STATE OF THE CLIMATE IN 2006

d. Circulation

1) Surface current observations—R. Lumpkin and G. Goni

Near-surface currents are measured in situ by satellite-tracked drifting buoys and acoustic point-measuring meters on ATLAS moorings.[2] In September 2005, the drifter array reached its target goal of 1250 drifters worldwide, becoming the first fully realized component of the GCOS-92. During 2006, surface currents were well sampled except in the far northern Pacific, in the southwest Pacific between 20° and 40°S, from 150°E to the date line, for the Arabian Basin of the Indian Ocean, and for the extreme Southern Ocean south of 55°S.

Weekly maps of absolute surface currents and geostrophic current anomalies for 2006 were calculated from a synthesis of in situ observations, near-real-time AVISO data gridded altimetry, and NCEP operational winds (Niiler et al. 2003). Anomalies are defined with respect to the 1993–98 mean.

In 2006, the most dramatic surface current anomalies were associated with the development of El Niño conditions late in the year in the Pacific Ocean basin. Anomalies elsewhere in the World Ocean were caused either by energetic mesoscale (60–90-day period) variations or by displacements of currents from their typical positions, or were associated with the seasonal reversals of currents in the Tropics.

(i) Pacific Ocean

Annual mean anomalies (Fig. 3.9) were most prominently organized in a coherent pattern in the western tropical Pacific Ocean, associated with the 2006 El Niño. Seasonal mean anomalies (Fig. 3.10) show a typical seasonal reversal of the equatorial surface current from January through June. During July, eastward anomalies began developing in the eastern (145°–170°E) equatorial Pacific (Fig. 3.11). By August, these anomalies had reached 70 cm s^{-1} at 160°E to the date line. In September, eastward anomalies of ~40 cm s^{-1} were seen at 120°–140°W. The largest eastward anomalies of 50 cm s^{-1} were seen in October at 160°E to the date line. These anomalies also propagated eastward while weakening to +25 cm s^{-1} in November. Anomalies in December were small.

(ii) Indian Ocean

The tropical Indian basin exhibited a band of anomalously eastward flow along 25°–30°S, immediately south of westward anomalies. This is the band where the westward SEC encounters Madagascar and is deflected southwestward to join the Agulhas Current system flowing southward against Africa's west coast. The anomaly pattern suggests that the SEC was displaced to the north of its climatological position. Seasonally averaged anomalies (not shown) were associated with monsoon-driven changes in the tropical basin and the complex pattern of mesoscale anomalies in the Agulhas Return Current. The eastward equatorial jet was prominent in April–June, but not in October–December.

(iii)Atlantic Ocean

The seasonal reversal of western tropical Atlantic Ocean currents (cf. Lumpkin and Garzoli 2005) was prominent in 2006. Anomalously strong westward anomalies were seen on the equator in July–September, reversing to eastward anomalies in October–December. This reversal is typical, but was more ener-

[2] Drifter data are distributed by NOAA/AOML's Global Drifter Program at the Drifter Data Assembly Center Web site (www.aoml.noaa.gov/phod/dac/dacdata.html). Moored current meter data are distributed by NOAA/PMEL's Tropical Atmosphere–Ocean Project at www.pmel.noaa.gov/tao. Altimetric time series of transports may be viewed at www. aoml.noaa.gov/phod/satprod. NCEP data are provided by the NOAA–CIRES Climate Diagnostics Center, Boulder, Colorado (www.cdc.noaa.gov). AVISO altimetry is produced by the CLS Space Oceanography Division as part of the Environmental and Climate EU ENACT project and with support of CNES.

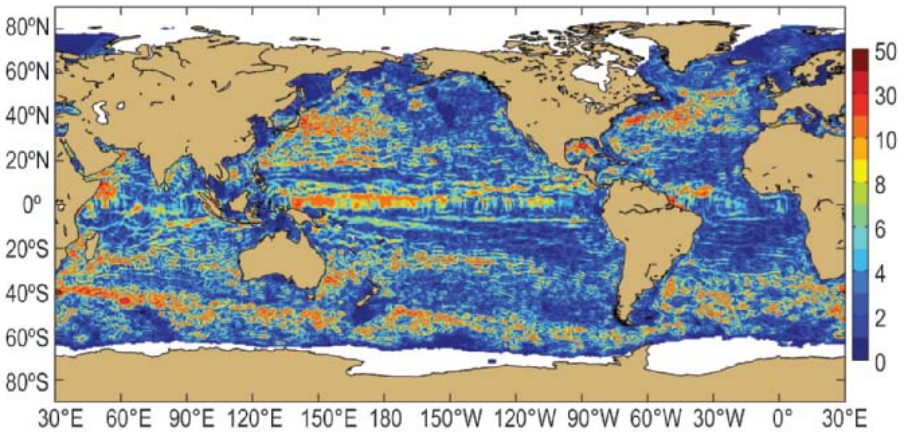

Fig. 3.9. Amplitude (cm s^{-1}) of 2006 averaged surface current anomalies, with respect to the 1993–98 mean.

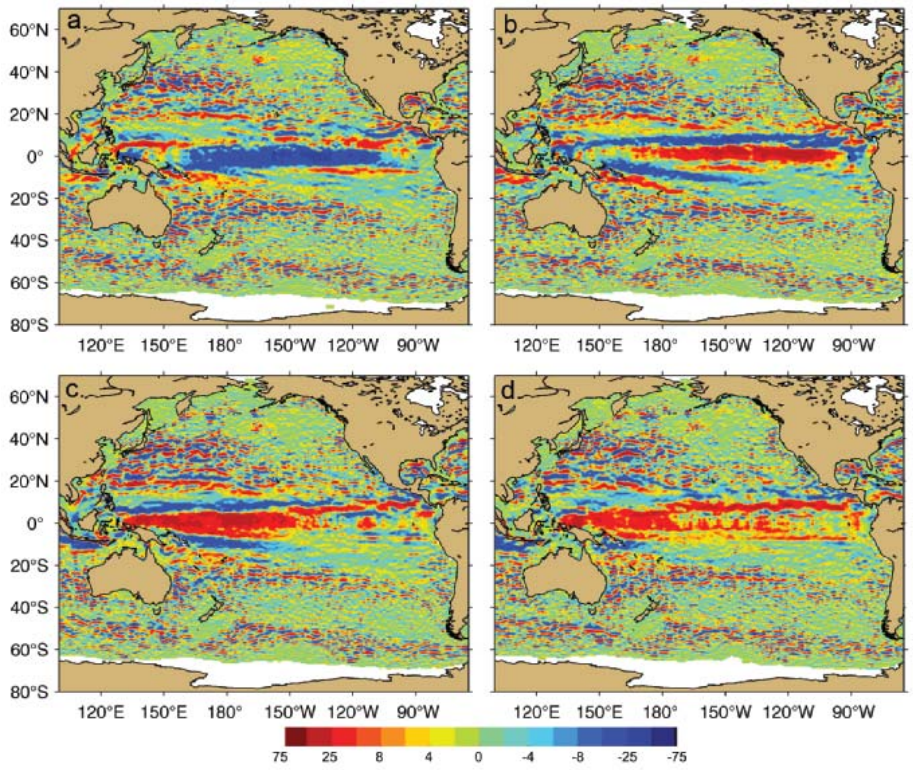

Fig. 3.10. Pacific seasonal anomalies of zonal current (positive = eastward) during (a) January–March, (b) April–June, (c) July–September, and (d) October–December 2006.

getic and dramatic in 2006. Anomalies elsewhere were associated with intense mesoscale features in the Gulf Stream, Brazil/Malvinas Confluence off the Brazilian coast, and the Agulhas retroflection west of the southern tip of Africa. Averaged over 2006, the Gulf Stream axis was close to its climatological position. Late in 2006, the Gulf Stream developed a dramatic pattern of alternating meanders at 50°–65°W.

Satellite altimetry observations indicate that the Agulhas Current, which runs southward against Africa's southeast coast, was somewhat larger than average during 2006. This current can serve to connect the Indian and Atlantic Oceans by transferring salty, tropical Indian water into the South Atlantic via Agulhas rings shed from the current. However, the number of rings shed in 2006, as revealed by altimetry, was lower than average. Thus, unless the few rings that were shed were unusually deep, the South Atlantic Ocean may reveal fresh anomalies in Argo-derived salinity maps for early 2007.

The NBC runs northward along the Brazilian coast, carrying South Atlantic water past the equator before it abruptly leaves the coast and flows eastward across the Atlantic. Rings shed by the NBC continue northwestward, and carry a large fraction of the upper-water exchange from the South Atlantic to the North Atlantic. This pathway is thus a critical part of the upper limb of the MOC in the Atlantic.

The space–time diagram of sea height residual (sea height anomaly with the annual cycle removed) along the pathway of NBC rings (not shown) reveals that five rings are shed by the NBC during 2006, which is approximately the historical mean. However, most of these rings did not enter the Caribbean Sea. The time series of geostrophic transport of the Yucatan Straits (not shown), connecting the Caribbean Sea to the Gulf of Mexico, indicates that the transport decreased during 2006. This is significant, because the flow through the Yucatan Straits feeds the Loop Current–Florida Current–Gulf Stream system. Consistently, the Florida Current transport, measured by an undersea cable running from South Florida to the Bahamas, decreased slightly from its historical average of 30–32 million tons s^{-1} in mid-October to around 28 million tons s^{-1} by the end of the year. Such anomalies are common in the record.

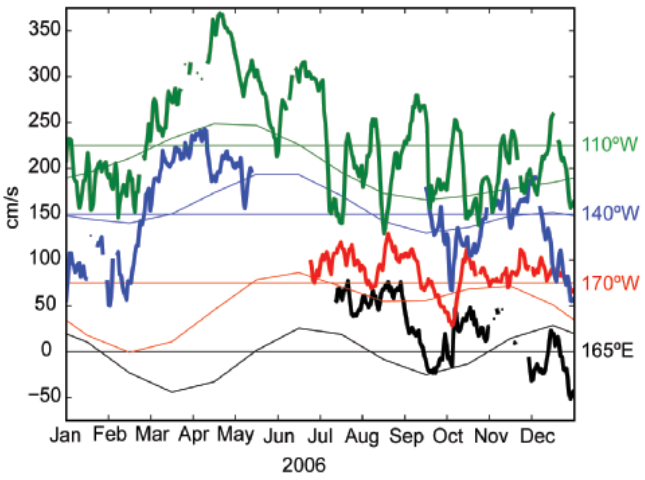

Fig. 3.11. Near-surface zonal current anomalies (daily averages) measured at equatorial TAO moorings. Time series east of the date line have been displaced vertically; the zero line for each is indicated by a horizontal line. Seasonal climatology at each site is indicated by thin curves.