Baroclinic Tides Estimated from SWOT Science Mission Data

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Overview

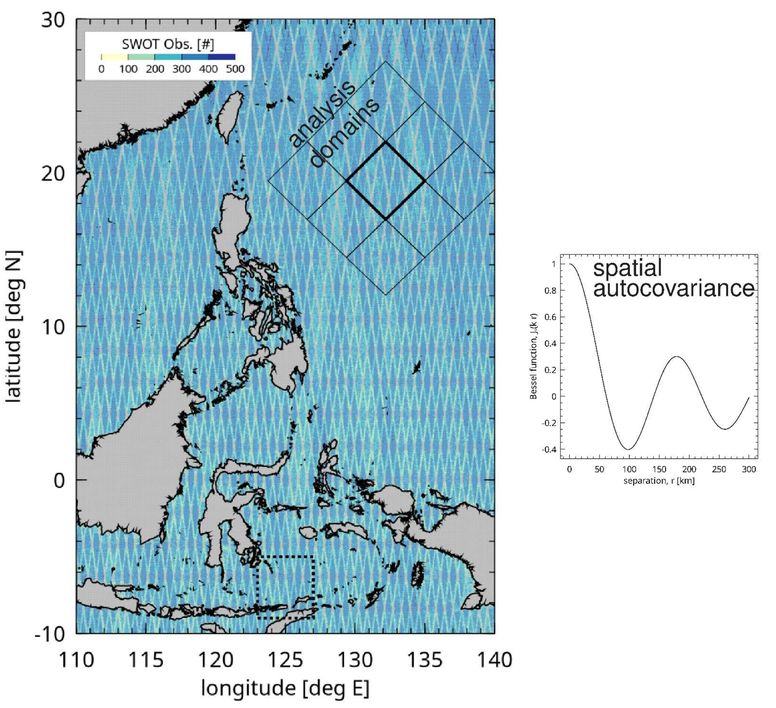
Goal: Obtain more accurate maps of the internal tides (1) to improve tidal prediction (e.g., to make better tidal corrections for altimetry), and (2) to enable studies of tidal dynamics (e.g., to infer tidally-driven mixing).

Approach: Perform harmonic analysis of the SWOT Science Mission data as follows: (1) remove the best available predictions of tidal and non-tidal SSH and instrument noise, (2) perform harmonic analysis of the spatially-binned residual time series, and (3) optimally smooth the residual harmonic constants via comparison with independent data, and (4) restore the HRET8.1 harmonic constants to obtain the newly-estimated harmonic constants.

Questions answered on this poster:

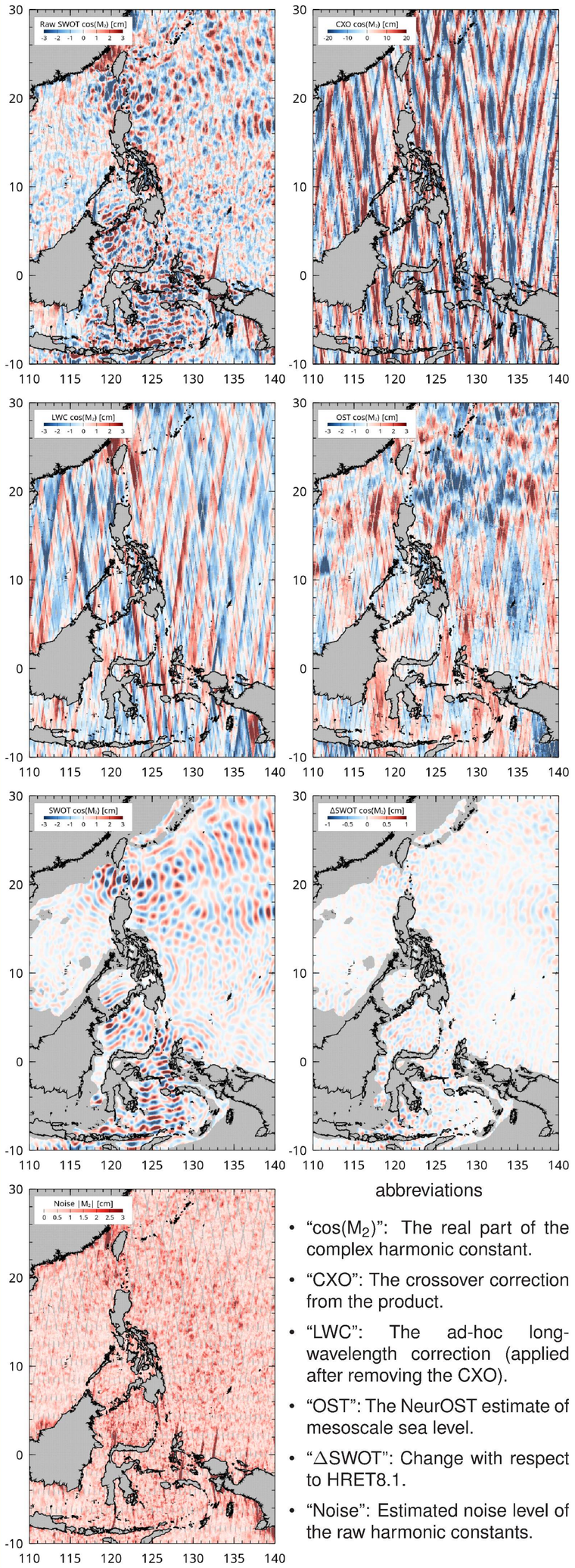
- How to determine the optimal degree of smoothing of the SWOT-derinved harmonic constants? (answer: Compute explained variance with respect to CryoSat-2 observations.)
- How to fill the data voids between SWOT swaths? (answer: Use objective analysis for mapping.)
- How to reduce the impact of non-tidal mesoscale SSH and instrument noise? (answer: Subtract the NeurOST SSH esimtate and perform long-wavelength adjustments prior to harmonic analysis of SWOT time series.)

Implementation Details



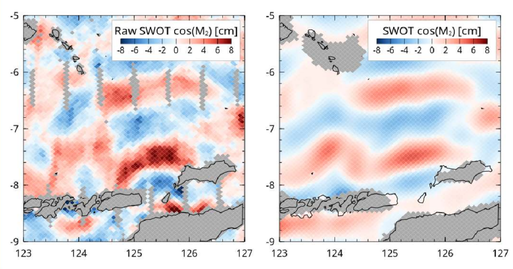
- The long wavelength correction uses a low-order auto-regressive moving average in the along-track direction; and bias, tilt, and curvature terms within each 1/2-swath.
- Spatial analyses (binning, mapping, smoothing) are based on a HealPix tesselation of the sphere. After the long wavelength correction, all subsequent data analysis occurs on HealPix grids.
- Objective analysis (the mapping algorithm) is localized within 1/3-overlapping 800-km analysis domains (see above left) and 6-km pixels.
- The spatial covariance used in the objective analysis is a Bessel function (see above right), the covariance of a random field of propagating plane waves. The wavelengths are computed from the phase speeds of mode-1 and mode-2 waves based on World Ocean Atlas climatological stratification and GEBCO water depth.
- To make the linear algebra tractable, the objective analysis algorithm is posed as a ridge-regression problem using about 4000 spatial basis functions to fit 25000 observations in the analysis domains.
- The degree of smoothing is optimized using CryoSat-2 data within the central 1/3 of the anlysis domain.
- The global solutions are obtained by weighted averaging of the overlapping domains using Wendland's continuously differentiable radial basis functions.

Western Pacific & Indonesian Seas



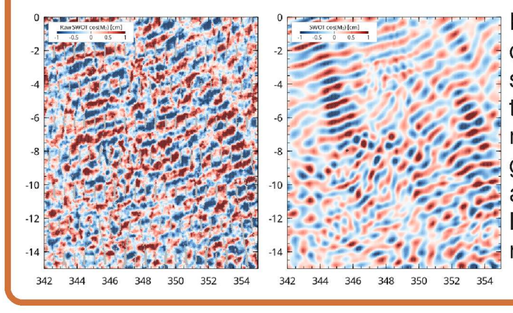
- "cos(M_2)": The real part of the complex harmonic constant.
- "CXO": The crossover correction from the product.
- "LWC": The ad-hoc long-wavelength correction (applied after removing the CXO).
- "OST": The NeurOST estimate of mesoscale sea level.
- "ΔSWOT": Change with respect to HRET8.1.
- "Noise": Estimated noise level of the raw harmonic constants.

Banda Sea



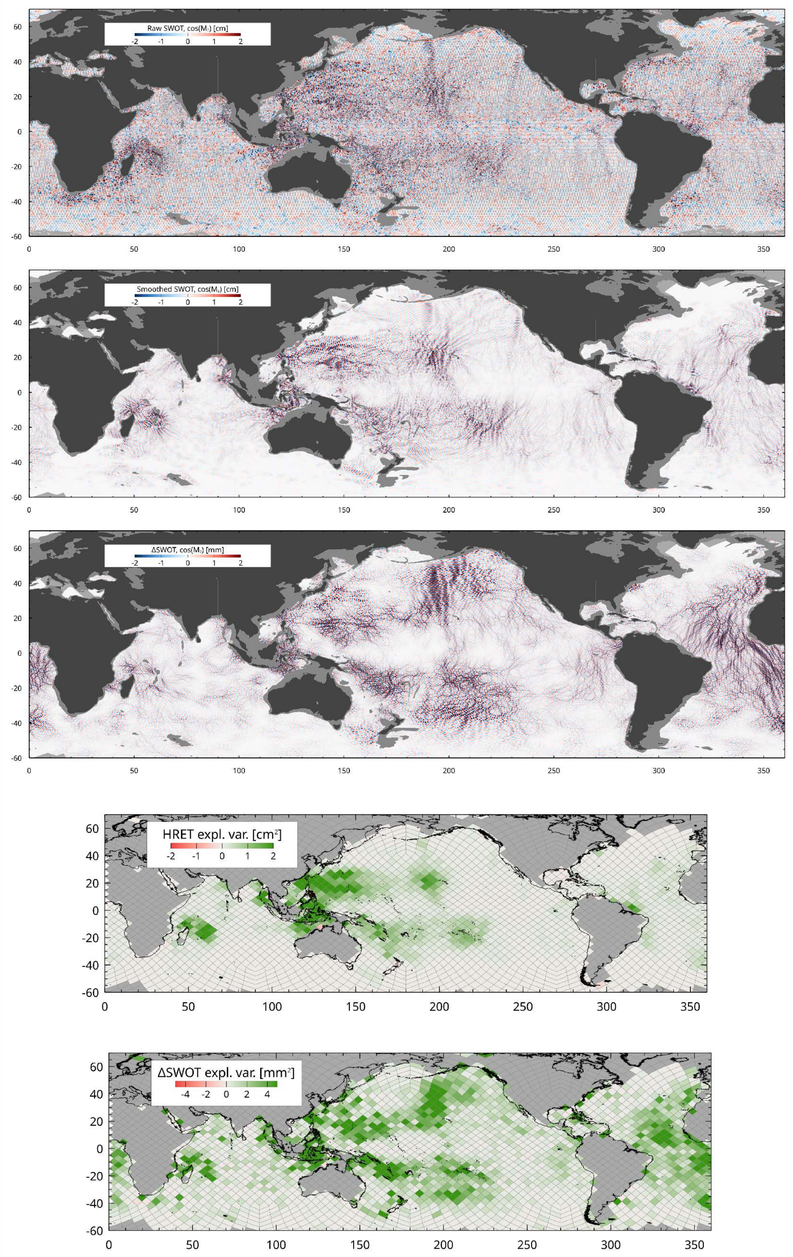
Raw SWOT harmonic constants (far left) provide a detailed image of waves in the southern Banda Sea. The details cannot be validated with CryoSat-2, so the *best estimate* is blurry (near left).

Eastern Tropical Atlantic



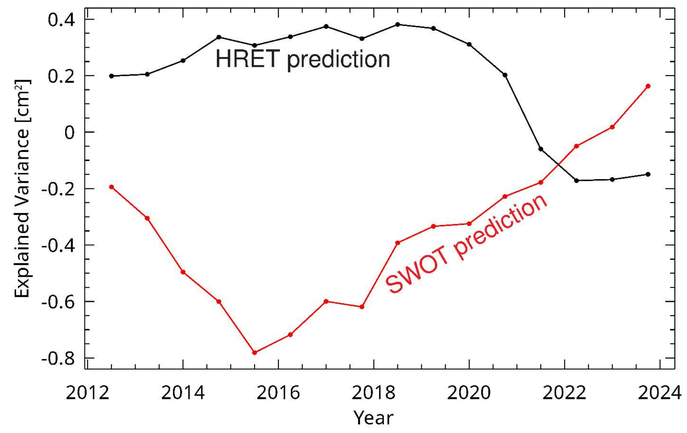
Raw SWOT harmonic constants (far left) are significantly larger amplitude than the best estimate (near left). This region is used as the example in the "Changes in Baroclinic Tides" in the right column.

Global Summaries



The bottom two panels (above) show the explained variance of the M_2 tide prediction with respect to the CryoSat-2 data (2012–2024). Note the different colorscale ranges used. On average, the SWOT-derived tide model explains about 10% more variance than the HRET8.1 model.

Changes in Baroclinic Tides



This example from the Tropical Atlantic shows how the explained variance varies as a function of time. Explained variance is computed from overlapping 3-year subsets of CryoSat-2 time series.

Conclusions & Other Activities

- The work shown above uses CryoSat-2 data for validation. As the length of the SWOT mission increases, it should be viable to withhold SWOT data and use it for validation instead.
- The spatial covariance used in the objective analysis is appropriate for modeling freely-propagating waves, uncoupled from topography and forcing. It might be fruitful to use a covariance structure optimized to explicitly represent topographic coupling.
- The incremental improvement compared to prior models of the phase-locked internal tide is small. Subsequent work should emphasize identification of the modulated tide (also called the "non-stationary" or "non-phase-locked" tide). Sam Kelly and I are working on an approach which should be viable for identfying the modulated tide (see his poster at this meeting).