Potential use of the SWOT satellite to characterize the hydrodynamics of the french rivers, estuaries and coasts
CNES, NASA, CSA, UKSA Mission – TOSCA-CNES Project

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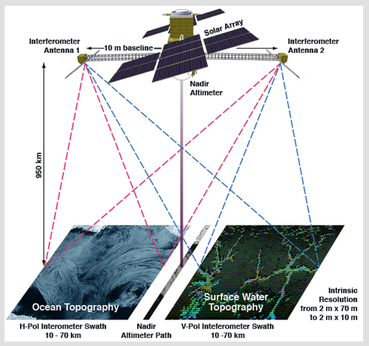
INTRODUCTION

The SWOT satellite by interferometry radar (Surface Water and Ocean Topography - NASA and CNES mission, with a CSA and UKSA contribution) will be launched in 2020 and will provide data on the water level with an high spatial resolution: 1 km for the oceans, 50-100 m of width for the rivers, 250m x 250m for the lakes. With such resolution, SWOT will have the capacity to measure changes in water levels of 68% of the lakes and many rivers, including those of small size that were previously inaccessible from other satellites



Ka-band SAR interferometric system with 2 swaths
Additional instruments:
conventional Jason-class altimeter for nadir coverage
AMR-class radiometer to correct for wet-tropospheric delay
Spatial Resolution
Ocean 1 km; Lakes 250x250m; Rivers width 50-100 m
Vertical accuracy of water level
Ocean ~ 3 cm ; Continental water ~ 10 to 25 cm
Cycle of 22 days with 1-7 passages according to the location

CONTEXT, DATA & METHOD

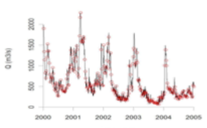
Approaches & Objectives

To answer to the question of the SWOT use in the french rivers, estuaries and coastal zones

To simulate SWOT data without error & with error (white noise on water level) from the SWOT orbit

We sample the time series of water level (5 years) according to the passage frequency of SWOT

Débits	Lat	Long	SWOT Passage (in hours)		
Seine	49,310815	1,236246	100,575	277,6056	362,9861

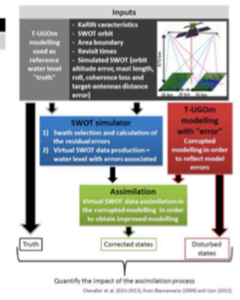


we characterize and compare the temporal hydrological variability of the in situ and simulated SWOT data from several analyses (trend, loess, wavelet analysis…)

Effect of the number of passages of SWOT to its capacity to record the hydrological temporal variability

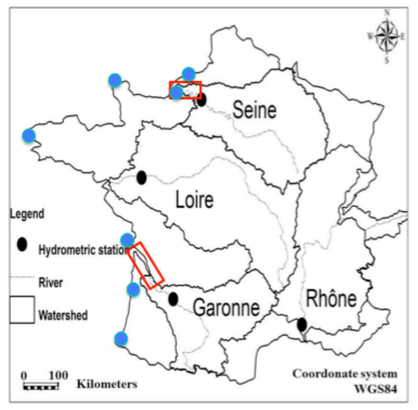
Accurate modeling of the spatial & temporal variability of water level
T-UGOm & DELFT 3D models

Coupling of the model data (input data) & the SWOT simulator HR



To study the capacity of SWOT to restitute the temporal & spatial hydrol. variability

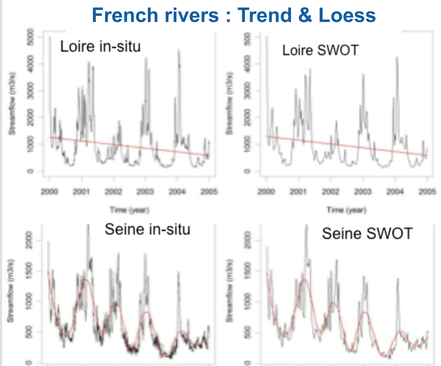
Study sites : Main french rivers, 2 estuaries, Channel & Atlantic coasts



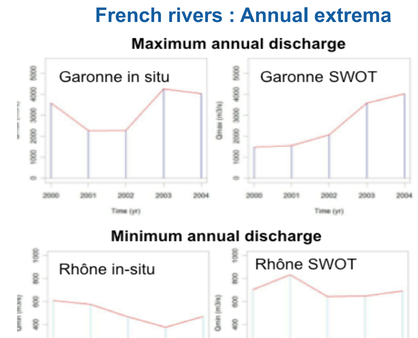
Gauges in the fuvial zone (in the downstream without the tide influence) of the Seine, Garonne (& Loire, Rhône)
Gauges of the Seine and Gironde estuaries
Tide gauges of the Channel & Atlantic coasts

SWOT ABILITY TO REPRODUCE THE TEMPORAL HYDROLOGICAL VARIABILITY

French rivers : Trend & Loess



French rivers : Annual extrema

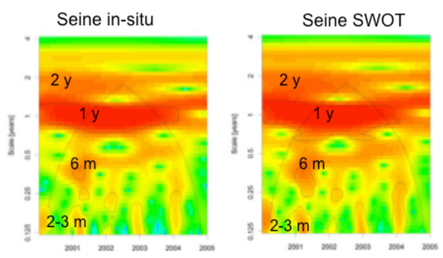


Decomposition of the Sea level into Astronomical tides & Residual surges in the Channel coastal zones

For the 4 french rivers (Seine, Garonne, Loire, Rhône) during the 3 studied periods (1965-1969, 1985-1989, 2000-2004),
Simulated SWOT data restitute well the trends, main modes of hydrological variability & mean annual discharge
But SWOT underestimate the maximum annual & overestimate the minimum annual discharge

For the coastal zone (Channel & Atlantic),
SWOT samples more the most frequent values (medium energy conditions) and less the maximum and minimum values of the sea level, astronomical tides and residual surges
But SWOT is able to sample some storm surges

French rivers : Modes of hydrological variability by wavelet analysis



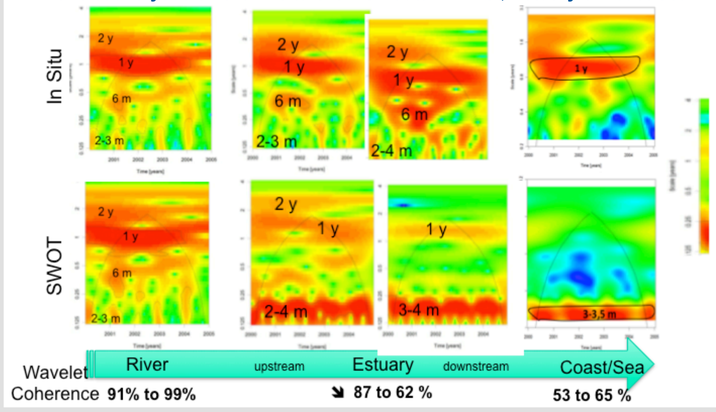
Simulated SWOT data reproduce very well the main modes of hydrological variability observed in the in-situ data :
2 y = NAO mode,
1 y and 6 months = hydro. cycle
2 to 3 months = flood period

For the 4 french rivers & for the 3 studied periods : Wavelet coherence between simulated SWOT data and in-situ water level indicates a
strong coherence, from 91% to 99%
for all frequencies (energy bands)

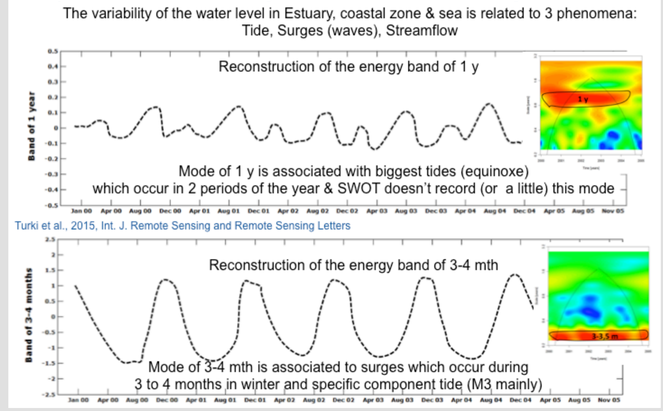
	1965-1970	1985-1990	2000-2005
Seine	99.5%	99.06%	99.38%
Garonne	96.36%	98.44%	96.25%
Loire	98.84%	99.02%	98.39%
Rhône	95.75%	91.30%	94.73%

Laignel et al., 2014, IAH ; Laignel et al., 2015, ESA

Wavelet analyses on the in-situ & SWOT data in River, Estuary & Coast/Sea



Explain of the wavelet analyses SWOT results in Estuary & Coast/Sea



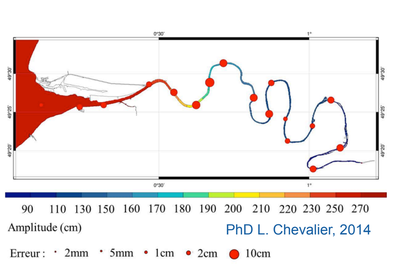
Turki et al., 2015, Int. J. Remote Sensing and Remote Sensing Letters

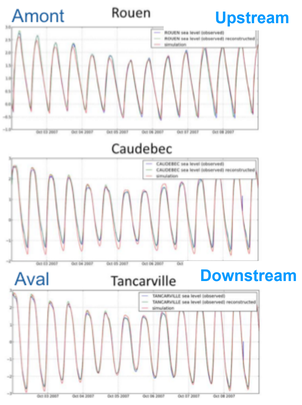
Similar results for river & upstream estuary: Simulated SWOT data reproduce very well variability modes
Similar results for coast/sea & downstream estuary: SWOT reproduces less or not the variability modes
Wavelet coherence decreases from river to the sea. In the downstream estuary and coast/sea, the energy of 1 y mode decreases and the 2-4 months mode is overexpressed by SWOT, because its passage frequency coincides with the frequency of the M3 tide component & SWOT overexpress this component

Laignel et al., 2014, IAH ; Laignel et al., 2015, ESA
Turki et al., 2015, J. Applied Earth Observations & Remote Sensing

SWOT ABILITY TO REPRODUCE THE SPATIAL HYDROLOGICAL VARIABILITY FROM MODELING

Modeling results in the estuaries: example of the Seine estuary





T-UGOm model
Data inputs in the model
Several Bottom coefficient & zonation
Bathymetry accuracy : 3 m

Throughout estuary, T-UGOm model reproduces well:
the main tide component M2 with an error less than 10 cm
the temporal hydrological variability and the water level amplitude

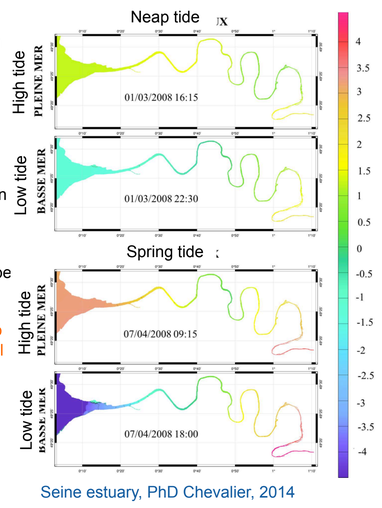
T-UGOm model results & interest of the SWOT resolution In the Seine estuary

Water level maps obtained by modeling in the Seine estuary (T-UGOm)

The water levels are spatialy, highly variable in
- different hydrodynamic conditions
- specific hydrodynamic condition

This high spatial variabilty of water level can be observed for distance less than 1 km

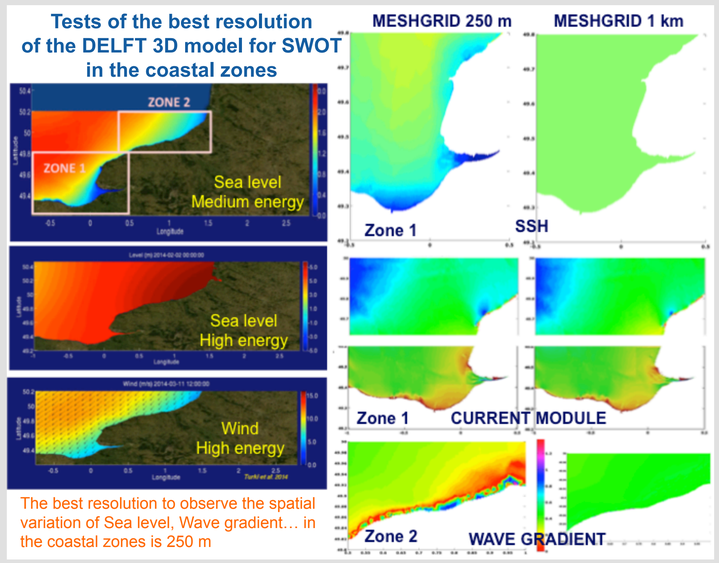
Only SWOT has sufficient spatial resolution to study & better understand & model this spatial variation in different hydrodynamic conditions



Laignel et al., 2015, ESA

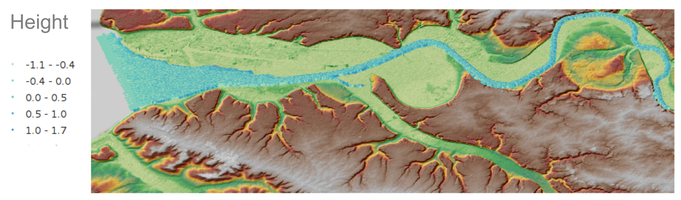
Seine estuary, PhD Chevalier, 2014

Tests of the best resolution of the DELFT 3D model for SWOT in the coastal zones



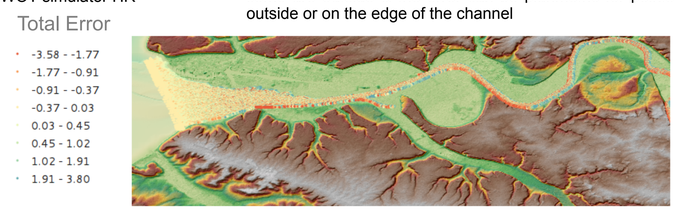
The best resolution to observe the spatial variation of Sea level, Wave gradient… in the coastal zones is 250 m

First result of SWOT Simulator HR in the Seine estuary



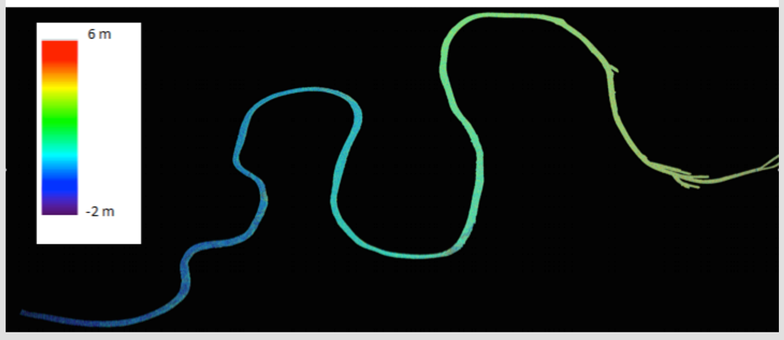
T-UGOm model data were used as imput data in the SWOT simulator HR

Majority of the SWOT measurement points are located in the channel, with low water level error (centimetric), but some are outside & the error can be plurimetric for points outside or on the edge of the channel



Geolocated water levels in the Seine estuary from improved geolocation method of the SWOT Simulator HR

PhD Desroches, 2016



The improved geolocation method of the SWOT simulator HR reproduces well the spatial variability of water level along the Seine estuary in the medium conditions of the flow and tide

CONCLUSION

✔ Simulated SWOT data reproduce
- very well the main modes of hydrological variability in the downstream part of the 4 main french rivers & in the upstream part of the Seine & Gironde estuaries:
NAO mode, hydrological cycle & flood period
- less the hydrological variability in the downstream part of the Seine & Gironde estuaries & in the coastal zone:
energy of 1 y mode (associated with biggest tides) is a bit or not recorded
mode of 3-4 mth (surges and specific component tide M3) is overexpressed by SWOT because its passage frequency coincides with the frequency of the M3 tide

✔ T-UGOm and DELFT 3D models results
- reproduce well the main tide component M2 & temporal hydrological variability & water level amplitude, throughout Seine estuary
- the water levels are spatialy, highly variable & this high spatial variation can be observed over distances of less kilometer in the estuaries & coastal zones
& this shows the importance of the high spatial resolution of SWOT to see these transitions in these environments

✔ Simulations from SWOT simulator HR (from model data as inputs)
Majority of the SWOT points are located in the channel and with low water level error & the improved geolocation method reproduces well the spatial variability of water level in the Seine estuary