Influence on the Upper Ocean

1D mixed layer heat budget:

\[
\rho_0 C_p \left[ \frac{\partial \Theta}{\partial t} + \mathbf{u} \cdot \nabla_{xy} \Theta + w \frac{\partial \Theta}{\partial z} \right] = \frac{\partial Q_{\text{net}}}{\partial z} \tag{2}
\]

where \( \Theta = \) conservative temperature (TEOS-10)

integrate over the temporally varying mixed layer depth \( h(t) \)

\[
\frac{\partial \tilde{\Theta}}{\partial t} \approx \mathcal{F}_{\text{Atmos.}} + \mathcal{F}_{\text{Eddies}} - \lambda \overline{\Theta} \tag{3}
\]

where: \( \overline{\Theta} = \int_{h(t)}^0 \Theta dz \)
**Influence on the Upper Ocean**

\[
\frac{\partial \Theta}{\partial t} \approx F_{\text{Atmos.}} + F_{\text{Eddies}} - \lambda \Theta
\]

\(F_{\text{Atmos.}} = \) Surf. Heat Flux + Ekman Advection + Ekman Pumping

\(F_{\text{Eddies}} = \) Geostrophic Advection + Entrainment at MLD Base

\(\lambda = \) damping parameter (inverse decay timescale)
Influence on the Upper Ocean

Standard Deviation of the (top): SST; (middle): Eddy Forcing; and (bottom): Atmospheric Forcing.
Influence on the Upper Ocean

Autocorrelation structure of the individual terms in the MLD heat budget.
Stochastic Model of the SST variation

In spectral space, MLD heat budget becomes:

\[
(\omega^2 + \lambda^2) P_{\Theta \Theta} = P_{F_{\text{atmos}}F_{\text{atmos}}} + P_{F_{\text{eddy}}F_{\text{eddy}}} - P_{F_{\text{atmos}}F_{\text{eddy}}} - P_{F_{\text{eddy}}F_{\text{atmos}}}
\]  

(4)

where \( P_{xy} \) is the power spectrum of the \( x \) and \( y \) (so we include cross terms)
Influence on the Upper Ocean

Power Spectrum of the stochastic model of SST variation
Conclusions

- Robust signature of variability on long (2-5 years) in the sub-surface Indian ocean;
- Teleconnection between eastern and western sides of the basin;
- Feature has a substantial surface expression and influence on SSTs on long time scales;
- Intrinsic mode: shows some predictability.
Supplementary: Influence on the Upper Ocean near Madagascar

Top: SST;
Middle: Temperature depth/time profile;
Bottom: $v_y$ depth/time profile
Supplementary: Influence on the Upper Ocean near Madagascar

Lagged autocorrelation function at lags between 1 month and 10 years
Supplementary: Physical Mechanism of Teleconnection

Complex EOF time series
Black: real component; red: imaginary part

(a) 1st EOF: 16.8% variance
(b) 2nd EOF: 8.3% variance
(c) 3rd EOF: 7.3% variance
Supplementary: Influence on the Upper Ocean

Complex (Hilbert) EOFs of SST
Colors: real part; contours: imaginary part
Supplementary: Influence on the Upper Ocean

Hovmöller (longitude/time) plots of SST along the northern (left) and southern (right) waveguides
Thank You

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