SWOT Data Assimilation With Correlated Error Reduction

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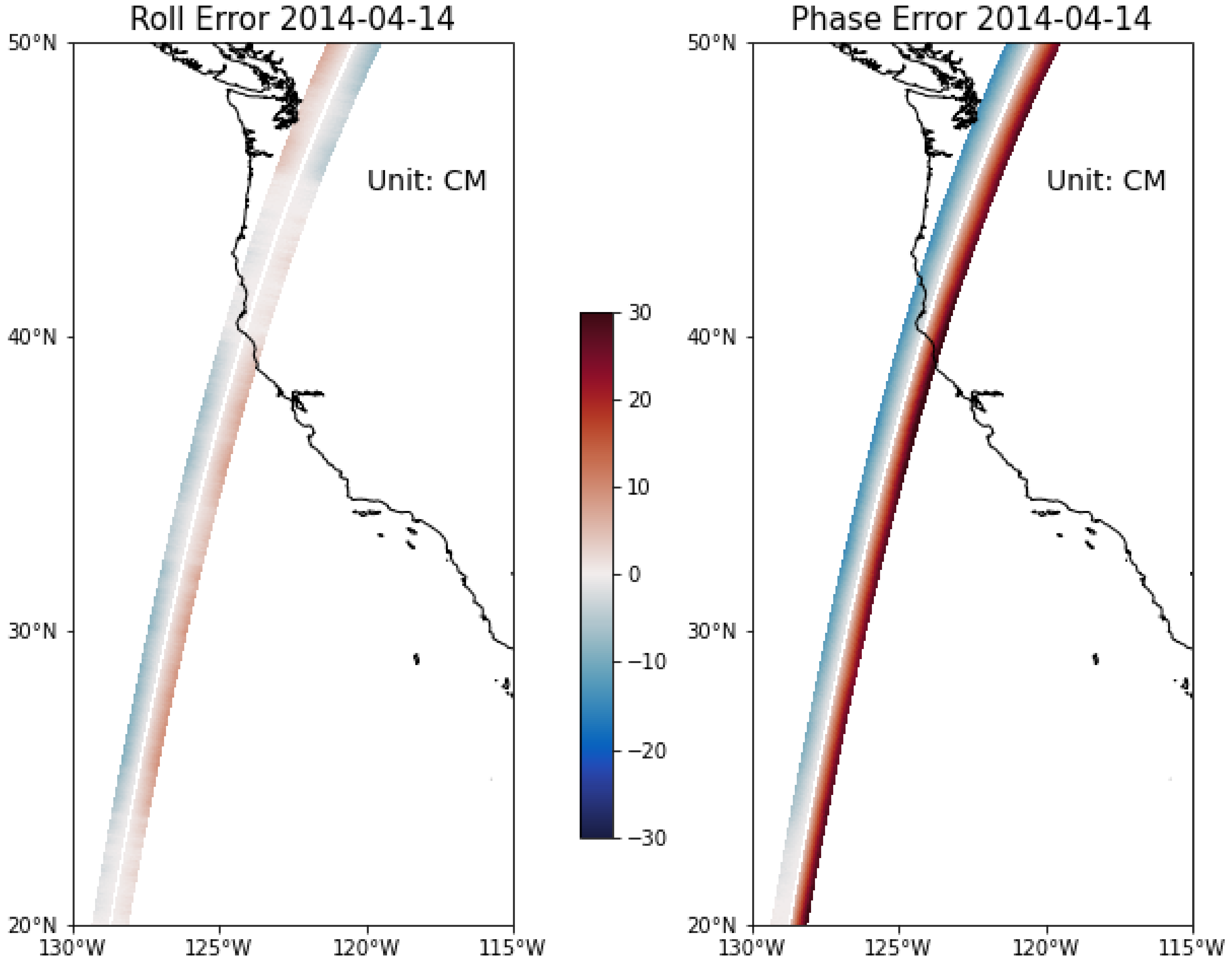
Introduction

SWOT Correlated Errors

- SWOT satellite generates 120-km swaths of SSH data with 20-km gap at its center.
- The SWOT SSH Data are expected to be impacted by spatially correlated errors (Gautier et al., 2016; Esteban-Fernandez, 2017; Metref et al., 2019 and 2020)
- This study focuses on reducing the cross-track variations of SWOT correlated errors and **solving for the correlated SWOT errors as part of the assimilation**.

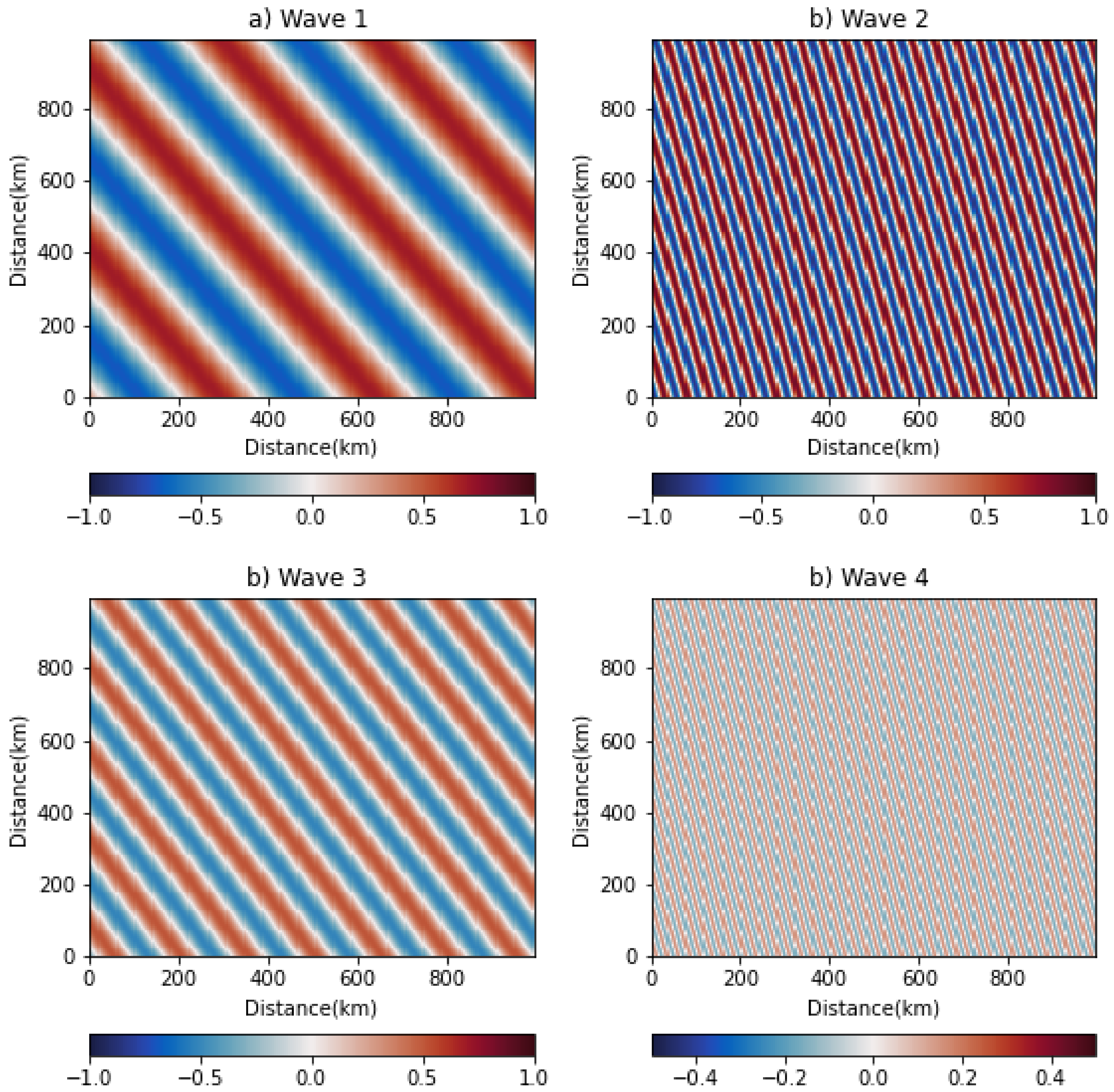


Methodology

Data Assimilation with Rossby Wave Model

- This study proposes a correlated-error reduction (CER) procedure that fits the SSH field and cross-track error (e.g. roll error) together during the inversion.

- The time-evolving SSH(x, y, t) is made of 4 Rossby waves:



$$SSH(\mathbf{x},t) = \sum_{m=1}^{M}\sum_{n=1}^{N}[a_{mn}\phi_m(0)cos(\mathbf{k}_n \cdot \mathbf{x} - \omega_n t) + b_{mn}\phi_m(0)sin(\mathbf{k}_n \cdot \mathbf{x} - \omega_n t)]$$

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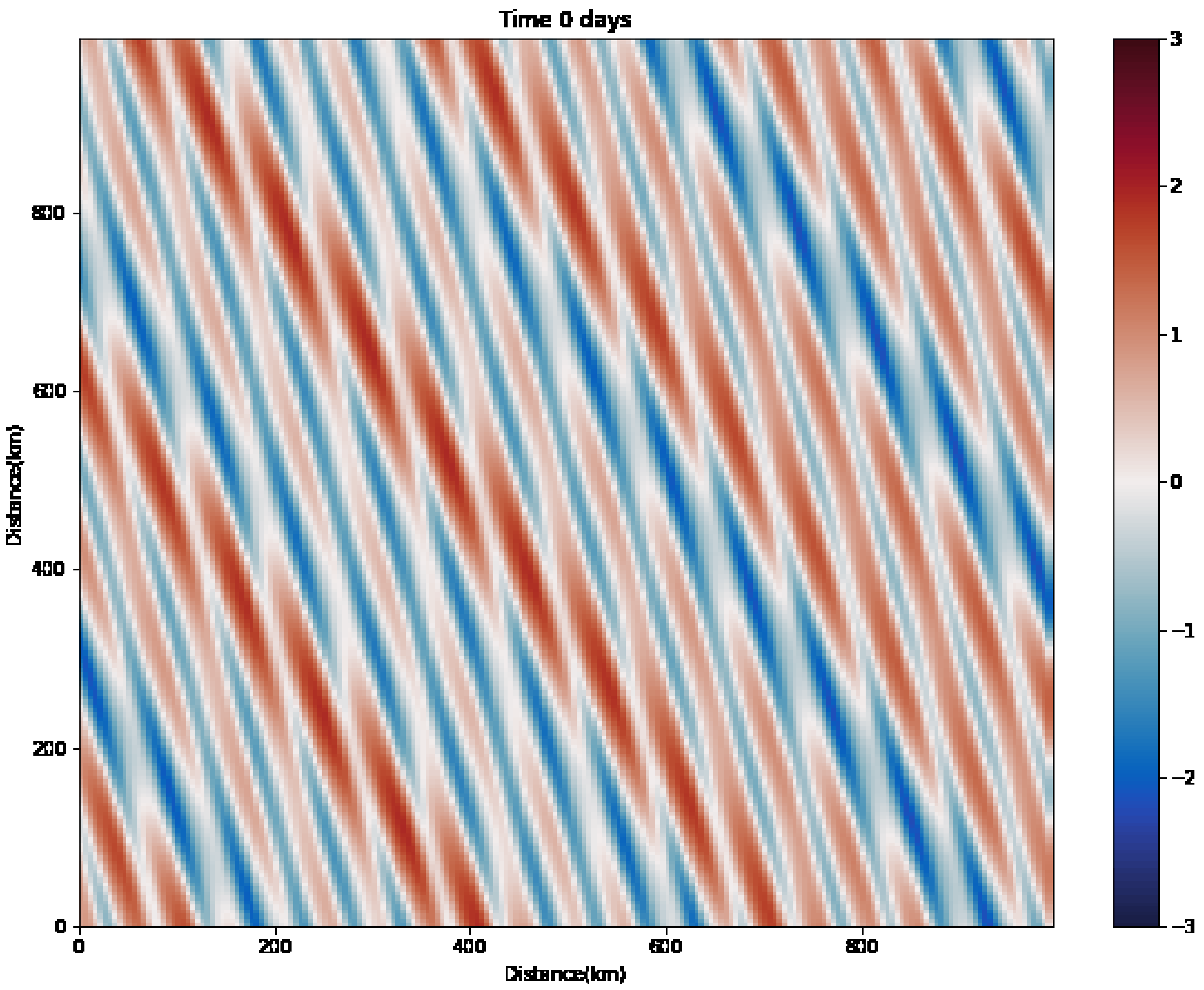

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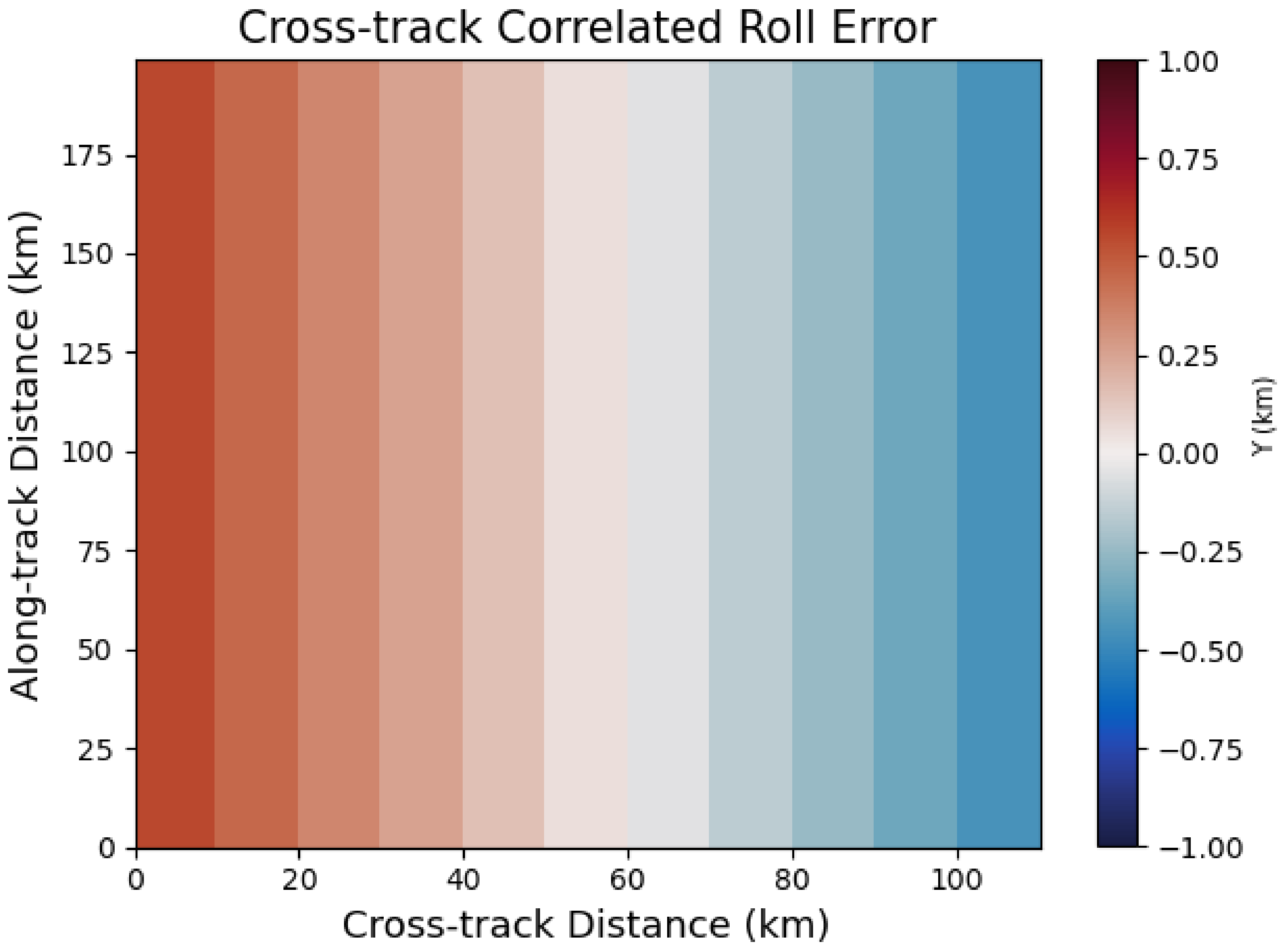
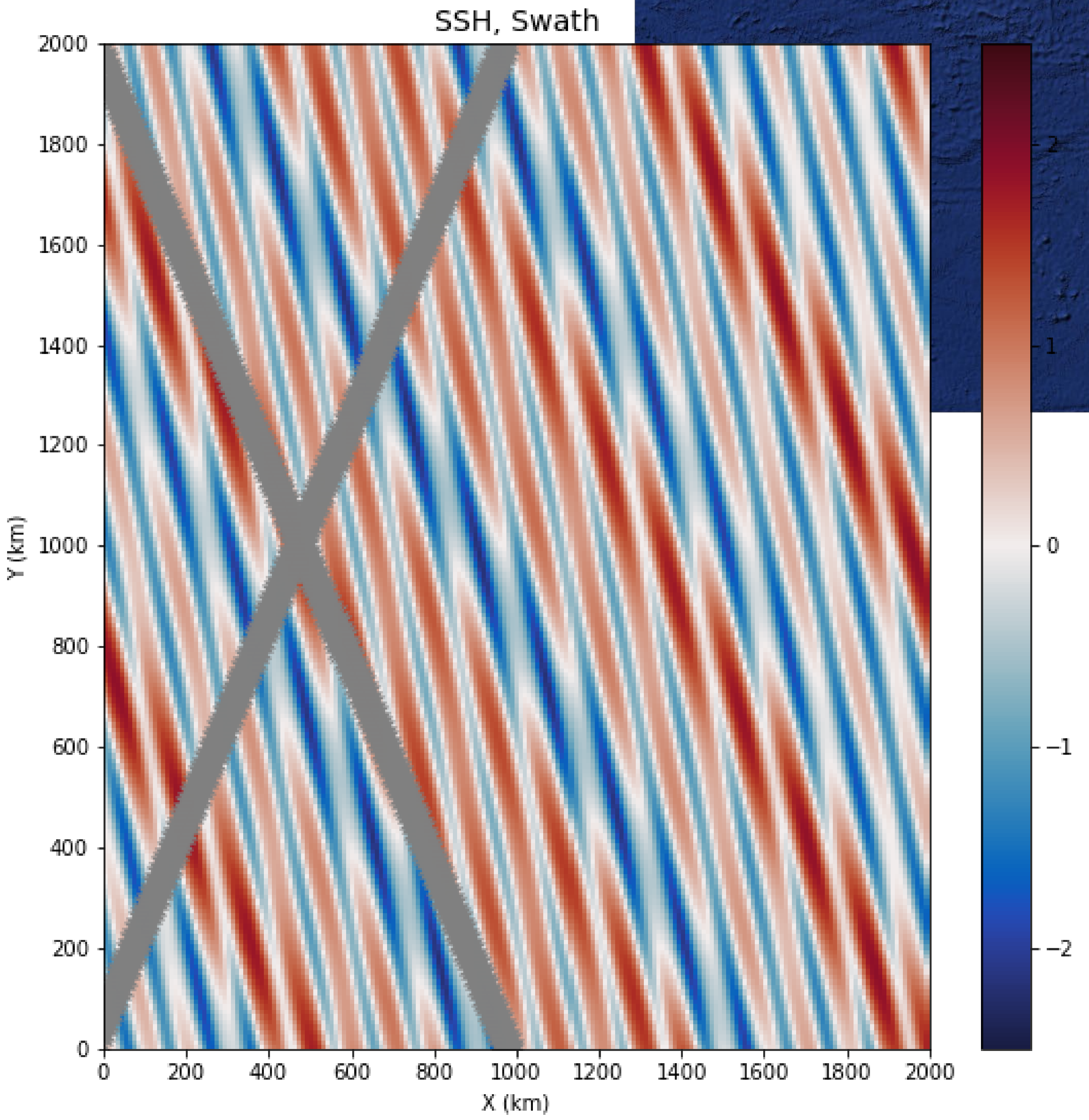
Methodology

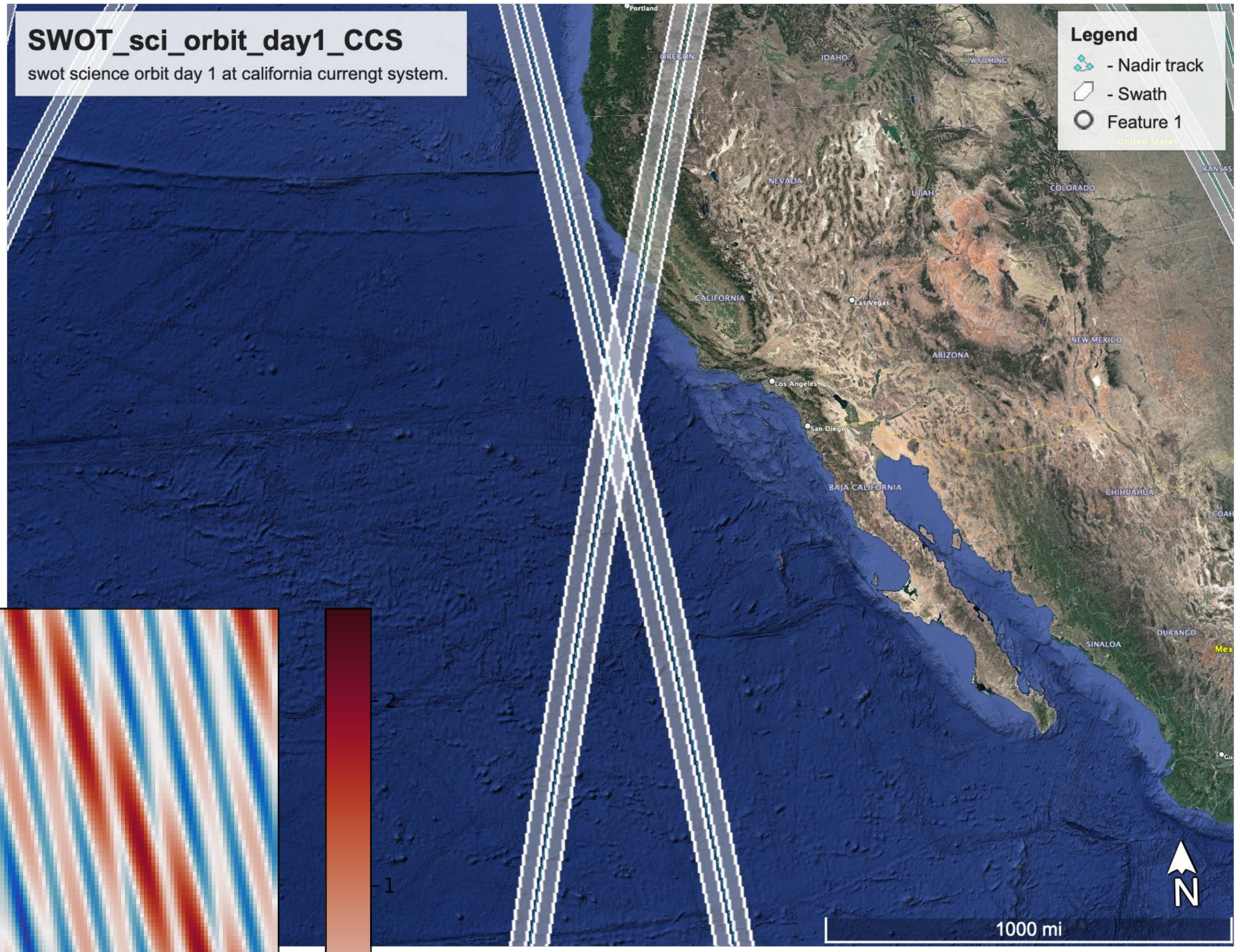
Simulated Swath and Roll Error

- Simulated 120-km swath with 20-km gap in the center

- Simulated roll error







Methodology

Bayesian Approach

- An ocean time series column vector **y** **(SSH)**

$$\mathbf{y} = \mathbf{H}\mathbf{x} + \mathbf{r},$$

- Where **H** is the model basis function, **x** are the model parameters and **r** represents the residual (Kachelein et al., 2022).

- With Bayesian approach, we solve for the most probable solution **x**

$$\hat{\mathbf{x}} = \left(\mathbf{H}^{T}\mathbf{R}^{-1}\mathbf{H} + \mathbf{P}^{-1}\right)^{-1}\mathbf{H}^{T}\mathbf{R}^{-1}\mathbf{y}.$$

- **One-step approach**: solving correlated error as part of the assimilation

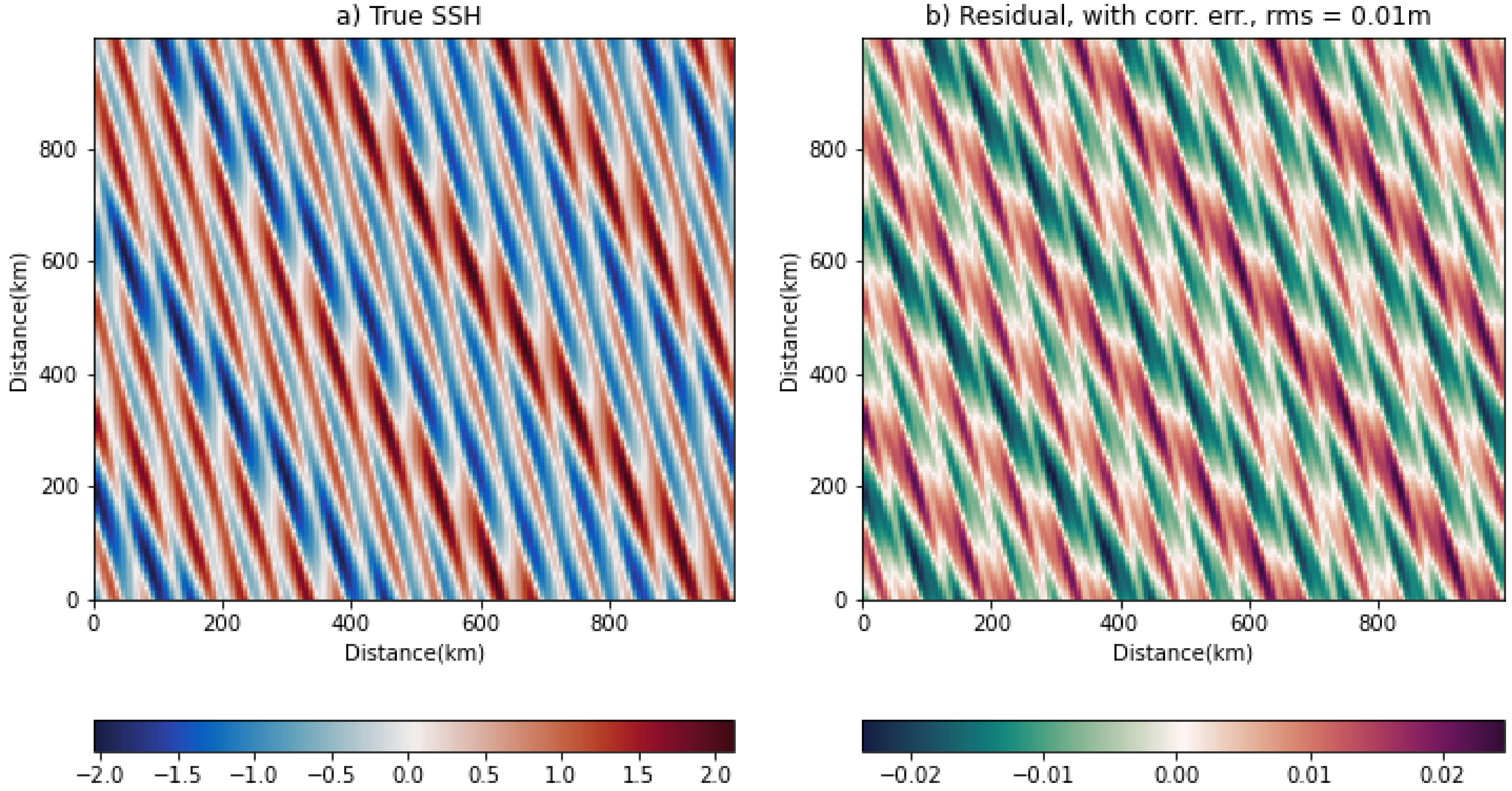
- **Two-step approach**: reconstructing the SSH separately from solving the correlated error (Metref et al., 2019 and 2020)

- **Hypothesis**: solving correlated errors as part of the assimilation can mitigate issues of mistaking ocean signals as engineering issues.

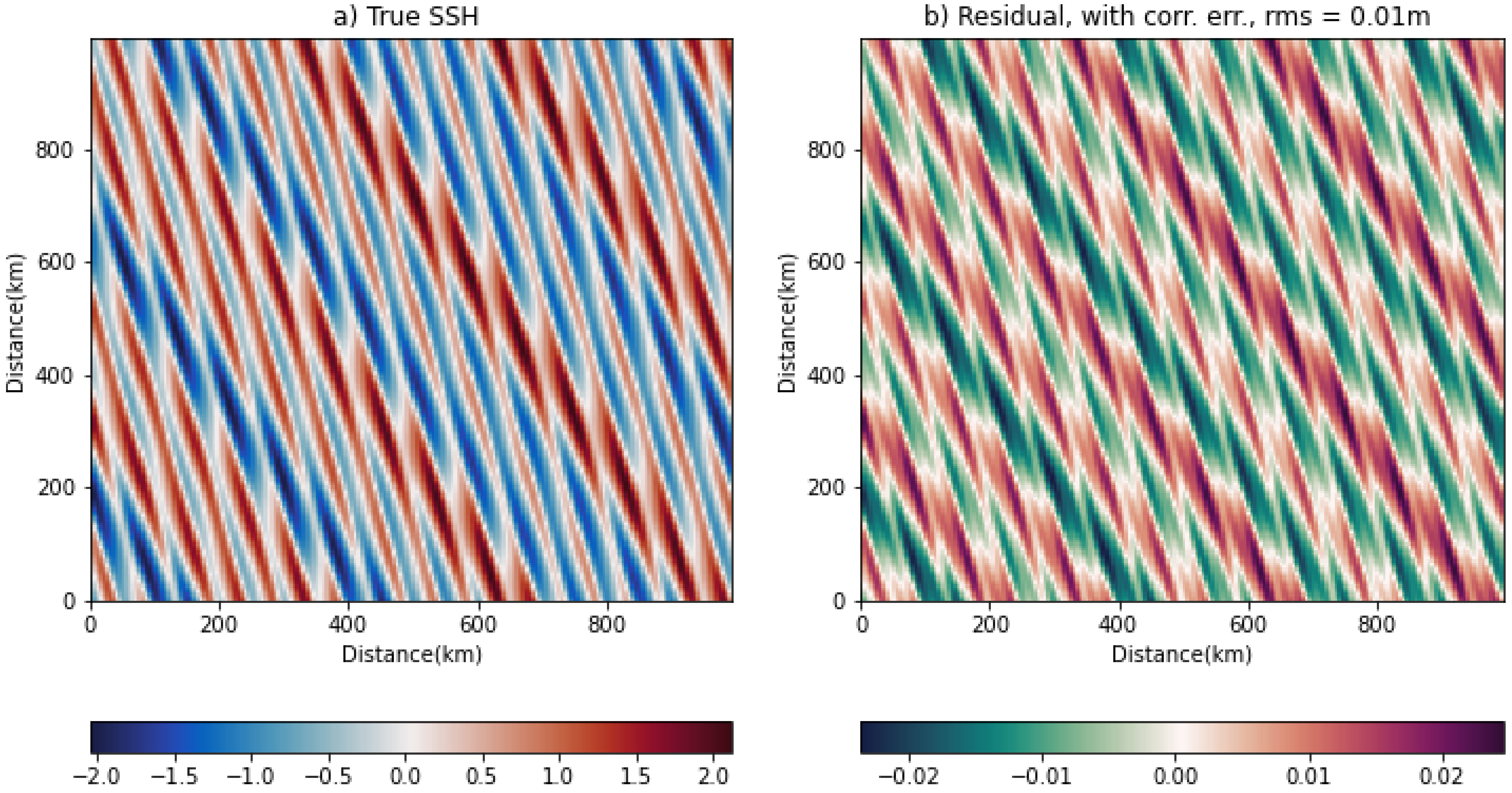
Results

Reconstructed SSH and Residual

- One-step approach



- Two-step approach



Conclusions and Future Work

SWOT Data Assimilation With Correlated Error Reduction (CER)

- The one-step data assimilation CER approach solves correlated error as part of the assimilation.
- In the simple 4-wave model, apart from efficiency, the one-step approach doesn't demonstrate significant advantage over the two-step approach on reconstructing SSH fields yet.
- In the future, we will examine when and to what extent the one-step approach will make a difference with more wave components and more complete error structure.

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