Indian Ocean cooling events: large-scale conditions and coupling

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• What drives intraseasonal SST variability in thermocline ridge?
• What is its relationship to large-scale ocean conditions?
• What is its connection to variations in atmospheric convection?
Subseasonal SSTA Variability

- Intraseasonal SST variability comparable to interannual variability.
- Variability seasonally dependent.
- Associated with atmospheric convection in both seasons/hemispheres.

Thermocline Ridge and Convection

Thermocline Ridge Index (TRI): SSTA (50°E-70°E, 12.5°S-2.5°S)

Concontour: Low OLR (atmospheric convection)

Mooring-based analysis suggests SST variability controlled by surface heat fluxes.

From (Vialard et al. 2008, GRL)
Character of Cooling Events
Cooling event definition:

SSTA – SSTA(30) ≤ −2.5σ
Mechanisms for Observed TRI Cooling

**Surface heat budget:**

\[
\frac{\partial (SST)}{\partial t} = \frac{Q_{sfc}}{\rho c_p H} - V \cdot \nabla (SST) + DIFF
\]

Initial approach:

\[
Q_{anom} = \rho c_p H \frac{\partial (SST_{anom})}{\partial t}
\]

**Right:** Composite of \( Q_{anom} \) and \( HF_{anom} \) for OBS (NCEP RA-2 fluxes and TMI SST data).

- Mixed layer depth \( H = 22m \) from Boyer Climatology (Boyer et. al. 2004) for DJF.

\( Q_{anom} \) does not match \( HF_{anom} \).
TRI Cooling Events in CGCM

**CM2.1 – 1990 control run (Delworth et. al. 2006)** Composite for 50 years daily data. **Atm**: $2^\circ \times 2.5^\circ$, 24 levels **ocean**: $1^\circ \times 1^\circ \,(1/3^\circ \,\text{at equator})$, 50 levels.

GFDL CM 2.4
Hi-Res Coupled Model

Sea Surface Temperature (°C)

Delworth et al (2009, in prep)
CGCM Cooling Event Magnitude Comparable to Observed
Both CGCMs indicate oceanic processes $O(1)$ to cooling events.

Look at less extreme intraseasonal swings

- More symmetric, and primarily due to heat fluxes.
- But not source of large negative skewness in IS-SST. (not “Cooling Events”)

![Graphs showing heat fluxes for different scenarios: OBS, PWP, CM2.1, CM2.4 with time (days) on the x-axis and heat flux (W/m²) on the y-axis.](image-url)
Ocean changes and Cooling Events
50°E-70°E changes - Quickscat forced OGCM

0.25°x0.25° MOM-2 used in Vecchi and Harrison (2006, JC)

Composite T' Day(0)

Composite w' Day(-5) (m/day)

Average circulation Day(-10to0)
Interannual T’Cline Ridge Variations and SST

Xie et. al. (2002):

Figure 14: a) Annual-mean depth of the 20°C isotherm (contours in m) and correlation of its interannual anomalies with local SST (color shades) (from Xie et al., 2002).
Subsurface temperature preconditioning in CGCM

Lloyd and Vecchi (2009, JC, Submitted)
CM2.1 Oceanic Changes

Lloyd and Vecchi (2009, JC)
Cooling Events Preconditioned by Cool/Shallow Thermocline Ridge

GFDL CM2.1

GFDL CM2.4
Cooling Events Associated with La Niña-like SSTA 5-12 weeks before

a) CM2.1 preconditioning

b) CM2.4 preconditioning
Moderate Intraseasonal SST Swings not preconditioned by ocean

GFDL CM2.1: 1.5-2.5std

a) CM2.1: Plus 30-day Temp anom (k) and current anom (m.s⁻¹)

GFDL CM2.4: 1.5-2.5std

c) CM2.4: Plus 30-day Temp anom (k) and current anom (m.s⁻¹)
Relationship to Convection
Cooling events are associated with a strong eastward convective perturbation. Phase speed matches MJO (~ 5 m/s).
Does strong SST variability feed back to the atmosphere and influence the MJO?

OLR Composite: based on TRI precipitation.

Below: Composite SST anom (K) for cooling events and precip events

Zhang and Anderson (2003)

Does strong SST variability feed back to the atmosphere and influence the MJO?
TRI cooling events and rainfall in CM2.1

Composite CGCM TRI Cooling Event (Control): 10°S-10°N Intraseasonal Precipitation Anomaly (mm/day)
TRI cooling events and rainfall in CGCM - data override in southern Indian Ocean (12°S-3°N)

Composite CGCM TRI Cooling Event (SC IO Override SST): 10°S-10°N In traseasonal Precipitation Anomaly
Summary

Thermocline ridge cooling events:

- Oceanic processes important to cooling in model:
  - appear important for average observed (need more data).

- CGCM able to produce strong SST changes
  - Intraseasonal cooling events preconditioned by oceanic conditions.
  - In CGCM cooling events seem important to e-ward propagating rainfall.

- Implications for Annual Cycle/MJO/Interannual Variability?

Lloyd and Vecchi (2009): “Submonthly Indian Ocean cooling events and their relation to large-scale conditions”, Submitted to J. Climate