Record of the temporal hydrological variability by SWOT
In the estuarine & coastal zones
Examples of Seine-Channel & Gironde-Atlantic

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TOSCA-CNES Project
Characterisation and modeling of the hydrological variability in the coastal zones in the framework of the SWOT mission
Application to the Seine and Gironde estuaries & coastline of the Up. Normandy

7 teams: M2C Rouen-Caen, LETG Caen, LDO Brest, EPOC Bordeaux, LEGOS Toulouse, SISYPHE Paris 6 et Mines ParisTech

Coordinator: Professeur Benoit Laignel, UMR CNRS 6143 M2C, Univ. Rouen
3 axes = 3 objectives

- Study the variability of water level & the contribution of different factors and the capacity of SWOT to reconstitute the temporal hydrological variability in using the signal processing & statistical methods applied to in-situ measurements.

- Modeling the spatio-temporal variability of water levels and factors and SWOT calibration/validation (Comparison of models & use of simulated SWOT data).

- Preparation/(Validation) of AirSWOT airborne campaign using the analysis of in-situ data and modeling.
Gauges in the fluvial 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
To study the capacity of SWOT to restitute the temporal hydrological variability, we simulate SWOT data:

From the SWOT orbits (873, 891 & 890)

We sample the time series of water level or discharge during 5 years according to the passage frequency of SWOT.

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

<table>
<thead>
<tr>
<th>Débits</th>
<th>Lat</th>
<th>Long</th>
<th>SWOT Passage (in hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seine</td>
<td>49.310815</td>
<td>1.236246</td>
<td>100.575</td>
</tr>
</tbody>
</table>

Exemple SWOT orbite : 891

Days

<table>
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<tr>
<th>Days</th>
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<tr>
<td>4,190625</td>
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</table>
simulated SWOT data reproduce the trend, but not exactly the amplitude

SWOT restitutes well the trend

SWOT reproduces the increase of sea level but the increase by SWOT is greater than the in situ data

SWOT restitutes the increase of sea level but the SWOT values are lower than the in situ data
Coastal zone: Density of probability of water level

Simulated SWOT data
In situ data

SWOT reproduce well the 2 main modes of water level but SWOT overestimate these 2 modes
Coastal zone: Explain of the results of the density of probability of water level.

SWOT samples more the most frequent values as the two main modes and less other values such as maximum and minimum values.
Coastal zone: Water level variability from wavelet analyses

Simulated SWOT data don’t reproduce exactly the same modes of hydro variability observed by in-situ measurements.

SWOT don’t restitute or restitute weakly cycle of 1 y but record a mode of 3-4 months, slightly visible in the in situ data.
Coastal zone: Explain of the wavelet analyses results

The variability of the water level in coastal zone is related to two phenomena: tide & surges (waves).

Reconstruction of the energy band of 1 y

Mode of 1 y is associated with biggest tides (equinoxe) which occur in 2 periods of the year.

Reconstruction of the energy band of 3-4 mth

Mode of 3-4 mth is associated to surges which occur during 3 to 4 months in winter.
Coastal zone: Explain of the wavelet analyses results

Simulated SWOT data restitute:
an energy band 28 days
= neap tide & spring tide cycle

The wavelet coherence between observed and SWOT simulated data for all frequencies (energy bands) indicates a coherence from 53 to 65 %
Estuaries: hydrological variability from wavelet analyses

In-situ data, we see almost the same results from upstream to downstream:
- modes of 2 y, 1 y & 6 mth,
- a mode of 2-3 or 2-4 mth located at the end and beginning of the year

SWOT simulated data, the results change from upstream to downstream:
- modes of 2 y, 1 y & 6 mth gradually decrease,
- a mode of 3-4 mth becoming stronger
Fuvial zone: 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:

- 2-3 years = NAO mode,
- 1 year and 6 months = hydro. cycle
- 2 to 3 months = flood period

For the 4 French rivers & for the 3 studied periods:

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<tr>
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<tbody>
<tr>
<td>Seine</td>
<td>99.5%</td>
<td>99.06%</td>
<td>99.38%</td>
</tr>
<tr>
<td>Garonne</td>
<td>96.36%</td>
<td>98.44%</td>
<td>96.25%</td>
</tr>
<tr>
<td>Loire</td>
<td>98.84%</td>
<td>99.02%</td>
<td>98.39%</td>
</tr>
<tr>
<td>Rhône</td>
<td>95.75%</td>
<td>91.30%</td>
<td>94.73%</td>
</tr>
</tbody>
</table>

Wavelet coherence between simulated SWOT data and in-situ water level indicates a strong coherence, from 91% to 99%.
Estuaries: Explain of the wavelet analyses results

Estuaries
= an intermediate response to the river and sea factors according to the location in the estuary

<table>
<thead>
<tr>
<th>In situ data</th>
<th>Simulated SWOT data</th>
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<tbody>
<tr>
<td>1y</td>
<td>1y</td>
</tr>
<tr>
<td>Hydro. cycle: river (Biggest tides, equinox)</td>
<td>Hydro. cycle: river</td>
</tr>
<tr>
<td>2-3 mth flood period</td>
<td>2-3 mth flood period</td>
</tr>
</tbody>
</table>

The wavelet coherence between observed and SWOT simulated data indicates a coherence from 62 to 87% Decrease from the upstream to the downstream
Influence of the orbit and the beginning of the cycle

We tested the influence of the orbit & the beginning of the cycle of 22 days on the ability of SWOT to restitute the temporal hydrological variability. We tested 3 orbits: 873, 891 & 890 km

Results

Choice of the orbit has little influence on the results whether for rivers, estuaries and coasts studied.

A shift of few hours or months can cause some changes of the results in the coastal zone, such as the trend and the probability of occurrence of two main modes of the water level.
Influence of the orbit and the beginning of the cycle

We tested the influence of the orbit & the beginning of the cycle of 22 days on the ability of SWOT to restitute the temporal hydrological variability. We tested 3 orbits: 873, 891 & 890 km.

**Results**

Choice of the orbit has little influence on the results for studied rivers, estuaries & coasts.

Coherence variability according to the orbites in Seine river: 1 % (max)
Coherence variability according to the orbites in Seine estuary: 2 - 11 %

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<tbody>
<tr>
<td></td>
<td>Orbit 891</td>
<td>Orbit 890</td>
<td>Orbit 873</td>
</tr>
<tr>
<td>Seine river</td>
<td>99.5%</td>
<td>99.51%</td>
<td>98.60%</td>
</tr>
<tr>
<td></td>
<td>99.06%</td>
<td>99.44%</td>
<td>98.89%</td>
</tr>
<tr>
<td></td>
<td>99.38%</td>
<td>99.36%</td>
<td>98.53%</td>
</tr>
<tr>
<td>Seine estuary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Honfleur</td>
<td>Downstream</td>
<td>61.93%</td>
<td>70.89%</td>
</tr>
<tr>
<td>Tancarville</td>
<td></td>
<td>72.37%</td>
<td>61.09%</td>
</tr>
<tr>
<td>Caudebec</td>
<td></td>
<td>75.98%</td>
<td>73.48%</td>
</tr>
<tr>
<td>Duclair</td>
<td>Upstream</td>
<td>81.01%</td>
<td>83.20%</td>
</tr>
<tr>
<td>Rouen</td>
<td></td>
<td>86.81%</td>
<td>88.91%</td>
</tr>
</tbody>
</table>
Influence of the orbit and the beginning of the cycle

Results

A shift of few hours or months can cause some changes of the results in the coastal zone, such as the trend and the probability of occurrence of two main modes of the water level.
Coastal zone: Density of probability of water level

Simulated SWOT data
In situ data

SWOT record less some values and more other values, however, SWOT reproduce well the 2 main modes of water level but SWOT overestimate these 2 modes.