Indian Ocean cooling events: large-scale conditions and coupling

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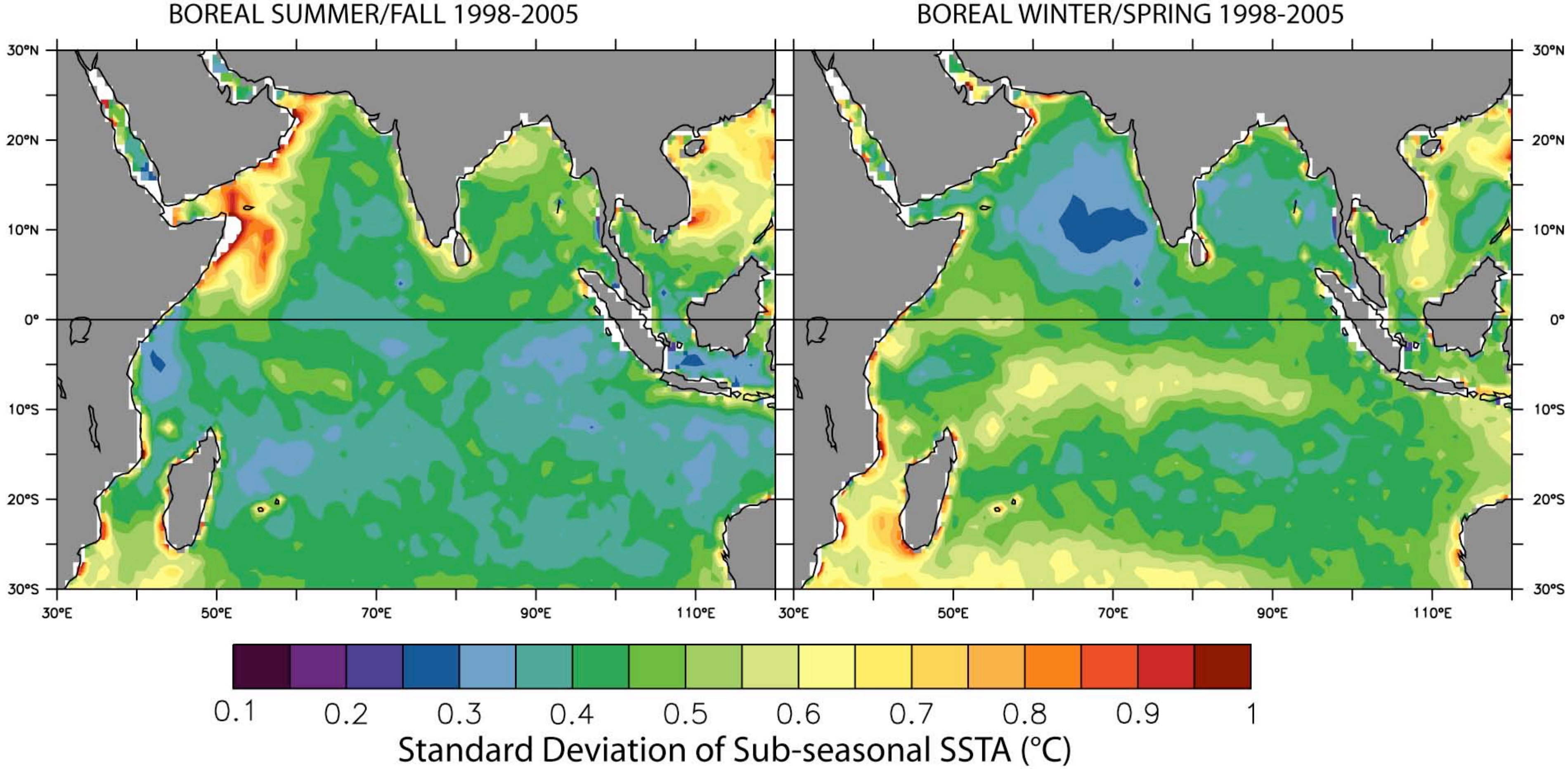
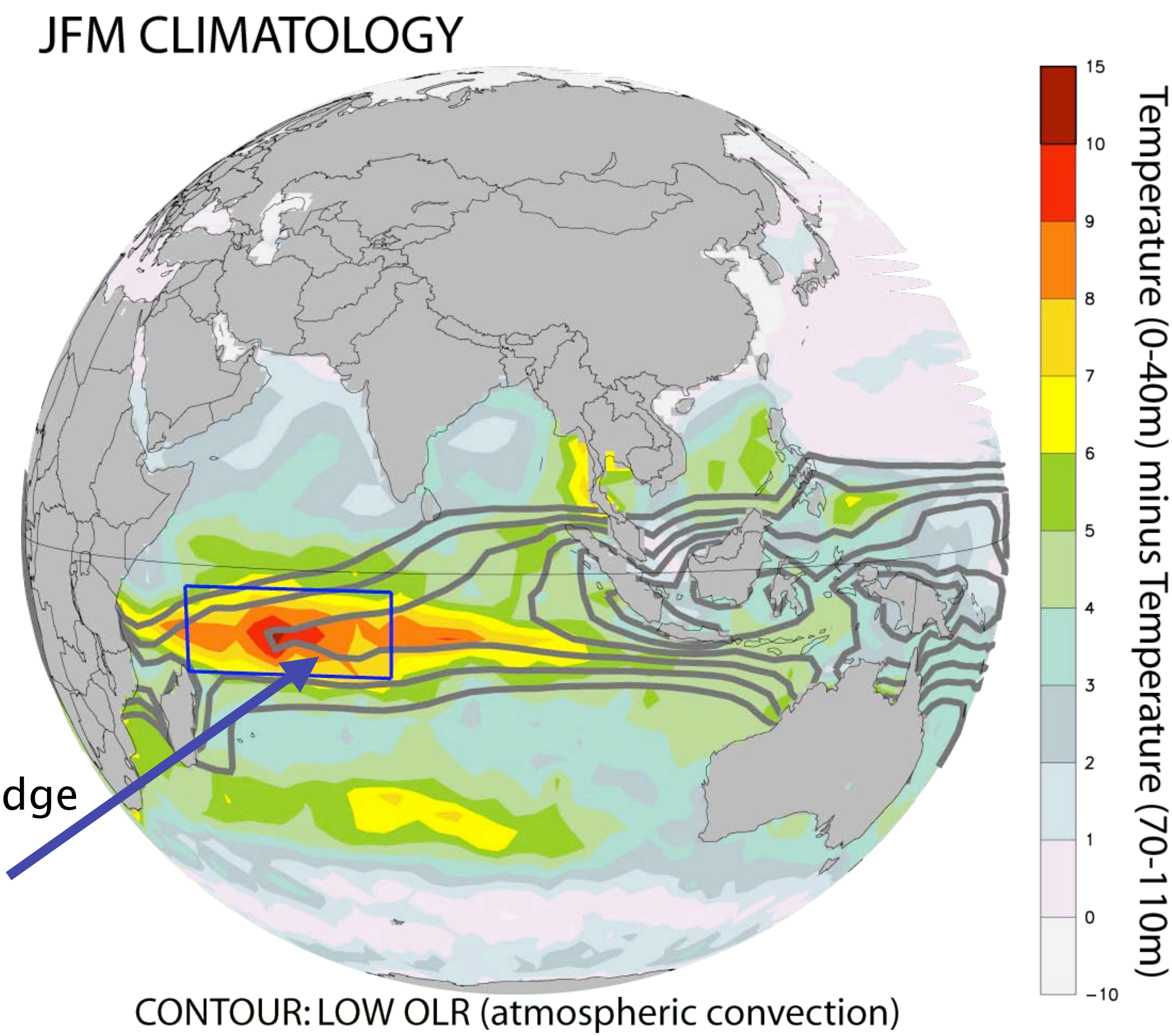
- What drives intraseasonal SST variability in thermocline ridge?
- What is its relationship to large-scale ocean conditions?
- What is its connection to variations in atmospheric convection?

Subseasonal SSTA Variability



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

  e.g. Harrison and Vecchi (2001), Sengupta et al (2002), Vecchi and Harrison (2002), Fu et al (2003), Duvel et al (2004), Wang et al (2005), Saji et al (2006) etc.

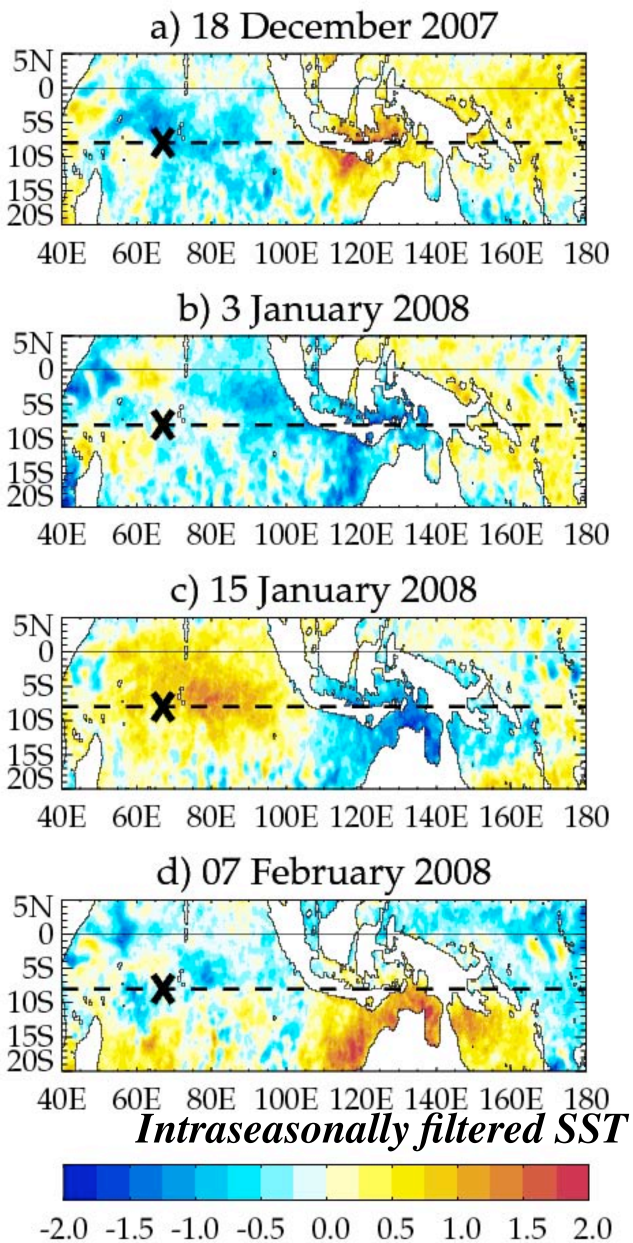


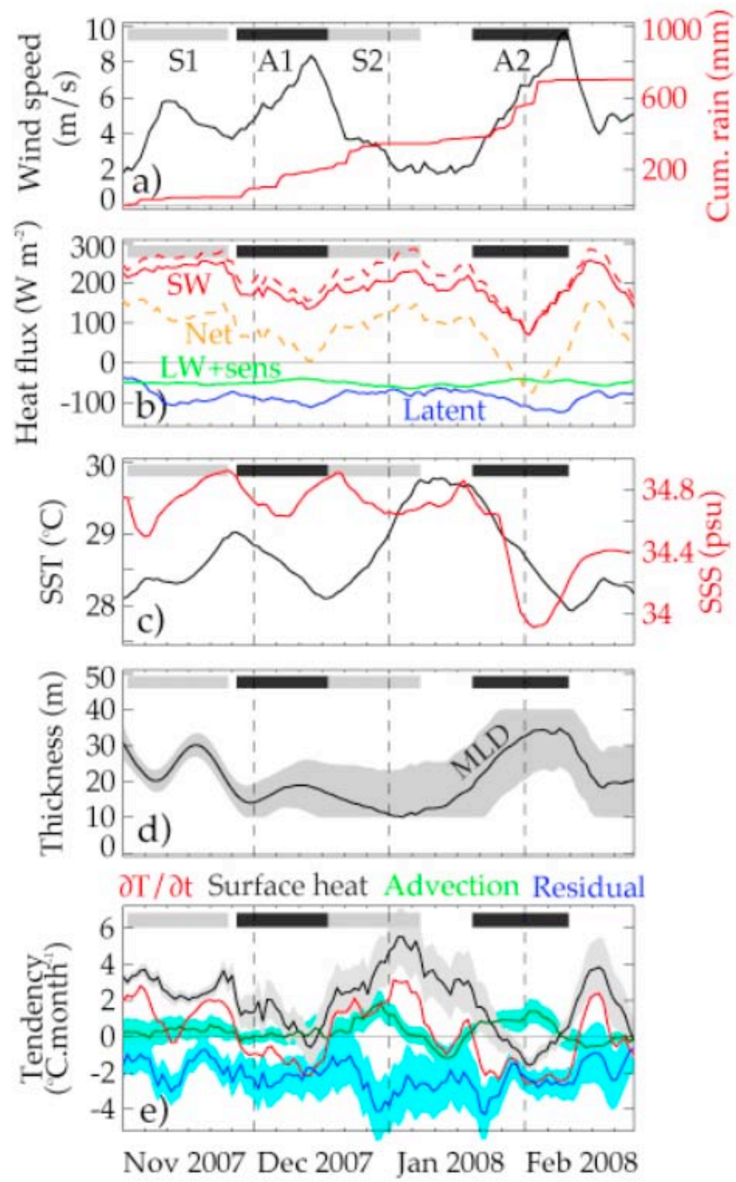
Thermocline Ridge Index (TRI):

SSTA (50˚E-70˚, 12.5˚S-2.5˚S)

From Lloyd and Vecchi (2009, J. Clim. Sub)

SST signature of MJO in Thermocline Ridge





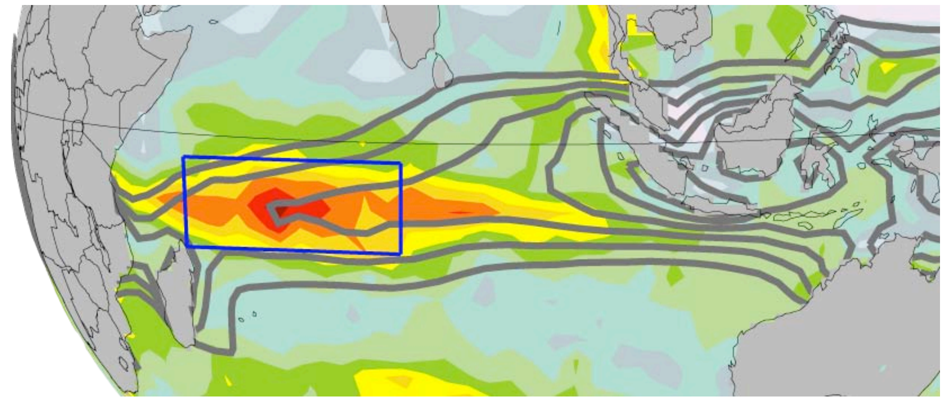
Mooring-based analysis suggests SST variability controlled by surface heat fluxes.

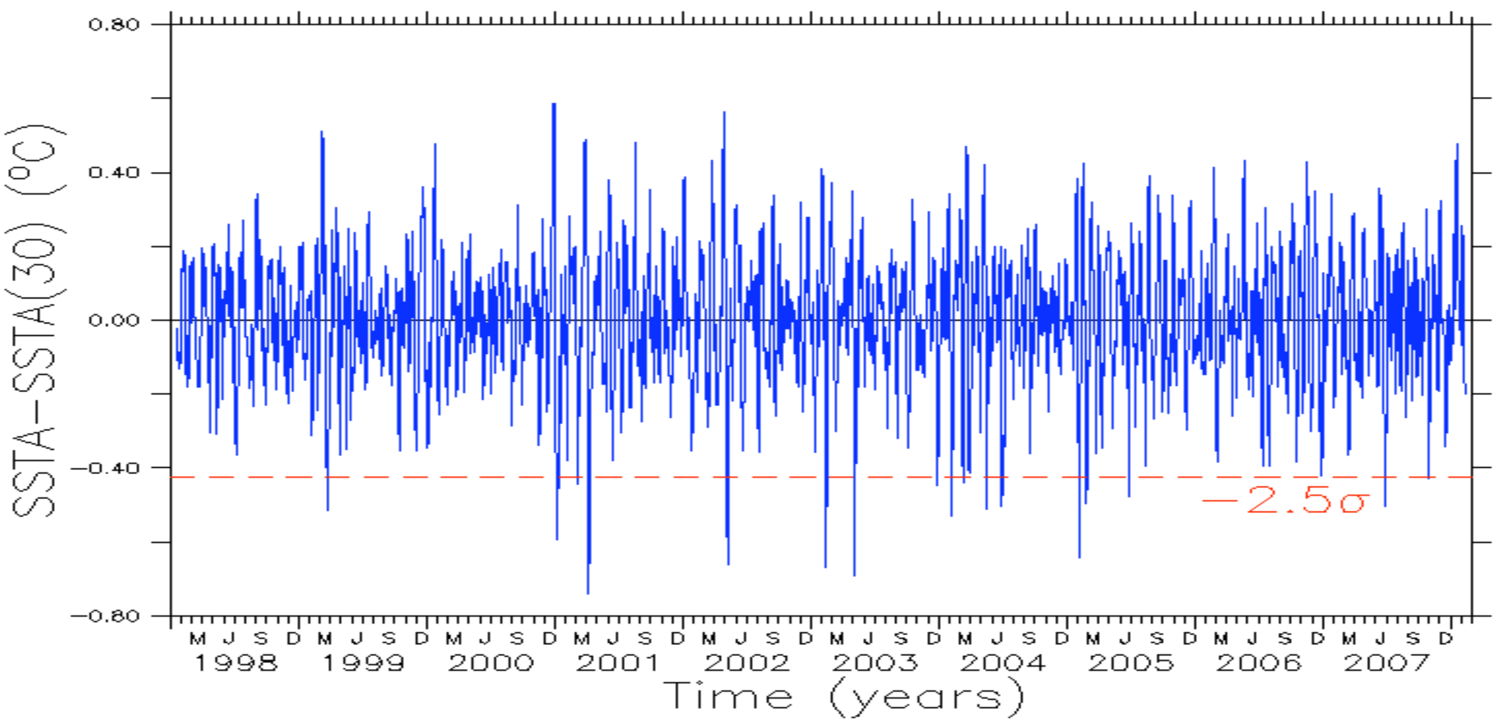
From (Vialard et al. 2008, GRL)

Character of Cooling Events

Cooling event definition

Compute sub-monthly TRI from TMI-SST.





Left: TMI SSTA – SSTA(30) for Region 1.

PDF has negative skew.

Cooling event definition: SSTA – SSTA(30) ≤ -2.5σ

Mechanisms for Observed TRI Cooling

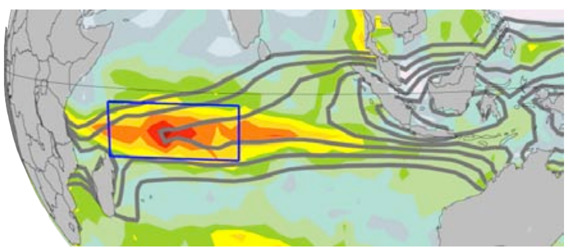
Surface heat budget: $$\frac{\partial(SST)}{\partial t} = \frac{Q_{sfc}}{\rho c_p H} - \underline{V} \cdot \underline{\nabla}(SST) + DIFF$$

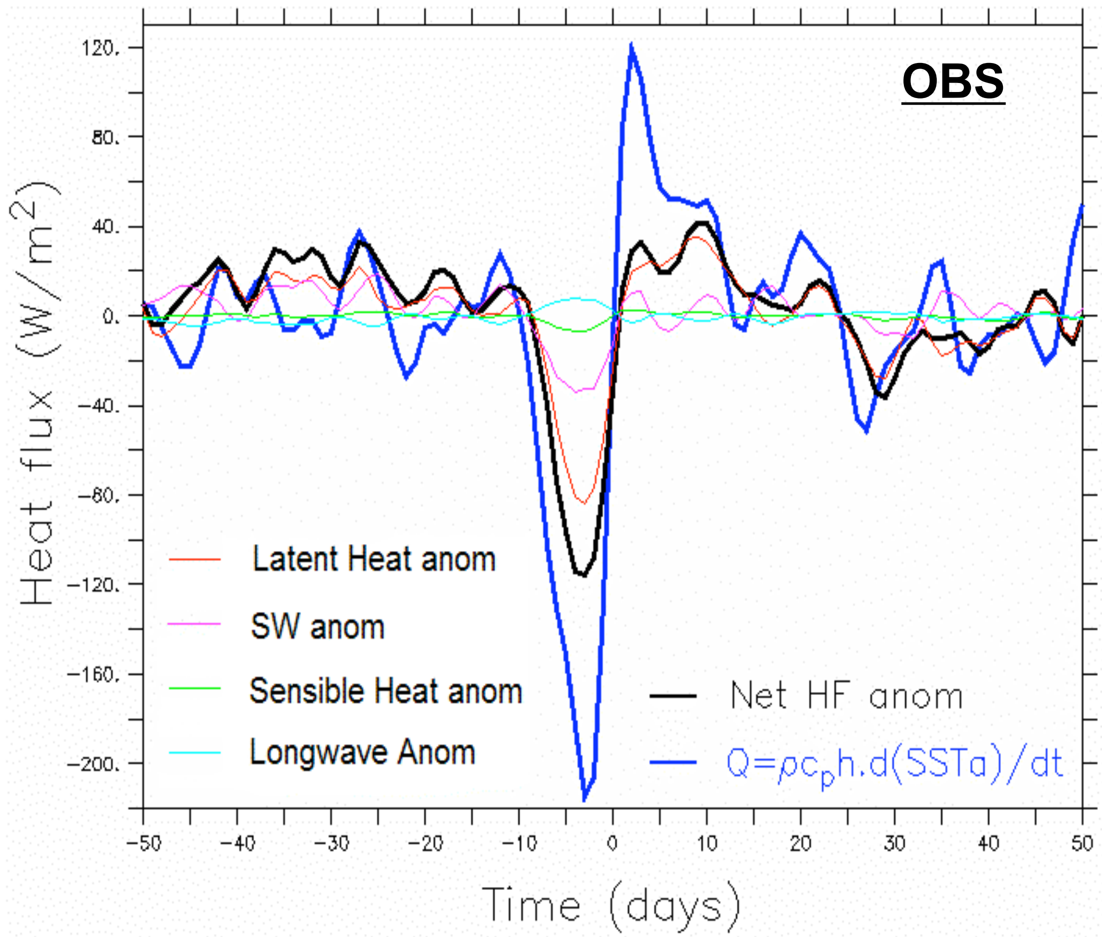
Initial approach:

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

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.

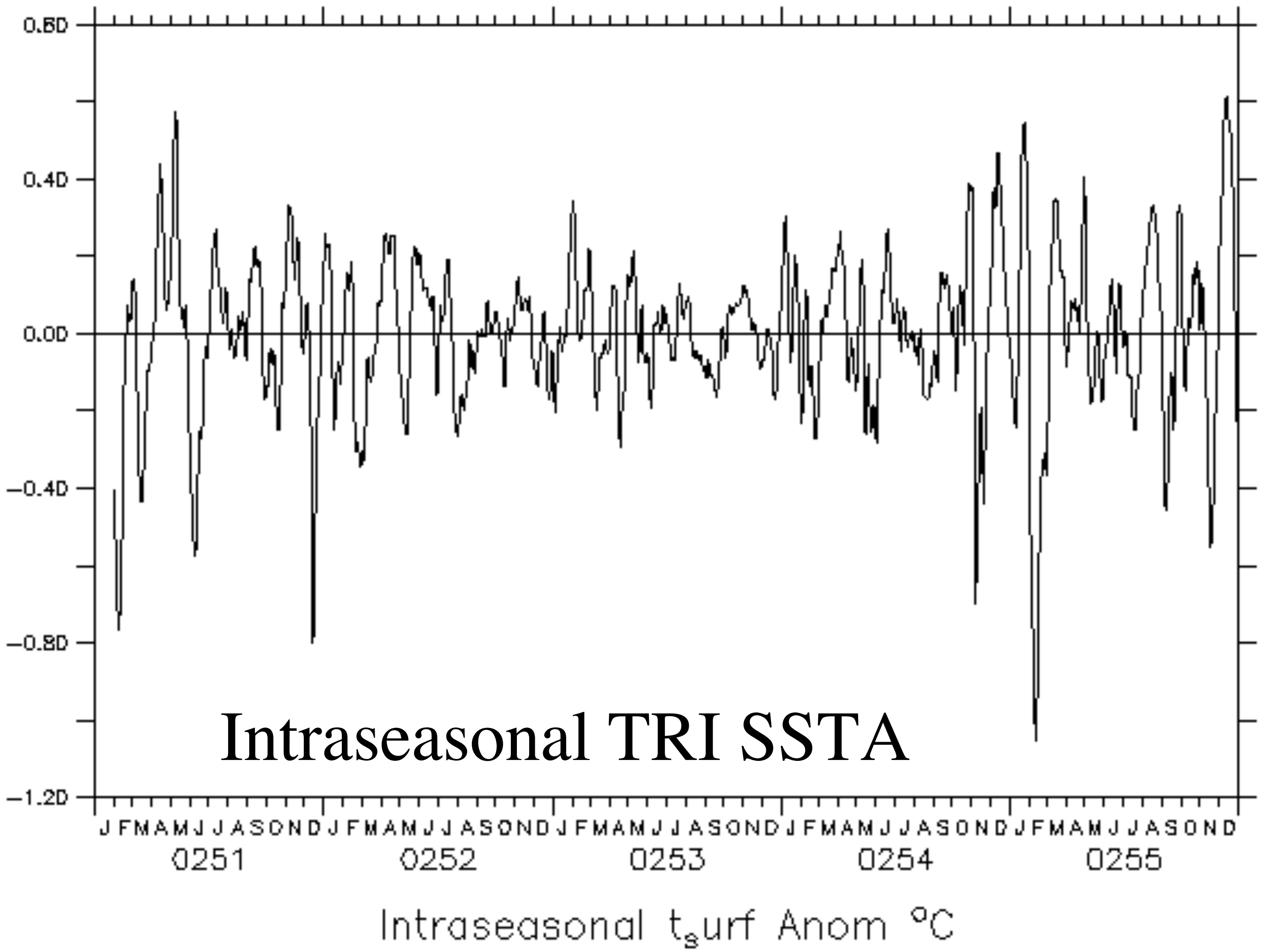




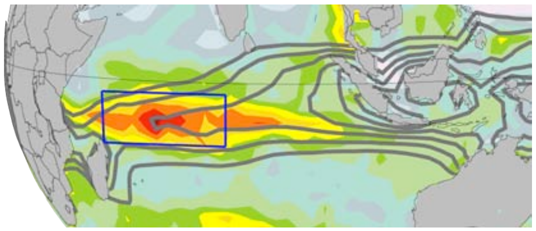
Q_{anom} does not match HF_{anom}.

TRI Cooling Events in CGCM

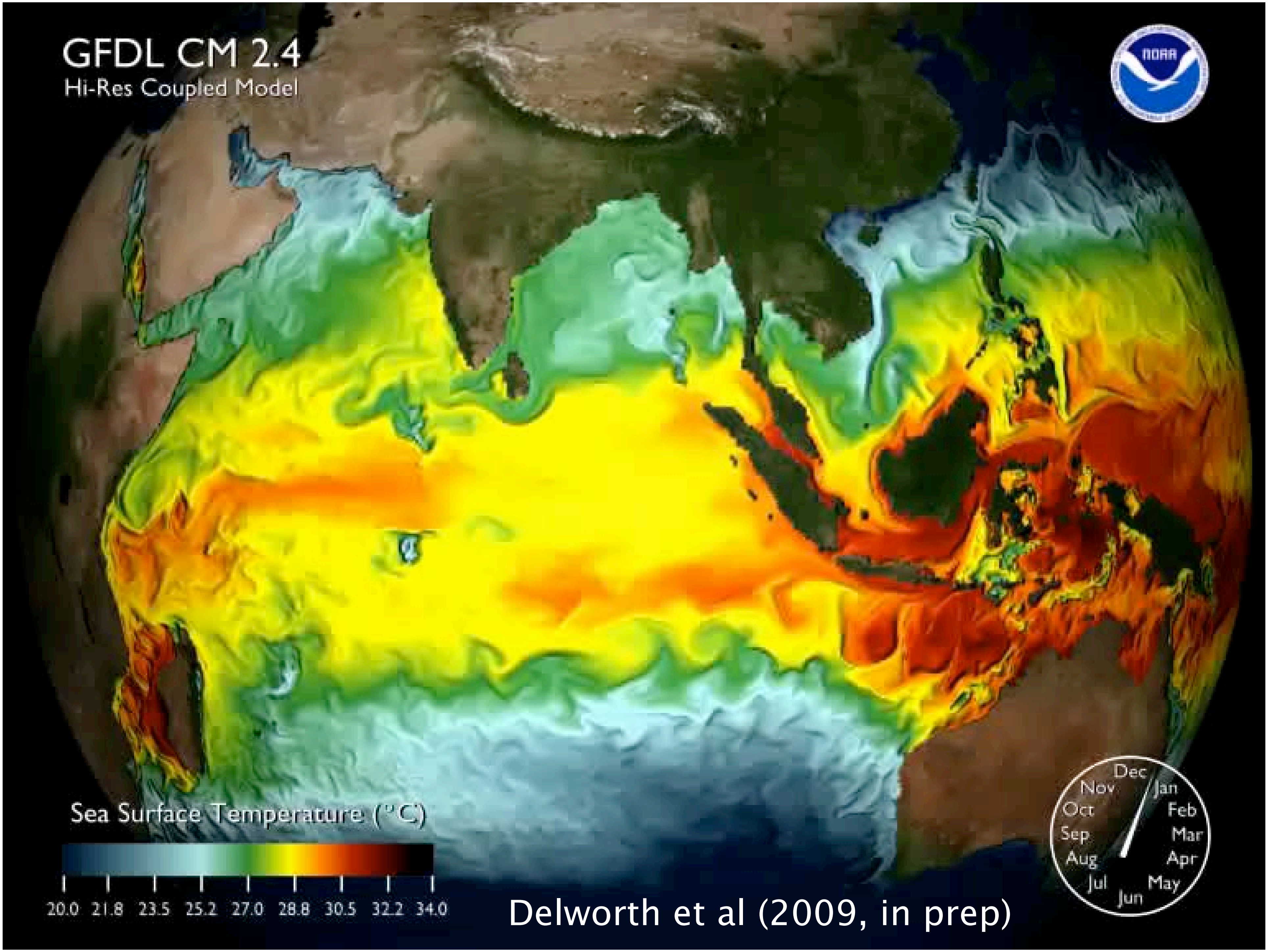
CM2.1 – 1990 control run (Delworth et. al. 2006) Composite for 50 years daily data. Atm: 2º x 2.5º, 24 levels ocean: 1º x 1º (1/3º at equator), 50 levels.



Averaged 12.5S-2.5S, 50E-70E

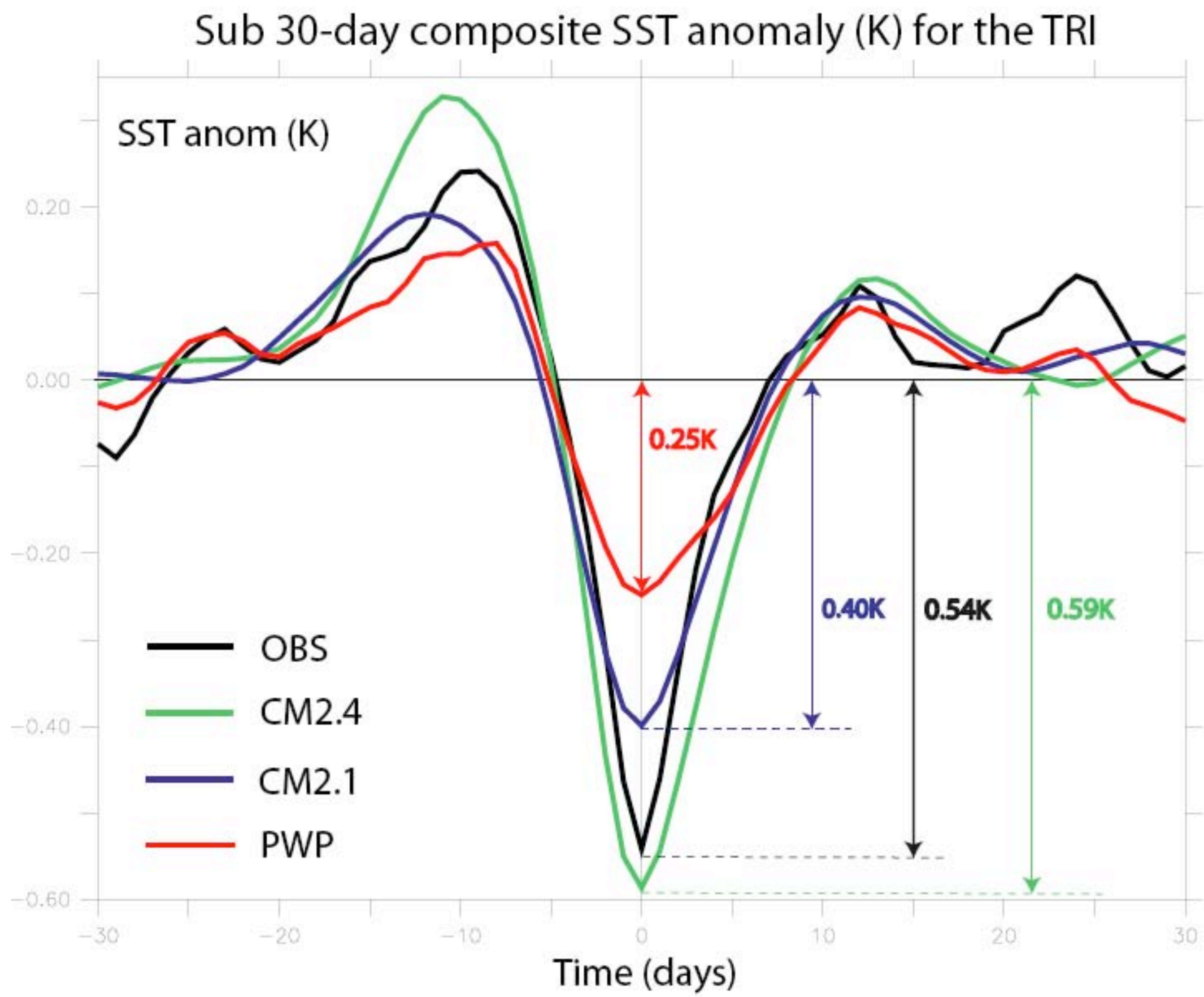


From Lloyd and Vecchi (2008) in prep.

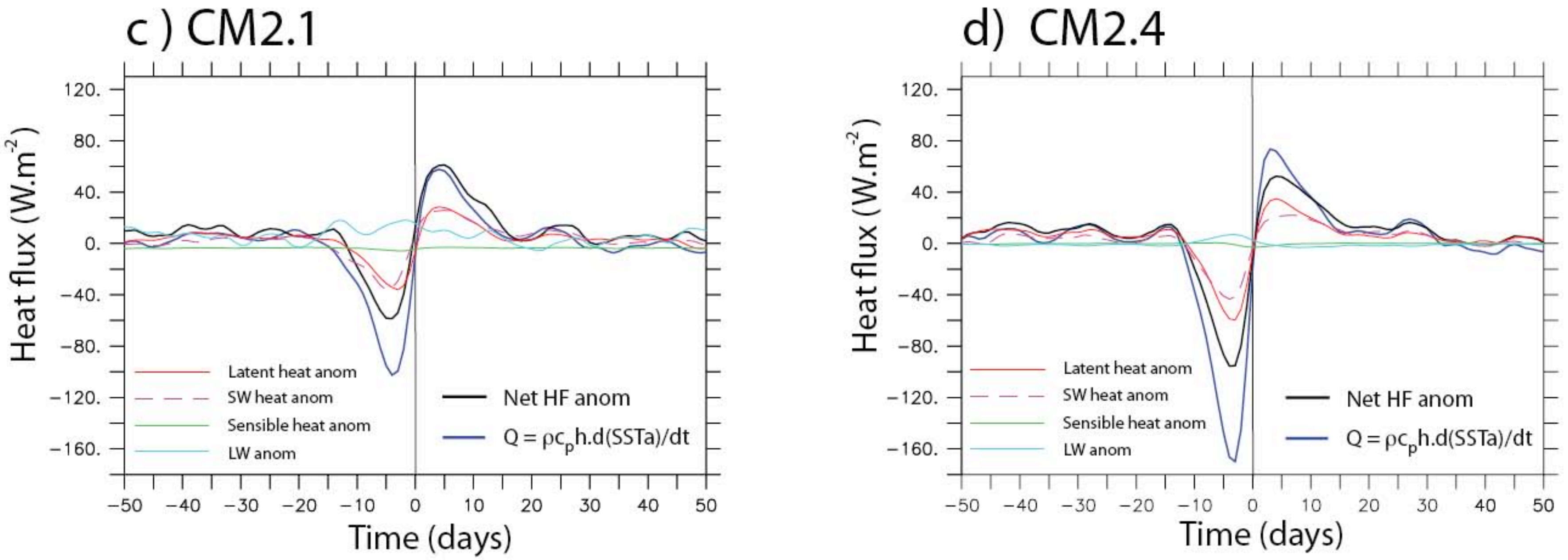


Delworth et al (2009, in prep)

CGCM Cooling Event Magnitude Comparable to Observed

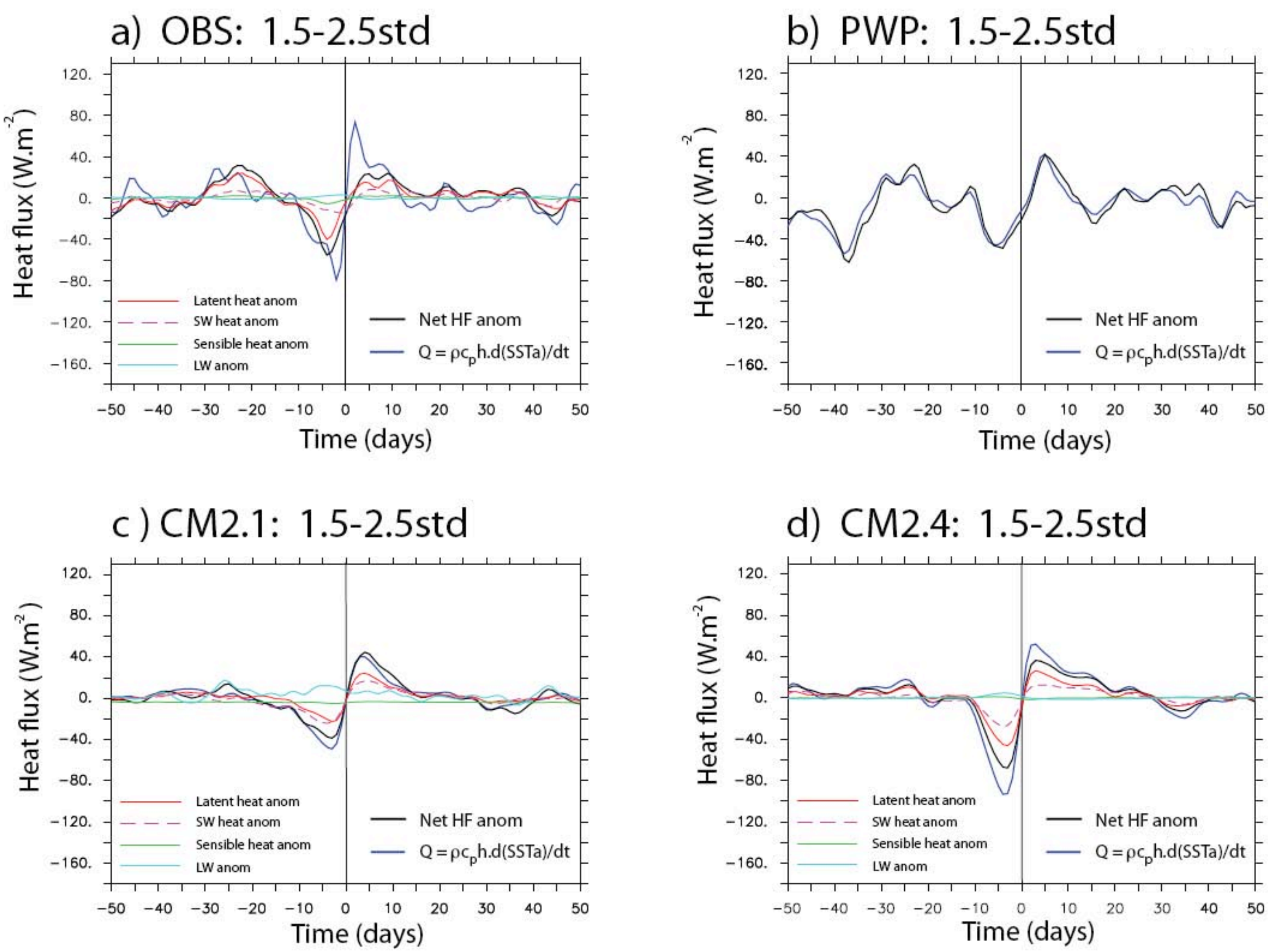


Cooling events in GFDL CGCMs



- Both CGCMs indicate oceanic processes O(1) to cooling events.
- Differs from results of Duvel et al (2004) and Vialard et al (2008) for particular events. Why?

Look at less extreme intraseasonal swings

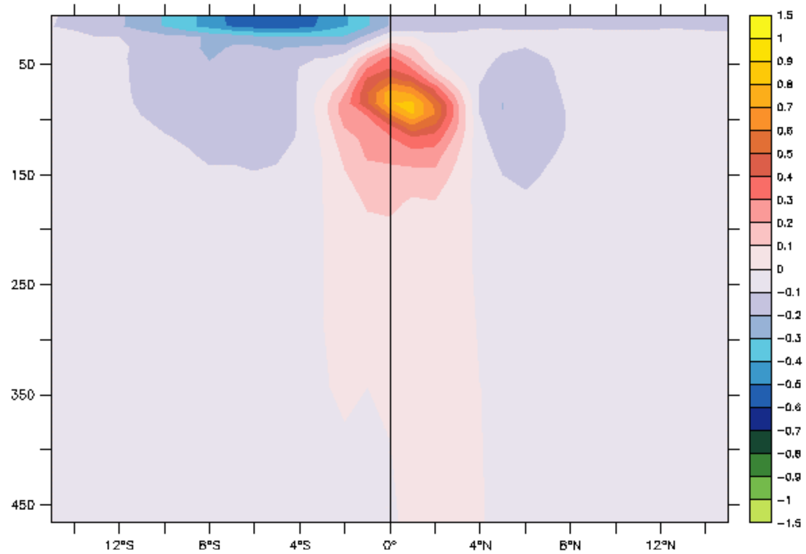


- More symmetric, and primarily due to heat fluxes.
- But not source of large negative skewness in IS-SST. (not “Cooling Events”)

Ocean changes and Cooling Events

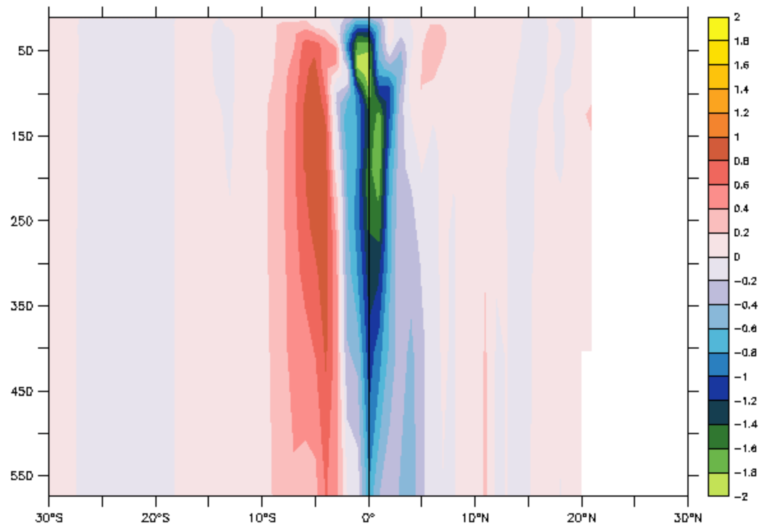
50˚E-70˚E changes - Quickscat forced OGCM

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

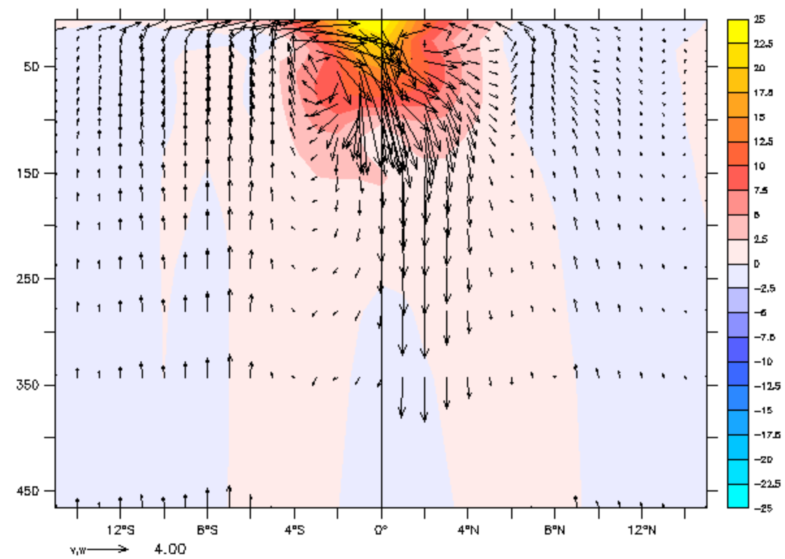


Composite T’ Day(0)

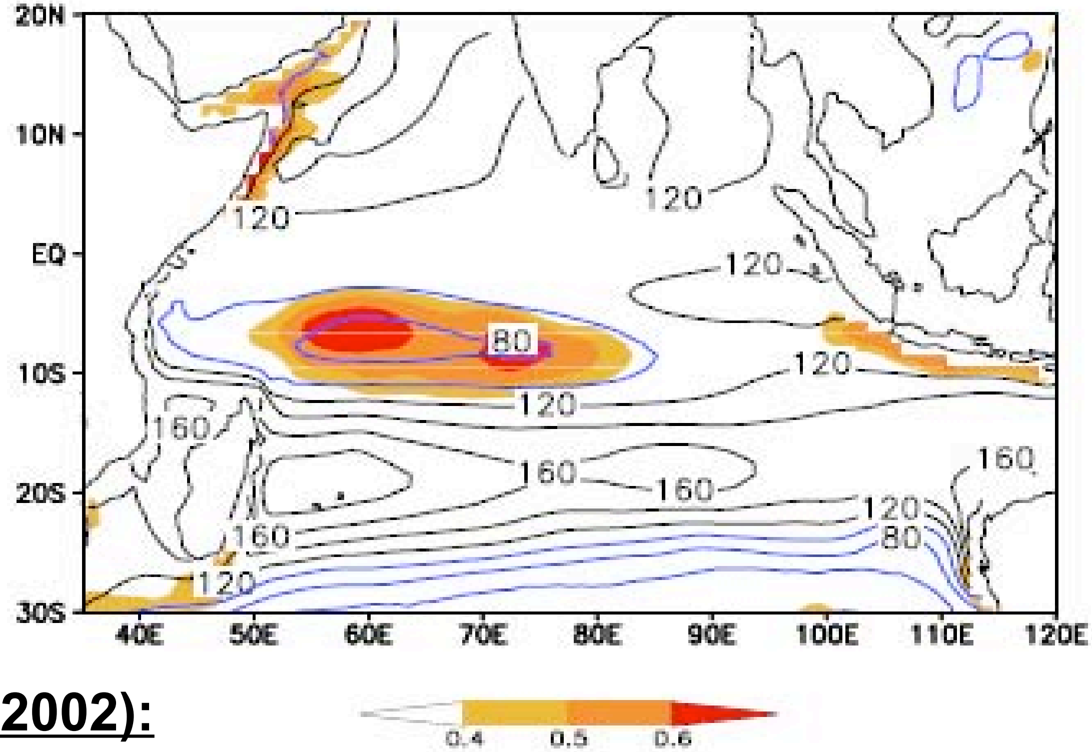
Composite w’ Day(-5) (m/day)



Average circulation Day(-10to0)



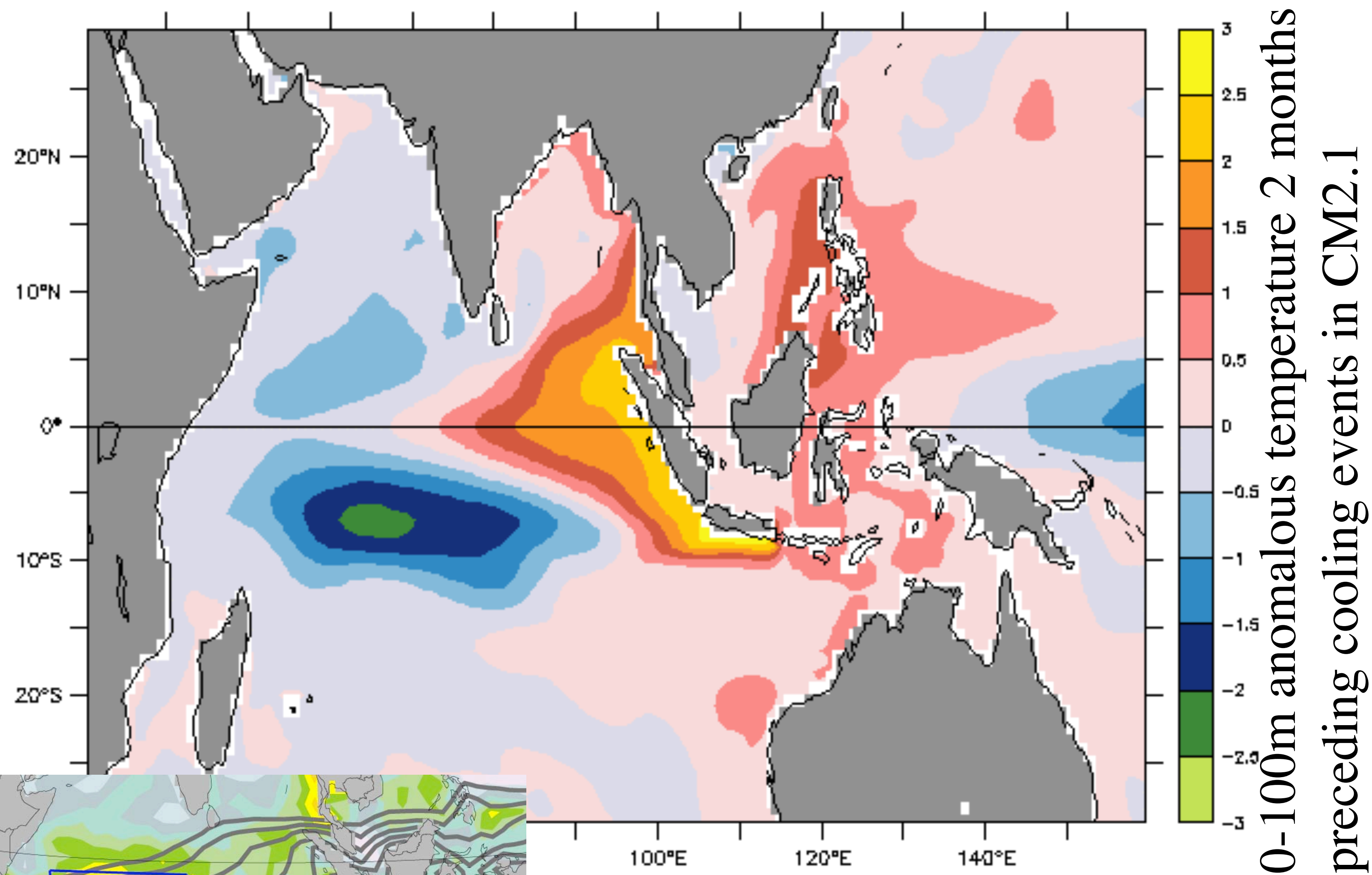
Interannual T'Cline Ridge Variations and SST

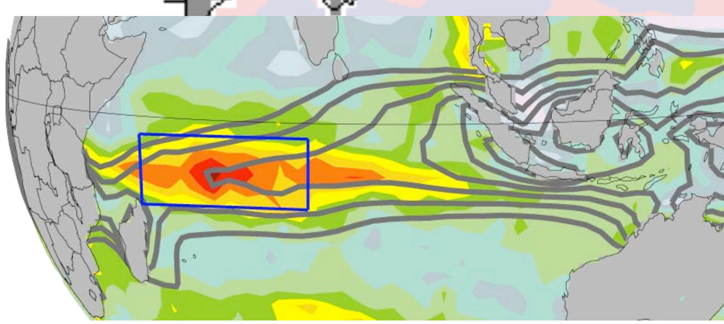


Xie et. al. (2002):

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).

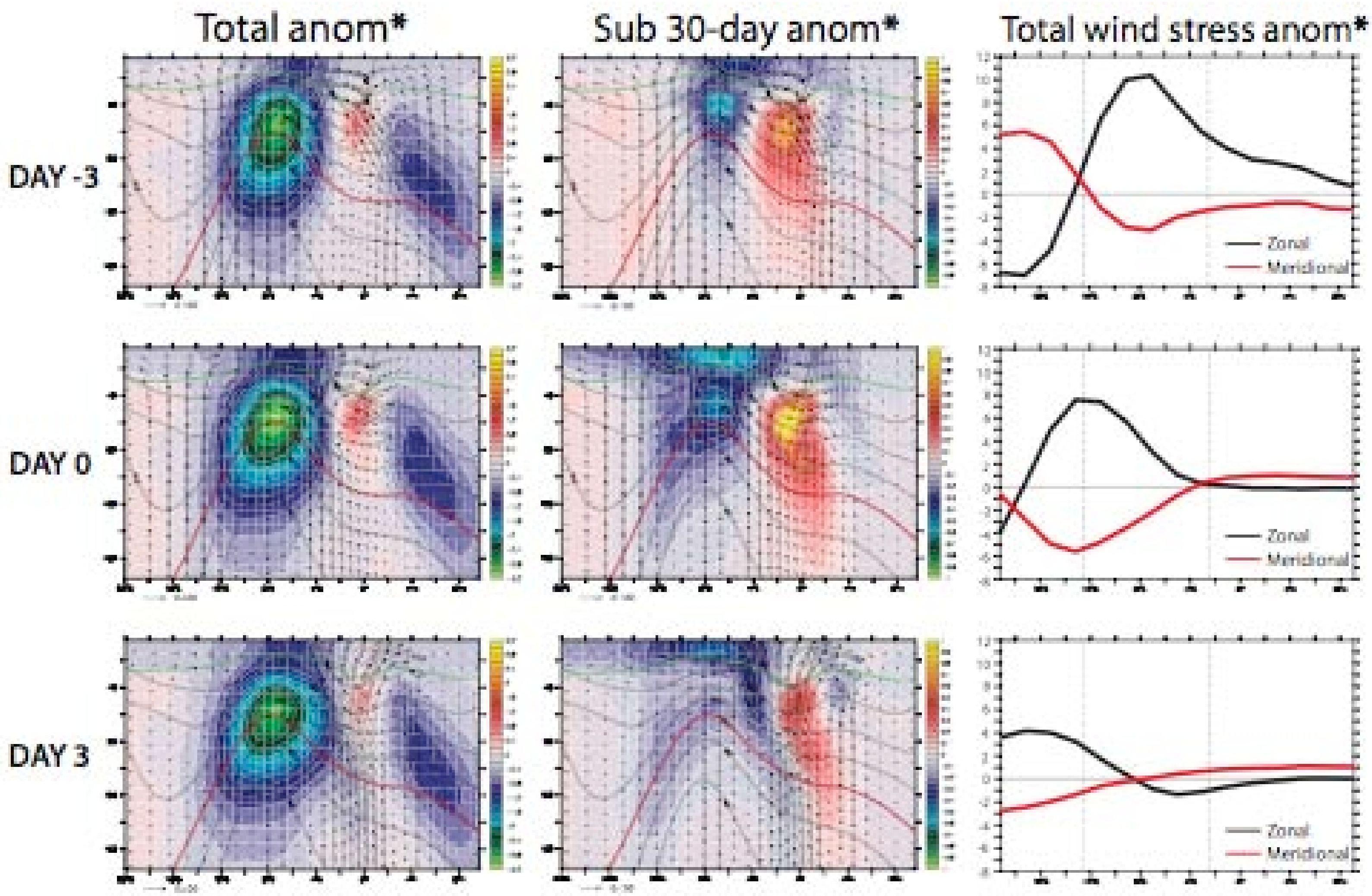
Subsurface temperature preconditioning in CGCM





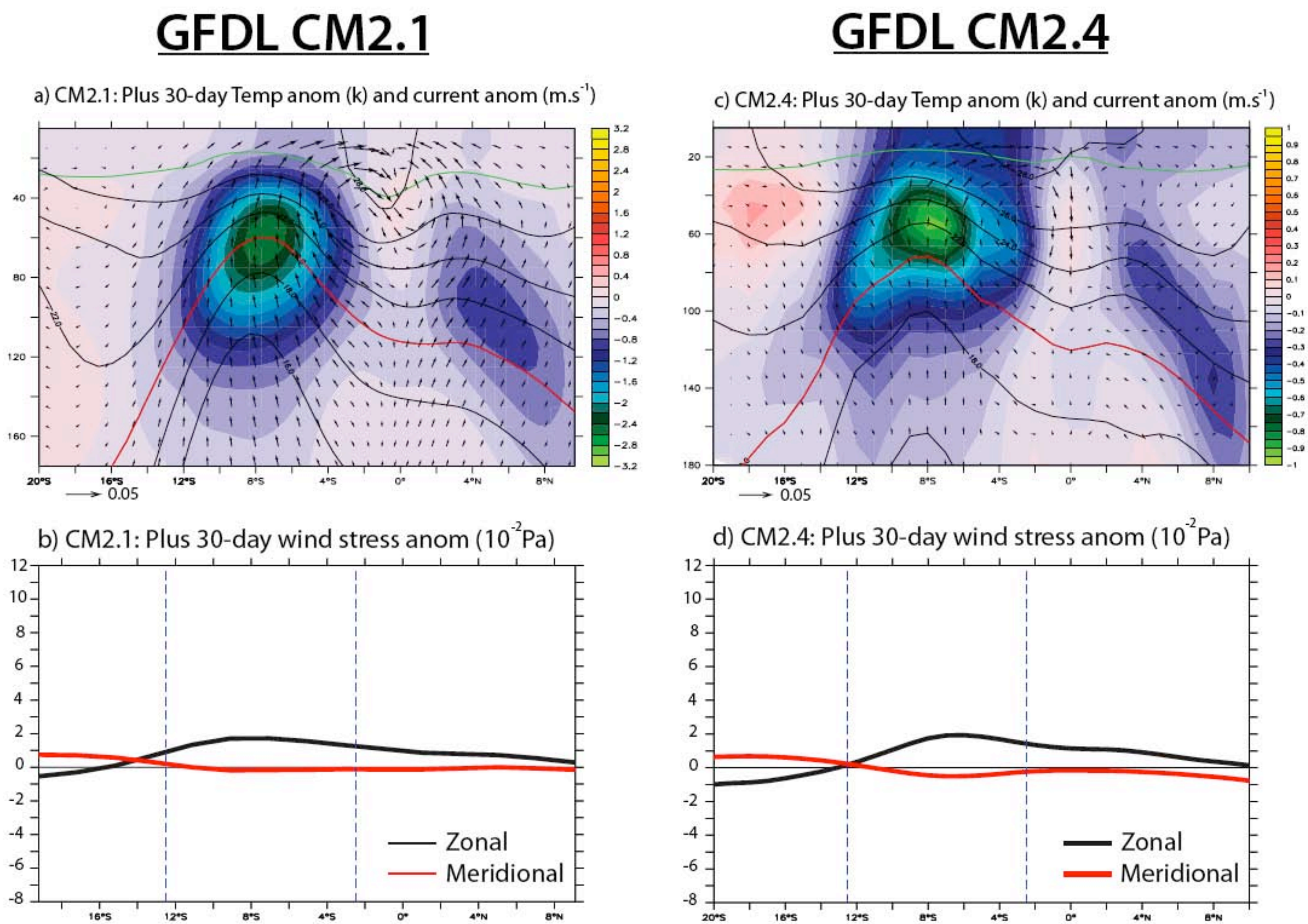
Lloyd and Vecchi (2009, JC, Submitted)

CM2.1 Oceanic Changes

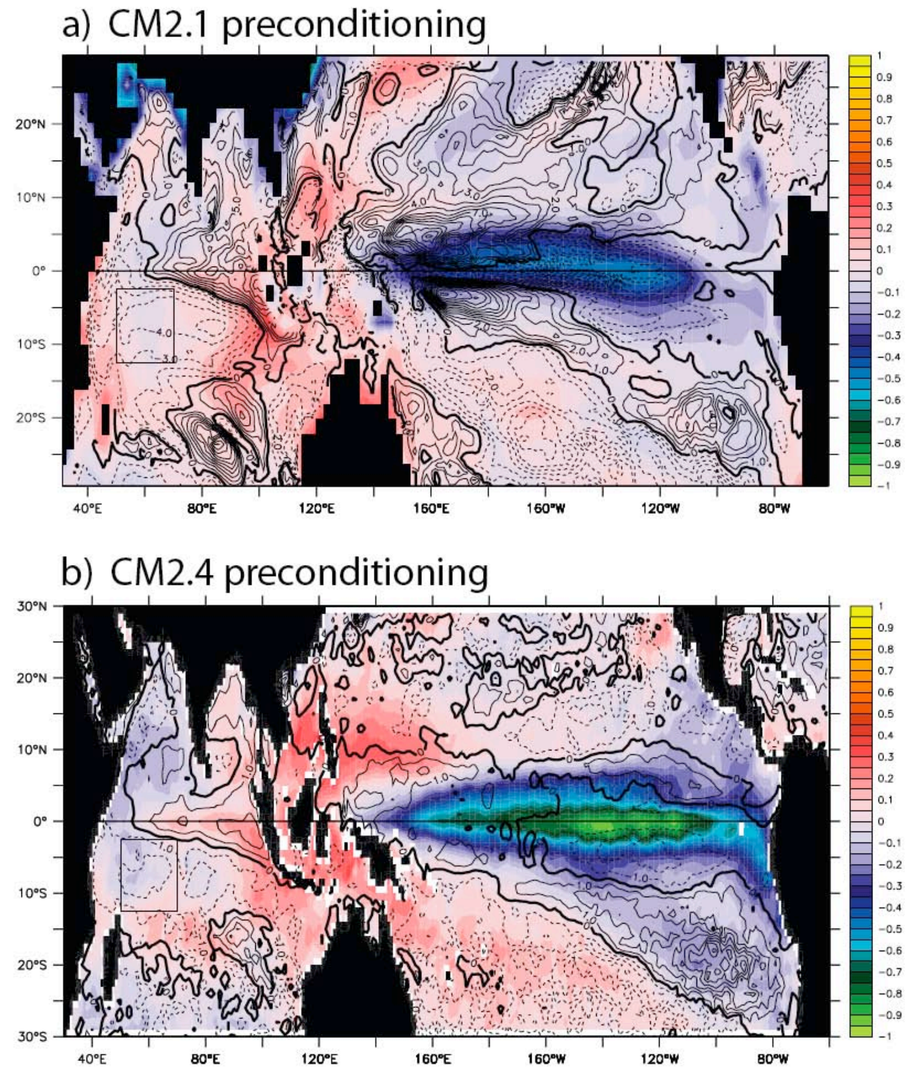


Lloyd and Vecchi (2009, JC)

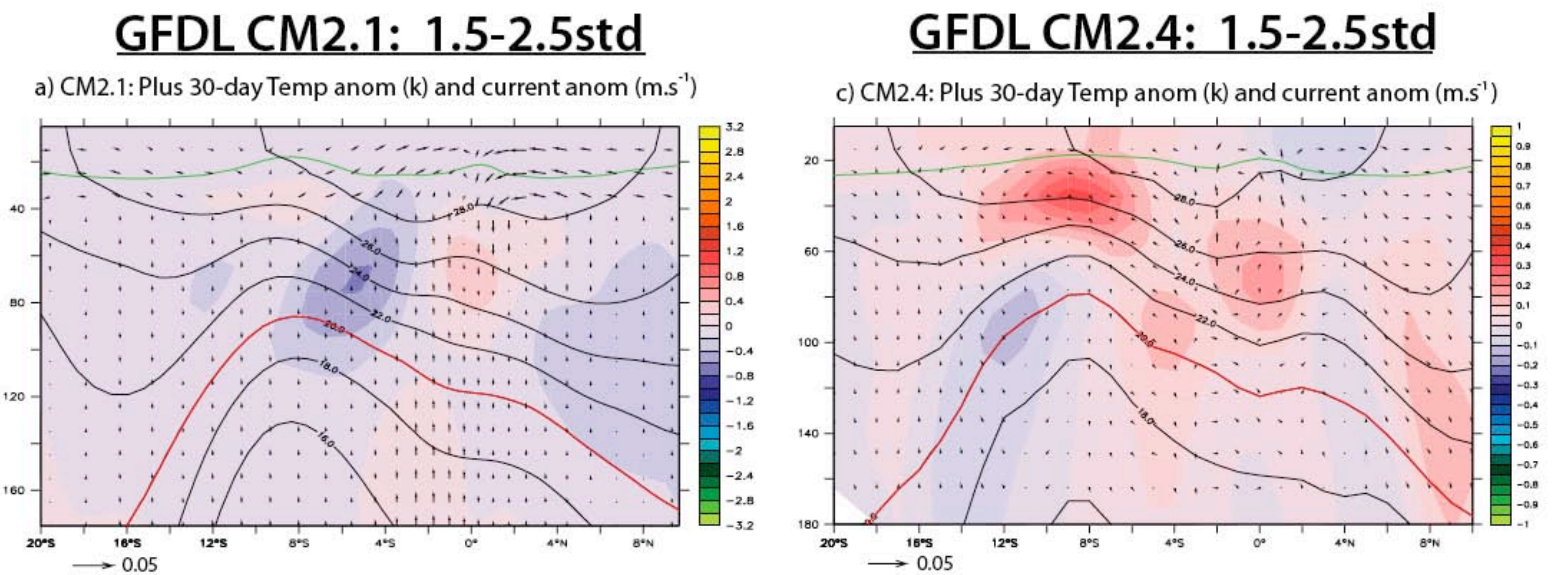
Cooling Events Preconditioned by Cool/Shallow Thermocline Ridge



Cooling Events Associated with La Niña-like SSTA 5-12 weeks before



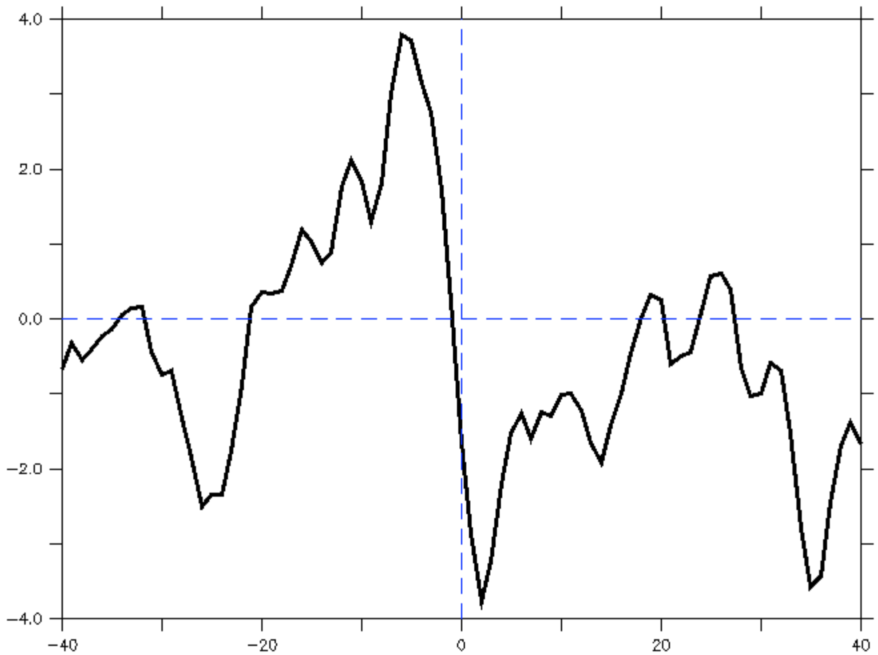
Moderate Intraseasonal SST Swings not preconditioned by ocean



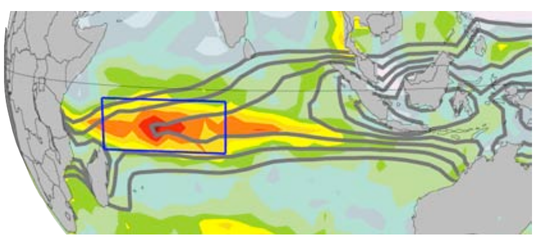
Relationship to Convection

TRI Cooling and Convection

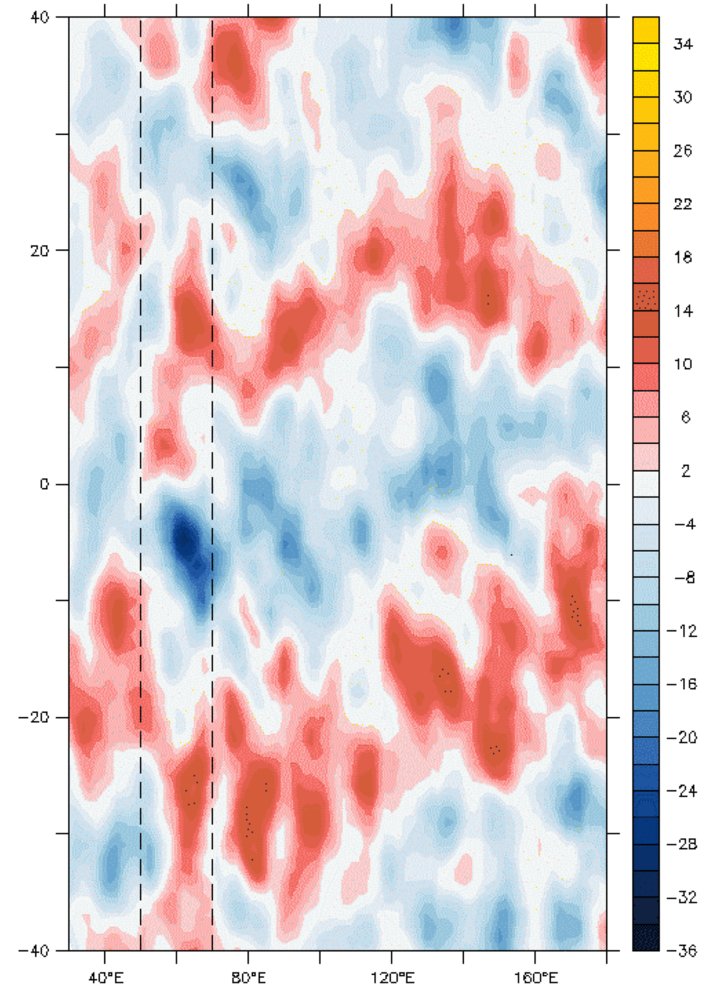
Below: composite NCEP RA2 precip anom (mm/day)



Precip anom (mm/day) vs. Time (days) for cooling event composite



OLR Composite based on TRI

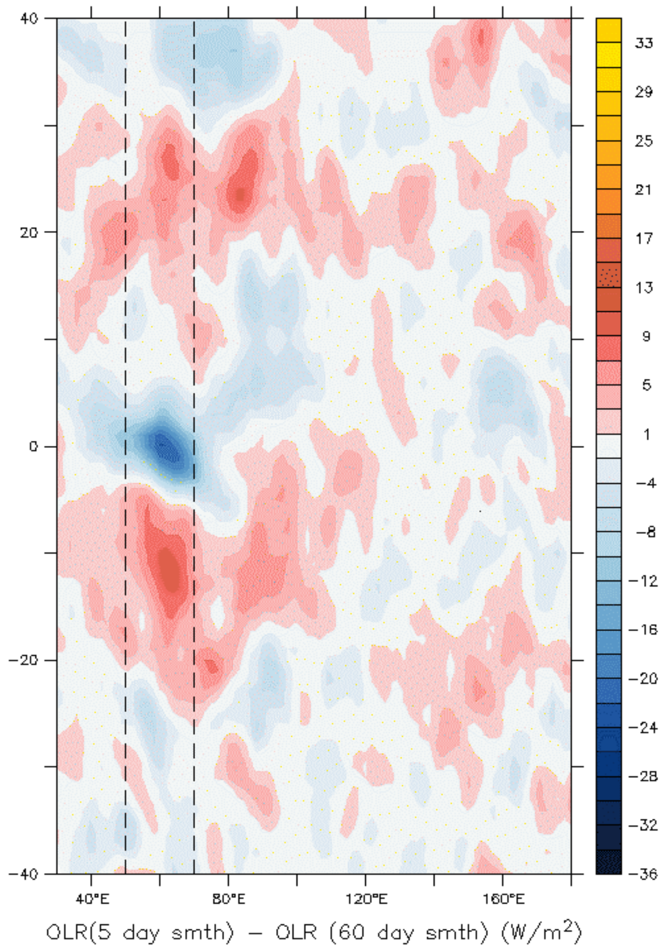


OLR(5 day smth) − OLR (60 day smth) (W/m^2)

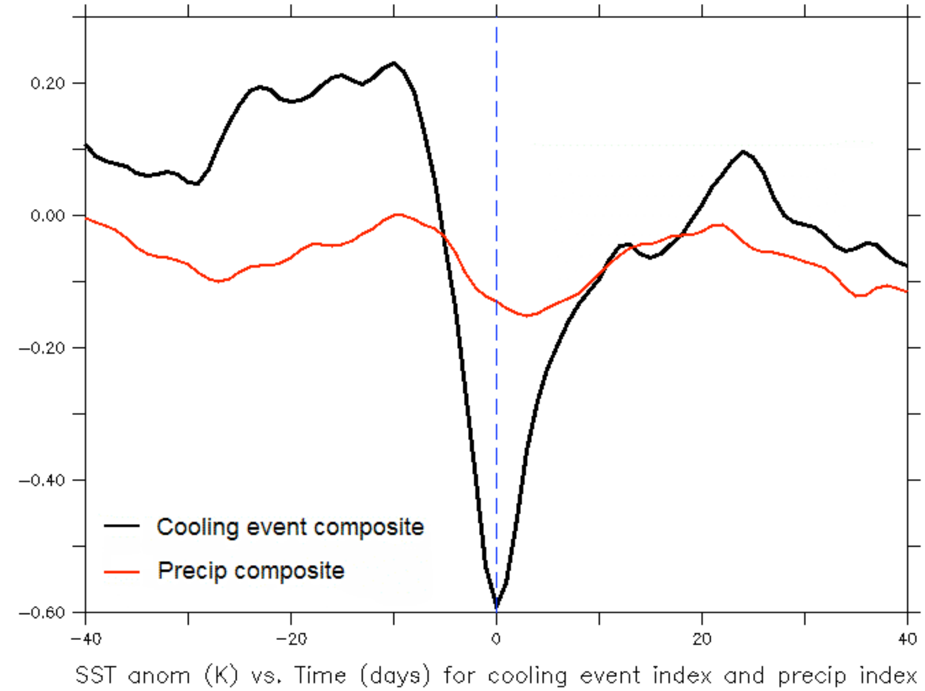
Cooling events are associated with a strong eastward convective perturbation. Phase speed matches MJO (~ 5 m/s).

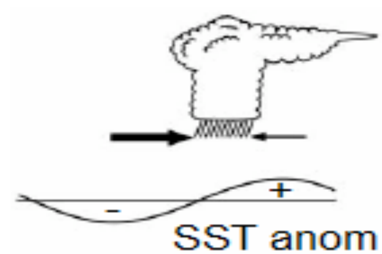
Precipitation Index Composites

OLR Composite: based on TRI precipitation.



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

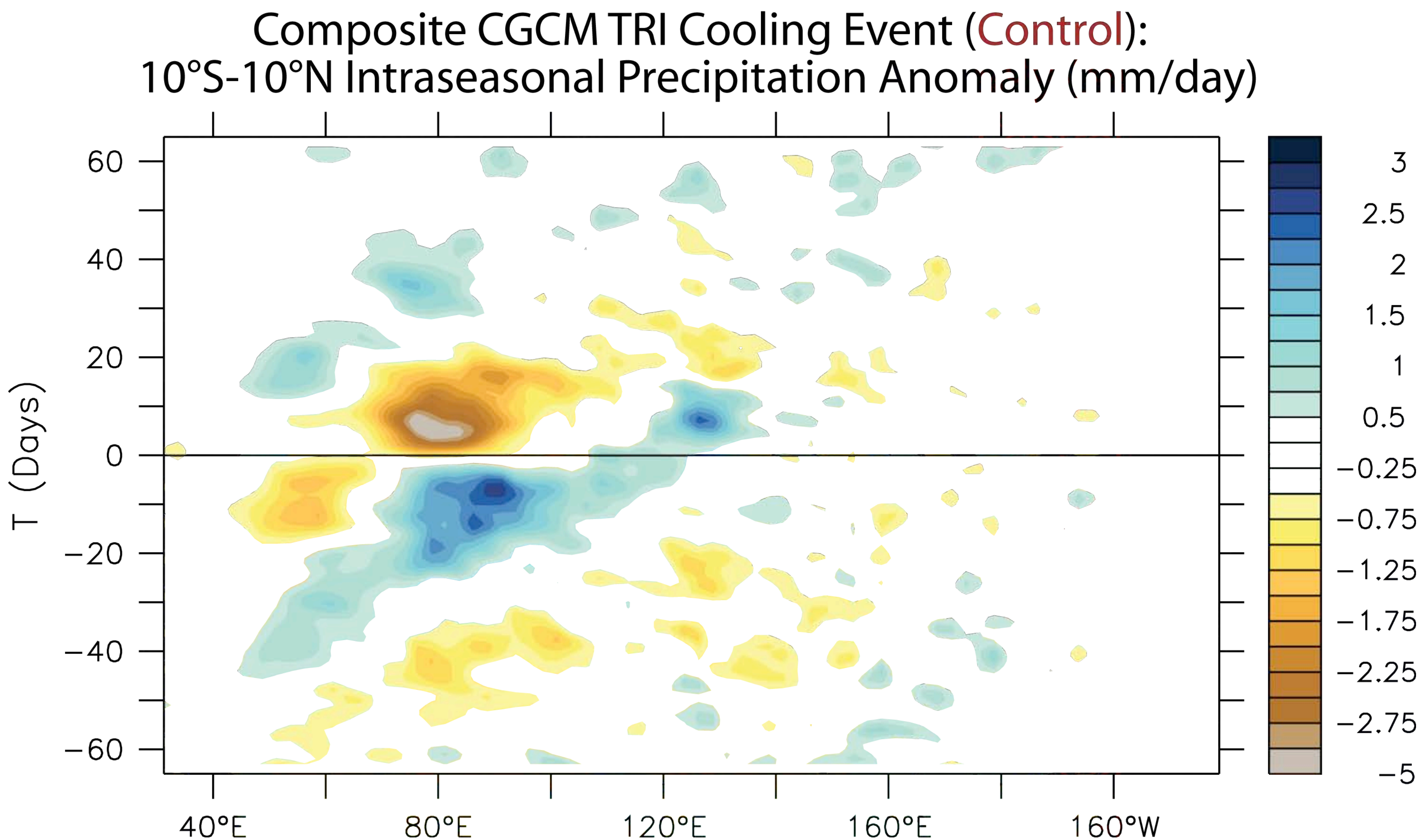




Zhang and Anderson (2003)

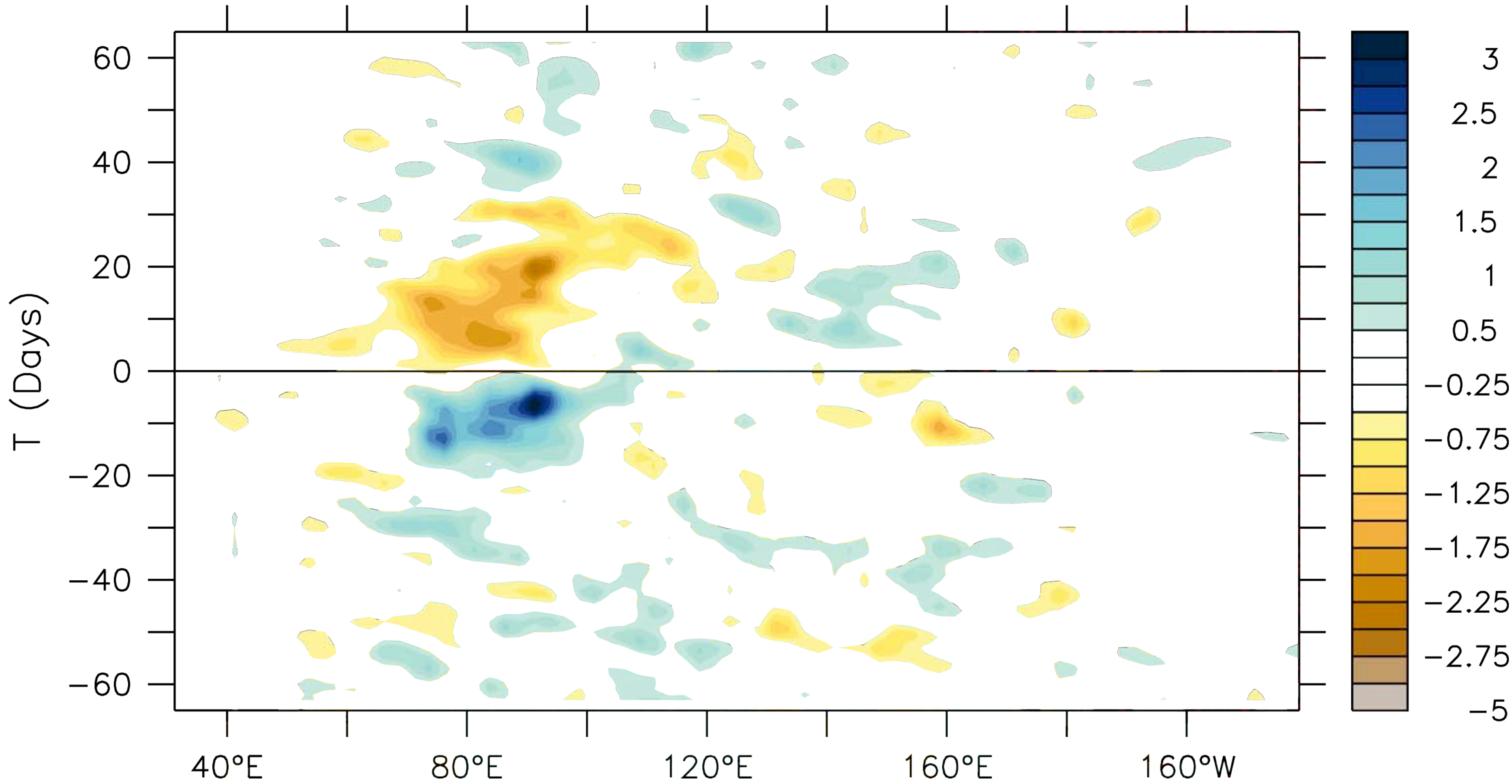
Does strong SST variability feed back to the atmosphere and influence the MJO?

TRI cooling events and rainfall in CM2.1



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