Nr 97, 2009

Oceanografi

Validation and correction of regionalised ERA-40 wind fields over the Baltic Sea using the Rossby Centre Atmosphere model RCA3.0

Anders Höglund, H.E. Markus Meier, Barry Broman and Ekaterini Kriezi

The wind meter at Gustaf Dalén. Photographer Markus Andersén.

Oceanografi
Nr 97, 2009

Validation and correction of regionalised ERA-40 wind fields over the Baltic Sea using the Rossby Centre Atmosphere model RCA3.0

Anders Höglund, H.E. Markus Meier, Barry Broman and Ekaterini Kriezi

Report Summary / Rapportsammanfattning

Issuing Agency/Utgivare	Report number/Publikation
Swedish Meteorological and Hydrological Institute S-601 76 NORRKÖPING Sweden	Oceanografi 97 Report date/Utgivningsdatum February 2009

Author (s)/Författare

Anders Höglund, H.E. Markus Meier, Barry Broman and Ekaterini Kriez

Title (and Subtitle/Titel

Validation and correction of regionalised ERA-40 wind fields over the Baltic Sea using the Rossby Centre Atmosphere model RCA3.0

Abstract/Sammandrag

Surface wind fields from ERA-40 regionalised with the Rossby Centre Atmosphere model RCA3.0 are underestimated. In this report a method for correcting the wind fields is evaluated. The method is based on the empirical linear relationship between gusty winds and mean wind. For the validation observations from 26 automatic stations along the Swedish coasts have been used. We found that the validation of wind over the open sea is difficult due to the impact of land that cannot be resolved properly by the atmospheric model as the horizontal grid resolution amounts to about 25 km. In addition, long homogeneous wind data sets are not available due to a switch from manual to automatic readings during the 1990s. The results show that the correction method improves the frequency distribution of simulated wind speed at most stations. Thus the corrected wind fields may be used to force Baltic Sea models during 1961-2004. However, the suggested correction method should be regarded only as a temporary solution while waiting for improved boundary layer parametrisations and higher horizontal grid resolution in regional atmospheric models.

Key words/sök-, nyckelord

Wind observation, wind validation, gustiness, regional climate model, RCA, Baltic Sea

Supplementary notes/Tillägg	Number of pages/Antal sidor	Language/Språk
	29	English

ISSN and title/ISSN och titel

0283-7714 Oceanografi

Report available from/Rapporten kan köpas från:

SMHI
S-601 76 NORRKÖPING
Sweden

Abstract

Surface wind fields from ERA-40 regionalised with the Rossby Centre Atmosphere model RCA3.0 are underestimated. In this report a method for correcting the wind fields is evaluated. The method is based on the empirical linear relationship between gusty winds and mean wind. For the validation observations from 26 automatic stations along the Swedish coasts have been used. We found that the validation of wind over the open sea is difficult due to the impact of land that cannot be resolved properly by the atmospheric model as the horizontal grid resolution amounts to about 25 km. In addition, long homogeneous wind data sets are not available due to a switch from manual to automatic readings during the 1990s. The results show that the correction method improves the frequency distribution of simulated wind speed at most stations. Thus the corrected wind fields may be used to force Baltic Sea models during 1961-2004. However, the suggested correction method should be regarded only as a temporary solution while waiting for improved boundary layer parametrisations and higher horizontal grid resolution in regional atmospheric models.

Contents

1 Introduction

Atmospheric surface wind fields from the global ERA-40 re-analysis performed by the ECMWF (Uppala et al. 2005) are too coarse to be used directly as forcing for oceanographic circulation and wave models for the Baltic Sea because the wind speeds are significantly underestimated (e.g. Omstedt et al. 2005). Higher resolution has been obtained by downscaling the data with the regional model RCA (Rossby Centre Atmospheric model, e.g. Jones et al., 2004; Kjellström et al. 2005). Unfortunately even the downscaled ERA-40 winds underestimate high wind speeds compared to observations (e.g. Ohlsson, 2007; Berg, 2008). Since mixing in the ocean is proportional to the third power of the wind speed, it is important to correct these wind fields before they can be used to force ocean circulation models in multi-year simulations. Also for wave models correct wind speeds are needed to avoid underestimated extremes of significant wave height (Kriezi and Broman 2008). In this report a method for postprocessing the model wind is investigated. The method is based on the empirical linear relationship between gusty winds (Nordström, 2006) and the mean wind (Davis and Newstein, 1968). Corrected and uncorrected model wind fields are compared with synoptic wind observations that are available at SMHI. The purpose of the investigation is to provide a corrected atmospheric model data set that could be used to force ocean circulation models for the Baltic Sea during 1961-2004 (e.g. Meier and Kauker, 2003).

2 Methods and data

2.1 Atmospheric model

In this report atmospheric model data from the regional model RCA version 3.0 forced with lateral boundary data from the ERA-40 reanalysis project (Uppala et al., 2005) are analysed. RCA3 is a further development of RCA2 (Jones et al., 2004) and the lake model PROBE (Ljungemyr et al., 1996) applied for lakes in an area approximately covering the Baltic Sea drainage basin.

Compared to the version of RCA3 that is described in Kjellström et al. (2005) there have been some changes including technically updated sub-routines, an increase from 4 to 10 halo points in the semi-lagrangian interpolation, more stored output fields, and no normal-mode initialisation. The model domain covers Europe and the coordinates of the South Pole in the rotated lat-long grid are (39.25S, 18.00E). Data are stored only on an inner model domain consisting of 170 x 190 grid points (ALONW=-21.72, ALATS=-20.68) for the period 19600901-20050531 (the last hours of 20050531 are missing). The first four months should not be analysed due to the spinup of the atmospheric circulation. At present the simulation will be continued until 2007/2008.

The horizontal and vertical resolutions of the simulation amount to 0.22×0.22 degrees (corresponding to about 24.5km) and 24 vertical levels, respectively. The model time step is 15 minutes.

The lateral boundary data, SSTs and sea-ice charts are from ERA-40 at 2° horizontal resolution and 60 vertical levels (of which only levels 13-60 are used). CO^2 increases linearly with time 0.125 ppm per month. All other external forcing conditions (aerosols, land use, solar constant = 1370 W/m^2) were held constant in the simulations.

All variables relevant to force ocean circulation or wave models are stored every third hour, e.g., 2 m air temperature, 2 m specific humidity, sea level pressure, 10 m wind speed, precipitation and total cloudiness.

2.2 Gustiness parametrisation

In RCA3.0 the wind gust estimate (WGE) method proposed by Brasseur (2001) is implemented (Nordström, 2006). The WGE method assumes that wind gusts develop when air parcels higher up in the boundary layer are deflected down to the surface by turbulent eddies. When these air parcels with a higher speed reach the surface they become gusty winds, i.e., sudden, brief increases of the mean wind speed. Gustiness can be estimated from the condition that the vertical component of the turbulent kinetic energy must be larger than the buoyant energy between the surface and the height of the air parcel. For details of the method the reader is referred to Brasseur (2001) and Nordström (2006).

2.3 Observations

Consistent and accurate observations for the whole time period of the model simulation at representative locations do not exist. Wind is inherently hard to measure in a consistent way over long time periods because the instruments are repositioned, nearby buildings are put up or torn down, forests grow up or get cut. The switch from manual to automatic stations is the most significant change during 1961-2004, since it affects all stations.

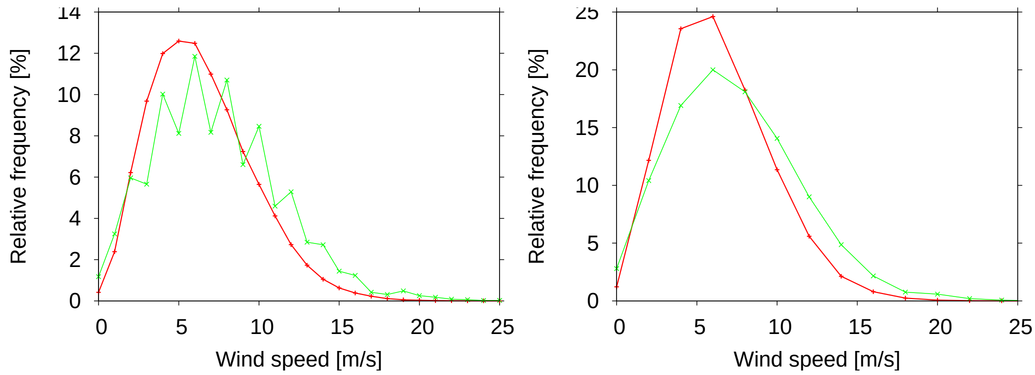

Figure 1: *Comparison of manual versus automatic wind observations at Landsort. Green: Manual station for the years 1961–1995. Red: Automatic station for the years 1996–2008. Left: The resolution on the x-axis is 1 m/s, showing manual readings giving preference for certain values. Right: The resolution on the x-axis is 2 m/s in order to smooth the manual readings.*

In Figure 1 observations from manual and automatic stations are shown for the location Landsort. This figure illustrates two major problems. The first is the quality of the manual reading, in this case some values are preferred over others. This can be dealt with since there is no reason to believe the error is systematic. The second problem is much more severe: the statistics for the two readings differ. As the time periods are different, perfect agreement should not be expected. However, the found differences are larger than the differences expected from decadal variations of about 0.2 – 0.3 m/s. The average of the observed wind is 7.4 m/s for the manual station and 6.4 for the automatic station. In the Appendix A the data of more manual and automatic stations are compared together with model results. For instance, in Figure 16 the observations at Landsort shown already in Figure 1 are compared with model results. The model data do not show the differences between decades as the observations do.

A hypothesis why the automatic stations are better is that newer equipment should be better than the one it replaces. However, conclusive evidence seems to be hard to find. In this report the rational is to use only observations from automatic stations. An alternative could have been to evaluate each station whether a longer time period could have been used. This must then be done in a systematic and objective way. Unfortunately this goes well beyond the the purpose of this report. One obvious way to compare manual and automatic stations would be to use the time period where data from both instrument types exist. This idea fails because during the overlap period many manual readings are from the new equipment.

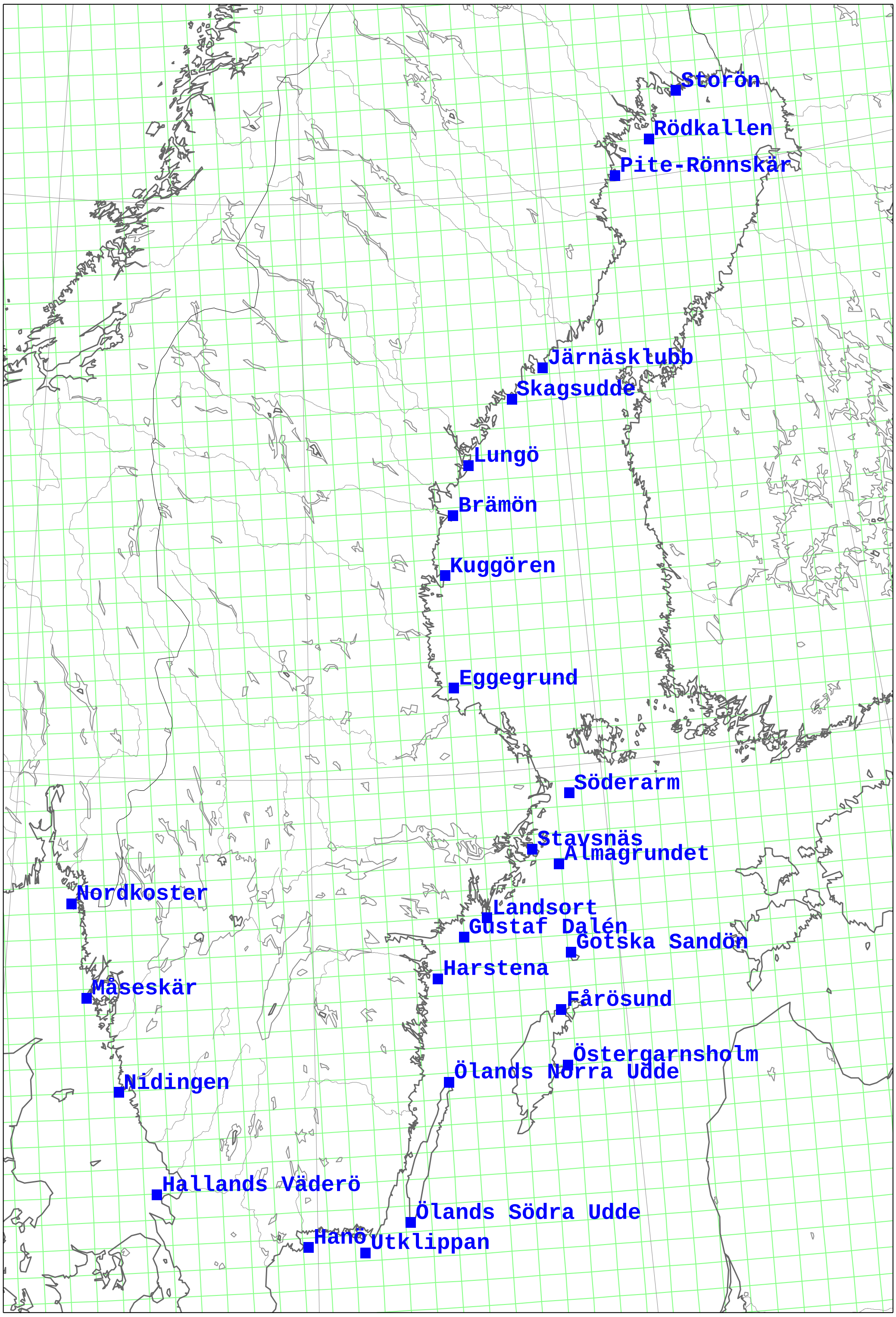

Figure 2: *Location of observation stations. Model grid in green where model points are in the middle of the squares.*

Table 1: *Basic facts about the stations used. The climate number is a Swedish identification number for the station. The number of observations are the number of observations coinciding with times when there are model data available. Model point denotes which of the four surrounding model grid points that has been used.*

Station name	Climate no	No obs	Model point	Remark
Storön	16390	25664	SE	
Rödkallen	16279	22733	SE	
Pite-Rönnskär	16171	26370	SE	
Holmön	14046	163	-	Excluded due to too few observations
Järnäsklubb	13926	21753	SE	
Skagsudde	13912	27121	SE	
Lungö	12839	26761	SE	
Brämön	12713	26763	SE	
Kuggören	11743	27067	SE	
Eggegrund	10744	25366	NE	
Söderarm	9945	26515	NE	
Stavsnäs	9816	26774	SE	
Almagrundet	9909	23118	SW	
Landsort	8744	26726	SE	
Gustaf Dalén	8736	21106	SE	
Gotska Sandön	8923	25883	NE	
Harstena	8714	26863	SE	
Fårösund	7855	26871	NW	
Östergarnsholm	7828	19343	SE	
Ölands norra udde	7721	27019	SE	
Ölands södra udde	6611	26527	SE	
Utklippan	5557	23480	SE	
Hanö	6402	26795	SE	
Hallands Väderö	6226	25915	NW	
Nidingen	7119	26923	NW	
Trubaduren	7136	1403	-	Excluded due to too few observations
Måseskär	8105	25908	SW	
Nordkoster	8154	10651	SW	

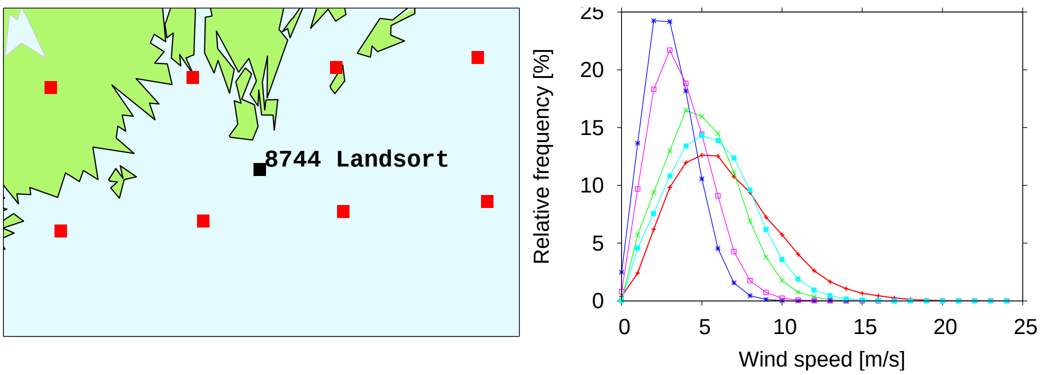

Figure 3: *Comparison of different model gridpoints at Landsort. Left: The location of Landsort station and the gridpoints in the model (red). Right: Observations (red) and model data from the four neighbouring model gridpoints (blue: northwest, purple: northeast, green: southwest, light blue: southeast).*

Non-Swedish stations have not been used because detailed information about these stations are missing.

The chosen stations and their locations are shown in Figure 2. In Table 1 some basic facts about the stations are shown. In this report stations are listed from the northern most locations in the Bothnian Bay, followed by the stations along the east coast to the south and then north along the west coast.

Wind close to the coast is influenced by land. Even though this affects the observations it is a larger problem for the model data. One possible explanation is the resolution of the model is coarse compared to the distance between the coast and the observation site and the model do not take into account where in the grid square the land is. This makes observations close to the coast less useful. Unfortunately most observations are close to the coast. The way this is handled here is to use model data from the closest grid point away from the coast even if there are other grid points much closer. In Figure 3 model data from the four surrounding grid points are shown together with observations from Landsort. The figure indicates that the size of the effect might be substantial.

2.4 Correction method utilising gustiness

From observations it was found that the average quotient between the gust and the mean wind speed over sea in 10 meter height amounts to about 1.6 (Davis and Newstein, 1968). In Figure 4 a scatterplot of gust against mean wind at Landsort is shown suggesting that there is a strong correlation between the two.

In Table 2 the quotient is shown for different observation stations, both observations and model results. It appears that the quotient in 18 out of 28 measurement stations is lower than the literature value of 1.6.

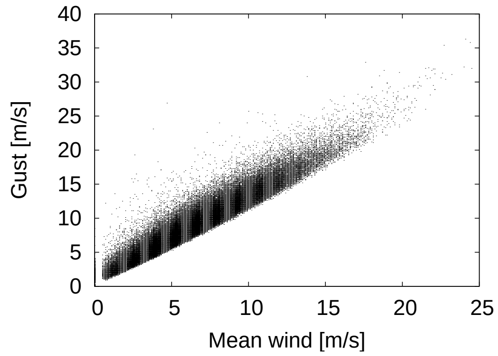

Figure 4: *Scatter plot of observed gust versus observed mean wind at Landsort.*

The method for adjusting the simulated mean wind utilises this empirical relationship. Whenever the quotient exceeds 1.6 the mean wind is replaced by the gust divided by 1.6. The direction of the wind is not altered. Figure 5 shows how often this happens in different locations.

3 Results

All statistics presented in this report are based only on points in time when both model data and observations are available. However, statistics from different positions may include data from different times with different lengths due to different availability of observations. Thus, geographical differences between stations might not be statistically significant.

In Appendix B graphs of the distributions of wind speeds before and after the modification as well as observations are shown. It is clearly an improvement for most stations, but not all. Focusing on the higher wind speeds, approximately 10–15 m/s, there are improvements in all stations except in Stavsnäs, Gotska Sandön and Harstena. The improvements in Järnäsklubb and Kuggören can be questioned.

The mean value is presented in Table 3. Improvements are shown in all stations except in Järnäsklubb, Stavsnäs, Gustaf Dalén, Gotska Sandön, Harstena, Ölands södra udde and Hallands Väderö. Already the unmodified model data for these

Table 2: *Quotient between gust and mean wind speed for observations, model data and modified model data. The first set of values are the mean of all quotients. The second set of values are the mean of only those values where the mean wind speed was 5 m/s or higher. The bars are proportional in size to the values before it, red is observations, green unmodified model data and blue modified model data.*

	Quotient all			Quotient >5m/s		
Station name	Obs	Model	Modified	Obs	Model	Modified
Storön	1.69	1.61	1.30	1.38	2.01	1.55
Rödkallen	1.43	1.30	1.20	1.33	1.34	1.26
Pite-Rönnskär	1.57	1.61	1.30	1.38	2.14	1.57
Järnäsklubb	1.68	1.33	1.22	1.50	1.36	1.28
Skagsudde	1.70	1.61	1.33	1.47	1.87	1.52
Lungö	1.67	1.91	1.38	1.44	2.32	1.59
Brämön	1.69	1.37	1.26	1.50	1.43	1.33
Kuggören	1.70	1.60	1.35	1.50	1.83	1.51
Eggegrund	1.48	1.36	1.23	1.37	1.41	1.30
Söderarm	1.40	1.56	1.37	1.32	1.66	1.46
Stavsnäs	1.85	1.47	1.34	1.66	1.53	1.40
Almagrundet	1.35	1.48	1.34	1.27	1.54	1.40
Landsort	1.49	1.43	1.32	1.39	1.48	1.37
Gustaf Dalén	1.48	1.43	1.31	1.36	1.47	1.36
Gotska Sandön	1.81	1.66	1.44	1.71	1.75	1.52
Harstena	1.73	1.41	1.29	1.62	1.46	1.34
Fårösund	1.58	1.81	1.46	1.47	1.93	1.57
Östergarnsholm	1.43	1.54	1.38	1.36	1.60	1.44
Ölands norra udde	1.56	1.61	1.40	1.44	1.80	1.53
Ölands södra udde	1.48	1.48	1.35	1.40	1.53	1.40
Utklippan	1.40	1.47	1.35	1.32	1.50	1.39
Hanö	1.46	1.61	1.39	1.37	1.79	1.51
Hallands Väderö	1.53	1.45	1.31	1.41	1.48	1.36
Nidingen	1.41	1.47	1.32	1.32	1.52	1.39
Måseskär	1.43	1.46	1.33	1.34	1.51	1.39
Nordkoster	1.59	1.68	1.42	1.49	1.82	1.54

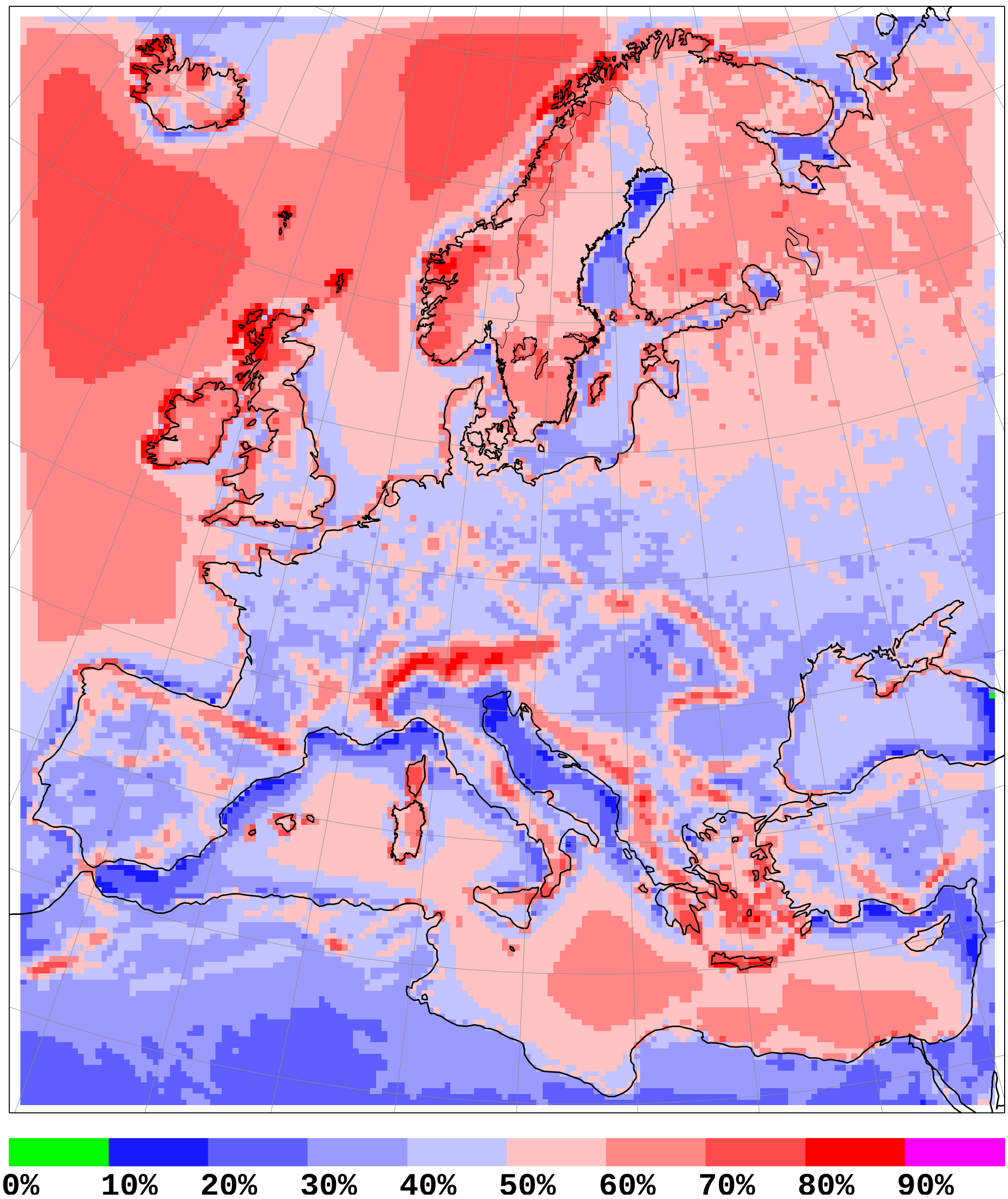

Figure 5: *Percentage of times when the gustiness has been used to correct the mean wind.*

Table 3: *Mean and standard deviation of observed and simulated wind at all stations. The bars are proportional in size to the values to the left, red is observations, green unmodified model data and blue modified model data. The improvement is the signed change of the unsigned difference between model results and observations, i.e.,* $\mathrm{abs}(Model - Obs) - \mathrm{abs}(Modified - Obs)$.

	Mean				Std. dev.			
Station name	Obs	Model	Modified	Imp	Obs	Model	Modified	Imp
Storön	4.53	3.39	4.16	+0.77	2.91	1.80	2.67	+0.87
Rödkallen	5.57	4.44	4.71	+0.27	2.96	2.42	2.73	+0.31
Pite-Rönnskär	5.08	3.32	4.10	+0.78	2.93	1.66	2.59	+0.93
Järnäsklubb	4.82	4.82	5.12	−0.30	2.90	2.63	2.95	+0.22
Skagsudde	4.77	4.15	4.97	+0.42	2.88	2.18	3.09	+0.49
Lungö	5.55	3.05	4.08	+1.03	3.32	1.55	2.51	+0.96
Brämön	5.45	4.90	5.24	+0.34	3.21	2.51	2.91	+0.40
Kuggören	4.89	4.44	5.23	+0.11	2.89	2.24	3.08	+0.46
Eggegrund	5.78	4.61	4.97	+0.36	3.02	2.45	2.87	+0.42
Söderarm	7.41	5.36	6.04	+0.68	3.72	2.60	3.23	+0.63
Stavsnäs	4.28	5.58	6.06	−0.48	2.33	2.61	3.08	−0.47
Almagrundet	6.76	5.63	6.13	+0.50	3.30	2.62	3.09	+0.47
Landsort	6.41	5.58	6.01	+0.43	3.19	2.59	3.01	+0.42
Gustaf Dalén	5.93	5.79	6.22	−0.15	3.02	2.67	3.10	+0.27
Gotska Sandön	5.50	5.75	6.57	−0.82	2.77	2.75	3.33	−0.54
Harstena	4.76	5.43	5.84	−0.41	2.46	2.55	2.99	−0.44
Fårösund	5.86	4.43	5.39	+0.96	3.33	2.20	2.89	+0.69
Östergarnsholm	6.49	6.00	6.62	+0.36	3.20	2.74	3.27	+0.39
Ölands norra udde	5.77	4.96	5.71	+0.75	3.12	2.34	3.08	+0.74
Ölands södra udde	6.14	5.97	6.46	−0.15	3.06	2.78	3.22	+0.12
Utklippan	6.80	6.14	6.60	+0.46	3.35	2.93	3.34	+0.41
Hanö	7.30	5.00	5.80	+0.80	3.65	2.37	3.20	+0.83
Hallands Väderö	6.06	5.83	6.32	−0.03	3.28	2.89	3.37	+0.30
Nidingen	6.91	5.30	5.78	+0.48	3.51	2.65	3.13	+0.48
Måseskär	7.14	5.90	6.39	+0.49	3.75	2.93	3.43	+0.50
Nordkoster	5.86	4.95	5.81	+0.86	3.16	2.54	3.33	+0.45

Table 4: *Median and 90% percentile of observed and simulated wind. The bars are proportional in size to the values to the left, red is observations, green unmodified model data and blue modified model data. The improvement is the signed change of the unsigned difference between model data and observations, i.e.,* $\text{abs}(Model - Obs) - \text{abs}(Modified - Obs)$.

	Median				90% percentile			
Station name	Obs	Model	Modified	Imp	Obs	Model	Modified	Imp
Storön	3.90	3.11	3.40	+0.29	8.70	5.84	8.07	+2.23
Rödkallen	5.20	4.03	4.12	+0.09	9.80	7.81	8.48	+0.67
Pite-Rönnskär	4.60	3.13	3.38	+0.25	9.20	5.60	7.86	+2.26
Järnäsklubb	4.20	4.42	4.56	−0.14	8.80	8.47	9.10	+0.03
Skagsudde	4.10	3.84	4.22	+0.14	8.90	7.16	9.32	+1.32
Lungö	4.90	2.89	3.48	+0.59	10.20	5.14	7.52	+2.38
Brämön	4.70	4.76	4.89	−0.13	9.90	8.43	9.16	+0.73
Kuggören	4.30	4.22	4.63	−0.25	8.70	7.49	9.51	+0.40
Eggegrund	5.30	4.12	4.29	+0.17	9.80	7.76	8.52	+0.76
Söderarm	7.10	5.17	5.61	+0.44	12.40	8.92	10.53	+1.61
Stavsnäs	4.00	5.36	5.64	−0.28	7.30	9.05	10.19	−1.14
Almagrundet	6.30	5.36	5.64	+0.28	10.90	9.05	10.19	+1.14
Landsort	6.00	5.38	5.61	+0.23	10.70	9.00	10.00	+1.00
Gustaf Dalén	5.50	5.56	5.77	−0.21	9.70	9.26	10.23	−0.09
Gotska Sandön	5.10	5.46	6.08	−0.62	9.10	9.37	11.05	−1.68
Harstena	4.30	5.20	5.39	−0.19	8.00	8.75	9.69	−0.94
Fårösund	5.20	4.17	4.96	+0.79	10.20	7.39	9.32	+1.93
Östergarnsholm	6.00	5.79	6.18	+0.03	10.70	9.63	11.02	+0.75
Ölands norra udde	5.40	4.71	5.09	+0.38	9.90	8.03	9.91	+1.86
Ölands södra udde	5.80	5.84	6.09	−0.25	10.30	9.68	10.82	+0.10
Utklippan	6.50	5.97	6.21	+0.24	11.30	10.04	11.05	+1.01
Hanö	6.80	4.74	5.18	+0.44	12.10	8.08	10.05	+1.97
Hallands Väderö	5.60	5.41	5.69	+0.10	10.70	9.54	10.50	+0.96
Nidingen	6.60	4.90	5.18	+0.28	11.80	8.79	9.74	+0.95
Måseskär	6.80	5.58	5.80	+0.22	12.40	9.77	10.80	+1.03
Nordkoster	5.40	4.47	4.99	+0.52	10.20	8.17	10.03	+1.86

stations have mean values which are too high or close to the right value. The modification can only increase the mean value and apparently it does so.

The spread of the values are given by the standard deviation (Table 3). All stations except Stavsnäs, Gotska Sandön and Harstena show improvements. While Stavsnäs has a high standard deviation before the modification the other two have about the right value. The method does not necessarily increase the spread even though that is the expected result.

Median values are shown in Table 4. Improvements are seen for eighteen stations while the eight stations Järnäsklubb, Brämön, Kuggören, Stavsnäs, Gustaf Dalén, Gotska Sandön, Harstena and Ölands södra udde gets worse median value. As in the case with mean value, these stations either already have good or too high median value and the modification can only increase the value.

In Table 4 also the 90% percentiles are shown. Improvements are seen in all stations except in Stavsnäs, Gustaf Dalén, Gotska Sandön and Harstena. The station Gustaf Dalén is overcompensated by the modification while the others have too high values already before the modification.

4 Discussions and conclusions

The wind statistics is clearly improved by the suggested modification. However, it is important to note that only the wind statistics improves. Other measures of quality, such as the RMS error, may get worse. This is easily understood by examining some time series of the wind.

In Figure 6 a time series for the first two weeks of 2005 is shown from the station Landsort. The unmodified model results are too smooth compared to observations but follow the larger events rather good even though they are generally too low. The modified wind is either the original mean wind or the gust divided by 1.6. This adds some variability that is not included in the observations, i.e., the modified wind record follows the unmodified wind record but shows some additional fluctuations that can in general not be motivated by the observations. However, in the overall statistics they compensate for the too smooth model wind. This behaviour of the correction method has a negative impact on measures that are sensitive to displacements in time such as the RMS error.

While the statistics is clearly improved on most stations there are a few stations where the examined measures get worse. These are mainly Stavsnäs, Gotska

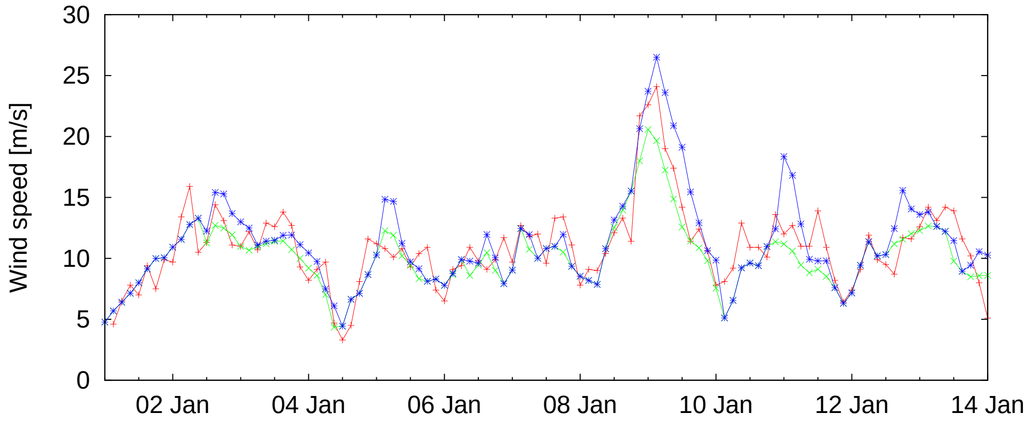

Figure 6: *Time series of the first two weeks of January 2005. Observations, model results and modified model results are denoted by red, green and blue lines, respectively. The large peak around the 9th of January is the storm Gudrun.*

Sandön and Harstena. From the graphs in Appendix B it is evident that the unmodified winds on those stations were already too strong and the modification could only make the situation worse. One problem is to find a model grid point which is representative for the location of the observations. It is important to make such choices in a consistent way to avoid subjective tuning of the results. Also from a data users point of view it is not always feasible to manually choose model grid points for all points of interest, especially for points where no observations are available. This becomes evident when, e.g., forcing fields for an oceanographic model are generated. As mentioned above, in this report the method is to choose the closest model grid point away from the coast in order to avoid a too strong land influence in the modelled wind. However, this strategy does not work when the observations are significantly influenced by land. In general, the validation should be performed only with stations far away from any coast.

In Appendix C the unmodified wind records from the four surrounding model grid points are compared with observations for all stations. In general, the model grid point away from the coast (normally the one with the strongest wind speeds) fits best with observations. This point is in many cases rather far away from the observation station as can be seen in the map in Figure 2.

For some stations the modelled winds for all surrounding model grid points are much too weak compared to observations. This applies to Storön, Pite-Rönnskär, Lungö, Söderarm, Hanö, Nidingen and Måseskär in varying degree. The examined correction method can only increase the wind and thus will improve the results for these stations unless an overcompensation occurs. The correction for Storön is impressive while the rest of the above listed stations are only slightly improved.

In the case of Harstena and Stavsnäs the closest model grid point away from the coast has too strong wind while the closest grid point in the other direction has too weak wind. Interpolation could solve the problem for these particular points but would in general give too weak wind.

The situation is different at Gotska Sandön where the simulated wind at all surrounding grid points is stronger than the observed wind. Perhaps the central location of the tower of the wind measurements on the island is the explanation why the observations do not represent open sea wind.

There are unfortunately no other observation stations that are far enough from the coast. The station with the next largest distance to the coast is Almagrundet. At this station the simulated wind is slightly underestimated.

Evidently there is a need for more observations over open sea. One possibility could be to use observations from ships (e.g. Bumke and Hasse, 1989). Observations from many different ships could be used to cover a large area but there might be problems to judge the quality of the observations. There is also a risk for the observations to be biased towards weaker wind speeds since the ships are likely to avoid the strongest storms.

There is also a need for long time series of observations. In this report only observations from 1996 and onwards have been used. This is due to the change to automatic stations. The statistics do not agree between the earlier manual observations and the new automatic stations. In Appendix A the periods with manual and automatic stations are compared, both for observations and model results. Some stations show a clear shift in the statistics which can not be explained with decadal variations. Such variations would have been visible in the model data as well. Other stations do not show this shift. It might have been possible to use older data from those stations in order to get longer time series. There is clearly a need to investigate and document the quality of the older observations for future use.

This report shows that the suggested correction method improves the simulated wind fields although some open questions remain. For instance, the reason for the underestimated model wind over the open sea is not understood. We can only speculate that the surface roughness length of the planetary boundary layer parametrisation or any other parameter is not appropriately chosen. Of course, the model parameterisations should be corrected instead of post processing the model results. More investigations are needed to generate better model wind fields that could be used to force ocean circulation models for the Baltic Sea.

5 Acknowledgements

This work has been financed by SMHI project resources through the project CLIMODUSE at the Research and Development department.

References

Berg, C. 2008. *Validation of the WAM-model over the Baltic Sea.* Department of Earth Sciences, Uppsala University, Student thesis, ISSN 1650-6553, No. 156, 30 pp.

Brasseur, O. 2001. *Development and application of a physical approach to estimating wind gusts.* Mon. Wea. Rev., 129, 5-25.

Bumke, K. and Hasse, L., 1989. *An analysis scheme for the determination of true surface winds at sea from ship synoptic wind and pressure observations.* Boundary-Layer Meteorol., 47, 295-308.

Davis, F. K. and Newstein, h., 1968. *The variation of gust factors with mean wind speed and with height.* J. Appl. Meteorol., vol. 7, 372-378.

Jones, C.G., Ullerstig, A., Willén, U. and Hansson, U., 2004. *The Rossby Centre regional atmospheric climate model (RCA). Part I: Model climatology and performance characteristics for present climate over Europe.* Ambio, 33(4-5), 199-210.

Kjellström, E., Bärring, L., Gollvik, S., Hansson, U., Jones, C., Samuelsson, P., Rummukainen, M., Ullerstig, A., Willén U. and Wyser, K., 2005. *A 140-year simulation of European climate with the new version of the Rossby Centre regional atmospheric climate model (RCA3).* Reports Meteorology and Climatology, 108, SMHI, SE-60176 Norrköping, Sweden, 54 pp.

Kriezi, E. and Broman, B., 2008. *Past and future wave climate in the Baltic Sea produced by the SWAN model with forcing from the regional climate model RCA of the Rossby Centre.* Extended abstract for US/EU-Baltic 2008 International Symposium in Tallinn, 27-28 Maj 2008, ISBN 978-1-4244-2268-5/08.

Ljungemyr, P., Gustafsson, N. and Omstedt, A., 1996. *Parameterization of lake thermodynamics in a high resolution weather forecasting model.* Tellus, 48A, 608-621.

Meier, H.E.M., and Kauker, F., 2003. *Modeling decadal variability of the Baltic Sea: 2. Role of freshwater inflow and large-scale atmospheric circulation for salinity.* J. Geophys. Res., 108(C11), 3368, doi:10.1029/2003JC001799.

Nordström, M. 2006. *Estimation of gusty winds in RCA.* Department of Earth Sciences, Uppsala University, Student thesis, ISSN 1650-6553, No. 101, 42 pp.

Ohlsson, A. 2007. *The accuracy of the wind stress over ocean of the Rossby Centre Atmospheric model (RCA).* Department of Earth Sciences, Uppsala University, Student thesis, ISSN 1650-6553, No. 124, 29 pp.

Omstedt, A., Chen, Y. and Wesslander, K., 2005. *A comparison between the ERA40 and the SMHI gridded meteorological databases as applied to Baltic Sea modelling.* Nordic hydrology., vol. 36, no. 4-5, pp. 369-380.

Uppala, S.M. and 45 coauthors, 2005. *The ERA-40 re-analysis.* Quarterly Journal of the Royal Meteorological Society, vol. 131, issue 612, pp. 2961-3012

Appendix A: Comparison between manual and automatic stations

This appendix contains frequency distributions of wind records from two time periods. The dashed line denotes data from 1995 and older where manual observations have been used. The solid line denotes data from 1996 and later where automatic observations have been used. In all figures observations, unmodified model results and modified model results are depicted as red, green and blue lines, respectively.

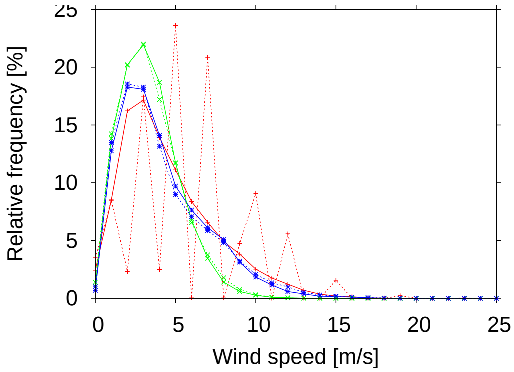

Figure 7: *Storön*

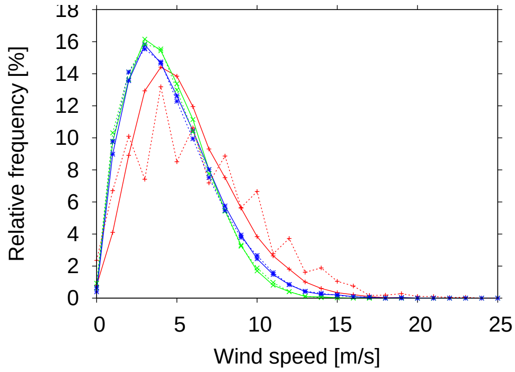

Figure 8: *Rödkallen*

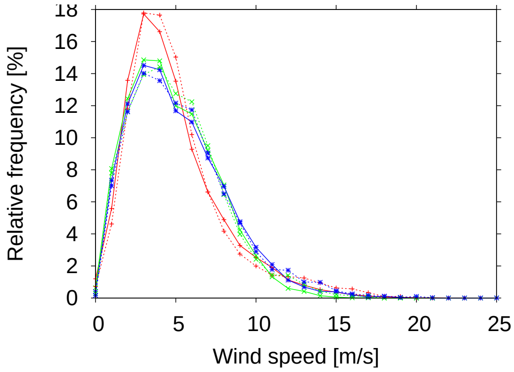

Figure 9: *Järnäsklubb*

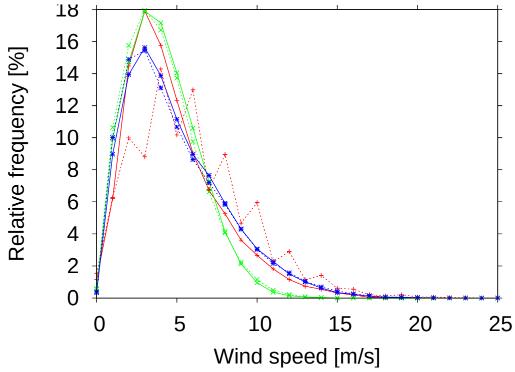

Figure 10: *Skagsudde*

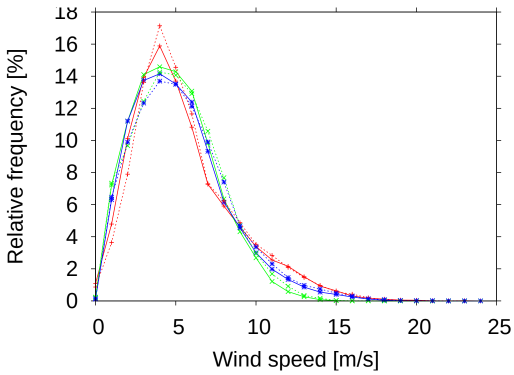

Figure 11: *Brämön*

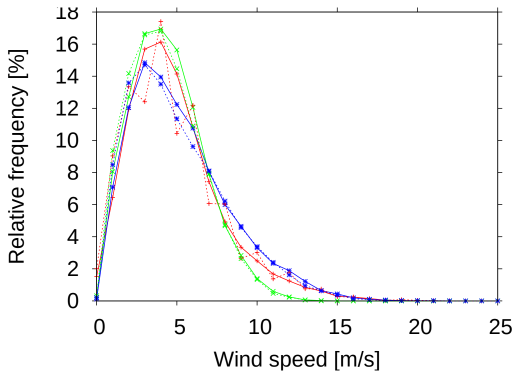

Figure 12: *Kuggören*

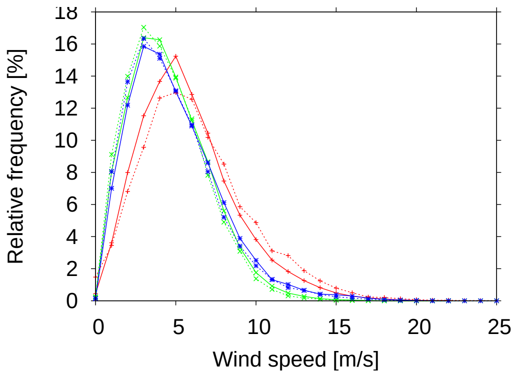

Figure 13: *Eggegrund*

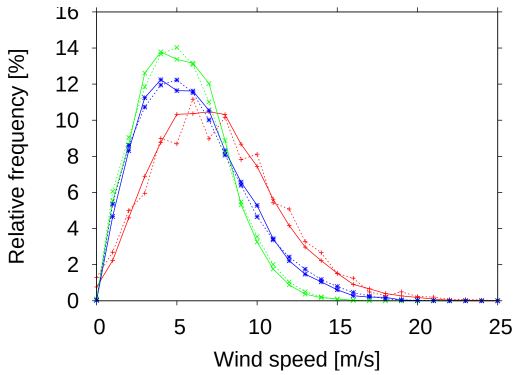

Figure 14: *Söderarm*

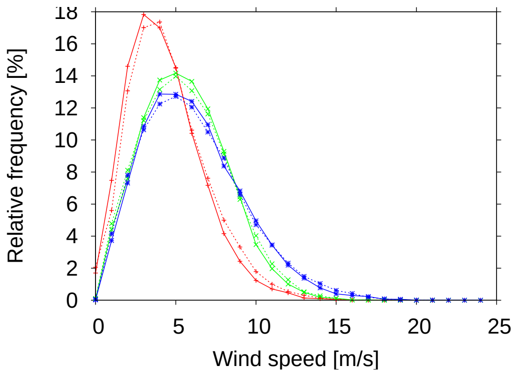

Figure 15: *Stavsnäs*

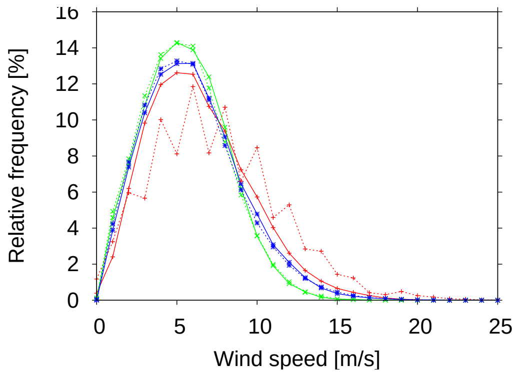

Figure 16: *Landsort*

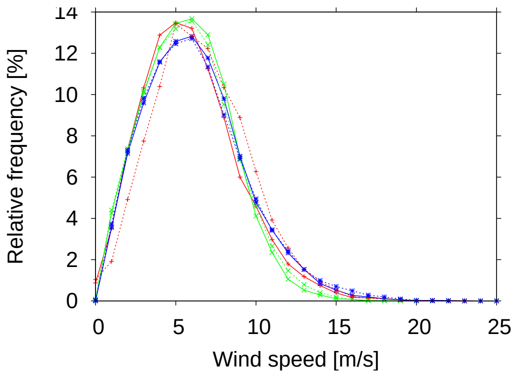

Figure 17: *Gustaf Dalén*

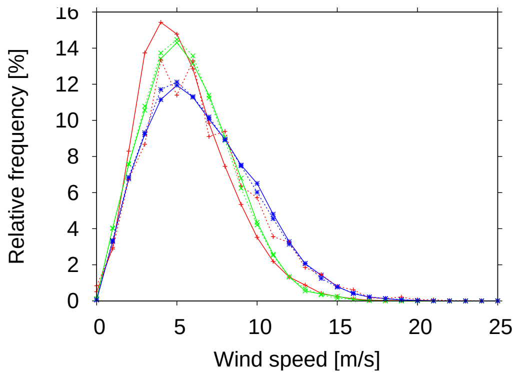

Figure 18: *Gotska Sandön*

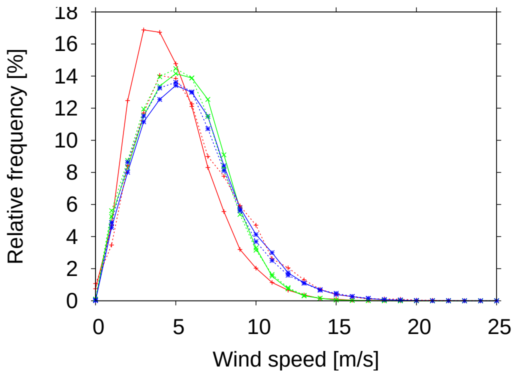

Figure 19: *Harstena*

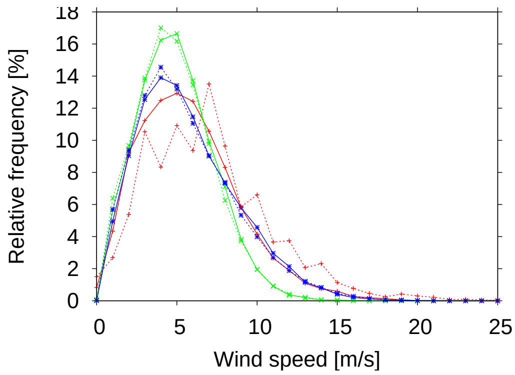

Figure 20: *Ölands norra udde*

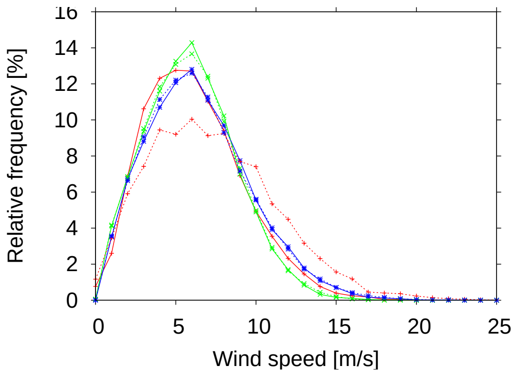

Figure 21: *Ölands södra udde*

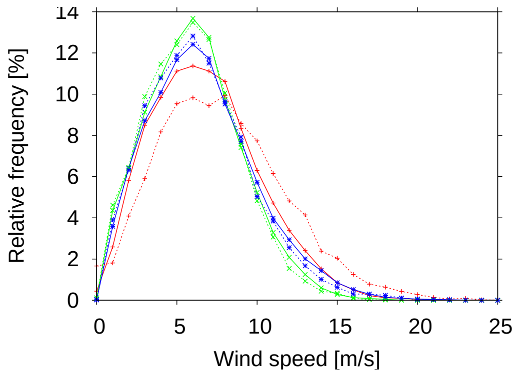

Figure 22: *Utklippan*

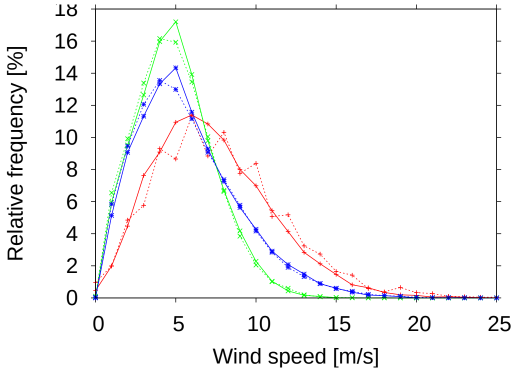

Figure 23: *Hanö*

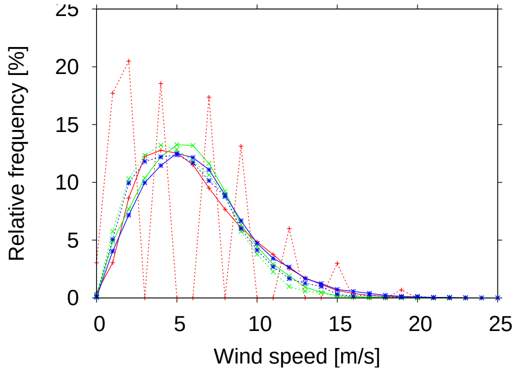

Figure 24: *Hallands Väderö*

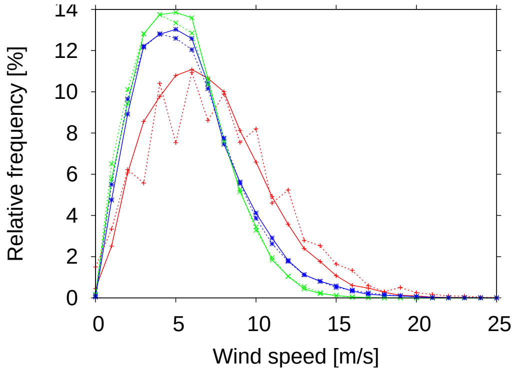

Figure 25: *Nidingen*

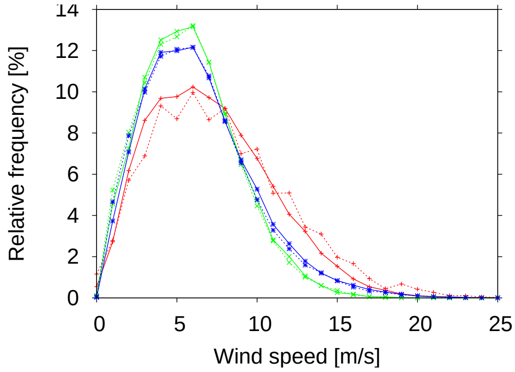

Figure 26: *Måseskär*

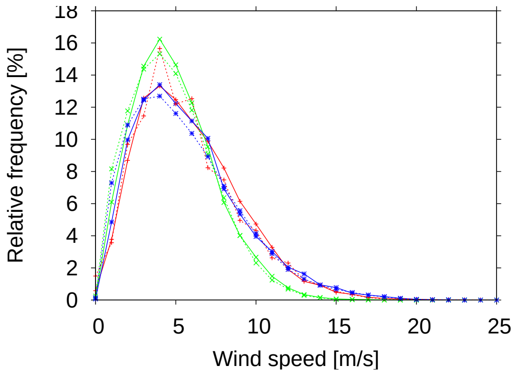

Figure 27: *Nordkoster*

Appendix B: Frequency distributions

This appendix contains graphs of the frequency distribution of observed and simulated winds. In all figures observations, unmodified model results and modified model results are depicted as red, green and blue lines, respectively.

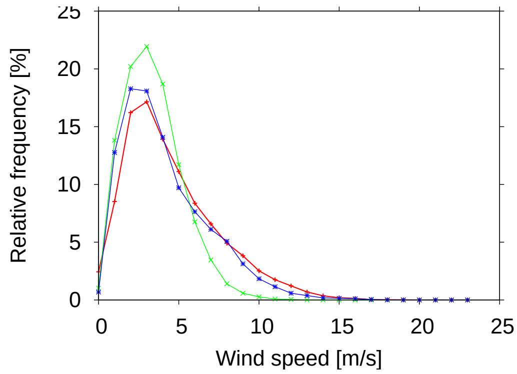

Figure 28: *Storön*

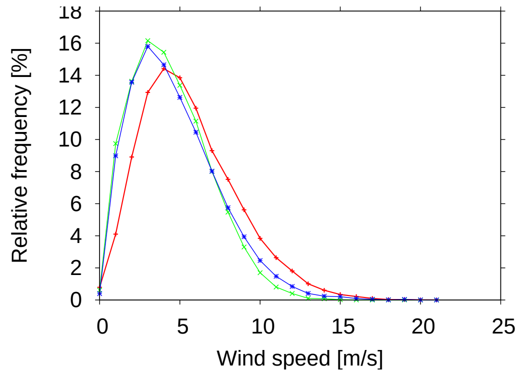

Figure 29: *Rödkallen*

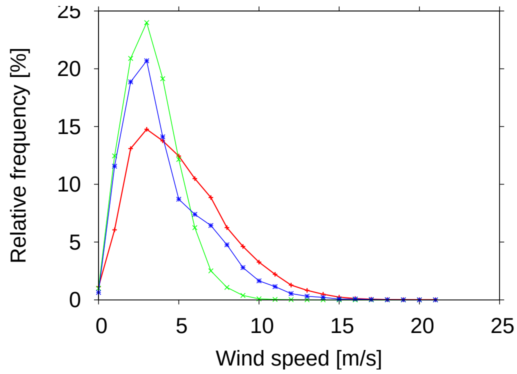

Figure 30: *Pite-Rönnskär*

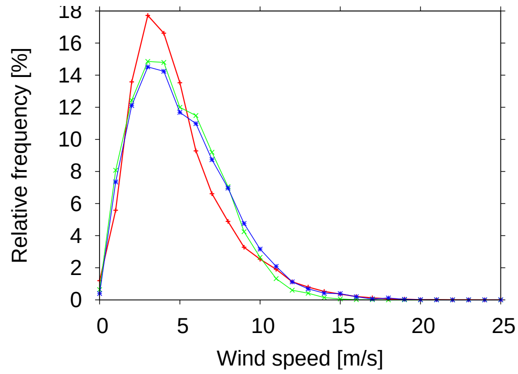

Figure 31: *Järnäsklubb*

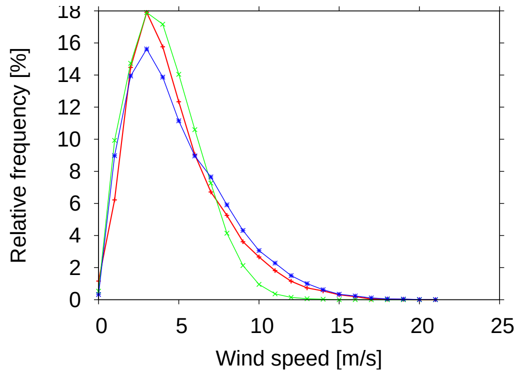

Figure 32: *Skagsudde*

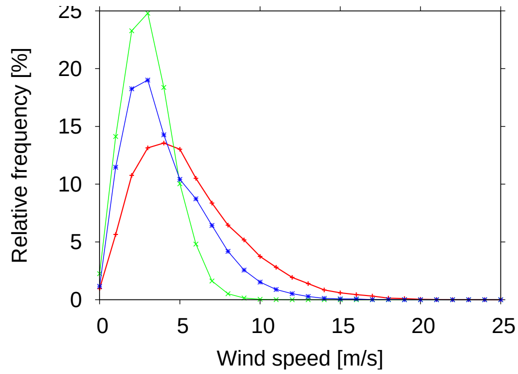

Figure 33: *Lungö*

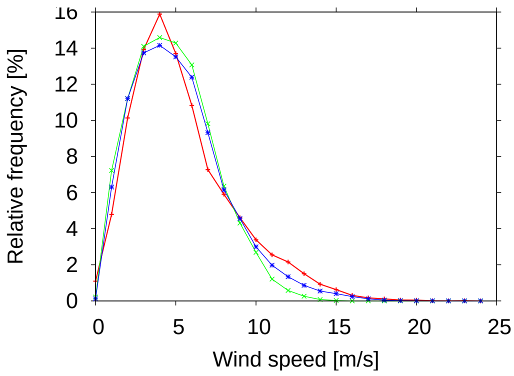

Figure 34: *Brämön*

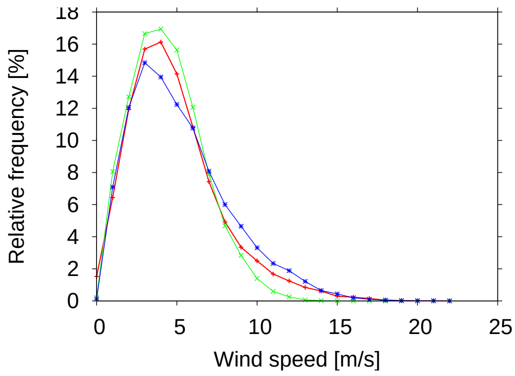

Figure 35: *Kuggören*

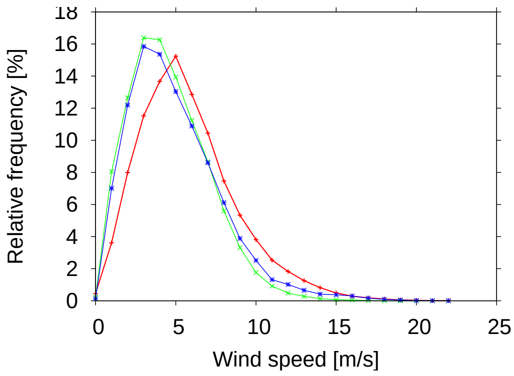

Figure 36: *Eggegrund*

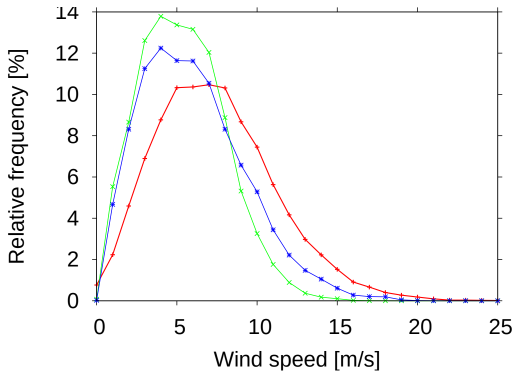

Figure 37: *Söderarm*

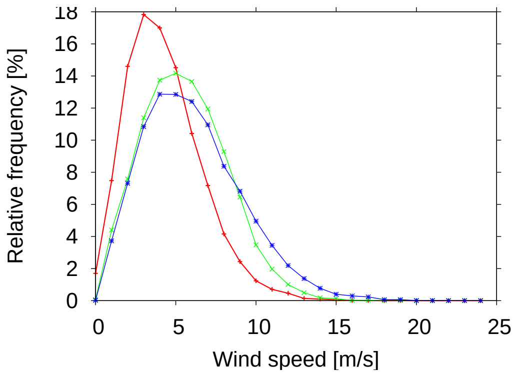

Figure 38: *Stavsnäs*

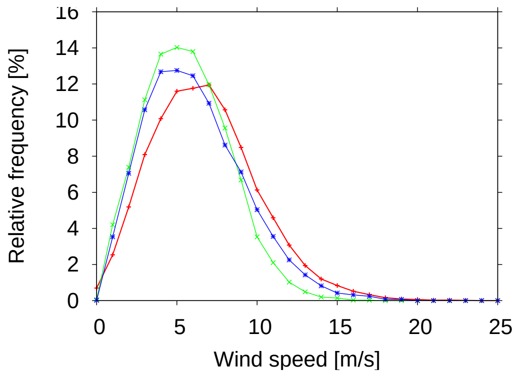

Figure 39: *Almagrundet*

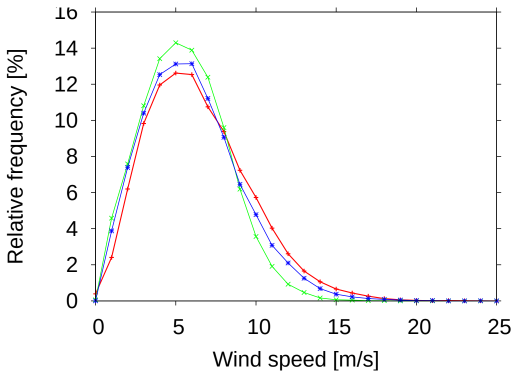

Figure 40: *Landsort*

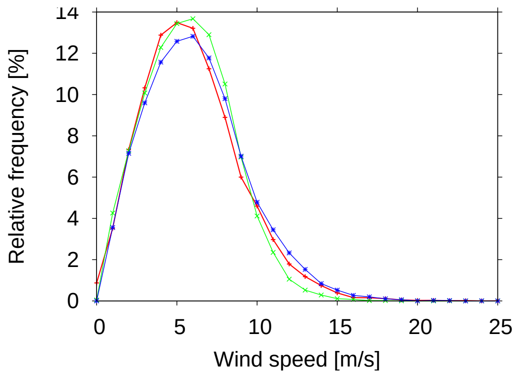

Figure 41: *Gustaf Dalén*

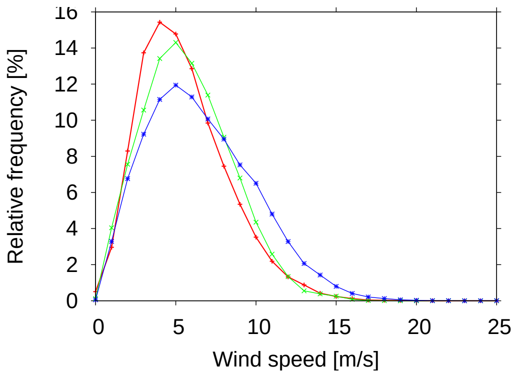

Figure 42: *Gotska Sandön*

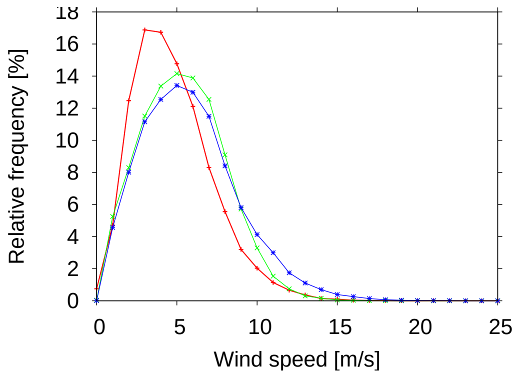

Figure 43: *Harstena*

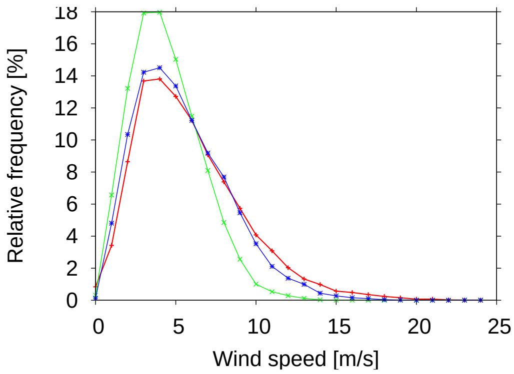

Figure 44: *Fårösund*

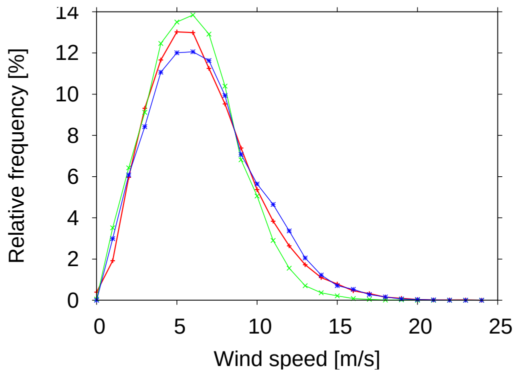

Figure 45: *Östergarnsholm*

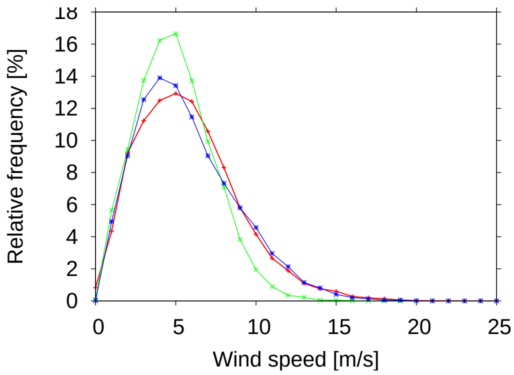

Figure 46: *Ölands norra udde*

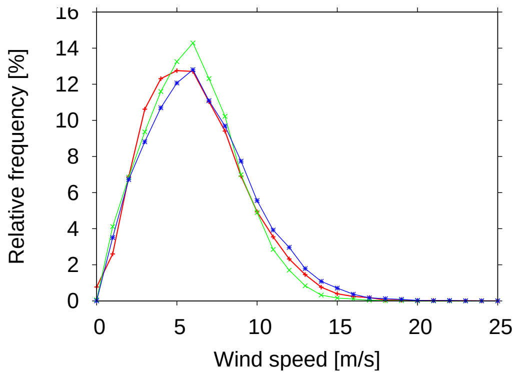

Figure 47: *Ölands södra udde*

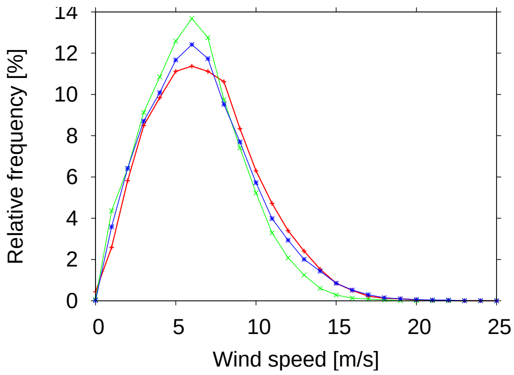

Figure 48: *Utklippan*

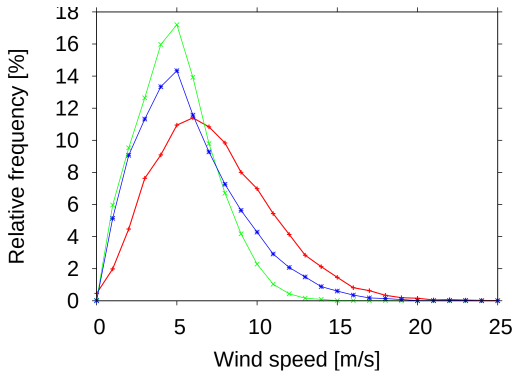

Figure 49: *Hanö*

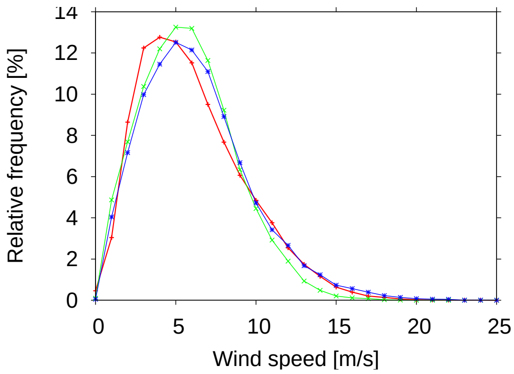

Figure 50: *Hallands Väderö*

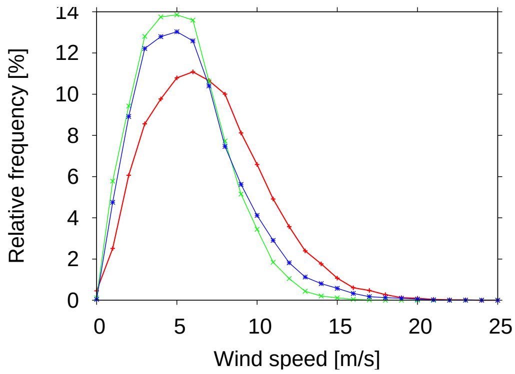

Figure 51: *Nidingen*

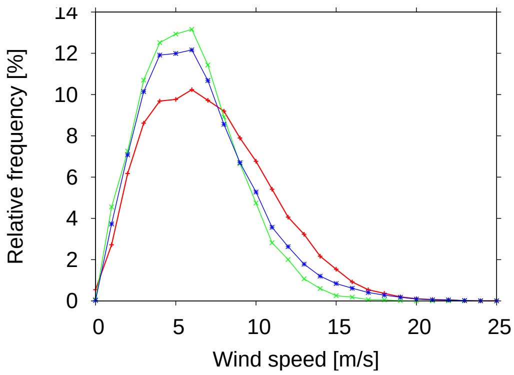

Figure 52: *Måseskär*

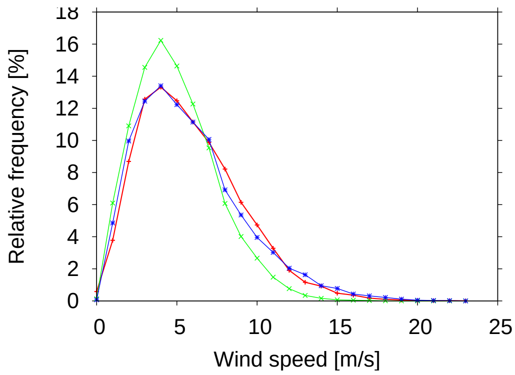

Figure 53: *Nordkoster*

Appendix C: Comparison between surrounding model grid points

This appendix contains comparisons of model results from the four surrounding model grid points and the observation stations. The red, green, blue, purple and light blue lines denote observations, the model wind from the closest model grid point to the southwest, northwest, northeast and southeast, respectively.

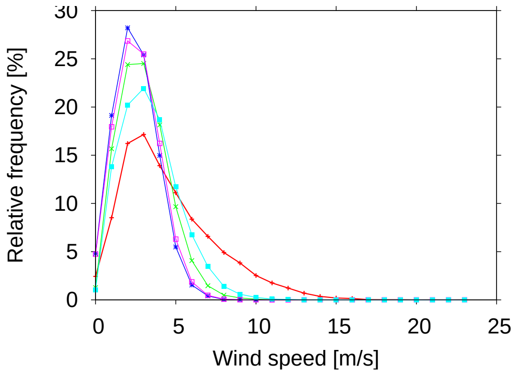

Figure 54: *Storön*

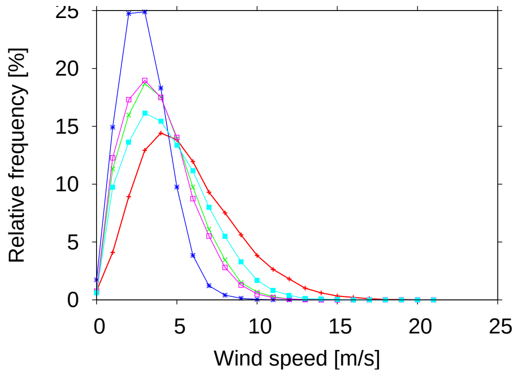

Figure 55: *Rödkallen*

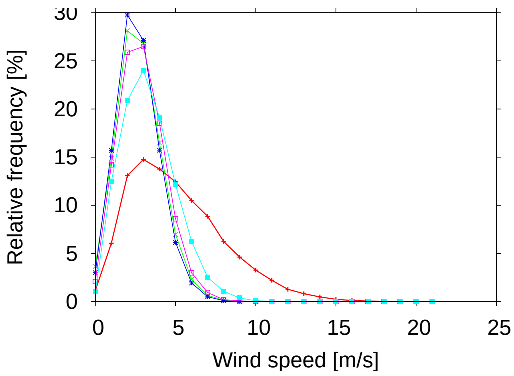

Figure 56: *Pite-Rönnskär*

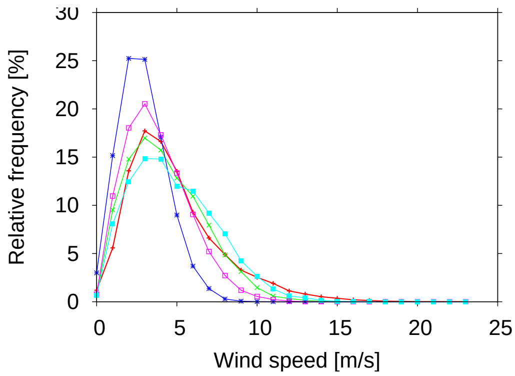

Figure 57: *Järnäsklubb*

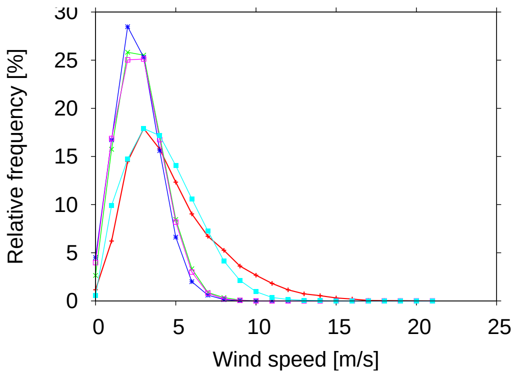

Figure 58: *Skagsudde*

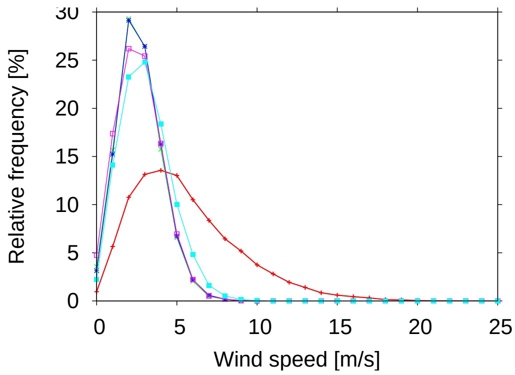

Figure 59: *Lungö*

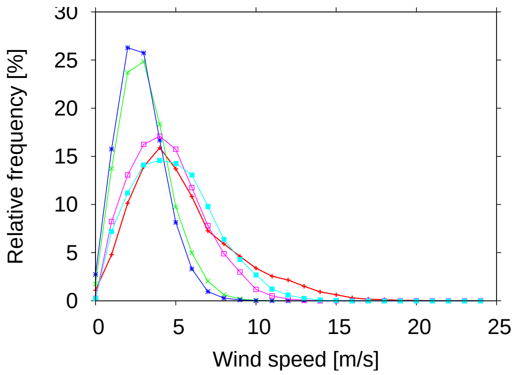

Figure 60: *Brämön*

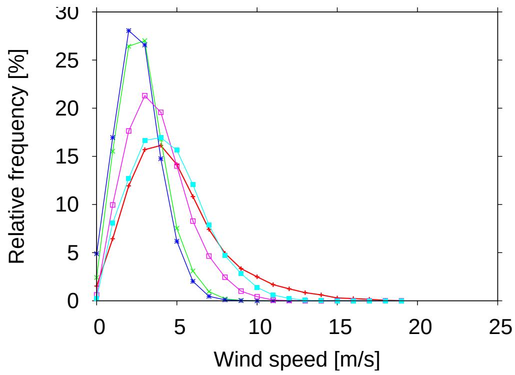

Figure 61: *Kuggören*

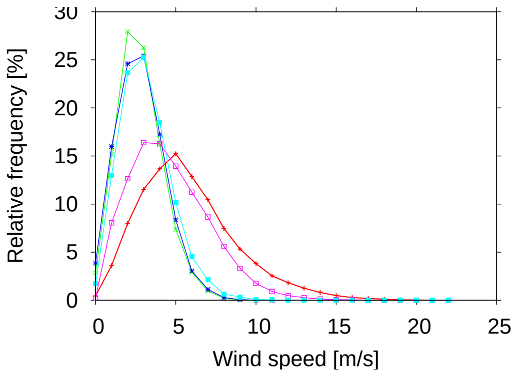

Figure 62: *Eggegrund*

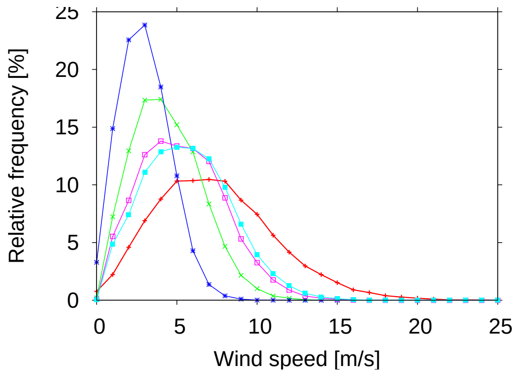

Figure 63: *Söderarm*

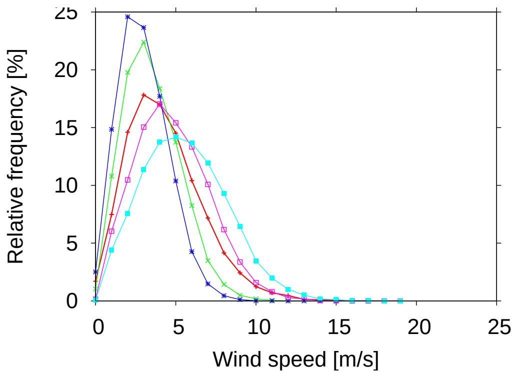

Figure 64: *Stavsnäs*

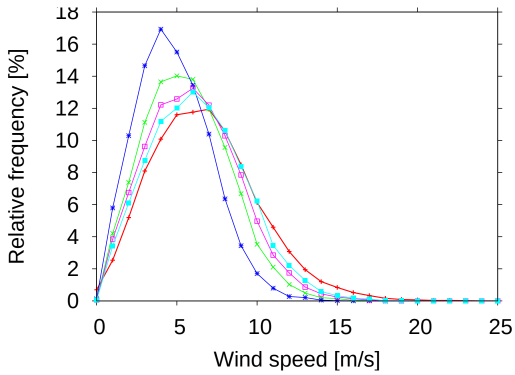

Figure 65: *Almagrundet*

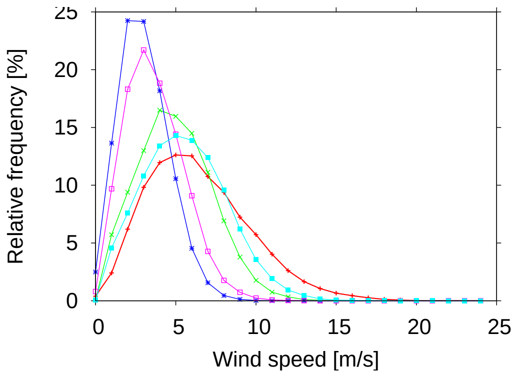

Figure 66: *Landsort*

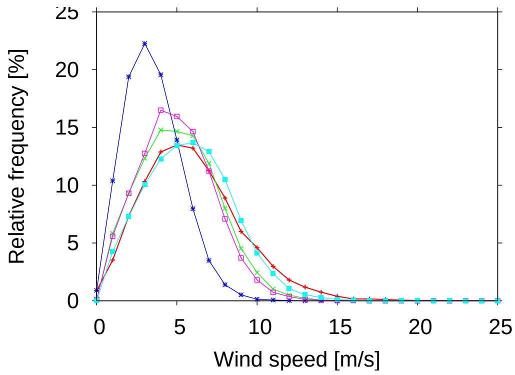

Figure 67: *Gustaf Dalén*

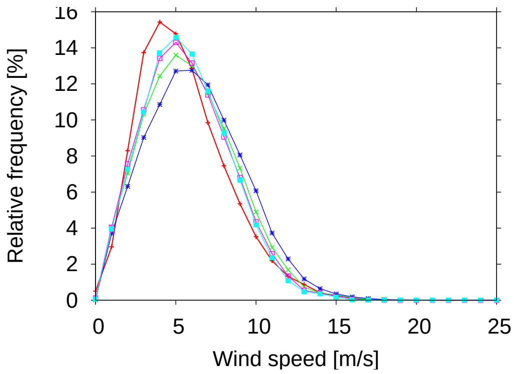

Figure 68: *Gotska Sandön*

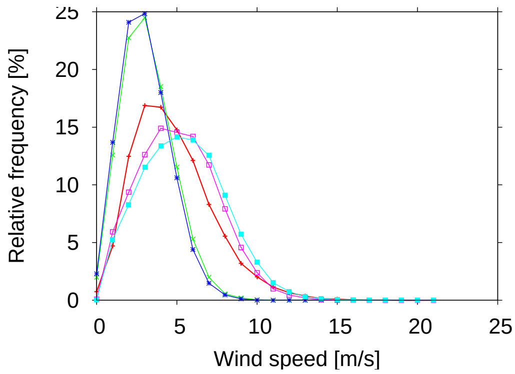

Figure 69: *Harstena*

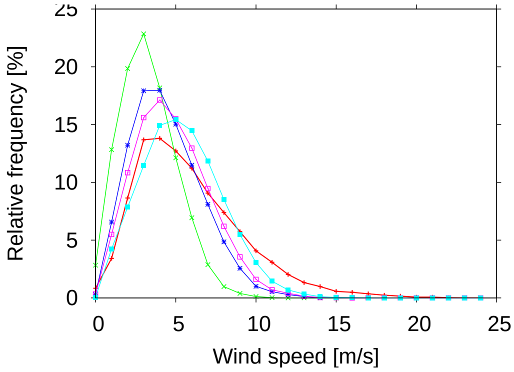

Figure 70: *Fårösund*

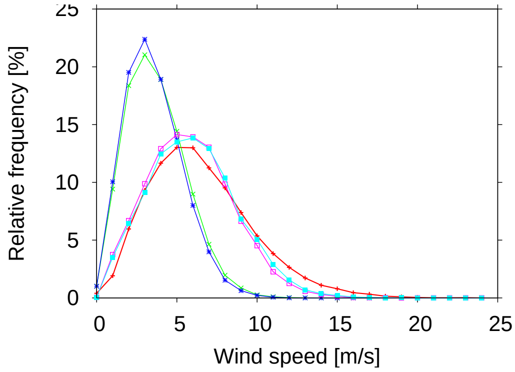

Figure 71: *Östergarnsholm*

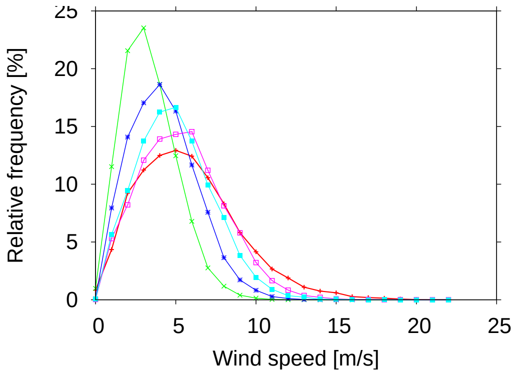

Figure 72: *Ölands norra udde*

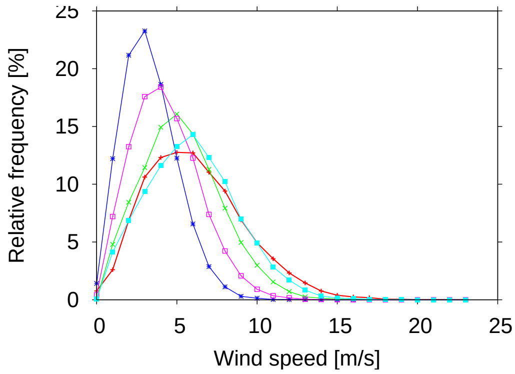

Figure 73: *Ölands södra udde*

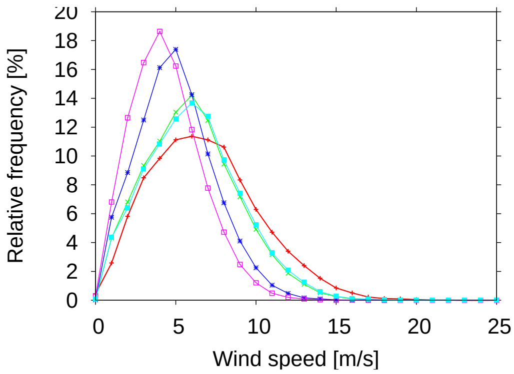

Figure 74: *Utklippan*

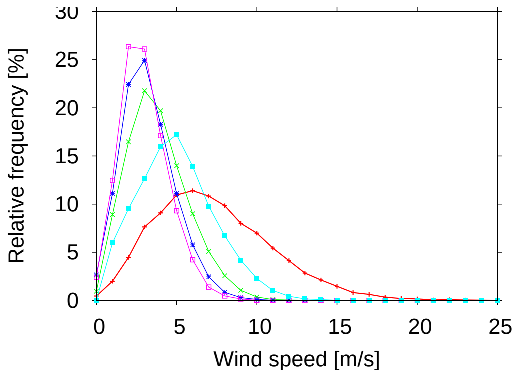

Figure 75: *Hanö*

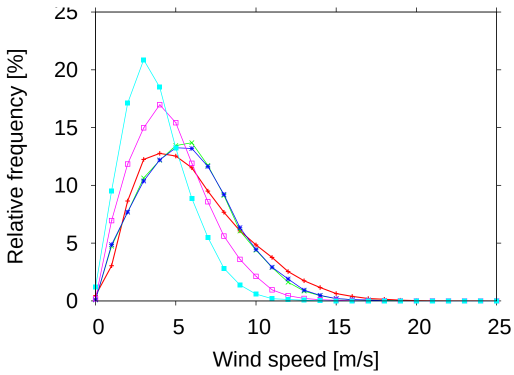

Figure 76: *Hallands Väderö*

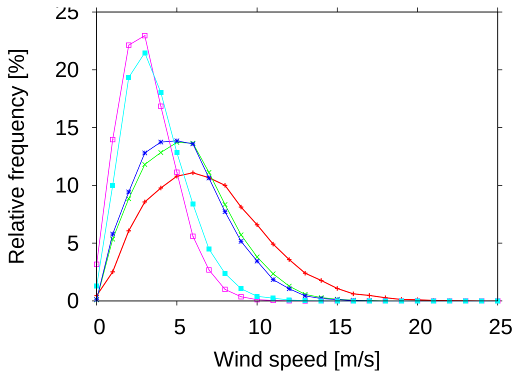

Figure 77: *Nidingen*

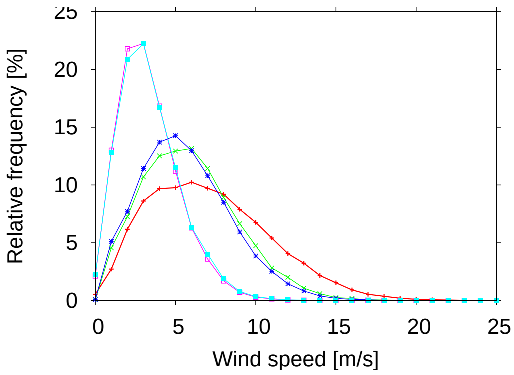

Figure 78: *Måseskär*

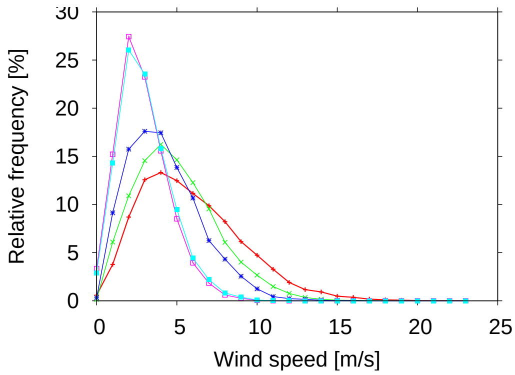

Figure 79: *Nordkoster*

SMHIs publiceringar

SMHI ger ut sex rapportserier. Tre av dessa, R-serierna är avsedda för internationell publik och skrivs därför oftast på engelska. I de övriga serierna används det svenska språket.

Seriernas namn	**Publiceras sedan**
RMK (Rapport Meteorologi och Klimatologi)	1974
RH (Rapport Hydrologi)	1990
RO (Rapport Oceanografi)	1986
METEOROLOGI	1985
HYDROLOGI	1985
OCEANOGRAFI	1985

I serien OCEANOGRAFI har tidigare utgivits:

1 Lennart Funkquist (1985)
En hydrodynamisk modell för spridnings- och cirkulationsberäkningar i Östersjön
Slutrapport.

2 Barry Broman och Carsten Pettersson. (1985)
Spridningsundersökningar i yttre fjärden Piteå.

3 Cecilia Ambjörn (1986).
Utbyggnad vid Malmö hamn; effekter för Lommabuktens vattenutbyte.

4 Jan Andersson och Robert Hillgren (1986).
SMHIs undersökningar i Öregrundsgrepen perioden 84/85.

5 Bo Juhlin (1986)
Oceanografiska observationer utmed svenska kusten med kustbevakningens fartyg 1985.

6 Barry Broman (1986)
Uppföljning av sjövärmepump i Lilla Värtan.

7 Bo Juhlin (1986)
15 års mätningar längs svenska kusten med kustbevakningen (1970 - 1985).

8 Jonny Svensson (1986)
Vågdata från svenska kustvatten 1985.

9 Barry Broman (1986)
Oceanografiska stationsnät - Svenskt Vattenarkiv.

11 Cecilia Ambjörn (1987)
Spridning av kylvatten från Öresundsverket

12 Bo Juhlin (1987)
Oceanografiska observationer utmed svenska kusten med kustbevakningens fartyg 1986.

13 Jan Andersson och Robert Hillgren (1987)
SMHIs undersökningar i Öregrundsgrepen 1986.

14 Jan-Erik Lundqvist (1987)
Impact of ice on Swedish offshore lighthouses. Ice drift conditions in the area at Sydostbrotten - ice season 1986/87.

15 SMHI/SNV (1987)
Fasta förbindelser över Öresund - utredning av effekter på vattenmiljön i Östersjön.

16 Cecilia Ambjörn och Kjell Wickström (1987)
Undersökning av vattenmiljön vid utfyllnaden av Kockums varvsbassäng.
Slutrapport för perioden
18 juni - 21 augusti 1987.

17 Erland Bergstrand (1987)
Östergötlands skärgård - Vattenmiljön.

18 Stig H. Fonselius (1987)
Kattegatt - havet i väster.

19 Erland Bergstrand (1987)
Recipientkontroll vid Breviksnäs fiskodling 1986.

20 Kjell Wickström (1987)
Bedömning av kylvattenrecipienten för ett kolkraftverk vid Oskarshamnsverket.

21 Cecilia Ambjörn (1987)
Förstudie av ett nordiskt modellsystem för kemikaliespridning i vatten.

22 Kjell Wickström (1988)
Vågdata från svenska kustvatten 1986.

23 Jonny Svensson, SMHI/National Swedish Environmental Protection Board (SNV) (1988)
A permanent traffic link across the Öresund channel - A study of the hydro-environmental effects in the Baltic Sea.

24 Jan Andersson och Robert Hillgren (1988)
SMHIs undersökningar utanför Forsmark 1987.

25 Carsten Peterson och Per-Olof Skoglund (1988)
Kylvattnet från Ringhals 1974-86.

26 Bo Juhlin (1988)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1987.

27 Bo Juhlin och Stefan Tobiasson (1988)
Recipientkontroll vid Breviksnäs fiskodling 1987.

28 Cecilia Ambjörn (1989)
Spridning och sedimentation av tippat lermaterial utanför Helsingborgs hamnområde.

29 Robert Hillgren (1989)
SMHIs undersökningar utanför Forsmark 1988.

30 Bo Juhlin (1989)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1988.

31 Erland Bergstrand och Stefan Tobiasson (1989)
Samordnade kustvattenkontrollen i Östergötland 1988.

32 Cecilia Ambjörn (1989)
Oceanografiska förhållanden i Brofjorden i samband med kylvattenutsläpp i Trommekilen.

33a Cecilia Ambjörn (1990)
Oceanografiska förhållanden utanför Vendelsöfjorden i samband med kylvatten-utsläpp.

33b Eleonor Marmefelt och Jonny Svensson (1990)
Numerical circulation models for the Skagerrak - Kattegat. Preparatory study.

34 Kjell Wickström (1990)
Oskarshamnsverket - kylvattenutsläpp i havet - slutrapport.

35 Bo Juhlin (1990)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1989.

36 Bertil Håkansson och Mats Moberg (1990)
Glommaälvens spridningsområde i nordöstra Skagerrak

37 Robert Hillgren (1990)
SMHIs undersökningar utanför Forsmark 1989.

38 Stig Fonselius (1990)
Skagerrak - the gateway to the North Sea.

39 Stig Fonselius (1990)
Skagerrak - porten mot Nordsjön.

40 Cecilia Ambjörn och Kjell Wickström (1990)
Spridningsundersökningar i norra Kalmarsund för Mönsterås bruk.

41 Cecilia Ambjörn (1990)
Strömningsteknisk utredning avseende utbyggnad av gipsdeponi i Landskrona.

42 Cecilia Ambjörn, Torbjörn Grafström och Jan Andersson (1990)
Spridningsberäkningar - Klints Bank.

43 Kjell Wickström och Robert Hillgren (1990)
Spridningsberäkningar för EKA-NOBELs fabrik i Stockviksverken.

44 Jan Andersson (1990)
Brofjordens kraftstation - Kylvattenspridning i Hanneviken.

45 Gustaf Westring och Kjell Wickström (1990)
Spridningsberäkningar för Höganäs kommun.

46 Robert Hillgren och Jan Andersson (1991)
SMHIs undersökningar utanför Forsmark 1990.

47 Gustaf Westring (1991)
Brofjordens kraftstation - Kompletterande simulering och analys av kylvattenspridning i Trommekilen.

48 Gustaf Westring (1991)
Vågmätningar utanför Kristianopel - Slutrapport.

49 Bo Juhlin (1991)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1990.

50A Robert Hillgren och Jan Andersson (1992)
SMHIs undersökningar utanför Forsmark 1991.

50B Thomas Thompson, Lars Ulander, Bertil Håkansson, Bertil Brusmark, Anders Carlström, Anders Gustavsson, Eva Cronström och Olov Fäst (1992).
BEERS -92. Final edition.

51 Bo Juhlin (1992)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1991.

52 Jonny Svensson och Sture Lindahl (1992)
Numerical circulation model for the Skagerrak - Kattegat.

53 Cecilia Ambjörn (1992)
Isproppsförebyggande muddring och dess inverkan på strömmarna i Torneälven.

54 Bo Juhlin (1992)
20 års mätningar längs svenska kusten med kustbevakningens fartyg (1970 - 1990).

55 Jan Andersson, Robert Hillgren och Gustaf Westring (1992)
Förstudie av strömmar, tidvatten och vattenstånd mellan Cebu och Leyte, Filippinerna.

56 Gustaf Westring, Jan Andersson, Henrik Lindh och Robert Axelsson (1993)
Forsmark - en temperaturstudie. Slutrapport.

57 Robert Hillgren och Jan Andersson (1993)
SMHIs undersökningar utanför Forsmark 1992.

58 Bo Juhlin (1993)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1992.

59 Gustaf Westring (1993)
Isförhållandena i svenska farvatten under normalperioden 1961-90.

60 Torbjörn Lindkvist (1994)
Havsområdesregister 1993.

61 Jan Andersson och Robert Hillgren (1994)
SMHIs undersökningar utanför Forsmark 1993.

62 Bo Juhlin (1994)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1993.

63 Gustaf Westring (1995)
Isförhållanden utmed Sveriges kust - isstatistik från svenska farleder och farvatten under normalperioderna 1931-60 och 1961-90.

64 Jan Andersson och Robert Hillgren (1995)
SMHIs undersökningar utanför Forsmark 1994.

65 Bo Juhlin (1995)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1994.

66 Jan Andersson och Robert Hillgren (1996)
SMHIs undersökningar utanför Forsmark 1995.

67 Lennart Funkquist och Patrik Ljungemyr (1997)
Validation of HIROMB during 1995-96.

68 Maja Brandt, Lars Edler och Lars Andersson (1998)
Översvämningar längs Oder och Wisla sommaren 1997 samt effekterna i Östersjön.

69 Jörgen Sahlberg SMHI och Håkan Olsson, Länsstyrelsen, Östergötland (2000).
Kustzonsmodell för norra Östergötlands skärgård.

70 Barry Broman (2001)
En vågatlas för svenska farvatten.

71 ***Vakant – kommer ej att utnyttjas!***

72 Fourth Workshop on Baltic Sea Ice Climate Norrköping, Sweden 22-24 May, 2002 Conference Proceedings
Editors: Anders Omstedt and Lars Axell

73 Torbjörn Lindkvist, Daniel Björkert, Jenny Andersson, Anders Gyllander (2003)
Djupdata för havsområden 2003

74 Håkan Olsson, SMHI (2003)
Erik Årnefelt, Länsstyrelsen Östergötland
Kustzonssystemet i regional miljöanalys

75 Jonny Svensson och Eleonor Marmefelt (2003)
Utvärdering av kustzonsmodellen för norra Östergötlands och norra Bohusläns skärgårdar

76 Eleonor Marmefelt, Håkan Olsson, Helma Lindow och Jonny Svensson, Thalassos Computations (2004)
Integrerat kustzonssystem för Bohusläns skärgård

77 Philip Axe, Martin Hansson och Bertil Håkansson (2004)
The national monitoring programme in the Kattegat and Skagerrak

78 Lars Andersson, Nils Kajrup och Björn Sjöberg (2004)
Dimensionering av det nationella marina pelagialprogrammet

79 Jörgen Sahlberg (2005)
Randdata från öppet hav till kustzons-modellerna (Exemplet södra Östergötland)

80 Eleonor Marmefelt, Håkan Olsson (2005)
Integrerat Kustzonssystem för Hallandskusten

81 Tobias Strömgren (2005)
Implementation of a Flux Corrected Transport scheme in the Rossby Centre Ocean model

82 Martin Hansson (2006)
Cyanobakterieblomningar i Östersjön, resultat från satellitövervakning 1997-2005

83 Kari Eilola, Jörgen Sahlberg (2006)
Model assessment of the predicted environmental consequences for OSPAR problem areas following nutrient reductions

84 Torbjörn Lindkvist, Helma Lindow (2006)
Fyrskeppsdata. Resultat och bearbetnings-metoder med exempel från Svenska Björn 1883 – 1892

85 Pia Andersson (2007)
Ballast Water Exchange areas – Prospect of designating BWE areas in the Baltic Proper

86 Elin Almroth, Kari Eilola, M. Skogen, H. Søiland and Ian Sehested Hansen (2007)
The year 2005. An environmental status report of the Skagerrak, Kattegat and North Sea

87 Eleonor Marmefelt, Jörgen Sahlberg och Marie Bergstrand (2007)
HOME Vatten i södra Östersjöns vattendistrikt. Integrerat modellsystem för vattenkvalitetsberäkningar

88 Pia Andersson (2007)
Ballast Water Exchange areas – Prospect of designating BWE areas in the Skagerrak and the Norwegian Trench

89 Anna Edman, Jörgen Sahlberg, Niclas Hjerdt, Eleonor Marmefelt och Karen Lundholm (2007)
HOME Vatten i Bottenvikens vatten-distrikt. Integrerat modellsystem för vattenkvalitetsberäkningar

90 Niclas Hjerdt, Jörgen Sahlberg, Eleonor Marmefelt och Karen Lundholm (2007)
HOME Vatten i Bottenhavets vattendistrikt. Integrerat modellsystem för vattenkvalitets-beräkningar

91 Elin Almroth, Morten Skogen, Ian Sehsted Hansen, Tapani Stipa, Susa Niiranen (2008)
The year 2006
An Eutrophication Status Report of the North Sea, Skagerrak, Kattegat and the Baltic Sea
A demonstration Project

92 Pia Andersson, editor and co-authors Bertil Håkansson*, Johan Håkansson*, Elisabeth Sahlsten*, Jonathan Havenhand**, Mike Thorndyke**, Sam Dupont** ***** Swedish Meteorological and Hydrological Institute ** Sven Lovén, Centre of Marine Sciences (2008)
Marine Acidification – On effects and monitoring of marine acidification in the seas surrounding Sweden

93 Jörgen Sahlberg, Eleonor Marmefelt, Maja Brandt, Niclas Hjerdt och Karen Lundholm (2008)
HOME Vatten i norra Östersjöns vatten-distrikt. Integrerat modellsystem för vattenkvalitetsberäkningar.

94 David Lindstedt (2008)
Effekter av djupvattenomblandning i Östersjön – en modellstudie

95 Ingemar Cato*, Bertil Håkansson**, Ola Hallberg*, Bernt Kjellin*, Pia Andersson**, Cecilia Erlandsson*, Johan Nyberg*, Philip Axe** (2008)
*Geological Survey of Sweden (SGU)
**The Swedish Meteorological and Hydrological Institute (SMHI)
A new approach to state the areas of oxygen deficits in the Baltic Sea

96 Kari Eilola, H.E. Markus Meier, Elin Almroth, Anders Höglund (2008)
Transports and budgets of oxygen and phosphorus in the Baltic Sea

Sveriges meteorologiska och hydrologiska institut
601 76 Norrköping
Tel 011 -495 80 00 · Fax 011-495 80 01

ISSN 0283-7714