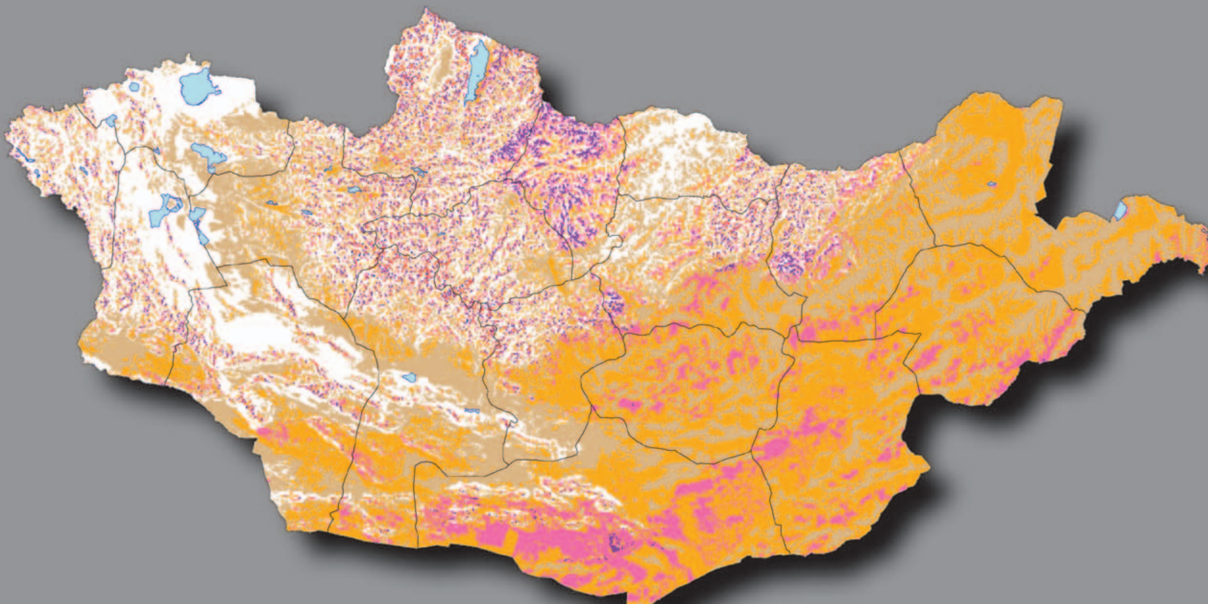
Wind Energy Resource Atlas of Mongolia



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Executive Summary

The wind energy resource atlas of Mongolia identifies the wind characteristics and the distribution of the wind resource in this country. This major project is the first of its kind undertaken for Mongolia. The information contained in the atlas is necessary to facilitate the use of wind energy technologies, both for utility-scale power generation and off-grid wind energy applications. A computerized wind-mapping technique developed at the National Renewable Energy Laboratory (NREL) generated detailed wind resource maps for the entire country. This technique uses Geographic Information Systems (GIS) to produce high-resolution (1-square kilometer [km^2]) annual average wind resource maps.

An accurate wind resource assessment is highly dependent on the quantity and quality of meteorological data used by the mapping system. The quality of the meteorological input depends on understanding the wind characteristics in the study region, including the seasonal and diurnal variability, and the wind direction frequency. NREL used innovative assessment methods on existing climatic data sets to develop a detailed understanding of these key wind characteristics. NREL's approach depended upon the critical analysis of all available (surface meteorological and upper-air) climatic data sets for Mongolia and the surrounding areas. The surface and upper-air (weather-balloon) data used in this project usually covered many years of record, with up to 40 years for some of the data sets. Global data sets maintained at NREL were supplemented with data sets obtained from Mongolia. We processed the data to generate wind characteristics summaries for hundreds of surface stations and numerous upper-air locations. These summaries were cross-referenced to aid in understanding the prevalent wind characteristics throughout Mongolia.

This critical data analysis is particularly important because NREL's wind-mapping system applies a "top-down" method in the adjustment of much of the available wind data. The NREL approach takes the ambient wind profile in the lowest kilometers above the surface and adjusts it down to the surface layer. With this method, NREL can produce reliable wind resource maps without having high-quality surface wind data for the study region.

Two major inputs to the mapping system were meteorological data and 1-km^2 gridded terrain data. The final meteorological inputs to the mapping system were vertical profiles of ambient wind power and wind power roses (the percentage of total potential wind power by direction sector). The GIS uses a combination of the meteorological and terrain data to calculate the wind power value for each 1-km^2 grid cell. The primary output of the mapping system was a color-coded map containing the estimated wind power, and equivalent wind speed, for each individual grid cell.

The values on the wind resource maps in the atlas are based on the estimated wind power density, at 30 m above ground level, not wind speed. Wind power density is a better indicator of the available resource than the average wind speed. Wind power density, expressed in watts per square meter (W/m^2), incorporates the combined effects of the wind speed frequency distribution, the dependence of the wind power on air density, and the cube of the wind speed. Six wind power classifications, based on ranges of wind power density, were used in the atlas. Each of the classifications was defined for two categories: utility-scale applications and rural power applications (ranging from moderate to excellent). In this atlas, the 30-m height was chosen as a compromise hub height between large utility-scale wind turbines (primarily between 30 m and 80 m) and small wind turbines (generally between 10 m and 30 m) used for rural power applications. In general, locations with an annual average wind resource greater than 300 W/m^2 or 6.4 m/s at turbine hub height are the most suitable for utility grid-connected wind energy systems. Rural or village power applications can be viable at locations with a wind resource as low as 100 W/m^2 or 4.5 m/s.

Mongolia Wind Resource

The annual average wind resource in Mongolia has considerable variability and the distribution of the resource is controlled by several factors. The key factors are the ambient characteristics of the mid-latitude westerly wind flow, the progression of weather systems across Mongolia, and topographic influences on the wind flow. All regions of Mongolia are influenced by the westerly jet stream, a high-speed ribbon of air several kilometers above sea level. Its interaction with major topographic features such as the large mountain ranges in western and central Mongolia is the primary factor influencing the distribution of the wind resource in the country. The jet stream also controls the progress of weather systems across Mongolia, and the pressure gradient between weather systems can exert significant influences on the wind resource, especially in areas subject to acceleration because of local terrain.

Spatial Variation of the Wind Resource

Throughout the plains of central and eastern Mongolia there are significant areas of good-to-excellent wind resource, especially for rural power applications. The aimags (provinces) with the most extensive areas of suitable resource are Umnugovi, Dundgovi, Dornogovi, and Sukhbaatar. The level of resource at a particular site on the plains is primarily influenced by its elevation relative to the surrounding area and the terrain upwind and downwind of the site.

Complex terrain consisting of large mountain ranges separated by valleys, plains, and basins dominates the topography of north-central Mongolia and all of Mongolia west of 105^o E. longitude. The distribution of the wind resource in the complex terrain is much more varied than the distribution of the wind resource on the plains, but a few general features still can be noted. Exposed ridge-top locations have the highest resource levels in Mongolia. At these sites, the wind power density can be greater than 600 W/m^2. These are the sites most directly influenced by the strong westerly jet stream. However, the resource can vary widely along the ridge crests, and the highest resource areas are generally scattered throughout the mountainous regions. The distribution of the wind resource in the valleys, plains, and basins of western Mongolia varies. In general, the wind resource is lower in the western third of Mongolia as compared to the rest of the country. The most extensive areas of lower elevation with moderate-to-good/excellent wind resource in western Mongolia extend from Umnugovi westward through southern Bayankhongor, southern Govi-Altai, and into extreme eastern Khovd. Finally, some mountain passes and corridors between terrain features may possess good-to-excellent resources.

The prevailing wind at the higher wind resource sites in Mongolia is generally from a westerly or northwesterly direction.

Seasonal and Diurnal Variation of the Wind Resource

There are large seasonal variations in the wind resource throughout Mongolia. Most of the lower elevation regions in Mongolia have maximum wind resource potential from March through June, with April and May being the windiest months. The wind resource decreases rapidly after this period, resulting in lower elevation areas having a wind resource minimum in July and August. The wind resource distribution for the period from October through February is more complex.

Some locations show a secondary wind resource maximum in October and November and a decrease in the resource from December through February before the primary resource maximum in the spring. A few lower-elevation locations have a winter (December through February) or autumn (October and November) wind resource maximum. Acceleration of the wind flow around local topographic features is the likely primary factor in creating these special seasonal wind resource patterns.

The seasonal wind resource distribution on ridge-crest locations varies from eastern and central Mongolia to western Mongolia. The eastern and central ridge-crest locations have a similar seasonal distribution of the wind resource to sites in the plains and other low-elevation areas. The resource reaches a maximum in April and May, has a secondary maximum in October and November, and is at a minimum in July and August. The seasonal wind resource on ridge crests in western Mongolia is different. The western Mongolia ridge crests have the maximum resource from October through December with a secondary maximum occurring in April and May. The minimum resource is during July and August.

The diurnal wind speed distribution, or wind speed versus time of day, is strongly influenced by site elevation and topography. The distribution at low-elevation sites in simple terrain on the plains typically features a maximum wind speed during the afternoon and a minimum near sunrise. Ridge-crest diurnal distributions differ from those of low-elevation sites. The strongest winds at ridge-crest locations occur at night while the lowest speeds are observed during the midday hours. Sites located in complex terrain and subject to wind flows caused by local conditions can have a diurnal pattern different from either the simple terrain of the plains or the ridge crests.

Conclusions

More than 160,000 km^2 of windy land areas in Mongolia have been estimated to have good-to-excellent wind potential for utility-scale applications. The amount of windy land is about 10% of the total land area (1,565,000 km^2) of the country. This amount of windy land, using conservative assumptions that result in about 7 megawatts (MW) of capacity per km^2, could support over 1,100,000 MW of installed capacity, and potentially deliver over 2.5 trillion kilowatt-hours (kWh) per year. All of the aimags have at least 6,000 MW of wind potential. There are 13 aimags that have at least 20,000 MW of wind potential, and 9 aimags that have greater than 50,000 MW of potential. Umnugovi alone is estimated to have over 300,000 MW of potential.

If additional areas with moderate wind resource potential (or good for rural power applications) are considered, the estimated total windy land area increases to more than 620,000 km^2, or almost 40% of the total land area of Mongolia. This amount of windy land could support over 4,300,000 MW of installed capacity and potentially deliver over 8 trillion kWh per year. There are 15 aimags with at least 50,000 MW, 12 aimags with at least 100,000 MW, and 9 aimags with at least 200,000 MW of wind potential.

The wind resource maps and other wind resource characteristic information will be useful in identifying prospective areas for wind-energy applications. A preliminary validation of the maps was done using high-quality data from recent monitoring programs. However, because validation data were quite limited, we strongly recommend that wind measurement programs be conducted to validate the resource estimates and to refine the wind maps and assessment methods where necessary.

1.0 Introduction

The United States Department of Energy (DOE) and the United States Agency for International Development (USAID) sponsored a project to help accelerate the large-scale use of wind energy technologies in Mongolia through the development of a wind energy resource atlas of Mongolia.

DOE's National Renewable Energy Laboratory (NREL) had the lead responsibility in administering and conducting this project and in collaborating with USAID and Mongolian organizations on project activities. The Mongolian organizations participating in this project were the Scientific, Production, and Trade Corporation for Renewable Energy (REC) and the Institute of Meteorology and Hydrology (IMH).

The primary goals of the project were (1) to develop detailed wind resource maps for all regions of Mongolia and to produce a comprehensive wind resource atlas documenting the results, and (2) to establish a wind-monitoring program to identify prospective sites for wind energy projects and help validate some of the wind resource estimates. Preliminary activities for this project are described in Elliott et al., 1998.

REC was primarily responsible for coordinating the wind-monitoring program in Mongolia, including identification of sites, installation of measurement systems, and collection of data. NREL provided 12 wind-monitoring systems and conducted training necessary to implement a successful monitoring program. IMH, which collects and archives meteorological data at a network of stations throughout Mongolia, was responsible for providing specific types of wind data for use in the project. REC was also responsible for identifying and providing useful wind data from sources in Mongolia, in addition to those being provided by IMH. NREL was responsible for obtaining meteorological data available from U.S. sources, such as the National Climatic Data Center (NCDC) and National Center for Atmospheric Research, which would be useful in the assessment.

This document, the “Wind Energy Resource Atlas of Mongolia", presents the wind resource analysis and mapping results for Mongolia. An advanced wind-mapping technique developed at NREL was applied in generating wind resource maps for the entire country. This technique uses Geographic Information Systems (GIS) to produce high-resolution (1-square kilometer [km^2]) annual average wind resource maps. In addition to the wind resource maps, the atlas includes information on salient wind characteristics such as seasonal and diurnal variability and wind direction frequency.

This atlas is the latest in a series of wind energy resource atlases and assessments produced by NREL. In addition to Mongolia, NREL has applied its new wind-mapping system to produce wind resource assessments of the Dominican Republic (Elliott 1999) and the Philippines (Elliott 2000), and specific regions of Chile, China, Indonesia, Mexico, and the United States (Schwartz 1999; Elliott et al. 1999).

We divided the report into seven sections. We present an overview of the geography and climate of Mongolia in Section 2.0. A summary of the fundamentals of wind resource estimation is given in Section 3.0. We provide a description of NREL’s wind resource methodology and mapping system in Section 4.0. A description of the wind resource data obtained and analyzed for the Mongolia assessment is presented Section 5.0. The wind resource characteristics of Mongolia and the wind-mapping results are presented in Section 6.0. Finally, we assess wind electric potential in Section 7.0.

In the appendices, we provide pertinent summaries of wind characteristics data from selected surface and upper-air meteorological stations and from selected wind-monitoring sites.

2.0 Geography and Climate of Mongolia

2.1 Geography

Mongolia is situated in central Asia, and is bordered on the north by Russia and on the south by China. The land area is approximately 1.565 million km^2 (604,000 mi^2). Mongolia is centered at approximately 105 degrees east longitude and 46 degrees north latitude.

Figure 2.1 is a political map of Mongolia, showing the internal political boundaries of the 18 aimags (provinces), provincial capitals, and municipalities. The population of Mongolia is estimated to be 2.6 million (1999). The capital of Mongolia and largest city is Ulaanbaatar, with a population of more than 700,000.

The terrain, shown in Figures 2.2 and 2.3, is varied and includes mountains, rolling plateaus, vast semideserts, and desert plains. Much of Mongolia is a high mountainous plateau, giving the country an average elevation of 1,580 meters (m) above sea level. The elevation of Ulaanbaatar is 1350 m. Mongolia has three major mountain ranges. The Altai Nuruu in the western and the southwestern part of the country is the highest and trends northwest to southeast. The highest point in Mongolia occurs in this range, Tavan Bogd Uul at 4,374 m in the Bayan-Ulgii aimag. The Khangain Nuruu, occupies much of central Mongolia and trends northwest to southeast. The Khentiin Nuruu, northeast of Ulaanbaatar, is the lowest mountain range and trends southwest to northeast.

The lowest point in the country is Khokh Nuur at 518 m in the Dornod aimag. Other low areas (generally less than 800 m) occur in the aimags of central Dornogovi, southern Bayankhongor and Govi-Altai, low valleys in Selenge, and northern Uvs. Mongolia contains a few large lakes, most notably Khuvsgul Nuur in the Khuvsgul aimag, with an area over 2,600 km^2 and depth of 238 m, and Uvs Nuur in the Uvs aimag.

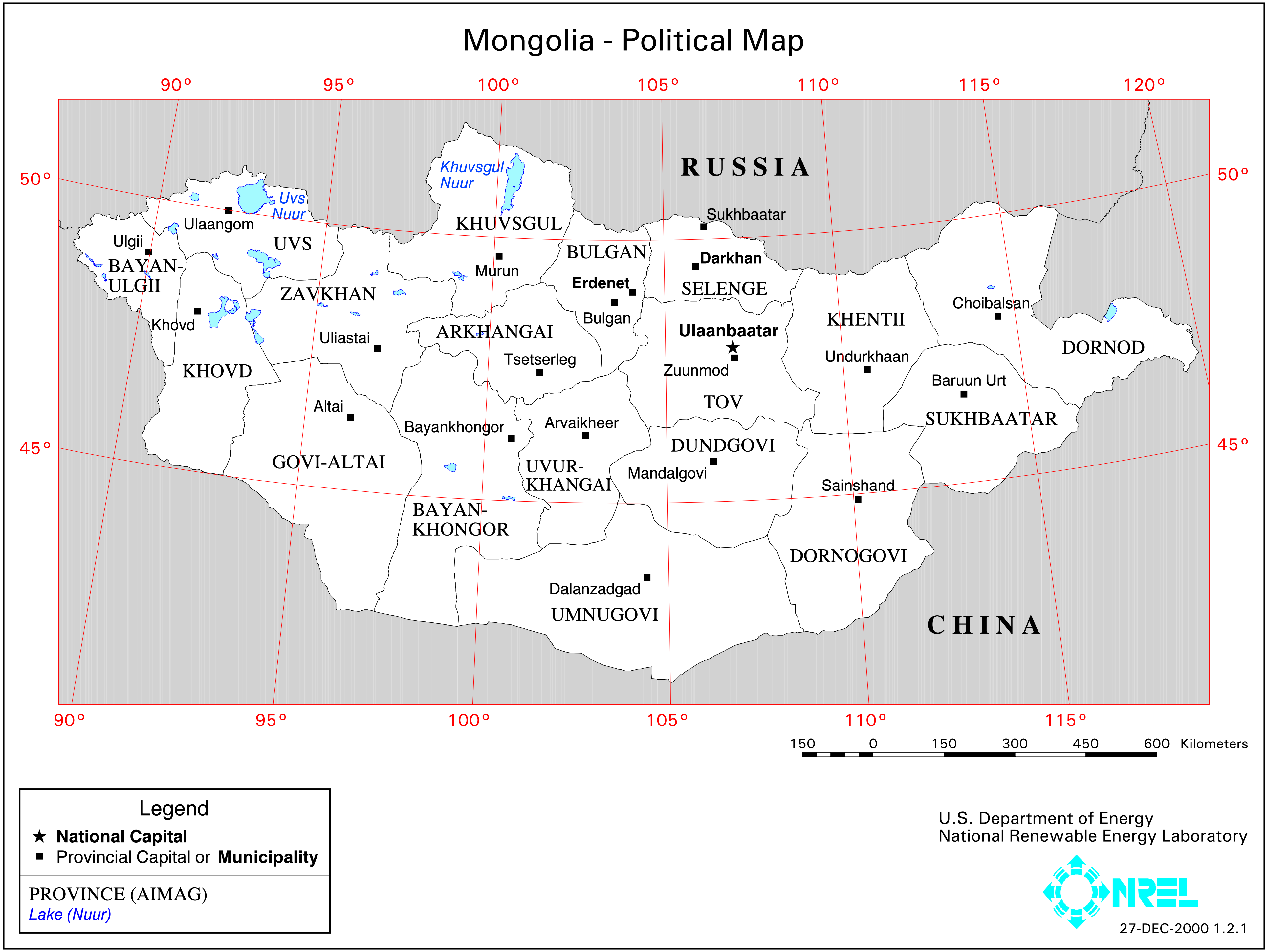
Much of eastern Mongolia consists of plains with plateaus, and areas of low hills and valleys. The Gobi Desert covers more than 400,000 km^2 in southeastern Mongolia and consists of hills and valleys covered with sparse grasslands. Only 3% of the Gobi is actually covered by sand and gravel desert.

2.2 Climate

Mongolia has a continental climate. In general, winters are cold and dry, whereas summers are warm with occasional precipitation. Conditions vary across the country and with elevation.

There are large variations in seasonal and diurnal temperatures. In Ulaanbaatar, the coldest month of the year (January) has an average temperature of –26 degrees Celsius (°C), with an average low of –32 °C and an average high of –19 °C. In the warmest month of the year (July) the average temperature is 17 °C, with an average low of 11 °C and an average high of 22 °C.

Northwestern Mongolia is at the center of the Asiatic high, a region of high atmospheric pressure that influences circulation over much of central Asia. The influence of the high causes Mongolia to be a semiarid to arid country. Precipitation is highest in the north, averaging 20 to 35 centimeters (cm) per year and lowest in the south, averaging 10 to 20 cm per year. It is not unusual for some locations in the Gobi to have no measurable precipitation during many years.


Mongolia - Political Map
RUSSIA
CHINA
KHUVSGUL
BULGAN
SELENGE
UVS
BAYAN-ULGII
ZAVKHAN
KHOVD
ARKHANGAI
KHENTII
DORNOD
TOV
SUKHBAATAR
DUNDGOVI
GOVI-ALTAI
UVUR-KHANGAI
BAYAN-KHONGOR
DORNOGOVI
UMNUGOVI
Ulaangom
Ulgii
Khovd
Uliastai
Altai
Murun
Tsetserleg
Bayankhongor
Arvaikheer
Erdenet
Bulgan
Sukhbaatar
Darkhan
Ulaanbaatar
Zuunmod
Mandalgovi
Dalanzadgad
Sainshand
Undurkhaan
Baruun Urt
Choibalsan
Khuvsgul Nuur
Uvs Nuur
90°
95°
100°
105°
110°
115°
120°
50°
45°
150 0 150 300 450 600 Kilometers
Legend
★ National Capital
■ Provincial Capital or Municipality
PROVINCE (AIMAG)
Lake (Nuur)
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National Renewable Energy Laboratory
NREL
27-DEC-2000 1.2.1

Figure 2-1

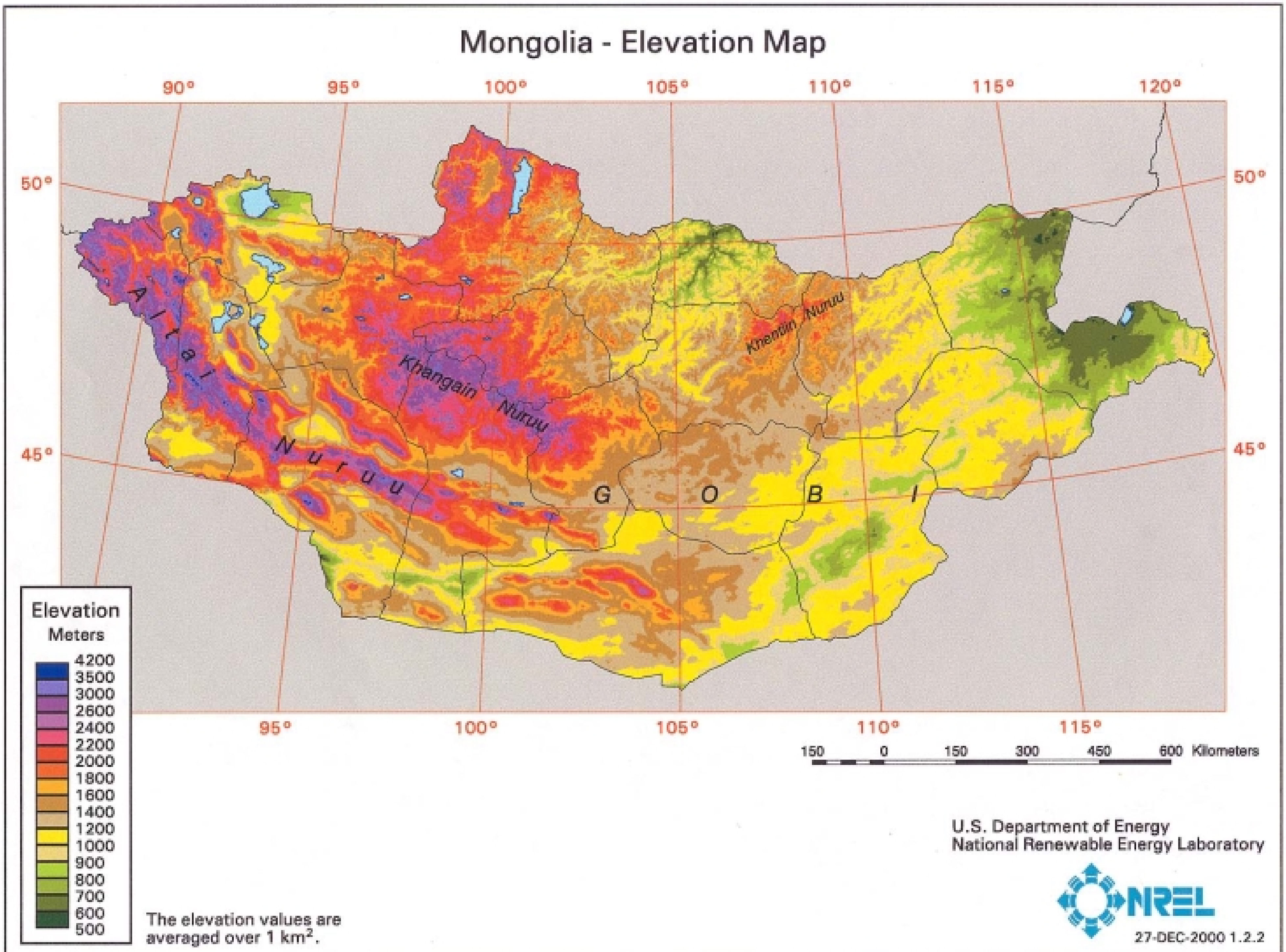
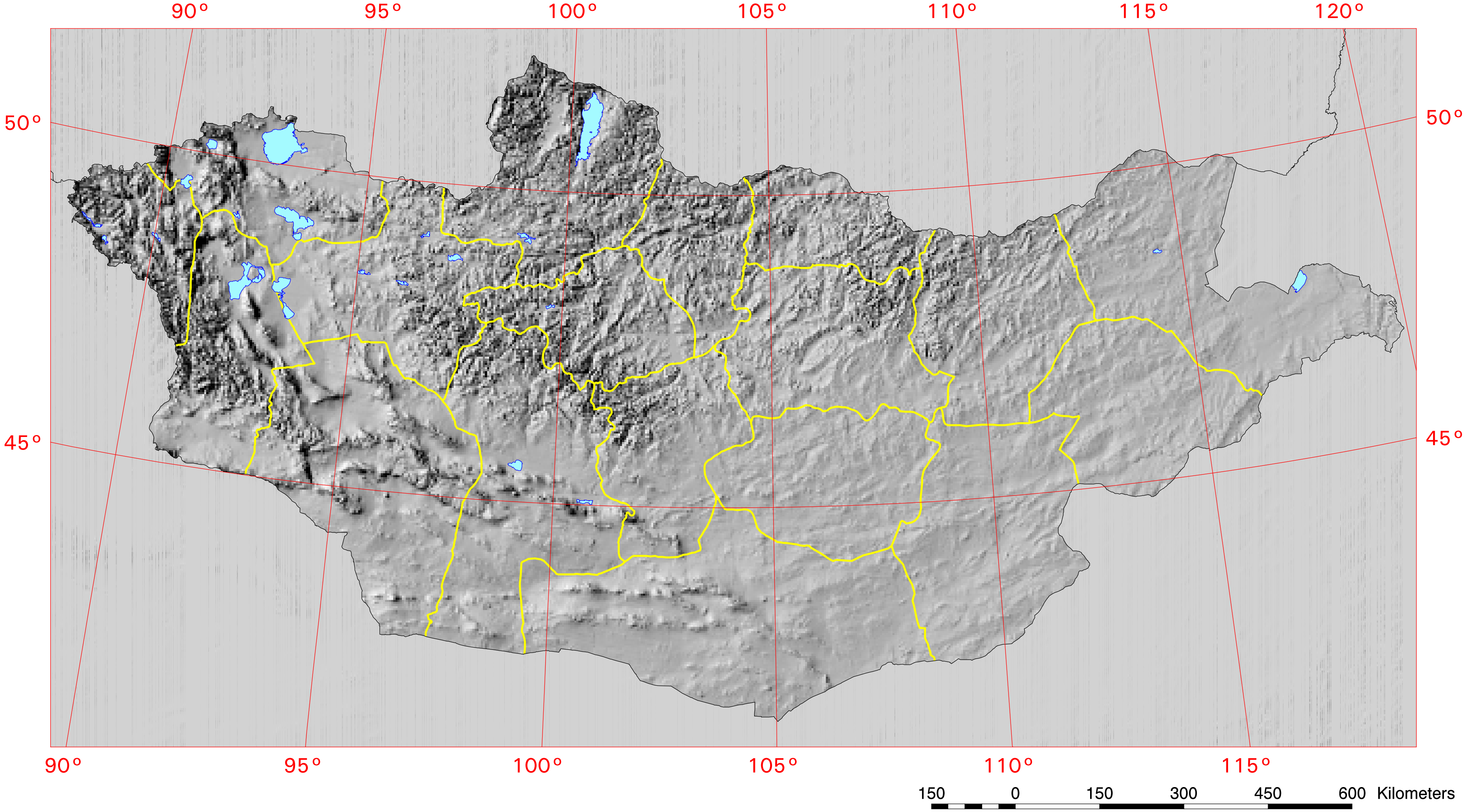

Mongolia - Elevation Map
90°
95°
100°
105°
110°
115°
120°
50°
45°
Altai Nuruu
Khangain Nuruu
Khentiin Nuruu
G O B I
Elevation
Meters
4200
3500
3000
2600
2400
2200
2000
1800
1600
1400
1200
1000
900
800
700
600
500
The elevation values are averaged over 1 km².
150 0 150 300 450 600 Kilometers
U.S. Department of Energy
National Renewable Energy Laboratory
NREL
27-DEC-2000 1.2.2

Figure 2-2

Mongolia - Hillshaded Relief Map



U.S. Department of Energy
National Renewable Energy Laboratory

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Figure 2-3

3.0 Fundamentals of Wind Resource Estimation

3.1 Introduction

This section introduces the basic concepts of wind resource estimation and presents some of the sources of data that can be used in an assessment study.

Wind resource assessment studies can be placed into three basic categories:

- Preliminary Area Identification
- Area Wind Resource Evaluation
- Micrositing.

NREL's wind resource atlases are useful for the first two categories, but do not contain the detailed information needed for micrositing studies. Details of micrositing and wind-monitoring programs can be found in the *Wind Resource Assessment Handbook* (NREL/AWS Scientific 1997).

3.2 Wind Speed and Direction

Wind speed is the simplest representation of the wind at a given point. Anemometers or other calibrated instruments measure wind speed. Wind speeds can be calculated as an average or expressed as an instantaneous value. Wind speed averaging intervals commonly used in resource assessment studies include 1or 2 minutes (weather observations), 10-minute (used in the NREL/REC monitoring programs), hourly, monthly, and yearly periods. It is important to know the measurement height for a given wind speed because of the variation of wind speed with height. It is also desirable to know the exposure of a particular location to the prevailing winds because nearby obstacles such as trees and buildings can reduce the apparent wind speed.

Wind direction is measured with a wind vane, usually located at the same height as the anemometer. Knowledge of the prevailing wind direction is important in assessing the available resource. Correct alignment of the wind vane to a reference direction is important to accurately measure the wind direction, but is not always properly done. Wind direction observations at meteorological stations are often based on a 36-point compass (every 10 degrees). Some wind direction data are expressed in less precise 8-point (every 45 degrees), 12-point (every 30 degrees), or 16-point (every 22.5 degrees) intervals.

The wind direction distribution is often presented as a wind rose, a plot of frequency of occurrence by direction. Wind roses can also represent quantities such as the average speed or the percent of the available power for each direction.

3.3 Wind Speed Frequency Distribution

The wind speed frequency distribution characterizes the wind at a given location in two ways. First, the frequency distribution determines how often a given wind speed is observed at the location; it also identifies the range of wind speeds observed at that location. This analysis is often accomplished by sorting the wind speed observations into 1 m/s bins, and computing the percentage in each bin. The wind speed distribution is important because sites with identical average wind speeds but different distributions can result in substantially different available wind resource. These differences can be as great as a factor of two or three.

3.4 Weibull Distribution Function

The wind speed frequency distribution in many areas can be closely approximated by the Weibull Distribution Function. The Weibull Function is defined as:

$$f(V) = (k/c)(V/c)^{k-1} \exp(-V/c)^k$$

where:

- $f(V)$ = the Weibull probability density function, the probability of encountering a wind speed of V m/s
- c = the Weibull scale factor, which is typically related to the average wind speed through the shape factor, expressed in m/s
- k = the Weibull shape factor, which describes the distribution of the wind speeds.

Detailed explanations of the Weibull Distribution Function and its application are available in many texts, such as that by Rohatgi and Nelson (1994).

3.5 Wind Power Density

The wind resource at a site can be roughly described by the mean wind speed; however, the wind power density provides a truer indication of a site's wind energy potential. Wind power density expresses the average wind power over one square meter. The power density is proportional to the sum of the cube of the instantaneous (or short-term average) wind speed and the air density. Due to this cubic term, two sites with the same average wind speed but different distributions can have very different wind power density values. The wind power density, in units of W/m^2, is computed by the following equation:

$$WPD = \frac{1}{2n} \sum_{i=1}^{n} \rho \cdot v_i^3$$

where:

- WPD = the wind power density in W/m^2
- n = the number of records in the averaging interval
- ρ = the air density (kg/m^3) at a particular observation time
- v_i^3 = the cube of the wind speed (m/s) at the same observation time.

This equation should only be used for individual measurement records (such as hourly and 10-minute) and not for long-term average records such as a monthly or yearly value. Using this equation with long-term averages will underestimate the wind power density, because the higher-speed records that would contribute the most to the calculated wind power density value will tend to have been smoothed out.

The air density term (kg/m^3) is dependent on temperature and pressure and can vary by 10% to 15% seasonally. If the site pressure and temperature are known, the air-density can be calculated using the following equation:

$$\rho = \frac{P}{R \cdot T}$$

where:

ρ = the air density in kg/m^3
P = the air pressure (Pa or N/m^2)
R = the specific gas constant for air (287 J/kg·K)
T = the air temperature in degrees Kelvin (°C+273).

If site pressure is not available, air density can be estimated as a function of site elevation (z) and temperature (T) as follows:

$$\rho = \left(\frac{P_0}{R \cdot T}\right)\varepsilon^{\left(\frac{-g \cdot z}{R \cdot T}\right)}$$

where:

ρ = the air density in kg/m^3
P_0 = the standard sea-level atmospheric pressure (101,325 Pa), or the actual sea-level adjusted pressure reading from a local airport
g = the gravitational constant (9.8 m/s^2)
z = the site elevation above sea level (m).

Substituting in the numerical values for P_0, R, and g, the resulting equation is:

$$\rho = \left(\frac{353.05}{T}\right)\varepsilon^{-0.034\left(\frac{z}{T}\right)}$$

This air density equation can be substituted into the wind power density (WPD) equation for the determination of each instantaneous or multiple average value.

3.6 Wind Shear and the Power Law

Wind shear is a change in horizontal wind speed with height. The magnitude of the wind shear is site-specific and depends on wind direction, wind speed, and atmospheric stability. By determining the wind shear, one can extrapolate existing wind speed or wind-power-density data to other heights. The following form of the power law equation can be used to make these adjustments:

$$\mathbf{U = U_0\,(z/z_0)^{\alpha}} \qquad \text{[Wind Speed]}$$

$$\mathbf{WPD = WPD_0\,(z/z_0)^{3\alpha}} \qquad \text{[Wind Power Density]}$$

where:

U = the unknown wind speed at height z above ground
U_0 = the known speed at a reference height z_0
WPD = the unknown wind power density at height z above ground
WPD_0 = the known wind power density at a reference height z_0
α = the power law exponent.

An exponent of 1/7 (or 0.143), which is representative of well-exposed areas with low surface roughness, is often used to extrapolate data to higher heights.

3.7 Sources of Wind Data

3.7.1 Surface Observations

Surface meteorological data are available from many sources. Most countries have a meteorological agency that collects data at a network of stations across the country. Other data may be available from regional agencies, scientific organizations, power utilities, and private companies.

For accurate wind resource estimation, wind speed and direction must be included, but temperature and pressure can also be helpful. A site's exposure, anemometer height, local topography, and site maintenance history are also quite useful to know.

Wind speeds at some sites are observed to decrease steadily over a period of years (the "disappearing winds" effect). This trend can be caused by new building construction near the site, tree growth near the site, or by lack of anemometer maintenance. Extra quality control procedures must be applied in analyzing data from sites with this wind speed trend.

3.7.2 Upper-air Observations

Upper-air stations measure the meteorological properties of the atmosphere above the surface by launching balloons, usually between one and four times daily. Pilot balloons, which are un-instrumented balloons that are tracked through theodolites, comprise the simplest upper-air observations. Pilot-balloon observations can only estimate wind speed and direction. Radiosonde (or rawinsonde) packages of instruments that relay atmospheric conditions to the base station by radio make more elaborate and accurate measurements. The instrumented packages measure temperature, pressure, and humidity data in addition to wind speed and direction.

3.7.3 Computer Model Climatic Data

Climatic data, including wind speed and direction, can be generated by computer weather prediction models. These computer models analyze meteorological data from many sources, and generate data sets of meteorological parameters at regular grid points. Model output often covers the entire globe and usually includes meteorological data at the surface and for a number of levels above the surface. The distance between grid points is often large (greater than 200 km). Computer model data is valuable for assessment work in data-sparse regions of the world. The major drawback of depending entirely on computer model data is that output data at a particular grid point can be strongly influenced by input meteorological data that may not be representative of the climatic conditions in the study region. Good meteorological judgement is required when computer model data is used in assessment work.

4.0 Wind Resource Methodology and Mapping System

4.1 Introduction

In this section, we present a description of the methodology used to analyze and evaluate the meteorological data used for this resource assessment, and the mapping system used to generate the resource maps. Both components are crucial for the production of a wind resource atlas that is accurate enough to stimulate the development of wind energy in the study area.

NREL has been developing its GIS-based wind resource mapping technique since 1996. This technique replaces the manual analysis techniques used in previous mapping efforts, such as the *Wind Energy Resource Atlas of the United States* (Elliott et al. 1987) and the "Mexico Wind Resource Assessment Project" (Schwartz and Elliott 1995). NREL developed the system with the following two primary goals in mind:

1) To produce a more consistent and detailed analysis of the wind resource, particularly in areas of complex terrain
2) To generate user-friendly, high-quality map products.

4.2 Methodology

4.2.1 Data Evaluation and Analysis

4.2.1.1 Initial Approach

The quality of the meteorological input depends on understanding the important wind characteristics in the study region such as the interannual, seasonal and diurnal variability of the wind, and the prevailing wind direction. NREL used innovative assessment methods on existing climatic data sets to develop a conceptual understanding of these key wind characteristics. These data sets, obtained from U.S. sources such as the National Climatic Data Center and National Center for Atmospheric Research, supplemented with data sets obtained from Mongolia, are maintained at NREL as part of its global archive. The surface and upper-air (weather balloon) data used in this project usually had a long period of record (greater than 20 years). NREL's approach depends upon the critical analysis of all the available (surface meteorological and upper-air) climatic data for Mongolia and the surrounding areas. We used a comprehensive data-processing package to convert the data to statistical summaries of the wind characteristics for hundreds of surface stations and many upper-air locations. The summaries were used to highlight regional wind characteristics.

4.2.1.2 Surface Data Evaluation

Researchers at NREL have found many problems with the available land-based surface wind data collected at meteorological stations in much of the world. Known problems associated with observations taken at the meteorological stations include a lack of information on anemometer height, exposure, hardware, maintenance history, and observational procedures. These problems can cause the quality of observations from the meteorological stations to be extremely variable.

In addition, many areas of the world with good or excellent potential wind resource sites have very little or no meteorological station data to help assess the level of the available wind resource.

NREL takes specific steps in its evaluation and analysis to overcome these problems. Site-specific products are screened for consistency and reasonableness. For example, the interannual wind speeds are evaluated to identify obvious trends in the data, or periods of questionable data. Only representative data periods are selected from the entire record for the assessment. The summarized products are also cross-referenced against each other to select the sites that apparently have the best exposure to the prevailing wind. These sites are used to develop an understanding of the wind characteristics of the study region.

4.2.1.3 Upper-Air Data Evaluation

Upper-air data can be useful in assessing the regional wind resource in several ways. First, upper-air data can be used to estimate the resource at low levels just above the surface. The low-level resource estimation is quite important in areas where surface data is either sparse or not available. Second, upper-air data can be used to approximate vertical profiles of wind speed and power. The vertical profiles are used to extrapolate the level wind resource to elevated terrain features and to identify low-level wind speed maximums that can enhance the wind resource at turbine hub-height.

We generated summaries of wind speed and wind power at specific pressure and height levels from the upper-air data. We also generated monthly and annual average vertical profiles of wind speed and power from the upper-air data. One problem that occurs in the evaluation of upper-air data is that many of the locations where the balloons are launched are blocked from the ambient wind flow by high terrain. Using vertical profiles from the “blocked” locations can be misleading because the profiles only represent conditions at the upper-air station and will not apply throughout the region of interest. Therefore, NREL’s analysis of the upper-air data uses vertical profiles that we judge to be representative of the ambient wind flow in a particular region.

4.2.1.4 Goals of Data Evaluation

The goal of the critical analysis and evaluation of the surface and upper-air data is to develop a conceptual model of the physical mechanisms, both regional and local, that influence the wind flow. When there is a conflict among the data as to wind characteristics in the analysis region, the preponderance of meteorological evidence from the region serves as the basis for the conceptual model. Several recent NREL papers (Schwartz and Elliott 1997; Elliott and Schwartz 1997; Schwartz 1999) describe the integration, analysis, and evaluation of the meteorological data sets typically used for wind resource assessments.

This critical data analysis and conceptual model is particularly important because NREL’s wind-mapping system applies a “top-down” method in the adjustment in much of the available wind data. This approach takes the ambient wind profile in the lowest few hundred meters above the surface and adjusts it down to the surface layer. A prime advantage of this method is that NREL can produce reliable wind resource maps without having high-quality surface wind data for the study region. The conceptual understanding developed by the critical analysis of the available data guides the development of empirical relationships that serve as the basis of the algorithms that calculate wind power in the wind-mapping system.

4.2.2 Wind Power Classifications

The values on the wind resource maps in the atlas are based on the wind power density, not wind speed. Wind power density is a better indicator of the available resource than the average wind speed. Wind power density, expressed in watts per square meter (W/m^2), incorporates the combined effects of the wind speed frequency distribution, the dependence of the wind power on air density, and the cube of the wind speed. Six wind power classifications, based on ranges of wind power density, were used in the atlas. Each of the classifications was qualitatively defined for two categories: utility-scale applications (marginal to excellent) and rural-power applications (moderate to excellent). In general, locations with an annual average wind resource greater than 300 W/m^2 or 6.4 m/s at turbine hub height are the most suitable for utility grid-connected wind energy systems. Rural, village power, or nomadic applications can be viable at locations with a wind resource as low as 100 W/m^2 or 4.5 m/s.

4.3 Description of Mapping System

The mapping procedure uses an advanced computerized mapping system known as a Geographic Information System (GIS). The main GIS software is ARC/INFO®, a powerful and complex package featuring a large number of routines for scientific analysis. None of the ARC/INFO® analysis routines is specifically designed for wind resource assessment work; therefore, NREL's mapping technique requires extensive programming in ARC/INFO® in order to create combinations of scientific routines that mimic direct wind resource assessment methods. The mapping system is divided into three main components: the input data, the wind power calculations, and the output section that produces the final wind resource map. These components are described below.

4.3.1 Input Data

The two primary model inputs are digital terrain data and meteorological data. The elevation information consists of Digital Elevation Model (DEM) terrain data that divide the analysis region into individual grid cells, each having its own unique elevation value. The United States Geological Survey's Earth Resource Observing Satellite Data Center recently produced updated DEMs for most of the world from previously classified United States Department of Defense data and other sources. The new data sets have a resolution of 1 km^2 and are available for large parts of the world. This represents a significant improvement in elevation data used by the mapping system. The model previously relied on 1:1,000,000 scale maps and 305-m (1,000-ft) elevation contours. The final wind resource maps are gridded to 1 km^2.

The meteorological inputs to the mapping system, following the data-screening process, are vertical profiles of wind power density, and wind power roses that express the percentage of total potential power from the wind by direction. The data are incorporated as ARC/INFO® compatible files and used in the power calculation algorithms. The vertical profiles are broken down into 100-m intervals centered every 100 m above sea level. The wind power rose is used to determine the degree of exposure of a particular grid cell to the power-producing winds.

4.3.2 Wind Power Calculations

We present the wind power calculation methodology in Section 3.5. The factors that either decrease or increase the base wind power value for a particular grid cell are terrain considerations, relative and absolute elevation, aspect (slope of terrain relative to the prevailing wind direction), distance from ocean or lake shoreline, and the influence of small-scale wind flow patterns. The factors that have the greatest influence on the adjustment of the base wind power for a particular grid cell are the topography of the area in the vicinity of the grid cell and a combination of the absolute and relative elevation of the grid cell. The wind power calculation module uses the wind power rose and vertical wind profile of a region to account for the effects of short-range (less than 10 km), medium-range (10-50 km), and long-range (greater than 50 km) blocking of the ambient wind flow by terrain. The slope and aspect of the terrain surrounding a particular grid cell and the relative elevation of a grid cell compared to its surroundings also affect the calculated wind power.

The wind power calculation module calls different routines depending upon the existence or proximity of large lakes to the mapping region. The land power routines are run for the entire area of the mapping region. The lake power routines are run only if there are lakes with an area of 50 km^2 or greater. These routines calculate the wind power only for the area within 5 km of any lake in the mapped region. Where routines are run for both land and lakes in a particular region, the results from the calculations are combined to produce the final wind map. For both land and lakes, identical routines use a general topographical description to adjust the base wind power density. The topographical description can be classified as either complex terrain (hills and ridges), complex terrain with large flat areas present, or areas that are designated as flat. The adjustment to the base wind power density depends on which terrain routine is activated during the mapping run.

4.3.3 Mapping Products

The primary output of the mapping system is a color-coded wind power map in units of W/m^2 and equivalent mean wind speed for each individual grid cell. The wind power classification scheme for the Mongolia maps is presented in Table 4.1. In this atlas, the 30-m height was

Table 4.1 Wind Power Classification

Class	Resource Potential		Wind Power Density (W/m^2) @ 30 m agl	Wind Speed [(a)] (m/s) @ 30 m agl
	Utility	Rural		
1	Marginal	Moderate	100 - 200	4.5 – 5.6
2	Moderate	Good	200 - 300	5.6 – 6.4
3	Good	Excellent	300 - 400	6.4 – 7.1
4	Excellent	Excellent	400 - 600	7.1 – 8.1
5	Excellent	Excellent	600 - 800	8.1 – 8.9
6	Excellent	Excellent	800 -1000	8.9 – 9.6

[(a)] Mean wind speed is estimated assuming an elevation of 1400 m and a Weibull distribution of wind speeds with a shape factor (k) of 1.8. The actual mean wind speed may differ from these estimated values by as much as 20 percent, depending on the actual wind speed distribution (or Weibull k value) and elevation above sea level.

chosen as a compromise hub height between large utility-scale wind turbines (which may range between 30 and 80 m) and small wind turbines (which may range between 10 and 30 m) for rural power applications.

The wind power is calculated only for those grid cells that meet certain exposure and slope requirements and, as a result, only the most favorable wind resource areas are highlighted. For example, a grid cell is excluded if there is major blocking of the ambient wind flow by local terrain features. A grid cell must be exposed to at least 70% of the available wind power of the ambient wind flow to be included in the most favorable wind resource area. A grid cell can also be excluded if the slope of the terrain is too steep. The slope of the terrain in a grid cell must be less than or equal to 20% to be included in the wind power calculations. The wind resource values presented are estimates for low surface roughness (e.g., grassland with no major obstructions such as trees or buildings).

The mapping system output uses software to produce the proper map projection for the study region, and to label the map with useful information in addition to the wind power density. Additional information includes a legend, latitude and longitude lines, political divisions of states or provinces, locations of meteorological and other wind measurement stations, important cities, and a distance scale. The DEM data can also be used to create a color-coded elevation map, a hill-shaded relief map, and a map of the elevation contours. When combined with the wind power maps, these products enable the user to obtain a feel for the three-dimensional distribution of the wind power in the analysis region.

4.3.4 Limitations of Mapping Technique

There are several limitations to the mapping technique, the first of which is the resolution of the DEM data. Significant terrain variations can occur within the DEM's 1-km^2 area; thus, the wind resource estimate for a particular grid cell may not apply to all areas within the cell. A second potential problem is the development of the conceptual model of the wind flow and its extrapolation to the analysis region. There are many complexities in the wind flow that make this an inexact methodology, including the structure of low-level jets and their interaction with the boundary layer, and localized circulations, such as land-sea breezes, mountain-valley flows, and channeling effects in areas of steeply sloping terrain. Finally, the power estimates are valid for areas with low surface roughness. Estimates for areas with a higher surface roughness need to be adjusted downward.

5.0 Wind Resource Data for Mongolia

5.1 Introduction

An accurate wind resource assessment depends on the quantity and quality of the input data. NREL reviews many sources of wind data and previous wind assessments as part of its overall evaluation. Several global data sets maintained at NREL, including surface and upper-air observations spanning many years of record, were used in this assessment. Because the quality of data in any particular data set can vary and high-quality data can be quite sparse in many regions of the world, multiple data sets are used. Each data set plays an integral role in the overall assessment. In this chapter, we summarize the data sets used to prepare the wind resource mapping activity for Mongolia. All data sets were analyzed and evaluated in accordance with the procedures outlined in section 4.0.

5.2 Surface Data

High quality surface wind data from well-exposed locations can provide the best indication of the magnitude and distribution of the wind resource in the analysis region. Historical wind data have been collected at more than 300 meteorological stations in Mongolia. However, the quality of these wind data is largely unknown due to lack of information on equipment maintenance and exposure of the equipment to the wind. Studies by NREL and others in many different regions of the world have found that surface wind data from meteorological stations are of varying quality and often are not reliable for wind resource assessment purposes. To help assess the quality of the meteorological wind data in Mongolia, new wind monitoring systems were installed very near 8 existing meteorological stations.

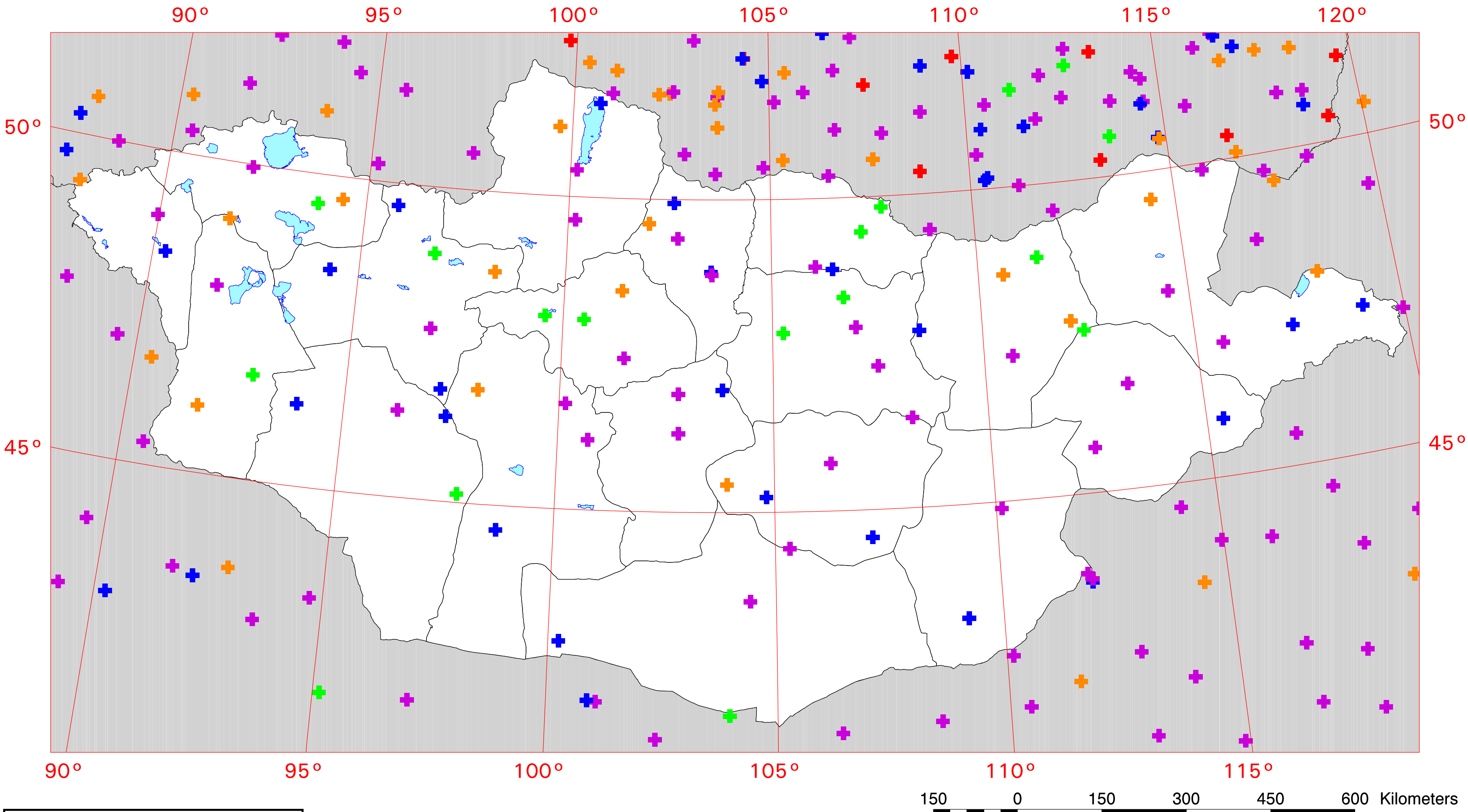
The following sections present a summary of the surface data sets obtained and examined in the assessment, as well as a summary of the quality evaluation of the historical meteorological data based on a comparison with high-quality data from the new wind monitoring systems.

5.2.1 DATSAV2 Data

This global climatic database was obtained from the NCDC and contains the surface weather observations, transmitted via the Global Telecommunications System (GTS), from first-order meteorological stations throughout the world. NREL currently has 26 years of DATSAV2 data in its archive, spanning the period 1973 to 1998. Meteorological parameters such as wind speed, wind direction, temperature, pressure and altimeter setting are extracted from the observations and used to create statistical summaries of wind characteristics. A unique six-digit number based on the World Meteorological Organization (WMO) numbering system identifies each station in the DATSAV2 data set.

There are 87 stations in Mongolia in the DATSAV2 climatic data set. Of these, 73 have sufficient meteorological data to use in this analysis. These data were supplemented by data from nearby DATSAV2 stations in China and Russia. The locations and number of observations for all stations are shown in Figure 5.1.

Mongolia - GTS Surface Meteorological Stations



Meteorological Stations
Total Observations

- 100,000 to 150,000
- 50,000 to 100,000
- 20,000 to 50,000
- 5,000 to 20,000
- 1,000 to 5,000

Total Stations (in Mongolia) = 73

The Global Telecommunication System (GTS) surface meteorological stations are part of NREL's global database.

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Figure 5-1

The number of observations at the individual sites within each year and from year to year are highly variable. Most stations in Mongolia typically transmitted observations every 3 hours during operation hours, although some stations did not transmit during late-night hours. At many stations, the transmission frequency changed over the years and was generally better in the 1970s and 1980s than in the 1990s.

The data records for each of these stations were processed to produce monthly and annual averages of wind speed and wind power. We present summaries for selected stations in Appendix A, Tables A.1 and A.2. These data are useful for evaluating the interannual and monthly variability, and the diurnal distribution of wind speed and wind power, plus the joint frequency of wind speed and direction.

5.2.2 IMH Station Data

IMH collects climatological data at a network of stations covering most of Mongolia. The IMH stations record rainfall, evaporation, temperature, and solar radiation, as well as wind speed and direction. These stations include both modern meteorological stations and the older "post" stations that are usually equipped with a flat-plate device for measuring wind speeds. Anemometer height is usually 10 m, but can range from 8 to 12 m.

For this project, NREL obtained monthly averages of wind speed from 227 IMH stations. The period of record of these data is typically 1975 to 1989, although some stations have shorter coverage. Locations for 11 of the stations were not given and could not be determined from other databases. The location of the 216 remaining IMH stations is shown in Figure 5.2, and a list of the stations and their wind speeds is given in Appendix A, Table A.2.

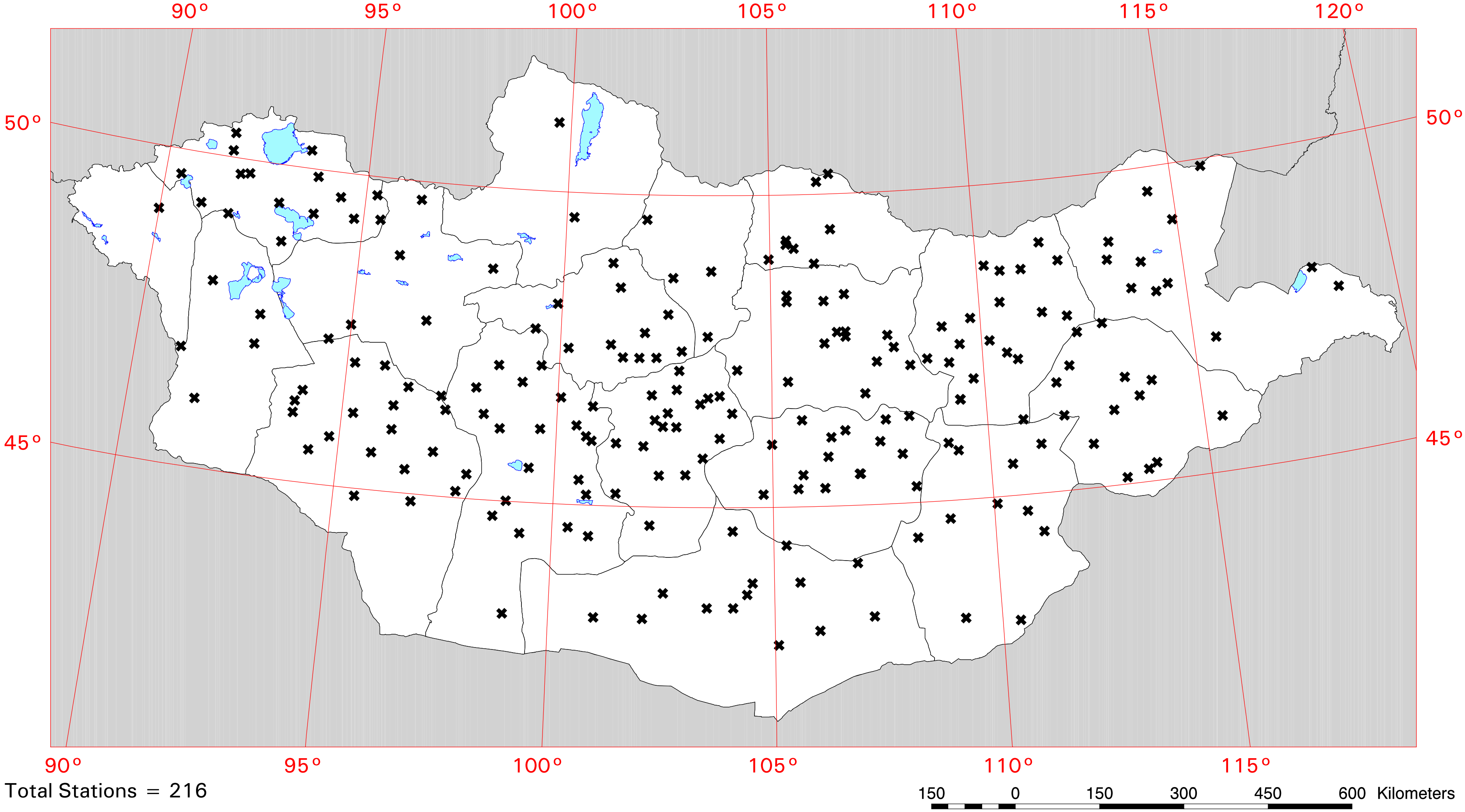
5.2.3 Provincial Meteorological Station Data

REC supplied NREL with reports prepared by each of the provincial meteorological organizations in Mongolia. NREL received 18 reports that included monthly wind speed averages for 313 meteorological stations across Mongolia. Locations for 299 of these could be determined. These stations and their average wind speeds are listed in Appendix A, Table A.3. The period of record for these data is not known. This data set helped characterize the monthly variations in wind speed across Mongolia. We present a map showing the locations from this data set in Figure 5.3.

5.2.4 NREL/REC Wind-Monitoring Program Data

REC is conducting a wind measurement program in southeastern Mongolia as part of this study. Twelve monitoring systems provided by NREL were installed in July and August of 1998. Each system consists of an NRG Systems, Inc., WindExplorer data logger mounted on a 20-m meteorological tower. A single anemometer and a wind vane are mounted 20 m above ground. The data are recorded every 10 minutes, and the logger is capable of storing up to 7 months of data. Data are collected every 3 months and then sent to NREL for final processing to produce summaries of important wind characteristics. These include monthly average wind speed and

Mongolia - IMH Surface Meteorological Stations



Total Stations = 216

The Institute of Meteorology and Hydrology (IMH) provided summaries of wind data for many of their surface meteorological stations.

Legend
✖ IMH Surface Meteorological Station

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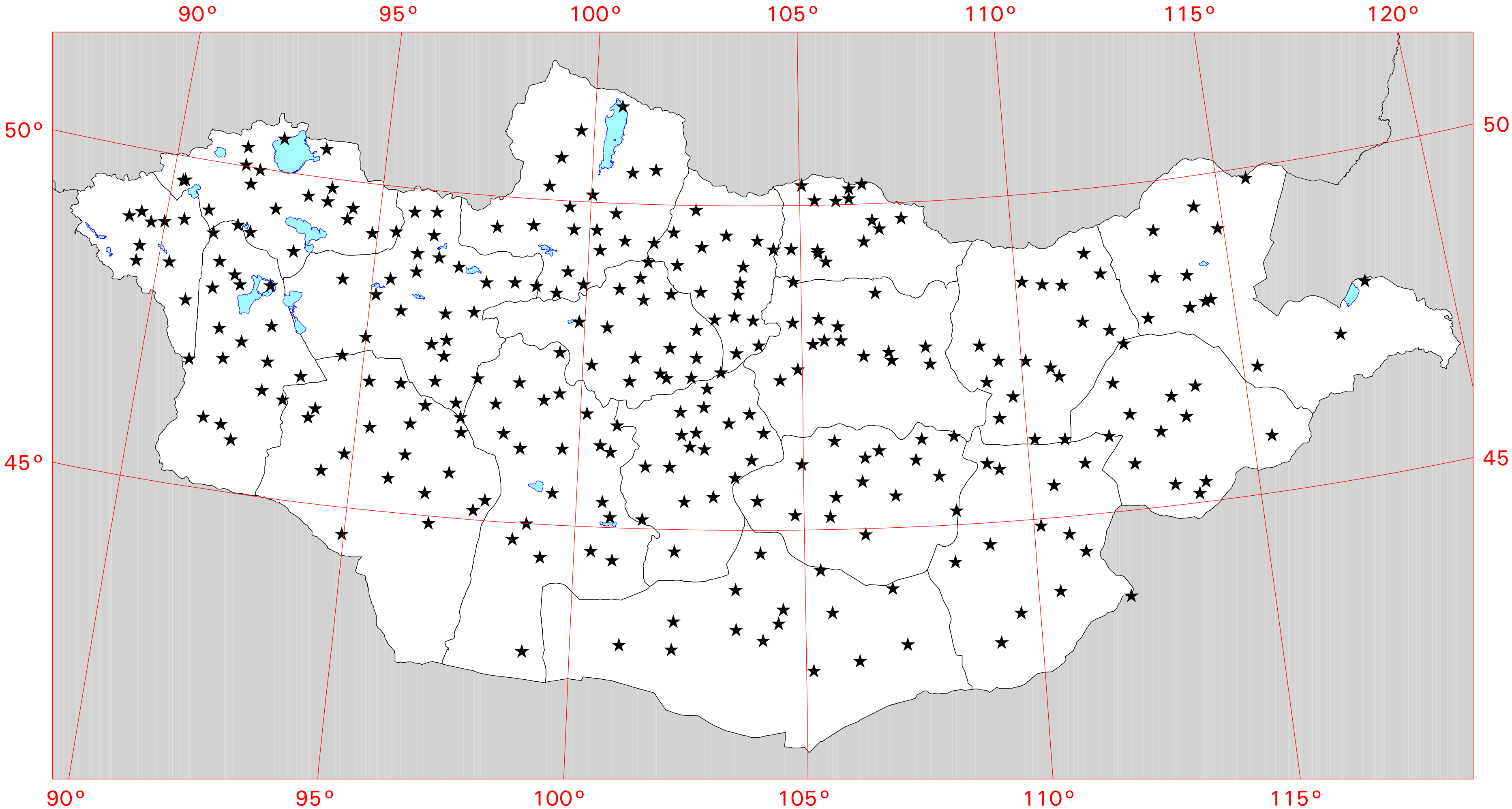
Figure 5-2

Mongolia - Provincial Surface Meteorological Stations



Total Stations = 299

150 0 150 300 450 600 Kilometers

The Renewable Energy Corporation provided summaries of wind data from the provincial surface meteorological stations.

Legend

★ Provincial Surface Meteorological Station

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National Renewable Energy Laboratory

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Figure 5-3

power, average wind speed and power by hour of the day, and joint frequencies of wind speed and wind direction.

The measurement sites are located in three regions in the aimags of Sukhbaatar, Dornogovi, and Umnugovi. Each region has a reference site located near a soum (district) center meteorological station, and three sites located within approximately 30 km of the reference site. All 12 sites are located on low grasslands, with no vegetation obstructing the wind. The terrain in each region is mostly gently sloping to slightly rolling.

In November of 1999, the monitoring program was expanded into Zavkhan aimag. The equipment at one of the sites in Sukhbaatar was moved to Tsagaanchuluut in Zavkhan in November 1999.

We present the location of the monitoring sites in Figure 5.4. NREL obtained and processed the hourly wind speed and wind direction data for these sites. Descriptions of the sites, annual average wind speed and power measured at each site are presented in Table 5.1. We provide graphs of annual and monthly summaries for specific wind statistics for these stations in Appendix B.

Table 5.1 NREL/REC Sites

Tuvshinshireet, Sukhbaatar Stations

Stn	Station Name	Lat (dd mm)	Lon (dd mm)	Elev (m)	Start Date	End Date	Wind Speed (m/s)	Wind Power (W/m^2)	% Calm	Weibull K
101	Center	46 12.59	111 48.32	1165	07/98	08/00	5.8	223	3.7	1.84
102	Bat-Ochir	46 23.95	111 51.91	913	07/98	01/00	4.1	135	18.2	1.30
103	Ochir	46 08.24	112 07.82	968	07/98	10/99	5.7	210	3.6	1.90
104	Sambuu	46 08.52	111 44.50	1072	07/98	08/00	5.2	198	8.6	1.58

Mandakh, Dornogovi Stations

201	Center	44 24.13	108 14.95	1317	08/98	08/00	6.2	257	2.9	1.92
202	Otgonbayar	44 35.73	108 16.87	1209	08/98	08/00	5.6	206	6.5	1.76
203	Tumurbaatar	44 24.14	108 28.64	1189	08/98	08/00	6.0	235	4.5	1.92
204	Itgel	44 22.97	108 00.07	1326	08/98	08/00	6.2	234	2.7	2.08

Manlai, Umnugovi Stations

301	Tserendavga	44 09.77	107 12.97	1187	08/98	08/00	5.2	193	9.0	1.58
302	Baatar	44 06.58	106 34.88	1336	08/98	08/00	6.1	243	3.9	1.92
303	Center	44 04.93	106 51.97	1299	08/98	06/00	6.6	281	3.0	2.10
304	Maam	44 10.98	106 40.25	1336	08/98	05/00	6.4	246	1.5	2.18

Zavkhan Station

401	Tsagaan-chuluut	47 06	96 40	2165	11/99	02/00	4.1	131	18.1	1.22

NOTES:
1) Speed and power values in this table were derived by averaging all available data. Partial years will tend to bias the averages, if there are more data from windy months than from calmer months or vice versa. This difference is estimated to be less than 0.2 m/s for the wind speed data presented here (corresponding to about 10% power difference).
2) Station 401 only has 3 months of data. The measurement equipment that was located at station 103 was moved to station 401 in October 1999.
3) Data recovery rate was 99-100% for all stations, except for 301, which had 87% due to battery problems from Feb-May 1999.
4) All anemometer heights are 20m.

5.2.5 TACIS/REC Wind Monitoring Program Data

TACIS (the European Union's Technical Assistance to the Commonwealth of Independent States program), in collaboration with REC, has been conducting a wind/solar/diesel hybrid power demonstration program in southern Mongolia. As part of this program, they have collected detailed 10-minute wind information at five sites in Bayankhongor and Uvurkhangai aimags. Anemometer and wind vane heights are 18 m above ground (except for the station at Bogd [Bayankhongor], which is at 12 m). The period of record of these sites is from September 1998 through early to- mid2000. Locations of these stations are shown in Figure 5.4, and site details are in Table 5.2. We provide graphs of annual and monthly summaries for specific wind statistics for these stations in Appendix B.

Table 5.2 TACIS/REC Sites

Uvurkhangai Stations

Stn	Station Name	Lat	Lon	Elev (m)	Start Date	End Date	Data %	Wind Speed (m/s)	Wind Power (W/m^2)	% Calm	Weibull K
1	Guchin-Us	45 28	102 25	1100	08/98	07/00	80%	5.0	142	2.1	1.86
2	Bogd	44 42	102 10	1200	08/98	04/00	74%	4.1	131	9.8	1.30

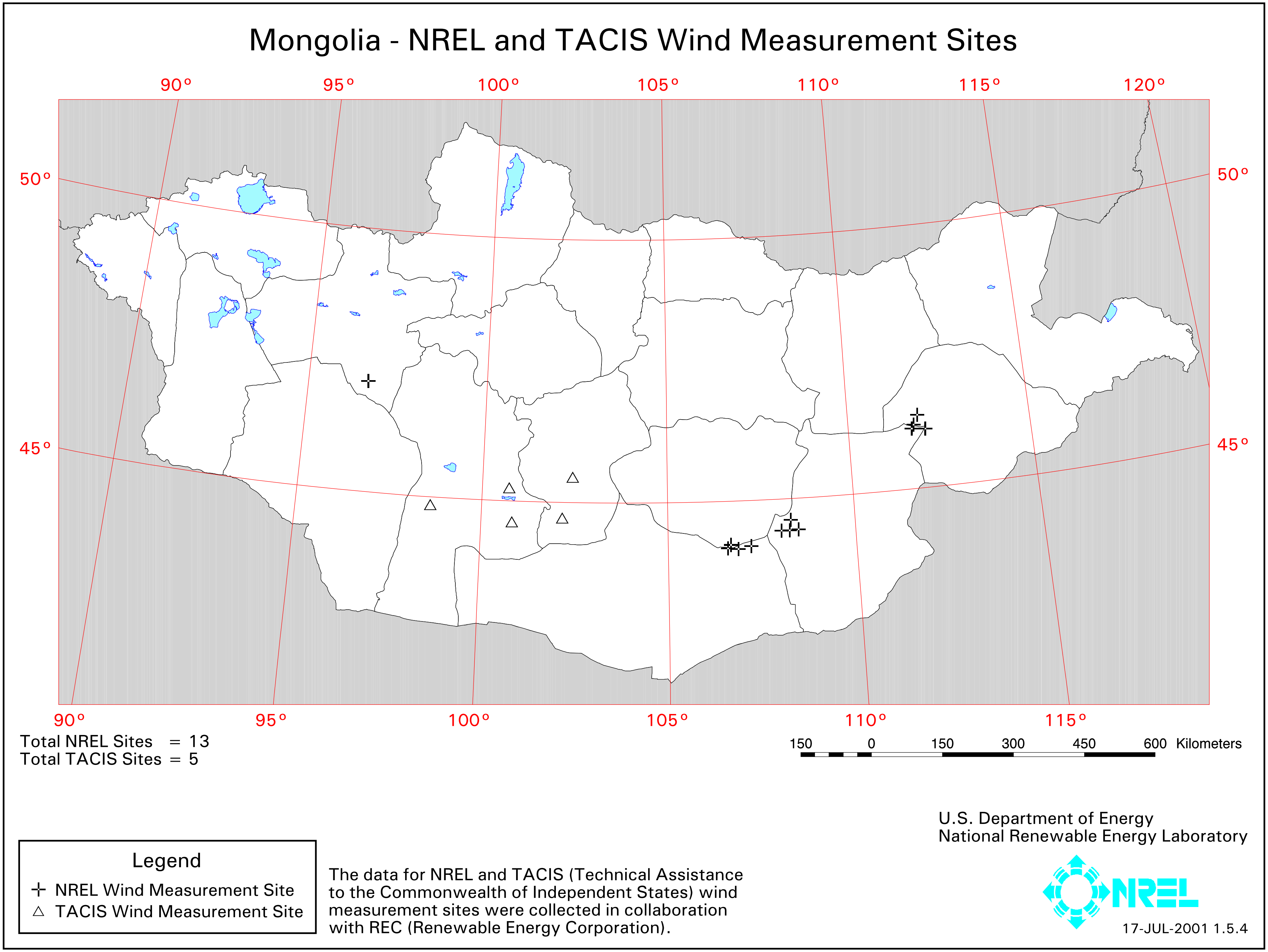
Bayankhongor Stations

Stn	Station Name	Lat	Lon	Elev (m)	Start Date	End Date	Data %	Wind Speed (m/s)	Wind Power (W/m^2)	% Calm	Weibull K
3	Bayanlig	44 36	100 49	1100	08/98	03/00	78%	4.2	101	4.8	1.60
4	Bayan-Undur	44 51	98 37	1600	08/98	05/00	96%	5.2	184	10.2	1.58
5	Bogd	45 15	100 43	1200	09/98	07/00	78%	5.3	228	1.6	1.48

NOTES:
1) Speed and power values in this table were derived by averaging all available data. Partial years will tend to bias the averages, if there are more data from windy months than from calmer months or vice versa.
2) Latitude (Lat) and longitude (Lon) are in degrees and minutes.
3) Elevations are rough estimates.
4) Anemometer heights are 18m, except for station 5 (Bogd/Bayankhongor) which is 12m.

5.2.6 Quality Assessment of Meteorological Station Wind Data

The siting of new wind monitoring systems very near meteorological stations with historical wind data provides an opportunity to evaluate the quality of wind data from the meteorological stations. There were 8 locations where sufficient data were available from a new wind monitoring system in close proximity to a meteorological station with historical wind data to conduct this study. We performed a comparison of the historical average wind speeds from the meteorological stations and the average wind speeds from the new wind measurement sites located nearby. Unfortunately, data were not available from the meteorological stations for the same time period as the new wind measurement sites. However, we estimate that the average wind speeds measured over 1-2 years at the new sites should be within about 10% of the historical average.



Mongolia - NREL and TACIS Wind Measurement Sites
90° 95° 100° 105° 110° 115° 120°
50° 45°
90° 95° 100° 105° 110° 115°
Total NREL Sites = 13
Total TACIS Sites = 5
150 0 150 300 450 600 Kilometers
Legend
NREL Wind Measurement Site
TACIS Wind Measurement Site
The data for NREL and TACIS (Technical Assistance to the Commonwealth of Independent States) wind measurement sites were collected in collaboration with REC (Renewable Energy Corporation).
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Figure 5-4

Table 5-3 presents the results of the comparison of the new wind measurement sites and the historical meteorological station data. At all 8 locations, the wind speeds measured at the new sites exceeded the historical average from the meteorological stations by anywhere from 0.3 m/s to 2.1 m/s. The average difference was about 1.1 m/s. The wind speed ratios of the site measurements to the historical averages ranged from 1.06 to 1.51. The average ratio was 1.29, meaning that the average wind speed measured at a new site was 29% greater than the historical average for a meteorological station. About 10% of this difference could be due to the difference in anemometer heights between the measurement sites and the meteorological stations. The anemometer heights at meteorological stations are typically about 10 m above ground, whereas the anemometer heights at the new measurement sites are mostly 18 m to 20 m above ground.

A direct comparison of the wind power density is not possible, because for the meteorological stations we did not have the hourly data or the wind speed frequency distributions needed to estimate the wind power density. However, we can approximate the wind power ratio by using the cube of average wind speeds from the measurement sites and meteorological stations. Table 5-3 shows that the wind power ratios among the 8 locations vary from 1.20 to 3.47, with a mean of 2.26. This indicates that the meteorological station wind data underestimates the actual wind power by roughly a factor of two and more than a factor of 3 at some locations. The results of this comparison provides evidence that the wind data from many meteorological stations in Mongolia may not be reliable for use in estimating the wind resource potential and that they generally underestimate the wind resource considerably.

The substantially lower wind speeds recorded at the meteorological stations may be caused by a variety of factors, such as the type of wind sensors used and maintenance procedures (or lack of), local obstructions to the wind sensors, frequency and method of recording the wind speeds, etc. Further documentation could be useful to determine why some stations appear to have better quality than others, and how to more accurately assess the data quality in the absence of new measurement data for direct comparison.

Table 5.3 Comparison of Wind Measurement and Historical Meteorological Station Data

Soum Center	Aimag	Historical Average WS (mps)	Measured WS (mps)	Wind speed difference	Wind speed ratio	Wind power ratio
Tuvshinshiree	Sukhbaatar	5.1	5.8	0.7	1.14	1.47
Mandakh	Dornogovi	4.1	6.2	2.1	1.51	3.46
Manlai	Umnugovi	5.5	6.6	1.1	1.20	1.73
Guchin-Us	Uvurkhangai	4.0	5.0	1.0	1.25	1.95
Bogd	Uvurkhangai	3.0	4.1	1.1	1.37	2.55
Bayanlig	Bayankhongor	3.2	4.2	1.0	1.31	2.26
Bayan-undur	Bayankhongor	4.9	5.2	0.3	1.06	1.20
Bogd	Bayankhongor	3.5	5.3	1.8	1.51	3.47
AVERAGE				**1.14**	**1.29**	**2.26**

Historical wind data are from the provincial (soum-center) meteorological stations, and were supplied by REC. Period of record is unknown.
Measured wind speeds were obtained from the NREL and TACIS wind studies conducted by REC.
Wind speed difference is computed as **WS(measured) – WS(historical)** .
Wind speed ratio is computed as **WS(measured) / WS(historical)** .
Wind power ratio is computed as **$WS(measured)^3$ / $WS(historical)^3$**.

5.3 Upper-Air Data

The upper-air data, consisting of profiles of wind speed and wind direction, are an important meteorological input parameter for the wind-mapping model. Upper-air data also provide an estimate of the wind resource just above the surface-layer and contribute to the understanding of the vertical distribution of the wind resource. This is useful in estimating the winds on elevated terrain features, as well as the wind resource at exposed locations in areas without reliable surface wind observations.

NREL's in-house data sets include both observational and computer model-derived upper-air information. NREL uses both types of data sets in its analysis. The following upper-air data sets were used in the assessment.

5.3.1 Observational Data Sets

5.3.1.1 Automated Data Processing Reports (ADP)

This data set contains upper-air observations from rawinsonde instruments and pilot balloons for approximately 1,800 stations worldwide. Observation times can include 00, 06, 12, and 18 Greenwich Mean Time (GMT). Wind information is available from the surface, the mandatory pressure levels (1000 millibar [mb], 850 mb, 700 mb, and 500 mb), the significant pressure levels as determined by the vertical profiles of temperature and moisture, and specified geopotential heights above the surface. The significant pressure levels and geopotential heights are different for each upper-air observation. The data set housed at NREL has approximately 26 years of observations, beginning in 1973.

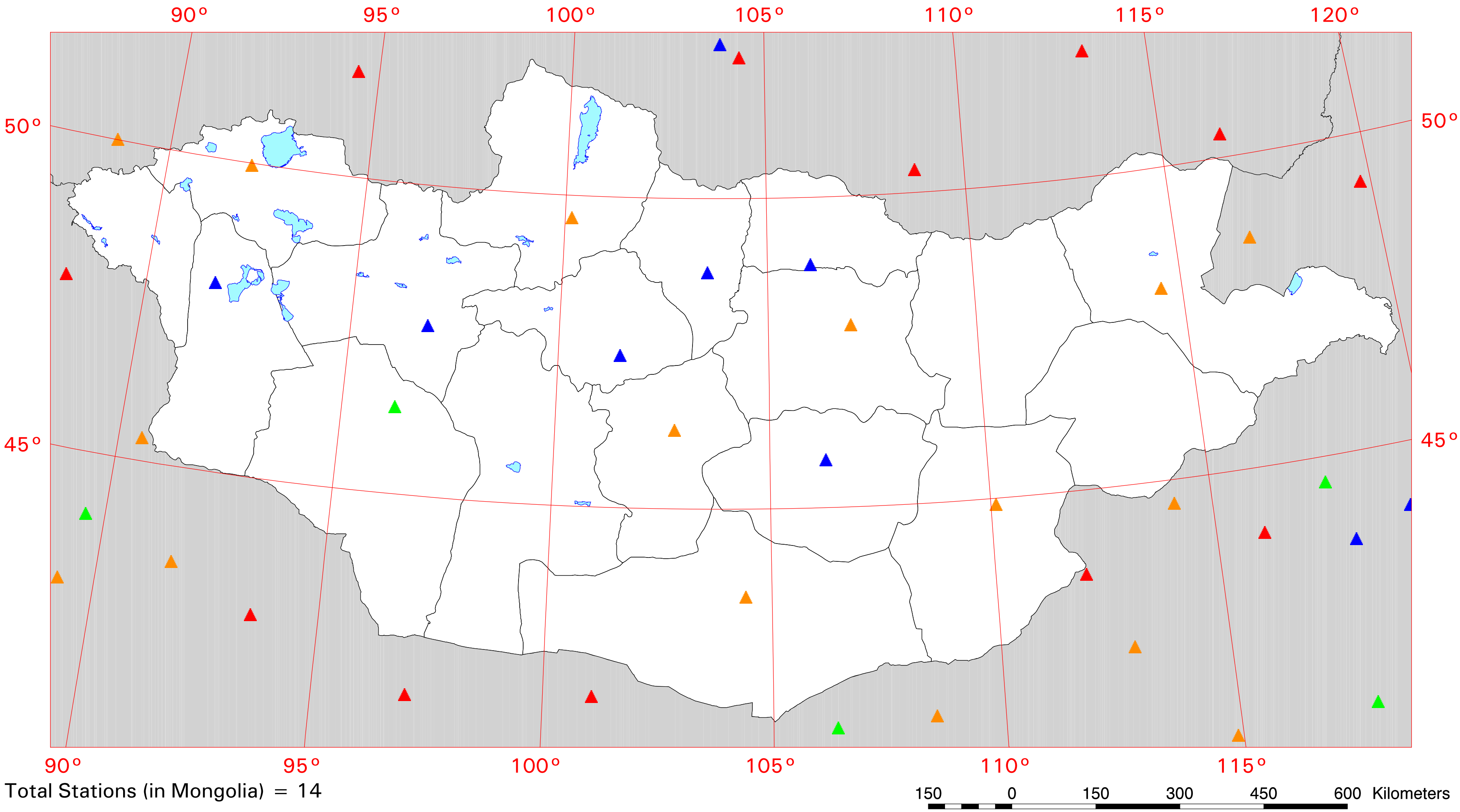
The ADP upper-air database consists of information obtained from surface-launched meteorological-instrument packages. These packages are usually launched via balloon once or twice daily, at 0000 GMT and 1200 GMT, and are managed under WMO guidance and procedures.

There are 14 locations in Mongolia where upper-air wind data are available from the ADP database. For our analysis, we also used data from 7 ADP stations in the former CIS countries and 17 stations in China. The Mongolia upper-air stations and their numbers of observations are listed in Appendix C, Table C.1. The locations of all of the upper-air stations are shown in Figure 5.5.

In the 1970s, most Mongolian stations were taking two measurements per day, at 0000 GMT and 1200 GMT. Around 1980, reporting for six stations (Khovd, Bulgan, Baruunkhara, Uliastai, Tsetserleg, and Mandalgovi) dropped sharply, eventually reaching only a few observations per year. Other stations continued to make two daily observations, but by 1993 only Ulaanbaatar was still at this level. The remaining six stations have been reporting at less than one observation per day during the 1990s.

The ADP data yielded profiles of monthly and annual average wind speed and frequency distributions of wind speed and wind direction for a number of pressure levels and height levels from the surface through 700 mb, or approximately 3,000 m. We present summaries of the wind data for selected upper-air stations in Appendix C.

Mongolia - GTS Upper-Air (Weather-Balloon) Stations



Total Stations (in Mongolia) = 14

Meteorological Stations

Total Observations

- ▲ 15,000 to 26,000
- ▲ 10,000 to 15,000
- ▲ 5,000 to 10,000
- ▲ 3,000 to 5,000

The Global Telecommunication System (GTS) upper-air (weather-balloon) stations are part of NREL's global database.

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Figure 5-5

5.3.1.2 IMH Upper-Air Data

NREL obtained near-surface upper-air data for 11 stations from the IMH. The data include wind speeds distributions at 10 m, 100 m, 200 m and 500 m above the surface. Each record consists of the wind speed distribution (in 1 m/s bins) at a given height for a given month. The complete data set covered 10 years (120 monthly records at each height for each station). The locations of the IMH upper-air stations are shown in Figure 5.6.

5.3.2 Computer Model-Derived Data Sets

5.3.2.1 Global Upper-Air Climatic Atlas (GUACA)

This data set contains computer model-derived monthly means and standard deviations of climatic elements for 15 atmospheric levels (surface and 14 pressure levels) at grid points every 2.5° throughout the world. GUACA was developed using analyses produced at the European Centre for Medium Range Weather Forecasts. The data at NREL were obtained from the NCDC and cover the period 1980 to 1991. This data set is used to supplement the ADP information in areas where upper-air data are scarce. The levels of interest for this study include surface and 850, 700, and 500 mb.

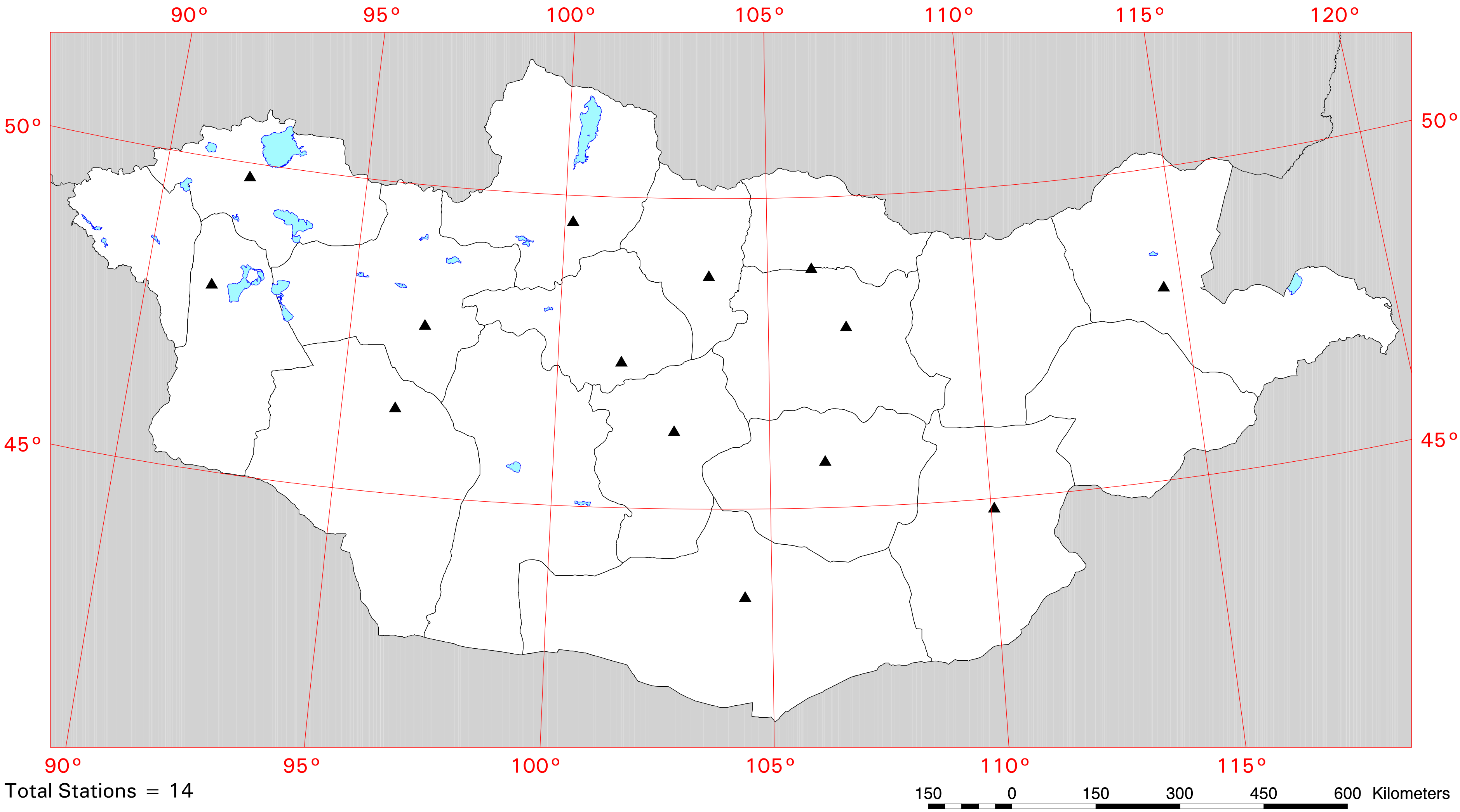
The GUACA data were used to generate wind roses showing the prevailing wind directions at various levels. They were also useful in estimating the wind speeds at 850 and 700 mb, which helps in analyzing the wind resource in the mountainous areas of Mongolia. Trends in wind speed and direction from across the GUACA grid helped to describe the large-scale wind patterns across the country.

5.3.2.2 Reanalysis Data

The United States National Centers for Environmental Prediction, in collaboration with the National Center for Atmospheric Research, has produced a data set known as reanalysis. This is a 40-year record of global analyses of atmospheric parameters. This project used a global weather prediction computer model to create worldwide data sets of wind, temperature, and other variables on a global 208-km-resolution grid. Reanalysis incorporates all available rawinsonde and pilot-balloon data, as well as observations from surface, ship, aircraft, satellites, and other data sources. Reanalysis data over Mongolia are available four times a day. A sample vertical profile of wind speed is in Appendix C.

We used the reanalysis data in this study to help create vertical wind speed profiles over the lowest few hundred meters in the plains and flat areas of Mongolia. We were thus able to identify low-level jets in the central and eastern parts of the country.

Mongolia - IMH Upper-Air (Weather-Balloon) Stations



Total Stations = 14

The Institute of Meteorology and Hydrology (IMH) provided summaries of wind data for many of their upper-air (weather balloon) stations.

Legend

▲ IMH Upper-Air (Weather-Balloon) Station

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Figure 5-6

6.0 Wind Resource Characteristics of Mongolia

6.1 Introduction

In this section, we present an overview of the input data files, wind-mapping results, and wind power density estimates for Mongolia. Two classification schemes for wind power density are used, one for wind power technology in rural areas and one for utility-scale applications. A description of the meteorological data files is also presented. Because of the large area and the variability of the meteorological attributes across Mongolia, we used a total of 17 different wind profiles for the modeling study.

6.2 Wind Power Classifications

We present the wind power classifications for Mongolia in Table 6.1. Two different classifications are used in the analysis, one for utility-scale applications and one for rural-power applications. For utility-scale applications, areas of class 2 and higher resource are considered suitable for wind power development. For rural applications, areas of class 1 and higher are considered suitable for wind power development. It is important to keep these classifications separate when reviewing the wind-mapping results. For example, an area considered to be marginal for utility-scale applications is considered to have moderate potential for rural-power applications.

Table 6.1 Wind Power Classification

Class	Resource Potential		Wind Power Density (W/m^2) @ 30 m agl	Wind Speed [a] (m/s) @ 30 m agl
	Utility	Rural		
1	Marginal	Moderate	100 - 200	4.5 – 5.6
2	Moderate	Good	200 - 300	5.6 – 6.4
3	Good	Excellent	300 - 400	6.4 – 7.1
4	Excellent	Excellent	400 - 600	7.1 – 8.1
5	Excellent	Excellent	600 - 800	8.1 – 8.9
6	Excellent	Excellent	800 -1000	8.9 – 9.6

[a] Mean wind speed is estimated assuming an elevation of 1400 m and a Weibull distribution of wind speeds with a shape factor (k) of 1.8. The actual mean wind speed may differ from these estimated values by as much as 20 percent, depending on the actual wind speed distribution (or Weibull k value) and elevation above sea level.

6.3 Approach

The mapping methodology used in this project was described in Section 4.0. NREL prepared the digital terrain data set from the Digital Elevation Model information for Mongolia. NREL also prepared the meteorological data files necessary for the modeling analysis. These meteorological data files were vertical profiles of the wind power density, and wind power roses that express the percentage of total wind power density by direction sector. The vertical profiles for complex terrain areas are divided into 100-m intervals centered every 100 m above sea level. The vertical profiles for the central and eastern plains are divided into 100-m intervals centered every 100 m above ground level except for the lowest layer, which is 50 m above ground level.

The vertical profiles are carefully selected and based primarily on the upper-air data, then subjectively modified for various regions. For example, the central and eastern plains were divided into seven zones, one for the eastern tip of Mongolia, two small zones near where the plains meet the Khangain Nuruu, and four zones across the bulk of the plains. The remaining 10 zones were derived for the complex terrain regions of extreme northern Mongolia, and the entire western part of Mongolia.

We developed wind power roses to account for the effects of blocking on the ambient wind flow by terrain, as well as for the amount of wind flow across large (greater than 50 sq. km) lakes. The terrain blocking was divided into short-range (less than 10 km), medium-range (10-50 km), and long-range (greater than 50 km) blocking. The effects of medium- and short-range blocking were incorporated into one set of wind roses, and long-range blocking effects were incorporated into a second set of wind roses. The effects of the wind flow across large lakes were incorporated into a third set of wind roses.

6.4 Wind Resource Distribution and Characteristics

6.4.1 Annual Wind Resource Distribution

We present the wind resource map for all of Mongolia in Figure 6.1. The annual average wind resource in Mongolia has considerable variability, and the distribution of the resource is controlled by several key factors, including the ambient characteristics of the mid-latitude westerlies, the progression of weather systems across Mongolia, and topographic influences on the wind flow. Mongolia is located beneath the mid-latitude westerly jet stream, a high-speed ribbon of air several kilometers above sea level that circles the globe and also affects the wind resource in North America and Europe. All regions of Mongolia are influenced by the westerly jet stream. Its interaction with major topographic features such as the large mountain ranges in western and central Mongolia is the primary factor influencing the distribution of the wind resource in the country. The jet stream also controls the progress of weather systems across Mongolia and the pressure gradient between weather systems can exert significant influences on the wind resource, especially in areas subject to acceleration because of local terrain. The summary of the wind resource distribution is divided into two sections, the resource on the extensive plains of central and eastern Mongolia, and the ridge-top and valley locations of north-central and western Mongolia.

The plains of central and eastern regions of Mongolia lie in an arc from southwest to northeast, from Umnugovi aimag in southern Mongolia to Dornod in northeastern Mongolia. The western boundary of the plains is near 105^o E. longitude in southern Mongolia and near 111^o E. longitude in northern Mongolia. Throughout the plains, including the Gobi, there are significant areas of good-to-excellent wind resource, especially for rural power applications. The aimags with the most extensive areas of 300 W/m ^{2} and higher resource at 30-m height (good for utility-scale applications and excellent for rural-power applications) are Umnugovi, Dundgovi, Dornogovi, and Sukhbaatar. A few locations in southeastern Sukhbaatar, western Dundgovi, and on favorable sides of the largest lakes are estimated to have wind resource greater than 400 W/m^2. The particular geography of Mongolia is the reason that the central and eastern plains have extensive areas of good-to-excellent resource. The plains are located downwind of the large mountainous regions (the Altai Nuruu and the Khangain Nuruu) of central and western Mongolia. The winds from the west are blocked by these extensive mountain ranges and must accelerate around these barriers. The acceleration around the barriers results in a low-level wind speed maximum from 300 to 500 m above the surface throughout the plains of southern and eastern Mongolia. This feature is mainly responsible for the broad areas of significant wind resource (greater than 200 W/m^2) depicted on the maps. A reanalysis vertical profile of wind speeds from a grid point south of Ulaanbaatar shows this low-level maximum in Appendix C. The level of resource at a particular site on the plains is influenced by its elevation relative to the surrounding area, the terrain upwind and downwind of the site, and whether the site is located on a lakeshore with a significant fetch of the prevailing winds across the lake. Sites with the highest relative elevation and/or favorable lakeshore locations have the greatest annual wind resource on the plains of southern and eastern Mongolia.

A complex terrain of large mountain ranges separated by valleys, plains, and basins dominates the topography of extreme north-central Mongolia and all of Mongolia west of 105^o E. longitude. The distribution of the wind resource in the complex terrain is much more varied than the distribution of the wind resource on the plains, but a few general features still can be noted. Exposed ridge-top locations have the highest resource levels in Mongolia. At these sites, the wind power density can be greater than 600 W/m^2. These are the sites most directly influenced by the strong westerly jet stream. However, the resource can vary widely along the ridge crests and the highest resource areas are generally scattered throughout the mountainous regions. Some mountainous areas have broader ridge tops and have more substantial areas of wind resource. An example is the mountainous region in Bulgan aimag and extreme eastern Khuvsgul, where there are broad areas of 400 W/m^2 to 600 W/m^2 along the ridge crests. Other mountainous areas with broader areas of significant wind resource are in southwestern Tov aimag and in western Khentii. The distribution of the wind resource in valleys, plains, and basins of western Mongolia varies. In general, the wind resource is lower in the western third of Mongolia than in the rest of the country. The most extensive areas of lower-elevation, moderate-to-good/excellent wind resource in the complex-terrain part of Mongolia extends from Umnugovi westward through southern Bayankhongor, southern Govi-Altai, and into extreme eastern Khovd. Uvurkhangai aimag also has some significant lower elevation areas with moderate-to-good/excellent resource. More localized moderate-to-good, lower-elevation resource areas are found in Zavkhan and in southwestern Khuvsgul. Finally, mountain passes and corridors between terrain features may possess good-to-excellent resource. Some wind corridors may be relatively small in extent and other good-to-excellent resource areas may have winds generated by local temperature gradients. These areas may not be depicted on the wind resource maps.

6.4.2 Seasonal Wind Resource Distribution

The lower elevations of Mongolia, whether located in the eastern or western part of the country, generally exhibit similar seasonal wind resource patterns. Most sites in the lower-elevation regions of Mongolia have maximum wind resource potential from March through June, with April and May being the windiest months. This period features a combination of strong surface pressure gradients and significant temperature contrasts between the warmer surface and the cooler upper-air layers 1000 to 2000 m above the ground. These conditions promote the mixing down of momentum from the westerly jet stream down to the surface. The wind resource decreases rapidly after this period. This results for lower-elevation areas having a minimum of wind resource in July and August. DATSAV2 plots of Mandalgovi and Sainshand showing the seasonal wind resource distribution are in Appendix A. The wind resource distribution for the period from October through February is more complex. Some locations show a secondary wind resource maximum in October and November and a decrease in the resource from December through February before the resource maximum in the spring. This pattern reflects the stronger surface pressure gradients caused by the transient weather systems in autumn compared to the mid-winter period, when the Asiatic surface high-pressure system dominates the weather. A few lower-elevation locations have a winter (December through February) or autumn (October and November) wind resource maximum. Acceleration of the wind flow around local topographic features is the likely primary factor in creating these special seasonal wind resource patterns.

The seasonal wind resource distribution on ridge-crest locations varies from eastern and central Mongolia to western Mongolia. The eastern and central ridge-crest locations have a similar seasonal distribution of the wind resource to sites in the plains and other low elevation areas. The resource reaches a maximum in April and May, has a secondary maximum in October and November, and is at a minimum in July and August. The seasonal wind resource on ridge crests in western Mongolia is different. The western Mongolia ridge crests have the maximum resource from October through December with a secondary maximum occurring in April and May. The minimum resource is during July and August. One interesting characteristic of the ridge-crest seasonal resource is that the minimum in the summer resource is much more noticeable in northern Mongolia than in southern Mongolia.

6.4.3 Diurnal Wind Speed Distribution

The diurnal wind speed distribution, or wind speed versus time of day, is influenced by site elevation and topography. The distribution at low-elevation sites in simple terrain on the plains typically features a maximum wind speed during the afternoon and a minimum near sunrise. The primary forcing mechanism for this pattern is daytime heating, which destabilizes the lower levels of the atmosphere. This results in the downward transfer of momentum to the surface. In the late afternoon and evening the declining supply of sunshine leads to surface cooling and increasing stability in the lower layers. Surface winds begin to decelerate while winds aloft maintain their speed. The minimum in surface wind speed near sunrise corresponds to the time of maximum atmospheric stability. This type of diurnal distribution tends to reach its maximum amplitude for the periods of March through May and in September and October. Plots of diurnal patterns are located in Appendices A and B.

Ridge-crest diurnal distributions differ from those of low-elevation sites. The strongest winds at ridge-crest locations occur at night, whereas the lowest speeds are observed during the midday hours. The magnitude of the diurnal variation on the ridge crests is generally less than what is observed at low-elevation sites.

Sites located in complex terrain and subject to winds caused by differential heating of the local topography (for example, plains and mountains) can have a diurnal pattern different from either the simple terrain of the plains or the ridge crests. A diurnal pattern that is commonly observed at this type of site has a wind maximum in the evening and early nighttime hours, with the minimum occurring in the middle of the morning.

6.4.4 Wind Direction Frequency Distribution

The prevailing wind at the higher wind resource sites in Mongolia is from a westerly direction. This is due to the mid-latitude jet stream that is the major influence on the wind resource. Ridge-top locations reflect the prevailing direction of the jet stream, which varies slightly across the country. The prevailing direction of the wind on ridge tops in the extreme northwestern tip of Mongolia is from the southwest. The prevailing direction is more from due west across the majority of the mountainous areas of western and central Mongolia. The wind direction at the higher elevations at the extreme eastern tip of Mongolia tends to be from the northwest. Examples from the ADP data set of the wind direction at 700 mb (3000 m) of elevation are shown in Appendix C.

6.5 Validation of Wind Resource Estimates

We conducted a study to compare the wind resource estimates given by the maps to actual measurements of the wind resource at 18 locations where new wind monitoring systems collected high-quality data for a period of 1 to 2 years. This validation study was made more difficult by the lack of precise station locations and elevations. Conflicting site information was resolved to the best of our ability. The results of this study are summarized in Table 6-2.

Two criteria were used to examine the accuracy of the wind resource estimates. One criterion was whether the estimated grid-point wind power density at the site location is within 20% of the measured wind power density. Generally, the wind speed is within 10% if the wind power is within 20%. This single criterion can be misleading in some cases, particularly if local variability in the wind resource is large. If the wind resource varies considerably within a few kilometers of the site due to local terrain influences, the estimated resource at the point may be in error if the 1-km^2 elevation and spatial coordinates are not perfectly aligned or if the station location is not known precisely. The elevation and geographic data come from different sources, and we have seen cases in areas of other countries (such as the Philippines) where the elevation data does not correctly align with the spatial coordinates. The shift may be quite small, but an error of only 1-2 km can be significant if the wind resource varies over short distances.

A second validation criterion was added to compensate for the effects of local variability. This criterion evaluates whether the measured wind power density is within the range of wind power densities estimated within 2 km of the site location. This criterion was established to cover instances where the uncertainty of the estimated point wind power value was large because of local variability of the wind power.

Measurement sites in this study were divided into low-wind and high-wind categories. There were 5 sites with a measured wind resource of less than 200 W/m^2. These sites have a low potential for wind development. The map predicts a low wind resource for 4 of these, with the fifth site predicted to be marginal.

In Table 6-2, we see that measured wind power was within 20% of the estimated point wind power at 9 of the 13 high-wind locations. At the four locations where the difference is greater than 20%, the local variability of the wind resource within 2 km of the site is usually very large, typically about a factor of two to three. At two of these sites, the measured wind power falls within the range of the estimated wind power in the local area.

There are only two locations out of 13 high-wind sites that are outside both the 20% point accuracy and range of the local area. The largest difference was found at station 5 (Bogd – Bayankhongor), where the measured wind power was roughly twice the map estimate and was well outside the local variability. This discrepancy could be caused by an unusually windy period at this location, local terrain details that are not shown at the scale of the DEM, or other causes. We note that the historical measured wind speeds at Bogd are much closer to the map estimate than the actual measured speeds. At site 301, the measured power was also significantly greater than the range shown on the map.

There appears to be no significant bias in the map estimates of the wind resource. At the high-wind sites, the estimated wind power is higher than the measured at 5 locations, lower at 7 locations, and equal at 1 location.

Table 6.2 Validation of Wind Power Estimates Against Measured Data

REC/NREL Stations

Site No.	Site Name	Aimag	Map WP	Min WP	Max WP	Measured WP	Within 20%?	Within range?
101	Soum	Sukhbaatar	295	265	310	267	Y	Y
102	Bat-Ochir	Sukhbaatar	180	180	255	172	Y	N
103	Ochir	Sukhbaatar	280	250	285	242	Y	N
104	Sambuu	Sukhbaatar	235	235	285	236	Y	Y
201	Soum	Dornogovi	370	340	375	308	Y	N
202	Otgonbayar	Dornogovi	230	200	325	245	Y	Y
203	Tumurbaatar	Dornogovi	320	310	360	282	Y	N
204	Itgel	Dornogovi	340	330	345	280	Y	N
301	Tserendavga	Umnugovi	180	130	180	247	N	N
302	Baatar	Umnugovi	205	180	305	289	N	Y
303	Soum	Umnugovi	280	250	320	320	Y	Y
304	Maam	Umnugovi	270	205	320	286	Y	Y
401	Tsagaanchuluut	Zavkhan	171	130	230	162	Y	Y

REC/TACIS Stations

Site No.	Site Name	Aimag	Map WP	Min WP	Max WP	Measured WP	Within 20%?	Within range?
1	Guchin-Us	Uvurkhangai	205	205	215	175	Y	N
2	Bogd	Uvurkhangai	115	90	160	170	N	N
3	Bayanlig	Bayankhongor	160	115	180	120	N	Y
4	Bayan-undur	Bayankhongor	155	90	290	215	N	Y
5	Bogd	Bayankhongor	160	90	175	330	N	N

Map WP is the map wind power estimate at the station location at 30m agl.
Min WP and **Max WP** are the minimum and maximum wind power estimates found within 2 km of the station location.
Measured WP is the measured wind power at the NREL or TACIS site, adjusted to 30m agl.
Within 20%? Is the measured wind power within 20% of the map estimate at the station location? Y = yes, N = no. If the wind power is within 20%, the wind speed is usually within 10%.
Within range? Is the measured wind power within range of minimum and maximum wind power estimates within 2 km of the station location? Y = yes, N = no.

In conclusion, the wind resource estimates validate quite well with the measurements. Considering the uncertainties discussed above and criteria applied to judge the accuracy of the estimates, the estimates were within reasonable accuracy levels at 15 of the 18 locations. The validation rate for the sites with good resource potential (> 200 W/m^2) was 85% (11 of 13 sites), which compares favorably with validation studies we have conducted in other areas of the world.

6.6 Regional Summaries of Wind Resource

Mongolia is divided into the following 21 regions, which are shown in Figure 6.2:

1) Southeastern Dornod
2) Northwestern Dornod
3) Sukhbaatar
4) Khentii
5) Northern Dornogovi and southern Khentii
6) Dornogovi
7) Selenge and northern Tov
8) Dundgovi and southern Tov
9) Eastern Umnugovi
10) Bulgan and eastern Arkhangai
11) Uvurkhangai
12) Western and central Umnugovi
13) Khuvsgul
14) Eastern Zavkhan, southern Khuvsgul, and western Arkhangai
15) Northern Bayankhongor
16) Southern Bayankhongor and western Umnugovi
17) Uvs and northwestern Zavkhan
18) Northern Govi-Altai and southern Zavkhan
19) Southern Govi-Altai
20) Bayan-Ulgii, western Uvs, and northern Khovd
21) Southern Khovd and northwestern Govi-Altai.

6.6.1 Southeastern Dornod

Southeastern Dornod is the most eastern region of Mongolia. Most of the region consists of a plain with small variations in elevation. The most significant topographic relief is near the extreme eastern tip of the aimag, near the border with China. Figures 6.3 through 6.6 show the significant political features, elevation features, shaded topographic relief, and potential wind resource of the region.

All locations in the region that are exposed to the prevailing wind have at least marginal wind resource for utility-scale applications and moderate resource for rural-power applications. There are two primary areas of enhanced wind resource. One area is located along the southern and eastern borders of the aimag and the other is a west-to-east band in the north-central part of the region. Both areas contain sections of good resource for rural applications; however, the southern and eastern border sections also contain sections that are rated good for utility-scale resource and excellent for rural-power resource. Another smaller area of good resource for utility-scale applications and good-to-excellent resource for rural power is found on the southeastern shoreline of Buyn Nuur.

6.6.2 Northwestern Dornod

The significant political features, elevation features, shaded topographic relief, and potential wind resource of northwestern Dornod are illustrated in Figures 6.7 through 6.10. Most of the plains in northwestern Dornod are estimated to have moderate wind resource for utility-scale applications and good resource for rural-power applications.

The most notable area of enhanced wind resource is located along the ridge crests of the low mountains in the extreme northwestern part of the region, near the border with Khentii. In general, these ridge crests are estimated to have good utility-scale resource and good-to-excellent rural-power resource. Other notable areas with enhanced resource occur along the southern lakeshore of Yahin Govi Nuur, and in the extreme northern part of Dornod, the southern lakeshore of Ozero Barun-Torrey. (The lake is located in Russia.)

6.6.3 Sukhbaatar

The significant political features, elevation features, shaded topographic relief, and potential wind resource of Sukhbaatar are illustrated in Figures 6.11 through 6.14. Sukhbaatar is part of the plains region of eastern Mongolia. There is generally little variation in elevation except for areas of significantly higher terrain in extreme northwestern and extreme southern parts of the aimag.

Sukhbaatar has many areas of at least moderate resource for utility-scale and good resource for rural-power applications. The significant areas of good utility-scale and excellent rural-power resource occur, for the most part, in the southern half of the aimag. The most concentrated areas of enhanced resource are in the higher hills of southern and southeastern Sukhbaatar near the border with China. Elevations in these areas can be as high as 1600 m, compared to elevations between 1,000 and 1,200 meters that are typical for much of the rest of the aimag. Other areas of greater wind resource include the relatively high elevation areas near Bayandelger in the southwestern and south-central part of Sukhbaatar, and the higher elevation area near Munkhkhaan in the northwestern part of the aimag.

6.6.4 Khentii

The significant political features, elevation features, shaded topographic relief, and potential wind resource of the central and northern regions of Khentii are illustrated in Figures 6.15 through 6.18. The Khentiin Nuruu and its foothills dominate the western and northern areas shown on the regional map. The southern and eastern areas of the regional map feature undulating terrain that forms the northern extent of the massive plains of central and eastern Mongolia.

The highest wind resource areas on the map are found along the ridge crests in the Khentiin Nuruu. The ridge crests are estimated to have good-to-excellent utility-scale resource and excellent rural-power resource. The broadest areas of high ridge-crest resource are found in the northeastern part of Khentii, and in west-central Khentii near the border with Tov.

The region south and east of the mountains generally has marginal (utility-scale) and moderate (rural-power) wind resource interspersed with areas of moderate-to-good resource.

6.6.5 Northern Dornogovi and Southern Khentii

The significant political features, elevation features, shaded topographic relief, and potential wind resource of northern Dornogovi and southern Khentii are illustrated in Figures 6.19 through 6.22. The topography of the region consists of the Mongolian plain that gently slopes from northwest to southeast. The major terrain feature in this plain region is a series of low hills that run generally west to east in southern Khentii near the Dornogovi border near Darkhan across to Sukhbaatar. There is a southern extension of the hills into northeastern Dornogovi near the border with Sukhbaatar.

The wind resource on these hills is significant, with good utility-scale resource and excellent rural-power resource. South of the Khentii hills, in northern Dornogovi, the wind resource on the plains is rated as moderate for utility-scale and good for rural-power applications.

6.6.6 Dornogovi

The significant political features, elevation features, shaded topographic relief, and potential wind resource of the central and southern parts of Dornogovi are illustrated in Figures 6.23 through 6.26. The area is part of the Mongolian plains, though there is more variation in elevation than in the plains to the north and east of this region.

A watershed divide in central Dornogovi that extends eastward from the border with Dundgovi and Umnugovi to just southwest of Sainshand is a prominent region of higher wind resource. This divide also is the location of four of the REC wind measurement sites. The resource on the divide is estimated to be good for utility-scale and excellent for rural power applications. There are other relatively hilly areas in southern and eastern Dornogovi, and the wind resource is similar to the resource found on the divide mentioned above. The remainder of Dornogovi generally has moderate-to-good wind resource, depending on the application.

6.6.7 Selenge and Northern Tov

The significant political features, elevation features, shaded topographic relief, and potential wind resource of Selenge and the northern part of Tov are illustrated in Figures 6.27 through 6.30. The aimag of Selenge largely consists of the drainage area of the Orkhon Gol and the Selenge Moron that is located between the western extent of the Khentiin Nuruu and the eastern part of the mountain ranges that are most prominent in Bulgan. Northern Tov contains the main area of the Khentiin Nuruu in the east and a high plain interspersed with significant hills and ridges in the western part of the aimag. The capital of Ulaanbaatar is located at the base of the southwestern part of the Khentiin Nuruu.

The lower-elevation areas of the Selenge and Orkhon drainage have poor wind resource. Some higher-elevation areas in the drainage may have moderate (utility-scale) or good (rural-power) resource, but these areas are few and scattered throughout the drainage. The greatest resource in

Selenge is found on the ridge crests in the extreme eastern and extreme western areas of the aimag. The wind resource on the higher ridges ranges from good to excellent.

Good-to-excellent wind resources in northern Tov are found on the highest ridge crests in the northeast part of the region and on the higher hills and ridges on the high plain north and west of Ulaanbaatar. Other exposed locations on the plain can have moderate-to-good resource, depending on the particular application.

6.6.8 Dundgovi and Southern Tov

The significant political features, elevation features, shaded topographic relief, and potential wind resource of southern Tov and Dundgovi are illustrated in Figures 6.31 through 6.34. The Mongolian plain covers Southern Tov and extends south through all of Dundgovi. The elevation of the plain in southern Tov is around 1500 m, while the typical elevation in Dundgovi is 1200 m.

Areas of good wind resource for utility-scale applications and excellent wind resource for rural-power applications are widely distributed in southern Tov and northern and central Dundgovi. A prominent area of this level of resource is found in Tov on the elevated area at the northern edge of the Mongolian plain just southwest of Ulaanbaatar and Zuunmod. Another region on the Dundgovi plain with this level of resource extends from near Delgerkhangai towards Mandalgovi and on to near Govi-Ugtaal. An area of small mountains in the southwestern part of this area is estimated to have excellent wind resource for both utility-scale and rural-power applications.

Excellent wind resource is also found in extreme western Tov on the broad ridge crests of the eastern spur of the Khangain Nuruu. These ridge crests are 300 to 500 m higher in elevation than the terrain to their north and northwest. Thus, these ridge crests are well exposed to the frequent, strong north and northwest winds in this region.

6.6.9 Eastern Umnugovi

The significant political features, elevation features, shaded topographic relief, and potential wind resource of eastern Umnugovi are illustrated in Figures 6.35 through 6.38. The southwestern portion of the Mongolian plain covers eastern Umnugovi. The terrain generally slopes from west to east. Isolated mountains are present in the southwestern section of the mapped region.

There are broad sections in eastern Umnugovi that are estimated to have good resource for utility-scale and excellent resource for rural-power applications. A prominent terrain feature with this level of resource is the watershed divide discussed in the Dornogovi section. In eastern Umnugovi the divide runs from northeast of Tsogttsetsii towards Manlai and then towards the border with Dornogovi. As in Dornogovi, this divide and its surrounding area are the locations of several of the REC wind measurement sites. Other relatively high elevation locations in the central and western parts of eastern Umnugovi also have good-to-excellent wind resource. The tops of the isolated mountains are estimated to have excellent wind resource for both utility-scale and rural applications. Lower elevations on the plains have moderate to good resource, depending on the particular application.

6.6.10 Bulgan and Eastern Arkhangai

The significant political features, elevation features, shaded topographic relief, and potential wind resource of Bulgan and eastern Arkhangai are illustrated in Figures 6.39 through 6.42. The topography of Bulgan features mountains of medium elevation (about 2000 m), with relatively broad ridge crests and plains between the mountain ranges. The topography of eastern Arkhangai is similar to that of Bulgan, though the mountains have narrower ridge crests than those in Bulgan.

The combination of high elevation, broad ridge crests, and exposure to northwest and north winds results in many prominent ridge crests having excellent wind resource potential. Many of these areas are concentrated in Bulgan. Mountainous regions near Mogod, Khishig-Undur, west of Bulgan city, Rashaant, Tarialan, Khantai, and along the Russia border, are some of the excellent wind resource areas. The narrower ridge crests in eastern Arkhangai also have excellent wind resource. The plains of southern Bulgan and southeastern Arkhangai generally have marginal-to-moderate utility-scale wind resource and moderate-to-good resource for rural-power applications.

6.6.11 Uvurkhangai

The significant political features, elevation features, shaded topographic relief, and potential wind resource of Uvurkhangai are illustrated in Figures 6.43 through 6.46. Uvurkhangai extends over a wide variety of topographic regions. The northern part of Uvurkhangai features terrain similar to that of southern Arkhangai. The eastern part of the Khangain Nuruu dominates the central and western part of the aimag. The southern part of Uvurkhangai serves as the western border of the Mongolian plain and also contains the extreme eastern spur of the Altai Nuruu.

The good-to-excellent wind resource in the main area of the Khangain Nuruu is confined to the highest ridge crests of the range. The resource on the highest (and most remote) peaks is outstanding, with average annual wind speeds over 8 m/s. The mountains at the extreme eastern end of the range near Esunzull and Burd are similar in elevation and broadness of the ridge crests to the mountains in Bulgan and are also estimated to have excellent wind resource. The southern and eastern foothills of the Khangain Nuruu also have areas with good resource for utility-scale and excellent resource for rural-power applications.

The northern section of the plains region of Uvurkhangai has moderate utility-scale resource and good rural-power application resource. The southern section of the plains is estimated to have marginal-to-moderate resource, depending on the particular application. Along the eastern spur of the Altai Nuruu, good-to-excellent wind resource is generally confined to the ridge tops, though there may be some localized areas of this level of resource where the wind is accelerated around the sides of the mountains.

6.6.12 Western and Central Umnugovi

The significant political features, elevation features, shaded topographic relief, and potential wind resource of western and central Umnugovi are illustrated in Figures 6.47 through 6.50. This is a transition region between the broad plains of central and eastern Mongolia and the basin-mountain range topography found in southwestern Mongolia.

The wind resource in the northeastern part of the region on the plains increases from north to south. For example, the area around Khankhongor has moderate-to-good resource depending on the particular application. The resource is estimated to be greater in the southern part of the region in the mixed basin and mountain range topography. This is due in part to the general acceleration of the winds around the southern flank of the Altai Nuruu. There is a broad area, in the lower elevations near the border with China, of good resource for utility-scale applications and excellent resource for rural power. One area that is estimated to have excellent resource for both utility-scale and rural power is on a divide that extends south from near Khurmen. Other isolated areas of excellent resource are found on the mountain ridge tops.

6.6.13 Khuvsgul

The significant political features, elevation features, shaded topographic relief, and potential wind resource of northern and central Khuvsgul are illustrated in Figures 6.51 through 6.54. This region is quite mountainous, with the highest peaks in the northern part of the region west of Khuvsgul Nuur. The lowest elevations are found in the Selenge Moron drainage.

The best wind resource in the region is found on the ridge crests. In the eastern part of the region near the border with Bulgan, the ridge crests are broad and excellent wind resource is estimated to be fairly widespread. Another broad ridge crest area is located on the eastern side of Khuvsgul Nuur. Elsewhere in this region the ridge crests are narrow and the excellent wind resource is confined to the tops of the ridges.

The highest wind resource level found in the lower-elevation areas of this region generally is moderate for utility-scale and good for rural-power applications. The most prominent lower elevation areas with this level of resource are found along the eastern shore of Khusvgul Nuur, and around Sanglyn Dalay Nuur.

6.6.14 Eastern Zavkhan, Southern Khuvsgul, and Western Arkhangai

The significant political features, elevation features, shaded topographic relief, and potential wind resource of eastern Zavkhan, southern Khuvsgul, and western Arkhangai are illustrated in Figures 6.55 through 6.58. This region is in the middle of the Khangain Nuruu and features high (3,000 m and higher) ridge tops and basins.

In this region, excellent wind resource areas for both utility-scale and rural-power applications are found on top of the ridge crests. Some of the more prominent ridge-crest areas are the Bulnayn Nuruu in extreme northern Zavkhan and southern Khuvsgul, the Tarvagatayn Nuruu in western Arkhangai, and the mountains in eastern Zavkhan near the border with Bayankhongor.

The windier areas at lower elevations in this region generally had moderate utility-scale resource and good rural-power resource. Notable windy lower elevation areas in this region include the area near Terhlyn Tsagaan Nuur in western Arkhangai, and the regions around Telmen Nuur and Oygon Nuur in Zavkhan.

6.6.15 Northern Bayankhongor

The significant political features, elevation features, shaded topographic relief, and potential wind resource of northern Bayankhongor are illustrated in Figures 6.59 through 6.62. The northern Bayankhongor region consists of the southern part of the Khangain Nuruu, the northern part of the Altai Nuruu, and the basin between these mountain ranges.

Excellent wind resource areas are confined to the highest ridge crests in the mountainous areas. These are most prominent in extreme northern Bayankhongor, with more isolated areas found in the Altai Nuruu in the southern part of this region.

The southern foothills of the Khangain Nuruu have broad areas of moderate utility-scale and excellent rural-power resource. The resource decreases towards the central basin. The northern part of the basin has some moderate resource for rural-power applications.

6.6.16 Southern Bayankhongor and Western Umnugovi

The significant political features, elevation features, shaded topographic relief, and potential wind resource of northern Bayankhongor are illustrated in Figures 6.63 through 6.66. The region is part of the basin and mountain range topographical area of southwestern Mongolia.

The basins in the region generally have moderate-to-good utility-scale resource and good-to-excellent rural-power wind resource. Good utility-scale and excellent rural-power wind resource is concentrated in western Umnugovi, though there are scattered areas in Bayankhongor with this level of resource. Most of southern Bayankhongor has moderate utility-scale and good rural-power wind resource.

Excellent wind resource areas are located on top of the ridge crests that are located throughout the region. Several more prominent mountains are located in the Altai Nuruu in Bayankhongor and in extreme western Umnugovi. Local areas of good-to-excellent resource may also be found where the wind is accelerated either between or around terrain features.

6.6.17 Uvs and Northwestern Zavkhan

The significant political features, elevation features, shaded topographic relief, and potential wind resource of central and eastern Uvs, northwestern Zavkhan, and extreme eastern Khovd are illustrated in Figures 6.67 through 6.70. The northwestern section of the Khangain Nuruu covers much of northwestern Zavkhan. The remainder of the region is composed of a series of basins that contain large lakes. The only other mountain range in the region is one that runs west to east across central Uvs.

The wind resource level is generally low in this region. The resource tends to decrease from east to west. Isolated areas of good-to-excellent resource are found on the ridge crests in this region. Basin areas have, at most, moderate resource for utility-scale applications and good resource for rural-power applications. The area around the western Khar Nuur in Zavkhan is the most prominent basin area with this level of wind resource.

6.6.18 Northern Govi-Altai and Southern Zavkhan

The significant political features, elevation features, shaded topographic relief, and potential wind resource of northern Govi-Altai and southern Zavkhan are illustrated in Figures 6.71 through 6.74. This region consists of the southwestern end of Khangain Nuruu, the central part of the Altai Nuruu, and the basins between the ranges.

The excellent wind resource areas are found on the highest ridge crests of the mountains. In Zavkhan these areas are concentrated close to the border with Bayankhongor. In Govi-Altai the excellent areas are found on two northwest-to-southeast trending mountain ranges in the northern and north-central parts of the aimag. The basins generally have low wind resource, though there are some areas, such as those around Tseel, that may have some moderate utility-scale and good rural-power wind resource.

6.6.19 Southern Govi-Altai

The significant political features, elevation features, shaded topographic relief, and potential wind resource of southern Govi-Altai are illustrated in Figures 6.75 through 6.78. Southern Govi-Altai is part of the mountain range and basin topography that is typical of southwestern Mongolia.

The lower elevations in southern Govi-Altai are more exposed to the prevailing winds than the basins in northern Govi-Altai and thus have greater wind resource than areas further north. Broad areas in southern Govi-Altai are estimated to have moderate utility-scale and good rural-power wind resource. The higher ridges of the isolated mountains in the basin areas have good utility-scale and excellent rural-power resource. Excellent resource areas for both utility-scale and rural power applications are confined to very high ridges concentrated in the Altai Nuruu.

6.6.20 Bayan-Ulgii, Western Uvs, and Northern Khovd

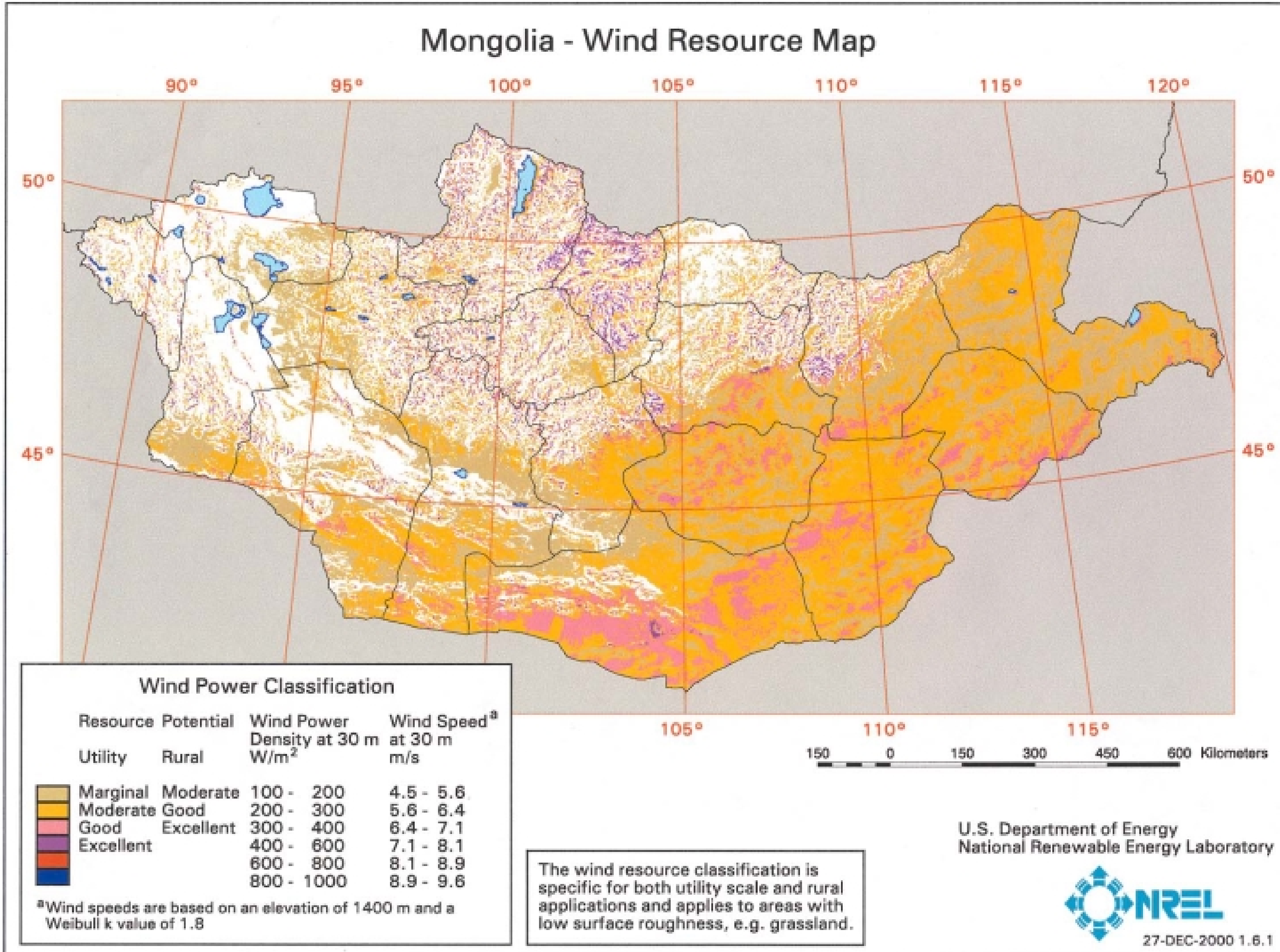
The significant political features, elevation features, shaded topographic relief, and potential wind resource of Bayan-Ulgii, western Uvs, and northern Khovd are illustrated in Figures 6.79 through 6.82. This region is located in the extreme northwestern part of Mongolia. The Altai Nuruu dominates the region with many peaks over 3,500 m. Basins with large lakes are found in northern Khovd and western Uvs.

The excellent wind resource areas are found on the ridge crests. In western Uvs the crests are located between Achit Nuur and Uureg Nuur. In Bayan-Ulgii the best ridge-crest locations are near Tolbo Nuur, along the border with Khovd, and to the north of Khoton Nuur.

6.6.21 Southern Khovd and Northwestern Govi-Altai

The significant political features, elevation features, shaded topographic relief, and potential wind resource of southern Khovd and northwestern Govi-Altai are illustrated in Figures 6.83 through 6.86. This region is the extreme southwestern section of Mongolia and features large elevation variations. Many mountain peaks in the Altai Nuruu are over 3,500 m high, whereas the basin in southern Khovd is around 1,000 m.

Excellent wind resource areas are found on the Altai Nuruu ridge crests in Khovd and western Govi-Altai. Sites in the basin that extends from the border with China in Khovd eastward into western Govi-Altai are exposed to the prevailing moderate west winds in the region. As a consequence, the wind resource is estimated to be marginal-to-moderate for utility-scale and moderate-to-good for rural-power applications in this basin. Areas with the highest wind resource in this basin are concentrated near the Khovd and Govi-Altai border.


Mongolia - Wind Resource Map
90°
95°
100°
105°
110°
115°
120°
50°
45°
Wind Power Classification
Resource Potential
Utility
Rural
Wind Power Density at 30 m W/m²
Wind Speed[a] at 30 m m/s
Marginal Moderate 100 - 200 4.5 - 5.6
Moderate Good 200 - 300 5.6 - 6.4
Good Excellent 300 - 400 6.4 - 7.1
Excellent 400 - 600 7.1 - 8.1
600 - 800 8.1 - 8.9
800 - 1000 8.9 - 9.6
[a]Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8
150 0 150 300 450 600 Kilometers
The wind resource classification is specific for both utility scale and rural applications and applies to areas with low surface roughness, e.g. grassland.
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National Renewable Energy Laboratory
NREL
27-DEC-2000 1.6.1

Figure 6-1

Mongolia - Atlas Mapping Regions

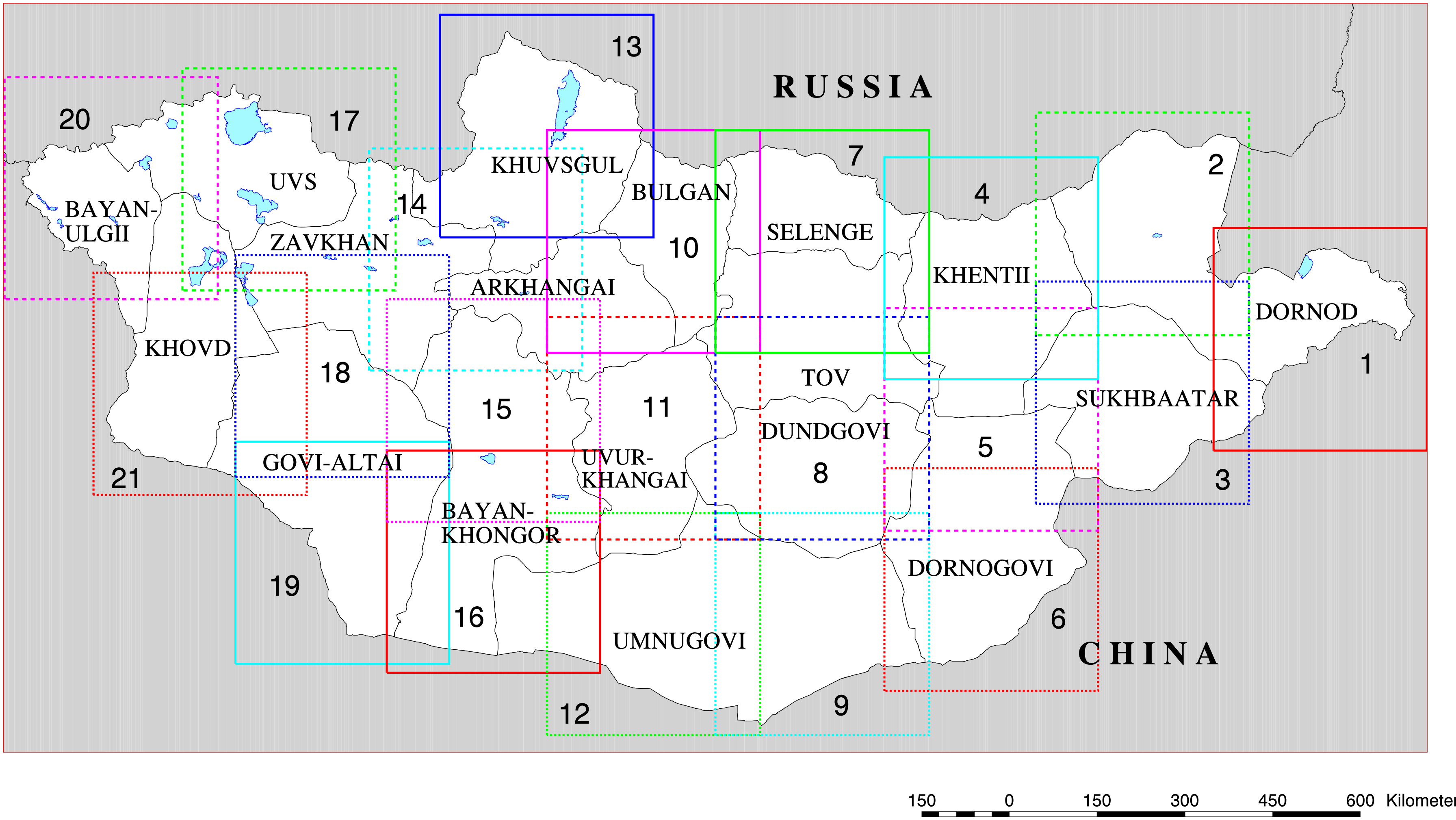

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Figure 6-2

Mongolia - Southeastern Dornod
Political Map

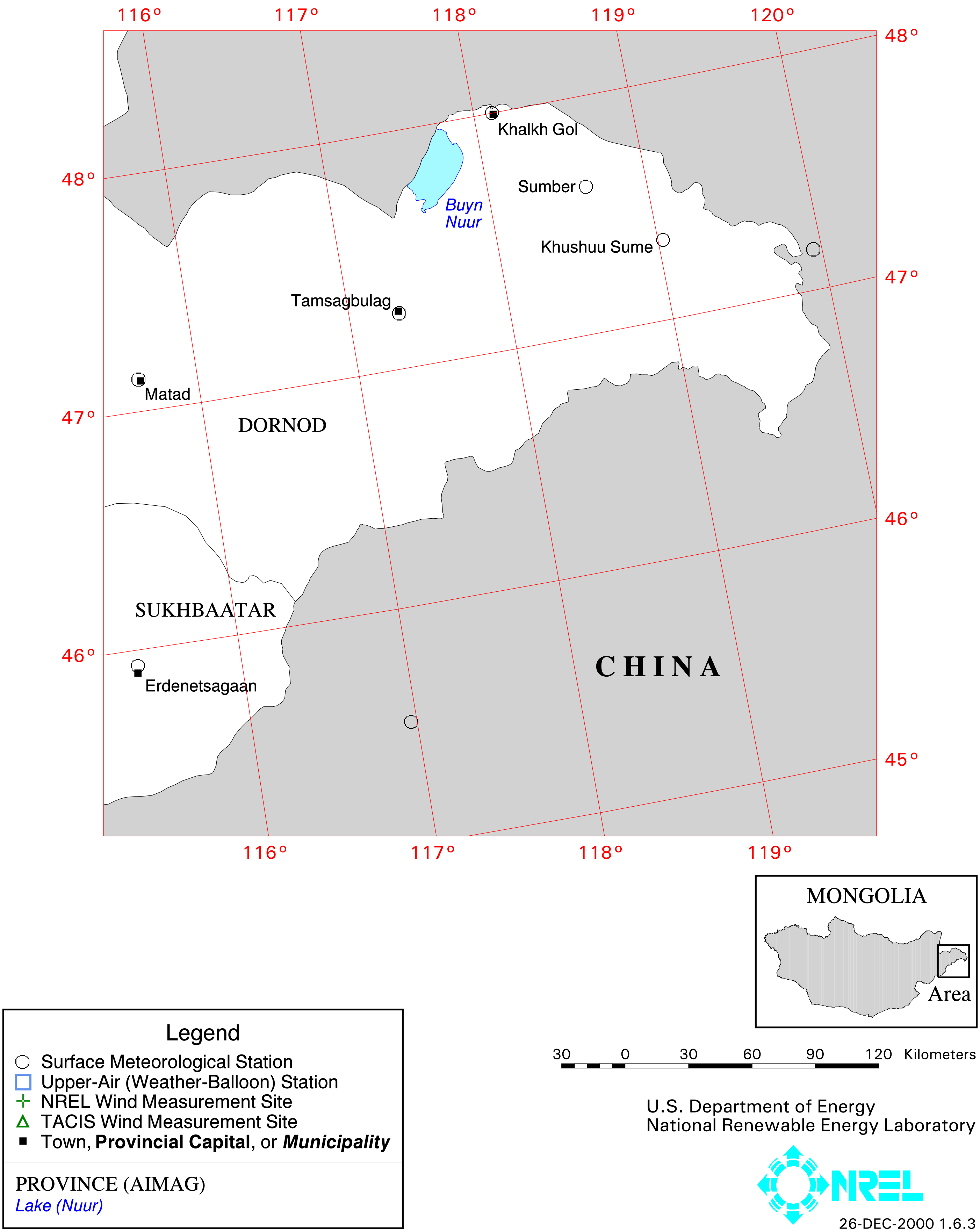
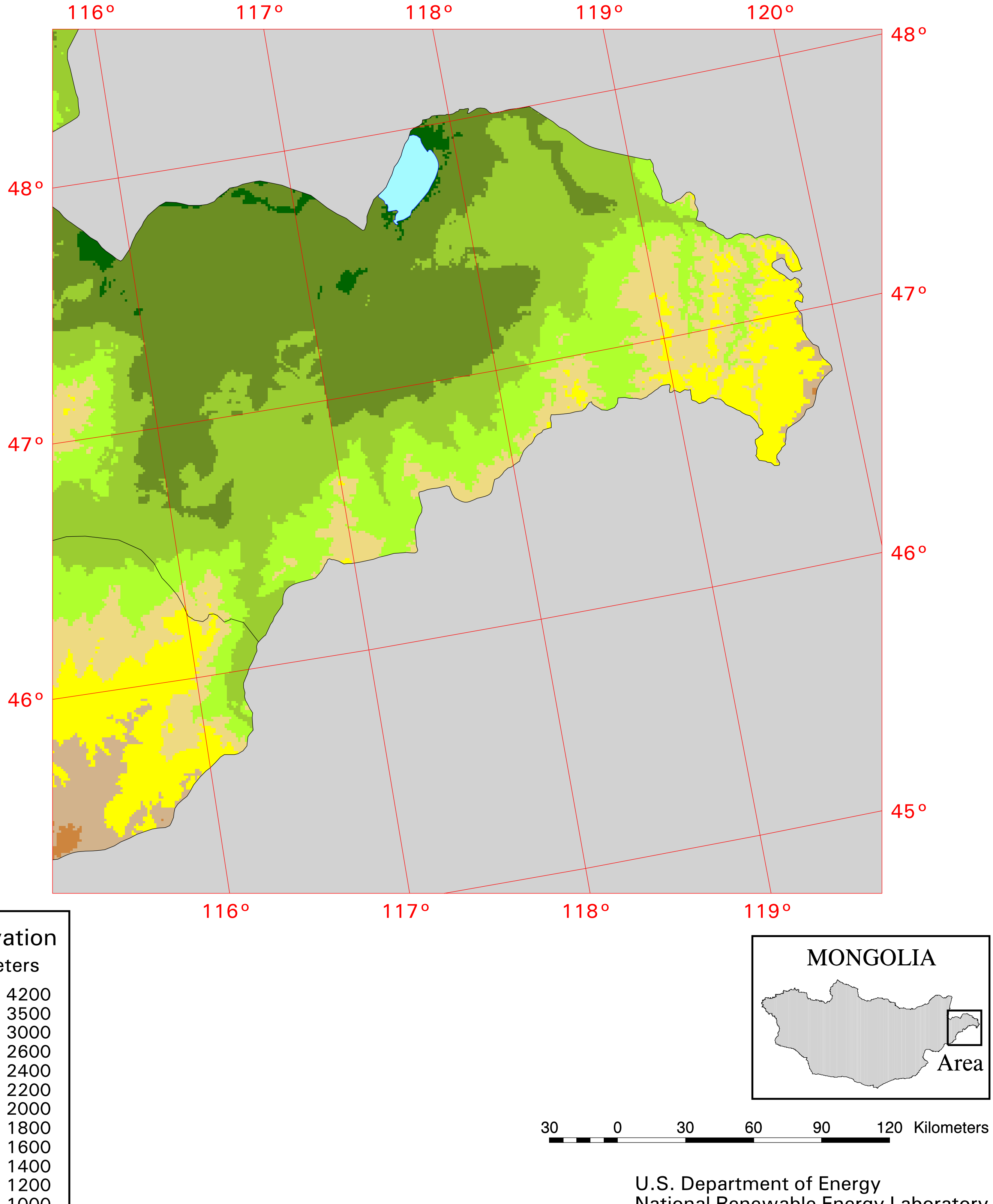


Figure 6-3

Mongolia - Southeastern Dornod
Elevation Map



The elevation values are averaged over 1 km^2.

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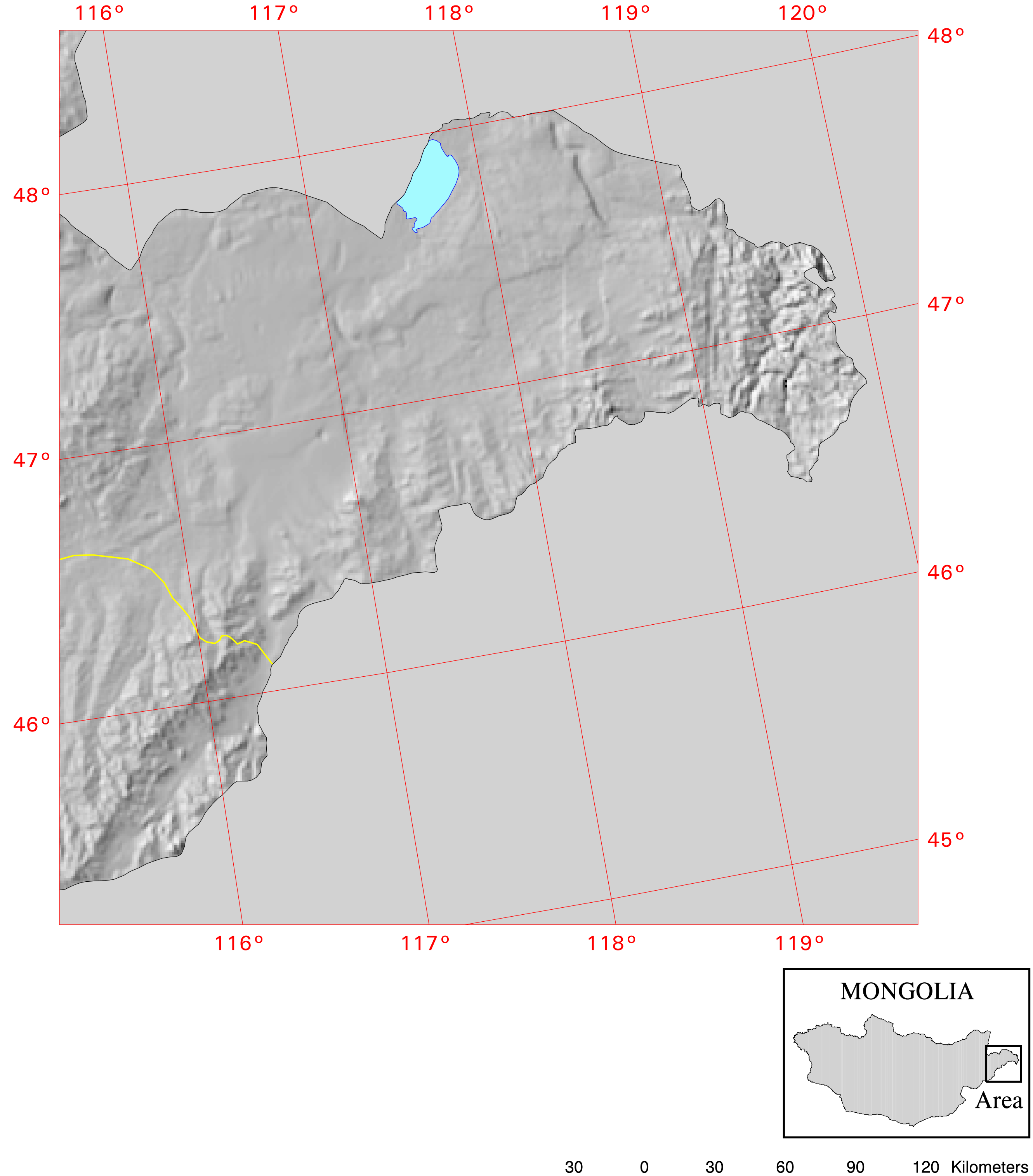
Figure 6-4

Mongolia - Southeastern Dornod
Hillshaded Relief Map



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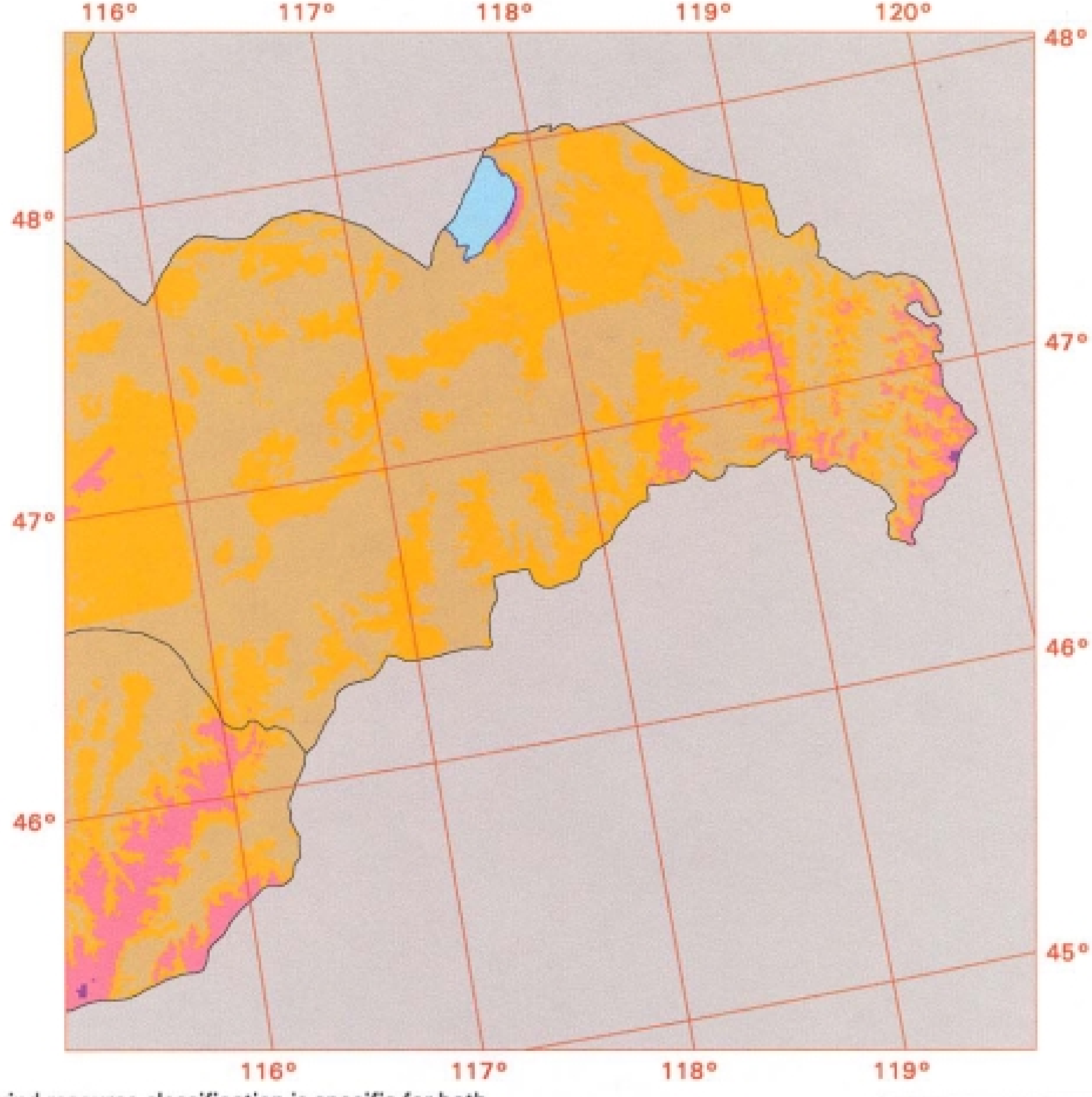
National Renewable Energy Laboratory

26-DEC-2000 1.6.5

Figure 6-5

Mongolia - Southeastern Dornod
Wind Resource Map

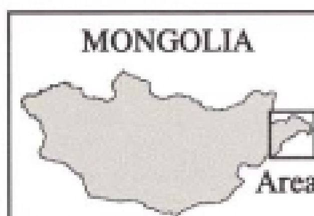


The wind resource classification is specific for both utility-scale and rural applications and applies to areas with low surface roughness, e.g. grassland.

Wind Power Classification

Resource Potential Utility	Rural	Wind Power Density at 30 m W/m²	Wind Speed[a] at 30 m m/s
Marginal	Moderate	100 - 200	4.5 - 5.6
Moderate	Good	200 - 300	5.6 - 6.4
Good	Excellent	300 - 400	6.4 - 7.1
Excellent		400 - 600	7.1 - 8.1
		600 - 800	8.1 - 8.9
		800 - 1000	8.9 - 9.6

[a]Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8



30 0 30 60 90 120 Kilometers

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National Renewable Energy Laboratory

NREL

26-DEC-2000 1.6.6

Figure 6-6

Mongolia - Northwestern Dornod
Political Map

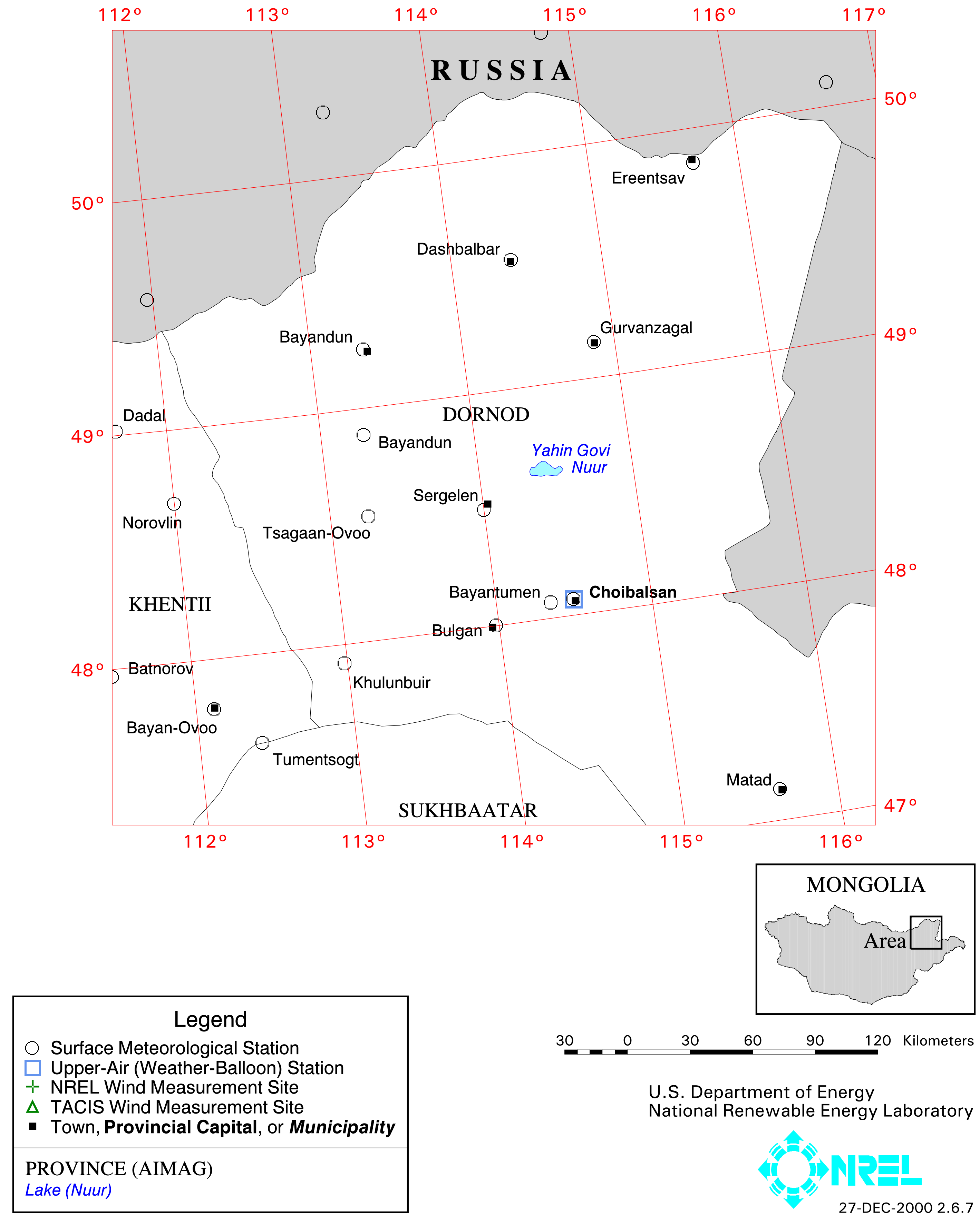


Figure 6-7

Mongolia - Northwestern Dornod
Elevation Map

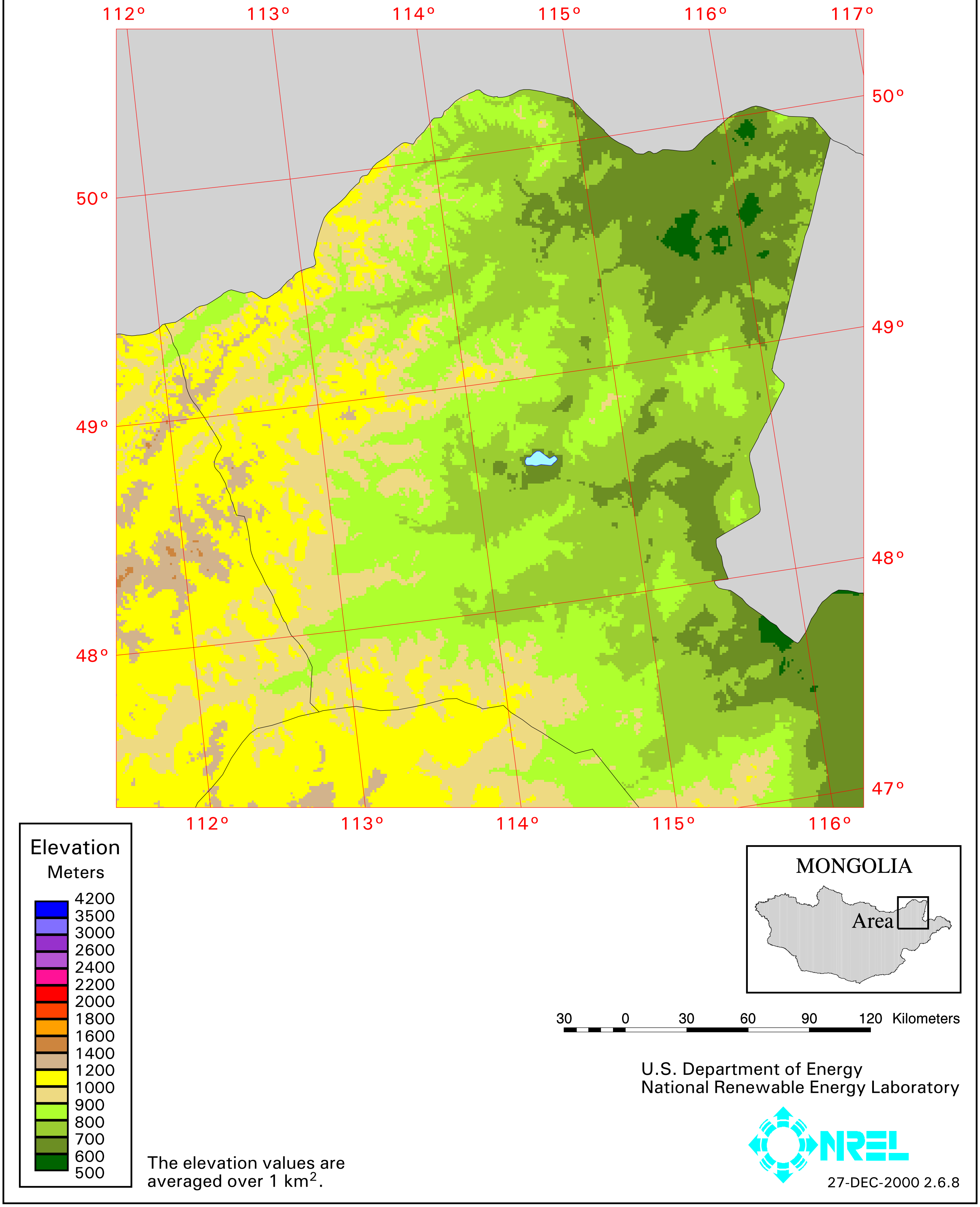
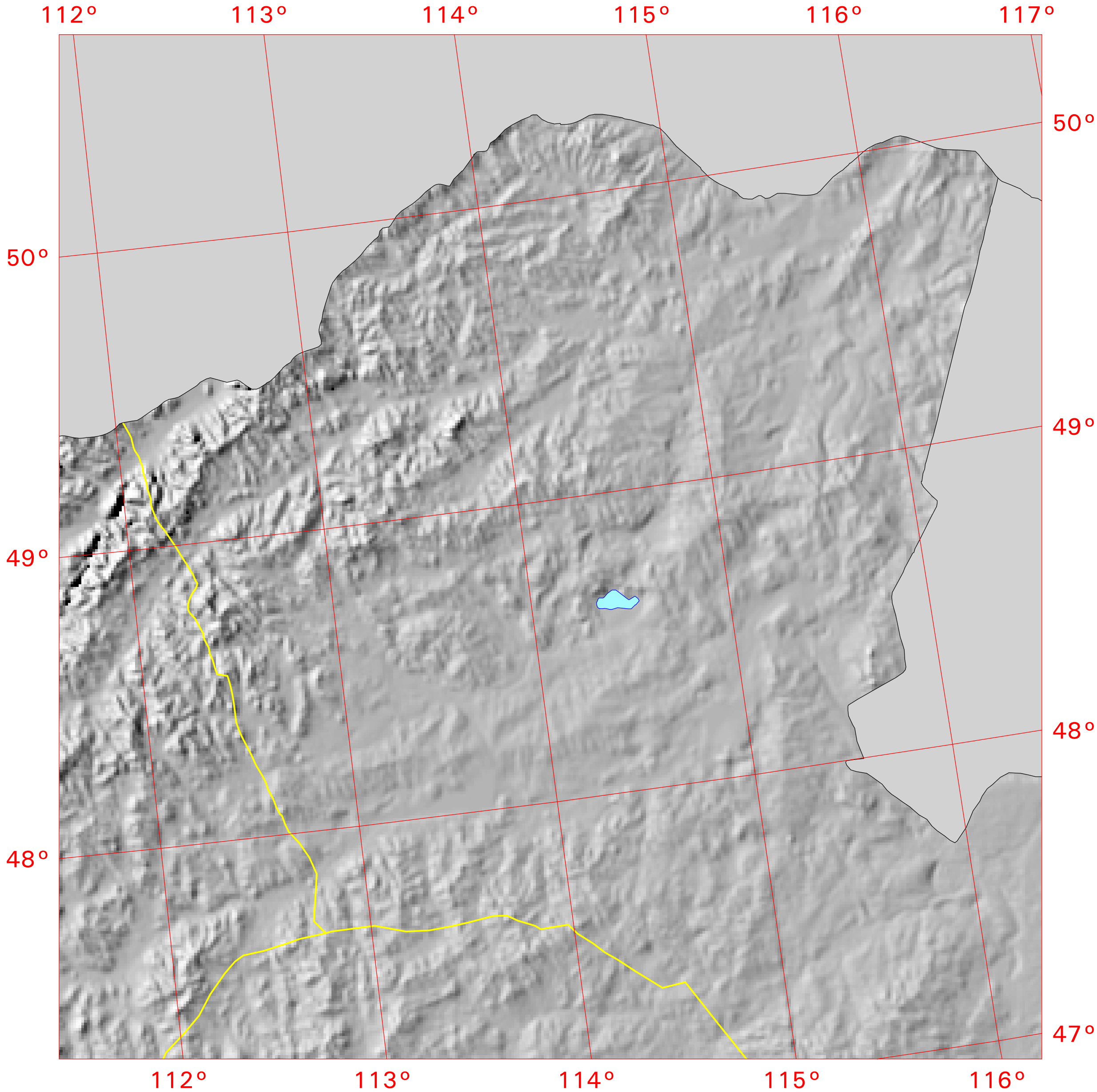
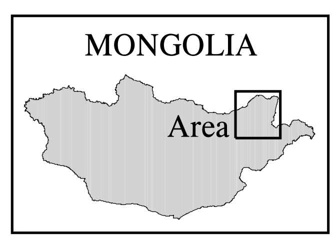


Figure 6-8

Mongolia - Northwestern Dornod
Hillshaded Relief Map





30 0 30 60 90 120 Kilometers

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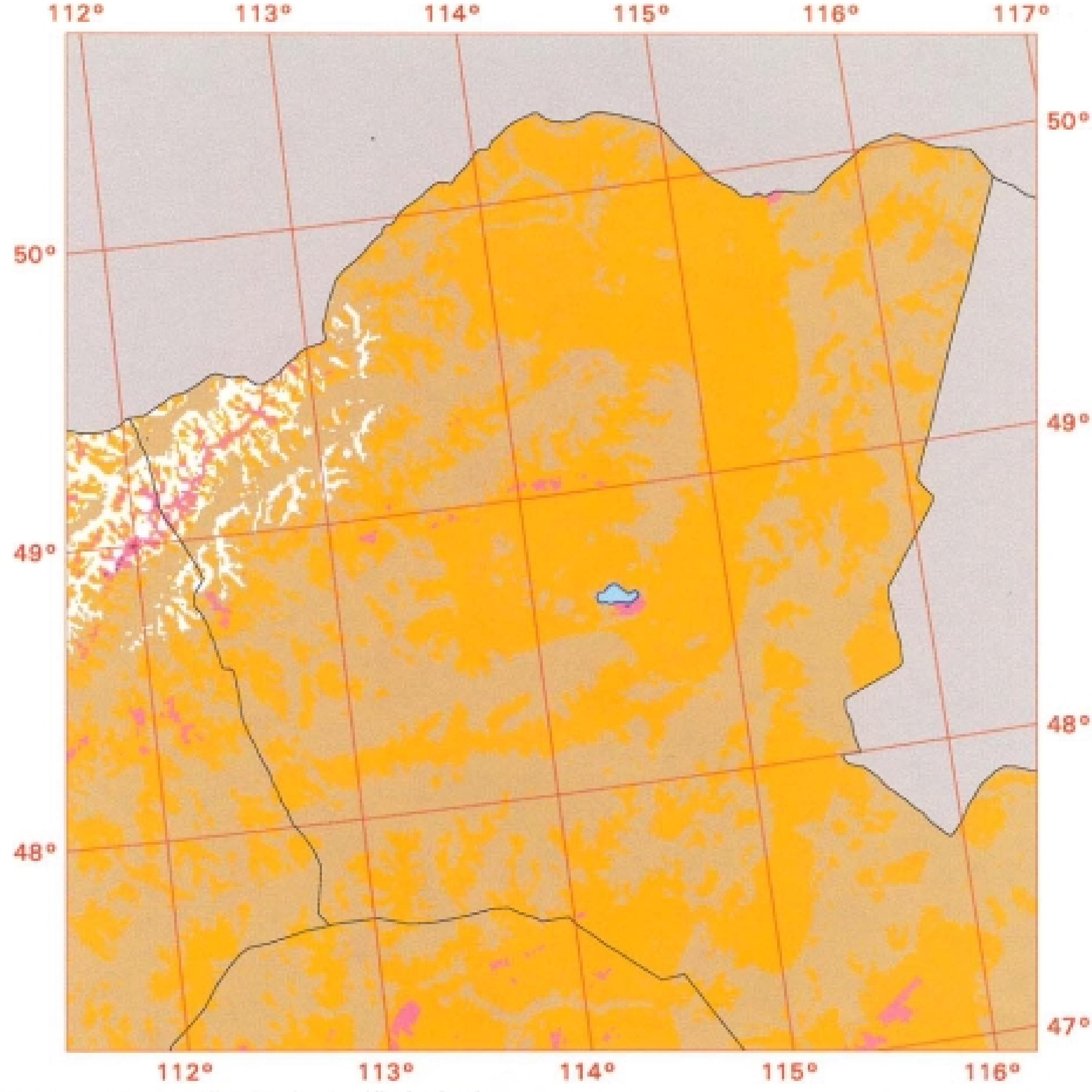
27-DEC-2000 2.6.9

Figure 6-9

Mongolia - Northwestern Dornod
Wind Resource Map



The wind resource classification is specific for both utility-scale and rural applications and applies to areas with low surface roughness, e.g. grassland.

Wind Power Classification

Resource Potential Utility	Resource Potential Rural	Wind Power Density at 30 m W/m^2	Wind Speed[a] at 30 m m/s
Marginal	Moderate	100 - 200	4.5 - 5.6
Moderate	Good	200 - 300	5.6 - 6.4
Good	Excellent	300 - 400	6.4 - 7.1
Excellent		400 - 600	7.1 - 8.1
		600 - 800	8.1 - 8.9
		800 - 1000	8.9 - 9.6

[a]Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8

30 0 30 60 90 120 Kilometers

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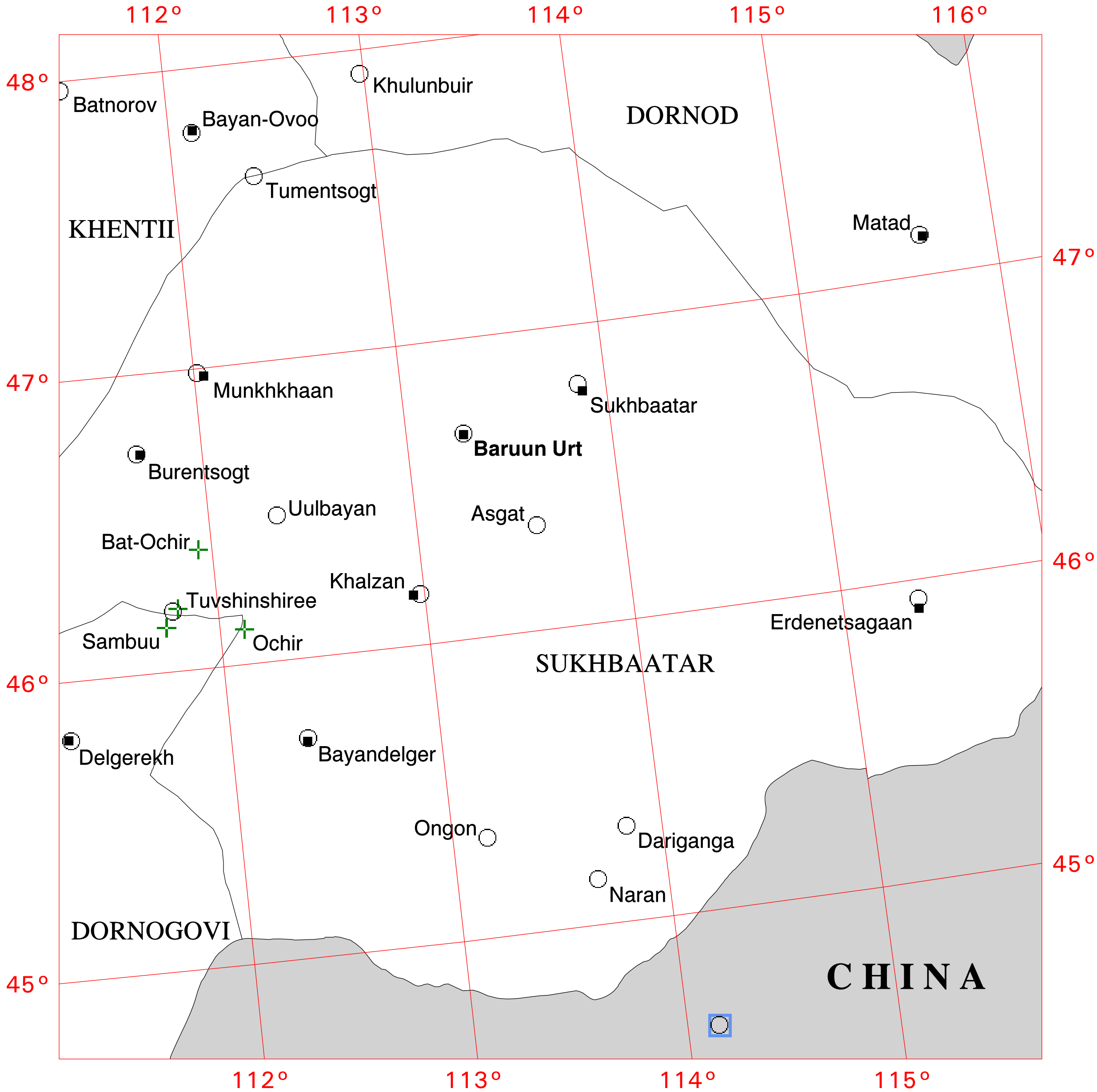
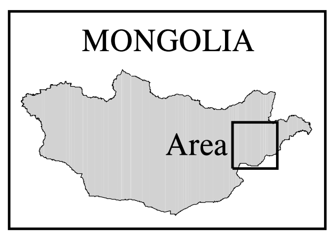
Figure 6-10

Mongolia - Sukhbaatar
Political Map





The data for NREL and TACIS (Technical Assistance to the Commonwealth of Independent States) wind measurement sites were collected in collaboration with REC (Renewable Energy Corporation).

Legend

- ○ Surface Meteorological Station
- □ Upper-Air (Weather-Balloon) Station
- + NREL Wind Measurement Site
- △ TACIS Wind Measurement Site
- ■ Town, **Provincial Capital**, or ***Municipality***

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Lake (Nuur)

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Figure 6-11

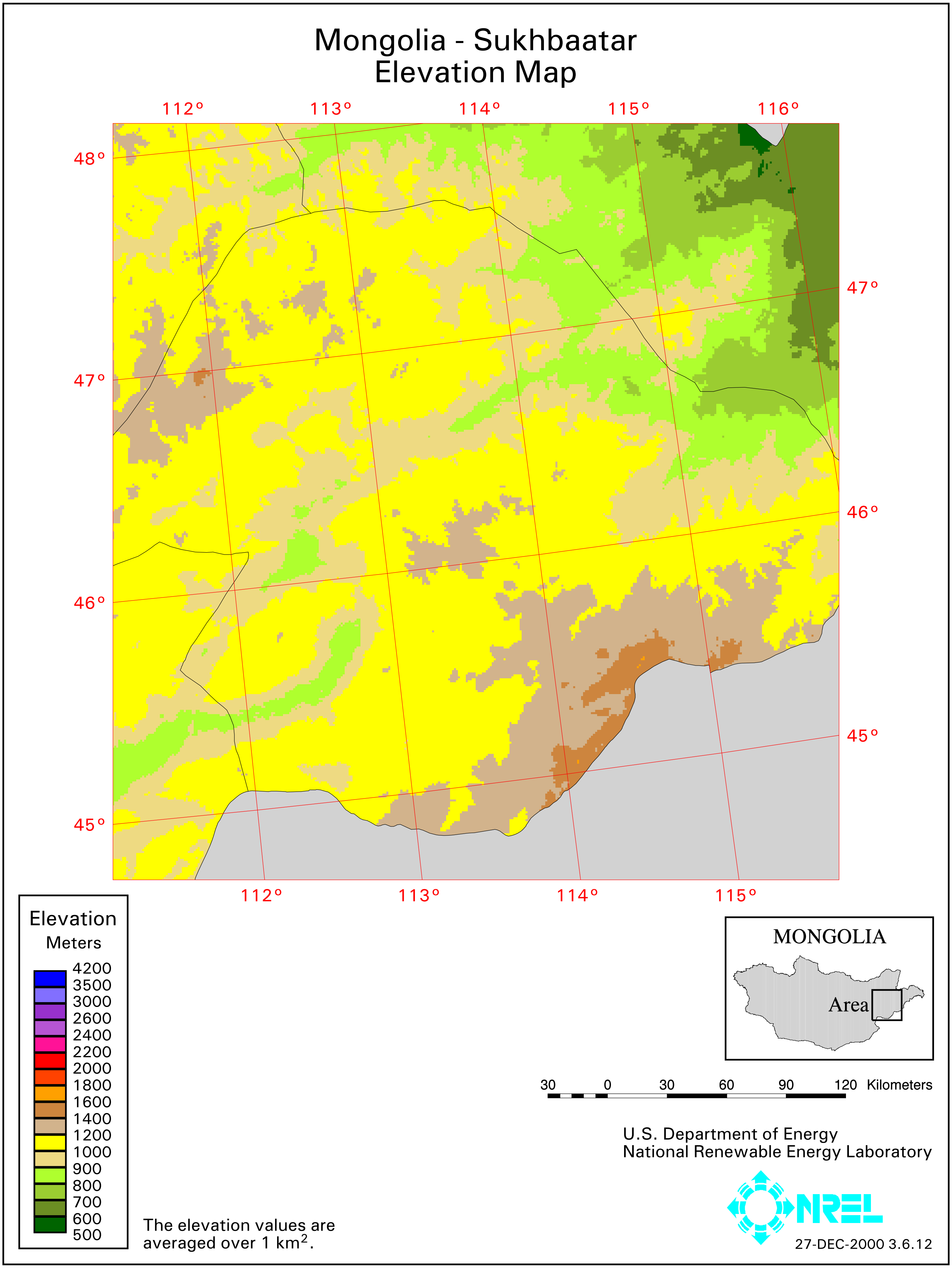
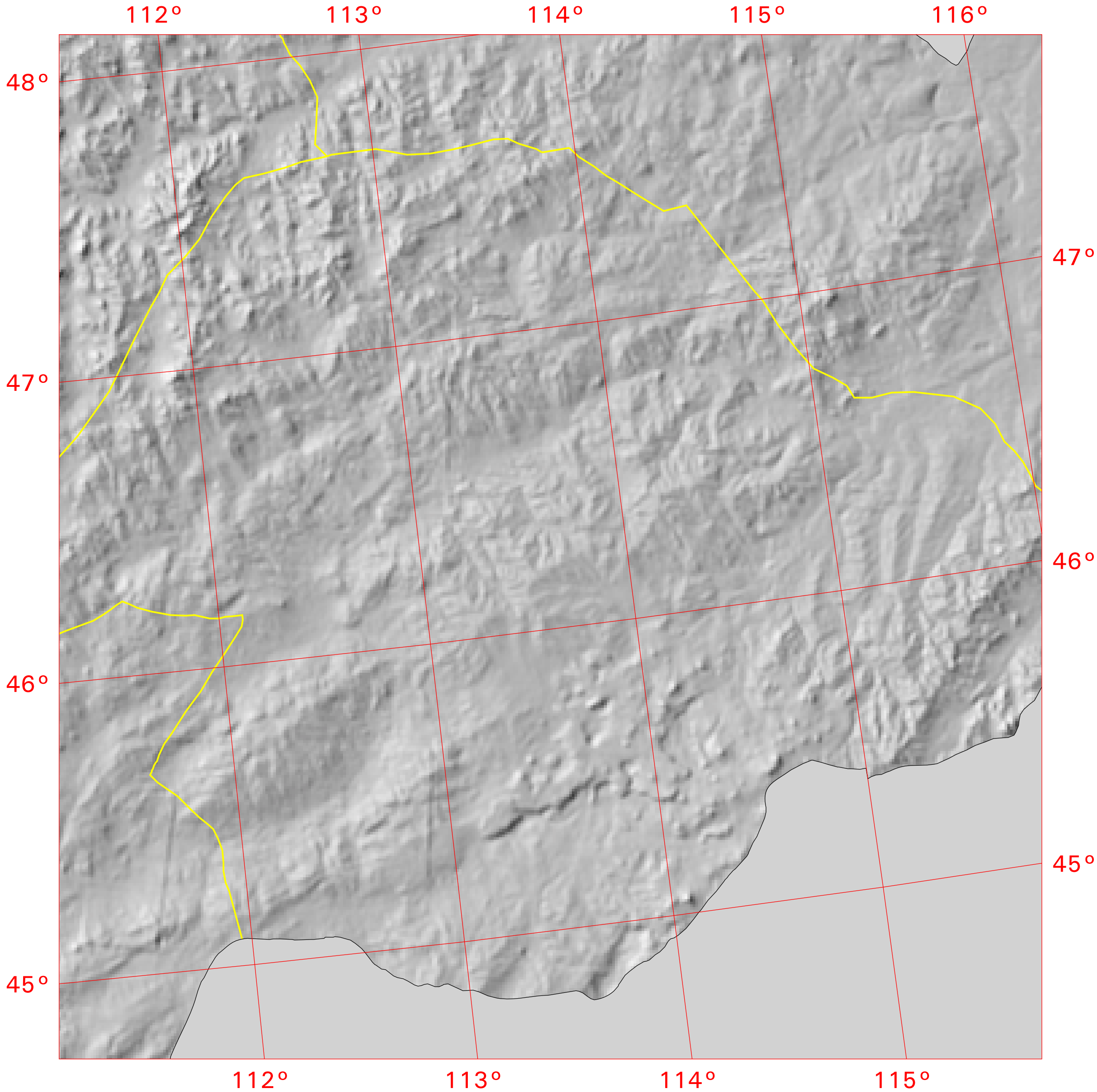
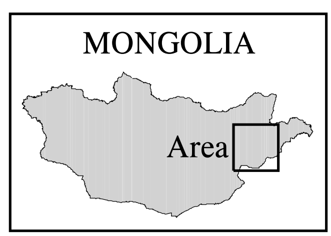

Mongolia - Sukhbaatar
Elevation Map
112°
113°
114°
115°
116°
48°
47°
46°
45°
Elevation
Meters
4200
3500
3000
2600
2400
2200
2000
1800
1600
1400
1200
1000
900
800
700
600
500
MONGOLIA
Area
30 0 30 60 90 120 Kilometers
U.S. Department of Energy
National Renewable Energy Laboratory
NREL
27-DEC-2000 3.6.12
The elevation values are averaged over 1 km².

Figure 6-12

Mongolia - Sukhbaatar
Hillshaded Relief Map





30 0 30 60 90 120 Kilometers

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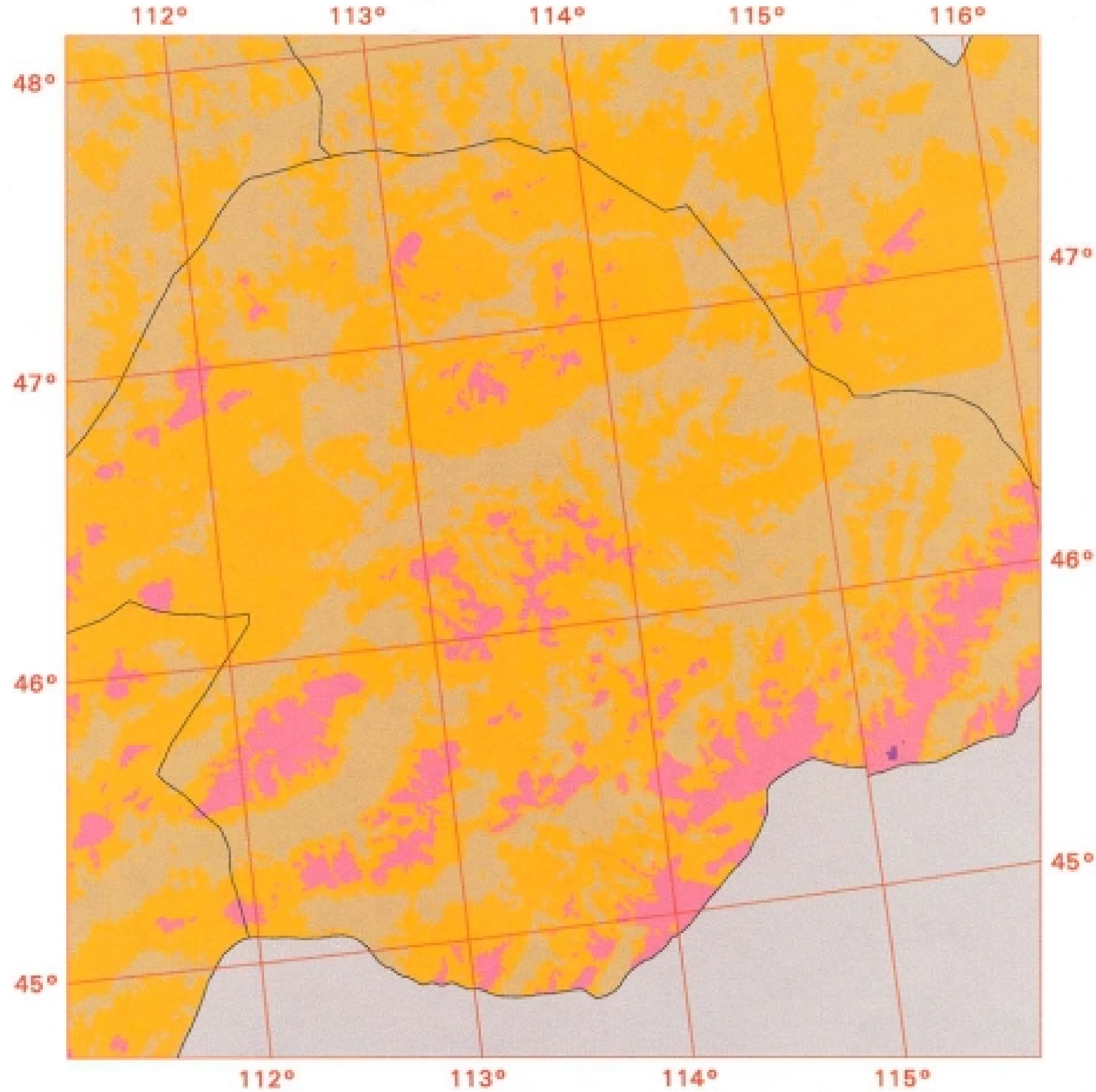
27-DEC-2000 3.6.13

Figure 6-13

Mongolia - Sukhbaatar
Wind Resource Map



The wind resource classification is specific for both utility-scale and rural applications and applies to areas with low surface roughness, e.g. grassland.

Wind Power Classification

Resource Potential Utility	Resource Potential Rural	Wind Power Density at 30 m W/m^2	Wind Speed[a] at 30 m m/s
Marginal	Moderate	100 - 200	4.5 - 5.6
Moderate	Good	200 - 300	5.6 - 6.4
Good	Excellent	300 - 400	6.4 - 7.1
Excellent		400 - 600	7.1 - 8.1
		600 - 800	8.1 - 8.9
		800 - 1000	8.9 - 9.6

[a] Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8

30 0 30 60 90 120 Kilometers

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Figure 6-14

Mongolia - Khentii
Political Map

Legend
- ○ Surface Meteorological Station
- □ Upper-Air (Weather-Balloon) Station
- + NREL Wind Measurement Site
- Δ TACIS Wind Measurement Site
- ■ Town, **Provincial Capital**, or ***Municipality***

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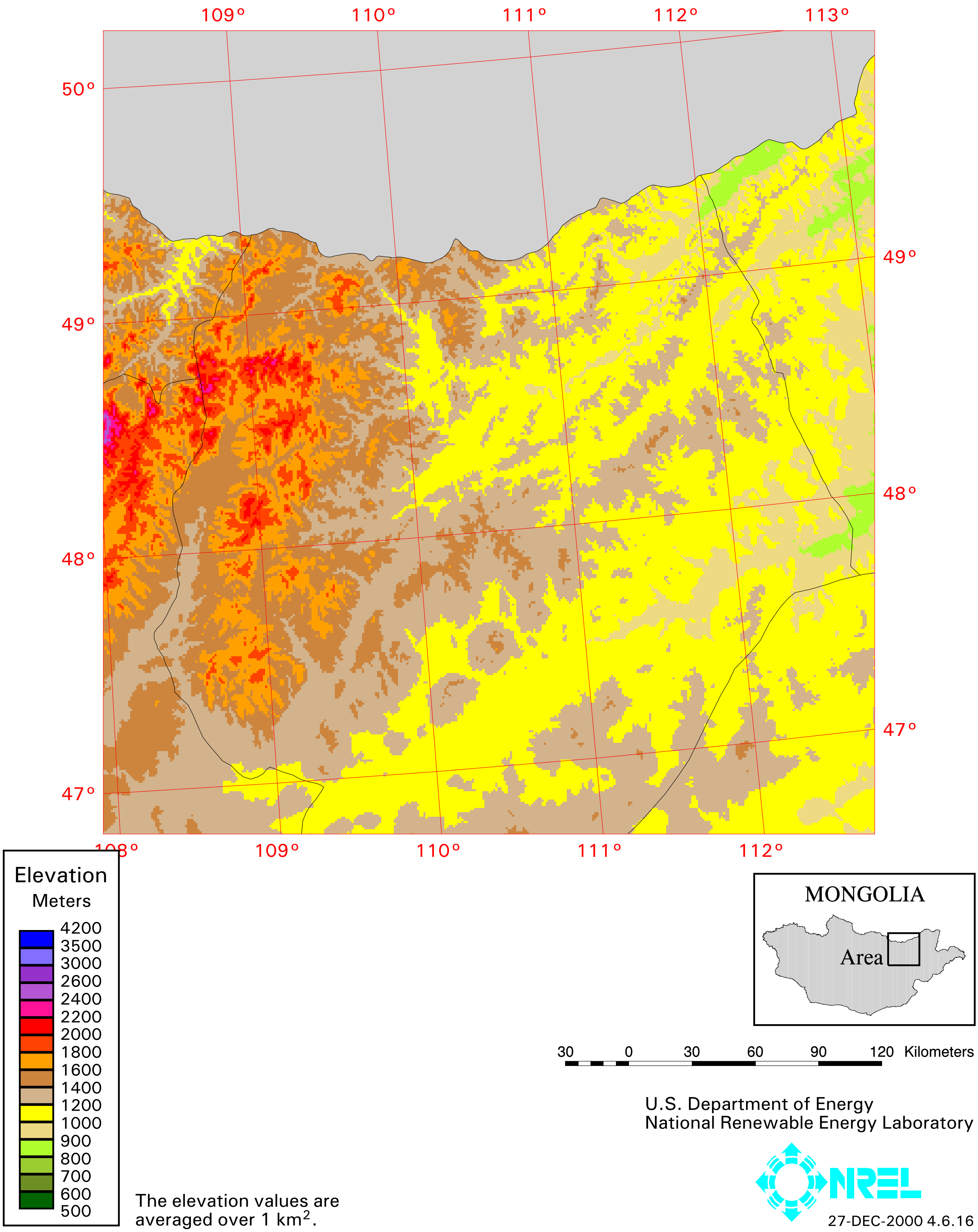
Lake (Nuur)

U.S. Department of Energy
National Renewable Energy Laboratory

27-DEC-2000 4.6.15

Figure 6-15

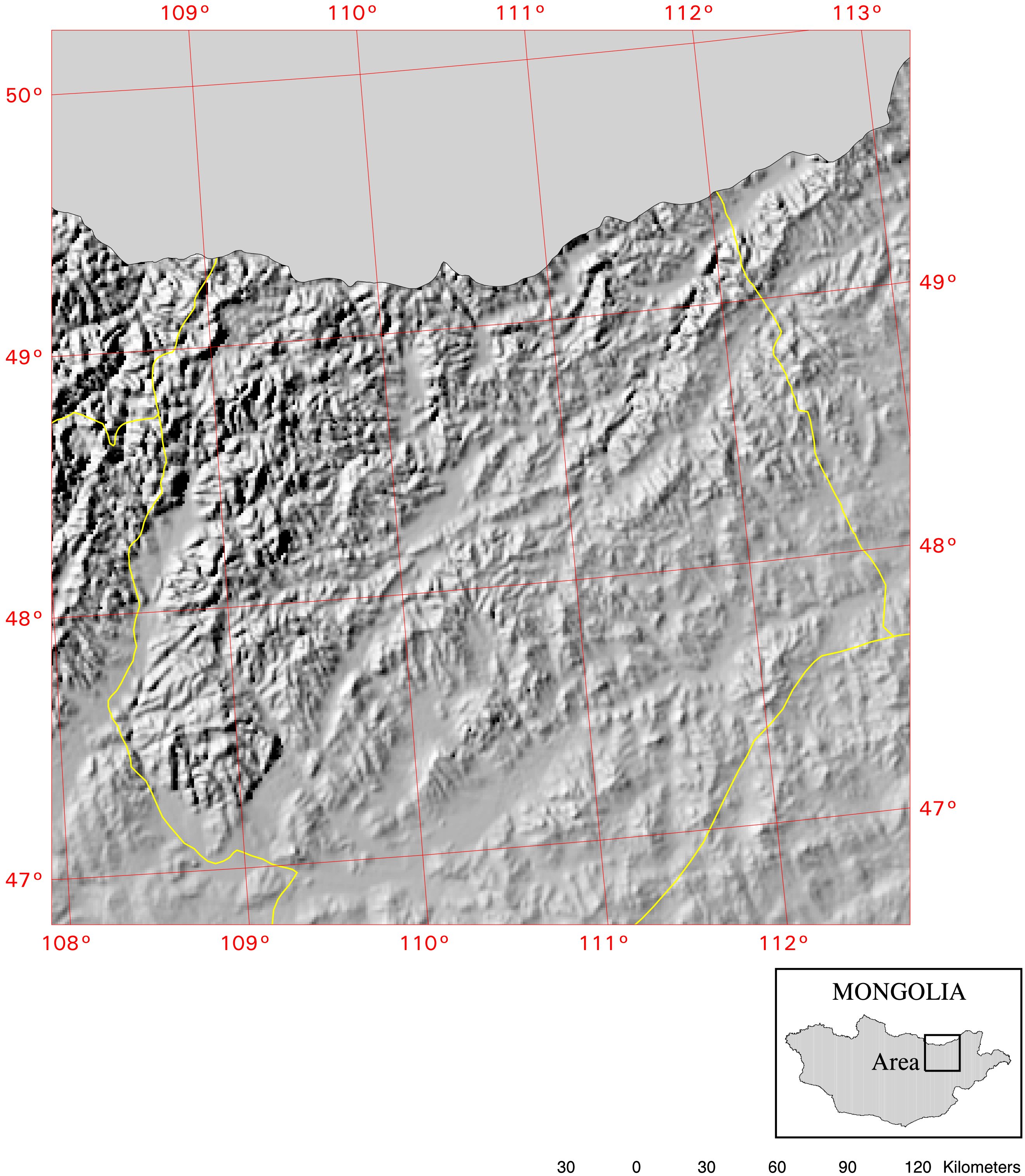
Mongolia - Khentii
Elevation Map



The elevation values are averaged over 1 km².

Figure 6-16

Mongolia - Khentii
Hillshaded Relief Map



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National Renewable Energy Laboratory

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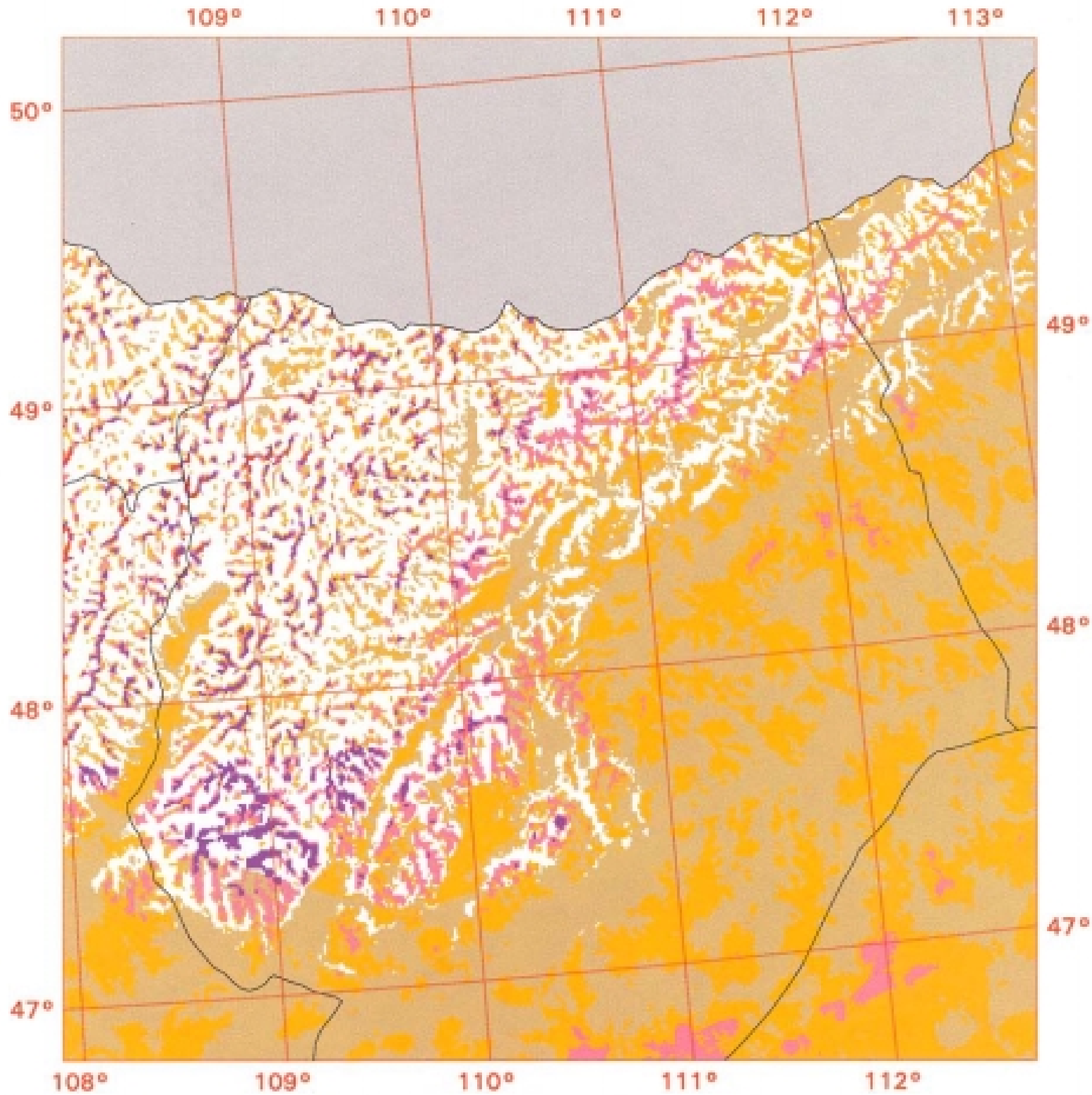
27-DEC-2000 4.6.17

Figure 6-17

Mongolia - Khentii
Wind Resource Map



The wind resource classification is specific for both utility-scale and rural applications and applies to areas with low surface roughness, e.g. grassland.

Wind Power Classification

Resource Potential Utility	Resource Potential Rural	Wind Power Density at 30 m W/m²	Wind Speed[a] at 30 m m/s
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Moderate	Good	200 - 300	5.6 - 6.4
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Excellent		400 - 600	7.1 - 8.1
		600 - 800	8.1 - 8.9
		800 - 1000	8.9 - 9.6

[a] Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8

30 0 30 60 90 120 Kilometers

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National Renewable Energy Laboratory

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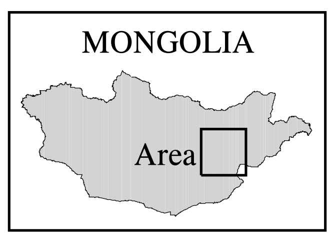
27-DEC-2000 4.6.18

Figure 6-18

Mongolia - Northern Dornogovi and Southern Khentii Political Map

The data for NREL and TACIS (Technical Assistance to the Commonwealth of Independent States) wind measurement sites were collected in collaboration with REC (Renewable Energy Corporation).



30 0 30 60 90 120 Kilometers

Legend

- ○ Surface Meteorological Station
- □ Upper-Air (Weather-Balloon) Station
- + NREL Wind Measurement Site
- △ TACIS Wind Measurement Site
- ■ Town, **Provincial Capital**, or ***Municipality***

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Lake (Nuur)

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16-JUL-2001 5.6.19

Figure 6-19

Mongolia - Northern Dornogovi and Southern Khentii Elevation Map

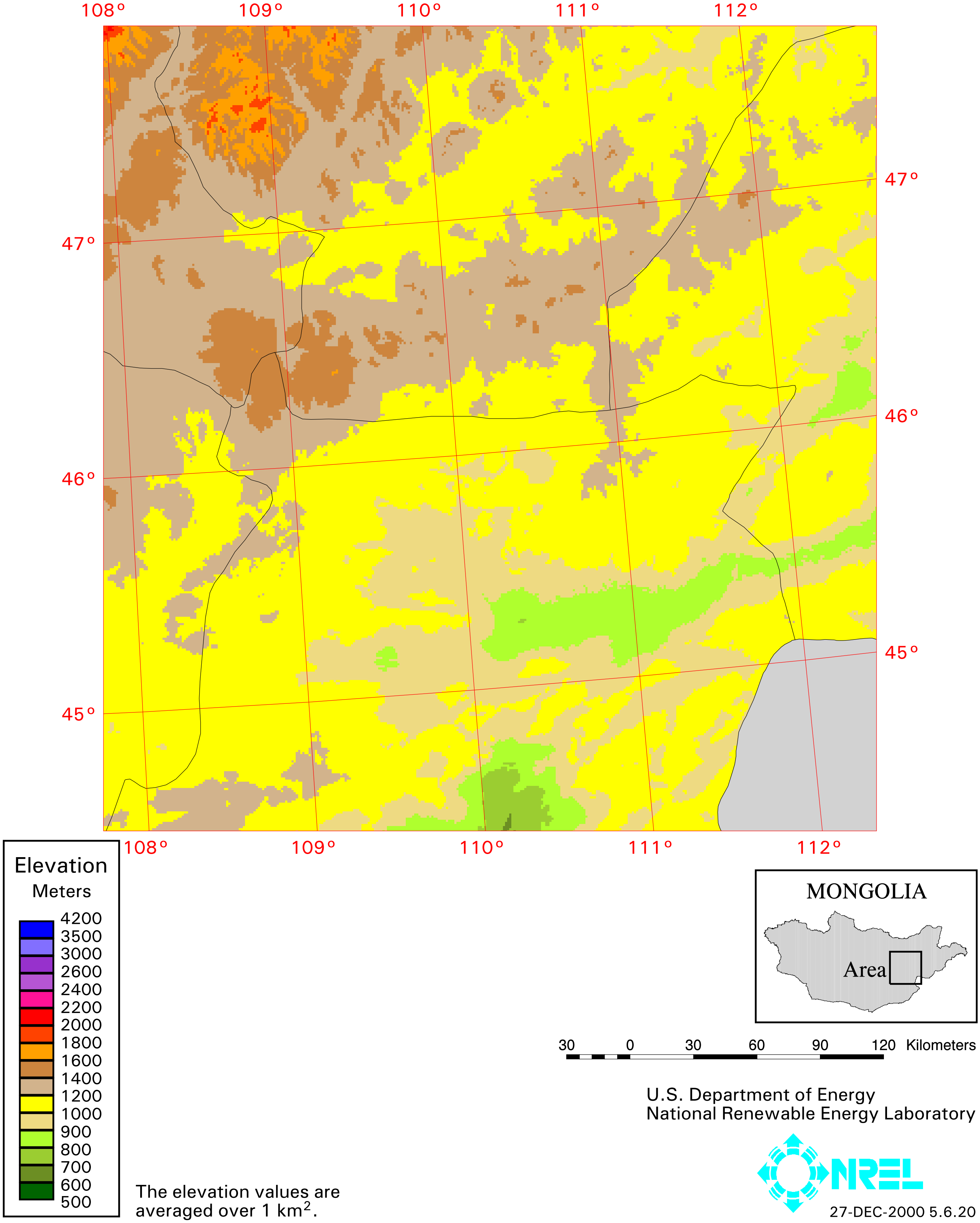
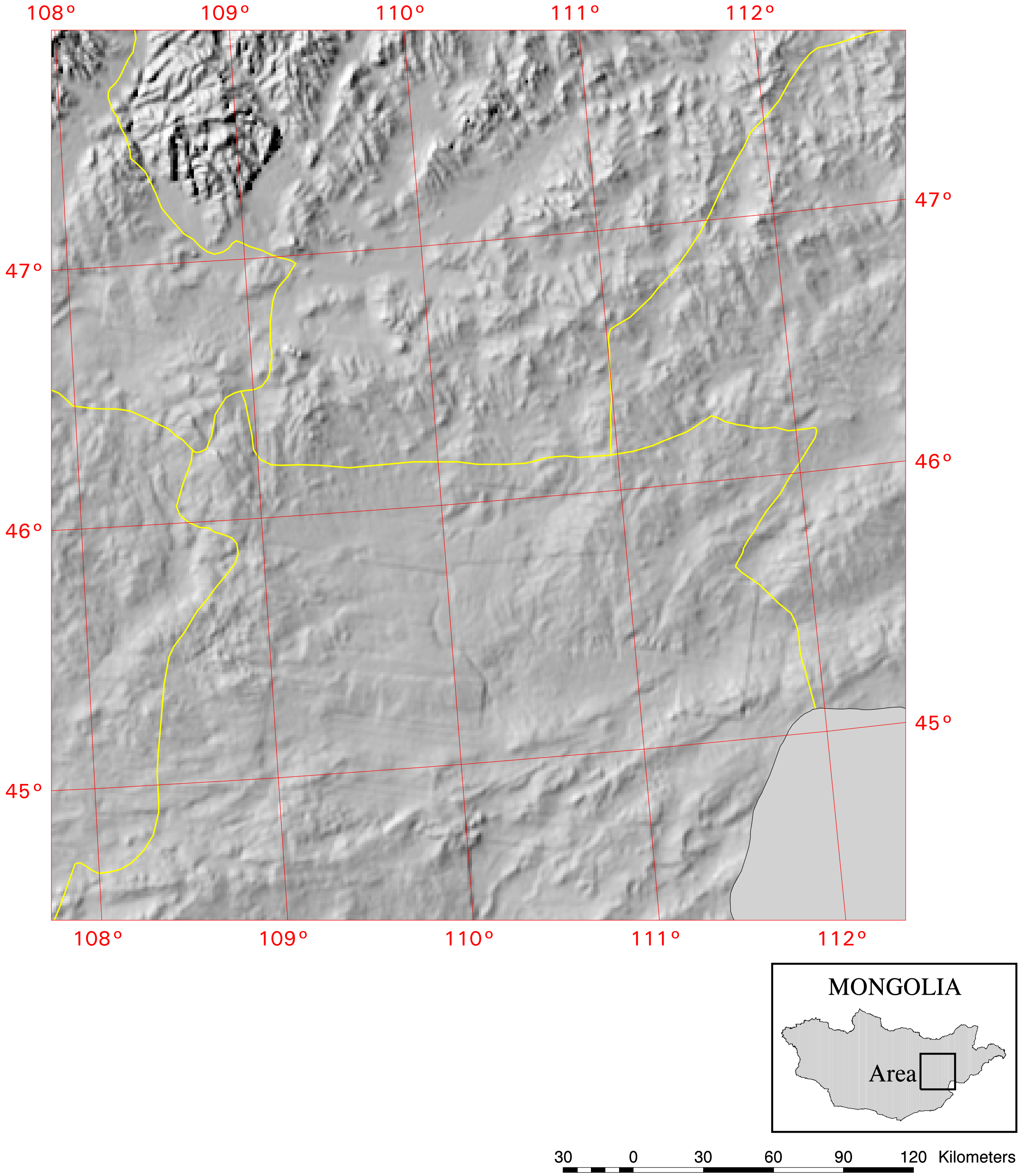


Figure 6-20

Mongolia - Northern Dornogovi and Southern Khentii
Hillshaded Relief Map



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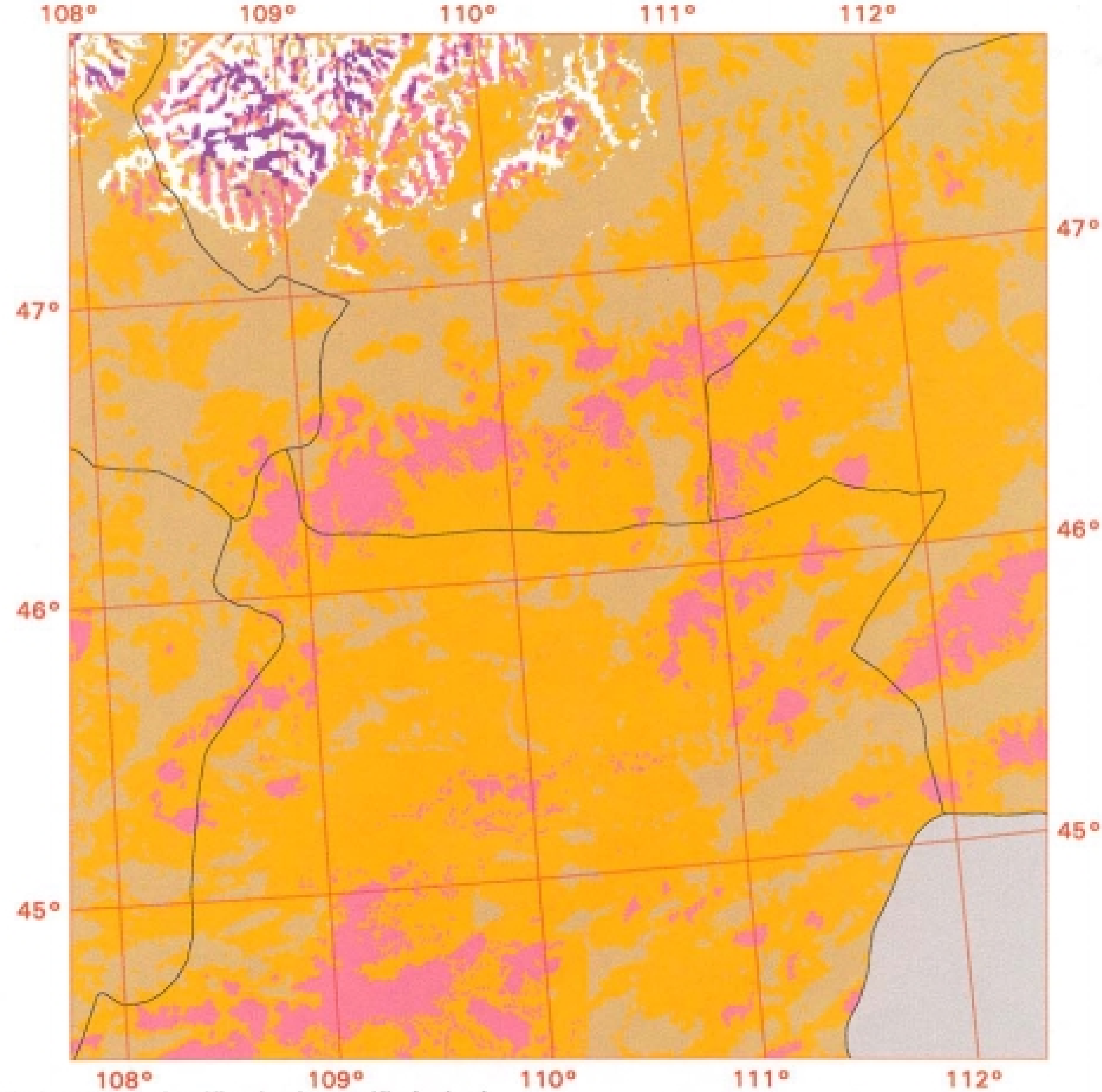
NREL

27-DEC-2000 5.6.21

Figure 6-21

Mongolia - Northern Dornogovi and Southern Khentii
Wind Resource Map



The wind resource classification is specific for both utility-scale and rural applications and applies to areas with low surface roughness, e.g. grassland.

30 0 30 60 90 120 Kilometers

Wind Power Classification

Resource Potential Utility	Resource Potential Rural	Wind Power Density at 30 m W/m²	Wind Speed[a] at 30 m m/s
Marginal	Moderate	100 - 200	4.5 - 5.6
Moderate	Good	200 - 300	5.6 - 6.4
Good	Excellent	300 - 400	6.4 - 7.1
Excellent		400 - 600	7.1 - 8.1
		600 - 800	8.1 - 8.9
		800 - 1000	8.9 - 9.6

[a]Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8

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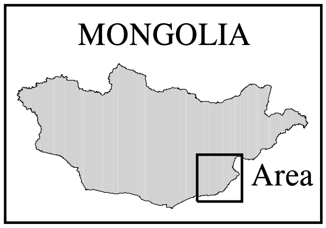
National Renewable Energy Laboratory

NREL

27-DEC-2000 5.6.22

Figure 6-22

Mongolia - Dornogovi
Political Map



The data for NREL and TACIS (Technical Assistance to the Commonwealth of Independent States) wind measurement sites were collected in collaboration with REC (Renewable Energy Corporation).

30 0 30 60 90 120 Kilometers

Legend

- ○ Surface Meteorological Station
- □ Upper-Air (Weather-Balloon) Station
- + NREL Wind Measurement Site
- △ TACIS Wind Measurement Site
- ■ Town, **Provincial Capital**, or ***Municipality***

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Figure 6-23

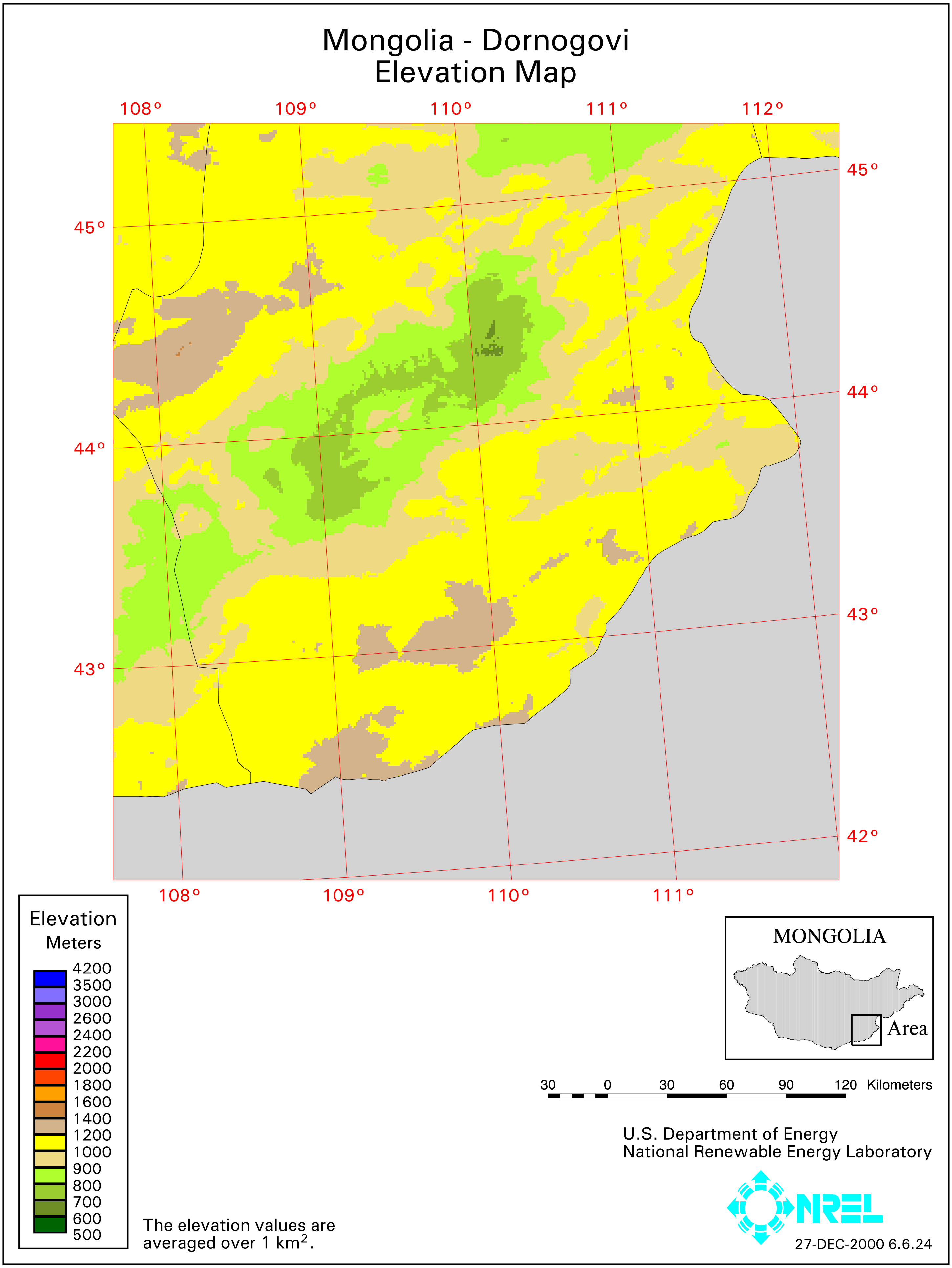
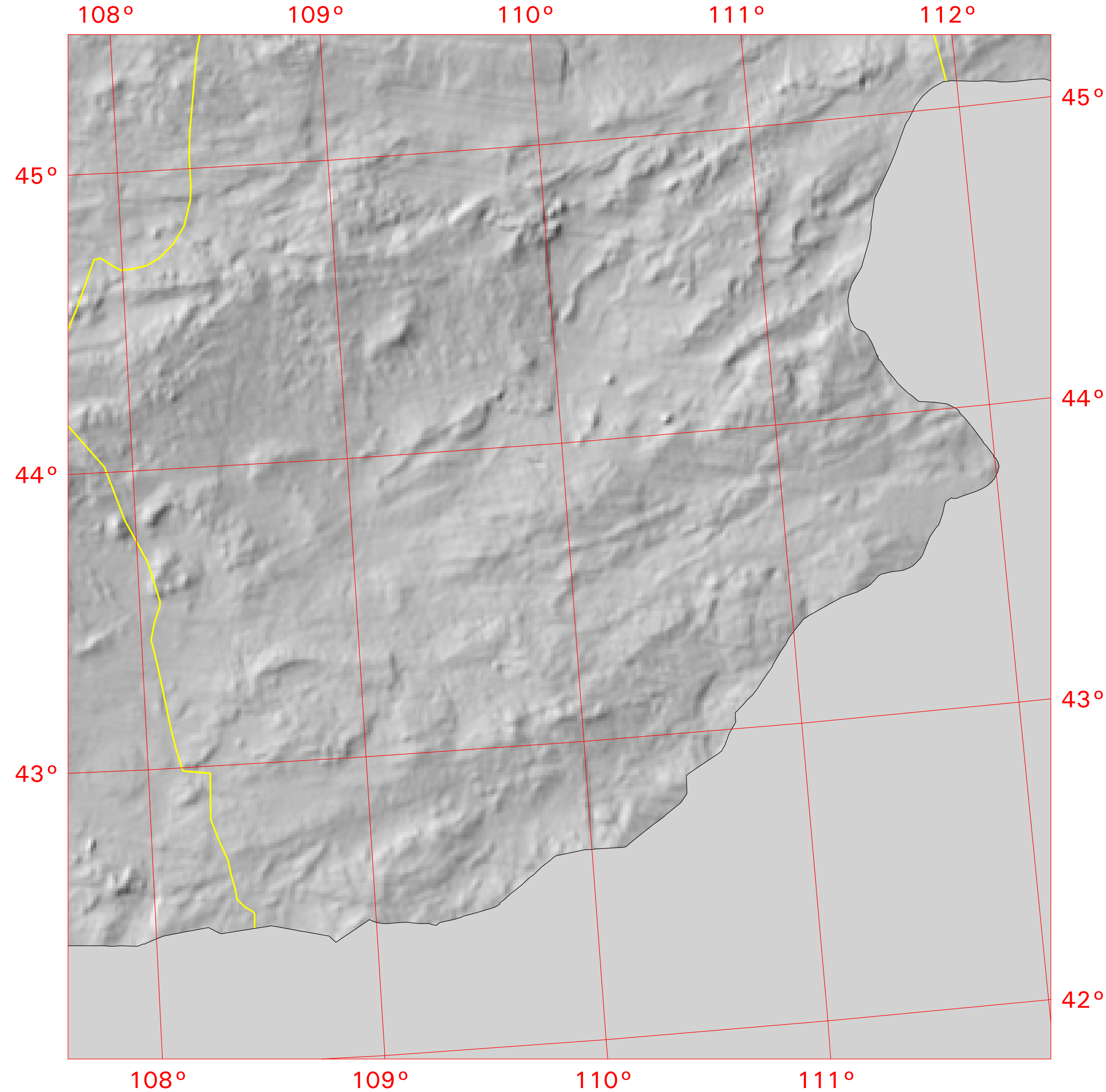
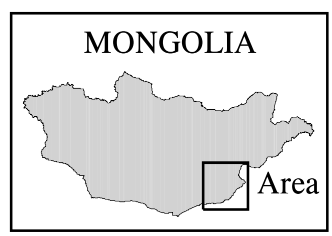

Mongolia - Dornogovi
Elevation Map
108°
109°
110°
111°
112°
45°
44°
43°
42°
Elevation
Meters
4200
3500
3000
2600
2400
2200
2000
1800
1600
1400
1200
1000
900
800
700
600
500
The elevation values are averaged over 1 km².
MONGOLIA
Area
30 0 30 60 90 120 Kilometers
U.S. Department of Energy
National Renewable Energy Laboratory
27-DEC-2000 6.6.24

Figure 6-24

Mongolia - Dornogovi
Hillshaded Relief Map





30 0 30 60 90 120 Kilometers

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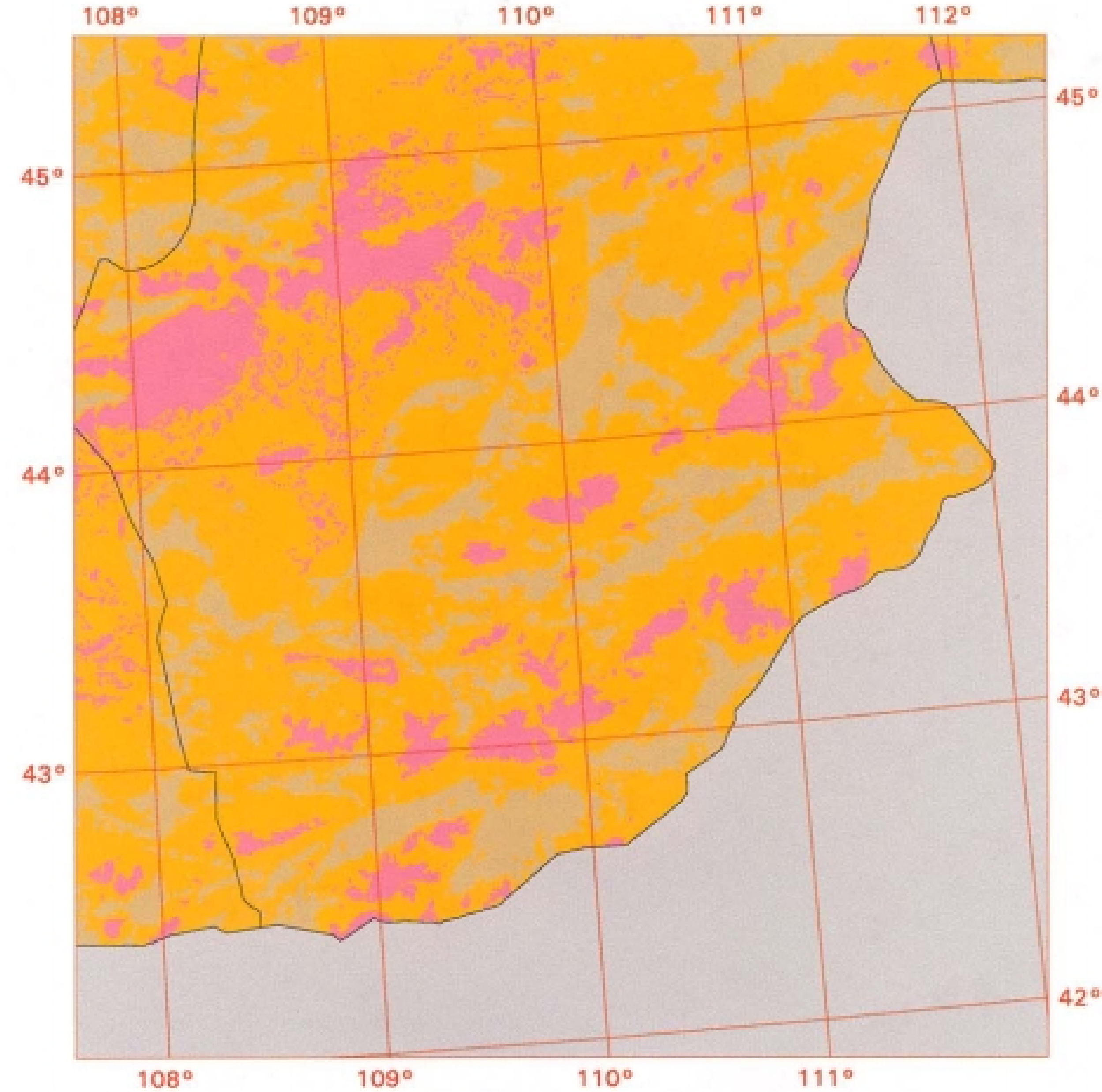
National Renewable Energy Laboratory

NREL

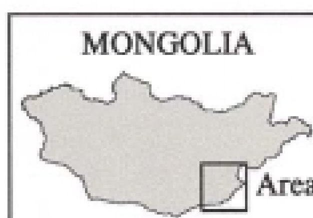
27-DEC-2000 6.6.25

Figure 6-25

Mongolia - Dornogovi
Wind Resource Map



The wind resource classification is specific for both utility-scale and rural applications and applies to areas with low surface roughness, e.g. grassland.



30 0 30 60 90 120 Kilometers

Wind Power Classification

Resource Potential Utility	Resource Potential Rural	Wind Power Density at 30 m W/m²	Wind Speed[a] at 30 m m/s
Marginal	Moderate	100 - 200	4.5 - 5.6
Moderate	Good	200 - 300	5.6 - 6.4
Good	Excellent	300 - 400	6.4 - 7.1
Excellent		400 - 600	7.1 - 8.1
		600 - 800	8.1 - 8.9
		800 - 1000	8.9 - 9.6

[a]Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8

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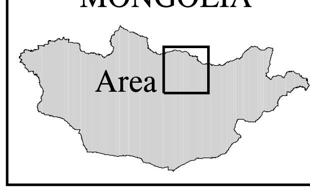
27-DEC-2000 6.6.26

Figure 6-26

Mongolia - Selenge and Northern Tov
Political Map



30 0 30 60 90 120 Kilometers

Legend

- ○ Surface Meteorological Station
- □ Upper-Air (Weather-Balloon) Station
- + NREL Wind Measurement Site
- Δ TACIS Wind Measurement Site
- ■ Town, **Provincial Capital**, or ***Municipality***

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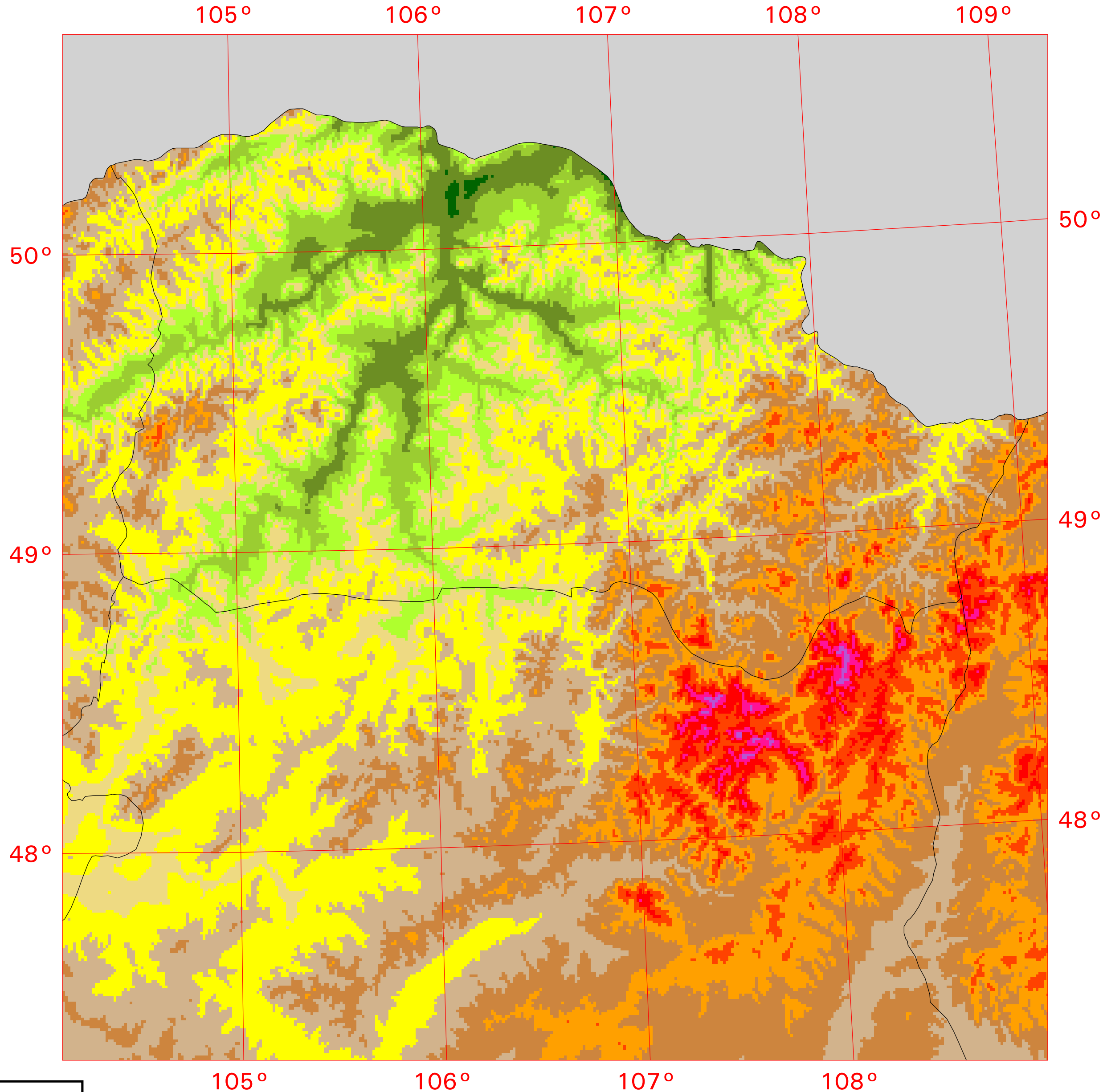
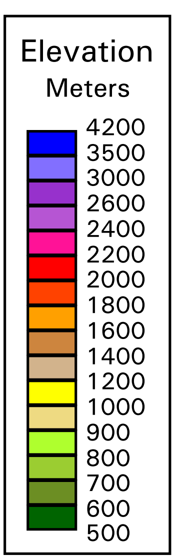
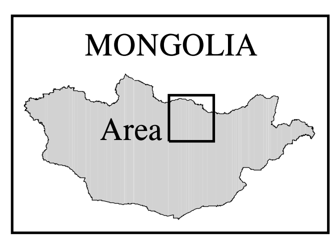
Figure 6-27

Mongolia - Selenge and Northern Tov
Elevation Map





The elevation values are averaged over 1 km^2.



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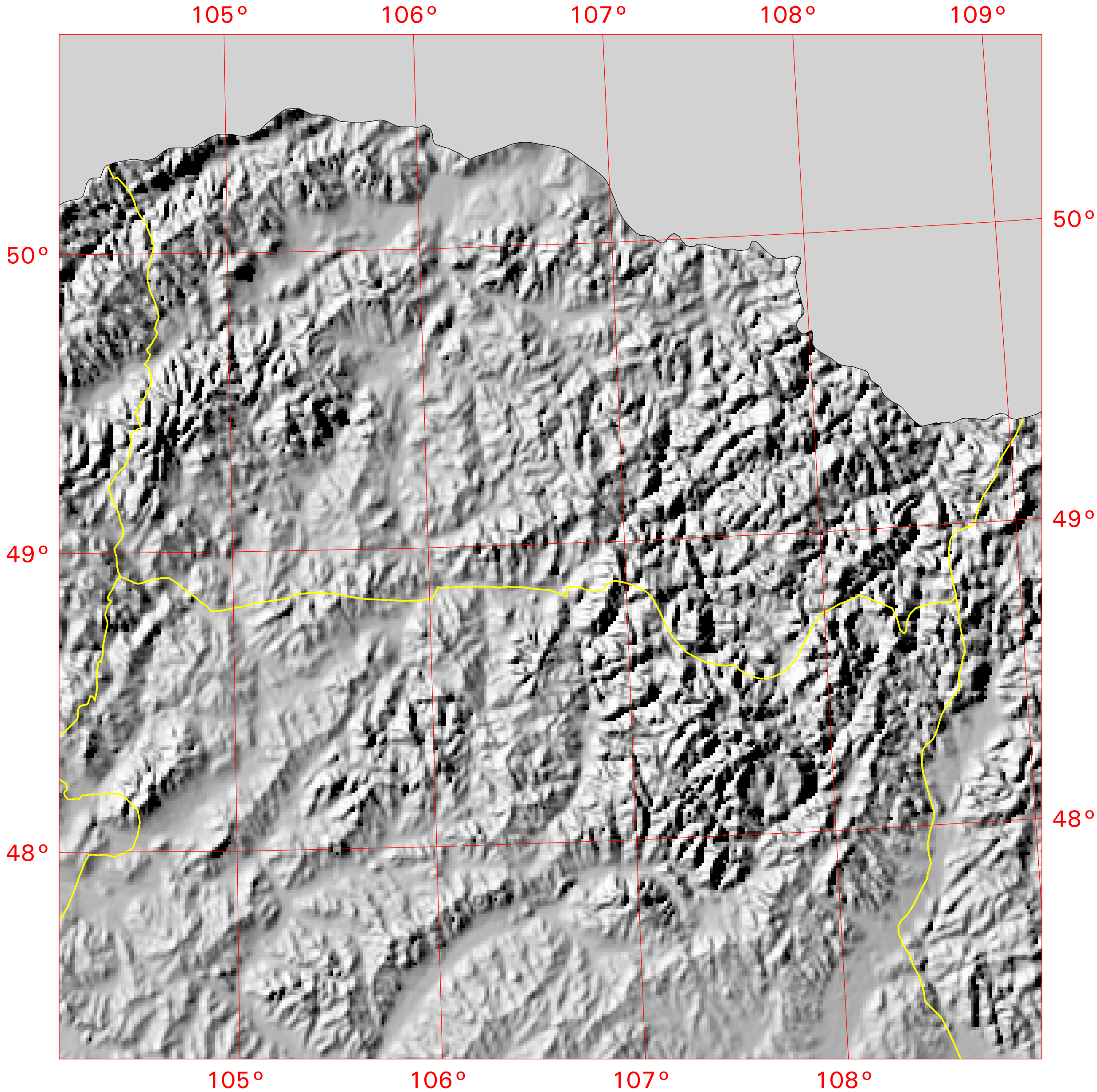
27-DEC-2000 7.6.28

Figure 6-28

Mongolia - Selenge and Northern Tov
Hillshaded Relief Map



30 0 30 60 90 120 Kilometers

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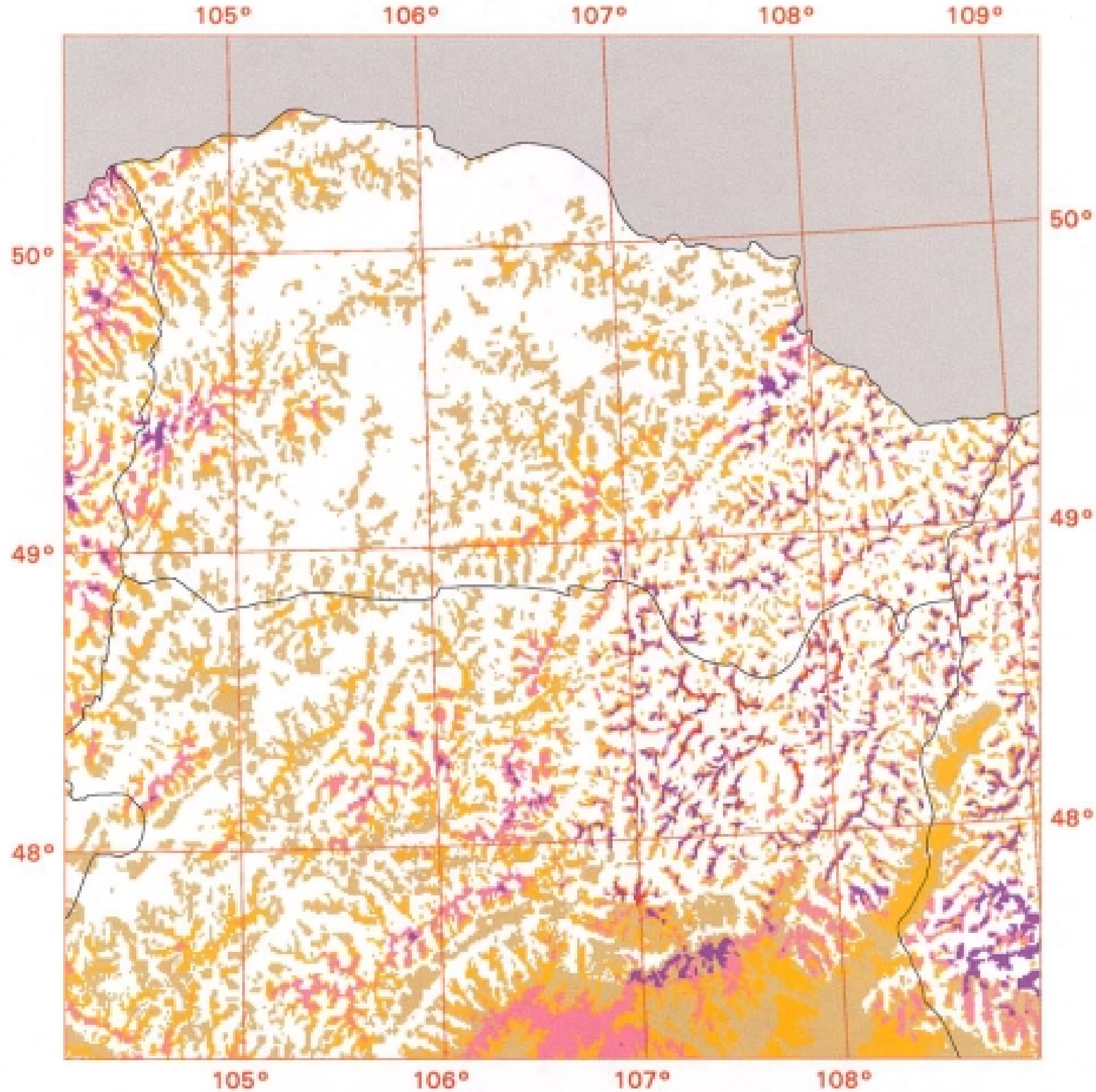
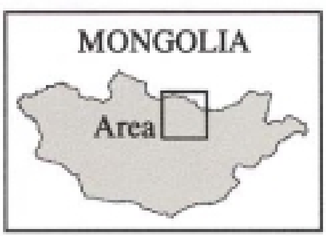
Figure 6-29

Mongolia - Selenge and Northern Tov
Wind Resource Map



The wind resource classification is specific for both utility-scale and rural applications and applies to areas with low surface roughness, e.g. grassland.



Wind Power Classification

	Resource Potential Utility	Resource Potential Rural	Wind Power Density at 30 m W/m²	Wind Speed[a] at 30 m m/s
(tan)	Marginal	Moderate	100 - 200	4.5 - 5.6
(orange)	Moderate	Good	200 - 300	5.6 - 6.4
(pink)	Good	Excellent	300 - 400	6.4 - 7.1
(purple)	Excellent		400 - 600	7.1 - 8.1
(red)			600 - 800	8.1 - 8.9
(blue)			800 - 1000	8.9 - 9.6

[a] Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8

30 0 30 60 90 120 Kilometers

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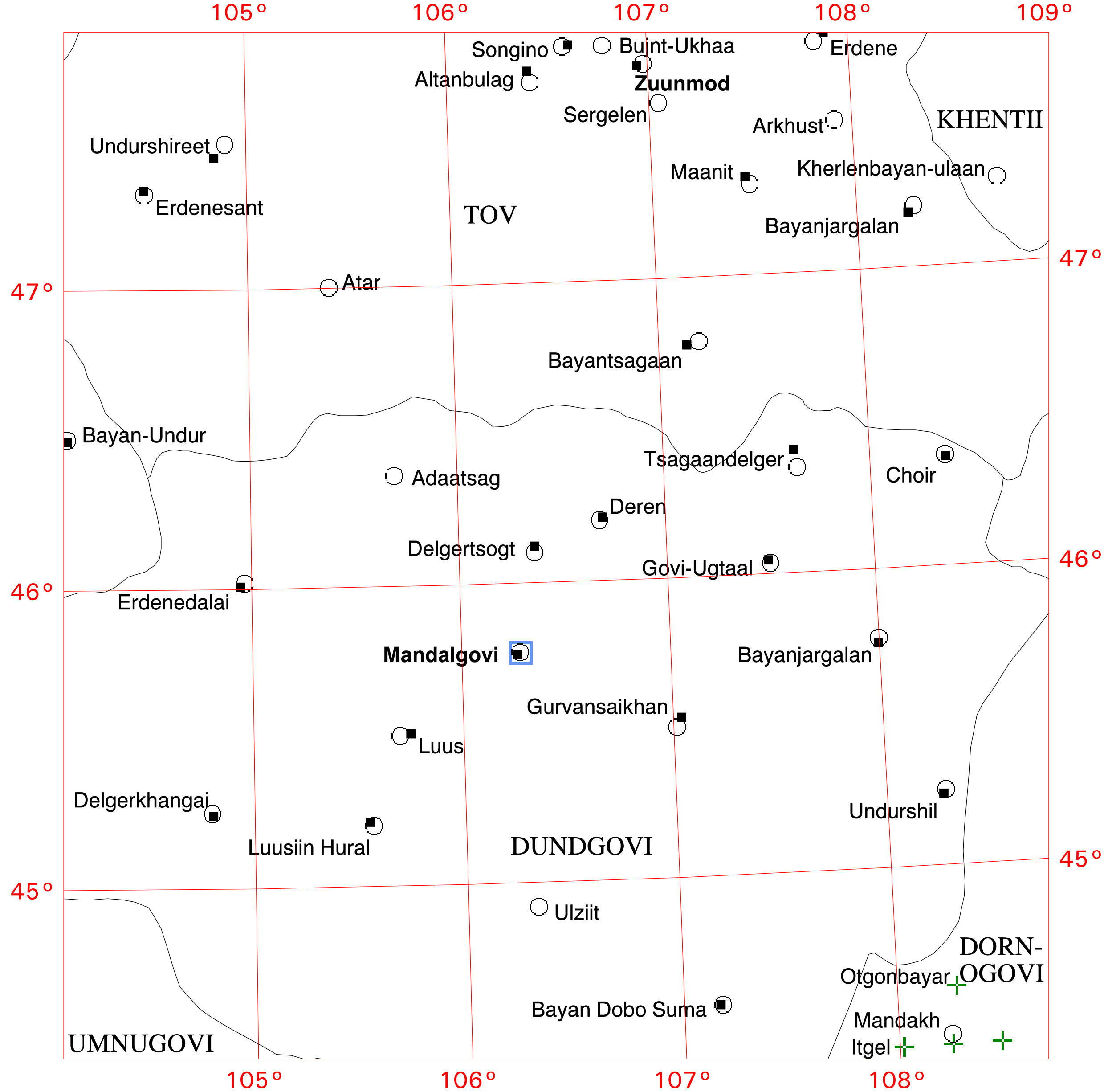
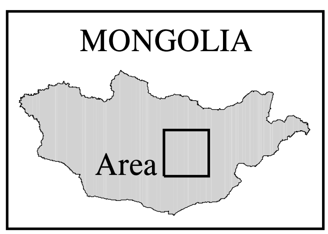
27-DEC-2000 7.6.30

Figure 6-30

Mongolia - Dundgovi and Southern Tov
Political Map





30 0 30 60 90 120 Kilometers

The data for NREL and TACIS (Technical Assistance to the Commonwealth of Independent States) wind measurement sites were collected in collaboration with REC (Renewable Energy Corporation).

Legend

- ○ Surface Meteorological Station
- □ Upper-Air (Weather-Balloon) Station
- + NREL Wind Measurement Site
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- ■ Town, **Provincial Capital**, or ***Municipality***

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Figure 6-31

Mongolia - Dundgovi and Southern Tov
Elevation Map

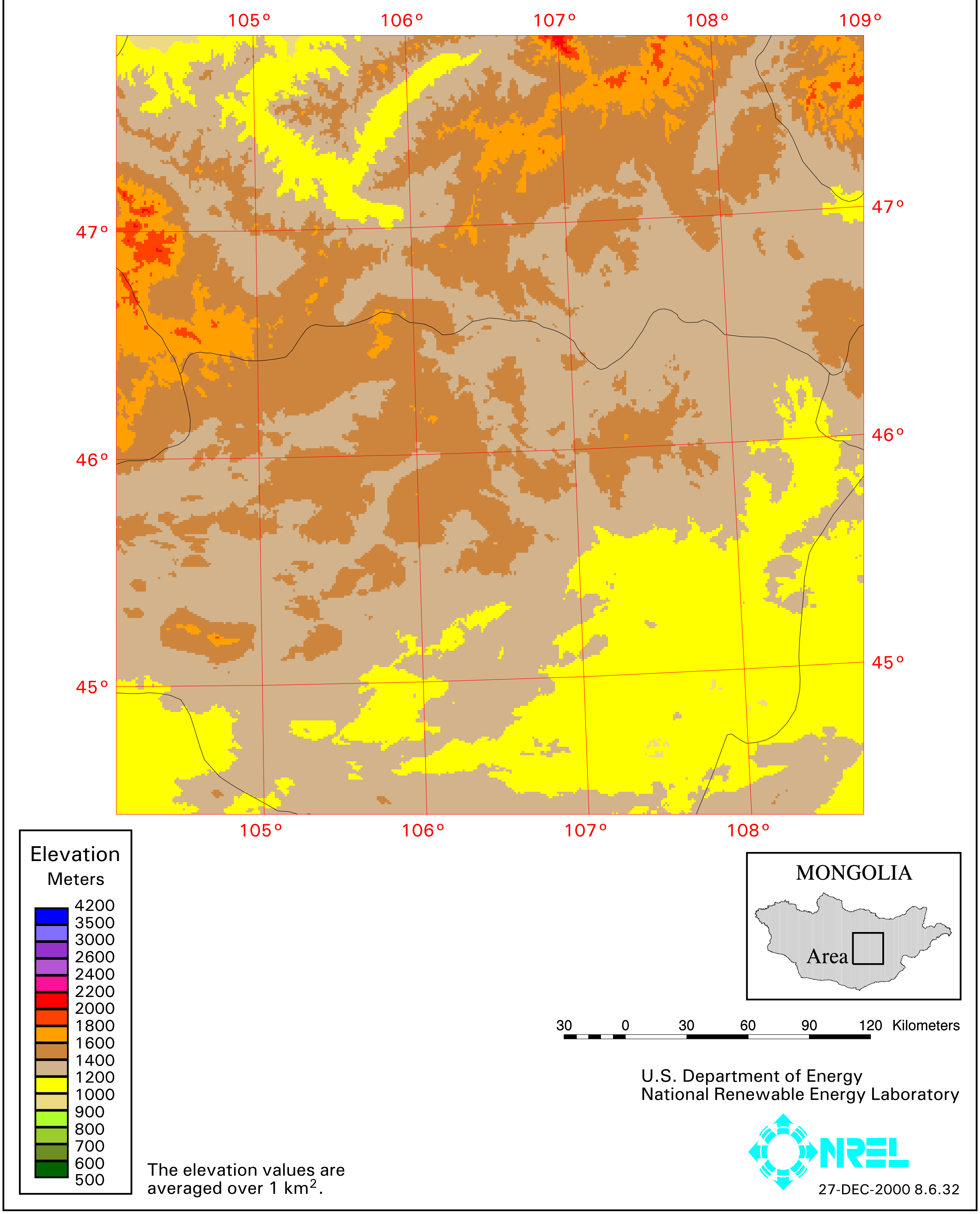
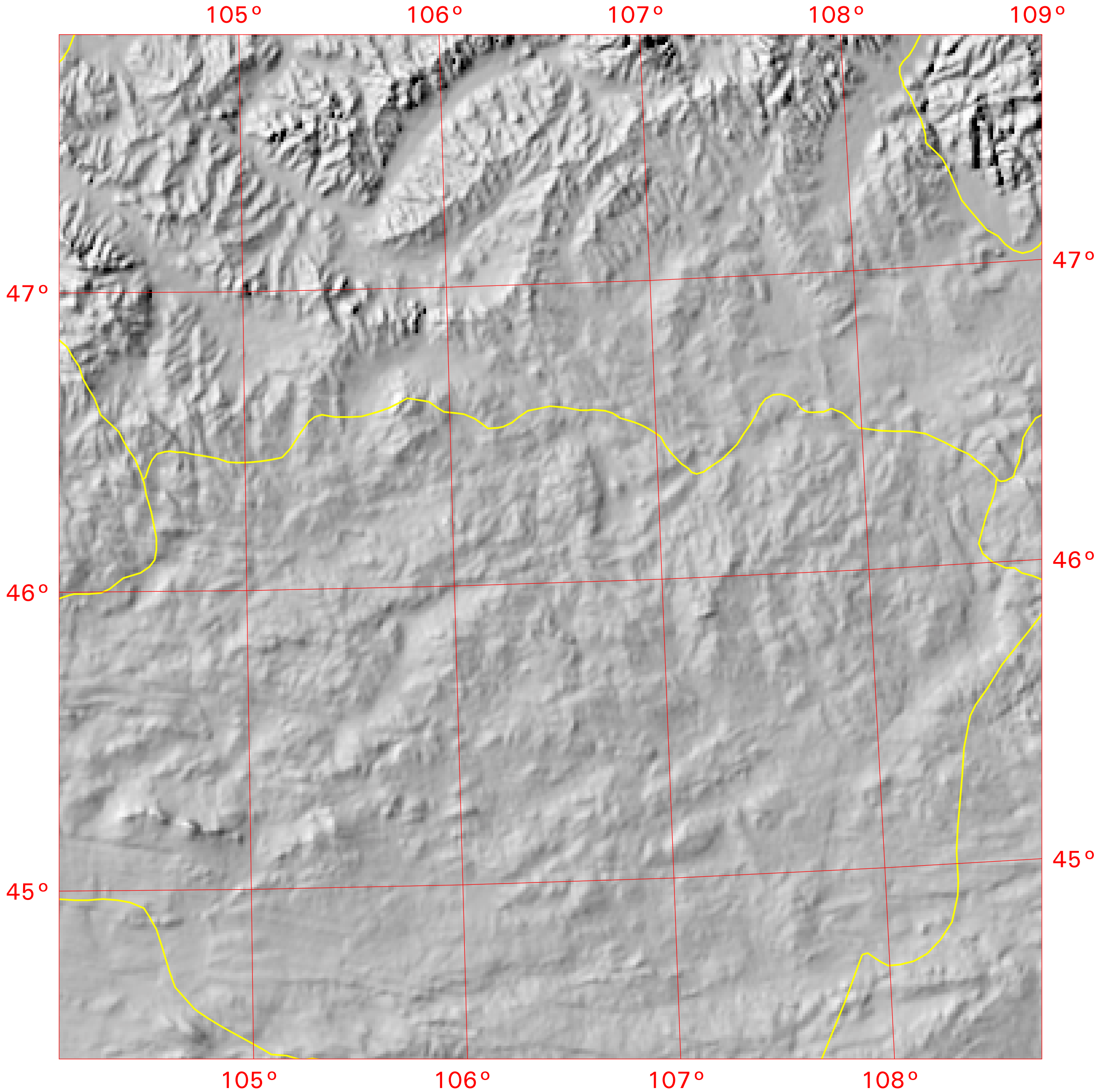
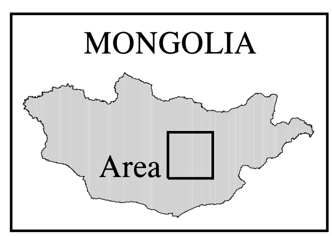


Figure 6-32

Mongolia - Dundgovi and Southern Tov
Hillshaded Relief Map





30 0 30 60 90 120 Kilometers

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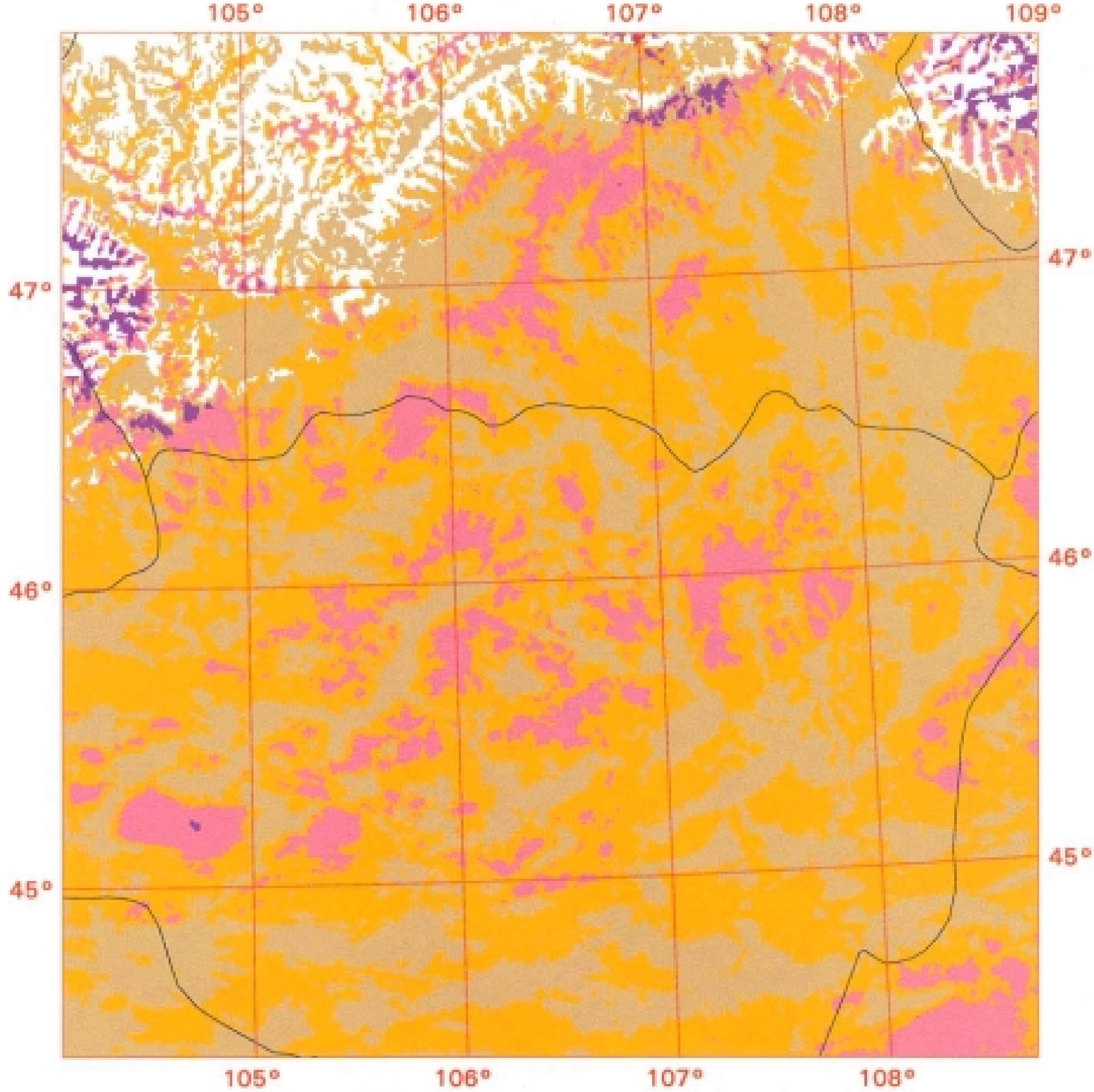
Figure 6-33

Mongolia - Dundgovi and Southern Tov
Wind Resource Map



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Wind Power Classification

Resource Potential Utility	Resource Potential Rural	Wind Power Density at 30 m W/m²	Wind Speed[a] at 30 m m/s
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Excellent		400 - 600	7.1 - 8.1
		600 - 800	8.1 - 8.9
		800 - 1000	8.9 - 9.6

[a]Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8

30 0 30 60 90 120 Kilometers

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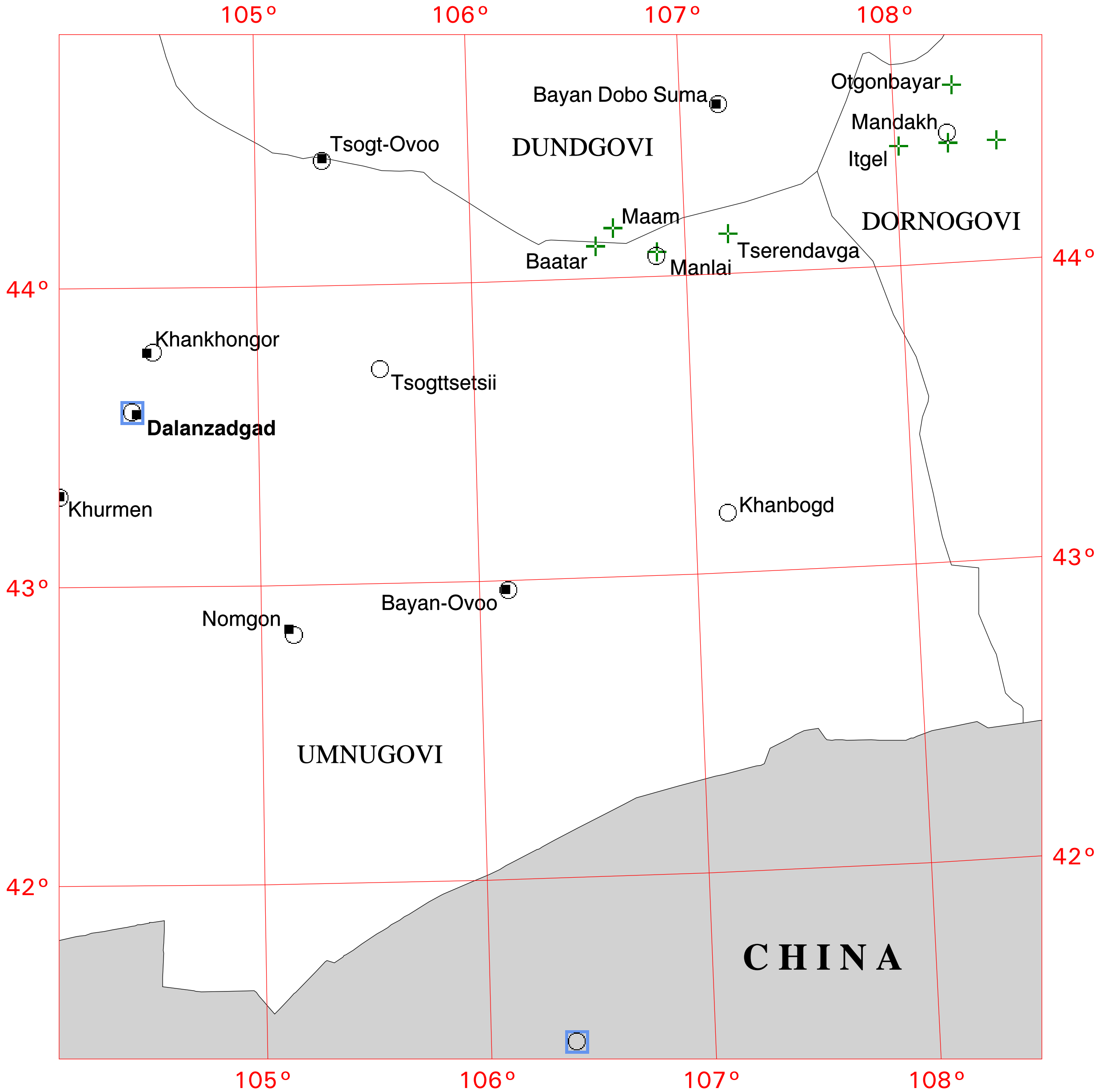
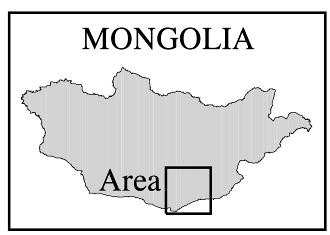
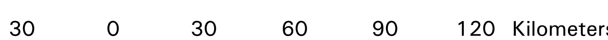
Figure 6-34

Mongolia - Eastern Umnugovi
Political Map







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Legend

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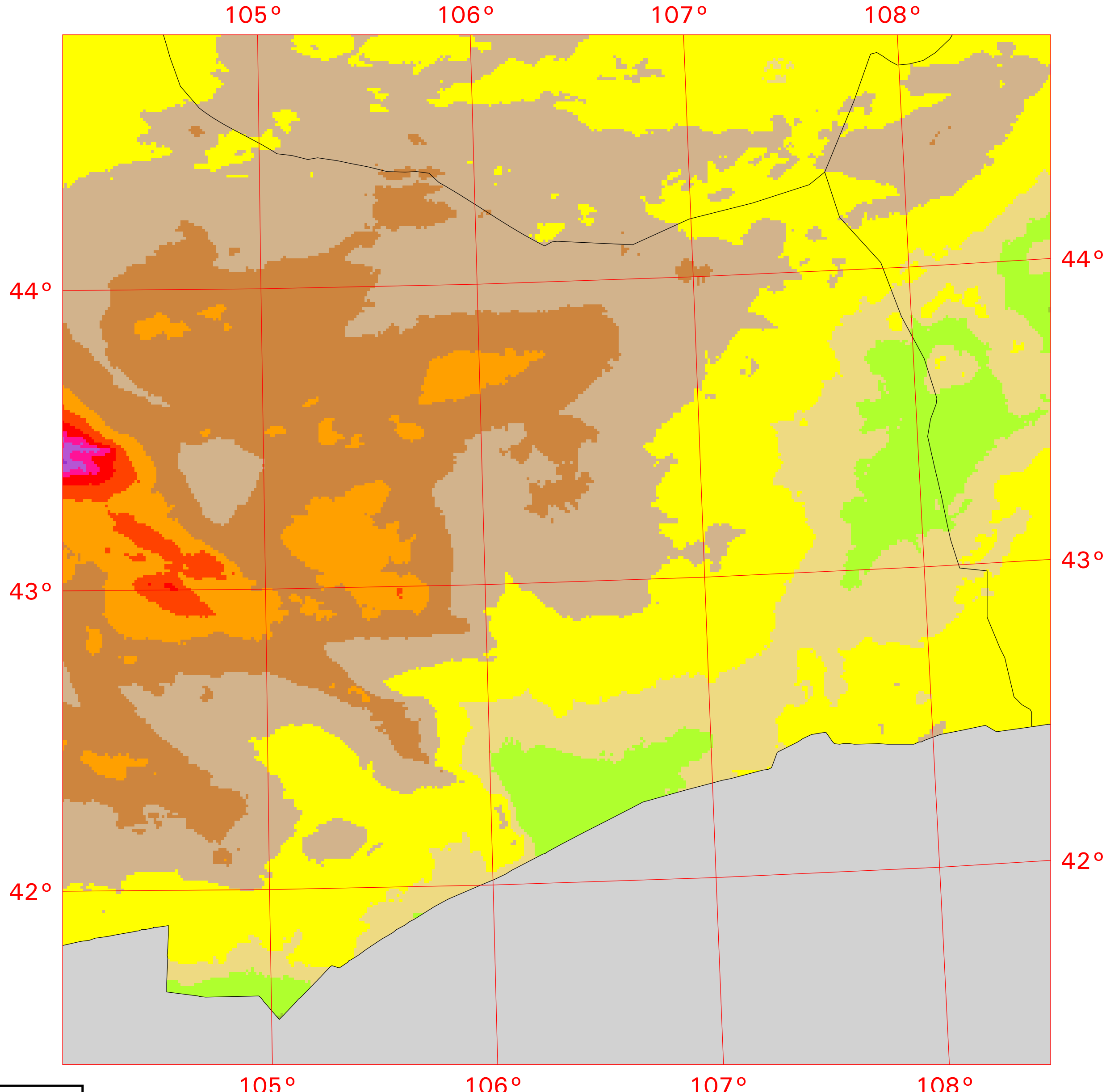
Figure 6-35

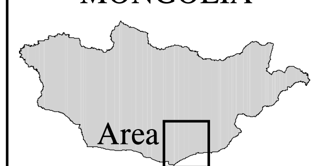
Mongolia - Eastern Umnugovi
Elevation Map



Elevation
Meters

4200
3500
3000
2600
2400
2200
2000
1800
1600
1400
1200
1000
900
800
700
600
500

The elevation values are averaged over 1 km^2.



30 0 30 60 90 120 Kilometers

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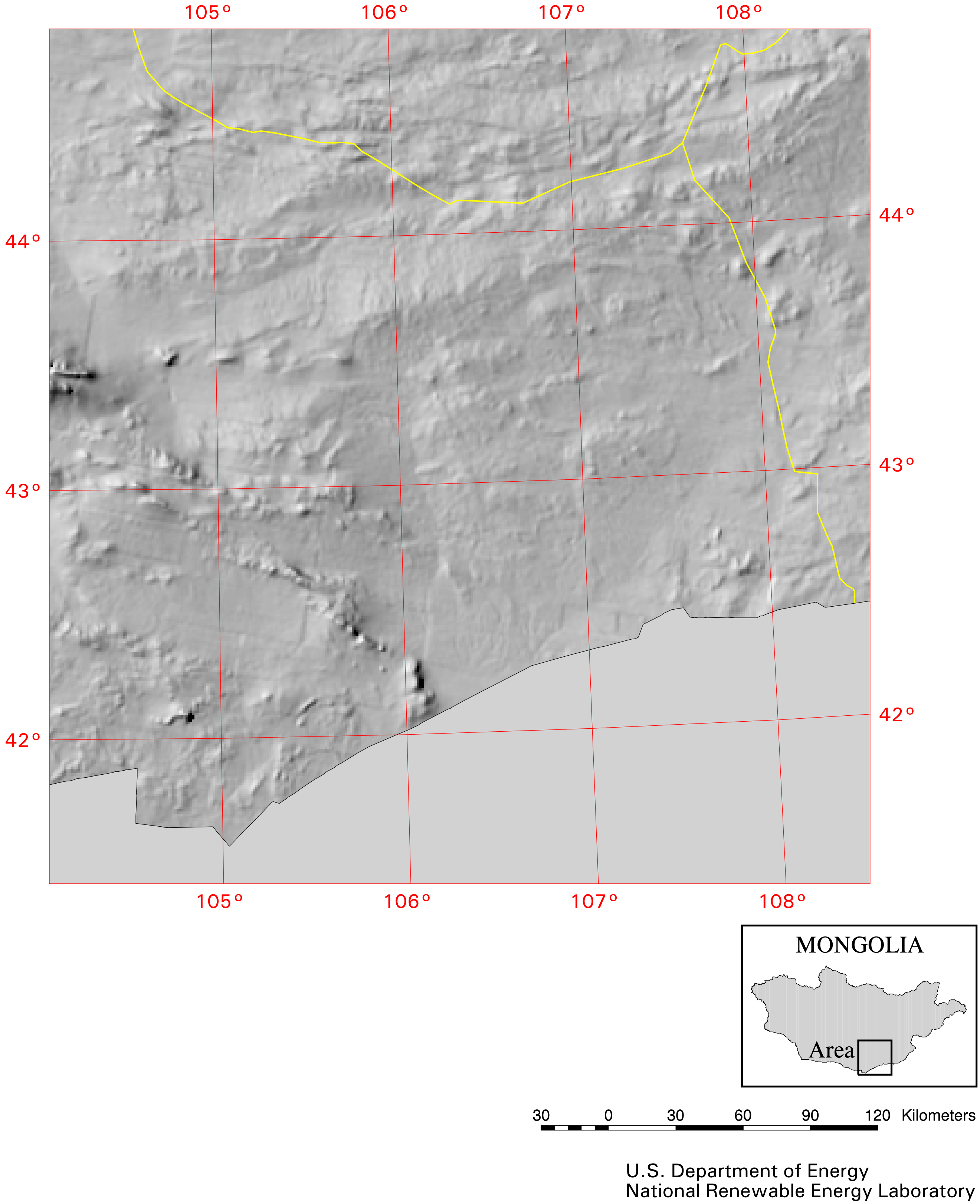
Figure 6-36

Mongolia - Eastern Umnugovi
Hillshaded Relief Map



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National Renewable Energy Laboratory

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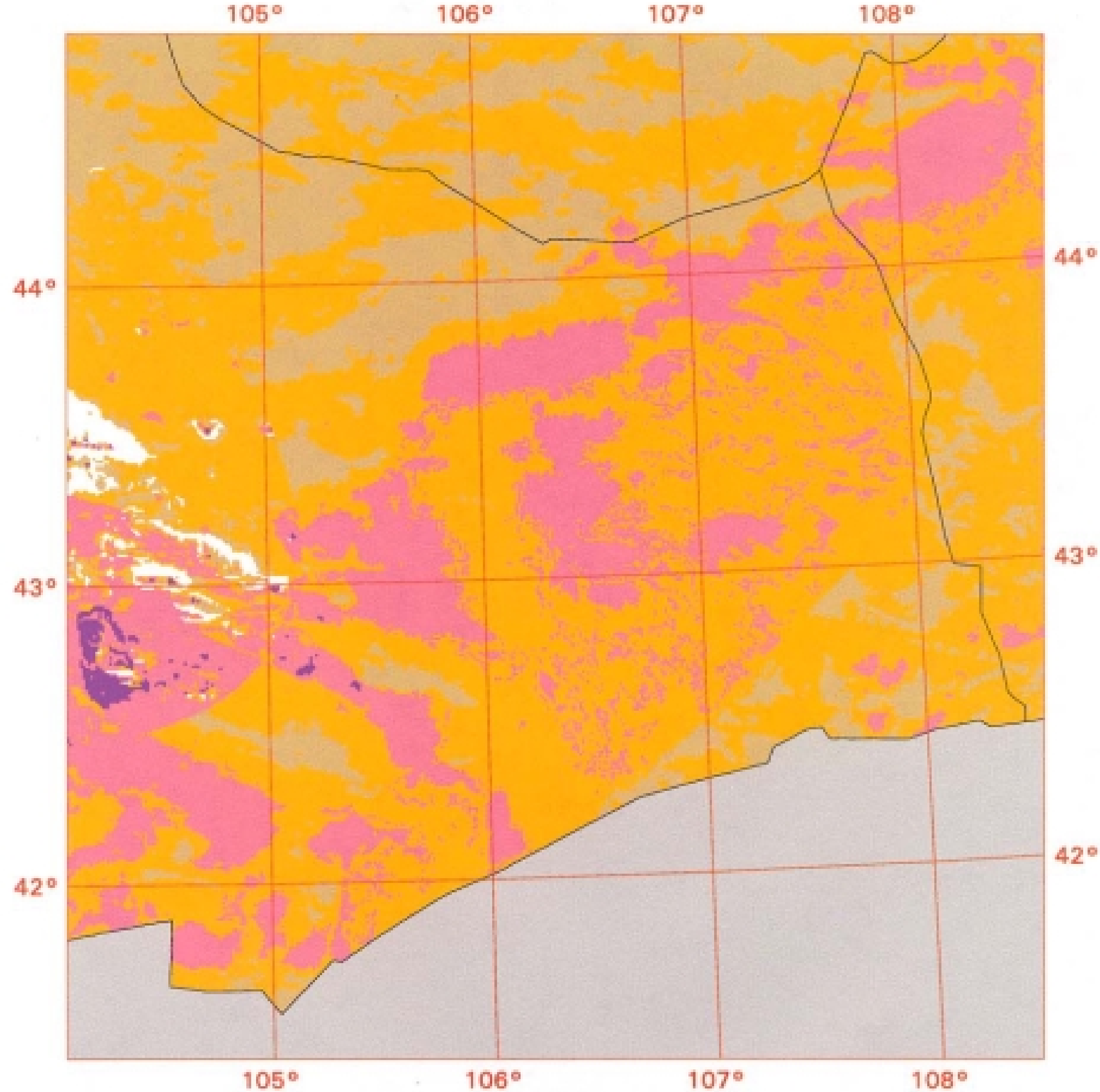
Figure 6-37

Mongolia - Eastern Umnugovi
Wind Resource Map



The wind resource classification is specific for both utility-scale and rural applications and applies to areas with low surface roughness, e.g. grassland.

Wind Power Classification

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		600 - 800	8.1 - 8.9
		800 - 1000	8.9 - 9.6

[a]Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8

30 0 30 60 90 120 Kilometers

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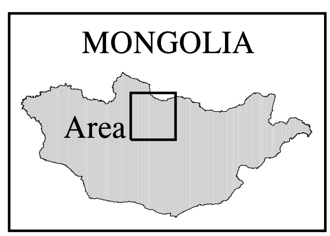
Figure 6-38

Mongolia - Bulgan and Eastern Arkhangai Political Map



30 0 30 60 90 120 Kilometers

Legend

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- □ Upper-Air (Weather-Balloon) Station
- + NREL Wind Measurement Site
- Δ TACIS Wind Measurement Site
- ■ Town, **Provincial Capital**, or ***Municipality***

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Figure 6-39

Mongolia - Bulgan and Eastern Arkhangai Elevation Map

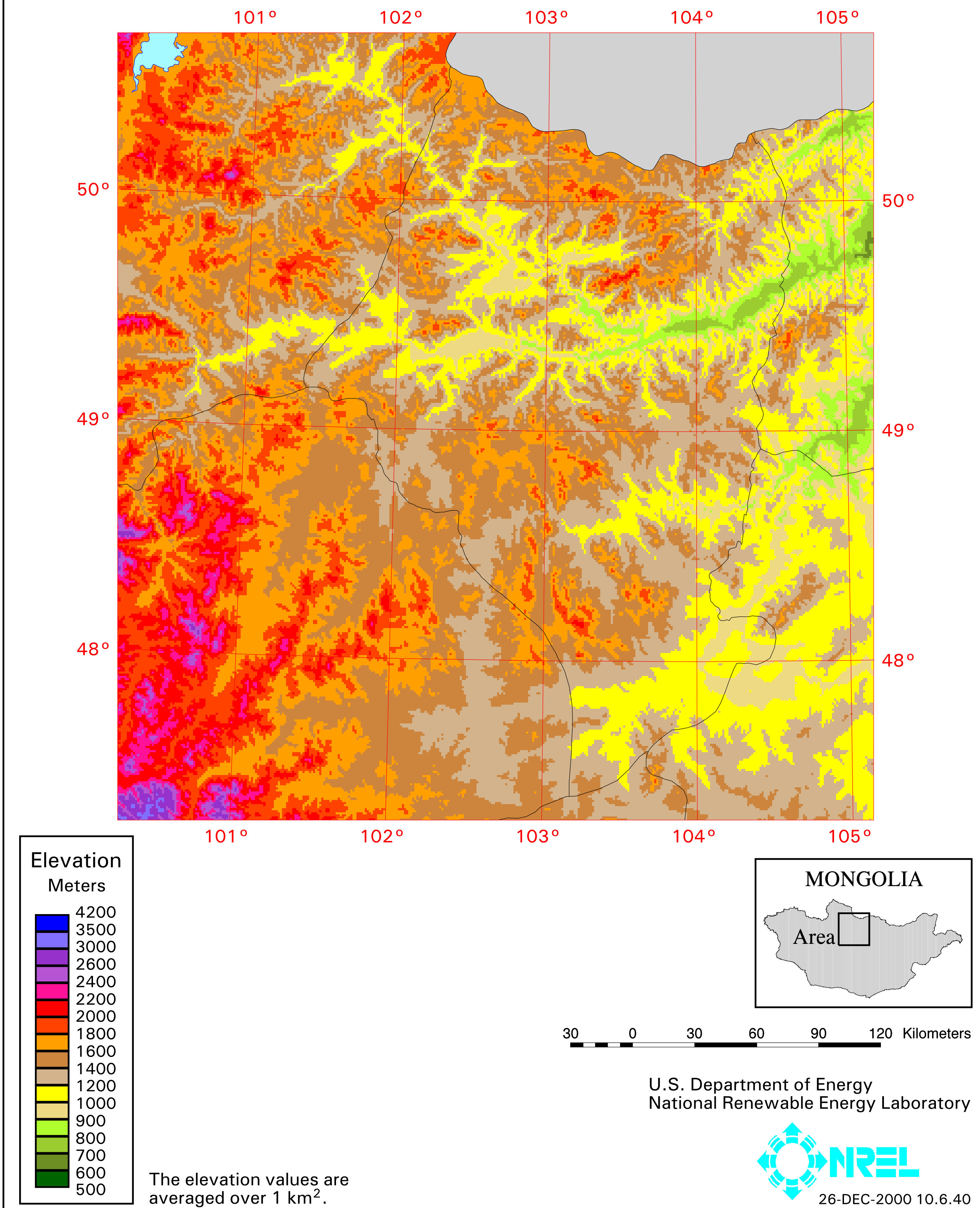
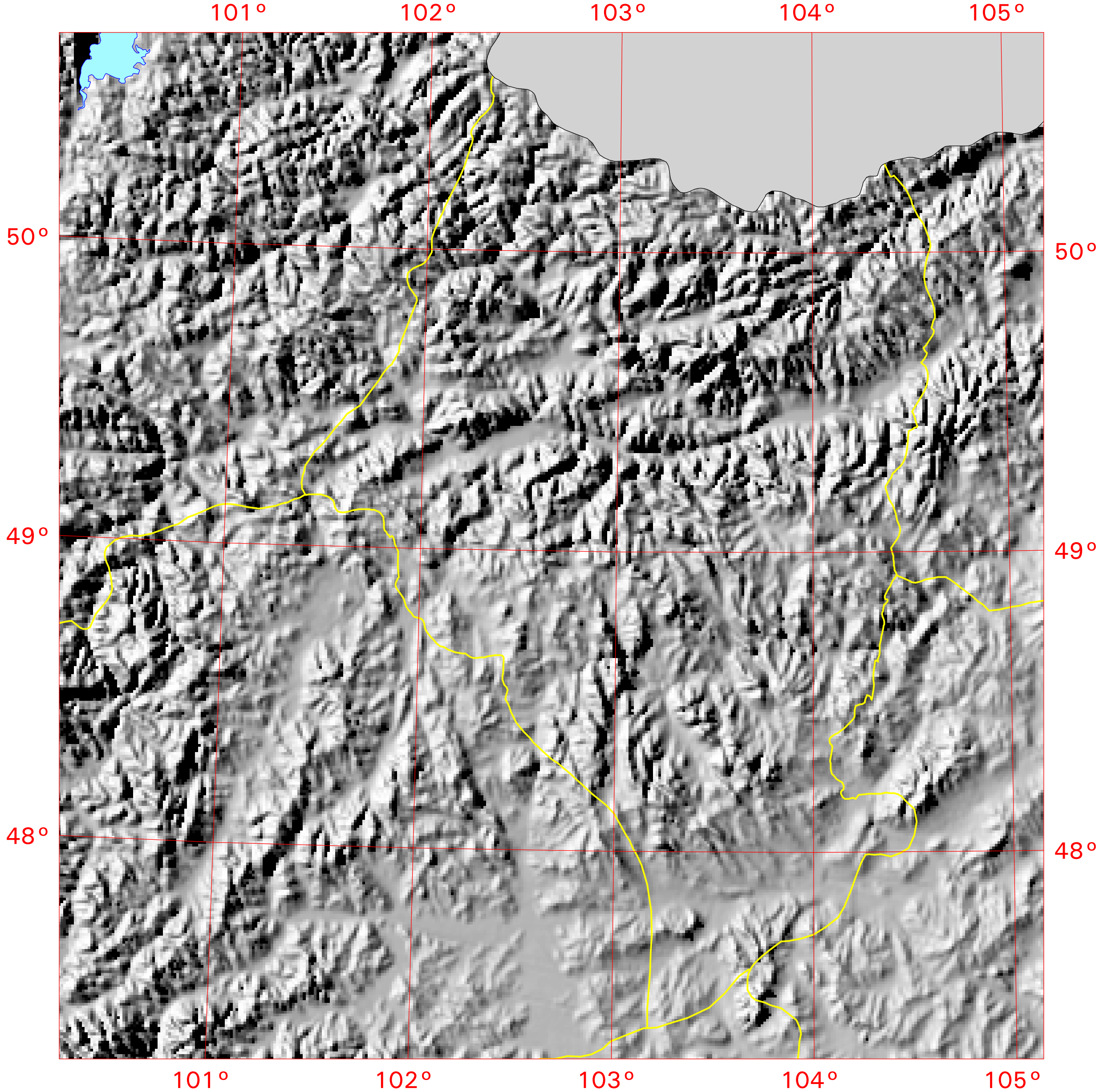
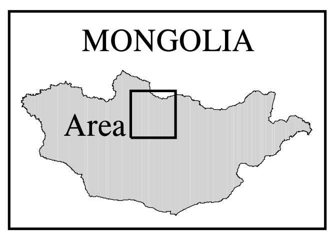


Figure 6-40

Mongolia - Bulgan and Eastern Arkhangai
Hillshaded Relief Map





30 0 30 60 90 120 Kilometers

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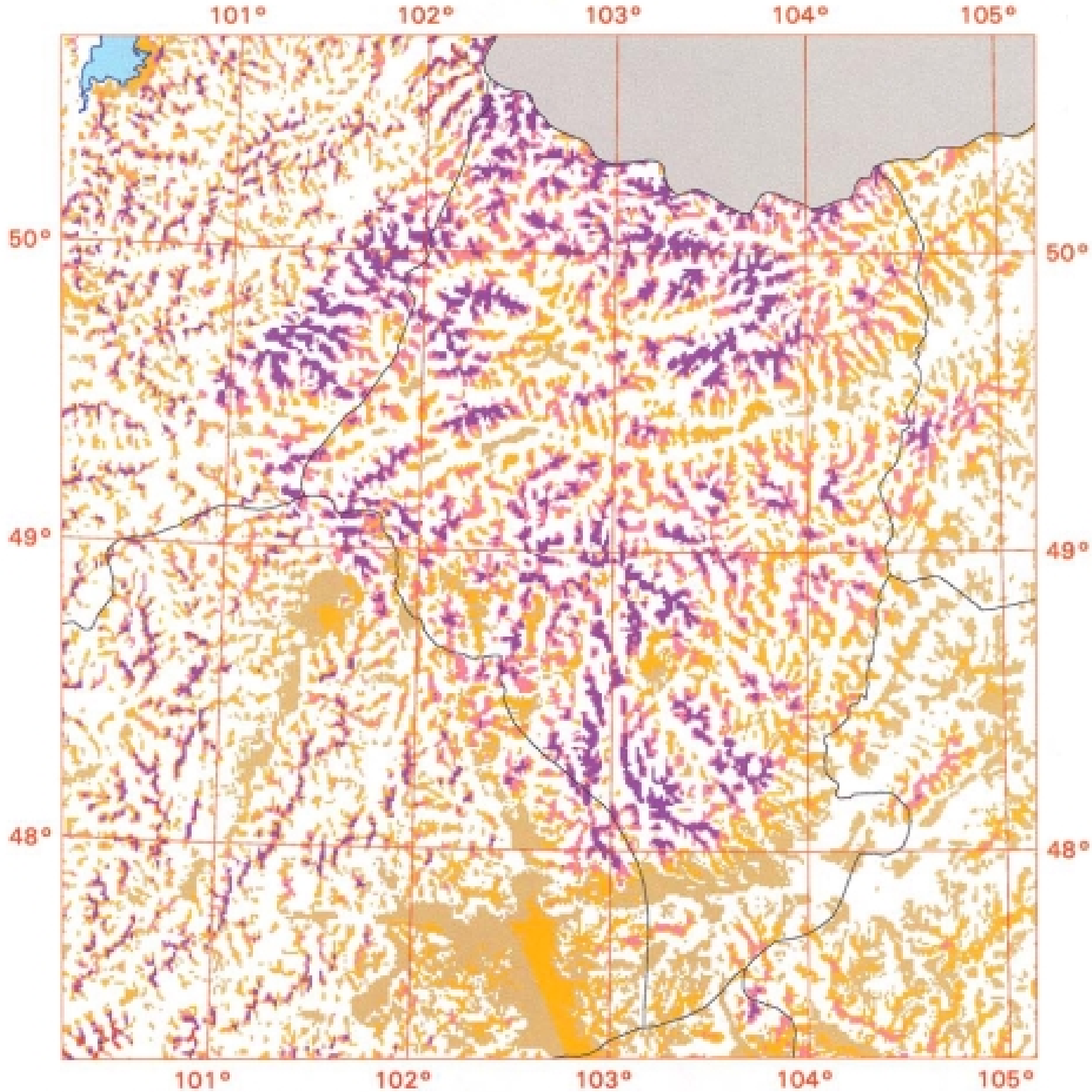
Figure 6-41

Mongolia - Bulgan and Eastern Arkhangai Wind Resource Map



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30 0 30 60 90 120 Kilometers

Wind Power Classification

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Excellent		400 - 600	7.1 - 8.1
		600 - 800	8.1 - 8.9
		800 - 1000	8.9 - 9.6

[a]Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8

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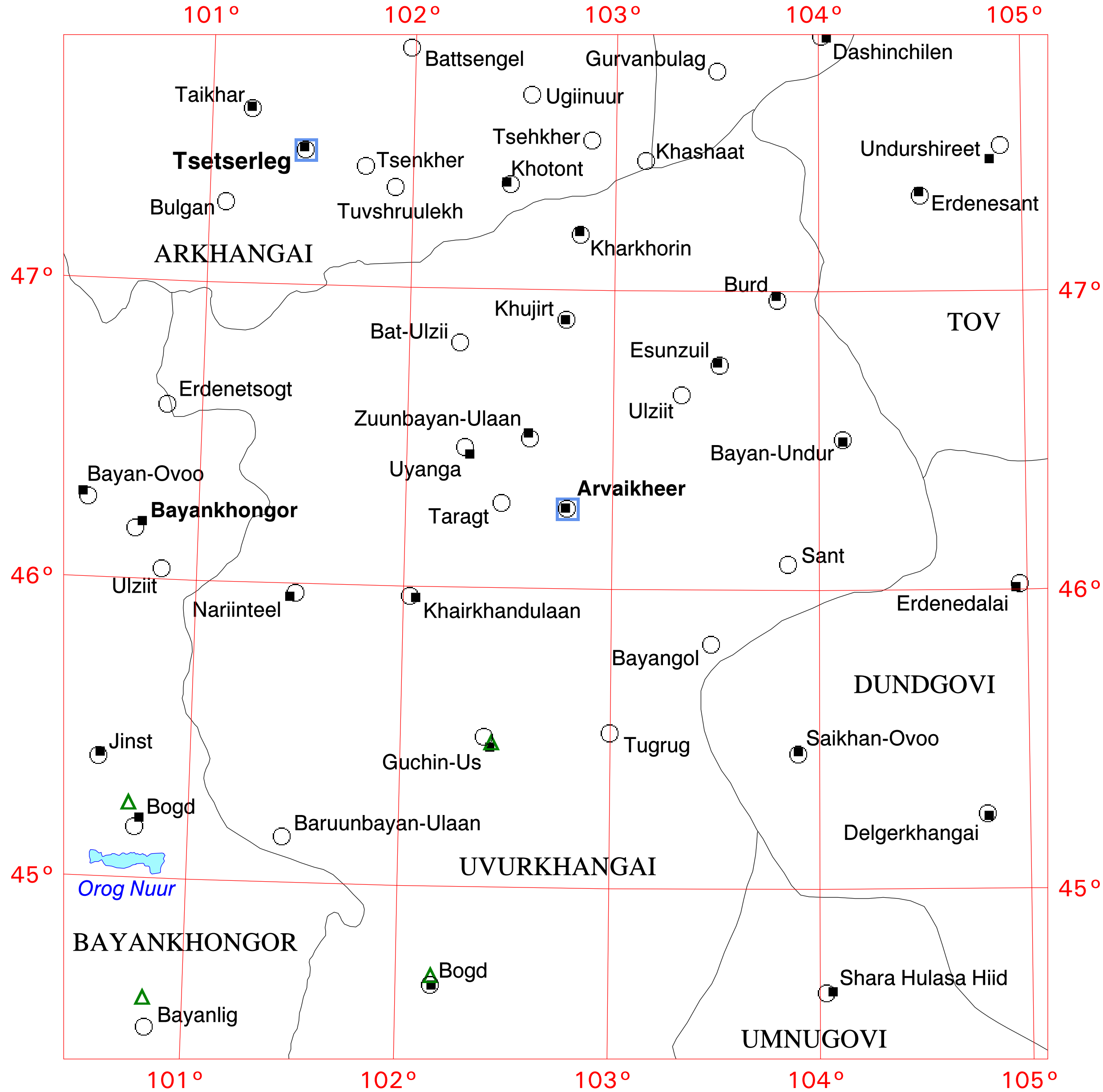
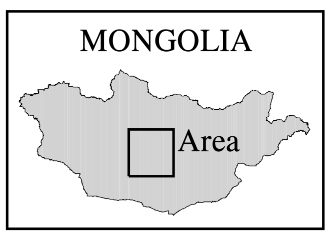
Figure 6-42

Mongolia - Uvurkhangai
Political Map





30 0 30 60 90 120 Kilometers

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Legend

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Figure 6-43

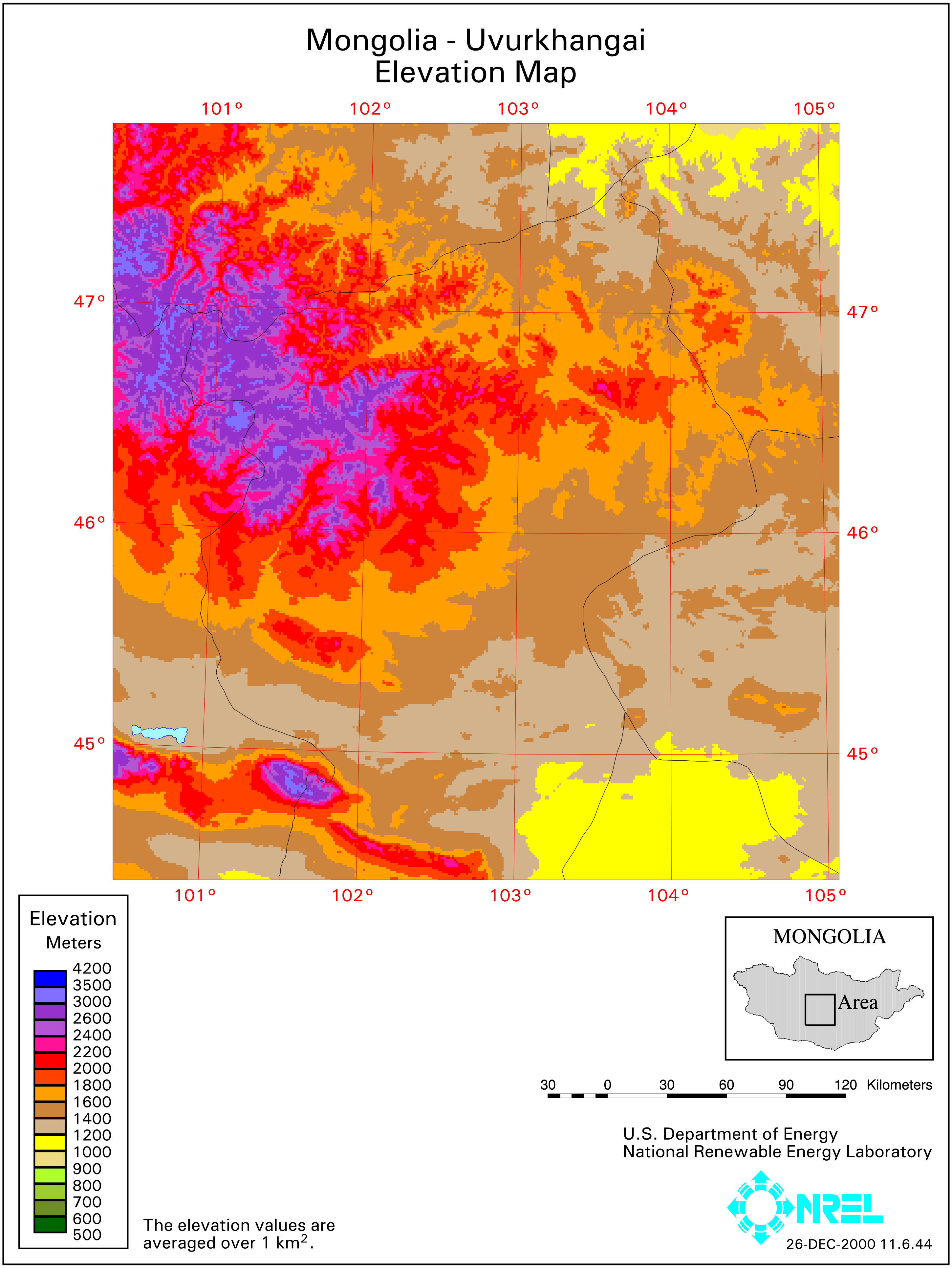
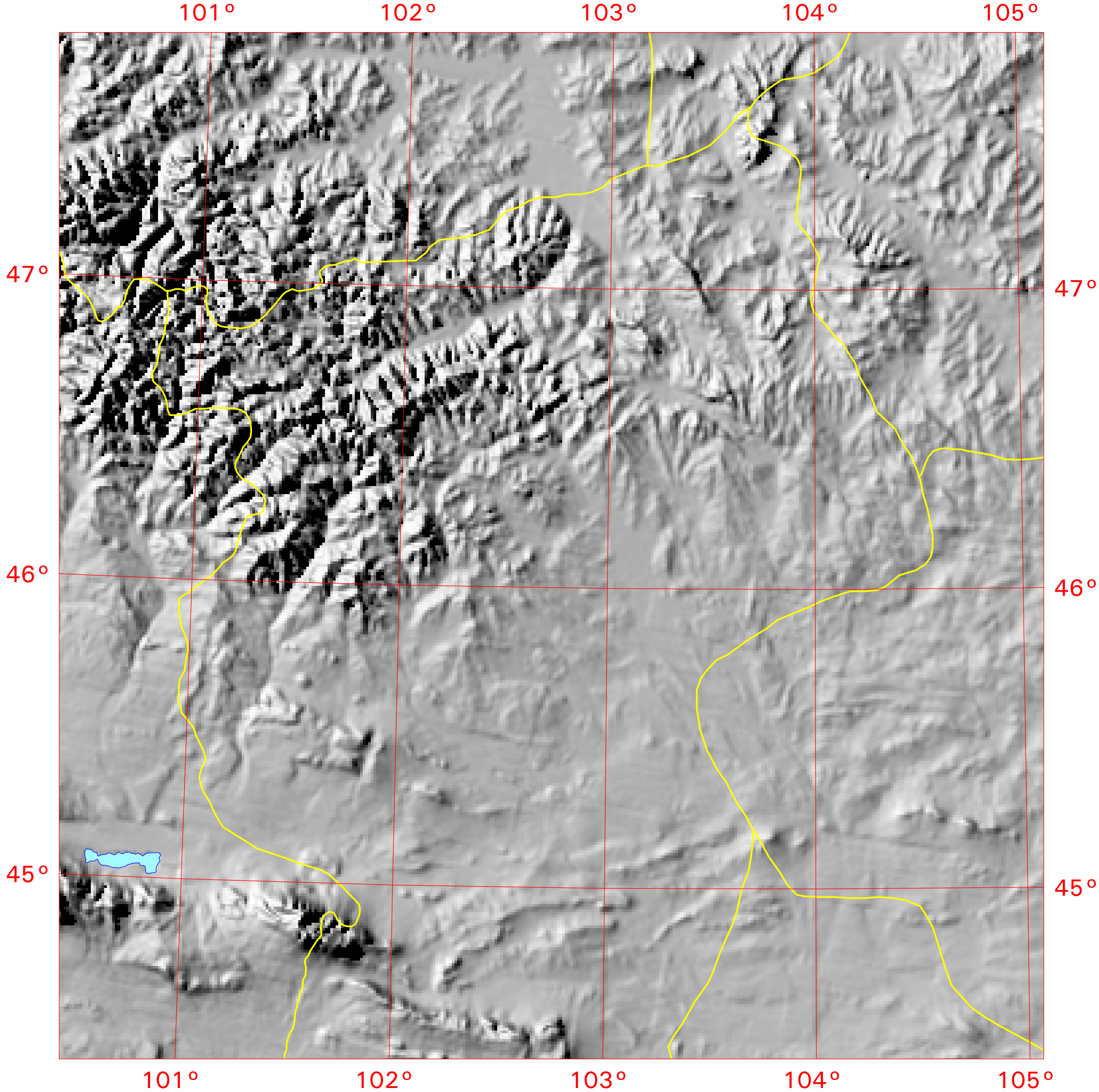
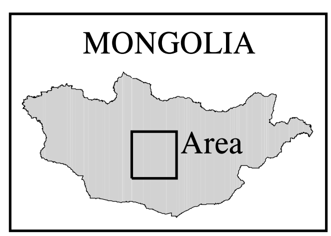

Mongolia - Uvurkhangai
Elevation Map
101°
102°
103°
104°
105°
47°
46°
45°
Elevation
Meters
4200
3500
3000
2600
2400
2200
2000
1800
1600
1400
1200
1000
900
800
700
600
500
The elevation values are averaged over 1 km².
MONGOLIA
Area
30 0 30 60 90 120 Kilometers
U.S. Department of Energy
National Renewable Energy Laboratory
NREL
26-DEC-2000 11.6.44

Figure 6-44

Mongolia - Uvurkhangai
Hillshaded Relief Map





30 0 30 60 90 120 Kilometers

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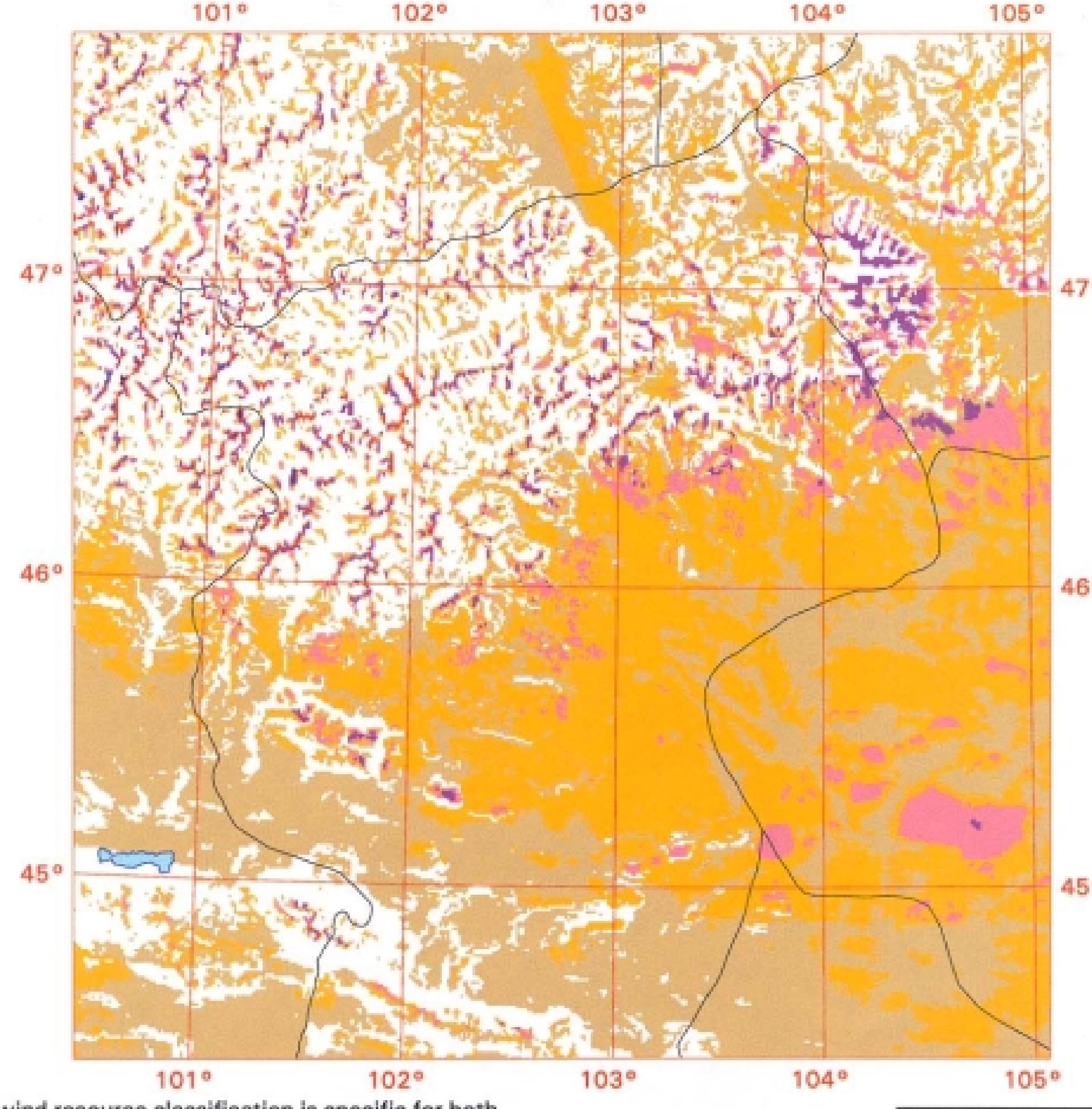
26-DEC-2000 11.6.45

Figure 6-45

Mongolia - Uvurkhangai
Wind Resource Map



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Wind Power Classification

	Resource Potential Utility	Resource Potential Rural	Wind Power Density at 30 m W/m²	Wind Speed[a] at 30 m m/s
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orange	Moderate	Good	200 - 300	5.6 - 6.4
pink	Good	Excellent	300 - 400	6.4 - 7.1
purple	Excellent		400 - 600	7.1 - 8.1
red			600 - 800	8.1 - 8.9
blue			800 - 1000	8.9 - 9.6

[a] Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8

30 0 30 60 90 120 Kilometers

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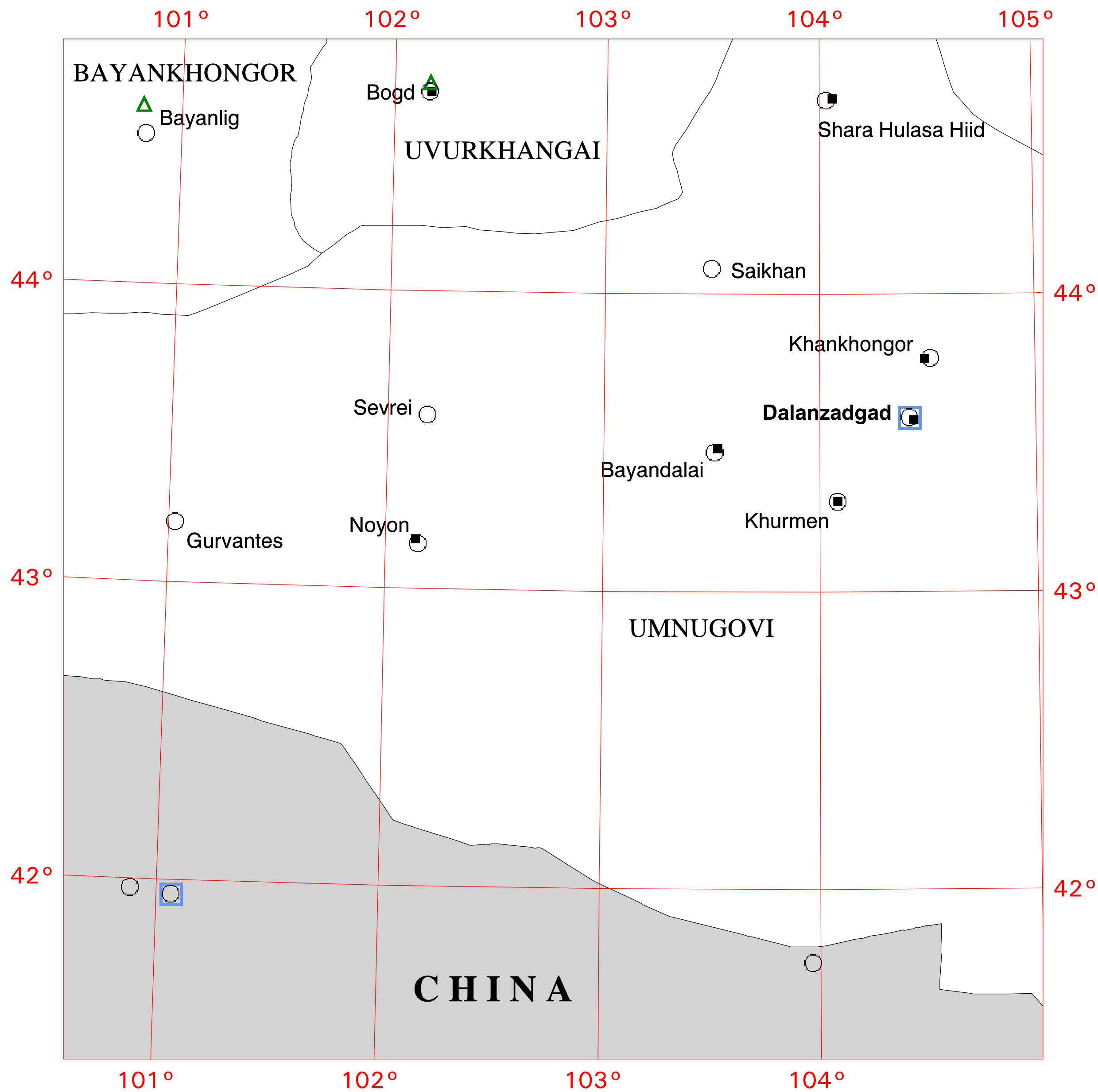
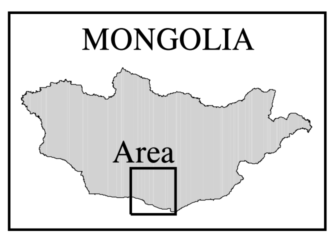
Figure 6-46

Mongolia - Western and Central Umnugovi
Political Map



The data for NREL and TACIS (Technical Assistance to the Commonwealth of Independent States) wind measurement sites were collected in collaboration with REC (Renewable Energy Corporation).



30 0 30 60 90 120 Kilometers

Legend

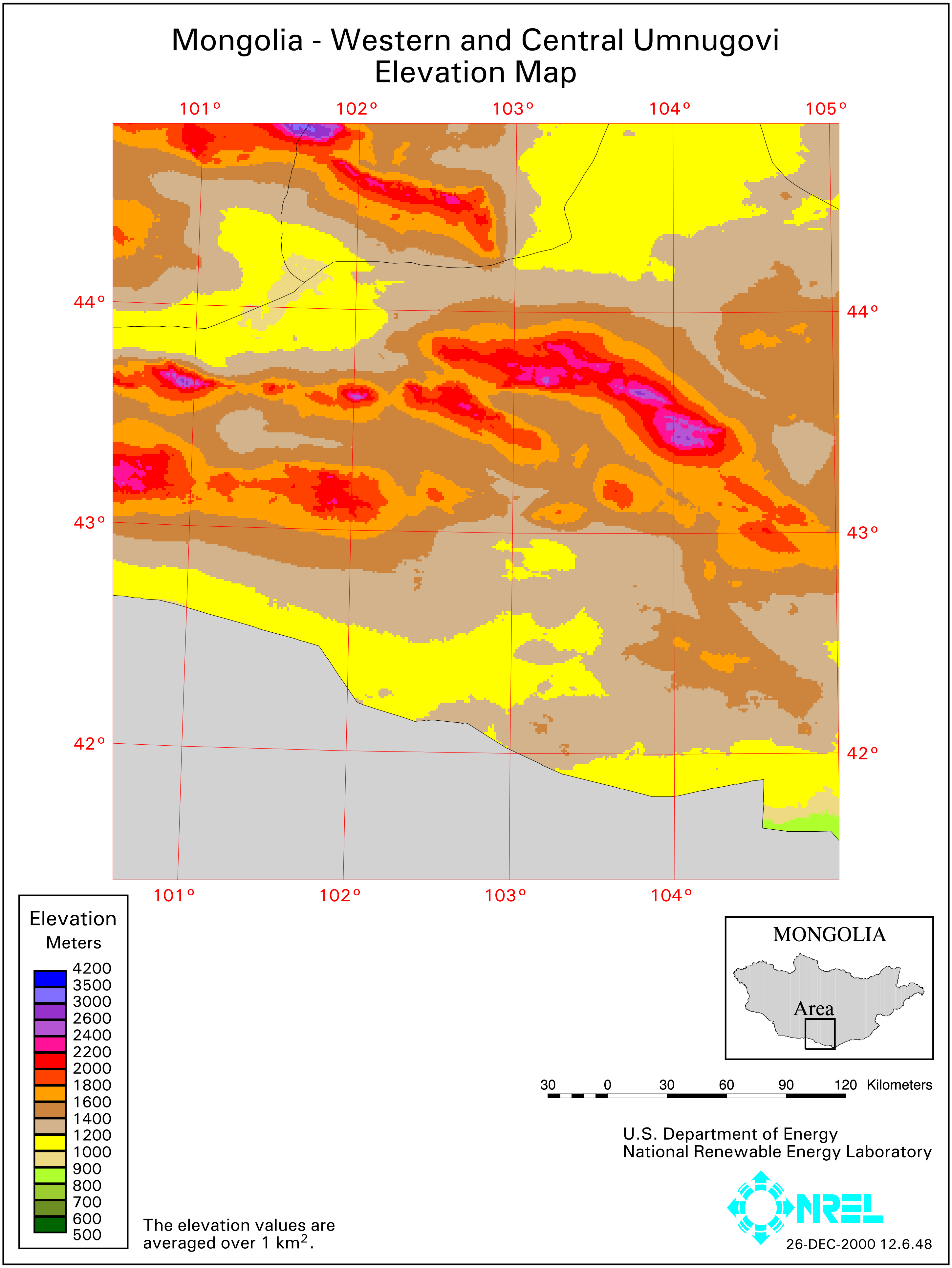
- ○ Surface Meteorological Station
- □ Upper-Air (Weather-Balloon) Station
- + NREL Wind Measurement Site
- △ TACIS Wind Measurement Site
- ■ Town, **Provincial Capital**, or ***Municipality***

PROVINCE (AIMAG)
Lake (Nuur)

U.S. Department of Energy
National Renewable Energy Laboratory

26-DEC-2000 12.6.47

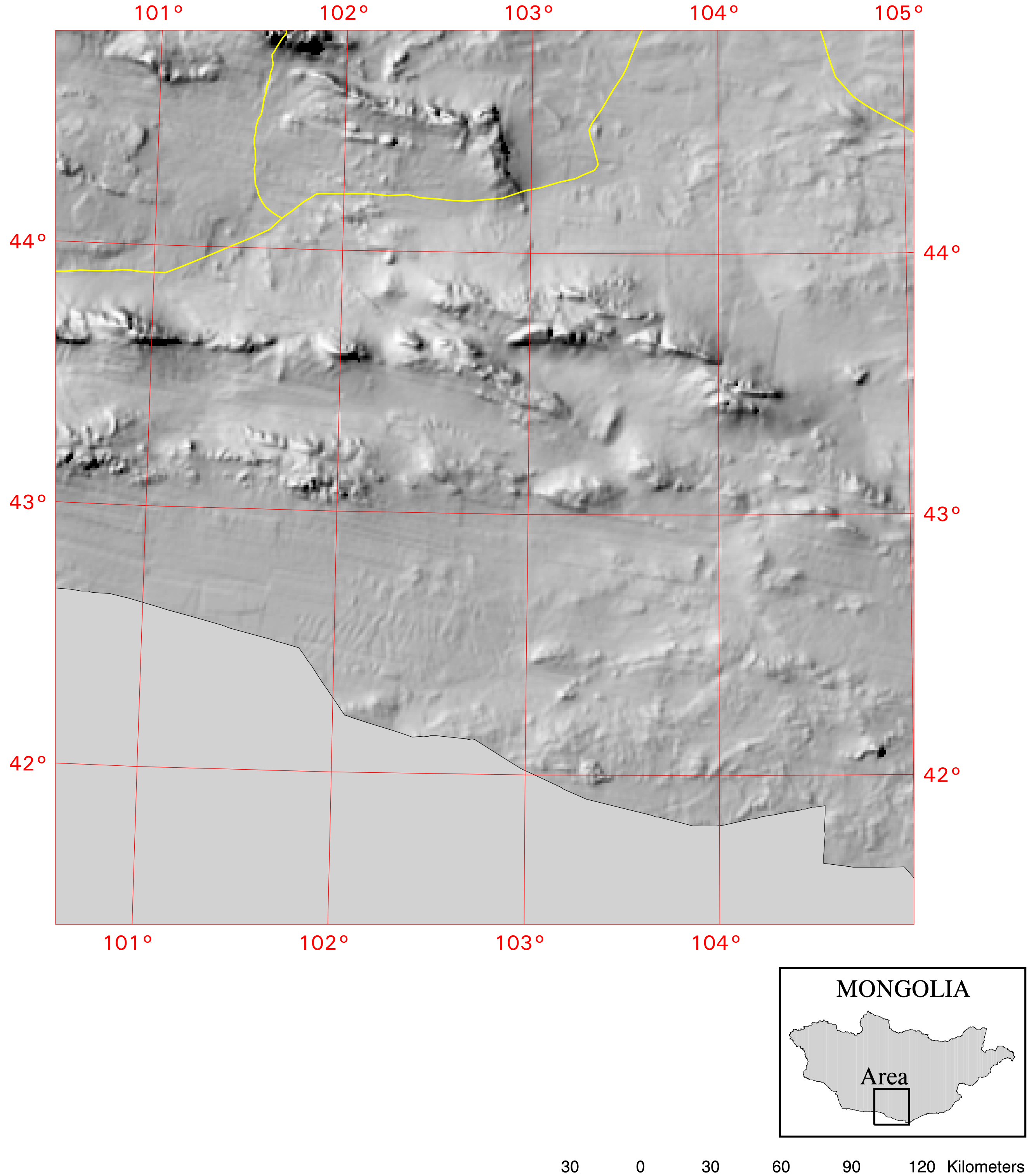
Figure 6-47



Mongolia - Western and Central Umnugovi
Elevation Map
101° 102° 103° 104° 105°
44° 43° 42°
101° 102° 103° 104°
Elevation
Meters
4200
3500
3000
2600
2400
2200
2000
1800
1600
1400
1200
1000
900
800
700
600
500
The elevation values are averaged over 1 km².
MONGOLIA
Area
30 0 30 60 90 120 Kilometers
U.S. Department of Energy
National Renewable Energy Laboratory
NREL
26-DEC-2000 12.6.48

Figure 6-48

Mongolia - Western and Central Umnugovi
Hillshaded Relief Map

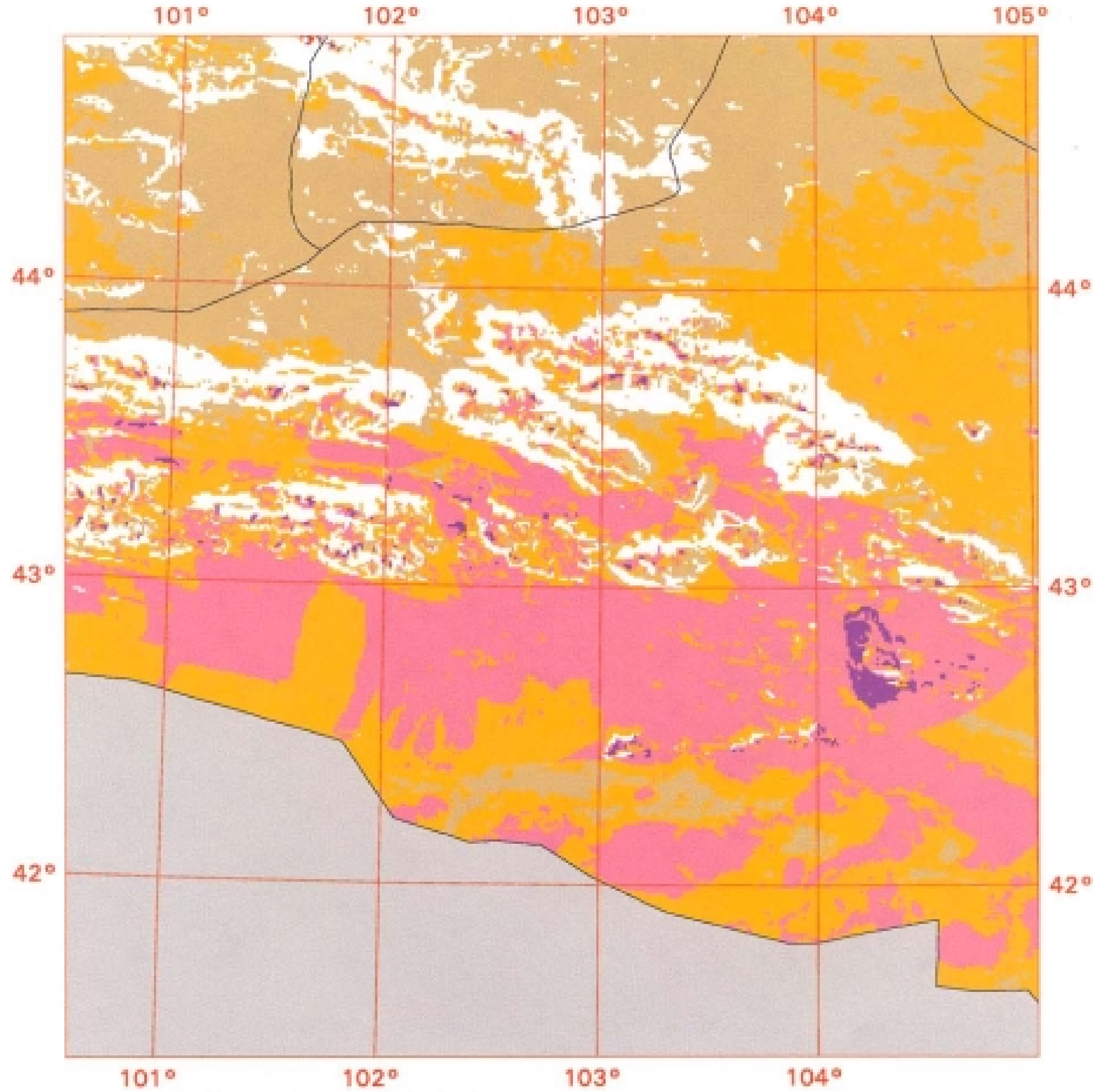


U.S. Department of Energy
National Renewable Energy Laboratory

26-DEC-2000 12.6.49

Figure 6-49

Mongolia - Western and Central Umnugovi
Wind Resource Map



The wind resource classification is specific for both utility-scale and rural applications and applies to areas with low surface roughness, e.g. grassland.

Wind Power Classification

Utility Resource Potential	Rural Resource Potential	Wind Power Density at 30 m W/m^2	Wind Speed[a] at 30 m m/s
Marginal	Moderate	100 - 200	4.5 - 5.6
Moderate	Good	200 - 300	5.6 - 6.4
Good	Excellent	300 - 400	6.4 - 7.1
Excellent		400 - 600	7.1 - 8.1
		600 - 800	8.1 - 8.9
		800 - 1000	8.9 - 9.6

[a] Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8

30 0 30 60 90 120 Kilometers

U.S. Department of Energy
National Renewable Energy Laboratory

NREL

26-DEC-2000 12.6.50

Figure 6-50

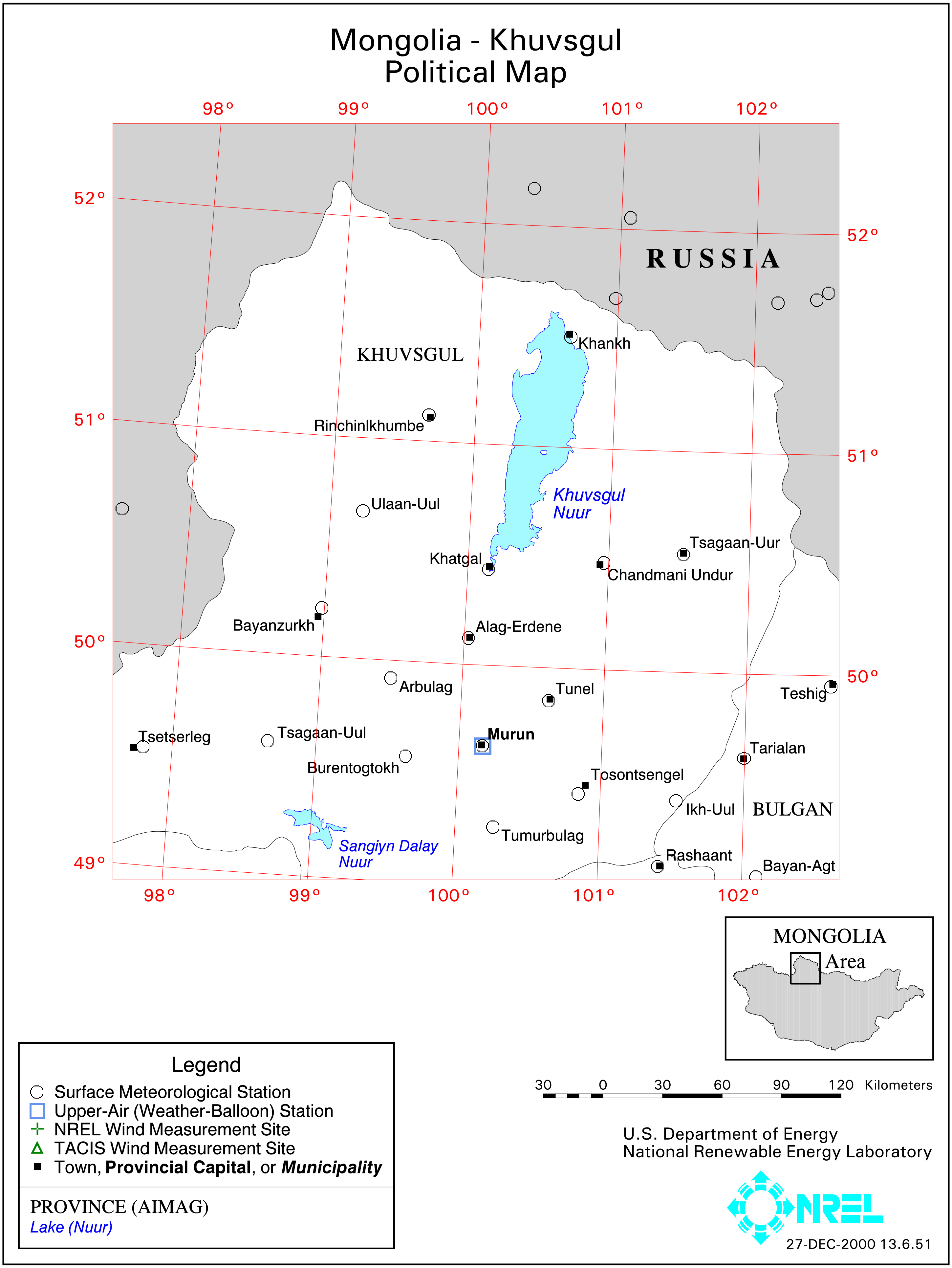

Mongolia - Khuvsgul
Political Map
98°
99°
100°
101°
102°
52°
51°
50°
49°
RUSSIA
KHUVSGUL
BULGAN
Khankh
Rinchinlkhumbe
Khuvsgul
Nuur
Ulaan-Uul
Tsagaan-Uur
Khatgal
Chandmani Undur
Bayanzurkh
Alag-Erdene
Arbulag
Tunel
Teshig
Tsetserleg
Tsagaan-Uul
Murun
Burentogtokh
Tarialan
Tosontsengel
Ikh-Uul
Tumurbulag
Sangiyn Dalay
Nuur
Rashaant
Bayan-Agt
MONGOLIA
Area
Legend
Surface Meteorological Station
Upper-Air (Weather-Balloon) Station
NREL Wind Measurement Site
TACIS Wind Measurement Site
Town, Provincial Capital, or Municipality
PROVINCE (AIMAG)
Lake (Nuur)
30 0 30 60 90 120 Kilometers
U.S. Department of Energy
National Renewable Energy Laboratory
27-DEC-2000 13.6.51

Figure 6-51

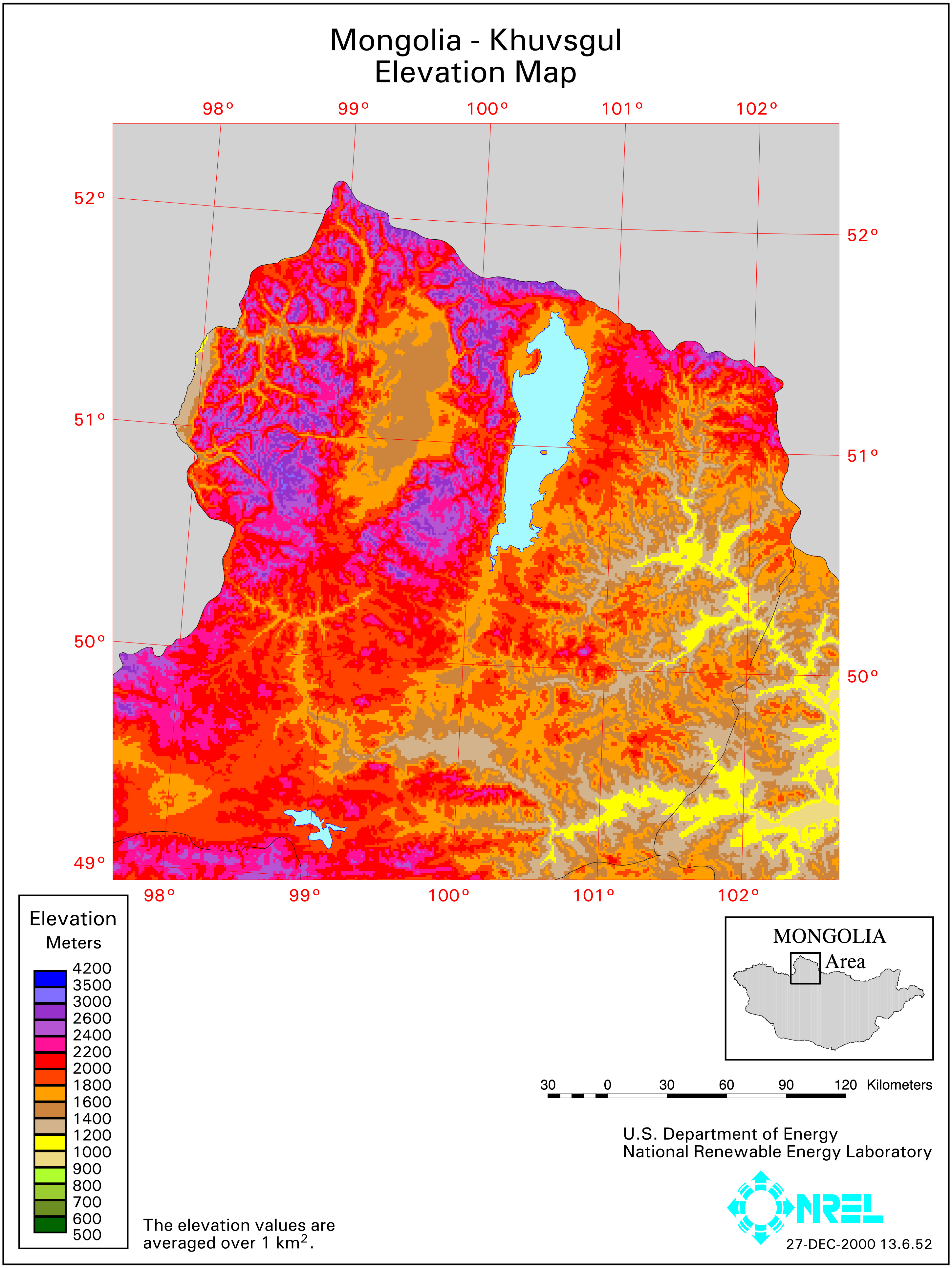
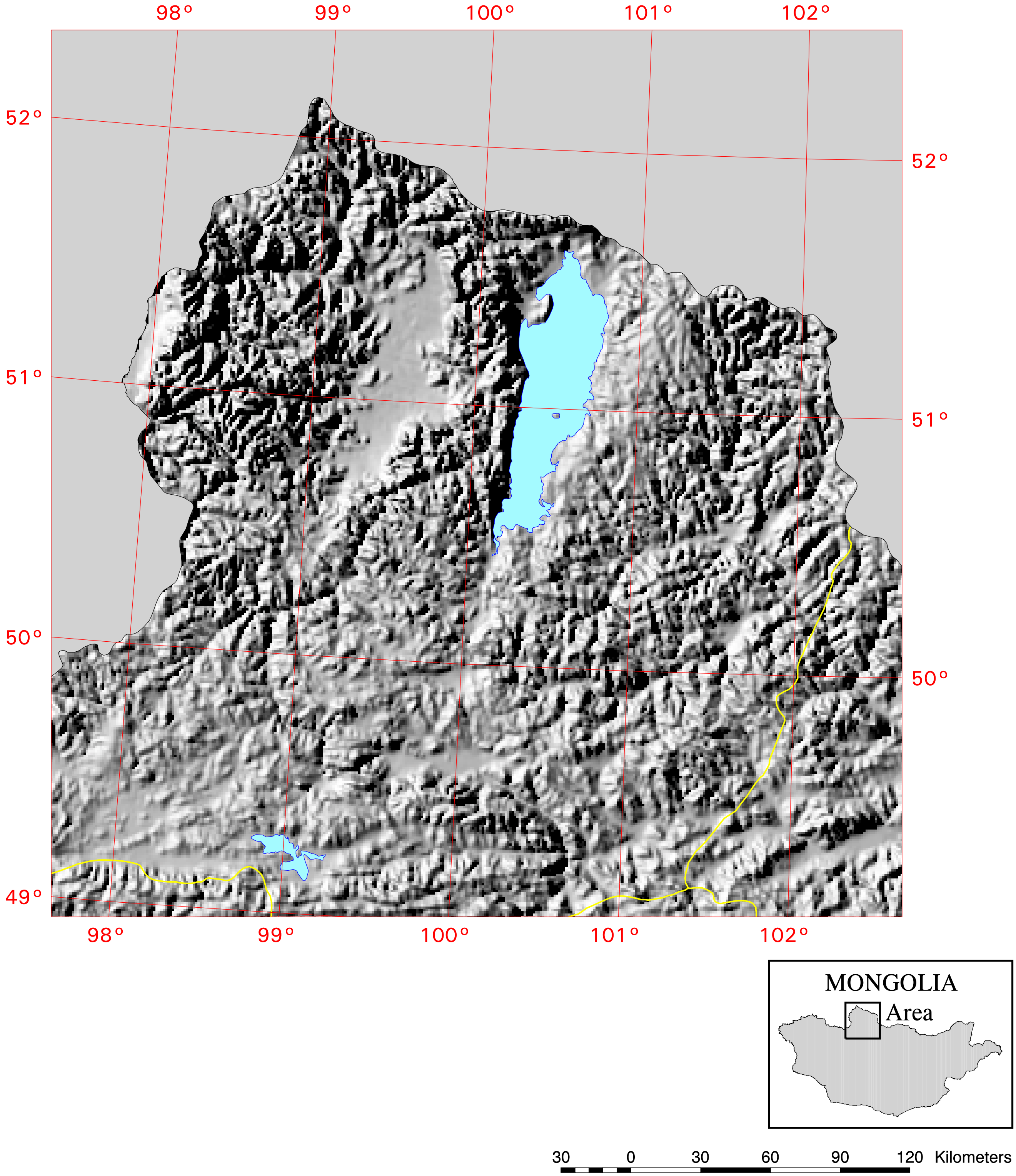

Mongolia - Khuvsgul
Elevation Map
98°
99°
100°
101°
102°
52°
51°
50°
49°
Elevation
Meters
4200
3500
3000
2600
2400
2200
2000
1800
1600
1400
1200
1000
900
800
700
600
500
The elevation values are
averaged over 1 km².
MONGOLIA
Area
30
0
30
60
90
120
Kilometers
U.S. Department of Energy
National Renewable Energy Laboratory
NREL
27-DEC-2000 13.6.52

Figure 6-52

Mongolia - Khuvsgul
Hillshaded Relief Map



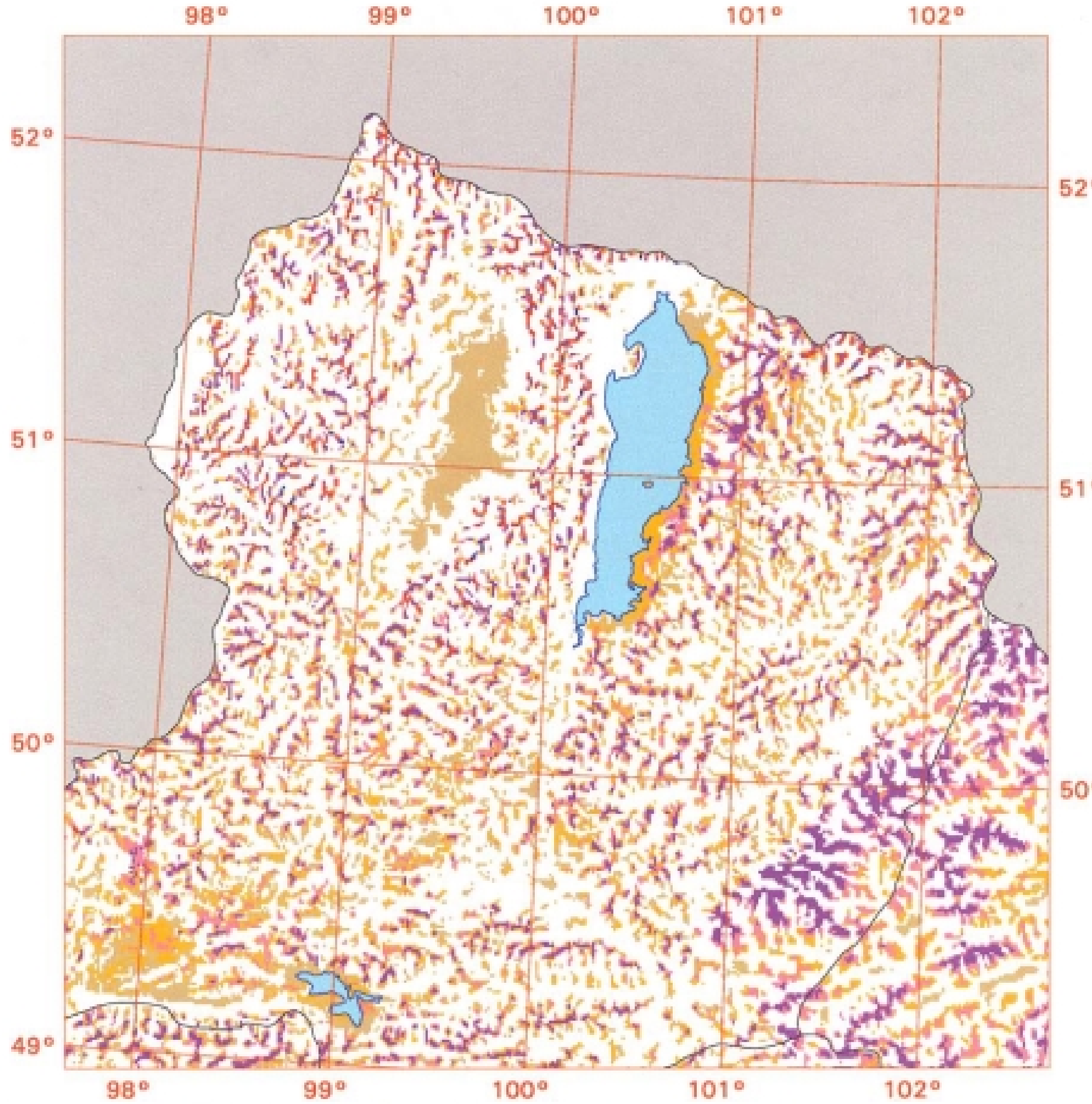
U.S. Department of Energy
National Renewable Energy Laboratory

NREL

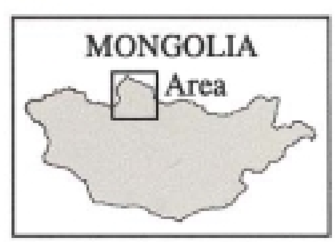
27-DEC-2000 13.6.53

Figure 6-53

Mongolia - Khuvsgul
Wind Resource Map



The wind resource classification is specific for both utility-scale and rural applications and applies to areas with low surface roughness, e.g. grassland.



30 0 30 60 90 120 Kilometers

Wind Power Classification

Resource Potential Utility	Rural	Wind Power Density at 30 m W/m²	Wind Speed[a] at 30 m m/s
Marginal	Moderate	100 - 200	4.5 - 5.6
Moderate	Good	200 - 300	5.6 - 6.4
Good	Excellent	300 - 400	6.4 - 7.1
Excellent		400 - 600	7.1 - 8.1
		600 - 800	8.1 - 8.9
		800 - 1000	8.9 - 9.6

[a] Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8

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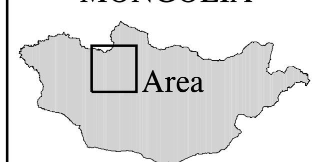
National Renewable Energy Laboratory

27-DEC-2000 13.6.54

Figure 6-54

Mongolia - Eastern Zavkhan, Southern Khuvsgul, and Western Arkhangai - Political Map



The data for NREL and TACIS (Technical Assistance to the Commonwealth of Independent States) wind measurement sites were collected in collaboration with REC (Renewable Energy Corporation).

Legend

- ○ Surface Meteorological Station
- □ Upper-Air (Weather-Balloon) Station
- + NREL Wind Measurement Site
- △ TACIS Wind Measurement Site
- ■ Town, **Provincial Capital**, or ***Municipality***

PROVINCE (AIMAG)
Lake (Nuur)

30 0 30 60 90 120 Kilometers

U.S. Department of Energy
National Renewable Energy Laboratory

NREL

27-DEC-2000 14.6.55

Figure 6-55

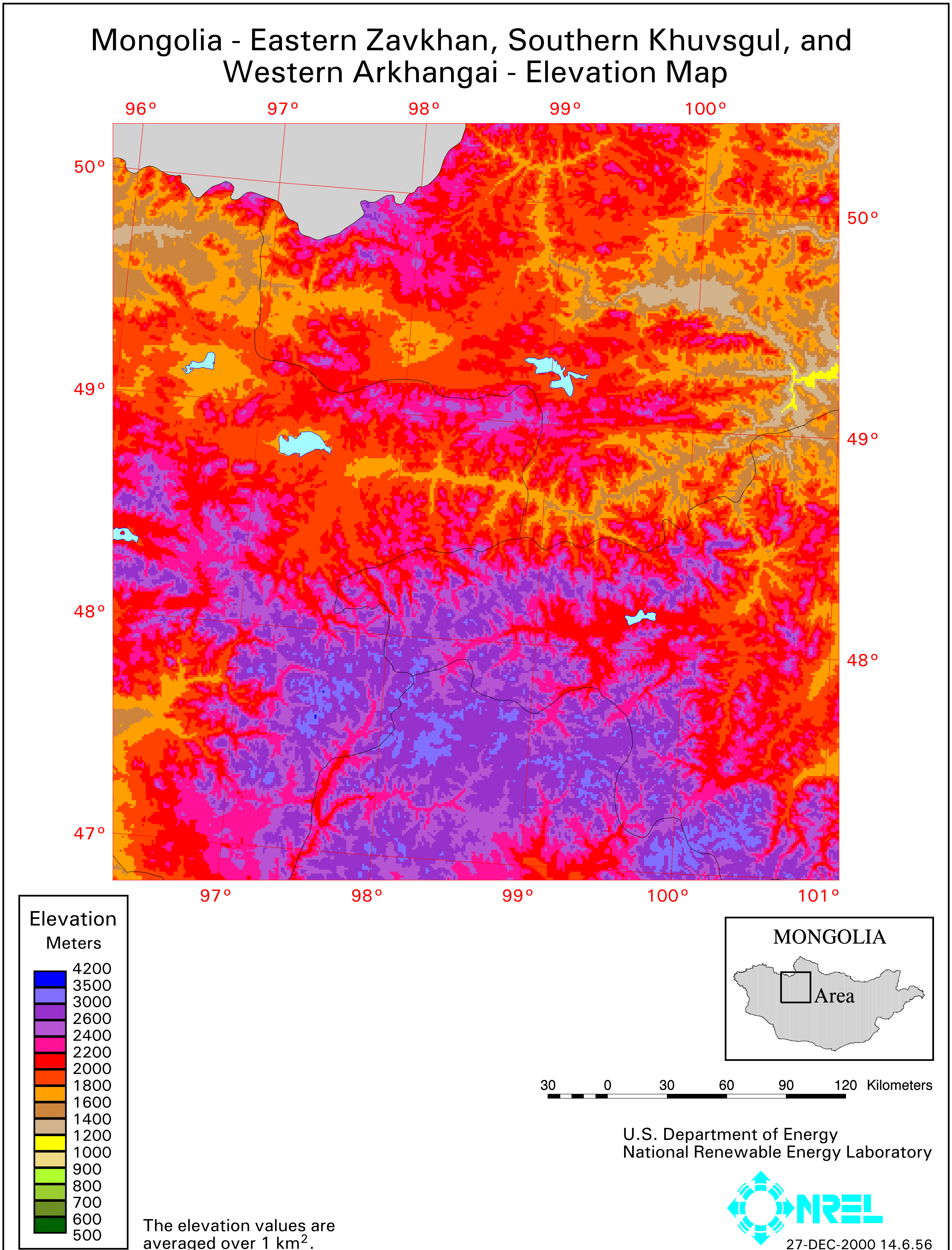
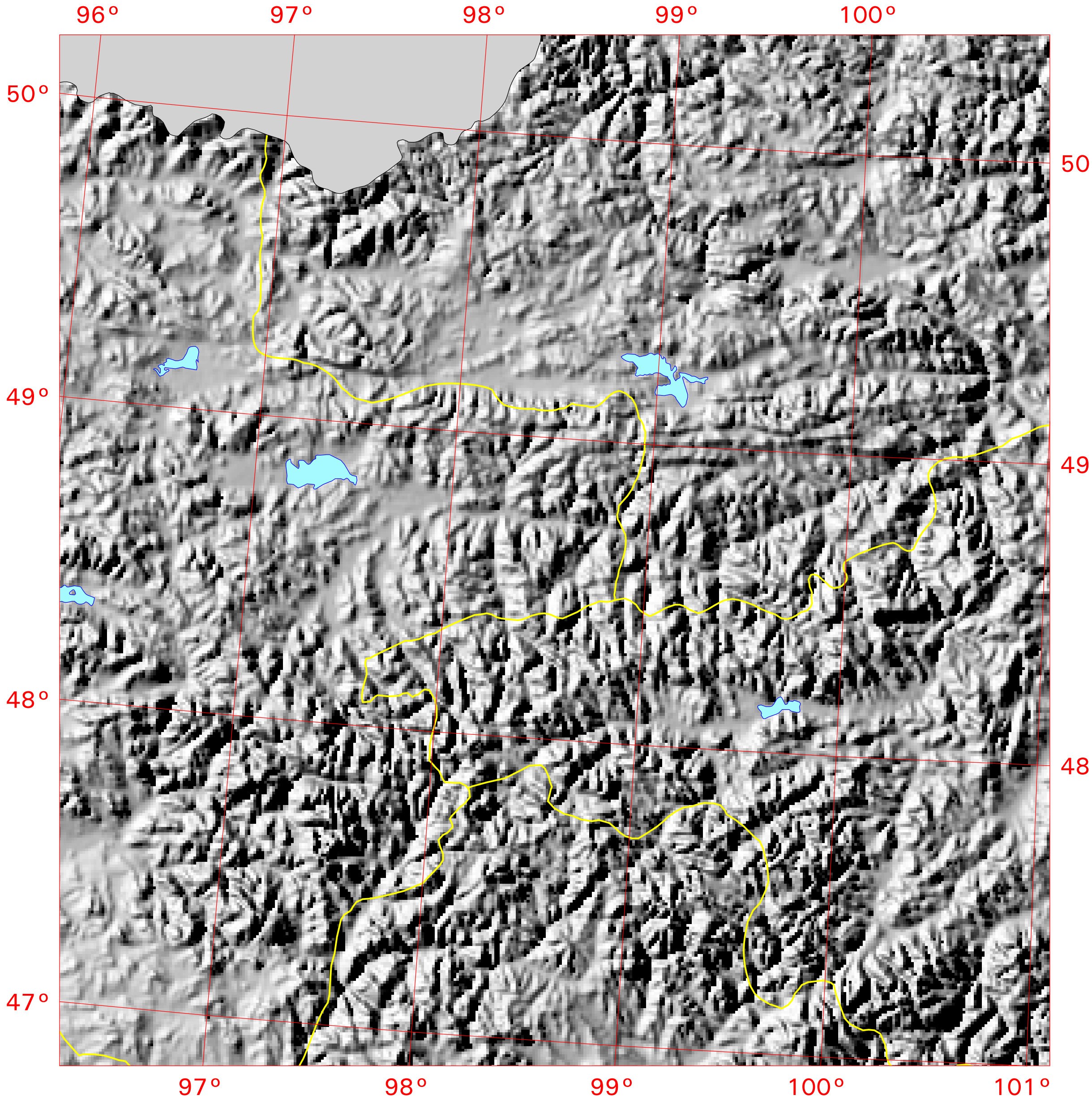
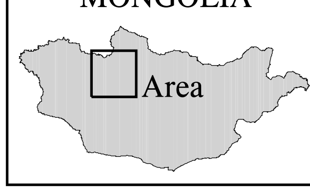

Mongolia - Eastern Zavkhan, Southern Khuvsgul, and
Western Arkhangai - Elevation Map
96°
97°
98°
99°
100°
101°
50°
49°
48°
47°
Elevation
Meters
4200
3500
3000
2600
2400
2200
2000
1800
1600
1400
1200
1000
900
800
700
600
500
The elevation values are averaged over 1 km².
MONGOLIA
Area
30 0 30 60 90 120 Kilometers
U.S. Department of Energy
National Renewable Energy Laboratory
27-DEC-2000 14.6.56

Figure 6-56

Mongolia - Eastern Zavkhan, Southern Khuvsgul, and Western Arkhangai - Hillshaded Relief Map





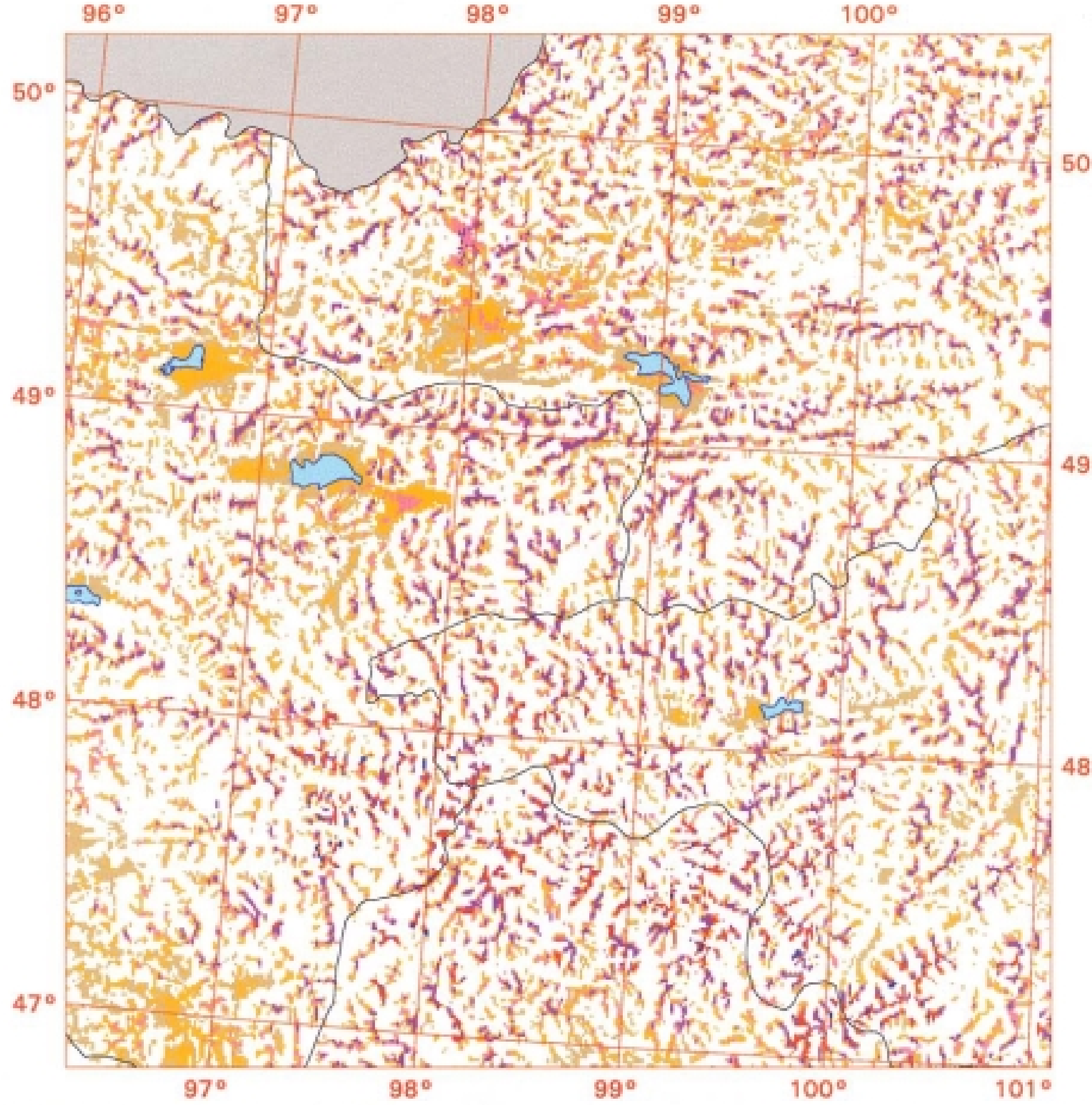
30 0 30 60 90 120 Kilometers

U.S. Department of Energy
National Renewable Energy Laboratory

27-DEC-2000 14.6.57

Figure 6-57

Mongolia - Eastern Zavkhan, Southern Khuvsgul, and Western Arkhangai - Wind Resource Map



The wind resource classification is specific for both utility-scale and rural applications and applies to areas with low surface roughness, e.g. grassland.

Wind Power Classification

Resource Potential: Utility	Resource Potential: Rural	Wind Power Density at 30 m W/m²	Wind Speed[a] at 30 m m/s
Marginal	Moderate	100 - 200	4.5 - 5.6
Moderate	Good	200 - 300	5.6 - 6.4
Good	Excellent	300 - 400	6.4 - 7.1
Excellent		400 - 600	7.1 - 8.1
		600 - 800	8.1 - 8.9
		800 - 1000	8.9 - 9.6

[a] Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8

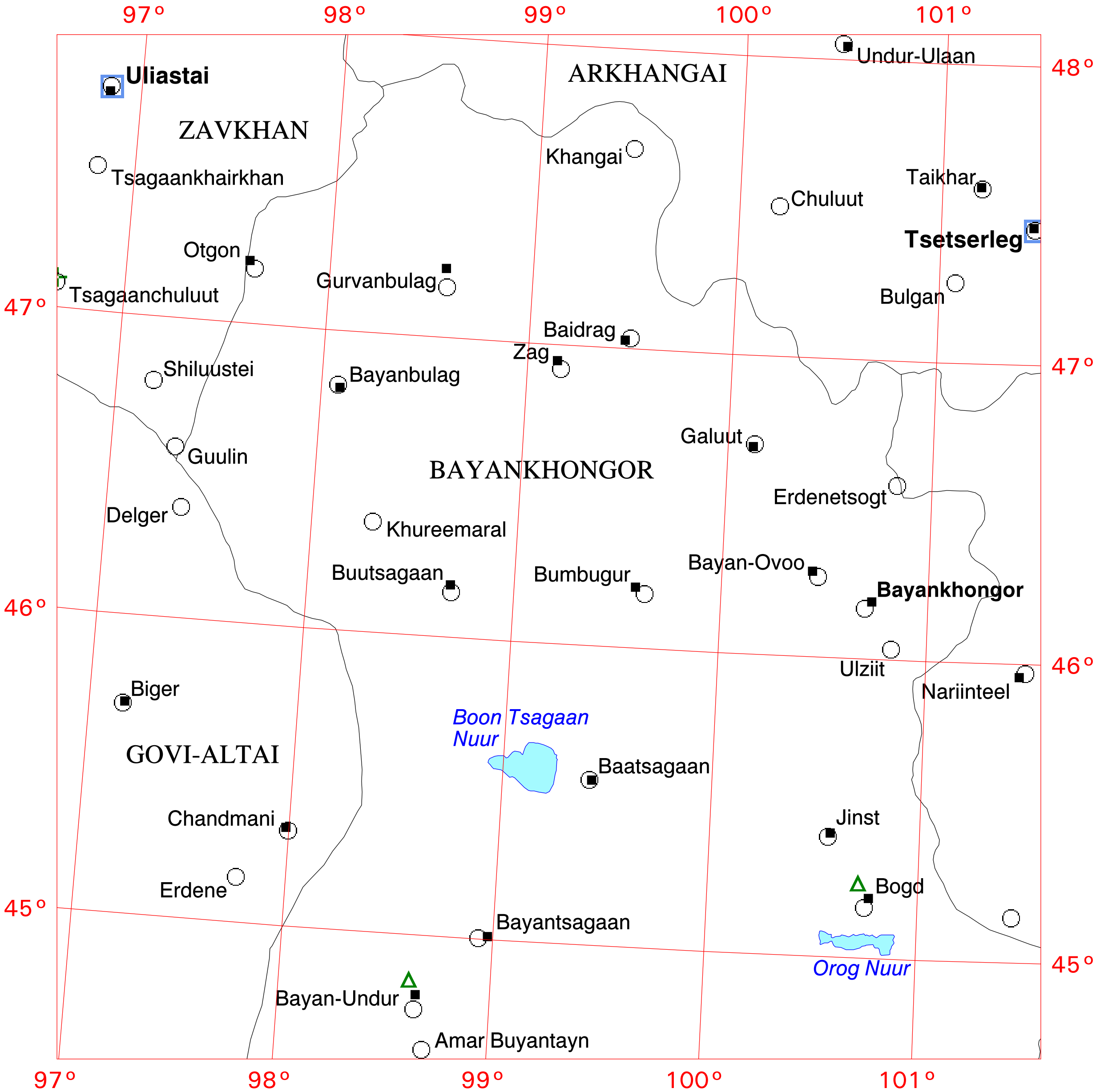
30 0 30 60 90 120 Kilometers

U.S. Department of Energy
National Renewable Energy Laboratory

27-DEC-2000 14.6.58

Figure 6-58

Mongolia - Northern Bayankhongor
Political Map



The data for NREL and TACIS (Technical Assistance to the Commonwealth of Independent States) wind measurement sites were collected in collaboration with REC (Renewable Energy Corporation).

30 0 30 60 90 120 Kilometers

Legend

- ○ Surface Meteorological Station
- □ Upper-Air (Weather-Balloon) Station
- + NREL Wind Measurement Site
- △ TACIS Wind Measurement Site
- ■ Town, **Provincial Capital**, or ***Municipality***

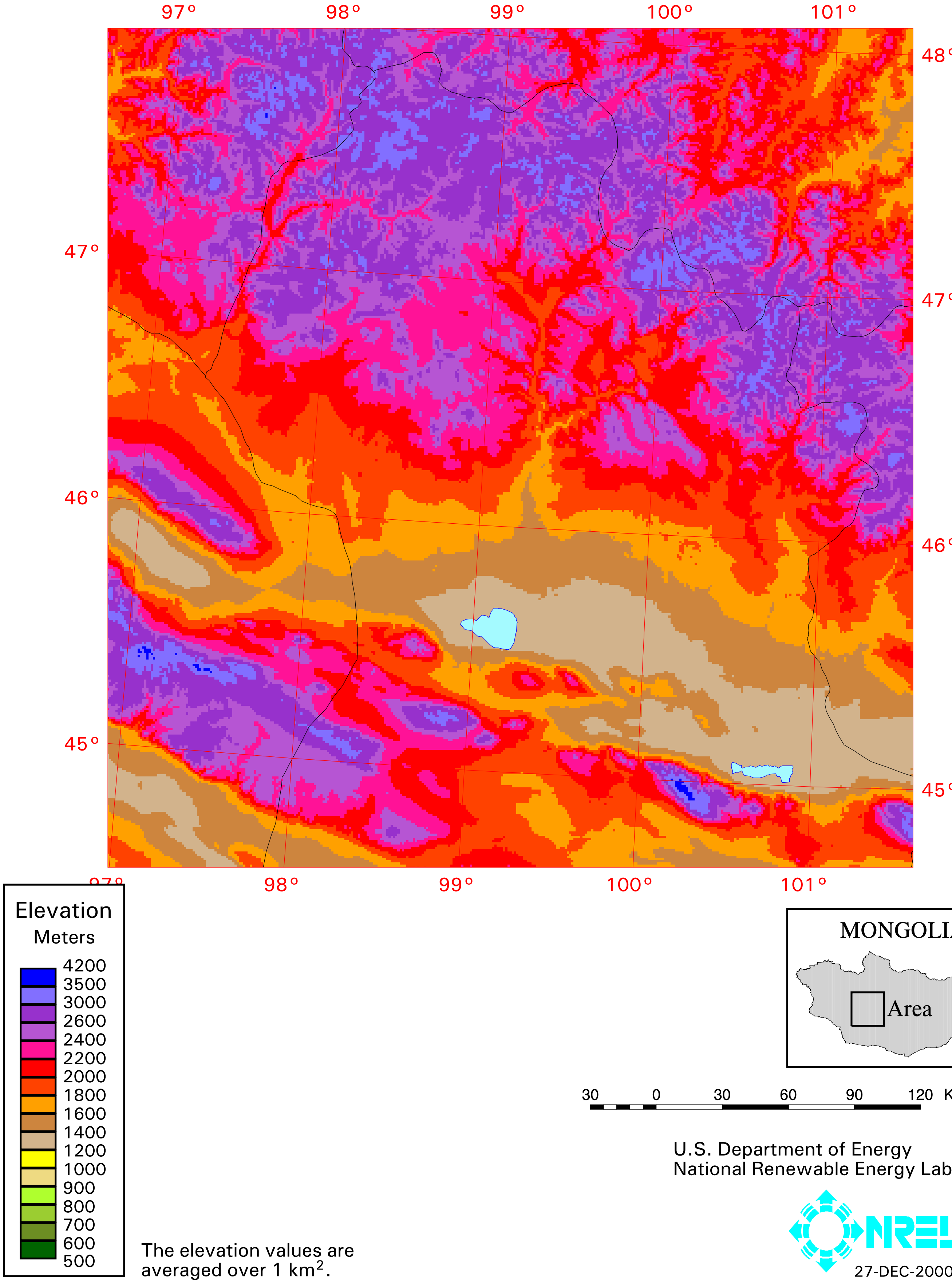
PROVINCE (AIMAG)
Lake (Nuur)

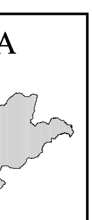
U.S. Department of Energy
National Renewable Energy Laboratory

27-DEC-2000 15.6.59

Figure 6-59

Mongolia - Northern Bayankhongor
Elevation Map





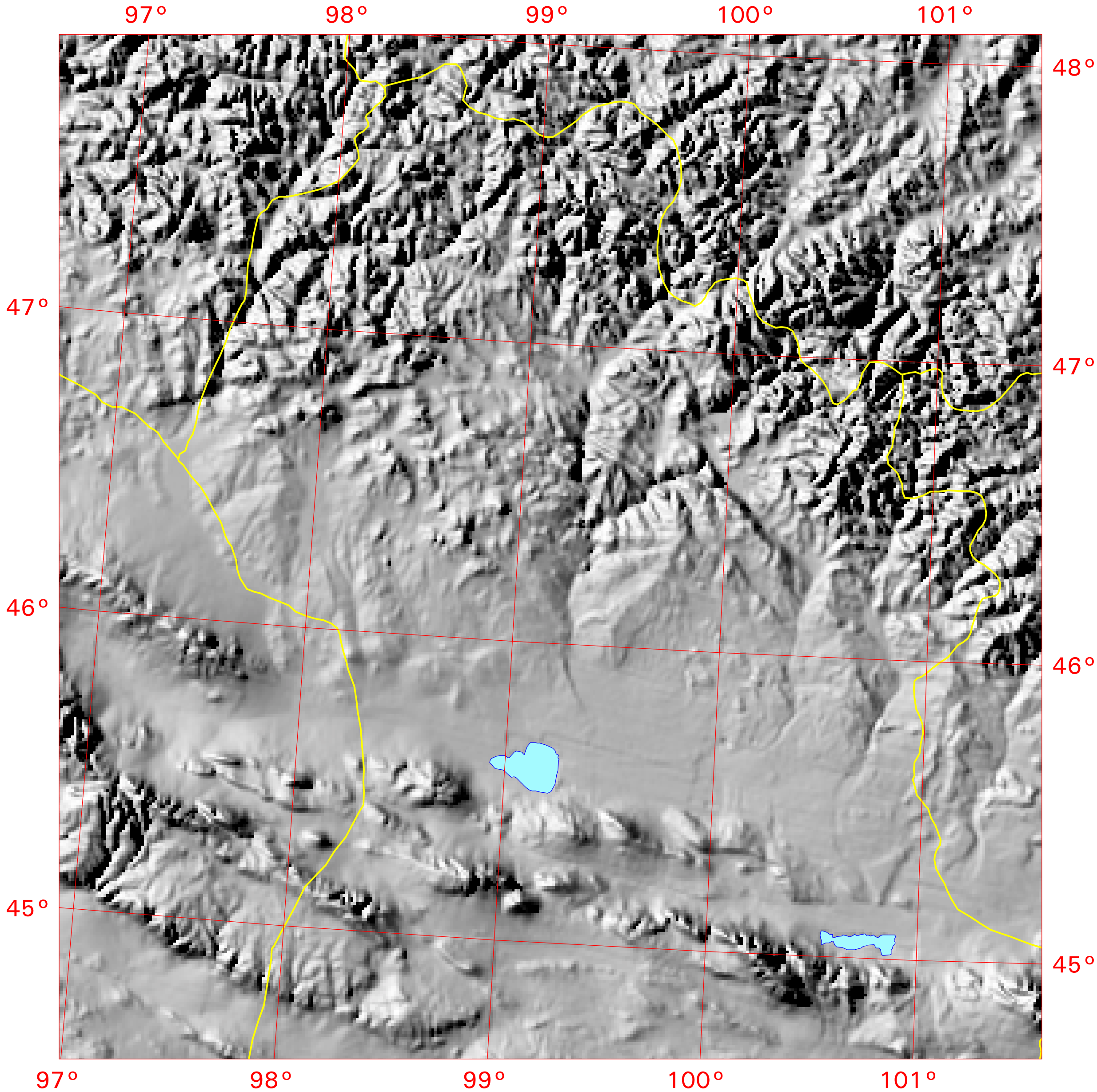
The elevation values are averaged over 1 km^2.

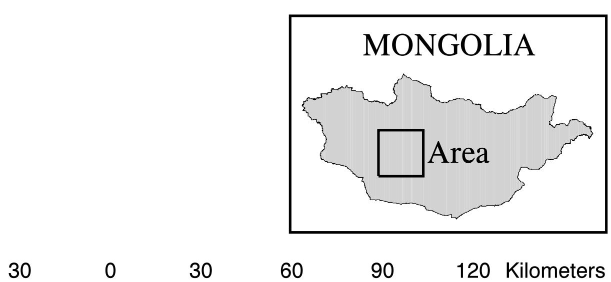
U.S. Department of Energy
National Renewable Energy Laboratory

27-DEC-2000 15.6.60

Figure 6-60

Mongolia - Northern Bayankhongor
Hillshaded Relief Map





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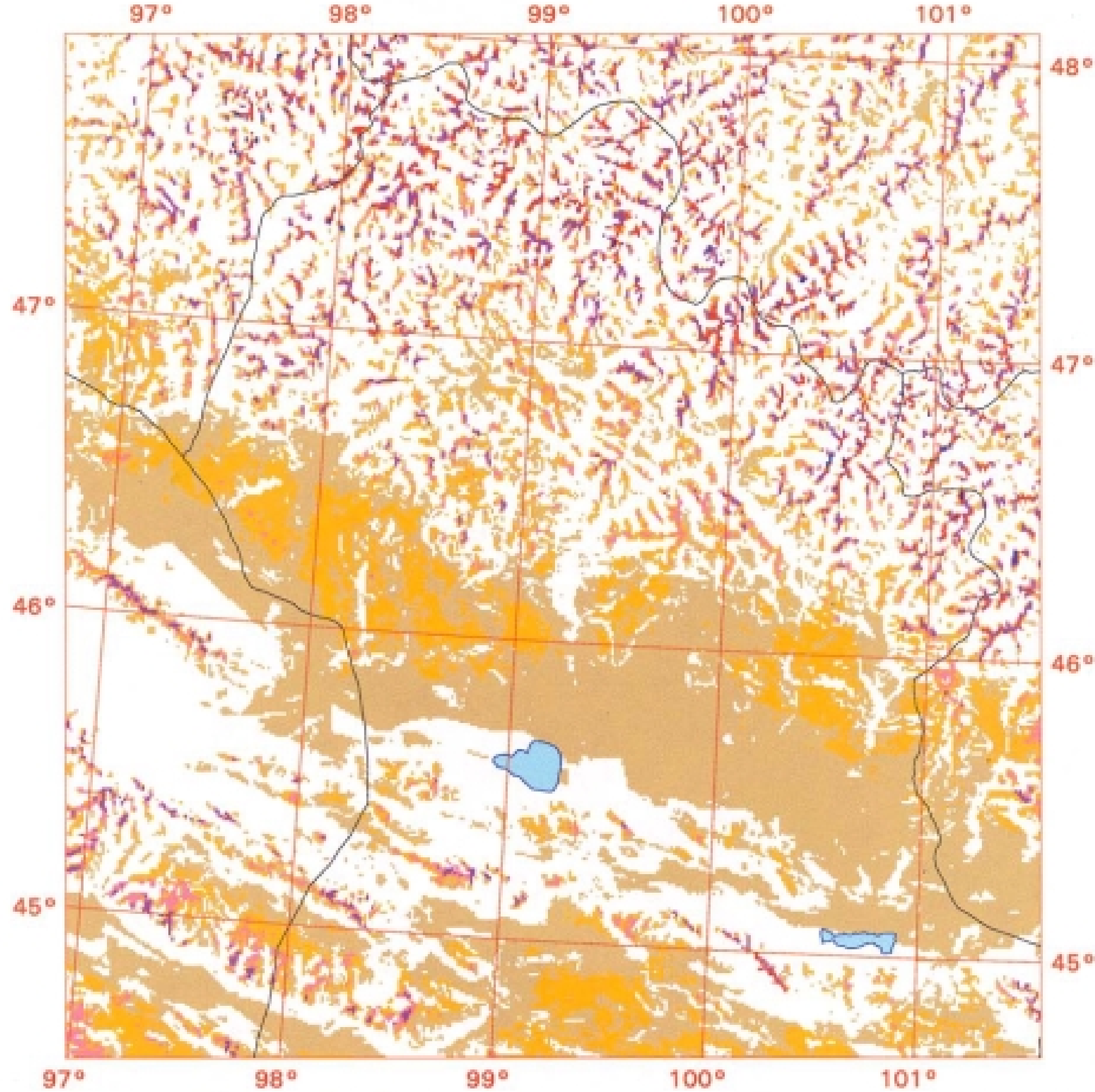
National Renewable Energy Laboratory

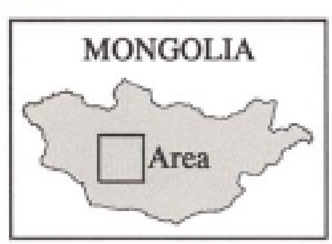
27-DEC-2000 15.6.61

Figure 6-61

Mongolia - Northern Bayankhongor
Wind Resource Map



The wind resource classification is specific for both utility-scale and rural applications and applies to areas with low surface roughness, e.g. grassland.



Wind Power Classification

Resource Potential: Utility	Resource Potential: Rural	Wind Power Density at 30 m W/m^2	Wind Speed[a] at 30 m m/s
Marginal	Moderate	100 - 200	4.5 - 5.6
Moderate	Good	200 - 300	5.6 - 6.4
Good	Excellent	300 - 400	6.4 - 7.1
Excellent		400 - 600	7.1 - 8.1
		600 - 800	8.1 - 8.9
		800 - 1000	8.9 - 9.6

[a]Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8

30 0 30 60 90 120 Kilometers

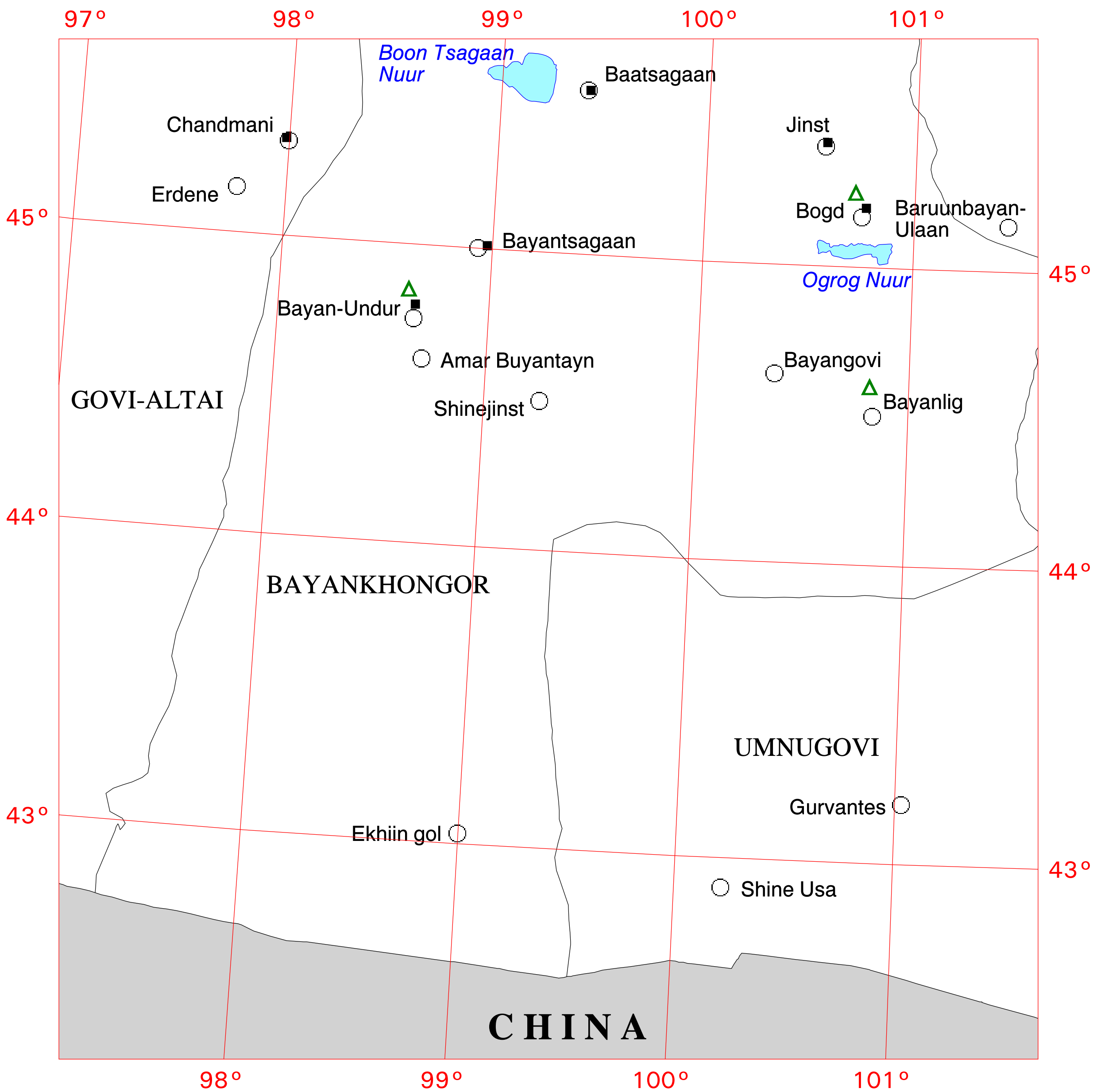
U.S. Department of Energy
National Renewable Energy Laboratory

NREL

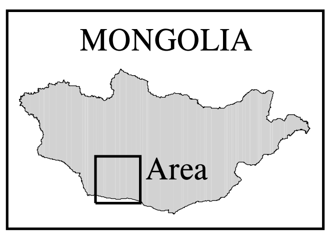
27-DEC-2000 15.6.62

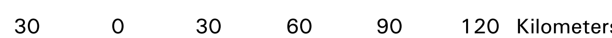
Figure 6-62

Mongolia - Southern Bayankhongor and Western Umnugovi Political Map



The data for NREL and TACIS (Technical Assistance to the Commonwealth of Independent States) wind measurement sites were collected in collaboration with REC (Renewable Energy Corporation).





Legend

- ○ Surface Meteorological Station
- □ Upper-Air (Weather-Balloon) Station
- + NREL Wind Measurement Site
- △ TACIS Wind Measurement Site
- ■ Town, **Provincial Capital**, or ***Municipality***

PROVINCE (AIMAG)
Lake (Nuur)

U.S. Department of Energy
National Renewable Energy Laboratory

NREL

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Figure 6-63

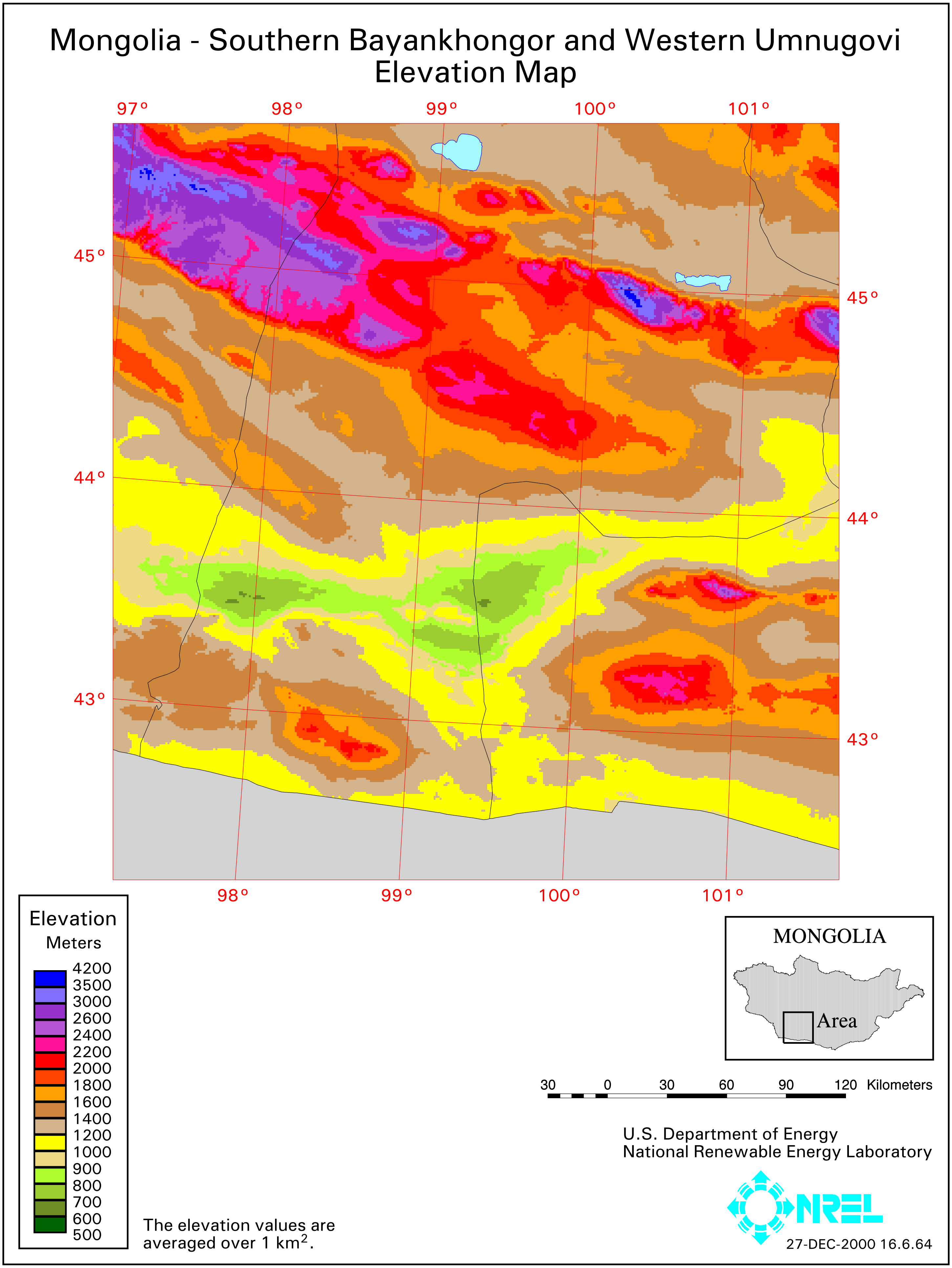
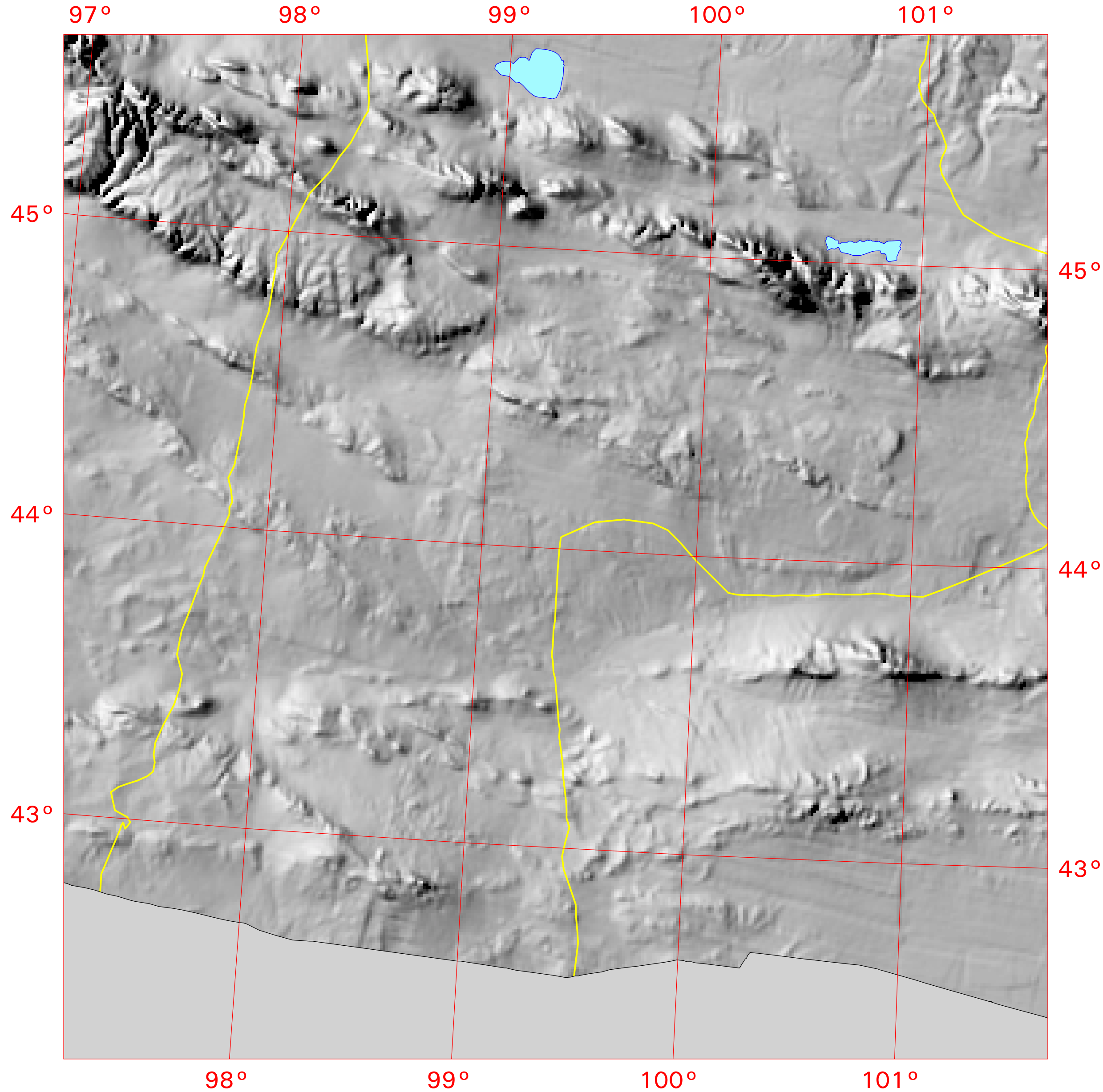
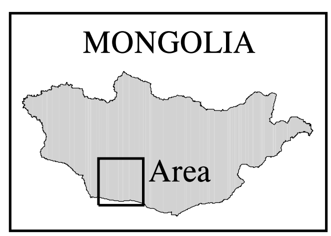

Mongolia - Southern Bayankhongor and Western Umnugovi
Elevation Map
97°
98°
99°
100°
101°
45°
44°
43°
Elevation
Meters
4200
3500
3000
2600
2400
2200
2000
1800
1600
1400
1200
1000
900
800
700
600
500
The elevation values are averaged over 1 km².
MONGOLIA
Area
30 0 30 60 90 120 Kilometers
U.S. Department of Energy
National Renewable Energy Laboratory
NREL
27-DEC-2000 16.6.64

Figure 6-64

Mongolia - Southern Bayankhongor and Western Umnugovi
Hillshaded Relief Map





30 0 30 60 90 120 Kilometers

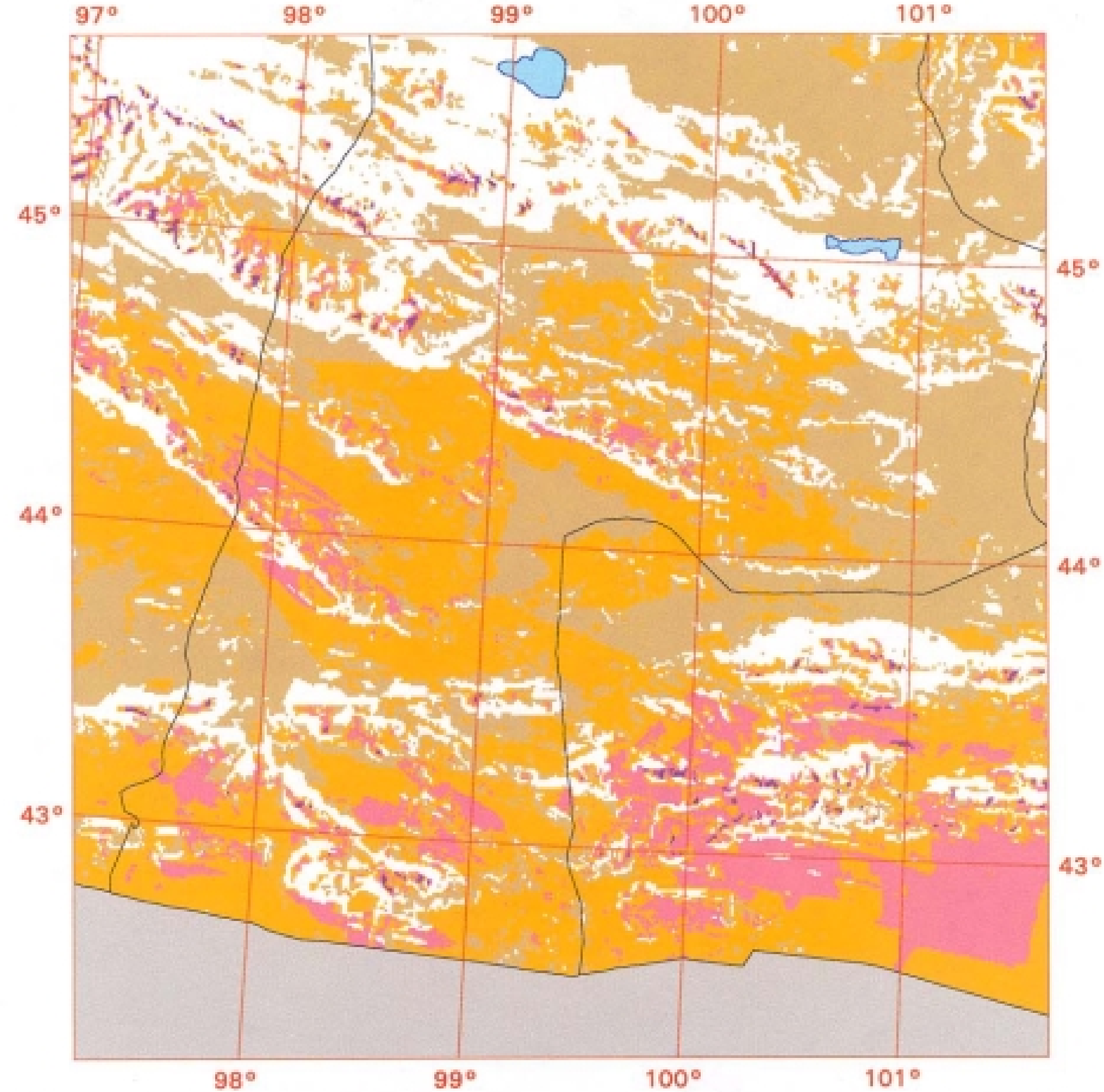
U.S. Department of Energy
National Renewable Energy Laboratory

NREL

27-DEC-2000 16.6.65

Figure 6-65

Mongolia - Southern Bayankhongor and Western Umnugovi Wind Resource Map



The wind resource classification is specific for both utility-scale and rural applications and applies to areas with low surface roughness, e.g. grassland.

Wind Power Classification

Resource Potential Utility	Resource Potential Rural	Wind Power Density at 30 m W/m²	Wind Speed[a] at 30 m m/s
Marginal	Moderate	100 - 200	4.5 - 5.6
Moderate	Good	200 - 300	5.6 - 6.4
Good	Excellent	300 - 400	6.4 - 7.1
Excellent		400 - 600	7.1 - 8.1
		600 - 800	8.1 - 8.9
		800 - 1000	8.9 - 9.6

[a]Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8

30 0 30 60 90 120 Kilometers

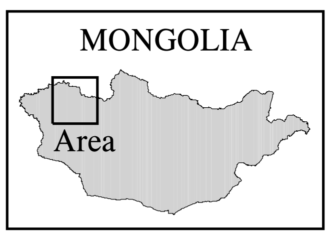
U.S. Department of Energy
National Renewable Energy Laboratory

NREL

27-DEC-2000 16.6.66

Figure 6-66

Mongolia - Uvs and Northwestern Zavkhan
Political Map



Legend

- ○ Surface Meteorological Station
- □ Upper-Air (Weather-Balloon) Station
- + NREL Wind Measurement Site
- △ TACIS Wind Measurement Site
- ■ Town, **Provincial Capital**, or ***Municipality***

PROVINCE (AIMAG)
Lake (Nuur)

30 0 30 60 90 120 Kilometers

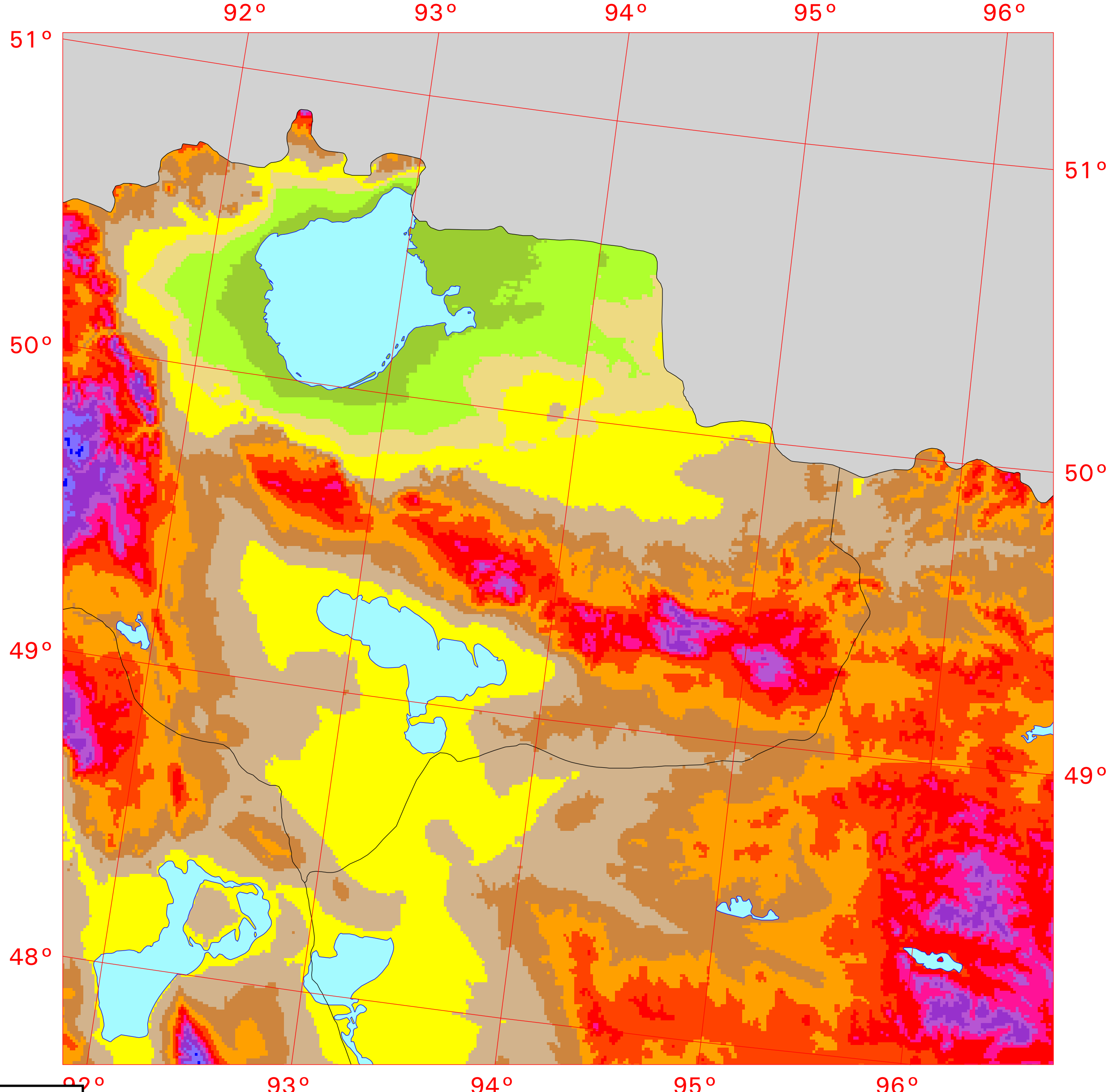
U.S. Department of Energy
National Renewable Energy Laboratory

NREL

27-DEC-2000 17.6.67

Figure 6-67

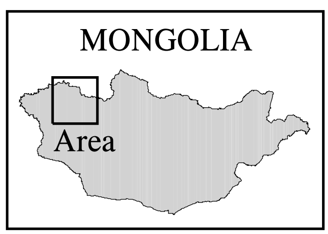
Mongolia - Uvs and Northwestern Zavkhan Elevation Map



Elevation
Meters

4200
3500
3000
2600
2400
2200
2000
1800
1600
1400
1200
1000
900
800
700
600
500

The elevation values are averaged over 1 km^2.



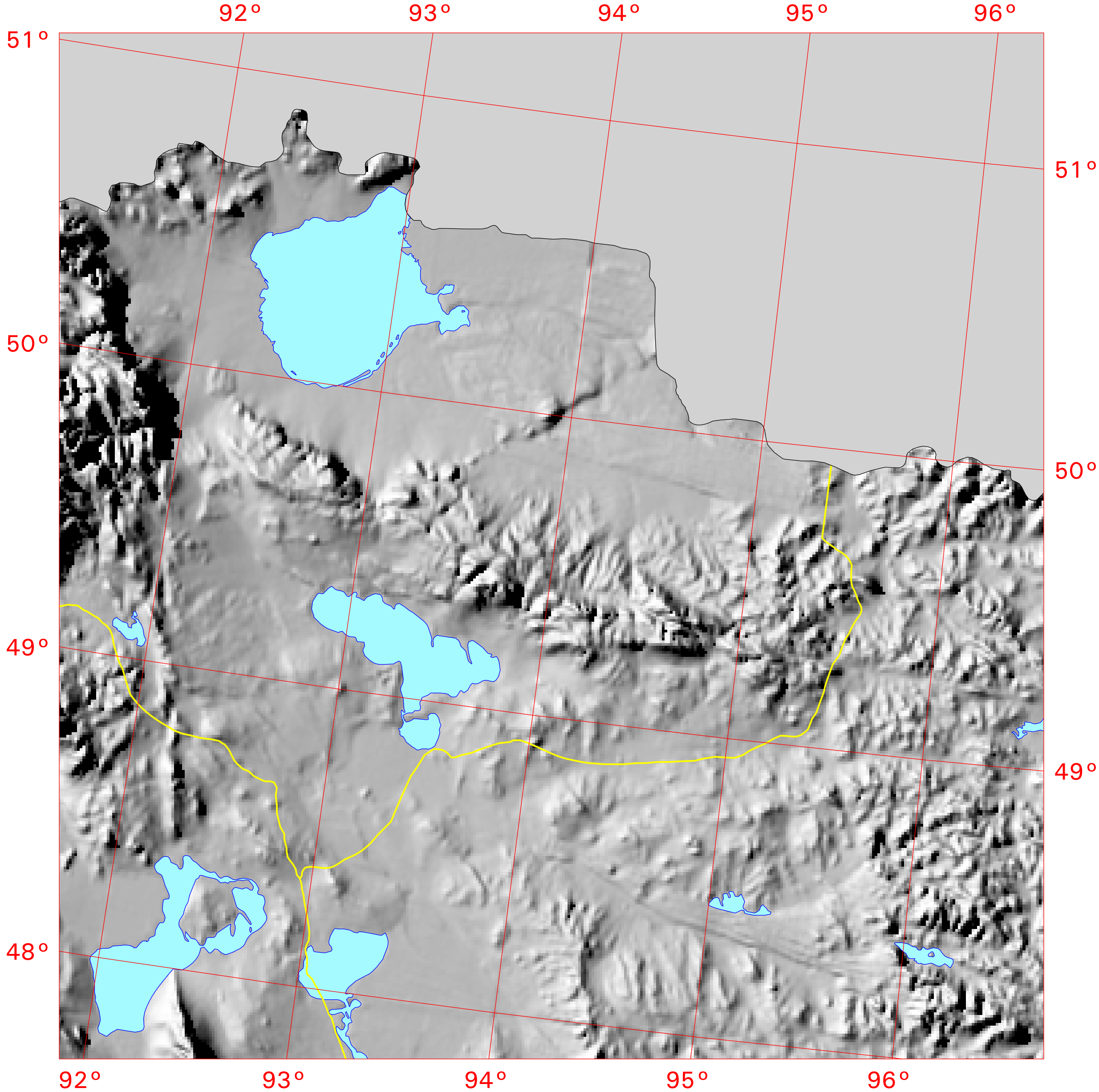
30 0 30 60 90 120 Kilometers

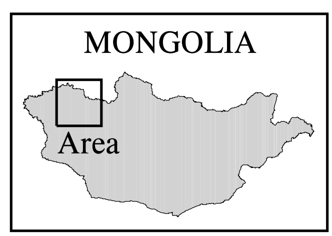
U.S. Department of Energy
National Renewable Energy Laboratory

27-DEC-2000 17.6.68

Figure 6-68

Mongolia - Uvs and Northwestern Zavkhan
Hillshaded Relief Map





30 0 30 60 90 120 Kilometers

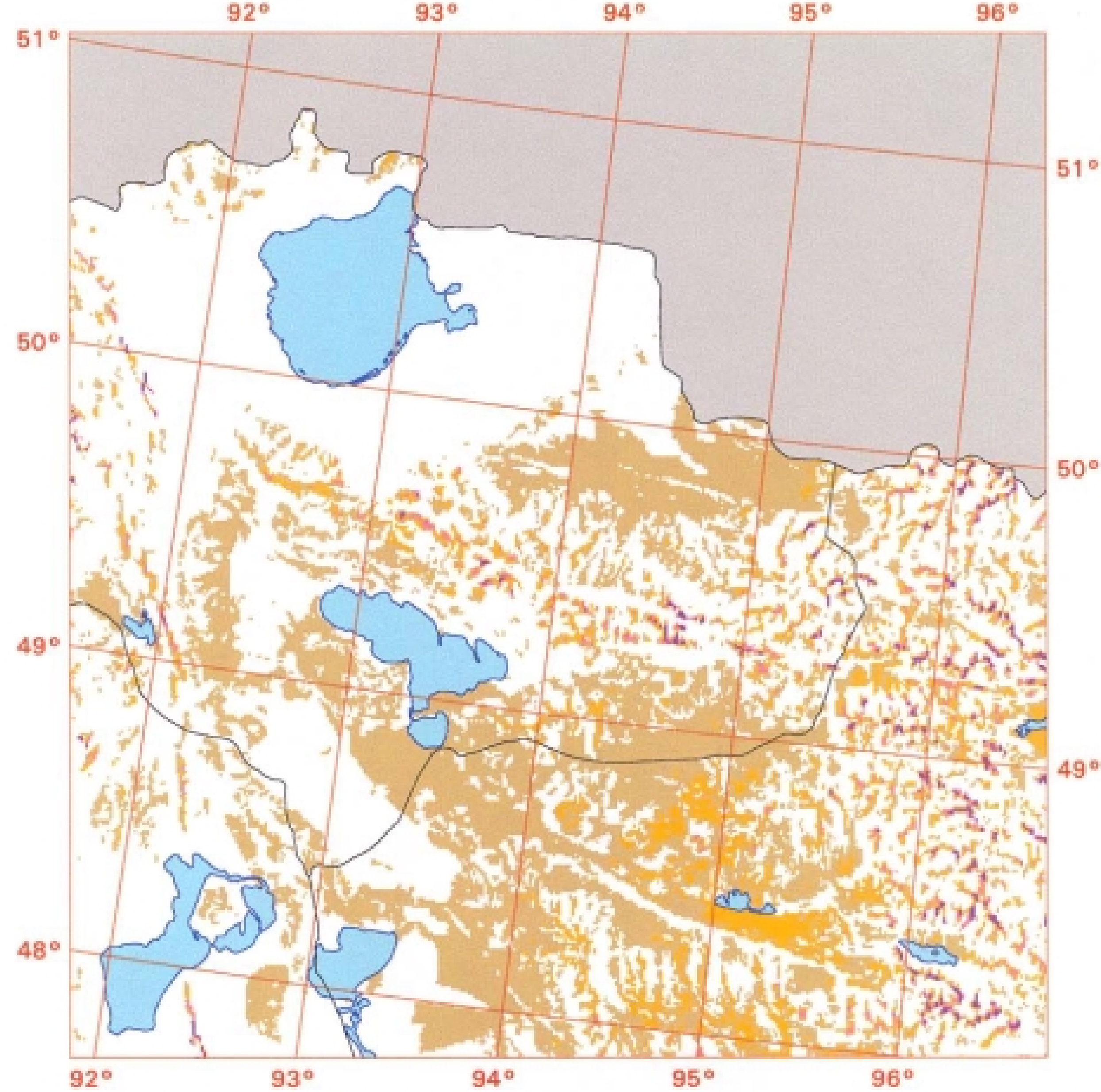
U.S. Department of Energy
National Renewable Energy Laboratory

NREL

27-DEC-2000 17.6.69

Figure 6-69

Mongolia - Uvs and Northwestern Zavkhan
Wind Resource Map

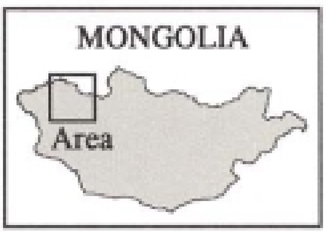


The wind resource classification is specific for both utility-scale and rural applications and applies to areas with low surface roughness, e.g. grassland.

Wind Power Classification

Resource Potential Utility	Resource Potential Rural	Wind Power Density at 30 m W/m^2	Wind Speed[a] at 30 m m/s
Marginal	Moderate	100 - 200	4.5 - 5.6
Moderate	Good	200 - 300	5.6 - 6.4
Good	Excellent	300 - 400	6.4 - 7.1
Excellent		400 - 600	7.1 - 8.1
		600 - 800	8.1 - 8.9
		800 - 1000	8.9 - 9.6

[a]Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8



30 0 30 60 90 120 Kilometers

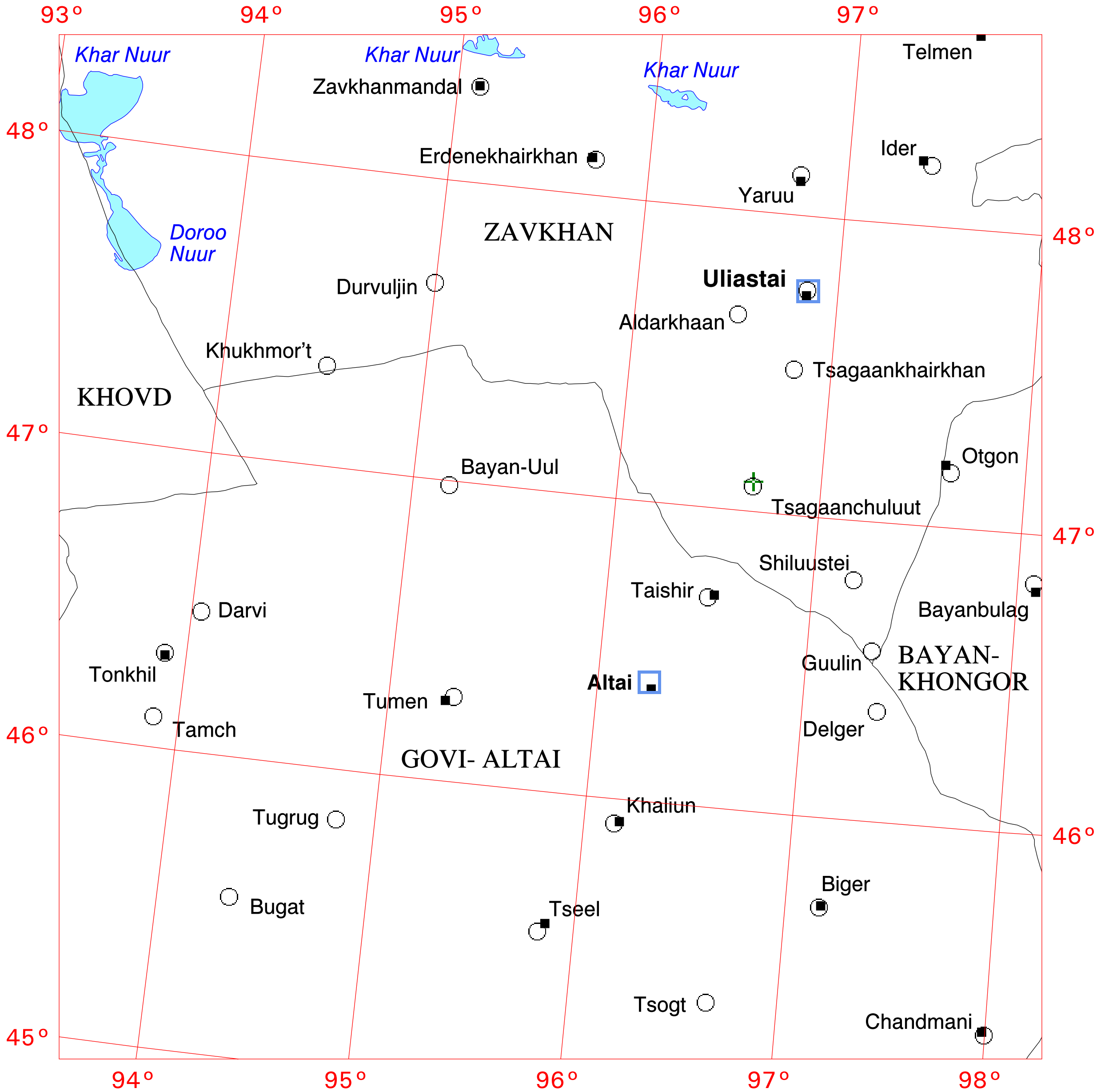
U.S. Department of Energy
National Renewable Energy Laboratory

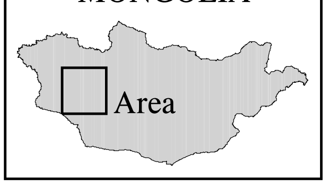
NREL

27-DEC-2000 17.6.70

Figure 6-70

Mongolia - Northern Govi-Altai and Southern Zavkhan
Political Map





The data for NREL and TACIS (Technical Assistance to the Commonwealth of Independent States) wind measurement sites were collected in collaboration with REC (Renewable Energy Corporation).

Legend

- ○ Surface Meteorological Station
- □ Upper-Air (Weather-Balloon) Station
- + NREL Wind Measurement Site
- △ TACIS Wind Measurement Site
- ■ Town, **Provincial Capital**, or ***Municipality***

PROVINCE (AIMAG)
Lake (Nuur)

30 0 30 60 90 120 Kilometers

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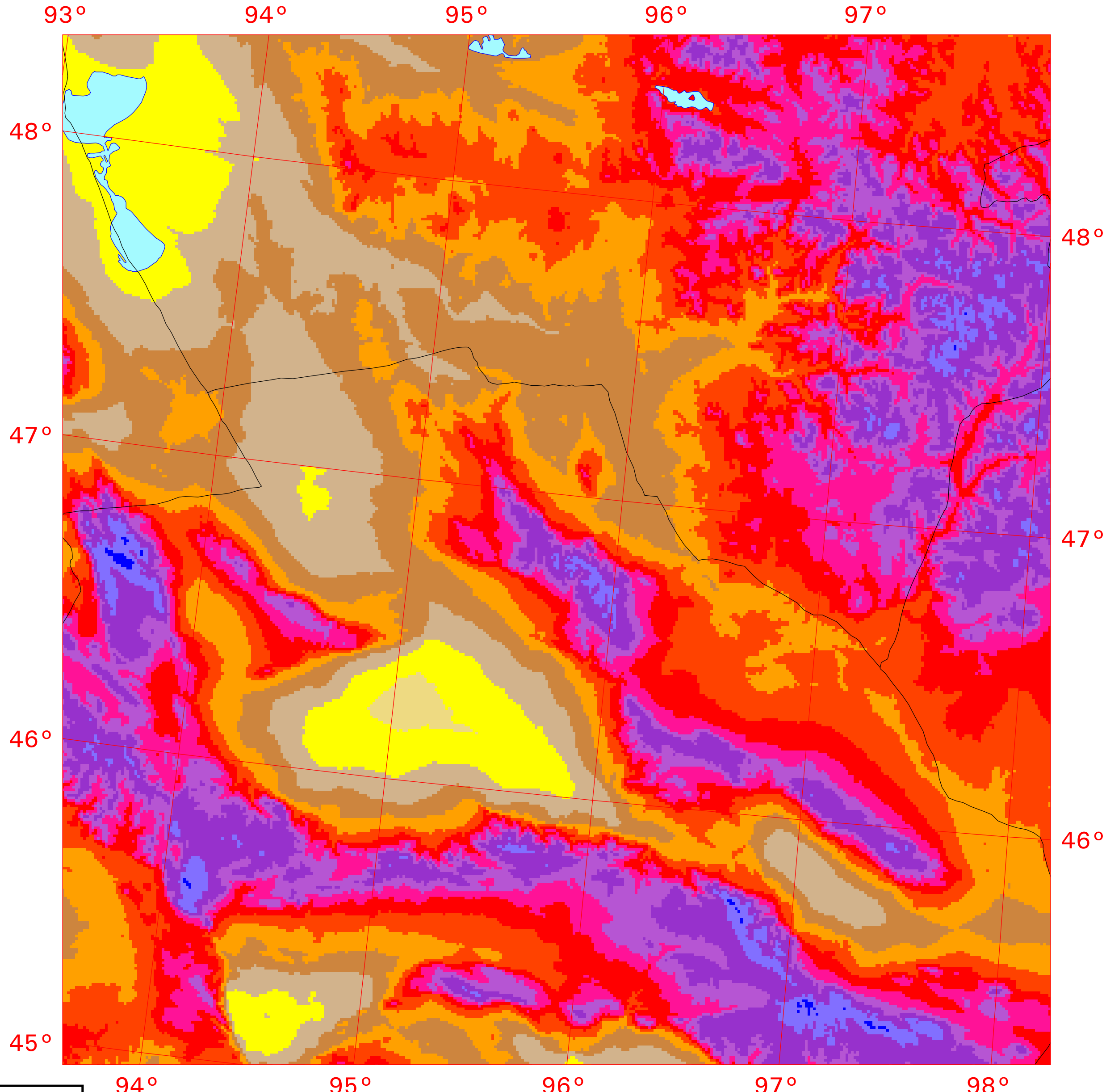
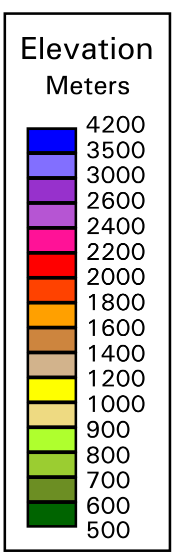
27-DEC-2000 18.6.71

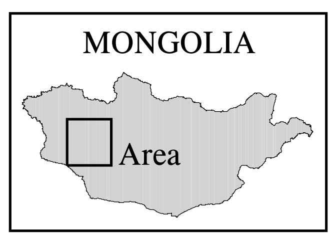
Figure 6-71

Mongolia - Northern Govi-Altai and Southern Zavkhan Elevation Map





The elevation values are averaged over 1 km^2.



30 0 30 60 90 120 Kilometers

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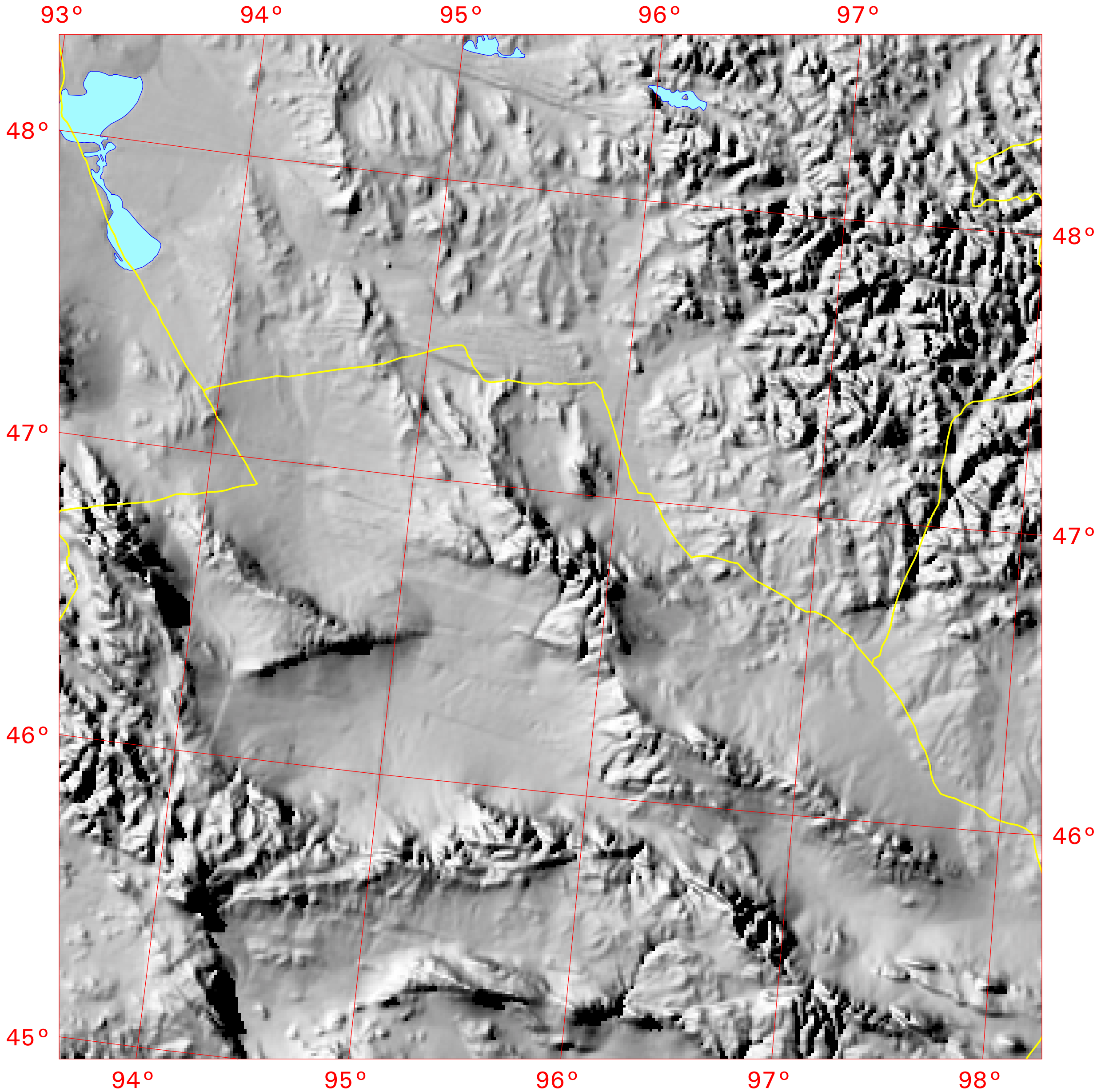
National Renewable Energy Laboratory

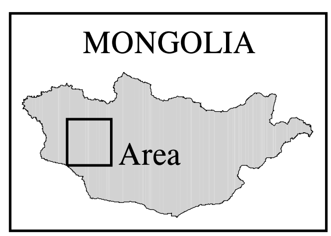
NREL

27-DEC-2000 18.6.72

Figure 6-72

Mongolia - Northern Govi-Altai and Southern Zavkhan
Hillshaded Relief Map





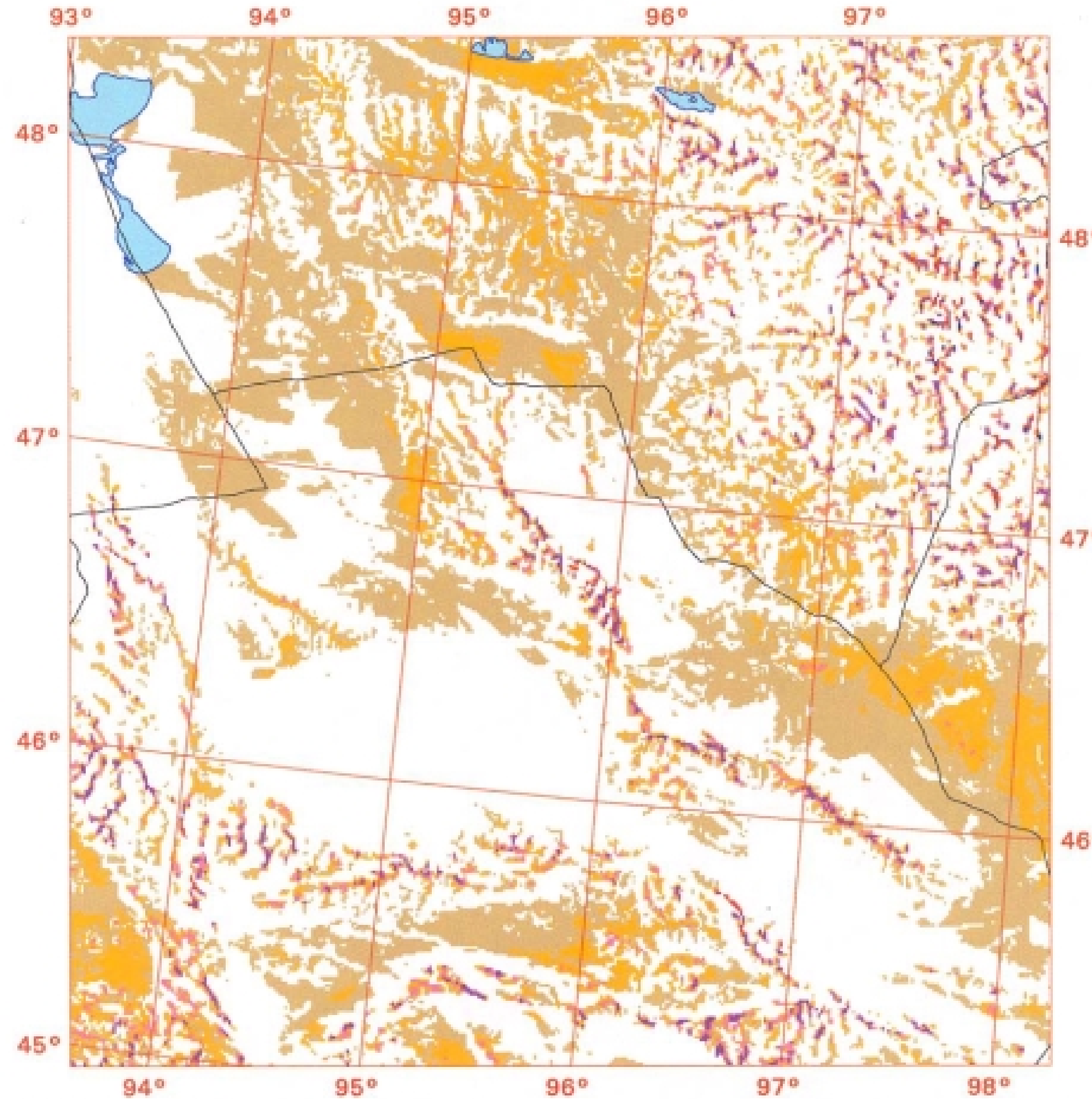
30 0 30 60 90 120 Kilometers

U.S. Department of Energy
National Renewable Energy Laboratory

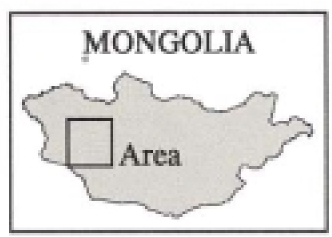
27-DEC-2000 18.6.73

Figure 6-73

Mongolia - Northern Govi-Altai and Southern Zavkhan Wind Resource Map



The wind resource classification is specific for both utility-scale and rural applications and applies to areas with low surface roughness, e.g. grassland.



30 0 30 60 90 120 Kilometers

Wind Power Classification

Resource Potential Utility	Rural	Wind Power Density at 30 m W/m²	Wind Speed[a] at 30 m m/s
Marginal	Moderate	100 - 200	4.5 - 5.6
Moderate	Good	200 - 300	5.6 - 6.4
Good	Excellent	300 - 400	6.4 - 7.1
Excellent		400 - 600	7.1 - 8.1
		600 - 800	8.1 - 8.9
		800 - 1000	8.9 - 9.6

[a] Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8

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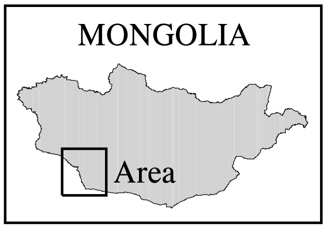
27-DEC-2000 18.6.74

Figure 6-74

Mongolia - Southern Govi-Altai
Political Map



30 0 30 60 90 120 Kilometers

Legend

- ○ Surface Meteorological Station
- □ Upper-Air (Weather-Balloon) Station
- + NREL Wind Measurement Site
- △ TACIS Wind Measurement Site
- ■ Town, **Provincial Capital**, or ***Municipality***

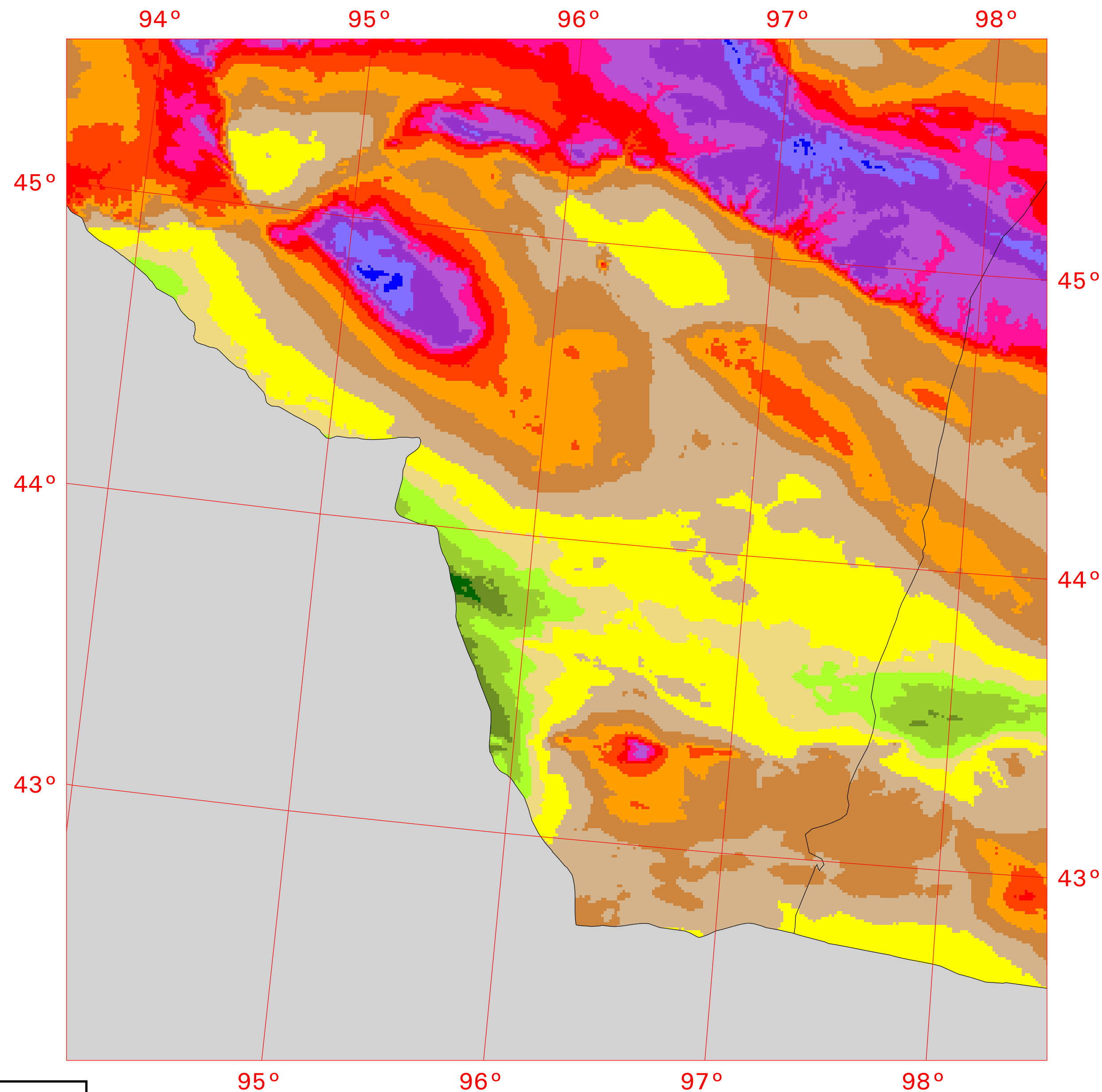
PROVINCE (AIMAG)
Lake (Nuur)

U.S. Department of Energy
National Renewable Energy Laboratory

27-DEC-2000 19.6.75

Figure 6-75

Mongolia - Southern Govi-Altai
Elevation Map



Elevation
Meters

4200	
3500	
3000	
2600	
2400	
2200	
2000	
1800	
1600	
1400	
1200	
1000	
900	
800	
700	
600	
500	

The elevation values are averaged over 1 km^2.

30 0 30 60 90 120 Kilometers

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27-DEC-2000 19.6.76

Figure 6-76

Mongolia - Southern Govi-Altai
Hillshaded Relief Map

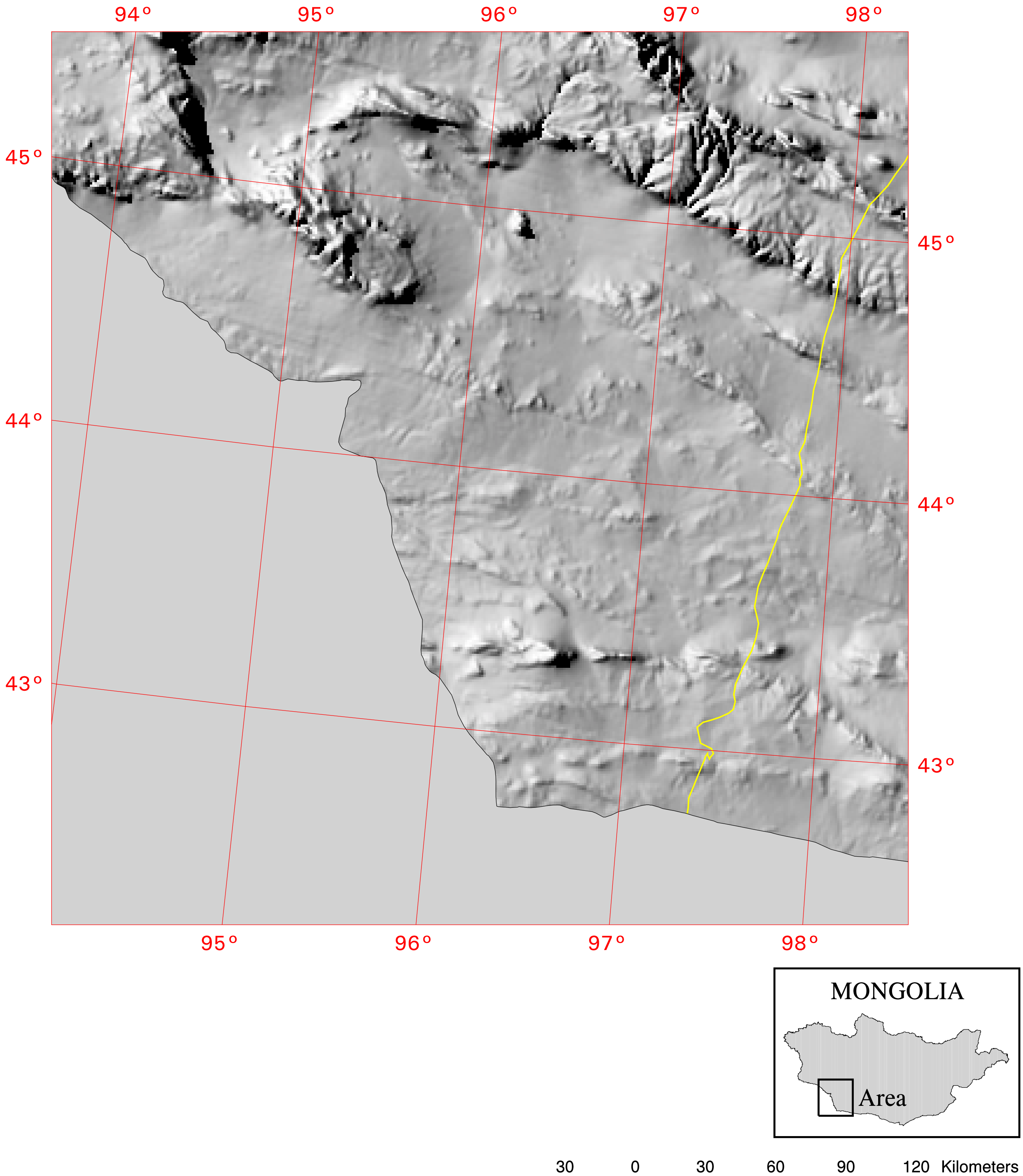

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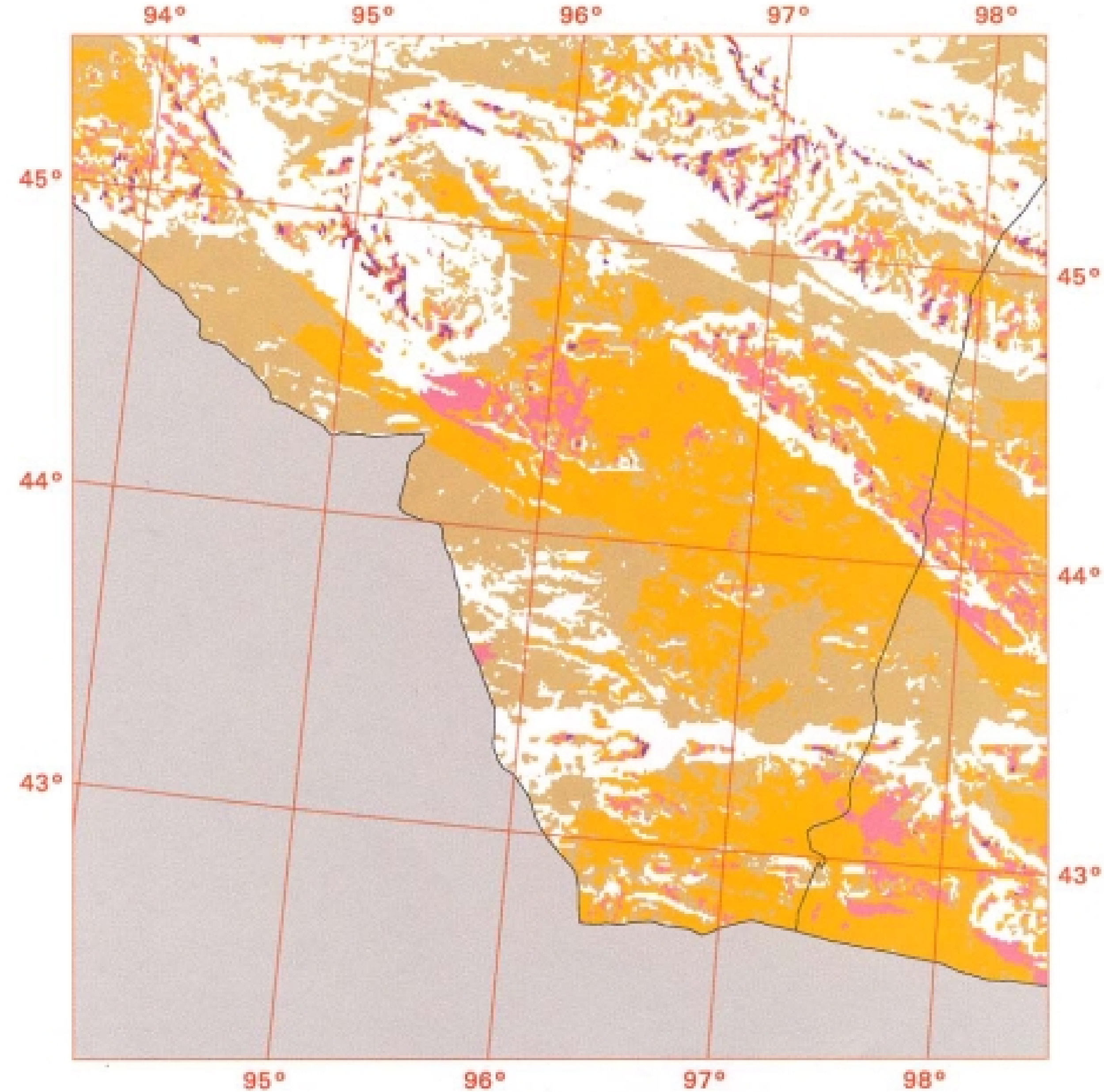
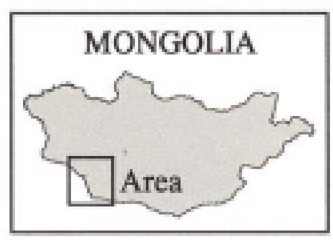
Figure 6-77

Mongolia - Southern Govi-Altai
Wind Resource Map



The wind resource classification is specific for both utility-scale and rural applications and applies to areas with low surface roughness, e.g. grassland.



Wind Power Classification

Resource Potential Utility	Rural	Wind Power Density at 30 m W/m²	Wind Speed[a] at 30 m m/s
Marginal	Moderate	100 - 200	4.5 - 5.6
Moderate	Good	200 - 300	5.6 - 6.4
Good	Excellent	300 - 400	6.4 - 7.1
Excellent		400 - 600	7.1 - 8.1
		600 - 800	8.1 - 8.9
		800 - 1000	8.9 - 9.6

[a]Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8

30 0 30 60 90 120 Kilometers

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27-DEC-2000 19.6.78

Figure 6-78

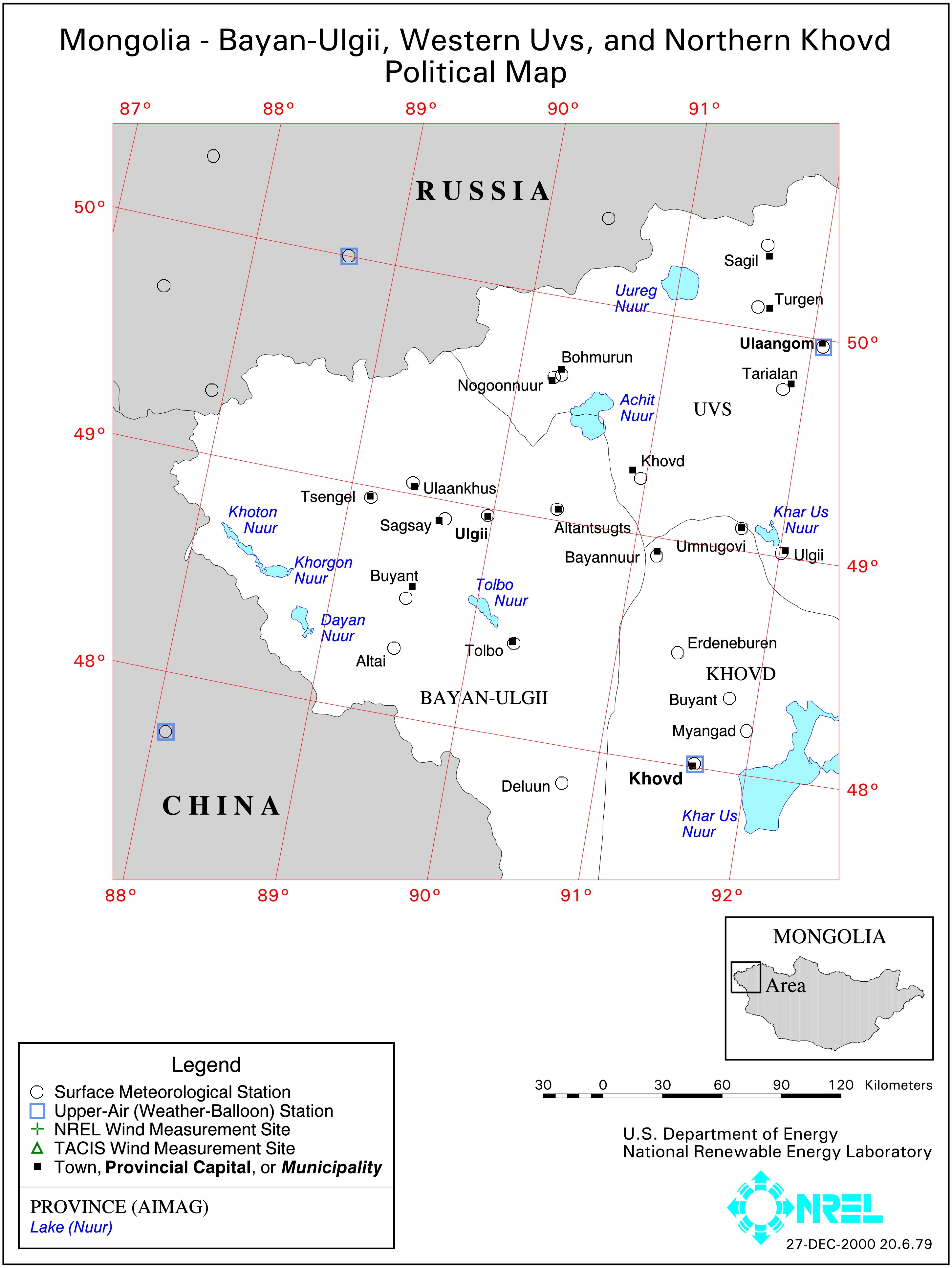
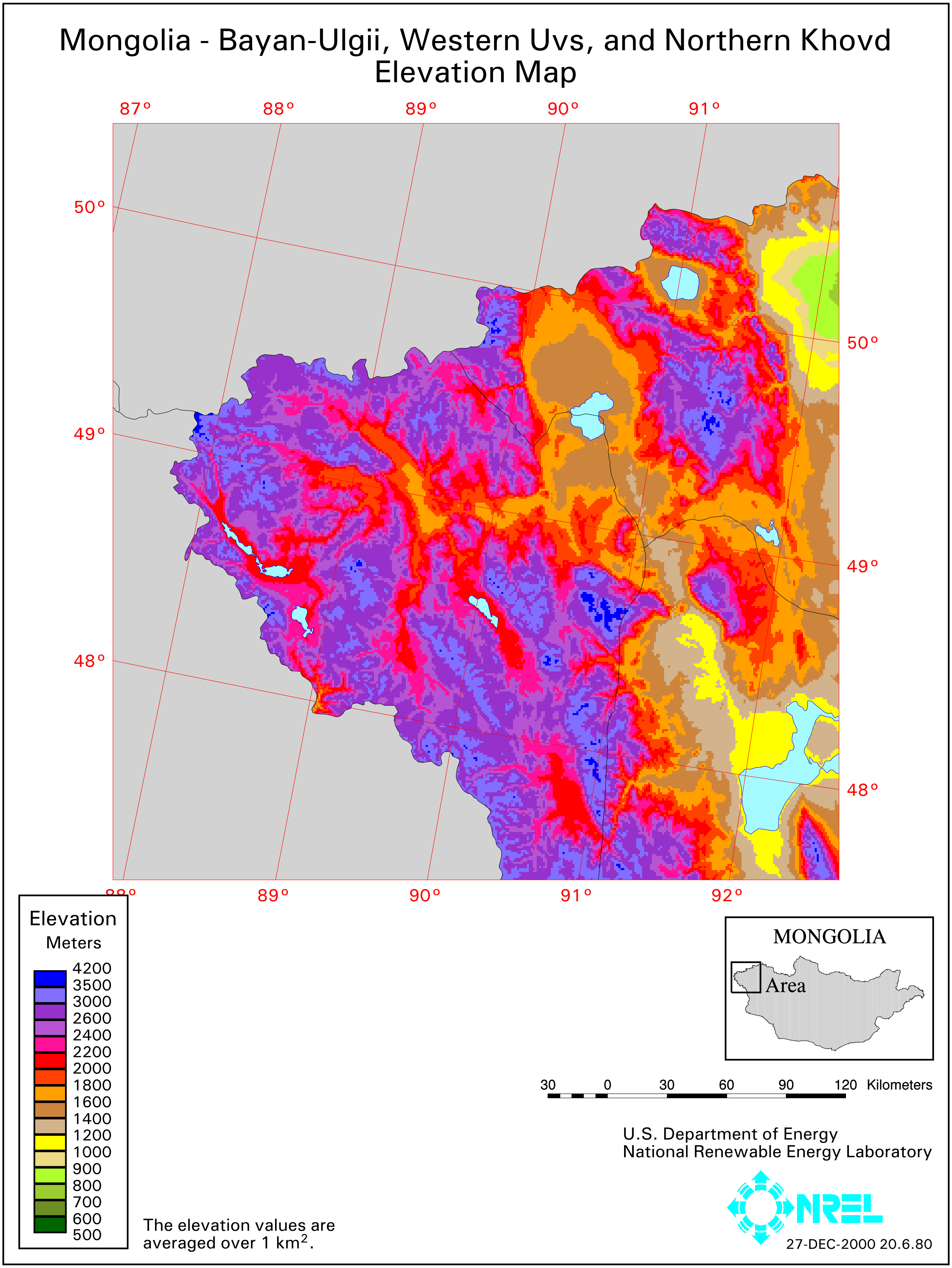

Mongolia - Bayan-Ulgii, Western Uvs, and Northern Khovd
Political Map
87° 88° 89° 90° 91°
50° 49° 48°
88° 89° 90° 91° 92°
RUSSIA
CHINA
UVS
KHOVD
BAYAN-ULGII
Sagil
Turgen
Ulaangom
Tarialan
Bohmurun
Nogoonnuur
Uureg Nuur
Achit Nuur
Khovd
Ulaankhus
Tsengel
Khoton Nuur
Sagsay
Ulgii
Altantsugts
Umnugovi
Khar Us Nuur
Ulgii
Bayannuur
Khorgon Nuur
Buyant
Tolbo Nuur
Dayan Nuur
Altai
Tolbo
Erdeneburen
Buyant
Myangad
Deluun
Khovd
Khar Us Nuur
MONGOLIA
Area
30 0 30 60 90 120 Kilometers
Legend
Surface Meteorological Station
Upper-Air (Weather-Balloon) Station
NREL Wind Measurement Site
TACIS Wind Measurement Site
Town, Provincial Capital, or Municipality
PROVINCE (AIMAG)
Lake (Nuur)
U.S. Department of Energy
National Renewable Energy Laboratory
NREL
27-DEC-2000 20.6.79

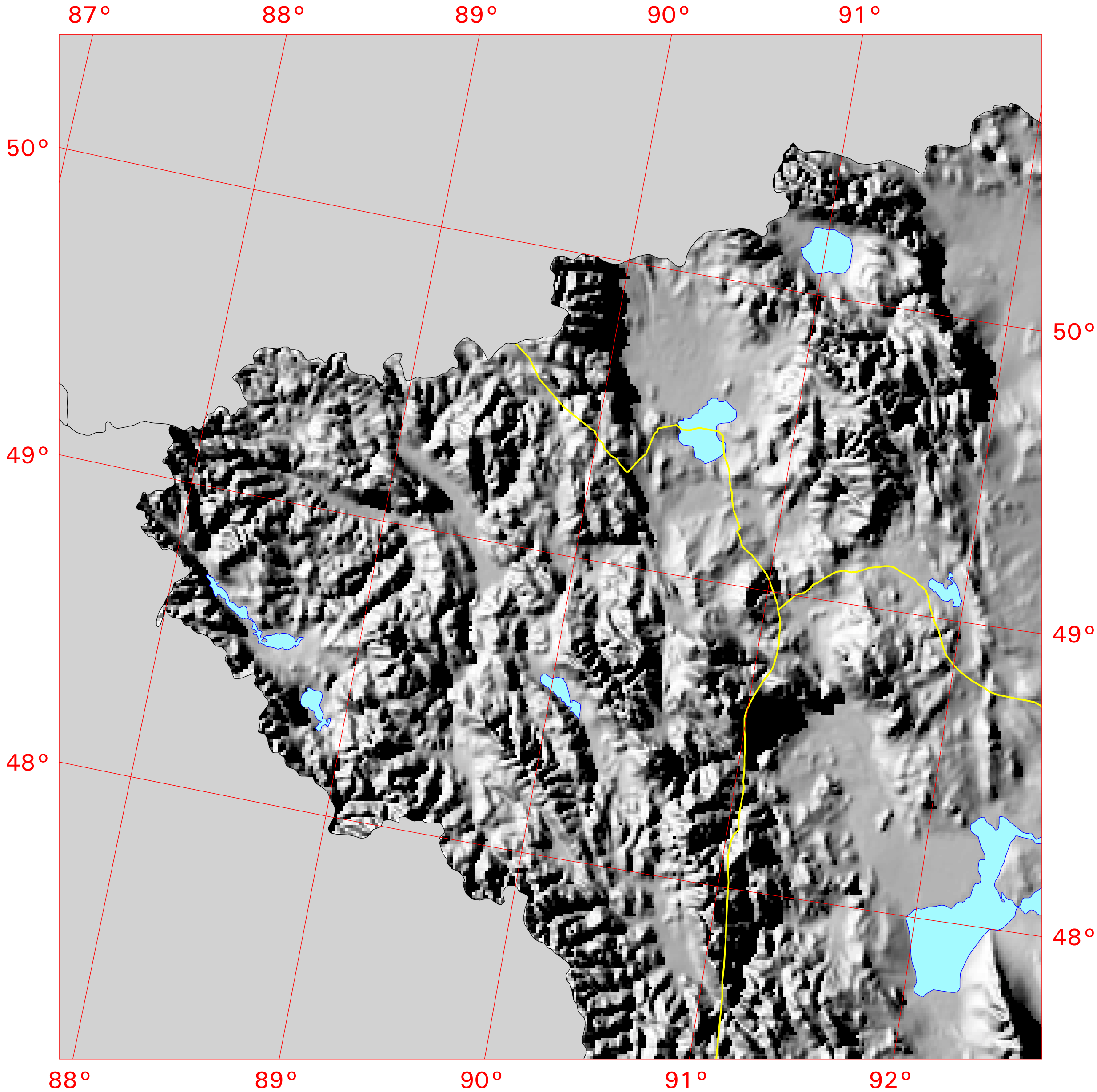
Figure 6-79



Mongolia - Bayan-Ulgii, Western Uvs, and Northern Khovd
Elevation Map
87°
88°
89°
90°
91°
50°
49°
48°
50°
49°
48°
88°
89°
90°
91°
92°
Elevation
Meters
4200
3500
3000
2600
2400
2200
2000
1800
1600
1400
1200
1000
900
800
700
600
500
The elevation values are averaged over 1 km^2.
MONGOLIA
Area
30
0
30
60
90
120
Kilometers
U.S. Department of Energy
National Renewable Energy Laboratory
27-DEC-2000 20.6.80

Figure 6-80

Mongolia - Bayan-Ulgii, Western Uvs, and Northern Khovd
Hillshaded Relief Map



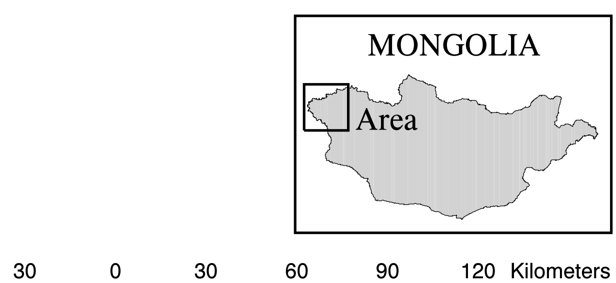


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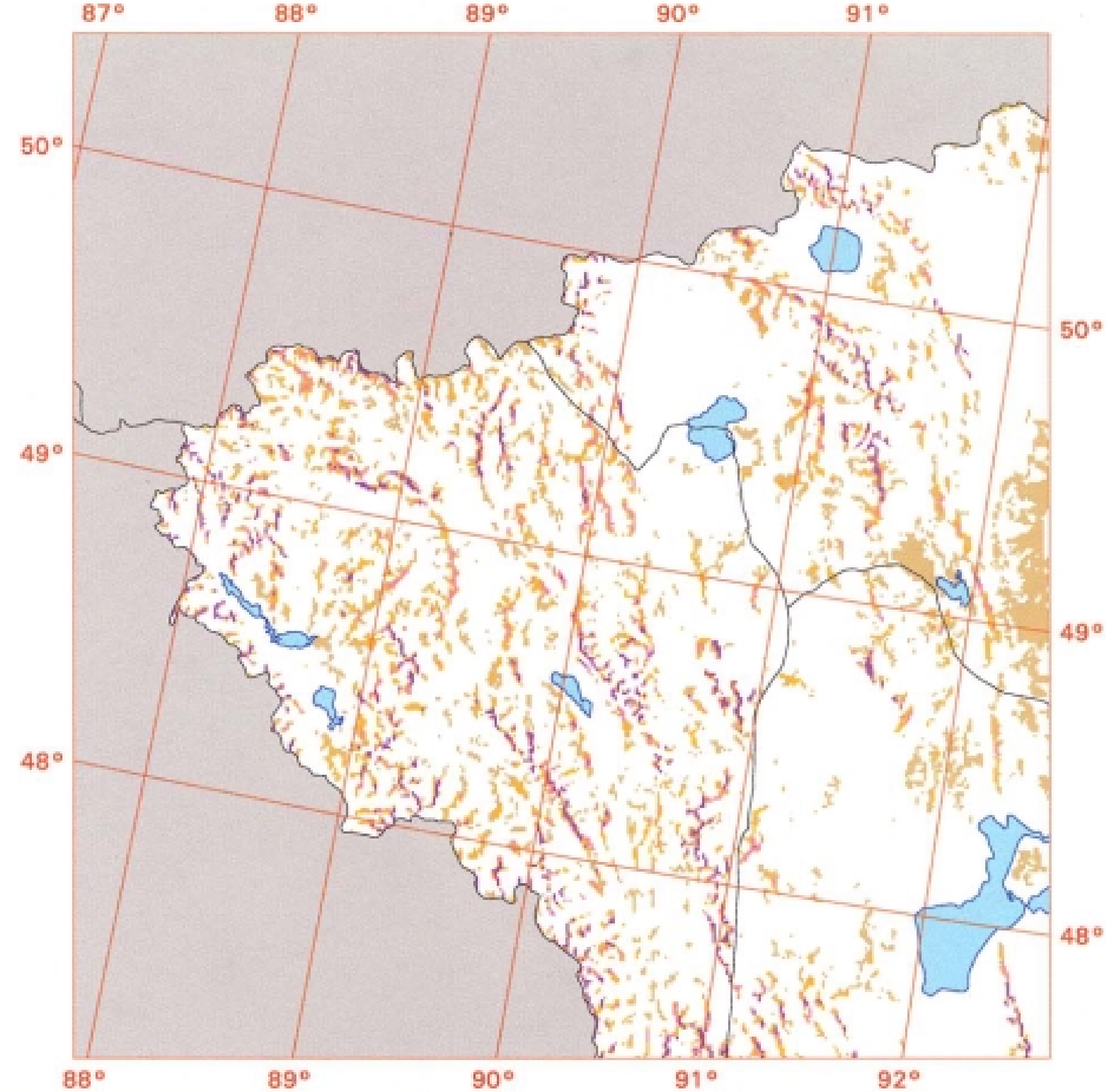
Figure 6-81

Mongolia - Bayan-Ulgii, Western Uvs, and Northern Khovd Wind Resource Map



The wind resource classification is specific for both utility-scale and rural applications and applies to areas with low surface roughness, e.g. grassland.

Wind Power Classification

Resource Potential Utility	Resource Potential Rural	Wind Power Density at 30 m W/m^2	Wind Speed[a] at 30 m m/s
Marginal	Moderate	100 - 200	4.5 - 5.6
Moderate	Good	200 - 300	5.6 - 6.4
Good	Excellent	300 - 400	6.4 - 7.1
Excellent		400 - 600	7.1 - 8.1
		600 - 800	8.1 - 8.9
		800 - 1000	8.9 - 9.6

[a] Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8

30 0 30 60 90 120 Kilometers

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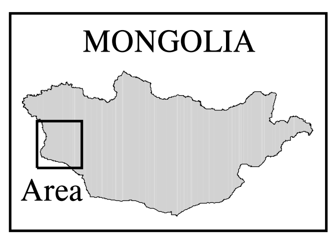
NREL

27-DEC-2000 20.6.82

Figure 6-82

Mongolia - Southern Khovd and Northwestern Govi-Altai Political Map



Legend

- ○ Surface Meteorological Station
- □ Upper-Air (Weather-Balloon) Station
- + NREL Wind Measurement Site
- Δ TACIS Wind Measurement Site
- ■ Town, **Provincial Capital**, or ***Municipality***

PROVINCE (AIMAG)
Lake (Nuur)

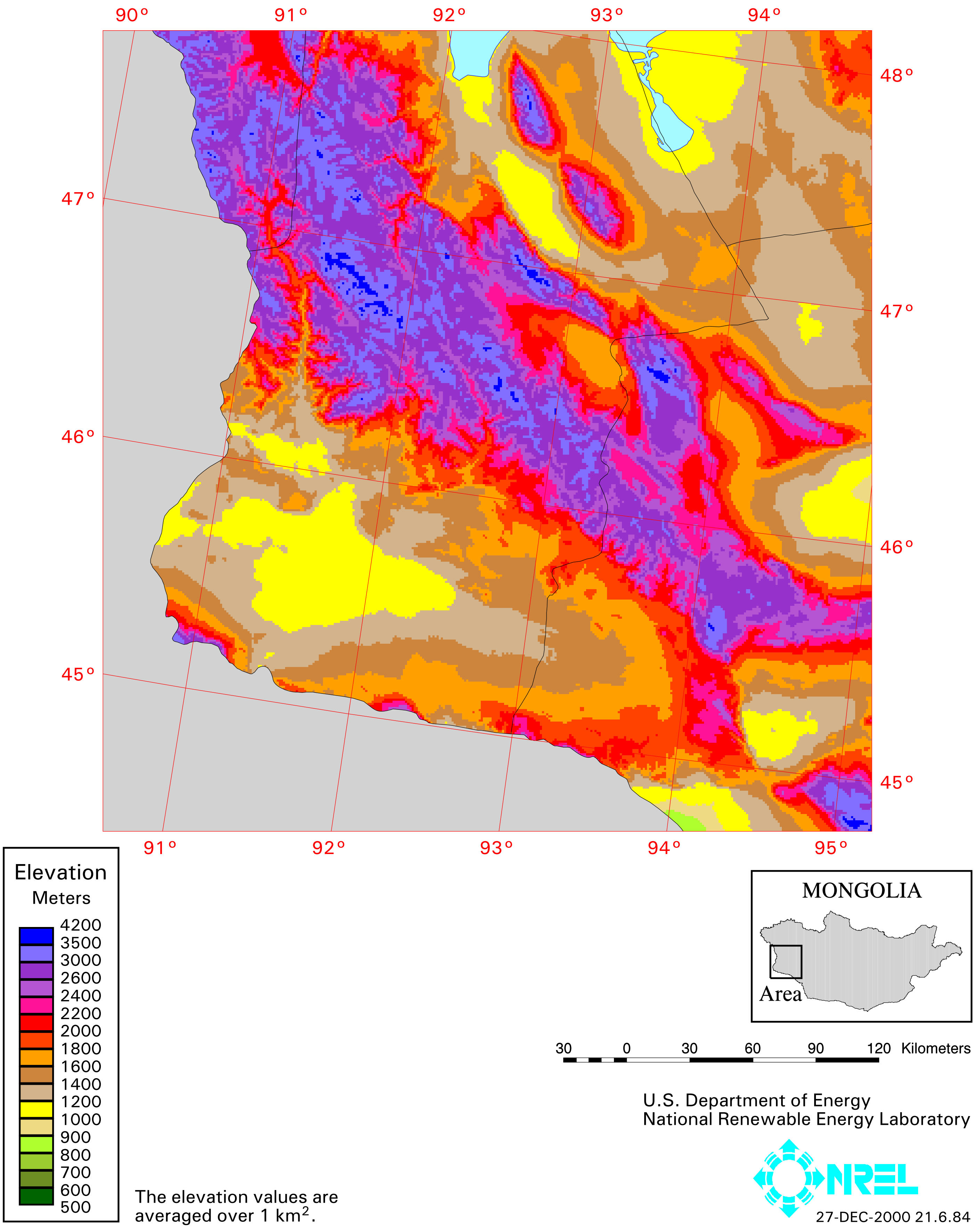
30 0 30 60 90 120 Kilometers

U.S. Department of Energy
National Renewable Energy Laboratory

27-DEC-2000 21.6.83

Figure 6-83

Mongolia - Southern Khovd and Northwestern Govi-Altai Elevation Map



The elevation values are averaged over 1 km^2.

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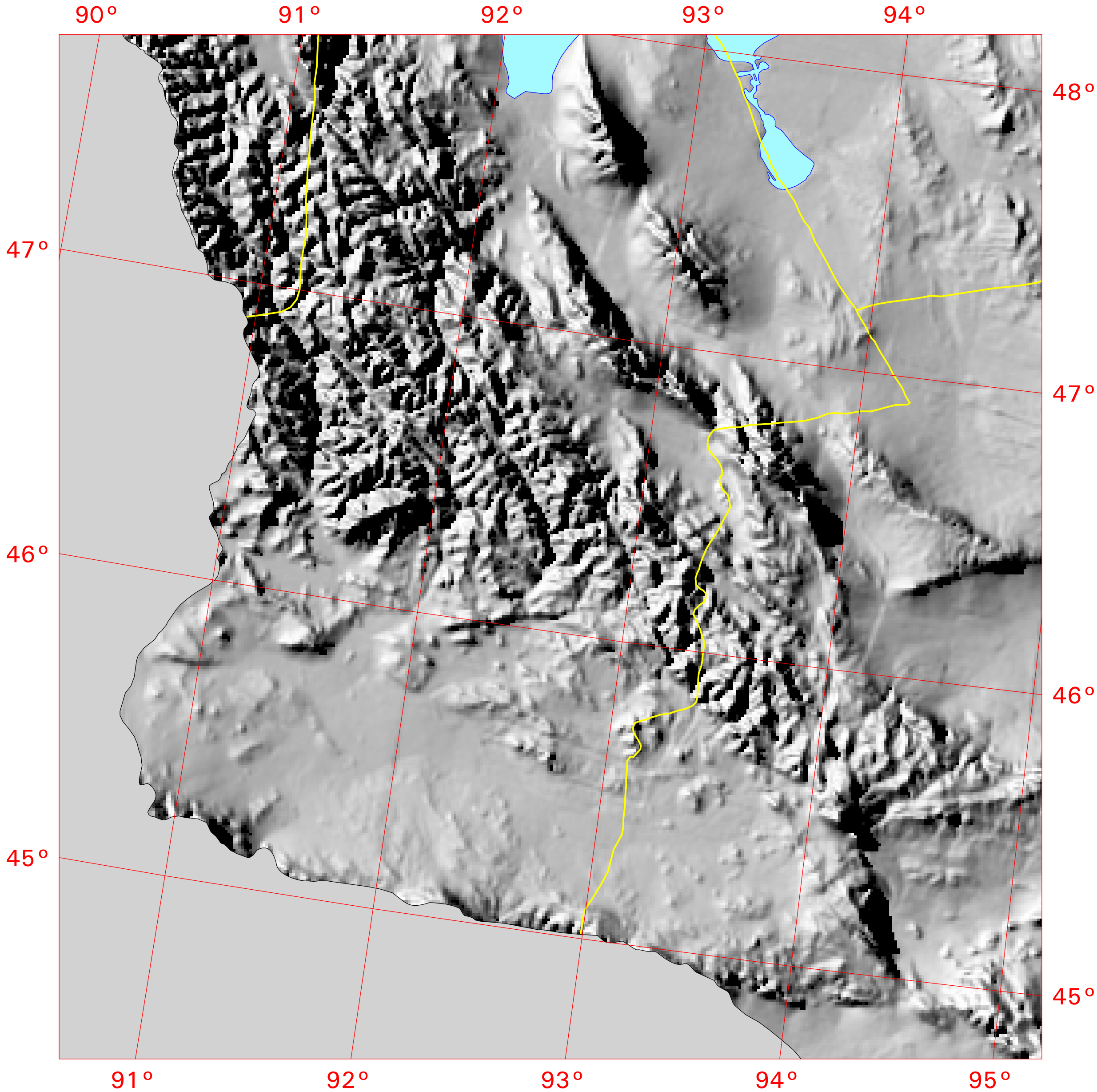
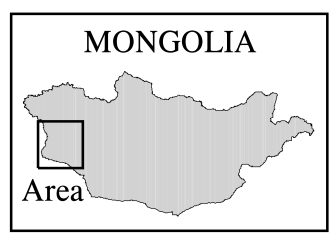
27-DEC-2000 21.6.84

Figure 6-84

Mongolia - Southern Khovd and Northwestern Govi-Altai
Hillshaded Relief Map





30 0 30 60 90 120 Kilometers

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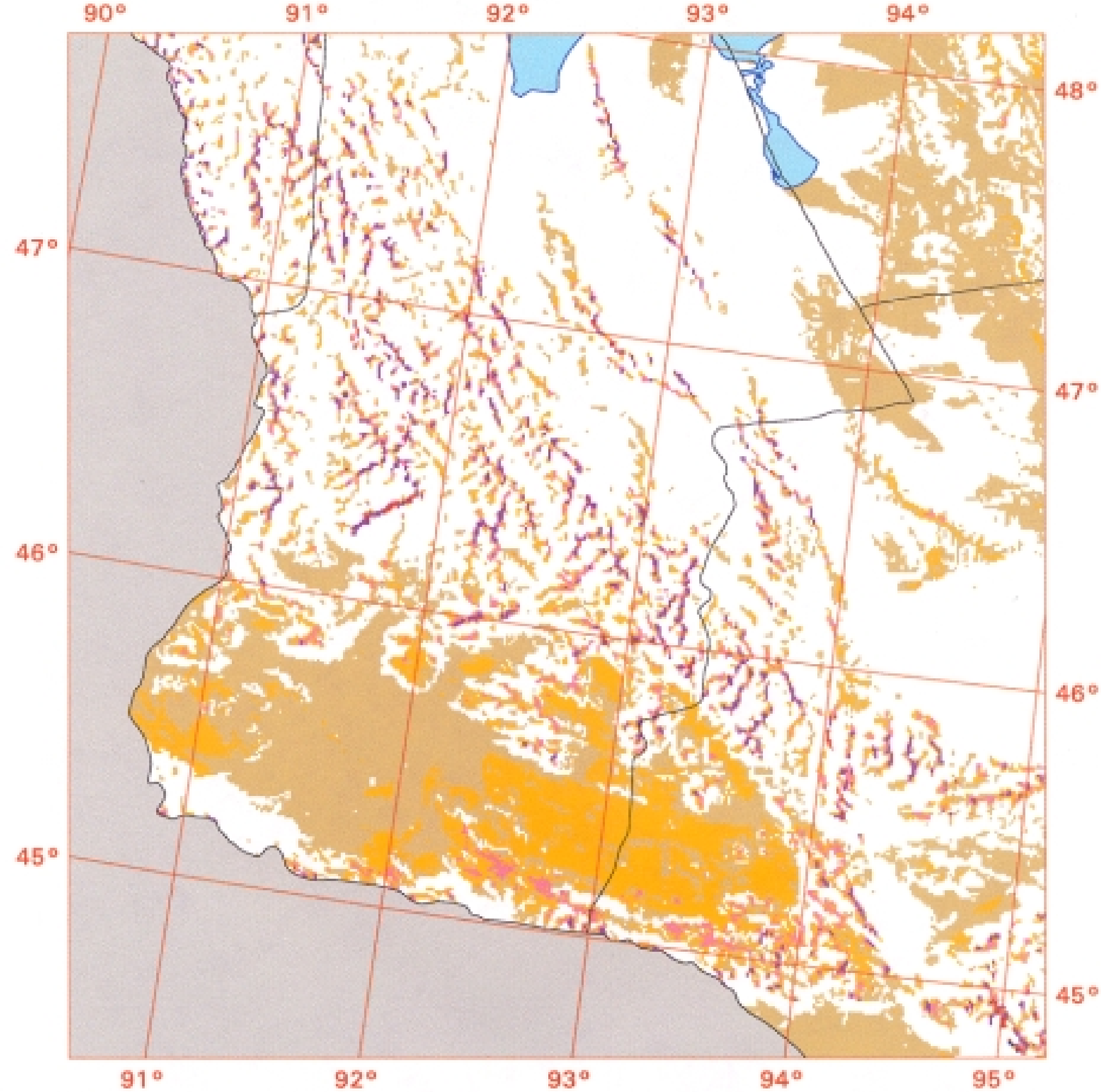
27-DEC-2000 21.6.85

Figure 6-85

Mongolia - Southern Khovd and Northwestern Govi-Altai Wind Resource Map



The wind resource classification is specific for both utility-scale and rural applications and applies to areas with low surface roughness, e.g. grassland.

Wind Power Classification

Resource Potential: Utility	Resource Potential: Rural	Wind Power Density at 30 m W/m^2	Wind Speed[a] at 30 m m/s
Marginal	Moderate	100 - 200	4.5 - 5.6
Moderate	Good	200 - 300	5.6 - 6.4
Good	Excellent	300 - 400	6.4 - 7.1
Excellent		400 - 600	7.1 - 8.1
		600 - 800	8.1 - 8.9
		800 - 1000	8.9 - 9.6

[a]Wind speeds are based on an elevation of 1400 m and a Weibull k value of 1.8

30 0 30 60 90 120 Kilometers

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Figure 6-86

7.0 Wind Electric Potential

7.1 Introduction

The methods for converting the wind resource to wind electric potential were based on those in the report *Renewable Energy Technology Characterizations* (DeMeo and Galdo 1997). The assumptions used for the wind potential calculations are listed at the bottom of Table 7.1.

Each color-coded square kilometer on the map has an assigned annual wind power density at the 30-m height, expressed in units of W/m^2. NREL developed an equation to compute the total net annual energy delivery for grid cells with an annual wind power density of 200 W/m^2 and greater. If the wind power density of a grid cell was less than 200 W/m^2 then the net potential was set equal to zero. Another scenario presented in this section included only those grid cells with an annual average power density of 300 W/m^2 and greater.

The wind resource classifications in Table 7.1 are the same as those shown on the wind resource map of Mongolia. The installed capacity and total power values in the table represent net wind electric potential not reduced by factors such as land-use exclusions. The net energy already has been reduced about 15% to 20% by expected losses such as wind turbine maintenance and wake effects, among other factors.

7.2 Wind Electric Potential Estimates

Over 160,000 km^2 of windy land areas have been estimated to have good-to-excellent wind resource potential. The proportion of windy land and potential wind capacity for each wind power category are listed in Table 7.1. The amount of windy land is about 10% of the total land area (1,565,000 km^2) of Mongolia. This amount of windy land, using conservative assumptions that result in about 7 MW of capacity per km^2, could support over 1,100,000 MW of installed capacity, and potentially deliver over 2.5 trillion kWh per year. Figure 7.1 shows the breakdown of wind potential by aimag for areas with good-to-excellent wind resource. All of the aimags have at least 6,000 MW of wind potential. Thirteen aimags have at least 20,000 MW of wind potential with 9 aimags having greater than 50,000 MW of potential. Umnugovi aimag alone is estimated to have over 300,000 MW of potential. Additional studies are required to more accurately assess the wind electric potential, considering factors such as the existing grid and accessibility.

If additional areas with moderate wind resource potential (or good for rural-power applications) are considered, the estimated total windy land area (as shown in Table 7.1) increases to more than 620,000 km^2, or almost 40% of the total land area of Mongolia. This amount of windy land could support over 4,300,000 MW of installed capacity and potentially deliver over 8 trillion kWh per year. Figure 7.2 shows that there are 15 aimags with at least 50,000 MW, 12 aimags with at least 100,000 MW, and 9 aimags with at least 200,000 MW of wind potential.

Table 7.1 Mongolia – Wind Electric Potential

Good-to-Excellent Wind Resource at 30 m (Utility Scale)

Wind Class	Wind Power at 30 m W/m^2	Wind Speed at 30 m m/s*	Total Area km^2	Percent Windy Land	Total Capacity Installed MW	Total Power GWh/yr
3	300-400	6.4-7.1	130,665	81.3	905,500	1,975,500
4	400-600	7.1-8.1	27,165	16.9	188,300	511,000
5	600-800	8.1-8.9	2,669	1.7	18,500	60,200
6	800-1000	8.9-9.6	142	0.1	1,000	3,400
Total			160,641	100.0	1,113,300	2,550,100

Moderate-to-Excellent Wind Resource at 30 m (Utility Scale)

Wind Class	Wind Power at 30 m W/m^2	Wind Speed at 30 m m/s*	Total Area km^2	Percent Windy Land	Total Capacity Installed MW	Total Power GWh/yr
2	200-300	5.6-6.4	461,791	74.2	3,200,200	5,572,900
3	300-400	6.4-7.1	130,665	21.0	905,500	1,975,500
4	400-600	7.1-8.1	27,165	4.4	188,300	511,000
5	600-800	8.1-8.9	2,669	0.4	18,500	60,200
6	800-1000	8.9-9.6	142	0.0	1,000	3,400
Total			622,432	100.0	4,313,500	8,123,000

***Wind speeds are based on a Weibull k value of 1.8 and an elevation of 1400m**

Assumptions
Turbine Size – 500 kW
Hub Height – 40 m
Rotor Diameter – 38 m
Turbine Spacing – 10D by 5D
Capacity/km^2 – 6.9 MW

Mongolia - Wind Electric Potential

Good-to-Excellent Wind Resource (Utility Scale Classification)

Wind Electric Potential

Megawatts

- 5,000 - 10,000
- 10,000 - 25,000
- 25,000 - 50,000
- 50,000 - 75,000
- 75,000 - 100,000
- 100,000 - 310,000

Mongolia Total - 1,100,000 MW = 1,100 GW

The following assumptions were used in calculating the total potential wind electric capacity installed:

Miniumum wind power - 300 W/m^2
Turbine size - 500 kW
Hub height - 40 m
Roter diameter - 38 m
5D side-to-side spacing - 190 m
10D front-to-back spacing - 380 m
Swept area - 1134 m^2
Turbines/km^2 - 13.9
Capacity/km^2 - 6.9 MW

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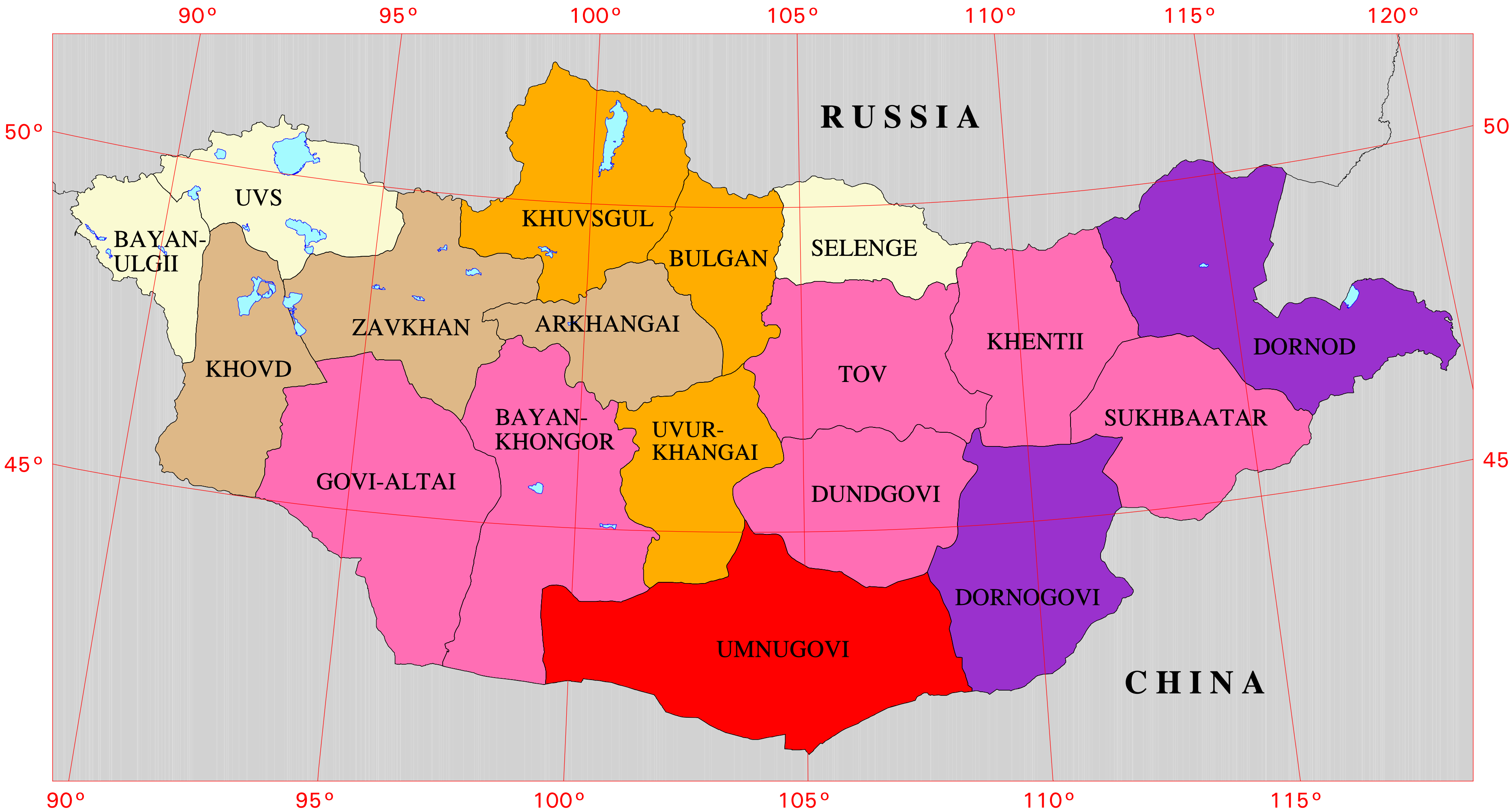
27-DEC-2000 1.7.1

Figure 7-1

Mongolia - Wind Electric Potential

Moderate-to-Excellent Wind Resource (Utility Scale Classification)



150 0 150 300 450 600 Kilometers

Wind Electric Potential
Megawatts

- 10,000 - 50,000
- 50,000 - 100,000
- 100,000 - 200,000
- 200,000 - 400,000
- 400,000 - 600,000
- 600,000 - 850,000

Mongolia Total - 4,300,000 MW = 4,300 GW

The following assumptions were used in calculating the total potential wind electric capacity installed:

Miniumum wind power - 200 W/m^2
Turbine size - 500 kW
Hub height - 40 m
Roter diameter - 38 m
5D side-to-side spacing - 190 m
10D front-to-back spacing - 380 m
Swept area - 1134 m^2
Turbines/km^2 - 13.9
Capacity/km^2 - 6.9 MW

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NREL

27-DEC-2000 1.7.2

Figure 7-2

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Appendix A

Surface Meteorological Stations
Tables and Analysis Summaries of Selected Stations

DATSAV2

Table A.1 Mongolia Stations from DATSAV2 Files

Sainshand Station Summaries
Mandalgovi Station Summaries

IMH

Table A.2 IMH Surface Stations

Provincial

Table A.3 Provincial Meteorological Stations

Table A.1 Mongolia Stations from DATSAV2 Files

WMO Number	Station	Lat	Lon	Elev (m)	From	To	Num Obs	Wind Speed (m/s)	Wind Power (W/m^2)
442030	Rinchinlhumbe	51 07	99 40	1583	04/83	08/98	34800	0.9	20
442031	Name Unknown	51 31	100 40	1652	04/74	11/82	3026	2.0	46
442070	Hatgal	50 25	100 09	1687	03/63	08/98	70893	2.9	62
442120	Ulan-Gom	49 58	92 04	936	07/57	08/98	79949	1.5	21
442130	Baruunturuun	49 38	94 24	1232	01/83	08/98	35947	1.0	19
442131	Name Unknown	49 31	93 47	1920	01/73	12/82	7016	1.1	22
442140	Ulgi	48 58	89 58	1730	01/59	08/98	77487	2.7	75
442150	Umnu-Gobi	49 06	91 43	1591	01/73	08/98	40324	2.0	54
442170	Tolbo	48 25	90 17	N/A	04/73	10/89	4871	1.7	41
442180	Hovdo	48 01	91 39	1406	10/56	08/98	81920	1.2	33
442190	Urgamal	48 31	94 17	N/A	01/75	10/89	2333	2.4	59
442210	Gandan Huryee	49 38	95 46	N/A	04/73	12/80	4432	1.0	18
442250	Tosontsengel	48 43	98 16	1723	01/69	08/98	39857	1.2	20
442251	Name Unknown	48 57	96 46	2134	01/73	02/80	7736	1.4	30
442290	Tariat	48 04	99 32	N/A	01/73	10/89	5059	3.4	56
442300	Tarialan	49 37	102 00	1236	01/83	08/98	37103	2.7	30
442301	Name Unknown	49 57	102 35	1524	01/73	11/82	4813	2.6	43
442310	Muren	49 37	100 10	1288	08/56	08/98	84404	2.1	47
442320	Hutag	49 22	102 42	949	03/63	08/98	71374	1.5	22
442360	Name Unknown	48 51	103 31	1295	10/73	08/78	4188	2.3	41
442370	Erdenemandal	48 31	101 22	1510	01/83	08/98	36746	2.4	46
442371	Name Unknown	48 02	100 28	2134	01/73	12/82	5096	2.9	56
442390	Bulgan	48 47	103 32	1210	08/56	08/98	83098	1.9	42
442400	Bata Sumber	48 25	106 43	1276	01/69	10/89	7877	2.6	57
442410	Barunhara	48 55	106 04	807	08/56	08/98	84439	2.1	41
442420	Hadatyn	49 27	107 12	762	01/73	10/89	5104	1.3	24
442430	Ulygaiin Dugang	49 49	107 43	883	01/73	10/89	7368	1.2	24
442450	Dzuunharaa	48 52	106 28	N/A	04/74	12/78	2631	1.5	33
442540	Tataal	48 51	111 27	N/A	03/63	10/89	12440	2.6	59
442560	Dashbalbar	49 32	114 24	705	12/83	08/98	32562	3.3	105
442570	Binder	48 37	110 35	747	08/56	10/89	23671	2.7	81
442590	Choibalsan	48 04	114 30	756	08/56	08/98	83796	3.8	130
442650	Most	46 40	92 49	2134	03/63	08/98	38586	1.2	25
442652	Name Unknown	46 40	92 49	2134	01/73	08/79	6512	1.5	32
442660	Tonhil	46 19	93 54	N/A	10/73	10/89	4052	2.7	73
442720	Uliastai	47 45	96 50	1753	09/56	08/98	83619	1.3	19
442750	Bayanbulag	46 49	98 04	2255	10/83	08/98	36704	2.1	52
442752	Name Unknown	46 47	97 12	2140	11/74	08/80	2357	2.2	64
442770	Altai	46 23	96 15	2147	08/56	08/98	85695	3.4	114
442780	Delger	46 22	97 22	N/A	10/73	07/89	3751	3.2	105
442820	Tsetserleg	47 27	101 28	1712	08/56	08/98	83621	2.4	50
442840	Galut	46 42	100 07	2117	07/57	08/98	76249	1.3	27
442850	Huzhirt	46 53	102 46	1675	04/58	08/98	76117	1.7	43
442860	Bat Oldziy Bund	46 58	103 47	1250	01/73	10/89	4894	2.6	64
442870	Baianhongor	46 07	100 40	1879	03/63	08/98	73415	2.8	62
442880	Arbaiher	46 16	102 46	1832	08/56	08/98	85186	3.7	138
442900	Lung	47 52	105 15	N/A	08/56	09/89	15686	3.1	94
442920	Ulan-Bator	47 55	106 58	1316	08/56	08/98	86241	2.5	52

442930	Name Unknown	47 49	108 30	N/A	08/56	12/58	2000	2.6	66
442940	Manit	47 17	107 28	1439	08/56	08/98	81114	3.4	100
442980	Choir	46 27	108 13	1285	08/56	08/98	85411	3.1	79
443020	Bayan-Ovoo	47 46	112 07	926	01/69	08/98	39235	3.6	112
443021	Name Unknown	47 37	112 24	N/A	01/73	05/81	8215	3.6	112
443040	Underhan	47 19	110 40	1029	08/56	08/98	84479	3.7	102
443050	Barum-Urt	46 40	113 16	986	01/60	08/98	74762	3.6	114
443130	Hushuu Sume	47 19	119 01	1067	10/83	08/98	29730	3.0	86
443132	Name Unknown	47 19	119 01	1067	04/73	08/81	2530	3.2	104
443140	Matad	47 08	115 31	911	08/75	08/98	56071	4.0	141
443150	Name Unknown	47 13	117 19	642	01/73	12/75	2641	3.7	100
443170	Erdene-Tsagaan	45 55	115 22	1067	01/73	05/88	4692	5.2	186
443250	Erdeni	45 08	97 46	N/A	03/63	10/89	14415	2.3	83
443290	Amar Buyantayn	44 37	98 42	2103	10/73	10/89	4388	2.8	86
443360	Saikhan-Ovoo	45 27	103 54	1329	10/83	08/98	33719	2.8	77
443362	Name Unknown	45 15	104 47	853	01/73	11/78	3983	3.0	107
443410	Mandalgovi	45 46	106 16	1398	08/56	08/98	83729	4.5	212
443470	Tsgot-Ovo	44 25	105 19	1298	01/69	08/98	67789	3.9	131
443480	Bayan Dobo Suma	44 34	107 10	N/A	11/73	10/89	4145	3.8	131
443520	Bajndelger	45 43	112 22	1096	10/56	08/98	74976	4.5	157
443540	Sainshand	44 53	110 07	936	08/56	08/98	82912	4.4	193
443580	Zamiin Ude	43 43	111 54	962	08/56	08/98	80306	2.9	98
443730	Dalanzadgad	43 34	104 25	1470	08/56	08/98	83634	3.6	138
443740	Shine Usa	42 53	100 13	1494	01/73	10/89	4746	3.3	113
443860	Name Unknown	43 10	109 13	N/A	01/73	05/87	4038	4.0	148

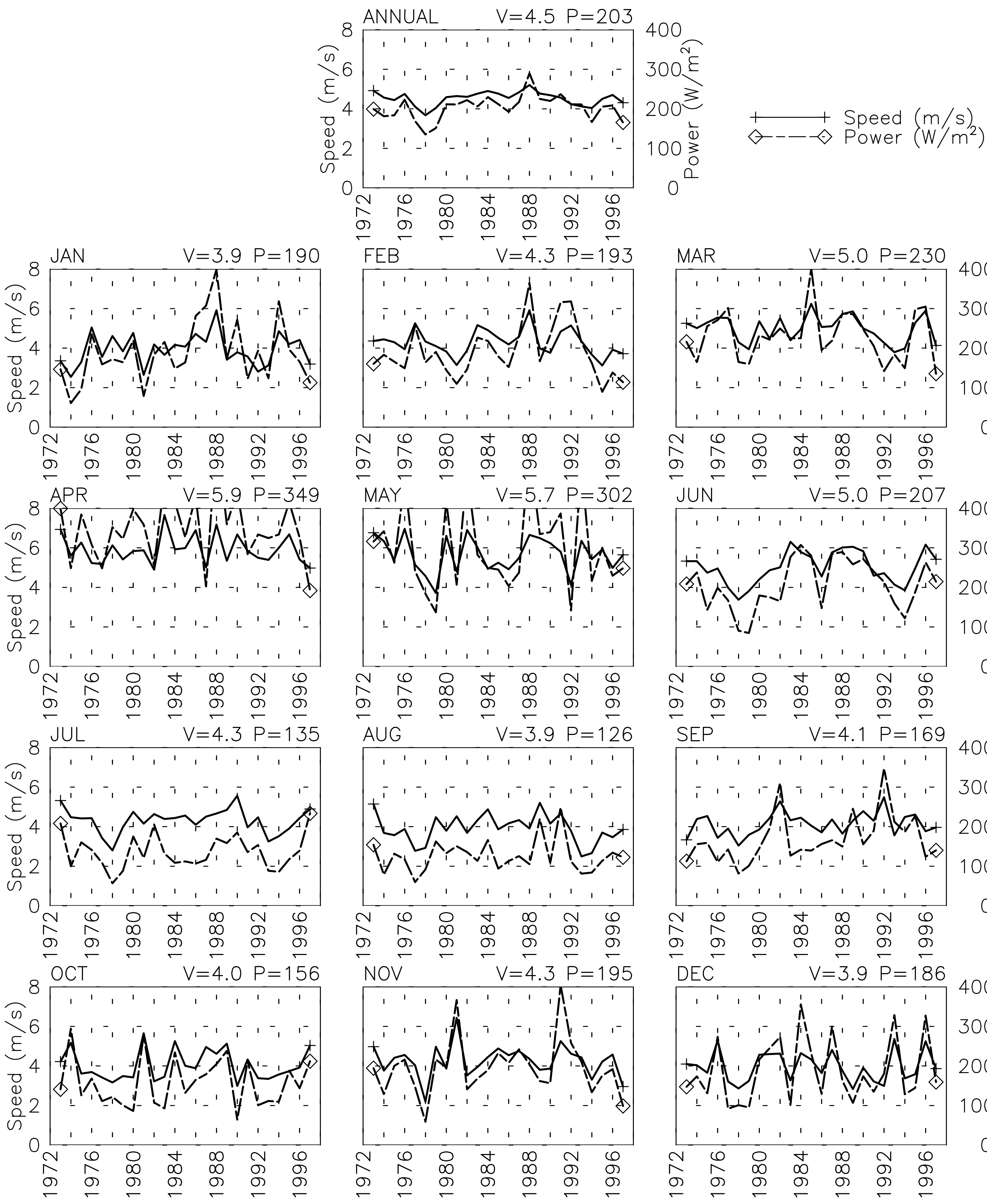
Latitude (Lat) and longitude (Lon) are in degrees and minutes.
Num Obs is the number of observations during the period of record.

SPEED AND POWER BY YEAR

SAINSHAND MO – 443540

44° 54' N 110° 07' E – Elev 936m *LST=GMT +8 hours NT= +7

01/73–12/97



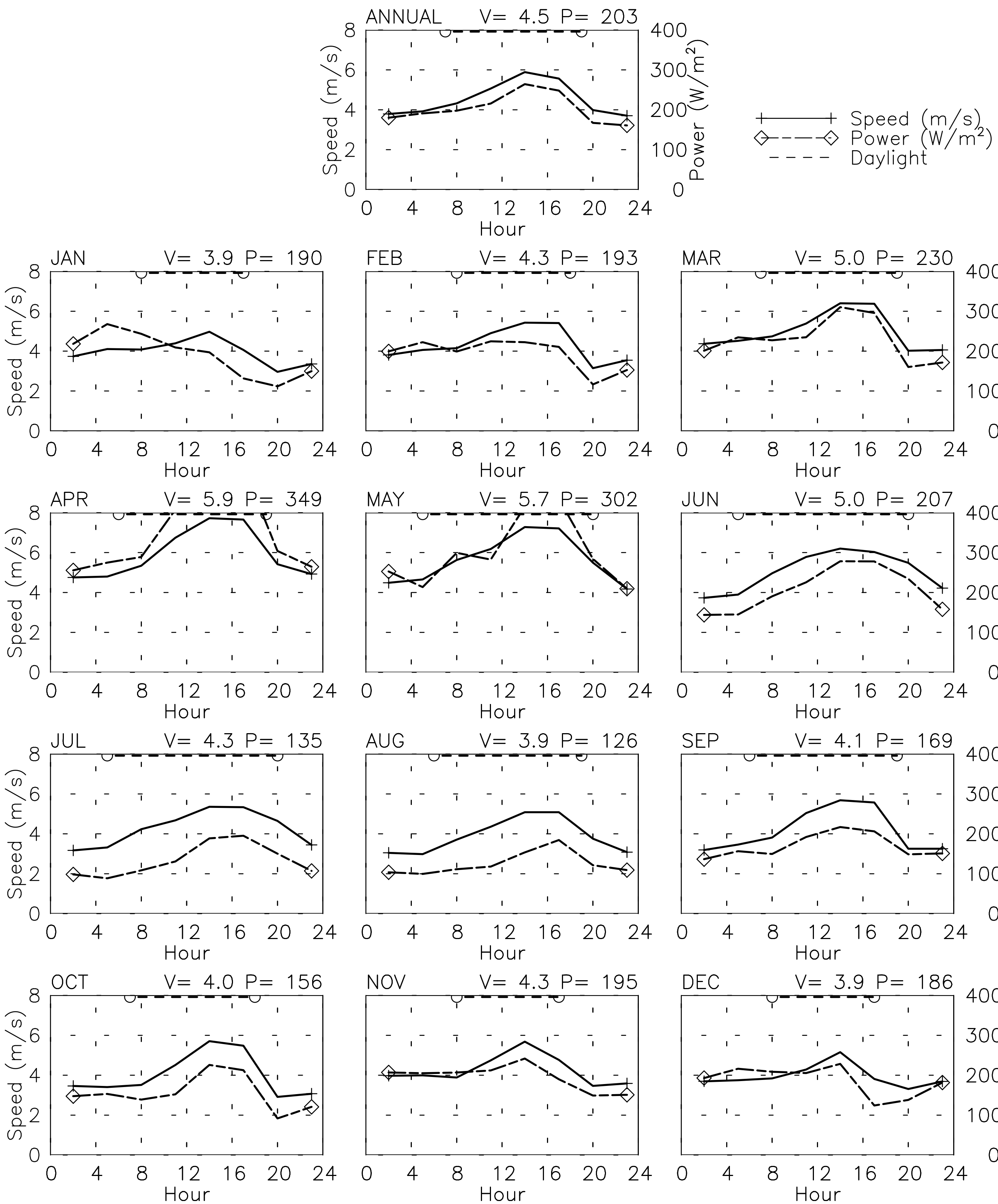
Wed Apr 11 17:35:19 2001

SPEED AND POWER BY HOUR

SAINSHAND MO – 443540

44° 54' N 110° 07' E – Elev 936m *LST=GMT +8 hours NT= +7

01/73–12/97



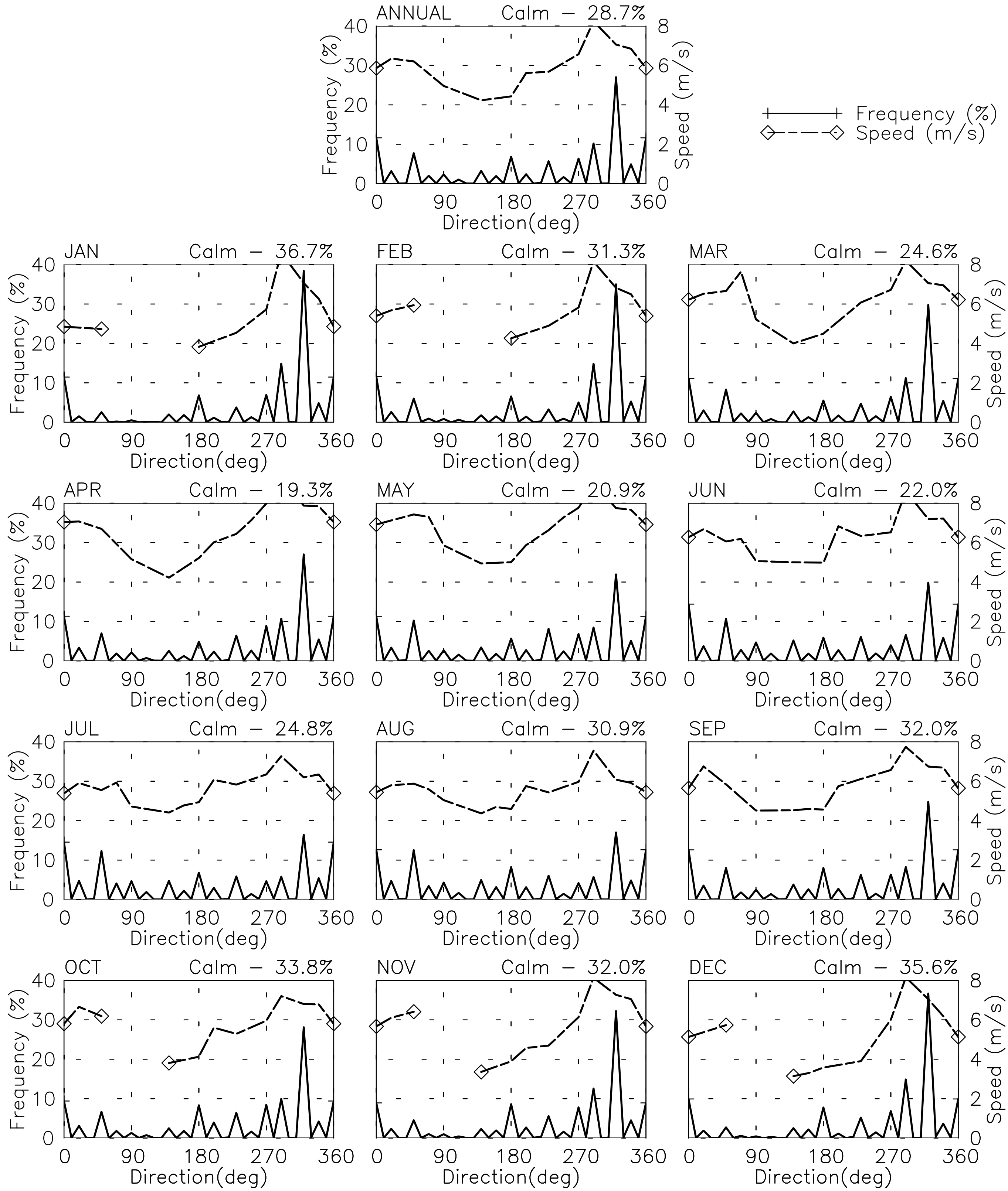
Wed Apr 11 17:35:23 2001

FREQUENCY AND SPEED BY DIRECTION

SAINSHAND MO – 443540

44° 54' N 110° 07' E – Elev 936m *LST=GMT +8 hours NT= +7

01/73–12/97



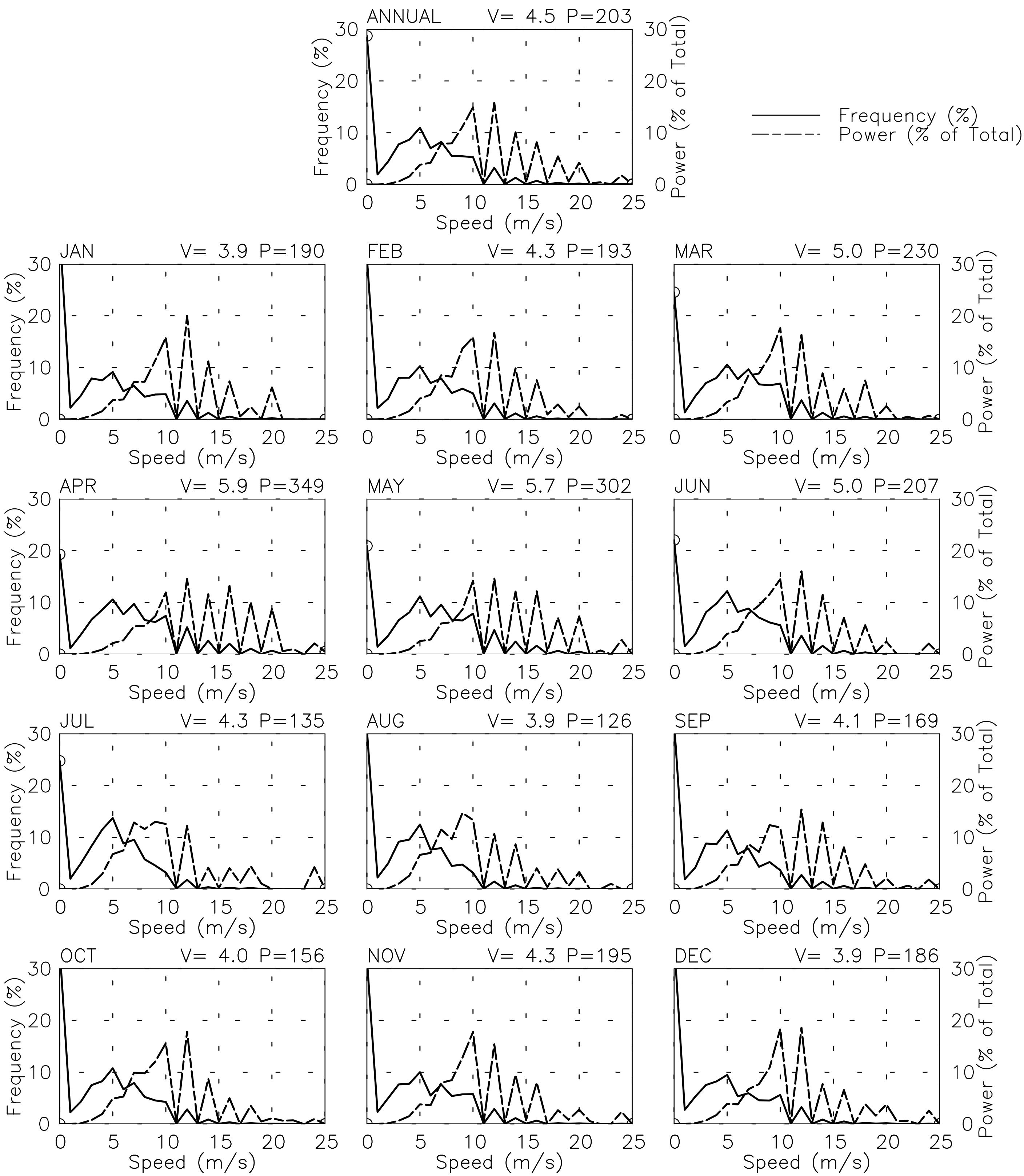
Wed Apr 11 17:35:27 2001

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

SAINSHAND MO – 443540

44° 54' N 110° 07' E – Elev 936m *LST=GMT +8 hours NT= +7

01/73–12/97



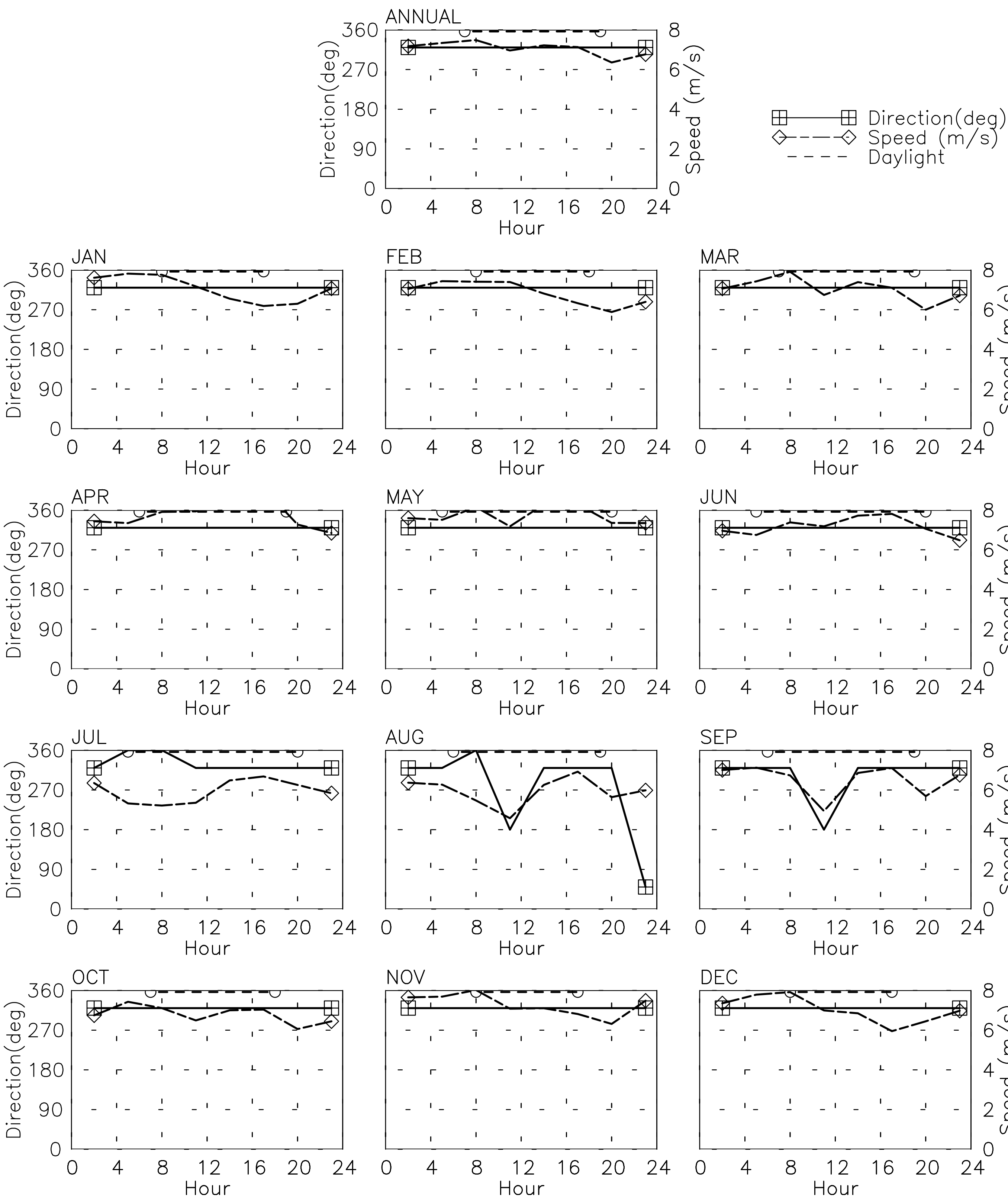
Wed Apr 11 17:35:30 2001

PREVAILING DIRECTION & SPEED BY HOUR

SAINSHAND MO - 443540

44° 54' N 110° 07' E - Elev 936m *LST=GMT +8 hours NT= +7

01/73-12/97



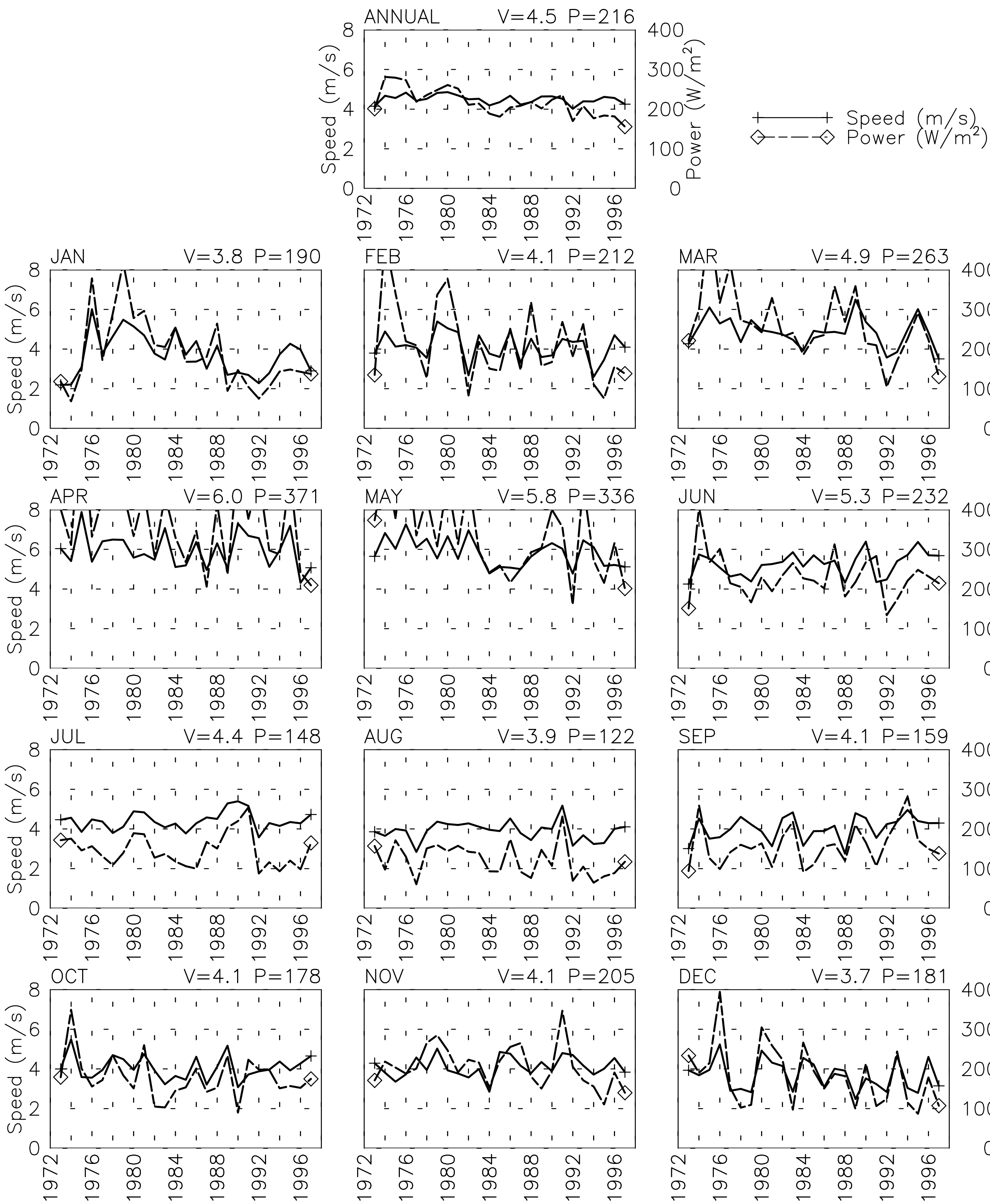
Wed Apr 11 17:35:33 2001

SPEED AND POWER BY YEAR

MANDALGOVI MO – 443410

45° 46' N 106° 17' E – Elev 1398m *LST=GMT +8 hours NT= +7

01/73–12/97



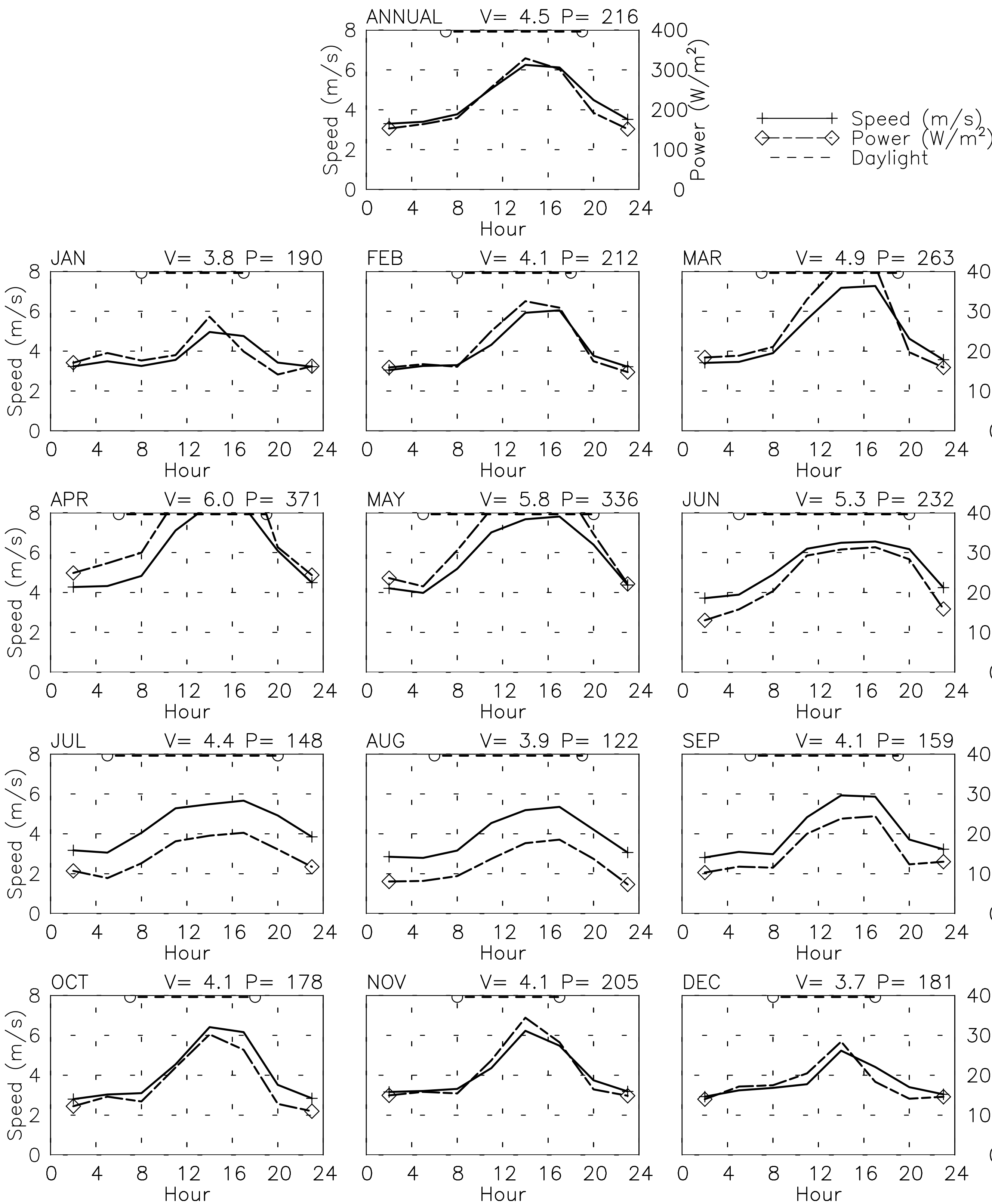
Wed Apr 11 17:34:49 2001

SPEED AND POWER BY HOUR

MANDALGOVI MO – 443410

45° 46' N 106° 17' E – Elev 1398m *LST=GMT +8 hours NT= +7

01/73–12/97



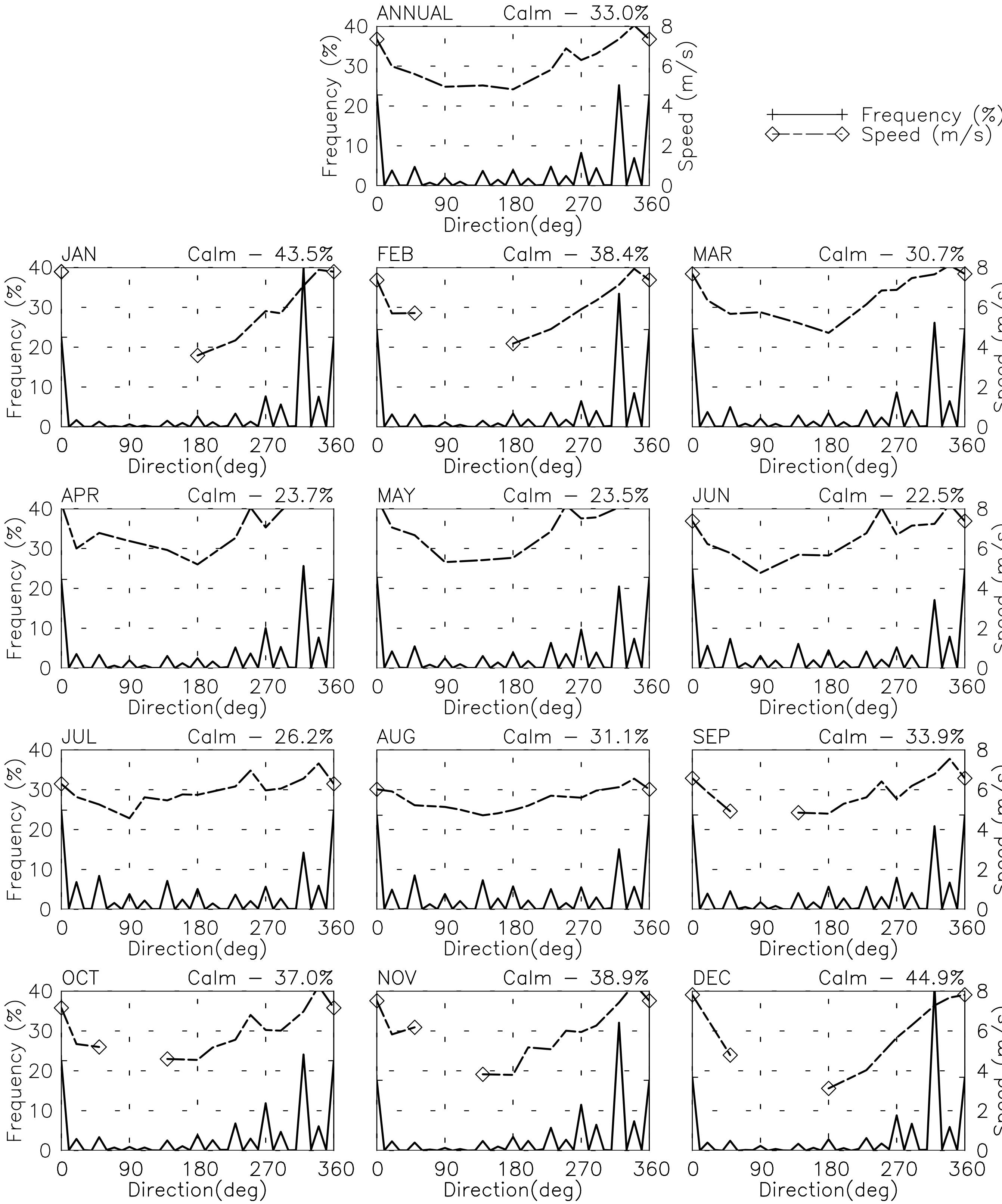
Wed Apr 11 17:34:53 2001

FREQUENCY AND SPEED BY DIRECTION

MANDALGOVI MO – 443410

45° 46' N 106° 17' E – Elev 1398m *LST=GMT +8 hours NT= +7

01/73–12/97



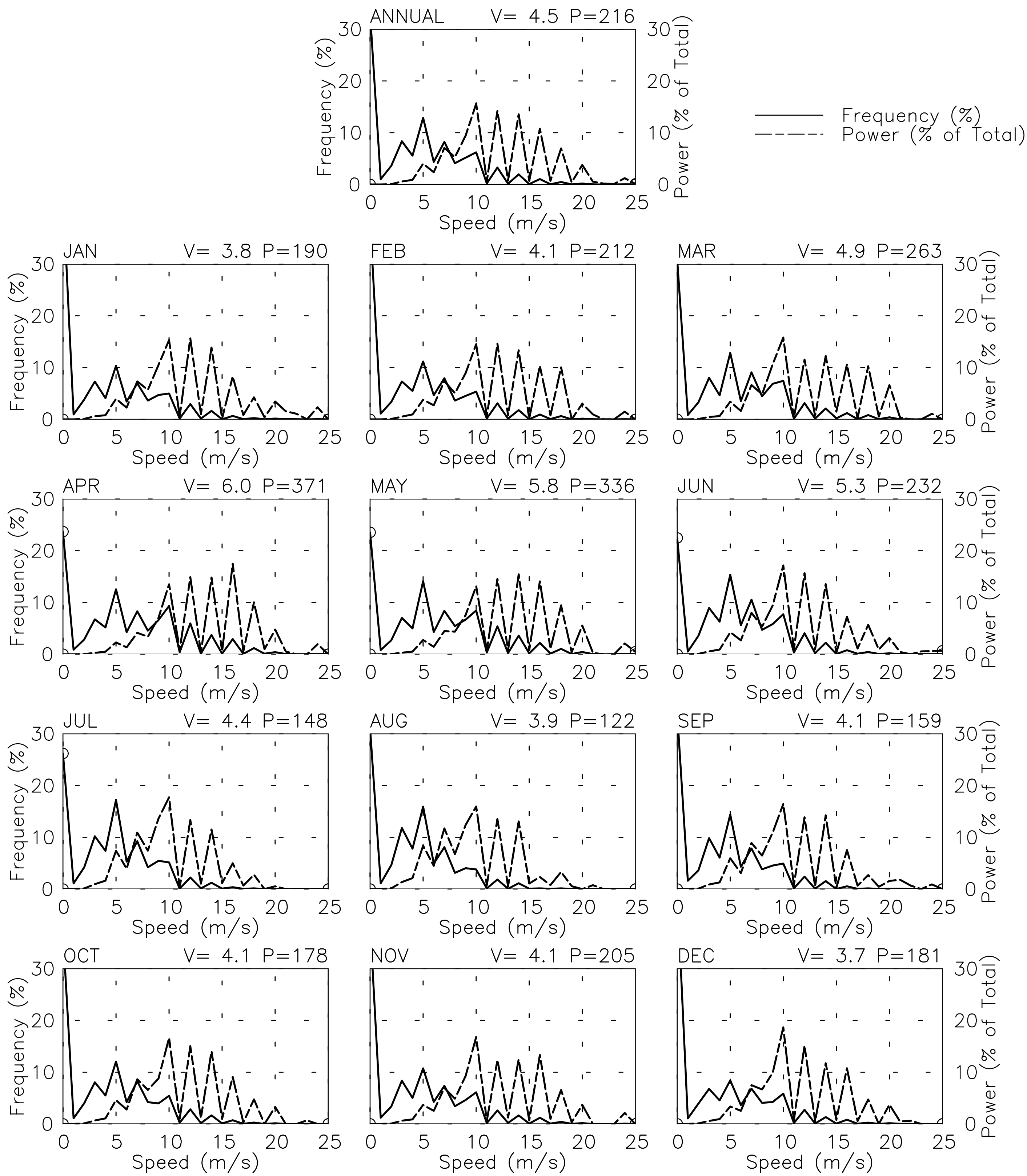
Wed Apr 11 17:34:57 2001

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

MANDALGOVI MO – 443410

45° 46' N 106° 17' E – Elev 1398m *LST=GMT +8 hours NT= +7

01/73–12/97



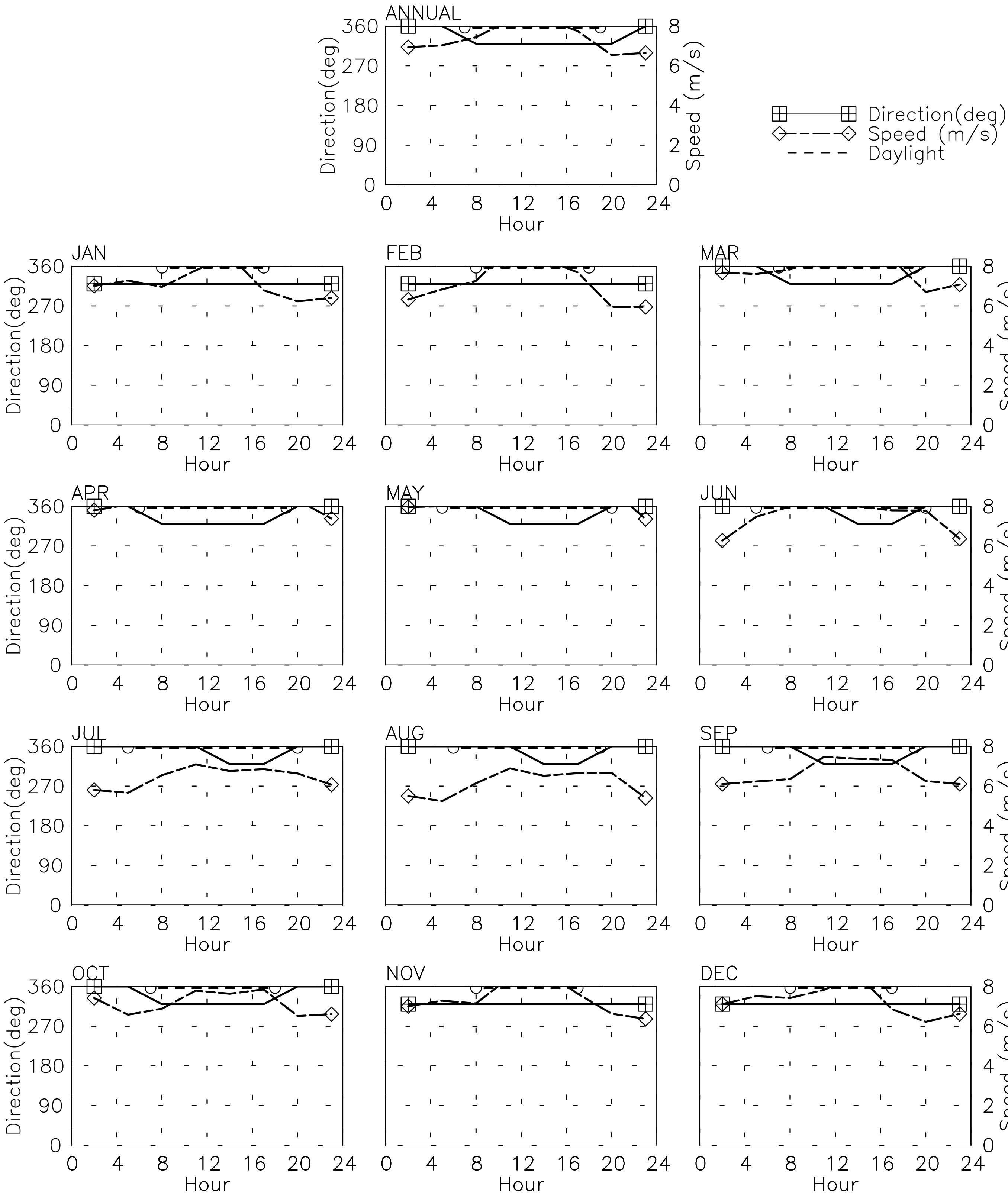
Wed Apr 11 17:35:00 2001

PREVAILING DIRECTION & SPEED BY HOUR

MANDALGOVI MO - 443410

45° 46' N 106° 17' E - Elev 1398m *LST=GMT +8 hours NT= +7

01/73-12/97



Wed Apr 11 17:35:03 2001

Table A.2 IMH Surface Stations

Name	Aimag	Lat	Lon	Elev (m)	Start Date	End Date	% Data	WS (m/s)
Battsengel	Arkhangai	47 46	102 00	1451	01/75	12/89	82%	2.76
Chuluut	Arkhangai	47 30	100 12	2032	01/75	12/89	93%	2.40
Erdenemandal	Arkhangai	48 30	101 24	1509	01/75	12/86	100%	2.71
Khangai	Arkhangai	47 46	99 24	2130	01/75	12/89	92%	2.52
Khotont	Arkhangai	47 22	102 16	1400	01/75	12/89	85%	2.30
Taikhar	Arkhangai	47 34	101 12	N/A	01/75	12/89	91%	3.55
Tariat	Arkhangai	48 12	99 54	2055	01/75	12/86	100%	3.00
Tsehkher	Arkhangai	47 30	102 52	N/A	01/75	10/89	91%	2.48
Tsetserleg	Arkhangai	47 22	101 30	1695	01/75	12/85	100%	2.45
Tsetserleg-Khujirt	Arkhangai	48 52	101 12	1700	01/75	11/89	91%	4.33
Tuvshruuleh	Arkhangai	47 22	101 52	N/A	01/75	12/89	90%	2.68
Ulziit	Arkhangai	48 04	102 32	N/A	01/75	12/89	88%	2.33
Duchinjil	Bayan-Ulgii	46 52	91 04	1951	01/77	12/86	100%	2.13
Jalalt	Bayan-Ulgii	N/A	N/A	N/A	01/75	12/86	100%	1.43
Nogoonnuur	Bayan-Ulgii	49 36	90 24	1480	01/85	12/86	100%	1.87
Ulgii	Bayan-Ulgii	49 00	90 00	1715	01/75	12/85	100%	2.37
Baidrag	Bayankhongor	47 12	99 34	2200	01/75	12/89	97%	2.24
Bayan-ovoo	Bayankhongor	46 16	100 28	N/A	01/75	12/89	90%	2.44
Bayan-undur	Bayankhongor	44 45	98 39	N/A	01/75	12/89	96%	5.21
Bayanbulag	Bayankhongor	46 46	98 04	2255	01/75	12/86	100%	2.34
Bayangovi	Bayankhongor	44 37	100 22	N/A	01/75	12/89	97%	3.36
Bayankhongor	Bayankhongor	46 06	100 42	1859	01/75	12/85	100%	2.66
Bayanlig	Bayankhongor	44 30	100 49	N/A	01/75	12/89	97%	4.04
Bayansair	Bayankhongor	45 32	99 25	N/A	01/75	12/89	95%	2.47
Bayantsagaan	Bayankhongor	45 00	98 55	N/A	01/75	12/89	95%	4.04
Bodi	Bayankhongor	45 23	100 34	N/A	01/75	12/89	95%	4.11
Bogd	Bayankhongor	45 10	100 45	N/A	01/75	12/89	98%	2.98
Bumbugur	Bayankhongor	46 10	99 37	N/A	01/75	12/89	93%	4.00
Buutsagaan	Bayankhongor	46 08	98 42	N/A	01/75	12/89	93%	2.38
Ekhiin-gol	Bayankhongor	43 12	99 00	974	01/79	12/86	100%	3.19
Erdenetsogt	Bayankhongor	46 34	100 49	N/A	01/75	12/89	93%	2.08
Galuut	Bayankhongor	46 42	100 04	2126	01/75	12/86	100%	1.37
Gurvanbulag	Bayankhongor	47 10	98 34	N/A	01/75	12/89	97%	2.85
Jinst	Bayankhongor	44 30	99 16	2219	01/75	12/86	100%	3.33
Khureemaral	Bayankhongor	46 22	98 17	N/A	01/75	12/89	92%	3.09
Ulziit	Bayankhongor	46 01	100 49	N/A	10/75	12/89	95%	1.20
Zag	Bayankhongor	46 55	99 10	N/A	10/75	12/89	99%	2.04
Bulgan	Bulgan	48 46	103 34	1209	01/75	12/85	100%	1.90
Saikhan	Bulgan	48 40	102 40	N/A	01/75	12/85	100%	4.32
Gurbanbulag	Bulgan	47 43	103 30	1097	01/83	12/86	100%	2.29
Matad	Dornod	47 09	115 32	907	01/76	12/86	100%	4.42
Bulgan	Dornod	48 06	113 42	760	01/76	11/89	73%	4.54
Orkhon	Dornod	N/A	N/A	N/A	01/75	12/89	95%	3.14
Kherlen	Dornod	N/A	N/A	N/A	05/75	12/89	61%	3.66
Bayandun	Dornod	48 52	113 16	940	01/75	12/89	60%	4.09
Halkhgol	Dornod	47 37	118 37	688	01/75	12/86	100%	2.44
Khalhgol	Dornod	47 00	118 04	585	12/75	12/89	75%	5.50
Sergelen	Dornod	48 30	114 00	N/A	12/75	12/89	78%	4.31

Ereentsav	Dornod	49 52	115 46	600	01/75	12/89	96%	4.35
Bayantumen	Dornod	48 00	114 16	793	12/75	09/89	89%	4.69
Choibalsan	Dornod	48 06	114 34	759	01/75	12/85	100%	3.83
Dashbalbar	Dornod	49 36	114 24	705	01/76	12/86	100%	3.95
Khulenbuir	Dornod	47 36	112 54	871	01/75	12/89	88%	4.55
Gurbanzagal	Dornod	49 06	114 54	751	01/75	11/89	42%	4.26
Tsagaanovoo	Dornod	48 36	113 12	793	01/75	12/89	90%	3.42
Airag	Dornogovi	45 46	109 16	1000	01/75	12/89	95%	3.10
Altanshiree	Dornogovi	45 30	110 30	1000	01/75	12/89	92%	3.54
Dalanjargalan	Dornogovi	45 55	109 04	N/A	01/75	11/89	82%	4.00
Delgereh	Dornogovi	45 46	111 12	1000	01/75	12/89	91%	3.63
Khashinbulag	Dornogovi	43 06	109 12	1135	01/75	11/89	88%	5.60
Mandah	Dornogovi	44 22	108 46	1308	01/75	12/86	100%	3.80
Saikhandulaan	Dornogovi	44 42	109 00	1200	01/75	12/89	78%	4.32
Sainshand	Dornogovi	44 52	110 04	936	01/75	12/85	100%	4.55
Tsagaantsav	Dornogovi	N/A	N/A	N/A	05/78	11/89	89%	3.92
Ulaan-uul	Dornogovi	44 22	111 04	1000	01/75	12/89	81%	3.43
Ulaanbadrakh	Dornogovi	43 00	110 24	1200	02/75	12/89	70%	2.83
Urgun	Dornogovi	44 43	110 45	N/A	01/75	09/89	74%	3.99
Adaatsag	Dundgovi	46 22	105 42	1680	01/75	12/89	80%	4.01
Bayanjargalan	Dundgovi	45 46	108 00	1250	01/76	12/89	88%	5.24
Choir	Dundgovi	46 22	108 12	1286	01/75	12/86	99%	2.69
Delgerkhangai	Dundgovi	45 12	104 46	1550	01/75	12/89	76%	3.15
Delgertsogt	Dundgovi	46 06	106 22	N/A	01/75	12/89	79%	4.29
Deren	Dundgovi	46 12	106 42	1469	01/75	12/89	92%	4.27
Erdenedalai	Dundgovi	46 00	105 00	1400	01/75	12/89	77%	5.49
Gobi-ugtaal	Dundgovi	46 00	107 30	1316	01/75	12/89	76%	4.67
Gurbansaikhan	Dundgovi	45 30	107 00	1200	01/85	12/86	100%	4.22
Gurvansaikhan	Dundgovi	45 30	107 01	N/A	01/75	11/83	76%	3.28
Khuld	Dundgovi	45 16	105 34	1350	02/75	12/89	87%	4.08
Luus	Dundgovi	45 30	105 42	1375	01/76	12/89	91%	4.65
Mandalgobi	Dundgovi	45 46	106 16	1393	01/75	12/85	100%	4.65
Tsagaandelger	Dundgovi	46 21	107 39	N/A	01/75	12/89	83%	4.61
Ulziit	Dundgovi	45 16	106 12	1140	02/75	12/89	90%	4.42
Undirshil	Dundgovi	45 15	108 16	N/A	01/75	12/89	91%	3.78
Ajbogd	Govi-Altai	44 52	95 30	1442	01/84	12/86	100%	3.50
Altai	Govi-Altai	46 22	96 12	2180	01/75	12/85	100%	3.56
Altai(Post)	Govi-Altai	N/A	N/A	N/A	01/75	02/89	58%	2.72
Bayanuul	Govi-Altai	47 00	95 12	1863	01/75	12/89	95%	2.85
Biger	Govi-Altai	45 42	97 12	1303	01/75	12/89	92%	3.38
Bugat	Govi-Altai	45 31	94 20	N/A	02/75	09/87	94%	3.34
Chandman	Govi-Altai	45 22	98 00	2323	02/75	12/89	92%	3.70
Dariv	Govi-Altai	46 28	94 02	N/A	01/75	12/89	92%	4.05
Delger	Govi-Altai	46 22	97 24	2035	11/75	12/88	92%	3.96
Erdene	Govi-Altai	45 06	97 46	2412	01/75	12/89	85%	3.84
Guulin	Govi-Altai	46 36	97 16	1843	01/75	12/89	96%	3.67
Hantaishir	Govi-Altai	N/A	N/A	N/A	01/81	12/86	100%	4.57
Jargalant	Govi-Altai	47 00	95 54	1557	01/75	12/89	85%	2.42
Khaliun	Govi-Altai	46 00	96 12	1441	01/75	12/89	92%	5.12
Khukhmor't	Govi-Altai	47 19	94 31	N/A	01/75	12/89	87%	2.94
Sharga	Govi-Altai	46 12	95 16	1165	01/75	11/89	94%	2.29
Taijir	Govi-Altai	46 42	96 30	1850	01/75	11/89	85%	3.34
Takhiin-tal	Govi-Altai	N/A	N/A	N/A	01/81	12/89	89%	1.96

Tamch	Govi-Altai	46 06	93 52	N/A	12/82	09/88	72%	3.05
Tonkhil	Govi-Altai	46 16	93 54	2222	01/75	12/86	100%	2.78
Tooroi	Govi-Altai	44 52	96 46	1183	01/75	12/86	100%	2.28
Tseel	Govi-Altai	45 36	95 46	2058	01/75	11/89	89%	4.39
Tsogt	Govi-Altai	45 22	96 34	2278	01/75	12/89	90%	2.92
Tugrug	Govi-Altai	45 46	94 46	1800	01/75	12/89	91%	3.47
Batnorov	Khentii	47 52	111 30	1050	01/75	12/89	86%	3.84
Batshireet	Khentii	48 42	110 12	1120	01/75	11/89	90%	2.58
Bayan-azarga	Khentii	48 36	111 04	1030	05/75	12/89	77%	3.24
Bayan-ovoo	Khentii	47 46	112 04	928	01/75	12/86	100%	3.46
Bayankhutag	Khentii	47 10	110 49	N/A	01/76	12/89	79%	3.96
Bayanmunkh	Khentii	46 55	109 45	N/A	06/75	12/89	82%	4.81
Binder	Khentii	48 36	110 34	1033	01/75	12/86	100%	2.51
Dadal	Khentii	49 00	111 34	994	01/75	12/86	100%	1.95
Darkhan	Khentii	46 36	109 25	N/A	02/75	08/83	76%	5.03
Delgerkhaan	Khentii	47 12	109 12	1243	01/75	12/89	92%	4.06
Galshar	Khentii	46 12	110 49	N/A	02/75	12/89	62%	4.11
Gurvanbayan	Khentii	48 06	110 31	N/A	07/83	12/89	88%	3.77
Jargaltkhaan	Khentii	47 28	109 28	N/A	05/75	12/89	67%	3.91
KherlenBayan Ulaan	Khentii	47 16	108 42	1280	03/82	12/89	64%	3.45
Muren	Khentii	N/A	N/A	N/A	01/75	12/89	79%	3.74
Norovlin	Khentii	48 40	112 00	N/A	01/75	10/89	79%	3.26
Orgil	Khentii	46 36	109 24	1271	01/85	12/86	100%	4.50
Tsenkhermandal	Khentii	47 46	109 04	1380	01/75	12/89	89%	2.94
Ulziit	Khentii	47 30	110 12	1150	06/79	12/89	82%	3.25
Umnudelger	Khentii	47 52	109 46	1320	01/76	12/89	67%	3.37
Undurkhaan	Khentii	47 16	110 34	1032	01/75	12/85	100%	3.36
Khubd	Khovd	48 00	91 34	1405	01/75	12/85	97%	1.27
Zereg	Khovd	47 06	92 46	1152	01/75	12/86	93%	1.09
Baitag	Khovd	46 06	91 34	1186	01/75	12/86	95%	1.45
Chandman'	Khovd	47 34	92 49	N/A	01/84	12/86	100%	2.03
Muren	Khuvsgul	49 36	100 12	1288	01/75	12/85	100%	2.16
Renchinlumbe	Khuvsgul	51 06	99 42	1583	01/75	12/86	99%	1.28
Tarialan	Khuvsgul	49 36	102 00	1236	01/75	12/86	100%	2.46
Eredenet-ovoo	Orkhon	N/A	N/A	N/A	01/75	12/85	100%	1.97
Altanbulag	Selenge	50 19	106 30	N/A	11/75	12/89	93%	2.19
Baruunkharaa	Selenge	48 52	106 04	807	01/75	12/86	100%	2.17
Bayankharaat	Selenge	N/A	N/A	N/A	09/77	12/89	79%	2.17
Nomgon	Selenge	49 07	105 35	N/A	11/77	12/89	93%	2.45
Orkhon	Selenge	49 12	105 24	748	01/75	12/86	100%	1.25
Orkhon-tuul	Selenge	48 58	104 58	N/A	03/75	12/89	91%	1.52
Shariin gol	Selenge	49 25	106 30	N/A	01/75	12/87	99%	2.53
Sukhbaatar	Selenge	50 12	106 12	616	01/75	12/85	100%	2.16
Tsagaantolgoi	Selenge	49 16	105 25	N/A	01/75	12/89	89%	1.63
Asgat	Sukhbaatar	46 22	113 34	1100	03/76	09/89	91%	3.85
Baruun-urt	Sukhbaatar	46 42	113 16	981	01/75	12/85	100%	3.68
Bayandelger	Sukhbaatar	45 42	112 24	1101	01/75	12/86	100%	4.71
Burentsogt	Sukhbaatar	46 43	111 40	N/A	05/85	12/89	85%	3.96
Dariganga	Sukhbaatar	45 16	113 46	1200	01/75	12/89	96%	4.30
Erdenetsagaan	Sukhbaatar	45 52	115 25	N/A	01/75	12/84	100%	5.24
Khalzan	Sukhbaatar	46 12	112 57	1100	01/75	12/89	93%	3.09
Munkhkhaan	Sukhbaatar	46 58	112 01	N/A	01/75	12/89	98%	4.46
Naran	Sukhbaatar	45 12	113 34	1200	01/75	12/89	96%	4.27

Ongol	Sukhbaatar	45 06	113 04	1040	01/75	12/89	98%	4.31
Sukhbaatar	Sukhbaatar	46 36	113 54	1990	01/75	12/89	91%	4.43
Tumentsogt	Sukhbaatar	47 30	112 16	1100	01/75	12/89	96%	3.90
Tuvshinshiree	Sukhbaatar	46 12	111 46	1025	01/75	12/89	93%	5.27
Atar	Tov	47 00	105 24	1150	05/78	12/89	87%	2.15
Maant	Tov	47 16	107 30	1430	01/75	12/82	100%	3.18
Erdene	Tov	47 42	107 46	N/A	01/75	11/89	78%	3.30
Ugtaal	Tov	48 16	105 24	1160	01/80	12/86	100%	2.12
Arkhust	Tov	47 30	107 55	N/A	10/77	12/89	91%	3.40
Bornuur	Tov	48 16	106 16	1100	02/75	12/89	98%	2.75
Zuunmod	Tov	47 42	106 46	1529	01/75	12/85	100%	2.52
Batsumber	Tov	48 22	106 46	1150	03/76	12/89	70%	3.04
Nukhurlel	Tov	N/A	N/A	N/A	01/79	12/89	77%	2.15
Altanbulag	Tov	47 36	106 16	1260	07/75	12/89	81%	2.71
Erdenesant	Tov	47 12	104 12	1356	01/75	12/86	100%	2.46
Zaluuchuud	Tov	48 22	105 24	1170	09/78	12/89	82%	2.84
Bayantsagaan	Tov	46 46	107 12	1360	01/75	12/89	94%	3.09
Bayanjargalan	Tov	47 12	108 16	1356	01/75	12/89	96%	4.75
Bujnt-Ukhaa	Ulaanbaatar	47 46	106 46	1272	01/75	12/85	100%	2.37
Morin-uul	Ulaanbaatar	47 46	106 34	1513	01/81	12/85	100%	5.03
Bayan-ovoo	Umnugovi	43 00	106 00	1200	01/75	12/89	94%	3.72
Bayandalai	Umnugovi	43 22	103 30	1600	01/75	12/89	91%	3.44
Dalanzadgad	Umnugovi	43 36	104 24	1462	01/75	12/85	100%	3.54
Gurbantes	Umnugovi	43 12	101 00	1726	01/75	12/85	100%	3.57
Khanbogd	Umnugovi	43 12	107 12	1114	01/76	12/85	100%	4.19
Khankhongor	Umnugovi	43 46	104 31	N/A	09/75	12/89	90%	4.88
Khurmen	Umnugovi	43 22	104 04	1700	11/75	12/89	85%	4.09
Mandal-ovoo	Umnugovi	44 37	104 04	1200	01/75	10/89	82%	3.01
Manlai	Umnugovi	44 04	106 52	N/A	04/75	12/89	94%	6.00
Nojn	Umnugovi	43 12	102 04	1800	01/75	12/89	90%	4.57
Nomgon	Umnugovi	42 46	105 04	1400	01/75	12/89	90%	3.47
Sevrei	Umnugovi	43 37	102 31	1600	01/75	12/89	94%	3.84
Tsogt-ovoo	Umnugovi	44 22	105 16	1299	01/75	12/85	100%	4.00
Tsogttsutsgii	Umnugovi	43 46	105 34	1600	01/75	12/89	92%	5.18
Baruunturuun	Uvs	49 36	94 24	1232	01/75	12/86	92%	1.04
Khajrgas	Uvs	49 16	93 46	1250	01/75	11/89	87%	2.19
Khar-us	Uvs	49 06	91 42	1591	01/75	12/86	100%	2.06
Khovd	Uvs	49 12	91 00	1400	01/75	12/89	88%	1.76
Malchin	Uvs	49 42	95 16	1390	01/75	12/89	89%	1.89
Naranbulag	Uvs	49 22	92 54	1100	01/75	12/89	83%	1.53
Sagil	Uvs	50 22	91 34	1140	01/75	12/89	92%	2.08
Tarialan	Uvs	49 45	91 50	N/A	09/75	12/89	91%	1.50
Tes	Uvs	50 16	93 31	N/A	01/75	12/89	90%	1.38
Turgen	Uvs	50 06	91 34	1220	09/75	12/89	84%	1.62
Ulaangom	Uvs	49 46	92 04	934	01/75	12/85	100%	1.29
Undurkhangai	Uvs	49 16	94 46	1880	01/75	12/89	87%	2.23
Zavkhan	Uvs	48 46	93 04	1051	01/76	12/86	97%	1.68
Zuungobi	Uvs	49 52	93 46	1000	01/75	12/89	88%	1.85
Zuunkhangai	Uvs	49 19	95 25	N/A	01/75	12/89	92%	2.96
Arvaiheer	Uvurkhangai	46 16	102 46	1813	01/75	12/85	100%	3.89
BaruunBayan-ulaan	Uvurkhangai	45 12	101 25	1260	05/75	12/89	93%	3.23
Bat-ulzii	Uvurkhangai	46 46	102 12	1670	01/75	11/89	92%	1.74
Bayan-undur	Uvurkhangai	46 30	104 04	1600	01/75	11/89	90%	2.34

Bayangol	Uvurkhangai	45 46	103 24	1430	11/75	12/89	88%	3.32
Bogd	Uvurkhangai	44 42	102 12	1519	01/75	12/86	100%	2.90
Burd	Uvurkhangai	46 46	103 46	1460	01/75	12/89	91%	2.79
Guchin-us	Uvurkhangai	45 30	102 24	1440	01/75	12/89	92%	4.06
Khairkhandulaan	Uvurkhangai	45 58	102 01	N/A	01/75	12/89	87%	3.43
Kharkhorin	Uvurkhangai	47 10	102 49	N/A	01/75	12/89	100%	4.88
Khujirt	Uvurkhangai	46 52	102 46	1662	01/75	12/86	100%	1.77
Nariinteel	Uvurkhangai	46 00	101 24	1800	01/75	12/89	91%	2.07
Sant	Uvurkhangai	46 06	103 46	N/A	01/75	12/89	92%	3.57
Taragt	Uvurkhangai	46 16	102 28	N/A	10/75	12/89	91%	3.37
Tugrug	Uvurkhangai	45 31	103 00	N/A	01/75	12/89	92%	3.43
Ujanga	Uvurkhangai	46 22	102 16	1980	01/75	12/89	88%	2.37
Ulziit	Uvurkhangai	46 38	103 19	N/A	11/76	12/89	87%	3.57
Zuil	Uvurkhangai	46 45	103 31	N/A	01/75	12/89	91%	3.06
ZuunBayan-ulaan	Uvurkhangai	46 30	102 34	1840	01/75	11/89	86%	3.47
Uliastai	Zavkhan	47 46	96 46	1751	01/75	12/85	100%	1.46
Bayan-uul	Zavkhan	49 42	96 24	1420	01/75	12/86	95%	0.94
Durvuljin	Zavkhan	47 36	95 00	1391	01/75	12/86	100%	2.35
Tsetsen-uul	Zavkhan	48 46	96 00	1928	01/76	12/86	100%	1.75
Tosontsengel	Zavkhan	48 42	98 16	1724	01/75	12/86	100%	1.38

Latitude (Lat) and longitude (Lon) are in degrees and minutes.

Table A.3 Provincial Meteorological Stations

Name	Aimag	Lat	Lon	WS (m/s)
Battsengel	Arkhangai	47 48	101 59	2.4
Bulgan	Arkhangai	47 16	101 05	1.7
Chuluut	Arkhangai	47 30	100 12	2.5
Erdenemandal	Arkhangai	48 32	101 20	3.0
Ikhtamir	Arkhangai	47 38	101 11	3.2
Jargalant	Arkhangai	48 41	100 46	3.7
Khairkhan	Arkhangai	48 38	101 58	2.9
Khangai	Arkhangai	47 40	99 28	1.5
Khashaat	Arkhangai	47 26	103 09	2.0
Khotont	Arkhangai	47 21	102 29	2.8
Tariat	Arkhangai	48 09	99 52	3.9
Tsenkher	Arkhangai	47 24	101 46	2.7
Tsetserleg	Arkhangai	48 52	101 15	3.8
Tuvshruulekh	Arkhangai	47 20	101 55	2.6
Ugiinuur	Arkhangai	47 39	102 35	2.8
Ulziit	Arkhangai	48 05	102 35	2.4
Undur-Ulaan	Arkhangai	48 05	100 31	2.6
Altai	Bayan-Ulgii	48 18	89 30	1.9
Altantsugts	Bayan-Ulgii	49 03	90 26	2.1
Bayannuur	Bayan-Ulgii	48 55	91 10	1.4
Bulgan	Bayan-Ulgii	46 57	91 05	2.1
Buyant	Bayan-Ulgii	48 32	89 31	2.4
Deluun	Bayan-Ulgii	47 50	90 47	2.1
Nogoonnuur	Bayan-Ulgii	49 38	90 15	1.5
Sagsai	Bayan-Ulgii	48 55	89 41	2.3
Tolbo	Bayan-Ulgii	48 22	90 16	1.5
Tsengel	Bayan-Ulgii	48 57	89 09	2.5
Ulaankhus	Bayan-Ulgii	49 03	89 25	1.2
Ulgii	Bayan-Ulgii	48 58	89 59	2.8
Baatsagaan	Bayankhongor	45 30	99 28	2.7
Baidrag	Bayankhongor	47 12	99 36	1.1
Bayan-Ovoo	Bayankhongor	46 16	100 28	2.1
Bayan-undur	Bayankhongor	44 45	98 39	4.9
Bayanbulag	Bayankhongor	46 49	98 05	2.5
Bayangovi	Bayankhongor	44 38	100 22	2.6
Bayankhongor	Bayankhongor	46 10	100 42	2.9
Bayanlig	Bayankhongor	44 30	100 50	3.2
Bayantsagaan	Bayankhongor	45 00	98 56	4.7
Bodi	Bayankhongor	45 24	100 34	3.6
Bogd	Bayankhongor	45 10	100 45	3.5
Bumbugur	Bayankhongor	46 11	99 38	3.9
Buutsagaan	Bayankhongor	46 09	98 42	2.9
Ekhiin gol	Bayankhongor	43 02	99 00	2.8
Erdenetsogt	Bayankhongor	46 35	100 50	1.7
Galuut	Bayankhongor	46 45	100 09	1.4
Gurvanbulag	Bayankhongor	47 10	98 35	3.0
Khureemaral	Bayankhongor	46 22	98 18	3.2
Shinejinst	Bayankhongor	44 30	99 16	3.1
Ulziit	Bayankhongor	46 02	100 50	1.1

Zag	Bayankhongor	46 55	99 10	1.9
Bayan-Agt	Bulgan	49 05	102 06	2.6
Bugat	Bulgan	49 04	103 39	2.3
Bulgan	Bulgan	48 49	103 35	2.2
Buregkhangai	Bulgan	48 14	103 53	2.8
Dashinchilen	Bulgan	47 51	104 01	0.9
Gurvanbulag	Bulgan	47 44	103 30	3.1
Khangal	Bulgan	49 20	104 22	2.3
Khantai	Bulgan	49 33	103 15	2.5
Khishig-Undur	Bulgan	48 18	103 27	2.4
Khutag	Bulgan	49 22	102 40	1.8
Mogod	Bulgan	48 15	103 00	2.3
Orkhon	Bulgan	48 38	103 32	1.4
Saikhan	Bulgan	48 40	102 40	2.4
Selenge	Bulgan	49 28	103 59	2.3
Teshig	Bulgan	49 56	102 31	2.1
Bayandun	Dornod	49 15	113 21	4.3
Bayantumen	Dornod	48 00	114 18	4.6
Bulgan	Dornod	48 00	113 59	4.5
Choibalsan	Dornod	48 01	114 36	4.2
Dashbalbar	Dornod	49 32	114 23	3.7
Ereentsav	Dornod	49 51	115 42	4.3
Gurvanzagal	Dornod	49 09	114 52	3.6
Khalkhgol	Dornod	47 59	118 04	4.5
Khulunbuir	Dornod	47 55	112 59	4.6
Matad	Dornod	46 58	115 19	4.4
Sergelen	Dornod	48 30	114 00	4.2
Tamsagbulag	Dornod	47 15	117 18	3.5
Tsagaan-Ovoo	Dornod	48 32	113 15	3.5
Airag	Dornogovi	45 49	109 20	2.8
Altanshiree	Dornogovi	45 30	110 30	3.4
Choir	Dornogovi	46 27	108 36	3.4
Dalanjargalan	Dornogovi	45 55	109 04	3.6
Delgerekh	Dornogovi	45 48	111 14	3.3
Erdene	Dornogovi	44 27	111 05	3.6
Ikh khet	Dornogovi	46 14	110 10	3.0
Khatanbulag	Dornogovi	43 09	109 08	5.4
Khuvsgul	Dornogovi	43 55	109 35	4.5
Mandakh	Dornogovi	44 26	108 15	4.1
Saikhandulaan	Dornogovi	44 40	109 01	3.5
Sainshand	Dornogovi	44 54	110 56	4.3
Ulaanbadrakh	Dornogovi	43 52	110 28	2.5
Urgun	Dornogovi	44 44	110 45	4.2
Zamin-Uud	Dornogovi	43 42	111 58	3.4
Adaatsag	Dundgovi	46 22	105 42	3.2
Bayanjargalan	Dundgovi	45 46	108 00	5.5
Delgerkhangai	Dundgovi	45 14	104 48	3.6
Delgertsogt	Dundgovi	46 06	106 22	4.1
Deren	Dundgovi	46 12	106 41	3.7
Erdenedalai	Dundgovi	46 01	104 58	6.1
Govi-Ugtaal	Dundgovi	46 02	107 30	5.1
Gurvansaikhan	Dundgovi	45 30	107 01	3.2
Khuld	Dundgovi	45 12	105 34	4.1

Luus	Dundgovi	45 30	105 42	4.4
Mandalgovi	Dundgovi	45 44	106 18	4.4
Saikhan-Ovoo	Dundgovi	45 27	103 58	3.1
Tsagaandelger	Dundgovi	46 21	107 39	4.2
Ulziit	Dundgovi	44 55	106 20	4.3
Undurshil	Dundgovi	45 13	108 20	3.9
Altai	Gobi-Altai	44 26	94 57	1.0
Altai khot	Gobi-Altai	46 24	96 12	3.5
Bayan-Uul	Gobi-Altai	47 01	95 11	3.8
Biger	Gobi-Altai	45 42	97 10	3.1
Bugat	Gobi-Altai	45 32	94 21	3.0
Chandman'	Gobi-Altai	45 19	98 00	2.6
Dariv	Gobi-Altai	46 28	94 03	4.0
Delger	Gobi-Altai	46 20	97 21	3.6
Erdene	Gobi-Altai	45 09	97 45	4.2
Guulin	Gobi-Altai	46 34	97 19	3.4
Jargalant	Gobi-Altai	47 00	95 54	2.5
Khaliun	Gobi-Altai	45 55	96 09	4.6
Khukhmor't	Gobi-Altai	47 20	94 31	2.8
Sharga	Gobi-Altai	46 17	95 19	2.8
Taishir	Gobi-Altai	46 42	96 30	3.7
Tonkhil	Gobi-Altai	46 19	93 55	2.8
Tooroi	Gobi-Altai	44 54	96 48	2.3
Tseel	Gobi-Altai	45 32	95 50	3.9
Tsogt	Gobi-Altai	45 21	96 40	2.8
Tugrug	Gobi-Altai	45 50	94 49	3.7
Batnorov	Khentii	47 58	111 29	3.4
Batshireet	Khentii	48 40	110 10	2.6
Bayan-Ovoo	Khentii	47 48	112 05	3.6
Bayanadarga	Khentii	48 34	111 05	2.6
Bayankhutag	Khentii	47 10	110 50	4.0
Bayanmunkh	Khentii	46 55	109 45	4.8
Binder	Khentii	48 36	110 38	2.9
Dadal	Khentii	49 01	111 40	2.1
Darkhan	Khentii	46 36	109 25	4.2
Delgerkhaan	Khentii	47 10	109 11	3.8
Galshar	Khentii	46 12	110 50	3.7
Jargaltkhaan	Khentii	47 29	109 29	3.8
Murun	Khentii	47 27	110 06	3.9
Norovlin	Khentii	48 41	112 00	3.3
Tsenkhermandal	Khentii	47 44	109 04	2.8
Undurkhaan	Khentii	47 18	110 36	3.6
Altai	Khovd	45 49	92 17	2.0
Baitag	Khovd	46 06	91 36	1.7
Buyant	Khovd	48 20	91 49	2.4
Chandman'	Khovd	47 35	92 50	1.6
Darvi	Khovd	46 56	93 38	2.3
Durgun	Khovd	48 15	92 40	2.1
Duut	Khovd	47 29	91 39	2.7
Erdeneburen	Khovd	48 30	91 25	1.5
Khovd	Khovd	48 05	91 21	2.2
Mankhan	Khovd	47 20	92 12	1.7
Munkhkhairkhan	Khovd	47 02	91 50	1.7

Must	Khovd	46 38	92 49	1.9
Myangad	Khovd	48 12	91 58	1.9
Tsetseg	Khovd	46 32	93 18	1.5
Uench	Khovd	46 02	92 01	1.8
Zereg	Khovd	47 05	92 51	1.2
Alag-Erdene	Khuvsgul	50 07	100 02	3.1
Arbulag	Khuvsgul	49 55	99 30	3.6
Bayanzurkh	Khuvsgul	50 13	98 59	2.0
Burentogtokh	Khuvsgul	49 34	99 38	3.0
Chandman'-Undur	Khuvsgul	50 29	100 58	2.4
Galt	Khuvsgul	48 44	99 55	2.9
Ikh-Uul	Khuvsgul	49 25	101 32	2.8
Jargalant	Khuvsgul	48 35	99 18	3.8
Khankh	Khuvsgul	51 30	100 40	3.4
Khatgal	Khuvsgul	50 26	100 10	2.9
Murun	Khuvsgul	49 35	100 10	2.1
Rashaant	Khuvsgul	49 07	101 25	2.7
Rinchinlkhumbe	Khuvsgul	51 06	99 40	1.4
Shine-Ider	Khuvsgul	48 55	99 32	2.9
Tarialan	Khuvsgul	49 35	102 00	2.6
Tosontsengel	Khuvsgul	49 26	100 51	3.8
Tsagaan-Uul	Khuvsgul	49 36	98 40	3.3
Tsagaan-Uur	Khuvsgul	50 32	101 32	1.3
Tsetserleg	Khuvsgul	49 32	97 48	5.9
Tumurbulag	Khuvsgul	49 16	100 16	4.3
Tunel	Khuvsgul	49 51	100 37	3.1
Ulaan-Uul	Khuvsgul	50 40	99 14	2.7
Altanbulag	Selenge	50 19	106 30	2.2
Baruunburen	Selenge	49 12	104 48	2.3
Baruunkharaa	Selenge	48 54	106 06	2.3
Eruu	Selenge	49 45	106 43	1.4
Khuder	Selenge	49 46	107 25	1.4
Nomgon	Selenge	49 08	105 36	2.5
Orkhon	Selenge	49 12	105 24	1.4
Orkhontuul	Selenge	48 57	104 58	1.6
Shaamar	Selenge	50 06	106 11	1.8
Shariin gol	Selenge	49 26	106 30	2.0
Sukhbaatar	Selenge	50 12	106 12	2.3
Tsagaannuur	Selenge	50 05	105 21	2.0
Tsagaantolgoi	Selenge	49 16	105 25	1.8
Zelter	Selenge	50 18	105 06	1.1
Zuunburen	Selenge	50 04	105 52	1.5
Zuunkharaa	Selenge	48 38	106 44	1.5
Asgat	Sukhbaatar	46 21	113 35	4.2
Baruun-Urt	Sukhbaatar	46 42	113 18	3.6
Bayandelger	Sukhbaatar	45 43	112 20	4.7
Dariganga	Sukhbaatar	45 19	113 50	4.9
Erdenetsagaan	Sukhbaatar	45 53	115 25	5.2
Khalzan	Sukhbaatar	46 10	112 59	3.5
Munkhkhaan	Sukhbaatar	46 59	112 01	4.5
Naran	Sukhbaatar	45 09	113 40	4.4
Ongon	Sukhbaatar	45 20	113 10	3.7
Sukhbaatar	Sukhbaatar	46 48	113 52	4.6

Tumentsogt	Sukhbaatar	47 34	112 22	3.9
Tuvshinshiree	Sukhbaatar	46 11	111 49	5.1
Uulbayan	Sukhbaatar	46 29	112 20	3.3
Altanbulag	Tov	47 40	106 25	2.5
Argalant	Tov	47 55	105 54	2.8
Arkhust	Tov	47 30	107 55	3.4
Bayankhangai	Tov	47 55	105 31	2.4
Bayantsogt	Tov	48 08	105 50	2.3
Erdene	Tov	47 46	107 50	2.8
Erdenesant	Tov	47 19	104 30	2.7
Lun	Tov	47 54	105 18	2.8
Sergelen	Tov	47 35	107 03	4.4
Ugtaal	Tov	48 15	105 24	2.1
Undurshireet	Tov	47 29	104 54	3.9
Zaamar	Tov	48 12	104 48	2.3
Zuunmod	Tov	47 43	106 59	2.6
Bayan-Ovoo	Umnugovi	42 58	106 08	3.5
Bayandalai	Umnugovi	43 28	103 31	3.2
Dalanzadgad	Umnugovi	43 34	104 25	3.4
Gurvantes	Umnugovi	43 12	101 02	3.6
Khanbogd	Umnugovi	43 12	107 09	4.0
Khankhongor	Umnugovi	43 47	104 31	4.7
Khurmen	Umnugovi	43 18	104 05	4.0
Mandal-Ovoo	Umnugovi	44 39	104 02	2.6
Manlai	Umnugovi	44 04	106 52	5.5
Nomgon	Umnugovi	42 50	105 09	2.9
Noyon	Umnugovi	43 09	102 09	4.2
Saikhan	Umnugovi	44 06	103 36	5.3
Sevrei	Umnugovi	43 35	102 11	4.1
Tsogt-Ovoo	Umnugovi	44 23	105 20	3.6
Tsogttsetsii	Umnugovi	43 43	105 30	5.0
Baruunturuun	Uvs	49 36	94 21	1.2
Bukhmurun	Uvs	49 39	90 18	2.2
Davst	Uvs	50 31	92 29	1.1
Khar-Us	Uvs	49 06	91 42	2.2
Khovd	Uvs	49 15	90 58	1.7
Khyargas	Uvs	49 39	93 44	2.6
Malchin	Uvs	49 42	93 95	1.7
Naranbulag	Uvs	49 16	92 32	1.9
Sagil	Uvs	50 18	91 39	2.1
Tarialan	Uvs	49 45	91 51	1.9
Tes	Uvs	50 17	93 32	1.3
Tsagaankhairkhan	Uvs	49 25	94 15	2.8
Turgen	Uvs	50 02	91 40	1.6
Ulaangom	Uvs	49 59	92 01	1.3
Ulgii	Uvs	49 01	92 01	1.4
Undurkhangai	Uvs	49 15	94 52	1.5
Zavkhan	Uvs	48 49	93 05	1.7
Zuungovi	Uvs	49 52	93 48	1.5
Zuunkhangai	Uvs	49 19	95 26	2.9
Arvaikheer	Uvurkhangai	46 15	102 48	3.8
Baruunbayan-Ulaan	Uvurkhangai	45 09	101 27	3.3
Bat-Ulzii	Uvurkhangai	46 49	102 15	1.7

Bayan-Undur	Uvurkhangai	46 30	104 07	2.5
Bayangol	Uvurkhangai	45 49	103 29	3.0
Bogd	Uvurkhangai	44 40	102 10	3.0
Burd	Uvurkhangai	46 48	103 48	1.8
Guchin-Us	Uvurkhangai	45 26	102 22	4.0
Khairkhandulaan	Uvurkhangai	45 58	102 02	3.4
Kharkhorin	Uvurkhangai	47 11	102 50	4.7
Khujirt	Uvurkhangai	46 54	102 46	2.2
Nariin teel	Uvurkhangai	46 00	101 24	2.0
Sant	Uvurkhangai	46 05	103 51	3.8
Taragt	Uvurkhangai	46 17	102 28	3.7
Tugrug	Uvurkhangai	45 31	103 00	3.1
Ulziit	Uvurkhangai	46 39	103 20	4.6
Uyanga	Uvurkhangai	46 24	102 18	2.0
Zuunbayan-Ulaan	Uvurkhangai	46 30	102 36	3.6
Aldarkhaan	Zavkhan	47 39	96 31	2.5
Bayankhairkhan	Zavkhan	49 19	96 20	2.0
Bayantes	Zavkhan	49 41	96 21	1.0
Bulnai	Zavkhan	48 42	98 19	1.7
Durvuljin	Zavkhan	47 39	95 00	2.5
Erdenekhairkhan	Zavkhan	48 07	95 44	2.1
Ider	Zavkhan	48 12	97 25	2.7
Ikh-Uul	Zavkhan	48 40	98 49	1.6
Numrug	Zavkhan	48 52	96 59	1.9
Otgon	Zavkhan	47 11	97 38	2.4
Santmargats	Zavkhan	48 35	95 25	1.5
Shiluustei	Zavkhan	46 47	97 11	2.2
Songino	Zavkhan	49 01	95 59	2.6
Telmen	Zavkhan	48 40	97 39	1.5
Tes	Zavkhan	49 39	95 49	1.6
Tsagaanchuluut	Zavkhan	47 05	96 40	4.2
Tsagaankhairkhan	Zavkhan	47 29	96 49	3.0
Tsetsen-Uul	Zavkhan	48 44	96 00	1.8
Tudevtei	Zavkhan	48 59	96 30	2.9
Uliastai	Zavkhan	47 44	96 51	2.0
Urgamal	Zavkhan	48 30	94 19	2.9
Yaruu	Zavkhan	48 08	96 46	3.5
Zavkhanmandal	Zavkhan	48 19	95 07	3.0

Latitude (Lat) and longitude (Lon) are in degrees and minutes.

Appendix B

Wind Monitoring Program Sites
Tables and Analysis Summaries of Selected Sites

NREL/REC

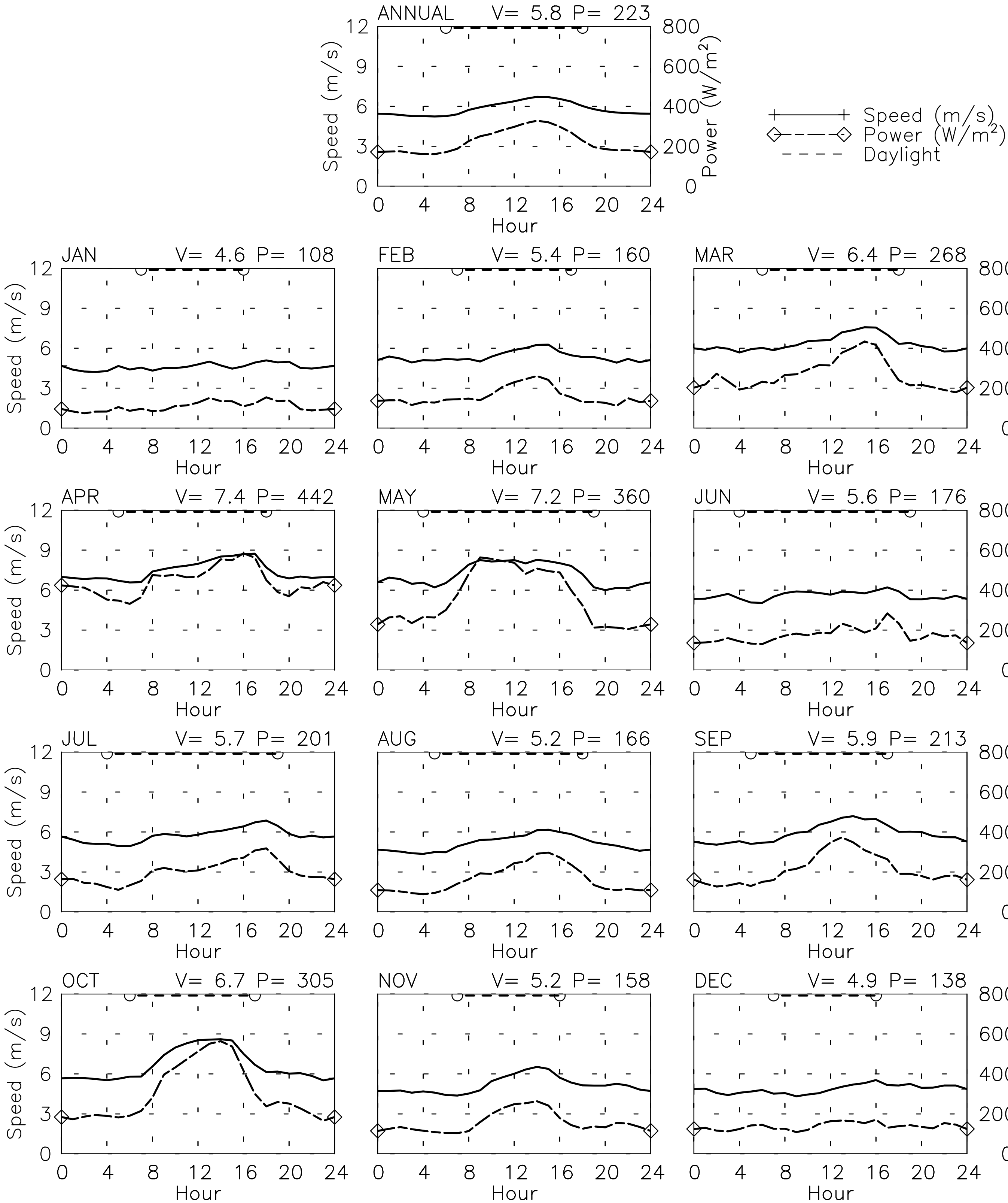
Tuvshinshireet Site Summaries
Mandakh Site Summaries
Manlai Site Summaries

TACIS/REC

Guchin-Us Site Summaries
Bogd (Uvurkhangai) Site Summaries
Bayanlig Site Summaries
Bayan-Undur Site Summaries
Bogd (Bayankhongor) Site Summaries

SPEED AND POWER BY HOUR

Center Tuvshin Sukh - 000101
46° 13' N 111° 48' W - Elev 1108m LST=GMT+99 hours *NT= -7
07/98-08/00



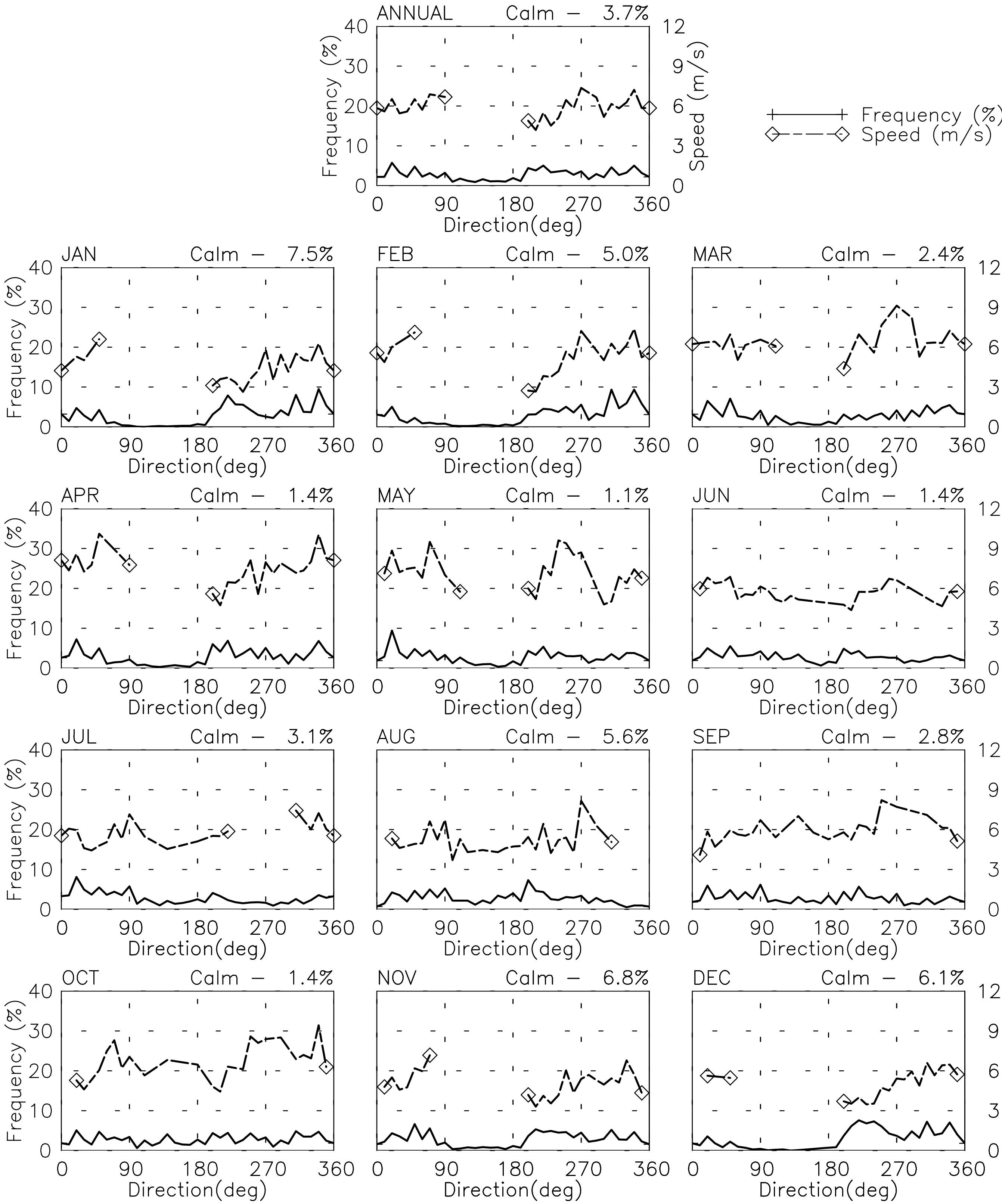
Mon Jul 16 15:55:25 2001

FREQUENCY AND SPEED BY DIRECTION

Center Tuvshin Sukh – 000101

46° 13' N 111° 48' W – Elev 1108m LST=GMT+99 hours *NT= –7

07/98–08/00



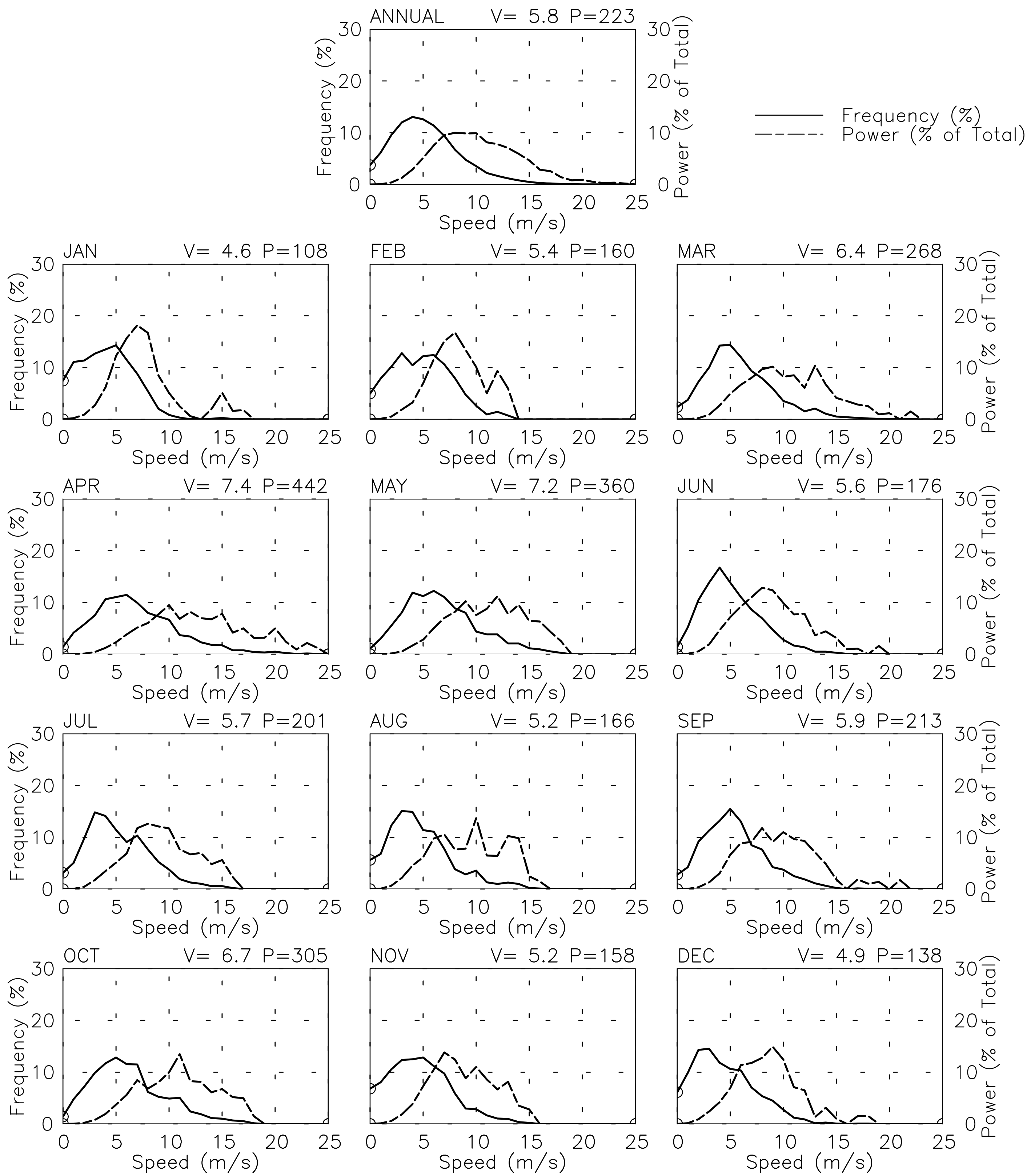
Mon Jul 16 15:55:29 2001

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

Center Tuvshin Sukh – 000101

46° 13' N 111° 48' W – Elev 1108m LST=GMT+99 hours *NT= –7

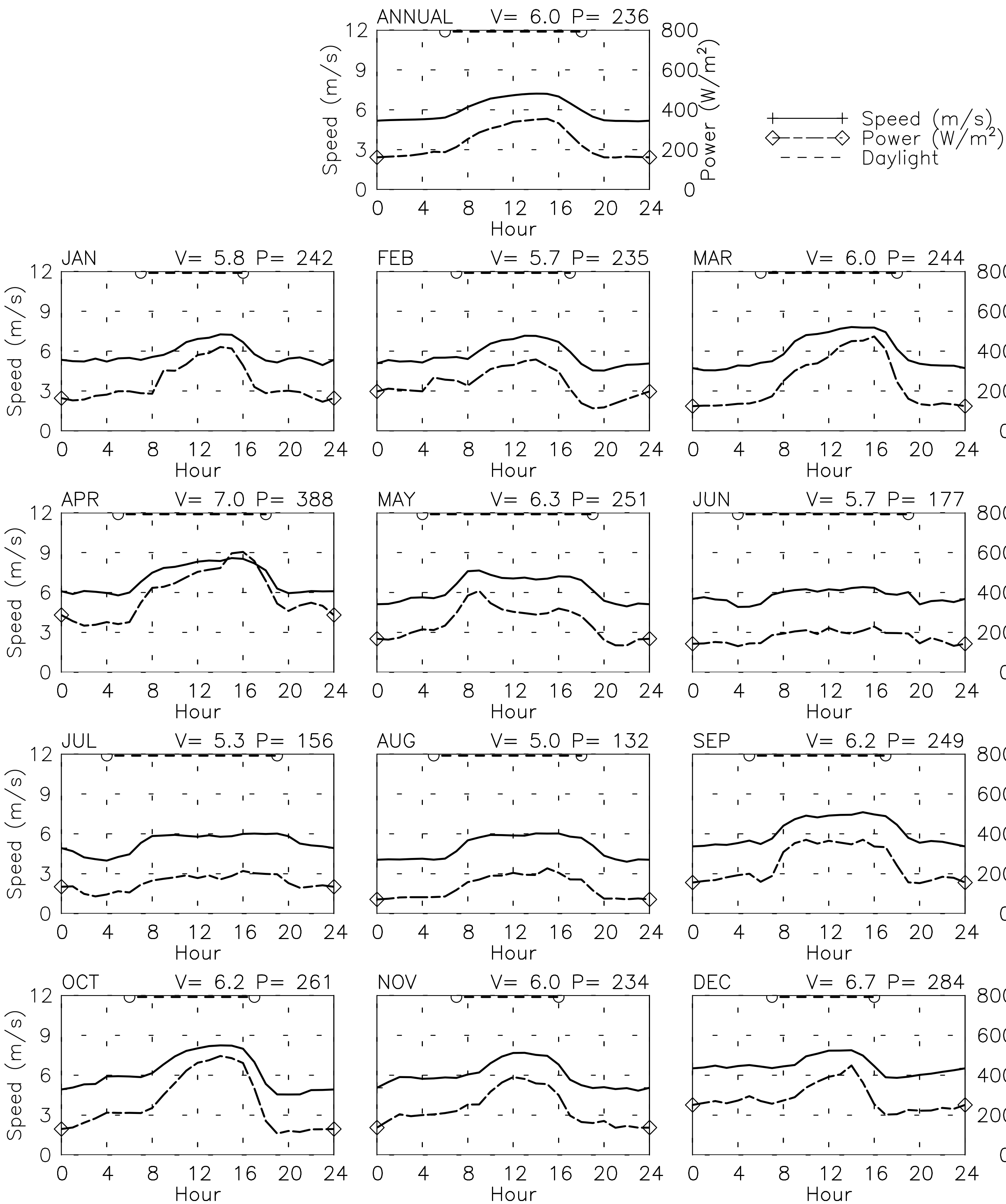
07/98–08/00



Mon Jul 16 15:55:32 2001

SPEED AND POWER BY HOUR

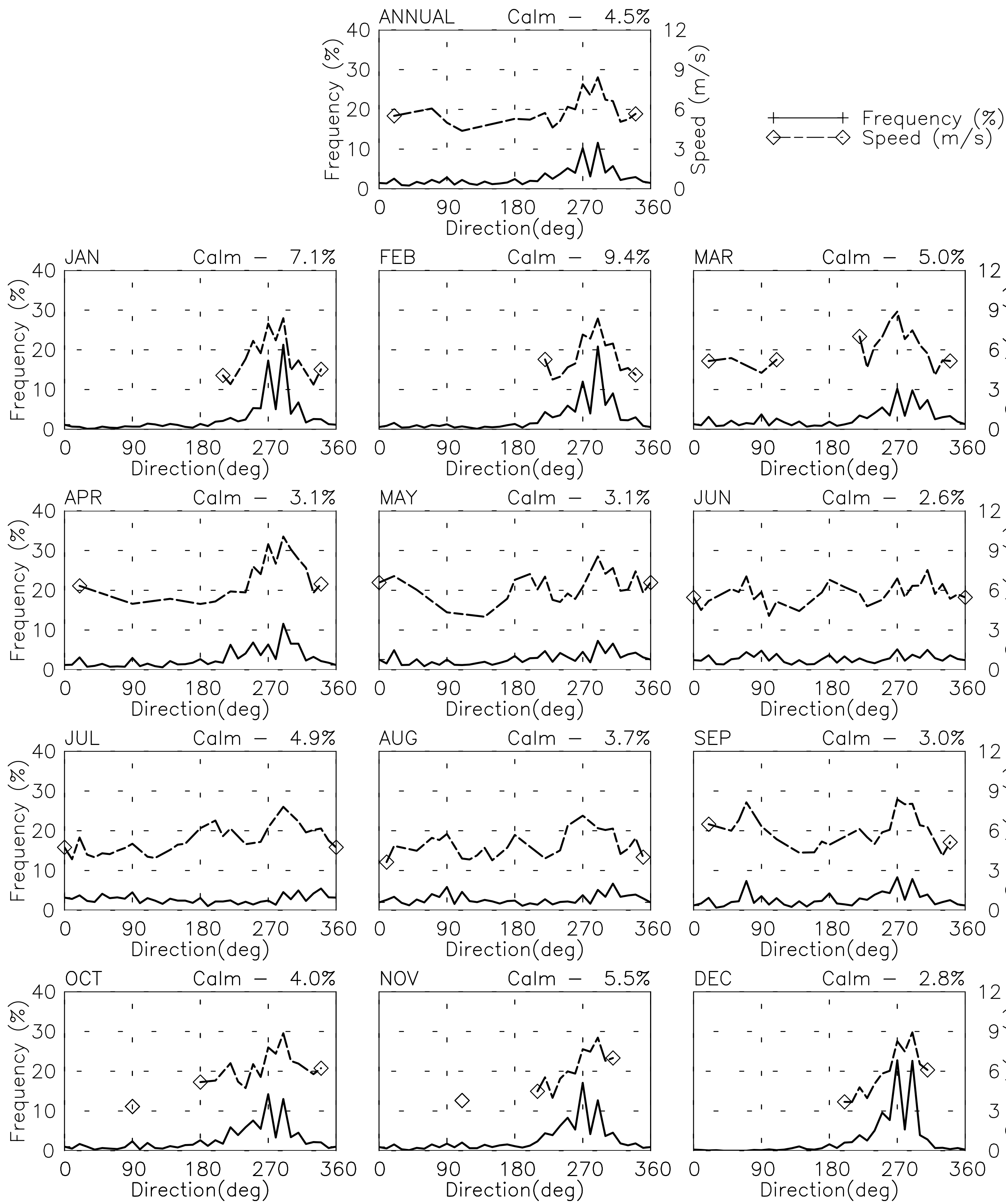
Tumurbaatar Mndk Dorn – 000203
44° 24' N 108° 29' W – Elev 1225m LST=GMT+99 hours *NT= –7
08/98–08/00



Mon Jul 16 15:55:39 2001

FREQUENCY AND SPEED BY DIRECTION

Tumurbaatar Mndk Dorn – 000203
44° 24' N 108° 29' W – Elev 1225m LST=GMT+99 hours *NT= –7
08/98–08/00



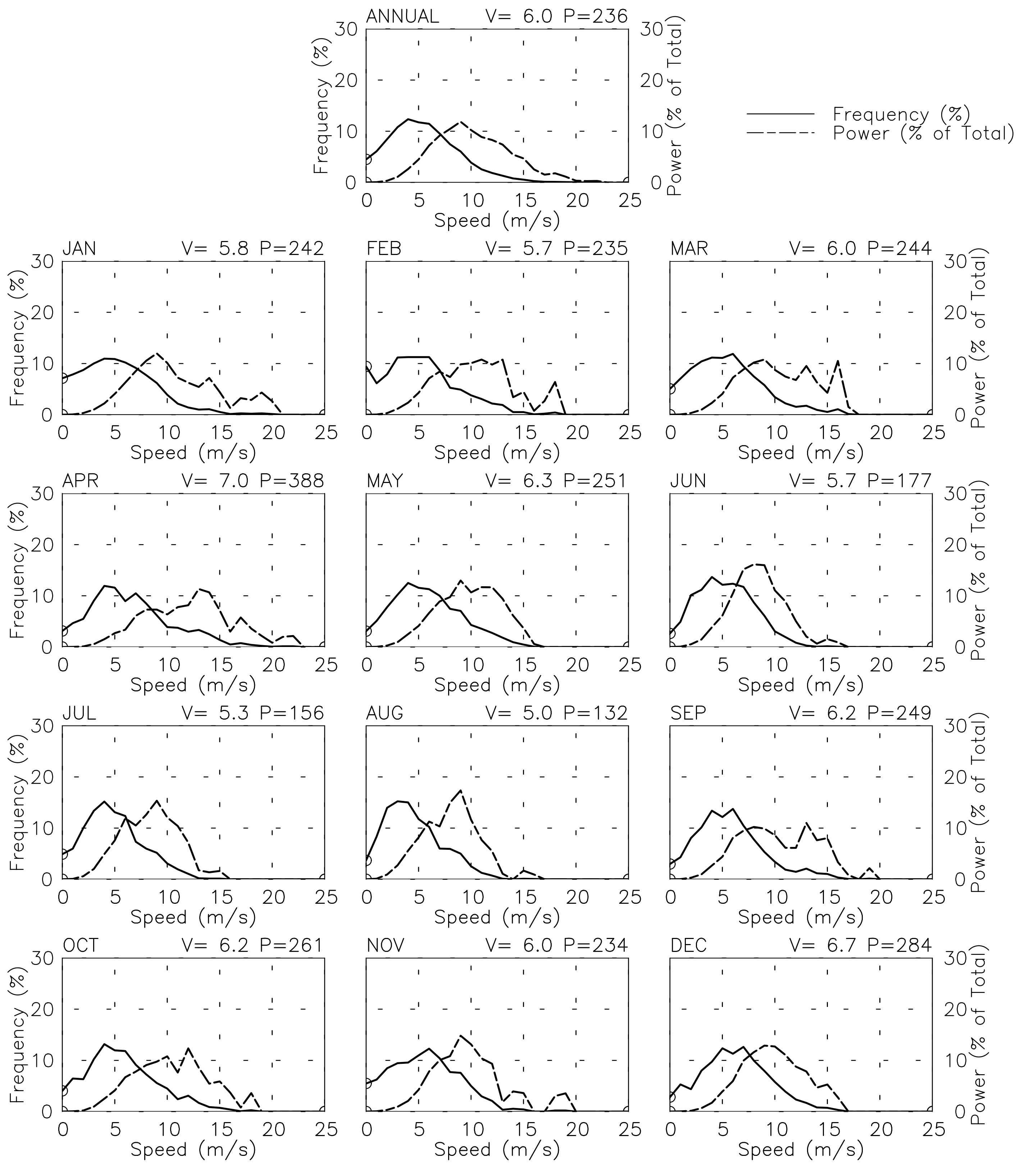
Mon Jul 16 15:55:42 2001

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

Tumurbaatar Mndk Dorn – 000203

44° 24' N 108° 29' W – Elev 1225m LST=GMT+99 hours *NT= –7

08/98–08/00



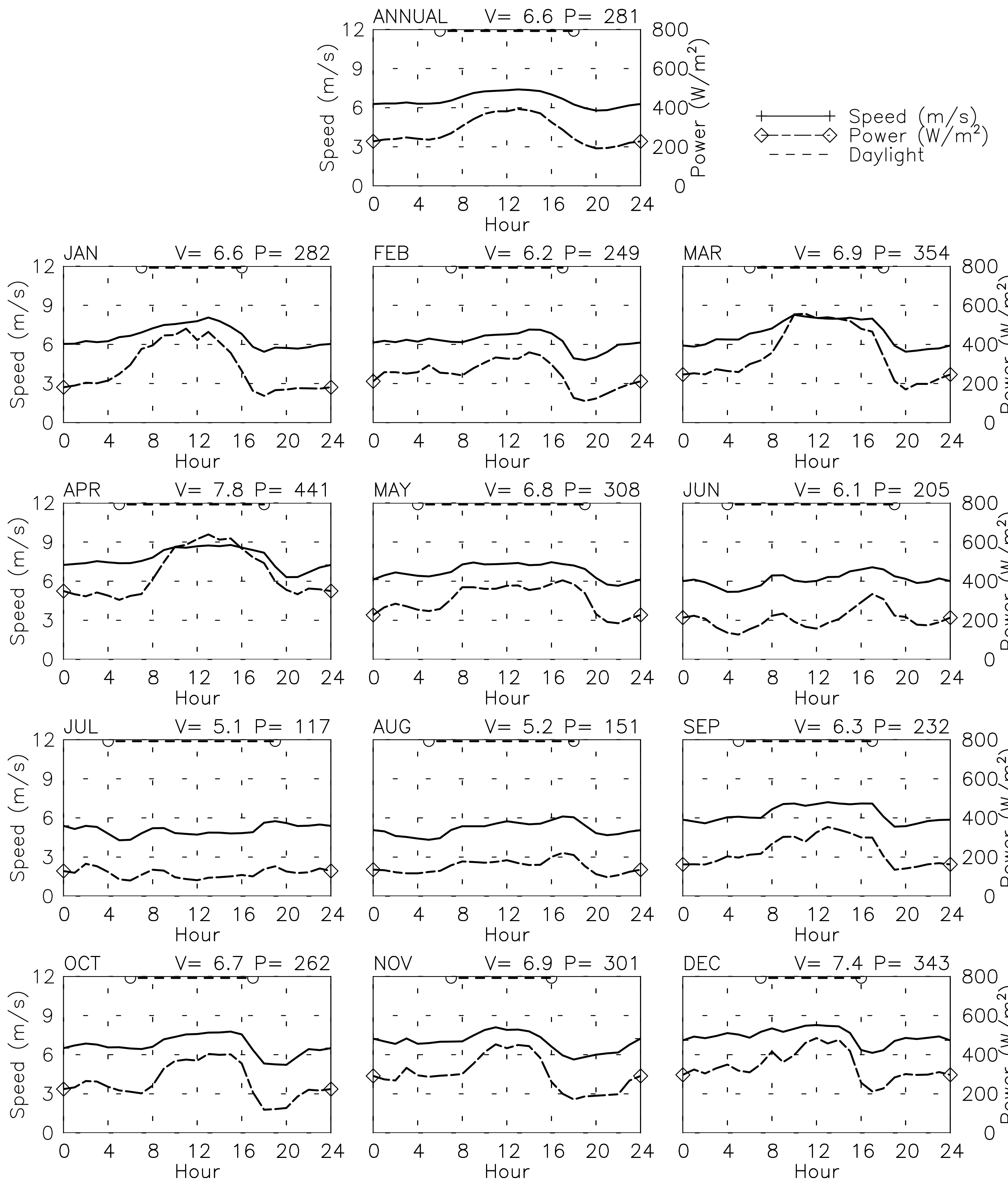
Mon Jul 16 15:55:45 2001

SPEED AND POWER BY HOUR

Center Manlai Umnu – 000303

44° 05' N 106° 52' W – Elev 1302m LST=GMT+99 hours *NT= –7

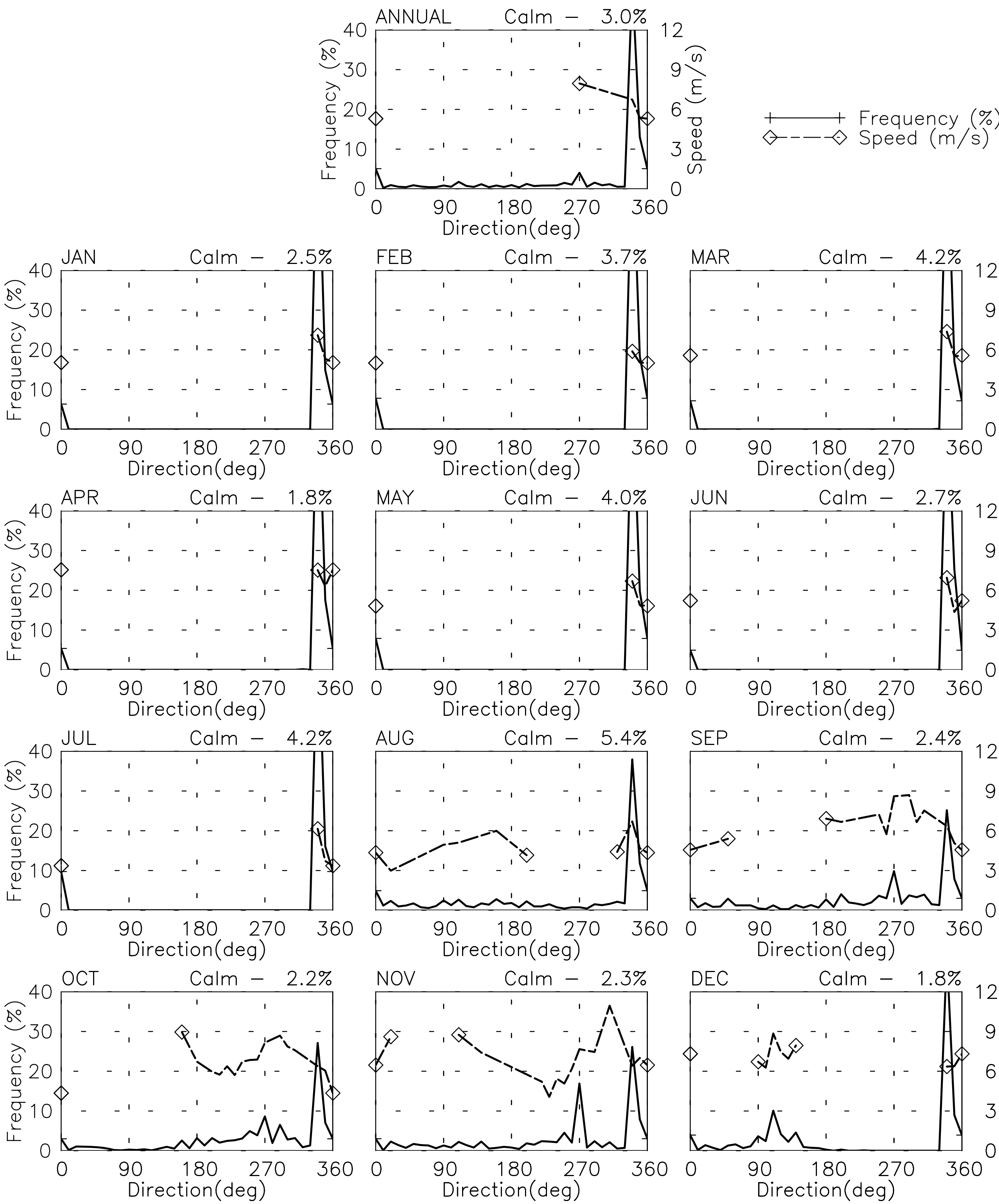
08/98–06/00



Mon Jul 16 15:55:51 2001

FREQUENCY AND SPEED BY DIRECTION

Center Manlai Umnu – 000303
44° 05' N 106° 52' W – Elev 1302m LST=GMT+99 hours *NT= –7
08/98–06/00



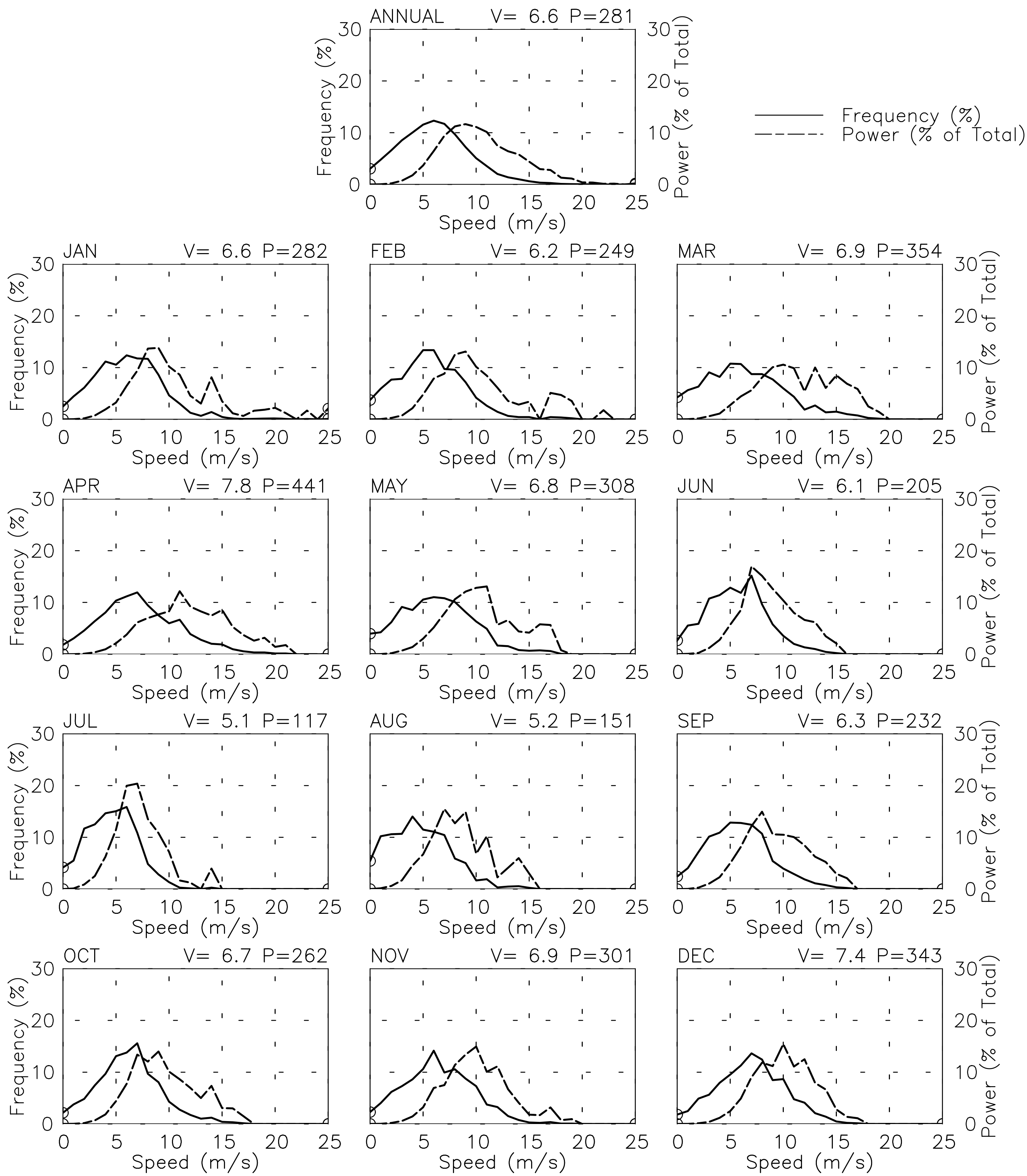
Mon Jul 16 15:55:54 2001

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

Center Manlai Umnu – 000303

44° 05' N 106° 52' W – Elev 1302m LST=GMT+99 hours *NT= –7

08/98–06/00



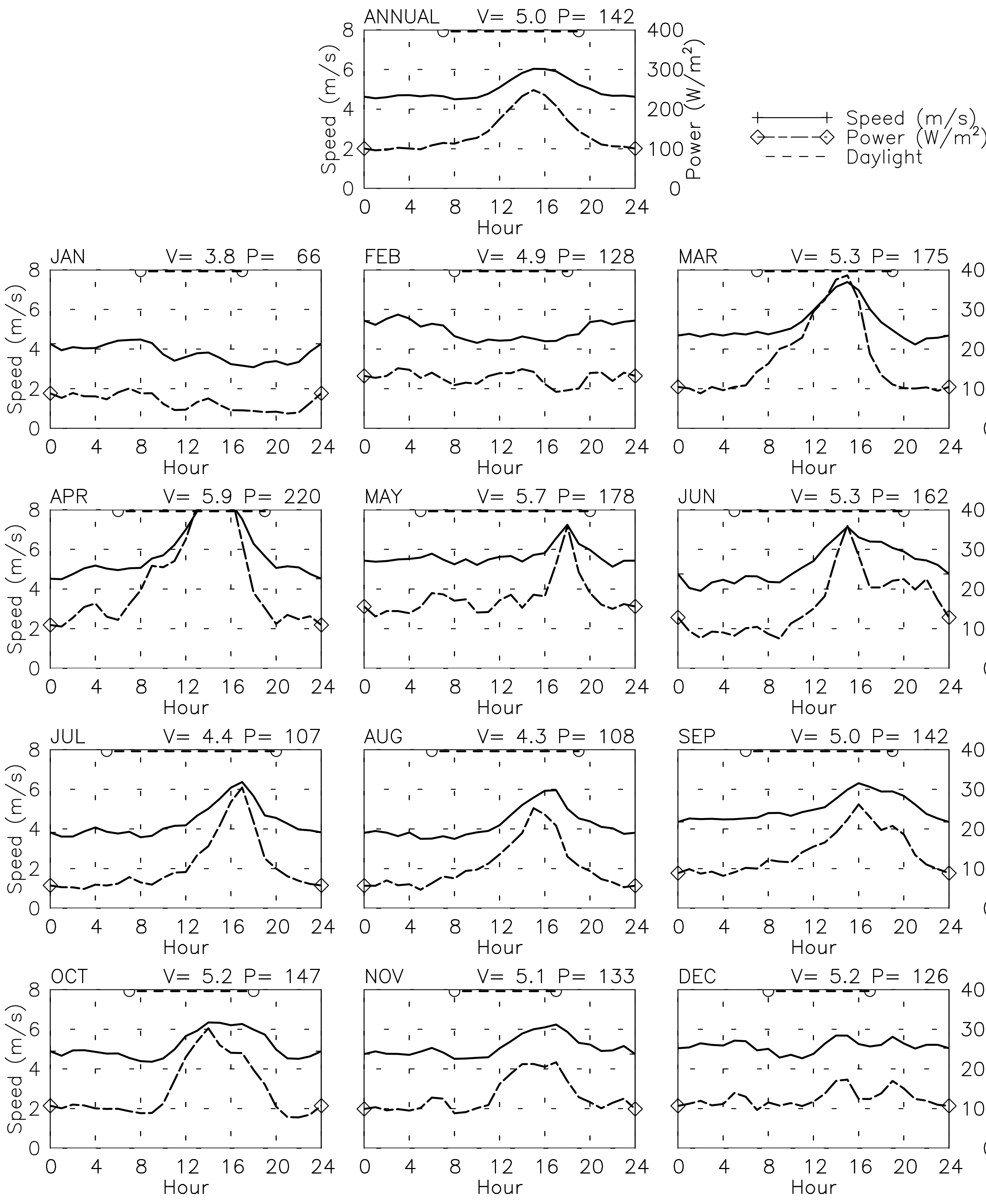
Mon Jul 16 15:55:58 2001

SPEED AND POWER BY HOUR

Guchin-Us (Uvurkh.) - 000001

45° 28' N 102° 25' E - Elev 1100m LST=GMT+99 hours *NT= +7

08/98-07/00



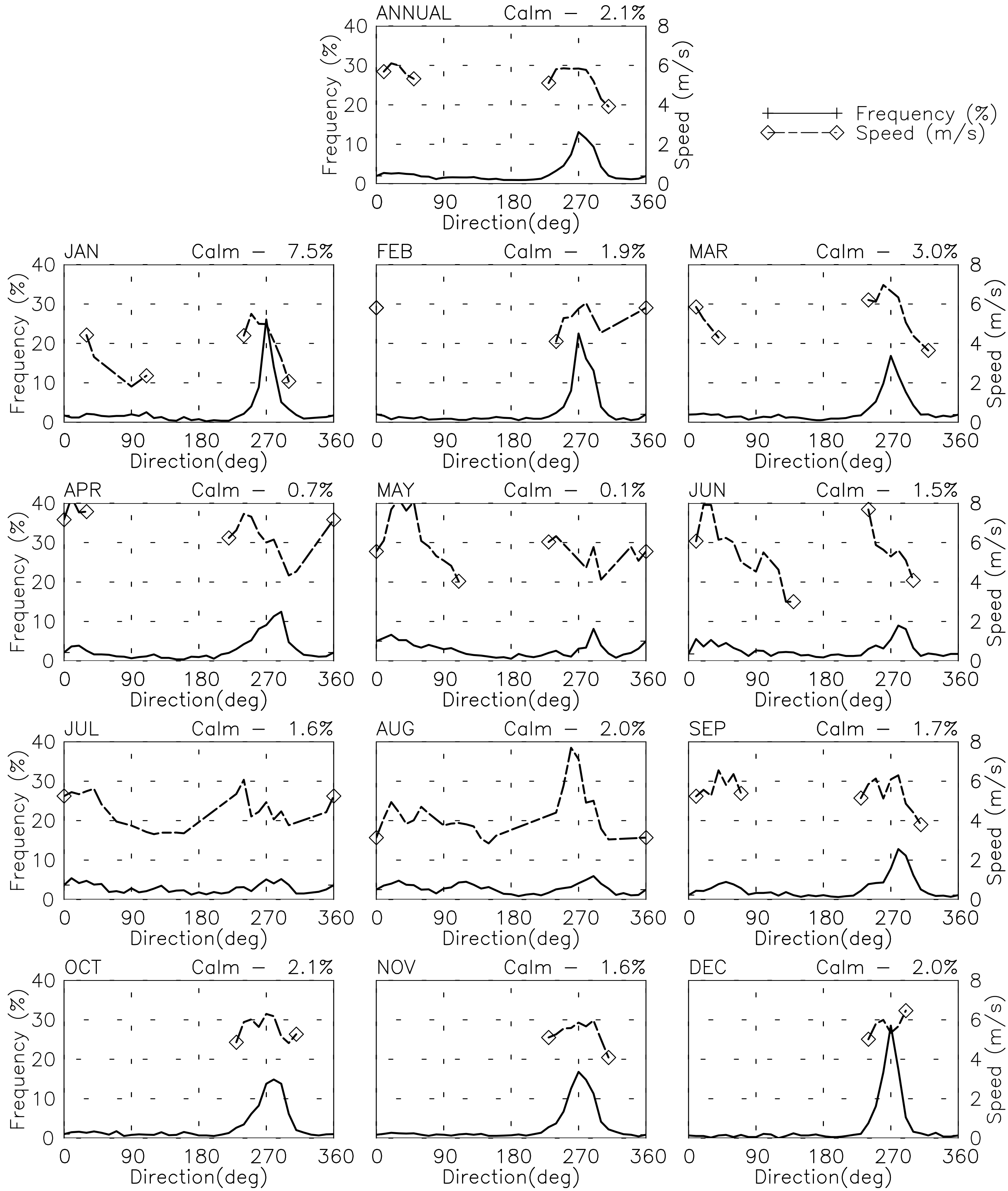
Mon Jul 16 15:28:39 2001

FREQUENCY AND SPEED BY DIRECTION

Guchin-Us (Uvurkh.) - 000001

45° 28' N 102° 25' E - Elev 1100m LST=GMT+99 hours *NT= +7

08/98-07/00



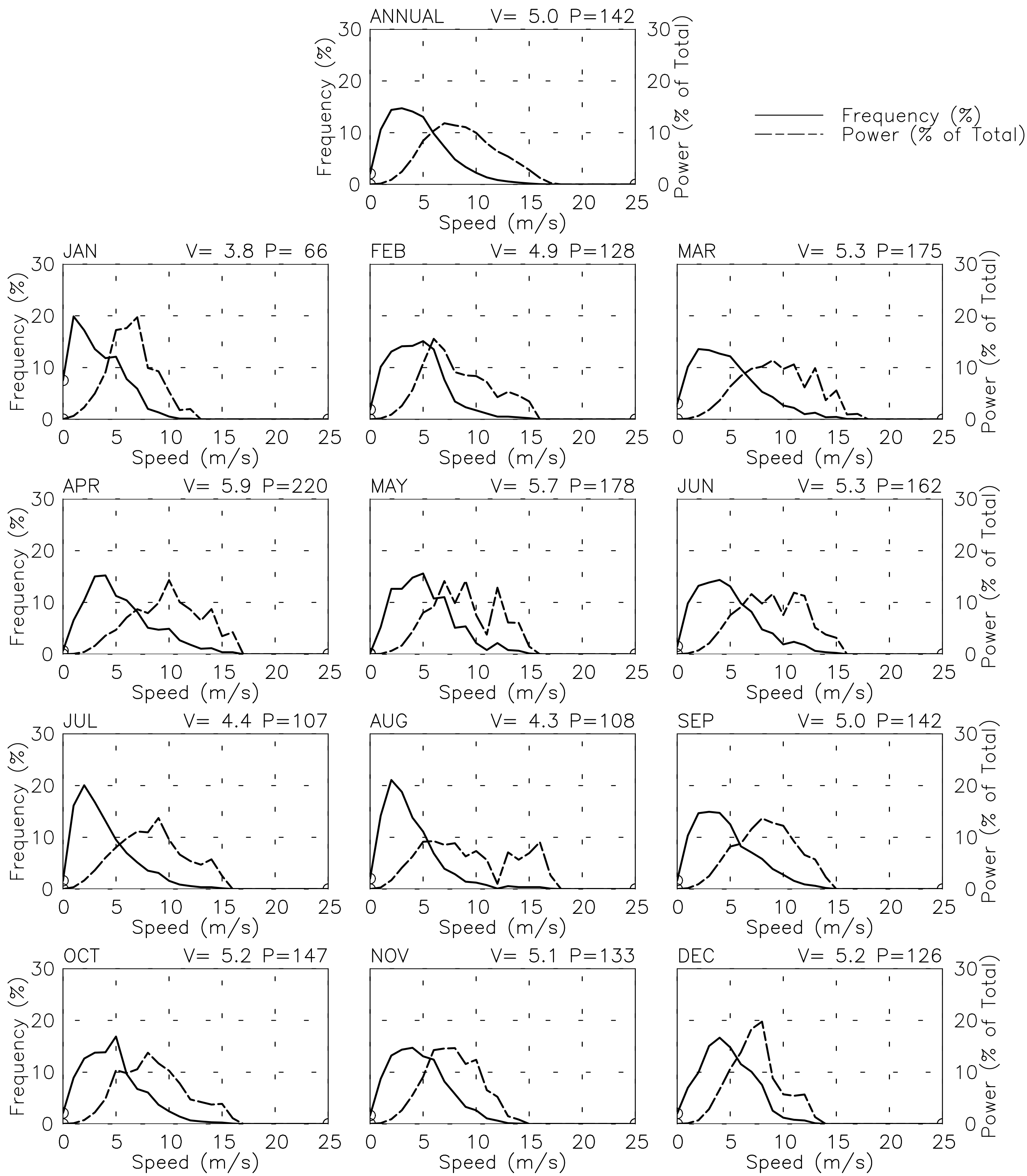
Mon Jul 16 15:28:42 2001

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

Guchin-Us (Uvurkh.) - 000001

45° 28' N 102° 25' E - Elev 1100m LST=GMT+99 hours *NT= +7

08/98-07/00



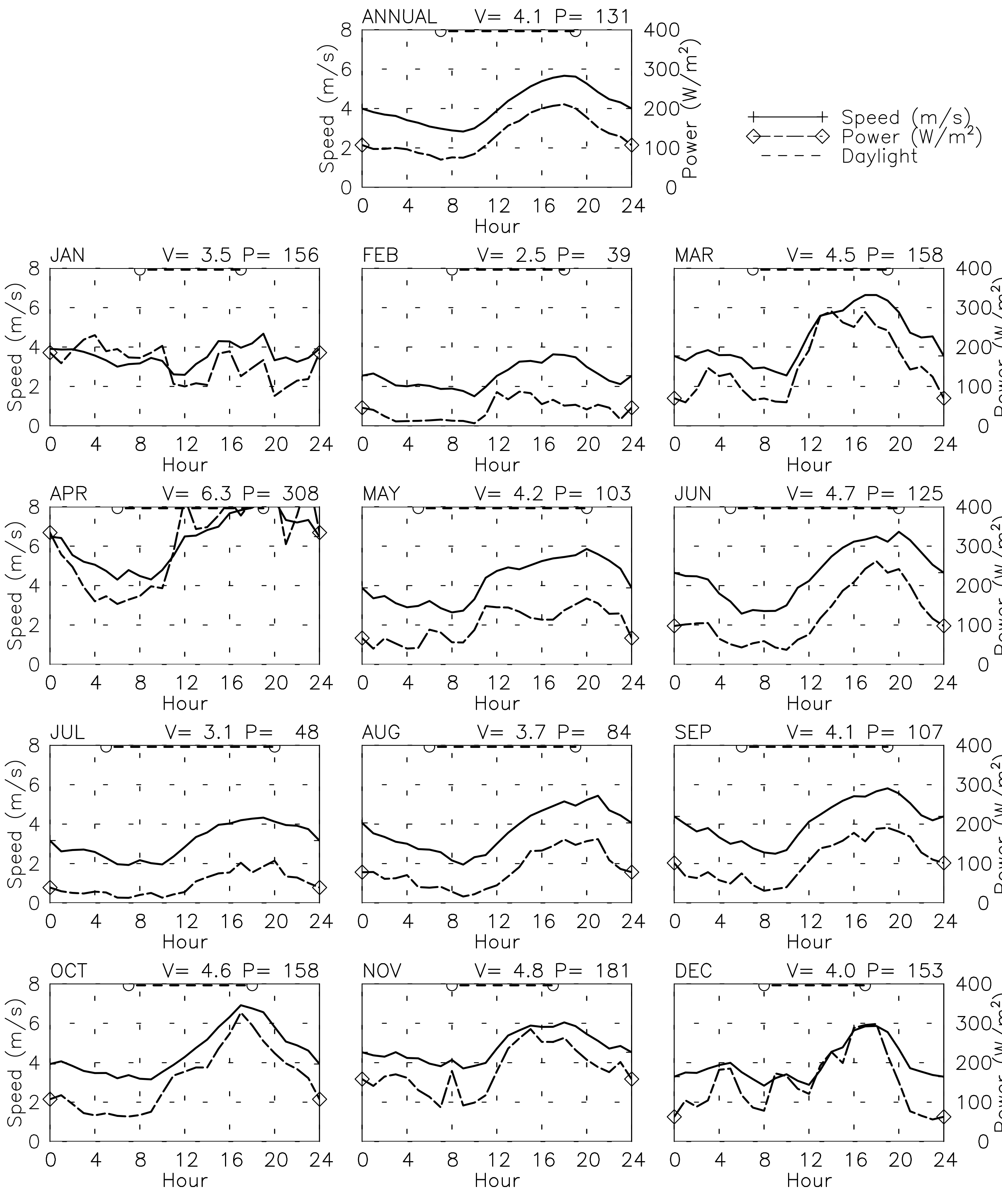
Mon Jul 16 15:28:45 2001

SPEED AND POWER BY HOUR

Bogd (Uvurkh.) – 000002

44° 41' N 102° 10' E – Elev 1200m LST=GMT+99 hours *NT= +7

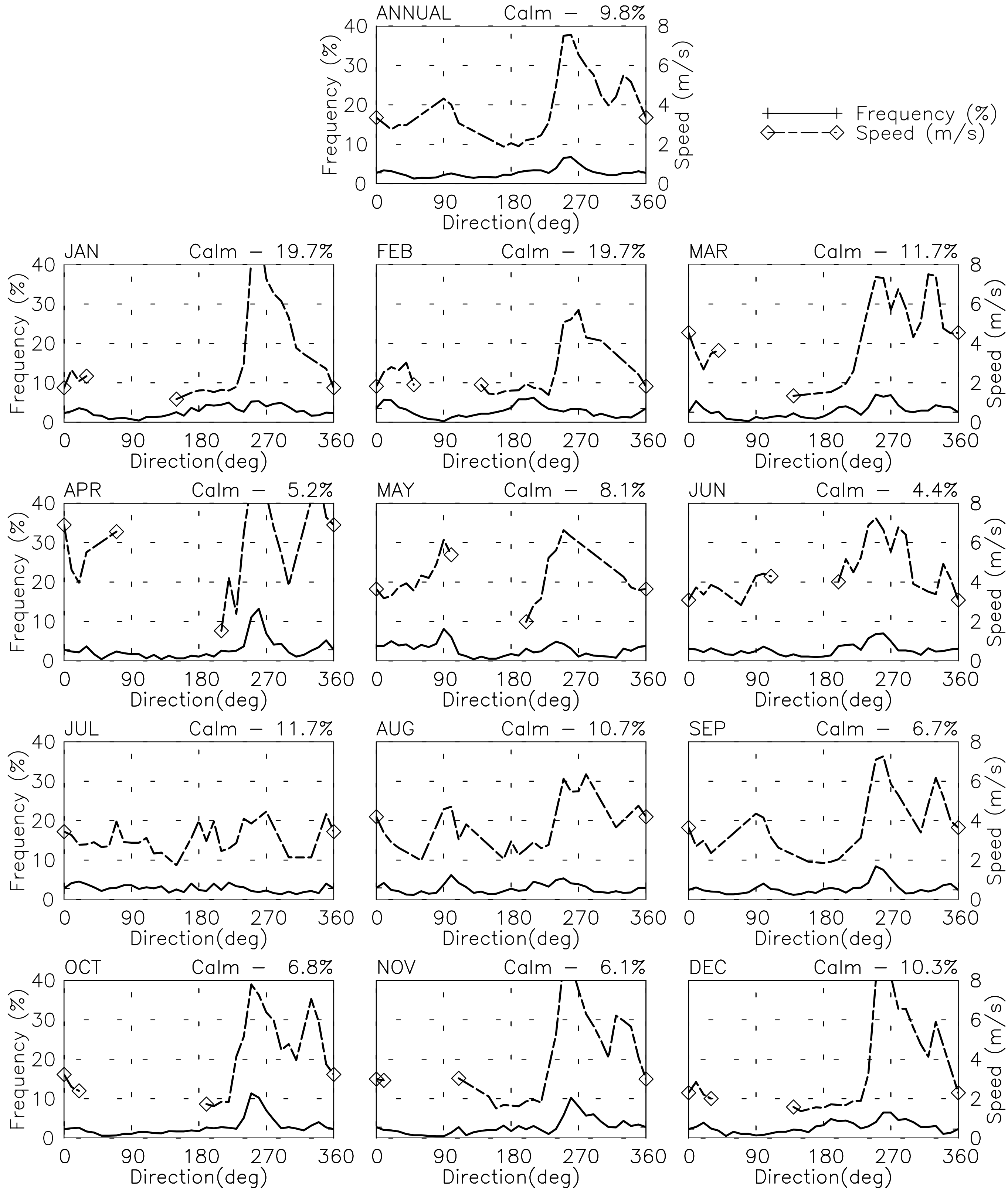
08/98–04/00



Mon Jul 16 15:28:50 2001

FREQUENCY AND SPEED BY DIRECTION

Bogd (Uvurkh.) - 000002
44° 41' N 102° 10' E - Elev 1200m LST=GMT+99 hours *NT= +7
08/98-04/00



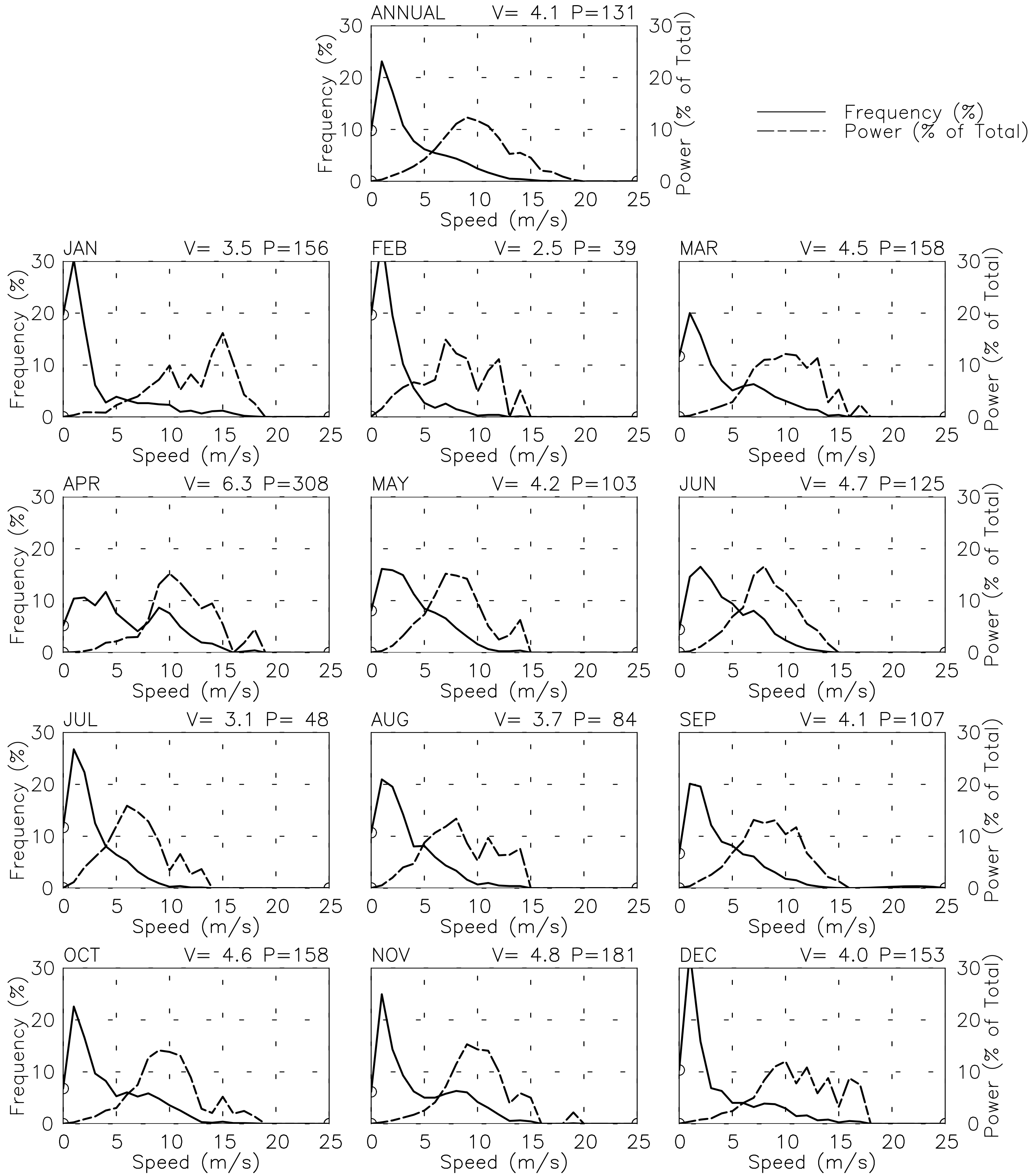
Mon Jul 16 15:28:53 2001

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

Bogd (Uvurkh.) – 000002

44° 41' N 102° 10' E – Elev 1200m LST=GMT+99 hours *NT= +7

08/98–04/00



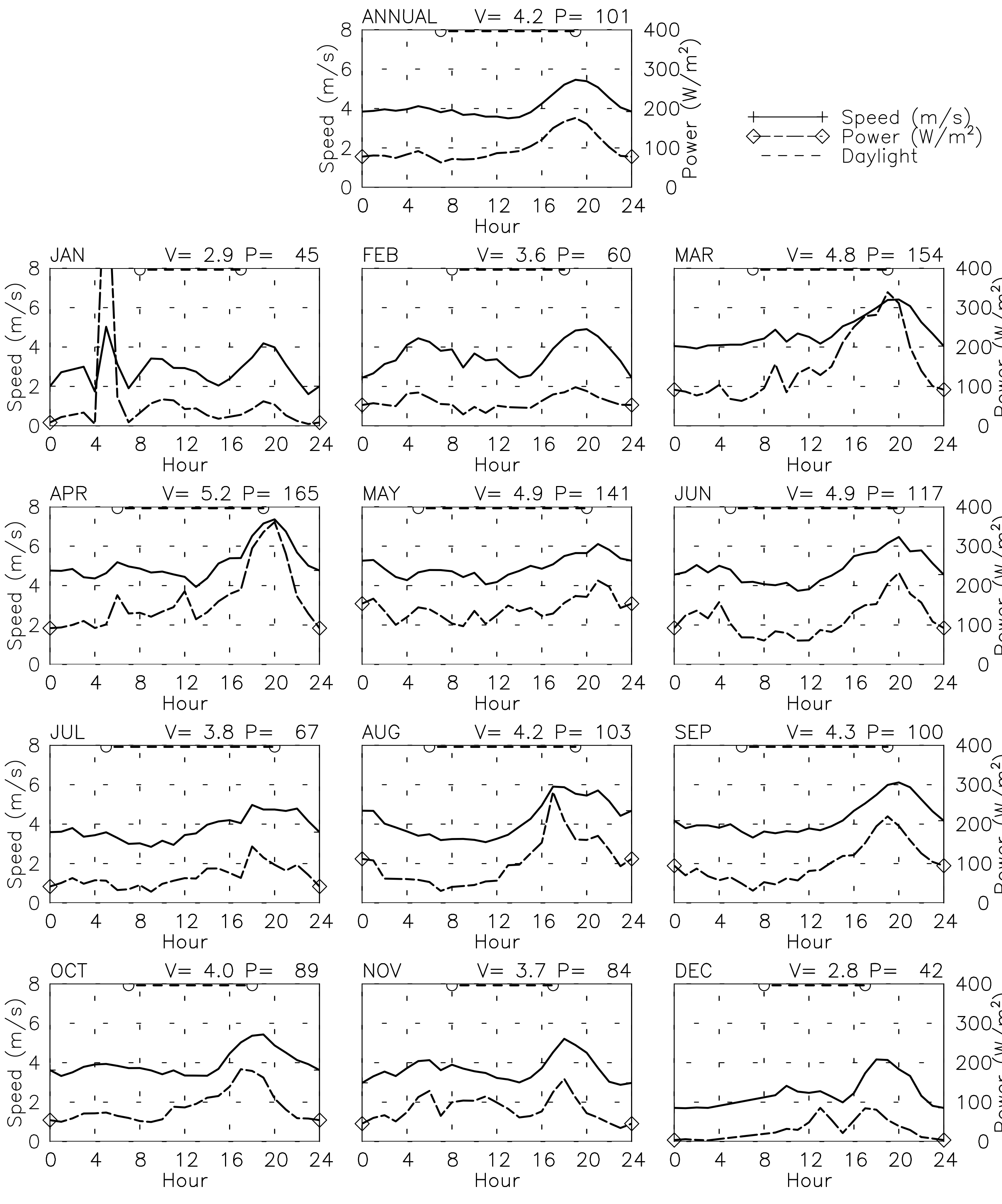
Mon Jul 16 15:28:56 2001

SPEED AND POWER BY HOUR

Bayanlig (Bayankh.) – 000003

44° 33' N 100° 50' E – Elev 1100m LST=GMT+99 hours *NT= +7

08/98–03/00



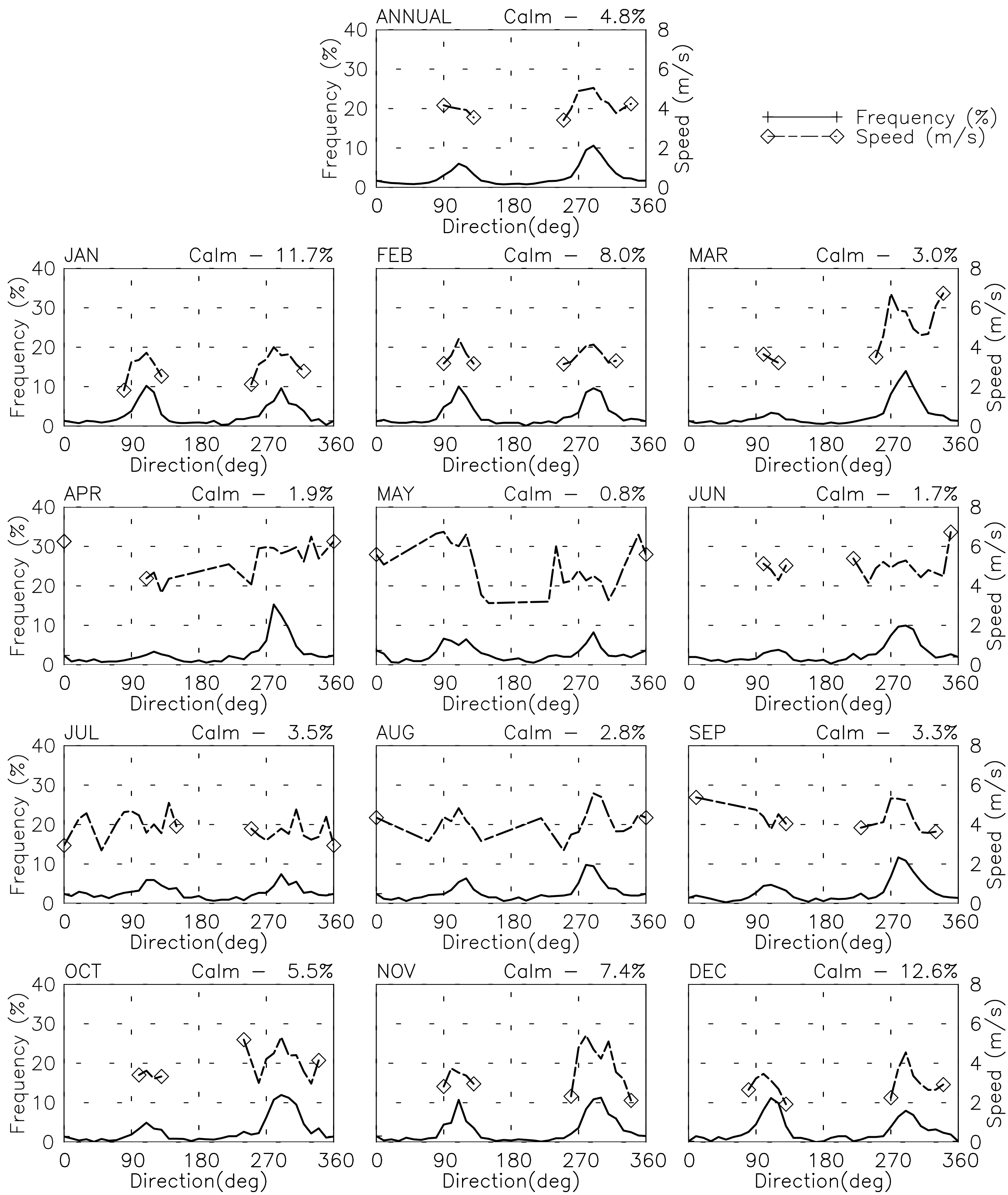
Mon Jul 16 15:29:01 2001

FREQUENCY AND SPEED BY DIRECTION

Bayanlig (Bayankh.) – 000003

44° 33' N 100° 50' E – Elev 1100m LST=GMT+99 hours *NT= +7

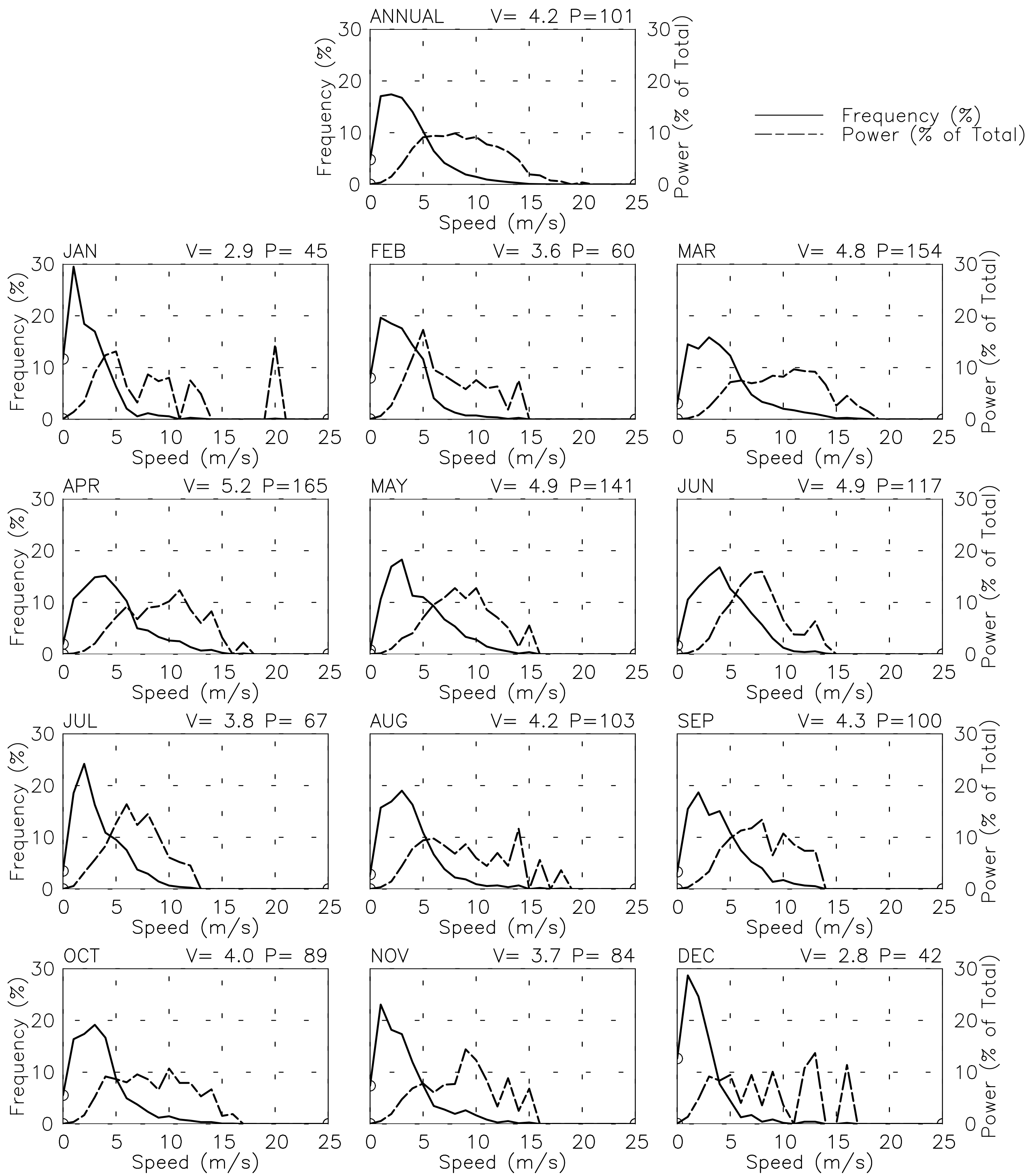
08/98–03/00



Mon Jul 16 15:29:05 2001

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

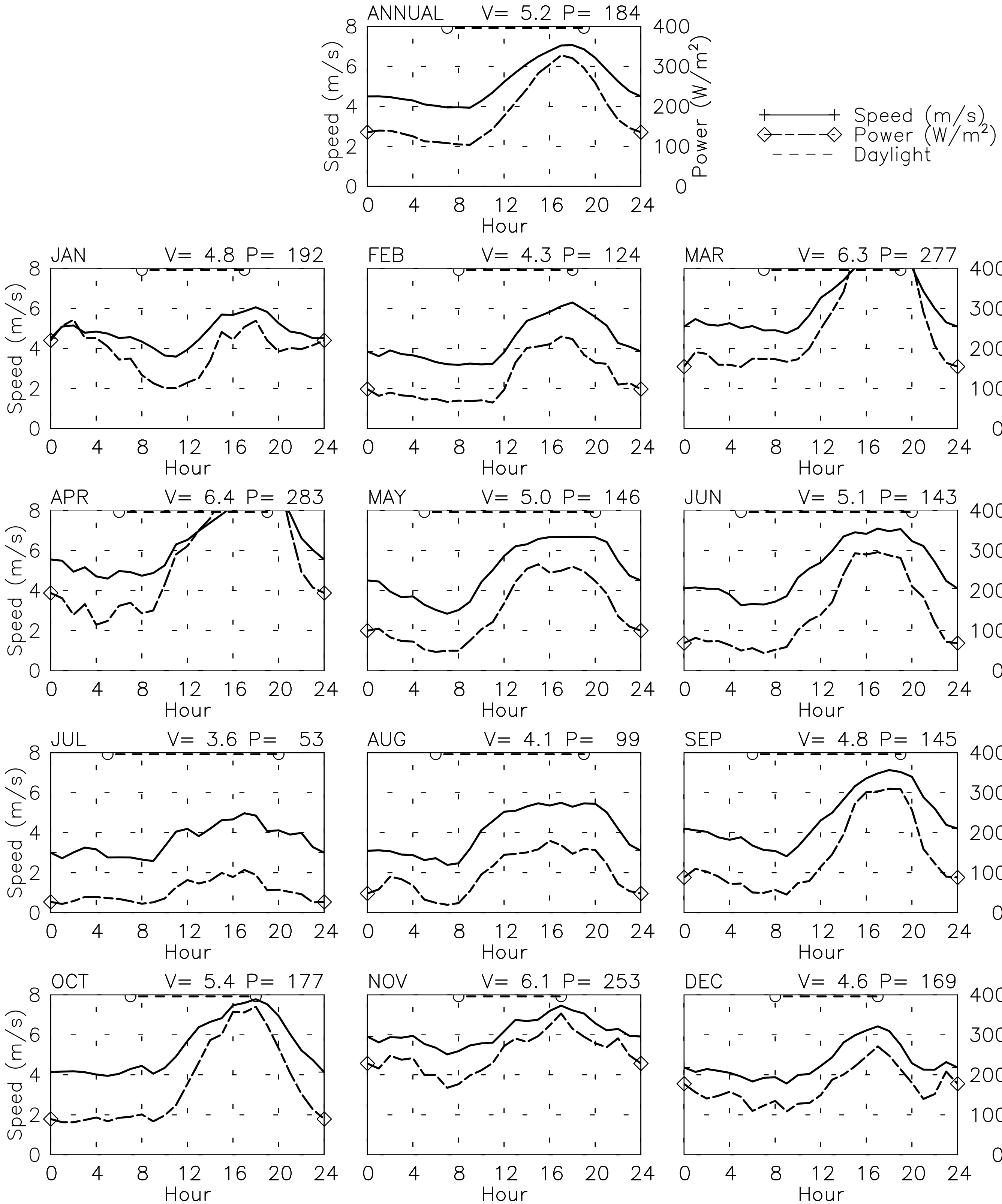
Bayanlig (Bayankh.) − 000003
44° 33' N 100° 50' E − Elev 1100m   LST=GMT+99 hours   *NT= +7
08/98−03/00



Mon Jul 16 15:29:08 2001

SPEED AND POWER BY HOUR

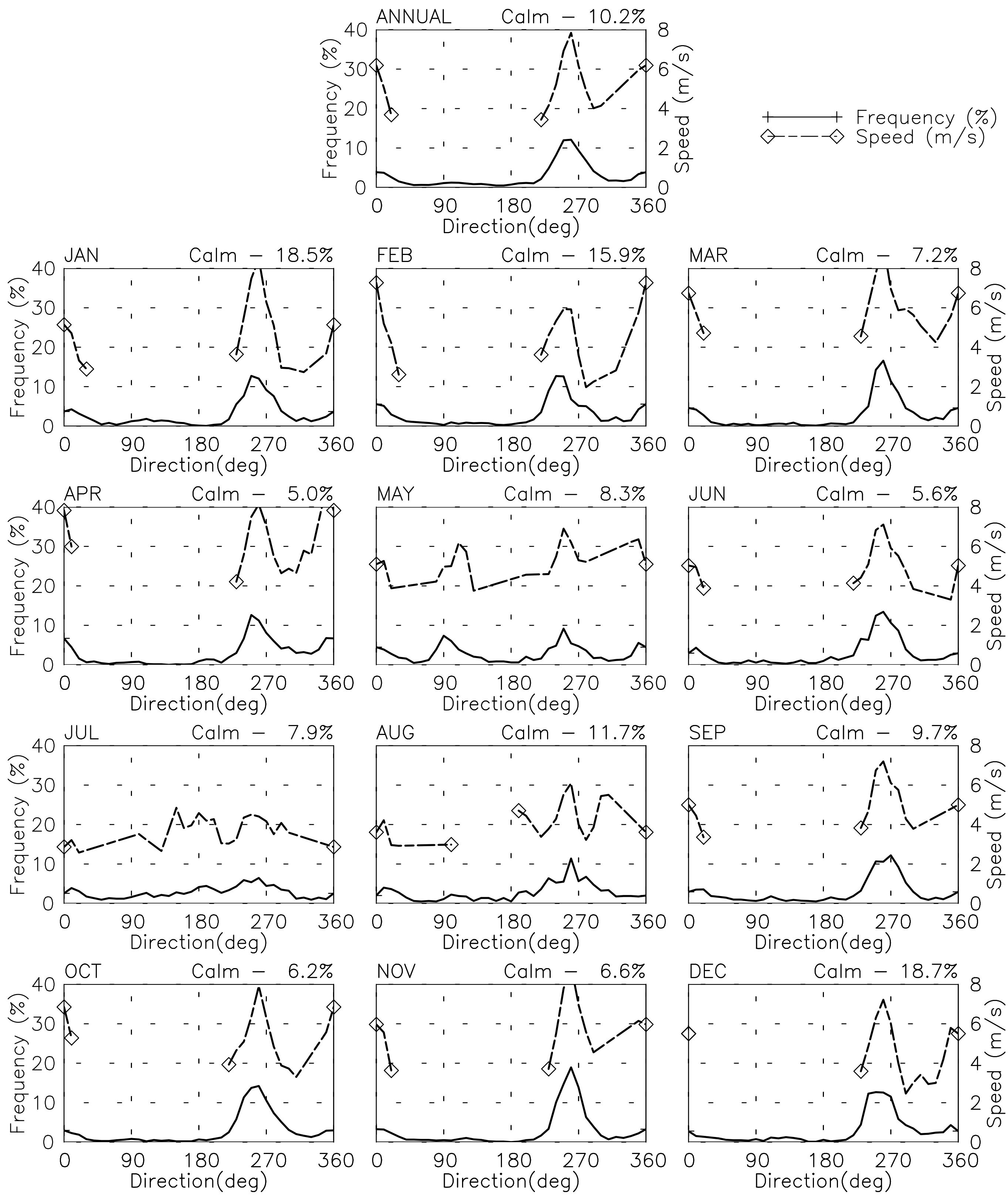
Bayan–Undur (Bayankh. – 000004
44° 48' N 98° 41' E – Elev 1600m LST=GMT+99 hours *NT= +7
08/98–05/00



Mon Jul 16 15:29:13 2001

FREQUENCY AND SPEED BY DIRECTION

Bayan-Undur (Bayankh. - 000004
44° 48' N   98° 41' E - Elev 1600m   LST=GMT+99 hours   *NT= +7
08/98-05/00



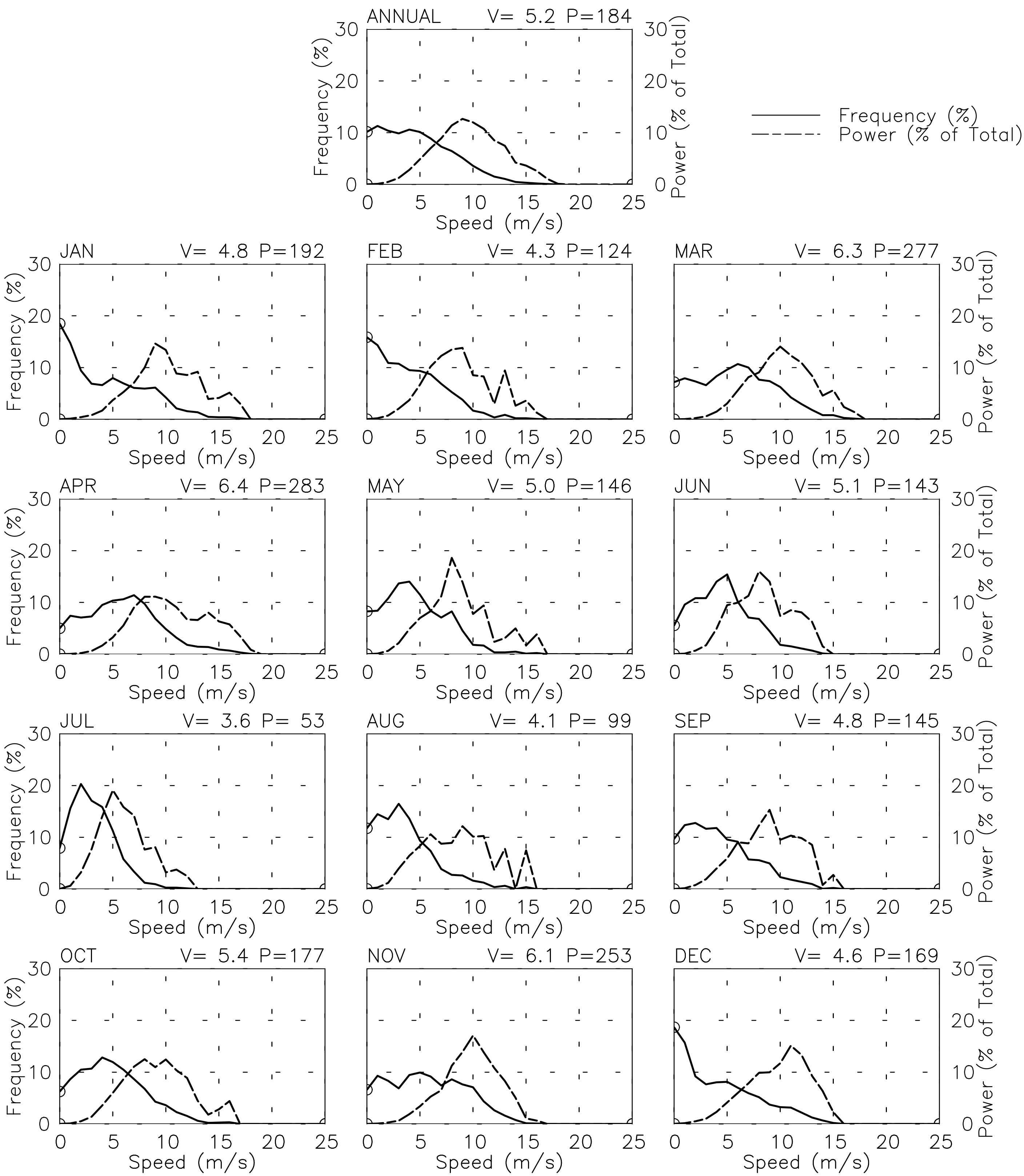
Mon Jul 16 15:29:16 2001

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

Bayan–Undur (Bayankh. – 000004

44° 48' N   98° 41' E – Elev 1600m   LST=GMT+99 hours   *NT= +7

08/98–05/00



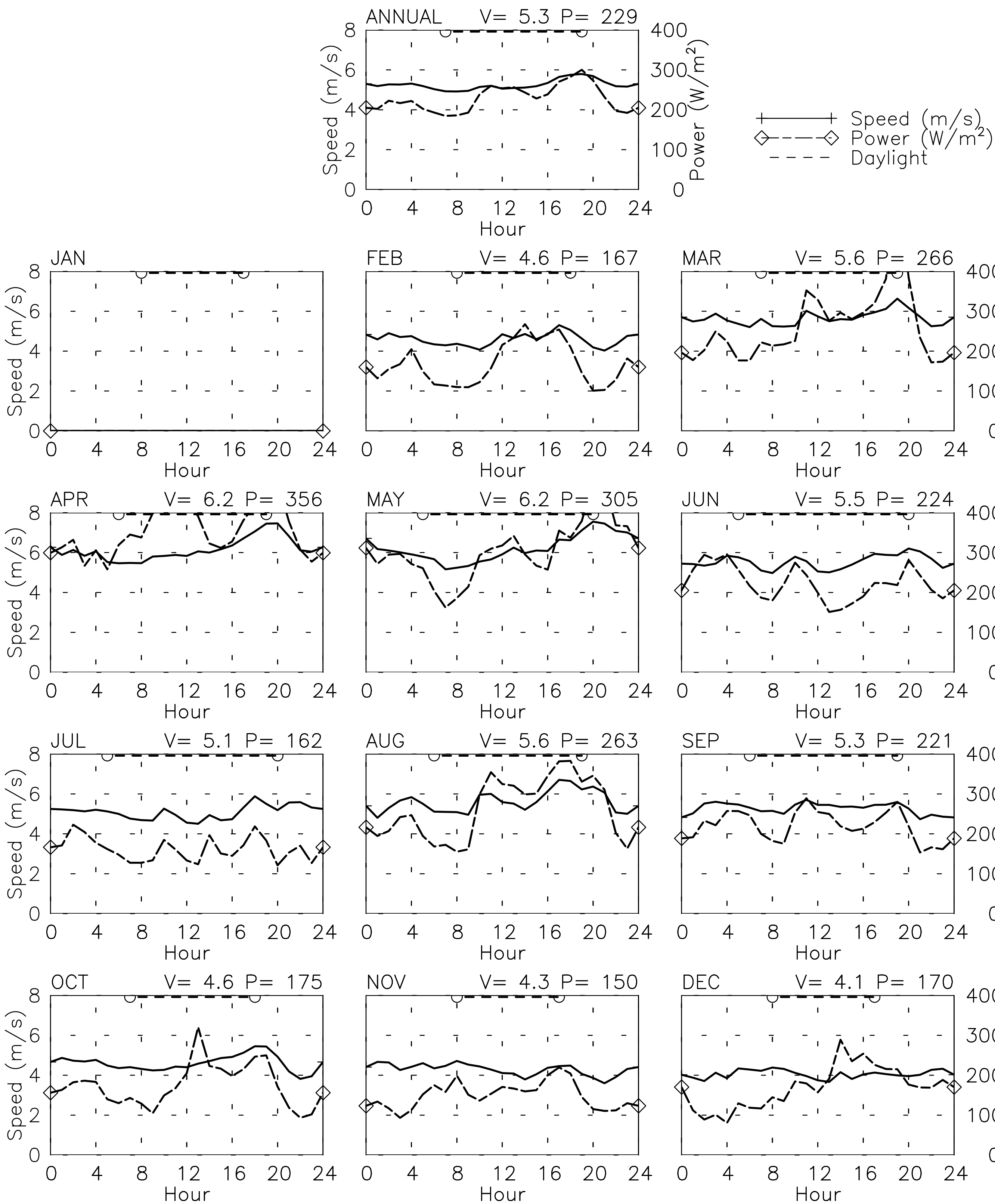
Mon Jul 16 15:29:20 2001

SPEED AND POWER BY HOUR

Bogd (Bayankh.) – 000005

45° 12' N 100° 46' E – Elev 1200m LST=GMT+99 hours *NT= +7

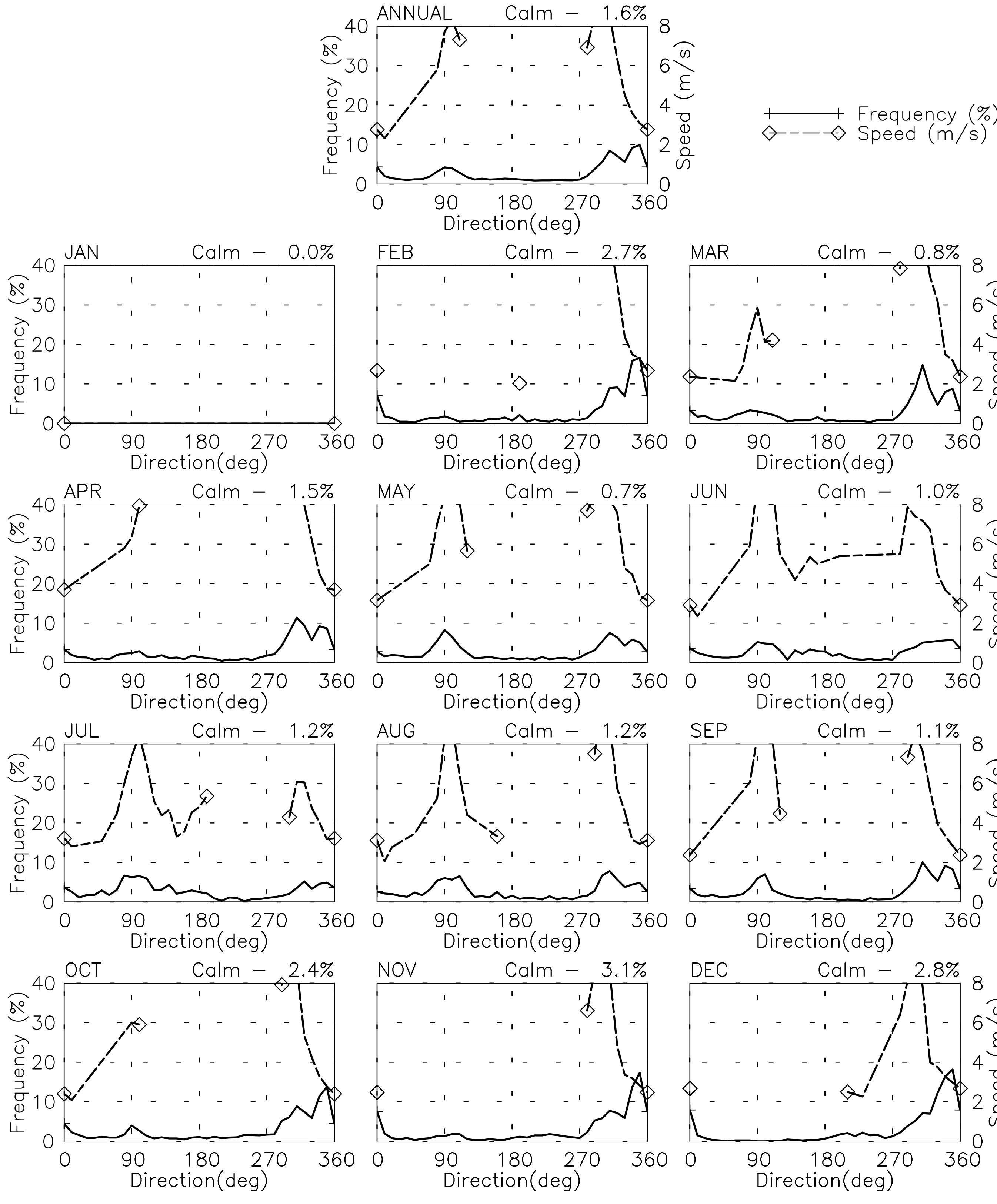
09/98–07/00



Mon Jul 16 15:29:25 2001

FREQUENCY AND SPEED BY DIRECTION

Bogd (Bayankh.) – 000005
45° 12' N 100° 46' E – Elev 1200m LST=GMT+99 hours *NT= +7
09/98–07/00



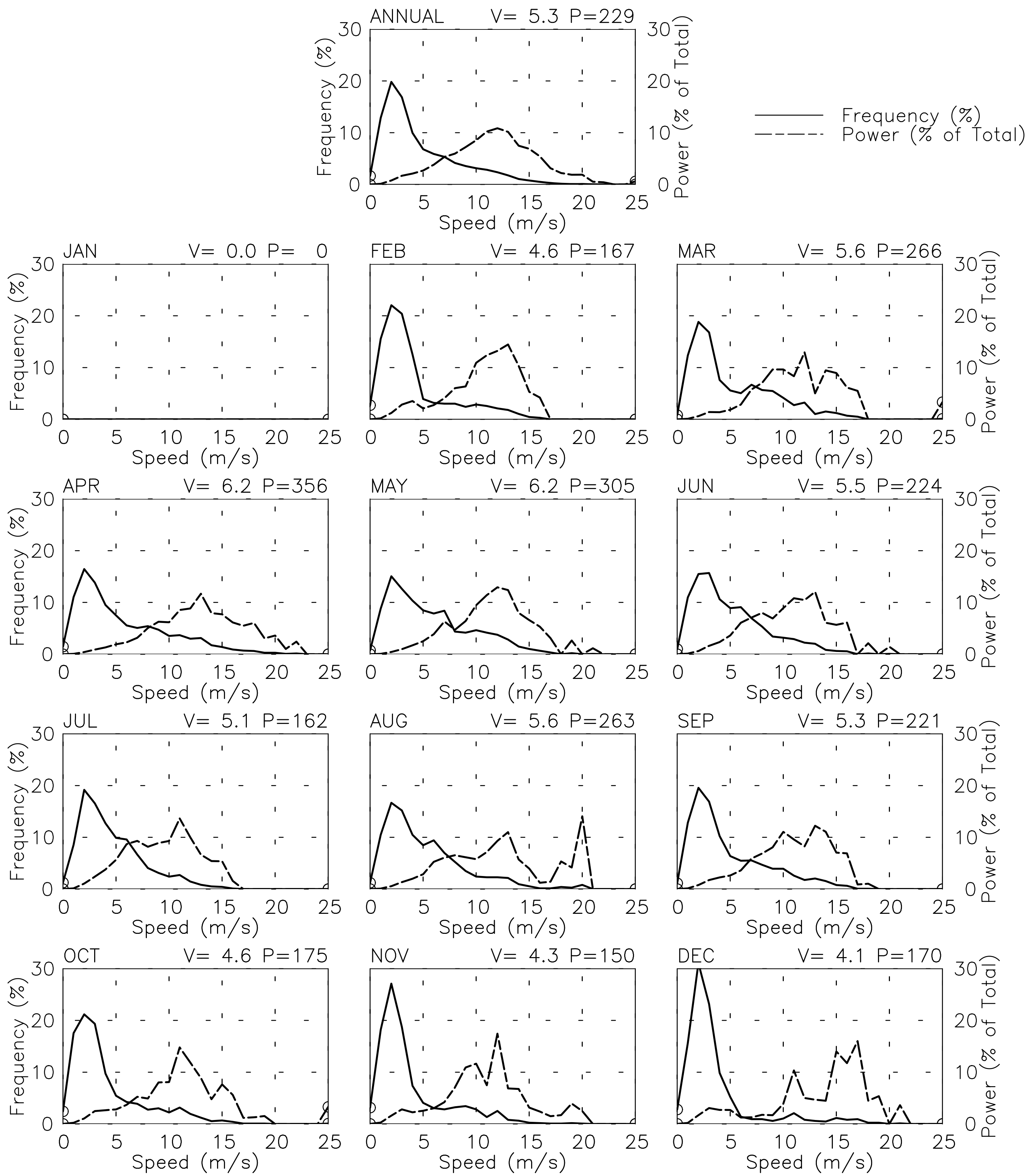
Mon Jul 16 15:29:28 2001

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

Bogd (Bayankh.) – 000005

45° 12' N 100° 46' E – Elev 1200m LST=GMT+99 hours *NT= +7

09/98–07/00



Mon Jul 16 15:29:31 2001

Appendix C

Upper-Air Stations
Tables and Analysis Summaries of Selected Stations

Table C.1 Upper-air Stations from ADP Database

Ulaanbaatar Station Summaries
Ulaangom Station Summaries

Table C.1 Upper-air Stations from ADP Database

WMO Number	Name	Aimag	Lat	Lon	Elev (m)	Start Date	End Date	Number of Obs
44212	Ulaangom	Uvs	49 48	92 05	939	01/73	03/97	12026
44218	Khovd	Khovd	48 01	91 39	1405	01/73	12/93	3568
44231	Muren	Khuvsgul	49 38	100 10	1283	01/73	03/97	12448
44239	Bulgan	Bulgan	48 48	103 33	1210	01/73	10/92	3577
44241	Baruunkharaa	Selenge	48 55	106 04	807	01/73	01/90	3607
44259	Choibalsan	Dornod	48 05	114 33	747	01/73	06/96	10736
44272	Uliastai	Zavkhan	47 45	96 51	1751	01/73	06/93	3351
44277	Altai	Govi-Altai	46 24	96 15	2181	01/73	03/97	8862
44282	Tsetserleg	Arkhangai	47 27	101 28	1693	01/73	06/91	2982
44288	Arvaikheer	Uvurkhangai	46 16	102 47	1813	01/73	03/97	11853
44292	Ulaanbaatar	Ulaanbaatar	47 55	106 52	1306	01/73	03/97	15314
44341	Mandalgobi	Dundgovi	45 46	106 17	1393	01/73	02/90	3394
44354	Sainshand	Dornogovi	44 54	110 07	936	01/73	09/92	10769
44373	Dalanzadgad	Umnugovi	43 35	104 25	1469	01/73	05/96	11469

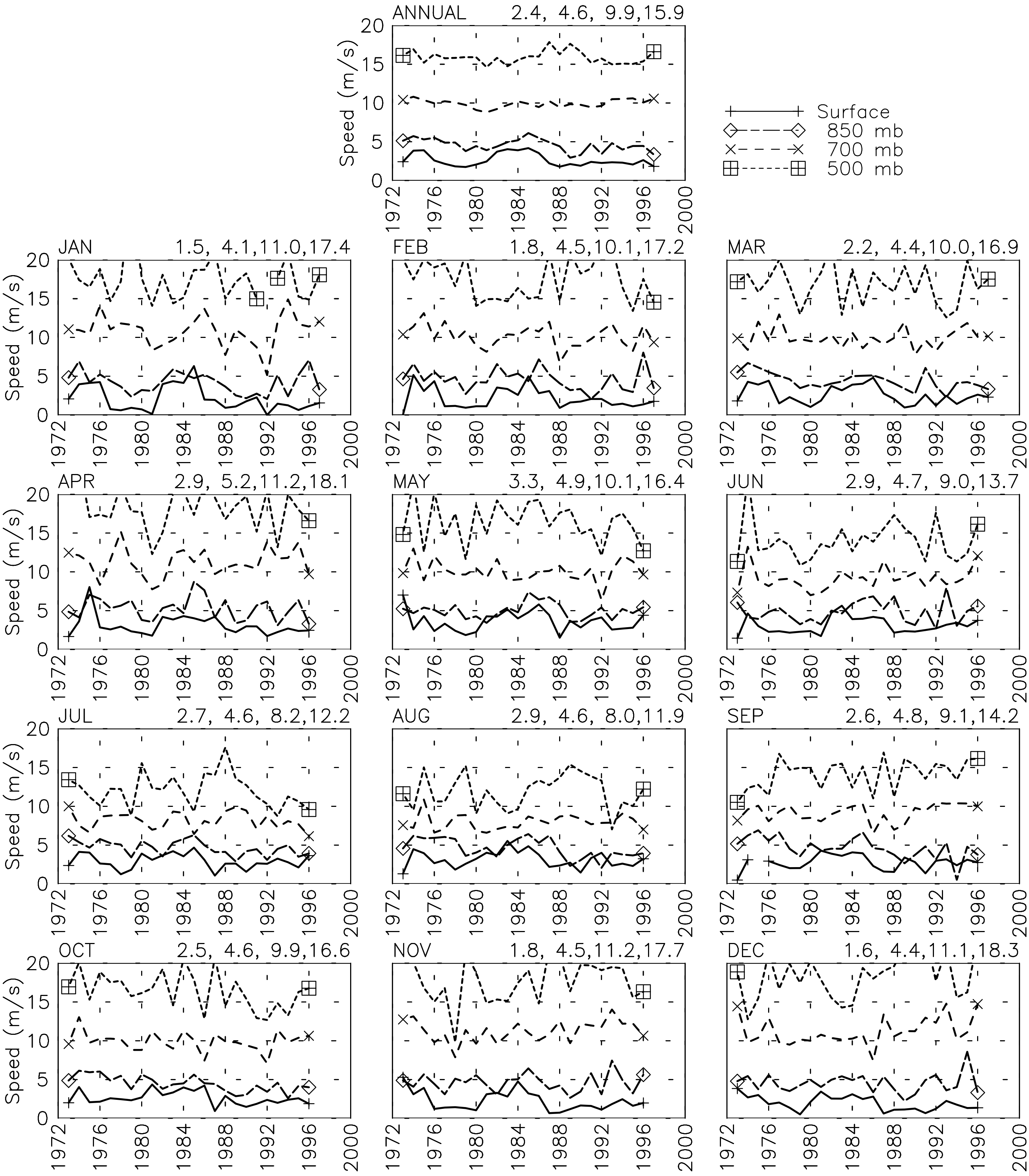
WMO Number	Name	Country	Lat	Lon	Elev (m)	Start Date	End Date	Number of Obs
30710	Irkutsk	RU	52 22	104 11	437	12/72	07/96	19545
30758	Chita	RU	52 01	113 20	668	12/72	03/97	26831
30935	Krasnyy Chikoy	RU	50 22	108 45	770	12/72	01/97	25607
30965	Borzya	RU	50 23	116 31	684	12/72	03/97	24313
36096	Kyzyl	RU	51 40	94 23	629	12/72	03/97	23358
36177	Semipalatinsk	RU	50 21	80 15	194	12/72	10/95	21745
36259	Kosh Agach	RU	50 00	88 40	1758	12/72	07/91	10314

WMO Number	Name	Country	Lat	Lon	Elev (m)	Start Date	End Date	Number of Obs
50527	Hailar	CI	49 13	119 45	611	12/72	03/97	18270
50603	Xin Barag Youqi	CI	48 40	116 49	556	01/73	03/97	14032
50834	Teposuk	CI	46 36	121 22	427	07/83	03/97	8737
51076	Altay	CI	47 44	88 05	737	12/72	03/97	18687
51243	Karamy	CI	45 36	84 51	426	01/73	03/97	15348
51288	Baytik	CI	45 22	90 32	1651	01/73	03/97	14771
51463	Urumqi	CI	43 47	87 28	919	12/72	03/97	19675
52203	Hami	CI	42 49	93 31	739	12/72	03/97	18957
52267	Ejin Qi	CI	41 57	101 04	941	12/72	03/97	18581
52323	Mazong	CI	41 48	97 02	1770	12/72	03/97	16899
52418	Dunhuang	CI	40 09	94 41	1140	12/72	03/97	18686
52495	Bayan Mod	CI	40 45	104 30	1329	01/76	03/97	13158
53068	Erenhot	CI	43 39	112 00	966	12/72	03/97	18457
53083	Naran Bulag	CI	44 41	113 42	1208	12/72	03/97	14239
53336	Haliut	CI	41 34	108 31	1290	12/72	03/97	15167
53463	Hohhot	CI	40 49	111 41	1065	12/72	03/97	16876
54102	Xilin Hot	CI	43 57	116 04	991	12/72	03/97	18349

Latitude (Lat) and longitude (Lon) are in degrees and minutes.

SPEED BY PRESSURE LEVEL & YEAR

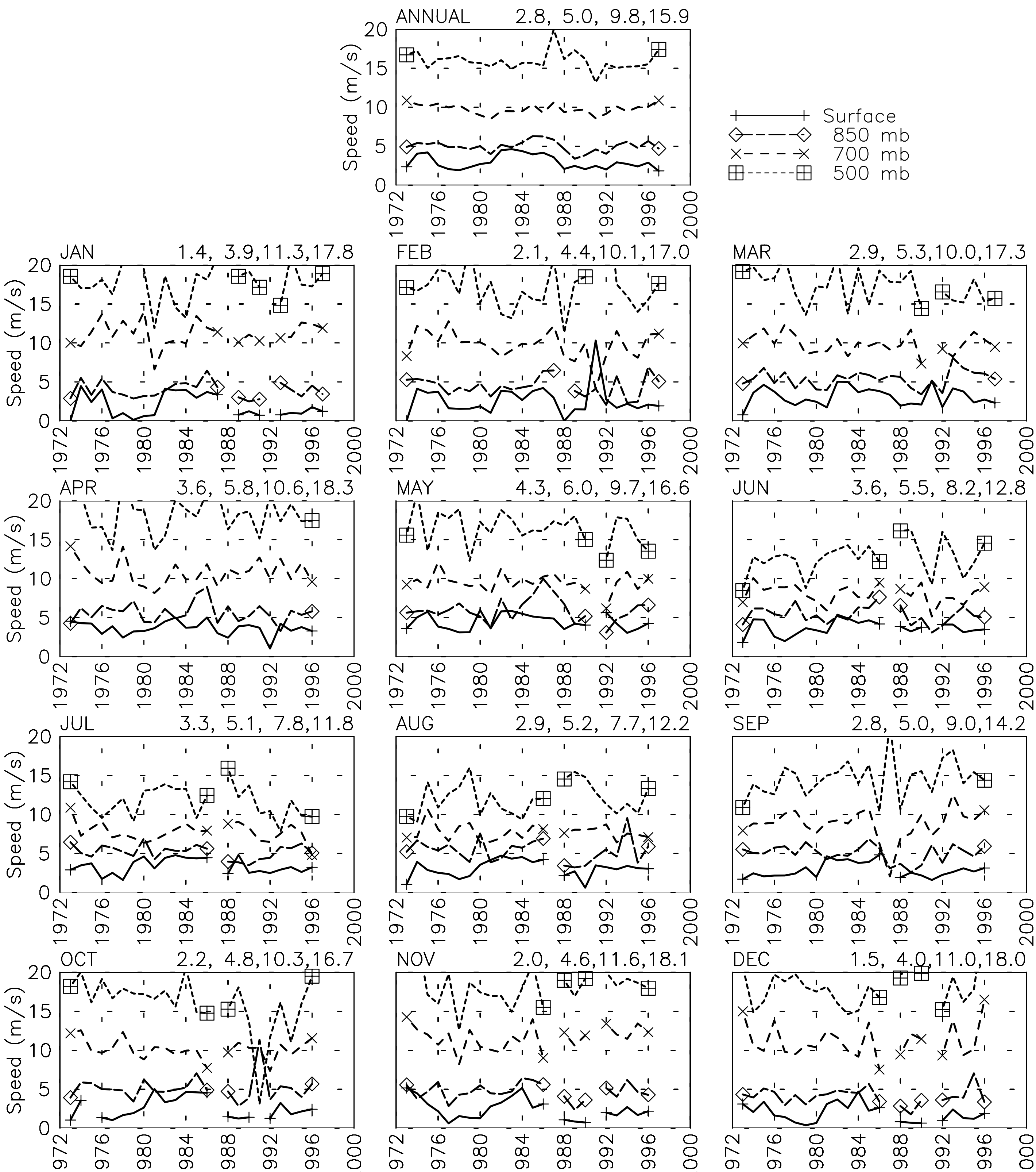
Ulan–Bator – 44292 – 0800 LST
47° 56' N 106° 59' E – Elev 1313m
01/73–03/97



Wed Apr 11 13:50:57 2001

SPEED BY PRESSURE LEVEL & YEAR

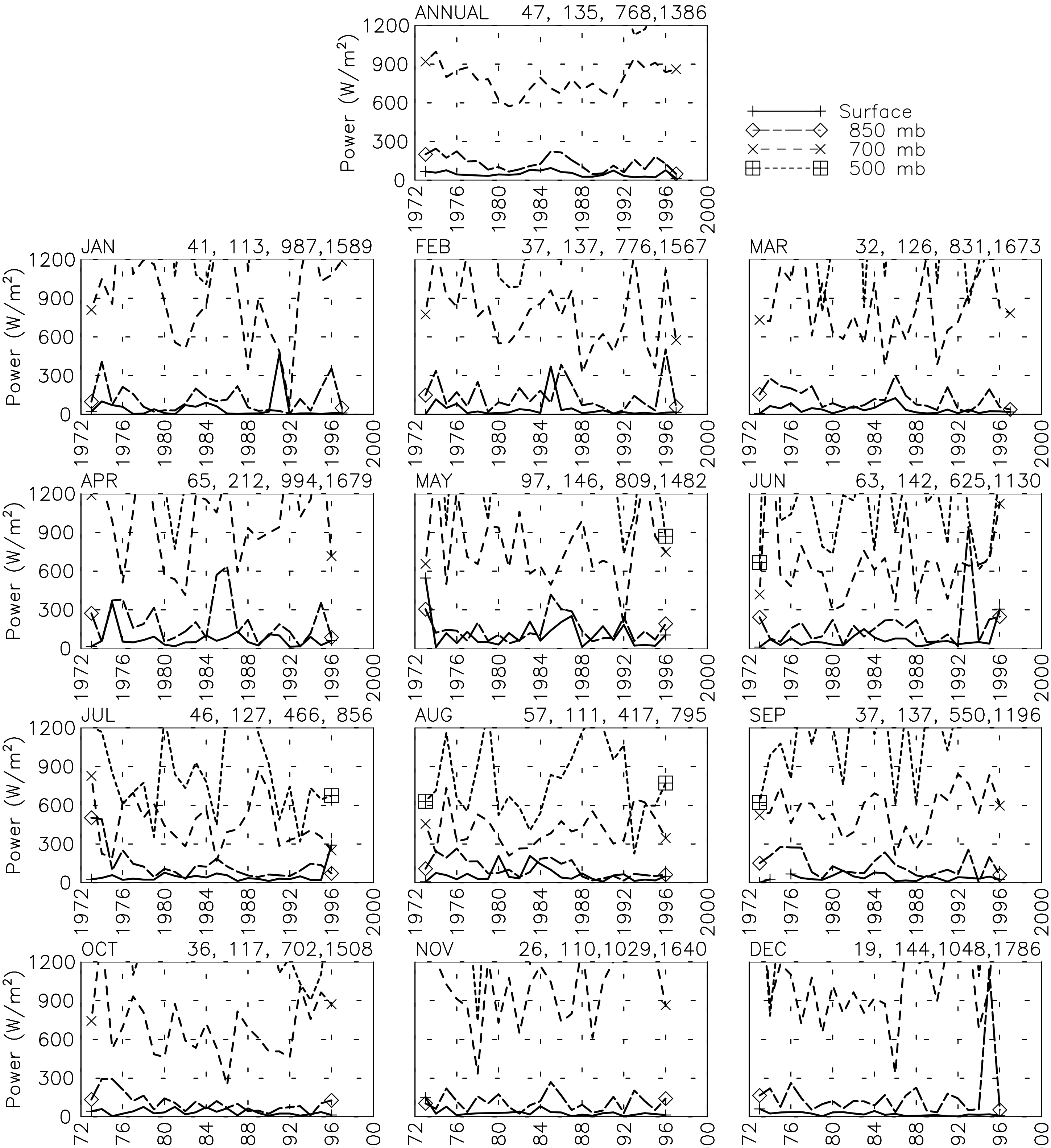
Ulan−Bator − 44292 − 2000 LST
47° 56' N 106° 59' E − Elev 1313m
01/73−03/97



Wed Apr 11 13:51:03 2001

POWER BY PRESSURE LEVEL & YEAR

Ulan–Bator – 44292 – 0800 LST
47° 56' N 106° 59' E – Elev 1313m
01/73–03/97



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POWER BY PRESSURE LEVEL & YEAR

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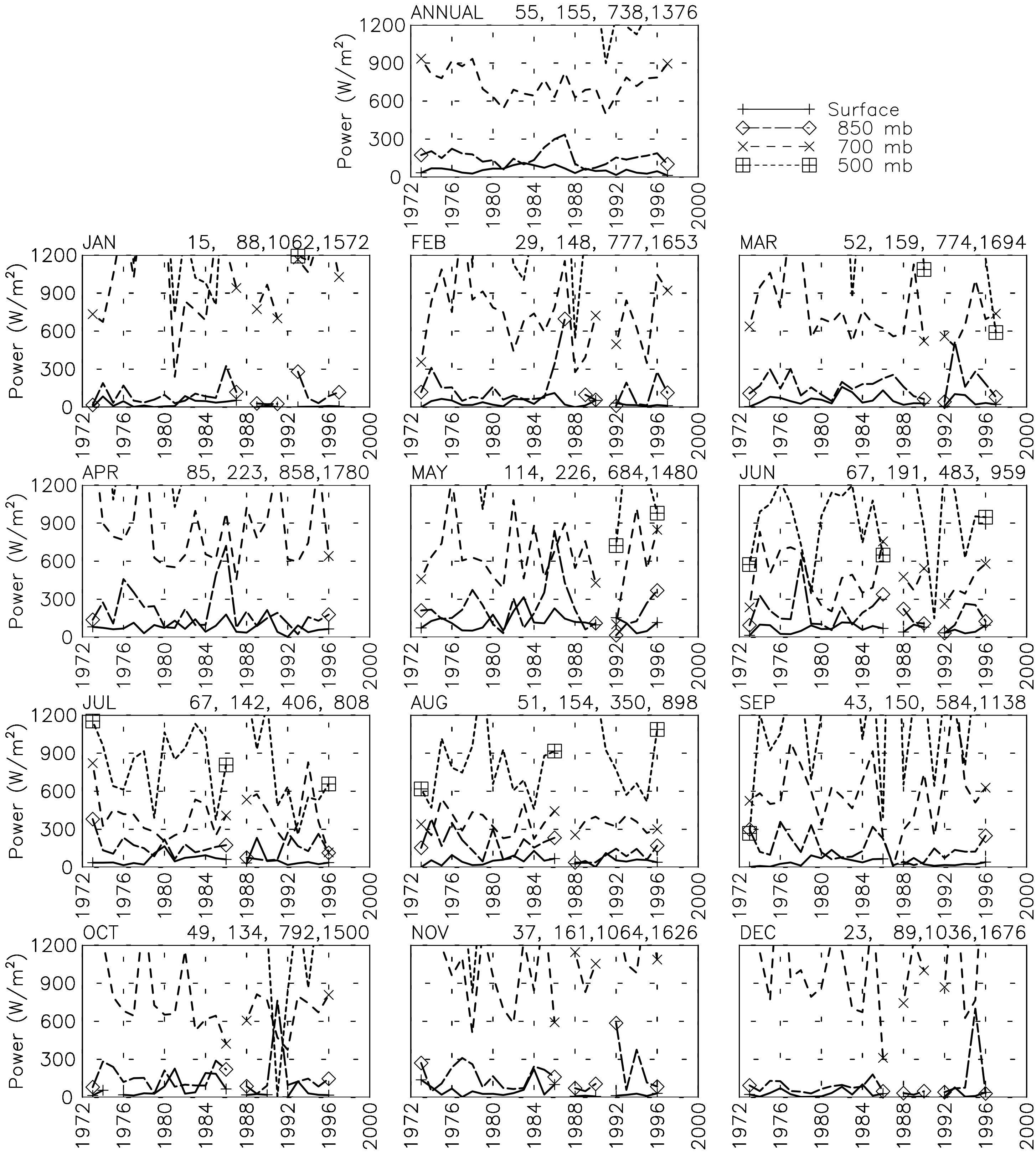
01/73–03/97



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FREQUENCY & SPEED BY DIRECTION

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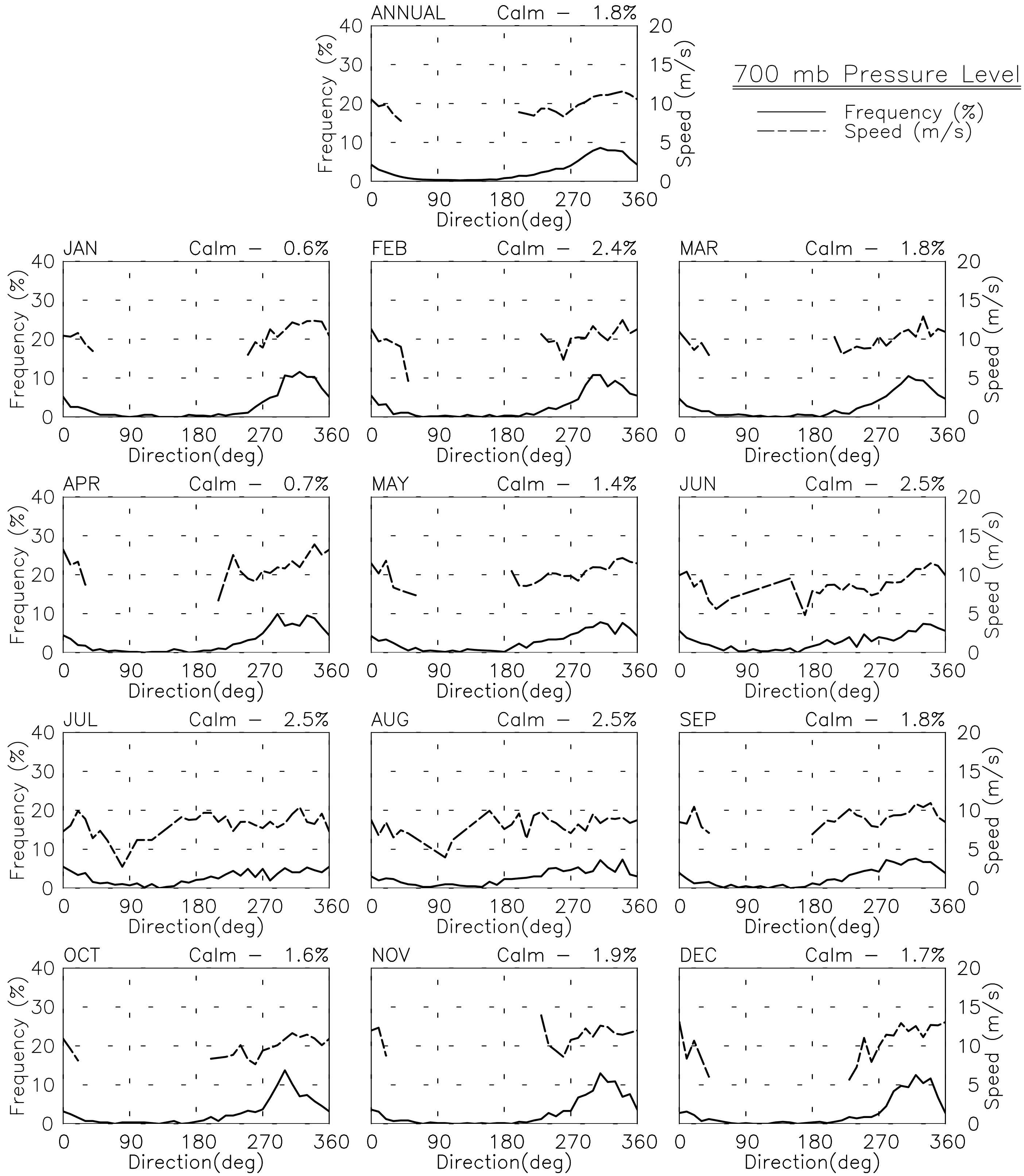
01/73–03/97



Wed Apr 11 17:20:18 2001

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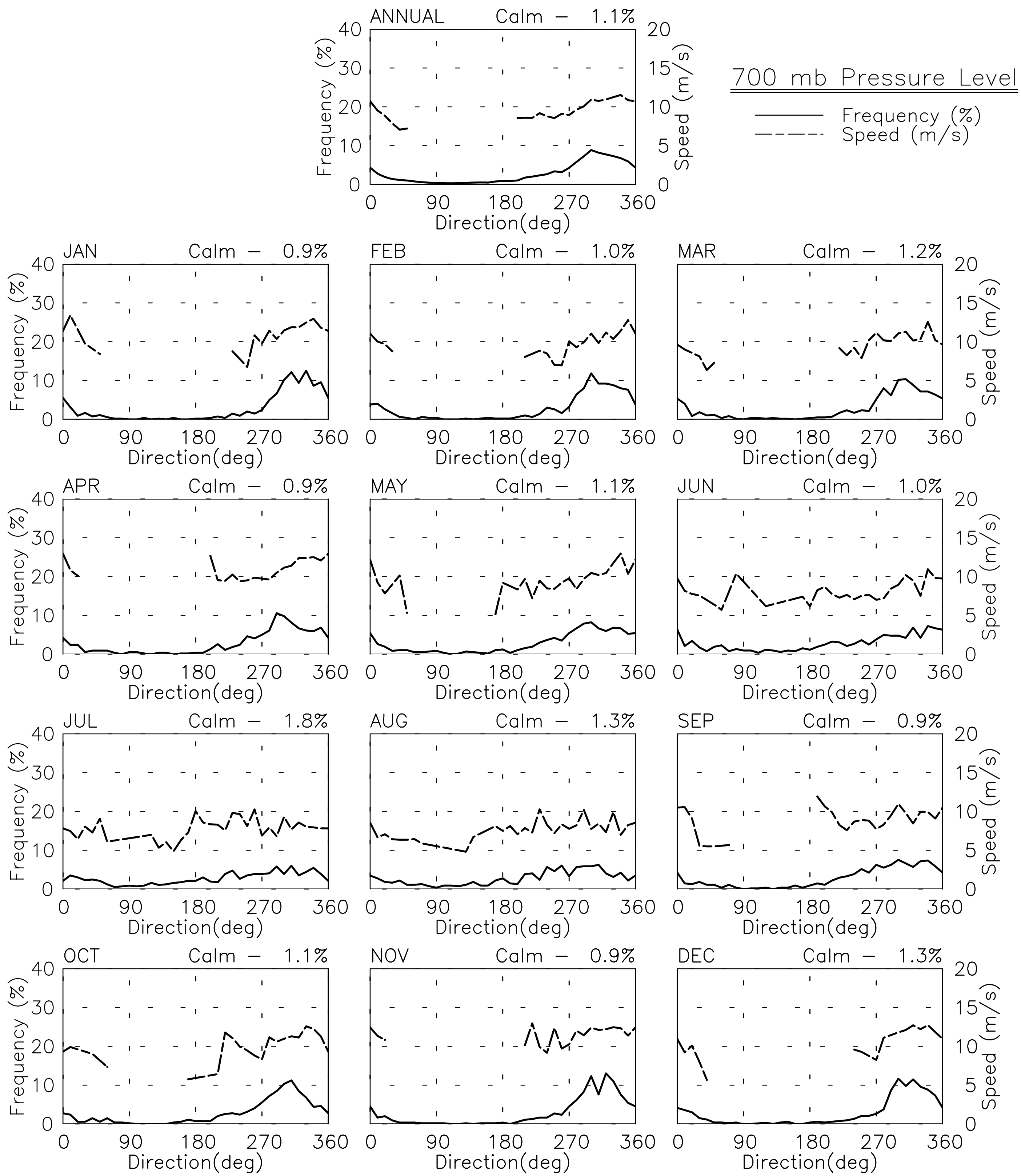
01/73–03/97



Wed Apr 11 17:20:21 2001

SPEED BY PRESSURE LEVEL & YEAR

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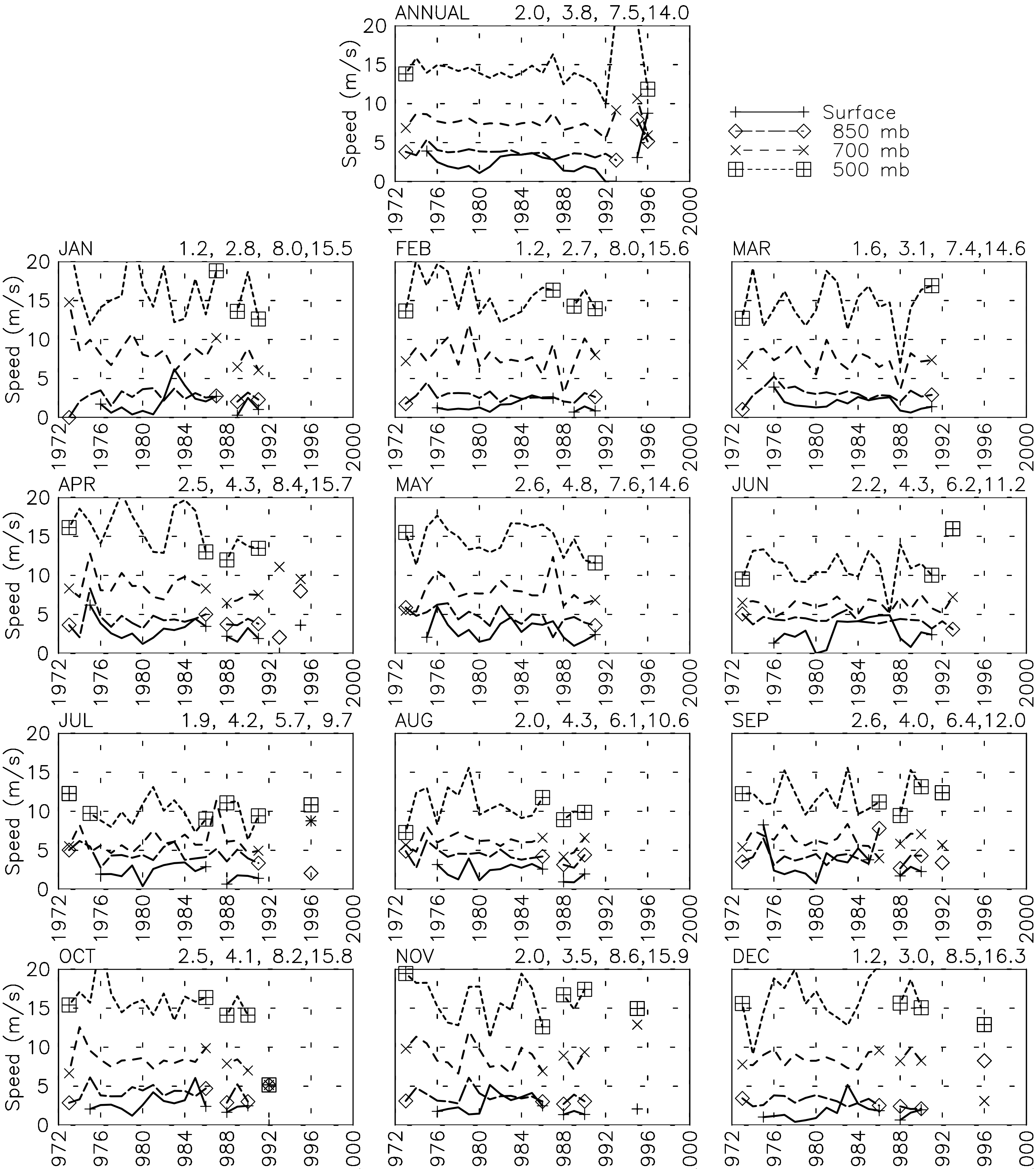
49° 58' N 92° 04' E – Elev 936m
01/73–03/97



Wed Apr 11 18:02:40 2001

SPEED BY PRESSURE LEVEL & YEAR

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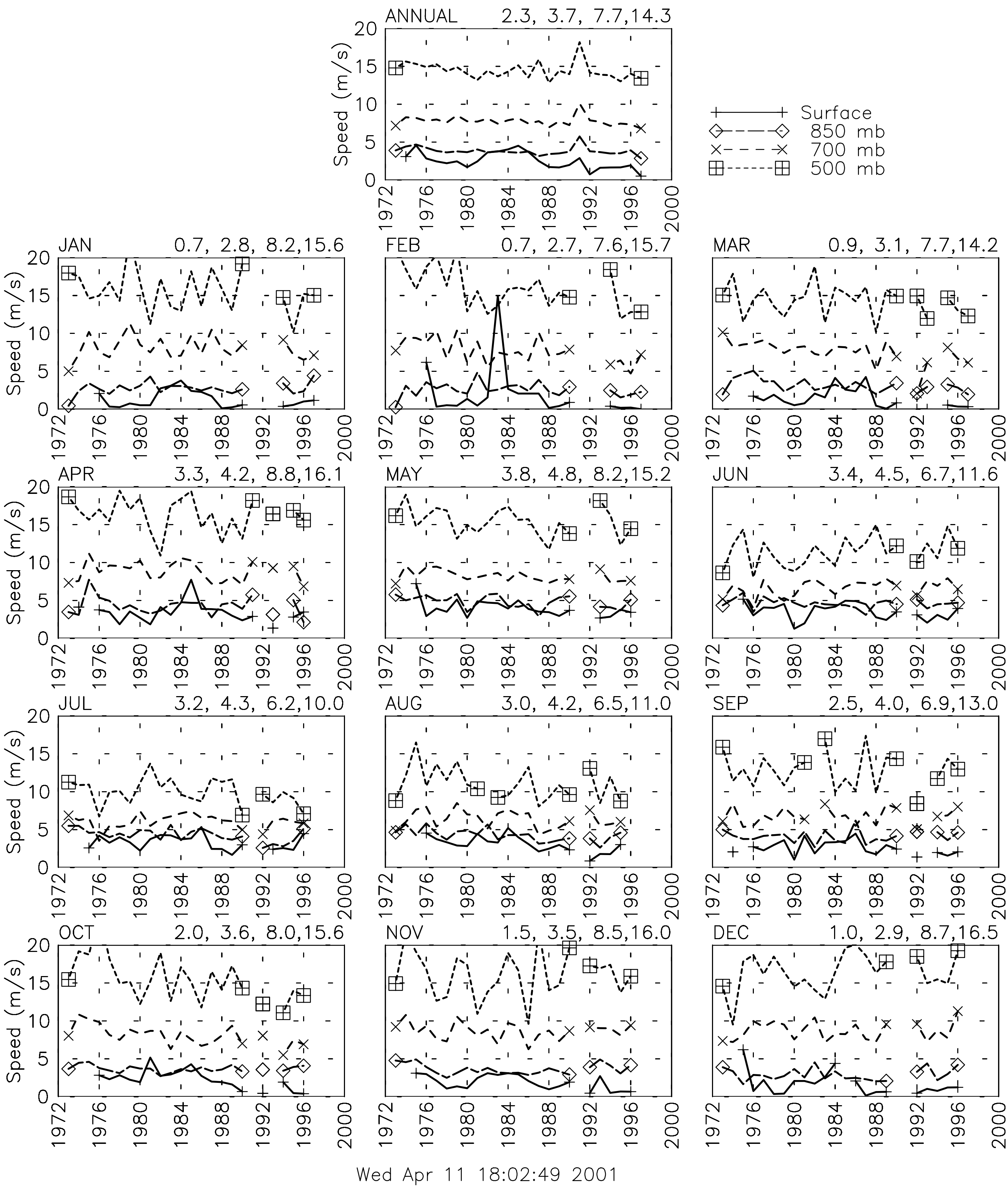
49° 58' N 92° 04' E - Elev 936m
01/73-03/97



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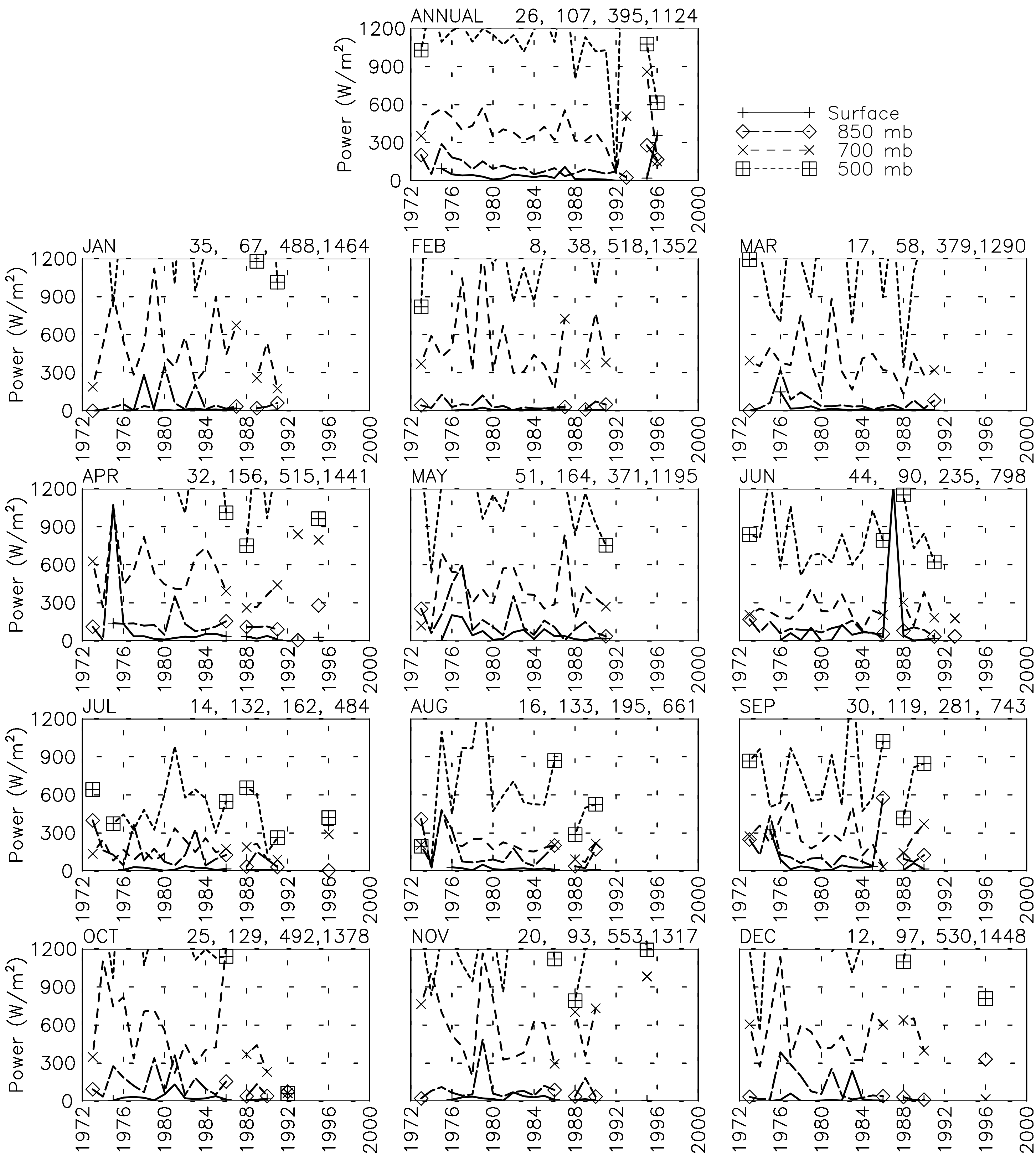
01/73-03/97



Wed Apr 11 18:02:59 2001

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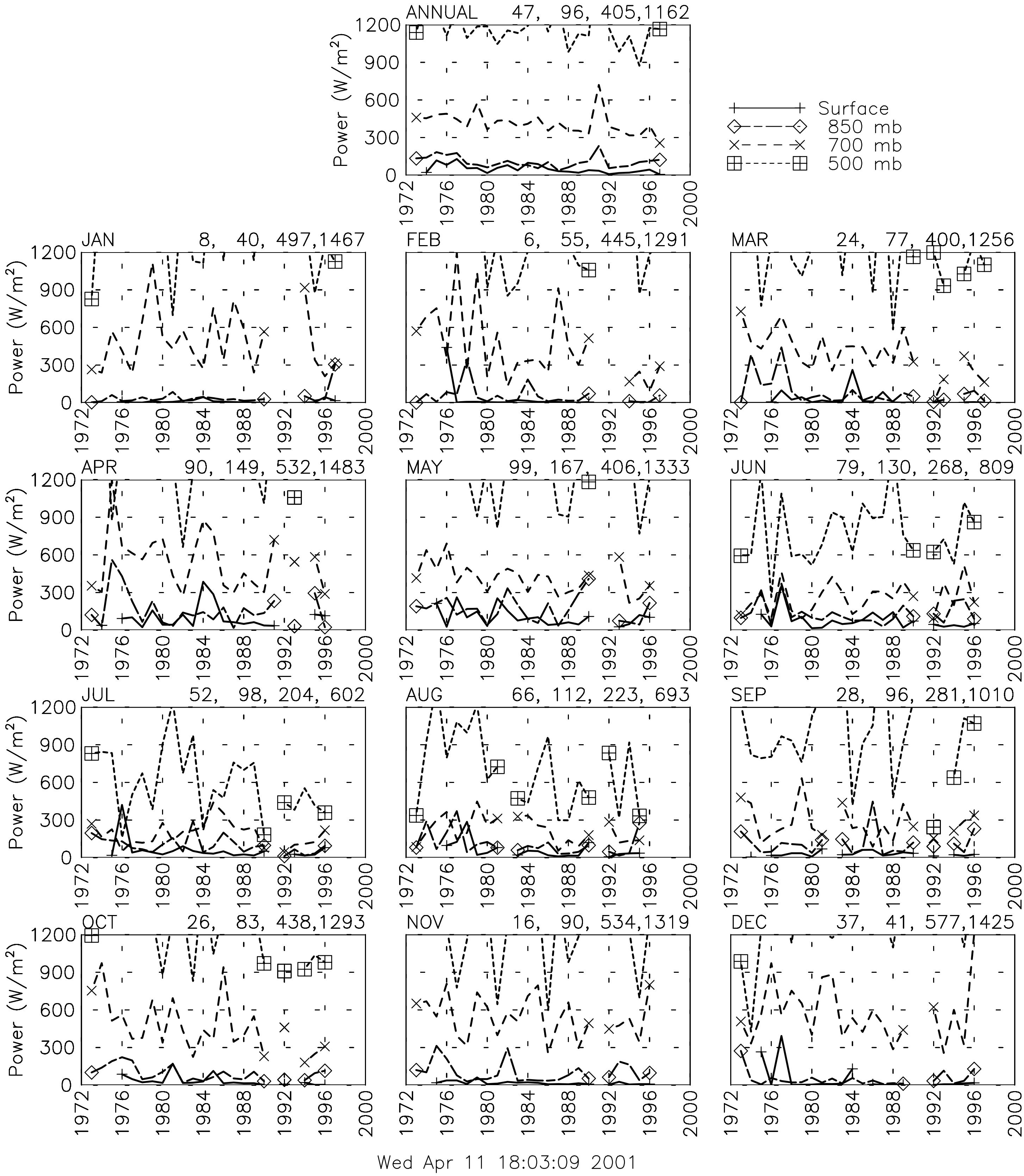
01/73–03/97



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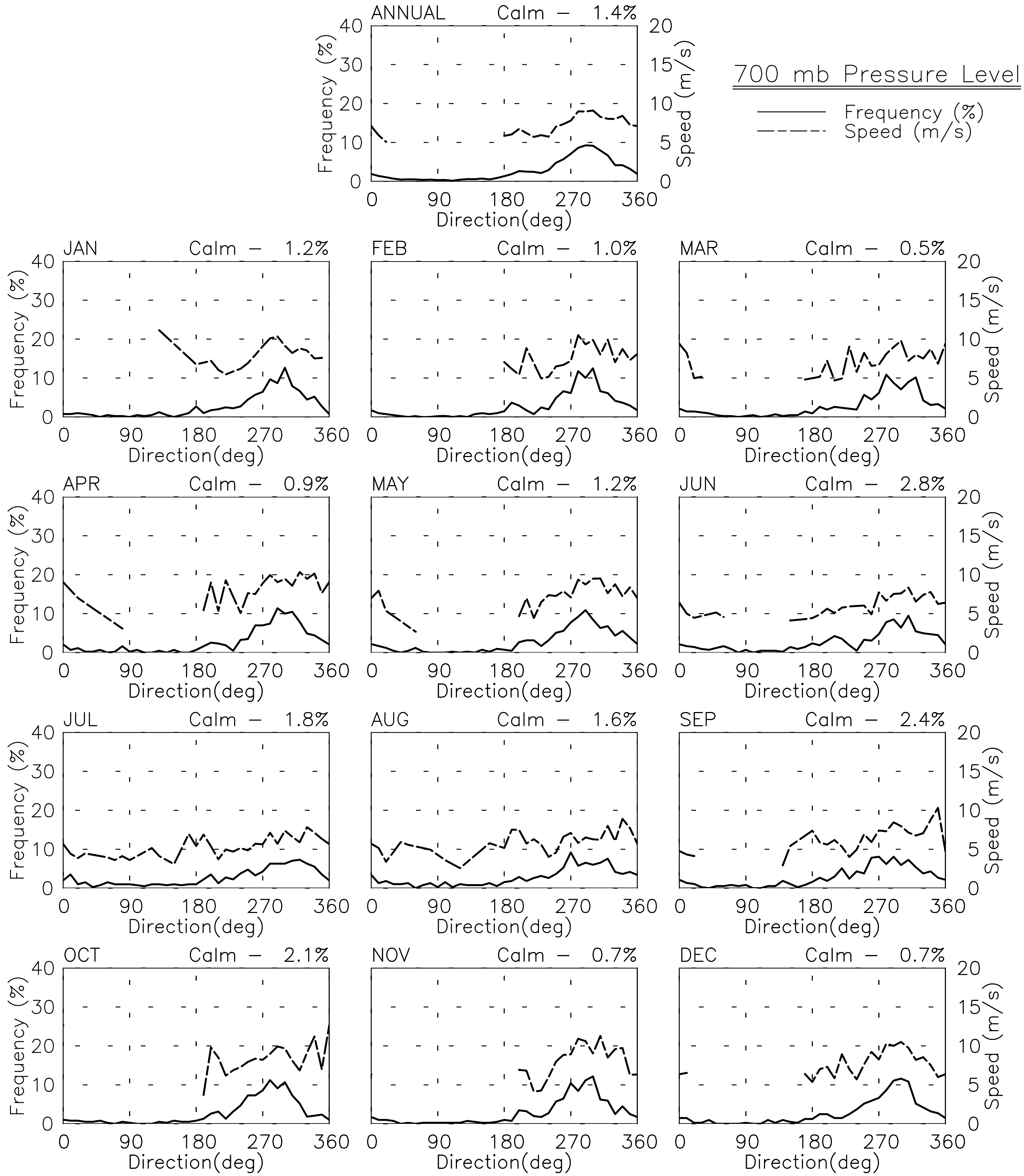
01/73-03/97



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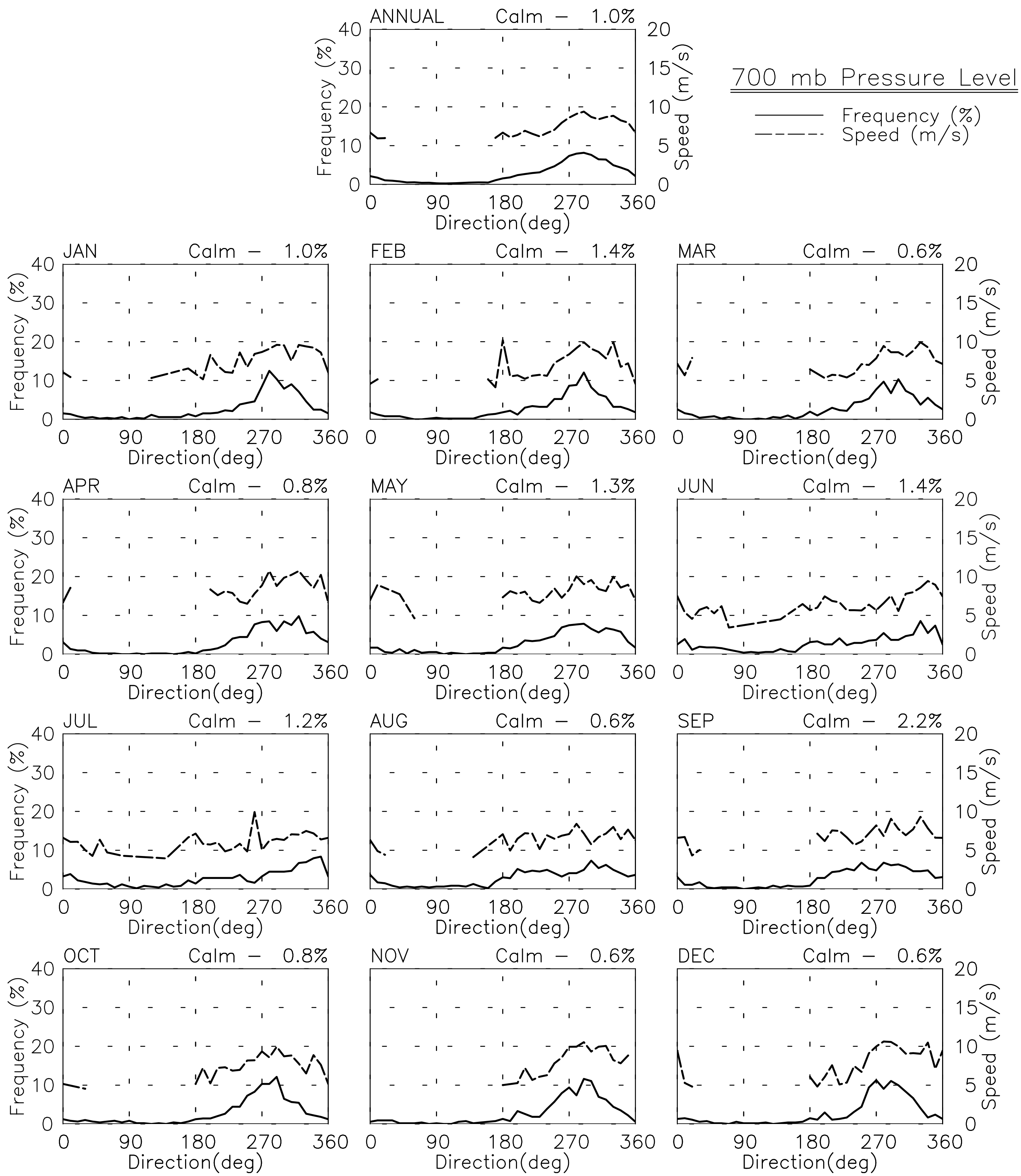
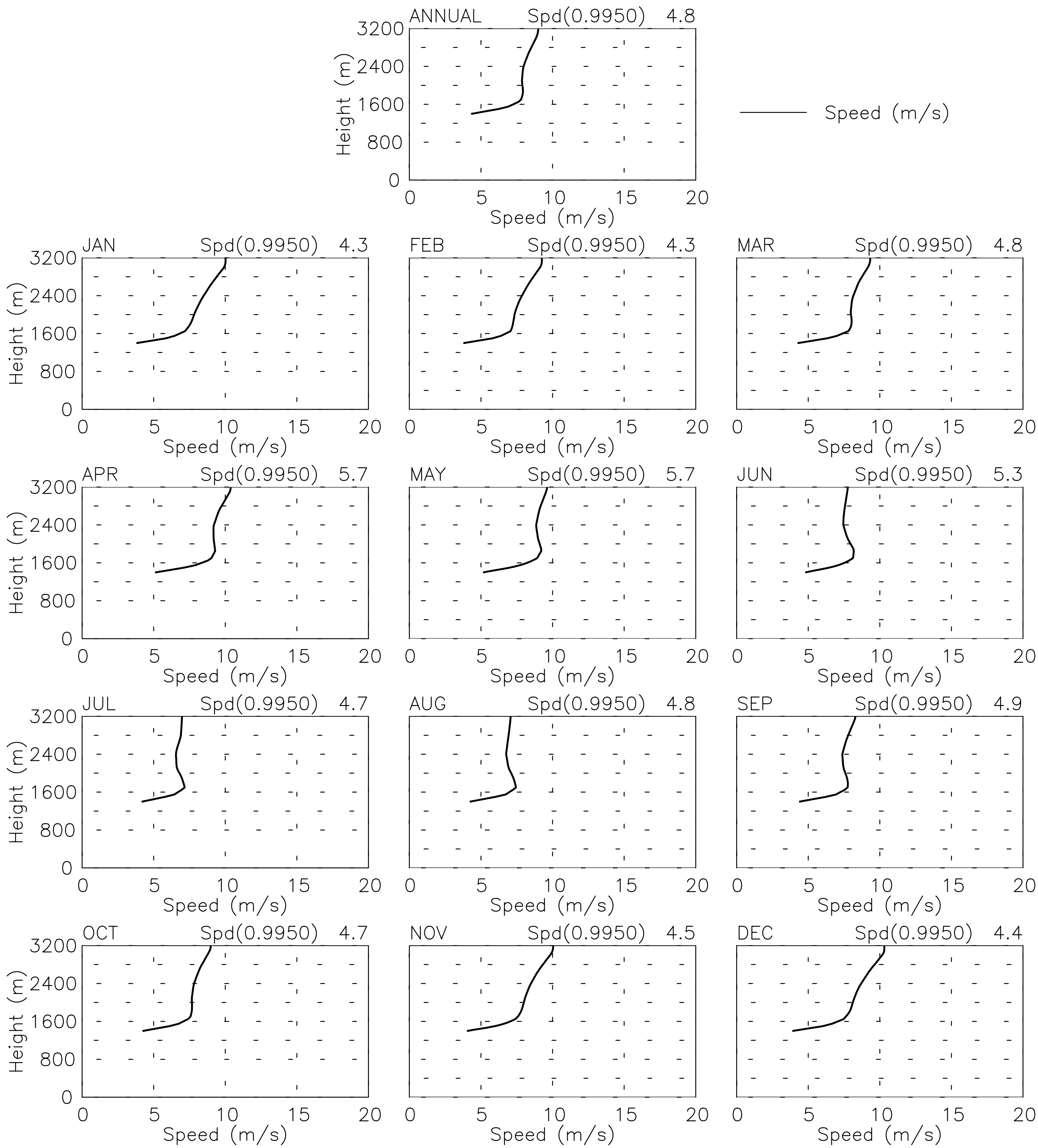
01/73-03/97



Wed Apr 11 17:17:58 2001

VERTICAL WIND SPEED PROFILE BY HEIGHT

Reanalysis T62 Gauss – 04281 – 0700 LST
46° 39' N 106° 52' E – Elev 1386m
01/58–12/97



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13. ABSTRACT *(Maximum 200 words)* The United States Department of Energy (DOE) and the United States Agency for International Development (USAID) sponsored a project to help accelerate the large-scale use of wind energy technologies in Mongolia through the development of a wind energy resource atlas of Mongolia. DOE's National Renewable Energy Laboratory (NREL) administered and conducted this project in collaboration with USAID and Mongolian. The Mongolian organizations participating in this project were the Scientific, Production, and Trade Corporation for Renewable Energy (REC) and the Institute of Meteorology and Hydrology (IMH). The primary goals of the project were to develop detailed wind resource maps for all regions of Mongolia for a comprehensive wind resource atlas, and to establish a wind-monitoring program to identify prospective sites for wind energy projects and help validate some of the wind resource estimates.

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