How Do Strong M2 Internal Tides Affect Mesoscale Predictability in the Philippine Sea?

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Introduction

- Numerical modeling of the ocean is complex as energy exists at many different, interacting temporal and spatial scales.
- The atmospherically-forced eddying ocean circulation is typically simulated without tides.
- How do the tides affect the mesoscale dynamics?

For ocean prediction, data assimilation techniques are used to constrain ocean circulation models using observational data.

- Unresolved internal tides may be a significant component of the observations.
- How do the non-deterministic internal tides (Kerry et al., 2014) affect the value of assimilated observations?

Unresolved internal tide SSH expression means the specified SSH errors must be higher.

- Internal tides can cause significant heating of isopycnals (over 100 km near the Luzon Strait in the Philippine Sea).
- Sub-surface observations sample this but in most cases (e.g., Argo floats, gliders, CTDs) cannot resolve the internal tide variability in the observations around the thermocline in constraining state estimates.

- Does including internal tides in the circulation model improve predictability of the sub-tidal circulation?

The Philippine Sea has energetic internal tides (e.g., Alford et al., 2011) and dynamic mesoscale circulation (Fig. 2, Qiu and Chen, 2010), making it a challenging region to predict and an ideal area to study the interactions of these processes in the ocean.

Methods

Model Description

- Regional Ocean Model System (ROMS), free-surface, hydrostatic, primitive equi. model.
- 8-km horizontal resolution with higher resolution of 4.5 km over the Luzon Strait.
- 25 vertical layers.
- Outer domain.
- Boundary and initial conditions from the Mercator general ocean circulation model.
- Atmospheric forcing from National Center for Environmental Prediction (NCEP) atmospheric model.
- Nested domain.
- Data assimilation performed on the inner domain.

Data Assimilation

- Solve for increments to model initial conditions, boundary conditions and forcing that minimize the difference between modeled solution and all available observations, over the assimilation window (4D).
- Difference between the obs. (y) and the NL model prior (x0), mapped to obs. space: (H - y - x0).
- Cost function, $J$, is a function of increments in model initial conditions, boundary conditions and forcing $\delta x = x - x_0$,

$$J = \frac{1}{2} \sum_{i=1}^{n} (x_i - x_0)^T (R + H_i - H_i)^T (x_i - x_0) + \frac{1}{2} \sum_{i=1}^{m} (H_i - H_i)^T (x_i - x_0)$$

- $R$, background error covariance; $P$, observation error covariance; $H$, NL, where $H$ is a linearization of $\frac{1}{2} \sum_{i=1}^{n} (x_i - x_0)^T (R + H_i - H_i)^T (x_i - x_0) + \frac{1}{2} \sum_{i=1}^{m} (H_i - H_i)^T (x_i - x_0)$

- Find x that minimizes $J(z)$ (with subsequent interations of the TL and ADJ models).

- The Analysis makes use of the dynamical connections between the model fields, that such observed variables propagate information to unobserved, dynamically-linked variables.

Observations - 2010

- Sea Surface Height (SSH), 4-day gridded (1/3 x 1/3 degree) mean sea level anomaly data.
- Sea Surface Temperature (SST).
- Salinity from the Oceanic Geosat Follow-On (OGFO) mission.
- Temperature and salinity from the Salinity, Temperature, Velocity (STV) moorings.
- Temperature and salinity from the DOOSA (depth of oceanographic simulation) CTDs.
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Results

Sea Surface Height Predictions

- 7-day assimilation windows, TL assimilation valid.
- Background error covariance is specified for forecast errors from preliminary year-long assimilation.
- Observe error covariances are the max of:
  - Instrument error
  - Errors of representativeness, "Super obs."
  - Typical variability.

- TPID is removed from SSH obs. for Twin 2.
- SSH error includes 3cm AVISO error for Twin 1, and AVISO error plus error due to not resolving the internal tides for Twin 2.
- SSH errors greater for Twin 1 and 0.04 (2.5°C)
- Sub-surface errors greater for Twin 2 to account for the unresolved internal tide variability.

Sea Surface Temperature Predictions

- How do the non-deterministic internal tides impact the models given observational data.
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Sub-Surface Temperature Predictions

- Temperature at 300m - depth of greatest variability.
- High frequency (> 48 hrs)
- Low frequency (< 15 hrs)

Conclusions

- The future impact of 2010 internal tides on the mesoscale is not resolved.
- High Freq. errors in Twin 2 are the difference between the "TRUE STATE" and the TPXO tidal SSH expression.

- Low Frequency (mesoscale) Sea Surface Height predictions are worse when the tides are not resolved.
- Partly in the SCS where the SSH obs. errors are high (Fig. 4), and in the dynamic Kuroshio.
- Greater adjustments are made in the analysis for Twin 1 as the specified obs. errors are lower.
- High Freq. SSH error for Twin 2 is the difference between the "TRUE STATE" and the TPXO tidal SSH expression.

- Low Frequency (sub-surface) temperature errors are worse when tides are not resolved, particularly in the Kuroshio and SCS regions.
- Skill is greatest in the Phl. Sea and lowest in the Kuroshio region.
- The Twin 2 SST Forecast is NOT better than Persistence in the Kuroshio and SCS regions.

References