The 3D Unstructured SCALDIS Model

A New High Resolution Model for Hydrodynamics and Sediment Transport in the Tidal Scheldt

Overview

- Introduction (framework, why a new model?)
- Calibration strategy
- Results
  - water levels
  - velocities
  - discharges
- Conclusions
Integrated Plan Upper Sea Scheldt

- Client: W&Z, aZS
- Project “Integrated Plan Upper Sea Scheldt”
  - Improve navigability of the Upper Sea Scheldt
  - Without negative effects on nature and safety against flooding
- Project Partners: INBO, UA-Ecobe, IMDC, Technum, FHR

Model Purpose

- HD for scenario analysis from Mouth area to Upper Sea Scheldt
- Include FCA and CRT areas
- Derived products
  - Sediment transport (Mud & Sand) by FHR
  - Ecosystem model (with UA – Ecobe)
  - Ecotope maps (with INBO)
  - Fish migration & Bird abundance with INBO
Model domain

Grid & Bathymetry

- 200 to 500 m in North Sea and mouth area
- 200 m in Eastern Scheldt
- 120 m in Western Scheldt
- 7 m in upper Sea Scheldt to 5 m at upstream boundaries

- 430,000 nodes in the horizontal
- 3D in 5 sigma layers
- 2,150,000 nodes in total

- Bathymetry from 2013-2014
Boundary Conditions Downstream

- Derived from CSM-ZUNO modeling train
- CSMv5 – Continental Shelf Model
  - driven at ocean boundaries by astronomical water levels (tidal components: M2, S2, N2, K2, O1, K1, Q1, P1, NU2, L2, SA)
- ZUNOv3 – Zuidelijke Noordzee Model
  - nested in CSM
- HIRLAM wind data
- ZUNO incl Salinity
- Run for 2013

Boundary Conditions Upstream

- 8 discharge boundaries with daily averaged discharge values:
  - Merelbeke, Dender, Zenne, Dijle, Kleine Nete, Grote Nete, Channel Ghent-Terneuzen, Channel Bath
Calibration strategy

- Data availability 2013
  - 48 WL stations (10’ TS)
  - 58 sailed ADCP campaigns (2005-2014)
  - 11 salinity stations (10’ TS)
  - 29 flux transects
- Weighted Dimensionless Cost Function
  - Vertical tide (water levels) 50%
  - Horizontal tide (velocities and discharges) 50%

Weighted Dimensionless Cost Function

\[ \text{Cost} = \sum_{\text{Factors}} \frac{\max(\text{Factor}_i, \text{Threshold}_i)}{\max(\text{Factor}_{i,\text{ref}}, \text{Threshold}_i)} \cdot \text{Weight}_i \]

Factor = Error against Measurement

- Vertical Tide
  - RMSE of the water level time series [m]
  - RMSE of high waters [m]
  - Harmonic Analysis: Vector Difference [m]
- Horizontal Tide
  - RMAE of Sailed ADCP transects [-]
  - RMSE of Q measurements [m³/s]
  - Measurement Uncertainty through Factor Threshold
  - Assessed using VIMM toolbox
Weighted Dimensionless Cost Function

<table>
<thead>
<tr>
<th>Zone</th>
<th>Objective Function</th>
<th>Weights [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western Scheldt</td>
<td>RMSE: Time Series</td>
<td>3.50%</td>
</tr>
<tr>
<td></td>
<td>RMSE: Level High Water</td>
<td>3.50%</td>
</tr>
<tr>
<td></td>
<td>Vector difference</td>
<td>3.50%</td>
</tr>
<tr>
<td></td>
<td>delta M2 amplitude</td>
<td>3.50%</td>
</tr>
<tr>
<td>Eastern Scheldt</td>
<td>RMSE: Time Series</td>
<td>1.25%</td>
</tr>
<tr>
<td></td>
<td>RMSE: Level High Water</td>
<td>1.25%</td>
</tr>
<tr>
<td></td>
<td>Vector difference</td>
<td>1.25%</td>
</tr>
<tr>
<td></td>
<td>delta M2 amplitude</td>
<td>1.25%</td>
</tr>
<tr>
<td>Lower Sea Scheldt</td>
<td>RMSE: Time Series</td>
<td>3.50%</td>
</tr>
<tr>
<td></td>
<td>RMSE: Level High Water</td>
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</tr>
<tr>
<td></td>
<td>Vector difference</td>
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</tr>
<tr>
<td></td>
<td>delta M2 amplitude</td>
<td>3.50%</td>
</tr>
<tr>
<td>Upper Sea Scheldt</td>
<td>RMSE: Time Series</td>
<td>4.25%</td>
</tr>
<tr>
<td></td>
<td>RMSE: Level High Water</td>
<td>4.25%</td>
</tr>
<tr>
<td></td>
<td>Vector difference</td>
<td>4.25%</td>
</tr>
<tr>
<td></td>
<td>delta M2 amplitude</td>
<td>4.25%</td>
</tr>
</tbody>
</table>

Horizontal Tide (Velocities and Fluxes)

Western Scheldt
- RMAE of Sailed ADCP deep zone: 10.00%
- RMAE of Sailed ADCP shallow zone: 2.50%
- RMSE of Discharges: 3.33%

Lower Sea Scheldt
- RMAE of Sailed ADCP deep zone: 10.00%
- RMAE of Sailed ADCP shallow zone: 2.50%
- RMSE of Discharges: 3.33%

Upper Sea Scheldt
- RMAE of Sailed ADCP deep zone: 15.00%
- RMAE of Sailed ADCP shallow zone: 2.50%
- RMSE of Discharges: 3.33%
Model performance: WL

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Western Scheldt and North Sea</th>
<th>Eastern Scheldt</th>
<th>Lower Sea Scheldt</th>
<th>Upper Sea Scheldt</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMSE time series (m)</td>
<td>0.10</td>
<td>0.09</td>
<td>0.14</td>
<td>0.14</td>
</tr>
<tr>
<td>RMSE HW (m)</td>
<td>0.08</td>
<td>0.10</td>
<td>0.13</td>
<td>0.12</td>
</tr>
<tr>
<td>RMSE LW (m)</td>
<td>0.07</td>
<td>0.09</td>
<td>0.09</td>
<td>0.11</td>
</tr>
<tr>
<td>Bias M2 amplitude (m)</td>
<td>-0.01 to 0.05</td>
<td>-0.01 to 0.03</td>
<td>-0.02 to 0.01</td>
<td>-0.03 to 0</td>
</tr>
<tr>
<td>Bias M2 phase (degrees)</td>
<td>-2 to 0</td>
<td>-2 to 4</td>
<td>-2 to -1</td>
<td>-3 to 2</td>
</tr>
</tbody>
</table>

M2 amplitude and phase
WL history Vlissingen, Antwerpen

WL history Schelle, Sint Amands
WL history Schoonaarde, Melle

Model performance ADCP Everingen

Max Ebb

Max Flood
Model performance
ADCP Liefkenshoek

Max Ebb
Model: Delft3D (Run: Scarle 004-b) Time: 22-Sep-2013 22:30:00
Measurement 20130009 Liefkenshoek | Time: 25-Jun-2013 14:00:00

Max Flood
Model: Delft3D (Run: Scarle 004-b) Time: 23-Sep-2013 08:00:00
Measurement 20130009 Liefkenshoek | Time: 25-Jun-2013 14:00:00

Model performance
ADCP Schoonaarde

Max Ebb
Model: Delft3D (Run: Scarle 004-b) Time: 21-Sep-2013 11:00:00
Measurement 20130027 Schoonaarde | Time: 27-May-2013 11:40:00

Max Flood
Model: Delft3D (Run: Scarle 004-b) Time: 21-Sep-2013 11:00:00
Measurement 20130027 Schoonaarde | Time: 27-May-2013 11:40:00
Model performance: velocities

- RMSE of velocity magnitude varies between 12 cm/s and 25 cm/s
- For most transects it is smaller than 20 cm/s

Stationary velocity: deep zone
### Stationary velocity: deep zone

<table>
<thead>
<tr>
<th>Location</th>
<th>Analysis vector</th>
<th>Magnitude</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MAE TS</td>
<td>RMSE TS</td>
<td>BIAS TS</td>
</tr>
<tr>
<td>Buoy 84 bottom</td>
<td>0.13</td>
<td>0.29</td>
<td>0.05</td>
</tr>
<tr>
<td>Buoy 84 top</td>
<td>0.12</td>
<td>0.25</td>
<td>0.03</td>
</tr>
<tr>
<td>Oosterweel bottom</td>
<td>0.10</td>
<td>0.20</td>
<td>0.02</td>
</tr>
<tr>
<td>Oosterweel top</td>
<td>0.14</td>
<td>0.22</td>
<td>-0.07</td>
</tr>
<tr>
<td>Driegoten (real)</td>
<td>0.16</td>
<td>0.35</td>
<td>0.05</td>
</tr>
<tr>
<td>Driegoten (proxy)</td>
<td>0.30</td>
<td>0.68</td>
<td>0.29</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.15</strong></td>
<td><strong>0.05</strong></td>
<td><strong>0.19</strong></td>
</tr>
</tbody>
</table>

*Model qualification (Sutherland et al., 2003)*

**Notes:**
- Driegoten real: too shallow in model
- Driegoten proxy: too high velocity
Stationary velocity: shallow zone

Western Scheldt:
- Hooge Platen Noord
- Hooge Platen West
- Plaat van Walsoorden

Sea Scheldt:
- INBO measurements

Hooge Platen Noord (depth average)
- Measured and modelled velocity [m/s], ARH10 Average Site (Waleroog, NL30)
- Measured water depth [m]

Plaat van Walsoorden (depth average)
- Measured and modelled velocity [m/s], ARH10 Average Site (Waleroog, NL30)
- Measured water depth [m]
Stationary velocity: shallow zone

Hooge Platen Noord (1.3 m above bottom)

Stationary velocity: shallow zone

Plaat van Walsoorden (1.3 m above bottom)

Stationary velocity: shallow zone

Paaardenschor (0.05 m above bottom)

Doel (0.05 m above bottom)
Stationary velocity: shallow zone

Lillo polder (0.05 m above bottom)

Notelaer (0.05 m above bottom)

Model Performance: discharges

R12 Wielingen

R1 Vaarwater boven Bath
Model Performance: discharges

Kruibeke

Driegoten

Model Performance: Salinity

29/06/2015 IAHR Scheldt Session
Model Performance: Salinity

Storm period: flood areas
Sinterklaasstorm in Bergenmeersen

Storm period: flood areas

Vlissingen

Bergenmeersen Scheldt
Storm period: flood areas

Bergenmeersen GGG

Bergenmeersen Scheldt

Conclusions

- Assessing model skill
  - Stated model purpose
  - Weighted dimensionless cost function to combine different physical quantities
  - VIMM toolbox (in-house development FHR)
    - Standardised statistics
    - Abstraction layer between model platform, data source and statistical method
    - Deep insight in model performance
Conclusions

- Combination of techniques to combine models and measurements
  - Harmonic Analysis of WL
  - Timeseries and extrema of WL
  - Comparable Tide
    - ADCP Sailed transects
    - Q measurements
  - Ensemble Analysis of velocities in shallow areas
  - Timeseries of salinity
  - Timeseries of WL during storm

Conclusions

- SCALDIS model, a new 3D high resolution hydraulics model
  - +500d of work
  - Let’s build exciting new products!
    - Ecosystem model with UA – Ecobe
    - Ecotope maps with INBO
    - Fish migration & Bird abundance with INBO
    - Sediment transport (Mud & Sand) by FHR
    - ...
  - Huge added value in multi-disciplinary work
Technical Report


Acknowledgements

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