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The Climate in the North and Baltic Sea Region

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Contents

1. Natural Region

The German coastal areas of the North and Baltic Seas are part of the North German Lowland. The North Sea shore merges seaward into wide tidal flats, the so-called "Watten" with flat dune islands. Only the island of Helgoland has a rocky coast landscape. The Baltic Sea coast is characterised by the varied relief of flat coasts lined by dunes, steep cliffs, spits and coastal lagoons known as "Bodden" or "Haffs". Here, the by far largest islands of Germany are situated: Rügen, Usedom and Fehmarn.

Fig. 1: Station map

2. Overview of the Climatic Conditions

The coastal areas of the North and Baltic Seas lie in the mid-latitude Westerly wind belt. The climate is predominated by low and high pressure areas that bring air masses of varying thermal and hygric properties, thus causing a continuous change in the weather conditions. In the Baltic Sea part of the region, the continental influence on the climate increases slowly towards the East. A characteristic climate feature of the North and Baltic Sea region is the constantly blowing wind. The following description of the climate of the German coastal areas is based on weather observations and the corresponding analyses for the period from 1971 to 2000. Fig. 1 gives an overview of the stations referred to and their location.

2.1 Air Temperature

The annual mean air temperatures in the North and Baltic Sea region (Fig. 2) range between 8 °C and 9 °C, with decreasing values towards the East and the North. The highest values, i.e. 9.4 °C, occur on the East Frisian Islands and on the island of Helgoland. Fig. 3 vividly illustrates a higher frequency of too warm years since the end of the 1980s.

Due to a higher heat capacity, the North and Baltic Seas have an attenuating effect on the daily and annual temperature variation. As an effect of the increasing influence of the continental climate, the annual curve (Fig. 4) shows more pronounced variations in the Baltic Sea part of the region and gives for the coldest months January and February mean temperatures of 2 °C in the North Sea and 1 °C in the Baltic Sea area. The warmest month is August, with a mean temperature of about 17 °C. The mean daily maximum temperatures

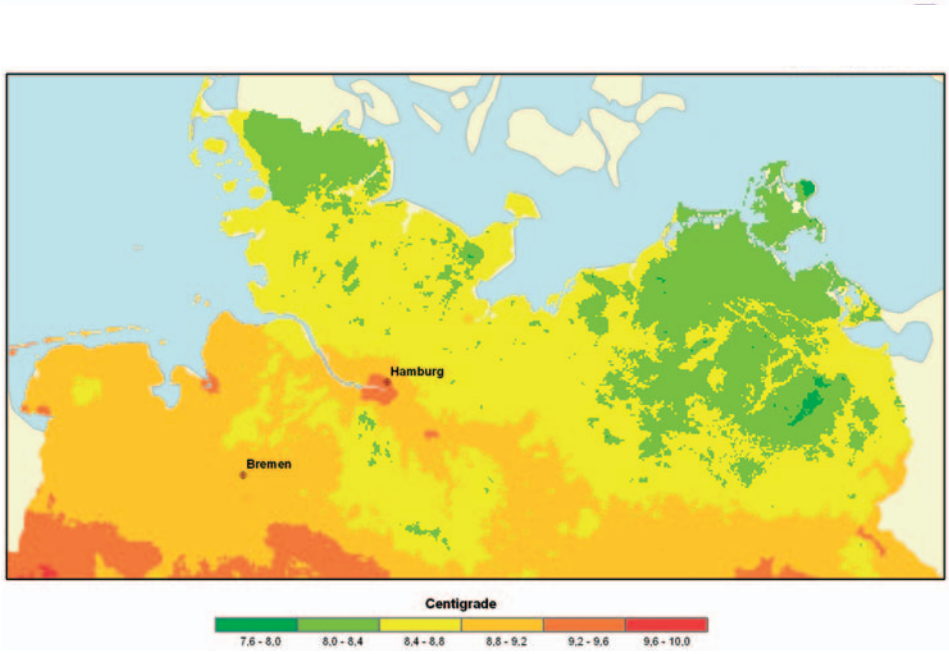

Fig. 2: Annual mean temperature, reference period 1971–2000

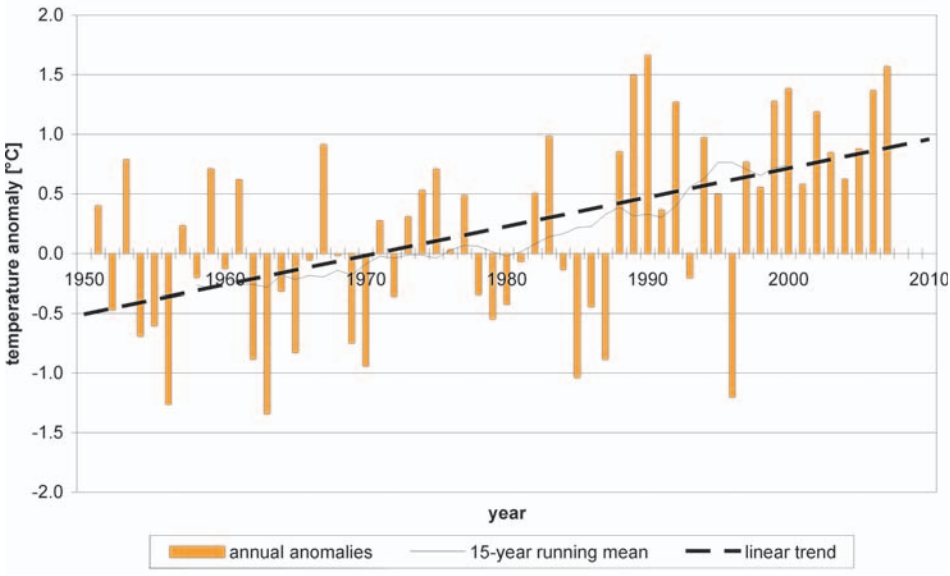

Fig. 3: Anomalies of annual mean temperatures in Boltenhagen from 1951–2007 (reference period 1961–1990)

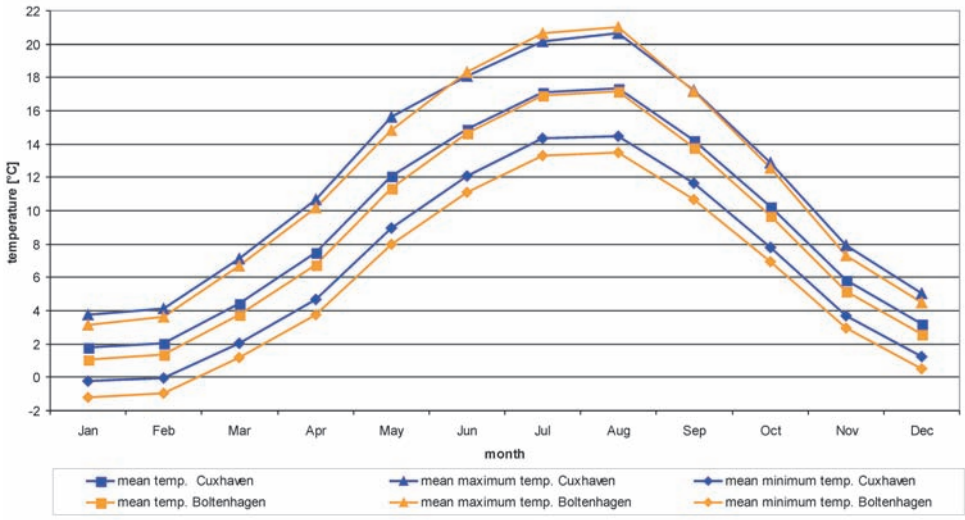

Fig. 4: Monthly variations of mean, mean maximum and mean minimum temperatures at Cuxhaven and Boltenhagen (reference period 1971–2000)

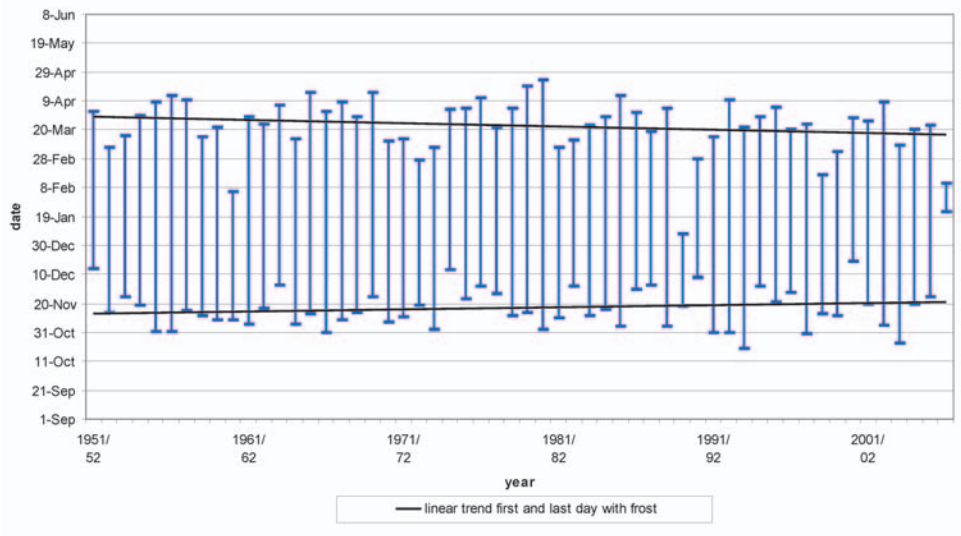

Fig. 5: Annual period between first and last frost (temperatures minimum below 0 °C) in Cuxhaven from 1951/52 to 2006/07

range between 3 °C and 4 °C in January and February and 20 °C to 22 °C in August. Between May and September, the daily temperatures can reach a maximum of about 30 °C. The highest temperatures were recorded in August on the Lower Saxony and Mecklenburg parts of the mainland coast, with a maximum of 36 °C. The mean daily minimum temperatures in January and February range between 0 °C and +1 °C in the North Sea and –1 °C in the Baltic Sea area. Lowest air temperatures occur if under a high pressure area, dry cold air prevails in clear, calm nights with snow cover. Under such conditions, temperatures may well go down to –15 °C. Very often, however, there is no frost due to the inflowing maritime air masses or the blowing winds. The probability of frost increases from the North towards the Baltic Sea and with increasing distance from the sea. For this reason, the annual mean number of days with air frost is 28 on Helgoland, 40 on the East Frisian Islands and about 50 on the coasts of the North Sea, whereas in the Baltic Sea area, there are about 60 frost days. The highest number, i.e. 75 to 80 frost days, is recorded east of the island of Rügen where the continental influence is strongest. In years with extremely cold winter months, such as in 1996, the number may even double (e.g. Boltenhagen had 112 frost days in 1996 and 60 on average in the period from 1971 to 2000), whereas in years with a very mild winter, such as 1974, 1990 or 2000, only about 10 to 20 frost days in the North Sea, 20 to 30 frost days in the Baltic Sea area and 30 to 40 frost days east of Rügen occurred. Since the end of the 1980s, an increasing frequency of occurrence of mild winters can be observed, which results in a significant decrease in the number of frost and ice days and in the shortening of the period between the first and the last frost. As shown in Fig. 5, Cuxhaven station provides an excellent example for this. What is noticeable here, is the extraordinarily mild winter of 2006/2007.

2.2 Water Temperature

As compared to the air temperature, the water temperature shows a delayed annual variation. In spring, the water does not warm up as rapidly as the air. In autumn, it cools down more slowly. The highest water surface temperatures are recorded in August, with a monthly average of 18 to 19 °C. Along the straight and flat coastline, where tourists enjoy themselves, the daily mean values even rise to 20 to 23 °C. From September to February, the sea is warmer than the air, reaching its maximum with an air-sea temperature difference of –2 Kelvin in November and December. The waters are coldest in February when the mean temperatures range from 2 to 3 °C or below (east of Rügen) or 4 °C in the German Bight. In winter, sea ice may form. Sea ice begins to grow preferably in the protected and shallow inner parts of fjords and bays or on the tidal flats of the North Sea. For the years 1961–2000, the sea ice season starts here in the last decade of December or within the first days of January on average. In the more open sea areas and visible from the coast, icing begins around January 10th. The ice season at the North Sea ends by the second half of February, at the Baltic Sea in the first half of March. The frequency of occurrence and duration of ice covers in the Baltic Sea exceed those of the North Sea. Due to predominant mild winter seasons, the ice cover has been poor since 1998.

2.3 Precipitation

Precipitation in northern Germany is mainly caused by Atlantic low pressure systems and their frontal systems. In the coastal areas, they are influenced by the destabilising and stabilising effects, which the water surfaces of the North and Baltic Seas exert on the air masses moving across. In Western Schleswig-Holstein, where westerlies prevail, coastal convergence and increasing friction effects behind the coastline intensify precipitation, whereas precipitation decreases due to divergence, cloud dissolution, and increasing continentality along the Baltic Sea coast. Annual mean precipitation heights (Fig. 6) decrease eastwards from about 900 mm in Western Schleswig-Holstein to 500 to 550 mm in the Szczecin Lagoon (Stettiner Haff). Precipitation in the North Sea area features a maritime maximum in late autumn, whereas at the coasts of the Baltic Sea, the influence of the continental climate expresses itself in summer precipitation maxima (Fig. 7). The lowest amounts of precipitation throughout the year are recorded in February and April, with 30 to 40 mm in the North Sea and 20 to 30 mm in the Baltic Sea area. In spring, the intensity of convective precipitation lessens due to the stabilising effects of the thermal stratification of the air masses moving over still cold sea surfaces. The month of May, when high pressure areas frequently produce long periods of dry weather, marks the transition into the summer months with precipitation amounts of about 60 to 70 mm per month in the North Sea and 50 to 60 mm in the Baltic Sea area. While precipitation amounts in the Baltic Sea area start decreasing again in autumn, the destabilisation of air masses over the warmer North Sea provokes another increase of the monthly totals to 80 to 90 mm. Even up to 100 mm/month on the west coast of Schleswig-Holstein have been recorded. By December, the weather in the North Sea area has also become dryer again. Depending on the large-scale synoptic situation or the occurrence of heavy precipitation events, the monthly totals may vary significantly between sometimes twice or three times the average rainfall or dry periods with only a few millimetres.

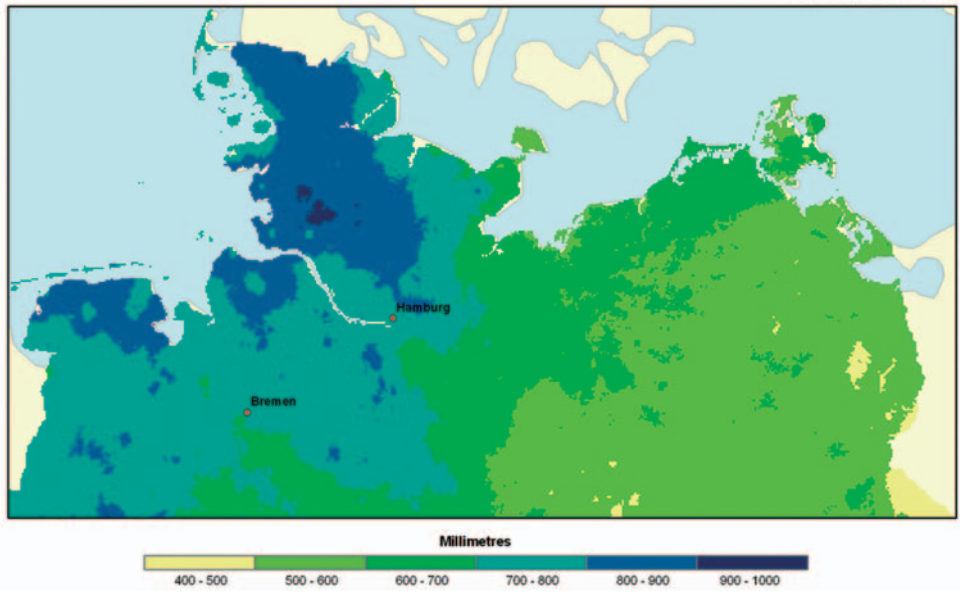

Fig. 6: Annual mean precipitation totals, reference period 1971–2000

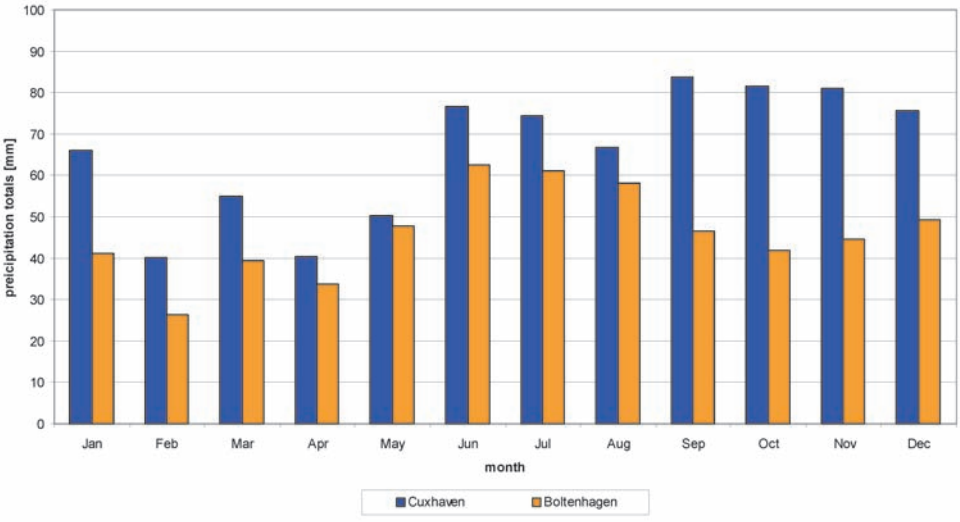

Fig. 7: Monthly variations of precipitation totals in Cuxhaven and Boltenhagen (reference period 1971–2000)

Between November and April, precipitation can occur as snow. The annual mean number of snow cover days is around 20 along the North Sea coast and between 20 to 30 days along the Baltic Sea shore. In years with heavy snow, the number of snow cover days may even rise to 70 to 80. A particular event to remember is the snow disaster at the turn of the year 1978/1979 with massive snow falls and storm. The weather stations along the North Sea coast

reported snow depths of about 70 cm. Regionally, snowdrifts were far higher. The more frequent occurrence of mild winters since the end of the 1980s is paralleled by a decrease in snow depths and the number of days with freshly fallen snow.

The number of thunderstorms in the coastal areas is relatively low. The sea winds during the summer months reduce the thermal lift needed for such an event. In the warm season, thunderstorms occur on 3 to 4 days per month on average. The annual average is about 20 days. In autumn, when the water is still relatively warm and there is an inflow of cold air, however, thunderstorms are more frequent on the islands than on the mainland. The least risk of thunderstorms occurs in the period between January and April in the North Sea and November and March in the Baltic Sea area.

2.4 Sunshine Duration

The map of annual sunshine (Fig. 8) distinctly shows the increasing number of sunshine hours from land to coast and from West to East. In the North Sea area, the annual sunshine duration ranges largely between 1,550 and 1,650 hours on the mainland coast and between 1,700 and 1,740 hours of sunshine on the islands. On the Baltic Sea side, the sunshine duration increases from the North towards the South. While north of the Kiel Bight (Kieler Bucht) the annual mean sunshine duration ranges between 1,550 and 1,600 hours, it amounts to between 1,650 and 1,750 hours per year in the area between the Lübeck Bight (Lübecker Bucht) and the Szczecin Lagoon (Stettiner Haff) as well as on the island of Fehmarn. Records on the islands of Rügen and Usedom show a particularly large amount of sunshine: with approx. 1900 sunshine hours they are the sunniest areas in Germany. Due to long days, frequent high pressure influence and the stabilising effect of the low sea temperatures, May has the highest average sunshine duration (Fig. 9), with between 230 and 270 hours.

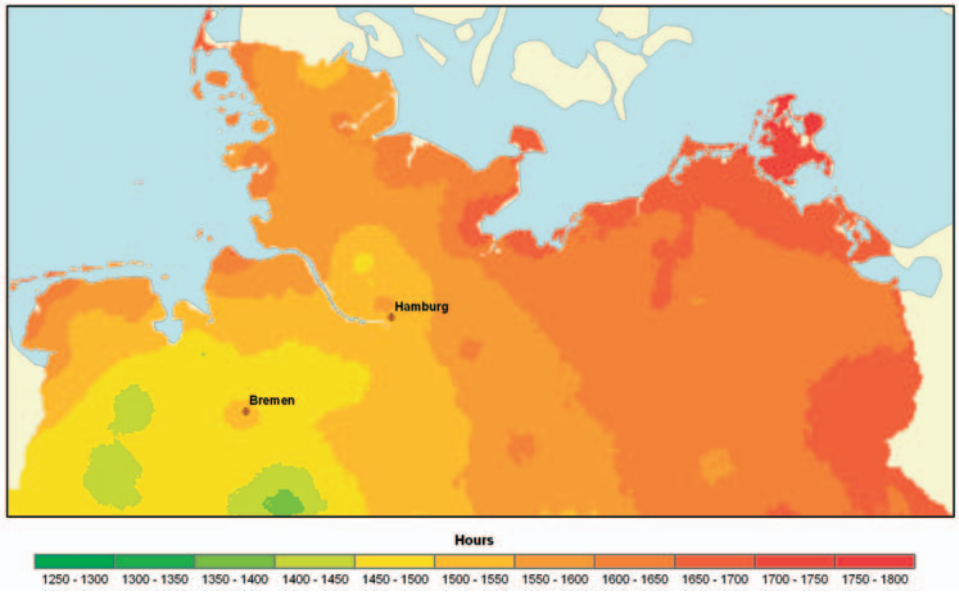

Fig. 8: Annual mean sunshine duration, reference period 1971–2000

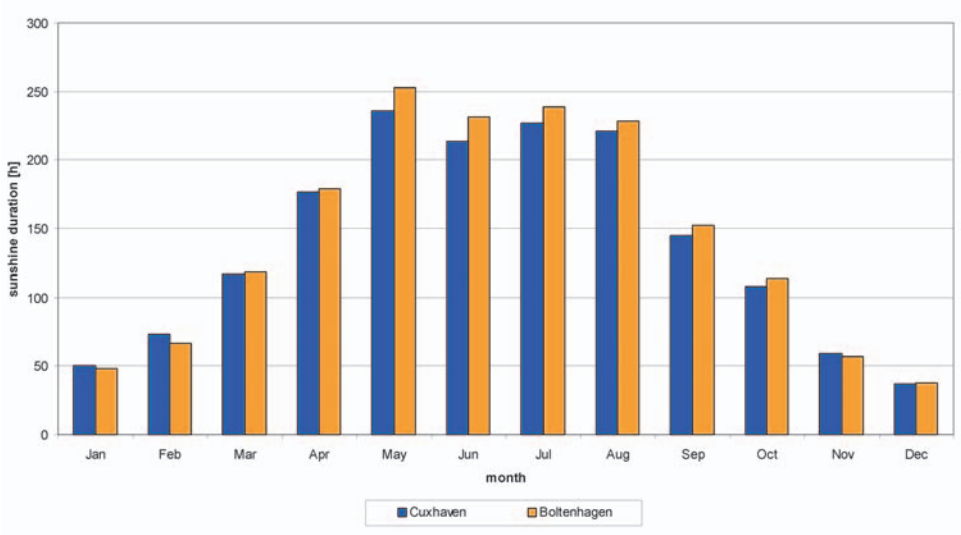

Fig. 9: Monthly variations of sunshine duration in Cuxhaven and Boltenhagen (reference period 1971–2000)

2.5 Cloudiness

A way of measuring cloudiness is to determine the cloud cover as the fraction of the sky covered by clouds in octa (e.g. a cloudless sky has a cloud cover of zero octa, an overcast sky of eight octa).

During the course of the year, the mean cloud cover shows only little variation, ranging between 6 octa in the winter months and 4 to 5 octa between April and September (or October at the coast of Mecklenburg-Western Pomerania).

The "lee effect of Scandinavia", is a particular phenomenon which occurs during weather situations with high reaching northerly airflows in the rear of large low pressure systems. Descending air on the leeward side of the Scandinavian mountains and the related decrease in air humidity result in dry weather with little cloud cover (Fig. 10) across Schleswig-Holstein and the western parts of the Baltic Sea.

2.6 Wind

The most distinctive climate element in the German coastal areas is the wind. Generally speaking, the mean wind speed is lower in the Baltic Sea than in the North Sea area (Fig. 11). The prevailing westerly and south-westerly winds blow towards or parallel to the North Sea coast. Therefore, they are mostly stronger than in the Baltic Sea area, where off-shore winds predominate along most parts of the coast. Along the islands and coastlines of East and North Frisia as well as of Hiddensee and Rügen in the Baltic Sea, that are exposed to the west, the mean wind speeds sometimes rise above 7 m/s. Along the other North Sea coastal regions they range between 6 and 6.8 m/s on both sides of the Elbe mouth, around 6 m/s in the northern parts of the Baltic Sea coast of Schleswig-Holstein and on the Darß and 4 to 5 m/s

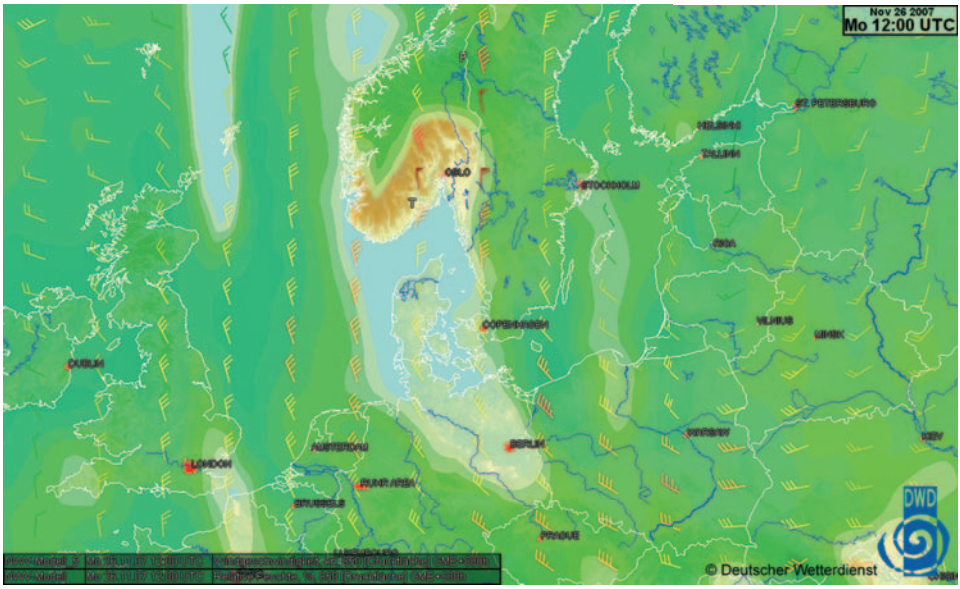

Fig. 10: Lee effect of Scandinavia

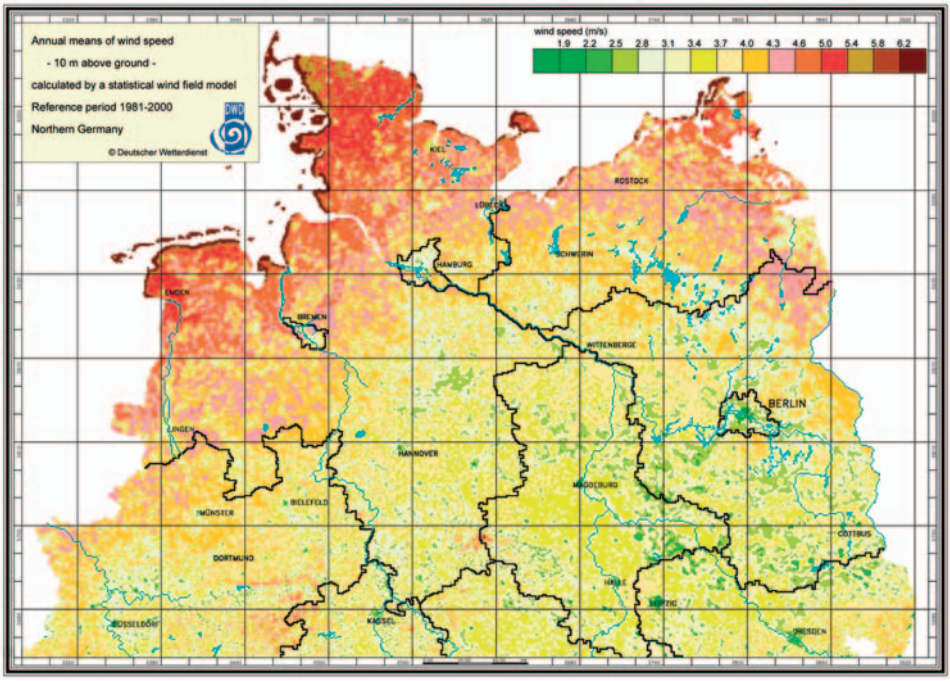

Fig. 11: Annual means of wind speed (reference period 1981–2000)

along the coasts of Mecklenburg-Western Pomerania and in the Lübecker Bucht (Lübeck Bight). With an annual mean wind speed close to 8 m/s, the windiest area is the island of Helgoland.

From the beginning of November until the end of March, the winds are stronger due to the larger temperature differences between the polar and the subtropical regions. Average wind speeds are approx. 1 to 2 m/s and higher in winter than in summer. They are weakest in May, June or August.

The richness of wind along the coasts manifests itself in the large number of days with strong wind or storm, i.e. days on which the maximum 10-minute mean wind speed is 11 m/s or higher. This corresponds to a Beaufort force 6 and above. Table 1 shows, that there is a wide spread of days with strong breezes ranging from between 30 to 40 days in the protected inner parts of fjords as well as in shallow bays to approx. 200 days at the exposed island sites, such as the most northern part of Rügen, Cap Arkona, and Helgoland in the North Sea. At open coastlines of North and Baltic Seas strong breezes are recorded on approx. 90 days. The more exposed the location, the higher is the frequency of occurrence of storms. Wind is defined as a storm if the 10-minute mean wind speed exceeds 34 m/s, corresponding to a force 8 on the Beaufort scale. In most parts of the region, the annual mean storm frequency varies from 5 to 10 days. In wind-rich island locations of the North Sea, it amounts to about 20 days. In protected bays, the average number of storm days per year is only one or two. Storm-force winds occur almost exclusively from the beginning of November until the end of March on 1 to 3 days per month. The highest average number of storm days per month, i.e. 6 to 8 days, is recorded at Cap Arkona. With the wind-rich years between 1991 and 1995, automatically a higher frequency of occurrence of storms is connected. In particular months, for example, the number of days with storm-force winds was up to 10 in wide parts of the region; at Cap Arkona it was even close to 20 days (January 1983).

Table 1: Mean monthly and annual numbers of days with wind forces of 6 Bft and more (reference period 1971–2000)

Station name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Helgoland	21	16	17	12	9	9	9	11	16	20	22	23	185
Norderney	13	10	12	10	9	9	9	8	10	11	13	14	127
Cuxhaven	10	9	10	7	7	5	5	5	6	9	9	10	92
List/Sylt	17	14	16	12	12	12	12	11	14	16	18	19	171
Westermarkelsdorf*	11	8	8	8	6	6	7	6	8	10	11	12	100
Boltenhagen	13	12	13	10	9	7	7	7	8	10	13	14	121
Rostock-Warnemünde	9	7	8	7	5	8	8	6	7	7	9	9	90
Arkona	22	19	20	17	16	13	14	14	17	19	21	23	214
Ueckermünde**	5	5	6	5	2	1	2	1	2	3	4	5	42

* Ref. period 21 years
** Ref. period 15 years

Table 2: Mean monthly and annual numbers of days with fog (reference period 1971–2000)

Station name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Helgoland	6	7	8	6	5	3	1	1	1	2	2	4	46
Norderney	8	7	6	5	3	2	1	1	2	4	5	7	52
Cuxhaven	8	7	6	4	2	1	1	1	2	4	5	6	49
List	10	9	9	7	3	2	1	1	2	5	5	8	63
Westermarkelsdorf*	5	6	6	4	2	1	1	2	2	2	3	5	41
Boltenhagen	6	5	5	4	3	1	1	2	3	5	4	4	45
Warnemünde	7	6	5	4	3	2	1	1	2	5	4	4	45
Arkona	8	7	8	7	5	3	2	2	3	5	5	7	59

Despite the relatively high number of days with strong wind, gentle to moderate winds (between Beaufort force 1 to 3 resp. wind speeds of 0.3 to 5.4 m/s and Beaufort forces 4 to 5 or wind speeds of 5.5 to 10.7 m/s) predominate with a share of 75 to 90 %. The percentage of gentle winds is higher at the Baltic Sea coast. Due to the frequent on-shore winds at the North Sea coast, the annual average share of gentle winds is 30 to 40 %, the annual average share of moderate winds 40 to 50 %. In the open coastal regions of the Baltic Sea, gentle and moderate winds are almost equally frequent, with a percentage of approx. 40 to 45 %.

In the German coastal areas, the wind mainly blows from the Southwest to West, making an annual average of 35 to 40 % (Fig. 12). Apart from that, winds vary around the eastern

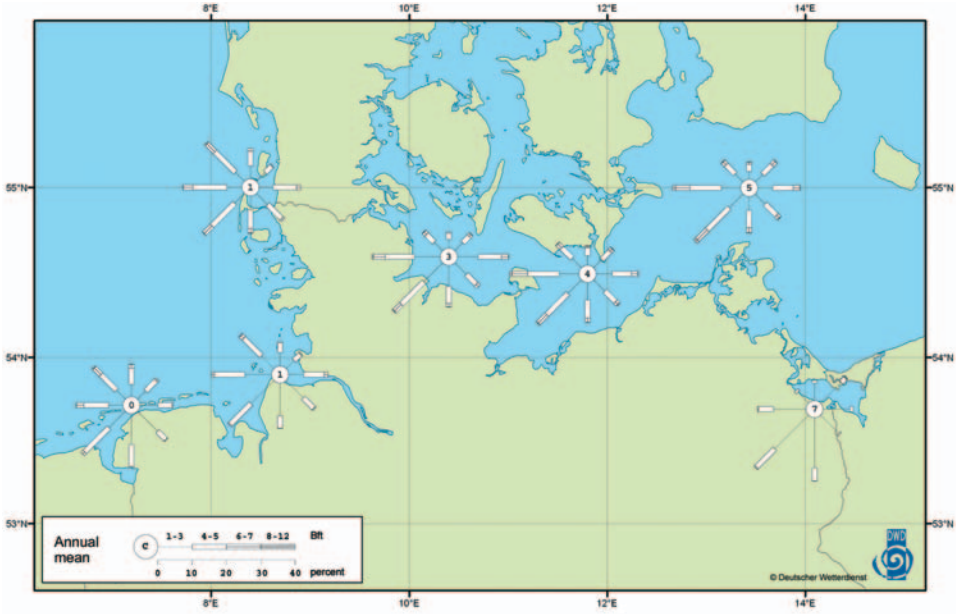

Fig. 12: Mean annual distribution of wind speed and direction

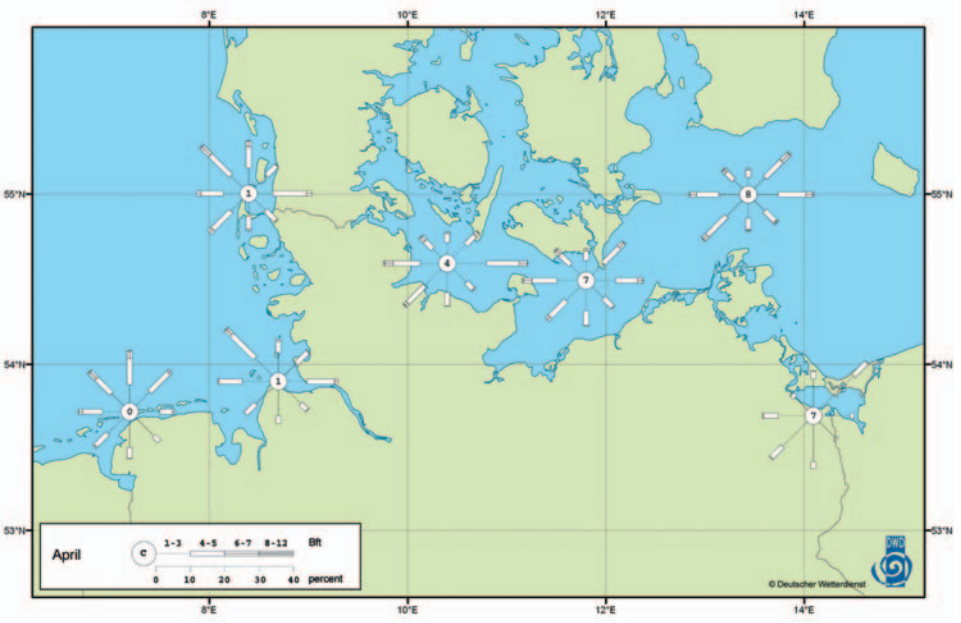

Fig. 13: Mean distribution of wind speed and direction in April

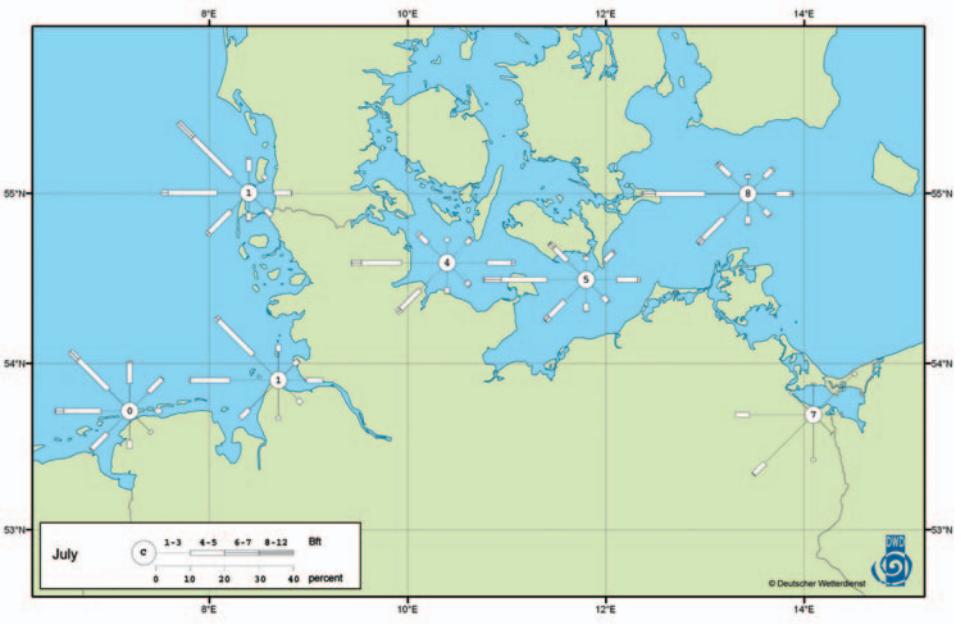

Fig. 14: Mean distribution of wind speed and direction in July

sector, i.e. from the Northeast to Southeast at about 30 % of the time or directly from the South at about 10 to 15 % of the time. The varying shape and changing orientation of the coastlines are the reason that general wind conditions are modified on a regional level. In the Szczecin Lagoon (Stettiner Haff), for example, the south-westerly winds give mainly way to southerly winds and, though less frequently, to westerly winds. The main wind direction varies throughout the year. In April, the wind very often blows from the northern to eastern direction (Fig. 13). Moderate winds from the western wind sector are more frequent in the summer in July (Fig. 14). North-westerly wind directions predominate at the North Sea coast, while the coasts along the Baltic Sea mainly receive westerly and south-westerly winds, which often blow gently. October is dominated by winds from southern directions (Fig. 15), with the winter being characterised by southerly/westerly winds at elevated wind speeds (Fig. 16).

Due to the different temperatures of land and water surfaces, land/sea circulation evolves during the warm season at high pressure situations with weak wind. This type of circulation is of a small scale and brings fresh air from the sea to the coastal areas during the day. In Northern Germany, it often extends only over a few kilometres into both directions along the coast, but may, however, also reach as far as 100 kilometres into the mainland. Above all, the land/sea circulation is responsible for the summer wind conditions in the Baltic Sea area where the on-shore wind reaches its maximum speed between 2 p.m. and 5 p.m. CEST. In the North Sea area, the phenomenon is less distinct. As an effect of the windward orientation of the coast, the wind freshens up due to the component from offshore and changes the direction of the large-scale wind towards a more onshore direction. At night, the nocturnal offshore wind often cannot prevail over the large-scale onshore winds.

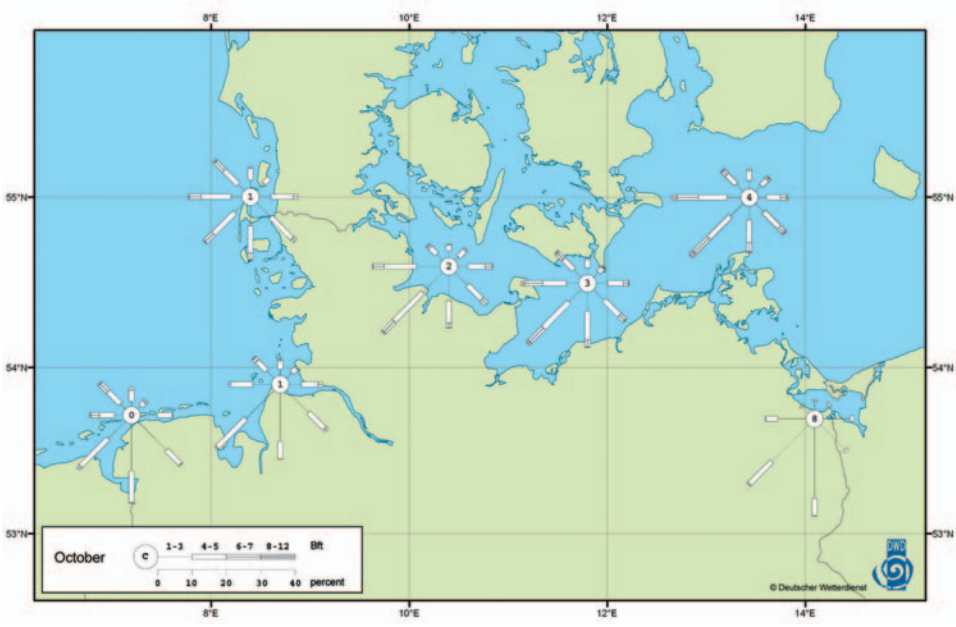

Fig. 15: Mean distribution of wind speed and direction in October

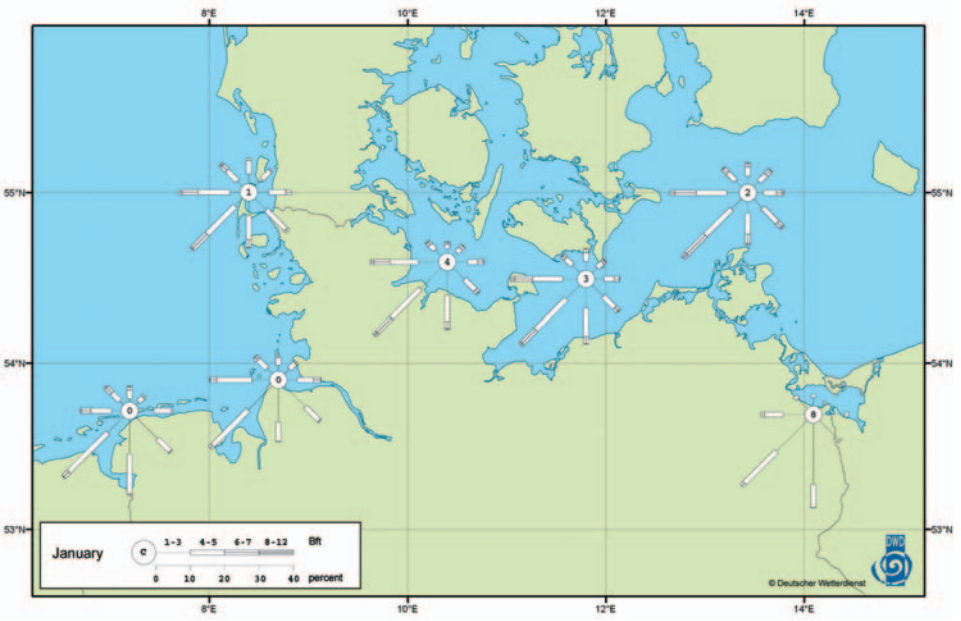

Fig. 16: Mean distribution of wind speed and direction in January

2.7 Visibility and Fog

Fog forms above the sea mainly in spring, when warm and humid air moves across cold water and cools down to temperatures below the dew point, or in autumn and winter, when cooler air drifts across the still relatively warm sea water. Above land, so-called radiation fog forms preferably in autumn and winter under clear high pressure weather conditions with little wind due to the nocturnal cooling resulting from radiation losses at the Earth's surface.

A particularity is the coastal and sea fog which mainly occurs in late spring. It forms when the water surface is much colder than the land surface. If the warm air masses then move horizontally from the land towards the sea, they cool down rapidly over the water and a thin fog layer develops over the water surface.

Such sudden occurrence of coastal fog causes considerable and sudden changes in the visibility and temperature conditions. The sudden occurrence of sea fog is extremely dangerous for people on mudflat excursions. These events are mostly limited to the specific part of the coast and in many cases are not recorded to their full extent by the weather and observing stations.

The frequency of occurrence of fog shows a distinct annual variation, with a maximum in winter when fog occurs mostly on 6 to 8 days per month, and a minimum in summer (Tab. 2). On average, there is only one day with fog in the months of July and August. The annual mean number of fog days is 40 to 50, in some regions even 60 days (Sylt and Rügen).

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