What caused the 2009 cold event in the Atlantic cold tongue region?

Kristin Burmeister[1], Peter Brandt[1,2], & Joke Lübbecke[1,2]

SFB 754

Key Points

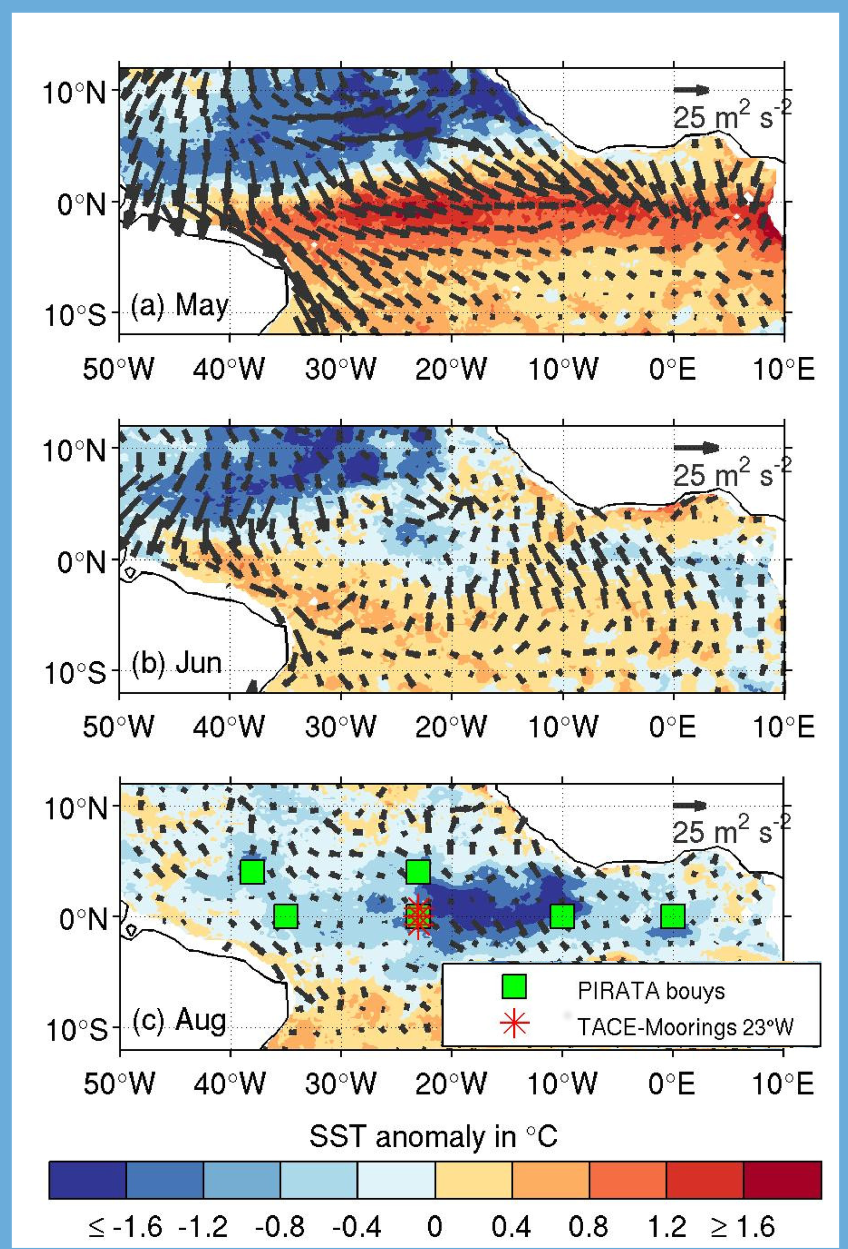
➔ The 2009 non-ENSO like cold event in the Atlantic is revisited, using in situ data, satellite and reanalysis products

➔ Meridional advection for non-ENSO like cold events seems to be less important than for non-ENSO like warm events

➔ Higher order baroclinic mode waves appear to contribute to the development of the 2009 cold event

The 2009 Cold Event

- Strong negative Atlantic meridional mode event associated with north-westerly wind anomalies along the equator from March to May 2009
- Instead from what would be expected from ENSO like dynamics, an abrupt cooling took place in the Atlantic cold tongue (ACT) region from May to August 2009



Anomalous TMI sea surface temperatures (shading) and CCMP pseudo wind stress (arrows) in 2009 with respect to the mean seasonal cycle (1998-2011).

Meridional Temperature Advection

Hypothesis I: Wind induced, warm temperature anomalies at ~4°N are advected into the ACT region by equatorward subsurface currents and can trigger warm non-ENSO like events (Richter et al., 2013). The same process may cause the 2009 cold event.

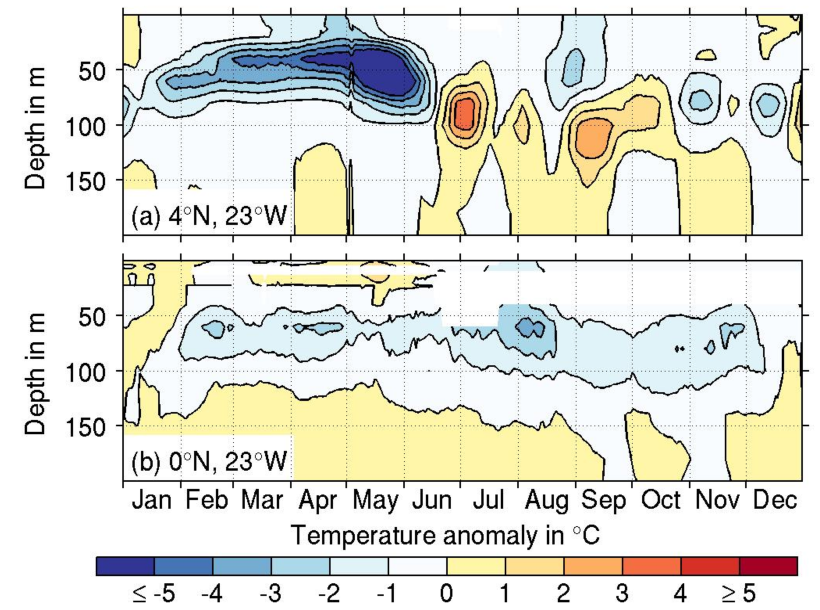
In Situ and Reanalysis Data 2009

- Moored observations show anomalous cold subsurface temperatures and equatorward subsurface currents in the equatorial Atlantic (EA) in 2009
- Quantification of Meridional Temperature Advection (MTA) in 2009 through reanalysis data
- Cooling by MTA after onset of 2009 cold event

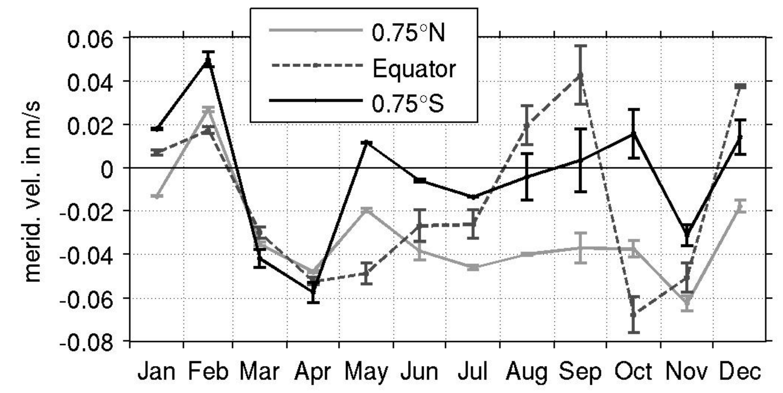
Conclusion:

- Anomalous north-westerlies (south-easterlies) that are associated with non-ENSO like cold (warm) events tend to weaken (strengthen) equatorward subsurface flow
- Hence, for cold events, there is no significant meridional advection of subsurface temperatures that can drive an anomalous cooling of the ACT region

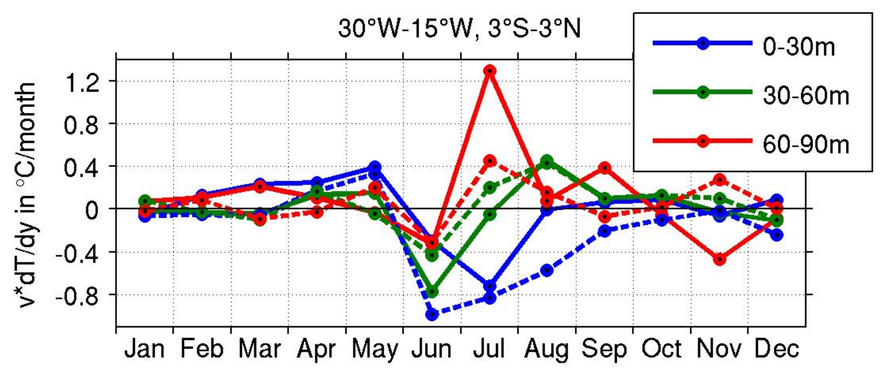
➔ **NOT applicable to the 2009 cold event**



Anomalous subsurface temperatures observed by PIRATA buoys in 2009 with respect to the mean seasonal cycle (2006-2013).



2009 meridional velocities observed by TACE moorings averaged in a depth of 35m-100m at 0°N, 50m-100m at 0.75°N, and 75m-100m at 0.75°S.



Anomalous MTA calculated from GODAS (solid lines) and ORAS4 (dashed lines) reanalysis data in 2009 with respect to the mean seasonal cycle (1980-2014).

Equatorial Wave Dynamics

Hypothesis II: Wind forced equatorial Rossby waves and reflected equatorial Kelvin waves transport cold sea surface temperature anomalies into the ACT region (Foltz and McPhaden, 2010). As the observed Kelvin wave signal in Sea Level Anomaly (SLA) data is weak, this mechanism is revisited.

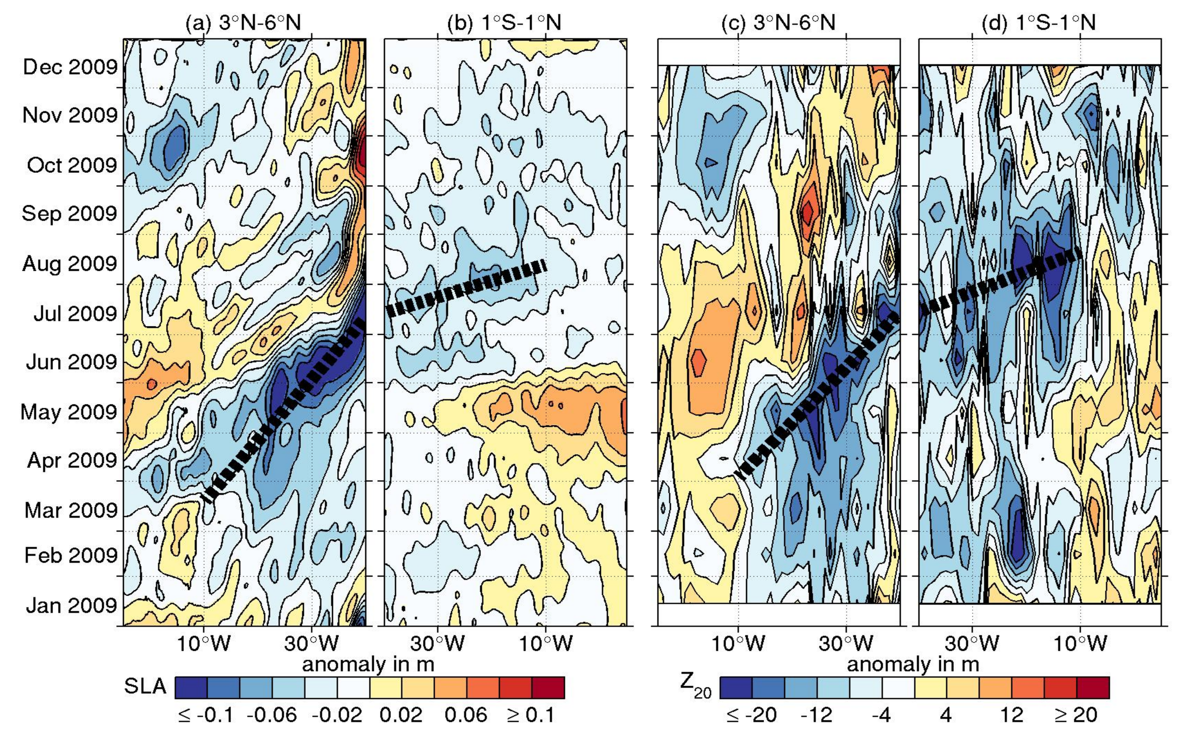
Satellite and In Situ Observations

- Strong signal of an reflected Kelvin wave in ARGO Z_{20} (depth of 20°C-isotherm) data
- Analysis of the vertical density structure of Argo float profiles reveals signals that propagate along the thermocline in the EA

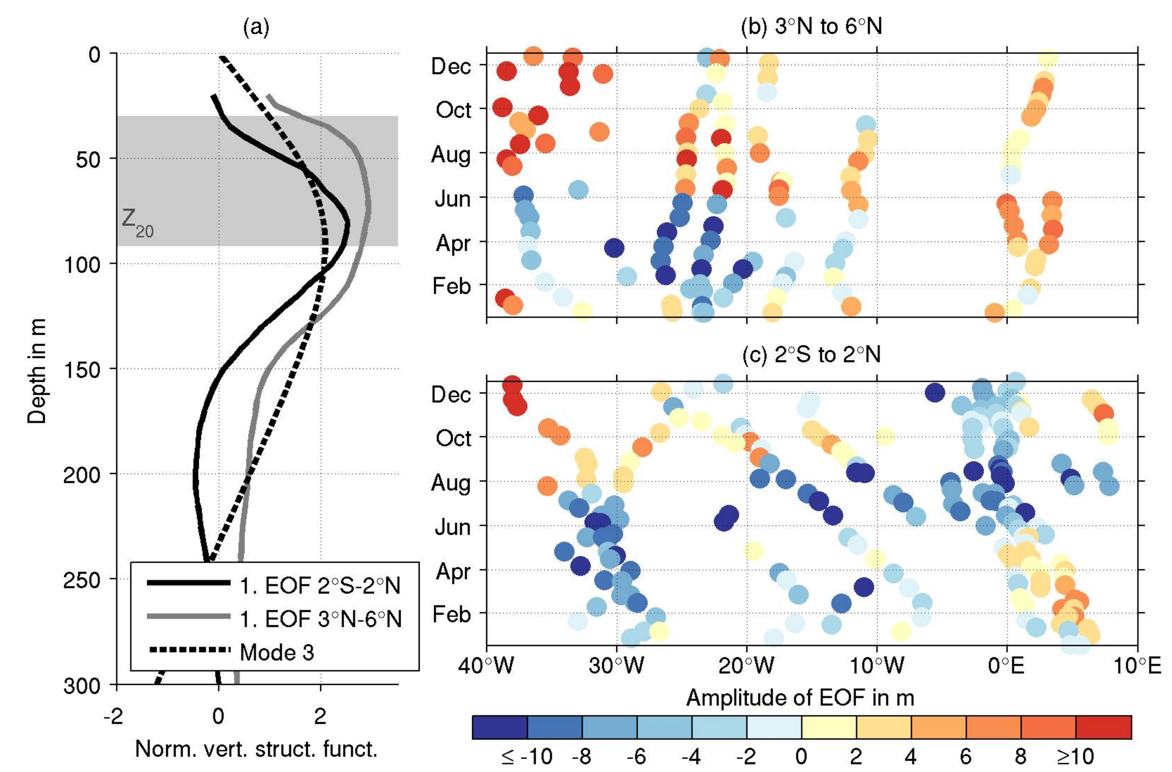
Conclusion:

- Higher order baroclinic mode waves transfer the upwelling signal in the thermocline westward from the central Atlantic just north of the equator and then eastward along the equator, from the western boundary toward the ACT region
- SLA signal is dominated by first and second baroclinic modes, which may explain the weak signal observed in SLA

➔ **Applicable to the 2009 cold event**



2009 anomalies of (a,b) AVISO SLA and (c,d) Argo Z_{20} with respect to the mean seasonal cycle (2005 to 2012), propagation speed of negative amplitudes (black lines).



Empirical orthogonal function analysis of density displacement profiles estimated from Argo floats profiles in the EA in 2009.

[1] GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany
[2] Christian-Albrechts-Universität zu Kiel, Kiel, Germany
Corresponding author: K. Burmeister (kburmeister@geomar.de)

Foltz, G. R., and M. J. McPhaden (2010a), Abrupt equatorial wave-induced cooling of the Atlantic cold tongue in 2009, Geophys. Res. Lett., 37 (September), 1–5, doi: 10.1029/2010GL045522.
Richter, I., S. K. Behera, Y. Masumoto, B. Taguchi, H. Sasaki, and T. Yamagata (2013), Multiple causes of interannual sea surface temperature variability in the equatorial Atlantic Ocean, Nat. Geosci., 6 (1), 43–47, doi:10.1038/ngeo1660.

Deutsche Forschungsgemeinschaft
Kiel University
Christian-Albrechts-Universität zu Kiel