Assimilation of SWOT to map geostrophic and internal tide currents

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Abstract

The **SWOT** mission extends the observability of **Sea Surface Height (SSH)** to the **sub-mesoscale signals** (<50 km), whereas conventional nadir altimetry is currently limited to the large mesoscale range (150-200 km). At the fine scales observed by **SWOT**, SSH variations are primarily driven by two dynamics - nearly geostrophic **Balanced Motions (BMs)** and wave motions due to **Internal Tides (ITs)**. Reconstructing and separating **BMs** and **ITs** contributions to SSH variations is essential for marine applications.

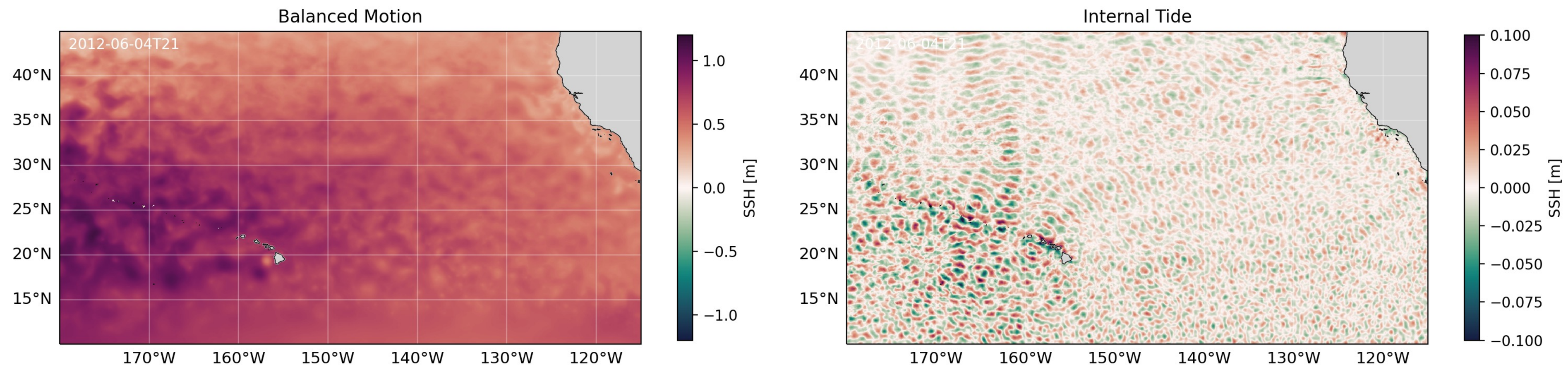


Fig1 : Balanced Motion and Internal Tide filtered from MITgcm LLC4320 hourly outputs.

We introduce an innovative method to **map and separate BMs and ITs (1st mode) SSH signals** from realistic altimetric observations **including SWOT**. It assumes that the SSH η results from the additive contribution of BMs (η_{BM}) and ITs (η_{IT}).

$$\eta = \eta^{BM} + \eta^{IT} = M^{BM}(\Phi^{BM}) + M^{IT}(\phi^{IT})$$

Each of these components is being simulated by a separate dynamical model M^{BM} and M^{IT}, controlled by a specific set of parameters Φ^{BM} and Φ^{IT}. The separation problem is expressed as the identification of the optimal set of parameters (Φ^{BM}, Φ^{IT}) that leads to the best fit between total gridded SSH η and the altimetric SSH observations η_{OBS}. This is formulated as a **4DVar data assimilation** problem, with the cost function :

$$J(\Phi^{BM}, \Phi^{IT}) = \|\Phi^{BM} - \Phi^{BM}_b\| + \|\Phi^{IT} - \Phi^{IT}_b\| + \|\eta - \eta_{OBS}\|$$

Method

$$\eta = \eta^{BM} + \eta^{IT}$$

reconstructs / reconstructs

M^{BM} : QG(*) model

(*) : quasi-geostrophic

$$\partial_t q + U_g \cdot \vec{\nabla} q = 0$$
$$q = \nabla^2 \psi - \psi / {L_R}^2$$
$$\psi = g\eta^{BM} / f_0$$

M^{IT} : LSW(*) model

(*) : linear shallow water

$$\partial_t u - fv = -g\partial_x \eta^{IT}$$
$$\partial_t v + fu = -g\partial_y \eta^{IT}$$
$$\partial_t \eta^{IT} = -H_e \vec{\nabla} \cdot U + \mathcal{F}_{ITG}$$

↑ controls

Φ^{BM} : BM parameters

- additive model error :

$$\eta^{BM}_{i+1} = \mathcal{M}^{BM}(\eta^{BM}_i) + \Phi^{BM}_i$$

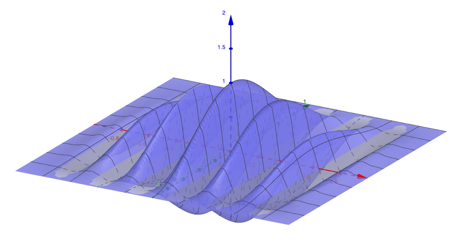


Fig2 : Wavelet basis used for parameter reduction

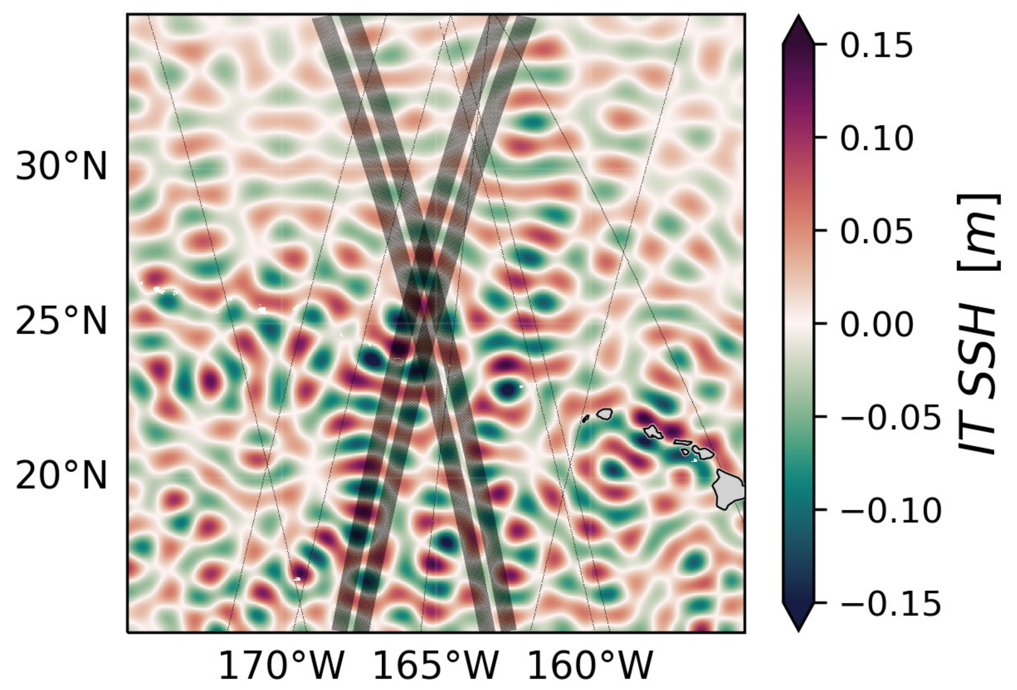
↑ controls

Φ^{IT} : IT parameters

- η^{IT} boundary conditions :
  ⇒ controlling entering waves
- equivalent height H_e :
  ⇒ controlling wave propagation
- IT wave generation (ITG) :
  $\mathcal{F}_{ITG} = \Phi^{ITG} * U_0 \cdot \vec{\nabla} H$
  Φ^{ITG} control is a corrective factor
  U_0 : barotropic tide velocity
  $\vec{\nabla} H$: bathymetry gradient

Experimental setup (Hawai'i)

Fig3 : 1st mode IT from MITgcm over Hawai'i with satellite tracks in black.

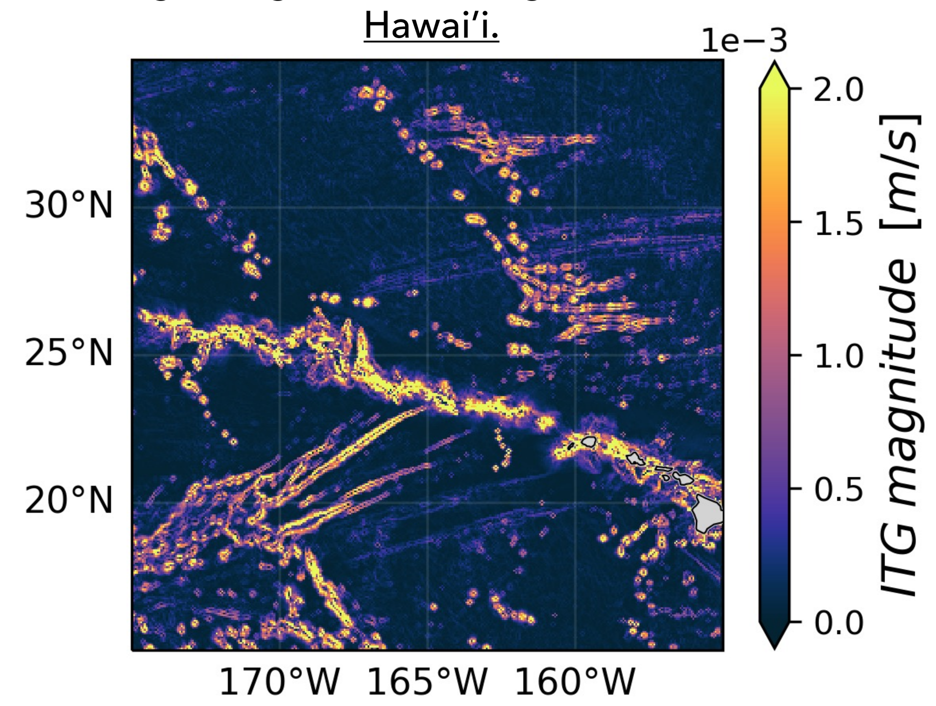


Observing System Simulation Experiment **(OSSE)** is carried out. **MITgcm LLC4320** (1/48° resolution, w. tidal forcing) simulation is the **reference**. It is used to **simulate SSH observations** inputs for mapping, and as a baseline to **evaluate SSH mapping results**. A filter is applied to SSH fields to **separate BMs and ITs** for specific evaluation *(cf. Fig1)*. For ITs the 1st baroclinic mode is extracted *(cf. Fig3)*.

Actual developments are focusing on setting up the **IT generation control** over IT production sites (i.e. strong bathymetry gradient and tidal currents). Hawai'i has been chosen as a study zone *(cf. Fig4)*.

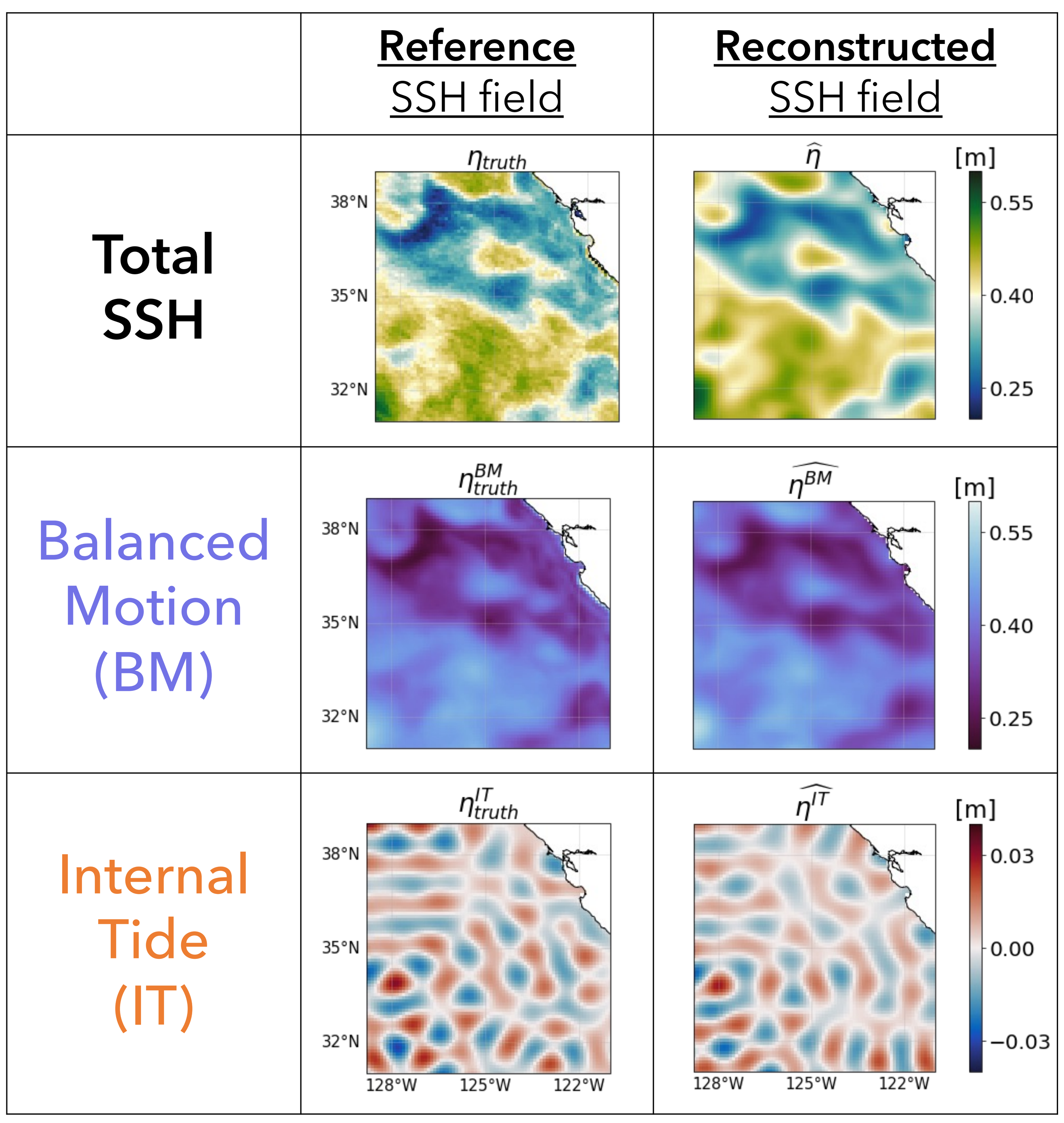
An **imaginary SWOT 1-day repeat crossover** is implemented over Hawai'i by shifting orbit coordinates, in addition to **5 Nadir altimeters** (Alt,C2, J3, S3A&B) *(cf. Fig3)*. The goal is to study the ability of **SWOT + Nadirs** to reconstruct the ITs around a generation site.

Fig4 : IT generation magnitude over Hawai'i.



Results & Conclusion

Fig5 : First results over Californian SWOT calibration site of separated BM/IT SSH mapping obtained in a simplified case (F. Le Guillou). ITs are controlled at the border with boundary conditions (entering waves only).



First results prove the feasibility of the **IT/BM separation method**. They were carried out over Californian Current System *(cf. Fig5)* in simplified configuration. Aim is to go toward a **global mapping of BMs and ITs** by including complexity related to the dynamics specificities.

Actual step deals with the **reconstruction of 1st mode ITs around generation sites**. Preliminary results use SSH altimetry data with 1st mode IT only *(cf. Fig6)*. Problems persist in IT SSH amplitude evaluation, which is overestimated.

Future developments will include the separation of ITs and BMs in a more realistic case (OSSE w. SWOT Pacific crossover) in order to prepare for SWOT real data mapping.

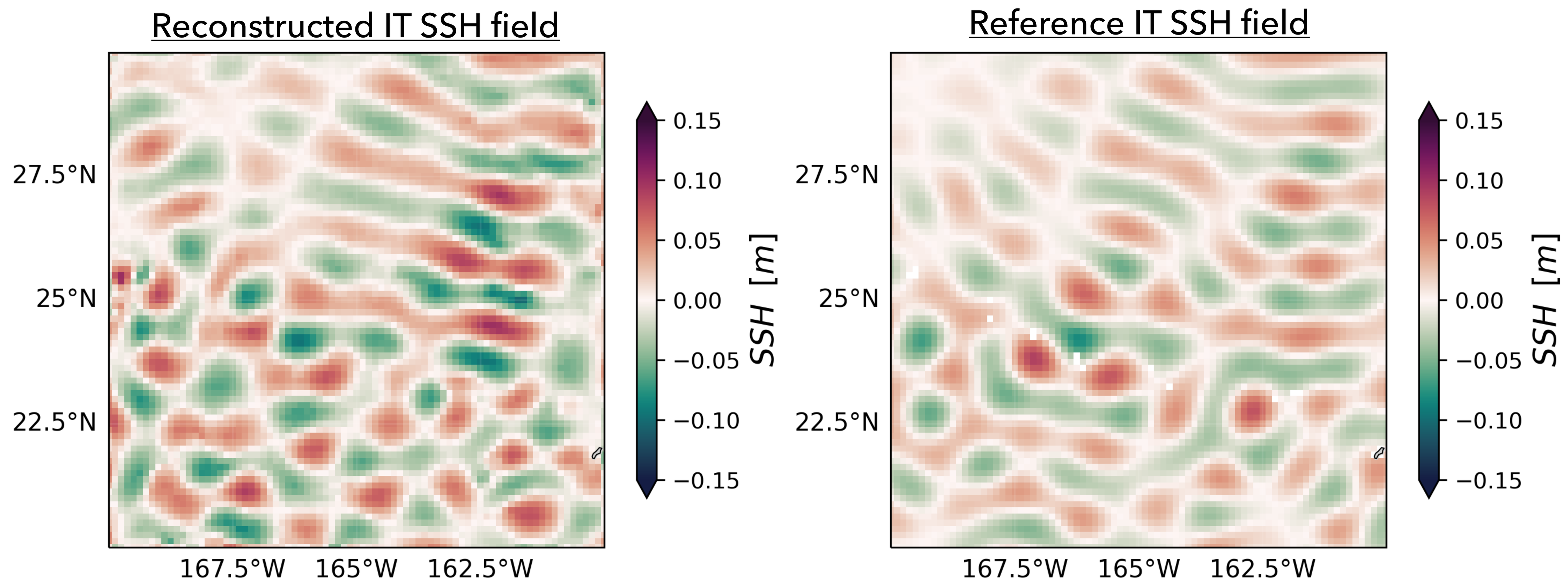


Fig6 : Reference and reconstructed IT SSH field around Hawai'i, with IT generation parameter. Mapping uses OSSE setup developed in the experiment section.

Abbreviations

BM : Balanced Motion – **IT** : Internal Tide – **SSH** : Sea Surface Height