Assessment of Subsurface Velocity and Variability in Assimilative Models in the Gulf of Mexico

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The deep circulation in the Gulf of Mexico has been shown previously to be highly energetic and to impact the time-dependent evolution of the Loop Current. Furthermore, the offshore oil and gas industry and other stakeholders need better prediction of currents at all depths in their working range (as deep as 3000m). Therefore, it is important to know how well numerical models are simulating subsurface velocity fields. The models considered here assimilate observations such as satellite-measured sea-surface height and profiling float T-S data. However, they do not currently assimilate subsurface float displacement-derived velocities, which makes these observations well-suited for model validation. To this end, we have begun to compare subsurface velocity in the assimilative (reanalysis) models with contemporaneous observations from deep floats. Such analyses could help determine which assimilative models reproduce subsurface velocity better and why.

We compare subsurface float observations to ocean fields in the Gulf of Mexico from two widely used global ocean reanalyses—GOFS (HYCOM+NCODA, 1/12°) and GLORYS12 (NEMO, 1/12°)—together with higher-resolution HYCOM-TSIS regional reanalyses at 1/25° and 1/100°. This setup allows us to evaluate the consistency between global products and to investigate how increasing horizontal resolution in the regional model influences the representation of the deep mean circulation and eddy kinetic energy (EKE) in the Gulf.

Research Questions:

- How well do assimilative models simulate observed deep velocity?
- Are some regions better modelled than others?
- How well are phenomenological events such as deep eddies under the Loop Current replicated?

Observations

Two observational data sets were used:

> Acoustically tracked RAFOS floats 2011-2015, 1-day temporal resolution, 1500-2500 m

> Argo floats 2019-2025, 5-day temporal resolution, 1400-1600 m

Float velocity observations were gridded onto 0.25-degree grid, with 0.5 x 0.5 degree overlapping boxes to provide spatial smoothing of the final fields. Degrees of freedom were found using the decorrelation time scale of 5 days. Only grid points with DOF greater than 5 are shown.

Statistical significance of each gridded velocity vector was found using the Student t test, where velocities that were significantly different than 0 at the 95% confidence level (p=0.05) are plotted in black, and those that are not are plotted in red.

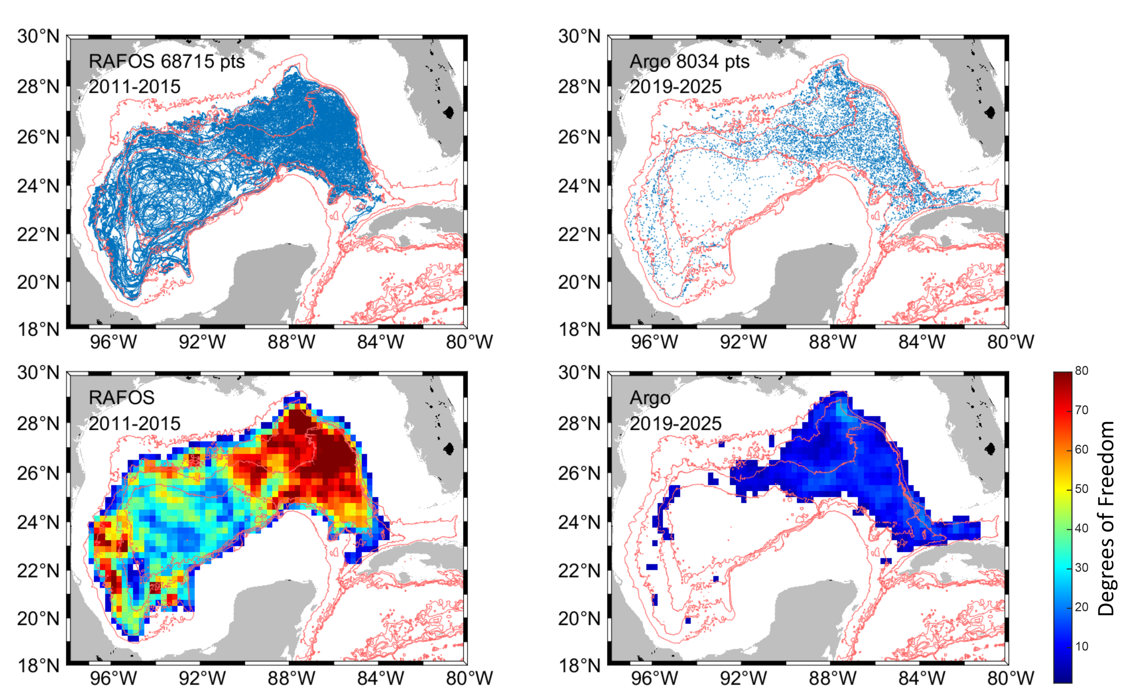

Figure: Data distribution (top row) and degrees of freedom (bottom row) of the observations from the 2011-2015 (left column) and 2019-2025 (right column) periods.

How do deep mean velocity and EKE differ across models?

Focusing on the earlier (RAFOS) observational period, the figures at right show full model means (all model data within the 2011-2015 observational period) of velocity and EKE , in depth range 1500-2500 m.

Higher resolution models (HYCOM-TSIS regional reanalyses at 1/25° and 1/100°) show higher EKE under the Loop Current and somewhat more detailed structure to the mean flow.

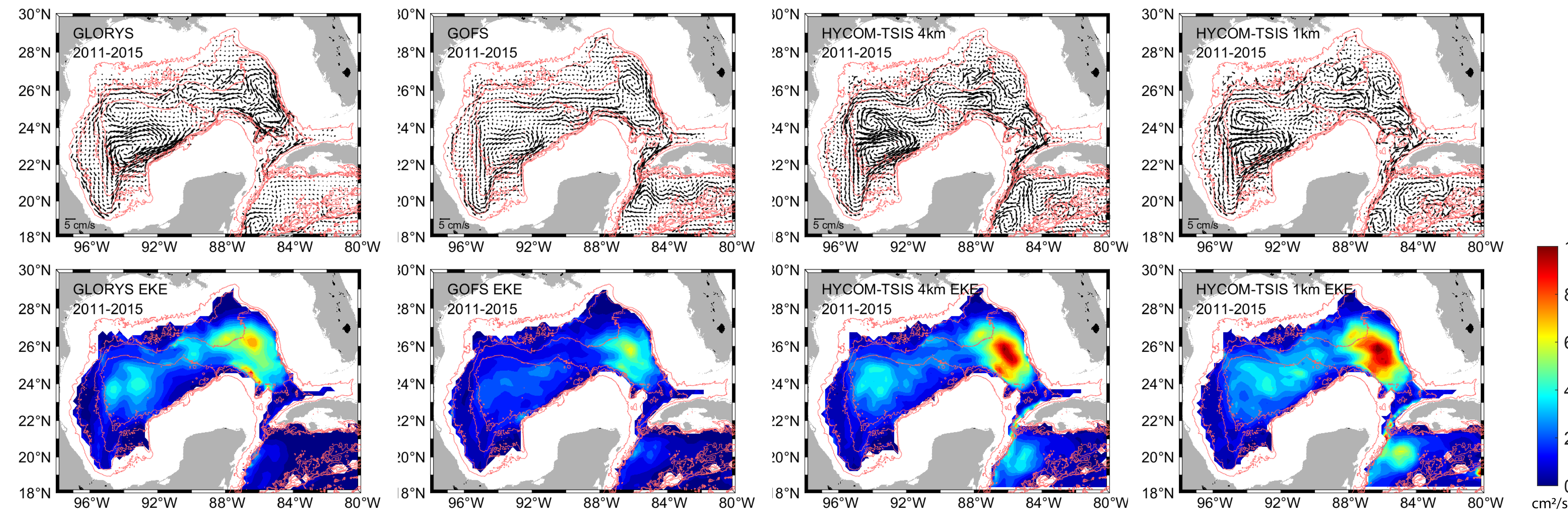

Figure: 2011-2015 gridded model mean velocity (top row) and EKE (bottom row) for the four assimilative models, from left to right: GLORYS 1/12°, GOFS 1/12°, HYCOM-TSIS 1/25°, and HYCOM-TSIS 1/100°.

How well do assimilative models match deep velocity observations?

We subsampled model output at time, position, and depth of each float observation, to ensure an **'apples-to-apples'** comparison. The subsampled model data were processed similarly to the observations; only grid points with DOF>=5 are included, and velocity vectors are color coded black if significantly different than 0 at the 95% confidence level.

Here we highlight two subsampled models, GLORYS 1/12° and HYCOM-TSIS 1/100° during the 2011-2015 observational period, when more plentiful observations yield higher degrees of freedom across the gulf. In the eastern Gulf, where the DOF is 60 or greater, HYCOM-TSIS 1/100° better captures the higher EKE measured by the floats. GLORYS 1/12° appears to best replicate the tripole mean velocity structure under the Loop Current.

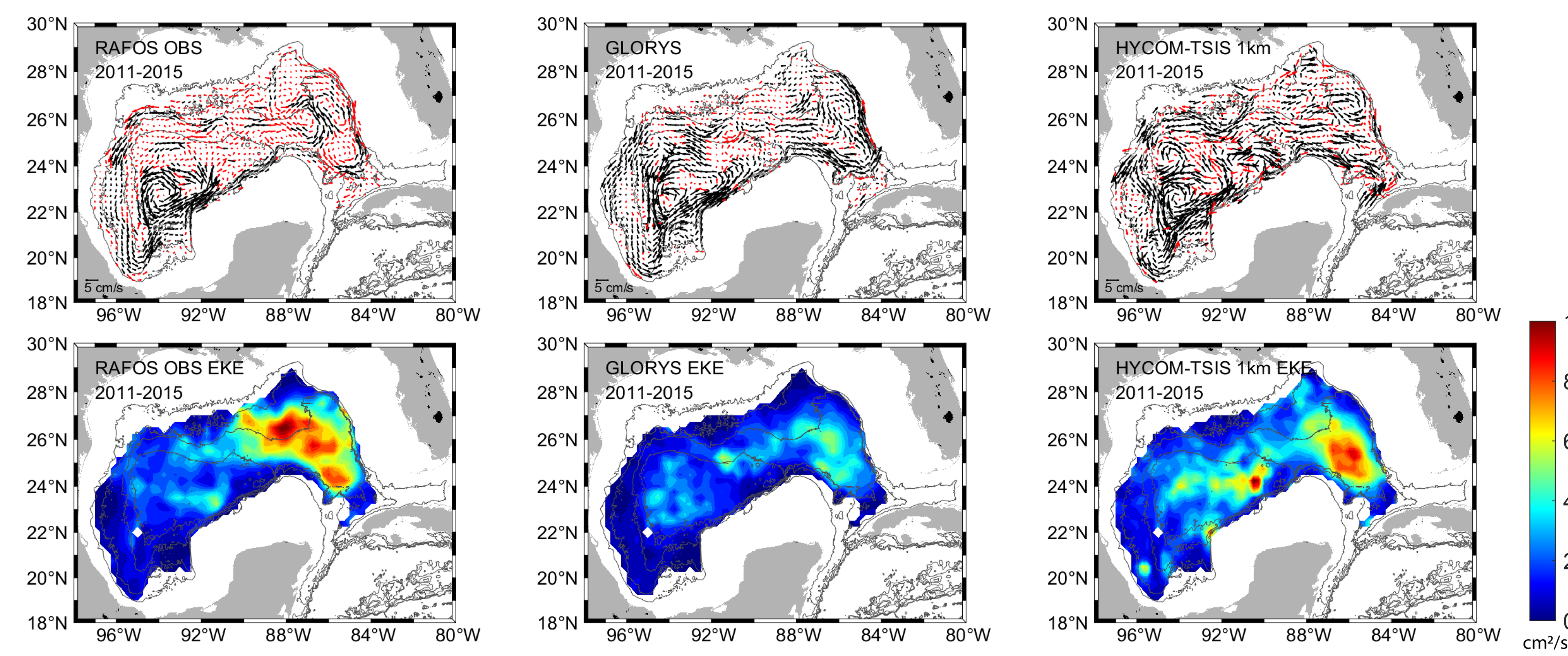

Figure: Gridded mean velocity (top row) and EKE (bottom row) from 2011-2015 observations (left), subsampled GLORYS 1/12°(middle) and HYCOM-TSIS 1/100° (right) models.

What are the EKE differences during the two time periods?

In contrast to the 2011-2015 observational period, during the 2019-2025 period in the eastern Gulf, the subsampled high resolution model (HYCOM-TSIS 1/100°) EKE levels and spatial distribution better replicate the observed EKE. Over the Mississippi Fan, the observed EKE is generally lower during this period and the high resolution model EKE is higher.

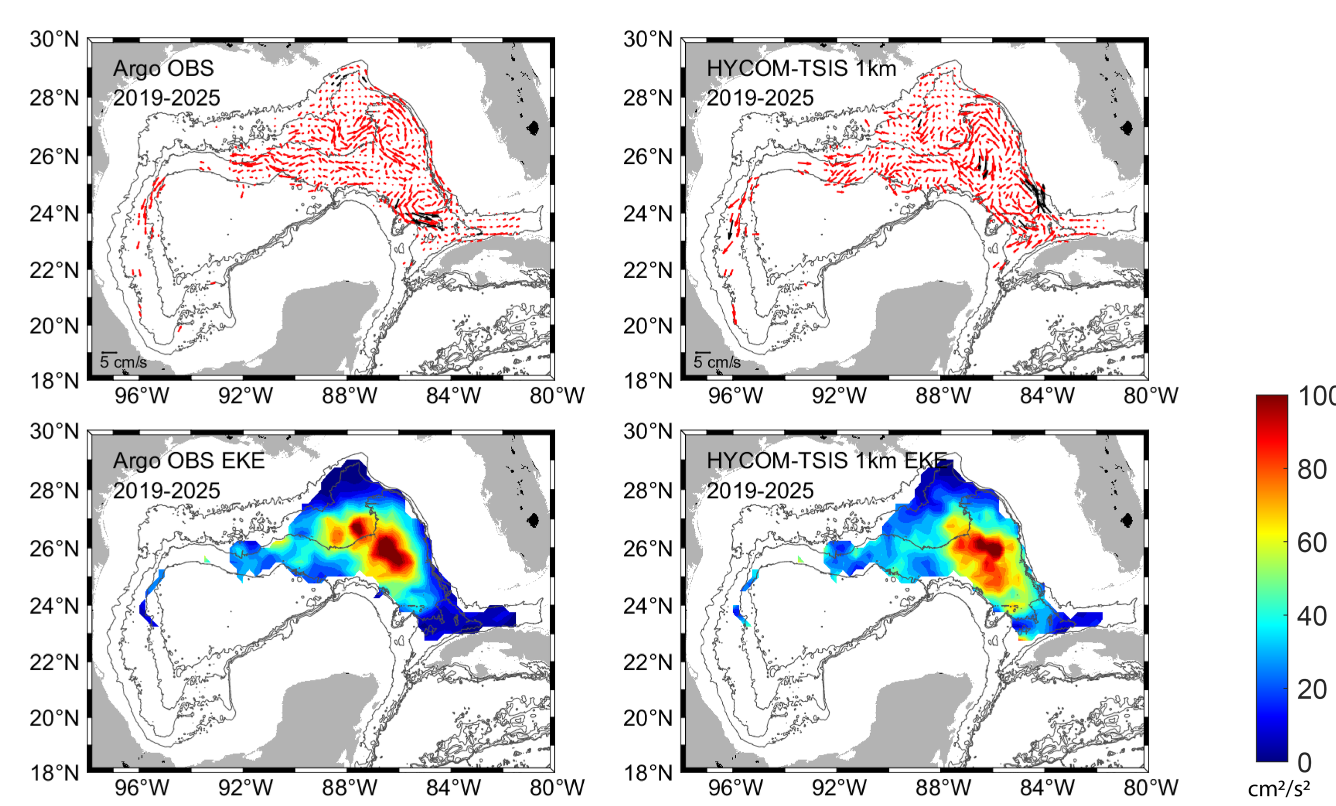

Figure: Gridded mean velocity (top row) and EKE (bottom row) from 2019-2025 observations (left), subsampled HYCOM-TSIS 1/100° model (right).

Next Steps

Explore why EKE differences exist between subsampled model and observation data in well-sampled regions. For example, why is there high EKE over the Mississippi Fan in the 2011-2015 period that is not represented in the models? Our next step will be to calculate EKE from the observations using different mean fields, e.g. the full model mean.

Explore why there are differences between observational periods. Why is there higher EKE observed over the Mississippi Fan during the 2011-2015 period than the 2019-2025 period? Is this due to float resolution differences? Or was the Loop Current more active over the Fan, exciting deep variability there, during the earlier observational period?

Quantitatively evaluate model-observation data set agreement.

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