# The processes determining the estuarine response of a salt wedge estuary under extreme drought conditions

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SALTISolutions

## 1. MOTIVATION

- Due to climate change, droughts are occurring more frequently. The impact of droughts on estuarine dynamics is unclear. Changes in dynamics can have implications on sediment supply, human activities, and ecology.
- The **most severe European droughts to date** happened in 2022. As a result of this drought, the Rhine-Meuse Delta (*RMD*) experienced several extreme salt intrusion events. The RMD is a dynamic mesotidal salt wedge estuary in the Netherlands. It is complex and highly branched.
- We focus on the differences between the responses of two estuary branches, the Old Meuse (OM) and the New Meuse (NM), which are both connected to the open sea through the New Waterway (NW). These experienced maximum salt intrusion events on different dates.
- We investigate the different terms in the (tidally averaged) along-channel momentum budget during the drought, to understand the processes influencing these extreme salt intrusion events.

## 2. METHODS

- We use an **unstructured 3D hydrostatic** (D-FLOW FM) model of the RMD to hindcast 2022.
- The model gets its boundary conditions from a model of the North Sea on the sea side and from measurements on the river side.
- We quantify the different terms in the **along-channel momentum balance** in the thalweg:

$$\underbrace{u_t}_{\text{along-channel advection}} + \underbrace{uu_x}_{\text{cross-channel advection}} + \underbrace{vu_y}_{\text{vertical advection}} + \underbrace{wu_z}_{\text{barotropic pressure gradient}} + \underbrace{g\eta_x}_{\text{baroclinic pressure gradient}} + \underbrace{\int_z^\eta \frac{1}{\rho_0}\rho_x dz}_{\text{Coriolis term}} - \underbrace{fv}_{\text{vertical stress divergence}} - \underbrace{\nu_v u_{zz}}_{\text{horizontal stress divergence}} - \underbrace{\nu_h u_{xx}}_{} \approx 0$$

**Fig. 1:** Europe with The Netherlands indicated in green box.

## 3. ESTUARINE RESPONSE AT MAXIMUM SALT INTRUSION

- The maximum salt intrusion length ($L_s$) occurs in the Hollandse IJssel (HY), a side branch of NM, on August 15th at maximum flood.
- The model captures the timing of the maximum $L_s$ in the estuary, based on measuremens (*see presentation Wegman et al.*)

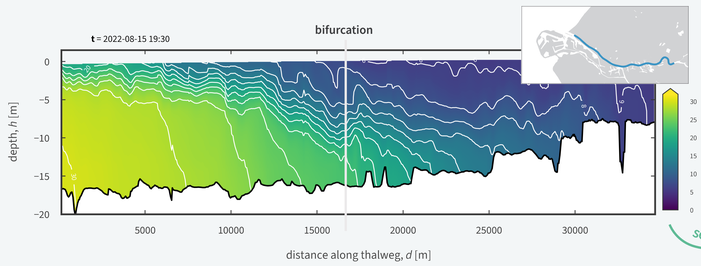



**Fig. 2:** Overview of salinity distribution along transect going through the New Waterway into the New Meuse on 15th of August, 2022.

see full tide

- The maximum $L_s$ in the OM occurs on June 23rd, at maximum ebb (at sea).
- The subtidally averaged maximum $L_s$ occurs at a different time, on August 20th.
- A phase difference in the barotropic tide is introduced in the OM.

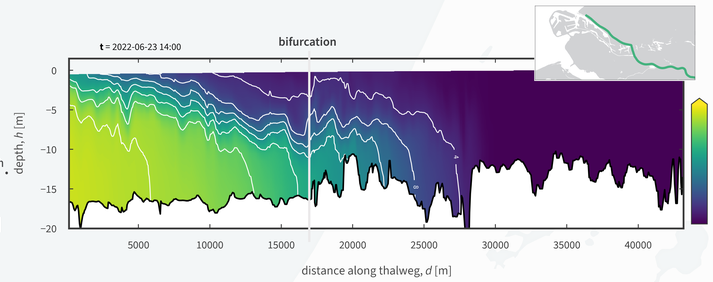



**Fig. 3:** Overview of salinity distribution along transect going through the New Waterway into the Old Meuse on 23rd of June, 2022.

see full tide in action

## A THE NEW WATERWAY

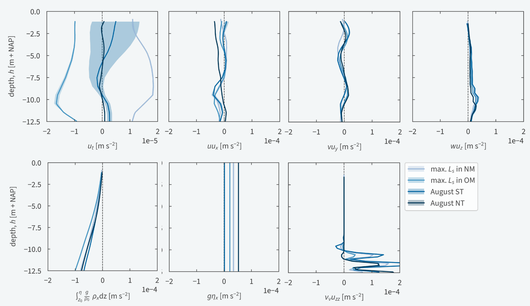



**Fig. 4:** Overview of tidally averaged along-channel momentum balance terms in the New Waterway during a spring tide, neap tide, during the tide with max. $L_s$ in the New Meuse (NM) and during the tide with max. $L_s$ in the Old Meuse (OM).

## B THE NEW MEUSE

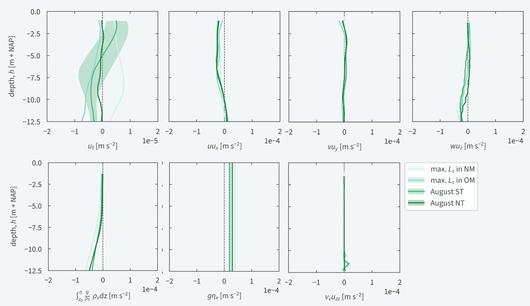



**Fig. 5:** Overview of tidally averaged along-channel momentum balance terms in the New Meuse during a spring tide, neap tide, during the tide with max. $L_s$ in the New Meuse (NM) and during the tide with max. $L_s$ in the Old Meuse (OM).

## C THE OLD MEUSE

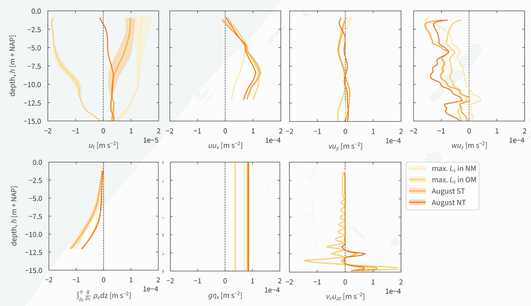
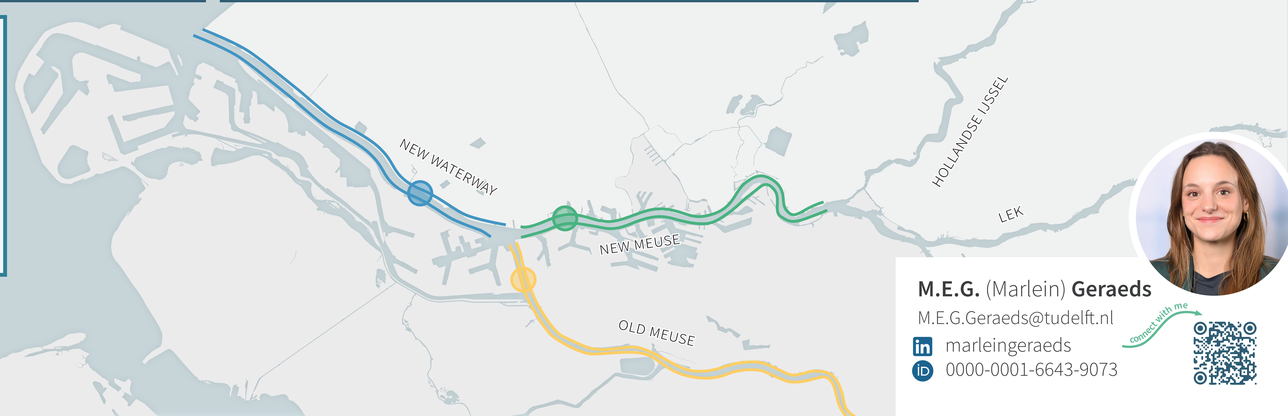



**Fig. 6:** Overview of tidally averaged along-channel momentum balance terms in the Old Meuse during a spring tide, neap tide,during the tide with max. $L_s$ in the New Meuse (NM) and during the tide with max. $L_s$ in the Old Meuse (OM).

## 4. PRELIMINARY CONCLUSIONS

- In all branches, the sign of the acceleration term ($u_t$) is opposite for the two salt intrusion events.
- The signs of the $u_t$ in the NM (and NW) and OM branches are out of phase. In the NW $u_t$ is largest at the bed during the event in the OM.
- In the OM the lateral advection term ($uu_x$) is much smaller than the other two terms - the vertical advection ($wu_z$) is almost always dominant.
- The vertical stress divergence ($\nu_v u_{zz}$) is oscillating over the entire vertical during the max. salt intrusion event in the OM.
- **Next steps**: what does this analysis look like for an average year? How do the salt intrusion events relate to wind forcing and set-up?

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