DJUNGAR GATE AND CHILIK CORRIDOR - KAZAKHSTAN

THE WIND ENERGY POTENTIAL

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A study carried out for the UNEP/GEF and Government of Kazakhstan project "Removing Barriers to Wind Power Production in Kazakhstan"

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Contents

Executive summary

This report presents the results of a comprehensive wind resource assessment programme in Kazakstan. The aim of the programme has been to establish the meteorological basis for the assessment of the wind energy resources in the Djungar Gate and in the Chilik Corridor and in particular in the areas around the measurement sites. The main objective has been to provide reliable and accurate wind data sets for evaluating the potential wind power output from large electricity producing wind-turbine installations at the two locations. The derived wind atlas data sets provide the background for detailed siting of large and small wind turbines, in clusters as well as in wind farms.

The study employs wind speed and direction measurements taken over one year from May 1998 to May 1999 at four meteorological masts in the centre of Djungar Gate and one mast in Chilik Gate. In addition, the global database *NCEP/NCAR- reanalysis* for 1965 - 1998 has been used to assist in quantifying the year to year wind climate variations. Further, historical data from previous investigations have been examined and compared with the present results. The five 32-m masts were instrumented specifically for the wind study, but provided information on other climate statistics as well: atmospheric pressure, air temperature, air temperature gradient, atmospheric stability, wind speed profiles, extreme wind speeds, and gustiness of the wind.

The wind data from the five stations are analysed using the Wind Atlas Analysis and Application Program (WasP), following the procedures and guidelines of the European Wind Atlas. For the five stations, the accuracy of the wind speed measurements has been secured by wind tunnel calibration of the cup anemometers. The roughness of the terrain has been assessed from topographical maps as well as during site visits. The height variations of the terrain which are used for assessing the influence of the orography on the wind measurements and wind climate estimations have been obtained by digitisation of topographical maps of a scale 1:50:000. The digitised topographical data have been complimented by data obtained from *GTOPO30* global data base, which has a resolution of 30 arc seconds, i.e. less than one kilometre.

The study documents the existence of a very high wind energy resource at both locations. With mean wind speeds and energy densities of the order 7.5 ms^{-1} and 525 Wm^{-2}, respectively, measured at a height of 10 m in Djungar Gate, the wind resource is comparable or better to the wind

resource found over the North Sea north of Scotland. The wind resource in Chilik Corridor is somewhat lower but still substantial: 5.8 ms^{-1} and 240 Wm^{-2}, respectively at the height of 10 m. This is comparable to a good open site in Northern Europe. The yearly power productions from three different common wind turbines have been estimated at the location of the meteorological masts. As an example, a wind turbine with a rated power of one MW and a 50 m hub-height will produce what corresponds to 4400 full load hours in Djungar Gate, which makes this location most likely to the best wind turbine site in the world. The corresponding number for Chilik Corridor is 3100 hours, which is very good compared to windy sites around the world.

The wind atlas methodology, originally developed for wind resource assessment and siting in Europe, has proven very useful in applications all over the world. Applied with care, it can provide accurate predictions of the wind climate at candidate sites for wind turbines in Djungar Gate and Chilik Corridor. The reliability of wind power calculations based on the statistics obtained by WasP program depends on the reliability of the data from the particular station from which the statistics have been derived, i.e. on the quality of the data and the amount of information available. Secondly, it depends on the complexity of the terrain; at the meteorological station as well as the sites of interest. Finally, the geographical variability of the wind resource will necessarily add to the uncertainty of the estimates. In the present study it is estimated that the power productions calculated at the measuring sites by means of the measured data can be considered representative for the yearly production over the life time of the wind turbine with an uncertainty of 15%. Due to the narrowness of Djungar Gate, the geographical representativeness of the measured wind climate has a limited extent - five kilometres up and down the valley from the sites. This is due to a suspicion of a relatively strong gradient along the valley, a suspicion that has partly been supported by preliminary modelling of the flow in the valley by means of a meteorological meso-scale model. The conditions in Chilik valley are much more homogeneous and the representativeness of the data is expected to extend 20 or more kilometres from the meteorological mast.

The present report covers only a period of one year, but the lay-out is that of a Wind Atlas - hence, if more years of measurements are obtained and more in-depth analysis is performed, the report can be completed to serve as a "true" *Wind Atlas for the Djungar Gate and the Chilik Corridor.*

Table 1. Table of main results. The measured and corrected mean wind speeds and energy densities are given for the lowest placed anemometers, approximately at the height of 10 metres. The same quantities are calculated by means of WasP for the height of 50 metres. The calculated power productions from three common types of turbines are also given. The calculations are based on the power curves provided by the manufactures: NEG Micon (750kW), Bonus (1000kW), and Vestas (1800kW).

STATION	MEASUREMENTS				POWER PRODUCTION GWh/y		
	10 meter		50 meter		750kW	1000kW	1800 kW
	m/s	W/m2	m/s	W/m2			
D1	7.55	525	9.67	1016	3.40	4.40	7.88
D2	7.66	543	9.79	1049	3.45	4.47	8.00
D3	7.09	435	9.46	939		4.30	
D4	7.19	492	9.79	1095	3.42	4.41	7.91
CC	5.84	237	7.77	510	2.49	3.19	5.71

Preface and acknowledgements

The present report is the result of an investigation of the climatic wind conditions at two locations in Kazakstan: The Djungar Gate and the Chilik Corridor.
Risø National Laboratory and the Ministry of Energy and Natural Resources, Kazakhstan conducted the investigation from March 1998 to the date of publication under the sponsorship of UNDP/GEF. The report concludes and reports the findings of a Wind Resource Assessment Programme, which is a components of the UNDP/GEF and Government of Kazakhstan project *Removing Barriers to Wind Power Production in Kazakhstan (KAZ/96/G41/A/1G/01).* The Wind Resource Assessment Programme has had four major objectives:

1. Establishment and maintenance of five meteorological stations in Kazakhstan.
2. Establishment of a data base of at least one year of wind data from the Djungar Gate and the Chilik Corridor.
3. Transfer tools and methods to the Project Management Office (PMO), Almaty for wind resource assessment.
4. A wind resource assessment based on the measured data and the wind atlas method for the two locations.

The detailed scope and extent of the Wind Resource Assessment Programme were determined during a survey mission at the start of the programme (E.L.Petersen, 1997).

Dr. Marat Kombarov of ALMATYENERGO and his team comprising Valeriy Zhiltsov and Yerik Bekessov were responsible for planning, co-ordination, and assistance during installation and putting into operation, operation and maintenance for the first half year (April to October 1998).
Mr. Michael Eberhardt (from MDE Consult Aps) performed operation and maintenance from November 1998 to June 1999.
Mr. Gennady Doroshin (Energy and Climate Change Programme Manager, UNDP) has carried out operation and maintenance from July 1999.

The success of the project would not have been possible without the continuing support by Mr. Vesa Rutanen, Climate Change Specialist, Global Environment Facility (GEF), UNDP and Mr. Knut Ostby, Deputy Resident Representative, UNDP, Almaty, Kazakhstan.

We are indebted to many of our colleagues for their help and support during the course of this project. At Risø we would especially like to thank Mr. Jan Nielsen for his effort during the establishment of the meteorological stations and Dr. Helmut Frank for providing us with extracted information from NCEP/NCAR reanalysis database and the GTOPO30 global data base in addition to running the Karlsruhe Atmospheric Mesoscale Model (KAMM). Mr. Alfred Jonsen performed the MCP analysis of the Djungar Gate data.

1 Introduction to the wind atlas method

The aim of a Wind Atlas study for a location or a region is to establish the meteorological basis for the assessment of the wind energy resources. The main objective is to provide suitable data for evaluating the potential wind power output from large electricity producing wind-turbine installations. An important characteristic of wind energy is that the power output of a wind turbine is proportional to the third power of the wind speed. Therefore the precision requirements of wind speed statistics for energy assessments are higher than for most other purposes.
Another noteworthy characteristic of the wind is the seasonal and year-to-year variations of the wind conditions. An accurate determination of wind climatologies must take account of these variations, therefore several years of wind data should be used in the analysis.
Hence, the application of wind measurements to wind power calculations demands long time series of high-quality wind data. The meteorological stations used for the present study have provided one year of wind data, where a high quality has been secured by wind tunnel calibration and careful maintenance.

The wind speed measured at a meteorological station is determined mainly by two factors: the overall weather systems, which often have an extent of several hundred kilometres, and the nearby topography out to a few tens of kilometres from the station. Strictly speaking, the direct use of measured wind speed data for wind resource calculations results in power estimates that are representative only for the actual position of the wind-measuring instruments. The application of measured wind speed statistics to wind energy resource calculations in a region therefore requires methods for the transformation of wind speed statistics.

In the present study, what has become known as the *wind atlas methodology* has been applied. This comprehensive set of models for the horizontal and vertical extrapolation of meteorological data and the estimation of wind resources was developed for the analysis presented in the European Wind Atlas (Troen and Petersen, 1989). The actual implementation of the models is now known as the *Wind Atlas Analysis and Application Program* -- or WAsP for short -- which is the software package that has been applied for the present study.

The models are based on the physical principles of flows in the atmospheric boundary layer and they take into account the effect of different surface conditions, sheltering effects due to buildings and other obstacles, and the modification of the wind imposed by the specific variations of the height of ground around the meteorological station in question. Figure 1
Illustrates the use of these models on measured wind data to calculate a regional wind climatology.

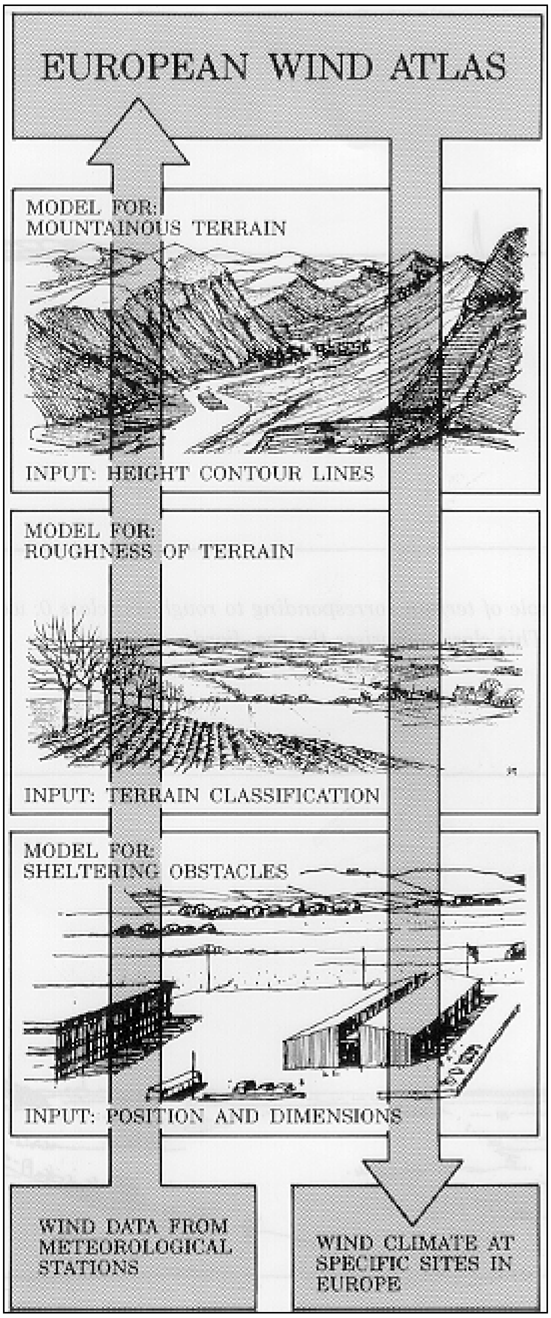


Fig.1. The wind atlas methodology of WasP. Meteorological models are used to calculate the regional wind climatologies from the raw data. In the reverse process -- the application of wind atlas data -- the wind climate at any specific site may be calculated from the regional climatology.

The figure also illustrates the so-called *application part* of the methodology, following a procedure in which the regional wind climatologies are used as input to the same models to

produce site-specific wind climatologies and, given the power curve of a wind turbine, production estimates.
For more detailed information on the models and the \wasp-program, the reader is referred to the European Wind Atlas (Troen and Petersen, 1989) and the WAsP User's Guide (Mortensen et al.; 1993a, 1993b), respectively.

Regional wind climatologies have been calculated for each of the five stations. These results are presented in Chapter Wind statistics and climatologies. The stations are shown on the map below, Fig. 2, and further listed in Table 2.

Table 2. The location of the five meteorological masts.

Station	Latitude	Longitude	Grid E	Grid N	Altitude
D1	45°25.88'	82°16.09'	14599239	5033752	
D2	45°26.01'	82°16.39'	14599627	5033999	
D3	45°26.79'	82°18.99'	14602994	5035499	
D4	45°27.61'	82°21.34'	14606033	5037069	
CC	43°43.13'	78°44.65'			

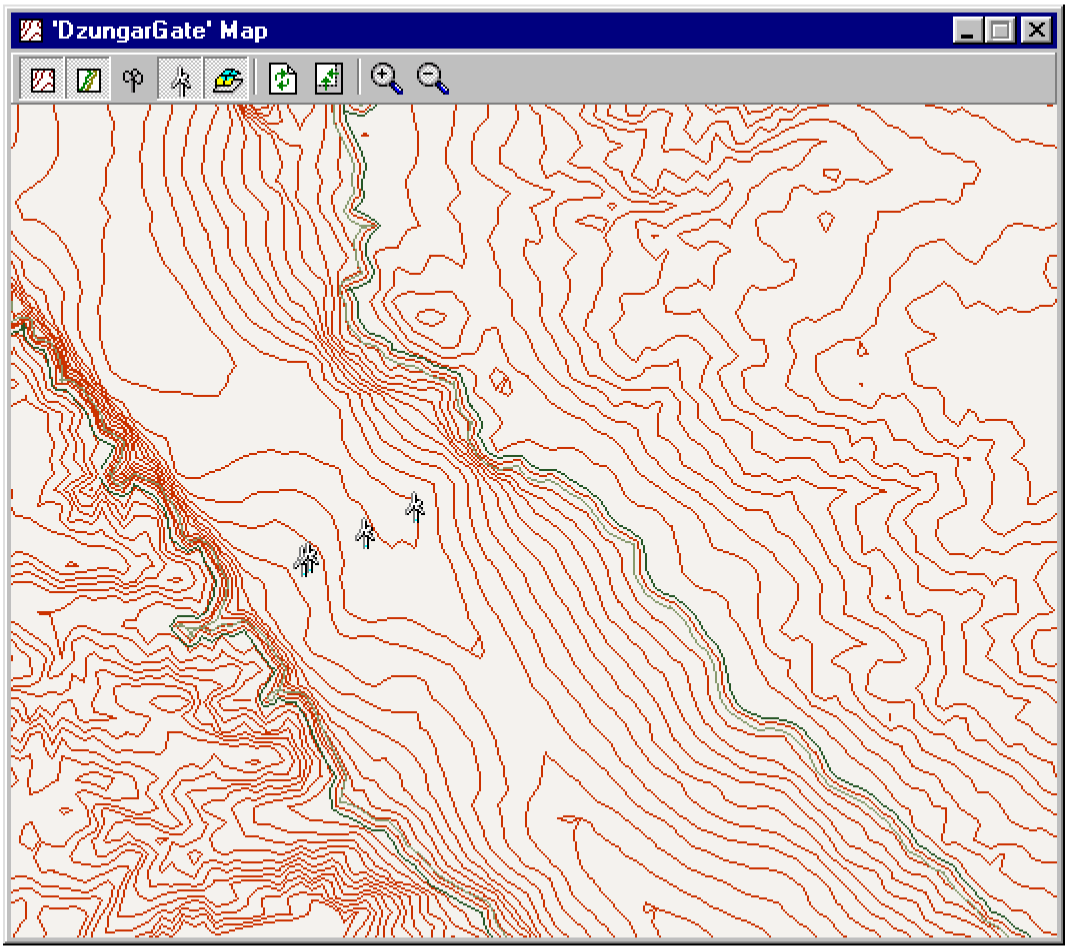


Fig.2. Map of the Djungar Gate. Overview map of the study area in Djungar Gate. The four main wind atlas stations are shown.

For each of the five stations time-series of wind speeds and directions were analysed, taken every ten minutes over a period of one year. In addition, an accurate description of the station and its surroundings was collected from maps, and during field trips, which included:

- terrain roughness, i.e. water areas, desert surfaces etc.
- nearby sheltering obstacles such as buildings
- terrain height variations (orography)

For the calculation of regional climatologies, the station descriptions and the models were used to transform the measured data set of wind speeds and directions from each station to what would have been measured at the location of the station if the surroundings were as follows:

- flat and homogeneous terrain
- no nearby obstacles
- and measurements had been taken at heights of 10, 25, 50,
- 100, and 200~m above ground level.

For example, one of the transformed data sets represents wind speed and directions at 25 metres above open water.

With four roughness classes and five standard heights, the measured data set from each station is thus transformed into 20 generalised data sets. These 20 data sets from each of the stations form the basis of the regional wind climatology, because through the transformation procedure the data sets were -- to the extent that the models can adequately describe the flow -- freed from the influence of local topography to become *regionally representative.*

How regionally representative a transformed data set is depends on the complexity of topography and obstacles surrounding the meteorological station. The representativeness of a station is severely reduced with increasing complexity of the surrounding orography. For the stations in the Djungar Gate the applicability of the wind atlas data to estimate the wind climate of the surrounding regions is strongly limited by the complexity of the terrain and the representativeness is also reduced by the spatial variation in the overall wind climate along the valley. At the Chilik Corridor, the large broad valley and homogeneous topographical conditions favours the use of the wind atlas statistics over a much larger area than is the case in Djungar Gate.

It must be emphasised that the regional climatologies, i.e. the 20 transformed data sets obtained from each station, are based on data measured at low levels i.e. at 32 or 10 metre height.
Not only might the transformation and use of such data for horizontal extrapolation lead to large uncertainties, but also the transformation up to greater heights is associated with errors. The physical theories which have been used to construct the vertical transformation procedures have proven their validity

up to heights of approximately 100 metres through comparisons with data sets from many meteorological towers, situated mostly in temperate climates. In the Djungar Gate and Chilik Corridor areas, large daily variations in the heatflux occur, leading to large variations in atmospheric stability and the vertical profiles of horizontal mean wind speed. Although the evidence presented in Chapter 3 shows good agreement between measured and modelled data at these two levels, the statistics derived for larger heights are associated with larger uncertainties than the uncertainties pertaining to the measurement level.

The most important statistic to be derived from a wind speed data set for use in wind energy resource estimation is the *probability distribution function*. This is because when this function has been determined for a given site, the calculation of the average yearly production of any wind turbine installed at the site is only a matter of integrating the product of this function and the power curve of the wind turbine.

A basic hypothesis of the Wind Atlas is that wind speed data are distributed according to the *Weibull distribution.* The Weibull distribution usually gives a very good fit to observed wind speed data and this has also been found to be true for the stations in this study. Chapter 3 and Appendix E provide both the raw data histograms and the fitted Weibull distribution curves. The distribution is characterised by two Weibull parameters: the scale parameter **A** is related to the mean value of the wind speed and the shape parameter **k** determines the shape of the Weibull curve.

The Weibull parameters fitted to the 20 transformed wind data sets are found in the Total columns of the station statistics, see Chapter 3. For the purpose of determining the wind resources at sites in which the roughness class changes with the wind direction -- for example a coastal site -- each of the 20 wind data sets has been divided into 12 further data sets according to wind direction. The parameters of the Weibull distribution function fitted to the wind speed/wind direction data sets are also given in the station statistics. Finally, the station statistics include a table with mean wind-speed values and the corresponding mean energy density of the wind for four roughness classes and the five standard heights.

The reliability of wind power calculations based on the wind atlas statistics depends on the reliability of the data from the particular station from which the statistics have been derived, i.e. on the quality of the data and the amount of information available. An appraisal of the data quality for the stations can be made by means of the figures and tables given in Chapter 3. The meteorological sensors and data acquisition systems used for the five stations are described in detail in Appendix A.

2 Wind resources of the Djungar Gate and the Chilik Corridor

This chapter presents an overview of the wind climate and wind resources in the Djungar Gate and the Chilik Corridor mainly based on the results of the Wind Resource Assessment Project, which are compared with results from previous investigations. The global database NCEP/NCAR - reanalysis for 1965 - 1998 is used to study the year to year wind climate variations

2.1 Previous investigations

The main information available to the Survey Mission (E.L.Petersen, 1997) was a note from Dr. Paiyzhan Kozhahmetov, Main Administration for Hydrometeorology, Weather Bureau, Almaty, summarising a thesis by himself concerning the wind pattern in Djungar Gate. The note gives basically the information that the highest wind speeds are found in the NW of the Gate (Zhalanashkol) compared to the SE (Druzhba), but also a higher seasonal variation, i.e. the wind speed in the winter is much higher in the NW but the summer wind lower. According the note the yearly averages are for NW and SE, 8.1 and 6.9 m/sec and the 20 years maximum 60 and 50 m/sec respectively. Further to the note, the measuring height is 10 meters and the period of observation 1961 - 80. The averages compare well with the measured averages at the stations D1 to D4 with values ranging from 7.09 to 7.66 m/s. The highest gust measured is 36.4 m/s at D2 metres, considerable lower than the numbers given above - but also only based on one year of data. Much data collection has been attempted in Djungar Gate but apparently in vain. There exist however half a year of measurements of wind speed and - direction at the height of 16 and 25m at Station D1. The data are hourly values from the period October 5., 1994 to March 23. 1995, but unfortunately the only evidence of these data is a very rudimentary analysis in a Pre-feasibility study (J. Slimak, 1995). The mean wind speeds found in this high wind season are 8.4 and 8.9 m/sec for the two heights. The maximum speeds are 22,2 and 24,0 m/sec, respectively. Compared with the measurements at D2 at 26.6 metres, we find the numbers that corresponds to 8.9 and 24.0 to be 9.5 and 34.5 m/s, e.i. considerably higher. However, it is known that during the half year of data collection the instruments suffered from occasional over-icing, which can account for the lower values.

Long term climatological data have been collected at three stations of interest for assessing the wind resources of Djungar Gate: Dzungaria,

Zhalanashkol, and Druzhba. Dzungaria is further to the NW of Zhalanashkol.
Data exists at least 40 years back from these stations but the only station in existence today is Zhalanashkol. That is to say, the anemometer blow down in 1996, hence there is no wind speed measurements from this station at present. The two other stations have been put out of operation presumably sometime after the independence in 1991.
Ín a report made by "Open Joint-Stock Company Kazselenergoproject, Kazakhstan" for UNDP/GEF monthly and yearly statistics are presented for the three stations for the period - approximately - 1956/1968. The averages for Zhalanashkol and Druzhba are given as 7.6 and 6.9 m/s respectively. This compares well with the results of the present project.
In 1998 the Netherlands Energy Research Foundation ECN published the Report "Wind Energy in Kazakhstan. Part1: Market Development Study" (F.J.L. Van Hulle et al., 1998). The project team had obtained long-term frequency distributions from a large number of meteorological stations in Kazakhstan based on measurements from 1950 to 1975. For the two stations Dzungaria and Druzhba the average wind speeds at 10m were found to be 6.8 and 7.0 m/s, respectively. The corresponding Weibull parameters were A;k: 6.8;1.09 and 8.2;1.7. Again, these numbers compare reasonable well with the values measured in the present project.

2.2 The wind climate of Djungar Gate.

The evidence of the wind climate of Djungar Gate that has been collected by the Project is, due to the short period of the measurements, of a fragmentary nature. But it ads to the evidence or indicators of a very famous wind climate. In the well- known comprehensive World Climate Survey, Ref.3, the following description can be found:

> "By far the most significant and most well known winds in Central Asia are those that blow from either direction through the Dzhungarian Gate on the Soviet-Chinese border east of Lake Balkhash between Lake Alakol on the Northwest and Lake Ebi-Nur on the Southeast in China. The Dzhungarian Gate is only 10 km wide at its narrowest near Lake Zhalanashkol. Zhalanashkol has strong winds 100 days per year with maximum velocities of 70 m/sec. January and December have strong winds about 18

> days per month. After temperatures have been 20 - 30 degrees C below zero thaws occur and clouds dissipate. The southeasterly winds are the best known since they create intense, broad-scale foehn conditions on the Soviet side of the border as they approach Lake Alakol. These are known as the “ibe” because they blow out of the Lake Ebi-Nur region. The local inhabitants in the Alakol´skoy Valley call these storm winds the “evgey”. The winds that blow from the Northwest across Lake Alakol´ into the Dzhungarian Gate are known as the “saykan”. During the late 1950´s and early 1960´s when the railroad was being laid through the pass to the Chinese border weather records were kept that show that the ibe frequently reached speeds of up to 60 m/sec and on one occasion the anemometer of Surazhskogo registered a wind of 80 m/sec. Wind blows there as if it were blowing through a wind tunnel. The meteorological station had to be built to withstand such high winds, and the observation tower had to be connected to the station with a cable so that it would not blow down. The speed of the winds is such that not only snow and sand but also light gravel is lifted to considerable heights into the air. Visibility is reduced to less than 5 m."

The strong wind climate of Djungar Gate has another physical basis than the climate in the Californian wind farm valleys where the large temperature difference between the Pacific Ocean and the desert behind the mountain passes gives rise to strong opposite diurnal winds. In Djungar Gate it is more the overall weather systems such as cyclones and anti-cyclones that are strongly affected when they approach and encounters the mountains. The flow is forced not alone through the Gate from the NW and SE entrances but also over the mountains. Some of the flow that goes over the mountains will enter into the Gate dependent on the upper air wind speed and wind direction and the vertical temperature profile. Therefor one can not expect the flow to be just bi-directional, i.e. from either of the to directions NW or SE. This is clearly depicted in the wind roses given in Chapter 3. showing that most of the winds come from the two quadrants 90 to 180 degrees (East to South) and 270 to 0 degree (West to North). In the latter, however there is almost none coming from 270 to 315 degrees (West to Northwest).

The picture which is emerging of the Djungar Gate wind climate is that the wind climate changes from one location to another dependent on the proximity to the mountains and the to entrances. One might expect the changes occur more gradually along the valley than across it. In order to get more insight into the nature of this variation it is necessary to apply a meteorological model to situation. Basically such a model solves the equation of motion numerically on a super-computer; it requires as input, among others, the topography, and an initial wind and temperature field. The model results, which are presented in Appendix D, were produced by applying the Karlsruhe Atmospheric Meteorological Model (KAMM) to topographic data with a spatial resolution of one km. The initial field of wind and temperature is given by a standard atmosphere, where the wind direction is selected at 10 different directions: 0; 30; 90; 120; 150; 180; 210; 270; 300; 330. The upper free wind was arbitrarily chosen to 10 m/sec (a common value for northwestern Europe). The model runs are only indicative, for a more thorough study it would be necessary to apply the NCEP/NCAR - reanalysis data for the upper air conditions over Djungar Gate. An overview of the statistics obtained from these data, representative for the atmosphere above Djungar Gate, is presented in Appendix C. It has not been possible to apply these data to the mesoscale modelling for the present study due to the model's excessive demand on computer time. Each of the runs presented in the Figures D1 to D10 takes 20 minutes on a super computer. It is envisioned to perform the modelling at a late stage - possibly at the completion of two years of measurements in Djungar Gate. This is because, it is necessary to have good long term surface data in order to calibrate the model for such extreme climatic and topographic conditions as those existing in the Gate.

Looking at Fig.D1 with the upper wind coming from the North: The punctured lines are height contours, the full lines are lines of equal wind speeds, and the arrows are wind vectors where the scale is given in the upper left corner. The numbers in the upper left corner outside the plot explain that the wind is calculated at the height of 25m, the upper air wind is 10 m/sec, and the direction is 0, i.e. from the North. The locations of the two meteorological stations, Zhalanashkol and Druzhba, and the location of the two masts are also shown. It is seen that the flow follows the valley in the middle, turning slightly towards a North-South direction. The wind increases going from North to South where it almost exceeds the upper air wind by a factor of two. This is a situation, which mainly occurs during summer. Here Druzhba experiences the highest wind speeds. Fig.D9 with the upper air wind coming from 330 degrees resembles that of the previous figure but turning further 30 degrees to 300 one see a strong gradient across the valley and a rather complicated picture. Going 30 further around to 270 (Fig.D7) a situation with almost no wind in the valley is depicted. This equals Fig.D2 with the upper wind from 90 degrees: very low winds in the valley. The Figures D3, D4, and D5 show situations most likely to appear during wintertime. The upper air directions are 120; 150; and 180. The winds are much lower in the South compared to the North.

The detailed results of the Wind Resource Assessment Project are found in Chapter 3 and Appendix C. A description of the stations and meteorological sensors employed for the Project is given in Appendix A, and the organisation of the data is accounted for in Appendix B. An overall summary of the wind climates measured at the five stations is given in Table 3and Table 4.

*Table 3. Overall summary May 1998 - May 1999 of wind observations at the height of ten metres at the five stations; data recovery rate (R), mean wind speed (**U**), maximum wind speed (MU), and maximum gust (MG).*

Station	R %	**U** m/s	MU m/s	MG m/s
D1	100	7.56	27.9	32.7
D2	91	7.53	27.5	
D3	100	7.11	22.9	
D4	91	6.97	22.9	
CC	80	5.78	23.8	

*Table 4. Overall summary May 1998 - May 1999 of wind observations at the height of 26 to 33 metres four stations; data recovery rate (R), mean wind speed (**U**), maximum wind speed (MU), and maximum gust (MG).*

Station	R %	**U** m/s	MU m/s	MG m/s
D2-27	91	8.41	30.6	36.4
D3-33	88	8.27	24.8	31.3
D4-33	91	8.28	27.0	36.6
CC-33	80	6.98	27.2	36.1

The data recovery in Djungar Gate is satisfactory and less so in Chilik Corridor. It appears from the tables in Appendix C, that the missing data periods occur over specific months, which adds to the uncertainty in the calculated wind atlas statistics. In order to reduce the uncertainty of the calculated statistics in Djungar Gate the gaps of missing data in the time series from D2 and D4 at ten metres were filled in by means of the data from D1 at ten metres and the *Measure - Correlate - Predict* method (MCP). Basically, the method establishes the correlation between to time series where they overlap and uses this correlation to predict one station by the other. The method is known to work well when the stations are well correlated which was found to be the case for the ten metres time series at Djungar Gate. Hence the complete time series of D1 was used to "repair" the time series of D2 and D4. The measurements from greater heights were not used in this study but will be part of a more comprehensive study, which will take the full data sets - hopefully two years or more - into account.
For the Chilik Gate nothing could be done to fill in the missing data.

In conclusion: We find that the measured statistics for the one-year period May98/May99 must be reasonably representative for a mean year. We base this conclusion on comparisons with the statistics obtained from the long term meteorological measurements at the three nearby meteorological stations, the statistics obtained from previous campaigns and finally the statistics calculated from the NCAR/NCEP- reanalysis project for the years 1965 to 1998 as presented in Appendix C.

3 Wind statistics and climatologies

In this chapter, the climatological data for the meteorological stations are presented in tables and graphs. For each station, the tables give the calculated regionally representative wind climatology obtained from the station data by applying the Wind Atlas analysis, together with a summary of the raw data and the measuring conditions. The raw data and some derived quantities are furthermore shown graphically in so-called wind climatological fingerprints (Troen and Petersen, 1989)

Raw data summaries

The raw data summary comprises the distributions of wind measurements in tabular and graphical form, as well as tables of the daily, seasonal and year-to-year variations of mean wind speed.

Daily and annual variation of wind speed. This table gives the mean wind speed as a function of time of day and month of the year. The time of day is given as Kazakhstan Standard Time, equivalent to Universal Co-ordinated Time + 5 hours.

Distribution of wind measurements. This table gives the sectorwise distribution of the raw wind speed measurements and the distribution of wind speeds within each sector. The frequency of occurrence of the winds in the sectors is given in per cent, whereas the distribution of wind speeds is given in per mille (tenths of per cent) i.e. normalised to 1000 within each sector. The table pertains to the anemometer height in metres above ground level (m~a.g.l.).

A Weibull distribution function has been fitted to the wind speed distribution in each sector. The resulting Weibull **A** m/s and **k** parameters are listed in the last two columns of the table.

The wind climatological fingerprint

The purpose of the graphical presentations of wind data given on the left-hand side of the second opening is to give a compact and informative overview of the wind data used for the Atlas. The first line states the name of the meteorological station and the period over which the data were collected. This is followed by the height above ground level where measurements were taken, the mean value, the standard deviation and the mean value of the cube of the measured wind speeds. The graphical presentation consists of five graphs:

The mean year

The average seasonal variation of the measured wind speed (full line) and cube of wind speed (dashed line) is shown in the top left graph. All data associated with the same calendar month are averaged and the results plotted at the midpoint in each of the

indicated monthly intervals. The unit on the ordinate is m/s for mean speeds and m3/sec3 for the mean of the cube of the wind speed. Values read from the graph must be multiplied by the scale factor given to the right.
The continuous curves are obtained by interpolation using a periodic cubic spline. The speed data are also contained in the tables on the station description pages.

The mean days

The average daily variation of the measured wind speed for the months of January and July are shown in the top right graph. The average hourly variation of wind speed is shown in full lines for January and July and for the cube of wind speed dashed lines are used. Data from all months of January (July) associated with the same time of day are averaged. Results obtained for each of the indicated standard hours are plotted using an interpolating smooth curve (periodic cubic spline). The mean ordinate for each curve is identical to the ordinate on the corresponding mean year curve (top left graph) at the January (July) points. The unit on the ordinate is m/s for mean speeds and m3/s3 for the mean of the cube of speed.
Values read from the graph must be multiplied by the scale factor given to the left. Mean days for each calendar month are calculated and define -- for each calendar month -- a mean or reference day which is used as reference in calculating the spectrum below. The speed values are contained in the tables in the station descriptions.

The wind rose

The relative frequencies of winds coming from each of twelve sectors are shown in the middle left graph as the radial extent of the circle segments spanning the sectors (thick lines). The contribution from each sector to the total mean speed and to the total mean cube of speed are given as the narrower segments and the central segments respectively. For each quantity the normalisation is such that the largest segment extends to the outer dotted circle. The corresponding value for each of the three quantities is given in the small box in per cent (numbers given to the nearest integer). The inner dotted circle corresponds to half of this value.

The spectrum

The contribution to the total variance of wind speed for a range of periods is shown by the full curve in the middle right graph. The vertical scale is arbitrarily adjusted to centre the curve. The abscissa gives the periods on a logarithmic scale. The curve is calculated from the total time series by first subtracting the monthly mean day values from each day data, hour by hour. The monthly mean days for all twelve months were calculated as described for January and July above. The mean days are in this context considered deterministic in contrast to the calculated time series of deviations, which form the stochastic part. This is followed by a Fourier transform of the deviations and the spectral estimates are squared and block averaged over bands of equal relative bandwidth corresponding to the widths of the steps in the curve.

The full vertical bar on the left side gives the contribution to the standard deviation of wind speed in the whole set of data from periods which fit into one year. This is calculated as the standard deviation of the mean year. The adjacent dashed bar gives similarly the mean year contribution to the standard deviation of the cube of wind speed. Units are per cent of the total standard deviation of the data. Similarly the bars on the right give the contributions to the standard deviations of speed and cube of speed by periods which fit into one day, i.e. 24, 12, 8 and 6 hours in the present case of basic 3-hourly data. The numbers listed at the top left inside the graph are the contribution to the total standard deviation in per cent by the random variations contained in the variance spectrum, divided into the part with periods longer than one year, periods between one year and one day, and periods smaller than one day (the sum of squares of the contributions of the three random parts together with the contributions from the deterministic mean year and mean day adds to unity). The numbers in the small box below the graph give the relative standard deviation for speed and cube of speed for the mean January day (first two numbers) and the mean July day (last two numbers).

The time print (not applicable for time series less or equal one year)

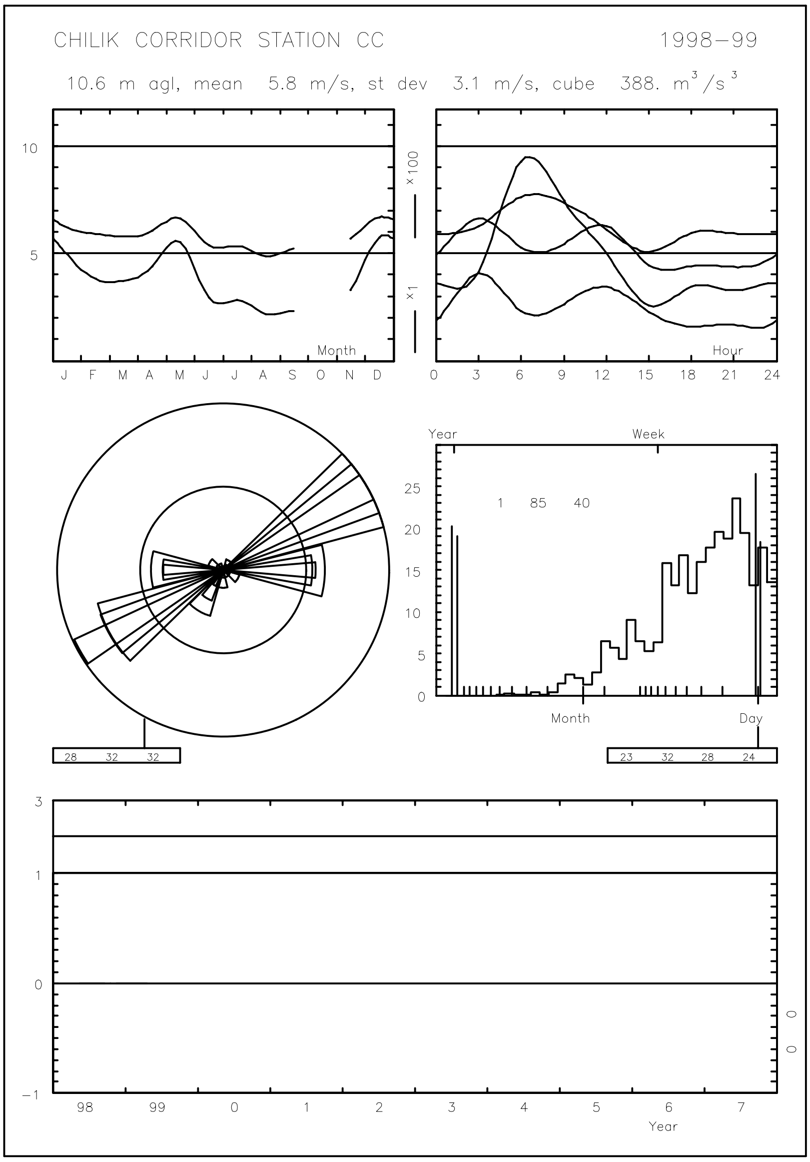
The month-by-month relative deviation from the mean months is shown in the bottom graph. For each month the average speed and cube of speed is calculated and the expected value from the corresponding calendar month in the mean year (top left) is subtracted. The relative deviation is shown by the jagged lines -- full line corresponding to speed and dashed line corresponding to cube of speed. The smoother full line shows the year-by-year relative deviation of mean speed from the total average. Each point on this curve gives the relative deviation in the period extending backwards and forwards one half year (centred block averages). The centre value for each calendar year thus gives the deviation for that particular year. The open circles show similarly the relative deviation of the mean cube of speed for each calendar year. The numbers to the right give the root mean square of the calendar year deviations in per cent for speed (lower number) and cube of speed (upper number). The vertical scale is linear from -1 to +1, and shifts at +1 to a coarser linear scale which is adjusted to accommodate the largest deviations.

CHILIK GATE STATION CC

Height of anemometer: 10.6 m a.g.l.

hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
0	5.9	5.8	5.1	4.7	5.4	4.0	5.0	4.1	5.1	4.0	6.1	6.3	5.2
1	6.1	5.7	5.1	5.1	6.2	4.3	5.2	3.8	4.6	4.9	5.8	6.1	5.3
2	5.8	5.4	5.5	6.0	7.4	4.9	6.3	5.2	5.4	6.1	5.7	6.2	5.9
3	6.3	5.6	5.9	6.8	8.2	5.7	6.6	6.7	6.9	7.4	6.0	6.1	6.4
4	6.2	5.9	6.3	7.4	8.2	5.7	6.4	6.8	7.1	9.6	6.1	5.7	6.5
5	7.0	6.3	7.0	8.0	8.2	5.8	5.8	6.5	6.6	9.2	6.5	6.2	6.7
6	7.6	6.3	7.1	8.1	7.8	6.0	5.3	6.3	6.4	9.6	6.8	6.6	6.8
7	7.8	6.4	7.2	8.1	7.6	6.3	5.3	6.1	6.0	8.7	7.1	7.3	6.9
8	7.3	6.4	6.8	8.1	7.5	6.0	5.2	5.3	5.1	8.9	7.2	7.1	6.7
9	7.4	6.5	6.7	7.9	7.2	6.0	5.4	4.7	5.1	8.4	7.2	7.3	6.6
10	6.9	6.8	6.9	7.2	7.5	6.6	5.9	4.4	5.6	8.0	6.9	7.1	6.6
11	6.1	6.4	6.5	6.7	7.9	6.9	6.0	4.2	6.2	6.3	6.2	7.2	6.5
12	6.1	5.7	6.3	6.9	7.7	6.8	6.3	5.4	7.0	4.6	5.6	7.2	6.5
13	5.5	5.7	5.4	6.1	7.6	7.1	7.5	5.4	5.8	3.9	5.1	7.3	6.3
14	5.2	5.6	5.0	5.5	6.5	6.3	5.3	4.6	5.2	3.7	4.8	6.8	5.6
15	5.1	5.6	5.4	5.7	5.5	5.9	4.4	4.8	4.7	4.4	4.4	6.6	5.3
16	5.2	5.7	4.8	5.1	5.8	5.4	4.7	4.7	4.2	4.1	4.3	7.0	5.2
17	5.3	5.9	4.9	5.1	5.4	4.8	4.9	4.3	3.7	3.9	4.4	7.0	5.2
18	5.9	5.7	5.0	5.0	5.3	4.6	4.4	3.8	3.9	4.0	4.5	6.7	5.1
19	6.3	5.8	4.9	4.1	5.2	4.2	4.2	3.7	3.8	4.5	4.9	6.8	4.9
20	6.3	5.5	5.3	4.1	5.0	4.1	4.4	3.6	3.4	4.2	5.2	6.5	4.9
21	5.9	5.9	5.3	4.5	5.2	3.7	4.4	4.0	4.2	5.2	5.2	6.5	5.0
22	6.0	5.7	5.0	4.4	5.2	3.8	4.3	4.3	4.0	4.6	5.3	6.4	5.0
23	5.8	6.0	5.0	4.5	5.2	3.8	4.9	4.4	4.7	5.4	5.6	6.7	5.2
tot	6.2	5.9	5.8	6.0	6.6	5.4	5.3	4.9	5.2	-1.0	5.7	6.7	5.8

SECT	FREQ	<1	2	3	4	5	6	7	8	9	11	13	15	17	>17	A	K
0	0.9	125	348	242	170	47	22	8	17	8	11	0	0	0	0	2.7	1.37
30	1.8	57	165	223	146	119	115	62	73	31	9	0	0	0	0	4.2	1.78
60	27.6	5	20	51	76	104	117	140	140	130	168	42	6	0	0	7.7	3.11
90	17.3	7	46	113	189	151	82	75	70	77	111	56	15	5	3	6.4	1.74
120	2.8	47	171	351	274	132	15	4	3	3	1	0	0	0	0	3.2	2.50
150	1.3	85	322	316	167	85	15	4	2	2	4	0	0	0	0	2.8	1.91
180	2.9	63	217	297	208	141	51	10	6	5	2	0	0	0	0	3.3	1.99
210	7.8	22	78	126	180	209	165	96	49	29	40	5	1	1	0	5.2	2.19
240	22.1	7	39	74	106	118	110	114	98	88	127	68	38	10	3	7.6	2.09
270	12.1	14	70	134	135	126	111	118	86	69	79	35	15	5	3	6.4	1.87
300	2.2	71	230	280	185	109	49	33	12	10	13	4	2	1	0	3.3	1.39
330	1.1	119	285	304	170	43	21	17	11	9	11	6	4	0	0	2.8	1.26
Total	100.0	17	66	114	134	127	103	101	89	80	107	41	15	4	2	6.6	1.97

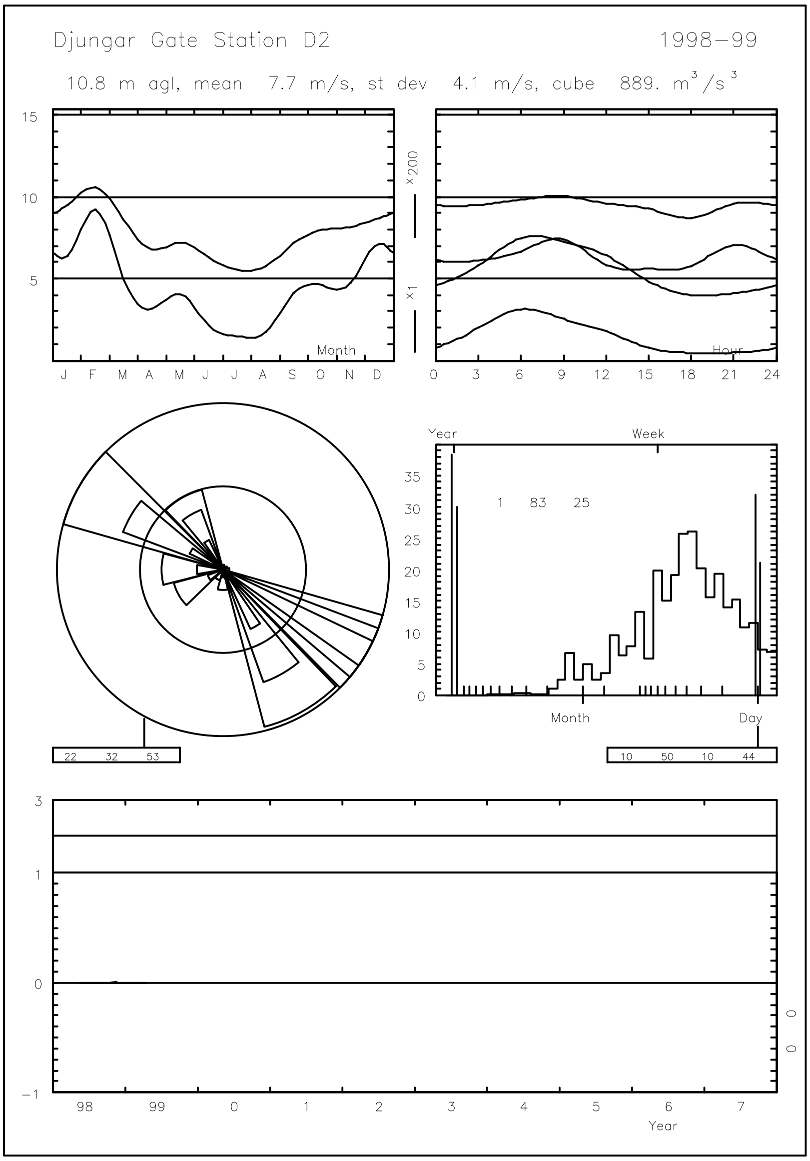

CHILIK CORRIDOR STATION CC
1998–99
10.6 m agl, mean 5.8 m/s, st dev 3.1 m/s, cube 388. m³/s³
Month
Hour
Year
Week
1 85 40
Month
Day
28 32 32
23 32 28 24
Year

DJUNGAR GATE STATION D2

Height of anemometer: 10.4 m a.g.l.

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
0	9.5	10.2	7.8	5.4	6.2	4.4	4.6	4.5	5.8	6.3	7.6	7.8	6.7
1	9.3	10.2	7.9	5.4	6.6	4.8	4.4	4.4	6.2	6.3	7.3	7.8	6.7
2	9.3	10.1	8.0	6.2	6.8	5.7	5.0	4.9	6.8	6.8	7.3	7.7	7.0
3	9.5	10.4	8.3	7.0	7.3	6.5	5.8	5.7	7.5	8.4	7.2	8.3	7.6
4	9.6	10.8	8.8	7.7	7.5	6.7	6.8	6.7	8.3	10.3	8.3	8.8	8.3
5	9.8	11.3	9.4	8.2	8.2	6.9	7.2	7.1	9.3	10.8	9.4	9.3	8.9
6	9.8	12.0	9.8	8.7	9.2	7.2	7.5	8.0	9.2	11.2	9.5	9.3	9.3
7	9.9	12.5	10.2	9.2	9.8	7.8	7.2	8.7	9.4	11.0	9.7	9.3	9.5
8	9.7	12.2	10.4	9.9	9.2	8.2	7.1	8.3	9.8	10.6	9.8	9.5	9.5
9	10.0	12.3	10.5	10.2	10.0	9.2	7.3	8.1	9.1	10.3	10.4	9.4	9.7
10	9.9	12.1	10.4	9.5	10.0	9.2	7.4	7.9	8.6	9.9	9.7	9.3	9.5
11	9.7	11.1	9.8	8.8	9.8	8.9	7.2	7.3	8.1	9.1	8.9	8.9	9.0
12	9.6	10.4	8.9	7.9	8.9	8.5	6.4	7.0	7.4	8.1	8.2	8.7	8.3
13	9.4	10.0	8.0	6.9	7.5	7.2	6.2	6.1	6.9	7.6	7.6	9.1	7.7
14	9.5	9.6	7.8	5.9	6.5	6.5	5.3	4.8	6.4	7.3	7.4	9.0	7.1
15	9.3	9.7	7.4	5.0	5.4	6.0	4.8	4.3	6.1	6.7	7.6	9.1	6.8
16	9.1	9.3	7.2	4.6	5.3	5.3	4.2	4.0	5.9	6.4	7.6	9.0	6.5
17	9.0	9.8	7.5	4.8	5.5	5.0	3.9	3.5	6.0	6.3	7.9	8.9	6.5
18	8.7	9.8	8.0	4.7	5.4	4.6	4.0	3.8	5.9	6.1	7.7	8.6	6.4
19	8.9	9.6	8.2	5.3	5.1	4.1	3.7	4.2	5.5	6.2	7.8	8.4	6.4
20	8.9	9.6	8.4	5.5	5.3	3.9	3.9	4.1	5.8	6.6	7.7	8.6	6.5
21	9.6	10.0	7.9	5.1	5.5	4.4	4.1	4.5	5.6	6.4	7.3	8.1	6.5
22	9.5	10.2	8.1	5.1	5.9	4.5	4.3	4.8	6.1	6.3	7.1	8.1	6.7
23	9.6	10.0	7.9	5.2	6.0	4.9	4.4	4.7	5.6	6.2	7.0	8.2	6.6
tot	9.5	10.6	8.6	6.8	7.2	6.3	5.5	5.7	7.1	8.0	8.2	8.7	7.7

Sect	Freq	<1	2	3	4	5	6	7	8	9	11	13	15	17	>17	A	k
0	0.6	55	212	166	92	43	43	18	3	22	46	95	132	71	3	6.6	1.24
30	0.3	109	442	256	171	8	0	0	16	0	0	0	0	0	0	2.3	1.69
60	0.7	57	167	86	83	66	66	155	307	11	0	0	0	0	0	5.8	2.85
90	0.8	100	337	277	133	85	28	17	14	7	2	0	0	0	0	2.8	1.53
120	22.4	7	22	31	35	42	51	53	51	52	150	153	134	108	110	12.6	2.75
150	21.8	4	23	43	53	79	109	115	97	88	156	150	54	17	14	9.1	2.38
180	3.0	34	122	187	194	163	141	88	23	11	15	19	3	0	0	4.6	1.80
210	1.5	27	173	170	231	171	115	66	30	10	5	3	0	0	0	4.2	2.10
240	7.0	3	51	265	436	158	59	19	5	2	1	0	0	0	0	3.8	2.87
270	8.3	6	30	71	189	306	245	91	38	14	9	1	0	0	0	5.2	3.25
300	22.5	1	11	27	51	91	153	166	159	145	144	41	10	1	0	7.9	3.13
330	11.1	3	16	30	37	59	63	86	125	153	246	102	62	14	3	9.6	3.27
Total	100.0	7	33	63	93	99	108	97	89	82	129	89	52	30	28	8.5	1.87

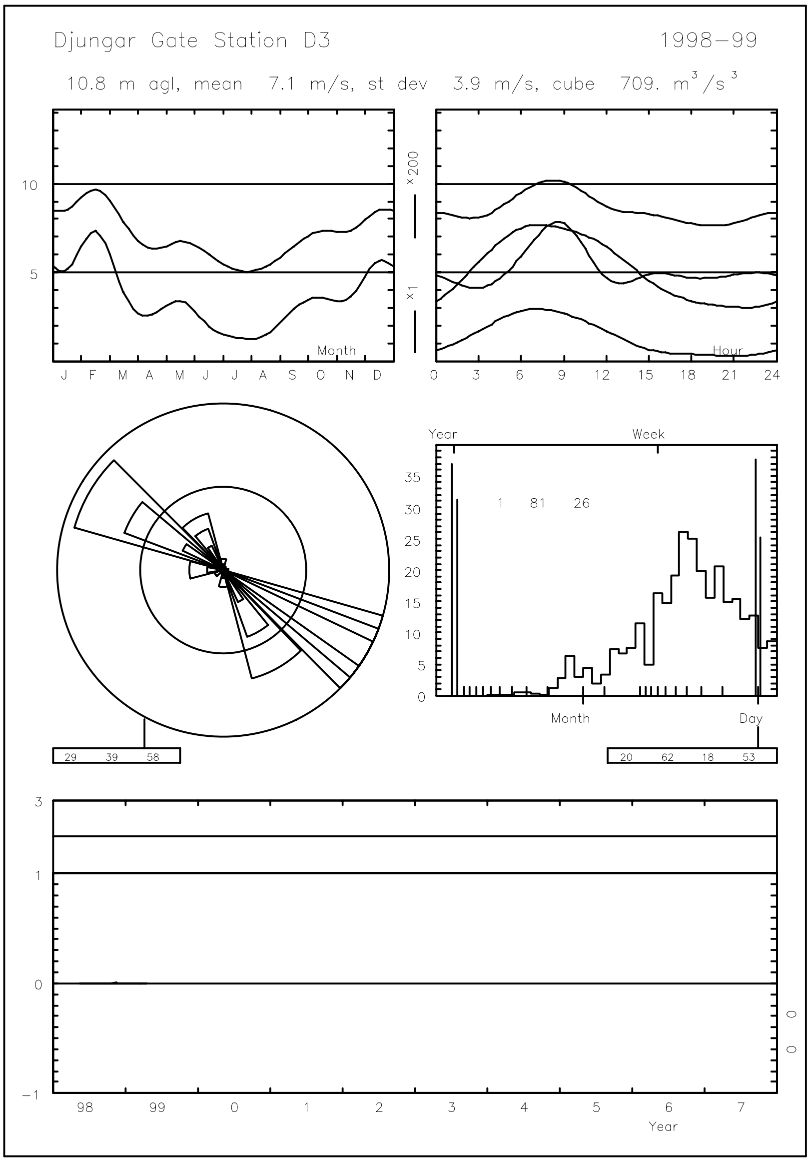

Djungar Gate Station D2
1998–99
10.8 m agl, mean 7.7 m/s, st dev 4.1 m/s, cube 889. m³/s³
Month
J F M A M J J A S O N D
×200
×1
Hour
0 3 6 9 12 15 18 21 24
22 32 53
Year
Week
1 83 25
Month
Day
10 50 10 44
98 99 0 1 2 3 4 5 6 7
Year

DJUNGAR GATE STATION D3

Height of anemometer: 10.7 m a.g.l.

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
0	8.4	9.3	6.8	5.0	5.5	3.8	3.4	3.5	5.1	5.9	6.2	7.6	5.9
1	8.4	8.8	6.6	5.0	6.2	4.4	3.6	3.4	5.2	5.8	6.3	7.6	5.9
2	7.8	8.8	6.7	5.9	6.5	5.4	4.8	4.5	5.7	6.5	6.3	7.8	6.4
3	8.1	9.2	7.5	6.6	7.1	6.3	5.6	5.4	6.8	8.2	6.4	8.0	7.1
4	8.7	10.5	8.4	7.4	7.4	6.4	6.5	6.5	7.8	9.7	7.6	8.4	7.9
5	9.2	11.1	8.7	8.1	7.8	6.9	7.0	6.8	8.5	10.2	8.8	8.9	8.5
6	9.5	11.3	9.3	8.2	8.7	7.2	7.5	7.7	8.7	10.5	8.8	9.4	8.9
7	9.8	11.7	9.8	8.8	9.3	7.8	7.2	8.4	8.6	10.4	9.2	9.4	9.2
8	9.8	11.7	9.8	9.4	9.1	8.1	6.8	8.2	9.1	10.1	9.4	9.3	9.2
9	10.1	11.6	10.0	9.6	9.6	9.0	7.5	8.0	8.6	9.7	9.5	9.0	9.3
10	9.7	11.3	9.7	9.1	9.6	9.0	7.4	7.6	8.4	9.2	9.0	9.1	9.1
11	8.9	10.5	9.1	8.5	9.5	8.8	7.1	7.0	7.7	8.4	8.0	8.5	8.5
12	8.7	9.6	8.4	7.5	8.5	8.2	6.5	6.8	7.0	7.3	7.5	8.6	7.9
13	8.4	8.8	7.2	6.7	7.2	6.9	6.1	5.9	6.0	6.4	6.9	8.9	7.1
14	8.2	8.7	6.8	5.5	6.1	6.2	5.0	4.5	5.8	6.3	6.6	8.7	6.5
15	8.3	8.6	6.5	4.5	4.8	6.1	4.5	3.8	5.4	6.0	6.8	8.4	6.1
16	7.9	8.6	6.4	4.3	4.9	4.9	3.6	3.8	5.2	5.8	7.0	8.2	5.9
17	7.8	9.0	6.7	4.1	4.8	4.4	3.3	3.1	5.1	5.8	6.9	8.3	5.7
18	7.7	8.7	6.9	4.0	4.8	4.2	3.4	3.4	5.5	5.6	6.7	8.5	5.8
19	7.5	8.9	7.3	4.6	4.5	3.8	3.1	3.9	4.9	5.7	6.6	8.4	5.8
20	7.7	8.7	7.6	4.9	4.9	3.7	2.9	3.9	5.2	5.8	6.7	8.6	5.9
21	7.8	9.0	7.5	4.7	4.9	4.0	3.0	4.0	5.1	5.6	6.6	8.1	5.8
22	8.3	8.9	7.3	4.4	5.0	4.4	3.5	3.9	5.1	5.4	6.2	8.3	5.9
23	8.6	9.0	7.0	4.6	5.2	4.5	3.3	3.7	5.0	5.6	6.3	8.2	5.9
tot	8.6	9.7	7.8	6.3	6.7	6.0	5.1	5.3	6.5	7.3	7.4	8.5	7.1

Sect	Freq	<1	2	3	4	5	6	7	8	9	11	13	15	17	>17	A	k
0	1.8	202	304	112	43	29	22	7	8	12	51	88	77	40	6	4.1	0.91
30	0.6	276	468	174	51	24	6	0	0	0	0	0	0	0	0	1.8	1.69
60	0.4	194	602	136	44	15	10	0	0	0	0	0	0	0	0	1.8	1.76
90	0.9	120	300	167	108	78	84	76	42	0	19	4	0	2	0	3.4	1.30
120	28.9	6	23	40	44	51	63	61	61	81	183	162	108	76	41	11.1	2.75
150	19.2	9	50	99	127	137	119	109	88	84	102	45	20	10	4	6.9	1.93
180	2.9	29	143	209	192	113	81	29	31	49	99	23	1	0	0	4.5	1.37
210	0.7	77	284	268	188	114	34	19	3	8	5	0	0	0	0	3.1	1.75
240	1.5	56	167	141	207	236	119	40	27	5	2	0	0	0	0	4.2	2.58
270	5.8	51	91	82	166	231	153	96	72	35	23	3	0	0	0	5.2	2.42
300	27.0	12	32	35	63	129	155	140	143	125	129	29	7	0	0	7.4	2.95
330	10.1	26	70	56	64	71	72	77	95	108	208	101	41	10	2	8.7	2.73
Total	100.0	22	59	66	83	106	105	92	89	88	134	76	42	26	13	8.1	1.96

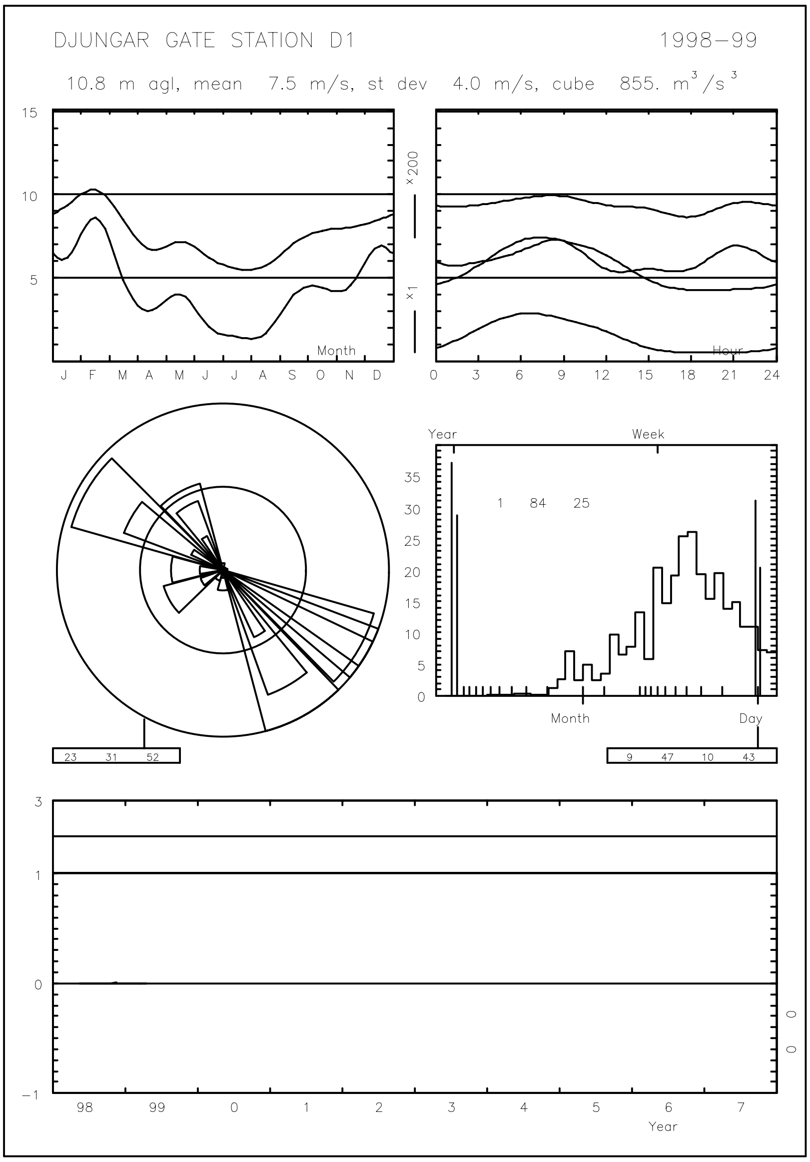

Djungar Gate Station D3
1998–99
10.8 m agl, mean 7.1 m/s, st dev 3.9 m/s, cube 709. m³/s³
10
5
Month
J F M A M J J A S O N D
x200
x1
Hour
0 3 6 9 12 15 18 21 24
29 39 58
Year
Week
35
30
25
20
15
10
5
0
1 81 26
Month
Day
20 62 18 53
3
1
0
−1
0
0
98 99 0 1 2 3 4 5 6 7
Year

DJUNGAR GATE STATION D1

Height of anemometer: 10.8 m a.g.l.

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
0	9.3	10.0	7.6	5.5	6.3	4.5	4.6	4.7	5.7	6.2	7.6	7.6	6.6
1	9.2	10.0	7.7	5.2	6.5	4.7	4.4	4.5	6.0	6.2	7.3	7.5	6.6
2	9.2	9.9	7.8	6.0	6.6	5.6	4.9	4.9	6.7	6.6	7.3	7.5	6.9
3	9.4	10.2	8.1	6.7	7.2	6.4	5.7	5.6	7.5	8.1	7.1	8.0	7.5
4	9.5	10.7	8.6	7.2	7.5	6.6	6.8	6.6	8.2	10.1	8.1	8.5	8.2
5	9.7	11.0	9.1	8.1	8.2	6.7	7.2	7.1	9.2	10.7	9.2	8.9	8.7
6	9.8	11.5	9.6	8.7	9.1	7.2	7.2	7.9	9.2	10.9	9.3	9.0	9.1
7	9.7	11.9	10.0	8.8	9.8	7.7	7.0	8.5	9.1	10.8	9.5	9.0	9.3
8	9.6	12.0	10.2	9.7	9.3	8.1	6.9	8.2	9.5	10.5	9.7	9.2	9.4
9	9.9	11.9	10.4	10.1	9.9	9.1	7.2	7.9	8.9	10.2	10.1	9.1	9.5
10	9.8	11.6	10.1	9.4	9.9	9.2	7.2	7.9	8.5	9.6	9.5	9.1	9.3
11	9.6	10.8	9.6	8.9	9.8	8.8	7.1	7.3	8.0	8.8	8.6	8.6	8.8
12	9.4	10.0	8.7	7.8	8.9	8.4	6.4	6.9	7.1	7.9	7.9	8.5	8.1
13	9.3	9.6	8.0	7.0	7.4	7.2	6.2	5.9	6.7	7.6	7.3	8.9	7.6
14	9.3	9.4	7.6	5.8	6.2	6.5	5.3	4.8	6.3	7.3	7.2	8.8	7.0
15	9.1	9.4	7.3	4.8	5.4	6.0	4.9	4.4	6.2	6.7	7.5	8.9	6.7
16	9.0	9.1	7.0	4.6	5.3	5.2	4.2	4.1	5.6	6.3	7.4	8.7	6.4
17	8.9	9.6	7.4	4.6	5.6	5.1	4.1	3.9	6.0	6.2	7.8	8.6	6.4
18	8.6	9.4	7.9	4.6	5.3	4.7	4.3	3.9	6.0	6.0	7.7	8.5	6.4
19	8.8	9.3	8.1	5.4	5.2	4.4	4.1	4.3	5.5	6.2	7.7	8.2	6.4
20	8.9	9.5	8.3	5.2	5.5	4.0	4.1	4.1	5.8	6.5	7.4	8.4	6.5
21	9.5	9.8	7.8	5.1	5.6	4.3	4.3	4.4	5.7	6.3	7.2	8.0	6.5
22	9.4	9.9	7.9	5.1	5.7	4.4	4.4	4.5	6.0	6.3	6.9	7.9	6.5
23	9.4	9.8	7.7	5.1	6.0	4.8	4.3	4.7	5.6	6.0	7.1	8.0	6.5
tot	9.3	10.3	8.5	6.6	7.2	6.2	5.5	5.7	7.0	7.8	8.0	8.5	7.5

SECT	FREQ	<1	2	3	4	5	6	7	8	9	11	13	15	17	>17	A	K
0	0.8	204	290	144	72	27	20	13	4	9	22	47	90	54	2	3.3	0.80
30	0.2	55	440	352	110	22	0	11	0	11	0	0	0	0	0	2.4	1.72
60	0.5	33	120	132	182	58	215	252	8	0	0	0	0	0	0	5.0	2.90
90	0.7	118	294	266	140	73	53	36	8	11	0	0	0	0	0	2.9	1.51
120	21.5	5	24	35	37	40	53	60	50	54	159	144	130	100	110	12.4	2.61
150	22.7	5	25	44	57	73	108	107	99	87	164	142	60	18	13	9.1	2.41
180	2.6	32	154	206	199	154	113	75	22	13	14	12	6	0	0	4.3	1.69
210	1.6	30	147	187	213	161	130	86	26	13	5	2	0	0	0	4.3	2.11
240	8.2	4	37	190	355	227	125	47	12	2	1	0	0	0	0	4.2	2.69
270	7.4	6	33	72	222	317	230	77	26	11	6	0	0	0	0	5.0	3.34
300	21.5	1	10	33	58	100	159	178	165	129	123	32	9	1	0	7.6	3.06
330	12.3	3	20	30	36	57	70	93	132	151	241	96	54	15	4	9.4	3.19
Total	100.0	8	33	62	94	104	113	101	89	79	129	83	51	28	27	8.4	1.83

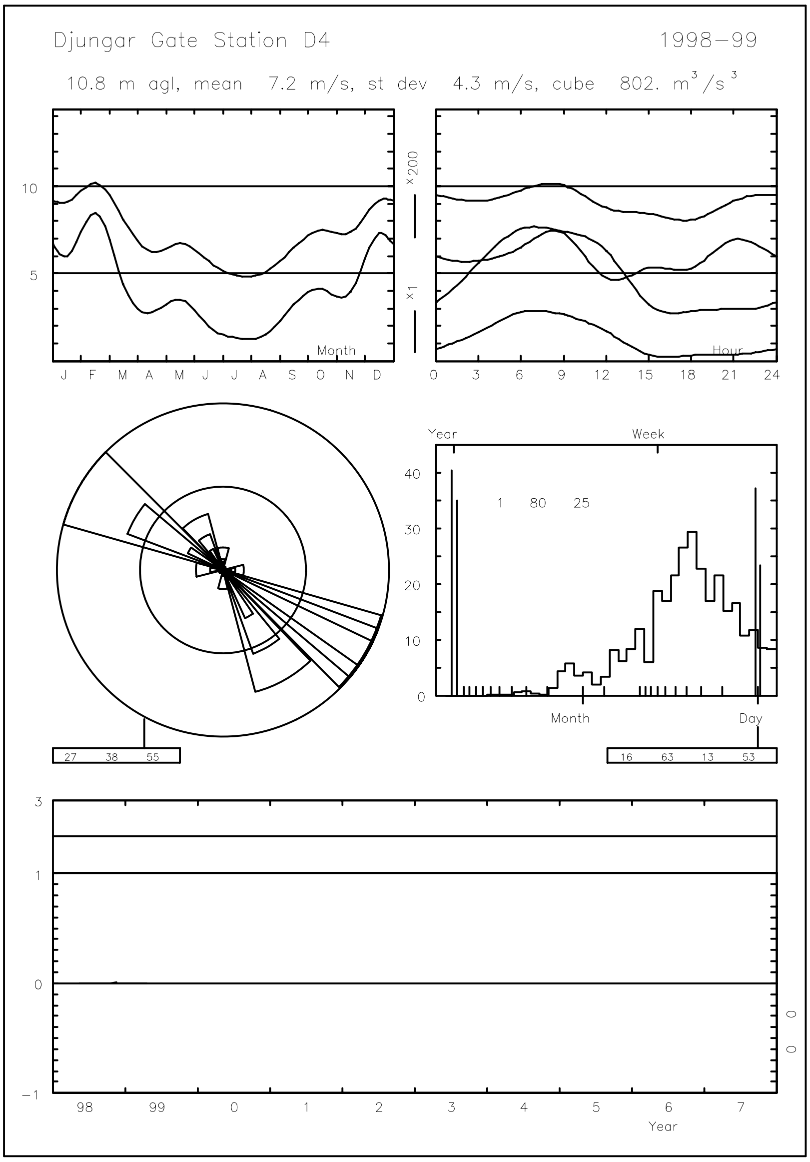

DJUNGAR GATE STATION D1
1998–99
10.8 m agl, mean 7.5 m/s, st dev 4.0 m/s, cube 855. m³/s³
Month
J F M A M J J A S O N D
×200
×1
Hour
0 3 6 9 12 15 18 21 24
Year
Week
1 84 25
Month
Day
23 31 52
9 47 10 43
98 99 0 1 2 3 4 5 6 7
Year

STATION D4 DJUNGAR GATE

Height of anemometre 10.6 m a.g.l.

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
0	9.5	9.5	7.4	4.4	4.9	3.3	3.4	2.9	4.5	5.9	6.3	8.4	5.9
1	9.2	9.6	7.0	4.9	5.5	4.0	3.4	3.0	5.4	6.0	6.5	8.8	6.1
2	9.2	9.6	7.4	5.6	6.5	5.4	4.4	4.1	5.6	6.7	6.1	8.5	6.6
3	9.1	10.2	7.9	6.7	7.2	6.1	5.6	5.5	6.8	8.5	6.4	8.9	7.4
4	9.6	11.2	8.6	7.7	7.5	6.8	6.7	6.6	7.5	9.9	7.7	9.2	8.2
5	9.7	11.6	9.0	8.2	7.8	7.0	7.4	7.1	8.7	10.3	8.9	9.3	8.7
6	9.8	11.8	9.6	8.6	8.9	7.4	7.5	7.9	8.9	10.6	9.3	10.1	9.2
7	9.8	12.0	10.1	9.1	9.6	8.2	7.3	8.5	9.0	10.6	9.4	10.6	9.5
8	9.5	12.2	10.2	9.8	9.3	8.5	7.0	8.4	9.4	10.4	9.7	10.4	9.5
9	10.0	12.0	10.1	10.0	9.8	9.1	7.4	7.9	8.9	10.1	9.8	10.0	9.6
10	9.6	11.5	9.8	9.4	9.9	9.1	7.3	7.7	8.6	9.7	9.2	9.6	9.3
11	9.0	11.2	9.2	8.6	9.5	9.1	7.1	7.0	7.8	9.1	8.1	9.0	8.7
12	8.8	10.3	8.5	7.4	8.7	8.1	6.3	6.4	7.0	7.4	7.4	8.9	7.9
13	8.5	9.5	7.5	6.2	7.3	7.0	5.4	5.3	6.0	6.7	6.8	8.9	7.1
14	8.7	9.1	7.3	4.8	6.2	5.9	4.2	4.1	5.7	6.5	6.4	9.2	6.5
15	8.4	8.8	6.9	4.1	4.6	5.3	3.2	3.4	5.6	6.1	6.9	9.0	6.0
16	8.5	9.1	6.7	4.0	4.4	3.8	2.8	3.5	5.5	5.9	6.9	8.8	5.8
17	8.5	9.3	6.7	4.0	5.0	3.0	2.7	3.3	5.3	5.7	6.8	9.1	5.8
18	8.1	9.0	7.2	4.2	4.8	3.3	2.8	2.9	5.0	5.6	6.6	8.8	5.7
19	8.2	9.2	7.5	4.7	4.5	3.4	2.7	3.2	4.4	5.8	6.1	9.3	5.7
20	8.3	9.2	7.7	4.8	4.4	3.1	3.0	3.3	4.8	5.4	6.4	9.1	5.8
21	9.1	9.2	7.7	4.6	4.7	3.1	2.9	3.6	4.9	5.7	6.2	8.8	5.9
22	9.4	9.3	7.6	4.2	4.9	3.5	3.4	3.4	4.8	5.6	6.3	9.1	5.9
23	9.4	9.5	7.2	4.2	5.1	3.2	3.2	3.2	4.9	5.6	6.2	8.8	5.9
tot	9.1	10.2	8.1	6.3	6.7	5.7	4.9	5.1	6.5	7.5	7.3	9.2	7.2

Sect	Freq	<1	2	3	4	5	6	7	8	9	11	13	15	17	>17	A	k
0	3.6	180	268	139	40	20	13	27	23	36	72	78	68	27	9	4.8	1.03
30	0.6	182	416	238	89	43	17	10	7	0	0	0	0	0	0	2.1	1.44
60	0.4	210	352	295	71	24	5	0	19	24	0	0	0	0	0	2.3	1.27
90	3.4	124	146	70	63	35	64	114	89	63	58	57	78	37	2	7.4	1.72
120	26.7	21	27	24	27	27	46	67	72	73	173	175	130	75	65	11.8	2.87
150	20.6	19	51	71	98	97	101	106	85	76	125	97	47	17	9	7.9	1.95
180	2.8	81	274	243	145	85	35	39	48	21	25	4	0	0	0	3.2	1.26
210	0.6	160	535	195	59	24	6	18	3	0	0	0	0	0	0	1.9	1.37
240	0.8	211	361	194	90	75	35	25	8	0	3	0	0	0	0	2.3	1.30
270	4.3	83	106	112	99	110	143	130	102	63	45	6	0	0	0	5.7	2.35
300	27.0	26	54	64	99	109	118	120	118	109	150	27	5	0	0	7.2	2.67
330	9.4	95	133	88	46	33	36	53	67	92	197	104	43	13	2	8.2	2.23
Total	100.0	46	81	71	72	70	79	89	85	80	138	89	55	27	20	8.4	1.95



Djungar Gate Station D4
1998–99
10.8 m agl, mean 7.2 m/s, st dev 4.3 m/s, cube 802. m³/s³
10
5
Month
J F M A M J J A S O N D
×200
×1
Hour
0 3 6 9 12 15 18 21 24
27 38 55
Year
Week
40
30
20
10
0
1 80 25
Month
Day
16 63 13 53
3
1
0
−1
0
0
98 99 0 1 2 3 4 5 6 7
Year

Table 5. Summary of statistics obtained from the Weibull statistics and the histograms.

	Mean vector dir.	Mean vector speed	Weibull A m/s	Weibull k	Mean wind m/s	Mean energy density m3/s3
CC	102	0.54	6.60	1.965	5.85	238
D1	157	1.53	8.36	1.831	7.43	526
D2	155	1.54	8.52	1.865	7.57	545
D3	138	1.26	8.06	1.958	7.15	436
D4	130	1.73	8.39	1.950	7.44	494

Regional climatology and mean values

The Wind Atlas tables. These tables give the calculated Weibull **A-** and **k-**parameters for 12 sectors, 5 heights and 4 roughness classes. In addition, the sectorwise distribution of wind speed is given in per cent for each roughness class. The Weibull **A-**parameters are given in m/s.

Estimated mean wind speed and mean power. The last table gives the estimated (calculated) mean wind speed [m/s] and total mean power of the wind [W/m2] for each of the five standard heights and four roughness classes. These are calculated using the Weibull parameters of the Wind Atlas tables.

Wind atlas: CHILIK CORRIDOR STATION CC

ROUGHNESS CLASS 0 (0.0002 M)

z	0	30	60	90	120	150	180	210	240	270	300	330	Total
10	3.96	5.72	10.85	9.82	6.72	4.19	4.54	7.15	10.28	9.49	7.12	4.32	9.22
	1.58	1.97	3.55	2.42	1.51	2.52	2.33	2.50	2.23	2.17	1.73	1.53	2.15
25	4.34	6.27	11.84	10.71	7.35	4.58	4.97	7.82	11.20	10.35	7.79	4.75	10.06
	1.63	2.03	3.63	2.47	1.54	2.60	2.40	2.58	2.26	2.21	1.78	1.58	2.19
50	4.67	6.74	12.66	11.44	7.88	4.92	5.34	8.39	11.95	11.05	8.36	5.11	10.76
	1.67	2.08	3.74	2.53	1.58	2.67	2.47	2.65	2.32	2.27	1.83	1.62	2.24
100	5.06	7.30	13.65	12.30	8.45	5.34	5.79	9.11	12.79	11.86	9.01	5.52	11.57
	1.62	2.02	3.65	2.48	1.55	2.58	2.39	2.56	2.28	2.23	1.78	1.57	2.21
200	5.56	8.06	14.96	13.38	9.16	5.91	6.40	10.08	13.81	12.87	9.85	6.07	12.60
	1.53	1.91	3.49	2.39	1.49	2.44	2.26	2.42	2.22	2.15	1.70	1.49	2.15
Freq	0.9	1.6	21.5	19.6	6.2	1.7	2.5	6.6	18.8	14.4	4.6	1.4	

Roughness Class 1 (0.0300 m)

z	0	30	60	90	120	150	180	210	240	270	300	330	Total
10	2.67	4.19	7.67	6.35	3.21	2.74	3.23	5.16	7.55	6.29	3.26	2.81	6.50
	1.37	1.77	3.09	1.74	2.48	1.91	1.98	2.18	2.08	1.86	1.38	1.26	1.93
25	3.23	5.03	9.07	7.50	3.83	3.28	3.87	6.17	8.87	7.45	3.94	3.41	7.69
	1.47	1.91	3.27	1.81	2.68	2.06	2.14	2.35	2.16	1.96	1.49	1.36	2.02
50	3.78	5.83	10.32	8.52	4.41	3.80	4.47	7.12	10.00	8.50	4.62	4.01	8.77
	1.65	2.15	3.57	1.94	3.02	2.31	2.41	2.64	2.29	2.13	1.67	1.52	2.16
100	4.51	6.93	11.97	9.77	5.22	4.51	5.30	8.44	11.36	9.83	5.50	4.79	10.14
	1.76	2.28	3.83	2.08	3.21	2.47	2.56	2.81	2.46	2.28	1.78	1.62	2.31
200	5.59	8.61	14.47	11.50	6.51	5.61	6.60	10.51	13.22	11.76	6.83	5.93	12.11
	1.68	2.18	3.69	2.01	3.07	2.35	2.45	2.69	2.38	2.20	1.70	1.54	2.27
Freq	0.9	1.8	27.6	17.3	2.8	1.3	2.9	7.8	22.1	12.1	2.2	1.1	

Roughness Class 2 (0.1000 m)

z	0	30	60	90	120	150	180	210	240	270	300	330	Total
10	2.54	5.45	6.64	5.50	2.84	2.51	3.17	4.82	6.52	5.46	2.93	2.51	5.67
	1.38	2.22	2.99	1.72	2.46	1.90	1.83	1.88	2.06	1.86	1.43	1.30	1.94
25	3.17	6.71	8.11	6.71	3.50	3.10	3.92	5.96	7.92	6.68	3.64	3.14	6.93
	1.47	2.37	3.14	1.79	2.63	2.03	1.96	2.02	2.13	1.95	1.53	1.39	2.02
50	3.76	7.84	9.38	7.75	4.09	3.64	4.60	7.00	9.09	7.75	4.31	3.73	8.03
	1.63	2.60	3.39	1.89	2.92	2.25	2.17	2.24	2.24	2.09	1.69	1.53	2.14
100	4.51	9.29	10.93	8.98	4.86	4.33	5.49	8.33	10.43	9.03	5.17	4.48	9.37
	1.79	2.87	3.72	2.07	3.21	2.47	2.38	2.46	2.44	2.29	1.85	1.68	2.33
200	5.55	11.42	13.15	10.56	6.00	5.34	6.77	10.28	12.17	10.78	6.36	5.51	11.18
	1.71	2.74	3.59	2.01	3.07	2.37	2.28	2.35	2.37	2.21	1.78	1.61	2.29
Freq	0.9	4.0	26.7	16.0	2.6	1.5	3.4	9.0	21.3	11.3	2.1	1.1	

Roughness Class 3 (0.4000 m)

z	0	30	60	90	120	150	180	210	240	270	300	330	Total
10	2.12	4.75	5.16	4.28	2.18	2.00	2.78	4.06	5.09	4.26	2.24	1.92	4.45
	1.37	2.60	2.87	1.71	2.26	1.84	1.88	1.81	2.08	1.85	1.38	1.27	1.95
25	2.82	6.22	6.74	5.58	2.87	2.64	3.67	5.33	6.61	5.58	2.97	2.56	5.82
	1.45	2.73	2.99	1.76	2.40	1.95	1.99	1.89	2.14	1.92	1.46	1.34	2.02
50	3.43	7.45	8.04	6.66	3.46	3.19	4.43	6.39	7.84	6.67	3.62	3.13	6.96
	1.57	2.94	3.18	1.85	2.60	2.12	2.16	2.01	2.23	2.04	1.58	1.45	2.12
100	4.18	8.87	9.51	7.87	4.16	3.85	5.34	7.62	9.21	7.92	4.41	3.83	8.25
	1.79	3.31	3.54	2.01	2.97	2.42	2.46	2.25	2.40	2.25	1.80	1.65	2.31
200	5.10	10.74	11.40	9.30	5.08	4.71	6.53	9.14	10.82	9.45	5.38	4.66	9.84
	1.72	3.22	3.48	2.01	2.86	2.33	2.37	2.20	2.42	2.22	1.74	1.59	2.31
Freq	1.1	7.1	25.6	14.3	2.4	1.7	4.0	10.7	20.1	10.1	1.9	1.1	

Z	CLASS 0		CLASS 1		CLASS 2		CLASS 3	
m	m/s	W/m2	m/s	W/m2	m/s	W/m2	m/s	W/m2
10	8.2	592	5.8	232	5.0	153	4.0	73
25	8.9	759	6.8	367	6.1	268	5.2	159
50	9.5	909	7.8	509	7.1	394	6.2	258
100	10.2	1146	9.0	744	8.3	583	7.3	401
200	11.2	1515	10.7	1285	9.9	1005	8.7	681

Wind atlas: DJUNGAR GATE STATION D1

ROUGHNESS CLASS 0 (0.0002 M)													
z	0	30	60	90	120	150	180	210	240	270	300	330	Total
10	12.46	10.29	7.15	16.04	16.44	13.23	11.32	8.58	7.48	8.70	10.37	11.65	11.95
	3.12	1.78	1.92	2.22	2.70	2.47	2.23	1.76	3.19	2.65	3.29	3.30	2.20
25	13.56	11.20	7.84	17.42	17.86	14.38	12.32	9.36	8.18	9.51	11.32	12.69	13.02
	3.16	1.80	1.98	2.23	2.72	2.49	2.26	1.78	3.29	2.73	3.38	3.37	2.23
50	14.44	11.93	8.42	18.48	18.95	15.29	13.11	10.00	8.78	10.21	12.11	13.53	13.88
	3.23	1.83	2.04	2.24	2.74	2.52	2.30	1.83	3.38	2.81	3.47	3.46	2.27
100	15.43	12.70	9.13	19.59	20.10	16.26	13.99	10.70	9.53	11.08	13.08	14.53	14.84
	3.19	1.82	1.97	2.26	2.75	2.52	2.28	1.80	3.27	2.72	3.38	3.39	2.28
200	16.64	13.59	10.07	20.77	21.35	17.38	15.02	11.54	10.56	12.27	14.36	15.76	16.00
	3.11	1.79	1.87	2.24	2.72	2.48	2.23	1.75	3.10	2.57	3.23	3.28	2.29
Freq	4.6	0.9	0.5	2.8	14.5	19.1	9.2	2.9	6.9	9.6	16.0	13.0	
Roughness Class 1 (0.0300 m)													
z	0	30	60	90	120	150	180	210	240	270	300	330	Total
10	8.94	4.22	5.30	11.82	11.84	8.87	7.57	5.44	5.25	6.34	7.45	8.76	8.52
	2.46	0.96	2.22	2.20	2.58	2.36	1.77	1.75	2.76	2.22	2.98	3.07	2.04
25	10.45	4.95	6.34	13.74	13.76	10.37	8.86	6.52	6.26	7.56	8.83	10.28	10.02
	2.53	0.97	2.40	2.22	2.61	2.43	1.81	1.88	2.99	2.38	3.17	3.19	2.10
50	11.71	5.55	7.31	15.23	15.28	11.61	9.94	7.54	7.20	8.68	10.07	11.57	11.30
	2.65	0.99	2.69	2.26	2.66	2.53	1.89	2.09	3.36	2.65	3.49	3.38	2.21
100	13.16	6.27	8.66	16.82	16.89	13.04	11.20	8.90	8.52	10.22	11.72	13.13	12.83
	2.83	1.03	2.87	2.32	2.76	2.71	2.02	2.23	3.57	2.83	3.74	3.63	2.38
200	15.07	6.99	10.79	18.58	18.75	14.91	12.76	10.98	10.62	12.60	14.25	15.32	14.90
	2.76	1.03	2.74	2.34	2.76	2.64	1.97	2.13	3.41	2.71	3.59	3.52	2.48
Freq	2.7	0.4	0.5	3.5	17.9	19.4	5.9	2.2	8.7	9.6	18.1	11.1	
Roughness Class 2 (0.1000 m)													
z	0	30	60	90	120	150	180	210	240	270	300	330	Total
10	7.76	1.85	5.35	10.26	10.21	7.58	6.36	4.51	4.59	5.64	6.53	7.74	7.42
	2.33	0.69	1.74	2.24	2.58	2.42	1.67	1.98	2.70	2.25	2.99	3.14	2.04
25	9.38	2.26	6.54	12.34	12.28	9.18	7.70	5.57	5.65	6.93	7.98	9.39	9.01
	2.38	0.69	1.81	2.26	2.61	2.48	1.71	2.12	2.88	2.38	3.16	3.24	2.10
50	10.69	2.57	7.57	13.96	13.90	10.48	8.80	6.53	6.59	8.07	9.24	10.74	10.33
	2.47	0.70	1.94	2.29	2.65	2.58	1.77	2.34	3.19	2.61	3.42	3.41	2.19
100	12.14	2.94	8.81	15.64	15.60	11.93	10.03	7.78	7.82	9.50	10.80	12.29	11.86
	2.63	0.71	2.12	2.35	2.74	2.77	1.88	2.58	3.51	2.87	3.76	3.72	2.36
200	13.92	3.32	10.45	17.48	17.49	13.76	11.49	9.60	9.67	11.59	13.06	14.35	13.81
	2.61	0.72	2.05	2.39	2.77	2.73	1.87	2.46	3.36	2.75	3.62	3.61	2.46
Freq	2.2	0.3	0.6	4.1	18.8	19.0	5.0	2.0	9.3	9.9	18.4	10.3	
Roughness Class 3 (0.4000 m)													
z	0	30	60	90	120	150	180	210	240	270	300	330	Total
10	6.10	2.21	5.18	7.96	7.75	5.94	4.94	3.59	3.73	4.59	5.20	6.09	5.82
	2.35	0.87	1.40	2.33	2.50	2.41	1.67	2.28	2.67	2.41	3.01	3.13	2.06
25	7.90	2.88	6.69	10.26	10.00	7.70	6.41	4.73	4.90	6.02	6.79	7.90	7.57
	2.40	0.88	1.42	2.35	2.53	2.47	1.70	2.42	2.84	2.54	3.14	3.23	2.12
50	9.32	3.42	7.86	12.03	11.73	9.09	7.57	5.69	5.90	7.21	8.10	9.34	8.97
	2.47	0.90	1.44	2.38	2.56	2.55	1.75	2.63	3.08	2.73	3.35	3.36	2.19
100	10.84	4.04	9.11	13.85	13.53	10.60	8.84	6.84	7.08	8.60	9.59	10.92	10.52
	2.60	0.93	1.47	2.44	2.63	2.70	1.84	2.99	3.51	3.09	3.73	3.60	2.32
200	12.56	4.70	10.45	15.78	15.45	12.33	10.27	8.37	8.66	10.42	11.51	12.81	12.32
	2.65	0.95	1.51	2.50	2.71	2.75	1.88	2.88	3.38	2.99	3.66	3.63	2.44
Freq	2.0	0.3	1.0	5.9	18.9	17.3	4.7	3.0	9.3	10.9	17.4	9.3	

Z	CLASS 0		CLASS 1		CLASS 2		CLASS 3	
m	m/s	W/m2	m/s	W/m2	m/s	W/m2	m/s	W/m2
10	10.6	1268	7.6	494	6.6	324	5.2	155
25	11.5	1622	8.9	778	8.0	566	6.7	334
50	12.3	1937	10.0	1067	9.2	822	7.9	538
100	13.1	2355	11.4	1475	10.5	1173	9.3	827
200	14.2	2946	13.2	2241	12.2	1795	10.9	1283

Wind atlas: DJUNGAR GATE STATION D2

ROUGHNESS CLASS 0 (0.0002 M)													
z	0	30	60	90	120	150	180	210	240	270	300	330	Total
10	12.77	11.04	8.22	15.74	16.68	13.26	11.12	8.55	6.79	8.63	10.53	11.78	12.02
	3.23	1.97	2.07	2.18	2.85	2.45	2.17	1.76	2.79	2.54	3.33	3.42	2.20
25	13.90	12.02	8.98	17.10	18.11	14.41	12.10	9.32	7.42	9.44	11.49	12.84	13.09
	3.27	1.99	2.12	2.19	2.86	2.47	2.19	1.79	2.88	2.62	3.42	3.48	2.22
50	14.80	12.79	9.62	18.15	19.22	15.32	12.89	9.96	7.97	10.14	12.28	13.68	13.96
	3.34	2.02	2.18	2.20	2.88	2.51	2.24	1.84	2.96	2.69	3.51	3.58	2.26
100	15.81	13.62	10.38	19.23	20.39	16.30	13.75	10.66	8.65	11.00	13.26	14.69	14.92
	3.31	2.01	2.12	2.21	2.90	2.51	2.22	1.81	2.86	2.60	3.42	3.51	2.28
200	17.03	14.57	11.38	20.39	21.66	17.41	14.76	11.51	9.58	12.18	14.54	15.94	16.08
	3.23	1.97	2.03	2.19	2.87	2.47	2.17	1.76	2.71	2.47	3.28	3.40	2.28
Freq	4.1	0.8	0.6	3.0	15.2	18.8	9.2	3.0	6.2	9.8	16.9	12.5	

Roughness Class 1 (0.0300 m)													
z	0	30	60	90	120	150	180	210	240	270	300	330	Total
10	9.43	4.08	6.07	11.71	12.02	8.80	7.41	5.40	4.79	6.37	7.59	8.88	8.58
	2.74	0.94	2.14	2.19	2.71	2.33	1.73	1.74	2.60	2.21	3.04	3.16	2.04
25	11.03	4.79	7.26	13.61	13.97	10.29	8.68	6.47	5.72	7.59	8.98	10.41	10.08
	2.82	0.96	2.31	2.21	2.75	2.40	1.78	1.87	2.80	2.37	3.22	3.29	2.11
50	12.34	5.39	8.38	15.09	15.51	11.53	9.74	7.49	6.59	8.71	10.23	11.71	11.36
	2.94	0.97	2.60	2.25	2.80	2.50	1.85	2.09	3.15	2.63	3.53	3.48	2.21
100	13.84	6.08	9.92	16.67	17.15	12.95	10.98	8.86	7.80	10.24	11.87	13.28	12.90
	3.14	1.01	2.77	2.31	2.90	2.67	1.98	2.23	3.36	2.81	3.78	3.74	2.37
200	15.81	6.79	12.35	18.42	19.04	14.80	12.53	10.95	9.72	12.59	14.38	15.49	14.96
	3.06	1.01	2.65	2.33	2.91	2.61	1.94	2.13	3.21	2.69	3.63	3.62	2.47
Freq	2.4	0.4	0.7	3.7	18.7	18.8	6.1	2.2	7.7	10.3	19.0	10.1	

Roughness Class 2 (0.1000 m)													
z	0	30	60	90	120	150	180	210	240	270	300	330	Total
10	8.33	2.23	5.88	10.24	10.37	7.52	6.24	4.45	4.13	5.70	6.65	7.85	7.47
	2.72	0.76	1.93	2.28	2.71	2.38	1.65	1.94	2.33	2.28	3.08	3.24	2.05
25	10.07	2.71	7.18	12.32	12.47	9.10	7.57	5.49	5.09	7.00	8.13	9.52	9.07
	2.79	0.76	2.01	2.30	2.74	2.44	1.69	2.08	2.49	2.42	3.25	3.35	2.11
50	11.46	3.10	8.28	13.93	14.12	10.39	8.65	6.44	5.95	8.15	9.40	10.89	10.40
	2.88	0.78	2.13	2.33	2.79	2.54	1.75	2.30	2.76	2.63	3.51	3.51	2.19
100	13.00	3.57	9.58	15.62	15.85	11.84	9.88	7.67	7.07	9.59	10.97	12.45	11.94
	3.07	0.80	2.34	2.40	2.88	2.74	1.87	2.53	3.03	2.90	3.85	3.83	2.35
200	14.89	4.04	11.31	17.46	17.77	13.65	11.32	9.47	8.74	11.68	13.22	14.52	13.87
	3.05	0.81	2.26	2.43	2.92	2.69	1.85	2.42	2.90	2.78	3.71	3.72	2.45
Freq	2.0	0.4	0.9	4.3	19.4	18.3	5.3	2.1	8.3	10.7	19.1	9.3	

Roughness Class 3 (0.4000 m)													
z	0	30	60	90	120	150	180	210	240	270	300	330	Total
10	6.47	2.33	5.70	8.01	7.88	5.88	4.87	3.40	3.46	4.64	5.29	6.18	5.87
	2.63	0.90	1.73	2.41	2.62	2.37	1.66	2.06	2.30	2.44	3.08	3.22	2.07
25	8.37	3.05	7.37	10.32	10.15	7.62	6.31	4.47	4.56	6.08	6.90	8.01	7.62
	2.68	0.92	1.76	2.43	2.64	2.42	1.69	2.18	2.44	2.56	3.21	3.31	2.12
50	9.86	3.62	8.68	12.10	11.91	9.00	7.47	5.40	5.49	7.28	8.22	9.47	9.03
	2.76	0.94	1.79	2.46	2.69	2.51	1.74	2.37	2.65	2.75	3.42	3.44	2.19
100	11.46	4.28	10.07	13.93	13.74	10.49	8.73	6.49	6.59	8.68	9.73	11.07	10.58
	2.89	0.97	1.86	2.52	2.76	2.65	1.83	2.71	3.02	3.10	3.79	3.68	2.32
200	13.26	4.98	11.58	15.88	15.68	12.21	10.14	7.94	8.06	10.49	11.66	12.96	12.38
	2.95	0.99	1.90	2.59	2.83	2.70	1.87	2.60	2.91	3.01	3.73	3.72	2.43
Freq	1.8	0.4	1.2	6.1	19.5	16.7	4.9	2.8	8.5	11.8	17.9	8.4	

z	Class 0		Class 1		Class 2		Class 3	
m	m/s	W/m2	m/s	W/m2	m/s	W/m2	m/s	W/m2
10	10.6	1293	7.6	504	6.6	331	5.2	158
25	11.6	1655	8.9	791	8.0	576	6.7	339
50	12.4	1976	10.1	1087	9.2	838	8.0	548
100	13.2	2401	11.4	1502	10.6	1197	9.4	842
200	14.2	3000	13.3	2272	12.3	1824	11.0	1305

Wind atlas: DJUNGAR GATE STATION D3

ROUGHNESS CLASS 0 (0.0002 M)

z	0	30	60	90	120	150	180	210	240	270	300	330	Total
10	10.59	2.95	2.72	15.67	15.82	11.44	8.53	5.93	6.72	9.70	10.96	11.38	11.86
	2.06	0.71	0.91	2.24	2.74	1.95	1.98	1.56	2.56	2.51	3.17	3.04	2.11
25	11.54	3.22	3.00	17.02	17.19	12.45	9.32	6.51	7.35	10.59	11.94	12.40	12.91
	2.09	0.72	0.93	2.24	2.76	1.97	2.03	1.61	2.64	2.57	3.24	3.10	2.13
50	12.29	3.43	3.26	18.06	18.24	13.24	9.97	7.00	7.89	11.32	12.75	13.22	13.76
	2.13	0.72	0.95	2.26	2.79	2.00	2.08	1.65	2.71	2.64	3.33	3.19	2.17
100	13.12	3.64	3.48	19.15	19.36	14.09	10.71	7.57	8.57	12.19	13.72	14.18	14.69
	2.12	0.72	0.93	2.27	2.80	1.99	2.04	1.60	2.62	2.58	3.26	3.13	2.17
200	14.09	3.84	3.74	20.31	20.59	15.05	11.66	8.33	9.48	13.31	14.95	15.38	15.80
	2.07	0.72	0.89	2.25	2.76	1.96	1.96	1.52	2.48	2.48	3.13	3.03	2.17
Freq	3.6	1.0	0.6	3.4	21.3	19.6	6.6	1.4	1.4	7.0	20.5	13.5	

Roughness Class 1 (0.0300 m)

z	0	30	60	90	120	150	180	210	240	270	300	330	Total
10	5.39	1.63	2.06	11.50	11.37	6.96	4.99	3.85	4.83	6.93	7.84	8.39	8.49
	1.13	0.65	1.15	2.20	2.60	1.83	1.47	1.33	2.40	2.22	2.83	2.70	1.97
25	6.31	1.92	2.51	13.37	13.22	8.19	5.96	4.67	5.77	8.20	9.24	9.85	9.96
	1.15	0.66	1.24	2.22	2.64	1.90	1.56	1.44	2.59	2.35	2.98	2.80	2.03
50	7.07	2.17	2.97	14.83	14.69	9.25	6.88	5.47	6.64	9.33	10.47	11.09	11.21
	1.18	0.67	1.39	2.26	2.70	2.02	1.71	1.61	2.92	2.54	3.21	2.97	2.12
100	7.97	2.48	3.56	16.39	16.27	10.53	8.05	6.52	7.87	10.78	12.04	12.59	12.69
	1.24	0.69	1.47	2.33	2.81	2.17	1.83	1.71	3.10	2.73	3.45	3.19	2.26
200	8.92	2.77	4.40	18.14	18.13	12.25	9.72	8.09	9.80	12.93	14.36	14.70	14.64
	1.22	0.69	1.41	2.35	2.81	2.10	1.76	1.64	2.96	2.63	3.33	3.10	2.32
Freq	1.9	0.8	0.5	4.4	26.5	17.4	3.2	1.0	1.6	8.8	24.1	9.7	

Roughness Class 2 (0.1000 m)

z	0	30	60	90	120	150	180	210	240	270	300	330	Total
10	3.63	1.44	1.80	9.92	9.77	5.82	3.96	3.38	4.50	6.12	6.83	7.37	7.38
	0.92	0.67	0.69	2.25	2.56	1.92	1.38	1.38	2.26	2.29	2.86	2.69	1.98
25	4.39	1.76	2.17	11.94	11.76	7.11	4.90	4.21	5.55	7.48	8.32	8.94	8.96
	0.93	0.67	0.69	2.27	2.60	2.00	1.46	1.47	2.42	2.41	2.99	2.78	2.03
50	5.02	2.05	2.49	13.51	13.32	8.20	5.77	4.99	6.49	8.65	9.59	10.23	10.26
	0.94	0.69	0.70	2.31	2.65	2.13	1.59	1.62	2.68	2.59	3.19	2.92	2.11
100	5.71	2.39	2.85	15.16	14.98	9.50	6.85	5.99	7.71	10.06	11.11	11.72	11.76
	0.97	0.71	0.71	2.37	2.74	2.33	1.74	1.78	2.95	2.84	3.50	3.19	2.24
200	6.44	2.71	3.22	16.97	16.84	11.23	8.30	7.36	9.53	12.04	13.22	13.68	13.63
	0.98	0.72	0.72	2.41	2.78	2.26	1.67	1.71	2.82	2.74	3.38	3.10	2.32
Freq	1.6	0.8	0.6	5.4	27.3	16.3	2.5	1.0	1.9	9.9	24.3	8.6	

Roughness Class 3 (0.4000 m)

z	0	30	60	90	120	150	180	210	240	270	300	330	Total
10	2.76	1.22	4.76	7.66	7.43	4.58	3.07	2.83	3.96	4.95	5.40	5.77	5.80
	0.90	0.69	1.24	2.33	2.45	1.93	1.37	1.53	2.06	2.44	2.85	2.65	1.99
25	3.57	1.61	6.14	9.87	9.59	5.97	4.06	3.75	5.22	6.45	7.03	7.48	7.53
	0.91	0.71	1.25	2.35	2.48	2.00	1.43	1.62	2.19	2.54	2.96	2.72	2.04
50	4.21	1.92	7.23	11.58	11.26	7.11	4.92	4.55	6.30	7.70	8.36	8.86	8.92
	0.92	0.72	1.26	2.39	2.53	2.11	1.54	1.76	2.38	2.69	3.13	2.84	2.11
100	4.91	2.29	8.36	13.35	12.99	8.40	5.95	5.52	7.58	9.10	9.85	10.36	10.44
	0.94	0.74	1.29	2.45	2.60	2.30	1.73	2.00	2.71	2.97	3.43	3.04	2.23
200	5.68	2.67	9.59	15.23	14.86	9.96	7.17	6.73	9.26	10.87	11.71	12.15	12.19
	0.97	0.75	1.33	2.52	2.67	2.29	1.68	1.93	2.61	2.94	3.40	3.07	2.31
Freq	1.5	0.7	1.1	8.1	26.2	14.5	2.3	1.1	2.8	11.8	22.4	7.7	

Z	CLASS 0		CLASS 1		CLASS 2		CLASS 3	
m	m/s	W/m2	m/s	W/m2	m/s	W/m2	m/s	W/m2
10	10.5	1288	7.5	506	6.5	331	5.1	159
25	11.4	1643	8.8	793	7.9	576	6.7	340
50	12.2	1958	9.9	1081	9.1	834	7.9	547
100	13.0	2381	11.2	1486	10.4	1189	9.2	836
200	14.0	2970	13.0	2234	12.1	1801	10.8	1293

Wind atlas: DJUNGAR GATE STATION D4

ROUGHNESS CLASS 0 (0.0002 M)

z	0	30	60	90	120	150	180	210	240	270	300	330	Total
10	10.10	5.54	4.15	16.03	17.12	13.19	9.90	5.38	4.89	10.58	10.87	11.11	12.49
	1.63	0.92	0.81	2.11	2.84	2.16	1.87	1.22	1.38	2.67	2.99	2.58	2.01
25	10.98	6.03	4.53	17.41	18.59	14.34	10.78	5.90	5.38	11.53	11.85	12.10	13.59
	1.64	0.92	0.81	2.12	2.85	2.18	1.89	1.24	1.42	2.72	3.04	2.63	2.03
50	11.69	6.43	4.82	18.47	19.73	15.23	11.49	6.33	5.80	12.30	12.65	12.90	14.47
	1.66	0.93	0.82	2.13	2.87	2.21	1.93	1.27	1.46	2.79	3.13	2.69	2.05
100	12.44	6.83	5.13	19.57	20.91	16.18	12.26	6.77	6.26	13.21	13.60	13.81	15.42
	1.66	0.93	0.82	2.14	2.88	2.21	1.91	1.25	1.41	2.74	3.06	2.65	2.06
200	13.26	7.22	5.41	20.73	22.20	17.24	13.17	7.29	6.86	14.35	14.80	14.92	16.51
	1.63	0.92	0.81	2.13	2.86	2.18	1.87	1.21	1.34	2.64	2.96	2.58	2.06
Freq	4.9	1.8	0.8	5.1	19.8	19.4	7.6	1.8	1.1	5.8	19.3	12.7	

Roughness Class 1 (0.0300 m)

z	0	30	60	90	120	150	180	210	240	270	300	330	Total
10	6.28	3.03	3.23	11.65	12.40	8.36	5.63	2.92	3.57	7.56	7.68	8.23	8.95
	1.22	0.77	0.82	2.04	2.76	1.95	1.38	1.06	1.22	2.38	2.62	2.23	1.88
25	7.34	3.53	3.78	13.54	14.41	9.78	6.64	3.58	4.34	8.91	9.05	9.64	10.47
	1.24	0.78	0.83	2.06	2.79	1.99	1.42	1.13	1.31	2.50	2.75	2.30	1.92
50	8.20	3.96	4.25	15.01	15.99	10.94	7.52	4.26	5.11	10.09	10.26	10.83	11.74
	1.26	0.79	0.84	2.09	2.84	2.07	1.49	1.27	1.47	2.68	2.96	2.41	1.99
100	9.18	4.45	4.79	16.56	17.66	12.26	8.57	5.12	6.11	11.55	11.78	12.22	13.20
	1.32	0.81	0.87	2.15	2.94	2.21	1.60	1.35	1.56	2.88	3.18	2.59	2.10
200	10.24	4.93	5.33	18.27	19.57	13.91	9.88	6.31	7.56	13.65	14.01	14.08	15.05
	1.31	0.81	0.87	2.17	2.95	2.16	1.56	1.29	1.49	2.78	3.07	2.52	2.15
Freq	3.8	1.2	0.7	6.5	23.7	18.2	4.2	1.1	1.1	7.4	23.2	9.0	

Roughness Class 2 (0.1000 m)

z	0	30	60	90	120	150	180	210	240	270	300	330	Total
10	5.23	2.46	4.38	10.19	10.68	7.06	4.35	2.40	3.69	6.58	6.68	7.25	7.79
	1.16	0.75	0.99	2.11	2.74	1.97	1.26	1.13	1.31	2.39	2.61	2.21	1.89
25	6.32	2.97	5.30	12.25	12.85	8.55	5.31	3.01	4.58	8.01	8.14	8.78	9.43
	1.17	0.76	1.01	2.13	2.77	2.02	1.30	1.21	1.39	2.49	2.72	2.27	1.93
50	7.19	3.39	6.02	13.85	14.54	9.76	6.14	3.61	5.42	9.22	9.38	10.03	10.77
	1.19	0.76	1.02	2.16	2.82	2.09	1.36	1.33	1.52	2.65	2.90	2.36	1.99
100	8.15	3.86	6.83	15.52	16.31	11.10	7.13	4.37	6.46	10.65	10.85	11.43	12.26
	1.23	0.78	1.04	2.21	2.90	2.23	1.48	1.46	1.67	2.90	3.19	2.54	2.10
200	9.18	4.36	7.67	17.32	18.25	12.73	8.26	5.36	7.86	12.59	12.89	13.18	14.06
	1.24	0.79	1.06	2.24	2.94	2.21	1.44	1.40	1.60	2.81	3.08	2.49	2.15
Freq	3.5	1.0	0.8	7.5	24.3	17.3	3.5	1.0	1.3	8.4	23.4	8.0	

Roughness Class 3 (0.4000 m)

z	0	30	60	90	120	150	180	210	240	270	300	330	Total
10	4.14	2.00	5.96	8.09	8.15	5.52	3.39	1.94	3.95	5.15	5.27	5.65	6.13
	1.17	0.76	1.51	2.28	2.64	1.96	1.26	1.12	1.69	2.45	2.59	2.14	1.92
25	5.36	2.59	7.69	10.42	10.50	7.15	4.43	2.59	5.18	6.71	6.86	7.31	7.93
	1.18	0.77	1.52	2.30	2.67	2.00	1.29	1.18	1.76	2.54	2.69	2.19	1.95
50	6.31	3.05	9.03	12.21	12.32	8.44	5.29	3.19	6.21	7.98	8.16	8.64	9.37
	1.20	0.78	1.54	2.33	2.71	2.06	1.35	1.28	1.87	2.67	2.83	2.26	2.00
100	7.33	3.57	10.42	14.06	14.19	9.83	6.27	3.93	7.39	9.40	9.61	10.08	10.92
	1.23	0.79	1.57	2.37	2.78	2.17	1.44	1.45	2.06	2.92	3.10	2.39	2.09
200	8.44	4.12	11.91	16.00	16.18	11.41	7.36	4.78	8.84	11.16	11.41	11.72	12.66
	1.26	0.81	1.62	2.44	2.85	2.21	1.45	1.40	2.03	2.91	3.08	2.43	2.16
Freq	3.2	1.0	1.5	9.5	23.7	15.6	3.2	1.0	2.1	10.4	21.5	7.4	

Z	CLASS 0		CLASS 1		CLASS 2		CLASS 3	
m	m/s	W/m2	m/s	W/m2	m/s	W/m2	m/s	W/m2
10	11.1	1582	7.9	624	6.9	408	5.4	196
25	12.0	2018	9.3	975	8.4	708	7.0	417
50	12.8	2405	10.4	1324	9.5	1021	8.3	669
100	13.7	2894	11.7	1781	10.9	1431	9.7	1014
200	14.6	3563	13.3	2582	12.4	2103	11.2	1532

References

A The meteorological Stations

Risø supplied the meteorological instrumentation used for the meteorological stations. It consists of a datalogger with a data storage unit together with sensors for measuring wind speed, wind direction, atmospheric pressure, air temperature and air temperature difference. In addition, the DG2, DG4 and CC stations are furnished with a satellite transmitter. The equipment is consuming extremely low power, enabling a station to be operated from a set of standard batteries for several months. The complete instrumentation is mounted on a guyed, lattice mast, supplied and erected by the Kazakhstan PMO. The height of the DG1, DG2 and the DG3, DG4, CC masts is 24m and 32m, respectively.

Datalogger

The datalogger used at the four stations is the Aanderaa Sensor Scanning Unit 3010. This 10-bit datalogger scans, converts and stores up to 12 channels of Aanderaa sensors. Other sensors can also be used provided they are interfaced properly. The sampling interval used is 10 minutes and a built-in quartz clock triggers scanning. The accuracy of the datalogger is ±1 data bit.

Data is stored on site in an Aanderaa Data Storage Unit 2990. This EEPROM-type memory module can store 65500 ten-bit data words and further incorporates a presetable, real-time clock for recording of data and time information as well as a LCD display indicating the number of readings stored. Data are transferred to a computer by means of a DSU Reader 2995.

Wind speed

Wind speed is measured with Risø P2546a Cup Anemometers of the Risø-70 type (Busch et al, 1980). This anemometer features a lightweight 3-cup rotor and is a sturdy, yet fast-responding anemometer. The calibration is linear with an offset (`starting speed') of about 0.15…0.25 m/s. The distance constant is about 1.7 m. The cup anemometers are individually calibrated in wind tunnel.

Kristensen (1993) recently reviewed the response characteristics and associated errors of this anemometer. Kristensen discusses four types of overspeeding: i) u-bias or `overspeeding' causing too high measured wind speeds because the cup anemometer responds more quickly to an increase in the wind than to a decrease of the same magnitude; ii) v-bias or the so-called DP-error (data processing `error') which accounts for the fact that the cup anemometer is not a vector instrument, but measures the mean of the total horizontal wind speed; iii) w-bias and iv) stress-bias which are equal to zero only if the anemometer has an ideal cosine response.

These four cup anemometer biases are proportional to $(\sigma u / U)^2$, $(\sigma v / U)^2$, $(\sigma w / U)^2$, $(uw) / U^2$, respectively. The errors associated with these biases (i.e. i, iii and iv) are for the Risø-70 anemometer of the order of 1% or less and can be neglected in most applications (Kristensen, 1993). The wind speed measurements reported here are therefore thought to be accurate to within 1% of the actual reading above about 5m/s, and to ± 0.05m/s below.

Wind direction

Wind direction is measured with an Aanderaa Wind Direction Sensor 3590. This sensor consists of a light wind vane pivoted on top of a cylindrical housing. Inside the housing an electronic compass, comprising four Hall elements, is magnetically coupled to the vane. Turning the vane modulates the Hall elements generating a signal representing the wind direction. A microcontroller reads this signal every second and calculates the running average wind direction valid from the last time the sensor was scanned by the datalogger.
The inaccuracy is specified to be better than 5 degrees, the threshold speed is less than 0.3 m/s and the operating temperature range is from –40 °C to 50 °C.
On the boom the wind vane is orientated towards magnetic north giving true magnetic readings.

Atmospheric pressure

Barometric air pressure is measured with an Aanderaa Air Pressure Sensor 2810. The sensing element is a small 4 x 4 mm silicon chip with 4 diffused resistors forming a Wheatstone bridge. A thin membrane at the centre of the chip is exposed to atmospheric pressure on one side and to vacuum on the other side. The output from the Wheatstone bridge provides an output signal proportional to the atmospheric pressure. The sensor is furnished with temperature compensating circuits keeping the chip at a constant temperature of 47 °C during measurement.

The sensor has a measuring range of 920…1080 hPa, a resolution of 0.2 hPa and an inaccuracy specified to ±0.2 hPa. The operating temperature range is from –40 °C to 47 °C.

Air temperature (and air temperature difference)

Air temperature is measured with the Risø P2742a Pt 500-resistance temperature sensor mounted in a Risø P2029a Radiation Shield. The sensor comprises a 500-Ohm platinum resistor connected in series with a 500 passive resistor forming an ohmic halfbridge, which is mounted in a stainless steel tube. The sensor has a measuring range from nominally –44 °C to 49 °C, a resolution of 0.1 °C and a time constant of about one-minute.
The sensor is calibrated with an uncertainty of 0.1 °C but the accuracy of the measurement depends entirely on the experimental set-up and efficiency of shielding of the sensor from radiation.

Air temperature difference is measured with two Risø P2642a Pt 500 resistance temperature sensors, each mounted in a Risø P2029a Radiation Shield, located at different heights on the mast.
Each sensor comprises a 500-Ohm platinum resistor, which is mounted in a stainless steel tube. When interconnecting the two sensors, an active half-bridge is formed.
The sensor has a measuring range of nominally ±25 °C, a resolution of 0.05 °C and a time constant of about one-minute.
The sensor is calibrated with an uncertainty of 0.05 °C and the accuracy in the temperature gradient is better than stated above for absolute temperature, since the errors in the two levels are of the same order.

The Risø P2029a Radiation Shield is a small, cylindrical, Thaller-type shield made from 9 stacked plastic plates. The plates are shiny-white on the outside and matte-black on the inside. It is a so-called passive shield, ventilated only by ambient airflow. Field comparisons of several active and passive radiation shields have shown (Mortensen and Jensen; 1986, 1987) this shield to be superior to the traditional Stevenson screen and comparable to active shields under most atmospheric conditions. Tests over grass-covered surfaces indicate that the average temperature differences between the Risø screen and active screens are less than 0.1 °C for wind speeds above 2…3 m/s. At lower wind speeds the radiation error increases with decreasing wind speed and errors of up to one or more degrees may be experienced in calm weather and very high solar insolation. These effects are probably augmented over sandy surfaces, which have a higher albedo than grass.

Satellite transmitter

The satellite transmitter utilises the Argos satellite-based system, which collects environmental data from autonomous platforms and delivers it to users worldwide. However, due to the low data-capacity, the satellite link is used only for monitoring a selected number of the datalogger scans. The transmitter receives all readings from the datalogger in parallel with the Data Storage Unit. However, it is programmed to update its message register, only once per hour. Each message contains 256 bit of sensor data, which are transmitted during a period of 0.9 s at a frequency of 401.65 MHz. The transmitter uplinks the message at preset intervals of approximately 200 s without interrogation by the satellite.

Satellite receivers are flown on board the NOAA Polar Orbiting Environmental Satellites. They receive the Argos messages from the transmitters, store the data and read them out to a main system ground station in France. The satellites rotate about the earth in a near polar orbit. At the latitude of the Kazakhstan stations, there will be approximately 12 satellite passes per day. The duration of transmitter visibility by the satellite is the time during which the satellite can receive messages from the transmitter.

Upon reception, the ground station in France retransmits the data to Risø over the Internet using FTP. At Risø data are validated and calibrated. Subsequently, data are stored in a database and presented on an Internet page.

B The meteorological data base

The meteorological measurements are stored in yearly, sequential ASCII data files with one observation (scan) per file record. The numbers in one record are separated by at least one blank character and can thus be read with either a fixed or free-format statement, e.g.:

```
17280  8.70 10.36  1.24 13.55 10.41 255 252  14.5  14.5  -0.12  948.4 199805010010
17281 10.69 12.23  1.22 14.79 12.27 246 245  14.6  14.6  -0.12  948.8 199805010020
17282 10.69 12.30  1.38 15.57 12.35 246 244  14.5  14.4  -0.16  949.0 199805010030
17283 10.46 12.23  1.26 15.72 12.23 243 242  14.2  14.0  -0.07  949.3 199805010040
17284  9.93 11.76  1.17 14.17 11.75 240 240  13.6  13.5  -0.07  949.3 199805010050
17285 10.85 12.54  1.20 15.26 12.57 237 237  13.0  13.0  -0.12  949.7 199805010100
17286 10.36 12.23  1.40 15.57 12.20 231 230  12.9  12.9  -0.12  949.7 199805010110
17287 10.32 11.84  1.17 14.48 11.75 226 226  13.0  12.9  -0.16  950.2 199805010120
17288  9.63 11.14  1.13 14.95 11.16 230 229  12.9  12.8  -0.16  950.2 199805010130
17289 10.59 11.99  1.22 14.79 11.94 226 226  12.7  12.5  -0.16  950.2 199805010140
17290  9.23 10.91  1.09 13.70 10.90 232 231  12.8  12.6  -0.12  950.5 199805010150
```

The contents and format of the data files are specified for each station below:

```
             **   Meteorological station CC at KAZAKHSTAN   **

                  From 13/4 1998 12:50 to


                 POSITION: North 43 43.13   East 78 44.65

                                                              Missing data

     Column  1: Scan no.
             2: Wind speed 10.6 m.            [m/s]         99.99
             3: Wind speed 33.1 m.            [m/s]         99.99
             4: Wind speed st. dev. 33.1 m.   [m/s]         99.99
             5: Wind speed gust 2 sec. 33.1 m. [m/s]        99.99
             6: Wind speed 32.9 m. (Vaisala)  [m/s]         99.99
             7: Wind direction 10.6 m.        [deg.]       999
             8: Wind direction 32.4 m.        [deg.]       999
             9: Temperature 4.7 m.            [deg.]       999.9
            10: Temperature 32.4 m.           [deg.C]      999.9
            11: Temp. diff. 32.4-4.7 m.       [deg.C]      999.99
            12: Pressure 4.7 m.               [hPa]       9999.9
            13: YEARMODAHOMI


     TIME: GMT

     199804131250: The period 13/4 1998 12:40 to 13/4 1998 12:50

     Column  9: Averaging time determined by the time constant.
            10:                      do
            11:                      do
            13:                      do
```

** Meteorological station D1 at KAZAKHSTAN **

From 8/4 1998 12:30 to

POSITION: North 45 25.88 East 82 16.09

Column			Missing data
1:	Scan no.		
2:	Emty		99.99
3:	Wind speed 10.8 m.	[m/s]	99.99
4:	Wind speed st. dev. 10.8 m	[m/s]	99.99
5:	Wind speed gust 2 sec. 10.8 m.	[m/s]	99.99
6:	Wind speed lull 10.8 m.	[m/s]	99.99
7:	Emty		99.99
8:	Wind direction 10.8 m.	[deg.]	999
9:	Temperature 4.7 m.	[deg.]	999.9
10:	Temperature 10.8 m.	[deg.C]	999.9
11:	Temp. diff. 10.8-4.7 m.	[deg.C]	999.99
12:	Emty		9999.9
13:	YEARMODAHOMI		

TIME: GMT

199804081230: The period 8/4 1998 12:20 to 8/4 1998 12:30

Column 9: Averaging time determined by the time constant.
10: do
11: do

** Meteorological station D2 at KAZAKHSTAN **

From 10/4 1998 05:50 to

POSITION: North 45 26.01 East 82 16.39

Column			Missing data
1:	Scan no.		
2:	Wind speed 10.8 m.	[m/s]	99.99
3:	Wind speed 26.6 m.	[m/s]	99.99
4:	Wind speed st. dev. 26.6 m	[m/s]	99.99
5:	Wind speed gust 2 sec. 26.6 m.	[m/s]	99.99
6:	Wind speed 26.4 m. (Vaisala)	[m/s]	99.99
7:	Wind direction 10.8 m.	[deg.]	999
8:	Wind direction 25.4 m.	[deg.]	999
9:	Temperature 4.7 m.	[deg.]	999.9
10:	Temperature 25.4 m.	[deg.C]	999.9
11:	Temp. diff. 25.4-4.7 m.	[deg.C]	999.99
12:	Pressure 4.7 m.	[hPa]	9999.9
13:	YEARMODAHOMI		

TIME: GMT

199804100550: The period 10/4 1998 05:40 to 10/4 1998 05:50

Column 9:-12 Averaging time determined by the time constant.

```
        **   Meteorological station D3 at KAZAKHSTAN   **

             From 10/4 1998 04:40 to


            POSITION: North 45 26.79   East 82 18.99


                                                    Missing data

Column  1: Scan no.
        2: Wind speed 10.7 m.            [m/s]         99.99
        3: Wind speed 33.0 m.            [m/s]         99.99
        4: Wind speed st. dev. 33.0 m.   [m/s]         99.99
        5: Wind speed gust 2 sec. 33.0 m. [m/s]        99.99
        6: Wind speed lull 33.0 m.       [m/s]         99.99
        7: Emty                                        99.99
        8: Wind direction 32.4 m.        [deg.]       999
        9: Temperature 4.7 m.            [deg.]       999.9
       10: Temperature 32.4 m.           [deg.C]      999.9
       11: Temp. diff. 32.4-4.7 m.       [deg.C]      999.99
       12: Emty                                      9999.9
       13: YEARMODAHOMI


TIME: GMT

199804100440: The period 10/4 1998 04:30 to 10/4 1998 04:40

Column  9: Averaging time determined by the time constant.
       10:                     do
       11:                     do
```

```
        **   Meteorological station D4 at KAZAKHSTAN   **

             From 10/4 1998 02:50 to


            POSITION: North 45 27.61   East 82 21.34


                                                    Missing data

Column  1: Scan no.
        2: Wind speed 10.6 m.            [m/s]         99.99
        3: Wind speed 33.1 m.            [m/s]         99.99
        4: Wind speed st. dev. 33.1 m.   [m/s]         99.99
        5: Wind speed gust 2 sec. 33.1 m. [m/s]        99.99
        6: Wind speed lull 33.1 m.       [m/s]         99.99
        7: Wind speed 33.1 m. (Vaisala)  [m/s]         99.99
        8: Wind direction 32.4 m.        [deg.]       999
        9: Temperature 4.7 m.            [deg.]       999.9
       10: Temperature 32.4 m.           [deg.C]      999.9
       11: Temp. diff. 32.4-4.7 m.       [deg.C]      999.99
       12: Emty                                      9999.9
       13: YEARMODAHOMI


TIME: GMT

199804100250: The period 10/4 1998 02:40 to 10/4 1998 02:50

Column  9: Averaging time determined by the time constant.
       10:                     do
       11:                     do
```

C Climatological tabels and graphs

For the five stations monthly statistics is given for all heights in graphical and tabular form:

- Mean-, maximum-, and gust wind speed (m/s)
- Mean-, maximum-, and minimum temperature (deg. C.)

For each monthly value the number of missing observations are given. One observation equals a 10 minutes average, a standard year has 8765 x 6 = 52590 ten minutes periods.

The last four pages presents statistics obtained from the NCEP/NCAR - reanalysis database at the geographical location 81.25 E; 46.25 N.
The statistics is calculated for the pressure levels 500, 700, 850, and 1000 hPa, corresponding to the approximate respective heights of 5600, 3050, 1000 and 150 metres. The first four graphs are as follows:

- Vh (m/s)   horizontal mean wind speed
- DD (deg.)   Mean wind vector direction
- E (W/m2) Mean energy density
- T (deg. K.) Mean virtual potential temperature and geopotential height (gpm)

The four small graphs to the left shows the same parameters as above but as yearly averages and the graphs to the right give the average year.

D Mesoscale model simulations

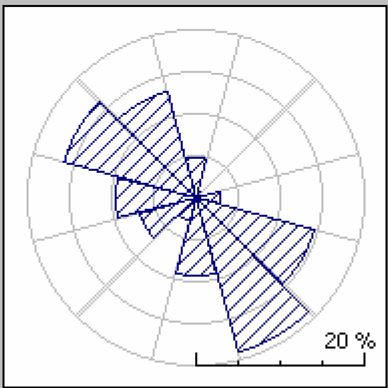
E WasP calculations

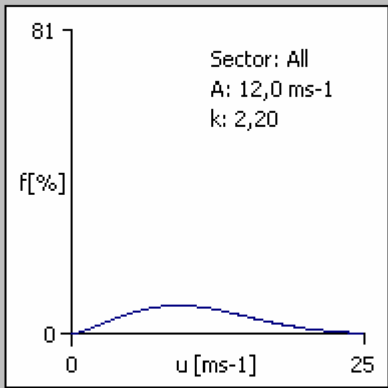
The following presents WasP calculations for the five stations: For each station is given a “wind atlas” with a table and two figures” and a “predicted wind climate” table for the 1MW wind turbine.
The wind atlas table gives the calculated statistics for five height and four roughness classes (R – class #), were class 0 corresponds the open sea and class 4 to a landscape with many sheltering obstacles. The two numbers are the mean wind speed and the mean energy density. The two figures give for the marked position in the table, the wind rose and the Weibull distribution.
The predicted wind climate table gives the calculated statistics and some model parameters for the hub height of the wind turbine. The first line gives the mean wind speed, the mean energy density and the power production. The distribution of the last two quantities on twelve 30 degrees sectors is given in the last two columns in the table (E) and (P). The first column (F) gives the wind rose – the frequency of occurrence in each sector. The columns WA and Wk give the Weibull distribution parameters.
It is remarkable that two sectors account for more than half of the production at the two locations: In Djungar Gate it is 120 and 150 and in Chilik Corridor it is 60 and 90.
The four station in Djungar Gate is place so that D1 is the most westerly and D4 the most easterly. There is approximately 10 km between these two stations.

DJUNGAR GATE. STATION D1.
STATISTICS.

'Untitled' Wind atlas

		R-class 0 (0,000 m)	R-class 1 (0,030 m)	R-class 2 (0,100 m)	R-class 3 (0,400 m)
Height 1 (z = 10 m)	ms-1 Wm-2	10,6 1268	7,6 495	6,6 325	5,2 156
Height 2 (z = 25 m)	ms-1 Wm-2	11,5 1622	8,9 778	8,0 566	6,7 334
Height 3 (z = 50 m)	ms-1 Wm-2	12,3 1938	10,0 1067	9,2 822	7,9 539
Height 4 (z = 100 m)	ms-1 Wm-2	13,1 2355	11,4 1475	10,5 1174	9,3 828
Height 5 (z = 200 m)	ms-1 Wm-2	14,2 2947	13,2 2241	12,2 1796	10,9 1284





WIND TURBINE 1000kW

'D1_final' Predicted wind climate

Wind climate | Wind energy | Wind power | Model output

Mean speed: 9,67 ms-1 Energy: 1016 Wm-2 Power: 4,40 GWhy-1

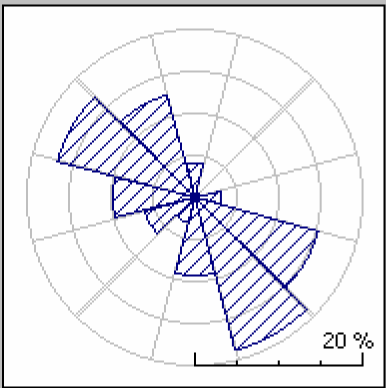
S	F	WA	Wk	Uc1	Uc2	Ob1	Ob2	Or1	Or2	R1	R2	R3	z0	E	P
0	2	11,1	2,55	0	0	0	0	-3	-4	0	0	0	0,03	21,9	0,11
30	0	3,4	0,81	0	0	0	0	-11	-3	4	0	1	0,07	1,1	0,00
60	1	6,8	2,11	0	0	0	0	-12	2	4	0	2	0,07	1,3	0,01
90	3	14,1	2,24	0	0	0	0	-6	4	2	0	1	0,05	68,0	0,19
120	18	15,4	2,65	0	0	0	0	1	3	0	0	0	0,03	421,0	1,13
150	20	11,7	2,49	0	0	0	0	2	-2	1	0	1	0,04	218,2	1,00
180	5	8,6	1,74	0	0	0	0	-4	-5	7	0	2	0,12	29,2	0,15
210	3	5,9	2,54	0	0	0	0	-11	-3	10	0	1	0,25	3,4	0,03
240	8	5,9	3,13	0	0	0	0	-13	2	9	0	2	0,20	10,2	0,09
270	10	7,6	2,64	0	0	0	0	-6	5	10	0	1	0,23	28,6	0,23
300	19	9,8	3,32	0	0	0	0	1	3	5	0	3	0,08	103,6	0,75
330	12	11,7	3,33	0	0	0	0	2	-1	0	0	0	0,03	110,5	0,62

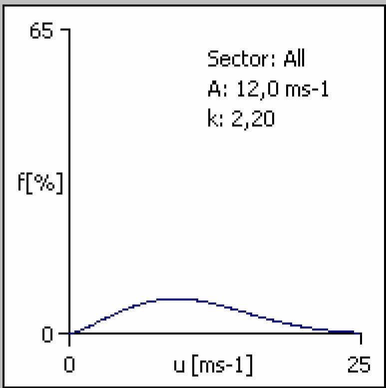
DJUNGAR GATE. STATION D2

STATISTICS

'D2_final' Wind atlas

		R-class 0 (0,000 m)	R-class 1 (0,030 m)	R-class 2 (0,100 m)	R-class 3 (0,400 m)
Height 1 (z = 10 m)	ms-1 Wm-2	10,6 1293	7,6 504	6,6 331	5,2 159
Height 2 (z = 25 m)	ms-1 Wm-2	11,6 1655	8,9 792	8,0 577	6,7 340
Height 3 (z = 50 m)	ms-1 Wm-2	12,4 1976	10,1 1087	9,2 838	8,0 548
Height 4 (z = 100 m)	ms-1 Wm-2	13,2 2402	11,4 1502	10,6 1197	9,4 842
Height 5 (z = 200 m)	ms-1 Wm-2	14,2 3001	13,3 2273	12,3 1825	11,0 1305





WIND TURBINE 1000kW

'D2_final' Predicted wind climate

Wind climate | Wind energy | Wind power | Model output

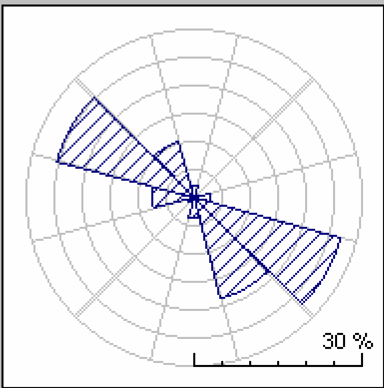
Mean speed: 9,79 ms-1 Energy: 1049 Wm-2 Power: 4,47 GWhy-1

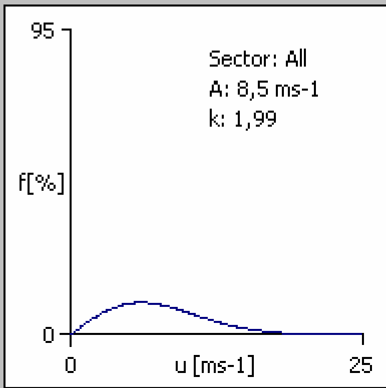
S	F	WA	Wk	Uc1	Uc2	Ob1	Ob2	Or1	Or2	R1	R2	R3	z0	E	P
0	2	11,8	2,81	0	0	0	0	-3	-4	1	0	1	0,04	21,4	0,11
30	0	3,6	0,86	0	0	0	0	-11	-3	4	0	1	0,07	1,1	0,00
60	1	7,6	2,24	0	0	0	0	-12	2	4	0	2	0,07	2,3	0,02
90	3	14,0	2,24	0	0	0	0	-5	5	2	0	1	0,05	70,7	0,20
120	19	15,6	2,78	0	0	0	0	2	2	0	0	0	0,03	451,9	1,22
150	19	11,7	2,46	0	0	0	0	2	-2	1	0	1	0,04	209,7	0,96
180	5	8,6	1,72	0	0	0	0	-4	-5	6	0	2	0,11	30,4	0,15
210	2	5,7	2,35	0	0	0	0	-11	-3	9	0	2	0,22	3,0	0,03
240	7	5,5	2,71	0	0	0	0	-12	2	8	0	2	0,18	7,6	0,06
270	11	7,7	2,61	0	0	0	0	-6	5	9	0	1	0,21	32,0	0,25
300	20	10,0	3,39	0	0	0	0	1	3	4	0	2	0,07	115,9	0,83
330	11	11,9	3,44	0	0	0	0	2	-2	0	0	0	0,03	104,5	0,59

DJUNGAR GATE. STATION D3.
STATISTICS

'Untitled' Wind atlas

		R-class 0 (0,000 m)	R-class 1 (0,030 m)	R-class 2 (0,100 m)	R-class 3 (0,400 m)
Height 1 (z = 10 m)	ms-1 Wm-2	10,5 1297	7,6 508	6,6 334	5,2 160
Height 2 (z = 25 m)	ms-1 Wm-2	11,5 1659	8,9 797	8,0 582	6,7 342
Height 3 (z = 50 m)	ms-1 Wm-2	12,2 1976	10,0 1091	9,1 840	7,9 553
Height 4 (z = 100 m)	ms-1 Wm-2	13,1 2399	11,3 1495	10,5 1196	9,3 844
Height 5 (z = 200 m)	ms-1 Wm-2	14,1 2986	13,0 2249	12,1 1813	10,8 1302





WIND TURBINE 1000 kW

'D3_finalx' Predicted wind climate

Wind climate | Wind energy | Wind power | Model output

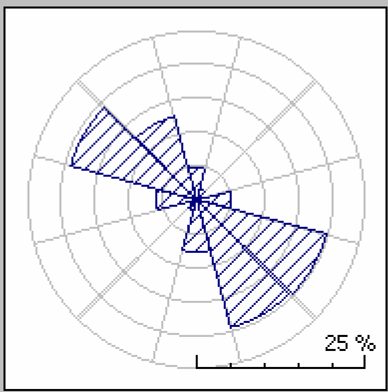
Mean speed: 9,46 ms-1 Energy: 939,2 Wm-2 Power: 4,30 GWhy-1

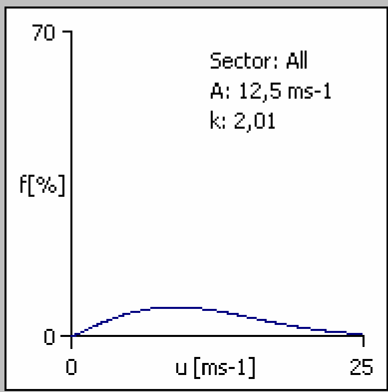
S	F	WA	Wk	Uc1	Uc2	Ob1	Ob2	Or1	Or2	R1	R2	R3	z0	E	P
0	2	5,9	1,05	0	0	0	0	-3	-2	2	0	1	0,05	11,0	0,03
30	1	2,0	0,69	0	0	0	0	-8	-3	5	0	1	0,10	1,4	0,00
60	1	2,5	0,72	0	0	0	0	-11	0	6	0	2	0,10	1,6	0,00
90	5	13,2	2,27	0	0	0	0	-9	3	3	0	2	0,06	75,4	0,25
120	25	14,1	2,69	0	0	0	0	-4	2	1	0	1	0,03	455,5	1,54
150	18	9,4	1,99	0	0	0	0	-1	0	0	0	0	0,03	127,2	0,66
180	3	6,2	1,63	0	0	0	0	-3	-2	3	0	2	0,06	6,7	0,05
210	1	4,9	1,69	0	0	0	0	-8	-3	6	0	2	0,11	1,2	0,01
240	2	6,1	2,65	0	0	0	0	-11	0	6	0	2	0,11	2,6	0,02
270	9	8,3	2,58	0	0	0	0	-9	3	6	0	2	0,10	34,2	0,26
300	23	9,9	3,17	0	0	0	0	-4	3	2	0	1	0,04	137,5	0,96
330	11	10,8	2,94	0	0	0	0	-1	0	0	0	0	0,03	85,0	0,51

DJUNGAR GATE. STATION D4.
STATISTICS

'D4_final' Wind atlas

		R-class 0 (0,000 m)	R-class 1 (0,030 m)	R-class 2 (0,100 m)	R-class 3 (0,400 m)
Height 1 (z = 10 m)	ms-1 Wm-2	11,1 1582	7,9 625	6,9 409	5,4 196
Height 2 (z = 25 m)	ms-1 Wm-2	12,0 2019	9,3 976	8,4 709	7,0 418
Height 3 (z = 50 m)	ms-1 Wm-2	12,8 2406	10,4 1325	9,5 1021	8,3 669
Height 4 (z = 100 m)	ms-1 Wm-2	13,7 2894	11,7 1782	10,9 1432	9,7 1015
Height 5 (z = 200 m)	ms-1 Wm-2	14,6 3563	13,3 2583	12,4 2103	11,2 1533





WIND TURBINE 1000kW

'D4_final' Predicted wind climate

Wind climate | Wind energy | Wind power | Model output

Mean speed: 9,79 ms-1 Energy: 1095 Wm-2 Power: 4,41 GWhy-1

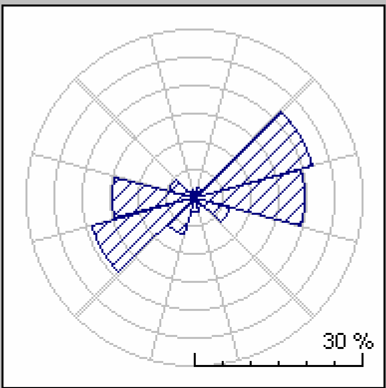
S	F	WA	Wk	Uc1	Uc2	Ob1	Ob2	Or1	Or2	R1	R2	R3	z0	E	P
0	3	7,0	1,17	0	0	0	0	-6	-4	5	0	2	0,09	24,8	0,08
30	1	3,2	0,79	0	0	0	0	-13	-4	8	0	2	0,17	3,5	0,01
60	1	6,6	1,19	0	0	0	0	-16	1	8	0	2	0,17	5,7	0,02
90	7	12,9	2,13	0	0	0	0	-12	4	5	0	2	0,09	106,5	0,34
120	23	15,0	2,80	0	0	0	0	-5	3	1	0	1	0,04	494,6	1,49
150	19	11,0	2,06	0	0	0	0	-2	0	0	0	0	0,03	202,5	0,86
180	4	6,7	1,43	0	0	0	0	-6	-4	2	0	1	0,04	15,0	0,08
210	1	3,5	1,31	0	0	0	0	-13	-4	4	0	1	0,07	0,6	0,00
240	1	4,7	1,51	0	0	0	0	-16	1	5	0	1	0,08	1,4	0,01
270	7	8,7	2,63	0	0	0	0	-11	4	3	0	2	0,07	30,1	0,22
300	23	9,7	2,93	0	0	0	0	-4	3	1	0	1	0,04	127,5	0,88
330	10	10,5	2,38	0	0	0	0	-2	0	0	0	0	0,03	82,3	0,44

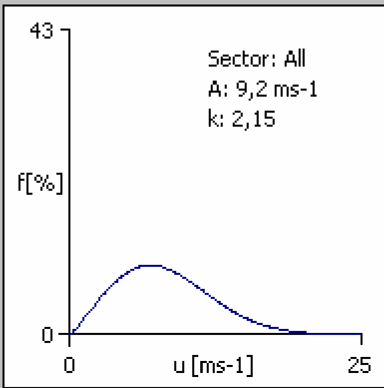
CHILIK GATE. STATION CC.

STATISTICS

'CC_final' Wind atlas

		R-class 0 (0,000 m)	R-class 1 (0,030 m)	R-class 2 (0,100 m)	R-class 3 (0,400 m)
Height 1 (z = 10 m)	ms-1 Wm-2	8,2 593	5,8 232	5,0 154	4,0 74
Height 2 (z = 25 m)	ms-1 Wm-2	8,9 760	6,8 368	6,1 269	5,2 159
Height 3 (z = 50 m)	ms-1 Wm-2	9,5 910	7,8 510	7,1 395	6,2 259
Height 4 (z = 100 m)	ms-1 Wm-2	10,2 1146	9,0 745	8,3 583	7,3 402
Height 5 (z = 200 m)	ms-1 Wm-2	11,2 1516	10,7 1286	9,9 1005	8,7 682





WIND TURBINE 1000kW

'CC_final' Predicted wind climate

Wind climate | Wind energy | Wind power | Model output

Mean speed: 7,77 ms-1 Energy: 509,6 Wm-2 Power: 3,19 GWhy-1

S	F	WA	Wk	Uc1	Uc2	Ob1	Ob2	Or1	Or2	R1	R2	R3	z0	E	P
0	1	3,8	1,65	0	0	0	0	0	0	0	0	0	0,03	0,5	0,00
30	2	5,8	2,15	0	0	0	0	0	0	0	0	0	0,03	2,8	0,02
60	28	10,3	3,57	0	0	0	0	0	0	0	0	0	0,03	175,1	1,23
90	17	8,5	1,94	0	0	0	0	0	0	0	0	0	0,03	90,1	0,53
120	3	4,4	3,02	0	0	0	0	0	0	0	0	0	0,03	1,4	0,01
150	1	3,8	2,31	0	0	0	0	0	0	0	0	0	0,03	0,5	0,00
180	3	4,5	2,41	0	0	0	0	0	0	0	0	0	0,03	1,8	0,01
210	8	7,1	2,64	0	0	0	0	0	0	0	0	0	0,03	18,5	0,15
240	22	10,0	2,29	0	0	0	0	0	0	0	0	0	0,03	159,1	0,88
270	12	8,5	2,13	0	0	0	0	0	0	0	0	0	0,03	57,1	0,37
300	2	4,6	1,67	0	0	0	0	0	0	0	0	0	0,03	2,2	0,02
330	1	4,0	1,52	0	0	0	0	0	0	0	0	0	0,03	0,9	0,01