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

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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

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 (southeasterlies) 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

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 Z₂₀ (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

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 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


NOT applicable to the 2009 cold event

Applicable to the 2009 cold event

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

2009 anomalies of (a,b) AVISO SLA and (c,d) Argo Z₂₀ with respect to the mean seasonal cycle (2005 to 2012), propagation speed of negative amplitudes (black lines).