A multi-peak model for peaky altimetric waveforms

P.Thibaut*
J.Severini**
C.Mailhes**
J.Y.Tourneret**
E.Bronner\textsuperscript{T}
N.Picot\textsuperscript{T}

* Collecte Localisation Satellite, France
** University of Toulouse / IRIT-ENSEEIHT-TESA, France
\textsuperscript{T} Centre National d’Etudes Spatiales, France

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When the nadir point is within 20 km off the coast (10 km typically for J1/2, Topex; 9 km for RA-2; 6 km for Poseidon-1 and altiKa; 5 km for ERS), land may alter the shape of ocean waveforms.

**How** the waveform is affected depends on \( \text{Area}_{\text{Land}} \times \sigma_{0,\text{Land}} \) relative to \( \text{Area}_{\text{Ocean}} \times \sigma_{0,\text{Ocean}} \).

- If \( \sigma_{0,\text{Land}} < \sigma_{0,\text{Ocean}} \) (often true), the effect can be small. If the coastal land is not mountainous and \( \sigma_0 \) is low, the waveform distortion may be mild until quite close to the coast, and simple (Brown model) retracking may work.

- In some environments, however (coral atolls) \( \sigma_{0,\text{Land}} > \sigma_{0,\text{Ocean}} \) and the effect is large on the waveform.

**The waveform can also be corrupted by the modification of the sea state within the FoV.**
A waveform classification algorithm (neural network) has been introduced in the Pistach processing in order to distribute all the waveforms in predefined classes and to propose appropriate retracking strategies for each of these classes.

- A red3 algorithm has been implemented (fit of a Brown model on a reduced portion of the waveform to discard corrupted samples at the end of the trailing edge)

- We will focus in this presentation on waveforms that present peak(s) on their trailing edge, waveforms that are not properly retracked by classical MLE algorithms based on Brown model

WF class definition and distribution as a function of distance to the coastline (Jason-2, Cycle 8)
Examples of observed waveforms

Jason-1, Cycle 188
Pass 37 (over Chile)
Ku band
Examples of observed waveforms

Jason-1, Cycle 188
Pass 37 (Amazonia)
Ku band
Examples of observed waveforms

Jason-2, Cycle 8
Pass 187
(Med Sea, Ibiza Island)
Ku band

RA-2
Pianosa Island
Ku band
(Quartly, Seattle OSTST, 2009
Gomez-Enri, Coastal Meeting,
Rome, 2009)
Mathematical formulation

The altimetric signal is modeled using a Brown model and a sum of Gaussian peaks

\[ \tilde{x}_k = s_k + p_k \]

with

\[ p_k = \sum_{i=1}^{q} A_i \exp \left[ -\frac{(kT_s - t_i)^2}{2\sigma_i^2} \right] \]

Parameters:
- Amplitudes \( A = (A_1, \ldots, A_q) \)
- Positions \( t = (t_1, \ldots, t_a) \)
- Widths \( \sigma^2 = (\sigma_1^2, \ldots, \sigma_q^2) \)

Of course, the observed signal accounts for multiplicative speckle noise
Mathematical formulation

• Maximum Likelihood Estimation for deep ocean signals (Quasi-Newton recursive method) \( \theta_B \) is the vector of parameters \((\tau, \text{SWH}, P_u)\)

\[
\theta_B(n + 1) = \theta_B(n) - \mu_n \left( B B^T \right)^{-1} B D,
\]

\[
B = \left( \frac{1}{x_k} \frac{\partial x_k}{\partial \theta_{B,i}} \right)_{i=1,\ldots,3, k=1,\ldots,N}, \quad D = \left( \frac{x_k - y_k}{x_k} \right)_{k=1,\ldots,N} \quad \text{et} \quad \mu_n = 1.
\]

• Maximum Likelihood Estimation with multi-peaks for coastal signals

Estimation of the parameter vector \( \theta = \left( \theta_B^T, \theta_P^T \right)^T \) using a similar Quasi-Newton recursive method

\[
\theta(n + 1) = \theta(n) - \mu_n \left( \tilde{B} \tilde{B}^T \quad \tilde{B} \tilde{P}^T \right)^{-1} \left( \tilde{B} \quad \tilde{P} \right) D,
\]

\[
\tilde{B} = \left( \frac{1}{x_k} \frac{\partial x_k}{\partial \theta_{B,i}} \right)_{i=1,\ldots,3, k=1,\ldots,N}, \quad \tilde{P} = \left( \frac{1}{x_k} \frac{\partial p_k}{\partial \theta_{P,i}} \right)_{i=1,\ldots,3q, k=1,\ldots,N} \quad \text{and} \quad \mu_n = 1.
\]
Simulated signals with $\theta_B = (130, 31, 2)$ and $\theta_P = (400, 75, 1)$

- Very good results on simulated signals in particular on sigma0 estimate but also on range and SWH
Results on real Wfs (mono-peak)

- Very good general fit of the echo
- Very good fit of the leading edge (impacting range and SWH) much better than MLE3
- Better estimation of Pu (thus wind and SSB)
Results on real Wfs (multi-peak)

Mono-peak fit

Multi-peak fit
Regression with MLE3 on normal WF

- No regression with respect to MLE3
- Very important to assure the continuity between retrackings when approaching the coasts (assures also the continuity of the SSB correction)

> Sometimes, no peaks are fitted

> Sometimes, small peaks are fitted
Conclusions

- A multi peak model can be used to retrack waveforms near the coast
- Mathematical formulation very close to the classical Quasi-Newton formulation used for deep ocean signals
- Possibility to use the same formulation on non-Gaussian signals
- Validations have been done on simulated and real signals
- Very good results on peaky waveforms provided that the peaks are not on the leading edge or too close to the leading edge (work to be done on that point)
- Doesn’t currently work with MLE4 estimation (under investigation)
- No regression on non-peaky waveforms
- Not available in the Pistach products
Quality of satellite derived river water level time series
(N. Bercher, P. Kosuth : UMR TETIS, CEMAGREF, Montpellier)
Quality of satellite derived river water level time series
(N. Bercher, P. Kosuth : UMR TETIS, CEMAGREF, Montpellier)

Products exact comparison
- 56 sites (Amazon basin)
- 4 products
- 2 missions (T/P & Jason-2)
- covering 2002-2009

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<th>RMS (m)</th>
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<td>AVISO – T/P – M-GDR</td>
<td>1.41</td>
<td>47.5</td>
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<td>CLS – T/P – Ice2</td>
<td>1.80</td>
<td>32.2</td>
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<td>AVISO – Jason-2 – Ice1</td>
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<td>(july 2008 – july 2009)</td>
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<tr>
<td>PISTACH – Jason-2 – Ice3</td>
<td>0.72</td>
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<td>(july 2008 – july 2009)</td>
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cf. Poster presentation in Ocean and hydrology applications workshop, Lisbonne 2010
« Quality and uncertainty of satellite derived river water level time series »
N. Bercher, P. Kosuth, F. Mercier

http://www.cls.fr