Forcing of mesoscale eddy kinetic energy variability in the southern subtropical Indian Ocean, from remotely sensed altimeter and scatterometer data

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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.

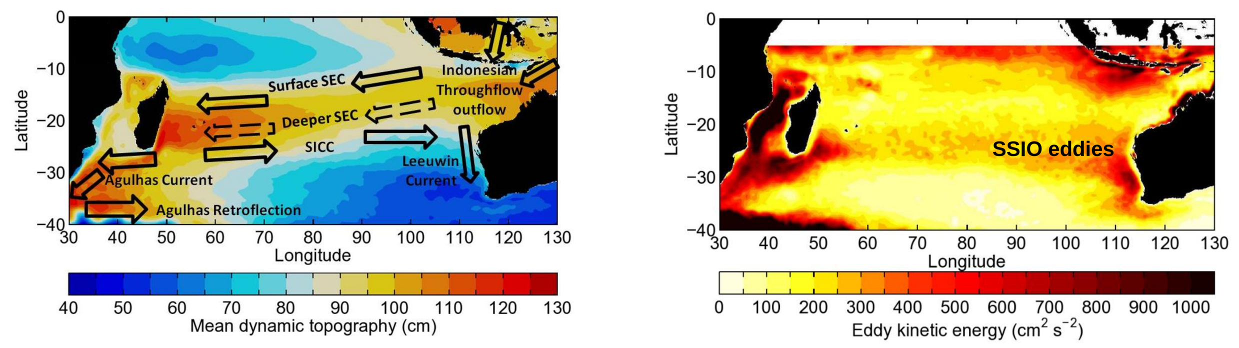

Figure 1. (left) Mean dynamic topography from AVISO, with currents annotated. (right) Time-mean eddy kinetic energy from AVISO.

Research questions

- **How does the interannual and decadal variability of eddy kinetic energy (EKE) in the SSIO propagate from the boundary to the interior?**
- **To what extent can this variability be explained by large-scale variations in the climate system?**

Method: Sea level decomposition

- Data used: AVISO gridded maps of sea level anomaly (SLA), with 1/4° spatial resolution
- 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}.

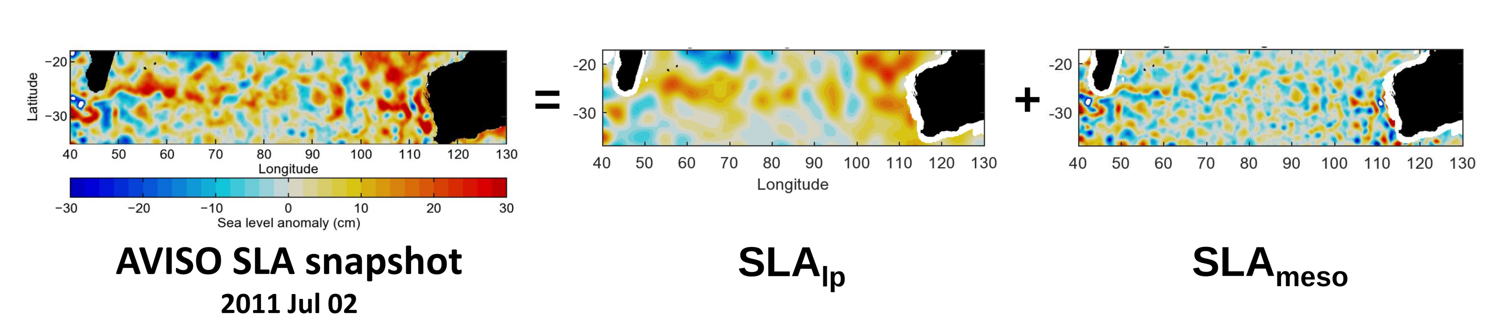

Figure 2. (left) Snapshot of AVISO sea level anomaly, 2011 Jul 02, with (center) low-passed sea level anomaly SLA_{lp}, and (right) the residual SLA field SLA_{meso} used to compute mesoscale EKE.

SLA as an indicator of EKE variability

- The variability of SLA values (and their spatial gradients) indicate changes in the currents where mesoscale eddies are generated.
- 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 western Pacific influence on the Leeuwin Current is mediated by planetary waves that propagate through the Indonesian Seas and along the coast.
  - Hence, 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.

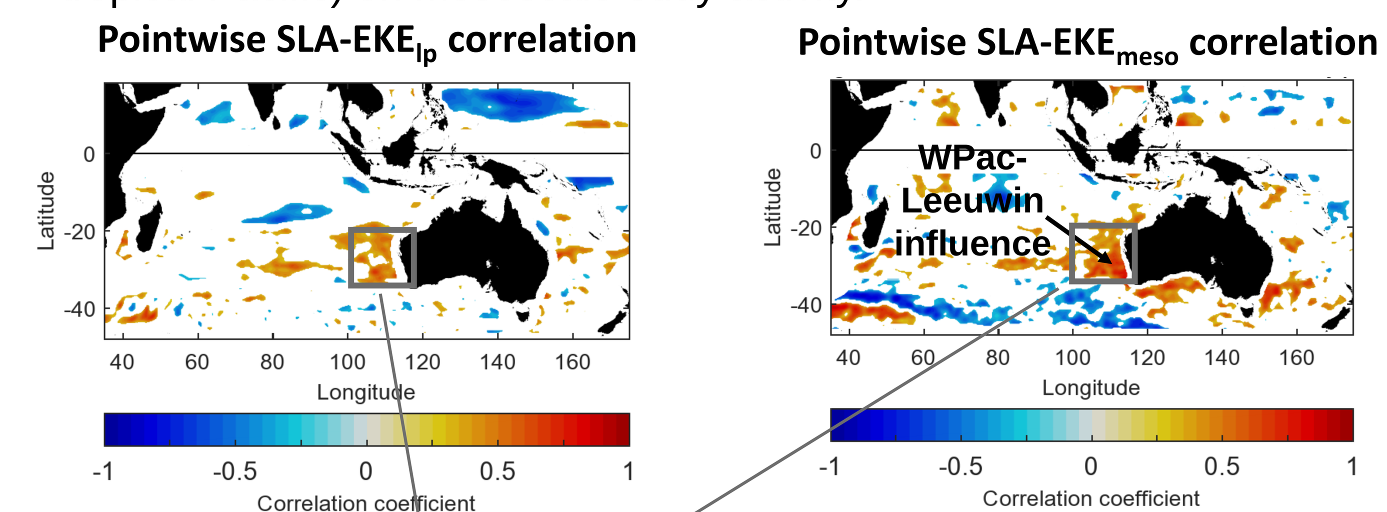

Figure 3. Pointwise zero-lag correlation of SLA with (left) EKE_{lp} derived from the low-passed SLA field, and (right) EKE_{meso} derived from the residual SLA field. All fields temporally low-passed for periods longer than 14 months.

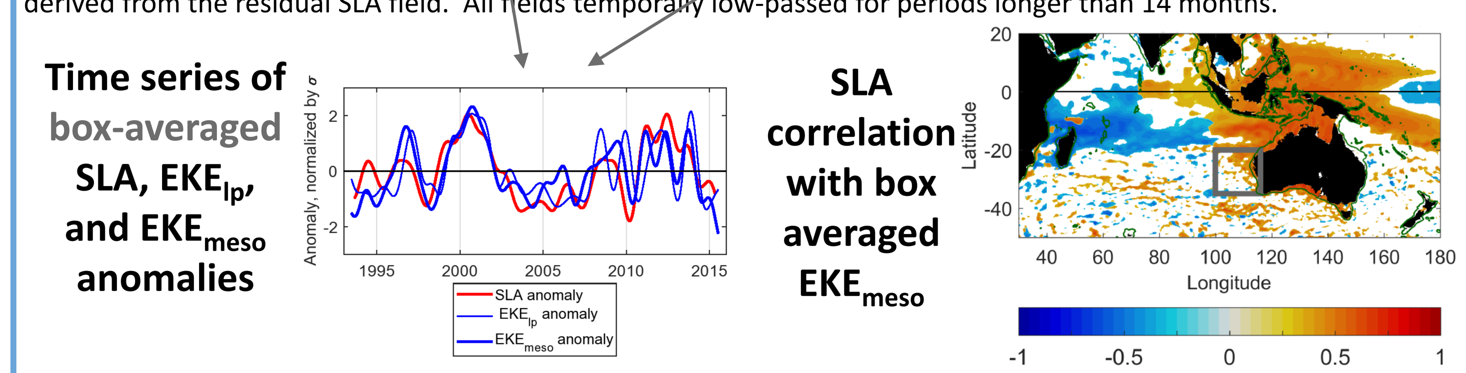

Figure 4. (left) Time series of box-averaged SLA, EKE_{lp}, and EKE_{meso} anomalies in the Leeuwin Current region, normalized by their standard deviations. (right) Optimum correlation coefficients of SLA with box-averaged EKE_{meso}, for SLA leading EKE_{meso} by 0-24 months.

Propagation of EKE

- Pulses of eddy activity propagate from east to west.
- Long Rossby wave activity diminishes south of 25°S.
- Mesoscale eddy activity diminishes in the interior south of 25°S, but remains robust in the eastern SSIO, with EKE anomalies generated at the boundary propagating to ~90°-100°E.

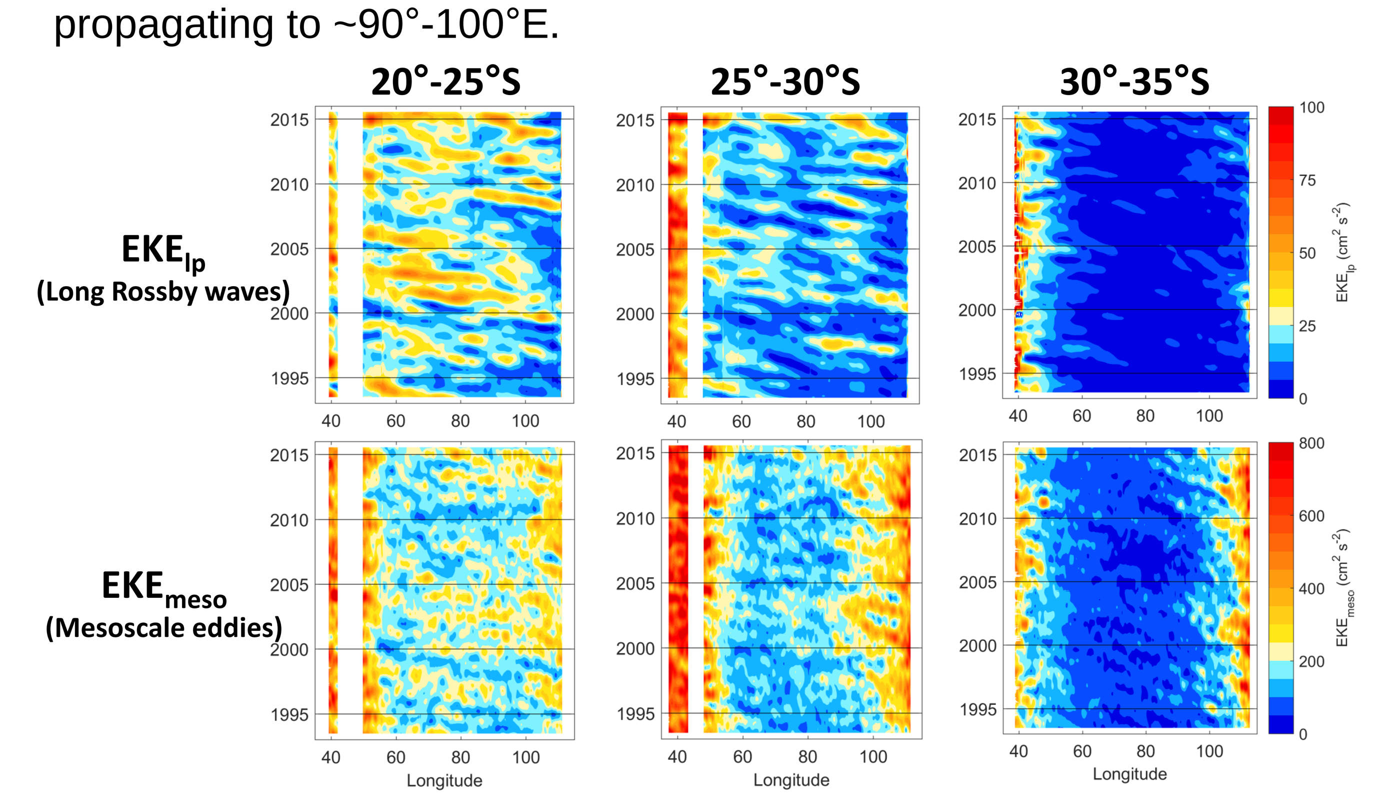

Figure 5. Hovmöller diagrams of EKE_{lp} and EKE_{meso}, meridionally averaged in 5° latitude bands, and temporally low-passed for periods longer than 14 months.

Climate modes and mesoscale EKE

- Jia et al. (2011) found a negative correlation between the Southern Annular Mode (SAM) index and box-averaged SSIO EKE, as well as a negative correlation between the Niño3.4 index and SSIO EKE. (La Niña → more eddy activity)
- Our analysis of the spatial distribution of mesoscale EKE indicates that the Niño3.4 index has consistent negative correlations with EKE_{meso} near the eastern boundary, with EKE_{meso} lags increasing away from the coast.
- The SAM index has patchy, mostly negative correlations with SSIO EKE_{meso}; EKE_{meso} lags SAM by 0-18 months.

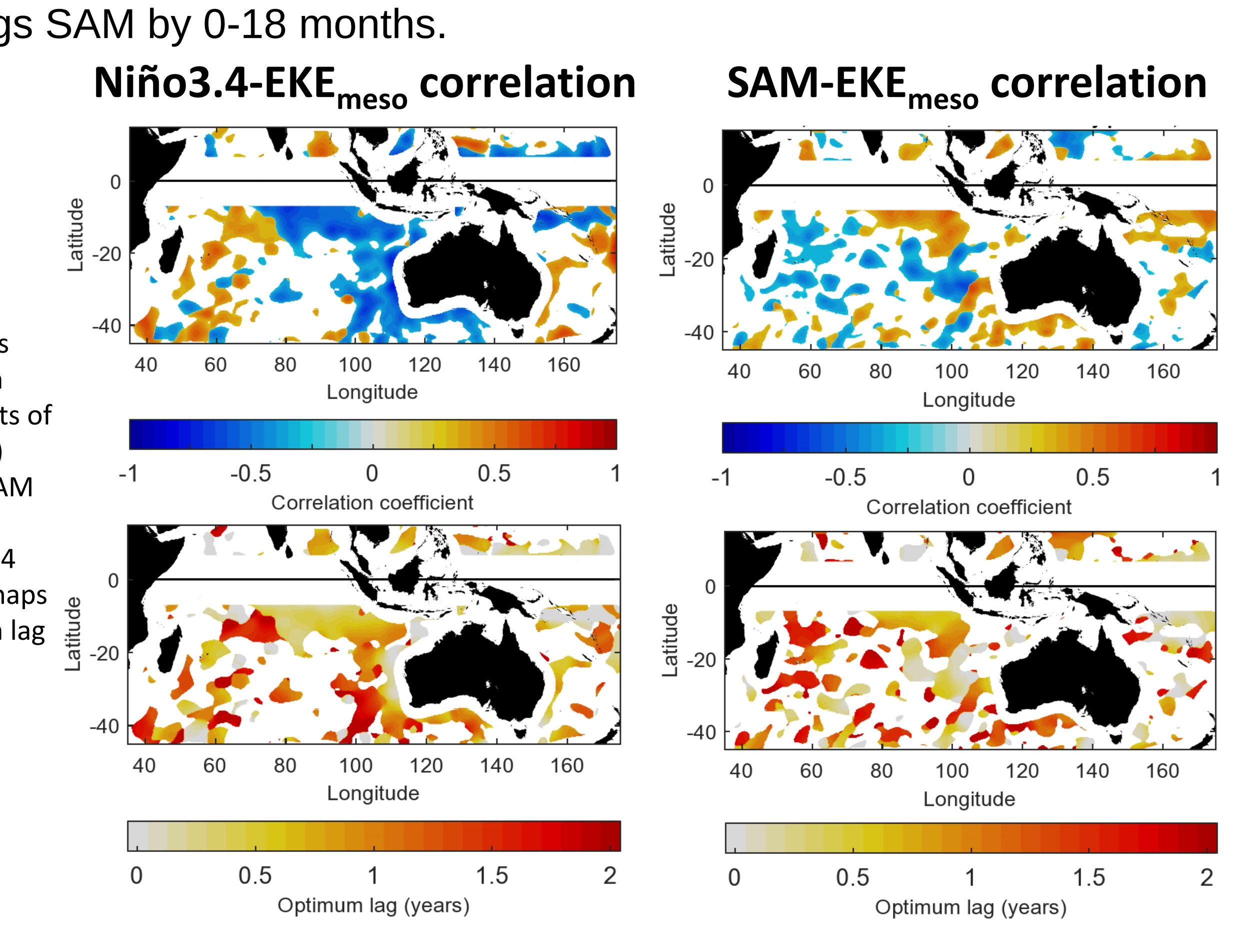

Figure 6. Upper maps indicate the optimum correlation coefficients of EKE_{meso} with the (left) Niño3.4 and (right) SAM indices, for EKE_{meso} lagging indices by 0-24 months. The lower maps indicate the optimum lag of the correlations.

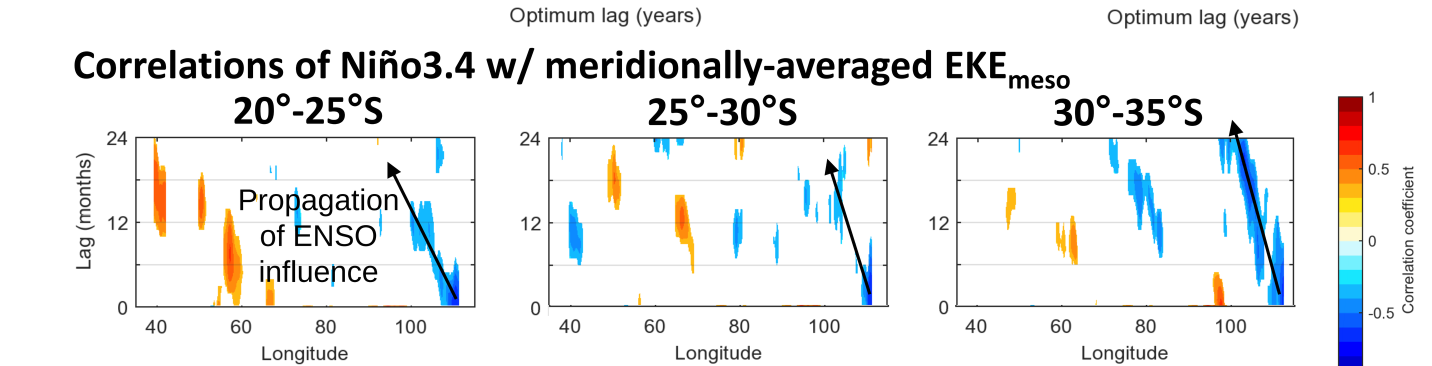

Figure 7. Lagged correlations of Niño3.4 index with EKE_{meso} meridionally averaged in 5° bands.

Conclusions and ongoing/future work

- 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.
- In the central and western SSIO, mesoscale EKE is weakly negatively correlated with the Southern Annular Mode index.
- Ongoing/future work: examine effects of vorticity gradients and wind forcing on EKE_{meso} in the interior, and analyze eddy generation using energy budgets calculated from ocean GCM output.

References & Acknowledgments

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