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Interactions of Tides, Storm Surge, and River Flow in the Microtidal Neretva River Estuary

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Sharing is encouraged

1 Microtidal Estuaries

Estuarine dynamics result from the interaction of tides, storm surges, river flows, and human activities such as hydropower peaking.

Previous studies mainly focused on **mesotidal** or **macrotidal** systems where tides dominate the hydrodynamic processes.

In **microtidal estuaries**, **storm surges** often have a stronger short-term influence on water levels than tides.

2 Non-stationary harmonic tidal model

Traditional **harmonic analysis** (HA) assumes that tidal properties (amplitudes and phases) are constant over time.

This method **cannot** capture the temporal variability of water levels in **estuaries**.

NS_Tide improves HA by directly incorporating non-stationary forcings (e.g., river flow, ocean tidal range) into the model.

It allows modeling both the **mean water level** (stage) and **tidal oscillations** as functions of these external drivers.

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b) Improve the understanding of how tides interact with storm surges and river flow in microtidal environments

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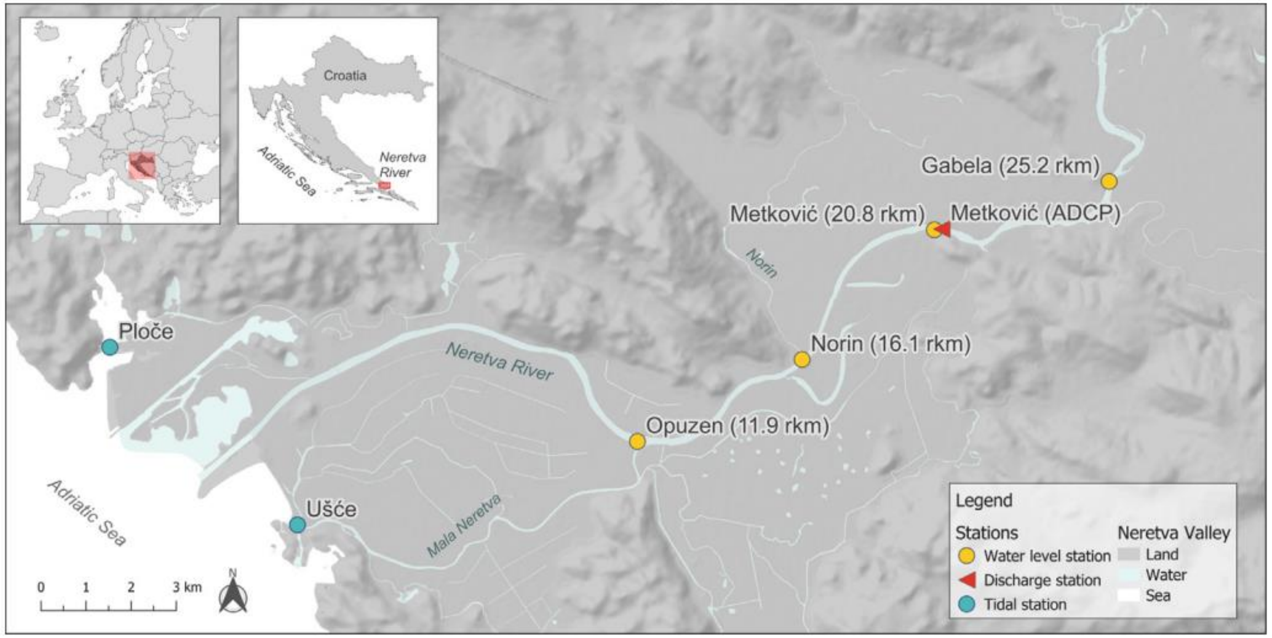
a) Propose a NS_Tide formulation for microtidal estuaries

3 Neretva River Estuary

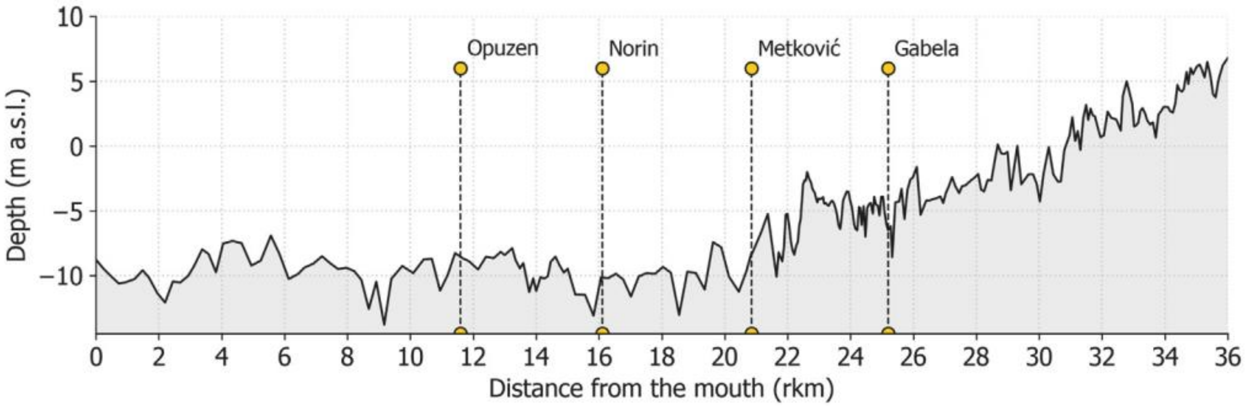
Microtidal estuary, ~20 km long estuarine zone and ~15 km long transitional tidal river zone.

Strong **seasonal** river discharge variations typical of Mediterranean climates.

(a) Map



(b) Longitudinal profile



4 „Old" NS_Tide model

Traditional tidal harmonic analysis (HA) :

$$\eta(t) = \eta_0 + \sum_{k=1}^{n} \left[c_k \cos(\omega_k t) + s_k \sin(\omega_k t)\right] + \epsilon(t),$$

NS_Tide model *(Matte et al., 2013)*

Water levels decomposed into **stage** (subtidal variations) and **tidal-fluvial** (tidal oscillations) terms.

$$\eta(t) = S(t) + F(t) + \epsilon(t),$$

$$F(t) = \sum_{k=1}^{n} \left[c_k(t) \cos(\omega_k t) + s_k(t) \sin(\omega_k t)\right]$$

$$S(t) = a_0 + a_1 Q^{2/3}(t - \tau_Q) + a_2 \frac{R^2(t - \tau_R)}{Q^{4/3}(t - \tau_Q)},$$

5 „New" NS_Tide model

Three new models tested for microtidal env:

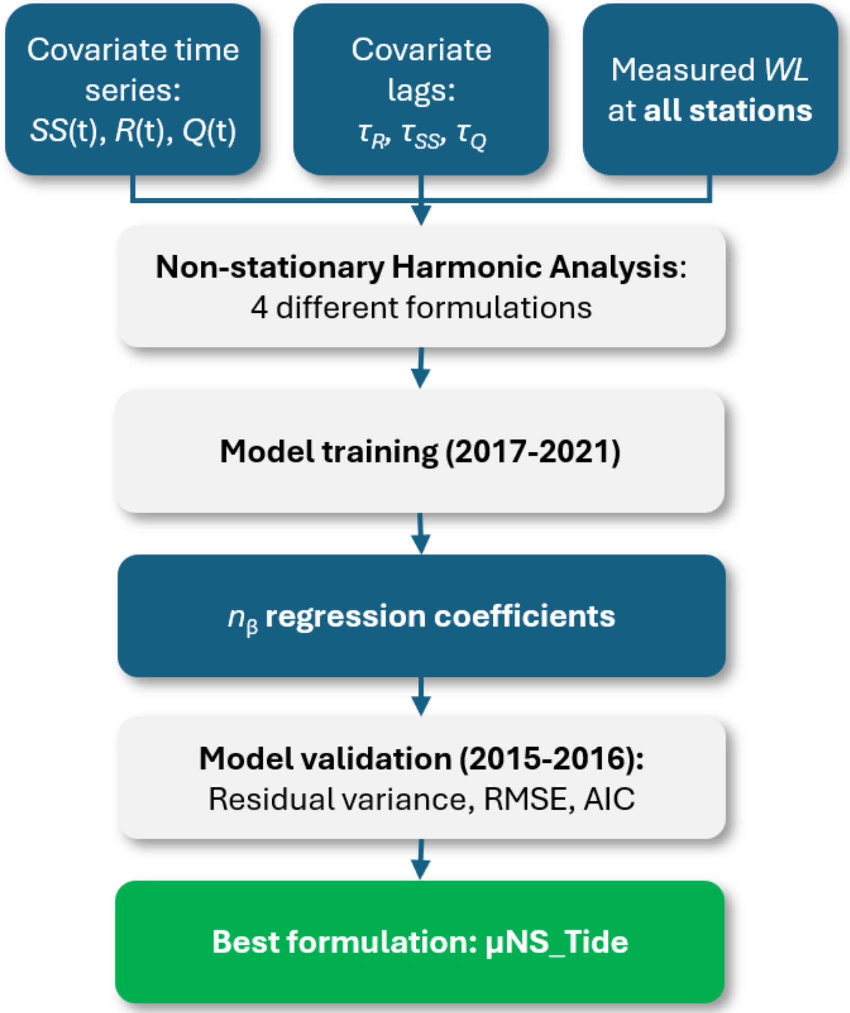
sNS_Tide: uses **storm surge** instead of tidal range.

qNS_Tide: **quadratic river discharge** term.

μNS_Tide: combines **quadratic discharge** and **storm surge**.

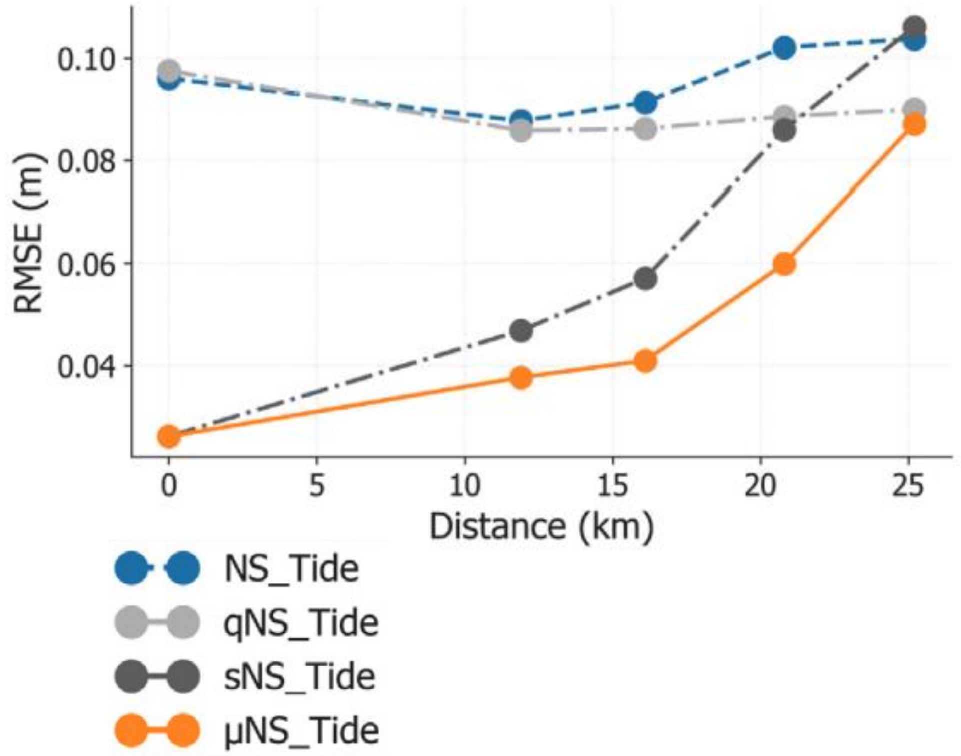
	Stage $S(t)$	Tidal-Fluvial $F(t)$
NS_Tide	$Q^{2/3},\ R^2/Q^{4/3}$	$Q,\ R^2/Q^{1/2}$
qNS_Tide	$Q,\ Q^2,\ R^2/Q^{4/3}$	$Q,\ R^2/Q^{1/2}$
sNS_Tide	$Q^{2/3},\ SS$	$Q,\ SS$
μNS_Tide	$Q,\ Q^2,\ SS$	$Q,\ SS$

6 Part I

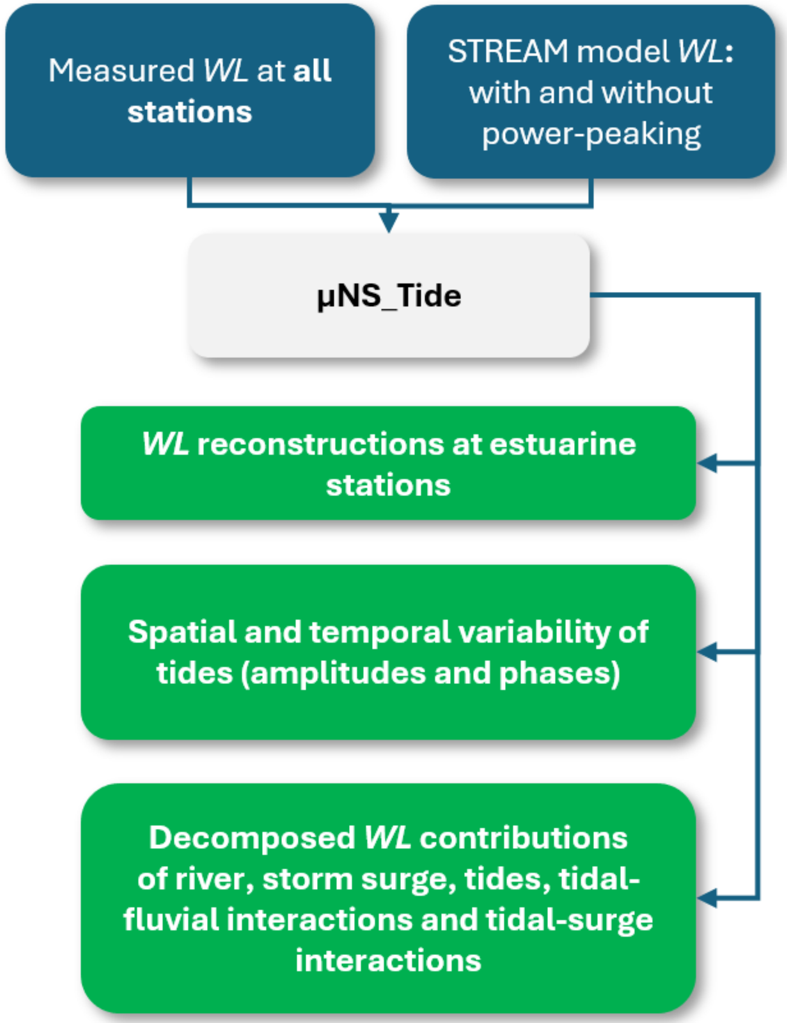


7 Validation

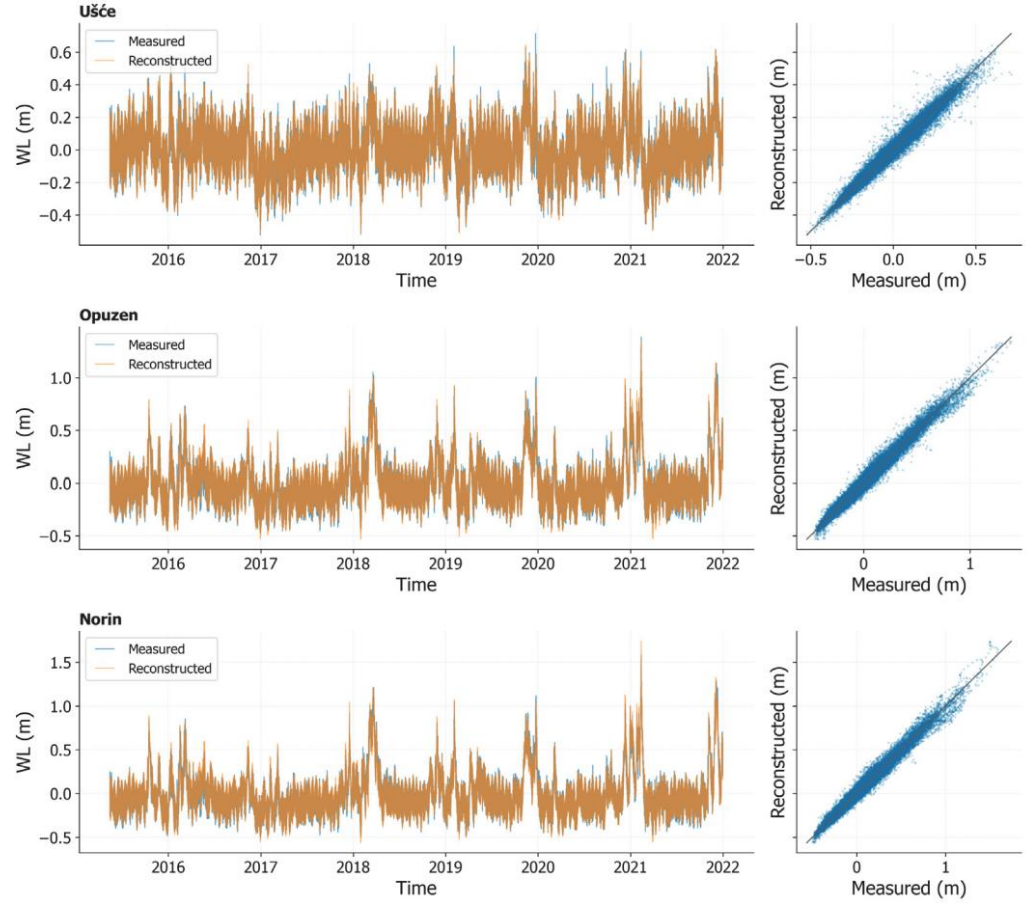
µNS_Tide had lowest residual variance (2–3%) and best reconstruction across all stations.



8 Part II

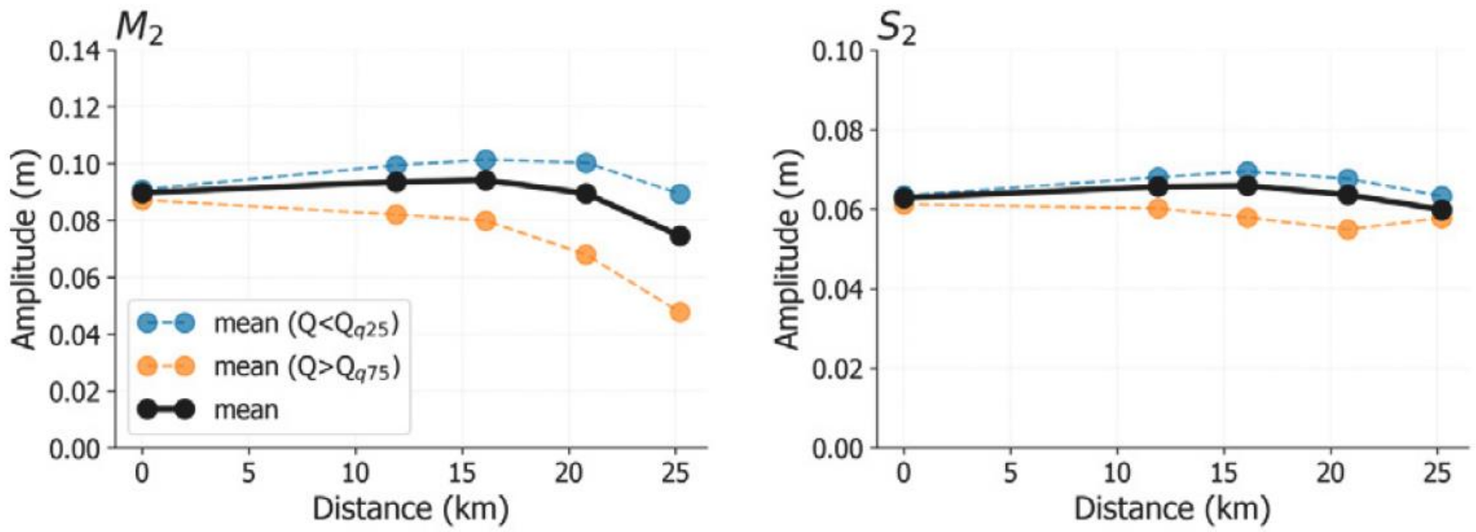


9 Water level reconstruction



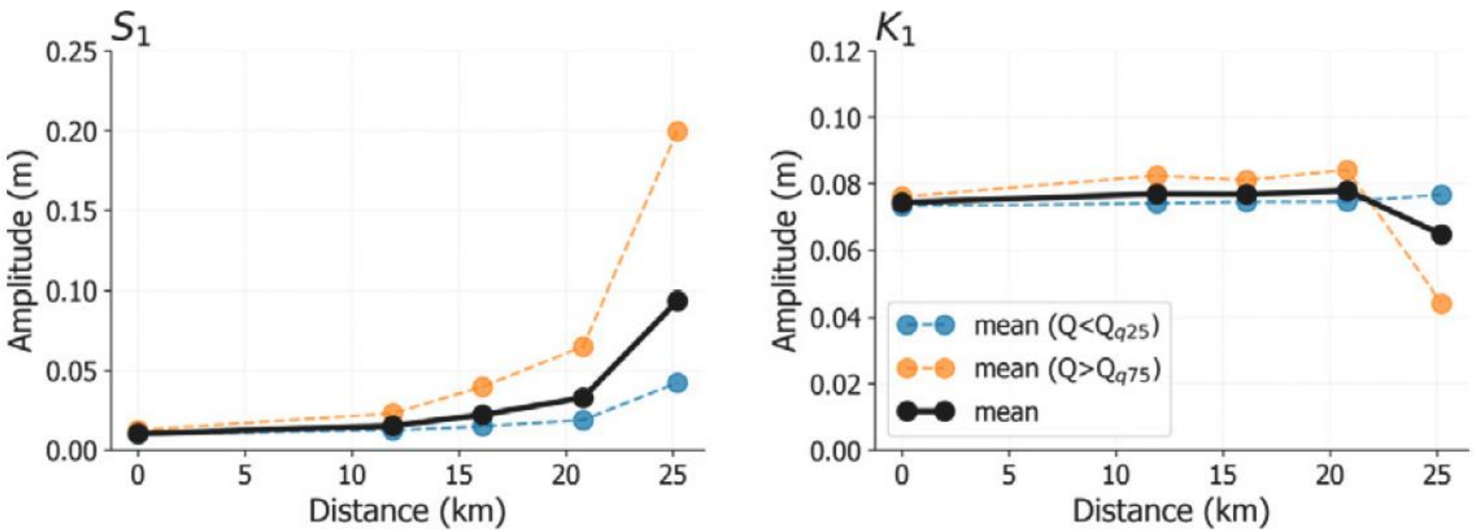
10 Semi-diurnal Constituents

Semi-diurnal constituents (M2, S2) **attenuate upstream**.



11 Diurnal Constituents

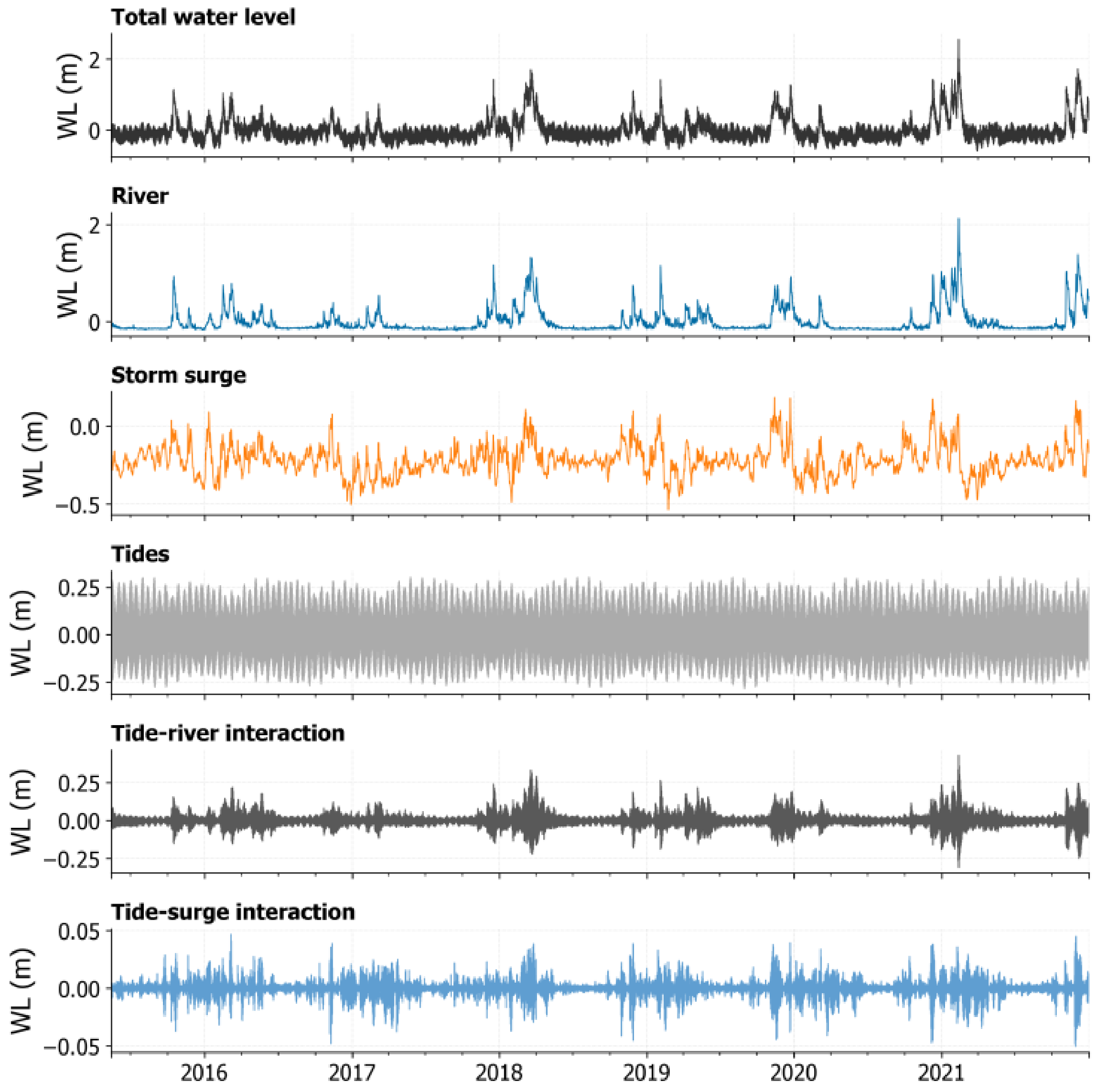
Diurnal constituent S1 **amplifies significantly upstream** (related to power peaking). While K1 does not.



Decomposition

Water levels along the estuary are decomposed into time series:

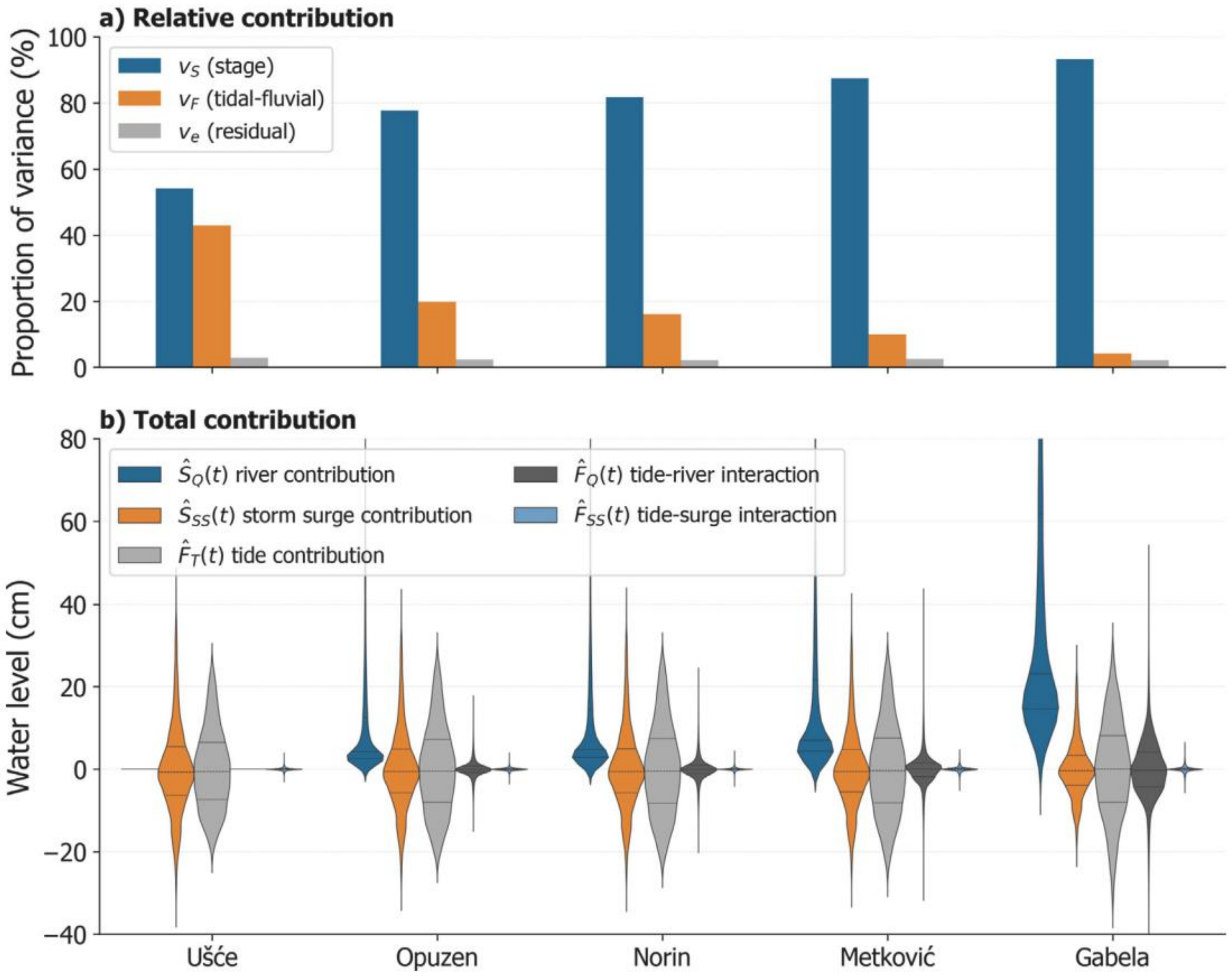
- River flow
- Storm surge
- Astronomical tides,
- Tide-river interaction
- Tide-surge interaction



13 Contributions

Contributions to total water levels along the estuary:

- **River flow** (dominant upstream),
- **Storm surge** (dominant at mouth, decreasing upstream),
- **Astronomical tides**,
- **Tide-river interaction** (grows upstream),
- **Tide-surge interaction** (minor contribution).



14 Key Findings

New **NS_Tide model** available as **MATLAB** and **Python** version (*pascal.matte@ec.gc.ca*)

New formulation of non-stationary tidal harmonic analysis for **microtidal estuaries**.

Decomposed contribution of river, storm surge, tides, and their interactions.

Estimation of **power peaking effects** on **tidal constituents** in microtidal settings.

Read the full paper here:

15 Future work will...

Investigate the adaptability and effectiveness of the new NS_Tide in **estuaries with more pronounced tide-surge-river dynamics**.

Combine NS_Tide with advanced machine learning for **river discharge reconstruction.**

Apply NS_Tide for assessing **compound flooding** in microtidal estuaries.

THANKS FOR YOUR ATTENTION

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