SWOT Data Assimilation with Correlated Error Reduction: Fitting Model and Error Together

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Motivation

Prior to launch, SWOT sea surface height data were anticipated to show correlated error related to slowly evolving satellite orbit parameters. Metref et al (2019, 2020) proposed a least-squares fitting technique to estimate the correlated error, prior to analyzing the oceanographic signal. In the event that correlated error projects onto the oceanographic signal, the approach has the potential to treat a portion of the oceanographic signal as error. Here we test an alternate approach that solves for the error and oceanographic signal simultaneously. Our method improves the root-mean-square error in both the oceanographic parameters and the error.

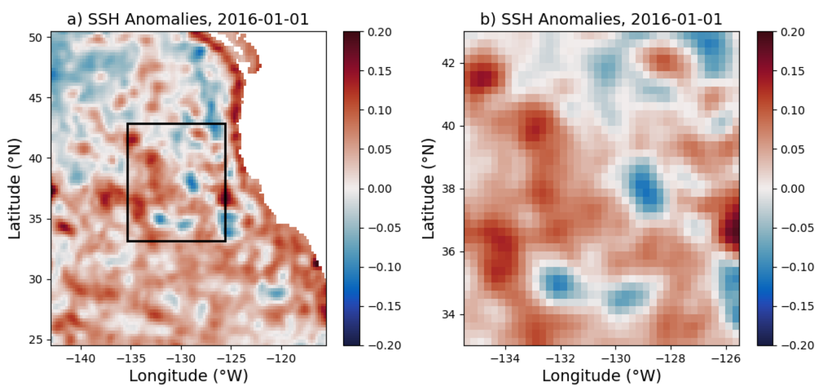

Figure 1. a) Sea Surface Height (SSH) anomalies in the California Current region on 1 June 2016. Black lines indicated within 10° by 10° region of interest for this study; b) Enlargement of daily mean SSH anomalies from the study region from panel a.

Data and Methodology

There are four sources of error: timing error, roll error, baseline dilation error, and phase error:

$$e_{\text{total}} = \alpha_0 + \alpha_1 x_c + \alpha_2 x_c^2 + [\alpha_3 + \alpha_4 x_c]\,\mathcal{H}(-x_c) + [\alpha_5 + \alpha_6 x_c]\,\mathcal{H}(x_c)$$

To reduce the systematic correlated errors, we incorporate correlated error reduction into a 1-stage data assimilation approach, enabling correlated SWOT residual errors to be assessed as part of the assimilation process. Results using a simplified daily mapped altimetry data set show that this 1-stage approach can reduce the correlated error while avoiding problems that arise in the 2-stage approach when errors and ocean signals are analyzed separately, and ocean signals can be confounded with instrument biases. The residual errors discussed here are expected to be in centimeters.

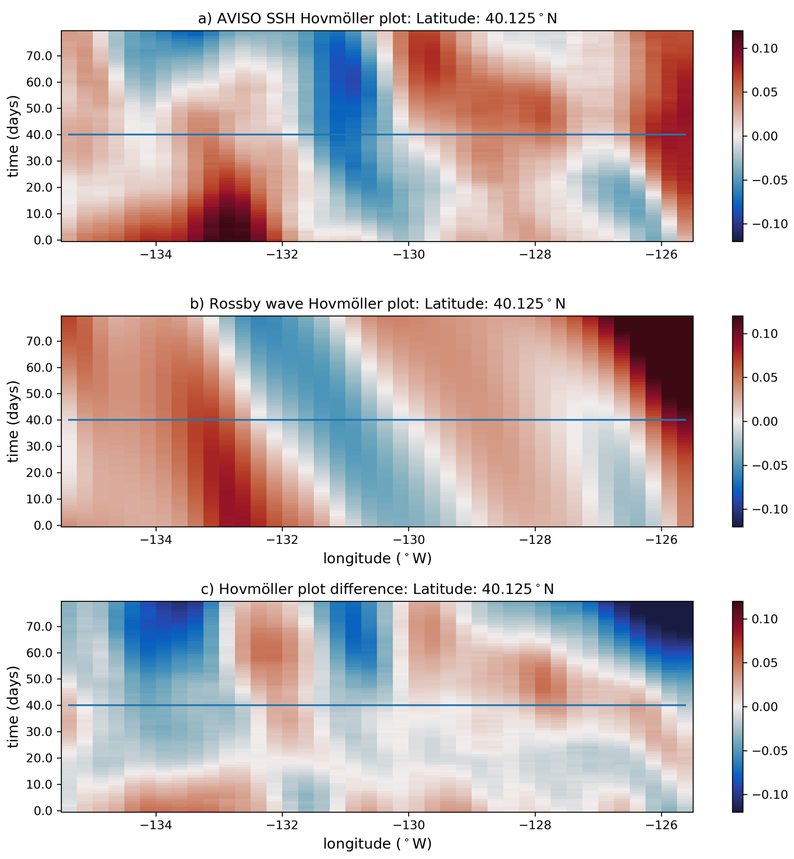

Figure 2. a) Hovmöller plot of observed SSH anomalies, b) Hovmöller plot of estimated SSH anomalies, used as idealized "truth" for this study, c) difference between Hovmöller plots of estimated ("true") and observed SSH anomalies.

Acknowledgment

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SSH and Error Estimate: In swath

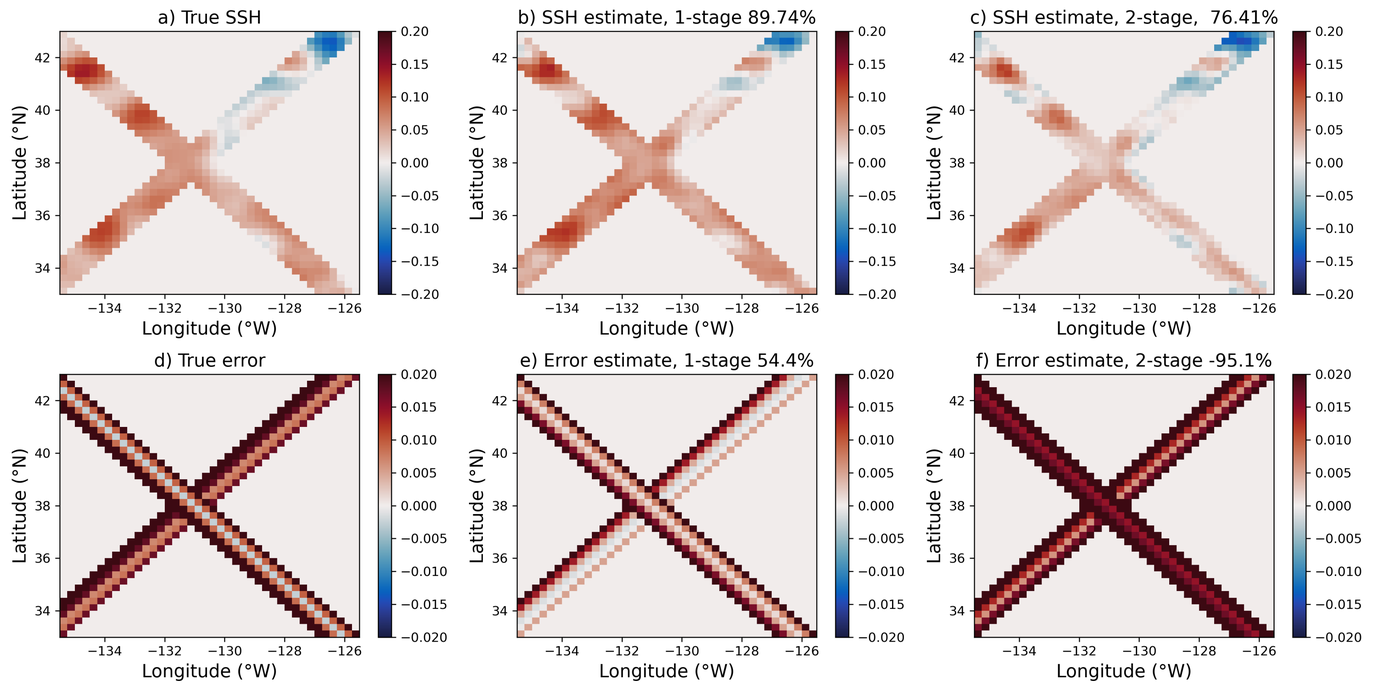
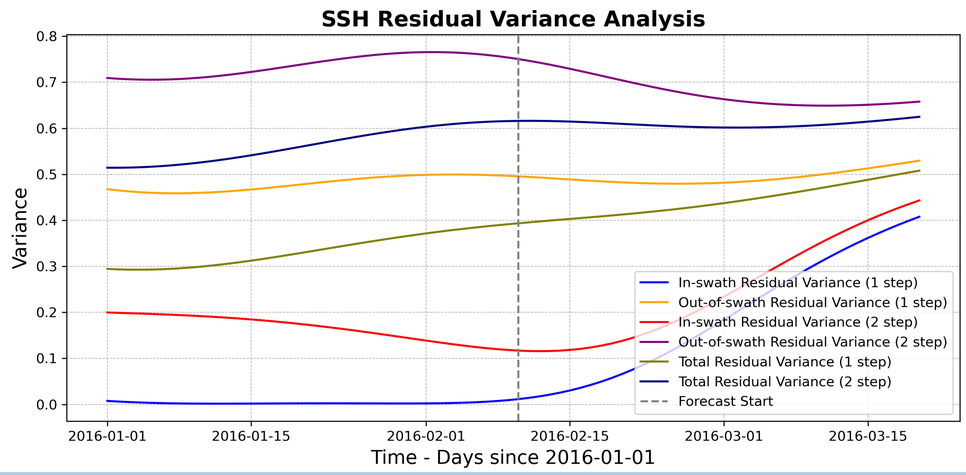


Figure 3. a) The true SSH; b) SSH estimate of a 190-wave Rossby wave model in the 1-stage approach; c) SSH estimate of a 190-wave Rossby wave model in the 2-stage approach; d) True error; e) estimated error in the 1-stage approach; f) estimated error in the 2-stage approach.



In-swath and off-swath residual variance

Figure 4. Time-evolving residual variance in-swath and off-swath with 1-step and 2-step approaches. Gray dashed line indicates the start of forecasts.

Multi-day Ensemble Analysis - in swath

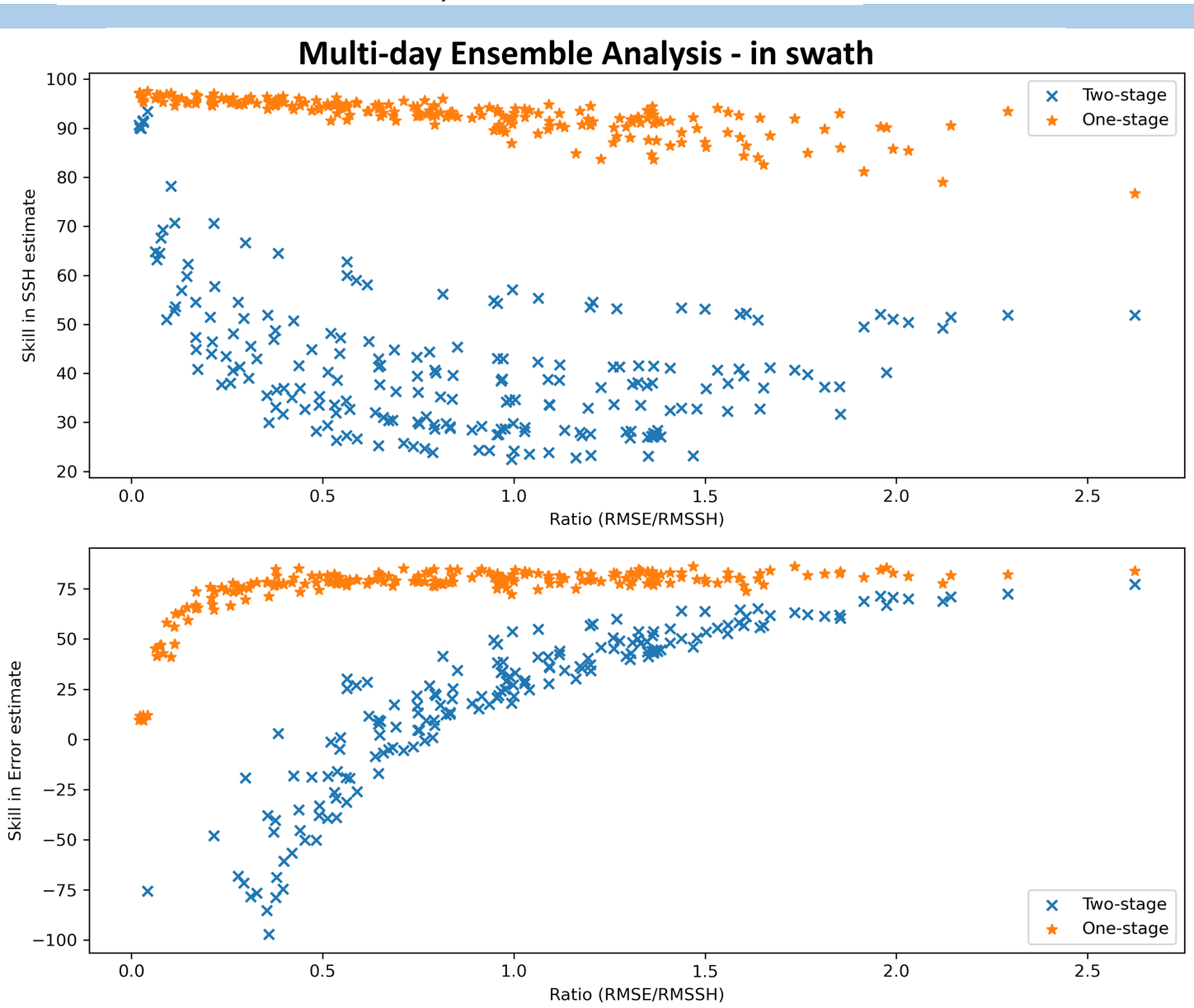


Figure 5. a) skill in Sea Surface Height (SSH) estimate and (b) skill in error estimate for the 1-stage and 2-stage approaches as a function of RMSE/RMSSH ratio. In both plots, blue 'x' markers represent the 2-stage approach, and red'*' markers represent the 1-stage approach.

Conclusions

- Results using a simplified data set show that this 1-stage approach can reduce the correlated error while avoiding problems that arise in the 2-stage approach when errors and ocean signals are analyzed separately and when ocean signals can be confounded with instrument biases.
- The 1-stage approach performs more robustly than the 2-stage approach when estimating SSH signal and correlated errors.
- Our findings suggest that solving for the correlated errors within the assimilation framework can help mitigate the impact of measurement errors on SSH estimates, improving the accuracy and reliability of assimilated SWOT products.