Improving the temporal and spatial resolution of water level time series over Po River (Italy) obtained by satellite altimetry

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New frontiers of altimetry

27–31 October 2014, Lake Constance, Germany
Po River

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Po River

ENVISAT

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Problem

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Problem

**temporal resolution**

- **positive aspects**
  - river is a dynamic system
  - asynchronous tracks

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Problem

**temporal resolution**  **spatial resolution**

positive aspects

river is a dynamic system

asynchronous tracks

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Problem

- **temporal resolution**
- **spatial resolution**
- **consistency**

Positive aspects:

- River is a dynamic system
- Asynchronous tracks

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Problem

- **temporal resolution**
- **spatial resolution**
- **consistency**

Positive aspects:
- River is a dynamic system
- Asynchronous tracks

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Problem

temporal resolution  spatial resolution  consistency

Positive aspects

River is a dynamic system  asynchronous tracks

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Problem

temporal resolution  spatial resolution  consistency

Goal

monitoring water level variation over the whole river as a network system

positive aspects

river is a dynamic system  asynchronous tracks
previous activities

• **No study** dedicated to this purpose so far
• As a collateral results, though, we have

  • Calmant et al. (2013) developed two regression models to link the altimetric level at virtual station to the nearby gauge
  • Birkinshaw et al. (2010) proposed a statistical method for outlier rejection considering all contemporaneous altimetry data

*Calmant et al. (2013), Detection of Envisat RA2/ICE-1 retracked radar altimetry bias over the Amazon basin rivers using GPS, Advances in Space Research, 51(8): 1551–1564. doi: 10.1016/j.asr.2012.07.033*
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N_A(t_t) - W(t_t) = b + \left[ s_0 + A \sin \left( 2\pi \frac{DOY_i}{365} + \varphi \right) \right] \times \Delta_t,
\]

\[
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Gauge data

water level [m]


0 5 10 15 20 25 30 35 40 45 50

Sermide
Borgoforte
Cremona
Pontelagoscuro
Piacenza

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water surface profiles

Longitude [°]

[°] 0
10
20
30
40
50
60
70
80
90
100
110
120

PIACENZA
BORGOFORTE
SERMIDE
CREMONA
PONTELAGOSCURO
dam
dam
108
401
337
129
65
358
294
86
22
315 251 4301
4302

Longitude [°]

[°] 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5

water surface profiles

[°] 0 20 40 60 80 100 120

8 8.5 9 9.5 10 10.5 11 11.5 12 12.5

8.5
10
12
12.5

water level [m]


0 5 10 15 20 25 30 35 40 45 50

Sermide
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Algorithm

1. time lag determination with respect to the considered VS
2. normalization of time series
3. confidence limit definition
4. outlier identification and rejection
5. scaling (back) the measurements at the considered VS
6. constructing the time series
Step 1: time lag determination

- **flow velocity estimation**

Bjerklie et al. (2005), Tommy S.W. Wong (2003)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W$</td>
<td>channel width</td>
<td>attained by the nearest cross-section information</td>
</tr>
<tr>
<td>$S$</td>
<td>slope</td>
<td>computed through the mean water level at virtual station</td>
</tr>
<tr>
<td>$L$</td>
<td>reach length</td>
<td>between two virtual stations</td>
</tr>
<tr>
<td>$\bar{V}$</td>
<td>local velocity</td>
<td>$\bar{V} = 2.3W^{0.8}S^{0.4}$</td>
</tr>
<tr>
<td>$c$</td>
<td>celerity</td>
<td>$c = \frac{5}{3}\bar{V}$</td>
</tr>
<tr>
<td>$T$</td>
<td>time lag</td>
<td>$T = \frac{L}{c}$</td>
</tr>
</tbody>
</table>
Step 1: time lag determination

- flow velocity estimation

Bjerklie et al. (2005), Tommy S.W. Wong (2003)

- **W** channel width attained by the nearest cross-section information
- **S** slope computed through the mean water level at virtual station
- **L** reach length between two virtual stations
Step 2: normalization

Normalize the data from each virtual station. The 10th percentile falls on 0 and the 90th percentile on 1.
Step 2: normalization

Normalize the data from each virtual station, the 10th percentile falls on 0 and the 90th percentile on 1.

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measurements at VS 86
Step 3: confidence limit definition

Definition of confidence limits of 99% using Student’s t-test for a sliding 1-month time window

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Step 4: outlier identification & rejection

Iterative data snooping and updating the confidence limits

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Step 5: scaling (back)

Rescaling the combined altimetric measurements to the considered virtual station

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Step 6: constructing the time series

two options:

1. simply connecting the measurements
2. 3-point moving average, distance weighted

from connecting the measurements
distance weighted averaging
Step 6: constructing the time series

two options:
1. simply connecting the measurements
2. 3-point moving average, distance weighted

long-term mean is removed...

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Validation

long-term mean is removed...

- in situ from connecting the measurements
  corr.=0.85, RMSE= 0.76 m, NSE=0.71
- averaging with weights according to distance
  corr.=0.86, RMSE= 0.73 m, NSE=0.73

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Validation

VS at [m] | RMSE | Correlation | NSE
---|---|---|---
Piacenza | 0.63 | 0.71 | 0.36
Cremona | 1.16 | 0.80 | 0.20
Borgoforte | 0.73 | 0.86 | 0.73
Sermide | 0.56 | 0.86 | 0.75
Pontelagoscuro | 0.62 | 0.86 | 0.74

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Summary and conclusion

- we investigated the water level time series over Po River at different virtual stations as a dynamic system
- the time lag between virtual stations is estimated
- the time series of individual VS are normalized and combined to each other
- outliers are removed using data snooping
- the time series are scaled back to the considered VS and a new time series is constructed by distance weighted averaging
- temporal resolution is improved from 35 day to an effective temporal resolution of $\sim 5$ day
- water level time series can be obtained at any location along the river using this approach
- we validate our results against daily in situ water level, we obtain Corr.$=0.85$, RMSE $=0.6$ m and NSE $=0.7$ for the unmanaged part of the river
Still open for future work

- bringing more hydraulic information into the modeling
- time variable slope consideration for time lag estimation
- improving the method over the managed part of river (before and after dam)
- multi-mission altimetry would definitely improve the temporal resolution
- bias consideration in case of multi-mission
Thank you

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