Flushing of the Dutch Wadden Sea

Analysing transport pattern and water exchange in the Dutch Wadden Sea

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In Short

- Hydrodynamic modelling of the Dutch Wadden Sea
- Analysing the period 1980-2017
- Investigation of water exchange and flushing time scales

The Wadden Sea is a highly dynamic system controlled by tides, wind, and river discharge. Additionally, the large-scale variations of the location of the North Atlantic salinity front or the baroclinic/barotrotic pressure gradient between the English Channel and the northern North Sea, controlling the throughflow of the English Channel, have an impact on the local dynamics.

Some of the potential important drivers have been identified in the Dutch-German project: "PACE (The future of the Wadden Sea sediment fluxes: still keeping pace with sea level rise?)" funded by NWO, the Netherlands (ZKO-project #839.11.003) and the German Federal Ministry of Research and Education (FKZ 03F0634A).

During the project, some knowledge could be gained by the help of numerical modelling (HLRN project: mvk00027, [1], [2]). However, still many questions remain unanswered, or even new questions appeared. One of the key location during these studies was the Marsdiep, the first tidal inlet in the Dutch Wadden Sea (highlighted by the green line in Fig. 1. Here, more or less continuous vessel mounted ADCP measurements exist, due to a ferry crossing between Den Helder and Texel [3]. Whereas the numerical estimates converge, there is a large discrepancy between the observations and model studies. This is partially explained by the different time period covered. However, the most likely explanation are the large errors associated with the reconstruction of the vessel based ADCP data. Additionally, the large tidal prism (volume of water exchanged during one tidal period) of $980 \cdot 10^6$ m^3, leads to a poor signal-to-noise ratio by measuring a mean value of approx. $\pm$500m^3/s. Thus, there are fundamental challenges in measuring these small residual flows. The here outlined challenges hold for sure also for the other tidal inlets, with large tidal prisms, but small residual flows.

Beside the investigation of the residual transport through all tidal inlets, the fate of the freshwater will also paid some attention. [2] did some prelimenary analysis of the freshwater transport pathways. However, from an ecological point of view the information of the turnover time of the freshwater is still missing. Here, we will use the combination of marked river water in combination with an age tracer. By doing so, we can compare the residence time of the freshwater with typical ecological time scales.

One lesson we learned during the PACE project was, that the time period was too short, to do proper statistics. The PACE consortium agreed that observations will newer give a good estimate of the throughflow, and thus, a well-calibrated numerical model is needed, which needs to run for a sufficiently long period. Now, we would like to pick that idea up again. In addition to the previous studies, we will have a time varying bathymetry. For the core PACE-period (2009-2011), the assumption of a steady bathymetry was justified due too the short integration period. As we aim now for a integration period of nearly 40 years, we have to deal with a changing bathymetry. Since the Dutch Rijkswaterstaat does a full bathymetric survey every 6 years, we will provide on a montly basis these time-interpolated maps. This will help to account for changes of the hydrodynamics due to movement of channels and shoals.

So far, we have only considered the model data of three consecutive years together. But how representative are these values (the median, for example) of each individual year, or of any other year? The mean residual flow varies strongly between the years, even in sign. The median is more robust and persistently negative (i.e., outflow), but still varies considerably. The implication of this result is that one cannot in a meaningful way speak of a typical yearly-mean residual flow since it varies so much between individual years, but one may broadly indicate a typical range for median values. This variability must be due to the difference between the wind patterns in the respective years since the tidal constituents hardly vary from year to year and the averaged fresh water discharged varies only in the order of some 100 m^3/s between different years. Clearly, the interannual variability is huge and a much longer record is needed to find reliable long-term mean and median values.

Therefore, the aim of this study is to investigate the transport pattern and water exchange in the Dutch Wadden Sea on a multi decadal to annual time scale (1980-2017). This should give some insights into the

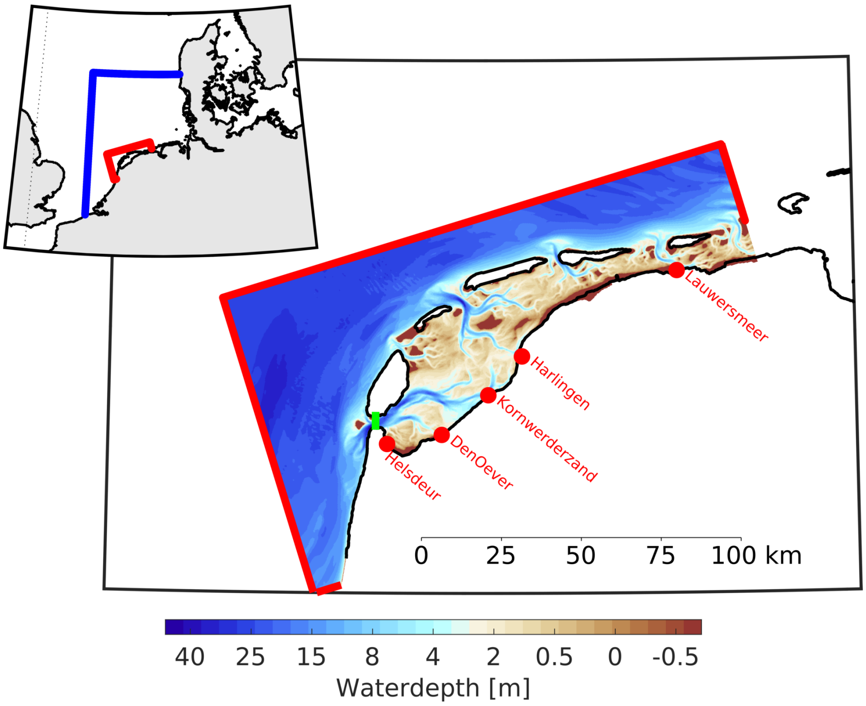

Figure 1: *Topography of the Dutch Wadden Sea. Color-coded is the water depth. The red dots mark the location of river discharges. The green line indicates the Marsdiep inlet. The insert shows the domain of the southern North Sea setup (blue line) with a resolution of 600 m.*

variability of the water exchange in the Dutch Wadden Sea and if a convergence to a "mean" transport exist. Moreover, we will investigate the dependence of the exchange strength on large-scale driver like the NAO, the English Channel through flow, but also the local wind or freshwater discharge. In addition, a number of tracers will be used (as detailed below) to study the exchange between basins and flushing times, which are of key interest to ecologists in view of the carrying capacity of the different basins.

WWW

https://www.io-warnemuende.de/pace.html

More Information

[1] U. Gräwe,G. Flöser, T. Gerkema, M. Duran-Matute, T. H. Badewien, E. Schulz, H. Burchard *Journal of Geophysical Research* **121(7)**, 5231-5251 (2016).

[2] D. Duran-Matute, T. Gerkema, G. J. de Boer, J. J. Nau, U. Gräwe, *Ocean Science* **10(4)**, 611-632 (2014).

[3] M. C. Buijsman, H. Ridderinkhof, *Journal of Sea Research.* **57(4)**, 237-256 (2007).

Project Partners

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