Subsurface variability and teleconnections in the Indian Ocean
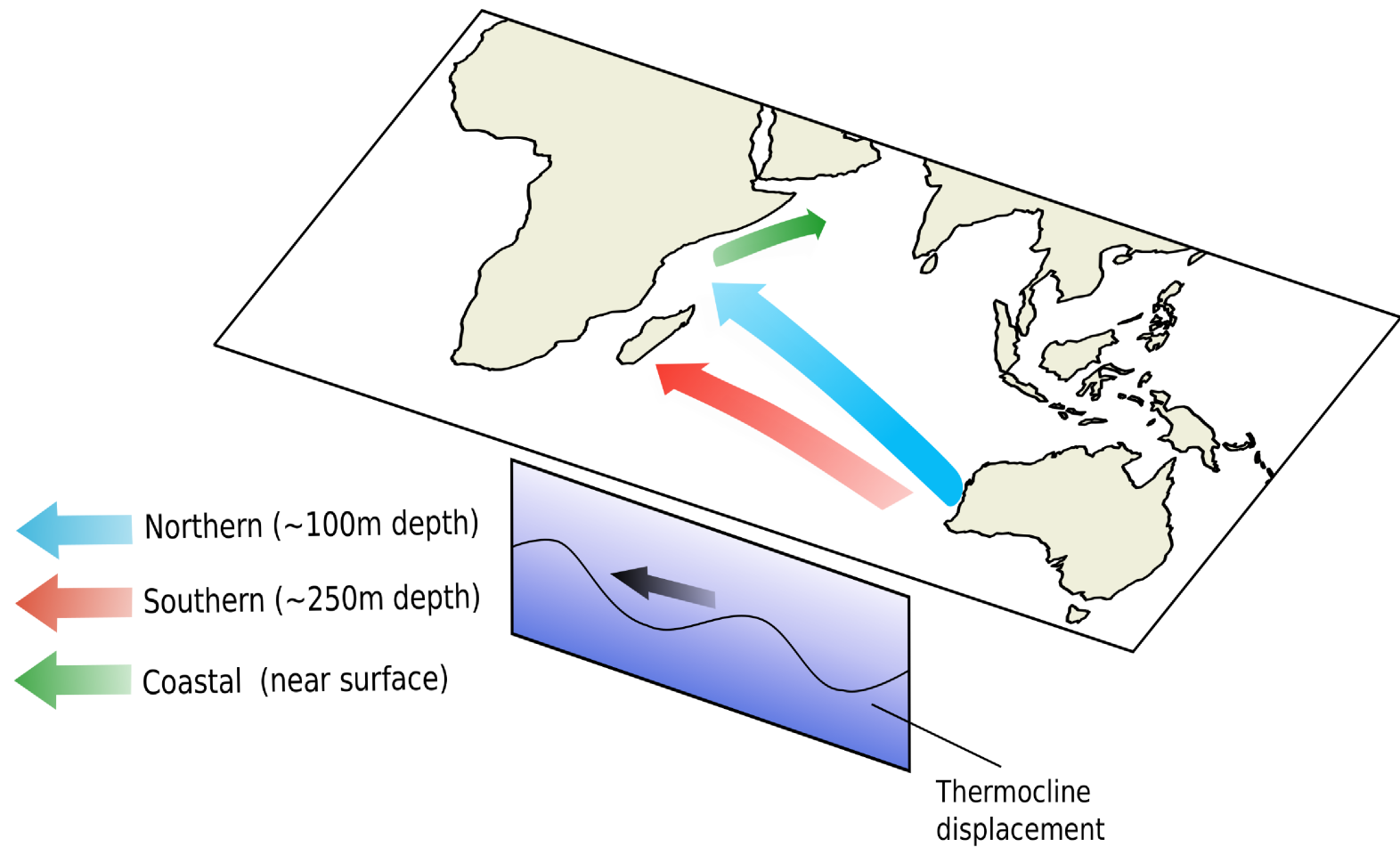
Chris Chapman, Bernadette Sloyan, Terry O'Kane

Didier Monselasen, Matt Chamberlain, James Risbey

CSIRO

Physical Mechanism of Teleconnection

Northern (~100m depth)

Southern (~250m depth)

Coastal (near surface)

Thermocline displacement

CSIRO

Physical Mechanism of Teleconnection

- Some signature in SSH altimetry (Briol & Morrow 2000);

- Intrinsic mode found in long, ocean-only, coarse resolution models (O'Kane et al. 2014; Wolfe et al. 2017) and SODA reanalysis (Vargas-Hernández et al. (2015);

- Possible signature in sea-surface salinity (Menezes et al. (2014);

- Not yet noted in in-situ measurements (we're working on it).

CSIRO

Coupled Climate Model

- We use the DFP's Climate Analysis Forecast Ensemble (CAFÉ) modelling system (O'Kane et al. 2018);

- Very similar to GFDL's CM2.1 (modified ocean grid);

- MOM4 ocean model; AM2 atmosphere; SIS sea-ice; LM2 land surface;

- $\sim 1^\circ$ grid in the ocean, telescopes to $\sim 1/3^\circ$ near the equator, 2.5° in the atmosphere;

- Restoring to WOD climatology below 2000m depth (1 year restoring time scale);

CLIMATE ANALYSIS FORECAST ENSEMBLE system
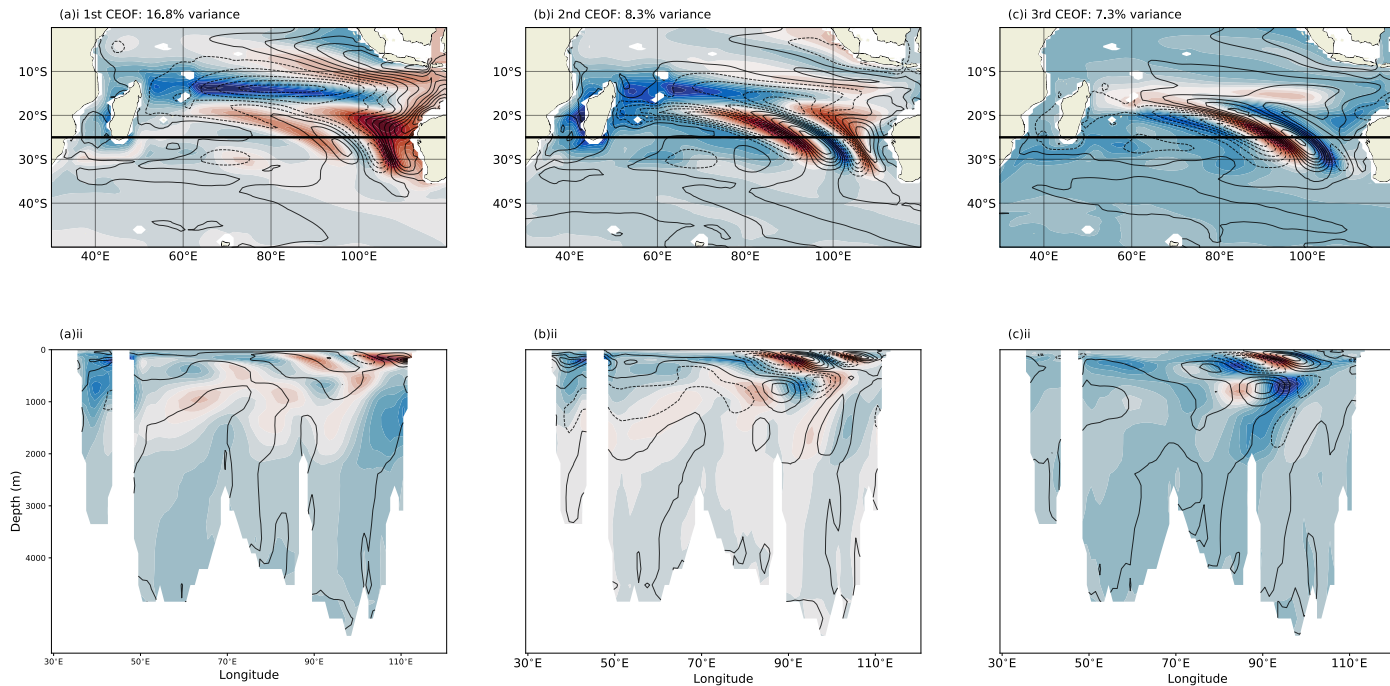
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Coupled Climate Model

- 500 year long control simulation - final 200 years used after the model is in an "almost" equilibrium state;
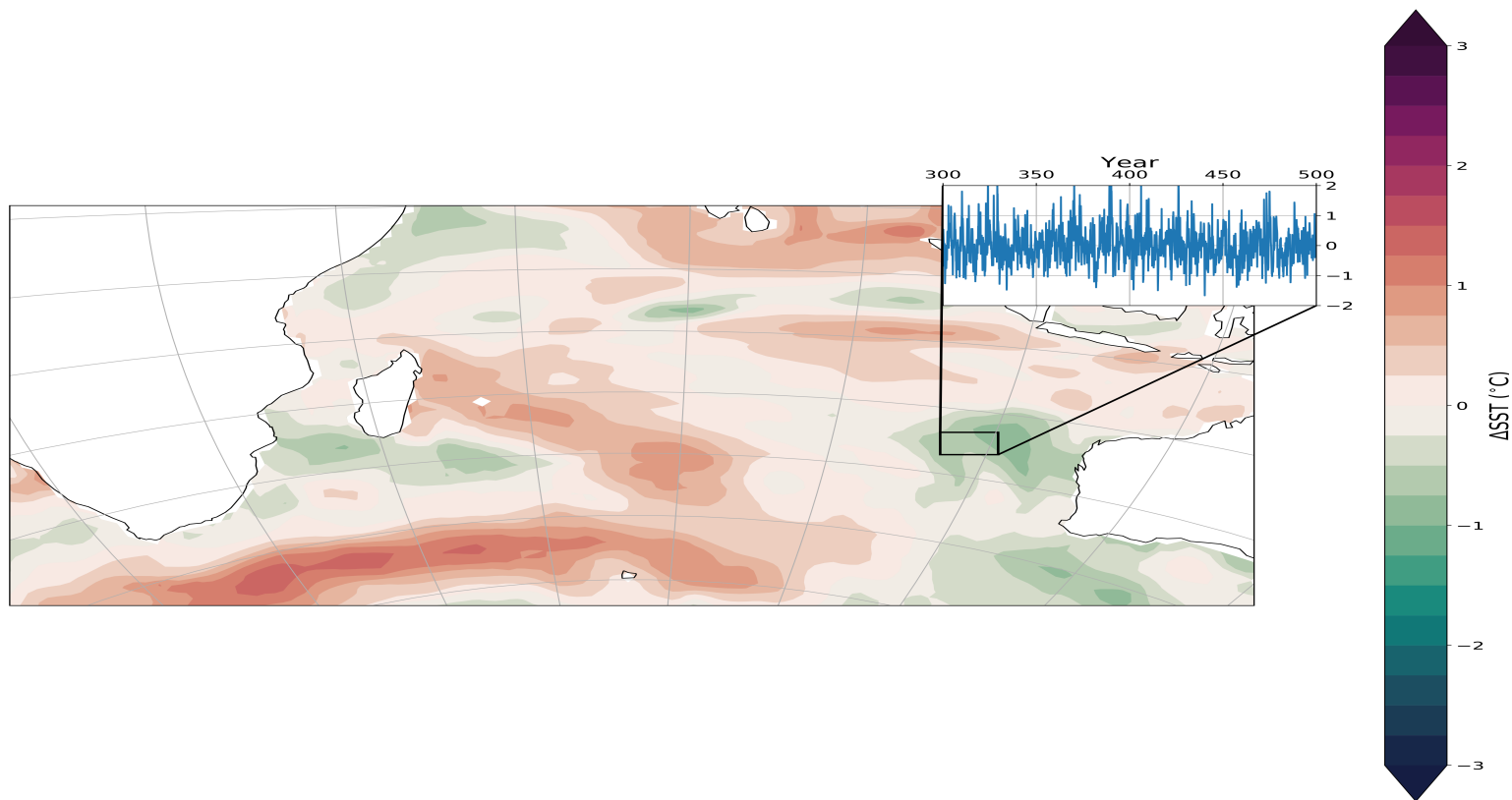
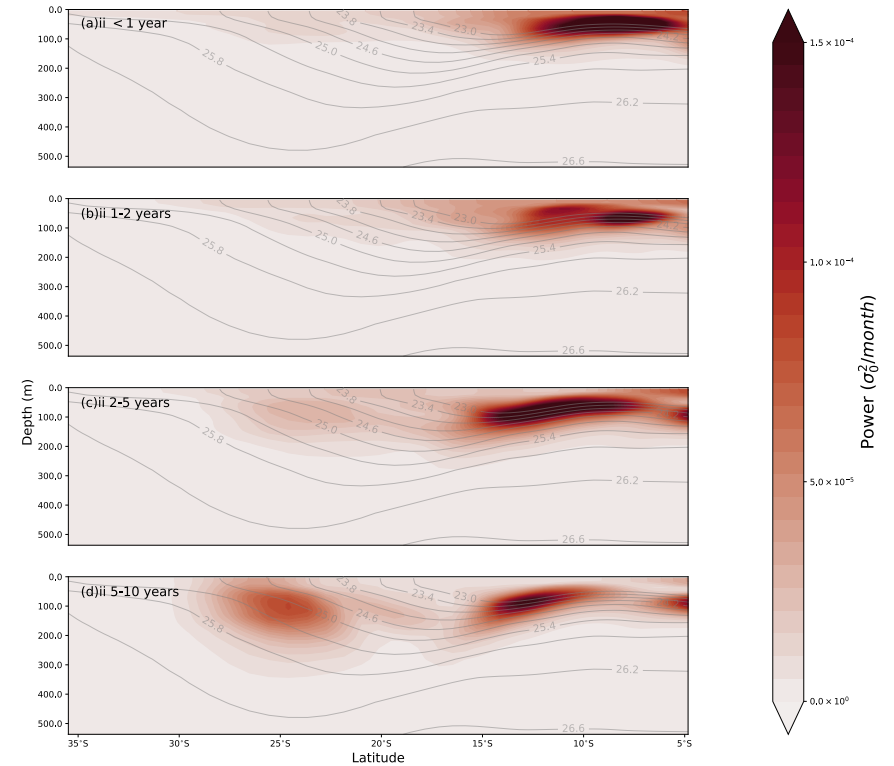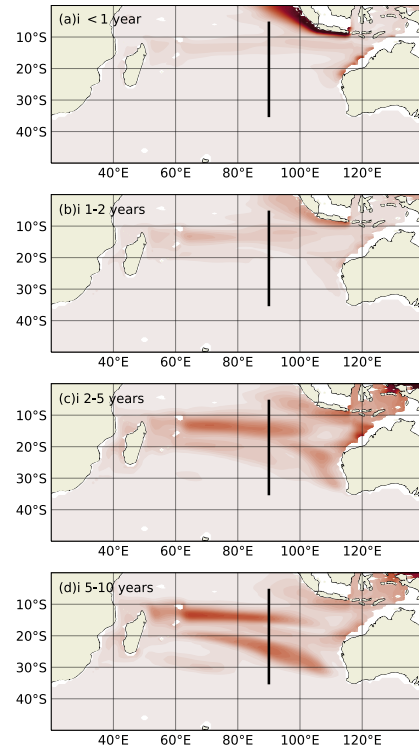# Physical Mechanism of Teleconnection

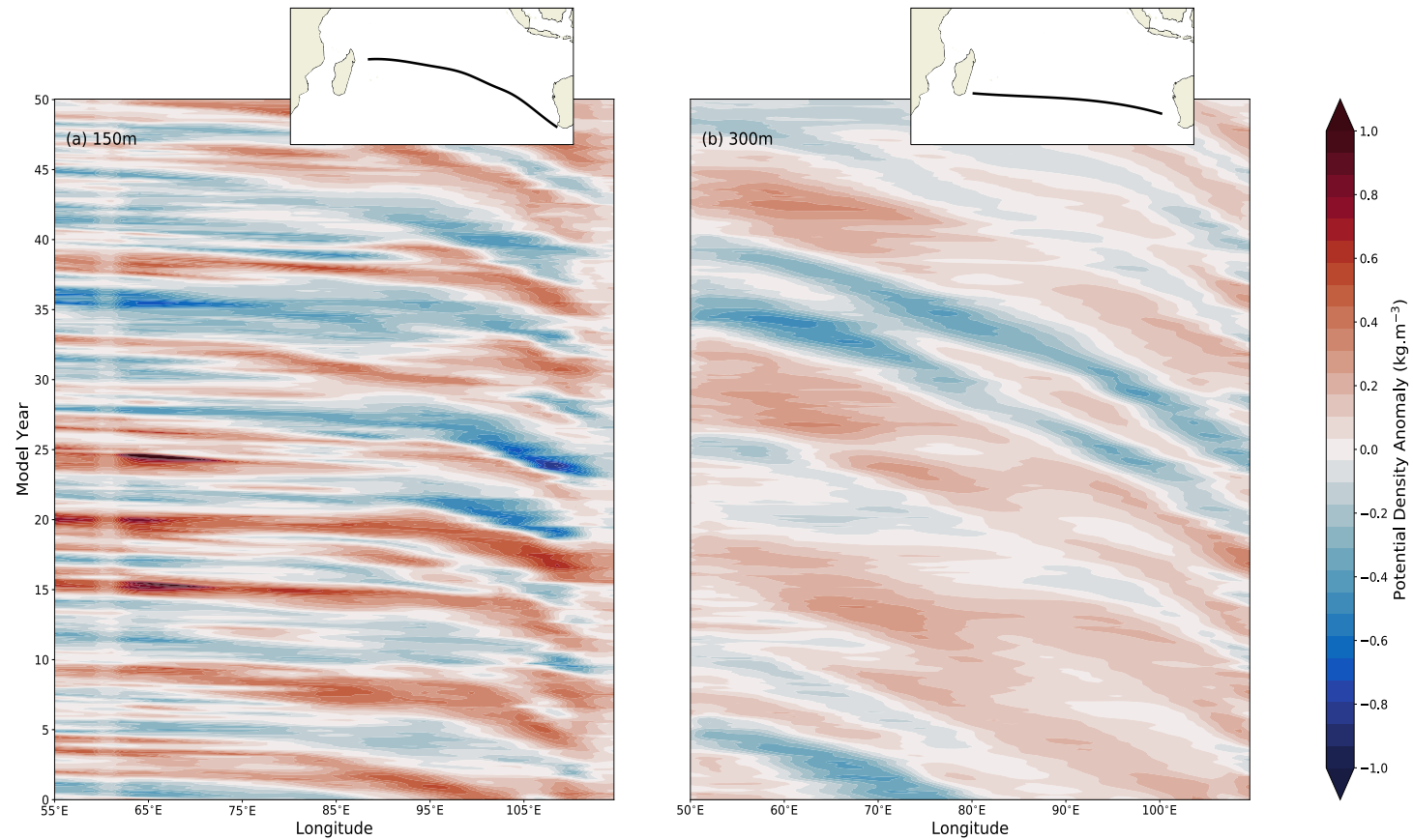3D complex (Hilbert) EOFs of σ_θ (referenced to the surface)

Colors: real part; contours: imaginary part

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Physical Mechanism of Teleconnection

In band variance of σ_θ (surface referenced)

CSIRO

Physical Mechanism of Teleconnection

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

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Summary of the Propagating Disturbance

- Basin crossing time scale: $\sim$4 years;

- Length Scale: 500–1000km;

- Propagation speed: 10cm/s (substantially slower than theoretical Rossby wave speed);

- Likely substantially non-linear;

- Shows evidence of topographic interaction;

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Influence on the Upper Ocean

To quantify the influence of the propagating disturbance on the surface ocean, we calculate the *Dynamic Height Anomaly* or *Relative Geostrophic Streamfunction* from model temperature and salinity:

$$\psi_g(x, y, t; p, p_{\text{ref}}) = -\int_{p_{\text{ref}}}^{p} \delta(x, y, t; p') \, dp' \qquad (1)$$

where:

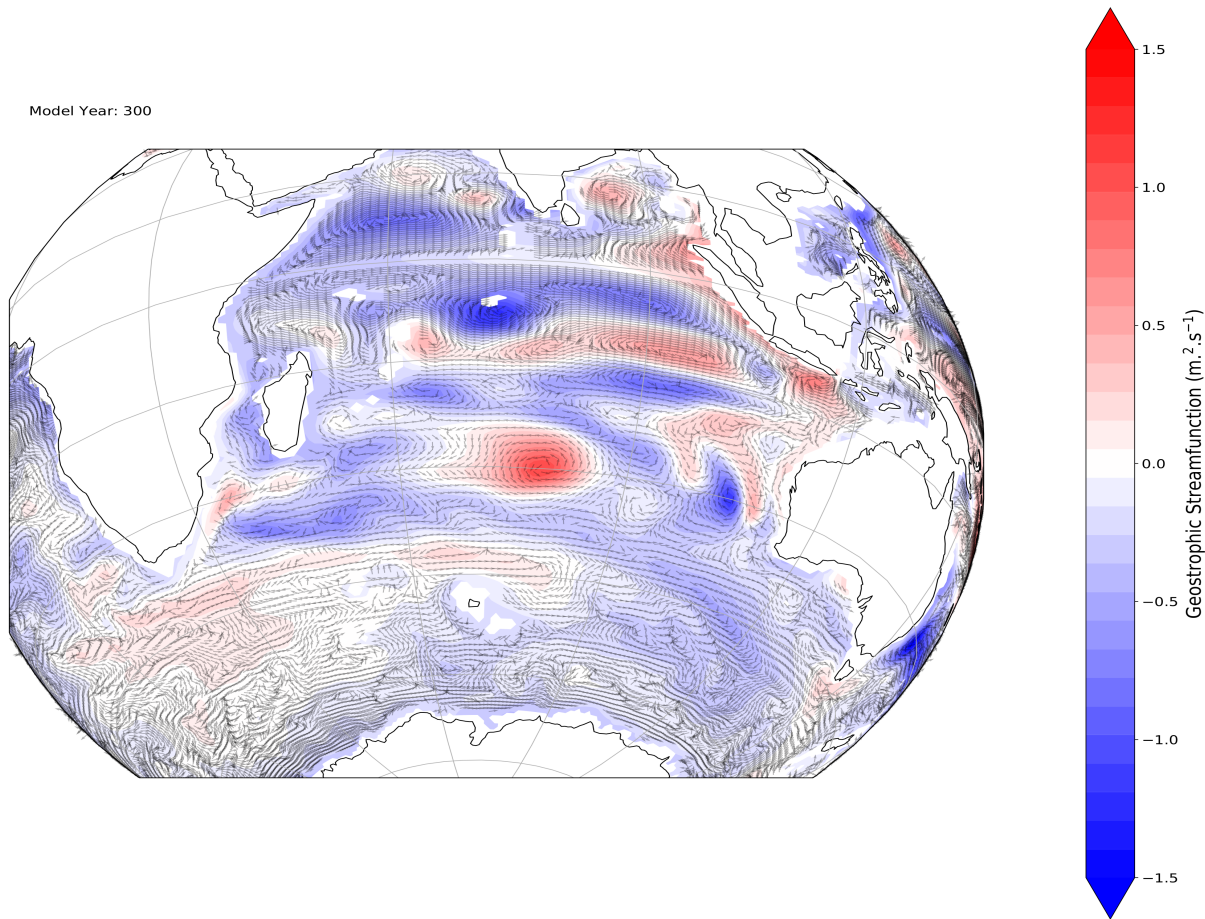δ=specific volume anomaly (function of temperature and salinity); and

$$\mathbf{e}_z \times \nabla\psi_g(p, p_{\text{ref}}) = f[\mathbf{u}(p) - \mathbf{u}(p_{\text{ref}})]$$
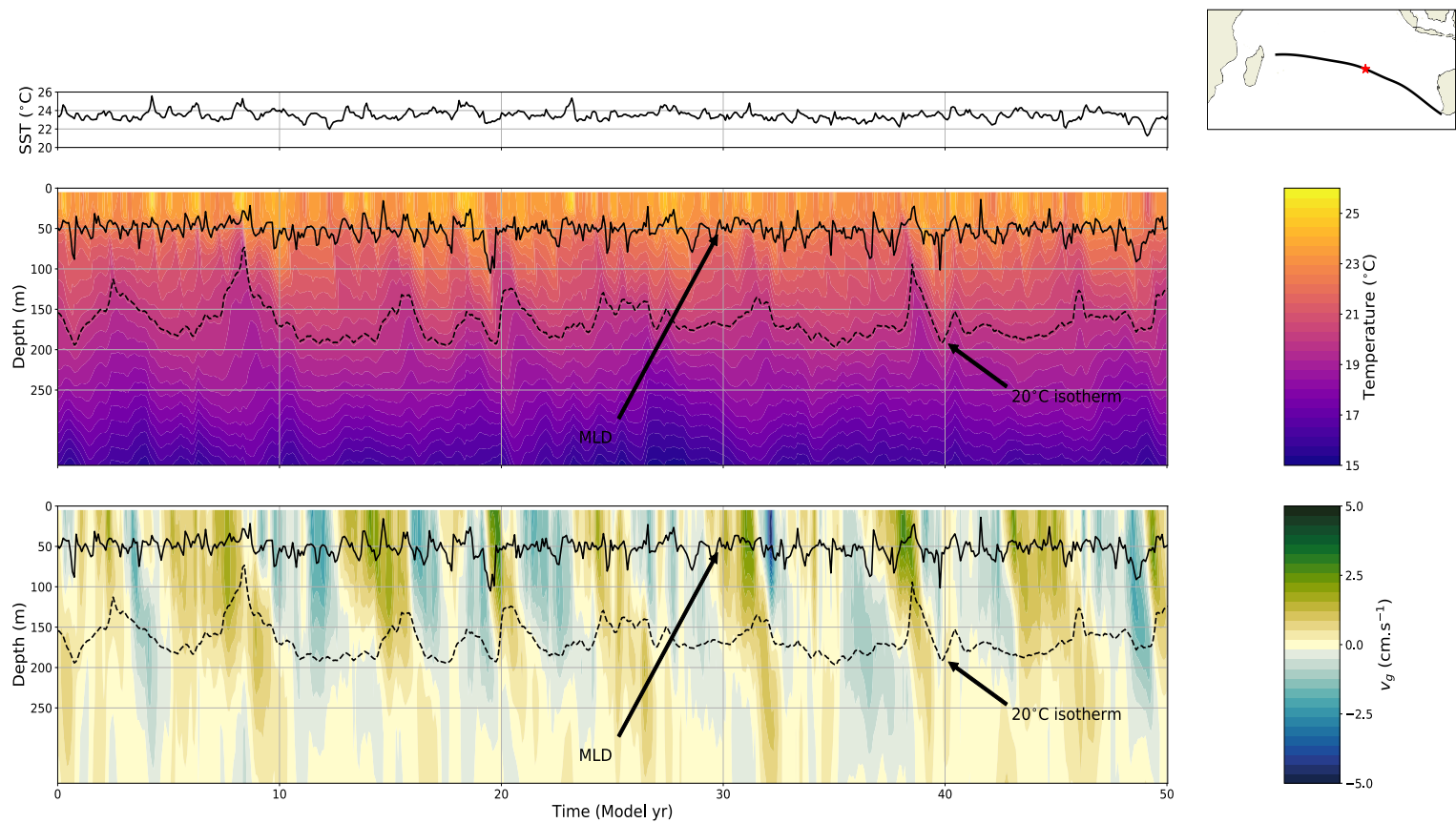
Has the benefit of being a *depth integrated measure*

Essentially the thermal wind.
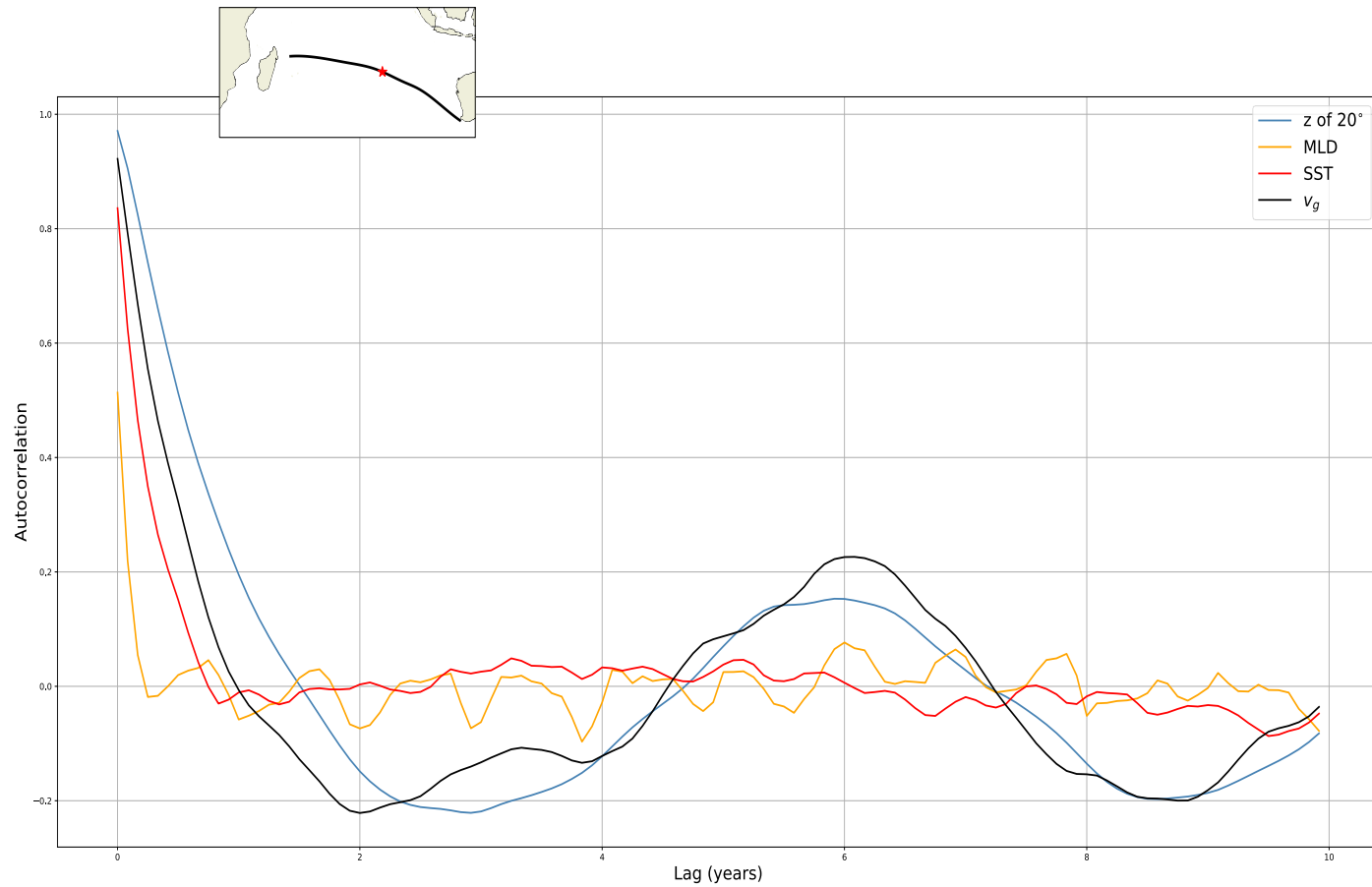
Influence on the Upper Ocean

Model Year: 300

Colors: Geostrophic streamfunction anomaly referenced to 500db
Vectors: Surface Geostrophic Current (relative to 500db flow)

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Influence on the Upper Ocean

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

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Influence on the Upper Ocean

Lagged autocorrelation function at lags between 1 month and 10 years