Application of a large dataset of sediment transport parameters: variability in sediment transport in the HBMC area

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Introduction

Distinguishing naturally- from anthropogenically-induced variability of the seabed is very difficult, as the range of natural variation is hard to quantify. Mostly, variations are described locally, using *in-situ* depth data (e.g., Van Lancker and Jacobs, 2000; Lanckneus et al., 2002; Degrendele et al., 2010; Roche et al., this volume), or are derived from newly acquired current and turbidity data. Still, in many cases the regional context is missing, and sound interpretations on the driving forces are not possible. Nevertheless the quantification of both naturally and man-made changes are needed for the definition of acceptable thresholds for alterations to the seabed (e.g., aggregate extraction, Van Lancker et al., this volume). Also, to assess the recovery potential of impacted areas after extraction, a critical parameter within Europe's Marine Strategy Framework Directive (MSFD), natural system variability needs to be quantified. This can be approached through statistical analyses of long-term databases on seabed evolution (cf. Dalyander et al. 2013). For the Belgian part of the North Sea, a 12-year long hindcast (1999-2010) on the main sediment transport parameters (i.e., bottom stress, bottom geometry, total load and bottom evolution) was therefore produced (Francken et al., 2014) and has now been expanded, and applied to case studies for validation.

In this case study we evaluate the natural variability of the total load sediment transport from a long-term database, as it directly impacts the bottom morphology.

Material and methods

Model data

Results from a subset (2012-2014) of the 16-year long hindcast (1999-2016) were used to assess the variability of sediment transport in the Hinder Banks. Purpose was to provide regional context to sediment processes in the monitoring area HBMC, being a subarea of the aggregate sector 4C (see Roche et al., this volume).

Wave hindcasts for the period were obtained using the Simulating Waves Nearshore (SWAN) wave model (Holthuijsen et al., 1993; Booij et al., 1999), a third generation phase-averaged wave model, suited for modelling waves in shallow water. The model calculates in time and space, the generation of waves, their propagation and shoaling, non-linear wave-wave interactions (quadruplets and triads), white-capping, bottom friction and depth-induced wave breaking. The wave model was coupled with the results from a hydrodynamic model, to account for current refraction and for the influence of the changing water depth on the waves. The model runs on a grid resolution of about 750 m x 750 m. The boundaries for the wave model were obtained from two larger scale WAM models (WAMDIG, 1988) covering the entire North Sea. Detailed information on the wave modelling can be found in Fernández (2011) and Van Lancker et al. (2012). The currents and water elevations were obtained from two-dimensional hydrodynamic models (Ozer et al., 1996; Yu et al., 1990). A finer resolution model, using the same grid as the wave model, was set up for the Belgian Part of the North

Sea, which was coupled with a lower resolution model for the entire West-European Continental Shelf. Atmospheric data (wind speed at 10 m height above sea level), were obtained from the United Kingdom Meteorological Office.

Currents and waves were used by the sediment transport model MU-SEDIM (Van den Eynde et al., 2010), calculating the total load, under the influence of the local hydrodynamic conditions. The MU-SEDIM model was improved in the framework of this project to include a more time effective method for calculating the combined wave-current bottom stresses, using the method of Soulsby and Clarke (2005). A new implementation for the calculation of the bottom geometry (ripple height and ripple length), which is important for the calculation of the total bottom roughness (including skin bottom roughness, bottom roughness from bedload and form bottom roughness), was executed based on Soulsby and Whitehouse (2005). The model calculates the current and wave generated ripples and takes into account their time evolution. The total load is then calculated using the Ackers-White formulae (Ackers and White, 1973), adapted for waves by Swart (1976, 1977). Model output resulted in 30 minutes time step sediment transport parameters (bottom stress, bottom geometry, total load and bottom evolution) on a 750 m grid resolution.

Statistical analysis

Yearly averages of the X and Y vectors of the total load were calculated at every grid node. The same routine was also used for every season, i.e., winter (January-March), spring (April-June), summer (July-September) and autumn (October-December), but is adaptable to cover any desired period. See Francken et al. (2014) for more details on the analysis.

Results and discussion

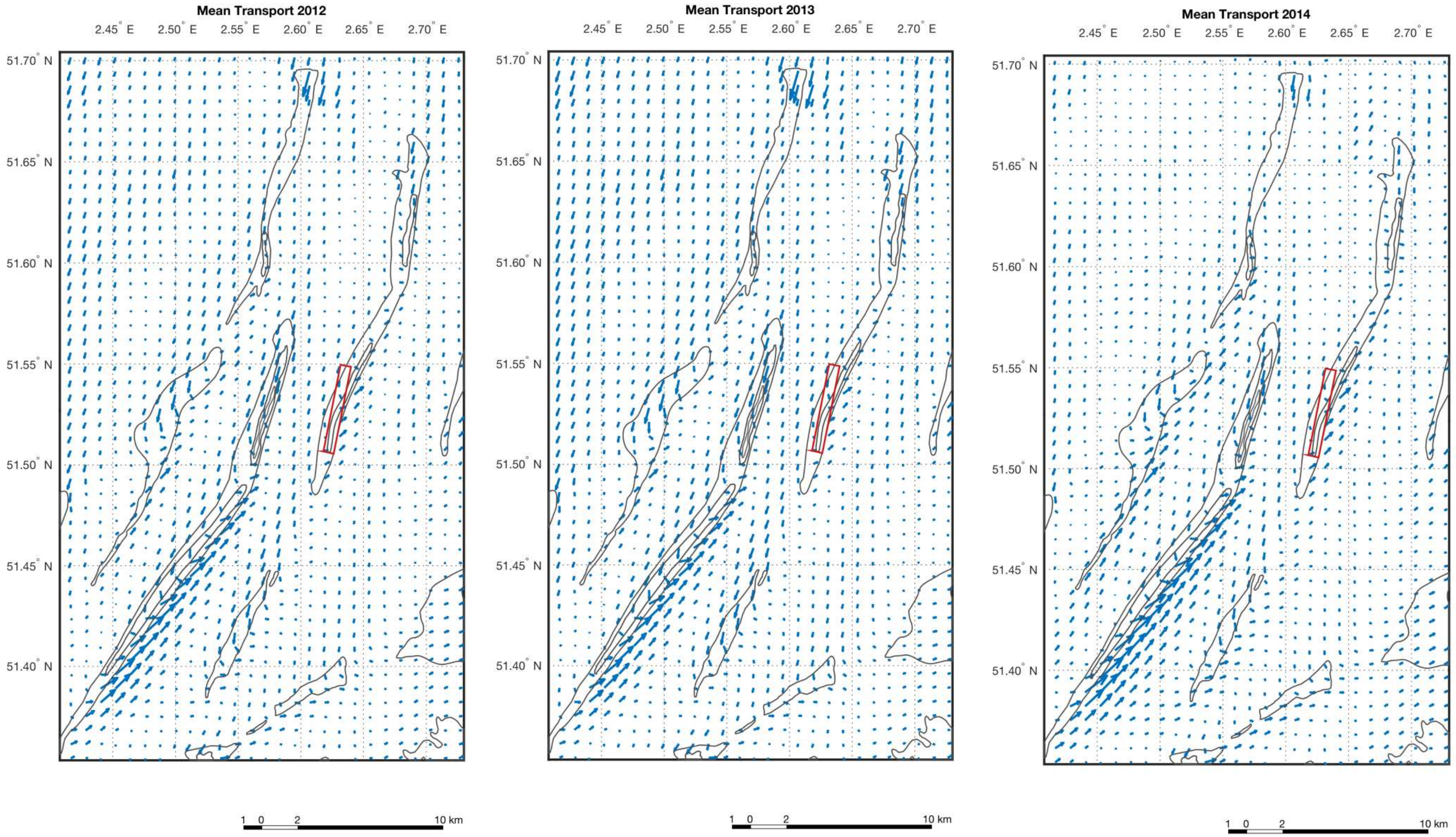
The results from the yearly averaging of the total load in the HBMC area are presented in Figure 1.

Comparing the mean transport in 2012, 2013 and 2014 (Figure 1) it is clear that the depth-averaged sediment is mostly NE-directed. Most striking is the magnitude of transport along the SE flank of the Westhinder sandbank, but also the local variation in the Hinder Banks region. In the northern part of the study area, the general transport direction is mainly SW-directed, except for 2014 where the mean transport was near zero. In this year, NE-directed transport dominated on average over the whole area.

To investigate the underlying reasons for this distinct year-to-year variability in total load sediment transport, all data was regrouped into seasonal averages and cross-related to atmospheric data coming from the measuring pile at the Westhinder Bank (MOW7) (Meetnet Vlaamse Banken, Agentschap Maritieme Dienstverlening en Kust). Averaged wind speed at 10m above the sea surface and averaged wind direction were combined in wind roses and compared to the total load sediment transport in the Figures 2 to 5.

Figures 2 and 3 show for 2013 overall predominant winds blowing from the SW and less frequent and less strong winds blowing from the NE, which is a normal regime for the Belgian part of the North Sea (Meetnet Vlaamse Banken). However, in winter, winds were predominantly blowing from the NE sector and were much stronger than in spring and summer. They were often equally strong than the SW winds that occurred less frequent. This had a clear effect on the total load. In the northern part of the area, as well along the deeper southern part of the Oosthinder sandbank, the mean transport was directed S to SW. In autumn, SW sector winds were predominant, but showed a large spread. Almost no wind came from the NE sector. This resulted in a predominant SW to NE oriented total load transport.

The next two figures (Figs. 4 and 5) show the wind roses and averaged total load sediment transport for the four seasons of 2014.


Mean Transport 2012

Mean Transport 2013

Mean Transport 2014

Figure 1: Yearly (2012-2013-2014) averaged direction of the total load sediment transport in the region of the Hinder Banks. HBMC area is shown in red.

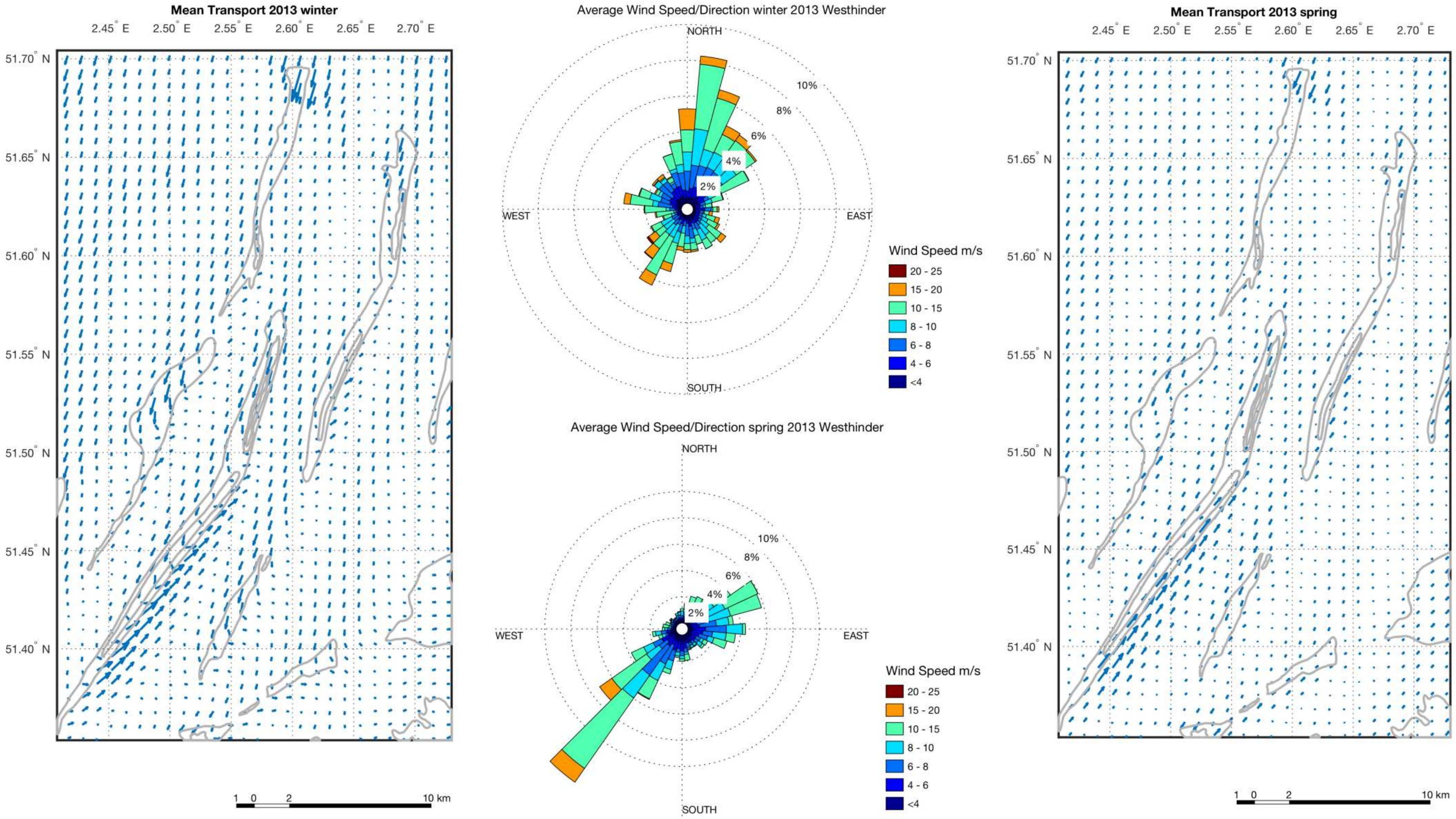


Figure 2: Seasonal averaged total load sediment transport and wind roses for winter and spring 2013.

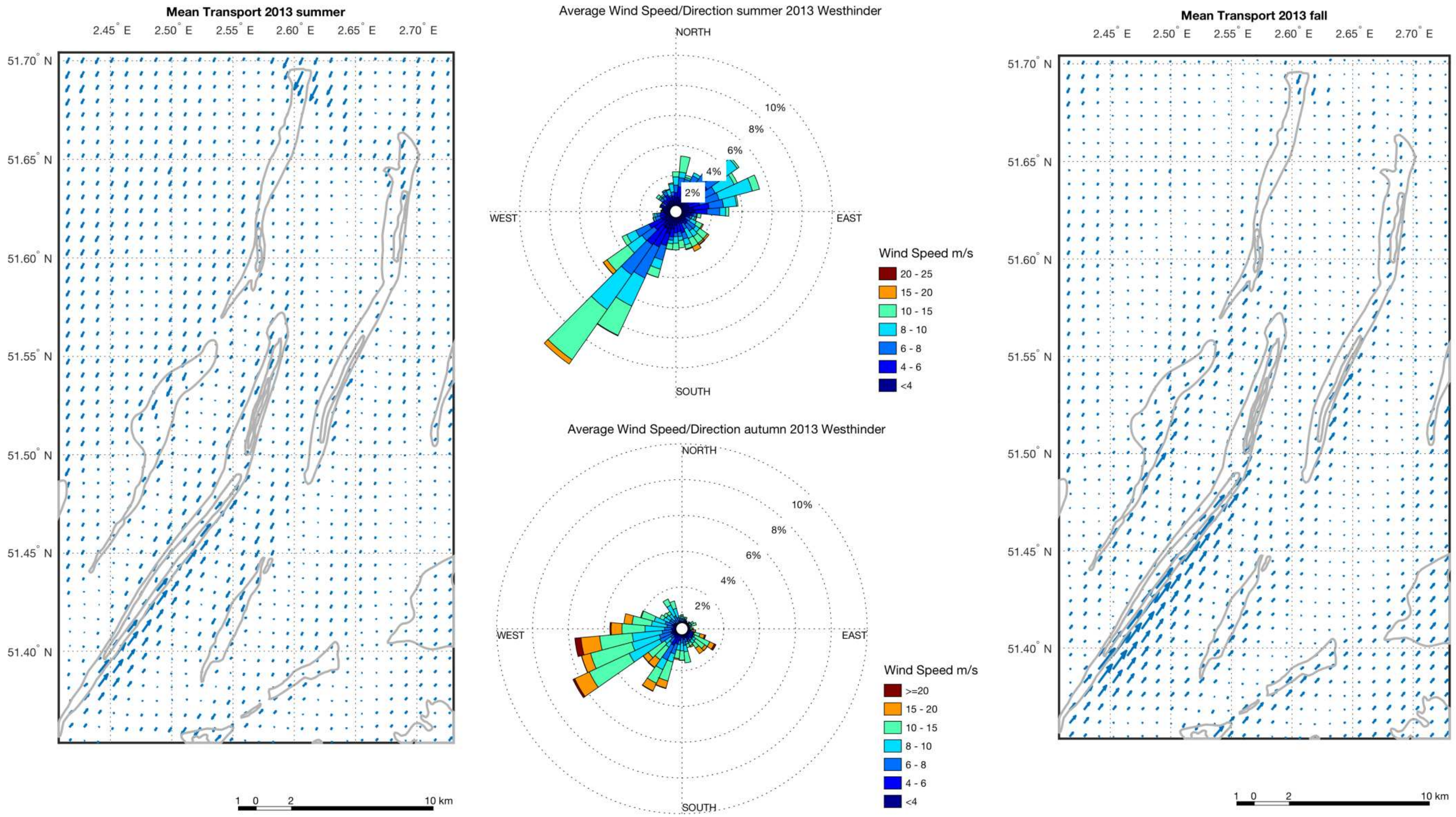


Figure 3: Seasonal averaged total load sediment transport and wind roses for summer and autumn (fall) 2013.

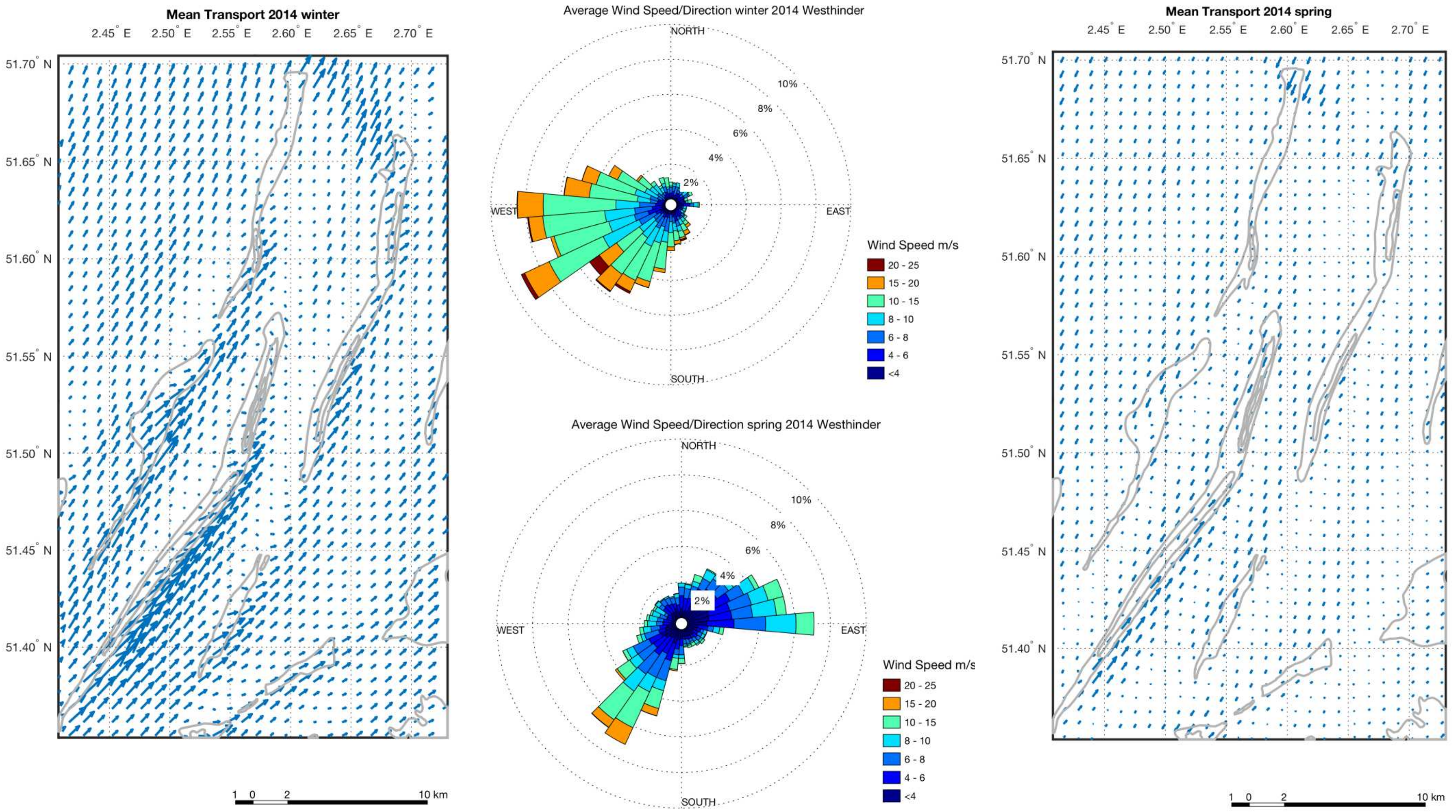


Figure 4: Seasonal averaged total load sediment transport and wind roses for winter and spring 2014.

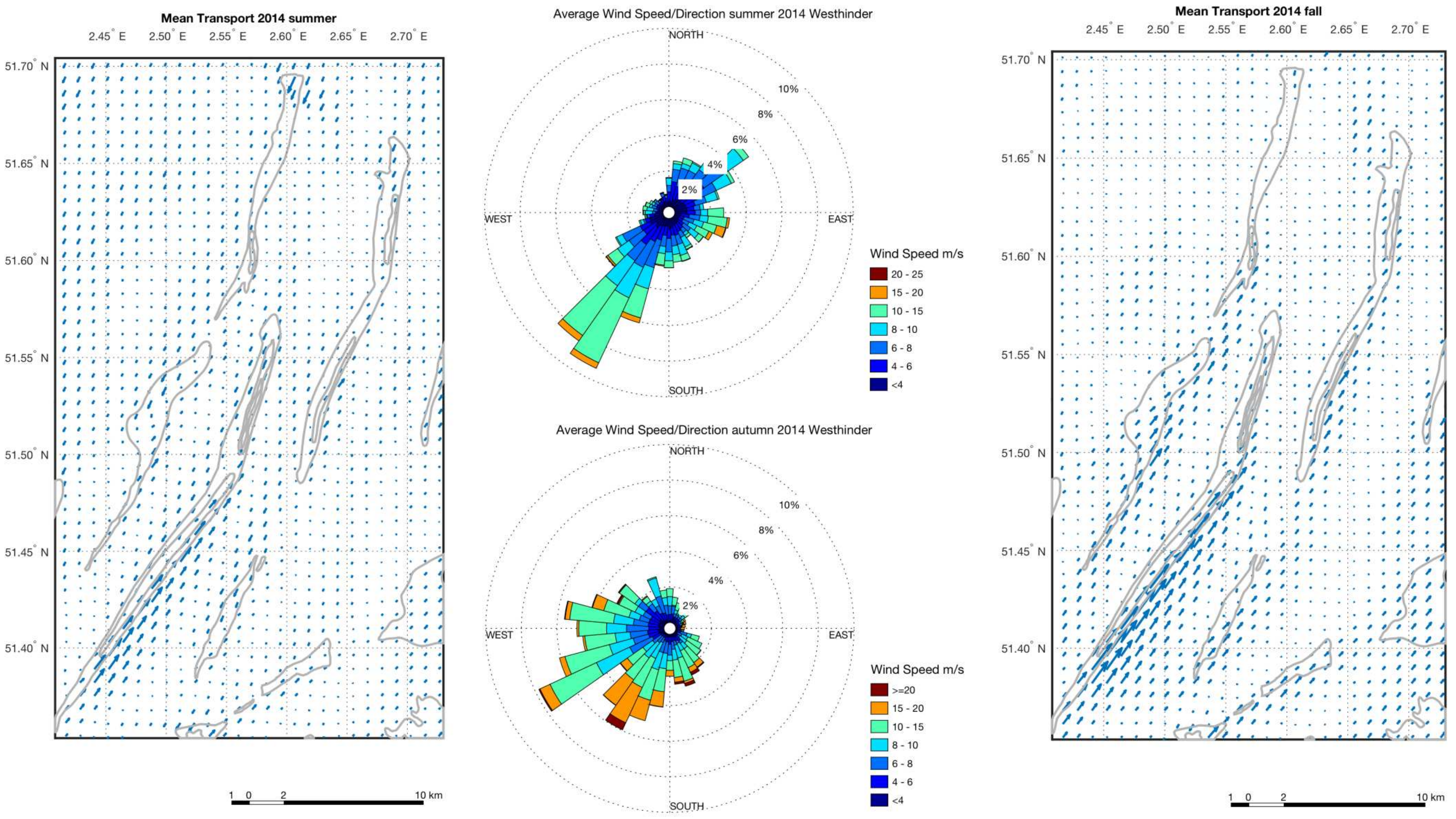


Figure 5: Seasonal averaged total load sediment transport and wind roses for summer and autumn (fall) 2014.

Figure 4 shows the winter of 2014 characterised by strong and very frequent winds blowing from the W and SW sector. Almost no wind originated from the N or the NE. The effect on the average total load transport direction is obvious. The global transport over the entire study area was SW-NE oriented. Spring and summer showed comparable patterns as in 2013. Both winds from the SW and NE sectors, giving rise to the same transport patterns as the previous year. Autumn 2014 again showed winds predominantly blowing from the W and SW sector, showing strong winds and wide spread.

It is clear that the winter of 2014 differed from the one of 2013. Model results show a distinct overall transport from the SW to the NE, which is at least partly explained by the meteorological conditions at that time. For the validation of the model results, measurements were sought on the depth and morphological evolution in the area. To this end FPS Economy, Continental Shelf Service provided a set of monitoring data (multibeam datasets) of the HBMC area on a 1m by 1m grid, for the years 2012 – 2014, each year containing two datasets.

In the SW part of the monitoring area a 2D profile was selected for the analysis of the morphological evolution (Figure 6).

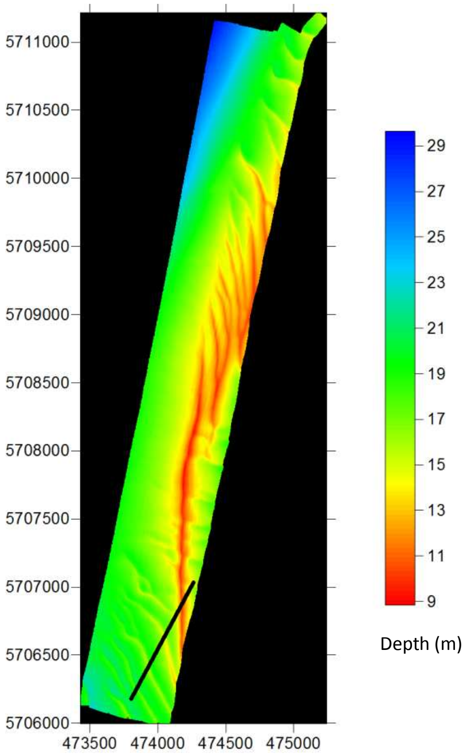


Figure 6: Digital elevation model of the HBMC area in 2012. Superimposed (south) is a profile along which depth data were extracted for comparison in time. Data courtesy FPS Economy, Continental Shelf Service.

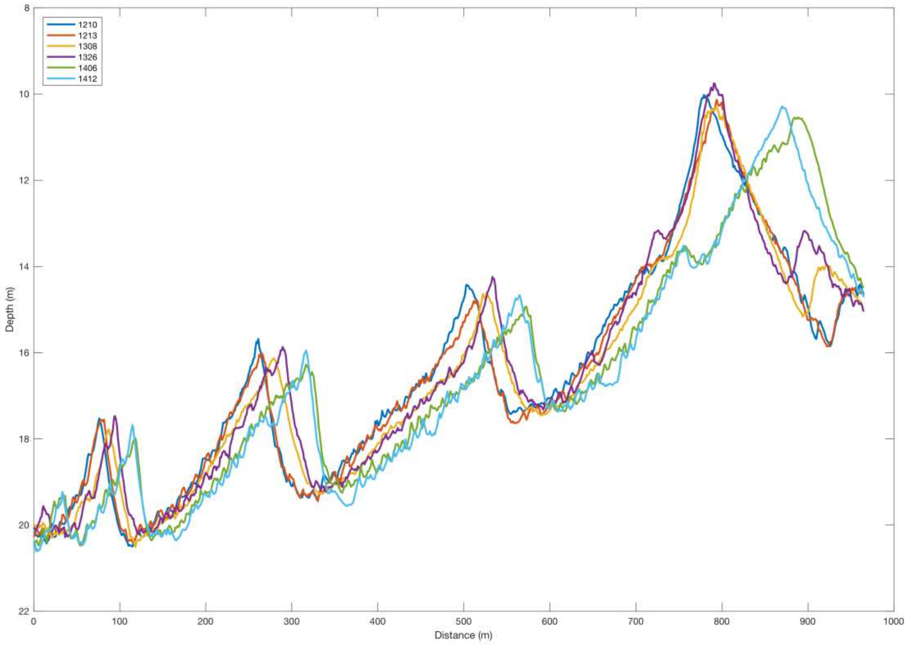


Figure 7: 2D profiles extracted from the digital elevation model time series. Dark blue and orange are profiles in 2012, yellow and purple in 2013, green and light blue in 2014.

Figure 7 shows the time series of the selected 2D profile. The dunes at the beginning of the profile (deeper water parts) show a yearly progressive migration. Most striking is the migration of the very large dune at the NE extremity of the profile, being located nearest to the top of the sandbank. The position of the dune was quasi stable in the years 2012 and 2013, but clearly a large bedform migration occurred at the end of 2013, beginning 2014 (winter 2014). In a period of several months, the top of the dune shifted for 80m in a NE direction and reduced in height. This testifies that also in the offshore area, dunes have dynamic behaviours and respond to changing hydro-meteorological conditions.

Conclusions

The previously created on-demand queryable sediment transport database (spanning 1999 – 2010) was expanded with four more years (2011 – 2014). From this, a subset (2012 – 2014) was selected to study variations in the total load sediment transport in the hinder Banks region. At first sight aberrant model output could at least be partially explained by deviant atmospheric conditions and the effects were validated by time series of a digital terrain model of the HBMC monitoring area in the aggregate sector 4C. Future applications are wide-spread and can include the estimation of the regeneration or recovery potential of the seabed, based on the natural deposition character of the area. It will also provide insight into the areas that are naturally more erosive, hence more vulnerable to the impact of human activities. With direct relevance to Europe's Marine Strategy Framework Directive, future work will concentrate also on the development of envelopes of natural variability, critical to distinguish naturally- versus anthropogenically-induced sediment dynamics.

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