KLIWAS North Sea Climatology (KNSC)

Processing of meterological data

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A cooperation of:

2 Processing of meteorological data

2.1 Summary

This is the first version (1.0) of a meteorological climatology for the North Sea in the range 47 ° to 65 ° N, 15 ° W to 15 ° E (quote: Remon Sadikni, Manfred Bersch Annika Jahnke-Bornemann (2013): Meteorological Climatology of the North Sea and Surrounding Regions, Center for Earth System Research and Sustainability (CEN) University of Hamburg). It contains monthly and annual mean air temperature, air pressure, and dew point on a 1°x1° grid for the period from 1950 to 2010. Climatologies were calculated for the standard periods 1951-1980, 1961-1990, 1971-2000 and 1981-2010.

2.2 Data Basis

All available quality-controlled maritime and meteorological data of the German Weather Service (DWD) for the period 1950-2010 were considered for the calculation of the mean values. They contain measurements of Voluntary Observing merchant Ships (VOS), light vessels, buoys and platforms. These are supplemented by ICOADS data (Worley et al., 2005). In total there are approximately 19.4 million data sets of maritime and meteorological parameters with quality flags included. With the help of Fortran the parameters air temperature, air pressure, wind speed, relative humidity and dew point were extracted and missing values were specified by -9999 or -9999.0.

The DWD uses automatic calculations on the basis of the routine of Hoeflich et al. (1975) as a quality control that was applied to all incoming data. They are comparable to the published procedure of Gandlin (1987) and Ishii et al. (2003). In a first step, the data is tested for duplication.

Climate and consistency tests follow, which ensure that the measured values depending on the geographic position are within reasonable meteorological limits (minimum and maximum values). Air pressure, air and water temperature are compared with ERA-Interim limits. Special routines finally check for consistency and compliance of meteorological laws (eg dew point <= air temperature). Now all observations are provided with quality flags and checked manually in case of a false or questionable value and if possible, corrected.

For the climatology data with an inadequate quality level were rejected and only the measurements at the times 0, 6, 12 and 18 UTC clock were used to prevent a dominance of automatic measurements. In addition, we obtain a more homogeneous data set, since the automatic, usually hourly Measurements increased significantly in the last decades. The number of values actually used are shown separately for each parameter in the results.

At first we looked at the original values, to gain an initial overview of the available data. Figure 1 shows, for example, the air temperature of the december months of 1950-59 and 1980-89.

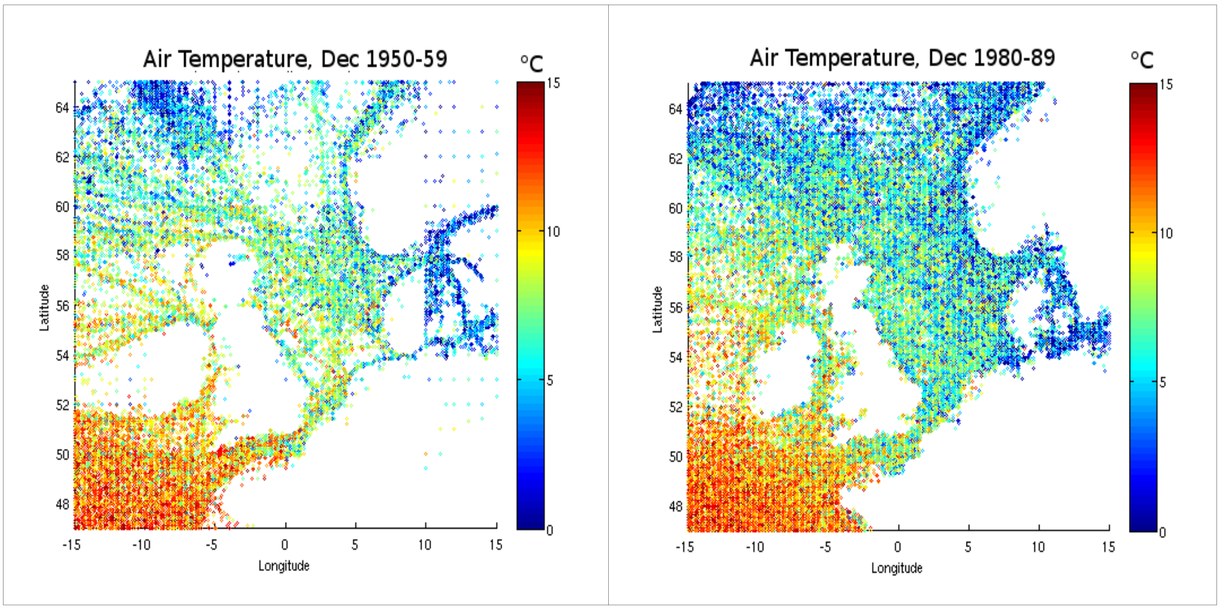
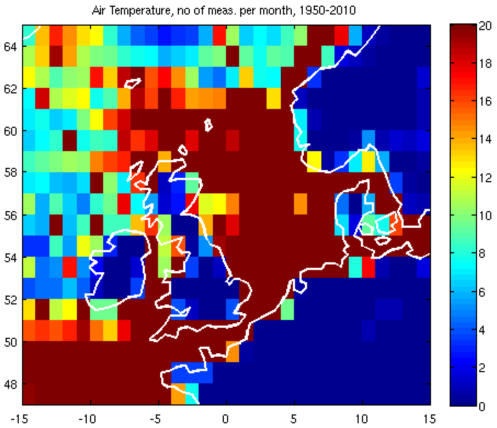
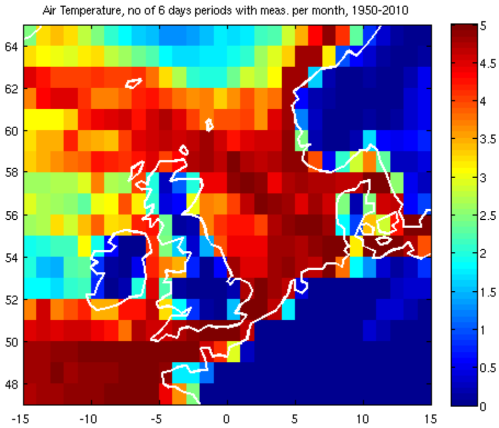


Fig 1: Original measurements of air temperature in ° C all in December, left 1950-59, right 1980-89

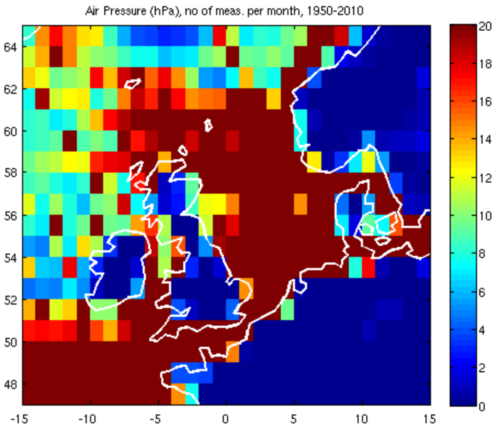
To get a picture of the spatial and temporal distribution of the measured data, statistical studies of the distribution of data in 1° x1° boxes were performed. Figure 2 shows the average number of measurements per month and box as well as the distribution of the measurements in 6-day windows per month (days 1-6, 7-12, 13-18, 19-24, 25-end of the month), to examine the temporal converage within a month.

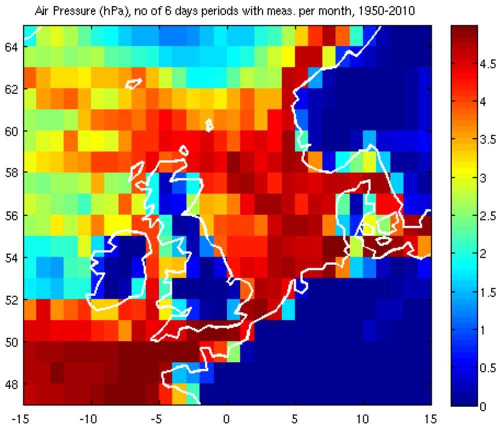
Average number of Measurements per month	**Average number of 6 - Days windows with measurements**



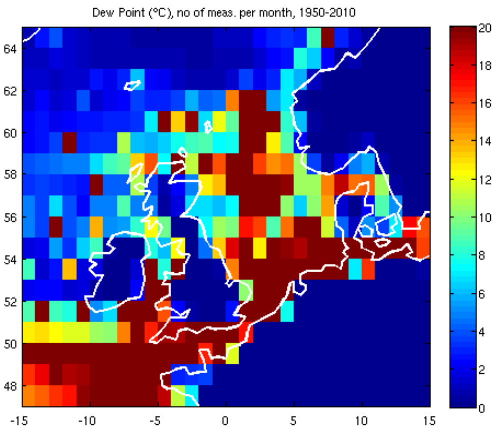


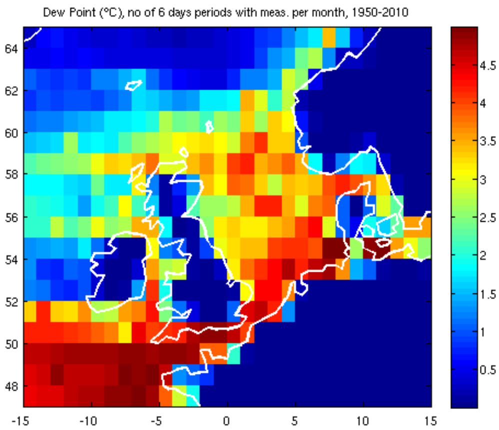
Air temperature	Air temperature





Air pressure	Air pressure





Dew Point	Dew Point

Fig 2: Left column: average number of measurements per month, right Column: average number of 6-day windows with measured values per month, each per box over the period 1950-2010 for the three parameters air temperature, air pressure and dew point

2.3 Method of calculating mean values

For the calculation of mean values, the observational data were grouped in 1°x1° grid boxes. The parameters Air temperature, Air Pressure, Wind speed, relative humidity and dew point were considered. In the The data distribution shows a relatively poor spatial and partly temporal coverage of the boxes. To recieve a better spatial coverage and to calculate averages for individual years and over 30 years, the following procedures were applied:

1) For parameters with an annual cycle and possibly daily cycle, all measurements were corrected by the mean daily and annual cycle in each grid cell. This allows the usage of unevenly distributed measurements over the month or the four main time steps of the day. It also prevents individual measurements from beeing overrated.

2) Neighbour boxes have been included for calculating the monthly mean, if a certain number of measurements per box went below a threshold. In the first step the 8 the neighbour boxes were included, in the second step further 16, so that the box mean was calculated from measurements of maximal 25 boxes.

The measured values were averaged arithmetically without distance weighting and the calculated means were assigned to the centers of the boxes:
Latitude: 47.5 °, 48.5 °, ..., 63.5 °, 64.5 ° N
Longitude: -14.5 °, -13.5 °, ..., 13.5 °, 14.5 ° E
The number of measurements, the standard deviation and the number of the neighbour boxes were stored for each box and every month.

The diurnal correction works as follows: First, the mean values of the main times 0, 6, 12 and 18 UTC were calculated. All measured values per month and box including the 8 neighbour boxes of the entire period from 1950 to 2010 were averaged arithmetically for each time.
A correction term was calculated as the difference from the daily mean (Fig. 3) for each time and box. After that all measured values of a box were corrected by the corresponding correction term. Thus, the diurnal variation was removed from the data.

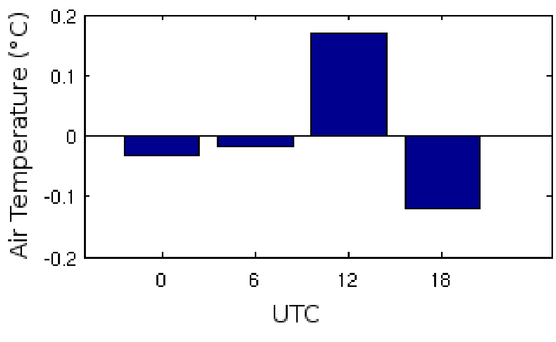


Fig. 3: Correction term: difference at 0, 6, 12, 18 UTC from the daily mean. Here you see as an example the air temperature of a box (56.5 ° N, 4.5 ° E) of all Decembers 1950-2010

To correct the parameter by the annual cycle, you certainly first had to examine whether the parameter has an annual cycle. The mean annual cycle was calculated from all daily averages of the considered box and its 8 surrounding boxes over the period 1950-2010 as the arithmetic mean (Fig. 4).

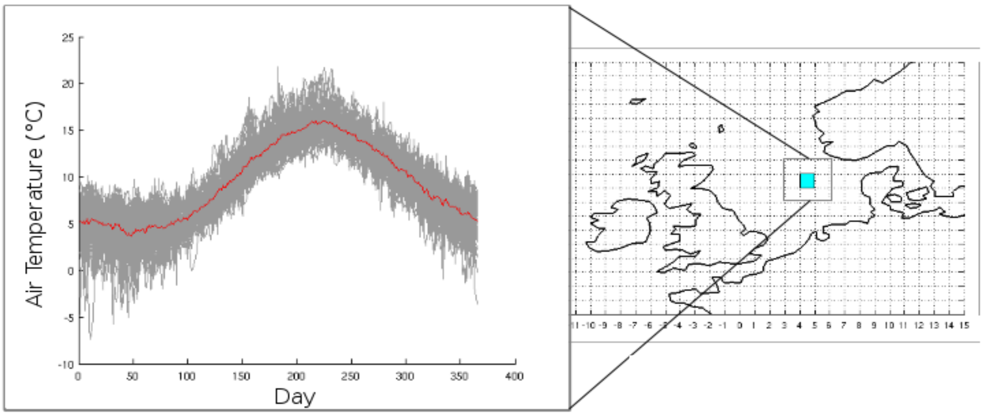


Abb. 4: The mean annual cycle of air temperature in ° C (red curve) was calculated from the considered box plus the 8 surrounding boxes over the period 1950-2010. Shown in gray: the individual annual cycles

The curve of the annual cycle was divided into the individual 12 months and approximated per month by a polynomial of second degree, because the annual cycle corresponds as a first approximation to a sine function. The five adjacent days of the previous and the following month were included to approximate the transition between the months. In each box a correction term per day was calculated as the difference of the fit from the total monthly average 1950-2010 (see Figure 5). All measured values of a box were then corrected by the corresponding correction term. Thus, the monthly variation has been removed from the data, however, the annual cycle was maintained in the 12 monthly values.

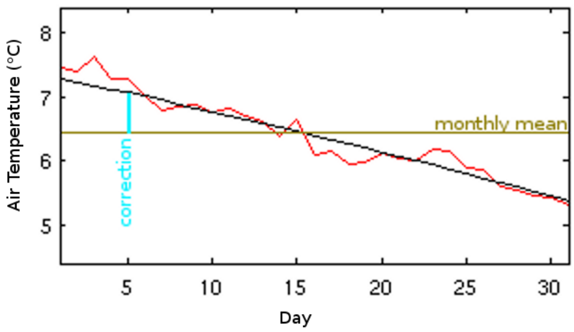


Fig. 5: correction term (turquoise) as the difference of the fit (black) from the total monthly average in December 1950 to 2010 (ocher). Here you see as an example the air temperature of a box of 5 December. The red curve shows the daily mean.

From the monthly averages the 30 year mean and annual mean values were calculated. Climatologies for the standard periods 1951-1980, 1961-1990, 1971-2000 and 1981-2010 were determined for each month. As a prerequisite for calculating the 30-year average in a box, at least 25 of 30 monthly mean values had to be present. As a prerequisite for the determination of the annual mean in a box, all 12 months had to be present.

2.4 Monthly and annual means

At first for each parameter was investigated whether an annual and diurnal variation exists.
Thereafter, the threshold value for including the neighbour boxes was determined. A default threshold of 20 measurements per month was assumed, which promises a reasonable coverage as you can see in fig 2. Afterwards, the climatological results were checked manually for inhomogeneities. If appropriate, the threshold was increased to include more measurements to the averaging process.
If there is no annual cycle in a parameter - and therefore no annual cycle correction was applied - the month was divided into 6-day windows (1-6, 7-12, 13-18, 19-24, 25-end of the month). In addition to the threshold criterion there had to be at least one measurement in 4 of these windows, so that the calculated mean value was taken.

2.4.1 Air temperature

Assumption: The air temperature has a daily and annual cycle.
Method: The approximately 7 million measurements were corrected by the diurnal and annual cycle. If less than 20 measurements per box and month were available, the environment boxes have been included in 2 steps (first 8, then possibly another 16 boxes). As an Example you can see in Figure 7, the monthly averages for December of 1950-64, in Figure 8, December 1980-1994.

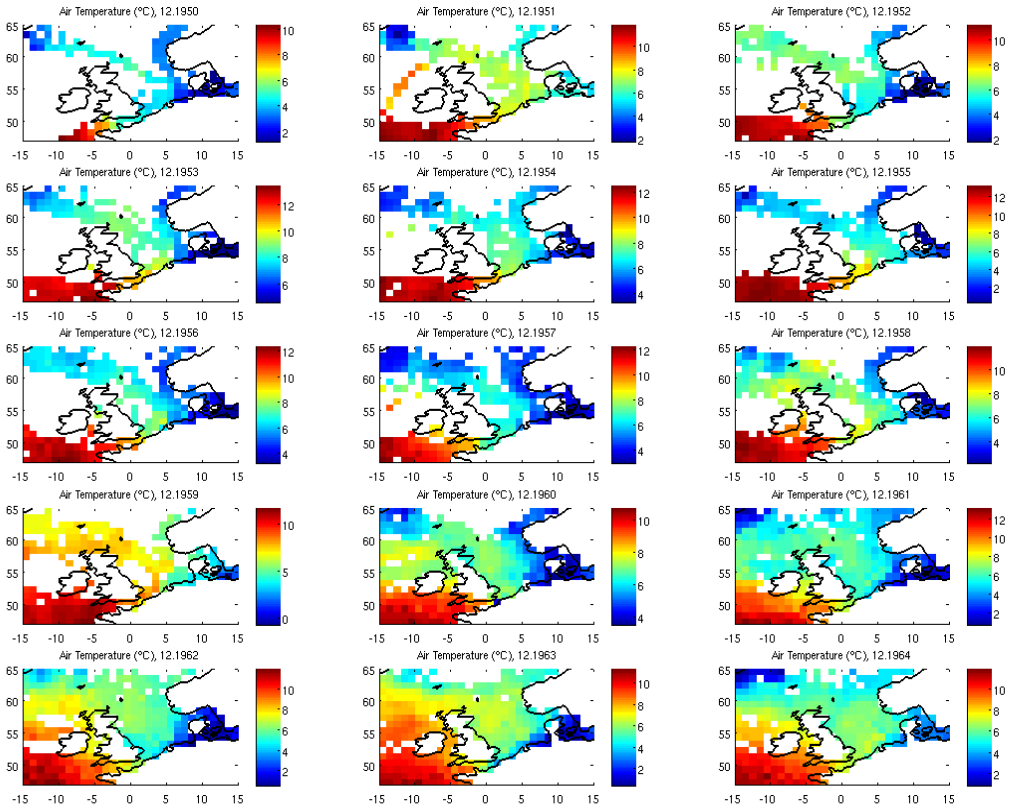


Fig. 7: Monthly averages of air temperature in °C for December 1950-64.

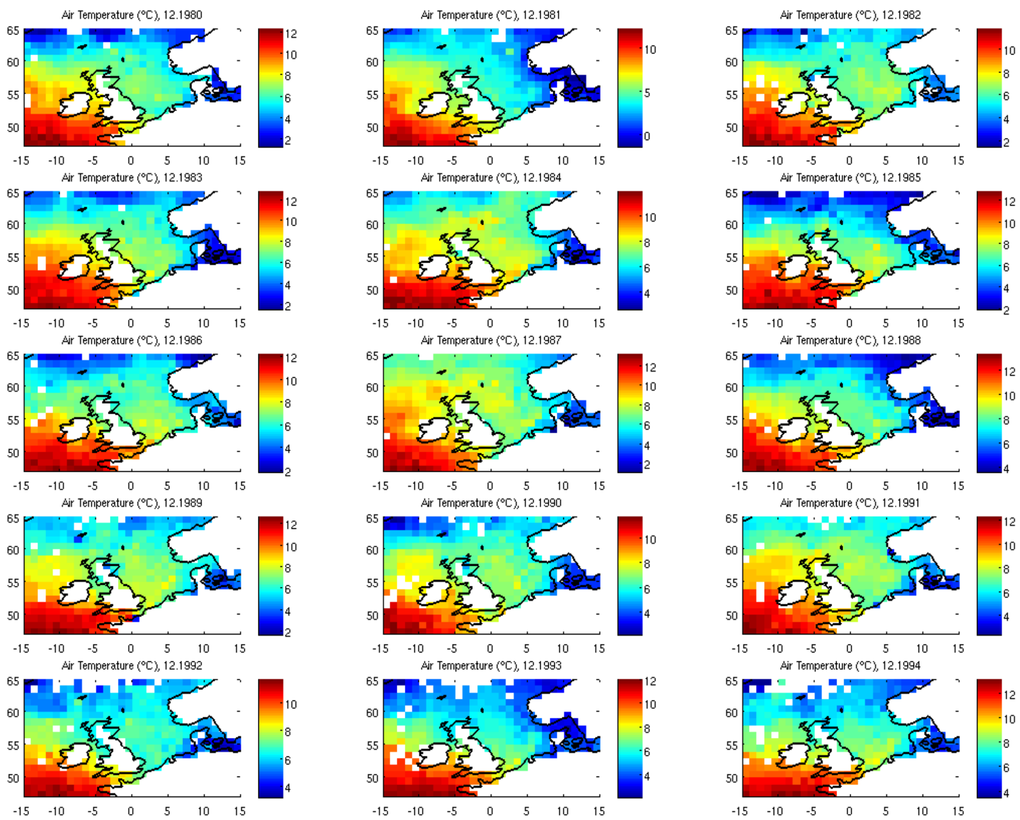


Fig. 8: Monthly averages of air temperature in °C for December 1980-94.

The 30-year means for June and December (1981-2010) are shown in Figure 9.

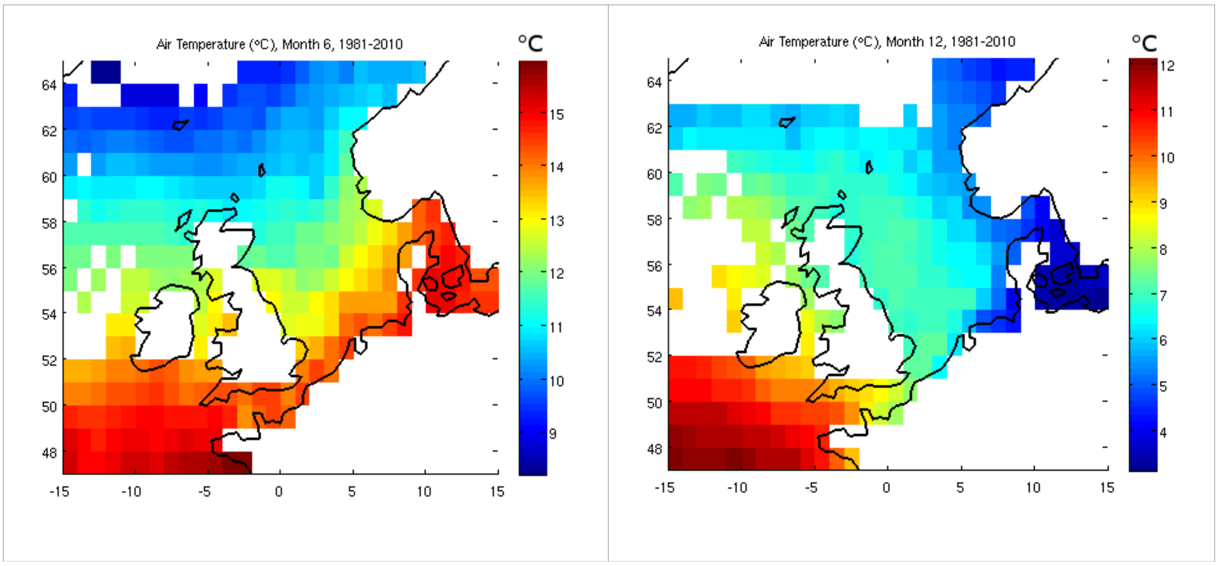


Fig. 9: The 30-year mean of air temperature in °C for June (left) and December (right) 1981-2010.

The results were compared with the climatology of the North Sea by Michaelsen (1998), it showed only minor deviations. Comparisons of monthly means with the reanalysis data sets NCEP reanalysis 1 (Kalnay et al., 1996) and 2 (Kanamitsu et al., 2002), ERA Interim (Berrisford et al., 2009) and ERA-40 (Uppala et al., 2005) as well as 20th Century V2 (Compo et al., 2011) showed a good correlation with a correlation coefficient greater than or equal to 0.97 (Table 2). All monthly means were compared regarding the common period (NCEP1: 1950-2010, NCEP2: 1979-2010, ERA Interim: 1979-2010, ERA-40: 1957-2002, 20th Century: 1950-2010) and visualized as scatter plots. Fig.10 shows an example of the comparison with the NCEP reanalysis 1

	NCEP-RA1	NCEP-RA2	ERAint	ERA40	20th Century V2
Air pressure	0.98	0.98	0.98	0.98	0.97
Air temperature	0.98	0.98	0.99	0.99	0.98
Relative humidity	0.66	---	---	---	0.36
Wind speed	0.89	0.90	0.90	0.92	0.86
Dew point	---	---	0.98	0.98	---

Tab. 2: Correlations between the KNSC and reanalysis data sets

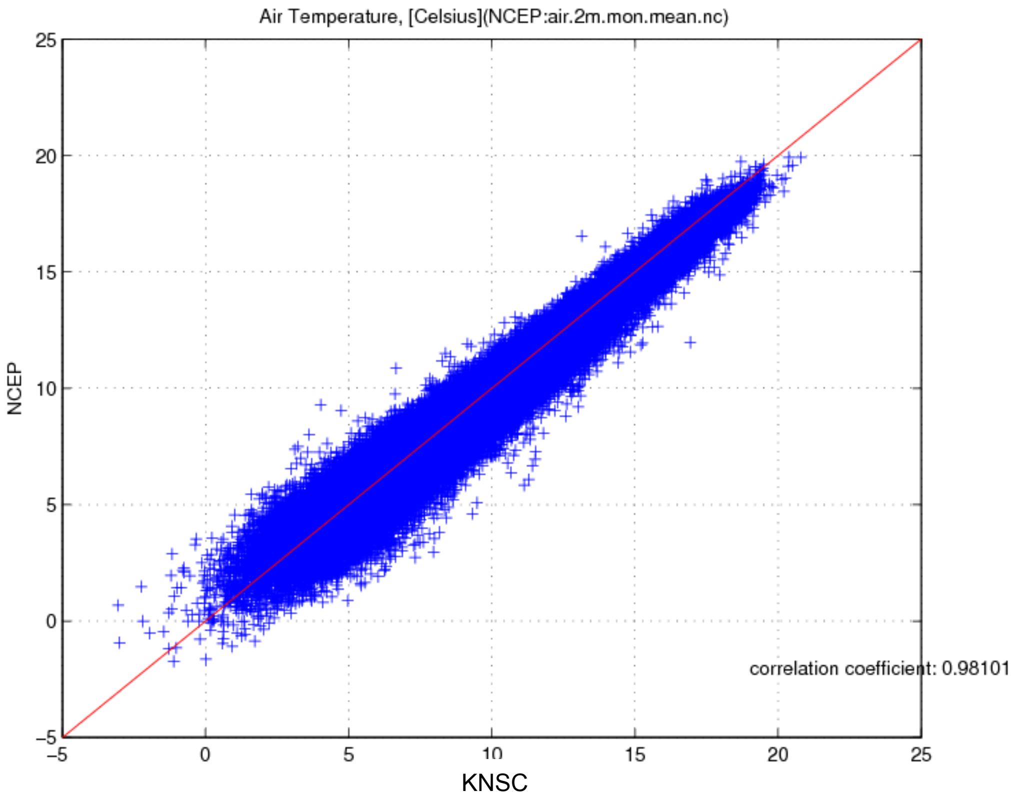


Fig.10: Scatter plot of the comparison of the monthly mean air temperature in °C of the KLIWAS North Sea climatology with the NCEP reanalyses over the period 1950 to 2010

2.4.2 Air pressure

Method: The approximately 7 million readings were not corrected by the annual or diurnal cycle. In the first experiment, a threshold value of 20 measured values was applied and recognized as insufficient. After manual iteration, a threshold of 500 measurements was fixed. Below this threshold measurements were included of the environment boxes in two steps (see air temperature). In addition, there had to be at least one measurement in 4 of the 6-day window of each month and box. In Figure 11, the 30-year mean for June and December from 1981 to 2010 is shown.

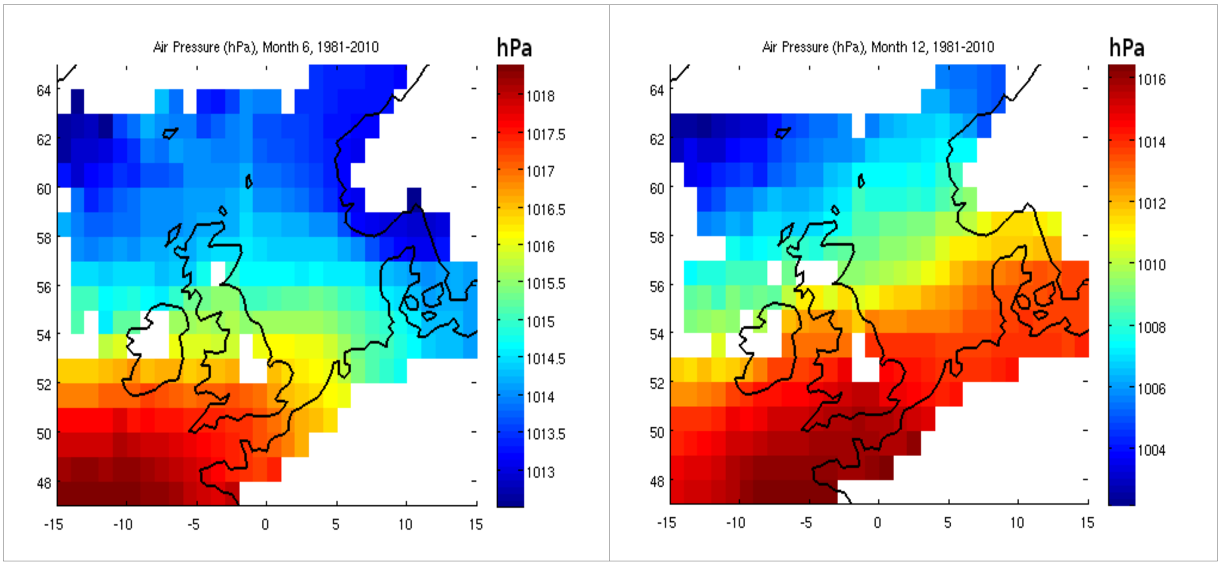


Fig. 11: The 30-year mean of air pressure in hPa for June (left) and December (right) 1981-2010.

Again, comparisons with the monthly mean climatology of Michaelsen (1998), showed a good agreement. The comparison with the reanalyses data sets showed correlation coefficients greater than or equal to 0.98 (Table 2). Figure 12 shows the comparison with the NCEP reanalysis 1 as scatterplot.

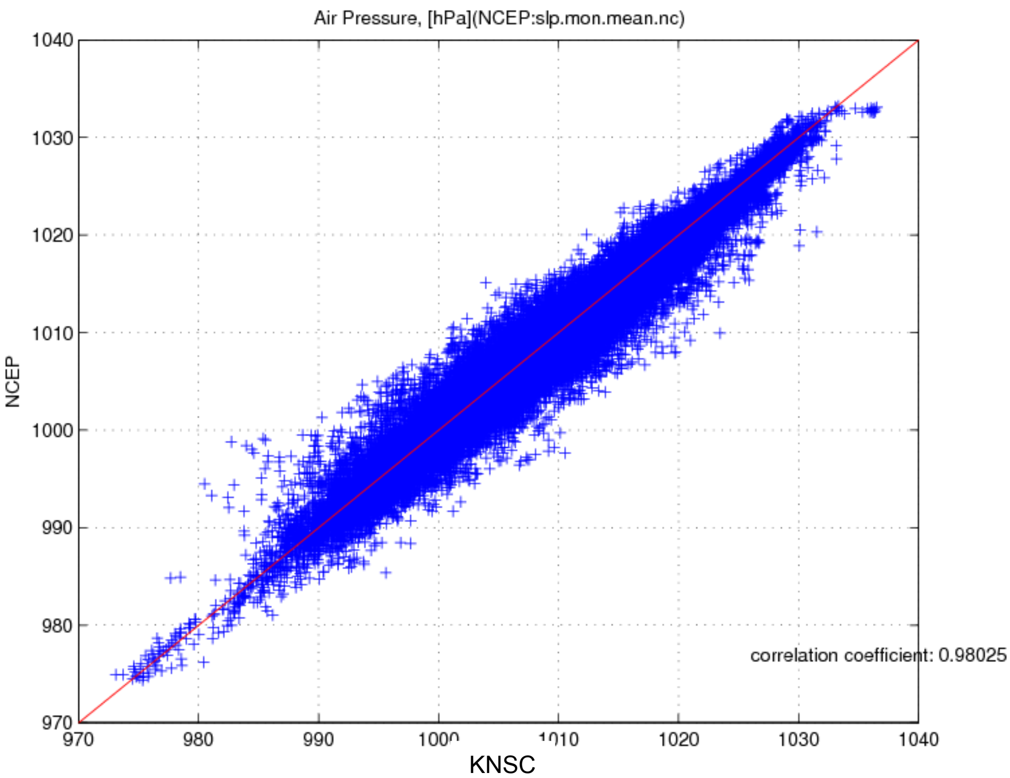


Fig. 12: Scatter plot of the comparison of the monthly mean air pressure in hPa of the KLIWAS North Sea climatology with the NCEP reanalyses over the period 1950 to 2010

2.4.3 Dew Point

Method: The approximately 4.6 million measurements has been corrected by the annual cycle. If less than 20 measurements were present, the neighboring boxes were included in 2 steps. In Figure 13, the 30-year mean for June and December from 1981 to 2010 is shown.

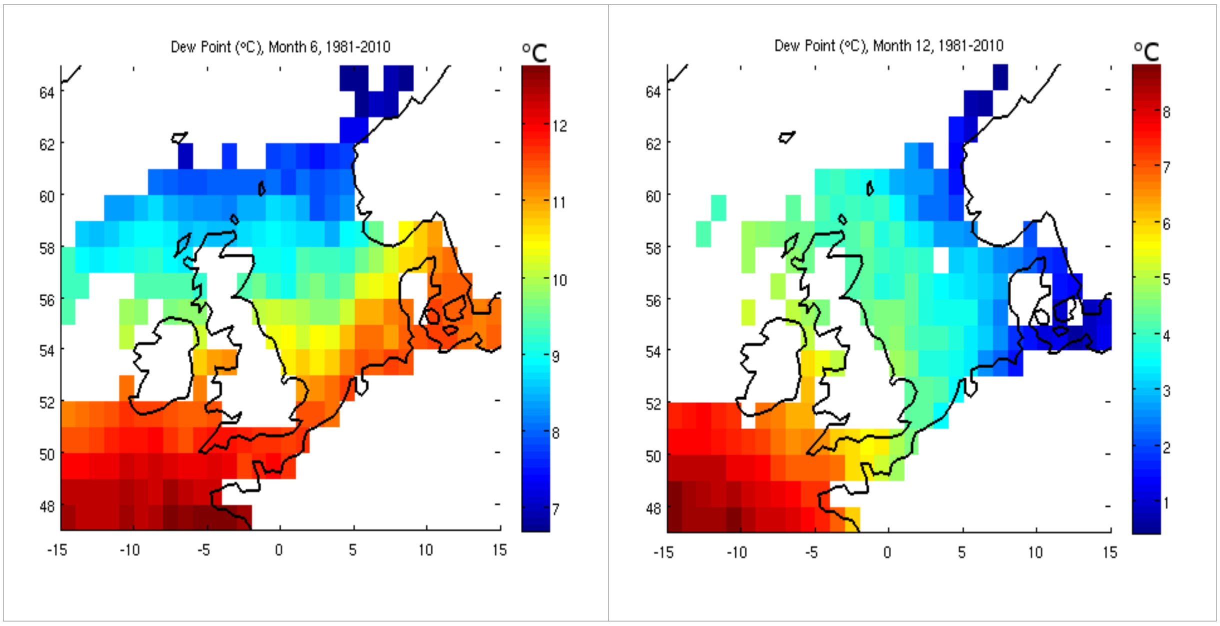


Abb. 13: The 30-year mean of dew point in °C for June (left) and December (right) 1981-2010.

Again, comparisons with the climatology of Michaelsen (1998), showed a good agreement. Comparisons with reanalyses data sets showed correlation coefficients greater than or equal to 0.98 (Table 2). Figure 14 shows the comparison with ERA-40 as a scatter plot, the dew point is not included in the NCEP reanalyses.

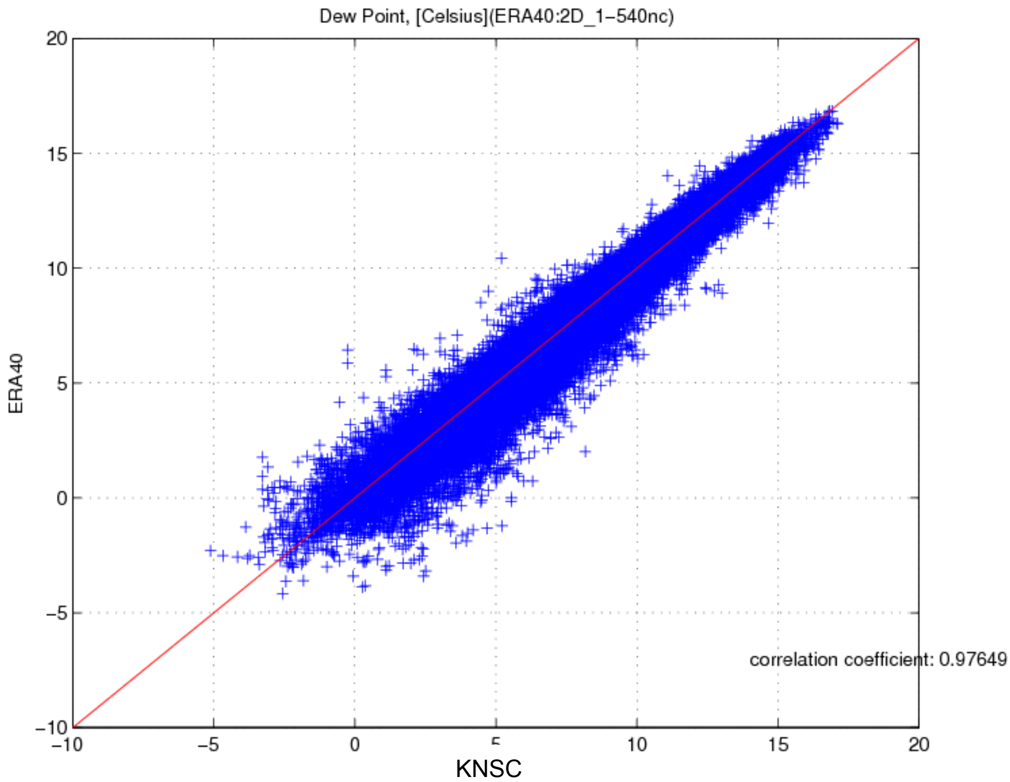


Fig 14: Scatter plot of the comparison of the monthly mean dew point in °C of the KLIWAS North Sea climatology with ERA 40 over the period 1957-2002

2.5 Data format

NetCDF files were created from the calculated mean values whose file names are constructed as follows:
Project_Parameter___Producer__Version__spatialresolution__temporalcoverage.nc

For example, the netCDF file for the monthly mean dew point for December 2010 is named as follows:
KNSC_Dew_Point___UHAM_ICDC__v1__1deg__201012.nc

The netCDF files contain in addition to the calculated mean values per parameter the standard deviation, the number of measurements and the number of neighboring boxes, which were included in the averaging process. Table 3 shows the parameters used names and units of the variables in the netCDF file.

Name	Units
airtemp (air temperature)	°C
airtemp_stddev (standard deviation)	°C
airtemp_noobs (number of observations)	-
airtemp_boxcount (number of boxes)	-
airpressure (air pressure)	hPa
airpressure_stddev (standard deviation)	hPa
airpressure_noobs (number of observations)	-
airpressure_boxcount (number of boxes)	-
dewpoint (dew point)	°C
dewpoint_stddev (standard deviation)	°C
dewpoint_noobs (number of observations)	-
dewpoint_boxcount (number of boxes)	-

Tab. 3: names of parameters and units in the netCDF files

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