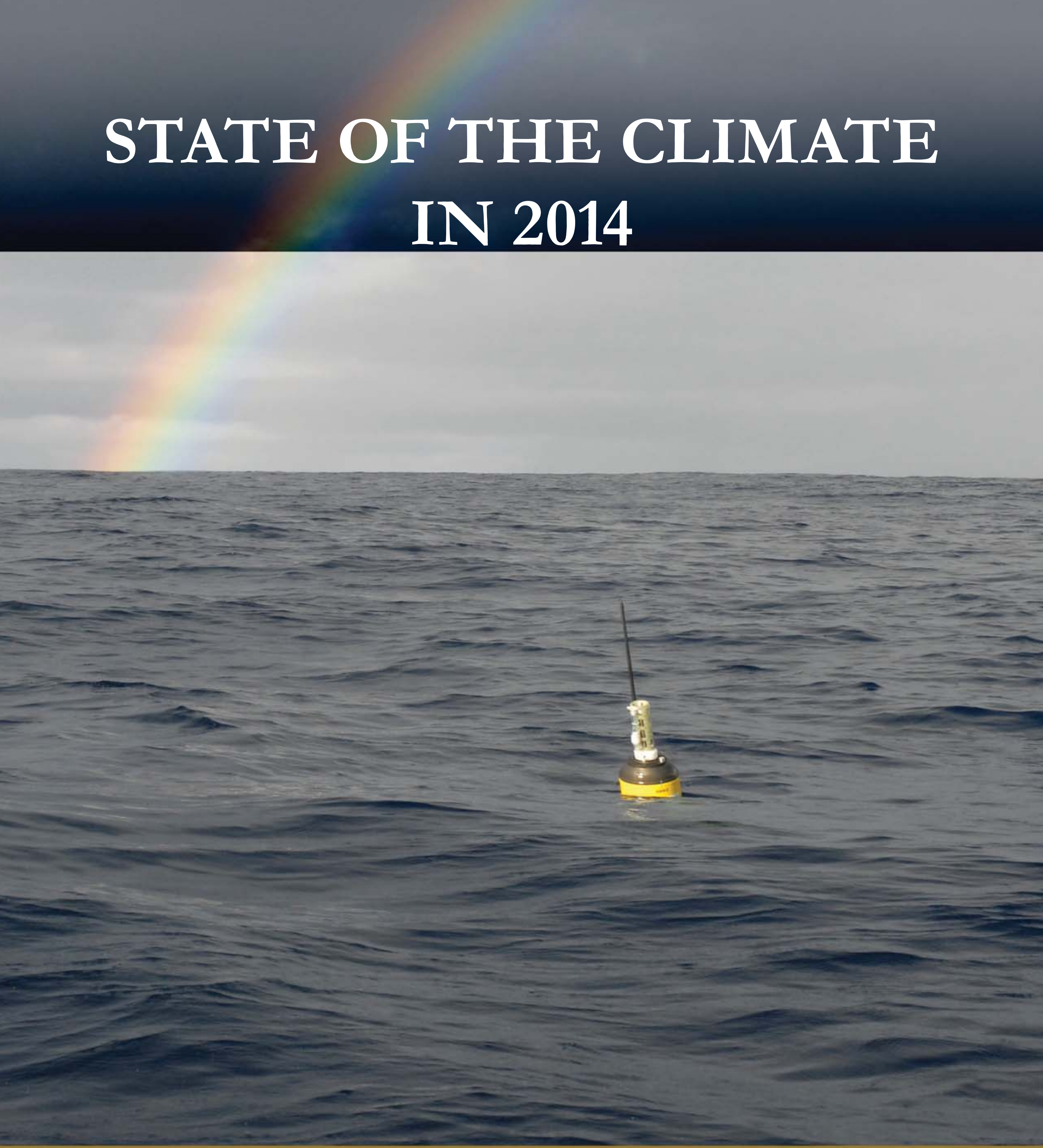
STATE OF THE CLIMATE IN 2014



Special Supplement to the
Bulletin of the American Meteorological Society
Vol. 96, No. 7, July 2015

i. Meridional oceanic heat transport in the Atlantic Ocean—M. O. Baringer, W. E. Johns, W. R. Hobbs, S. Garzoli, S. Dong, and J. Willis

The meridional heat transport (MHT) is the integral of the ocean velocity (circulation) times the ocean temperature (heat capacity) over cross sections that span the entire width and depth of an ocean basin. MHT is related to the meridional overturning circulation (MOC; section 3h) and variability of MHT can impact heat storage, sea level rise, and air–sea fluxes, hence influencing local climate on land. Time series of oceanic heat transport are rarer than time series of the MOC because they involve the co-variability of temperature and velocity and are only meaningful as a flux (and hence independent of the absolute temperature scale used) when the total mass transport can be accounted for (i.e., sums to zero). This report includes MHT time series data from 26°N, 41°N, and 35°S in the Atlantic Ocean.

The MHT at 26°N is based on the RAPID/MOCHA/WBTS array of moorings, cabled observations, and Argo profiling float data (Johns et al. 2011; McCarthy et al. 2015). MHT estimates from this array have been updated to include new data spanning October 2012–March 2014 (mooring servicing cruises are now being completed every 18 months so the next data update will be available sometime after the fall of 2015). At 26°N the median MHT from April 2004 to March 2014 was 1.2 ± 0.4 PW (1 PW = 10^{15} W; Fig. 3.23), statistically indistinguishable from the value reported last year (1.3 ± 0.4 PW). The total MHT is composed of the sum of mass-conserving temperature transport from the Florida Current (FC; median 2.51 ± 0.26 PW standard deviation), Ekman temperature transport (0.36 ± 0.30 PW), and interior ocean temperature transport (–1.62 ± 0.23 PW). During the updated period, the average MHT of the FC and Ekman transport were approximately the long-term average; however, the interior component of the MHT was slightly stronger to the south, thus weakening slightly the MHT transport in 2012 and 2013. At shorter periods than annual, the FC and Ekman transport influence the MHT more strongly. The MHT was significantly low during 26 October–2 November 2012, 20–25 November 2012, 28 February–16 March 2013, and 9–10 March 2014 (significance defined by the 95% daily confidence limits). These are essentially the same time periods with low MOC transport (see section 3h). The October 2012 and March 2013 events were the second and third lowest MHT events in the 10-year record. During March 2013, the MHT reached values as low as –0.24 PW, averaging 0.09 PW. The Ekman transport contributed the most to this low heat transport (values 0.77 PW lower than average) with the FC also contributing (0.49 PW lower than average). The interior mass transport (circulation component) was negligibly different than the long-term mean, but the heat transport (temperature component) was relatively high, offsetting the decreased MHT from the Ekman and FC (+0.15 PW above the long-term mean). The MHT total was only briefly significantly high—during a single day, 1 December 2012. Unlike the MOC, the interior circulation appears to play a lesser role in the variability overall; however, it can

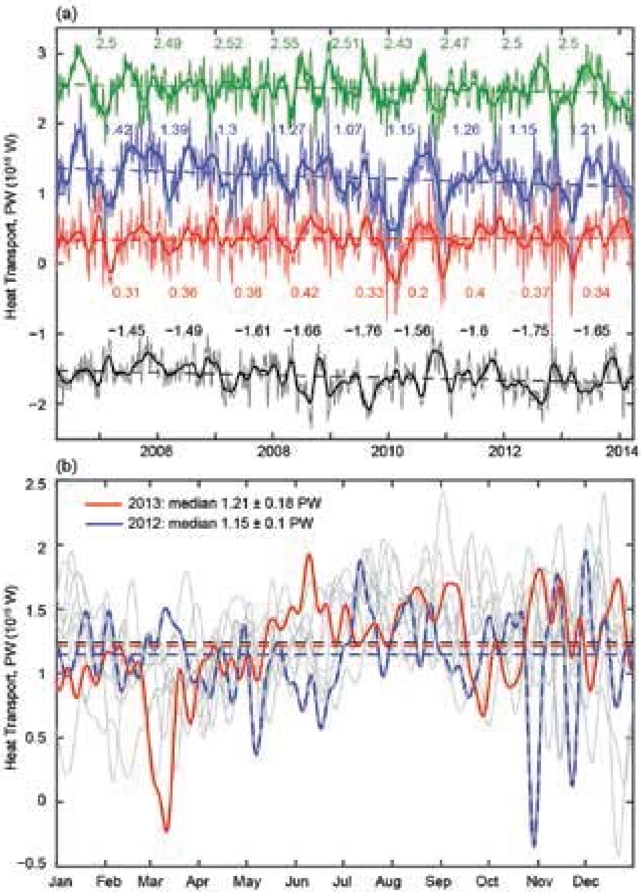


Fig. 3.23. (a) Daily estimates at 26.5°N of meridional heat transport (10^{15} W; blue line) and its associated temperature transport components: Florida Current (green), wind-driven Ekman transport (red) and geostrophic interior (black), as measured by the RAPID/MOCHA/WBTS. High frequency heat transports have a 10-day low-pass filter applied to the daily values (McCarthy et al. 2015). Smooth curves (heavy lines) represent 90-day low pass filtered data and dashed lines linear trends of the full time series. Annual average transports (in PW or 10^{15} W) for each year are given (colored text). (b) MHT from 2013 (red), 2012 (dashed blue) and all other years (gray) plotted versus month. Thin horizontal dashed lines are annual mean values for 2013 (red), 2012 (blue), and all years (black).

be a dominant factor during certain time periods (e.g., McCarthy et al. 2012) and, as shown here, the MHT carried in the interior transport is impacted by temperature as well as circulation changes. The MHT showed a statistically significant decrease of −0.27 ± 0.19 PW decade^{-1} (95% confidence limits) from April 2004 to March 2014 (using the full time series). This long-term trend is due to the interior transport trend (−0.18 ± 0.12 PW decade^{-1}) with no significant contribution from the FC (−0.12 ± 0.13 PW decade^{-1}) or Ekman (+0.03 ± 0.11 PW decade^{-1}) heat transports. As with the MOC, different components of the circulation appear to dominate the total transport depending on time scale and processes, interior transport dominating long-term trends and FC and Ekman transport playing important roles on shorter time scales.

There are two other published time series estimates of the MHT in the Atlantic that are being maintained: At 35°S in the South Atlantic MHT has been estimated using a combination of expendable bathythermograph (XBT) data and Argo profiling floats (Garzoli et al. 2012) and at 41°N the MHT is estimated (Hobbs and Willis 2012) using altimetry, Argo profiling float data, and Argo drift velocities at 1000 m. The 35°S and 41°N time series have been updated from last year's report to include data to the end of 2014. From July 2002 to December 2014 the median of the MHT near 35°S remained stable at 0.55 ± 0.16 PW (± 1 standard deviation; Fig. 3.24). The median MHT near 41°N was 0.48 ± 0.07 PW, updated since Baringer et al. (2014) to include new estimates during September 2010–December 2014. The new data at 41°N include significantly low transport during November 2013–January 2014 and again in December 2014. The only other significantly low transport event happened November–December 2009, coincident with the low transport seen at 26°N. Previous analyses have identified the leading mechanisms for the low winter 2009/10 transport (McCarthy et al. 2012) and associated subtropical cooling (Cunningham et al. 2013). The more recent low transport event in the winter of 2013/14, however, appeared only at 41°N; the 26°N data showed a relatively high MHT during November 2013–January 2014. This pattern resulted in a large advective heat convergence between 26°N and 41°N. Considering the changes in MHT using only overlapping time periods of the three records, a significant decreasing MHT trend is seen in northern latitudes: −0.19 ± 0.09 PW decade^{-1} at 41°N and −0.27 ± 0.19 PW decade^{-1} at 26°N. Near 35°S however, the trend is not statistically significant—but increasing (0.1 ± 0.18 PW decade^{-1}). This result implies an advective heat convergence in the ocean between 35°S and 26°N, and implies an ocean heat content increase unless atmospheric fluxes in the region have increased proportionally.

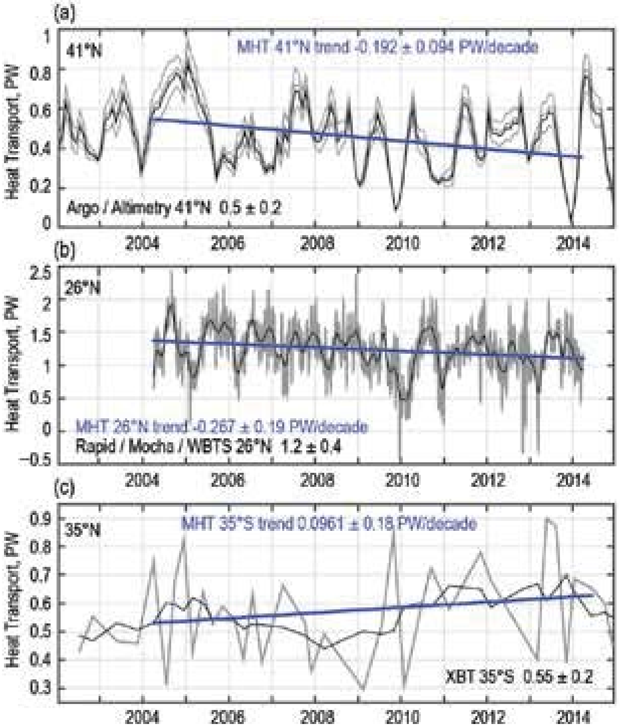


Fig. 3.24. Observed time series of meridional heat transport (MHT) in the Atlantic at (a) 41°N (profiling floats), (b) 26°N (mooring/hydrography), and (c) 30°–35°S (XBTs). At 41°N (a) the black line is the estimated MHT and gray lines represent the uncertainties (Hobbs and Willis 2012). At 26°N (b) the black line is the observed data filtered with a 3-month low-pass filter and the gray lines are the 12-hourly data. At 35°S (c) the gray line is the quarterly estimated MHT from XBTs and the black line is a yearly boxcar filter applied to those quarterly estimates.

j. Sea level variability and change—M. A. Merrifield, P. Thompson, E. Leuliette, G. T. Mitchum, D. P. Chambers, S. Jevrejeva, R. S. Nerem, M. Menéndez, W. Sweet, B. D. Hamlington, and J. J. Marra

Climate variations impact global and regional sea level through changes in air–sea momentum and buoyancy fluxes, and exchange of water between oceans and continents. During 2014, regional sea level variations measured by satellite altimetry highlighted recent shifts in ENSO and NAO climate modes, and other changes in the upper ocean wind-driven circulation. Ongoing comparisons with satellite gravity (ocean mass) and Argo (ocean heat) observations provide a framework for assessing contributions to global mean sea level (GMSL) trends and fluctuations. The highest values of sea level over the year from tide gauge observations are used to provide information on the severity of storm conditions recorded. This