Forcing of mesoscale eddy kinetic energy variability in the southern subtropical Indian Ocean, inferred from altimetry

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Introduction

- A band of elevated mesoscale eddy activity spans the southern subtropical Indian Ocean (SSIO).
- Eddies are generated from mixed barotropic and baroclinic instability in the Leeuwin Current near the eastern boundary (e.g., Morrow and Birol, 1998), and also from baroclinic instability associated with the South Equatorial Current (SEC) and South Indian Counter Current (SICC) in the interior (e.g., Palastanga et al., 2007).
- The interannual variability of SSIO eddy activity has implications for meridional heat transport between the mid-latitudes and tropics, as well as for marine chlorophyll productivity.

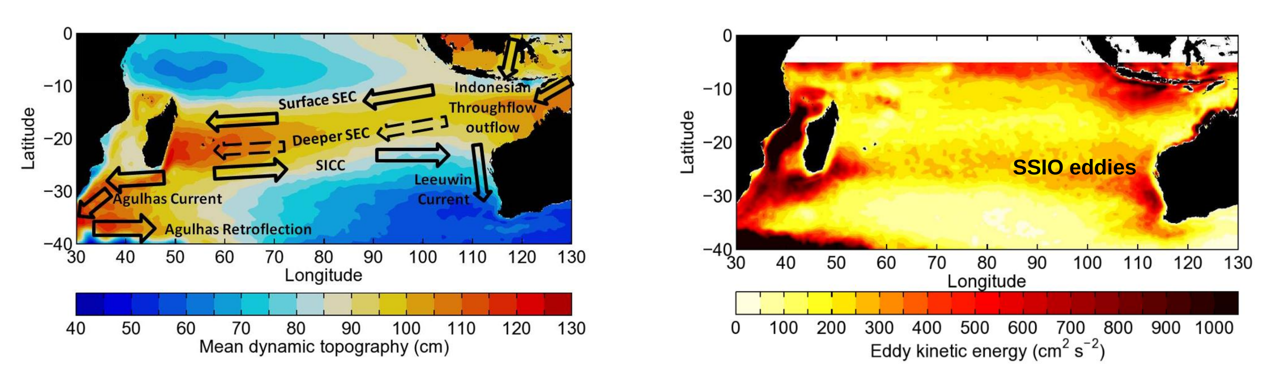

Figure 1. (left) Mean dynamic topography from AVISO, with currents annotated. (right) Time-mean eddy kinetic energy from AVISO.

Research questions

- **What is the relationship of mesoscale eddy activity to sea level in the SSIO?**
- **To what extent is the interannual variability of mesoscale eddy kinetic energy (EKE) in the SSIO driven by large-scale climate modes? What role could internal ocean dynamics play?**

Mesoscale sea level decomposition

- Data used: AVISO delayed-time, multi-mission gridded maps of absolute dynamic topography with 1/4° spatial resolution, and temporal mean removed to obtain sea level anomaly (SLA).
- To distinguish between oceanic variability associated with large-scale Rossby waves and mesoscale eddies
  → Zonal and meridional spatial low-pass filters (6° cutoff) were applied to the sea level anomaly field.
  - The low-pass SLA field (SLA_{lp}) consists mostly of Rossby waves; the residual field (SLA_{meso}) consists mostly of mesoscale eddies.
  - **EKE_{lp}** (long Rossby wave EKE) and **EKE_{meso}** (mesoscale EKE) are derived respectively from SLA_{lp} and SLA_{meso}.

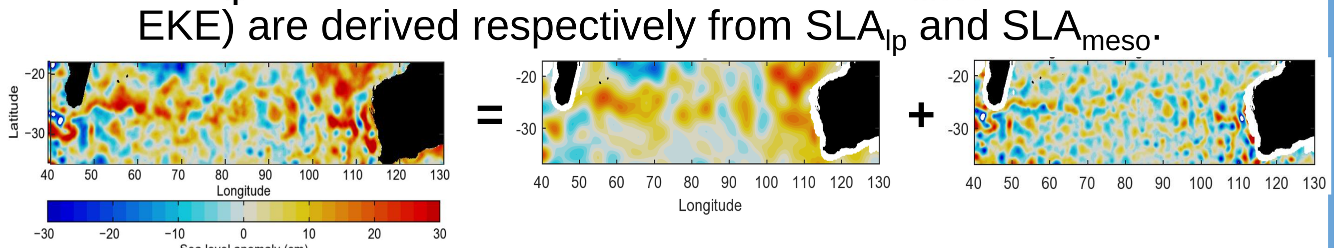

Figure 2. (left) Snapshot of AVISO sea level anomaly, 2011 Jul 02, with (center) low-passed sea level anomaly SLA_{lp}, and (right) the residual SLA field SLA_{meso} used to compute mesoscale EKE.

EKE-SLA relationship

- SLA variations in the Leeuwin Current region (SSIO eastern boundary) are closely related to SLA variations in the western tropical Pacific, particularly on decadal timescales (Lee and McPhaden, 2008).
- The pointwise correlation of SLA with EKE_{meso} near the Leeuwin Current reflects the influence of the Leeuwin Current (and the western tropical Pacific) on mesoscale eddy activity.

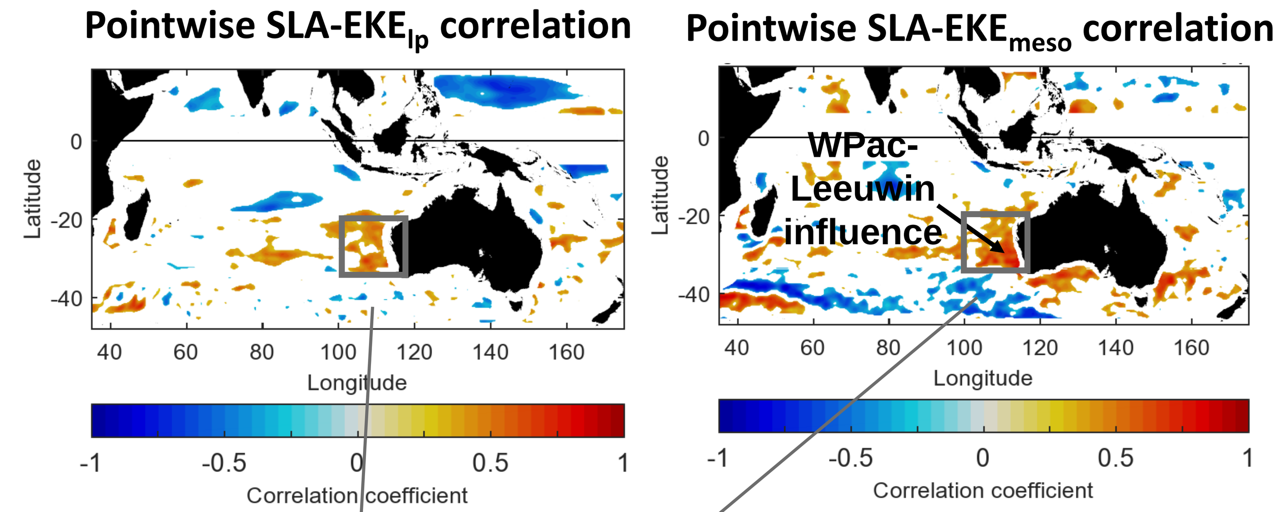

Figure 3. Pointwise zero-lag correlation of SLA with (left) EKE_{lp} derived from the low-passed SLA field, and (right) EKE_{meso} derived from the residual SLA field. All fields temporally low-passed (LP) for periods longer than 14 months.

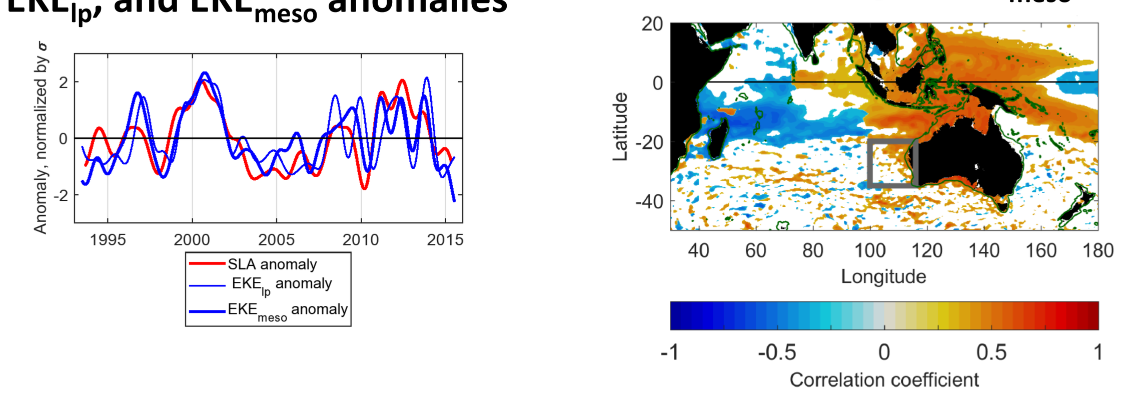

Figure 4. (left) Time series of box-averaged SLA, EKE_{lp}, and EKE_{meso} anomalies in the Leeuwin Current region, normalized by their standard deviations. (right) Optimum correlation coefficients of SLA with box-averaged EKE_{meso}, for SLA leading EKE_{meso} by 0-24 months, with 14-month LP filter.

EKE_{meso}-climate mode relationships

- An earlier analysis (Jia et al., 2011) of regionally-averaged SSIO EKE emphasized a negative correlation with the Southern Annular Mode (SAM) index.
- Our analysis of the spatial distribution of mesoscale EKE indicates a robust negative Niño3.4-EKE_{meso} near the eastern boundary (La Niña → more eddy activity). Lags increase away from the coast, indicating westward EKE_{meso} propagation.
- The SAM index has patchy, mostly negative correlations with SSIO EKE_{meso}; EKE_{meso} lags SAM by 0-18 months.

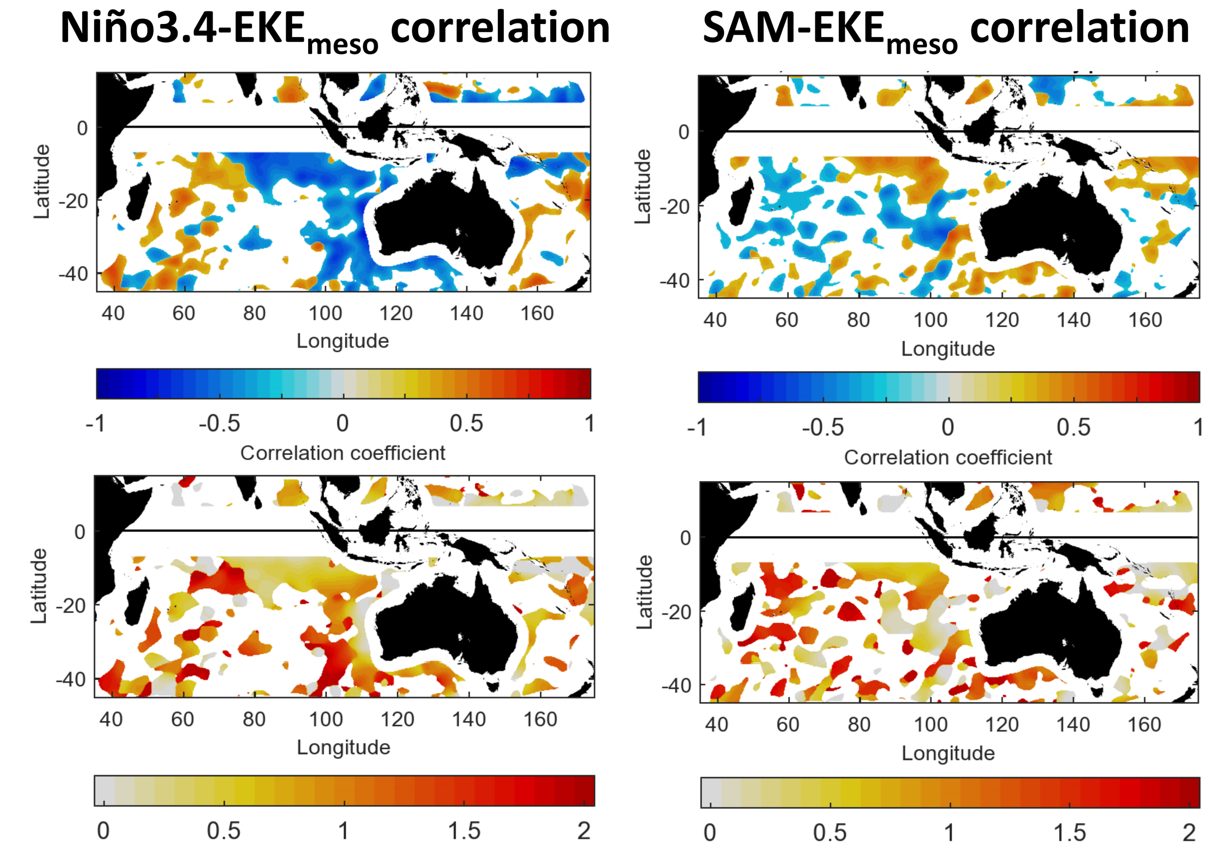

Figure 5. Upper maps indicate the optimum correlation coefficients of EKE_{meso} with the (left) Niño3.4 and (right) SAM indices, for EKE_{meso} lagging indices by 0-24 months, with 14-month LP filter. The lower maps indicate the optimum lag of the correlations.

EKE_{meso} propagation to interior

- Mesoscale EKE variations in the central and western SSIO are not robustly explained by ENSO, and only marginally correlated with SAM.
- However, EKE_{meso} anomalies in this region are led by EKE_{meso} anomalies SW of Australia, at ~45°-35°S.
- The mesoscale EKE signal propagates towards the northwest, most likely because of northwestward advection below the thermocline, and westward eddy & Rossby wave propagation.

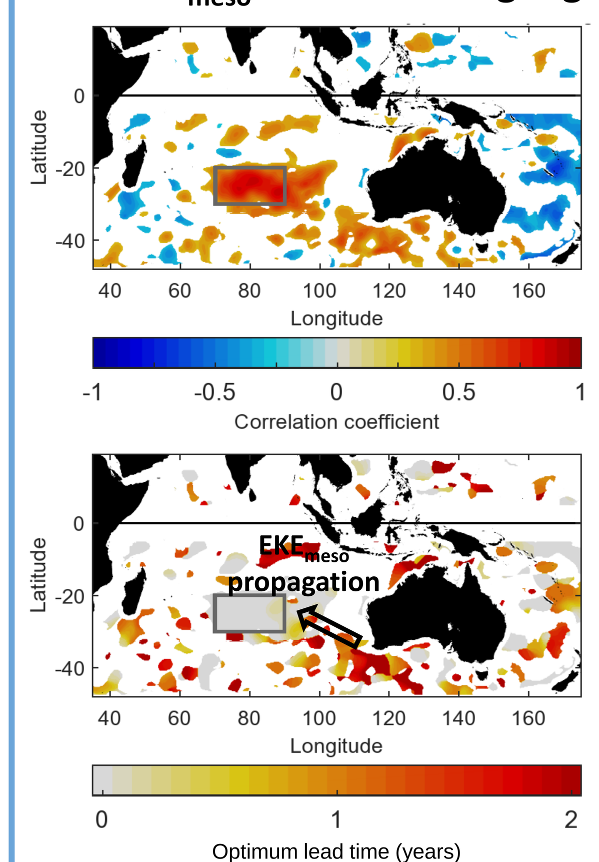

Figure 6. (Upper) Optimum correlation coefficients of EKE_{meso} averaged in the gray box with EKE_{meso} elsewhere in the domain; domain EKE_{meso} leads box-averaged by EKE_{meso} by 0-24 months, with 14-month LP filter. (Lower) The optimum lead time of the correlations.

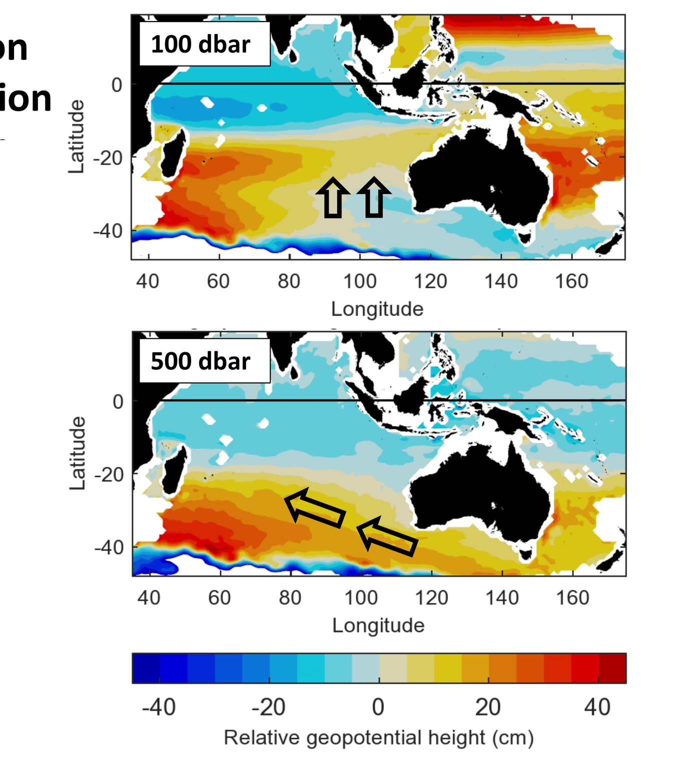

Figure 7. Long-term mean relative geopotential height at 100 and 500 dbar, computed from AVISO dynamic topography and World Ocean Atlas 2013 v2 density data.

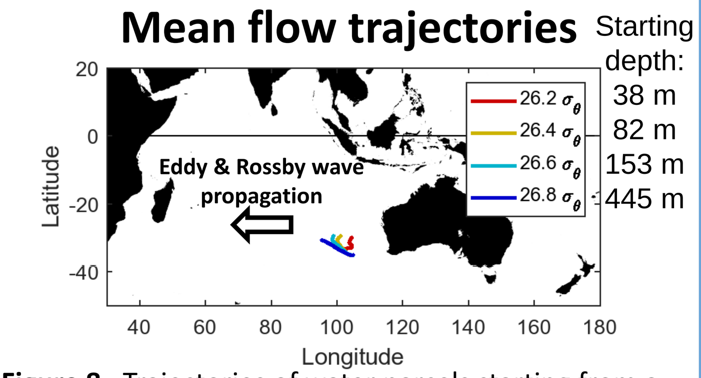

Figure 8. Trajectories of water parcels starting from a fixed geographic point, following long-term mean flow along isopycnal surfaces for a duration of 2 years. Data from AVISO and WOA13v2.

Conclusions

- Mesoscale eddy activity near the eastern boundary of the SSIO (the Australian coast) is closely related to SLA variability, reflecting the influence of the western tropical Pacific.
- In the SSIO eastern boundary region, mesoscale EKE is robustly negatively correlated with the Niño3.4 index. The ENSO influence controls eddy activity in the region more than previously shown, propagating ~20° into the interior.
- Mesoscale EKE anomalies propagate from higher latitudes near the SW corner of Australia, to the central and western SSIO, aided by northwestward advection below the thermocline.

References & Acknowledgments

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