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Modeling the combined effect of wind and waves on the sediment dynamics of the Ameland Inlet during storms

Introduction

- Ameland Inlet is a 'hot spot' for research projects (SEAWAD)
- Lenstra, et al. (2019) focused on the effect of waves and tides on sediment dynamics. However, wind can also exert significant influence on sediment transports.
- Li (2018) included wind, but neglected waves.

Research Question

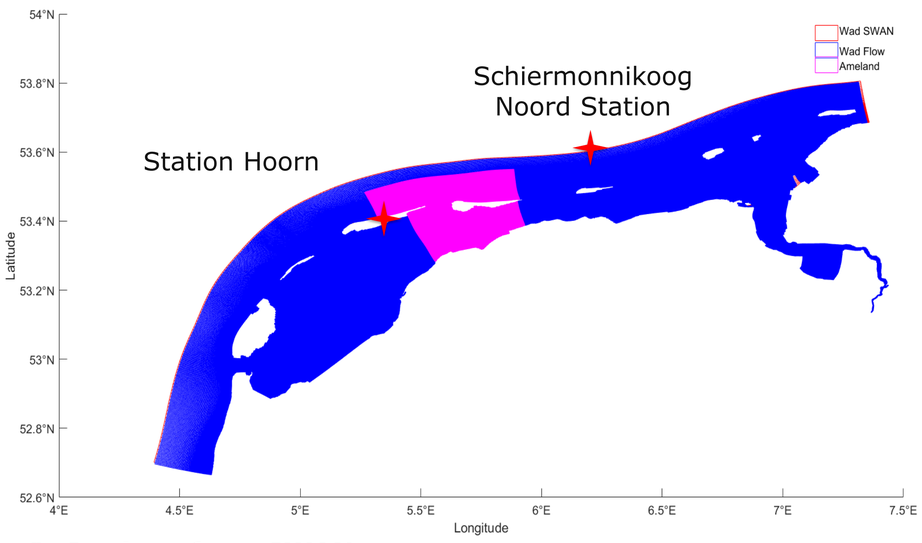
What is the combined effect of waves and wind (various intensities & directions) on sediment dynamics at the Ameland inlet?

Methodology

1. Online Coupling of Delft3D-FLOW&SWAN.

2. Settings for Delft3D-FLOW:

- Two coupled model domains via domain decomposition.
- Water level boundaries from 'The Northwest European Shelf and North Sea Model'.
- Meteorological data derived from WRF model and HIRLAM model.
- Sediment transport: Van Rijn (2004) with D_{50} = 250 μm.



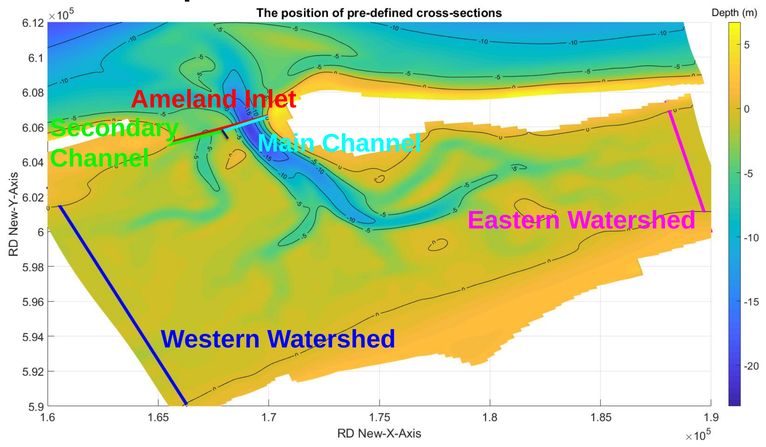
3. Settings from SWAN:

- Nesting of two grids.
- Wave boundary uses data from Schiermonnikoog Noord Station.

4. Selected wind events based on data from Station Hoorn:

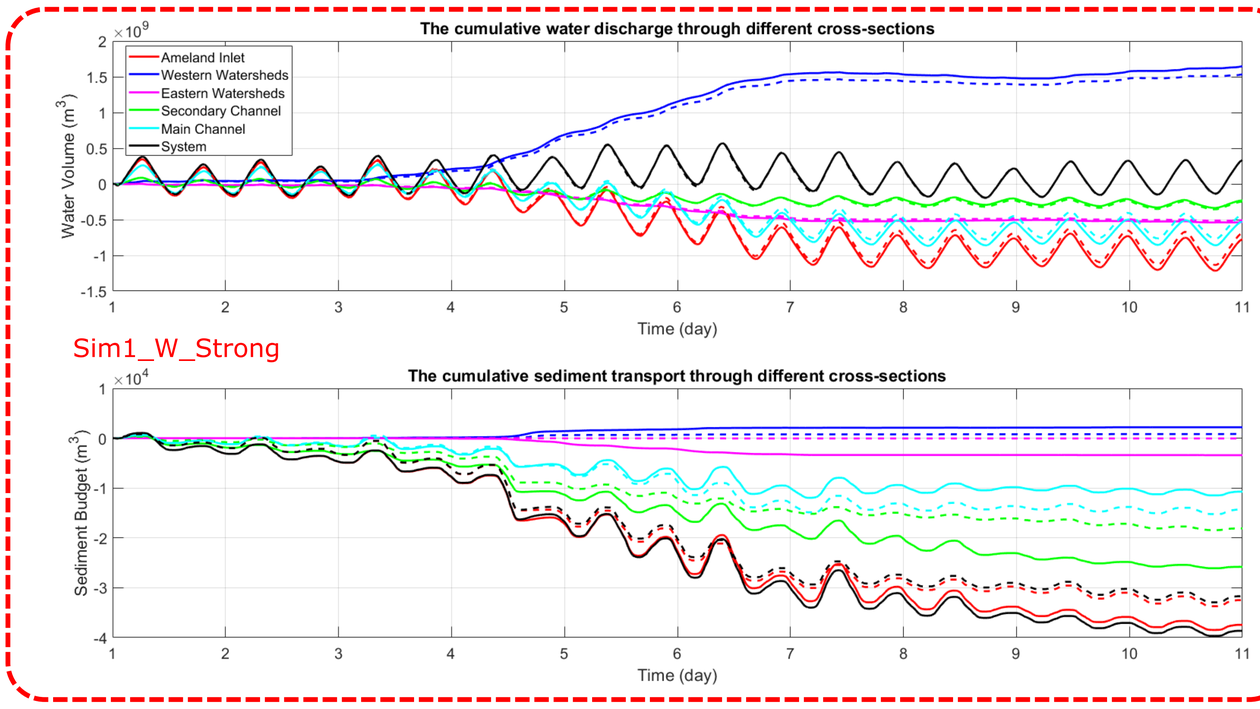
Simulations	Duration	Peak Hsig
Sim1_W_Strong	**09/09/2011-19/09/2011**	**3.7m**
Sim2_W_Quiet	10/08/2007-20/08/2007	2.1m
Sim3_NW_Strong	02/12/2011-12/12/2011	6.3m
Sim4_NW_Quiet	04/08/2011-14/08/2011	3.7m
Sim5_N_Strong	08/01/2012-18/01/2012	4.7m
Sim6_N_Quiet	30/03/2007-09/04/2007	2.7m
Sim7_NE_Strong	**24/04/2012-04/05/2012**	**2.7m**
Sim8_NE_Quiet	05/02/2007-15/02/2007	2m
Sim9_SW_Strong	01/03/2007-11/03/2007	1.5m
Sim10_SW_Quiet	13/07/2011-23/07/2011	1.9m

5. Position of pre-defined cross-sections:

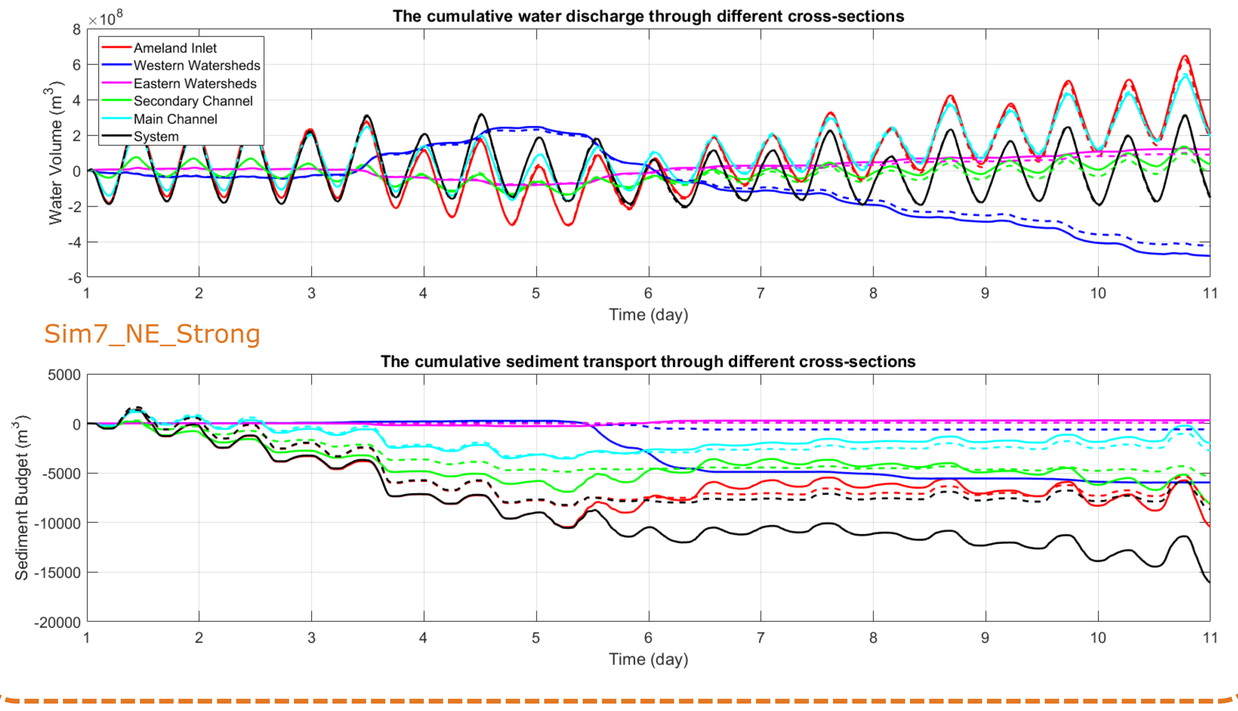


6. Use of 'Godin Filter' for residual values (detiding the signal).

Results

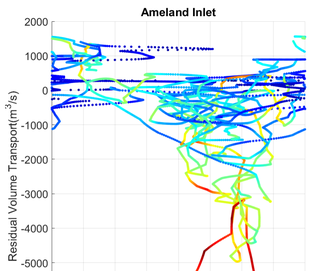


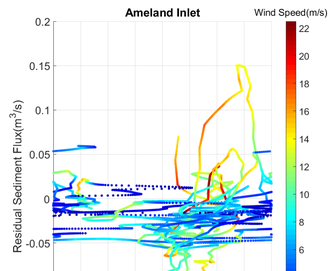
Sim1_W_Strong



Sim7_NE_Strong

Positive into basin; solid lines with waves; dashed lines without waves.



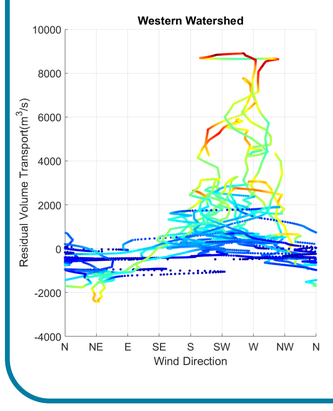


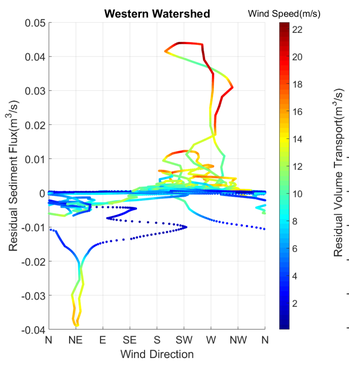
Waves significantly influence the sediment transport via the cross-sections while the effects differs between W storms and NE storms.

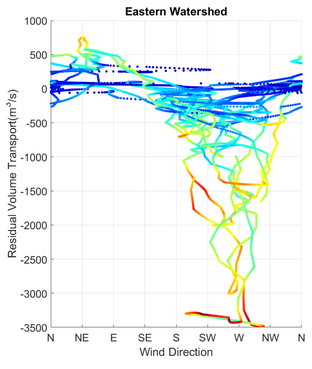
The inlet is the main path of sediment transport even though the western watershed transports a similar volume of water.

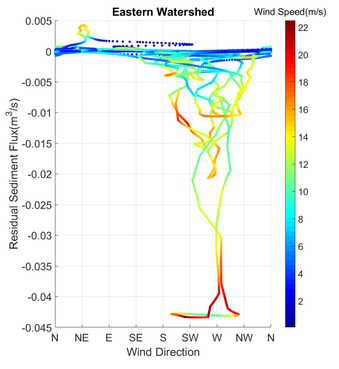
All three cross-sections are responsive to SW-NW and NE wind, among which the western watershed has the highest sensitivity.

Fastest wind usually, but not always, results in the largest residual volume transport and residual sediment flux.









Discussion and conclusions

- Similarities with the results of Sassi et al., (2015) and Duran-Matute et al., (2016).
- During storms more water and sediment transport over western than over eastern watershed.
- Inflow (outflow) over western watershed and outflow (inflow) over eastern watershed and through inlet for western (northeastern) wind and waves.
- All simulations indicate a net loss of sediment during the storms, except for Sim5_N_Strong.
- Storms from SW-NW have more influence on sediment transport than those from NE even with the same wind speed.
- **The combined effect of wind and waves is dominated by the wind.**

Reference

Duran-Matute, M., Gerkema, T., & Sassi, M. G. (2016). Quantifying the residual volume transport through a multiple-inlet system in response to wind forcing: The case of the western Dutch Wadden Sea. Journal of Geophysical Research: Oceans, 121(12), 8888-8903.

Lenstra, K. J. H., Pluis, S. R. P. M., Ridderinkhof, W., Ruessink, G., & van der Vegt, M. (2019). Cyclic channel-shoal dynamics at the Ameland inlet: the impact on waves, tides, and sediment transport. Ocean Dynamics, 1-17.

Li, H. (2018). The Ameland Inlet during the Sinterklaas Storm: the role of flooding of watersheds (Master's thesis).

Sassi, M., Duran-Matute, M., van Kessel, T., & Gerkema, T. (2015). Variability of residual fluxes of suspended sediment in a multiple tidal-inlet system: the Dutch Wadden Sea. Ocean Dynamics, 65(9-10), 1321-1333.