Argo profiles nonlinear feedback processes associated with the Indian Ocean Dipole

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• Skewness of the IOD

• Debate on the cause of the IOD skewness (much is based on modelling & reanalysis)

• What real observations (Argo and others) tell us about the forcing of the skewness

Skewness of the IOD

From Hong et al. (2008)
(1) Nonlinear dynamical feedback (could be positive, could be negative)

\[
NAT = \left[-\dot{U} \frac{\partial \dot{T}}{\partial x}\right] + \left[-\dot{W} \frac{\partial \dot{T}}{\partial z}\right]
\]

pIOD: 
- - - -  
- + + +

nIOD: 
- + +  
- - - -
(2) SST-cloud-radiation feedback (damping)

A breakdown of the damping allows cold SST anomalies to grow freely.

Is there a problem with SODA temperature?

Hong and Li (2010), using SODA2.0.2, and ERA 40
(3) Thermocline -- SST feedback (positive feedback)

GFDL CM2.1 SON all months
20 degC thermocline - SST

Slope = 0.05
Correl. = 0.48
p-value = 2.6e-05

A ratio of 2.5 : 1
Zheng et al. 2010

GFDL CM2.1 SON all months
20 degC thermocline - Temperature at 45m

Slope = 0.14
Correl. = 0.8
p-value = 4.1e-17

A ratio of 3.6 : 1
Using SODA again, Hong and Li (2010) show that the thermocline feedback does NOT work.
Cai et al. 2012a
SST-cloud-radiation feedback (damping) in other products
Real observations: May – Nov., monthly

- Argo period (Roemmich and Gilson 2009)
  The skewness is -1
- Wind data from QuikSCAT (Liu et al. 2000)
- TRMM 3B43-V6 product (Huffman et al. 2007)
- Objective Analysis Flux (OAFlux, Yu and Weller 2007)
- Ocean Surface Current Analyses-Real Time (OSCAR) currents (Bonjean and Lagerloef 2002)
The DMI
(1) Nonlinear dynamical feedback (could be positive, could be negative)

(a) grid-point NDH with IODE SST

(b) NDH & IODE

(c) NDH & DMI
(2) SST-cloud-radiation feedback (damping)
(3) Thermocline -- SST feedback (positive feedback)
Response of wind to SST & Response of Z20 to wind

(a) IODE SST & grid-point zonal wind

(b) Zonal wind & IODE SST

\[ R^2 = 0.47 \]
\[ \text{Slope} = 1.35 \]
\[ p = 0.000 \]

\[ R^2 = 0.008 \]
\[ \text{Slope} = 0.21 \]
\[ p = 0.733 \]
Conclusions

1. The role of a nonlinear dynamical heating process is re-affirmed.

2. A thermocline-temperature feedback asymmetry is the primary forcing of the IOD skewness. This asymmetry is a part of the nonlinear Bjerknes-like positive feedback loop, involving winds, SST, and the thermocline.

3. Damping of IODE cool anomalies increases with the cool SST anomalies. Thus, the IOD skewness is generated in spite of a greater damping for negative SST anomalies.
Thank You

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Isothermal layer (IL) depth is the depth where temperature is 0.2°C lower than that at the 10m depth.

Mixed-layer (ML) is depth with a density of that at 10 m plus the density difference brought about by a temperature decrease of 0.2°C.

Isothermal layer (IL) depth is the depth where temperature is 0.2°C lower than that at the 10m depth.

Barrier layer (BL) depth = IL - ML
Fig. 3. As in Fig. 2, but using DMI instead of Niño-3.4.