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Towards quantifying variations in wind parameters across the Gulf of Finland

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Abstract. Several features of the spatial structure of wind patterns over the Gulf of Finland in the NE part of the Baltic Sea are analysed on the basis of wind parameters measured at two lighthouses (Tallinnamadal near the southern coast of the gulf and Kalbådagrund near its northern coast), which are compared with the High Resolution Limited Area Model (HIRLAM) 6.4.0 outputs for the period of April 2007–March 2008. It is shown that both the average air flow and the wind direction turn considerably clockwise when the air masses cross the gulf obliquely. Consequently, the influence of the Estonian mainland on the wind properties over the Gulf of Finland extends at least to a distance of 20 km to the Tallinnamadal Lighthouse area but hardly reaches a distance of 60 km where Kalbådagrund is located. The HIRLAM model captures well the wind direction at Tallinnamadal, whereas at Kalbådagrund the modelled wind direction is turned by >20° counter-clockwise from the measured direction. The HIRLAM output matches well the wind speed at Kalbådagrund, but underestimates it at Tallinnamadal by more than 1 m/s.

Key words: wind speed, wind direction, air flow, Gulf of Finland, HIRLAM version 6.4.0.

INTRODUCTION

The reliability and quality of the output of contemporary scientific and operational marine models are largely determined by the quality of wind data for the particular basin. Unfortunately, the meteorological stations and other measurement points are sparse in the open-sea area. In this respect the Gulf of Finland offers unique possibilities for marine modellers: it has a measurement site at Kalbådagrund (an offshore lighthouse in the central part of the gulf, approximately 20 km from the Finnish archipelago) where wind properties are virtually not affected by the archipelago and the mainland. These data are most widely used in different studies. Soomere (2005) applies Kalbådagrund wind data as a driving force for a high-resolution wave model to describe the wave regime in Tallinn Bay. Lips et al. (2008) investigate circulation of water masses in the Gulf of Finland and use Kalbådagrund wind data to calculate the surface layer Ekman transport. Uiboupin & Laanemets (2009) use wind data from the island of Utö (located near the entrance to the gulf and also reflecting well the open-sea winds) or Kalbådagrund to calculate the along-gulf component of the cumulative wind stress to estimate the wind forcing during the upwelling events.

In the majority of modelling efforts, however, one-point, albeit high-quality, wind data are not sufficient for an adequate representation of the sea state. The necessary forcing fields in offshore areas of the semi-enclosed basins are, to the first approximation, extrapolated with coastal measurements (Lo et al. 1994; WMO 2001). This procedure is highly nontrivial because the wind speed difference obviously depends on a number of parameters such as the wind direction, the stability of the air flow and the effects of the variable surface roughness and orography. For the Gulf of Finland Soomere & Keevallik (2003) present some criteria to judge whether a specific coastal site represents only local winds or the wind regime in a wider marine area. According to these criteria, Vilsandi, Utö, Hanko, Isosaari and Kotka are the best sites for describing the marine wind regime along the coasts of the Gulf of Finland.

In general, the relevant approximations for the ratio of the wind speed over water and over land are highly nonlinear, essentially site-specific, usually exhibit strong seasonal variability (Lo et al. 1994) and substantially depend on the local stratification of the air flow and also on the differences in atmospheric surface layer stability conditions driven, for example, by difference in the temperature of water and land (Resio & Vincent 1977; USACE 2002). The wind speed over land is usually (for low and moderate winds) smaller than that over the water surface (cf. Niros et al. 2002 for the Gulf of Finland conditions). For higher wind speeds (>15 m/s) the situation may be different and the wind speed over land may exceed the open sea wind speed (Resio & Vincent 1977). Moreover, this dependence has a significantly different nature for onshore and offshore winds, as shown by Launiainen & Saarinen (1982) by comparison of atmospheric parameters at Kalbådagrund and at the Loviisa coastal meteorological station.

Alternatively, one can define the properties of wind forcing near the sea level either from the overall patterns of the air flow or from local atmospheric models. The former approach makes the results virtually independent of local distortions of winds at ground measurement sites which are frequently quite large at coastal observation sites in the Baltic Sea (Keevallik 2003; Soomere & Keevallik 2003; Soomere et al. 2008). The most popular way consists in the use of geostrophic wind fields that are adjusted to the 10 m level by means of a simplified procedure in which the geostrophic wind speed (usually retrieved from the Swedish Meteorological and Hydrological Institute database) was multiplied by 0.6 and the direction turned 15° counter-clockwise (Bumke & Hasse 1989). This approximation is becoming increasingly popular in studies of circulation and wave patters in the Baltic Sea (Andrejev et al. 2004; Zhurbas et al. 2008; Myrberg et al. 2010; Räämet & Soomere 2010).

The most contemporary approach to marine modelling is the use of the results of local high-resolution atmospheric models as the forcing data. This is the only feasible way, for example, in operational oceanography. The most widely applied numerical weather prediction model in the Baltic Sea region is the High Resolution Limited Area Model (HIRLAM) (Källén 1996). The HIRLAM wind data are of key importance in operational oceanography, e.g. for driving the HIROMB (stands for High Resolution Operational Model for the Baltic Sea) circulation and water level model (Funkquist 2001), whereas its use in climatological studies and for hindcast of historical events is fairly limited because of its relatively short temporal coverage.

None of these products is perfect. The largest error is apparently present in simple restorations of marine wind fields from coastal data. Large discrepancies may also exist between model outputs and surface measurements. Zhurbas et al. (2008) compared surface-level winds deduced from geostrophic data with measurements at Kalbådagrund and Utö as well as onboard the research vessel *Aranda*. It turned out that winds from the geostrophic flow were underestimated. As a result, a factor of 2.04 was necessary to correct the wind stress values. In other words, wind speed was underestimated by about 30%. In many aspects the HIRLAM output shows good match with the ground truth. For example, Pirazzini et al. (2002) validated the boundary-layer structures of HIRLAM (version 4.6.2) over the Baltic Sea on the basis of rawinsonde soundings and surface observations during *r/v Aranda* expeditions in 1999. In general, the HIRLAM wind profiles agreed well with the observations. In October 1999, when the model validation was performed far from the coasts, the wind direction profile was accurate within 10° and the wind speed within 1 m/s.

The situation is particularly complex in areas such as the Gulf of Finland where the predominant air flow is oriented obliquely with respect to the coast. The changes in the wind properties after crossing the coastline are not limited to spatial variations in the wind speed but also involve substantial changes in the wind direction. The physical reason for such changes is that surface-level winds over a rough surface are turned more counter-clockwise than winds over a smooth surface (Holton 2004). Theoretically, the predominant south-western winds over Estonia should first turn more to the east after crossing the Estonian coastline and then back more to the north when the air flow starts to feel the Finnish archipelago (Savijärvi et al. 2005). This effect may substantially contribute to the development of wind wave systems aligned with the axis of the Gulf of Finland in so-called slanted fetch conditions (Pettersson et al. 2010).

This sensible behaviour of the air flow is largely ignored in studies of spatial variations in wind properties in this water body. This manner of changes in wind direction should become evident as a systematic discrepancy between the numerically modelled (that are given for a certain quite large grid cell) and measured winds at certain locations that do not coincide with the centre of the relevant cell. For example, Ansper & Fortelius (2001) verified HIRLAM version 4.6.2 winds during a three-month period of 01.11.1999–31.01.2000 by using measurements at four Finnish (Kalbådagrund, Kemi, Märket, Nahkiainen) and three Estonian (Kunda, Sõrve, Vilsandi) meteorological stations. During this period the predicted wind direction had a systematic bias up to 10° counter-clockwise from the measured data. The model also overpredicted wind speed for some directions.

The aim of this paper is to identify and quantify the potential changes in the air flow properties, especially in the wind direction over the Gulf of Finland from the existing open sea data sets and to compare the results with the state-of-the-art local model outputs. Obviously, from such analysis it cannot be detected, which data set more exactly represents the real situation. Surface measurements are affected by local orography and surroundings of the measurement site. Lighthouse measurements may be distorted by landing platforms or other screening objects that act as obstacles for particular wind directions. Therefore, one cannot be completely sure whether or not the data sets obtained from the surface and lighthouse measurements are reliable enough for making final conclusions and both data sets should be handled with care.

The problem is addressed by means of a thorough comparison of wind measurements at two lighthouses – Kalbådagrund and Tallinnamadal. The results of the comparison are verified against the HIRLAM 6.4.0 wind outputs. Tallinnamadal Lighthouse is located near the southern coast of the Gulf of Finland (about 20 km from the coastline) where air flow is obviously affected to some extent by the Estonian mainland, whereas Kalbådagrund is situated to the north of the gulf axis, about 60 km from this coast, and therefore more adequately reflects the free flow properties for southerly winds. In the light of the above discussion, the aim of the paper is definitely not to validate one data set against another, assuming that one of them is more reliable than the other. Our intention is to detect the existing differences that the modellers of the Gulf of Finland could account for when constructing forcing data for the marine models.

METEOROLOGICAL DATA

The key data set for this study of wind speed and direction was obtained at two lighthouses – Kalbådagrund and Tallinnamadal during the period of April 2007–March 2008. The averages of wind speed and direction over 10 min before the synoptic observation times (00, 03, 06, 09, 12, 15, 18, 21 GMT) were recorded by Väisälä automatic weather stations. From this data set observations at 00, 06, 12 and 18 GMT were chosen. These observations are not used in HIRLAM Analysis (see below) and are thus independent criteria for evaluating the model outputs.

Kalbådagrund (59°59′N, 25°36′E) is a lighthouse near the northern coast of the Gulf of Finland, about 20 km from the archipelago (Fig. 1). The wind is measured at the height of 32 m above mean sea level. Tallinnamadal Lighthouse (59°43′N, 24°44′E) is situated about 20 km from the Estonian islands of Naissaar and Aegna. The wind is measured at the height of 36 m above sea level.

The annual cycle of monthly average wind speed is almost identical at both measurement sites, showing large values from November to February and low values from June to August (Fig. 2). The wind speed registered at Kalbådagrund is somewhat less than at Tallinnamadal. The zonal component of the air flow shows rather good accordance between the two sites, but the meridional component is systematically larger at Tallinnamadal.

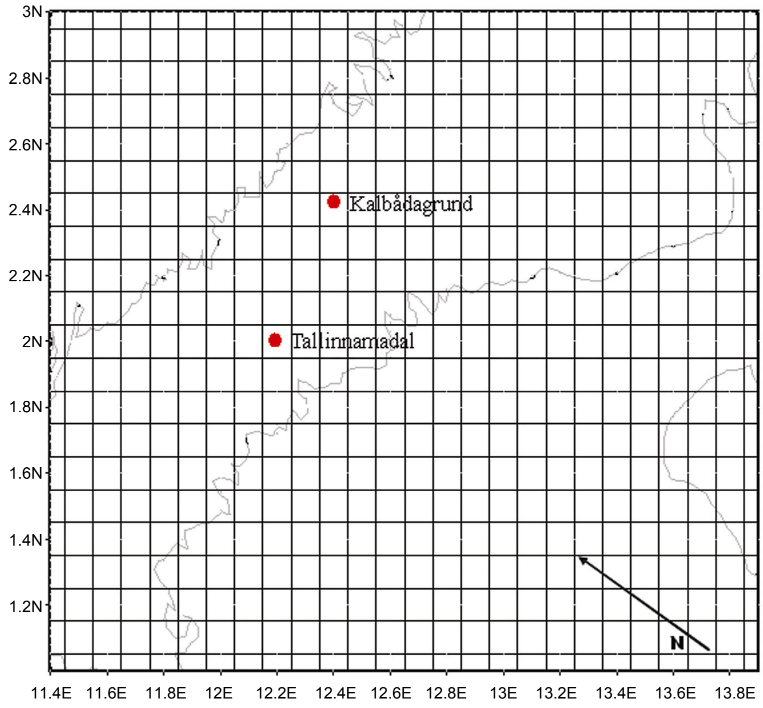

Fig. 1. The central part of the Gulf of Finland, with the measurement sites and the model grid in rotated HIRLAM latitude–longitude coordinates.

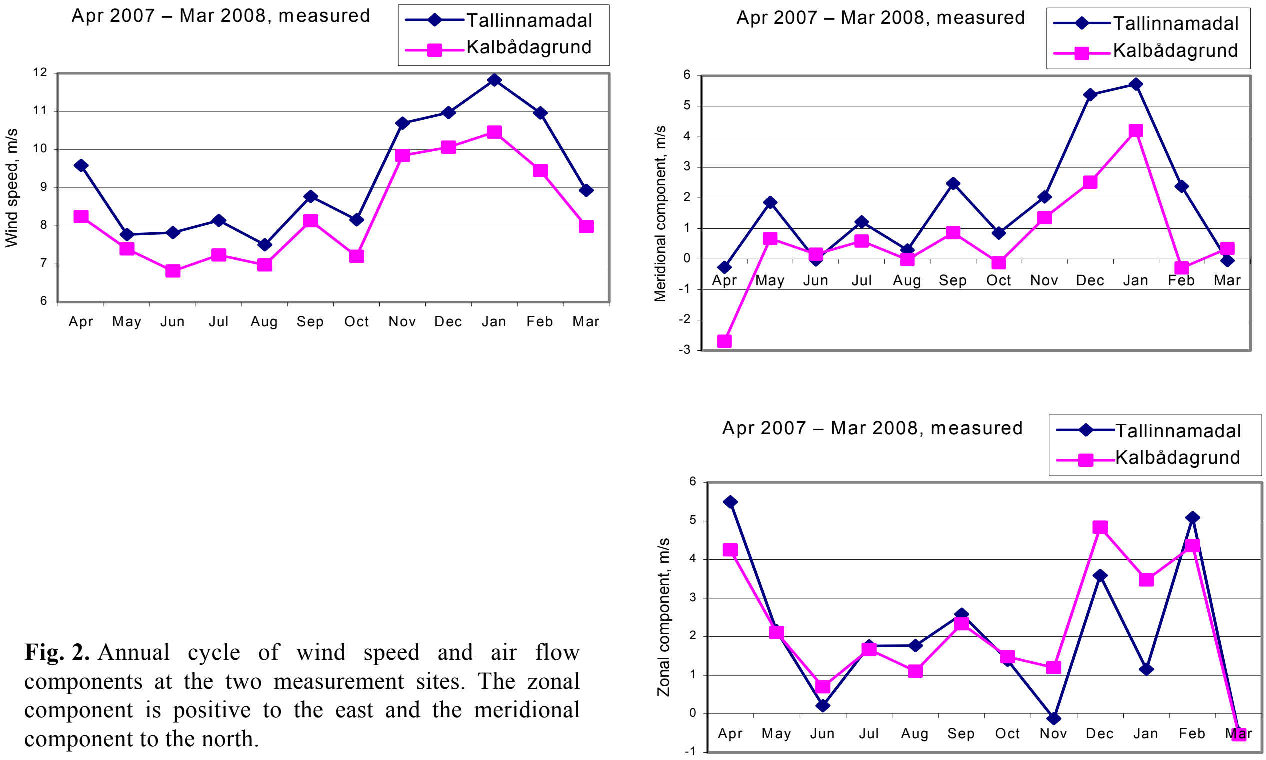

Fig. 2. Annual cycle of wind speed and air flow components at the two measurement sites. The zonal component is positive to the east and the meridional component to the north.

MODELLED WIND DATA

For comparison with in situ measured wind data, we use the numerical weather prediction (NWP) data that were obtained from the NWP environment of the Estonian Meteorological and Hydrological Institute by employing HIRLAM version 6.4.0 with minor modifications (see Keevallik et al. 2010 for details). The main modelling area, named ETA, has a horizontal resolution of 11 km. A hydrostatic semi-implicit semi-Lagrangian integration scheme with a 400 s time-step is applied in the forecast model. The model grid contains 114 × 100 points in the horizontal directions and has 40 levels. The boundary fields to the NWP environment are provided by the Finnish Meteorological Institute (FMI). They are cut out from forecasts of the FMI operational model which has a horizontal resolution of 22 km and is run four times a day with the forecasting start-points at the main synoptic hours 00, 06, 12 and 18 GMT. The time step of boundary fields for ETA is 3 h.

The 54-h forecasts together with the three-dimensional variational data assimilation system (3DVAR) analysis (later Analysis) of the meteorological fields are also produced four times a day for the main synoptic hours. Wind data were drawn from the lowest HIRLAM model level that is located approximately 30 m above the ground. The data from lighthouses used in comparisons below were measured at almost the same height. We use three data sets extracted from the HIRLAM outputs: the Analysis, 0-h (Initialization) and 24-h forecast results of 30 m winds. Doing so sheds some light also to the problem of finding the best way to hindcast marine winds. Wind components at the geographical locations of the measurement sites (that did not coincide with the model grid points) were approximated by means of a bilinear interpolation, using the relevant values at the four closest grid points. Finally, the wind direction, calculated by HIRLAM in a rotated coordinate system, was transformed to the standard geographical system.

The overall direction of the air flow (interpreted here as a vector, the components of which are the averages of the zonal and meridional components of wind velocity (Keevallik & Soomere 2008)) at Kalbådagrund near the northern coast of the Gulf of Finland is from the WSW (Fig. 3) and thus has quite a small meridional component and is almost aligned with the axis of the Gulf of Finland (which deviates from the zonal direction approximately by 15°). The average direction of the air flow at Tallinnamadal, however, is almost exactly from the SW. The distance between the two sites is about 60 km, whereas Kalbådagrund is located nearly precisely downwind from Tallinnamadal for the predominant air flow from WSW to SW. The relatively small distance combined with their mutual location suggests that wind

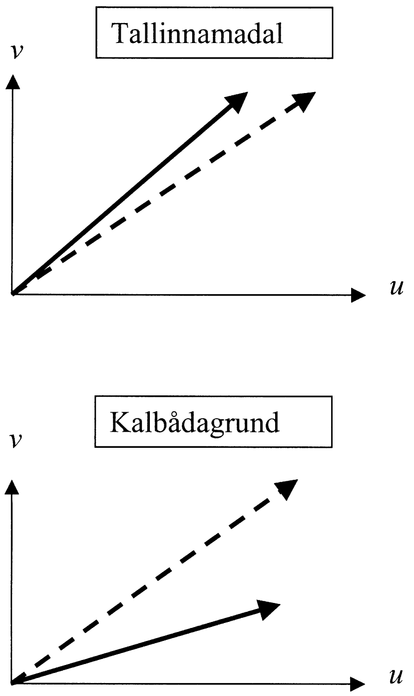

Fig. 3. Average air flow at the measurement sites from measurements (solid line) and HIRLAM Analysis (dashed line); *u*, zonal component; *v*, meridional component.

properties at these sites are predominantly affected by the same wind system. Therefore the data suggest that, on average, the air flow undergoes a substantial change in its direction (up to 30°) when the air masses cross the Gulf of Finland.

Interestingly, the modelled air flow direction is almost the same for Kalbådagrund and Tallinnamadal (Fig. 3). The measured average air flow has much richer variation: it is directed slightly more counter-clockwise from the modelled one at Tallinnamadal but deviates substantially clockwise at Kalbådagrund.

COMPARISON OF AIR FLOW COMPONENTS

To compare the HIRLAM outputs with measurements at lighthouses, mean difference (bias) and the root mean square deviation (RMSD) were calculated for the air flow components for the above-discussed three different HIRLAM outputs (Table 1). The bias is positive when HIRLAM overestimates the wind component, i.e. when NWP values are larger than the measured ones. As there is nearly no difference between the HIRLAM Analysis and 0-h forecast estimates, only the HIRLAM Analysis outputs are used in what follows.

Interestingly, the HIRLAM model output matches the measured values of the zonal component better at Kalbådagrund and the meridional component better at Tallinnamadal. This feature may be interpreted as representing the different magnitude of the impact of mainland on the air flow properties at the measurement sites (Fig. 3). The air flow at Kalbådagrund is nearly aligned with the axis of the Gulf of Finland, the fetch length is large and there are no obstacles that could complicate wind modelling. At Tallinnamadal the general air flow is influenced by the mainland, but the relevant phenomena may not be properly resolved by the model.

The bias of the meridional wind component at Tallinnamadal is negligible, but there seems to be a certain problem with its numerical reproduction at Kalbådagrund. Here the annual average of the meridional component is 0.63 m/s. As its bias (1.26 m/s for the Analysis) is twice as large as the mean value, it is not even clear whether the modelled data in question adequately capture the overall flow direction (to the south or north).

The presence of large uncertainties in the detection of the meridional component of air flow becomes clearer from the analysis of scatter-plots of measured and calculated wind components (Fig. 4). The linear regression relations between the measured and modelled data are frequently used to adjust the modelled values of different hydrometeorological parameters. The scatter of data points around the regression line is the largest (and the relevant correlation coefficient the smallest) for the meridional wind component at Kalbådagrund. The scatter is especially large in the cases where HIRLAM Analysis shows small positive values of the north–south wind component, equivalently, for winds mostly aligned with the gulf axis.

Table 1. Comparison of HIRLAM outputs and lighthouse measurements for wind velocity components: *u* is the zonal and *v* the meridional component

HIRLAM output	Tallinnamadal				Kalbådagrund			
	Bias, m/s		RMSD, m/s		Bias, m/s		RMSD, m/s	
	u	*v*	*u*	*v*	*u*	*v*	*u*	*v*
Analysis	0.53	0.08	3.00	3.09	0.12	1.26	2.86	3.61
0-h forecast	0.56	0.05	2.96	3.08	0.13	1.26	2.84	3.56
24-h forecast	–0.30	–0.43	3.05	3.26	–0.56	0.71	3.38	3.73

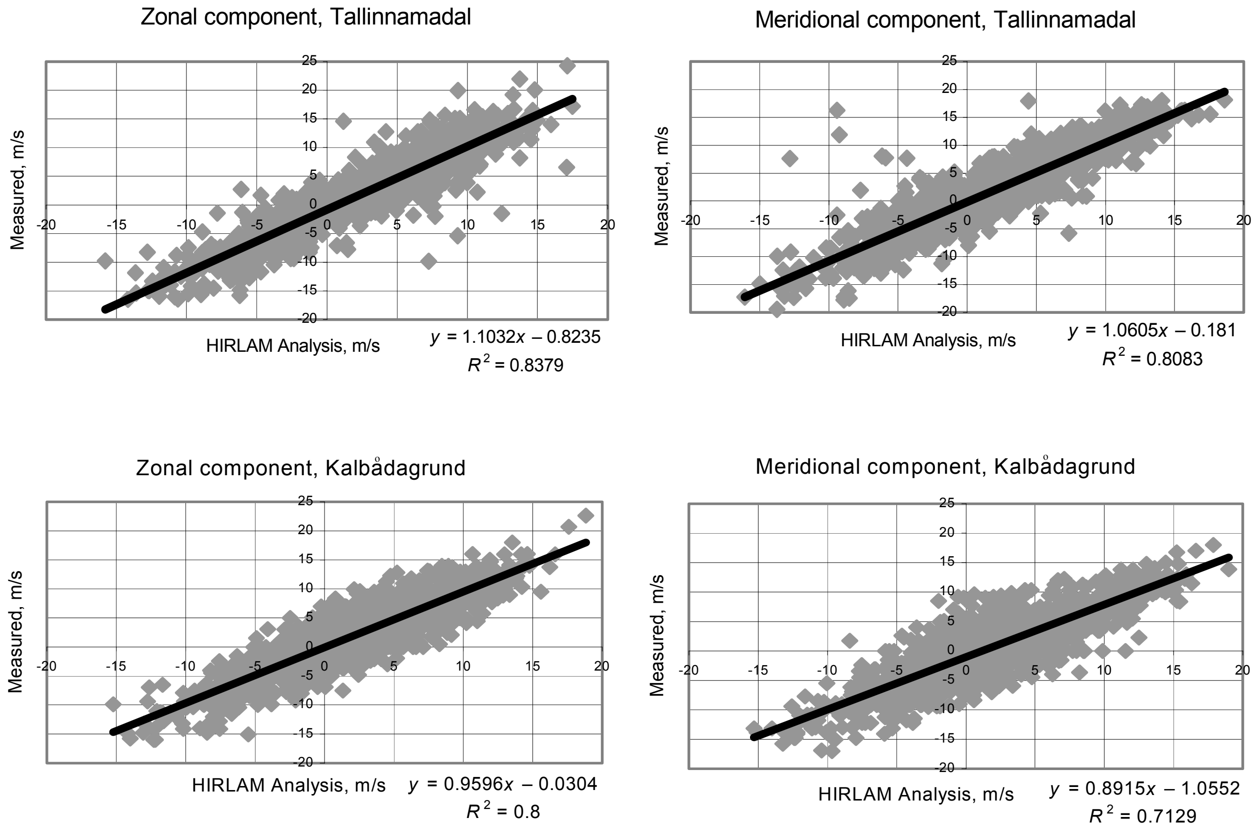

Fig. 4. Scatter plots and regression lines between HIRLAM Analysis and measured wind components at Kalbådagrund and Tallinnamadal.

WIND SPEED AND DIRECTION

Additional information on differences in the measured and modelled air flow components and on the structure of wind patterns over the Gulf of Finland can be extracted from the comparison of the modelled and measured wind speed and direction. A negative bias in wind speed (Table 2) shows that HIRLAM underestimates this parameter, especially at Tallinnamadal (where also the RMSD is somewhat larger than at Kalbådagrund). This feature apparently results from certain over-estimation of the impact of the roughness of the Estonian mainland in the HIRLAM model.

Consistently with the above analysis, the bias in wind direction is relatively small (actually negligible, given the realistic accuracy of wind direction measurements a few degrees) and positive at Tallinnamadal, but substantial and negative at Kalbådagrund. In other words, the wind direction predicted by HIRLAM is turned, on average, slightly clockwise from the measured direction at Tallinnamadal and significantly counter-clockwise at Kalbådagrund. The bias in wind direction at Kalbådagrund is almost the same as the difference in the average flow direction at this site (Fig. 3). The relatively large values of the RMSD of wind direction evidently reflect large uncertainties connected with the relevant measurements in gusty wind conditions. If the differences in the measured and modelled wind directions had a Gaussian distribution, the values of the RMSD in Table 2 would indicate that approximately 70% of wind direction predictions by HIRLAM would be within a sector of ±35° around the measured values.

The results of the performed comparison match similar results in other studies in the sense that the differences in wind direction are frequently much larger than those in wind speed. For example, an analogous study (Ansper & Fortelius 2003) resulted in a much smaller value (17°) of the RMSD of wind direction for Kalbådagrund for November 1999–January 2000 in case of 6-h forecast, whereas a systematic deviation in wind direction at all stations was identified. This qualitatively supports our findings. The largest difference between our analysis and that of Ansper & Fortelius (2003) is the relatively small bias (–0.8°) at Kalbådagrund for the winds >3 m/s. Our value for all winds during November 2007–January 2008 is –23.9°.

Table 2. Comparison of HIRLAM Analysis with measured wind parameters

Wind parameter	Tallinnamadal		Kalbådagrund	
	Bias	RMSD	Bias	RMSD
Speed, m/s	–1.22	2.77	–0.30	2.02
Direction, degrees	2.5	36.0	–23.8	37.9

Several researchers have noticed large deviations in the predicted and measured wind directions. Mass et al. (2002) report the mean absolute deviation in wind direction of 40°. This did not diminish much when the grid space was reduced to 4 km. On the other hand, the bias of the modelled wind direction on the eastern coast of the Gulf of Bothnia was less than 10° (Tisler et al. 2007). However, it must be kept in mind that the orientation of the Gulf of Finland with respect to predominant winds and its coastal orography may introduce special features into the wind regime (Savijärvi et al. 2005).

One might find a contradiction between the results in Tables 1 and 2: the biases of *u* and *v* at Tallinnamadal are positive, but the bias of wind speed is negative. Actually, the wind vector components are combinations of wind speed and direction and their averages can behave completely differently from the averages of wind speed, as seen from Table 3.

Heuristically, it is obvious that the impact of the coasts of the Gulf of Finland on wind properties substantially depends on the direction of the air flow. For example, almost no influence is expected for winds blowing along the axis of the gulf. To get a better understanding about the match of the modelled and measured wind speed and direction for different wind conditions, we analyse this match for 45° wide sectors, the central directions of which correspond to the eight major rhumbs. Thus, each sector covers the range of wind directions ±22.5° from the north, northeast, east, etc. Each measured wind data entry from a respective sector was compared with the relevant HIRLAM estimate for the same time instant even when the modelled direction was out of the respective sector.

Table 3. Average values of wind velocity and wind speed according to measurements and HIRLAM Analysis

	Modulus of the air-flow vector, m/s		Wind speed, m/s	
	Measured	Calculated	Measured	Calculated
Tallinn	2.70	3.14	9.26	8.06
Kalbådagrund	2.27	3.00	8.34	8.06

In the light of the above analysis, it is not unexpected that the HIRLAM model strongly underestimates the wind speed at Tallinnamadal for north (and somewhat less for south) winds and that the modelled and measured values match each other best for E, NE, W and NW winds (Fig. 5). At Kalbådagrund the bias in wind speed is slightly positive for SW and W winds, whereas the modelled wind speeds are systematically smaller than the measured values for all other directions. There is uniformly good match between the output of HIRLAM and the measured wind direction at Tallinnamadal, but a substantial bias between the HIRLAM's estimate (which systematically predicts wind directions to the left from the measured ones) and the measured wind direction at Kalbådagrund. The difference is the largest for N, NW and NE winds, reaching values of more than 35° for N winds.

The picture is somewhat different for the deviations of measured data from the HIRLAM Analysis output (Fig. 6). Such information is interesting for modellers

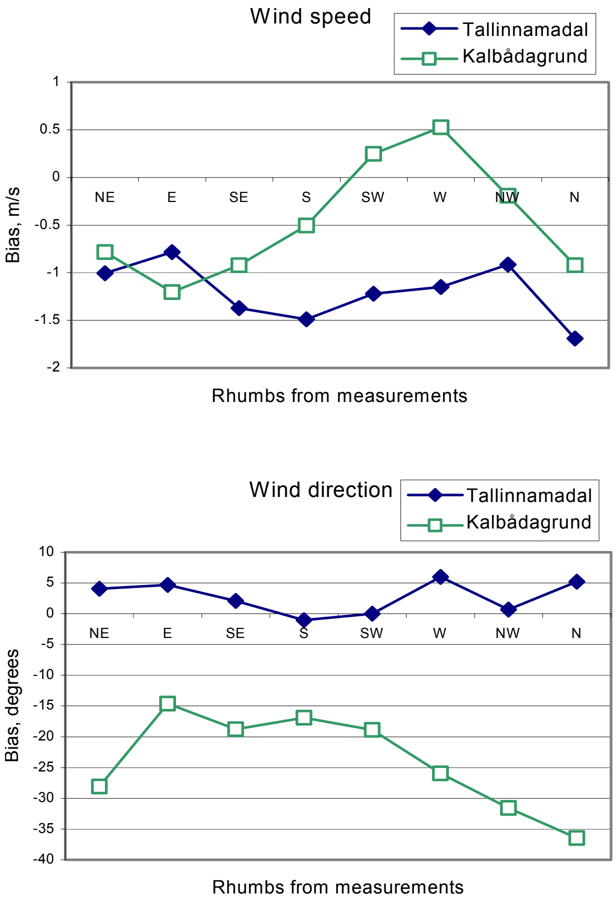

Fig. 5. Average differences of the modelled wind properties from the measured ones within ± 22.5° sectors around the principal rhumbs.

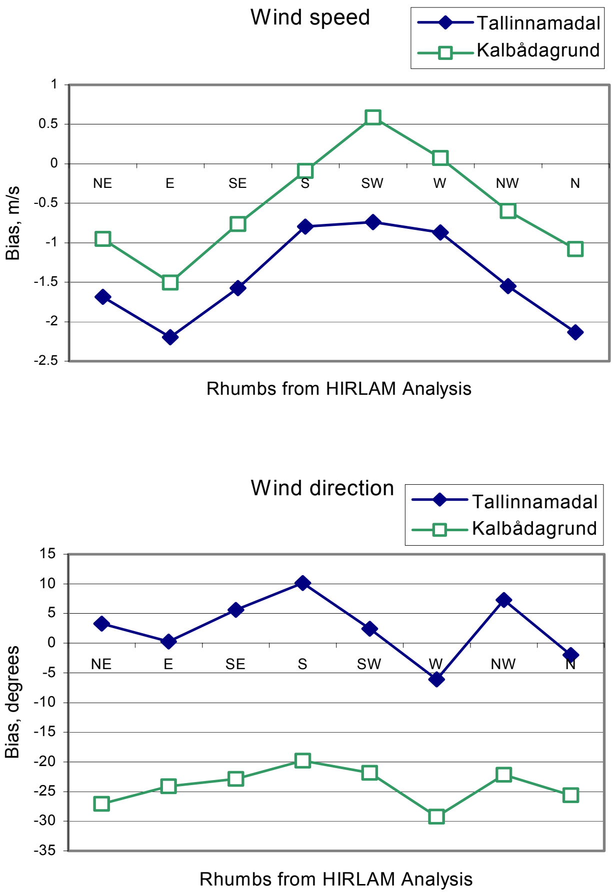

Fig. 6. Average differences of the measured wind properties from the modelled ones within ± 22.5° sectors around the principal rhumbs.

who have only NWP outputs at their disposal. The modeller could expect that the wind speed at Kalbådagrund is modelled well (within ±0.5 m/s) for S, SW, W and NW winds, whereas wind direction is uniformly biased by about 25° counter-clockwise. Wind speed is generally underestimated at Tallinnamadal, where the largest bias, over 2 m/s, occurs for E and N winds. There is, however, a good match in wind direction at Tallinnamadal.

DISCUSSION AND CONCLUSIONS

The performed analysis of wind parameters at two offshore sites in the Gulf of Finland first reveals a substantial change up to 20° in the overall direction of the average air flow over an about 60 km long distance between Tallinnamadal and Kalbådagrund. This clockwise turn can be interpreted as resulting from the interplay of the influence of the sequence of mainland and open sea sections on the wind regime of the Gulf of Finland. Namely, the angle between geostrophic flow and actual balanced air flow (that is diverted to the left in the northern hemisphere) increases with the roughness of the underlying surface (Holton 2004). The turn reflects, in particular, the reaction of the predominant, most frequent and relatively strong (Soomere & Keevallik 2003) oblique winds from the southwest on the difference in surface roughness between the mainland and the sea surface. The prevailing offshore SW winds on the southern coast of the gulf are affected by the Estonian mainland so that the relatively large deviations of both their speed and direction from that of the free flow in upper layers reflect land surface roughness. The fetch length for the winds near the northern coast is about 80 km over which the surface winds are affected by much smaller sea surface roughness. When air flow propagates over this section, it adjusts more to the free flow properties so that the average air flow vector turns clockwise when crossing the gulf.

This effect evidently plays a role in the formation of the two-lobe shape of angular distributions of wind directions at measurement sites of the Gulf of Finland which adequately reflect marine wind properties (Keevallik 2003; Soomere & Keevallik 2003; Soomere et al. 2008). Such a turn in wind direction towards alignment with the axis of the gulf apparently accelerates the development of wave systems propagating along this axis in slanted fetch conditions (Pettersson et al. 2010) by means of the initial excitation of wave systems almost aligned with the axis and, later on, contributes to the growth of this wave system more efficiently compared to the winds blowing under a larger angle with respect to the axis.

Comparison of the analysed data sets from the two measurement sites allows rough estimation of the distance over which the influence of Estonian mainland extends. The match of the measured and modelled flow properties in Fig. 3 suggests that the influence extends at least to Tallinnamadal (where the modelled data apparently adequately reflect this influence), whereas at Kalbådagrund it is much smaller. Therefore, at a distance of 20 km the influence of mainland on the surface-level flow is still quite strong, whereas at a distance of 60 km it has either disappeared or is minor. This conjecture, although estimated here very roughly for two measurement sites only, is essential for the efforts of reconstruction of the open sea wind direction based on coastal wind information.

Although from the performed analysis it cannot be exactly identified which data set more exactly represents the real situation, it is still remarkable that the HIRLAM model in use does not reproduce this turning of the average air flow at all. A potential reason is the insufficient spatial resolution (11 km) of the current HIRLAM version 6.4.0 that is running at the Estonian Meteorological and Hydrological Institute. The distance between the two measurement sites is only four grid points, being apparently too short in the model scale for adequate adjustment of the modelled air flow. The fact that the wind direction predicted by HIRLAM is turned counter-clockwise from the measured wind direction at Kalbådagrund can, however, be also interpreted as showing that HIRLAM version 6.4.0 overestimates the sea surface roughness.

Another interesting and somewhat unexpected conclusion is that the results of the analysis of the directional distributions of the deviations in wind speed and direction substantially depend on the choice of the reference data set. This feature may severely complicate the relevant analysis and also partially explain the discussed incompatibility of the results of different studies.

In many cases in practice the modeller has only modelled data at his/her disposal. The analysis above suggests that in the conditions of the Gulf of Finland one could expect that HIRLAM version 6.4.0 approximates well the speed of the winds blowing from the south, southwest and west. This is good news for modellers as the most frequent strong winds blow from these directions. For other directions, however, the HIRLAM model obviously underestimates the wind speed over the entire Gulf of Finland. This underestimation is especially large at Tallinnamadal for north and east winds. Further, one should account for the possibility that the wind directions predicted by the HIRLAM model generally deviate by 20–30° to the left from the actual wind direction in all sectors of the northern Gulf of Finland. The deviation of wind direction is generally less than 10° in the southern Gulf of Finland. There may exist seasonal variations in the listed features that unfortunately cannot be adequately evaluated on the basis of the short time series in use.

In conclusion, the basic message from the performed research is that neither the wind speed nor the wind direction for winds blowing obliquely to the Gulf of Finland can be considered to be constant. On the contrary, the wind direction may substantially (>20°) turn at a distance of a few dozens of kilometres from the coast, whereas the original direction is restored at the other coast. The presence of this sort of ‘internal’ structure of many wind conditions over the Gulf of Finland may considerably affect hydrodynamic and hydrophysical processes in this water body. A challenge for modellers is that this turn is not represented even in the very best contemporary operational models.

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Tuule parameetrite ruumilise muutlikkuse kvantitatiivsest hindamisest Soome lahel

Sirje Keevallik ja Tarmo Soomere

Kahes avamere tuletornis (Tallinnamadal Soome lahe lõunaranniku ja Kalbådagrund põhjaranniku lähistel) ajavahemikul aprillist 2007 kuni märtsini 2008 mõõdetud tuule parameetrite alusel on analüüsitud Soome lahe tuulevälja ruumilise struktuuri mõningaid jooni ning võrreldud neid numbrilise ilmaennustussüsteemi HIRLAM 6.4.0 väljunditega. On näidatud, et nii keskmine õhuvool kui tuule suund pöörduvad päripäeva, kui õhumassid ületavad lahe selle teljega mingi nurga all. Järelikult ulatub Eesti mandriosa mõju valitsevate tuulte omadustele vähemalt 20 km kaugusele, kus asub Tallinnamadal, ent on ebaoluline 60 km kaugusel, kus asub Kalbådagrund. HIRLAM-i väljundid langevad suhteliselt hästi kokku tuule suuna mõõtmistega Tallinnamadala tuletornis, aga Kalbådagrundis on HIRLAM-i arvutatud tuule suund pööratud enam kui 20° võrra mõõdetud tuule suunast vastupäeva. Tuule kiirust modelleerib HIRLAM hästi Kalbådagrundis, kuid hindab rohkem kui 1 m/s võrra alla Tallinnamadala tuletornis.