

S1.5.1 Sea areas and land stations

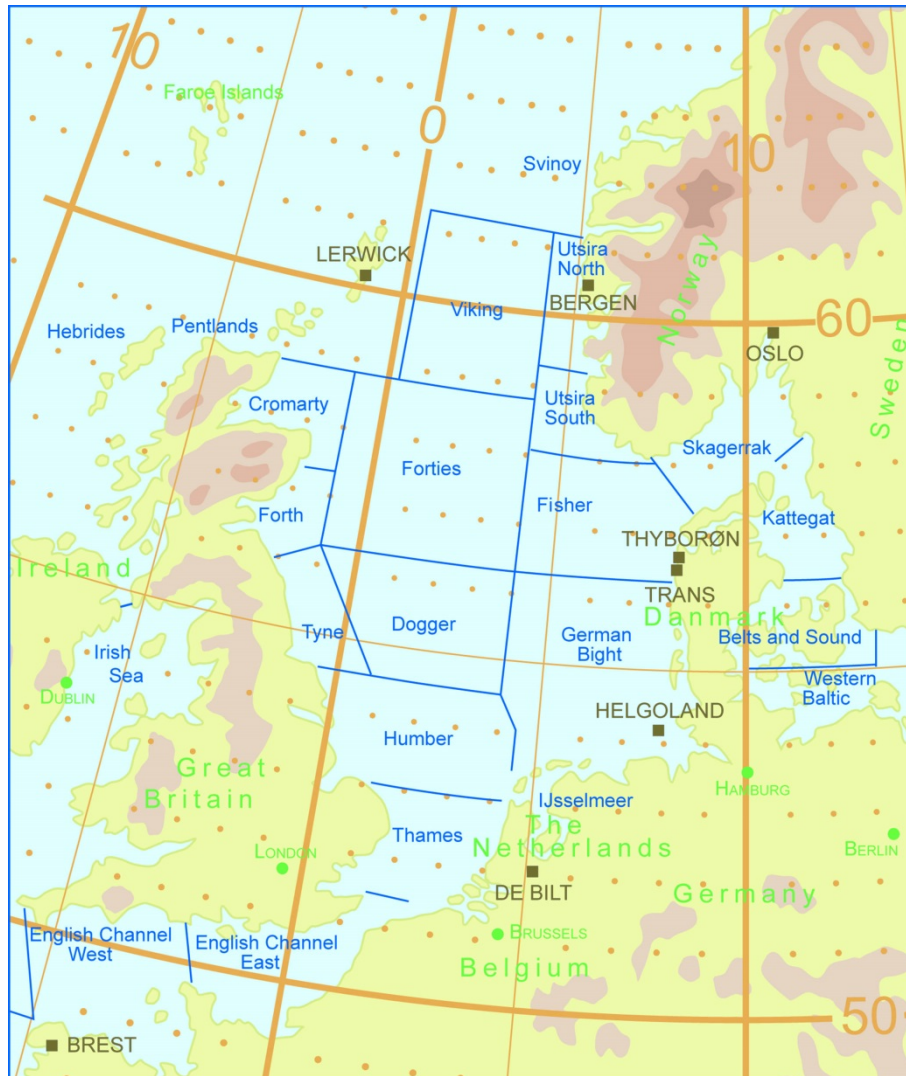


Fig. S1.5.1 Sea areas (*blue*) and land stations (*brown*) as used in chapter 1.5 (Source: DWD' s template for manual weather analysis on board (No. 9), modified extract)

S1.5.2 Weather conditions and weather types

Grosswetterlagen and Lamb Weather Types

To classify the atmospheric circulation pattern on a more regional scale two other indices are frequently used, the 'Grosswetterlagen' (Baur et al. 1943; Hess and Brezowsky 1952, 1969, 1977) and the 'Lamb Weather Types' (Lamb 1950, 1972). Both methods are based on daily surface pressure distribution. They were developed before the computer age and are both subjectively biased. The 'Grosswetterlage' is characterized by a mean air pressure distribution of a large area of at least the extent of Europe for a several days duration, in which the characteristic trait of a sequence of weather situations does not change. Based on this definition and the prerequisite, that a Grosswetterlage lasts at least for 3 days, a catalogue of Grosswetterlagen for Central Europe was developed and later revised by Hess and Brezowsky (1952, 1969, 1977). The time series starting in 1881 was updated by Gerstengarbe et al. (1999) and has been continued since then by the German Meteorological Service (DWD). The Lamb Weather types, dividing the prevailing synoptic conditions into one of ten

categories, eight directional categories and two vorticity categories (cyclonic or anti-cyclonic), are restricted to the area of the British Isles. It is available from 1861 to February 1997 and was generated by Lamb himself ('origLWT'). Objective classification methods were developed e.g. by Jenkinson and Collison (1977) and by Jones et al. (2012) basing on the Lamb weather type scheme and by James (2007) adapting the Grosswetterlagen (GWL) of Hess and Brezowsky (HB). To simplify the investigation of variations and trends, James (2007) combined 29 Grosswetterlagen to six circulation types, according to the four main compass points as well as cyclonic and anti-cyclonic conditions. Comparisons of both, the subjective and the objective classifications of the Grosswetterlagen (James 2007) in Fig S1.5.2 and Lambs weather types (not shown) depict differences in detail. But there is predominantly a good agreement. The most frequent circulation types are cyclonic, anti-cyclonic and westerly. Less frequent are northerly, easterly, southerly (and north-westerly) types. In the course of a year, the cyclonic types show a strong springtime frequency maximum and another distinct peak around mid-November. The anti-cyclonic types (not shown in Fig. S1.5.2 since they are complementary to the cyclonic types) have a maximum in late September (objective GWL) and in October (HB GWL), corresponding to the dry and stable conditions, known in Germany as 'Altweibersommer'. Westerly types show a well pronounced minimum in May and a maximum in December/January. The further peak in August is not mirrored in the HB catalogue. Northerly types show a pronounced peak in mid-April and are generally frequent from late May to mid-July, reflecting the well-known cold spells around 20 May and mid-June (in Germany named 'Eisheilige', 'Schafskälte'). Northerly types have a minimum in October, while southerly types are most frequent at that time and have a maximum in spring. Easterly types also show a maximum in spring and in early August. There is a considerable inter-annual variability in the occurrence of the different Grosswetterlagen. Sometimes a GWL lasts for more than 10 days, sometimes it is absent for a longer period. James (2007) detected, that the frequent GWL type WZ (cyclonic westerly) did nearly not occur in 1959 and 2003, years which were characterised by dry, warm and prolonged summers. The variability of the circulation types in the period 1960 to 2002 in Fig. S1.5.3 (James 2007) shows a break in cyclonic types about 1990 and a peak of the westerly pattern from the late 1980s to the early 1990s, being in good accordance with the high positive NAO indices.

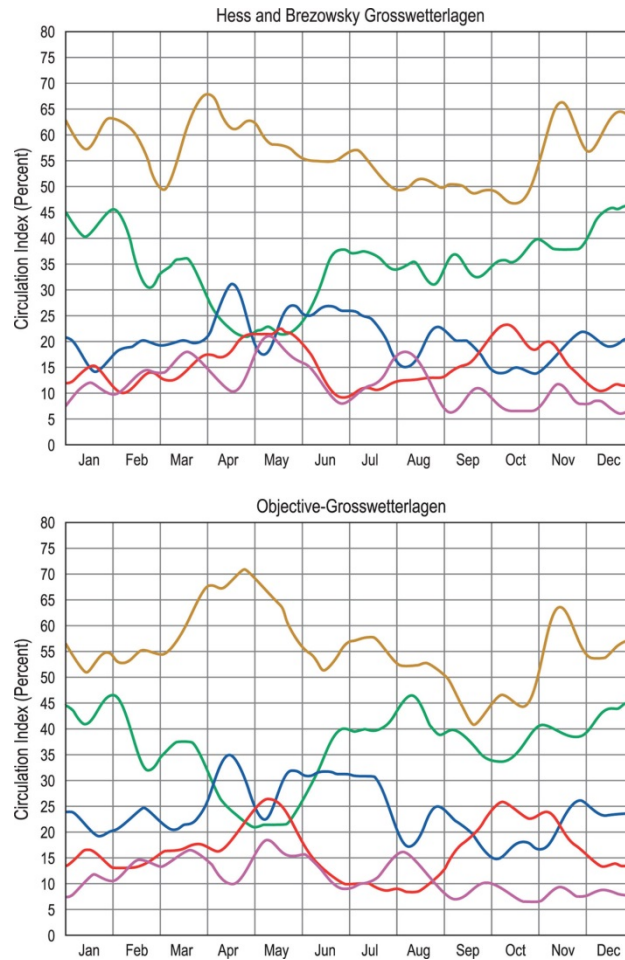


Fig. S1.5.2 Mean seasonal cycle of large-scale circulation types over Europe, derived from Hess and Brezowski (*upper*) and objective (*lower*) Grosswetterlagen frequencies, smoothed with a 31-day linearly tapered filter. The curves show the percentage of the time with westerly (*green*), easterly (*pink-lilac*), northerly (*blue*), southerly (*red*) and cyclonic (*dark gold*) circulation types, respectively (James 2007)

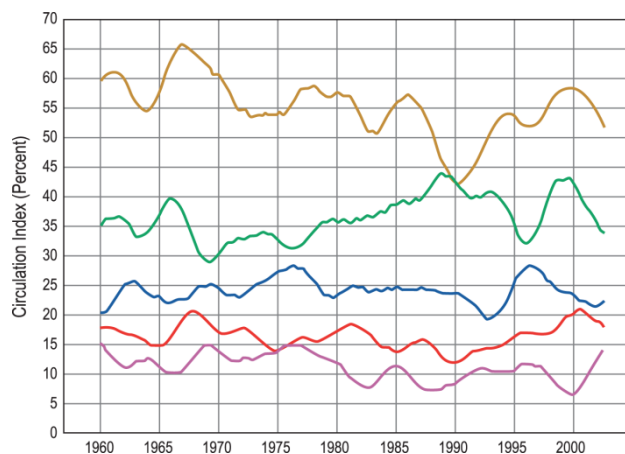


Fig. S1.5.3 Time-series of climatological indices of the large-scale circulation over Europe from 1960 to 2002, derived from objective Grosswetterlagen frequencies based on ECMWF ERA-40 reanalyses (ECMWF operational analyses after August 2002), smoothed with a 5-year linearly tapered filter. The curves show the percentage of time with westerly (*green*), easterly (*pink-lilac*), northerly (*blue*), southerly (*red*) and cyclonic (*dark gold*) circulation types, respectively (James 2007)

S1.5.3 Additional material wind

Figure S1.5.4 depicts the geostrophic wind fields derived from the ERA-40 and the higher spatially resolved ERA Interim reanalyses of sea level pressure for the period 1981-2000. Though the variations of the ERA Interim fields are larger, the differences to the ERA-40 wind speeds are less than 1 ms^{-1} (Ganske et al. 2012). A comparison of Fig. 1.22 (book) and Fig. S1.5.4 displays the differences in annual wind speed between the periods 1971-2000 and 1981-2000. The shorter period shows higher wind speeds, because it is more influenced by the wind intensive phase from the late 1980s to the 1990s.

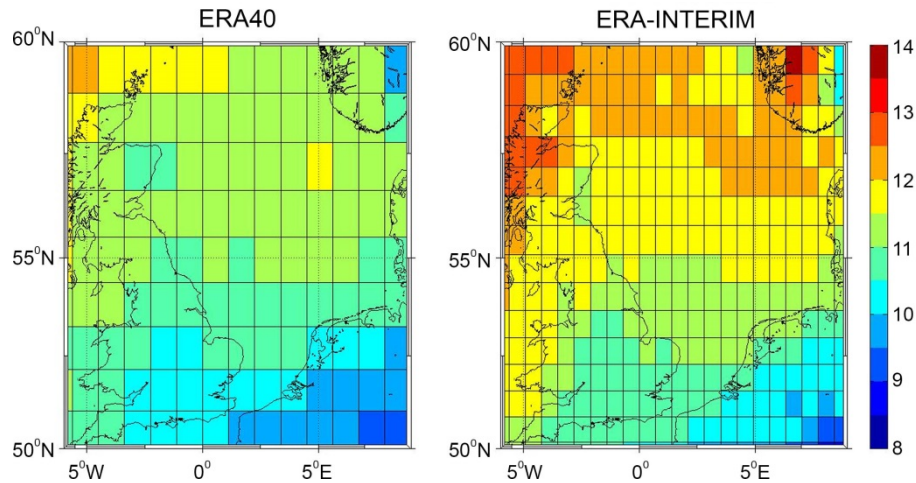
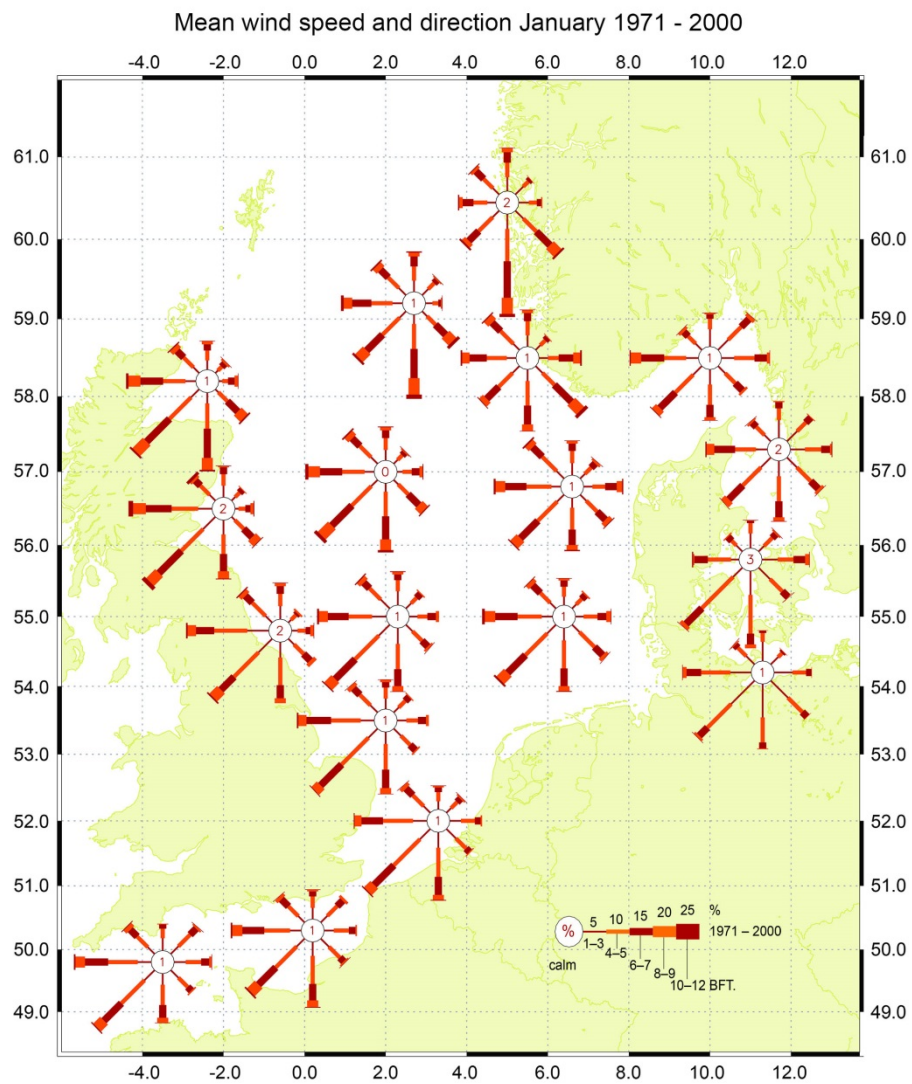


Fig. S1.5.4 Mean geostrophic wind speed from 1981-2000, calculated from ERA-40 (*left*) and ERA Interim sea level pressure (*right*) (Ganske et al. 2012)

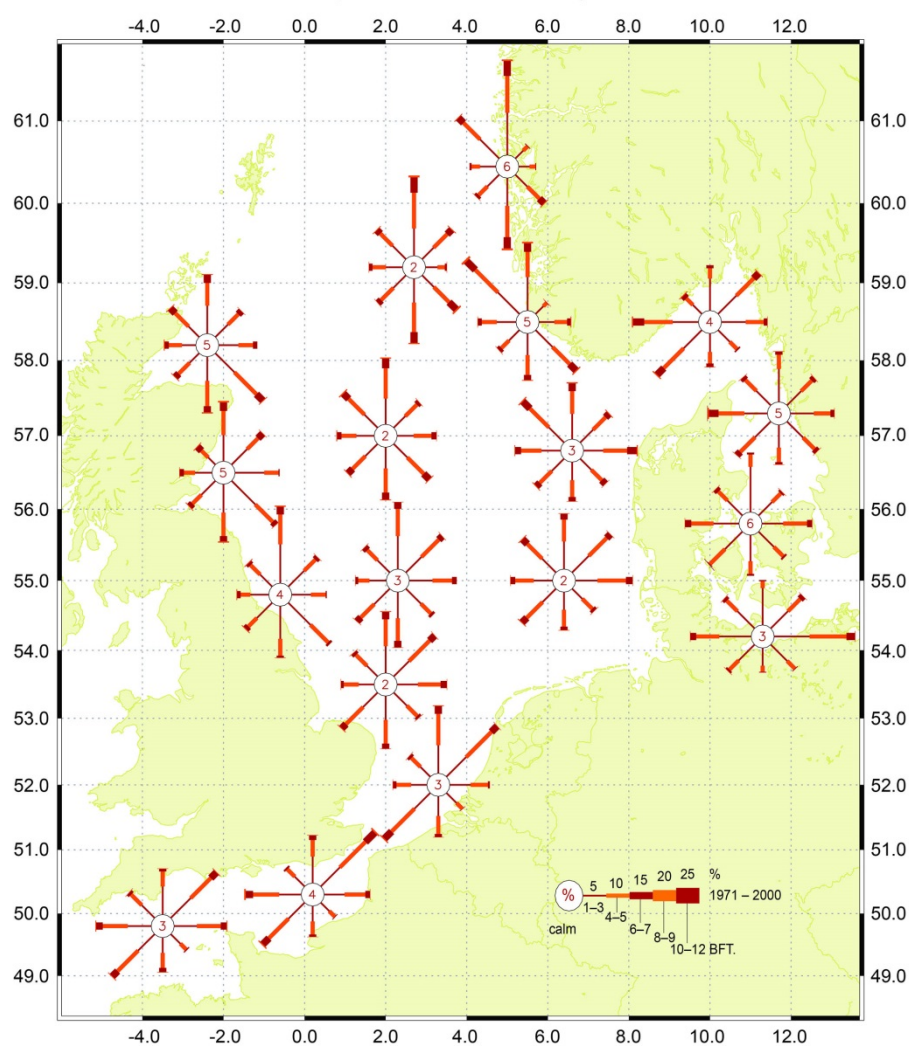
The publication “Naturverhältnisse Nordsee und Englischer Kanal” (2009) depicts frequency distributions of observed wind forces (in Beaufort) for different sea areas, showing, that on average, calms and light winds (0-3 Bft) occur to 30 to 35 % of all observations during the year. In the sea area Tyne (see Fig. S1.5.1) their portion goes up to 44 %, because it is located in the lee of the British Isles for winds from westerly and south-westerly directions. These weak winds occur preferably in July, partly in May and June with a portion of 40 to 50 % of the monthly observations. In the sea area of Tyne they are observed in 64 % of all cases in June and July. Except for Tyne, moderate to fresh breezes (4-5 Bft) are observed most frequently, with a portion of about 40 to 45 % of the year. Wind forces of 6 and 7 Bft show an annual frequency of mostly 20 to 23 %, in the sea areas of Tyne and Forth, however, it is only 14-15 %. These strong winds are most often in January and December with monthly portions of about 30 %, in the sea area of Shetland/Orkneys of 34 %. Gales (8-9 Bft) mainly occur to about 5 % of the annual observations. They are most often in January, in parts of the southern North Sea including the English Channel in December. Their monthly frequencies vary between 6 % in Forth and about 14 % in the sea areas of Forties and Shetland/Orkneys. Storms of Bft 10 to 12 are reported very seldom with a frequency of less than 1 % of all observations. This is partly due to the tendency of ship’s commands to avoid these stormy areas. In the northerly sea areas they are observed most frequently in 1 to 2 % of all cases from November to March.

Long time series of geostrophic wind speeds show significant variations on time scales of tens of year (compare Chap. 2). To investigate more recent changes in wind speed and direction across the North Sea during the period 1958 to 1997 in more detail Siegismund and Schrum (2001) used NCEP/NCAR reanalysis data. In this time section, the mean annual wind speed rose from 7.4 ms^{-1} to about 8.1 ms^{-1} in 1997, with a high inter-annual variability in the 1960s and 1980s. They also showed that the strong wind events in the wind intensive phase from the mid-1980s to 1997 shifted to February and March. They used a wind density function, which is defined as the product of the mean wind speed for a chosen direction and the relative frequency of wind from this direction. Evaluating decadal time sections they found an intensification of west-south-westerly wind directions for October to January compared to the first decade 1957 to 1967 and a well pronounced preference for west-south-westerly winds in February to March within the decade 1988 to 1997 (Fig. S1.5.6). In the first three decades wind blew favourably from southerly directions in the northern North Sea sector. A correlation of 0.69

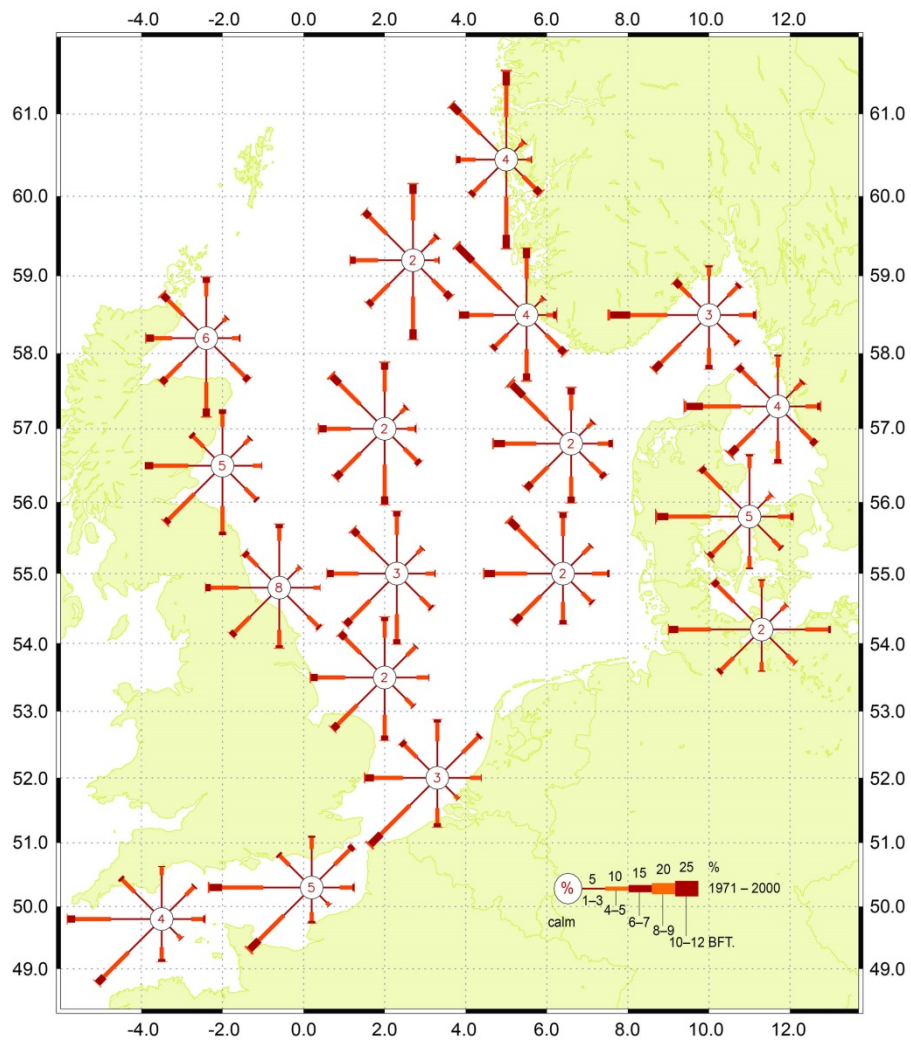
confirms the close connection between the NAO index and the mean wind speed for the period from December to March of this 40 years period.



Mean wind speed and direction May 1971 - 2000



Mean wind speed and direction August 1971 - 2000



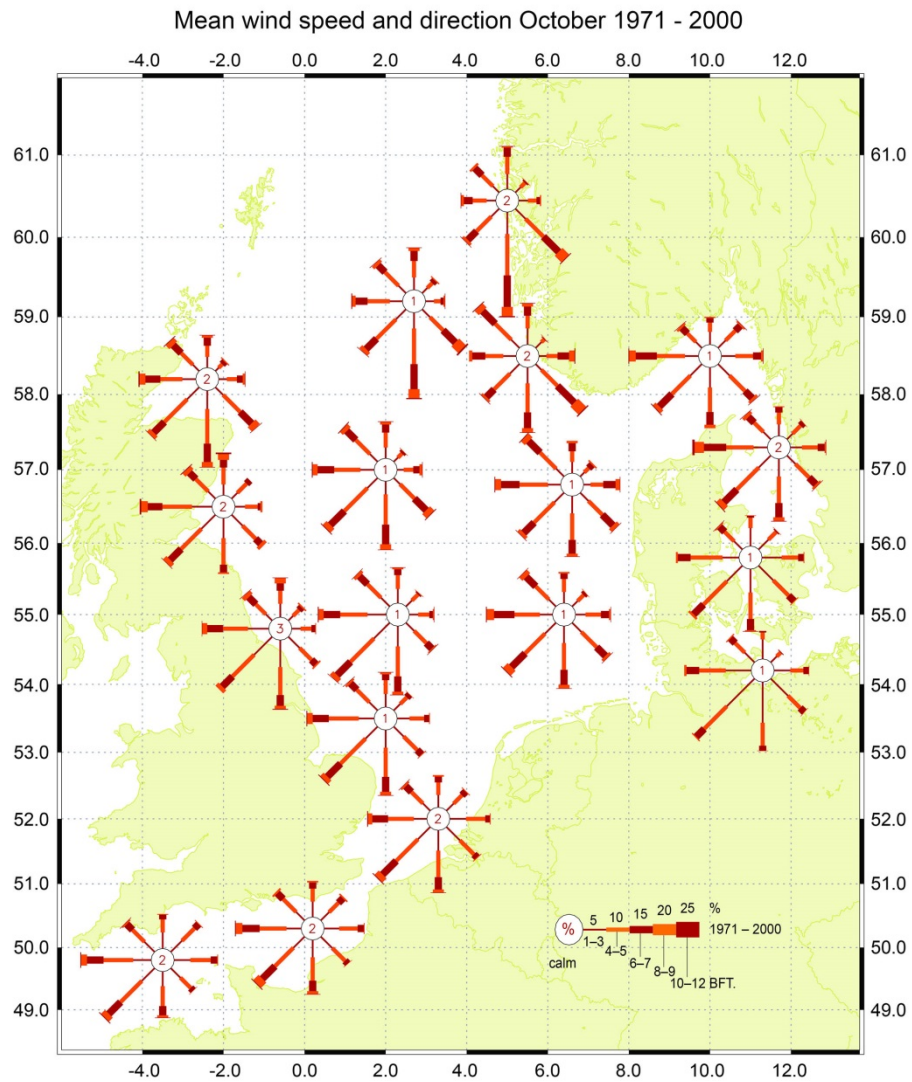


Fig. S1.5.5 Monthly distributions of wind forces (Bft) for January, May, August and October (*from top to bottom*) derived from ships observations for different sea areas of the North Sea in the period 1971-2000 (by DWD)

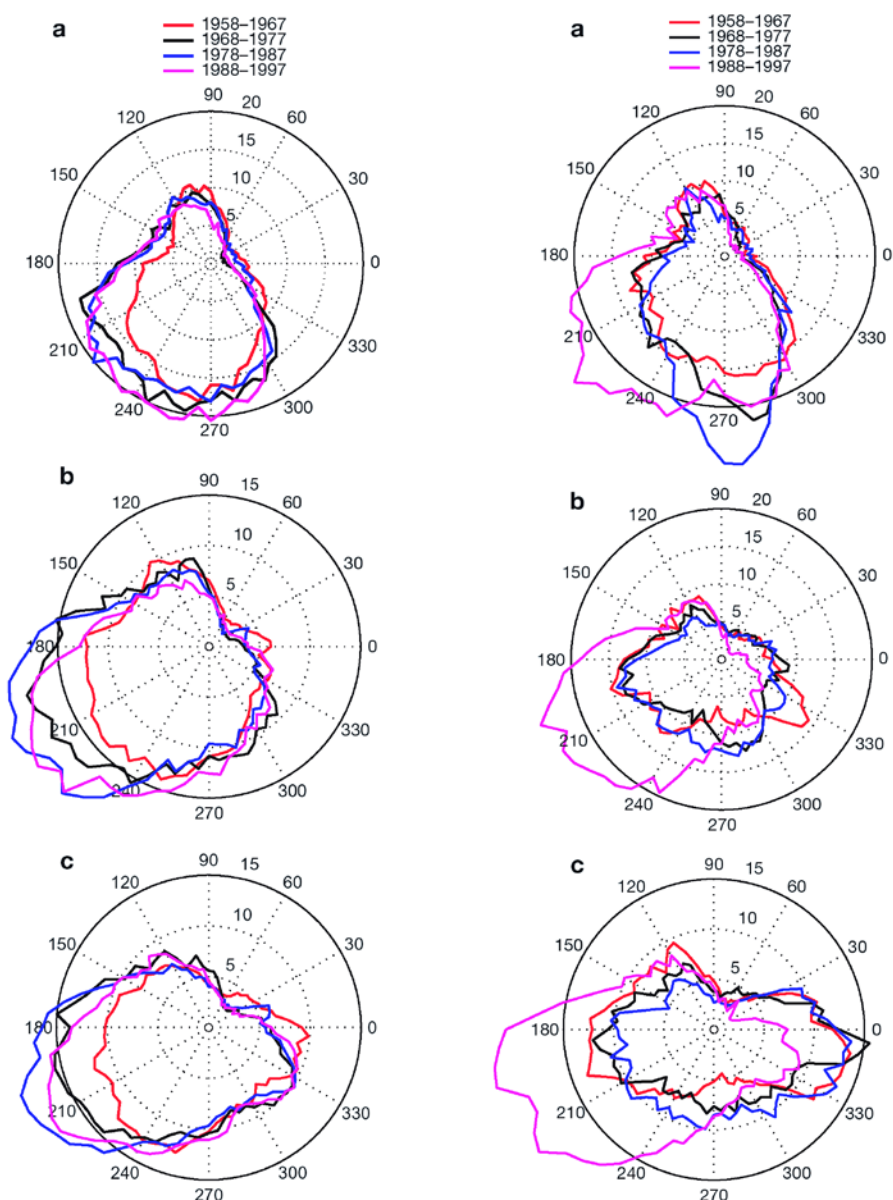


Fig. S1.5.6 Normalised wind density functions for the periods October to January (*left*) and February to March (*right*) for each of the 4 decades from 1958 to 1997. (a) northern North Sea [north of 59°N], (b) western North Sea [west of 2.5°E], (c) eastern North Sea [east of 2.5°E] (Siegismund and Schrum, 2001)

S1.5.4 Additional material temperature

The frequency distribution of 2 m air temperatures of the ERA-40 reanalysis and the ENSEMBLES RCMs for the four North Sea boxes northwest, northeast, southwest, southeast of the period 1971-2000 is displayed in Fig. S1.5.7. It shows two maxima, one at about 7 °C and 13 to 15 °C and a relative minimum at about 10 °C with variations between the different sea areas and models.

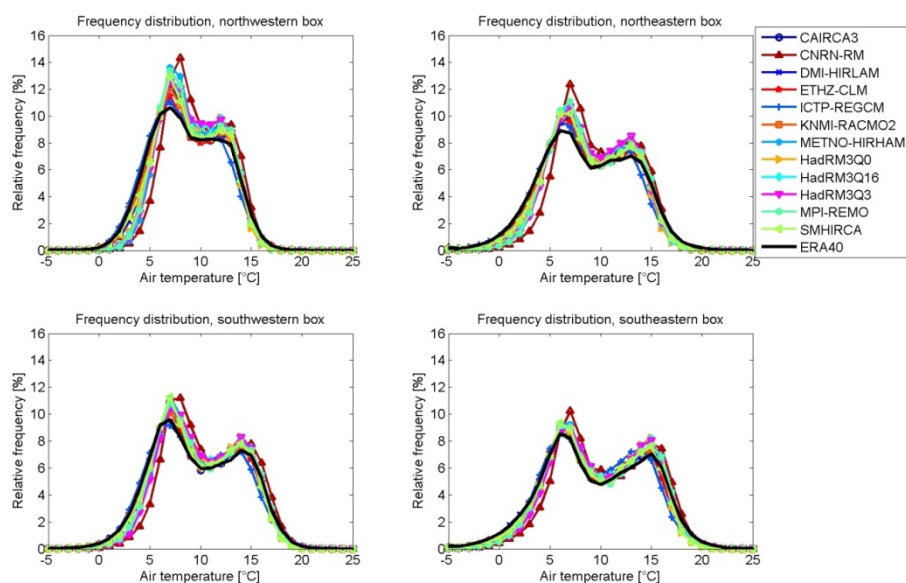


Fig. S1.5.7 Relative frequency distributions of 2 m air temperatures from the ERA-40 reanalysis and the ENSEMBLES RCMs for the four North Sea boxes in the period 1971-2000 (Bülow et al. 2013)

S1.5.5 Additional material precipitation

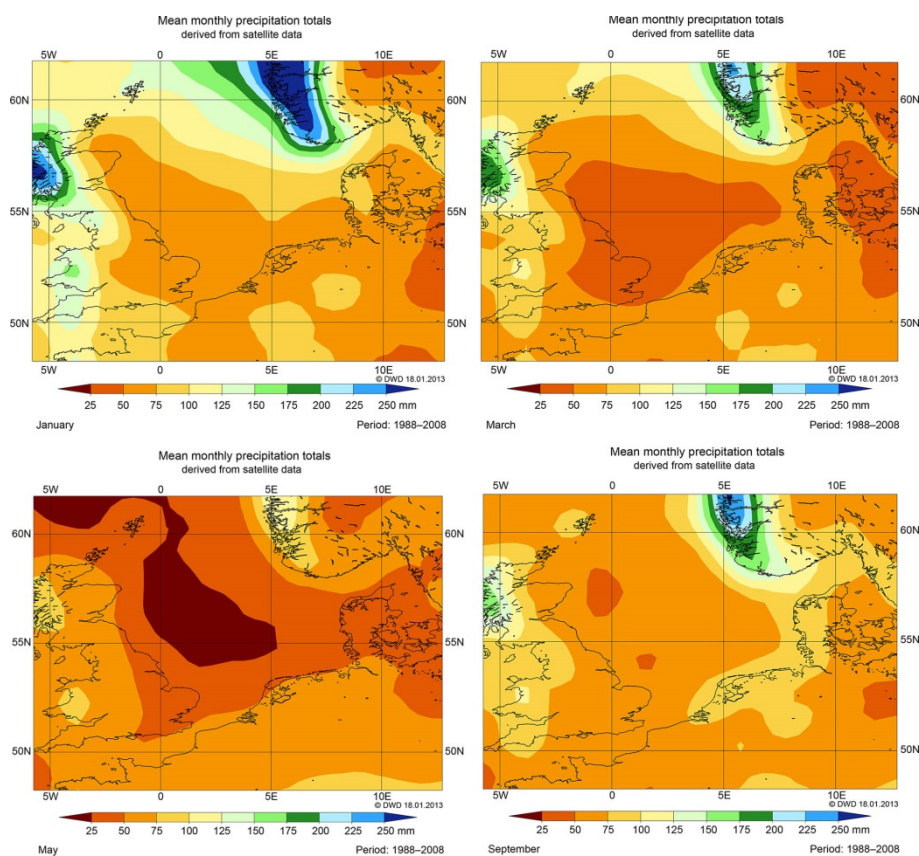


Fig. S1.5.8 Mean annual and monthly spatial distributions of precipitation (mm) for January, March, May and September across the North Sea region derived from the combined HOAPS-3 and GPCC data set for the period 1988 to 2008

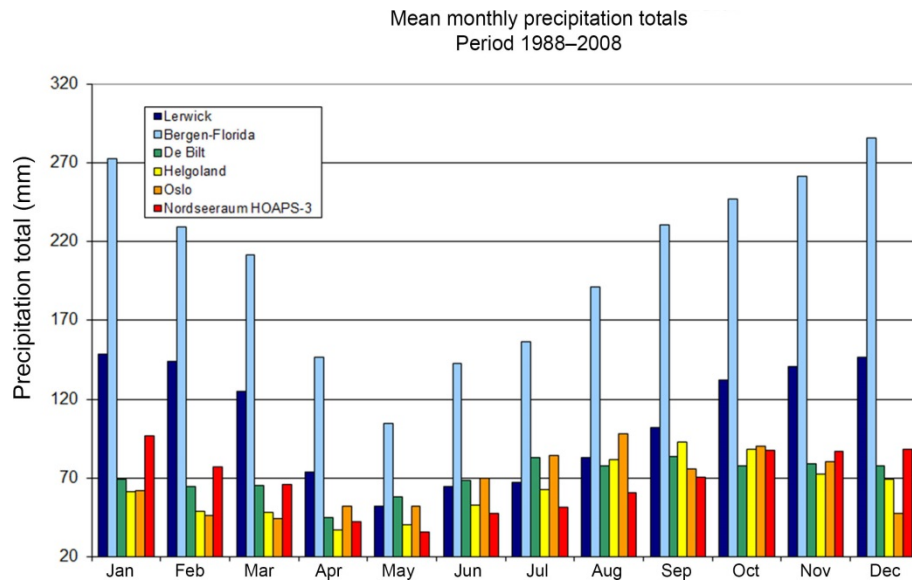


Fig. S1.5.9 Annual cycle of precipitation (mm) from selected coastal stations and the sea area for the period 1988 to 2008. The position of the land stations is shown in Fig S1.5.1.

S1.5.6 Additional material radiation

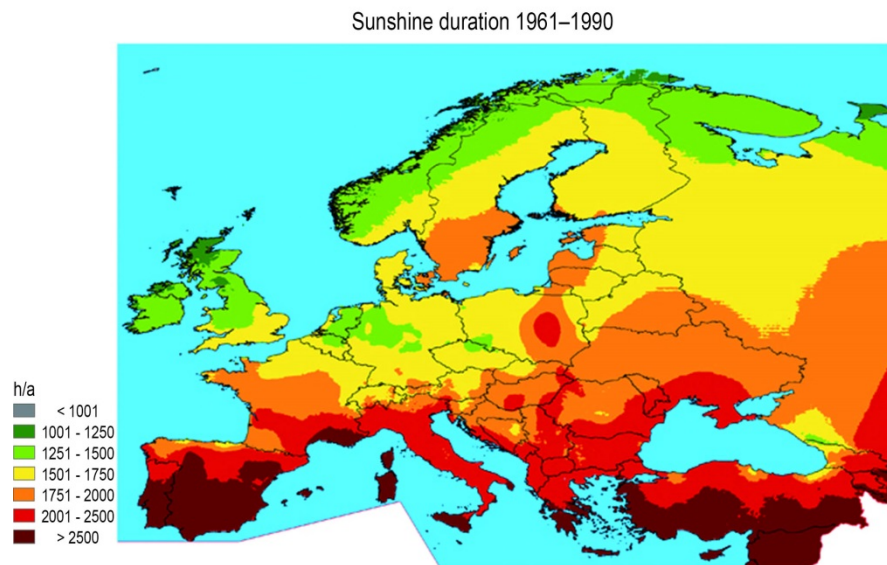


Fig. S1.5.10 Spatial distribution of mean annual sunshine duration (hours/year) in Europe for the period 1961-1990 (http://www.dwd.de/EN/ourservices/rcccm/int/rcccm_int_suncli.html)

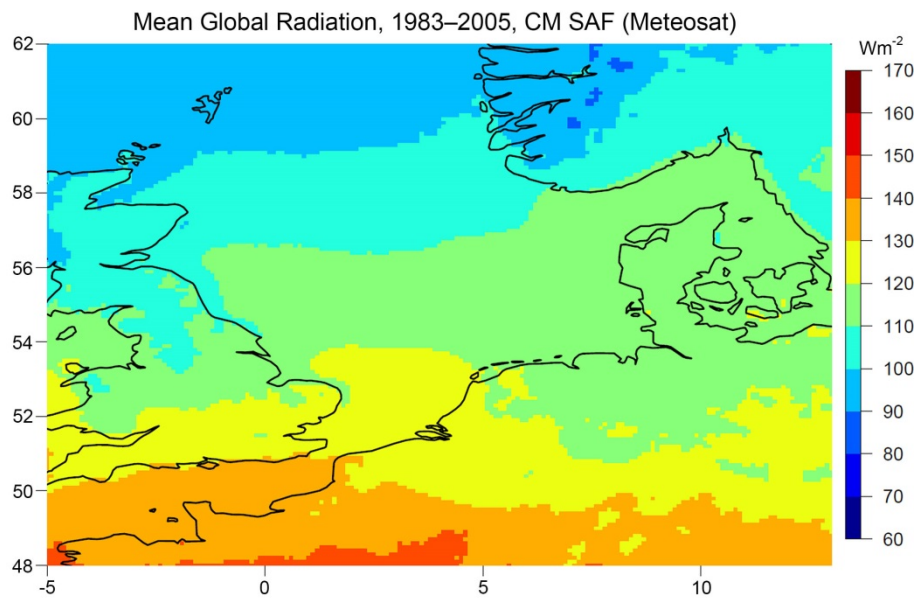


Fig. S1.5.11 Annual mean global radiation (Wm^{-2}) for the period 1983 to 2005 derived from satellite data by CM-SAF

S1.5.7 Additional material cloud cover

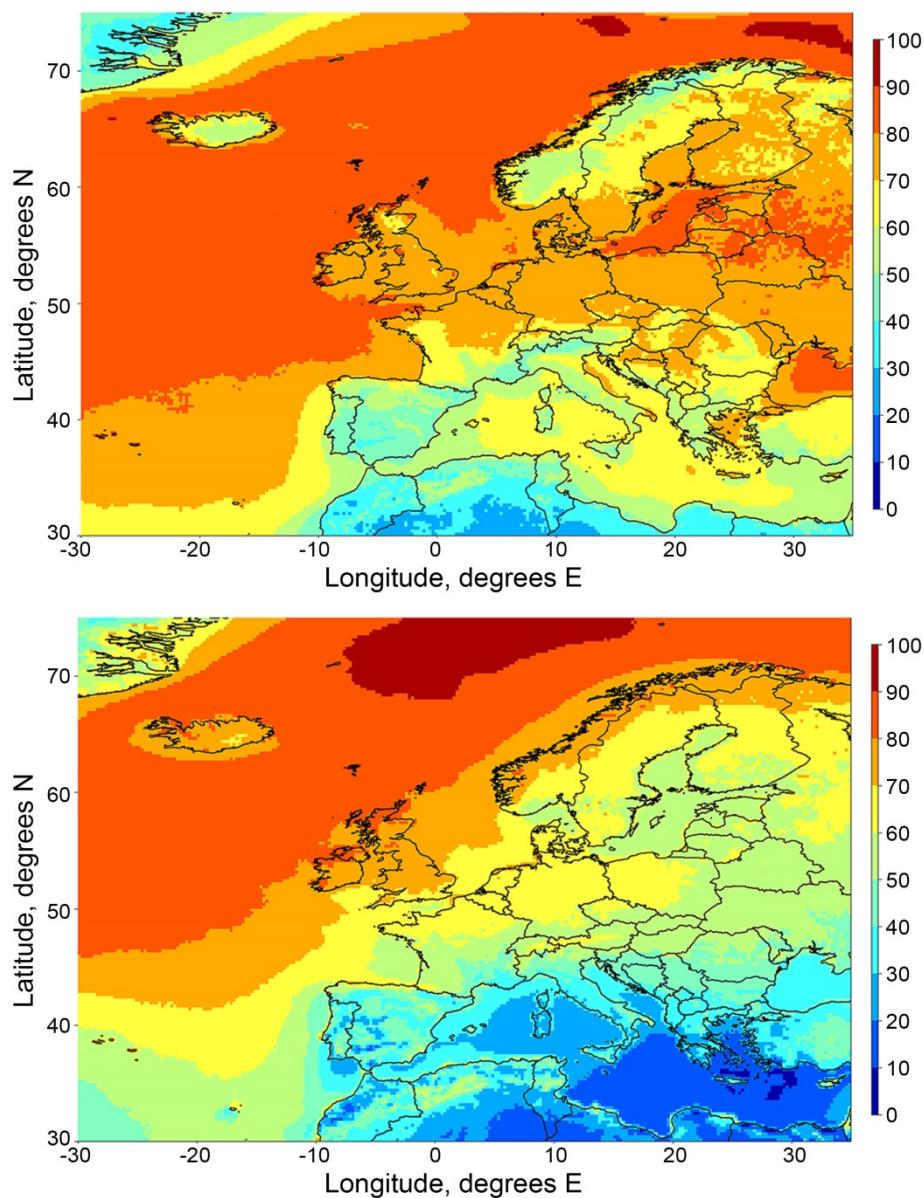


Fig. S1.5.12 Seasonal cloud cover from CM_SAF, 1982-2009, winter (*upper*) – summer (*lower*)
http://www.eumetsat.int/website/home/Images/ImageLibrary/DAT_2266050.html

Tab. S1.5.1 Mean monthly and annual cloud cover (in octa) derived from ship observations for the sea areas (Naturverhältnisse Nordsee und Englischer Kanal 2009)

Sea Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Shetlands/ Orkneys	6.5	6.4	6.4	6.1	6.0	6.2	6.5	6.3	6.3	6.3	6.2	6.3	6.3
Viking	6.4	6.3	6.2	5.8	5.6	6.0	6.3	6.0	6.1	6.3	6.2	6.3	6.1
Utsira, North/South	6.2	5.8	5.8	5.4	5.2	5.5	5.7	5.6	5.9	6.1	6.0	6.2	5.8
Crommarty	5.7	5.8	6.0	5.7	5.6	5.9	6.1	5.9	6.0	5.9	5.8	5.8	5.9
Forth, Tyne	5.7	5.8	5.8	5.7	5.6	5.8	5.8	5.8	5.7	5.6	5.5	5.5	5.7

Forties	6.3	6.1	6.0	5.7	5.4	5.8	6.0	5.8	5.9	6.0	6.1	6.2	5.9
Fisher, Dogger, German Bight	6.1	5.9	5.7	5.3	5.0	5.3	5.4	5.2	5.6	5.8	6.1	6.1	5.6
Skagerrak	5.8	5.5	5.1	4.7	4.5	4.5	4.4	4.3	4.8	5.5	5.8	5.8	5.1
Humber	6.0	5.7	5.7	5.4	5.0	5.3	5.3	5.1	5.4	5.6	5.9	5.8	5.5
Thames	5.8	5.7	5.5	5.2	4.9	5.1	5.2	4.8	5.2	5.5	5.8	5.9	5.4
English Channel, West/East	6.0	5.8	5.5	5.1	4.9	4.9	4.8	4.7	5.0	5.5	5.8	6.0	5.3

References

- Baur F, Hess P, Nagel H (1943) Kalender der Großwetterlagen Europas vom 1. Januar 1881 bis 31. Dezember 1942 [Calender of the Grosswetterlagen of Europe from 1 January 1881 to 31 December 1942]. Bad Homburg v.d.H., Forschungsinstitut für langfristige Witterungsvorhersage [Research Institute for long range weather forecast]
- Bülow K, Ganske A, Heinrich H, Hüttl-Kabus S, Klein B, Klein H, Möller J, Rosenhagen G, Schade N, Tinz B (2013) Comparing meteorological fields of the ENSEMBLES regional climate models with ERA-40-data over the North Sea. KLIWAS-Schriftenreihe, KLIWAS-21/2014. doi: 10.5675/Kliwas_21.2013_ERA40data
- Ganske A, Rosenhagen G, Heinrich H (2012) Validation of Geostrophic Wind Fields in ERA-40 and ERA Interim Reanalyses for the North Sea Area, Poster for 4th WCRP, International Conference on Reanalyses, Silver Spring Maryland, USA
- Gerstengarbe F-W, Werner PC, Rüge U (1999) Katalog der Großwetterlagen Europas (1881-1996) nach Paul Hess und Helmuth Brezowsky [Catalogue of the Grosswetterlagen of Europe (1881-1996) according to Paul Hess and Helmuth Brezowsky]. 5. vollständig neu bearbeitet Auflage, Berichte des Deutschen Wetterdienstes 113, Offenbach am Main [5 completely revised edition. Reports of German Met. Service]
- Hess P, Brezowsky H (1952) Katalog der Großwetterlagen Europas [Catalogue of the Grosswetterlagen of Europe]. Berichte Dt. Wetterdienst in der US Zone 33 [Reports of German Met. Service]
- Hess P, Brezowsky H (1969) Katalog der Großwetterlagen Europas [Catalogue of the Grosswetterlagen of Europe.]. 2. neu bearbeitete und ergänzte Aufl., Berichte des Deutschen Wetterdienstes 113, Offenbach am Main [revised and completed edition. Reports of German Met. Service]
- Hess P, Brezowsky H (1977) Katalog der Großwetterlagen Europas 1881-1976 [Catalogue of the Grosswetterlagen of Europe 1881-1976]. 3. verbesserte und ergänzte Aufl., Berichte des Deutschen Wetterdienstes 113, Offenbach am Main [3rd improved and completed edition. Reports of German Met. Service]
- James PM (2007) An objective classification method for Hess and Brezowsky Grosswetterlagen over Europe. Theor. Appl. Climatol. 88, 17–42. DOI: 10.1007/s00704-006-0239-3
- Jenkinson AF, Collison FP (1977) An initial Climatology of gales over the North Sea. Synoptic Climatology Branch Memorandum, No. 62, UK Met Office, Bracknell

Jones PD, Harpham C, Briffa KR (2012) Lamb weather types derived from reanalysis products. *Int. J. Climatol.*, 2012 DOI: 10.1002/joc.3498

Lamb HH (1950) Types and spells of weather around the year in the British Isles. *Quart. J. R. Met. Soc.*, 76, 393–438

Lamb HH (1972) 'British Isles weather types and a register of daily sequence of circulation patterns', 1861-1971: *Geophysical Memoir*, vol. 116, HMSO, London

Naturverhältnisse Nordsee und Englischer Kanal (2009) Teil B zu den Seehandbüchern für die Nordsee und den Kanal[Natural conditions North Sea and English Channel (2009) Part B of the Marine Manual for the North Sea and English Channel]. Bundesamt für Seeschifffahrt und Hydrographie, BSH-Nr. 20062

Siegismund F, Schrum C (2001) Decadal changes in the wind forcing over the North Sea. *Clim. Res.*, Vol. 18, 39–45