Environnement et Changement climatique Canada | Environment and Climate Change Canada

Water level extremes at ungauged locations along the St. Lawrence fluvial estuary

ECCC problem

ARPI - 20 May 2024

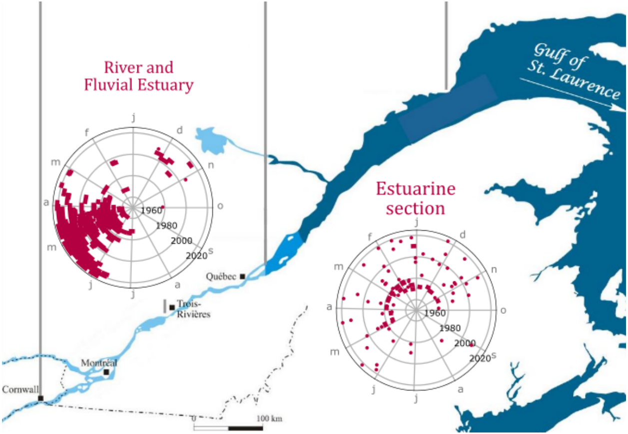
Canada

Water-level extremes along the St. Lawrence River

Complex spatio-temporal structure

Interaction of

- River discharge
- Tides
- Ocean variability
- Storm surges and winds
- Seasonal processes



[Plain d'action St. Laurent]

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e.g., for descriptive and model verification purposes

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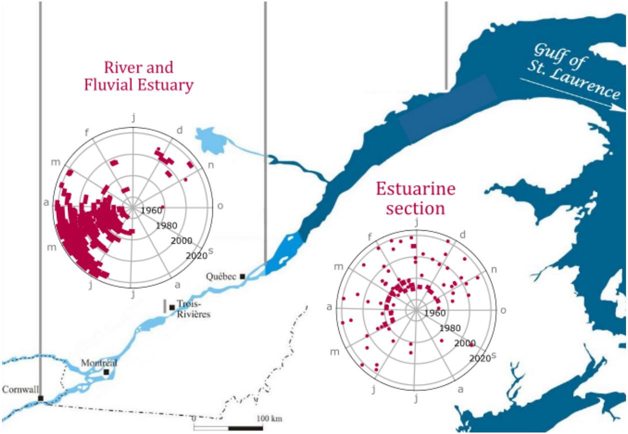

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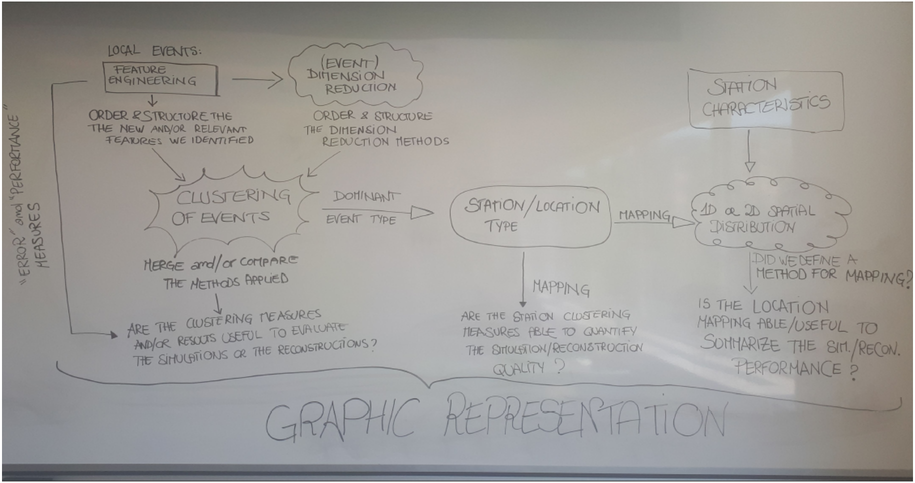
Problem solving: workflow

Obj. Define a set of measures that summarize the (dominant) event characteristics and can be compared between the simulated and observed series



Feature Engineering: define new water levels statistics

Water level variability (signal amplitude) combined with flow direction:

1. Number of hours before/after consecutive events
2. Number of stations in the event
3. **Event direction**: upstream $\rightarrow$ downstream, or vice-versa
4. Standardized peakness in 27-hr window around the peak:
   - **Relative peak** in time interval
   - **Peak intensity** relative to events at station

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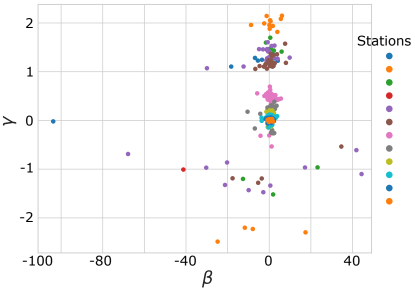
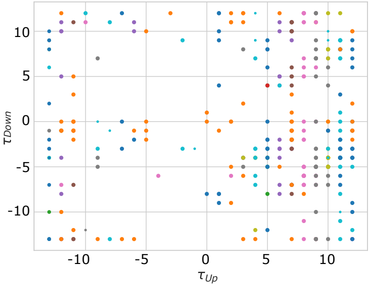
Similar statistics were computed for 5 covariates representing downstream and upstream signals influencing water levels.

Feature Engineering: simplified dynamic model coefficients

Coefficients of a discrete model based on differential equations using one upstream and downstream station (Sorel and Sept-Iles).

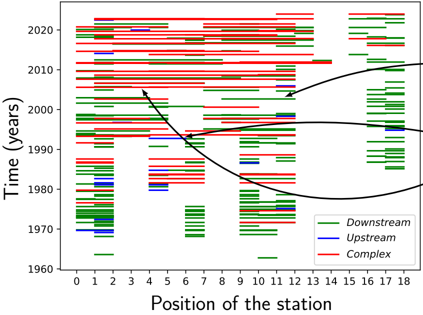
$$\mathrm{WL}(t) = \alpha + \beta\ \mathrm{WL}_{\mathsf{D}}(t - \tau_D) + \gamma\ \mathrm{WL}_{\mathsf{U}}(t - \tau_U)$$

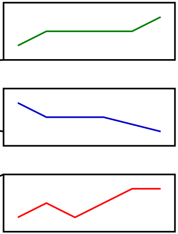


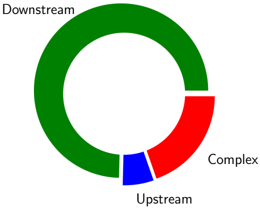


Feature Engineering: from local to regional extreme events

Geometrical characterization of flow direction and intensity





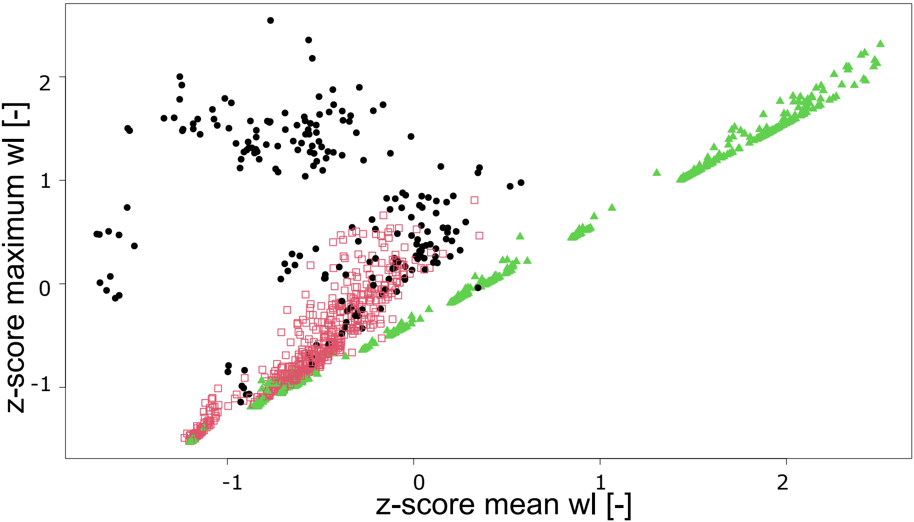


- The frequency of long-lasting events increases over the period
- The complexity is correlated with the event amplitude.

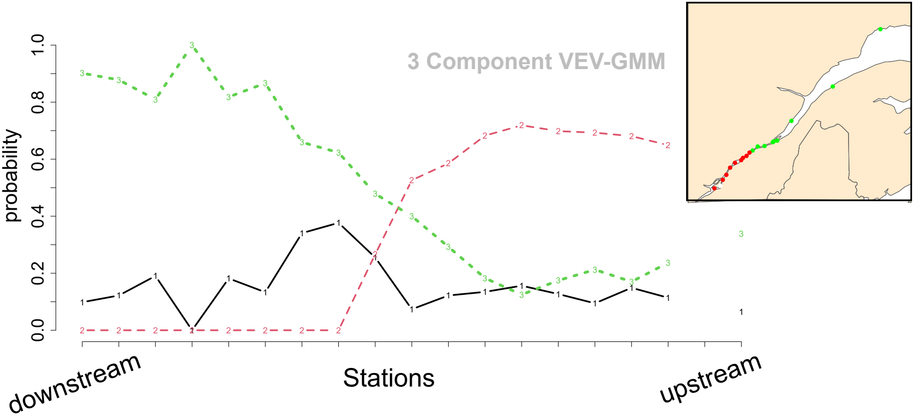
Clustering of events

1. We evaluated a variety of clustering methods, e.g. hierarchical Clustering, K-means, Gaussian mixture models (GMM), and vine copula mixture models
   - GMM is best in terms of explainability while providing very sharp cluster assignments
2. We find 3 mixture components with very good separation in feature space and are reasonably interpretable.

Separation of Components



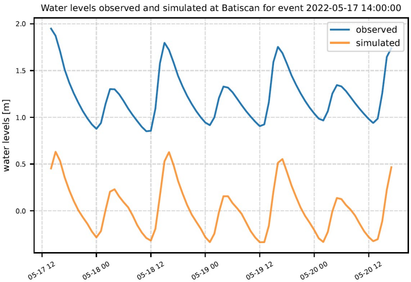
Relative Event Probabilities by Location

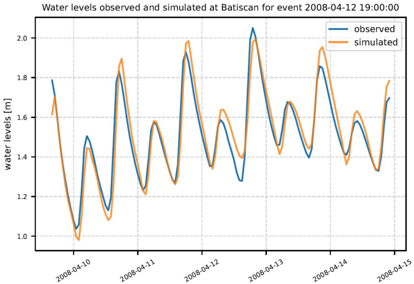


Model assessment

Obj. We want to select and rank statistical/hydrodynamic models based on their ability to reproduce extremes.

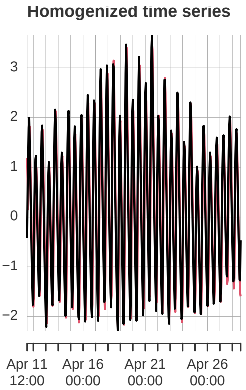
- We compare series with observations and look at their differences.

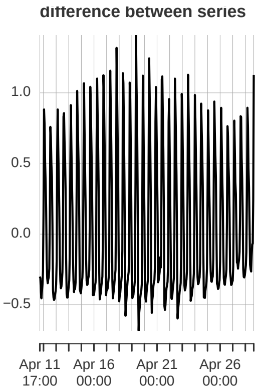


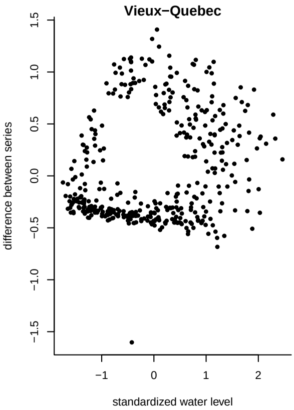


Observations versus model output

There are features (systematic bias, phase shift, etc.) inherent to some models. These can be characterized using suitable summary statistics.







Errors above are due to phase-shift of the series (horizontal translation) and asymmetry of the original signal.

Measurements

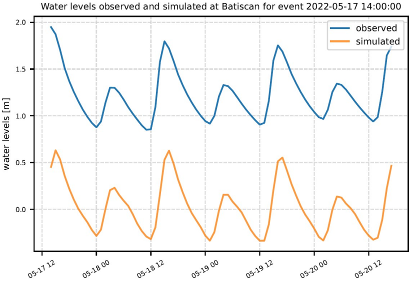
We define various metrics based solely on summary statistics of series and simulations.

- location and scale transformation minimizing the L_1 distance
- measure of phase-shift between series
- heteroscedasticity (variance increasing with measurements)
- asymmetry of variance for positive/negative values

Clear spatial gradient (upstream $\rightarrow$ downstream) for the metric values.

Model assessment using covariates

1. 55 features were obtained for each extreme local event.
2. We use **principal component analysis** for dimension reduction
   - 5 first principal components explain more than 70% of the variability.
   - Apply the same linear combinations to features of simulated extremes.
3. We compute the difference between each of the first 5 principal component (Δ PC) for simulated versus observed.
4. We then compute the L_2 distance between the 5 vectors of Δ PC.



- Δ PC$_1$ = 0.08
- Δ PC$_2$ = -0.67
- Δ PC$_3$ = -1.60
- Δ PC$_4$ = -0.35
- Δ PC$_5$ = 2.00
- L_2 distance = 2.67

Dashboard

Presents a quick view of the extreme event characteristics.

- Python: dash, pandas, plotly
- Callback functions to animate and update datasets used in the app
- Parallelizable with Python library dask
- Compatible for customization with Markdown and CSS files

Check it out:

https://ipsw24-py-67a531435269.herokuapp.com/

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Merci pour cette opportunité