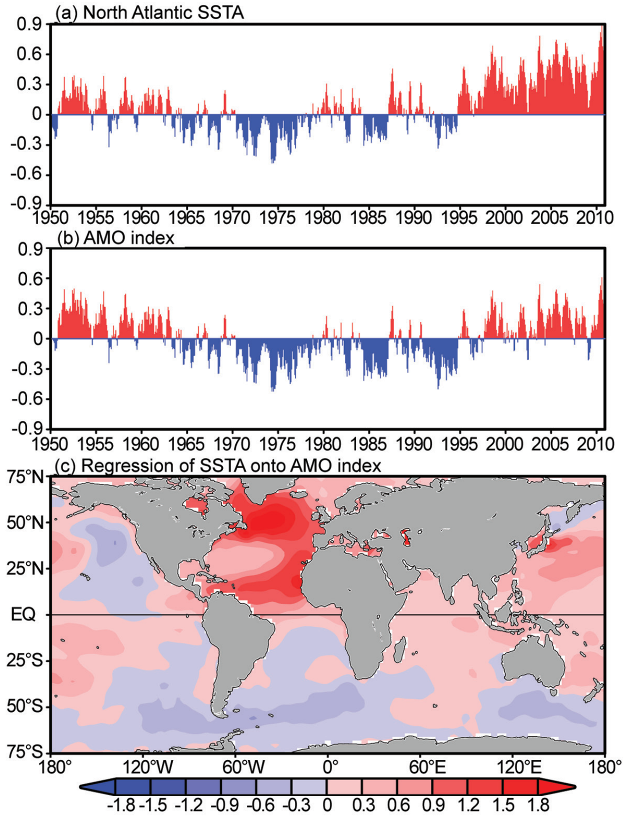

Fig. 4.35. The index of the Atlantic Multidecadal Oscillation (AMO) and its spatial pattern. Shown are: (a) the sea surface temperature (SST) anomalies (°C) in the North Atlantic for 0°–60°N and from the east coast of the Americas to 0° longitude; (b) the AMO index (°C) defined by the detrended (removing the linear trend) North Atlantic SST anomalies; and (c) regression (°C per °C) of global SST anomalies onto the AMO index of (b). The monthly SST anomalies are calculated as departures from the 1971–2000 climatology.

remarkable as it encompassed a very large area of the North Atlantic, and is more than 0.6°C above the second largest value of 25.5° C recorded in April 2005 in this region. The warming persisted throughout most of the year, losing intensity only in November, while La Niña conditions remained moderate-to-strong.

As a result, the ITCZ did not exert a significant contribution towards the rain in northeastern Brazil in 2010, with a large portion of the region experiencing much drier conditions than average, especially in February and March when the climatological influence of the ITCZ towards the Southern Hemisphere should have been important (Fig. 4.34).

g. Atlantic Multidecadal Oscillation—C. Wang

The Atlantic Multidecadal Oscillation (AMO) is an oscillatory mode defined by the detrended North Atlantic SST anomalies over the region of 0°–60°N and from the east coast of the Americas to 0° longitude (Figs. 4.35a,b; Delworth and Mann 2000; Enfield et al. 2001; Wang et al. 2008a; see also Sidebar 1.1). A driving mechanism for the AMO is the Atlantic meridional overturning circulation (Delworth and Mann 2000; Knight et al. 2005; Dijkstra et al. 2006; Zhang et al. 2007; see also section 3h for detailed information on the meridional overturning circulation). The AMO demonstrates an interannual variation via its connection to the tropical Atlantic Warm Pool (AWP; a large body of warm water comprising the Gulf of Mexico, Caribbean Sea, and the western tropical North Atlantic), and as such has exhibited a seasonal influence on the behavior of tropical cyclones (TCs) in the Atlantic and Eastern North Pacific (ENP) basins. The extended reconstructed SST (ERSST) data from 1950 to 2010 shows that the AMO was in the cold phase from the late 1960s to the early 1990s and in the warm phase before the late 1960s and again, after the early 1990s. The AMO is related to SST anomalies over the global oceans as shown in Fig. 4.35c.

The AMO variability is associated with changes of climate and extreme events, such as drought and flood in North America and Europe, and Atlantic hurricane activity (Enfield et al. 2001; McCabe et al. 2004; Goldenberg et al. 2001; Bell and Chelliah 2006; Wang et al. 2008a). Recent studies show that the importance of the AMO is due to its tropical component since the climate response to the North Atlantic SST anomalies is primarily forced at the low latitudes (Sutton and Hodson 2007; Wang et al. 2008b). Since the AWP is at the center of the main development region (MDR) for Atlantic tropical cyclones, the influence of the AMO on climate and Atlantic TC activity operates through the mechanism of the AWP-induced atmospheric changes by having an effect on vertical wind shear in the MDR. A large AWP reduces such shear, while a small AWP enhances it. A large AWP also weakens the southerly Great Plains low-level jet, thus reducing the northward moisture transport from the Gulf of Mexico to the eastern U.S. and decreasing the boreal summer rainfall over the central U.S., while a small AWP has the opposite effect (Wang et al. 2006; Wang et al. 2008b). It has also been shown that AWP variability can produce the observed out-of-phase relationship between TC activity in the tropical North Atlantic and ENP (Wang and Lee 2009).

The AMO in 2010 remained in its warm phase and showed extremely positive SST anomalies in the North Atlantic (Fig. 4.36a). The warm phase of the AMO was strongest in August (+0.90°C) and weakest

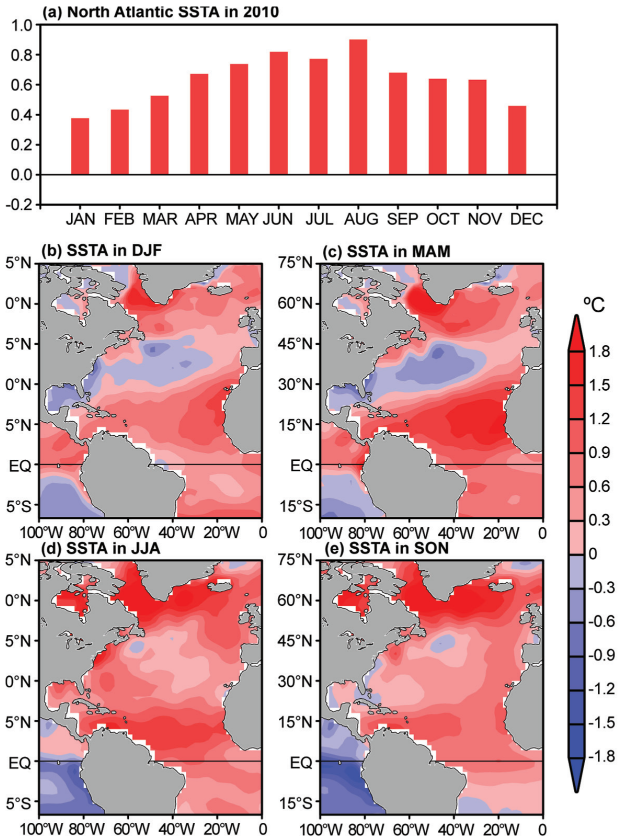

Fig. 4.36. The Atlantic Multidecadal Oscillation (AMO) in 2010. Shown are: (a) the monthly North Atlantic sea surface temperatures (SST) anomalies (°C) in 2010; (b) the DJF (December 2009–February 2010) SST anomalies (°C); (c) the MAM (March–May 2010) SST anomalies; (d) the JJA (June–August 2010) SST anomalies; and (e) the SON (September–November 2010) SST anomalies. The monthly SST anomalies are calculated as departures from the 1971–2000 climatology.

in January (+0.38°C). Spatially, the North Atlantic SST anomalies during the boreal winter and spring seasons showed a tripole pattern with the positive SST anomalies in the subpolar North Atlantic and the tropical North Atlantic and the negative SST anomalies in the subtropical North Atlantic (Figs. 4.36b,c). The SST anomaly pattern divided the AWP into two parts: a colder Gulf of Mexico and a warmer Caribbean Sea/western tropical North Atlantic. The opposite SST anomaly pattern was consistent with a previous study (Muñoz et al. 2010), which showed that the air-sea fluxes associated with ENSO events in the tropical Pacific and local processes were responsible for the SST anomaly distribution.

During the boreal summer and fall of 2010, the cold SST anomalies in the subtropical North Atlantic almost disappeared and the North Atlantic was consistently warm (Figs. 4.36d,e). During the 2010 Atlantic TC season, the AWP was also consistently large and the entire tropical North Atlantic was warm. A large AWP also tends to shrink the North Atlantic subtropical high eastward (C. Wang et al. 2007) and hurricanes are therefore steered away from the eastern coast of the United States. The extremely large AWP in 2010 was also associated with the out-of-phase relationship between TCs in the North Atlantic and the ENP as documented in sections 4d2 and 4d3.

h. Indian Ocean Dipole—J. J. Luo

Year-to-year climate variability in the tropical Indian Ocean (IO) is largely driven by local ocean-atmosphere interactions and ENSO. The Indian Ocean Dipole (IOD), as one major internal climate mode in the IO, may sometimes be originated from complex interactions between the IO and Pacific (J.-J. Luo et al. 2010). Owing to the warm mean state in the IO, the IOD often causes large climate anomalies in many countries surrounding the IO despite the fact that SST anomalies related to IOD are usually weak and more localized compared to the ENSO signal. During late boreal summer to fall in 2010, a negative IOD (nIOD) occurred, five years after the last nIOD event in 2005 (Luo et al. 2007). Compared to previous events, the 2010 nIOD was strong, with a peak warming of about 1°C above normal in the eastern IO (Fig. 4.37b) during 2010 fall season; this event may have

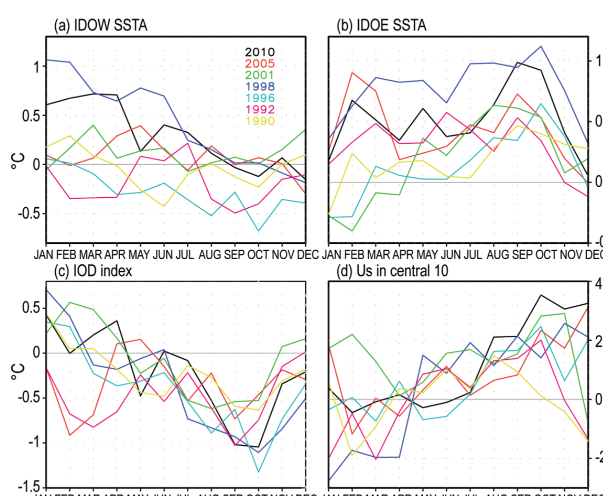

Fig. 4.37. Monthly anomalies of (a) sea surface temperatures (SST) in the western Indian Ocean (IODW, 50°E–70°E, 10°S–10°N); (b) SST in the eastern IO (IODE, 90°E–110°E, 10°S–0°); (c) the IOD index (measured by the SST difference between IODW and IODE) during the seven negative IOD events; and (d), as in (c), but for the surface zonal wind anomaly in the central equatorial IO (70°E–90°E, 5°S–5°N).