZ was somewhat more active than usual at about 10°S during April–June (Fig. 4.10b). Associated with this enhanced convection, SSTs were 0.5°–1.0°C above normal throughout the central and western subtropical South Pacific (see Fig. 4.2d).

In September, the tropical Pacific edged closer to La Niña conditions, with anomalous cooling in the eastern and central tropical Pacific, an increase in the Southern Oscillation index, and more enhanced easterly trade winds in the central and western equatorial Pacific. During the last quarter of 2017, La Niña conditions became more consistent across both atmospheric and oceanic features. The ITCZ and SPCZ remained at their climatological locations west of the dateline; on average, however, both were displaced poleward of their normal positions to the east of the dateline (Fig. 4.10d).

In the central north Pacific (180°–120°W), rainfall was well below normal from the equator to the latitude where the ITCZ rainfall peaked (about 8°–9°N as depicted in Fig. 4.10d). In the 180°–150°W sector, the latitude of peak rainfall matched well with previous La Niña events, but the intensity was the lowest since the beginning of the TRMM satellite record. Figure 4.12 shows the south–north rainfall transect of Fig. 4.10d, except that every year from 1998 is shown, color-coded according to NOAA's Oceanic Niño index. October–December 2017, classified as a La Niña quarter, is highlighted separately in black. Although rainfall north of the equator was unusually weak for a La Niña, conditions along the equator and southwards followed the expected La Niña behavior. Islands near the equator (e.g., Nauru and all the Kiribati groups) thus continued the dry conditions they had experienced since the weak La Niña at the end of 2016. In the Southern Hemisphere during October–December, the SPCZ matched well with past La Niña periods with respect to both intensity and latitudinal location (Fig. 4.12).

2) Atlantic—A. B. Pezza and C. A. S. Coelho

The Atlantic ITCZ is a well-organized convective band that oscillates approximately between 5°–12°N during July–November and 5°N–5°S during January–May (Waliser and Gautier 1993; Nobre and Shukla 1996). Equatorial atmospheric Kelvin waves can modulate the ITCZ intraseasonal variability (Guo et al. 2014). ENSO and the southern annular mode (SAM) also influence the ITCZ on the interannual time scale (Münnich and Neelin 2005). The SAM is typically positive during La Niña events, and it was generally so in 2017 (from April onwards) when the equatorial Pacific started to anomalously cool from ENSO neutral (Fig. 4.13a) to a La Niña state (Fig. 4.13b). The SAM is the primary pattern of climate variability in the Southern Hemisphere (Marshall 2003; Thompson et al. 2011), influencing latitudinal rainfall

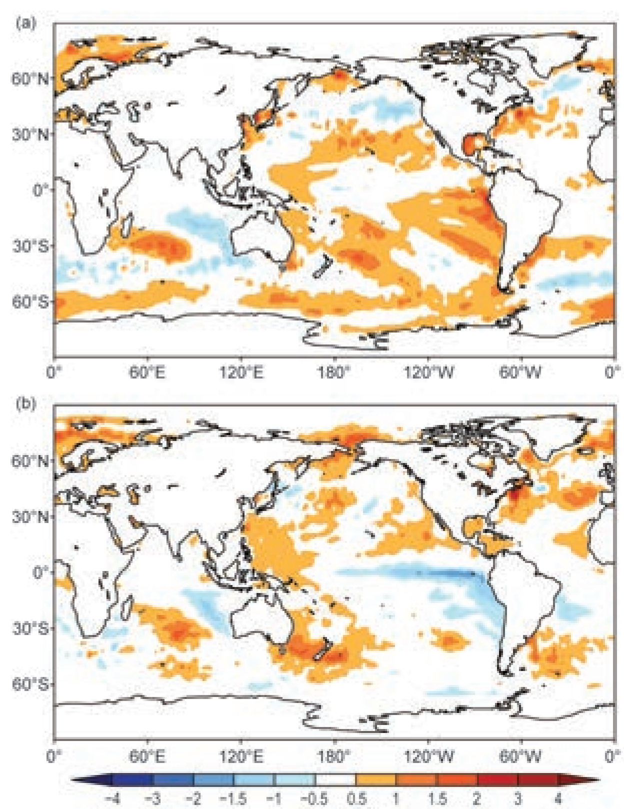

Fig. 4.13. Spatial distribution global SST anomalies (°C; Reynolds et al. 2002) for (a) Jan–Apr and (b) Sep–Dec 2017.

distribution and temperatures from the subtropics to Antarctica. The station-based index of the SAM is based on the zonal pressure difference between the latitudes of 40°S and 65°S. As such, the SAM index measures a "see-saw" of atmospheric mass between the middle and high latitudes of the Southern Hemisphere (Marshall 2003). A positive SAM value can be indicative of a number of things; for instance, a positive SAM coupled with La Niña conditions may lead to increased extratropical cyclone transition of tropical cyclones across or toward New Zealand (Diamond and Renwick 2015).

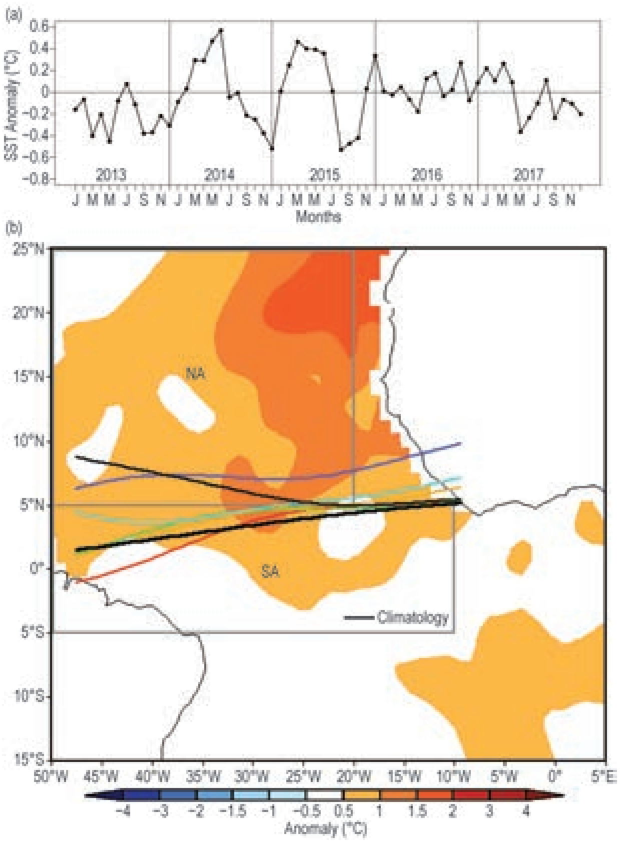

Fig. 4.14. (a) Monthly OISST (Smith et al. 2008) anomaly time series averaged over the South American sector (SA region, 5°S–5°N, 10°–50°W) minus the SST anomaly time series averaged over the North Atlantic sector (NA region, 5°–25°N, 20°–50°W) for 2013–17, forming the Atlantic index. Positive phase of the index indicates favorable conditions for enhanced Atlantic ITCZ activity. (b) Atlantic ITCZ position inferred from OLR (Liebmann and Smith 1996) during May 2017. Colored thin lines indicate the approximate position for the six pentads of the month. Black thick line indicates the Atlantic ITCZ climatological position for May. The SST anomalies (°C) for May 2017 based on the 1982–2016 climatology are shaded. The two boxes indicate the areas used for the calculation of the Atlantic index in (a).

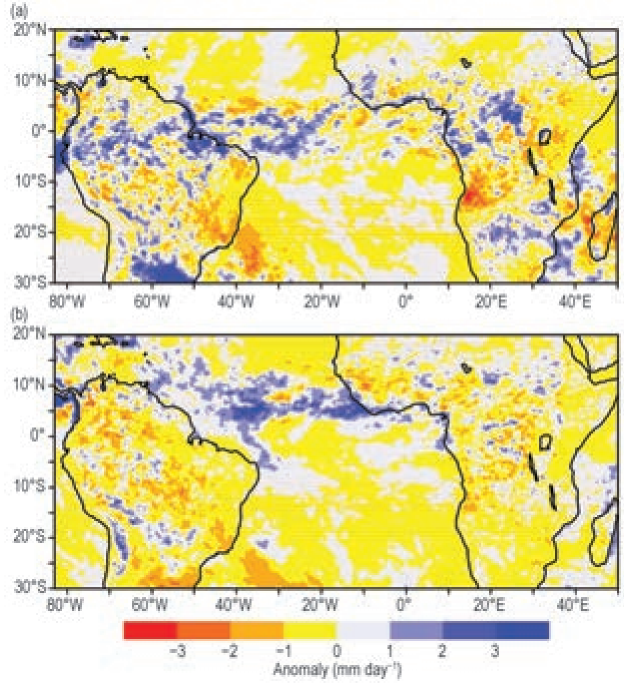

Fig. 4.15. Observed 2017 precipitation anomalies (mm day^{-1}) for tropical and subtropical South America during (a) Jan–May and (b) Jun–Dec. Anomalies calculated based on the 1998–2016 climatology derived from CMORPH (Joyce et al. 2004).

While in principle this reversal toward the cool ENSO phase would tend to favor the Atlantic ITCZ moving south, in reality the change occurred too late in the ITCZ's southern migration season in order to have a positive effect on the rainy season in northeastern Brazil, even though overall the ITCZ was very active over the ocean. For the most part an enhanced South Atlantic anticyclone, increased trade winds, and relatively warmer waters north of the equator prevailed. This was accompanied by a mostly negative South American sector (SA) index, although not so pronounced as in some previous years (Fig. 4.14a). The SA index, as defined in Fig. 4.14, is given by the SST south of the equator minus the SST north of the equator over key areas of ITCZ influence. The ITCZ tends to shift toward the warmer side of this gradient. Indeed, it was generally north of its climatological position for most of 2017, especially in May when it is typically at its southernmost location (Fig. 4.14b).

As discussed above, the overall convection was active over the ocean, and although northeastern Brazil remained dry, the eastern Amazon region (Para state) had above-normal precipitation during the wet season (Fig. 4.15a). The ITCZ remained active for the remainder of the year, mostly over the ocean, as La Niña developed (Fig. 4.15b).

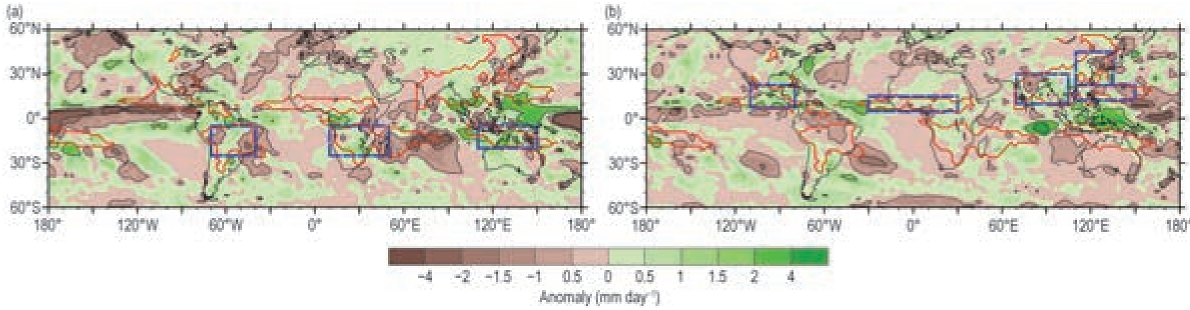

Fig. 4.16. Precipitation anomalies (mm day^{-1}) averaged for (a) northern winter season: Nov 2016–Apr 2017 and (b) northern summer: May–Oct 2017. The red lines outline the global monsoon precipitation domain defined by (a) annual range (local summer minus winter) precipitation exceeding 300 mm and (b) summer mean precipitation >55% of the total annual precipitation amount (Wang and Ding 2008). Here the local summer denotes May–Sep for the NH and Nov–Mar for the SH. Precipitation indices for each regional monsoon are defined by the areal mean precipitation in the corresponding rectangular regions (dashed blue boxes), which are highly correlated with the precipitation averaged over the corresponding real regional monsoon domains (see Table 4.1). Rainfall data were taken from the Global Precipitation Climatology Project (GPCP; Huffman et al. 2009). Note that the threshold of 300 mm excludes a small latitudinal band of the monsoon in the Sahel.

e. *Global monsoon summary*—B. Wang

The global monsoon (GM) is the dominant mode of annual variations of tropical–subtropical precipitation and circulation (Wang and Ding 2008) and thus a defining feature of seasonality and a major mode of variability of Earth's climate system. Figure 4.16 summarizes the monsoon rainfall anomalies for both the SH summer monsoon (SHSM) from November 2016 to April 2017 and the NH summer monsoon (NHSM) from May to October 2017.

Global land monsoon precipitation is strongly influenced by the status of ENSO, especially the land areas of Asia, Australia, northern Africa, and Central America (Wang et al. 2012). As documented in Fig. 4.1 for this year, the equatorial Pacific SSTs evolved from a weak La Niña from NDJ to a neutral state, then toward another weak La Niña during SON. Figure 4.16 indicates that the monsoon precipita-

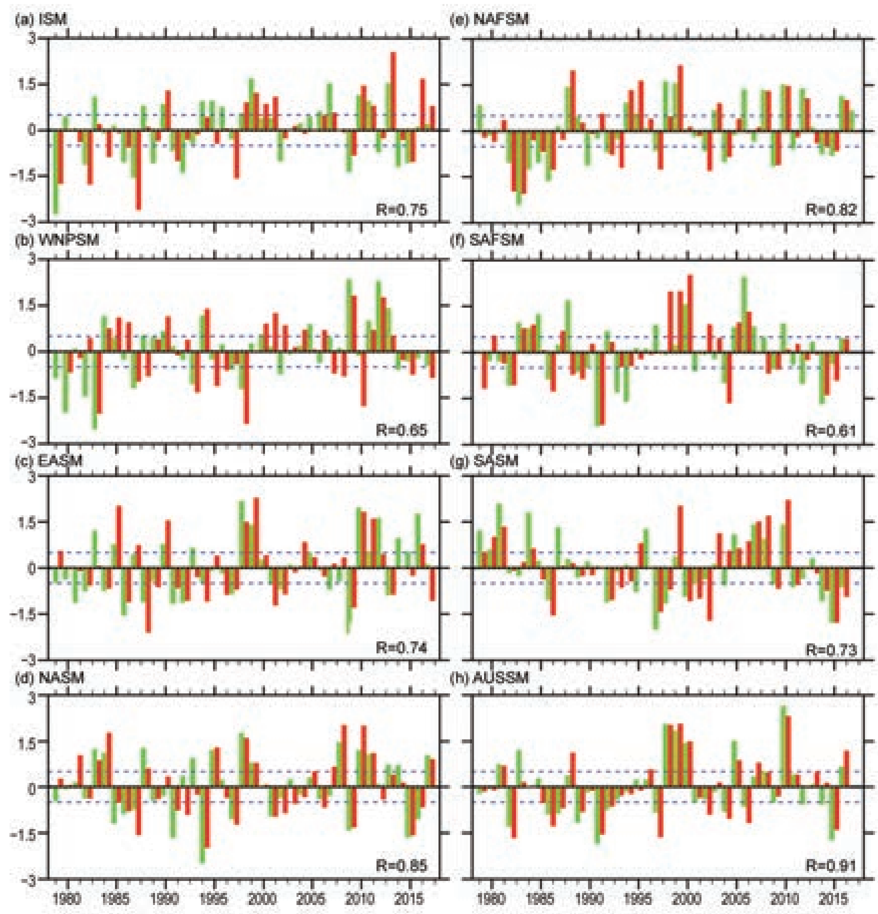

Fig. 4.17. Normalized summer mean precipitation (green) and circulation (red) indices in each of eight regional monsoon regions (see Table 4.1). Indices are normalized by their corresponding std. dev. Numbers shown in the corner of each panel denote the correlation coefficient between seasonal mean precipitation and circulation indices. Dashed lines indicate std. dev. of ±0.5. Here the summer denotes May–Oct for the NH and Nov–Apr for the SH. [Source: GPCP for precipitation; Upper air indices as described in Yim et al. (2014).]