Submonthly Indian Ocean Cooling Events and their Interaction with Large-Scale Conditions (J. Clim., in press)

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Introduction: The Indian Ocean exhibits strong SST variability on intraseasonal timescales

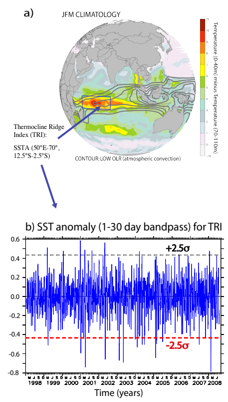
Goals:

- Diagnose the physical mechanisms responsible for cooling events, in both observations and models.

- Investigate relation between cooling events and large-scale conditions.

The Thermocline Ridge Index (TRI) is of particular interest: Shallow thermocline and mixed layer cause strong intraseasonal SST variability, including short timescale (sub 30-day) 'cooling events' (Harrison and Vecchi 2001; Duvel et. al. 2004; Saji et. al. 2006).

The Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) satellite allows for new insights into air-sea processes.



Cooling events are diagnosed in observations and models using a composite approach

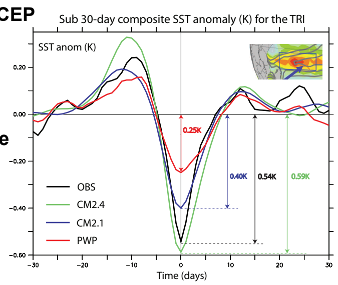
Observations:
TMI-SST data (1998-2007)

1-d Ocean Mixed-Layer Model (Price et. al. 1986):
"PWP" model forced with NCEP Reanalysis-2 fluxes and QuikScat winds (1999-2007)

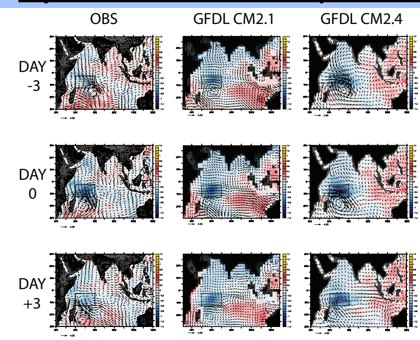
GFDL coupled models:
50 year control runs, with 1990's radiative and land use conditions, for two models:

GFDL CM2.1: Atmosphere 2.5°x2°, ocean ~1°x1°
GFDL CM2.4: Atmosphere 1°x1°, ocean ~0.25°x0.25°

- We use a composite approach to diagnose a large number of cooling events.
- We define a cooling event as: Sub 30-day SST anomaly ≤ 2.5σ



The cooling event composite response is reproduced in GFDL coupled models

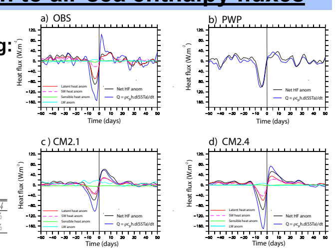


Oceanic processes are important for cooling events, in addition to air-sea enthalpy fluxes

- Air-sea enthalpy fluxes precede maximum cooling: Cooling events are driven by the atmosphere.

- Air-sea fluxes alone are not sufficient to explain SST changes.

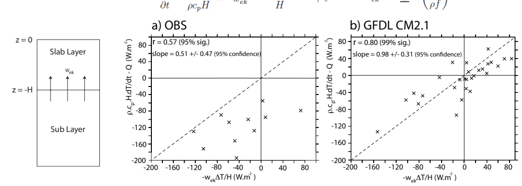
Quantity (J/m^2)	OBS	CM2.1	CM2.4
Vertical processes: $\int_{-15}^{0}(Q-HF).dt$	45.1%	50.1%	45.0%
Air-sea fluxes: $\int_{-15}^{0}(HF).dt$	54.9%	49.9%	55.0%



Ekman upwelling plays a role in cooling events

- For GFDL CM2.1, a slab-layer approximation indicates that Ekman upwelling is important (Lloyd and Vecchi 2009).

$$\frac{\partial \bar{T}'}{\partial t} - \frac{Q'_{sfc}}{\rho c_p H} = -w'_{ek}\frac{(\langle T\rangle - \langle T_{-H}\rangle)}{H} + \epsilon \qquad w_{ek} = -\underline{\nabla} \times \left(\frac{\underline{\tau}}{\rho f}\right)$$

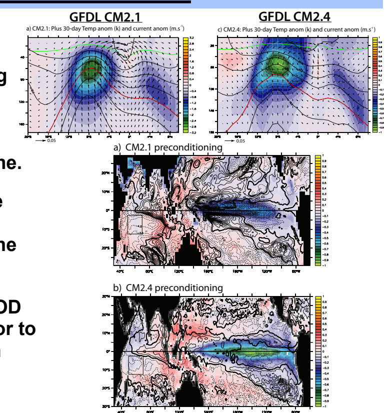


Cooling events are preconditioned by large-scale conditions

- Large-scale ocean conditions are important for cooling events; and coupled models are preconditioned by a shallower thermocline.

- Cooling events are preconditioned by a shallower thermocline in the TRI.

- La Niña/negative IOD conditions exist prior to cooling events, with increased Walker circulation.

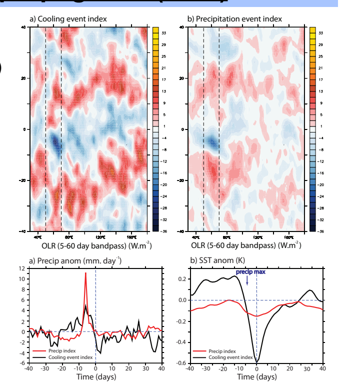


Cooling events are linked to strong eastward convective propogation (MJO)

- Hovmoller diagrams showing OLR have stronger eastward propagation (~5m/s) when using an index based on cooling events instead of precipitation events.

- Stronger SST cooling implies stronger Madden-Julian Oscillation (MJO) signal.

- Does intraseasonal SST variability in the thermocline ridge region influence the MJO through ocean-atmosphere coupling?



References

- Duvel, J. P., R. Roca, and J. Vialard, 2004: Ocean mixed layer temperature variations induced by intraseasonal convective perturbations over the Indian Ocean. J. Atmos. Sci., 61, 3056–3082.
- Harrison, D. E. and G. A. Vecchi, 2001: January 1999 Indian Ocean cooling event. Geophys. Res. Lett., 28, 3717–3720.
- Lloyd I. D., Vecchi G. A., 2009: Submonthly Indian Ocean Cooling Events and their Interaction with Large-Scale Conditions. J. Climate: In Press.
- Price, J. F., R. A. Weller, and R. Pinkel, 1986: Diurnal cycling: Observations and models of the upper ocean response to diurnal heating, cooling, and wind mixing. J. Geophys. Res., 91, 8411–8427.
- Saji, N. H., S.-P. Xie, and C. Y. Tam, 2006: Satellite observations of intense intraseasonal cooling events in the tropical south Indian Ocean. Geophys. Res. Lett., 33, L14 704, doi: 10.1029/2006GL026525.