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

M. Geraeds[1], J.D. Pietrzak[1], M. Verlaan[1,2], and C.A. Katsman[1]

[1] Delft University of Technology, Delft, The Netherlands, [2] Deltares, Delft, The Netherlands

SALTISolutions

1. MOTIVATION

- Droughts are occurring more frequently as a result of climate change. The impact of droughts on estuarine dynamics is unclear. Changes in dynamics can have implications on sediment supply, human activities, and ecology.
- We use the Rhine-Meuse Delta (RMD) and the most severe European drought to date (2022) as a case study. The RMD is a dynamic mesotidal estuary with a persistent salt wedge structure in the Netherlands. It is complex and highly branched, so different branches may react differently to a drought.
- In this work, we aim to understand the dynamics of the Rhine-Meuse Delta during a drought. We approach the problem by assessing the relative importance of different terms in the momentum budget in the estuary during drought conditions. 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 sea through the New Waterway (NW).

2. METHODS

- We use an **unstructured, high resolution 3D hydrostatic** model of the Rhine-Meuse Delta to model the dynamics in a hindcast of the year 2022.
- On the sea side, the model gets its boundary conditions from a larger high-resolution model of the North Sea, and on the river side the boundary conditions are generated from measurements.
- We quantify the different terms in the **simplified along-channel momentum balance** from model data in the thalweg:

$$\underbrace{u_t}_{\text{local acceleration}} + \underbrace{uu_x}_{\text{along-channel advection}} + \overbrace{vu_y}^{\text{cross-channel advection}} + \underbrace{wu_z}_{\text{vertical advection}} + \overbrace{g\eta_x}^{\text{barotropic pressure gradient}} + \underbrace{\int_0^z \frac{1}{\rho_0}\rho_x dz}_{\text{baroclinic pressure gradient}} - \overbrace{fv}^{\text{Coriolis term}} - \underbrace{\nu_v u_{zz}}_{\text{vertical stress divergence}} - \overbrace{\nu_h u_{xx}}^{\text{horizontal stress divergence}} \approx 0$$

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

3. ESTUARINE RESPONSE AT MAXIMUM SALT INTRUSION

- The maximum instantaneous salt intrusion length (L_s) in the Lek, Noord, and Hollandse IJssel (New Meuse) occurs on the 15th of August, at 19:30.
- The model is able to capture the timing of the maximum salt intrusion length in the estuary, based on measurement stations in the Hollandse IJssel and Lek.

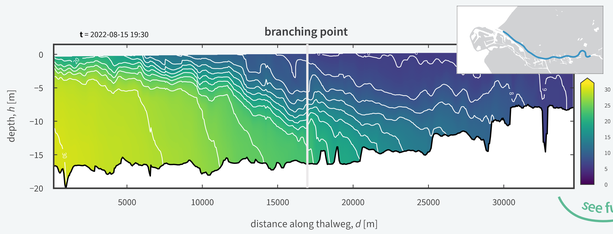


Fig. 2: Overview of salinity distribution along transect going through the New Waterway into the New Meuse on 15th of August, 2022.

- The maximum instantaneous L_s in the Old Meuse occurs on the 23rd of June, 2022.
- The subtidally averaged maximum L_s occurs at a completely different time, on the 23rd of June, 2022.
- There is a big difference in the timing of the maximum L_s. What processes could be behind this?

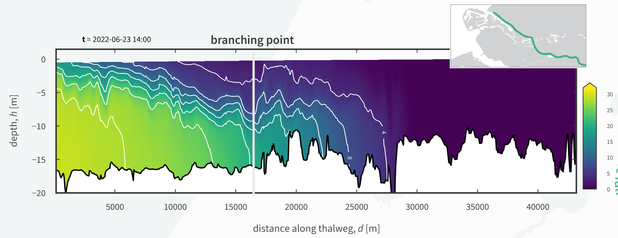


Fig. 3: Overview of salinity distribution along transect going through the New Waterway into the Old Meuse on 23rd of June, 2022.

A THE NEW WATERWAY

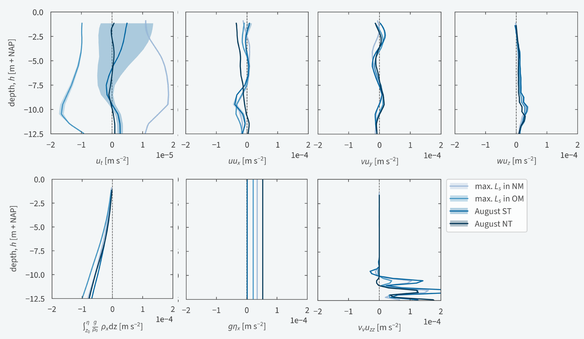


Fig. 4: Overview of tidally averaged along-channel momentum balance terms in the New Waterway during a spring tide, neap tide, during the tide with max. L_s in the New Meuse (NM) and during the tide with max. L_s in the Old Meuse (OM).

B THE NEW MEUSE

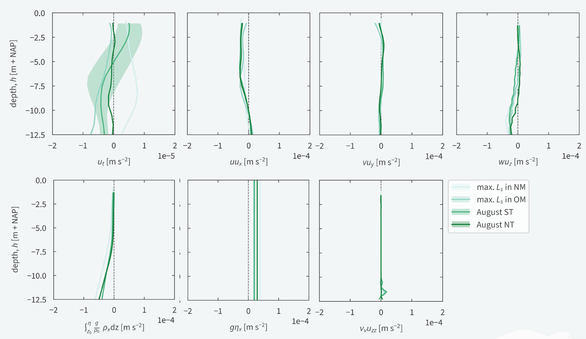


Fig. 5: Overview of tidally averaged along-channel momentum balance terms in the New Meuse during a spring tide, neap tide, during the tide with max. L_s in the New Meuse (NM) and during the tide with max. L_s in the Old Meuse (OM).

C THE OLD MEUSE

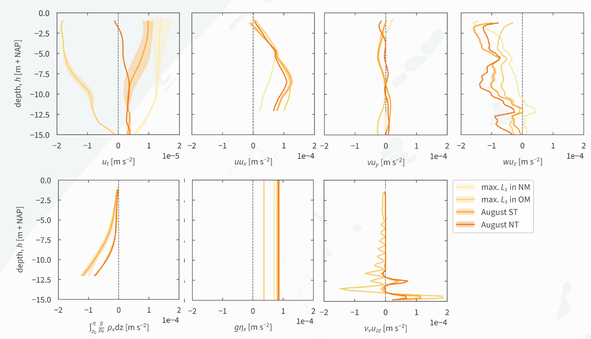
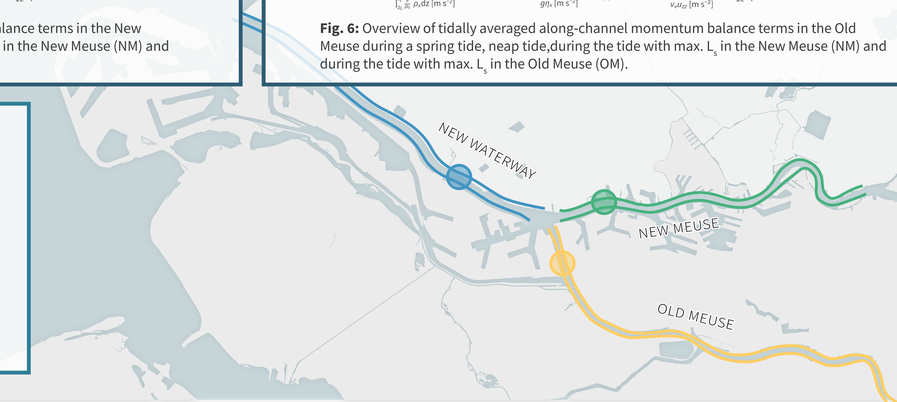


Fig. 6: Overview of tidally averaged along-channel momentum balance terms in the Old Meuse during a spring tide, neap tide,during the tide with max. L_s in the New Meuse (NM) and during the tide with max. L_s in the Old Meuse (OM).

3. PRELIMINARY CONCLUSIONS

- The sign of the acceleration term (u_t) is different for the two salt intrusion events in all branches. The signs of the NM (and NW) and OM branches are consistently in opposite directions. In the NW, the u_t is largest at the bed during the salt intrusion event in the OM.
- The 3D advection terms are generally similar in size, except for in the OM, where the lateral advection term (uu_x) is much smaller than the other two terms. Interestingly, the vertical advection term (wu_z) is almost always dominant in the OM for all our examined cases.
- The vertical stress divergence ($\nu_v u_{zz}$) seems to be oscillating over the entire vertical for the tide with the maximum salt intrusion 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?



M.E.G. (Marlein) **Geraeds**
M.E.G.Geraeds@tudelft.nl
marleingeraeds
0000-0001-6643-9073
Connect with me