Synergy of fine-resolution regional model and SWOT measurements to study coastal dynamics

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Introduction

SWOT (Surface Water and Ocean Topography) altimetry mission has made remarkable advancements in resolution, coverage and overall water surface observability. Although SWOT's primary objective is to monitor both open ocean and inland water bodies at an unprecedented spatial resolution, its potential application in coastal regions shows great promise. However, fine scale SWOT measurements in the coast faces major challenges regarding fine scale correction of tide and coastal dynamic processes. In this context, the objective of this study is to asses the relevance of high resolution coastal model and it's application in analyzing high resolution SWOT observations in a macrotidal region.

Study Area

- Coastal region of Pertuis Charentais (Bay of Biscay, France).
- Semi-enclosed macro-tidal coastal regime with tidal range 1.5 m to 5.5 m.
- Located under 2 SWOT passes (348, 419) along with several nadir altimetry mission.
- Covered by a network of tide gauges and pressure sensors.

Model Description SCHISM (Semi-Implicit Cross-scale Hydroscience Integrated System Model)

- A semi-implicit cross-scale hydrodynamic model which solves Navier-Stokes equations (in hydrostatic form) in 3D unstructured grid (Zhang et al., 2016).
- SCHISM in depth-averaged barotropic mode with 2DH configuration developed by Tranchant et al., (2021).
- 57,828 grid nodes with 3 km resolution towards the open ocean and 50 m resolution near the coast.
- Boundary forcing → tide (Tranchant et al., 2021), sea level pressure and wind (ECMWF-ERA5).

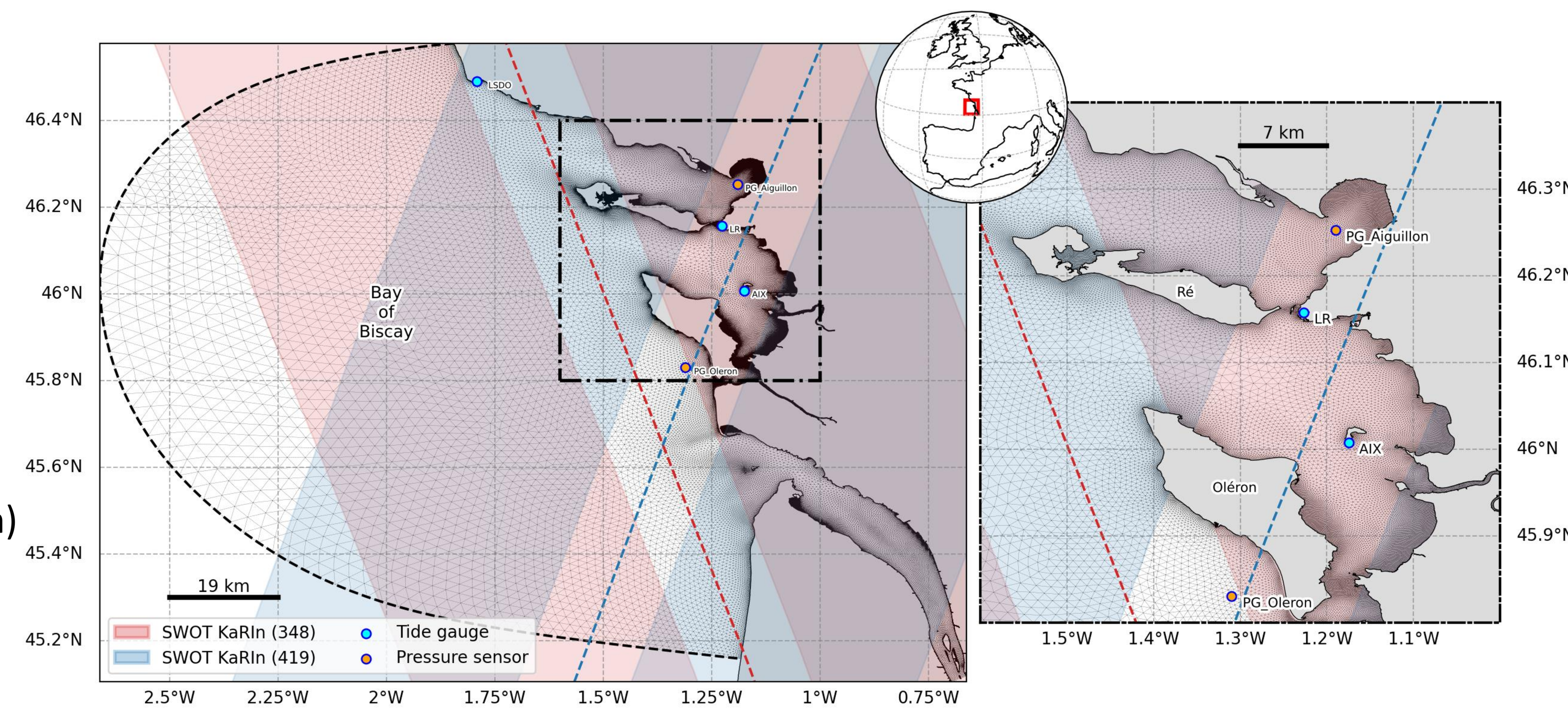


Fig 1: SCHISM model mesh with SWOT passes overlay and available tide gauges in the study area

SWOT (Surface Water and Ocean Topography)

Wide-swath 2D altimetry mission using Ka-band Radar Interferometry (**KaRIn**)

Joint project of NASA, **CNES**, the Canadian Space Agency and UK Space Agency

Launched on **16th December, 2022**

Mission duration: **3 years**

Repeatability:
- Calibration phase: **1 day** (5th April to 11th July of 2023)
- Science phase: **~21 days** (26th July, 2023 to onward)

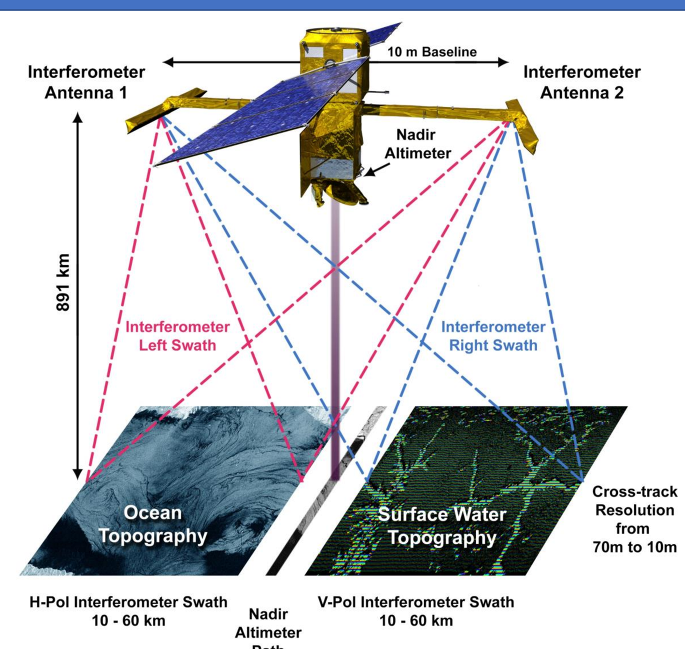


Fig 2. Diagram of SWOT Data Collection
https://swot.jpl.nasa.gov/resources/104/diagram-of-swot-data-collection/

Data type and observability

Ocean
- Low Resolution (LR)
- **250 m x 250 m**
- Characterizing meso- and sub-mesoscale 2D ocean circulations

Inland
- High Resolution (HR)
- **5 m** (along-track) **x 10-70 m**
- Observation of water bodies with width larger than 100 m

Coast
- No dedicated product
- **Both LR and HR coverage**
- Possibility of observing fine scale coastal dynamics, surges etc.

Model Performance

Tidal constituents considered for model performance validation

Astronomical	K1	O1	M2	N2	S2	K2	MU2	NU2	M3
Shallow-water	M4	M6	MN4	MS4					

$$\Delta z = A_{obs}e^{i\emptyset_{obs}} - A_{model}e^{i\emptyset_{model}}$$

A = amplitude, $\emptyset$ = phase

$$\sigma_{station} = \sqrt{\frac{1}{2}\sum_{wave}|\Delta z|^2}$$

$$\text{RSS} = \sqrt{\frac{1}{2N_{station}}\sum_{Station}\sum_{wave}|\Delta z|^2}$$

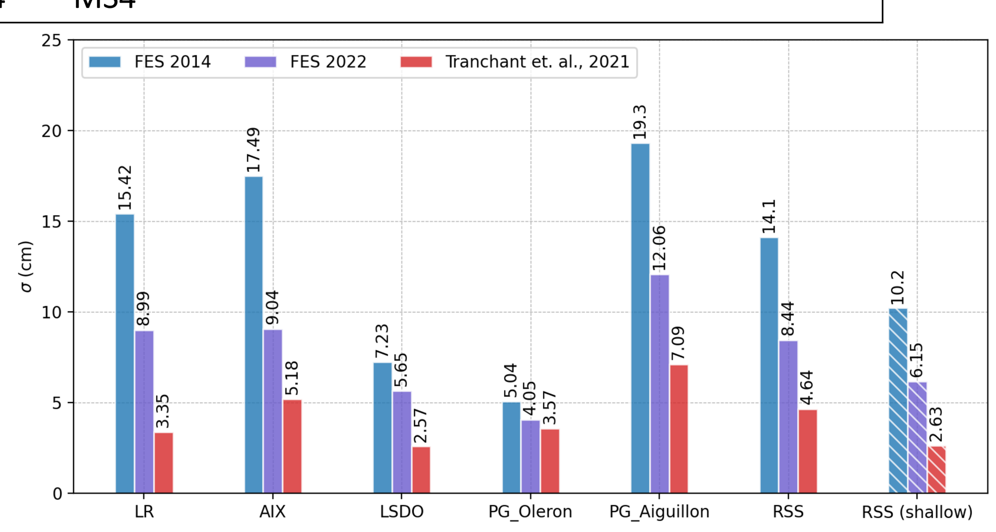
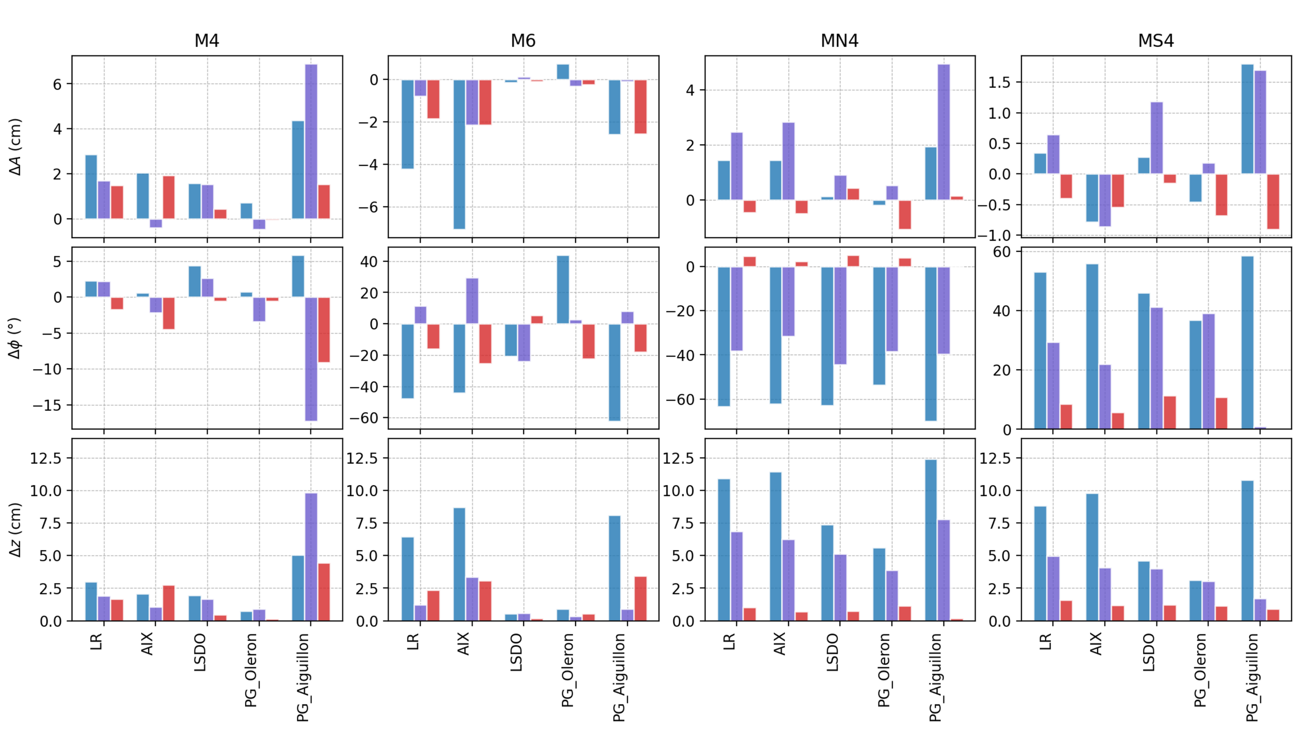


Fig 3: Model performance evaluation using complex error (σ) between observed and modelled tidal constituents. The estimation of σ accounts for both amplitude and phase difference.

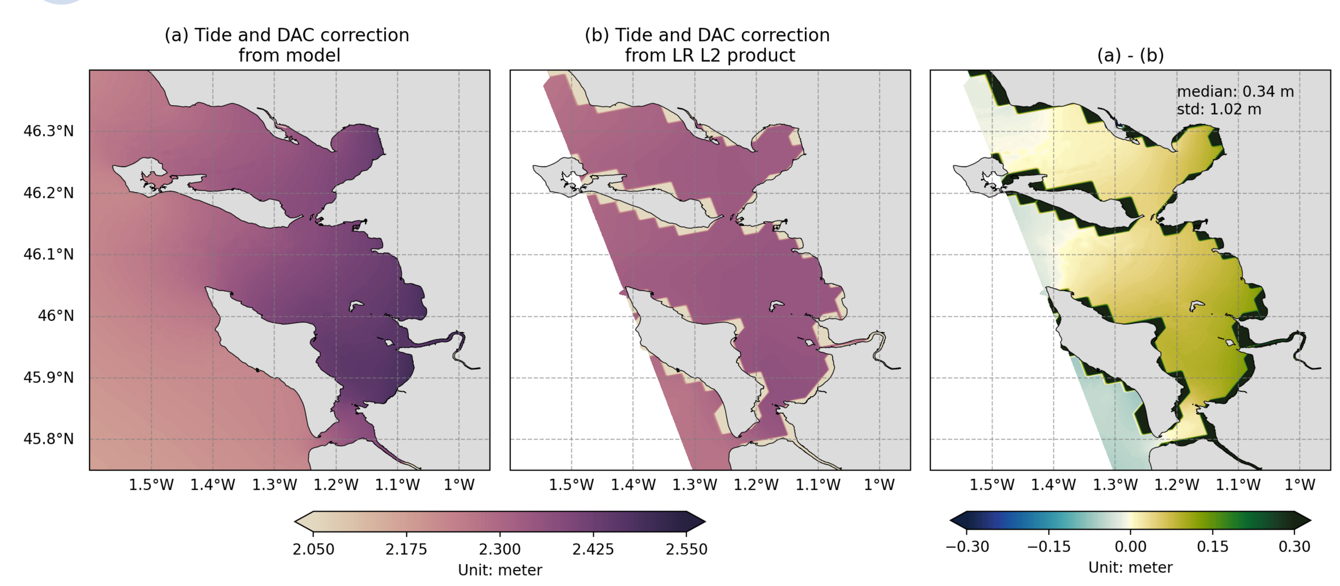


- Error reduction in regional model
  - 67 % compared to FES 2014
  - 45% compared to FES2022
- Error contribution due to shallow water constituents
  - 70% in FES models
  - 50% in regional model

Fig 4: Comparison of modelled shallow water constituents with observation. Top panels show the amplitude differences, mid panels show the phase differences and bottom panels show the complex differences between observation and FES 2014 (blue bars), FES 2022 (violet bars) and Tranchant et.al., (2021) (red bars).

Result

High resolution coastal model: a necessity for SWOT !!



- Insufficient resolution in the coast
- Gradient is not well represented

Fig 5: Tide and dynamic atmospheric correction (dac) from regional model (a) and from SWOT LR level 2 product (b) and their comparison.

SWOT observed coastal gradient

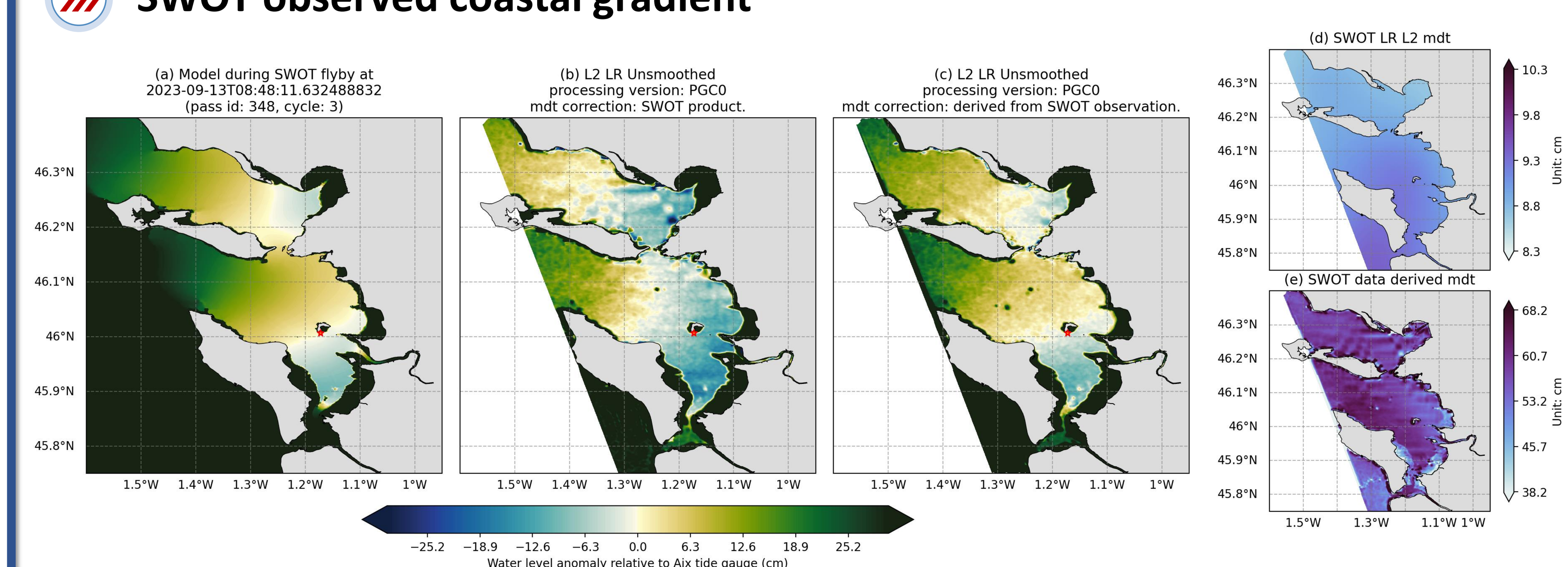


Fig 6: Coastal SSHA gradient from model (a) and SWOT (b, c) relative to Aix island tide gauge location (red star). SSHA in (b) and (c) are computed using Eqn 1. Mean dynamic topography (mdt) correction used in (b) is from SWOT L2 product (d) and correction used in (c) is computed with 15 cycles of SWOT data (e) using Eqn 2, which includes mdt and stationary SWOT artifacts.

$$SSHA_{SWOT} = ssh\_karin\_2 + xover\ cor(crossover\ correction) - geoid - mdt - solid\ earth\ tide - load\ tide - pole\ tide - internal\ tide \quad \text{Eqn. 1}$$

$$mdt_{SWOT} = \frac{1}{N}\sum_{cycle=1}^{cycle=N} ssh_{karin_2} + xover\ cor - geoid - (ocean\ tide + dac)_{model} - (solid\ earth\ tide + load\ tide + pole\ tide + internal\ tide)_{L2\ product} \quad \text{Eqn. 2}$$

- With appropriate geophysical correction SWOT can observe coastal sea surface gradient.
- SWOT data derived mdt includes some stationary artifacts and ocean dynamics in SWOT measurements.

Conclusion and Perspective

- In the coastal region, high resolution SWOT measurements can bring crucial information regarding fine scale coastal dynamics.
- High resolution regional models for geophysical corrections are essential to fully use SWOT's potential.
- The regional model used in this study is performing well compared to both FES 2022 and FES 2014 global model . Further improvement in representation of shallow water constituents are ongoing.
- Current model will be coupled with Wind Wave Model (WWM) to include short wave dynamics.
- Dedicated multi-sensor field campaigns are currently being cunducted over the study area to complement the modelling (c.f. Poster by Audrey Hyeans) in assessing SWOT measurements in coasts.

Recommendation

- Dedicated SWOT data products for coastal region are required to utilize the unique dataset of SWOT at it full potential in the coastal region.
- Observed permanent artifacts in the SWOT measurements near coasts should be further investigated by the SWOT processing team.

References

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