Utilisation du futur satellite SWOT pour l'étude de la variabilité hydrologique temporelle et spatiale des fleuves français et perspectives pour les fleuves africains
Mission CNES, NASA, CSA, UKSA – Projet TOSCA-CNES

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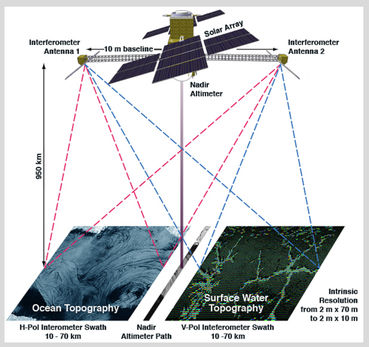
INTRODUCTION

Among the future satellites, the SWOT mission (Surface Water and Ocean Topography) of the french (CNES), american (NASA), canadian (CSA) and United Kingdom (UKSA) spatial agencies will provide global data on the water level with an high spatial resolution : the SWOT mission, with Ka-band SAR interferometric system and 2 swaths, will have the capacity to measure changes in water levels of 68% of the lakes (> 250m x 250m) and many rivers, including those of small size (with a width upper or egal to 100 m), that were previously inaccessible from other satellites…



Ka-band SAR interferometric system with 2 swaths
An additional instruments:
conventional Jason-class altimeter for nadir coverage
AMR-class radiometer to correct for wet-tropospheric delay
Spatial Resolution
Ocean: 1 km ; Lakes: 250 m² ; 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

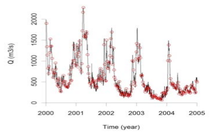
Approaches & Objectives

To answer to the question of the SWOT use in the french rivers & estuaries

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	

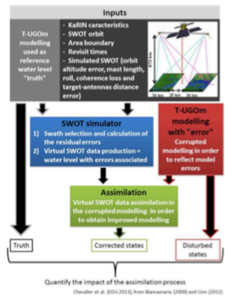


we characterize and compare the temporal hydrological variability of the in situ and simulated SWOT data from several analyses (trend, loess, wavelet analysis…)

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

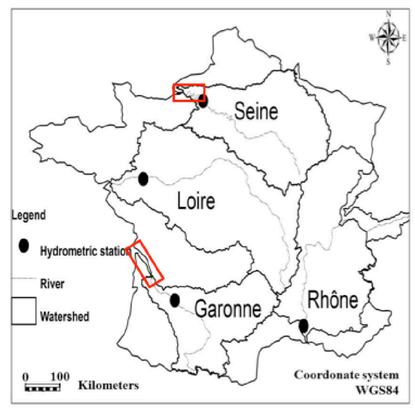
Accurate modeling of the spatial & temporal variability of water level
T-UGOm model

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



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

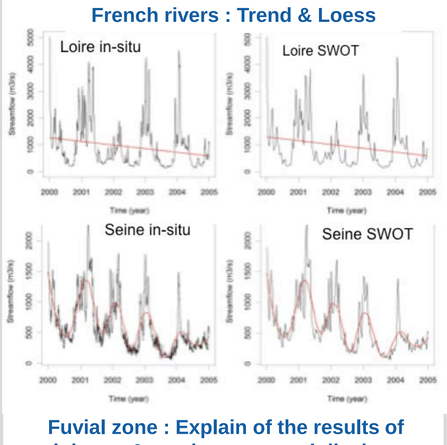
Study sites : Main french rivers & 2 estuaries



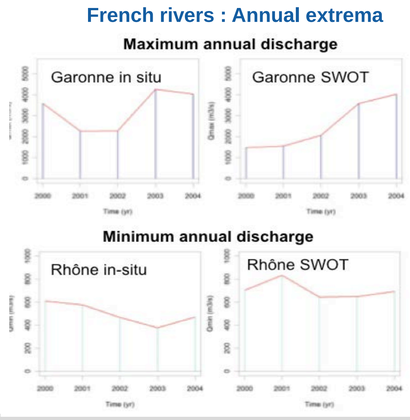
Gauges in the fuvial zone (in the downstream without the tide influence) of the Seine, Garonne (& Loire, Rhône)
Gauges of the Seine and Gironde estuaries

SWOT ABILITY TO REPRODUCE THE TEMPORAL HYDROLOGICAL VARIABILITY

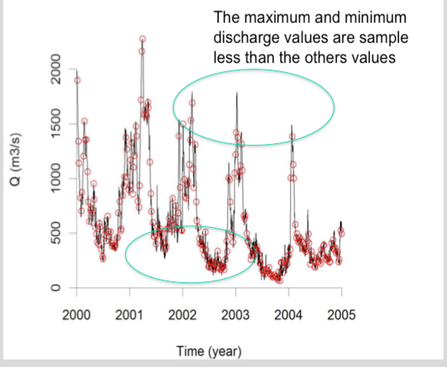
French rivers : Trend & Loess



French rivers : Annual extrema



Fuvial zone : Explain of the results of minimum & maximum annual discharge



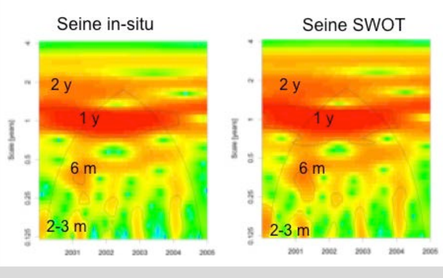
Simulated SWOT data restitute well :
- trend
- main modes of hydrological variability observed by the loess

for the 4 french rivers (Seine, Garonne, Loire, Rhône)
during the 3 studied periods (1965-1969, 1985-1989, 2000-2004)

SWOT reproduce well the mean annual discharge

but SWOT underestimate the maximum annual
& overestimate the minimum annual discharge

French rivers : Modes of hydrological variability by wavelet analysis



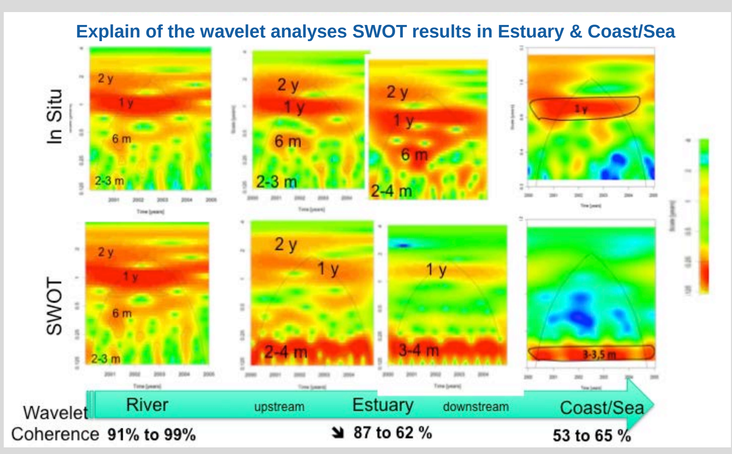
Simulated SWOT data reproduce very well the main modes of hydrological variability observed in the in-situ data :
2 y = NAO mode,
1 y and 6 months = hydro. cycle
2 to 3 months = flood period

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%

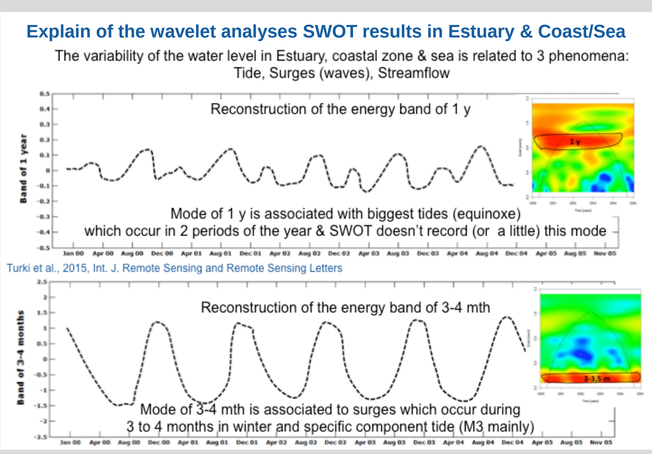
Laignel et al., 2014, IAH ; Laignel et al., 2015, ESA

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



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

The variability of the water level in Estuary, coastal zone & sea is related to 3 phenomena: Tide, Surges (waves), Streamflow



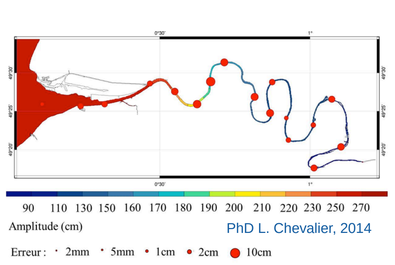
Turki et al., 2015, Int. J. Remote Sensing and Remote Sensing Letters

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

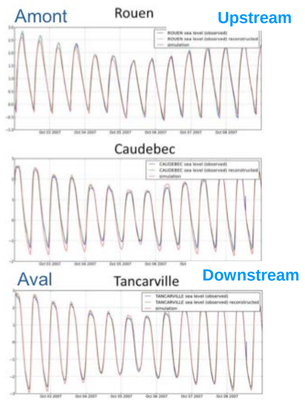
Laignel et al., 2014, IAH ; Laignel et al., 2015, ESA

SWOT ABILITY TO REPRODUCE THE SPATIAL HYDROLOGICAL VARIABILITY

Modeling results in the estuaries: example of the Seine estuary



PhD L. Chevalier, 2014



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

Model results & SWOT contributions

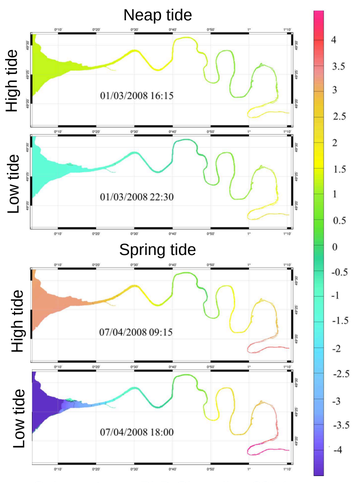
Water level maps obtained by modeling in the Seine estuary (T-UGOm)

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

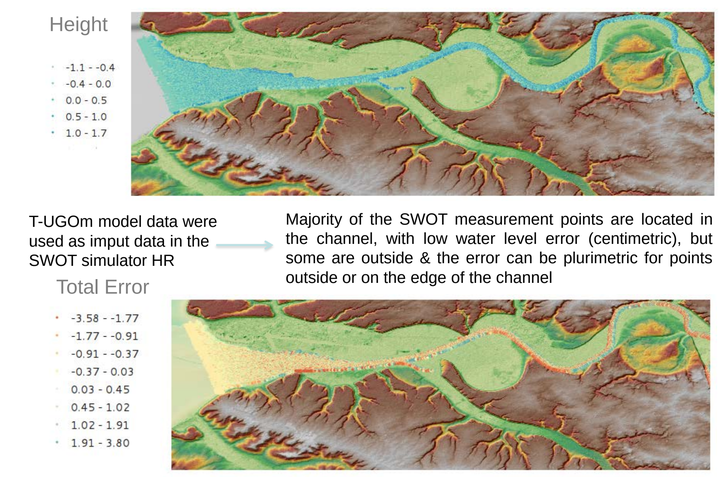
Only SWOT has sufficient spatial resolution to study & better understand & model this spatial variation in different hydrodynamic conditions

Laignel et al., 2015, ESA



Seine estuary, PhD Chevalier, 2014

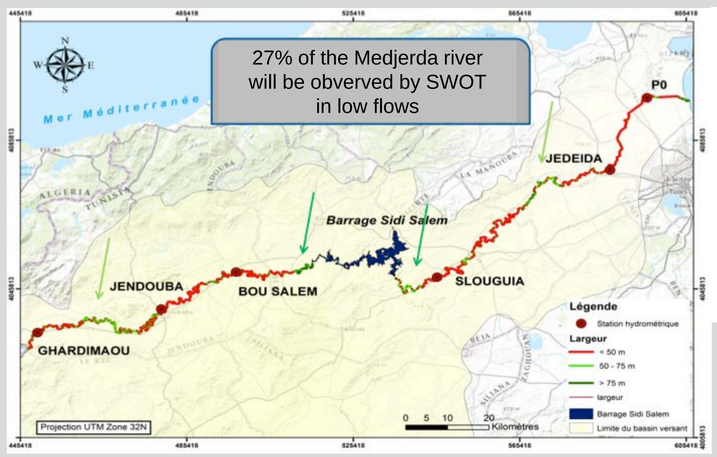
First results of SWOT Simulator HR in the Seine estuary

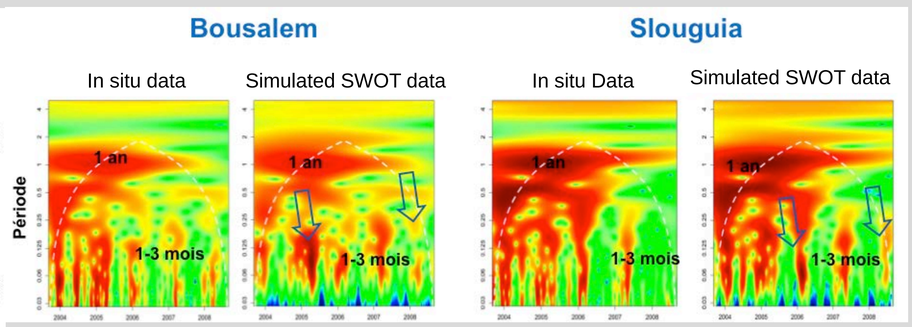


T-UGOm model data were used as imput data in the SWOT simulator HR

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

PERSPECTIVES AFRICAN RIVERS





SWOT can observe 27 % of the Medjerda river (Tunisia) in low flows (width > 50 m) and can thus observe many African rivers such as the Nile, Congo, Senegal…
Simulated SWOT data reproduce very well the main modes of hydrological variability of the Medjerda river, with a strong coherence between 85 and 99 %

Master 2 Jelassi, 2015

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 model results
- reproduce well the main tide component M2 & temporal hydrological variability & water level amplitude, throughout estuary
- the water levels are spatialy, highly variable & this high spatial variation can be observed over distances of less kilometer
& this shows the importance of the high spatial resolution of SWOT to see these transitions in these environments

✔ First simulation from SWOT simulator HR (from model data as inputs)
promising results: majority of the SWOT points are located in the channel and with low water level error