Mud transport under climate change

--- from 2013 to 2050

Qilong Bi, Sven Smolders, Joris Vanlede

Flanders Hydraulics Research, Antwerp, Belgium
Climate change

- Sea level rise is one of the main consequences of global warming
- The Antarctic ice sheet is potentially the largest contributor to future sea level rise
- Global mean sea level rise could range from 15 cm to 40 cm by 2050 relative to the situation in 2013 (IMDC)

- How it will affect cohesive sediment transport in the Scheldt by 2050? And the ecological impact to the system? (Integraal plan Boven-Zeeschelde)
3D Mud Transport Model

- Focus on the Upper Sea Scheldt (110km – 170km from the estuary mouth)
- Modelled with TELEMAC suite
- Based on the calibrated 3D hydrodynamic model (SCALDIS)
- Salinity is included
- Only has 1 class of fine sediment particles
- Sediment dumping is included
3D Mud Transport Model

- Unstructured mesh
- Mesh size ranges from 500m to 5m
- 472,400 nodes per plane
- 5 planes in vertical
Model Results (SSC)

Mean sediment concentration showing a ETM zone near Antwerp
Climate scenarios

• **Sea level rise**
  - The “current” situation (CN, +0 cm in 2013);
  - The “low” scenario (CL, +15 cm in 2050);
  - The “high” scenario (CH, +40 cm in 2050).

• **Change of tidal amplitude**
  – tidal amplitude at Schelle 5.40m (current situation A0)
  – tidal amplitude at Schelle 5.00m (future scenario A-)
  – tidal amplitude at Schelle 5.70m (future scenario A+)

• **Increase of the mean upstream discharge by 2050**
## Climate scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Discharge</th>
<th>Tidal amplitude</th>
<th>Sea level rise</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013_REF_A0CN</td>
<td>Q2013</td>
<td>A0</td>
<td>CN(2013)</td>
</tr>
<tr>
<td>2050_REF_AminCL</td>
<td>Q2050</td>
<td>A-</td>
<td>CL (2050)</td>
</tr>
<tr>
<td>2050_REF_AplusCH</td>
<td>Q2050</td>
<td>A+</td>
<td>CH (2050)</td>
</tr>
</tbody>
</table>
Scenario Analysis

- The sea level rise is well reproduced across the entire domain

- The increase of Q also impact the tidal amplitude near the upstream boundary
Scenario Analysis

- Sea level rise makes the system less ebb dominant
- Increase of Q increases the ebb dominance near the boundary
- Increase of tidal amplitude makes system less ebb dominant
Scenario Analysis

- Decomposed sediment transport/flux
  (uses cross-sectionally averaged quantities for simplicity)

- Tidally averaged transport
  \[ \langle T \rangle = T_A + T_P + T_R \]

- Transport due to mean flow
  \[ T_A = \langle C \rangle(\langle U \rangle\langle A \rangle + \langle U' A' \rangle) \]
  due to tidal pumping
  \[ T_P = \langle U'C' \rangle \langle A \rangle \]
  residual part
  \[ T_R = \langle U \rangle\langle C'A' \rangle + \langle U'C'A' \rangle \]

- The decomposed flux
  \[ \langle Q \rangle = Q_A + Q_P + Q_R = \frac{T_A + T_P + T_R}{\langle A \rangle} \]
Scenario Analysis

- The main transport is through $T_A$, $T_P$ is only a small fraction in this region
- $T_A$ (and $T_{total}$) has direction towards downstream, suggesting an ebb system
- Q contributes to both $T_A$ and $T_P$
Scenario Analysis

- $Q_A$ indicates the transport efficiency
  - Increase $Q$ $\rightarrow$ more sediment transported downstream
  - Increase tidal amplitude $\rightarrow$ less sediment transported downstream
  - The effect of increasing $Q$ decays towards downstream as the transect area increase
A- reduces the sedimentation while A+ increases it, suggesting higher tidal amplitude, less ebb dominant.
Conclusions

- Climate change has impact on the mud transport in the Upper Sea Scheldt
  - Sea level rise tends to reduce the ebb dominance thus could reduce seaward mud transport (based on tidal asymmetry)
  - Increasing the upstream discharge could increase the ebb dominance and seaward mud transport
  - Increasing tidal amplitude could make the system less ebb dominant, reduce the seaward transport and more sedimentation in the upstream
Thanks for your attention!