# 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: $\overline{\Theta} = \int_{h(t)}^{0} \Theta dz$

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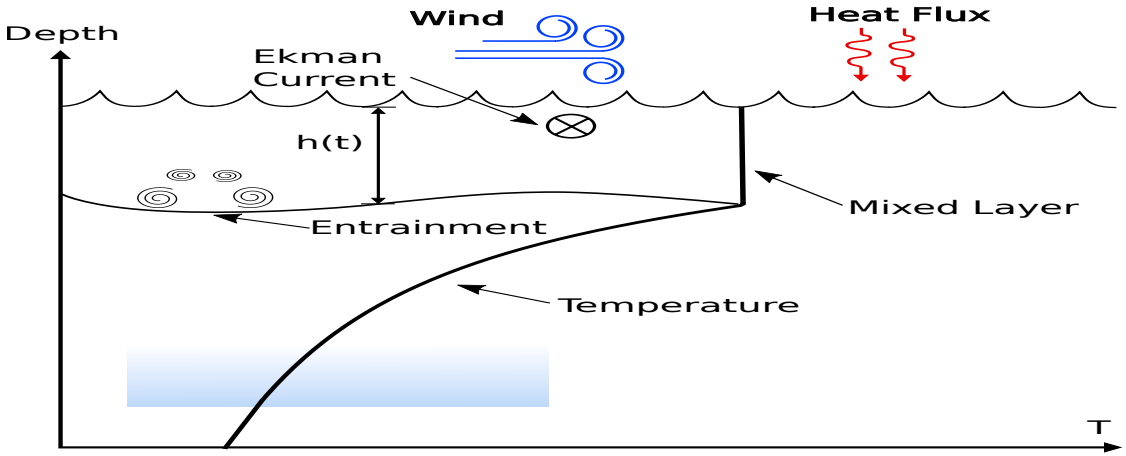
$$\frac{\partial \overline{\Theta}}{\partial t} \approx \mathcal{F}_{\text{Atmos.}} + \mathcal{F}_{\text{Eddies}} - \lambda \overline{\Theta}$$

$$\begin{aligned} \mathcal{F}_{\text{Atmos.}} &= \text{Surf. Heat Flux} + \text{Ekman Advection} + \text{Ekman Pumping} \\ \mathcal{F}_{\text{Eddies}} &= \text{Geostrophic Advection} + \text{Entrainment at MLD Base} \\ \lambda &= \text{damping parameter (inverse decay timescale)} \end{aligned}$$



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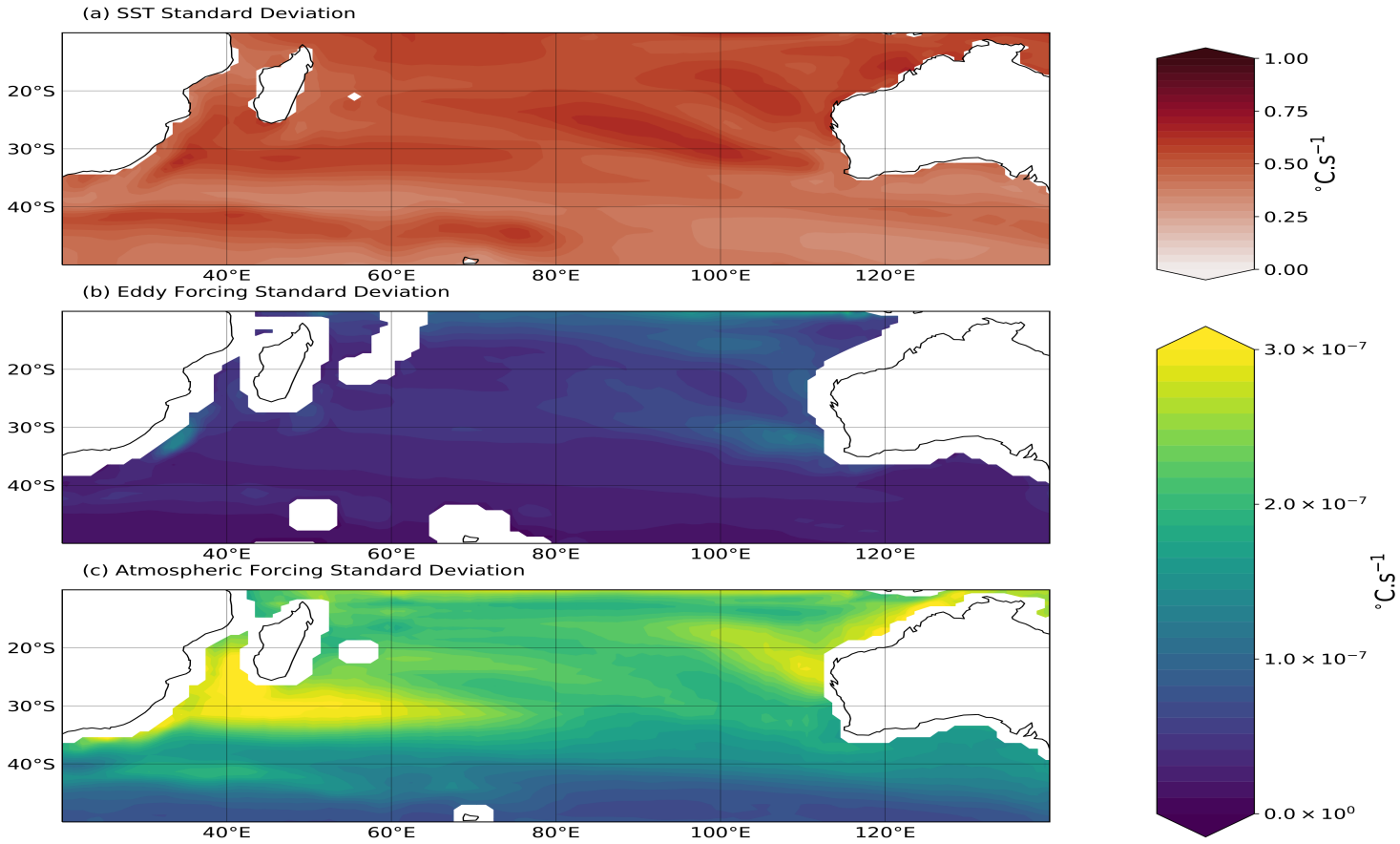


Standard Deviation of the (top): SST; (middle); Eddy Forcing; and (bottom): Atmospheric Forcing.

# 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:

$$\left(\omega^2 + \lambda^2\right) P_{\Theta\Theta} = P_{F_{\text{atmos}} F_{\text{atmos}}} + P_{F_{\text{eddy}} F_{\text{eddy}}} - P_{F_{\text{atmos}} F_{\text{eddy}}} - P_{F_{\text{eddy}} F_{\text{atmos}}} \tag{4}$$

where $P_x y$ = is the power spectrum of the $x$ and $y$ (so we include cross terms)

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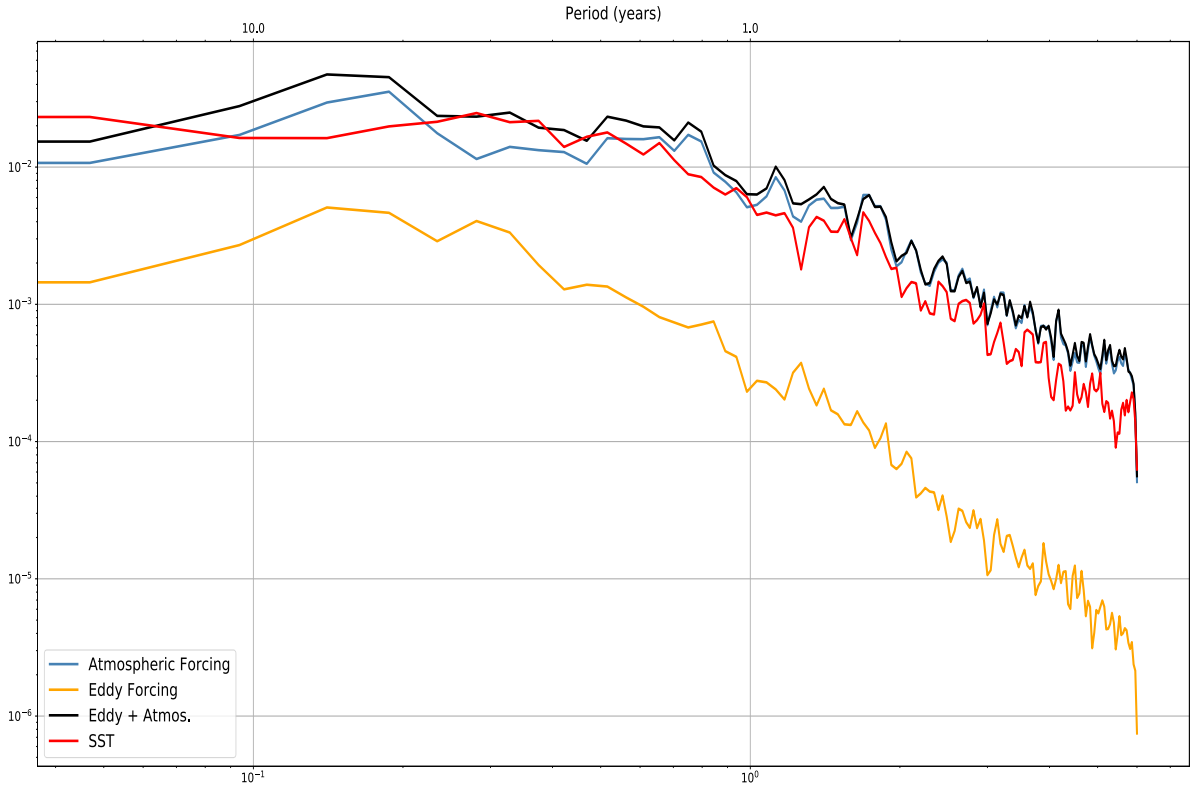
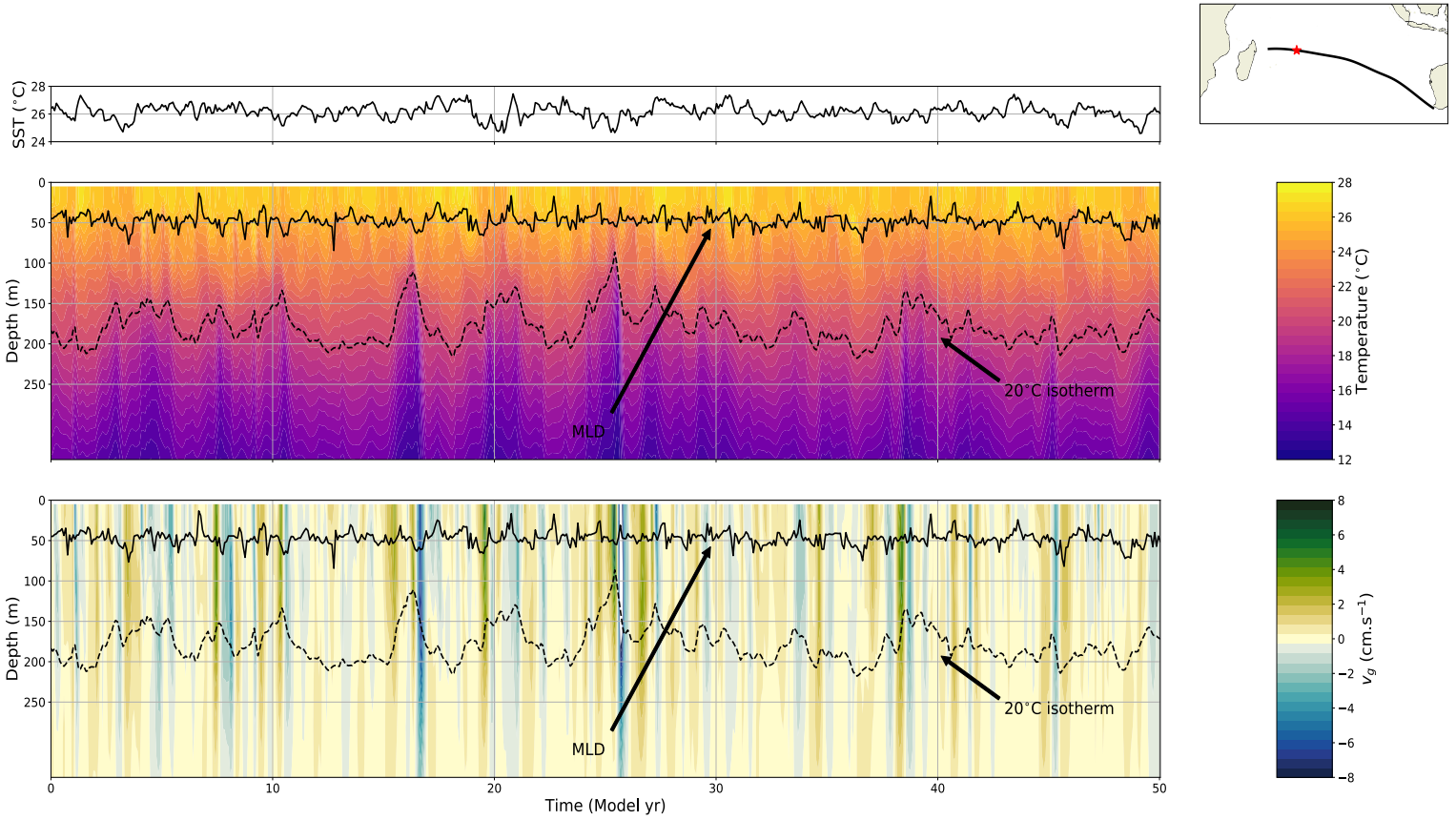



Power Spectrum of the stochastic model of SST variation

# 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 predectability.

# Supplementary: Influence on the Upper Ocean near Madagascar




Top: SST;
Middle: Temperature depth/time profile;
Bottom: $v_g$ depth/time profile

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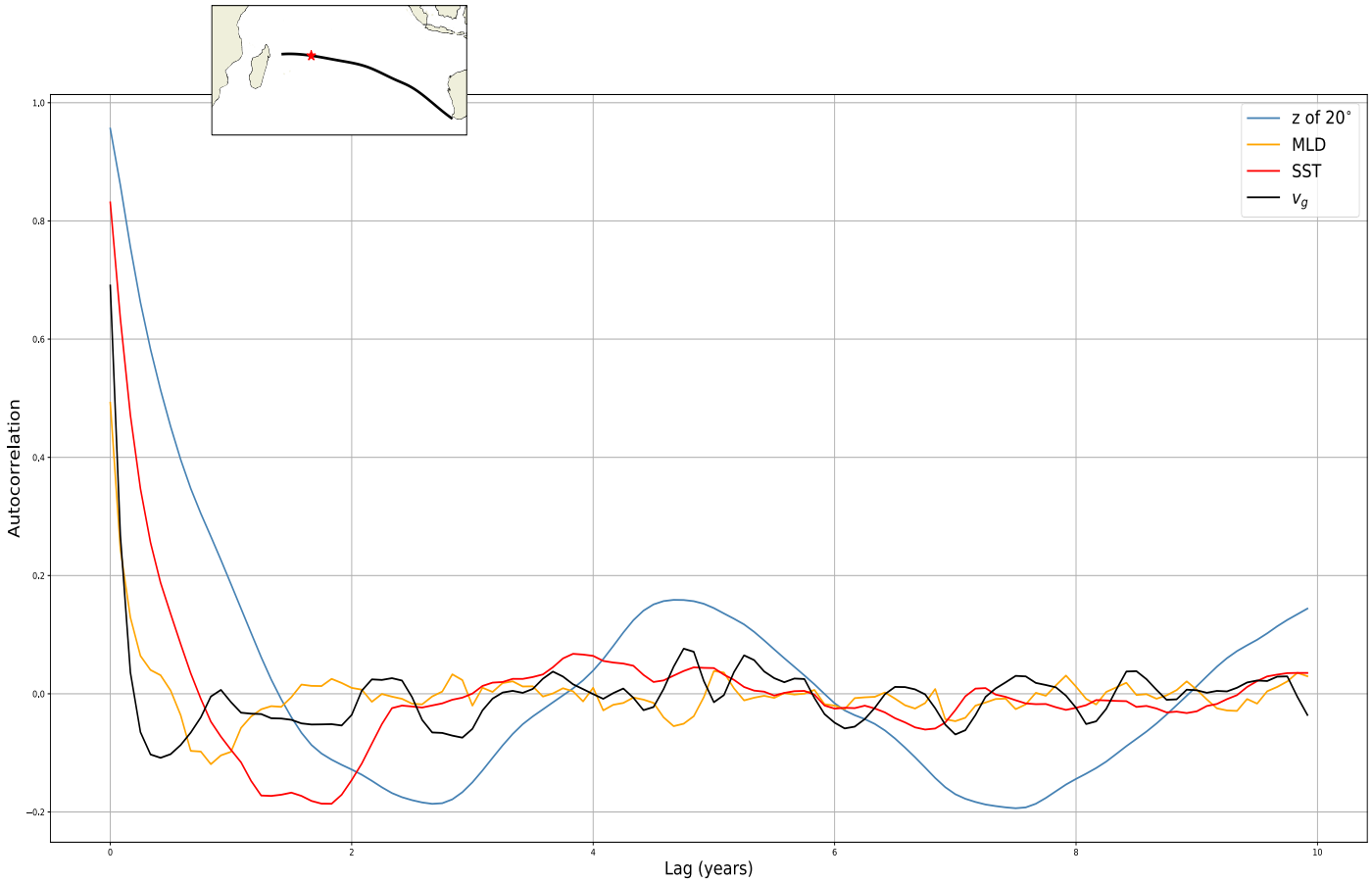
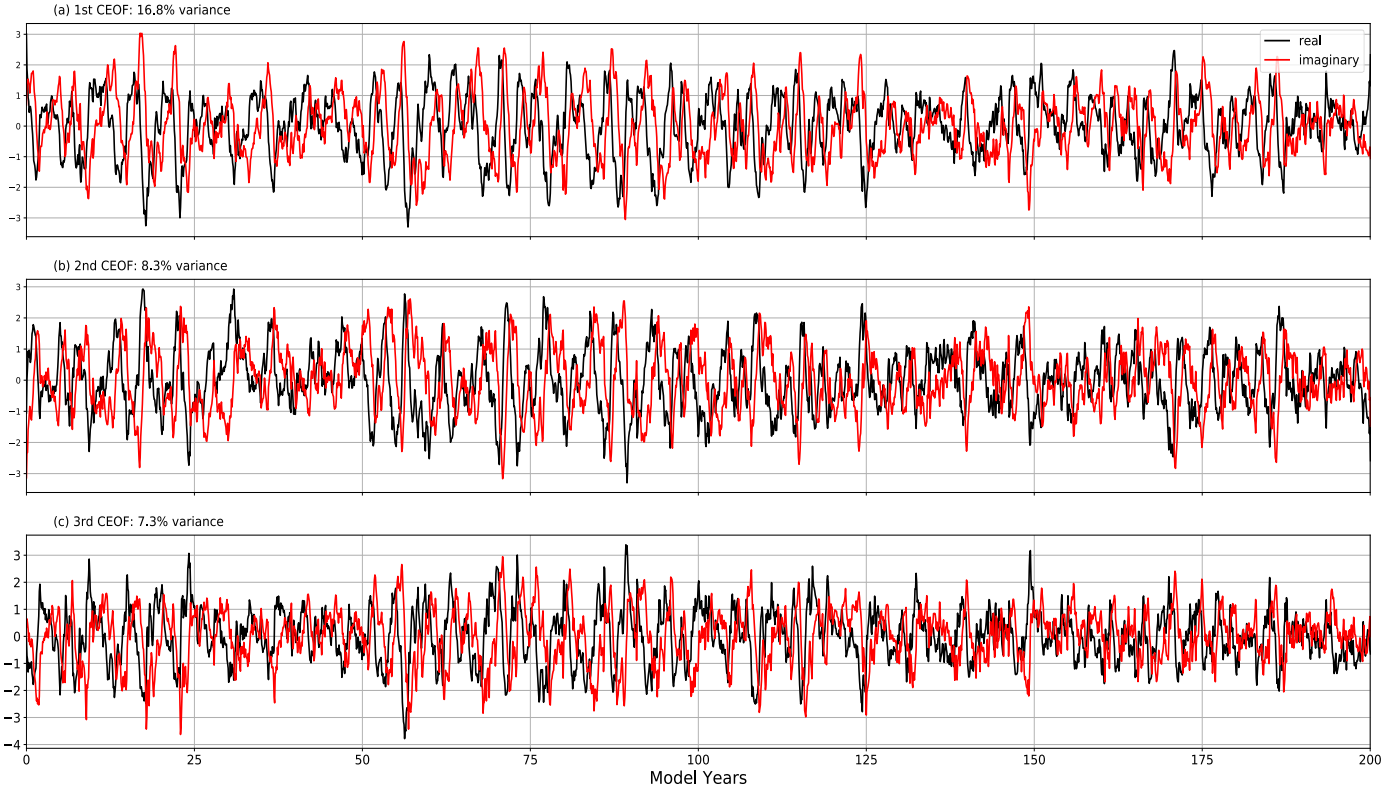



Lagged autocorrelation function at lags between 1 month and 10 years

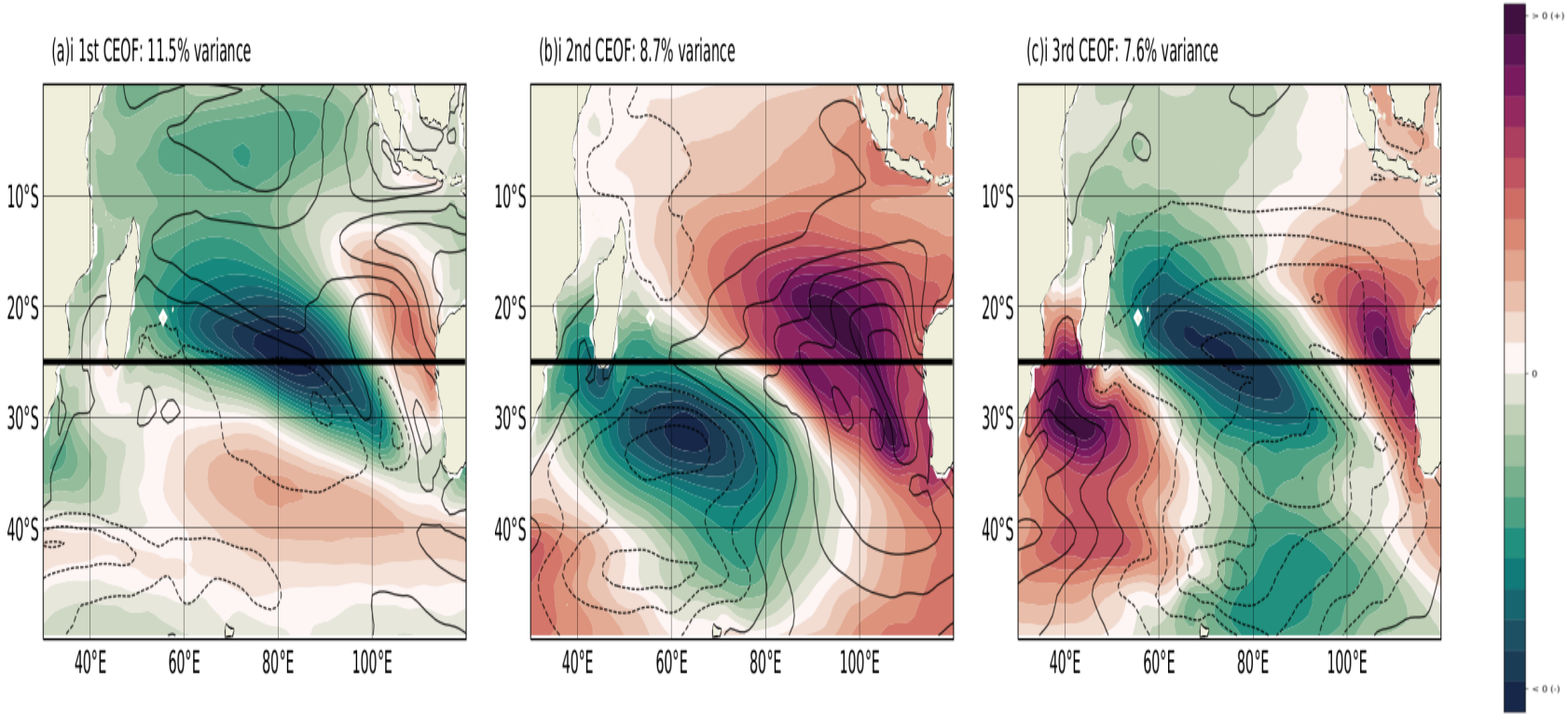
# Supplementary: Physical Mechanism of Teleconnection




Complex EOF time series

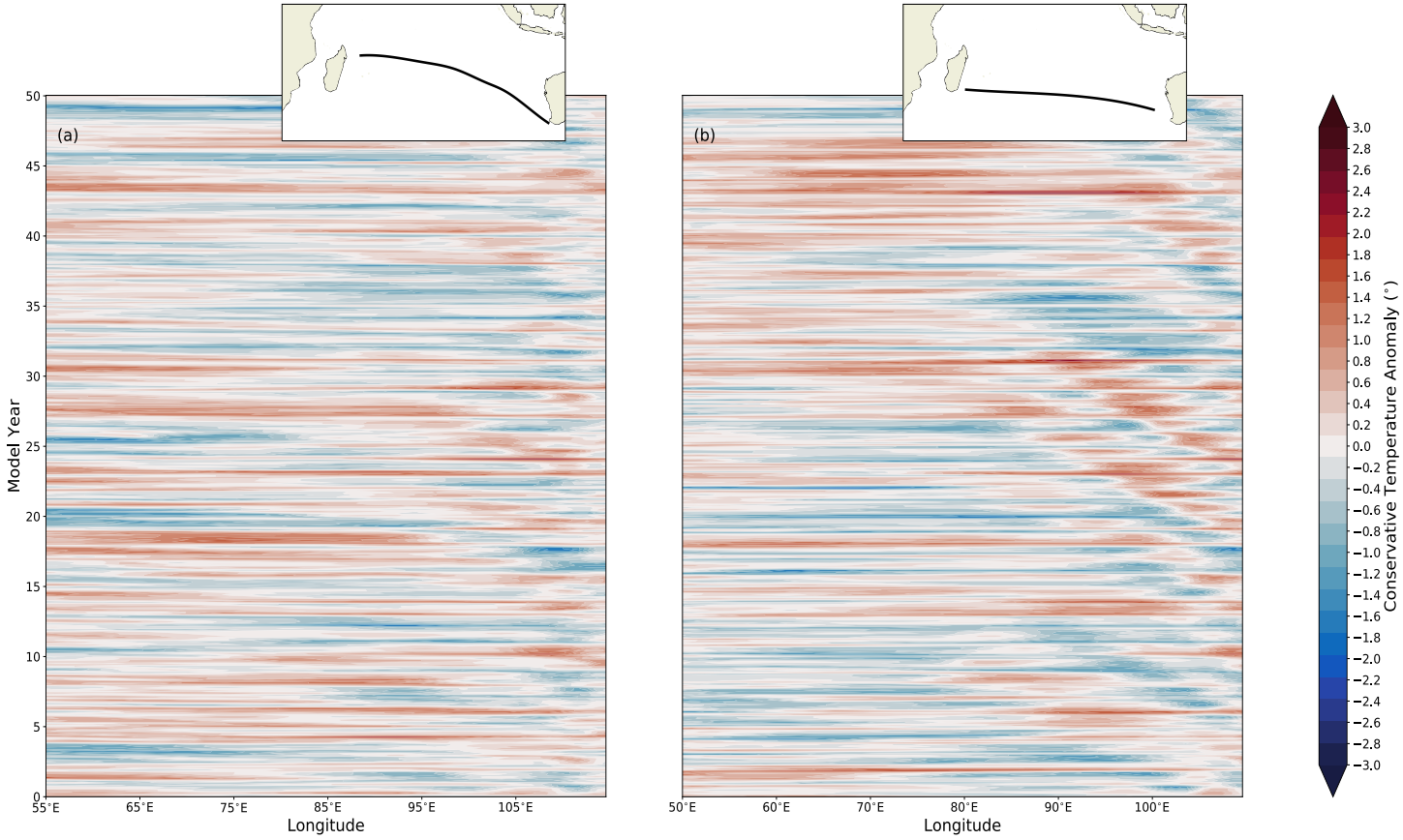
Black: real component; red: imaginary part

# 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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