SYMPOSIUM OP'24
ADVANCING OCEAN PREDICTION SCIENCE FOR SOCIETAL BENEFITS

Theme #5.2 (Data Assimilation)

Quantifying Unconstrained Scales in a Global Ocean Analysis

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Overview

Ocean analysis systems have features that are resolved by the ocean model, but can not be constrained by the observational network. Mesoscale eddies are a good example of this. For the (~¼°) eddy-permitting model used in this study, mesoscale eddies are partially resolved, but the constellation of altimeters used to constrain the eddies to observation may not be sufficient to properly place smaller eddies at the correct place and time. This is unconstrained variability. An ensemble of ocean analysis can be used to quantify this unconstrained variability – and through the ensemble mean, remove it.

Ensemble System

- Based on ECCC GIOPS system (Smith et al. 2016).
- Members are individual copies of GIOPS restrained by identical obs.
- Spread comes from differing external forcing applied to background model state from day 1 of GEPS ensemble forecast (Peterson, 2022).
- Additional spread generated by SPP and SPPT stochastic parametrizations (Storto and Andriopolous, 2021).

Unconstrained Scales in Ocean Analysis

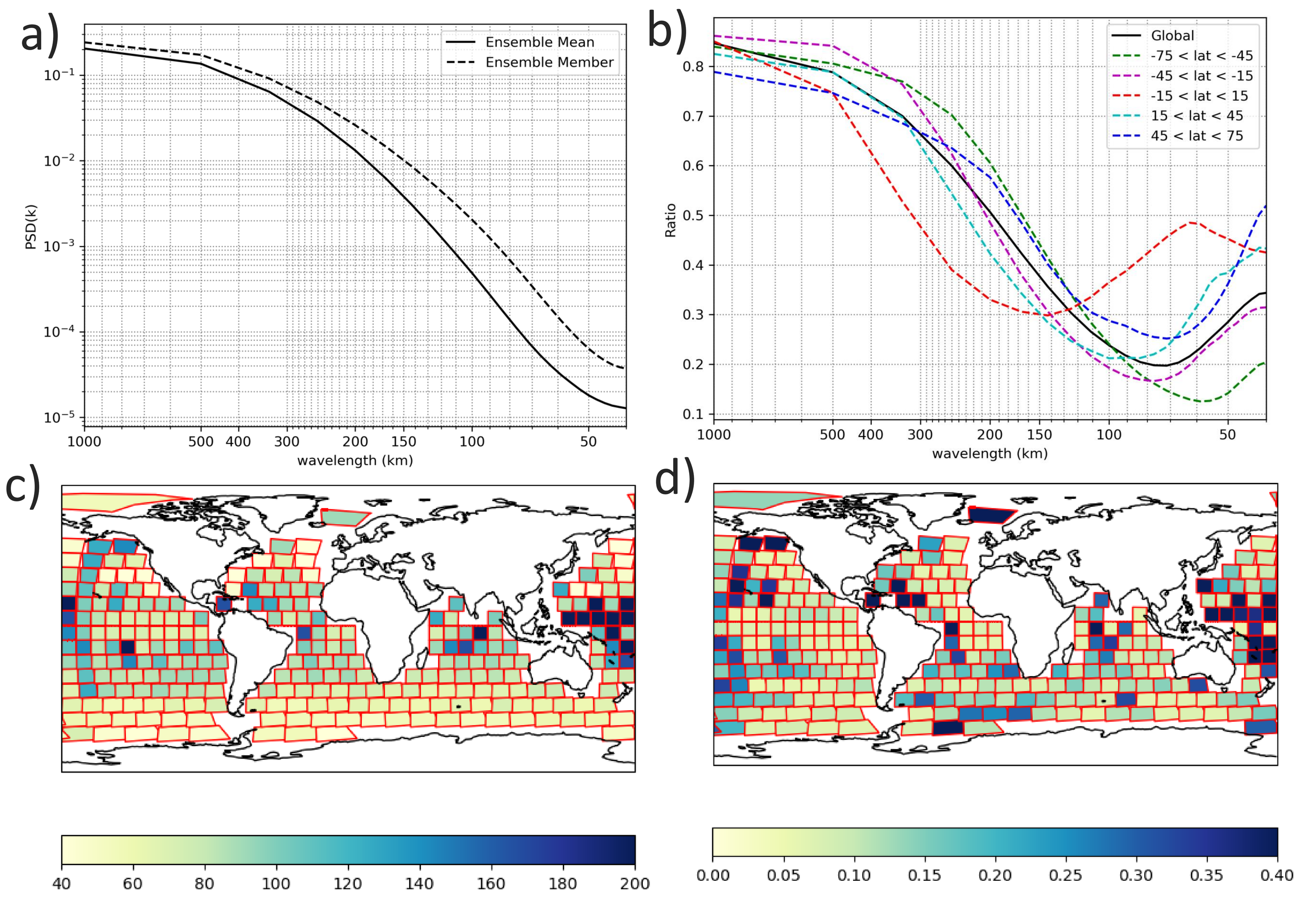

Figure 1: Power Spectrum of ensemble mean versus ensemble members for 15m velocities. a) Log-log plot of power spectral density (PSD) of ensemble mean (solid line) versus average PSD of members (dashed). PSD is calculated as average PSD along x-grid and along y-grid components of velocity here being displayed as a global average (average over 256 boxes displayed in c). b) Ratio of PSD of ensemble mean to ensemble members. Separate lines are displayed for latitudes as defined by color coding. c) Value of length scale for the minimum ratio are shown as color shading for each box over which the PSD's are calculated. d) Value of fraction of power remaining in the ensemble mean in each box (minimum ratio plotted in b).

Conclusions

- Unconstrained lengthscales – scales resolved by model resolution, but unconstrained by observation are present in ocean analysis.
- These scales can be removed in the ensemble mean of an ensemble system as they would be randomly generated by members.
- For unconstrained scales in ocean near-surface currents, this would be related to mesoscale eddy activity, as is exemplied by the latitudinal Rossby radius dependence of the unconstrained lengthscales in the system analysed – **Figure 1**.
- Removing these unconstrained scales improves the error characteristics of the system – **Figure 3**.

References

- Aijax et al. 2023: https://doi.org/10.1016/j.ocemod.2023.102241
- Jacobs et al. 2021: https://doi.org/10.1016/j.asr.2019.09.018
- Peterson et al. 2022: https://doi.org/10.1002/qj.4340
- Smith et al. 2016: https://doi.org/10.1002/qj.2555
- Storto and Andriopoulous 2021: https://doi.org/10.1002/qj.3990

Quantifying Constrained Scales

- Constrained Scales in Ocean Forecasting (Jacobs et al, 2021).
- Unconstrained scales are randomly generated in each ensemble member and therefore suppressed by the ensemble mean assuming each member's variability is independent.
- Unconstrained scales should be present in PSD of ensemble members, but absent in PSD of ensemble mean (PSD = Power Spectral Density).
- **Figure 1a** shows suppressed power in ensemble mean at shorter lengthscales.
- With a well defined minimum in the ratio of the two power spectrums at the unconstrained length scale – **Figure 1b**.
- This minimum varies with latitude (Rossby radius) – **Figure 1b/c**.
- Unconstrained scales in the ocean are independent of unconstained scales coming from atmospheric forcing shown in **Figure 2**, or scales generated by SPP and SPPT processes with coherence length scales of 650km and 300km, respectively.

Unconstrained Scales in Forcing Atmosphere

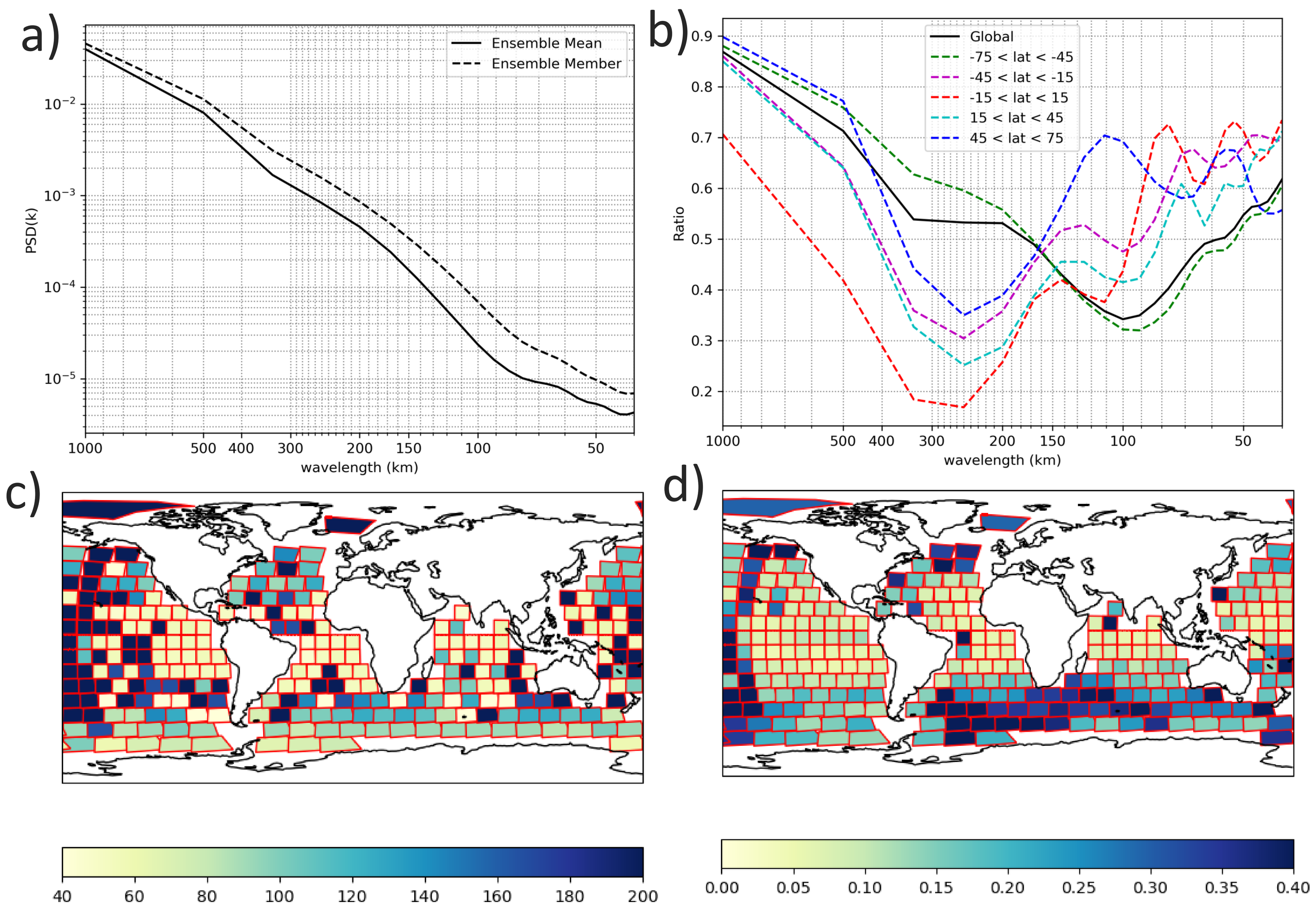

*Figure 2: Power Spectrum of ensemble mean versus ensemble members for applied wind stress from atmosphere. Individual plots as in **Figure 1**, except for wind stress.*

RMSE in 15m Velocities

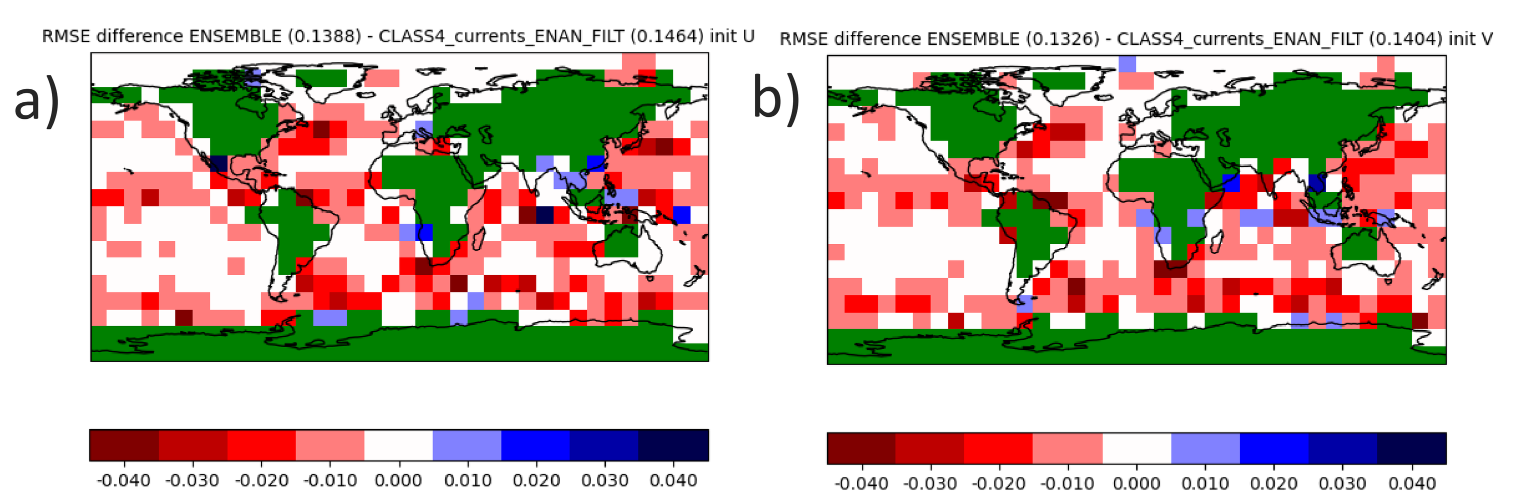

Figure 3: RMSE error improvement of ensemble mean relative to control member (negative red values are lower rmse) of 15m velocities for a) westward and b) northward components of velocities. Model and observation have been compared at observation location and then averaged over 10° degree bins. Observed velocities are from the motion of drifting buoys (Aijaz et al, 2023).

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CONCEPTS

Ocean Predict In partnership with unesco Intergovernmental Oceanographic Commission

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