Wind Energy Resource Atlas of Armenia

D. Elliott, M. Schwartz, G. Scott, S. Haymes, D. Heimiller, R. George

National Renewable Energy Laboratory

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Executive Summary

This wind energy resource atlas identifies the wind characteristics and distribution of the wind resource in the country of Armenia. The detailed wind resource maps and other information contained in the atlas facilitate the identification of prospective areas for use of wind energy technologies for utility-scale power generation and off-grid wind energy applications. The maps portray the wind resource with high-resolution (1-km^2) grids of wind power density at 50-m above ground. The wind maps were created at the National Renewable Energy Laboratory (NREL) using a computerized wind mapping system that uses Geographic Information System (GIS) software.

NREL's sophisticated wind mapping methodology integrates terrain and climatic data sets, GIS technology, and analytical and computational techniques. The meteorological data sources include surface and upper-air data taken from measurement stations and model-derived estimates. Mesoscale model data from TrueWind Solutions (an NREL subcontractor) were used for initial estimates of the wind power in Armenia. Estimates for certain regions were adjusted after NREL's evaluation of the available meteorological data. The adjusted regions were generally enhanced wind flow regions through several mountain passes that were too small to be resolved by the mesoscale model data. The area near the northern tip of Lake Sevan and some ridges in northern and southern Armenia were also adjusted before the final maps were produced.

NREL's wind-mapping results show many areas that are estimated to have good-to-excellent wind resources in Armenia. The best wind resource areas in Armenia are generally located on top of the higher ridges or mountains or in wind corridors such as mountain passes. Good wind resource areas can be found in the northern, eastern, and southern parts of Armenia. Mountain passes estimated to have high wind resources include Karakhach, Pushkin, and Jajur in the Bazum Range, Sevan in the Areguni Range, and Sisian in the Zangezur Range. The ridges around these passes are also predicted to have excellent wind resources. Mount Aragats and the Geghama Range have areas of good-to-excellent resource but many of these sites are 3000 m to 4000 m in elevation and would be difficult to develop. The hills between Sisian and Goris are estimated to have areas of good-to-excellent resource. The elevations in this region are as low as 1800 m to 2000 m, and a major highway runs through the area. Finally, the Zod region and the Megrhi area serve as regional wind corridors. These wind corridors allow for accelerated wind flow between the low elevation plains in the Caspian Sea region with basins such as the Lake Sevan Basin in the case of the Zod region, and the Nakhichevan basin in the case of the Megrhi area. Wind energy measurements have been taken in two of these regions, the Bazum Range and the Zod Region.

NREL estimates that there are about 1000 km^2 of land areas with good-to-excellent wind resource potential in Armenia. This windy land represents less than 4% of the total land area (28,400 km^2) of Armenia. Using a conservative assumption of 5 MW per km^2, this windy land could support almost 5000 MW of potential installed capacity. Additional studies are required to accurately assess the wind electric potential, considering factors such as the existing transmission grid and accessibility.

If areas with moderate wind resource potential are considered, the estimated total windy land area increases to more than 2200 km^2, or almost 8% of the total land area of Armenia. This amount of windy land could support more than 11,000 MW of installed capacity.

Although the wind resource maps and other characteristic information provided by NREL will help identify prospective areas for wind energy applications we strongly recommend that wind measurement programs be conducted to validate the resource estimates and to refine the wind maps and assessment methods. NREL has identified nine major wind resource areas that should be considered for future wind measurement programs.

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 widespread use of wind energy technologies in Armenia through the development of a wind energy resource atlas of Armenia.

DOE's National Renewable Energy Laboratory (NREL) led the project in collaboration with USAID, SolarEn International Corporation, and its Armenian subsidiary SolarEn LLC. The primary goals of the project were to (1) develop detailed wind resource maps for all regions of Armenia and produce a comprehensive wind resource atlas documenting the results and (2) establish a wind monitoring program to identify prospective sites for wind energy projects and help validate some of the wind resource estimates.

SolarEn was primarily responsible for coordinating the wind monitoring program in Armenia, including identification of sites, installation of measurement systems, and collection of the data. NREL provided four wind monitoring systems and conducted training necessary to implement a successful monitoring program. SolarEn also supplied wind measurement data from an ongoing monitoring program in eastern Armenia.

In addition to coordinating the wind monitoring program, SolarEn identified and provided useful wind data from sources in Armenia, such as monthly summaries of historical wind speed data for 66 stations collected by the Department of Hydrometeorology of the Republic of Armenia (Armhydromet).

NREL was responsible for obtaining meteorological data available from U.S. sources, such as the National Climatic Data Center (NCDC) and the National Center for Atmospheric Research (NCAR) that would be useful in the assessment. NREL was also responsible for data analysis, development of the wind resource maps, and production of the final wind atlas.

The “Wind Energy Resource Atlas of Armenia" presents the wind resource analysis and mapping results for Armenia. An advanced automated wind mapping technique, developed at NREL with assistance from U.S. consultants, was used to generate 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 important wind characteristics, including 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 Armenia, NREL has applied its wind mapping system to produce wind resource assessments of the Dominican Republic (Elliott et al., 2001), the Philippines (Elliott et al., 2001), Mongolia (Elliott et al., 2001) and specific regions of Chile, China, Indonesia, Mexico, and the United States (Schwartz, 1999; Elliott et al., 1999). Many of NREL’s international wind resource maps, and some produced by others, can be found on the Web at http://www.rsvp.nrel.gov/wind_resources.html.

The Armenia Atlas is divided into seven sections. Section 2.0 contains an overview of the geography and climate of Armenia. Section 3.0. contains a summary of the fundamentals of wind resource estimation. Section 4.0 contains a description of NREL’s wind resource methodology and mapping system. Section 5.0 contains a description of the wind resource data obtained and analyzed for the Armenia assessment. Section 6.0 contains the wind resource characteristics of Armenia and the wind mapping results, and Section 7.0 contains an assessment of the wind electric potential .

The Appendices provide pertinent summaries of wind characteristics data from selected surface stations and wind monitoring sites.

2.0 Geography and Climate of Armenia

2.1 Geography

Armenia is situated in southwestern Asia, and is bordered by Georgia, Azerbaijan, Iran, and Turkey. Its size is approximately 29,800 km^2 (11,500 mi^2). Armenia is centered at approximately 45 degrees east longitude and 40 degrees north latitude.

Figure 2.1 is a political map of Armenia that shows major cities and provincial capitals. The population of Armenia is around 3.3 million (2002). The capital of Armenia and largest city is Yerevan, with a population of approximately 1,300,000.

Armenia's terrain, shown in Figures 2.2 and 2.3, is varied and includes mountain ranges, isolated volcanoes, and plains. Much of Armenia is a mountainous, with half the country higher than 2000 meters (m) above sea level. The elevation of Yerevan is around 900 m. The northern part of the country is dominated by the Lesser Caucasus Mountains. The Armenian Plateau stretches to the southwest, and contains large volcanic peaks such as Mt. Aragats, which, at 4095 m, is the highest point in Armenia. Rugged mountains separated by a broken network of valleys and deep gorges characterize the southern part of the country.

The lowest point in the country (400 m) is in the Debed River Valley in northern Armenia. Armenia contains a single large lake, Lake Sevan, which is almost 80 km in length and located in east-central Armenia at an altitude of about 2000 m.

2.2 Climate

Armenia has a continental climate. In general, winters are cold and dry, and summers are warm. Mountains in Turkey and Georgia block much of the moisture from the Mediterranean and the Black Sea, causing much of the country to be semiarid. The amount of precipitation is determined largely by elevation, with the higher elevations receiving as much as three times as much as the lower elevations. Precipitation varies from 25 to 30 centimeters (cm) per year in the lower Aras River Valley to 80 cm per year in the higher mountains.

There are significant variations in seasonal and diurnal temperatures. For example, in Yerevan, the coldest month of the year (January) has an average temperature of –4 degrees Celsius (°C), with an average low of –8 °C and an average high of 1 °C. In the warmest months (July and August) the average temperature is 25 °C, with an average low of 17 °C and an average high of 33 °C.

Armenia - Political Base Map

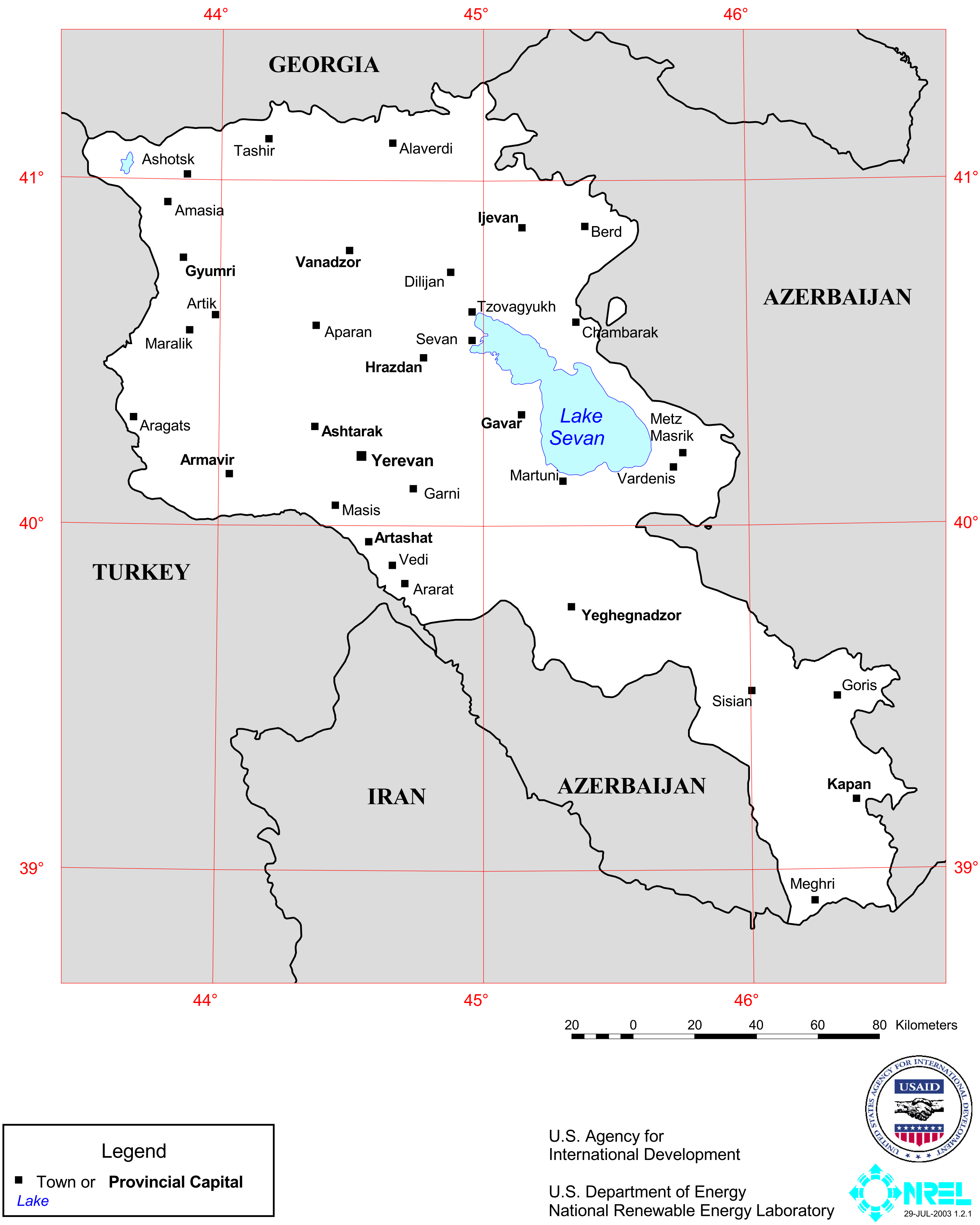

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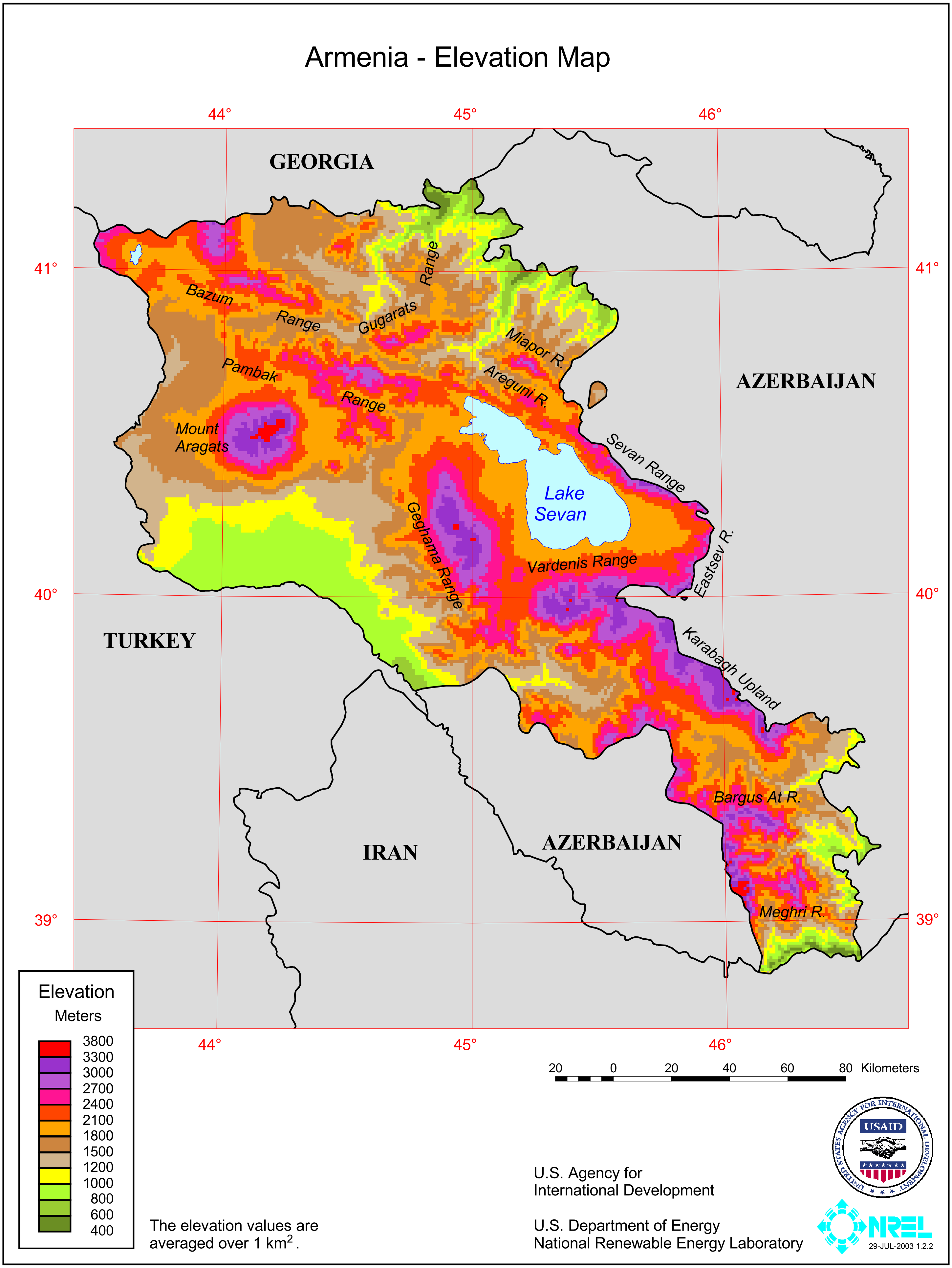
Figure 2-1



Armenia - Elevation Map
44°
45°
46°
41°
40°
39°
GEORGIA
AZERBAIJAN
TURKEY
IRAN
AZERBAIJAN
Bazum
Range
Gugarats
Range
Pambak
Range
Miapor R.
Areguni R.
Mount
Aragats
Sevan Range
Lake
Sevan
Geghama Range
Vardenis Range
Eastsev R.
Karabagh Upland
Bargus At R.
Meghri R.
Elevation
Meters
3800
3300
3000
2700
2400
2100
1800
1500
1200
1000
800
600
400
20 0 20 40 60 80 Kilometers
The elevation values are averaged over 1 km².
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Figure 2-2

Armenia - Hillshaded Relief Map

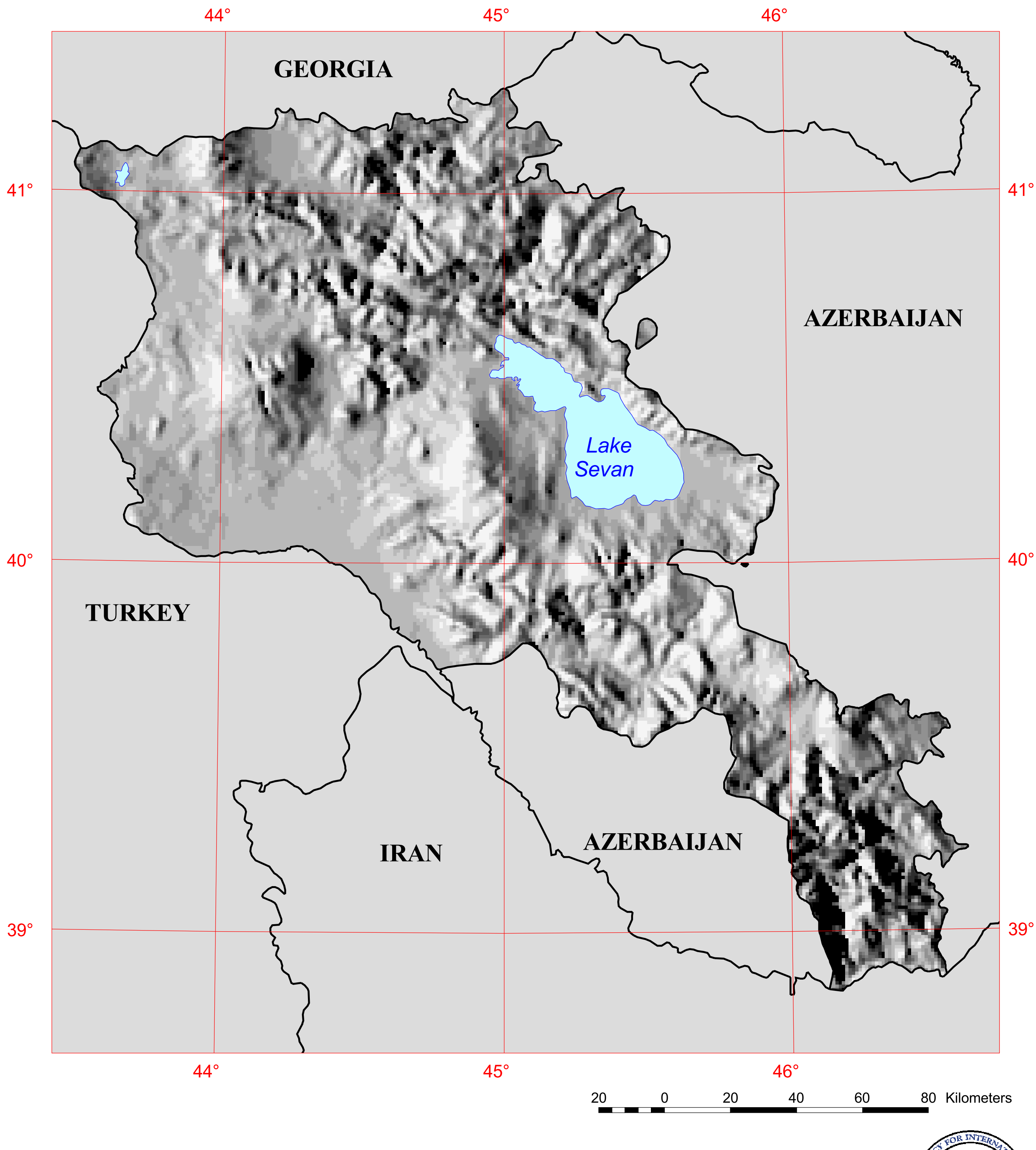

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Figure 2-3

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 about 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 1 or 2 minutes (weather observations), 10-minute (used in the NREL/SolarEn 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 and second, it identifies the range of wind speeds observed at that location. This analysis is often accomplished by sorting the wind speed observations into 1 meter per second (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, but 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 (W/m^2). 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 (hourly, 10-minute, etc.) 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 long-term averages will not include most of the higher-speed records that would more accurately calculate the wind power density.

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 airdensity can be calculated using the following equation:

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

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:

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

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:

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

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

3.6 Wind Shear and the Power Law

The wind shear is a description of the change in horizontal wind speed with height. The magnitude of the wind shear is site-specific and dependent 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 from 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.

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 balloons 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

Computer weather prediction models can generate climatic data, including wind speed and direction. These computer models analyze meteorological data from many sources and generate sets of meteorological parameters at regular grid points. The large-scale model output covers the entire globe and usually includes meteorological data at the surface and for a number of levels above the surface. The horizontal distance between grid points for the large-scale data is often greater than 200 kilometers (km). Meteorological output from what is referred to as mesoscale computer models covers specified regions. The data grid points from the mesoscale model are much closer together than those from the large-scale data with the horizontal distance ranging from about 2 km to 20 km. Computer model data are 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 judgment is required when computer model data is used in assessment work.

4.0 Wind Resource Methodology and Mapping System

4.1 Introduction

This section describes 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 uses a GIS-based wind resource mapping technique to produce the maps presented in this atlas. This technique was also used in the production of wind atlases for the Philippines (Elliott et al. 2001), the Dominican Republic (Elliott et al. 2001), Mongolia (Elliott et al. 2001), and Southeast China (Elliott et al. 2002), and maps of specific regions of Chile, Indonesia, Mexico, and the United States (Schwartz, 1999; Elliott et al., 1999; Schwartz and Elliott, 2001; Elliott, 2002). NREL developed the mapping system with two primary goals in mind:

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

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 Armenia, 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 on the critical analysis of all the available (surface meteorological and upper-air) climatic data for Armenia and the surrounding areas. NREL used a comprehensive data-processing package to convert the data to statistical summaries of the wind characteristics for hundreds of surface stations and numerous upper-air locations. The summaries were used to highlight regional wind characteristics.

4.2.1.2 Surface Data Evaluation

Years of work at NREL revealed many problems with the available land-based surface wind data collected at meteorological stations in much of the world. 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 to be extremely variable. In addition, many areas of the world with good or excellent potential wind resource areas have very little or no meteorological station data to help assess the level of the available wind resource.

NREL took specific steps in its evaluation and analysis to overcome these problems. Site-specific products were screened for consistency and reasonableness. For example, the interannual wind speeds were evaluated to identify obvious trends in the data or periods of questionable data. Only representative data periods were selected for the assessment. The summarized products were also cross-referenced to select the sites that appeared to have the best exposure to the prevailing wind. These sites were 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.

NREL generated summaries of wind speed and wind power at specific pressure and height levels using upper-air data, as well as monthly and annual average vertical profiles of wind speed and power. One problem that continually 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 a critical analysis and evaluation of surface and upper-air data is to develop a conceptual model of the physical mechanisms on a regional and local scale that influence the wind flow. When there is conflicting wind characteristic data in an analysis region, the preponderance of meteorological evidence from the region serves as the basis for the conceptual model. Several NREL papers (Elliott, 2002; Schwartz and Elliott, 1997; Elliott and Schwartz, 1998; Schwartz, 1999) describe the integration, analysis, and evaluation of meteorological data sets typically used for wind resource assessments.

The critical data analysis and the conceptual model are particularly important because a key component of NREL's wind mapping system requires that empirical adjustments be made to the wind power values before the final maps are produced. The conceptual understanding developed by the critical analysis of the available data guides the development of empirical relationships that are the basis of algorithms used to adjust the wind power. This empirical approach depends on an accurate ambient wind profile of the few hundred meters closest to the surface and being able to adjust 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.

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 because it 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. Seven wind power classifications, based on ranges of wind power density, were used in the atlas. Each of the classifications was qualitatively defined for utility-scale applications (poor to excellent). In general, locations with an annual average wind resource greater than 400 W/m^2 or 7.5 m/s at 50 m above ground are the most suitable for utility-scale applications. Rural or village power applications can be viable at locations with lower levels of wind resource. In Armenia, such applications may be viable with wind resources greater than 200 W/m^2 or 6.0 m/s at 50 m above ground.

4.3 Description of Mapping System

NREL's mapping system uses GIS mapping software. The main GIS software, ArcInfo®, is a powerful and complex package that features a large number of routines for scientific analysis. None of the ArcInfo® analysis routines are specifically designed for wind resource assessment work; therefore, NREL's mapping technique requires extensive programming in ArcInfo® to create combinations of scientific routines that mimic direct wind resource assessment methods. For more information about GIS and wind energy research at NREL, see Heimiller and Haymes (2001).

The mapping system is divided into three main components: the input data, the wind power adjustments, 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 U.S. Geological Survey's Earth Resource Observing Satellite Data Center produced updated DEMs for most of the world from previously classified U.S. Department of Defense data and other sources. The 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 use a 1 km^2 grid.

The meteorological inputs to the mapping system come in two phases. The first phase provides wind power data for each grid cell obtained via output from a mesoscale numerical model. The second phase, following the data screening process, provides the appropriate vertical profiles of wind power density and wind power roses that express the percentage of total potential power from the wind by direction. 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. These inputs and the original wind power grid are incorporated as ARC/INFO® compatible files and used in the power adjustment algorithms.

4.3.2 Wind Power Calculations

The wind power calculation methodology is presented in Section 3.5. TrueWind Solutions (TWS), a U.S. company in Albany, New York, provided the initial wind power density values for each grid cell in Armenia to NREL. TWS used its proprietary MesoMap system (Brower et al, 2001) to calculate the wind power density values. The MesoMap system consists of the MASS (a mesoscale model) and WindMap a mass conserving wind flow model.

The MASS model simulated weather conditions over Armenia and the surrounding regions for 366 days randomly selected from a 15-year period. The random sampling was stratified so that each month and season was represented equally. Each simulation generates wind and other meteorological variables throughout the model domain for a particular day and stores the information at hourly intervals. The simulations use a variety of meteorological and geophysical data. MASS uses climatic data to establish the initial conditions for each simulation as well as lateral boundary conditions for the model. The model determines the evolution of atmospheric conditions within the study region during each simulation.

The main geophysical inputs into MASS are elevation, land cover, greenness of vegetation, and soil moisture. The MASS translates both land cover and vegetation greenness into important surface parameters such as surface roughness.

The MASS was run with a horizontal resolution of 2 km. After all the simulations were completed, the results were processed into summary data files that were input into the WindMap model. WindMap then calculated the wind power density down to a 1-km^2 grid.

The wind power adjustment modules in NREL's wind mapping system use different routines depending on the results of NREL's data evaluation. Power adjustment modules can be activated to account for blocking of the ambient flow by terrain; the relative elevation of particular regions; acceleration and enhanced wind flow areas; proximity to lakes, oceans, or other large water bodies; or any combination of the above. The power adjustment routines use general topographical descriptions classified as either complex terrain (hills and ridges), complex terrain with large flat areas present, or areas designated as flat. The adjustment to the initial wind power density depends on which routines are activated during the final 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 Armenia maps is presented in Table 4-1. In this atlas, the 50-m height above ground level (agl) was chosen as a compromise hub height for large utility-scale wind turbines that may range between 30 m and 80 m.

The wind power is shown only for those grid cells that meet certain slope requirements. A grid cell is 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 based on the surface roughness for each grid cell derived from the MASS model output.

Table 4.1. Wind Power Classification

Class	Resource Potential (Utility Scale)	Wind Power Density (W/m^2) @ 50 m agl	Wind Speed [a] (m/s) @ 50 m agl
1	Poor	0 - 200	0.0 – 6.0
2	Marginal	200 - 300	6.0 – 6.8
3	Moderate	300 - 400	6.8 – 7.5
4	Good	400 - 500	7.5 – 8.1
5	Excellent	500 - 600	8.1 – 8.6
6	Excellent	600 - 800	8.6 – 9.5
7	Excellent	> 800	> 9.5

[a] Mean wind speed is estimated assuming an elevation of 2000 m and a Weibull distribution of wind speeds with a shape factor (k) of 2.0. 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.

The mapping system output uses software to produce the proper map projection for the study region, and to label the map with useful information such as a legend, latitude and longitude lines, 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 provide the user with a three-dimensional image of the 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 lies with the extrapolation of the conceptual model of the wind flow to the analysis region. Many complexities in the wind flow exist that make this an inexact methodology. The complexities include the structure of low-level jets and their interaction with the boundary layer; localized circulations, such as land-sea breezes, and mountain-valley flows; and channeling effects in areas of steeply sloping terrain. Finally, the power estimates are based on each grid cell's surface roughness based on the MASS output. Because the geophysical input to MASS is not 100% accurate, there can be errors in the surface roughness estimate and consequently the level of wind resource for particular locations.

5.0 Wind Resource Data for Armenia

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 Armenia. All data sets were analyzed and evaluated in accordance with the procedures outlined in section 4.0.

5.2 Surface Data

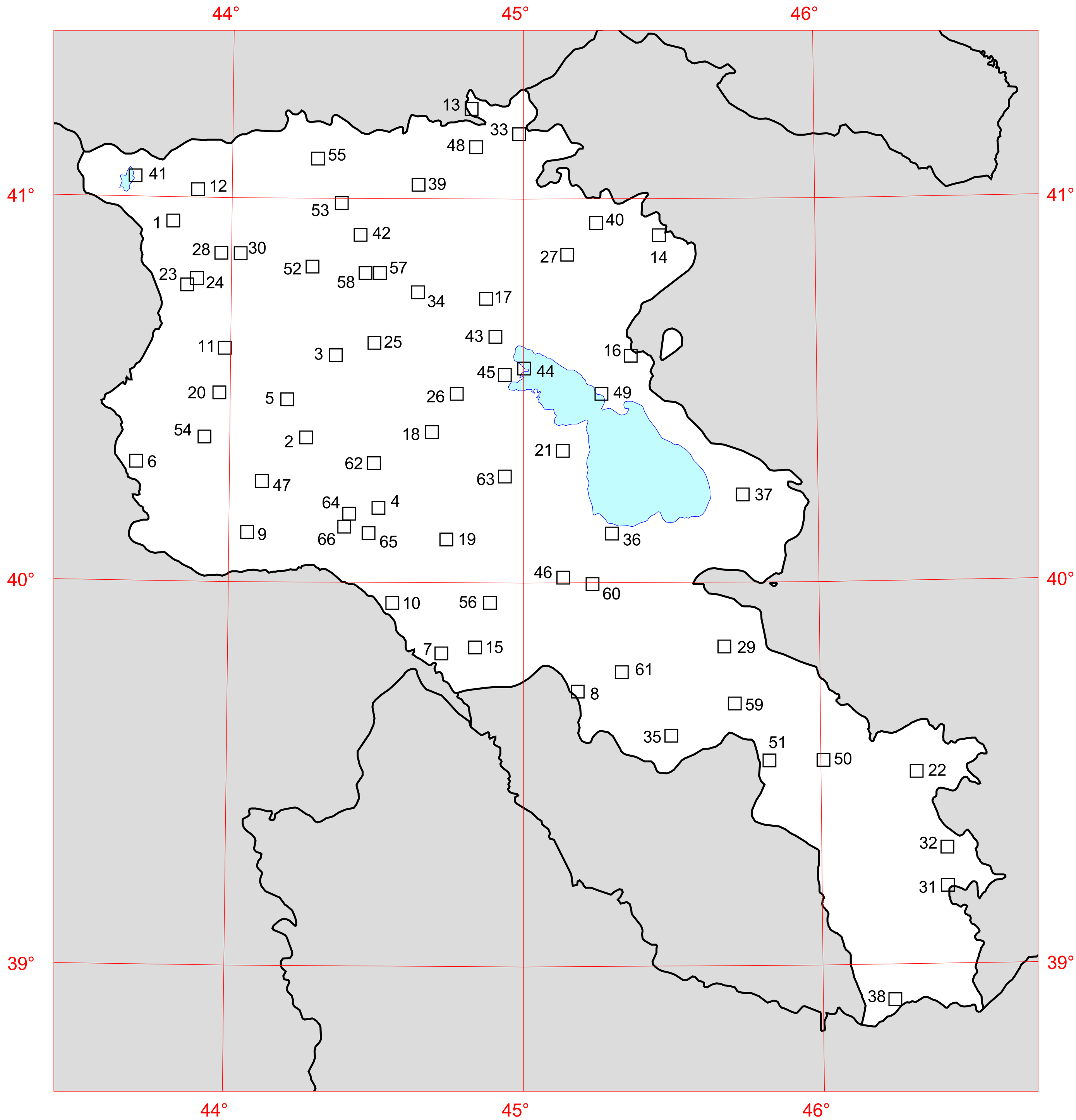
High quality surface wind data from well-exposed locations can provide the best indication of the magnitude and distribution of the wind resource in the region. Studies by NREL and others in many different regions of the world have found that the quality of surface wind data from meteorological stations varies and is often unreliable for wind resource assessment purposes.

The following sections present a summary of the surface data sets obtained and examined in the assessment.

5.2.1 Historical Meteorological Data

The Department of Hydrometeorology of the Republic of Armenia (Armhydromet) has a database of historical wind data that have been collected at more than 80 meteorological stations throughout the country. SolarEn provided NREL with historical monthly average wind speeds from 66 of these stations, with some data going back as far as the 1890s. These stations and speeds are shown in Table A.1, and their locations are shown in Figure 5.1. Graphs of monthly wind speeds are also presented in Appendix A. The quality of these wind data is largely unknown because of the lack of information on equipment maintenance and exposure to the wind. The graphs in Appendix A show that many of the stations in Armenia had obvious trends or abrupt changes in the historical wind speeds recorded on an interannual basis. Figure 5.2 shows an example of the "disappearing wind syndrome", as evidenced by the downward trend in the historical wind speeds at three meteorological stations. New construction, growth of trees around the meteorological station, or degradation of the measurement equipment may have caused the decrease in wind speeds. The factor of 2 to 3 reduction in wind speeds over the 40+ years at these stations may correspond roughly to an order of magnitude or greater reduction in the wind power density. For these reasons, the long-term historical average may not be a reliable indicator of the wind resource. In Table A.1, we also list the maximum 5-year average wind speed, which may be a better indicator of a station's wind resource.

Armenia - Armhydromet Meteorological Stations



20 0 20 40 60 80 Kilometers

The Department of Hydrometeorology of the Republic of Armenia (Armhydromet) provided summaries of wind data for these surface meteorological stations.

Total Stations in Armenia = 66

Legend

□ Armhydromet Station

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Figure 5-1

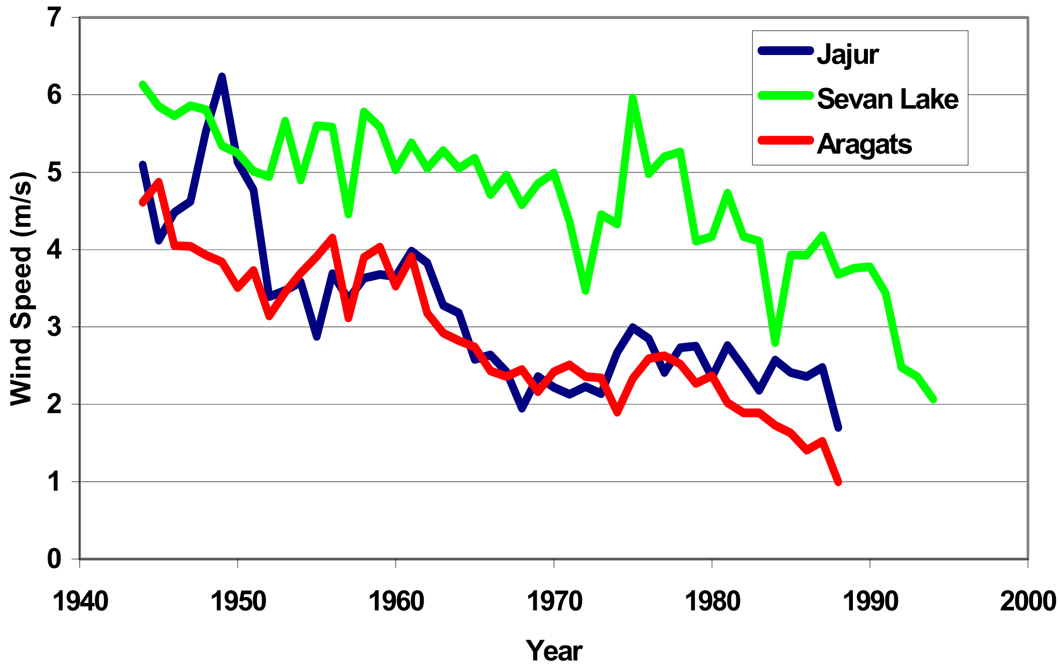


Figure 5.2 Disappearing Winds at Armenia Meteorological Stations.

5.2.2 DATSAV2 Data

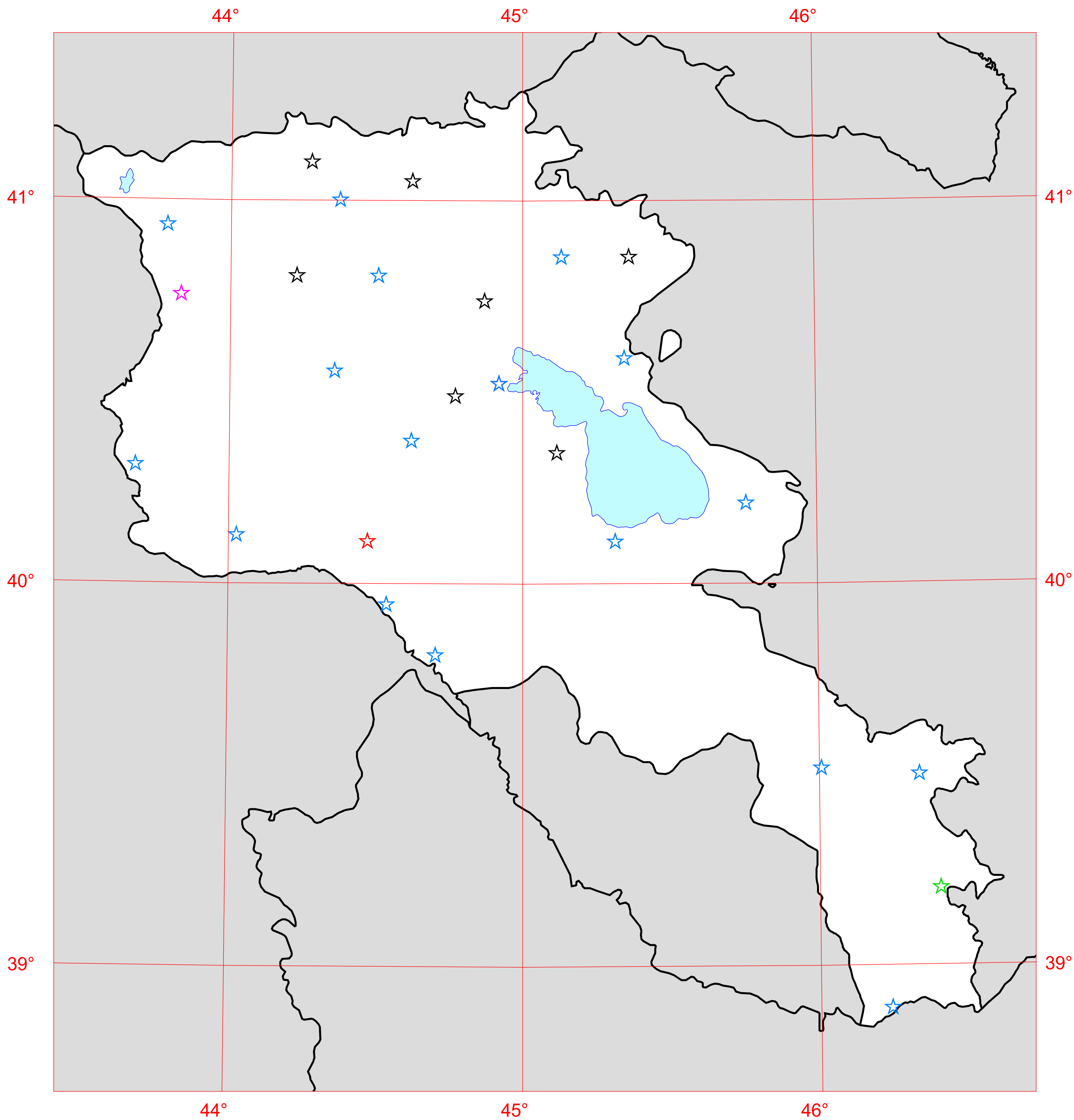
The DATSAV2 global climatic database obtained from the NCDC contains the surface weather observations, transmitted via the Global Telecommunications System (GTS), from first-order meteorological stations throughout the world. Meteorological parameters such as wind speed, wind direction, temperature, pressure and altimeter setting are 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 30 stations in Armenia in the DATSAV2 climatic data set. Of these, 28 have sufficient meteorological data to use in this analysis. These data were supplemented by data from DATSAV2 stations in nearby countries. Figure 5.3 shows the locations and number of observations for the Armenian stations.

The number of observations at the individual sites for each year and from year to year are highly variable. During the 1970s and early 1980s, the stations at Yerevan, Sevan, and Leninakan reported every 3 hours. Data collection at other times and at other stations was much more sporadic.

The processed data records for each of these 28 stations contained monthly and annual averages of wind speed and wind power. Table B.1 provides location data and wind speed summaries for these stations and graphical summaries for selected stations in Appendix B. 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.

Armenia - GTS Surface Meteorological Stations



Meteorological Stations
Total Observations

- ☆ 100,000 to 160,000
- ☆ 50,000 to 100,000
- ☆ 20,000 to 50,000
- ☆ 5,000 to 20,000
- ☆ 1,000 to 5,000

Total Stations in Armenia = 28
There are 2 stations at Sevan.

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

20 0 20 40 60 80 Kilometers

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Figure 5-3

5.2.3 NREL/SolarEn Wind-Monitoring Program Data

SolarEn International Corporation conducted a wind measurement program in Armenia as part of this study. Four monitoring systems provided by NREL were installed in August and November of 2001. Each system consists of an NRG Systems, Inc. (NRG), Model 9300 data logger mounted on a 40-m meteorological tower. Anemometers are mounted at 40 m, 20 m, and 10 m agl and wind vanes are mounted at 40 m and 20 m agl. The systems also include sensors for temperature, barometric pressure and relative humidity. The data are recorded every 10 minutes, and the logger is capable of storing approximately two months of data. Data are collected every few weeks and then sent to NREL for final processing to produce summaries of important wind characteristics. These include monthly average wind speed and 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 northwest, north-central, and south-central Armenia. Two of the sites (Karakhach and Vorotan Pass) are located on passes, while the others are in rolling terrain. All sites are in regions of low grasslands with no trees or other obstacles.

Figure 5.4 shows the locations of the monitoring sites. NREL obtained and processed the hourly wind speed and wind direction data presented in Table 5.1 with the power measured at each site. Appendix C contains graphs and tables of annual and monthly summaries for specific wind statistics for these stations, and the time series data are available on the CD-ROM that accompanies this report.

Table 5.1 NREL/SolarEn Measurement Sites

Stn	Name	Ht	Lat	Lon	Elev	NObs	WS	WPD	Calm
201	Karakhach	40	41 00 44	43 58 40	2316	31960	7.1	356	3.0%
201	Karakhach	20	41 00 44	43 58 40	2316	61172	6.3	242	3.5%
201	Karakhach	10	41 00 44	43 58 40	2316	62407	5.7	189	5.9%
301	Aparan	40	40 39 59	44 20 59	2098	29217	4.0	144	25.5%
301	Aparan	20	40 39 59	44 20 59	2098	29183	3.4	90	27.5%
301	Aparan	10	40 39 59	44 20 59	2098	29271	2.9	56	29.1%
302	Aparan #2	40	40 38 57	44 24 05	2685	22376	5.1	114	5.8%
302	Aparan #2	20	40 38 57	44 24 05	2685	22376	5.0	109	5.6%
302	Aparan #2	10	40 38 57	44 24 05	2685	22376	4.8	98	6.3%
401	Gagarin	40	40 32 16	44 51 27	1921	52972	4.9	164	13.6%
401	Gagarin	20	40 32 16	44 51 27	1921	52995	4.4	121	16.0%
401	Gagarin	10	40 32 16	44 51 27	1921	52959	4.1	102	14.5%
501	Vorotan Pass	40	39 41 34	45 42 40	2408	48516	6.1	237	9.9%
501	Vorotan Pass	20	39 41 34	45 42 40	2408	48583	5.8	209	11.3%
501	Vorotan Pass	10	39 41 34	45 42 40	2408	48543	5.4	179	12.5%

NOTES:
1) Heights (Ht) are in meters above ground. Latitudes (Lat) are in deg/min/sec N, longitudes (Lon) in deg/min/sec E. Elevations (Elev) are in meters above sea level. Number of observations (NObs) is defined as the number of records. Wind speeds (WS) are in meters/sec and wind power densities (WPD) are in W/m^2. Percent calm (Calm) is defined as the percentage of observations with wind speeds less than 1.0 meter/sec.
2) 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).
3) Station (Stn) 301 could not be located in the desired location due to weather conditions. In June 2002, the measurement equipment was relocated to the better location at Stn 302.

Armenia - SolarEn Measurement Sites

Total Stations in Armenia = 23

Legend

△ NREL-SolarEn Wind Measurement Site
○ Zod Area Wind Measurement Site

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Figure 5-4

5.2.4 SolarEn Measurement Sites in the Zod Pass Area

SolarEn International is conducting a wind measurement program near Zod Pass in eastern Armenia and has shared the collected data with NREL. The monitoring program was started in September 1999 as part of an effort to develop a commercial grid-connected wind power plant. SolarEn had collected almost two years of wind data by the time NREL started the Armenia wind atlas project in 2001. As of late 2002, measurements had been taken at 20 sites, mostly located on the ridge at Zod Pass and in the valley to the west. SolarEn has sent NREL data from 18 of these sites, and 9 have more than a year of data. Three different models of NRG loggers were used, and measurements were taken at 10 m, 20 m, and 40 m. (Some stations had only one or two measurement levels.)

A topographic map of the Zod Pass area and station locations is shown in Figure 5.5. Figure 5.6 shows a view looking eastward at four of the northern ridge stations (3, 8, 9 and 42). Table D.1 lists the stations, locations, and wind speeds for these sites, while Tables D.2 through D.4 show monthly summaries of wind speed, power, and number of observations. During the course of the 3-year project, some of the stations were moved to other prospective sites. As of late 2002, 9 monitoring stations were operating in the region. Station number 0007 in Figure 5.5 and Station 77 in Appendix D both refer to the station in the town of Zod.

Experience gained in the Zod monitoring project will be useful for future micro-scale monitoring projects in other candidate regions of Armenia.

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 and the wind resource at exposed locations without reliable surface wind observations.

NREL's in-house data sets include both observational and computer model-derived upper-air information. The following upper-air data sets were employed for the assessment.

5.3.1 Automated Data Processing Reports (ADP) Data

The ADP data set contains upper-air observations from rawinsonde instruments and pilot balloons for approximately 1800 stations worldwide. Observation times can include 00, 06, 12, and 18 Universal Coordinated Time (UTC). 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. NREL's data set has more than 25 years of observations.

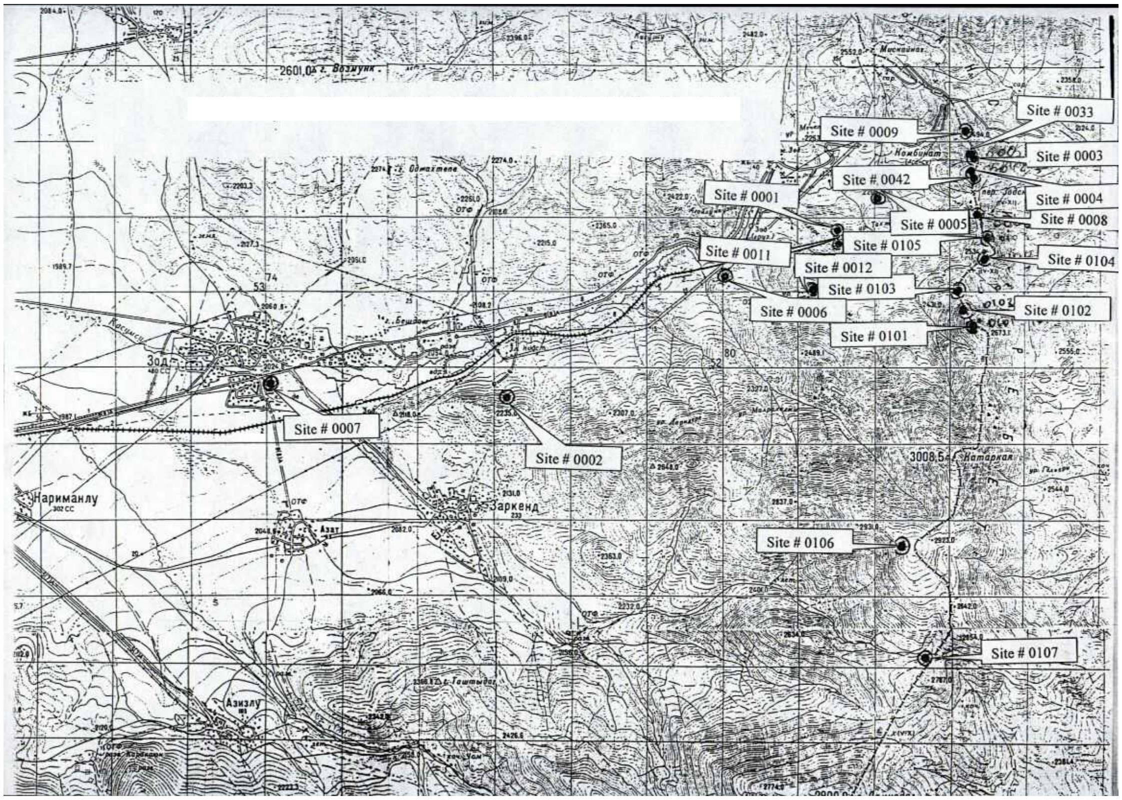


Figure 5.5 Armenia – SolarEn Zod Measurement Sites.

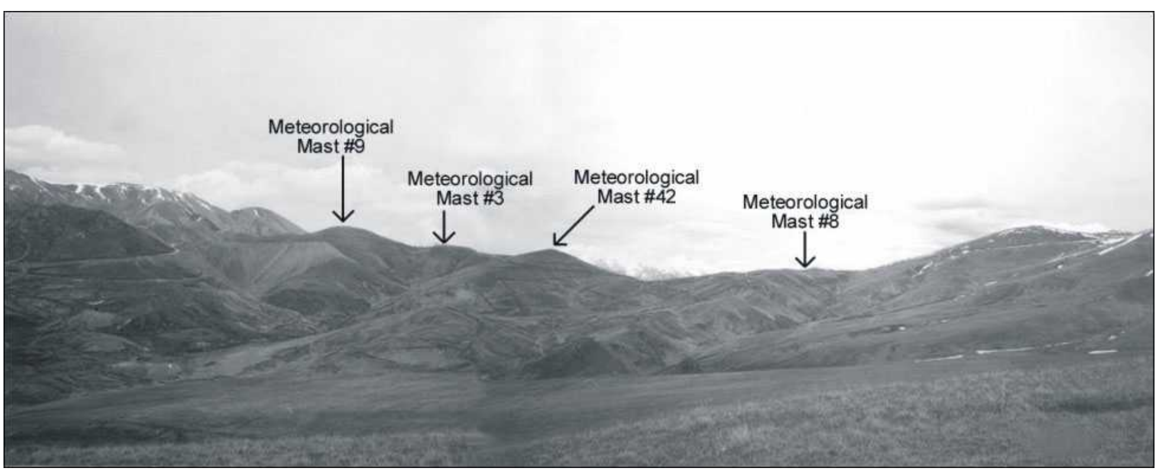


Figure 5.6 View of Northern Ridge SolarEn Measurement Sites.

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

The ADP database contains upper-air wind data for only one location in Armenia shown in Table 5.2. Data from surrounding countries were also used for this analysis.

Table 5.2 Upper-Air (Weather Balloon) Stations in Armenia

ID	Name	Lat	Lon	Elev	From	To
37789	Yerevan/Zapadnyy	40 07	-44 28	907	01/73	03/97

During the late 1970s and early to mid-1980s, the station took two measurements per day, at 0300 and 1500 local time (corresponding to the 0000 and 1200 UTC times). During some years, there were also observations at 0900 and 2100 local time.

The ADP data yielded profiles of monthly and annual average wind speeds and frequency distributions of wind speed and wind direction for a number of pressure levels and height levels from the surface through 700 mb (approximately 3,000 m).

5.3.2 Computer Model-Derived Data Sets

5.3.2.1 Global Upper-Air Climatic Atlas (GUACA)

The GUACA 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. NREL's data, obtained from the NCDC, covers the period from1980 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, 850 mb, 700 mb, and 500 mb.

The GUACA data were used to generate wind roses of the prevailing wind directions and to estimate the wind speeds at 850 mb and 700 mb for the analysis of the wind resource in the mountainous areas of Armenia. 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 U.S. National Centers for Environmental Prediction, in collaboration with NCAR, produced a reanalysis data set. 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 Armenia were produced for four times a day.

5.3.2.3 Mesoscale Model Data

TrueWind Solutions, of Albany, New York, provided NREL with wind speed and wind power data for Armenia on a 1 km^2 horizontal resolution at levels from 30 m to 500 m above ground as well as surface roughness and elevation data from its proprietary MesoMap system. This data set was used as an initial estimate for the distribution of the wind resource (power) throughout the country.

6.0 Wind Resource Characteristics of Armenia

6.1 Introduction

This section presents an overview of the wind mapping results and wind power density estimates for Armenia. The classification scheme for wind power density used in the atlas is applicable for utility-scale applications.

6.2 Wind Power Classifications

Table 6.1 shows the wind power classifications for utility-scale applications in Armenia. Wind resource areas of Class 4 and higher are considered suitable for utility-scale wind power development. Rural or off-grid applications require less wind resource for a project to be viable. For these types of applications, Class 2 and higher resources may be sufficient for viable wind power development.

Table 6.1. Wind Power Classification

Class	Resource Potential (Utility Scale)	Wind Power Density (W/m^2) @ 50 m agl	Wind Speed [a] (m/s) @ 50 m agl
1	Poor	0 - 200	0.0 – 6.0
2	Marginal	200 - 300	6.0 – 6.8
3	Moderate	300 - 400	6.8 – 7.5
4	Good	400 - 500	7.5 – 8.1
5	Excellent	500 - 600	8.1 – 8.6
6	Excellent	600 - 800	8.6 – 9.5
7	Excellent	> 800	> 9.5

[a] Mean wind speed is estimated assuming an elevation of 2000 m and a Weibull distribution of wind speeds with a shape factor (k) of 2.0. 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. The mesoscale model data from TrueWind Solutions were used as the initial estimate of the wind power in Armenia. Adjustments to the initial power estimates in certain regions were made after NREL's evaluation of the available meteorological data. The adjusted regions were generally enhanced wind flow regions through several mountain passes where the extent of the mountain pass was often too small to be resolved by the mesoscale model data. The area near the northern tip of Lake Sevan and some ridges in northern and southern Armenia were other areas for which NREL used its empirical adjustment technique to produce the final maps.

6.4 Wind Resource Distribution and Characteristics

6.4.1 Annual Wind Resource Distribution

Figure 6.1 shows the wind resource map for Armenia. Armenia's best wind resource areas are generally located on top of the higher ridges and mountains or in wind corridors such as mountain passes. Armenia 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 Asia. The interaction of the jet stream and the major topographic features of Armenia is one of the factors that have a significant influence on the distribution of the wind resource. The jet stream also controls the progress of weather systems across Armenia and the Trans-Caucus region. The pressure gradient between weather systems can have a major effect on the wind resource in areas subject to acceleration because of local terrain. The jet stream influence is greatest from October through March. In the warmer part of the year (April through September), the jet stream is considerably weaker, and differential heating caused by the elevation changes within Armenia and between Armenia and locations to the north and east of the country controls the distribution of the wind resource. The differential heating among the plateaus, ridge tops, and low elevation areas produce regional and local temperature and pressure gradients that cause the wind to blow. As a result of the regional and local winds, the wind resource distribution in Armenia during the warm season is quite disparate. Some locations have little wind resource and other locations, especially in some passes, have high wind resource. Overall, the combination of jet stream and regional heating influences produce a complex wind resource pattern in Armenia and it is highly recommended that measurements be made before any wind energy project is established.

Figure 6.2 shows nine specified regions in Armenia with high wind resource (Class 4 and higher grid cells). There are a few other areas with high resource but these are extremely rugged and remote high mountain peaks on which the chance of developing wind energy projects is negligible. Five of the nine areas are clustered in the northern part of the Armenia, one is located in extreme eastern Armenia, and three are in the southern part of the country. Mountain passes estimated to have high wind resources include Karakhach, Pushkin, and Jajur in the Bazum Range, Sevan in the Areguni Range, and Sisian in the Zangezur Range. The ridges around these passes are also predicted to have excellent wind resources. Mount Aragats and the Geghama Range have areas of good-to-excellent resource but many of these sites are 3000 m to 4000 m in elevation and would be difficult to develop. The hills between Sisian and Goris are estimated to have areas of good-to-excellent resource. The elevations in this region are as low as 1800 m to 2000 m, and a major highway runs through the area. Finally, the Zod region and the Megrhi area serve as regional wind corridors. These wind corridors allow for accelerated wind flow between the low elevation plains in the Caspian Sea region with basins such as the Lake Sevan Basin in the case of the Zod region, and the Nakhichevan basin in the case of the Megrhi area. Wind energy measurements have been taken in two of these regions, the Bazum Range and the Zod Region. NREL recommends that all nine of the areas be considered for future wind measurement programs.

6.4.2 Seasonal Wind Resource Distribution

The seasonal distribution of the wind resource in Armenia is quite complex. Figure 6.3 shows the seasonal patterns at six stations in Armenia. The good-to-excellent wind resource sites that are heavily influenced by the jet stream have a maximum resource from November through February. If the thermal circulations in the warm part of the year do not influence these sites, then the minimum resource occurs during July and August. Mount Aragats, the highest ridge tops in the Geghama Range (Yeratumber), and Pushkin Pass exhibit this type of seasonal pattern. However, both the jet stream and thermal circulations influence many of the high resource locations in Armenia. This is the case on many of the mountain passes and in regional wind corridors. The peak of the thermal circulation influence is generally in July and August but can be a factor in the level of resource from May through September. The result of these different influences is a complex pattern of seasonal resource often dependent on local and regional terrain. At some locations, such as Sisian Pass, there are distinct resource maximums in winter and summer, while nearby sites could have much different seasonal patterns some with a winter maximum and some with a summer maximum. Vorotan Pass is an example of a site with a summer wind resource maximum. Karakhach Pass (complete graphs in Appendix C) is an example of a location with complex seasonal distribution that is not easily characterized. From August 2001 to August 2002, summer wind speeds at Karakhach were slightly higher than winter speeds, but the measured wind power was noticeably higher in winter than in summer. This means that while the thermal circulations are steadier than the winter jet stream/weather system winds, the instances of strong winds in winter can provide more available power. A summary of the seasonal wind resource maximums throughout Armenia is presented in Figure 6.4. The stations on this map include the Armhydromet and the SolarEn measurement locations. There is a significant variation of the seasonal resource across Armenia. Because the seasonal distribution of the wind resource is dependent on local and regional terrain, specific candidate locations for a wind energy project should be monitored to determine its exact resource distribution.

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 the low-resource sites in the basins and plains of Armenia 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, 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.

The sites at mountain passes or wind corridors can have a diurnal pattern different from either the low-elevation areas or the ridge crests. At these locations, both the jet stream winds and differential heating influence the diurnal patterns. For example, 40 m measurements at Karakhach Pass (Appendix C) show a fairly flat diurnal pattern with an afternoon maximum and the minimum shortly after sunrise. In contrast, the 40 m measurements at Vorotan Pass (Appendix C) exhibit slight maximums in the late afternoon/evening and near midnight. The evening wind maximums there occur during summer and are quite strong (11-12 m/s at 40 m) in July and August. Afternoon wind maximums occur during the autumn, winter, and early spring.

6.4.4 Wind Direction Frequency Distribution

The prevailing direction of the jet stream winter winds is from the west. In contrast, the prevailing direction of the winds caused by the thermal circulations is from the east. Thus, there is a seasonal reversal of wind direction at many of the high wind sites in Armenia. Karakhach Pass (Appendix C) is a good example of this trend. There, the west winds are dominant from November through March, the months when the jet stream winds are strongest. April and May are transition months when the west and east winds are about equal in frequency. East winds predominate from June through September. October is another transition month before the prevailing westerly winds start in November. This seasonal reversal of wind direction is common in many mountain passes and wind corridors. The exact directions of the wind are controlled by the local topography at a particular location.

6.4.5 Local Variability of the Wind Resource

Most of the good or excellent wind resource sites in Armenia are located either on high ridge tops or in areas that can accelerate the wind such as mountain passes or wind corridors. These are complex terrain areas with large local variability of the wind resource. There are three major factors that control the local variability of the resource; terrain blocking, acceleration caused by the terrain, and atmospheric stability. The interaction among the three factors can result in large variations in the average annual resource, the seasonal distribution of the resource, and the diurnal profile over several kilometers in these types of areas. An example of the variability is presented in Figure 6.5. This figure shows the seasonal distribution of wind speed for several stations in the Zod region. The distance between Mazra, on the plain near Lake Sevan, and the mountain summits is less than 20 km. Yet, the seasonal distribution of the wind resource is quite different. The mountain summit and pass stations clearly have a winter resource maximum. In contrast, the station located on the western slope of the ridge (Number 1) only 3 km to 4 km from the summit has a summer resource maximum. The summer resource maximum also prevails down the western slope through the town of Zod to Mazra. The maps, while showing locations of high resource areas, may not depict all of the resource variability. Any location being considered for a wind energy project should be monitored to define the exact wind characteristics of that site.

6.5 Regional Summaries of Wind Resource

Armenia is divided into two regions for this atlas. The Northern Armenia region extends from the northern border to about 40^{o} North Latitude. The Southern Armenia covers the area from 40^{o} south to the border with Iran. There is some overlap between the two regional maps.

6.5.1 Northern Armenia

Northern Armenia is a mixture of plains, basins, and mountain ridges. The two most prominent geographic features of this region are Mount Aragats, a volcanic peak that reaches over 4000 m in elevation, in the western part of the region, and Lake Sevan located in the eastern part of northern Armenia. Figures 6.6 and 6.7 show the elevation features, and potential wind resource of this region.

The large contiguous areas of good-to-excellent resource for utility applications are located either at mountain passes or on ridge crests. These areas include the Bazum Range northeast of Gyumri, the Jajur Pass between Gyumri and Spitak, the Pambak and Aregunt Ranges near the northern end of Lake Sevan (including the Sevan Pass), the slopes and peak of Mt. Aragats, the south-central portion of the Geghama Range, the Zod region of extreme eastern Armenia, and the eastern end of the Vardenis Range. Smaller areas of good resource are found at Mt. Achkasar near the border with Georgia, the northern part of the Gehama range, the Sevan Range east of the lake, and scattered areas in the Vardenis Range.

Many of the best resource areas are located in very rugged and complex terrain. A primary concern for the development of the wind resource in northern Armenia is accessibility and cost. High resource areas close to existing roads such as the Karakhach, Pushkin, Jajur, and Sevan passes and the Zod region could be the best regions to develop in the near future.

6.5.2 Southern Armenia

Southern Armenia is characterized by rugged mountain ranges and by fairly narrow valleys and gorges. The only broad plain area is the southern part of the Arashat Plain that covers the extreme northwest part of the region. Figures 6.8 and 6.9 show the elevation features and the potential wind resource of this region.

The most concentrated areas of good-to-excellent utility-scale resource are found in the Bargusat Range, the part of the Zangezur Range bordering Nakhichevan, the gorge area along the Araks River near Megrhi, and the hills between Sisian and Goris. A major road crosses this latter area, and the terrain is not as steep as other areas in southern Armenia. There is little historical wind data for this area and no wind energy measurements have been taken. This area seems worth investigating for wind energy development because it is fairly accessible and shows potential for good wind resources.

Minor areas of good-to-excellent resource occur along hills on the eastern edge of the Arashart Plain, in the Megrhi Range, and at Sisian Pass. Sisian Pass is intriguing because measurements from the historical meteorological station indicate average wind speeds around 8 m/s. However, it is difficult to know how much of the good-to-excellent resource extends from the pass eastward. The map also indicates some good-to-excellent resource on the ridges surrounding the pass. Further investigation of the Sisian Pass area appears to be warranted.

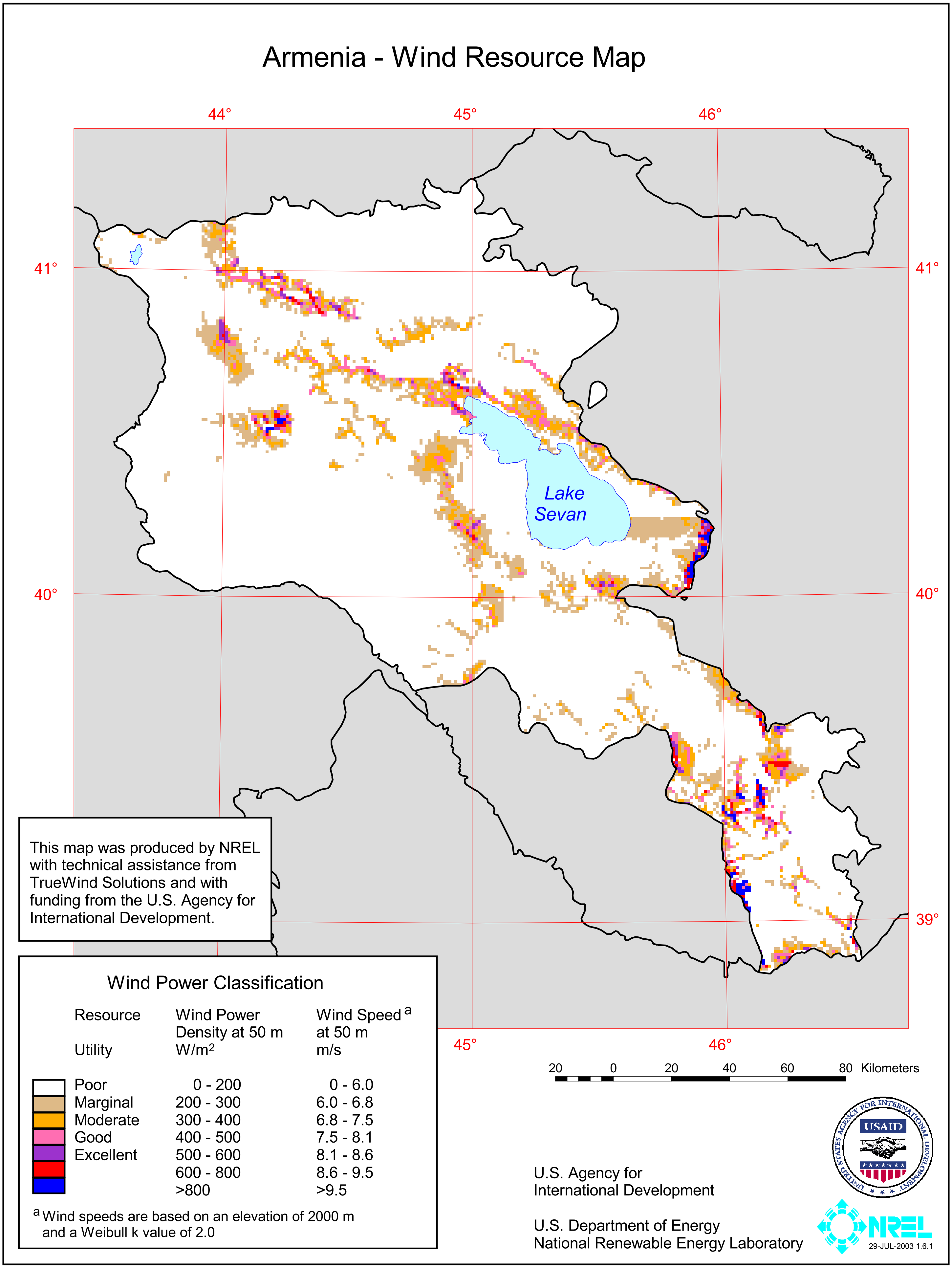
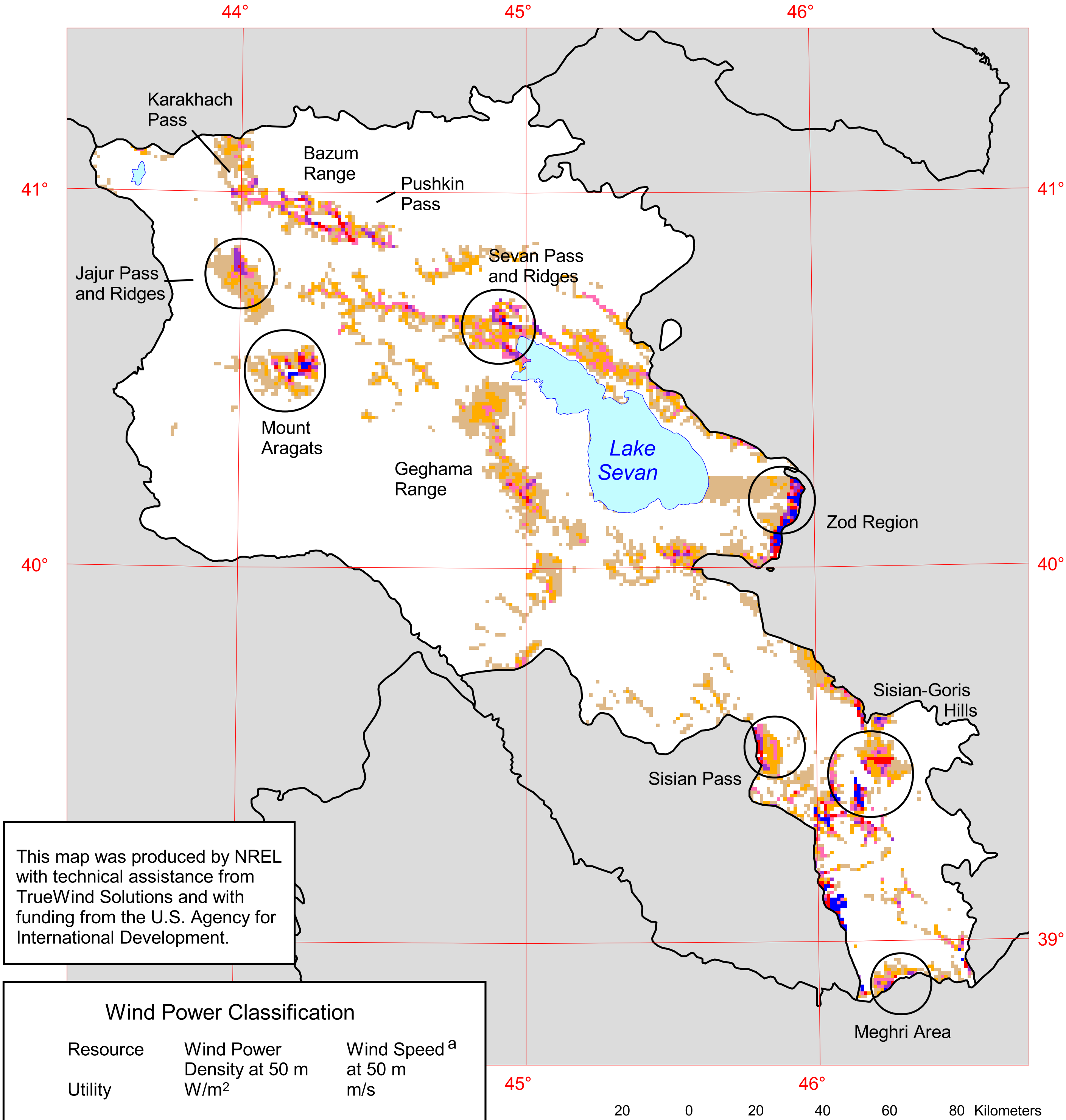

Armenia - Wind Resource Map
44°
45°
46°
41°
40°
39°
Lake Sevan
This map was produced by NREL with technical assistance from TrueWind Solutions and with funding from the U.S. Agency for International Development.
Wind Power Classification
Resource Utility
Wind Power Density at 50 m W/m2
Wind Speed [a] at 50 m m/s
Poor 0 - 200 0 - 6.0
Marginal 200 - 300 6.0 - 6.8
Moderate 300 - 400 6.8 - 7.5
Good 400 - 500 7.5 - 8.1
Excellent 500 - 600 8.1 - 8.6
600 - 800 8.6 - 9.5
>800 >9.5
[a] Wind speeds are based on an elevation of 2000 m and a Weibull k value of 2.0
20 0 20 40 60 80 Kilometers
USAID
U.S. Agency for International Development
U.S. Department of Energy
National Renewable Energy Laboratory
NREL
29-JUL-2003 1.6.1

Figure 6-1

Armenia - Major Wind Resource Areas



This map was produced by NREL with technical assistance from TrueWind Solutions and with funding from the U.S. Agency for International Development.

Wind Power Classification

Resource Utility	Wind Power Density at 50 m W/m^2	Wind Speed [a] at 50 m m/s
Poor	0 - 200	0 - 6.0
Marginal	200 - 300	6.0 - 6.8
Moderate	300 - 400	6.8 - 7.5
Good	400 - 500	7.5 - 8.1
Excellent	500 - 600	8.1 - 8.6
	600 - 800	8.6 - 9.5
	>800	>9.5

[a] Wind speeds are based on an elevation of 2000 m and a Weibull k value of 2.0

U.S. Agency for International Development

U.S. Department of Energy
National Renewable Energy Laboratory

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Figure 6-2

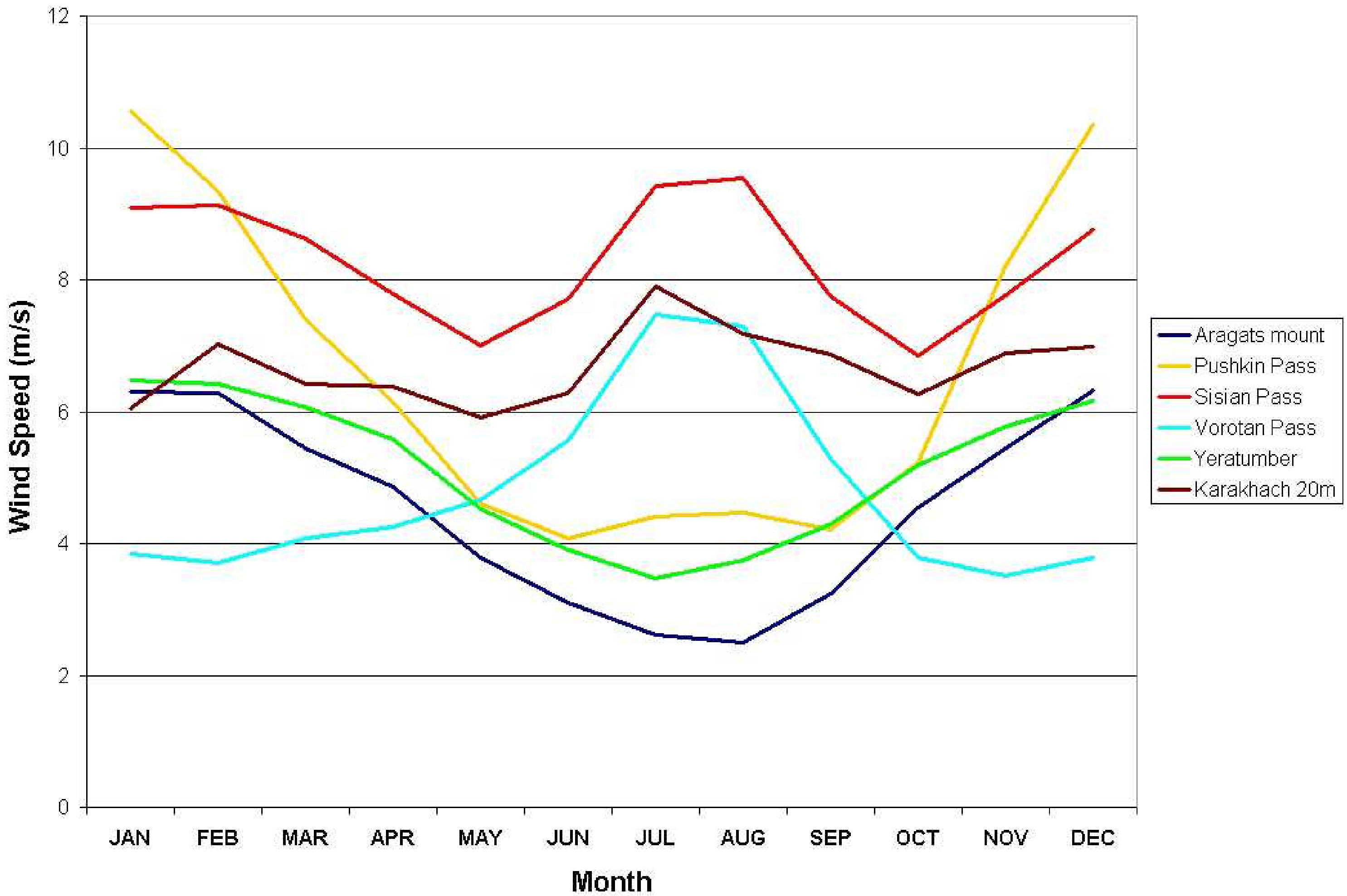


Figure 6.3 Armenia – Seasonal Wind Pattern at Six Measurement Stations.

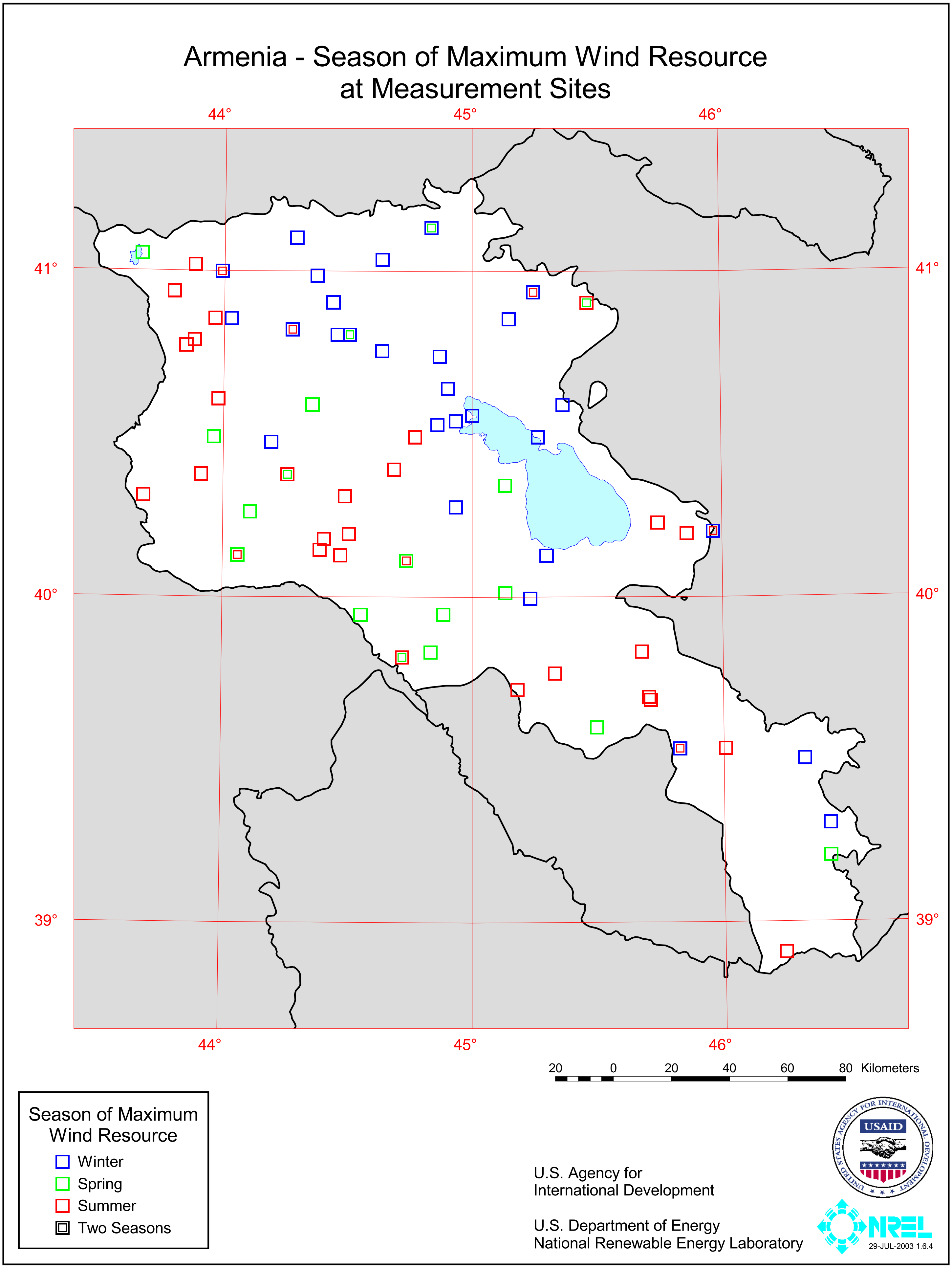

Armenia - Season of Maximum Wind Resource
at Measurement Sites
44°
45°
46°
41°
40°
39°
20 0 20 40 60 80 Kilometers
Season of Maximum
Wind Resource
Winter
Spring
Summer
Two Seasons
U.S. Agency for
International Development
U.S. Department of Energy
National Renewable Energy Laboratory
29-JUL-2003 1.6.4

Figure 6-4

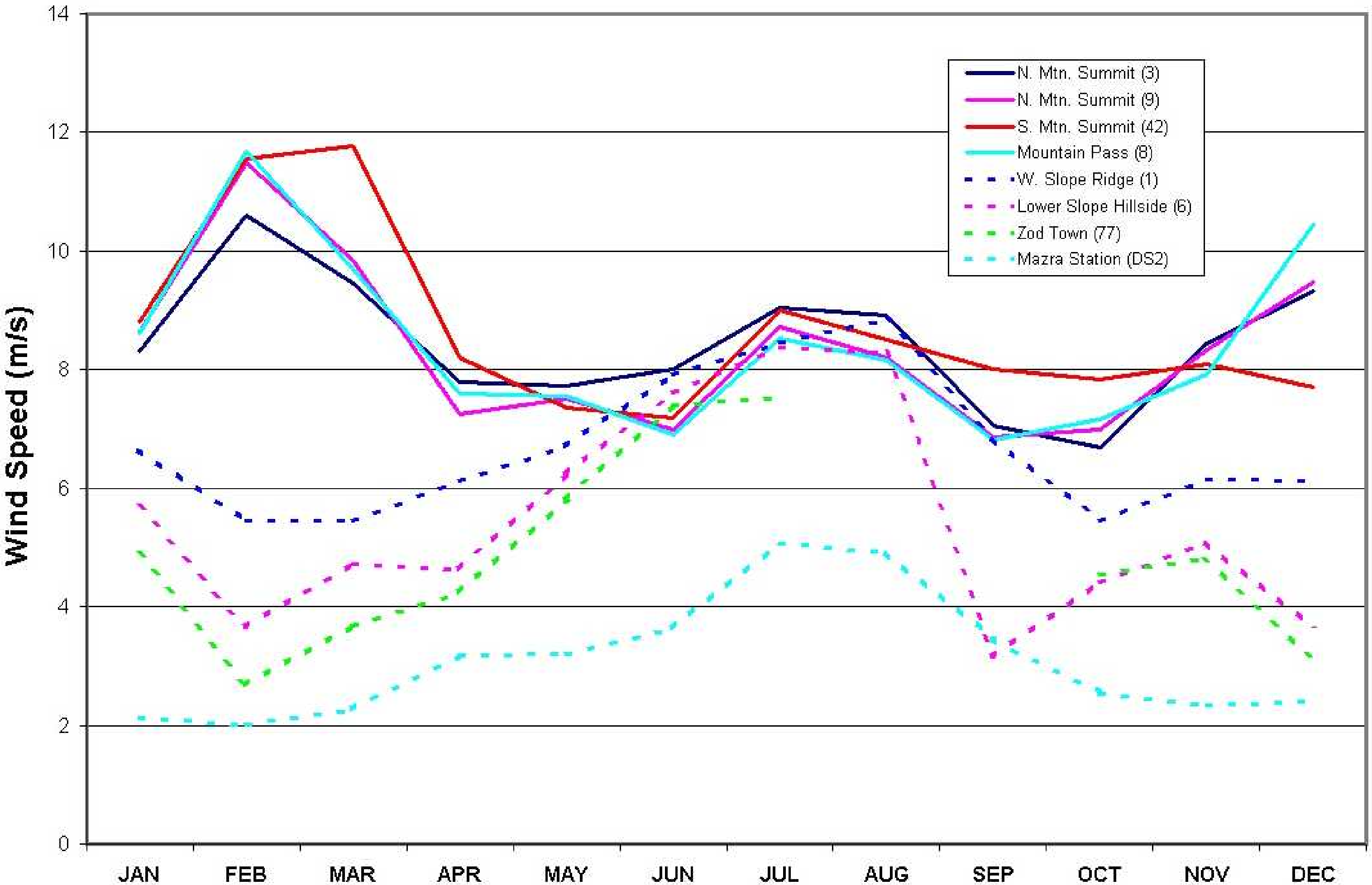
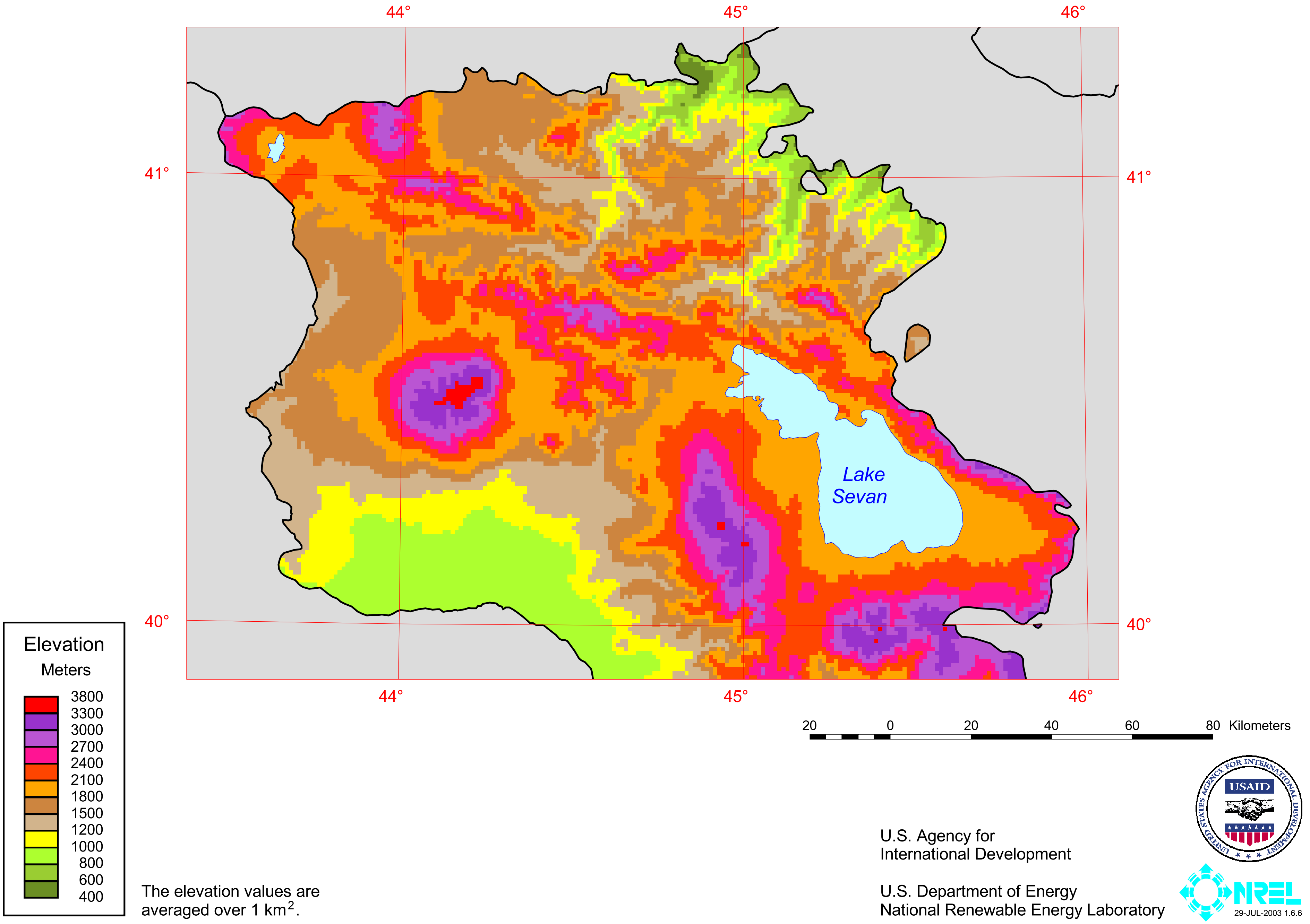


Figure 6.5 Zod Region – Seasonal Variability.

Northern Armenia Elevation Map



The elevation values are averaged over 1 km^2.

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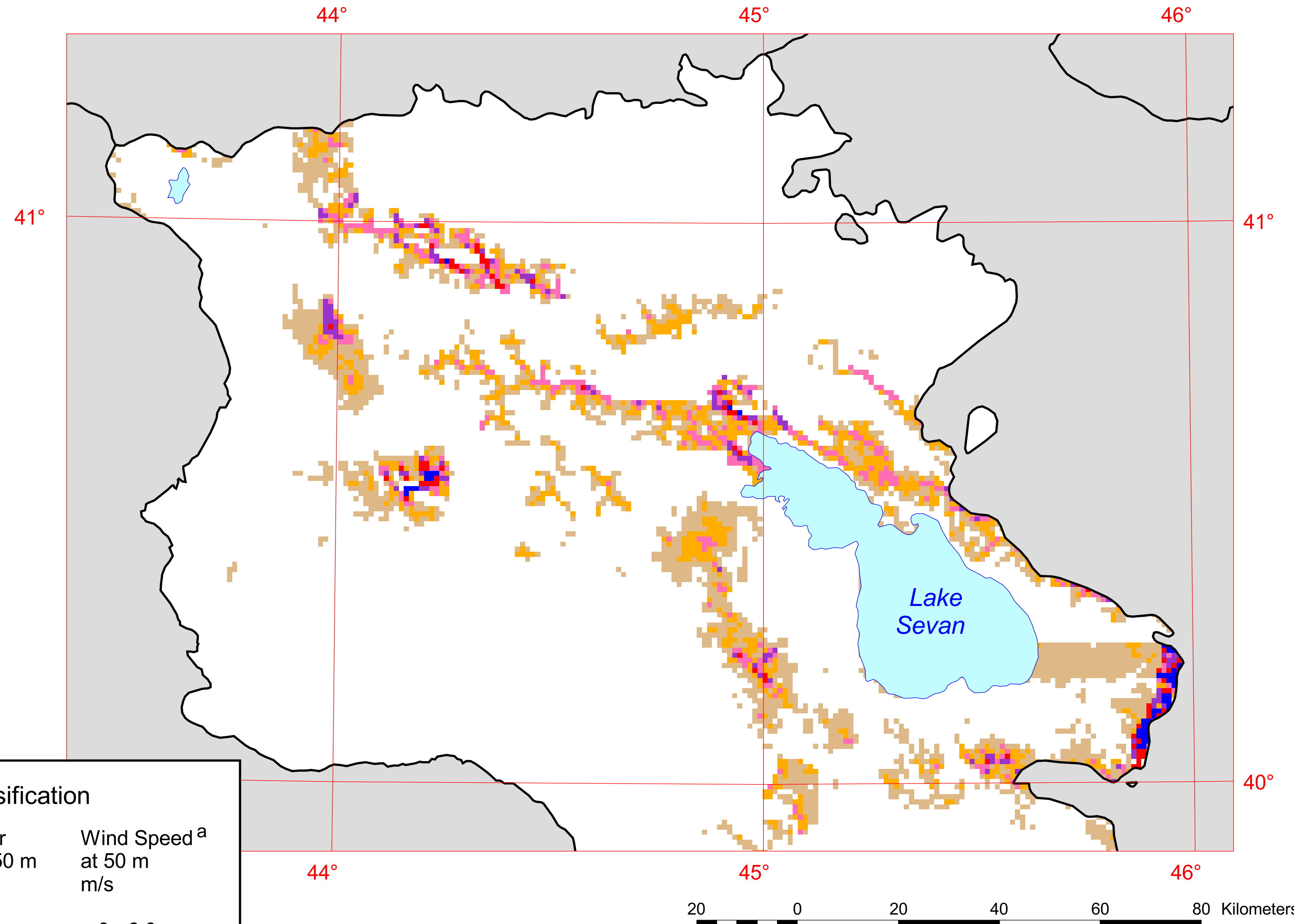
Figure 6-6

Northern Armenia Wind Resource Map



Wind Power Classification

Resource Utility	Wind Power Density at 50 m W/m²	Wind Speed[a] at 50 m m/s
Poor	0 - 200	0 - 6.0
Marginal	200 - 300	6.0 - 6.8
Moderate	300 - 400	6.8 - 7.5
Good	400 - 500	7.5 - 8.1
Excellent	500 - 600	8.1 - 8.6
	600 - 800	8.6 - 9.5
	>800	>9.5

[a] Wind speeds are based on an elevation of 2000 m and a Weibull k value of 2.0

This map was produced by NREL with technical assistance from TrueWind Solutions and with funding from the U.S. Agency for International Development.

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Figure 6-7

Southern Armenia Elevation Map

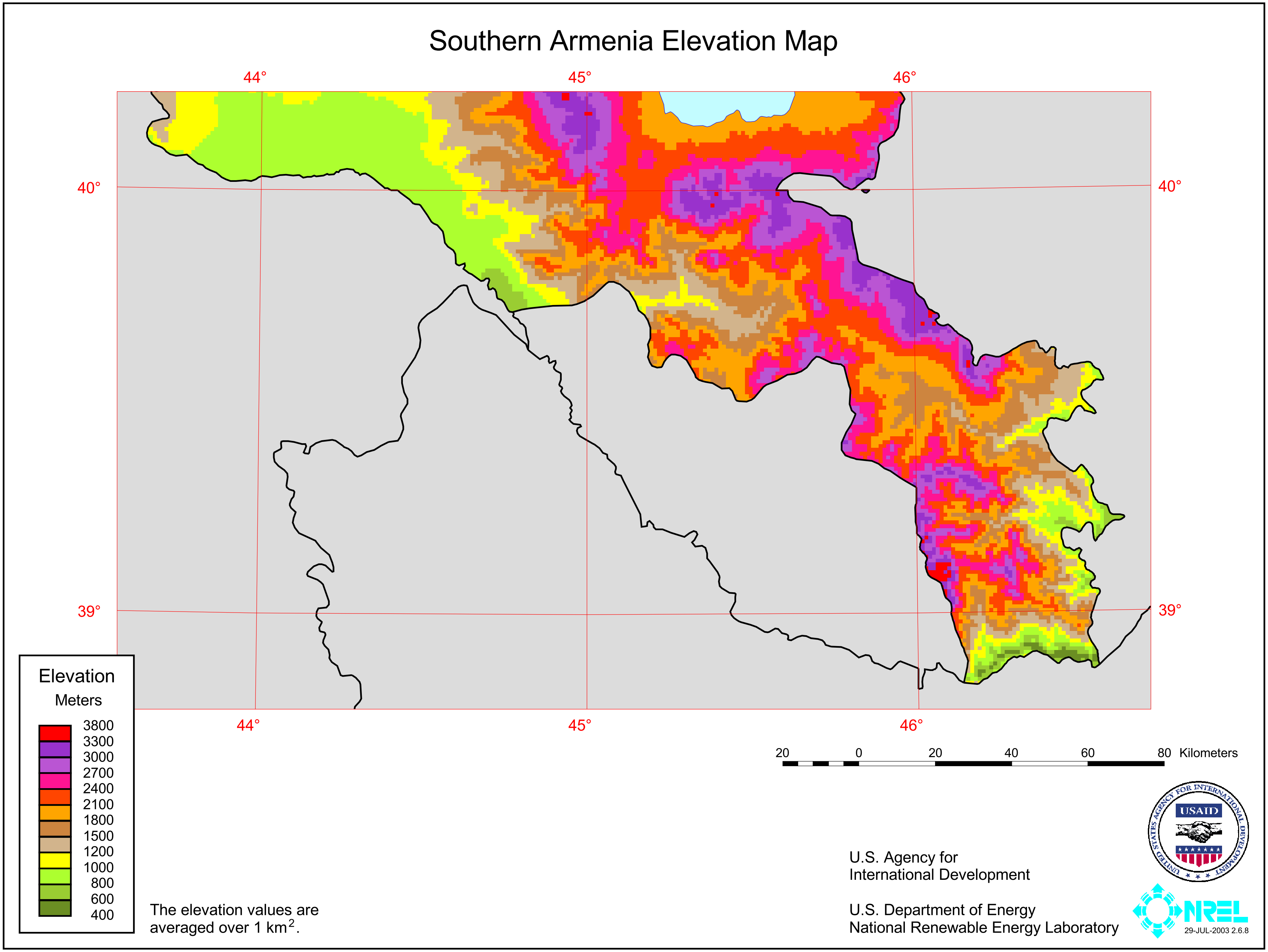
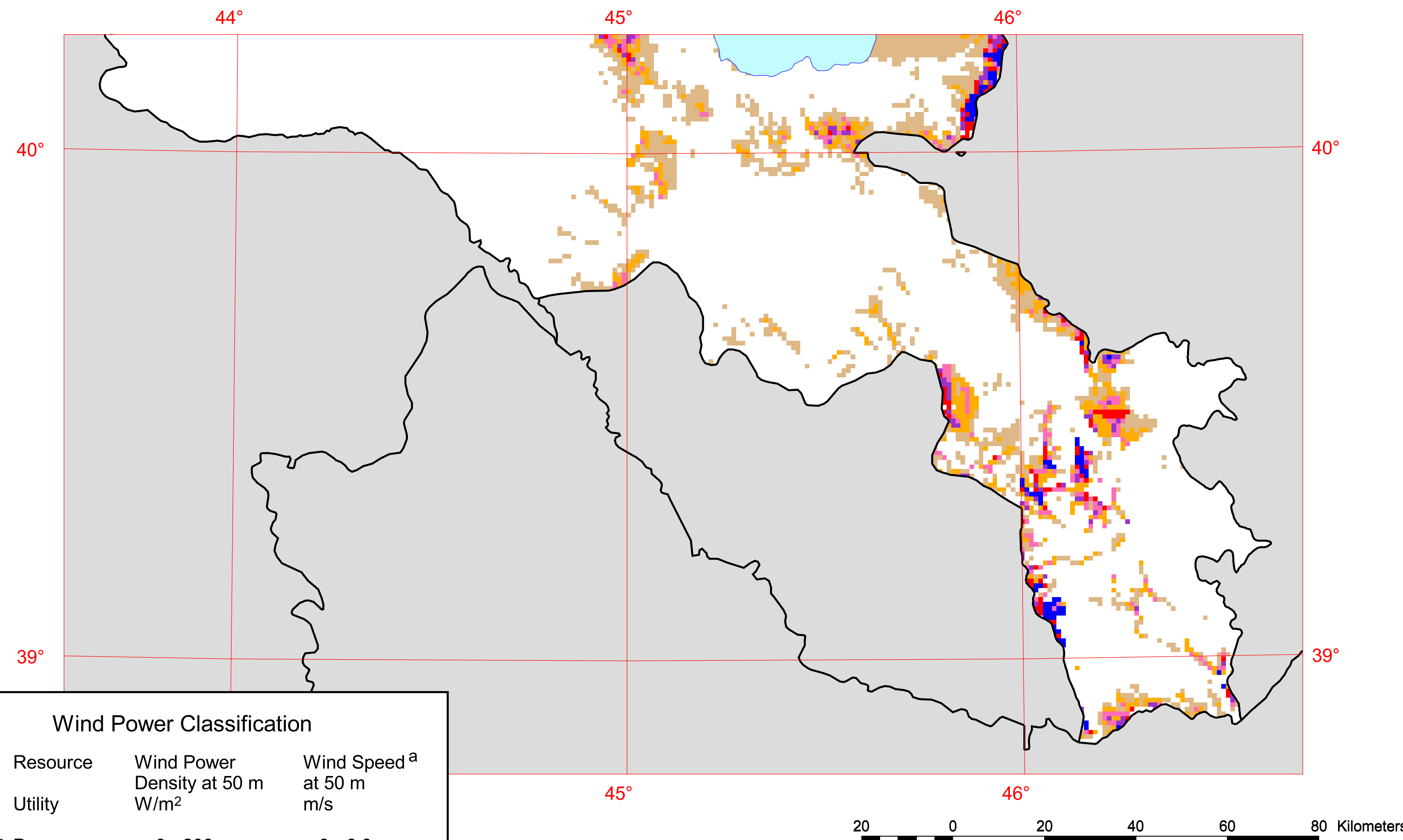


Figure 6-8

Southern Armenia Wind Resource Map



Wind Power Classification

Resource Utility	Wind Power Density at 50 m W/m^2	Wind Speed [a] at 50 m m/s
Poor	0 - 200	0 - 6.0
Marginal	200 - 300	6.0 - 6.8
Moderate	300 - 400	6.8 - 7.5
Good	400 - 500	7.5 - 8.1
Excellent	500 - 600	8.1 - 8.6
	600 - 800	8.6 - 9.5
	>800	>9.5

[a] Wind speeds are based on an elevation of 2000 m and a Weibull k value of 2.0

This map was produced by NREL with technical assistance from TrueWind Solutions and with funding from the U.S. Agency for International Development.

U.S. Agency for International Development

U.S. Department of Energy National Renewable Energy Laboratory

29-JUL-2003 2.6.9

Figure 6-9

7.0 Wind Electric Potential

7.1 Introduction

The wind resource classifications in Table 7.1 match those shown on the wind resource maps for Armenia. The installed capacity in the table represents net wind electric potential not reduced by factors such as land-use exclusions. The methods for converting the wind resource to wind electric potential are those used regularly by NREL. 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 50-m height expressed in units of W/m^2. NREL uses a simple formula to compute the potential installed capacity for grid cells with an annual wind power density of 300 W/m^2 and greater. If the wind power density of a grid cell was less than 300 W/m^{2,} then the potential installed capacity was set equal to zero. Another scenario presented in this section included only those grid cells with an annual average power density of 400 W/m^2 and greater.

7.2 Wind Electric Potential Estimates

We estimate that there are about 1000 km^2 of land areas with good-to-excellent wind resource potential in Armenia. The proportion of windy land and potential wind capacity in each wind power category is listed in Table 7.1. This windy land represents less than 4% of the total land area (28,400 km^2) of Armenia. Using a conservative assumption of 5 MW per km^2, this windy land could support almost 5,000 MW of potential installed capacity. Additional studies are required to accurately assess the wind electric potential, considering factors such as the existing transmission 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 2,200 km^2, or almost 8% of the total land area of Armenia. This amount of windy land could support more than 11,000 MW of installed capacity.

Table 7.1 Armenia – Wind Electric Potential

Good-to-Excellent Wind Resource at 50 m

Wind Resource Utility Scale	Wind Class	Wind Power at 50 m W/m^2	Wind Speed at 50 m m/s*	Total Area km^2	Percent Windy Land	Total Capacity Installed MW
Good	4	400-500	7.5-8.1	503	1.8	2,500
Excellent	5	500-600	8.1-8.6	208	0.7	1,050
Excellent	6	600-800	8.6-9.5	165	0.6	850
Excellent	7	>800	>9.5	103	0.4	500
Total				979	3.5	4,900

Moderate-to-Excellent Wind Resource at 50 m (Utility Scale)

Wind Resource Utility Scale	Wind Class	Wind Power at 50 m W/m^2	Wind Speed at 50 m m/s*	Total Area km^2	Percent Windy Land	Total Capacity Installed MW
Moderate	3	300-400	6.8-7.5	1,226	4.3	6,150
Good	4	400-500	7.5-8.1	503	1.8	2,500
Excellent	5	500-600	8.1-8.6	208	0.7	1,050
Excellent	6	600-800	8.6-9.5	165	0.6	850
Excellent	7	>800	>9.5	103	0.4	500
Total				2,205	7.8	11,050

*** Wind speeds are based on an elevation of 2000 m and a Weibull k value of 2.0**

Assumptions
Installed capacity per km^2 = 5 MW
Total land area of Armenia = 28,400 km^2

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Appendix A

Surface Meteorological Stations
Tables and Analysis Summaries of Selected Stations

Armhydromet Stations

Table A.1
Armenia Historical Wind Measurement Sites

	Name	Lat	Lon	Elev	From	To	Nmon	WS	Max5Yr	Max WS 5	Max Season
1	Amasia	40 57	43 47	1866	1932/05	1999/06	725	2.93	1942	4.05	3
2	Amberd (Koshabulakh)	40 23	44 15	2071	1929/07	1991/12	743	1.76	1933	2.94	2,3
3	Aparan	40 36	44 21	1889	1935/08	1991/12	664	2.49	1939	3.59	2
4	Arabkir (Yerevan GMO)	40 12	44 30	1113	1955/01	1991/12	444	2.21	1955	2.64	3
5	Aragats mount	40 29	44 11	3227	1930/01	2000/03	758	4.55	1938	5.42	1
6	Aragats r/r st.	40 19	43 40	1254	1940/01	1988/05	578	3.02	1941	4.57	3
7	Ararat	39 49	44 43	818	1950/01	1991/12	504	2.2	1955	2.69	2,3
8	Areni	39 43	45 11	1009	1949/11	1988/05	463	1.3	1958	2.62	3
9	Armavir Hoktemberian	40 08	44 03	853	1942/01	1991/12	590	1.13	1942	1.64	2,3
10	Artashat	39 57	44 33	829	1930/01	1991/12	734	0.92	1930	1.59	2
11	Artik	40 37	43 58	1724	1936/01	1999/06	657	2.65	1952	3.74	3
12	Ashotsk (Ghukasian)	41 02	43 52	2012	1957/10	1999/04	415	2.79	1984	3.35	3
13	Bagratashen Debetashn	41 15	44 49	451	1953/12	1991/12	452	0.88	1956	1.93	0
14	Berd	40 55	45 28	695	1934/12	1991/12	680	1.82	1958	2.95	2,3
15	Beziyanniy Pass	39 50	44 50	2122	1960/12	1991/12	373	2.04	1961	3.25	2
16	Chambarak Krasnoselsk	40 36	45 22	1853	1934/12	1991/12	680	3.06	1940	3.51	1
17	Dilijan	40 45	44 52	1256	1940/01	1991/11	622	2.06	1953	2.84	1
18	Fontan	40 24	44 41	1800	1935/09	2000/03	693	3.21	1937	4.15	3
19	Garni	40 07	44 44	1422	1941/04	1988/05	564	1.2	1941	2.09	2,3
20	Garnhovit	40 30	43 57	2166	1951/01	1988/03	447	3.56	1979	4.14	2
21	Gavar (Kamo)	40 21	45 08	1960	1891/01	1991/12	1049	2.02	1929	3	2
22	Goris Hydro	39 30	46 20	1307	1927/01	1991/12	755	1.68	1954	2.26	1
23	Gyumri (Leninakan)	40 48	43 52	1528	1895/08	1964/09	676	2.48	1931	3.11	3
24	Gyumri AMSG (new)	40 47	43 50	1528	1961/06	1991/12	363	1.46	1964	2.43	3
25	Hankavan	40 38	44 29	1992	1957/09	1987/03	341	0.98	1958	1.86	0
26	Hrazdan	40 30	44 46	1765	1966/01	1991/12	312	2.19	1975	2.83	3
27	Ijevan	40 52	45 09	732	1913/12	1991/12	790	2.25	1913	3.44	1
28	Jajur r/r st.	40 52	43 57	1792	1904/09	1988/05	901	3.52	1947	5.26	3
29	Jermuk	39 50	45 41	2064	1947/08	1991/12	532	1.67	1957	2.41	3
30	Kaltakhchi	40 52	44 01	1833	1955/01	1975/12	227	3.41	1967	3.59	1
31	Kapan	39 12	46 26	704	1934/04	1991/12	667	1.34	1987	2.11	2
32	Khotanan Verin	39 18	46 26	1406	1947/08	1975/12	333	1.53	1951	1.83	1
33	Kokhb	41 11	44 59	743	1933/01	1960/12	233	1.9	1933	2.38	0
34	Lermontovo	40 46	44 38	1798	1935/05	1988/05	628	3.2	1972	4.01	1
35	Martiros	39 36	45 30	1957	1938/01	1980/12	507	2.71	1952	2.94	2
36	Martuni	40 08	45 18	1943	1926/10	2000/03	794	2.95	1929	4.57	1
37	Masrik (Mazra)	40 14	45 45	1939	1927/06	2000/12	832	3.16	1942	4.31	3
38	Megri	38 54	46 15	627	1940/01	1991/12	622	1.67	1951	2.24	3
39	Odzun (Uzunlar)	41 03	44 38	1105	1952/01	1991/12	470	1.46	1956	1.89	1
40	Onut (Uzuntala)	40 57	45 15	505	1949/10	1964/05	175	1.83	1950	2.03	1,3
41	Paghakn (Shurabad)	41 04	43 39	2005	1940/01	1990/05	595	2.61	1951	3.86	2

42	Pushkin Pass	40 55	44 26	2066	1963/01	2000/03	374	6.6	1977	7.36	1
43	Semyonovka	40 39	44 54	2104	1926/07	2000/03	794	3.12	1929	4.65	1
44	Sevan Lake GMO	40 34	45 00	1917	1927/05	2000/03	780	4.8	1944	5.88	1
45	Sevan AMSG	40 33	44 56	1936	1895/06	1987/12	851	3.64	1911	4.29	1
46	Sevkar	40 01	45 08	925	1949/09	1975/12	312	1.12	1950	1.4	2
47	Shamiran	40 16	44 06	1157	1949/12	1964/05	174	1.96	1954	2.1	2
48	Shnokh	41 09	44 50	656	1933/02	1988/05	656	1.41	1933	1.86	1,2
49	Shorzha	40 30	45 16	1917	1927/06	2000/03	794	3.39	1990	4.15	1
50	Sisian	39 32	46 01	1580	1931/10	1991/12	716	2.67	1939	3.58	3
51	Sisian Pass	39 32	45 50	2380	1950/12	1988/10	448	8.29	1958	9.06	1,3
52	Spitak	40 50	44 16	1552	1929/10	1991/12	717	3.52	1960	4.8	1,3
53	Stepanavan	41 00	44 22	1397	1932/01	2000/03	738	1.81	1958	3.01	1
54	Talin Verin	40 23	43 54	1637	1930/11	1991/11	713	2.2	1953	3.06	3
55	Tashir (Kalinino)	41 07	44 17	1507	1914/04	1999/12	712	2.19	1961	2.67	1
56	Urtsadzor (Chimankend)	39 57	44 53	1064	1949/11	2000/03	514	1.44	1952	2.07	2
57	Vanadzor	40 49	44 30	1353	1936/01	1964/08	344	2.03	1944	2.32	1,2
58	Vanadzor AMSG	40 49	44 27	1376	1961/02	1991/12	371	2.49	1964	3.22	1
59	Vorotan Pass (Kochbek)	39 41	45 43	2387	1961/12	1991/12	360	4.76	1987	5.27	3
60	Yanikh	40 00	45 14	2334	1941/11	1991/12	599	4.14	1975	5.12	1
61	Yekhegnadzor	39 46	45 20	1267	1941/01	2000/03	642	1.4	1967	1.84	3
62	Yeghvard	40 19	44 29	1337	1942/03	2000/03	617	2.78	1946	3.82	3
63	Yeratumber	40 17	44 56	3101	1958/11	1988/05	355	5.14	1958	5.65	1
64	Yerevan Argo	40 11	44 24	942	1938/02	1990/12	622	2.12	1951	3.83	3
65	Yerevan Erebuni (old)	40 08	44 28	910	1940/01	1991/12	624	1.7	1985	2.27	3
66	Yerevan Zvartnots new	40 09	44 23	865	1966/05	1991/12	308	2.4	1966	2.94	3

Lat is the latitude in deg/min N
Lon is the longitude in deg/min E
Elev is the elevation in meters above seal level
From/To is the period of record in yr/mo
Nmon is the number of months of data actually received
WS is the wind speed in meters/sec
Max5Yr is the start of the 5-year period with the greatest wind speed
Max WS 5 is the maximum 5-year average wind speed
Max Season:

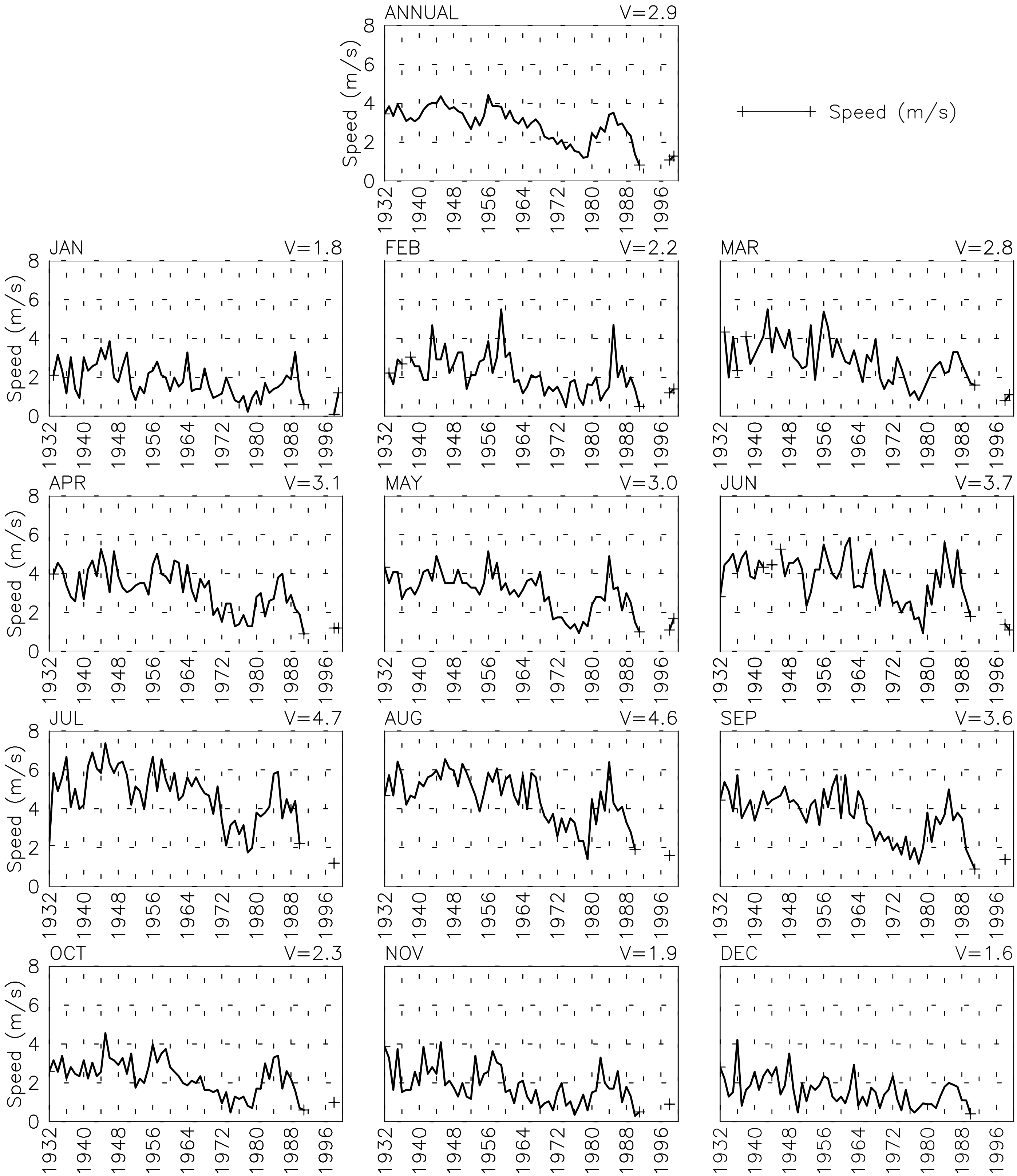
1=Winter (Dec, Jan, Feb)
2=Spring (Mar, Apr, May)
3=Summer (Jun, Jul, Aug)
4=Fall (Sept, Oct, Nov)
0=No Obvious Maximum

SPEED BY YEAR

Amasia – 000001

40° 57' N 43° 47' E – Elev 1866m LST=GMT+99 hours *NT= +3

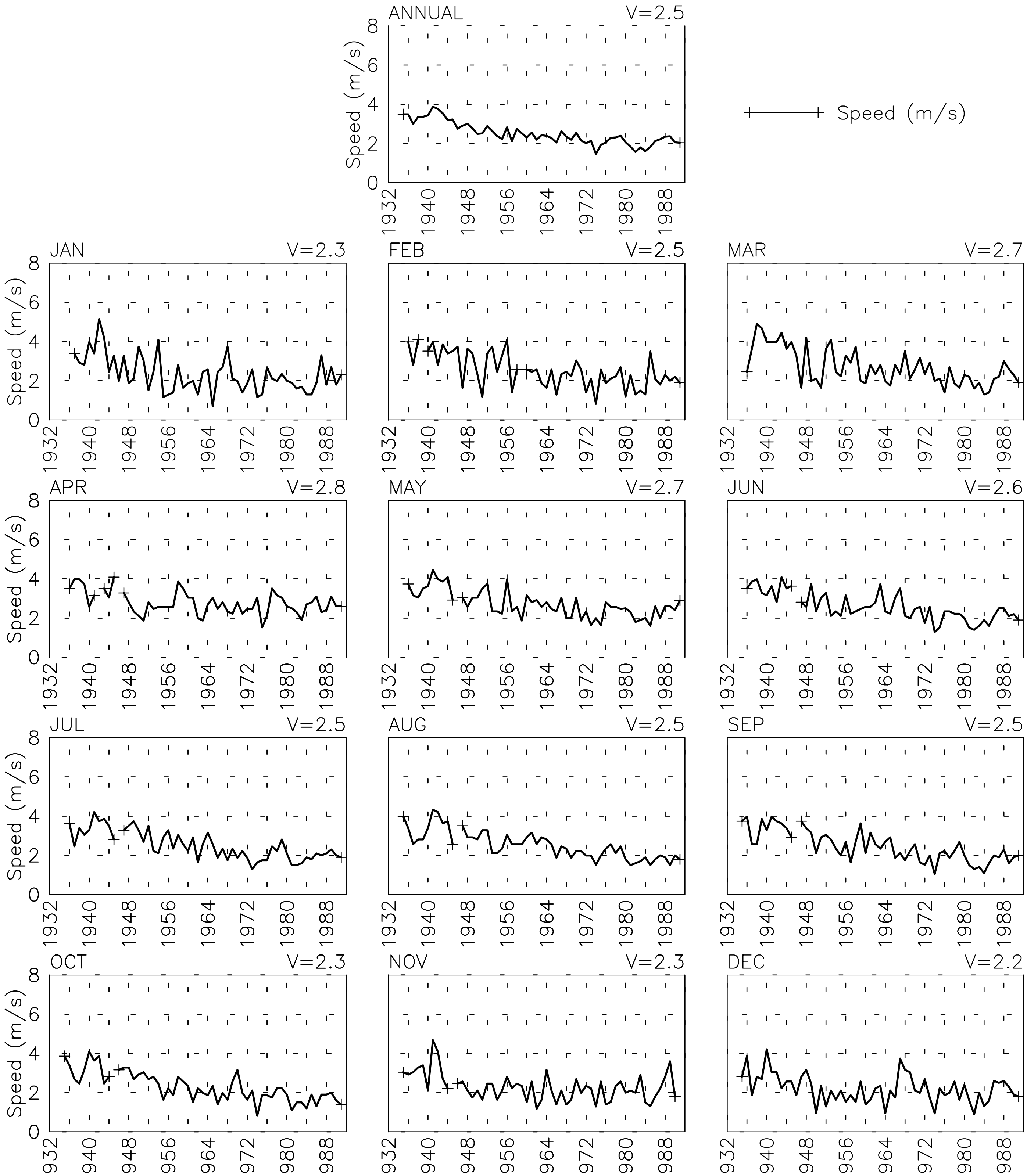
05/32–11/91 01/98–06/99



Mon Mar 24 11:38:47 2003

SPEED BY YEAR

Aparan – 000003
40° 36' N 44° 21' E – Elev 1889m LST=GMT+99 hours *NT= +3
08/35–12/91



Mon Mar 24 11:38:49 2003

SPEED BY YEAR

Arabkir (Yerevan GMO) – 000004

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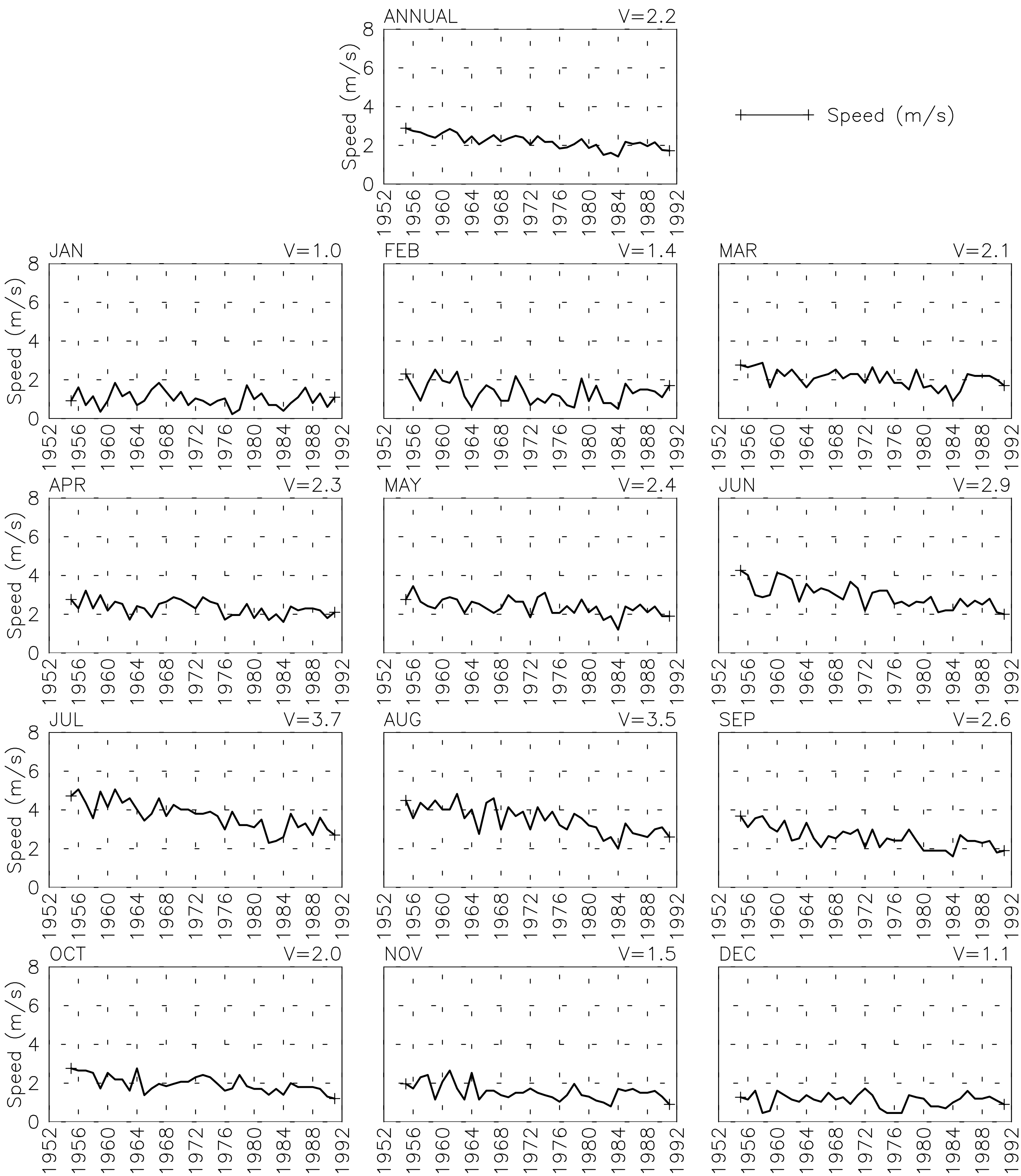
01/55–12/91



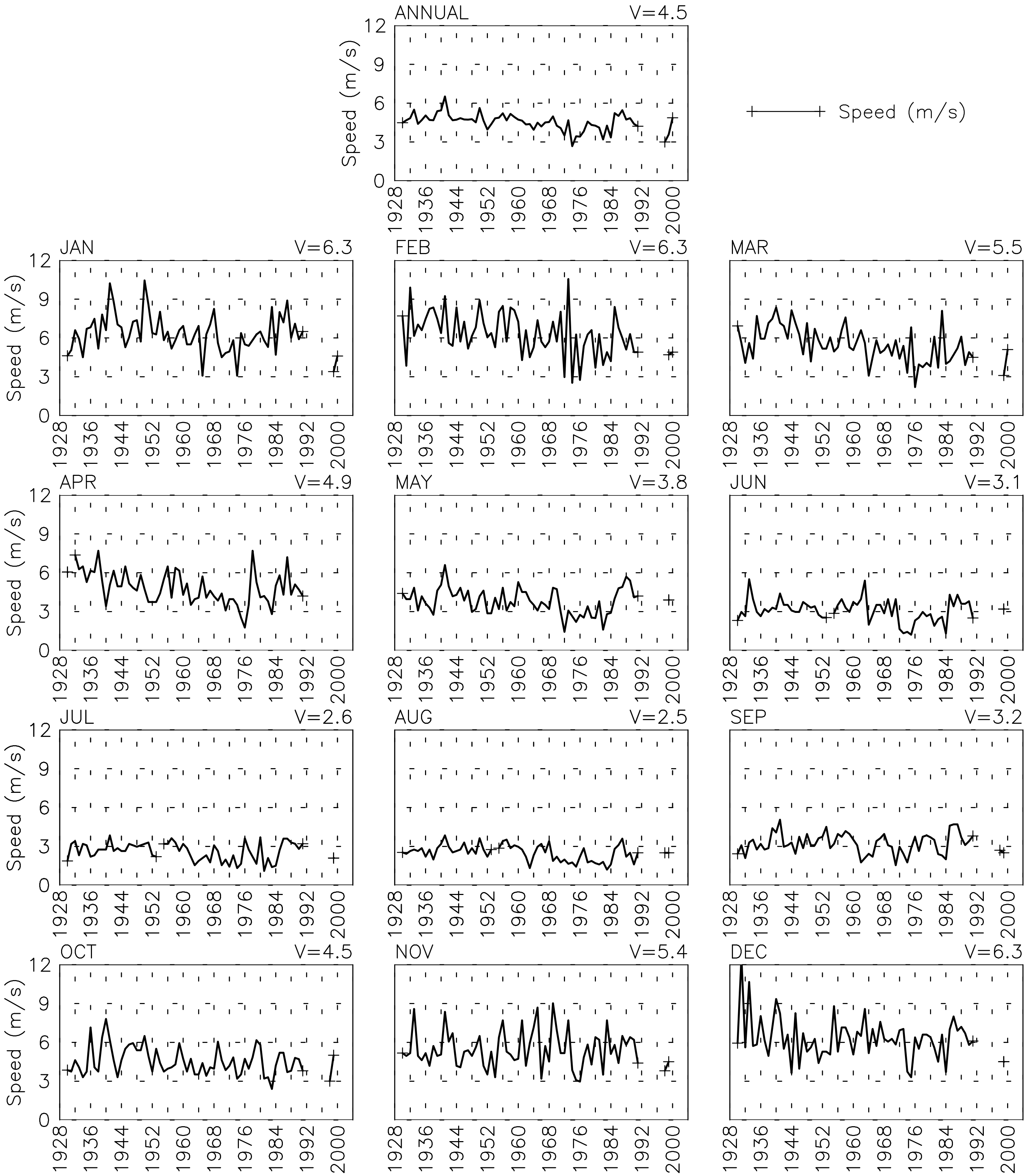
Mon Mar 24 11:38:50 2003

SPEED BY YEAR

Aragats mount – 000005

40° 29' N 44° 11' E – Elev 3227m LST=GMT+99 hours *NT= +3

01/30–12/91 08/98–03/00



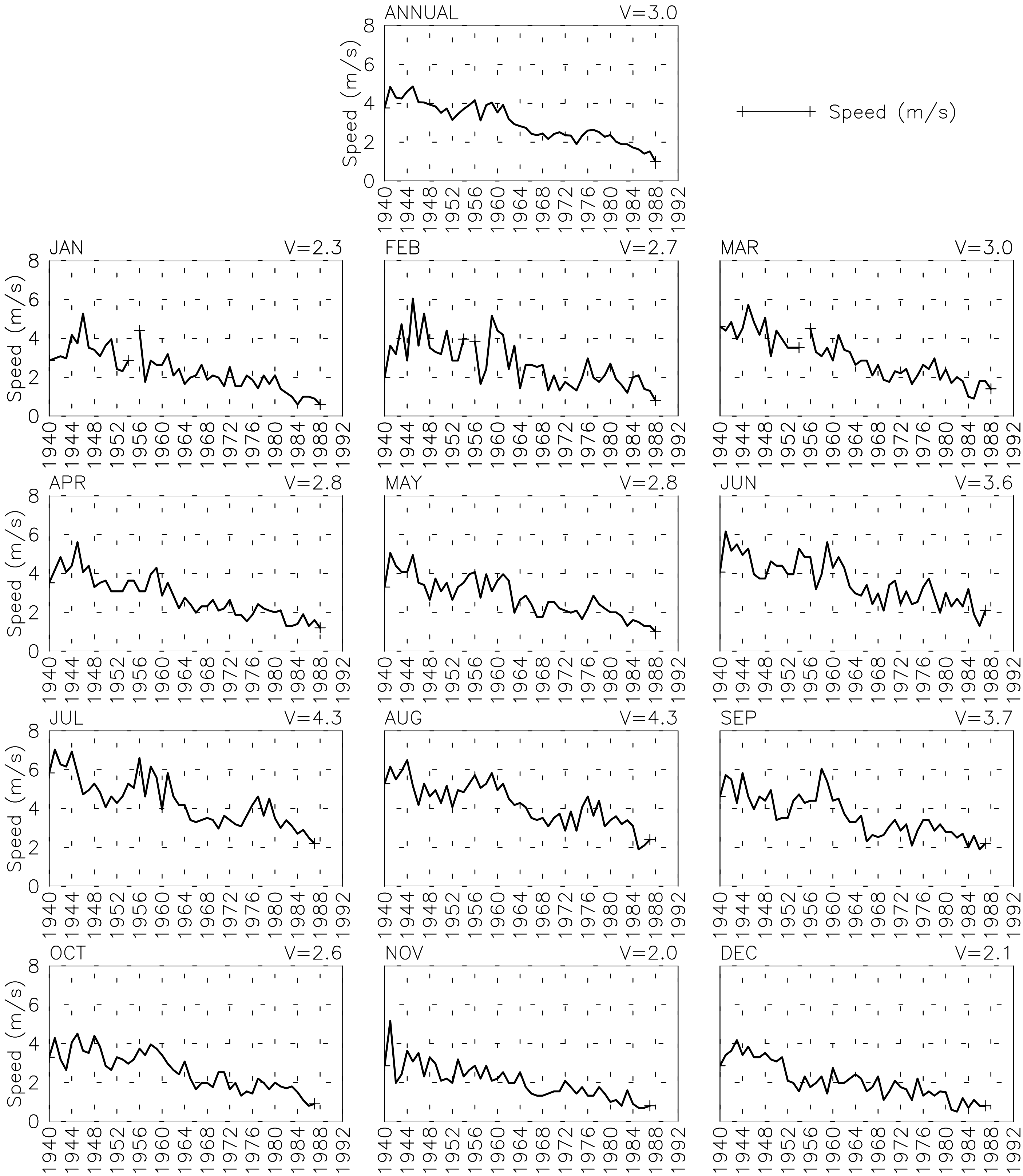
Mon Mar 24 11:40:22 2003

SPEED BY YEAR

Aragats r/r st. – 000006

40° 19' N   43° 40' E – Elev 1254m   LST=GMT+99 hours   *NT= +3

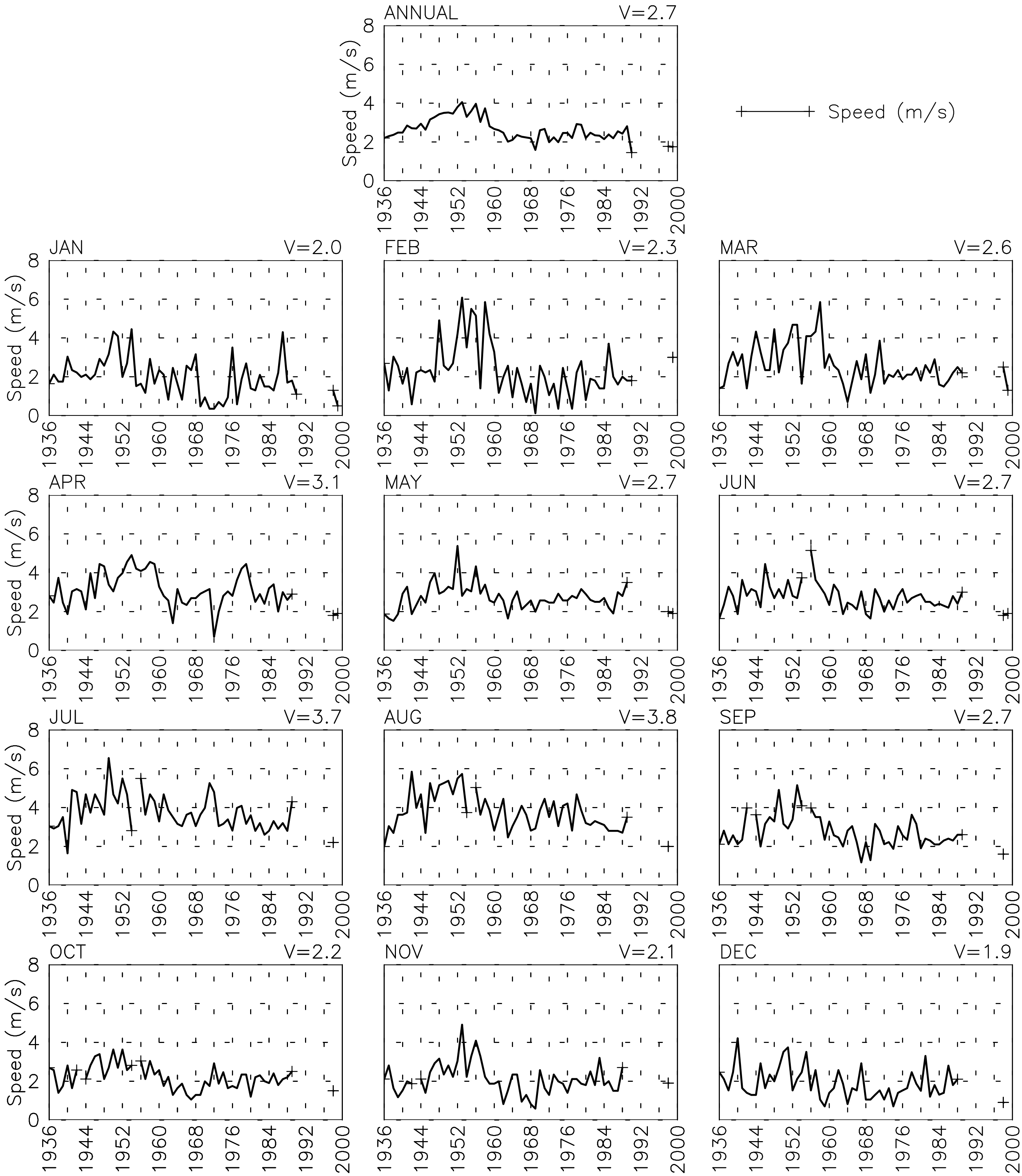
01/40–05/88



Mon Mar 24 11:38:52 2003

SPEED BY YEAR

Artik – 000011
40° 37' N 43° 58' E – Elev 1724m LST=GMT+99 hours *NT= +3
01/36–02/90 01/98–06/99



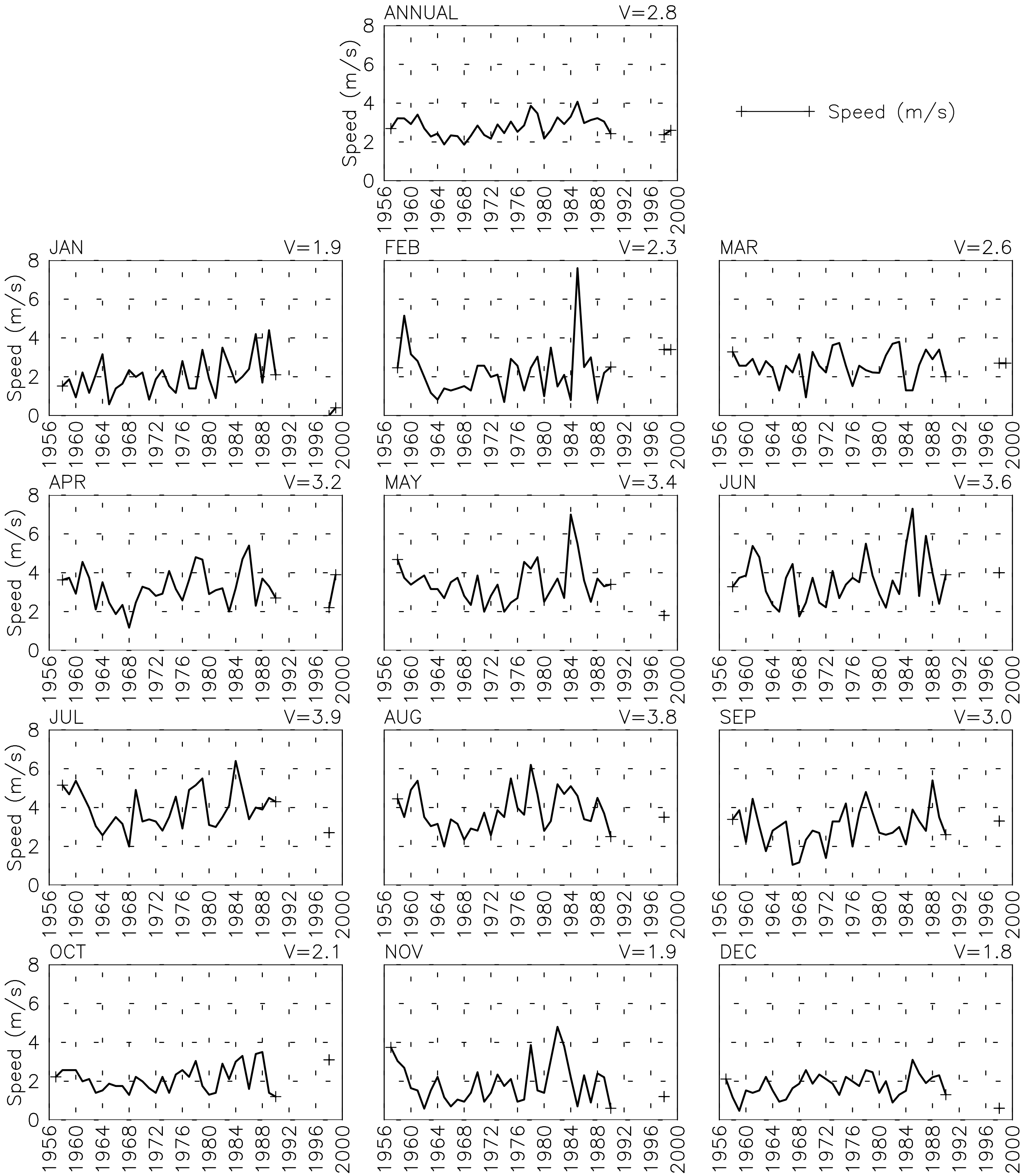
Mon Mar 24 11:38:53 2003

SPEED BY YEAR

Ashotsk (Ghukasian) – 000012

41° 02' N   43° 52' E – Elev 2012m   LST=GMT+99 hours   *NT= +3

10/57–12/90 01/98–04/99



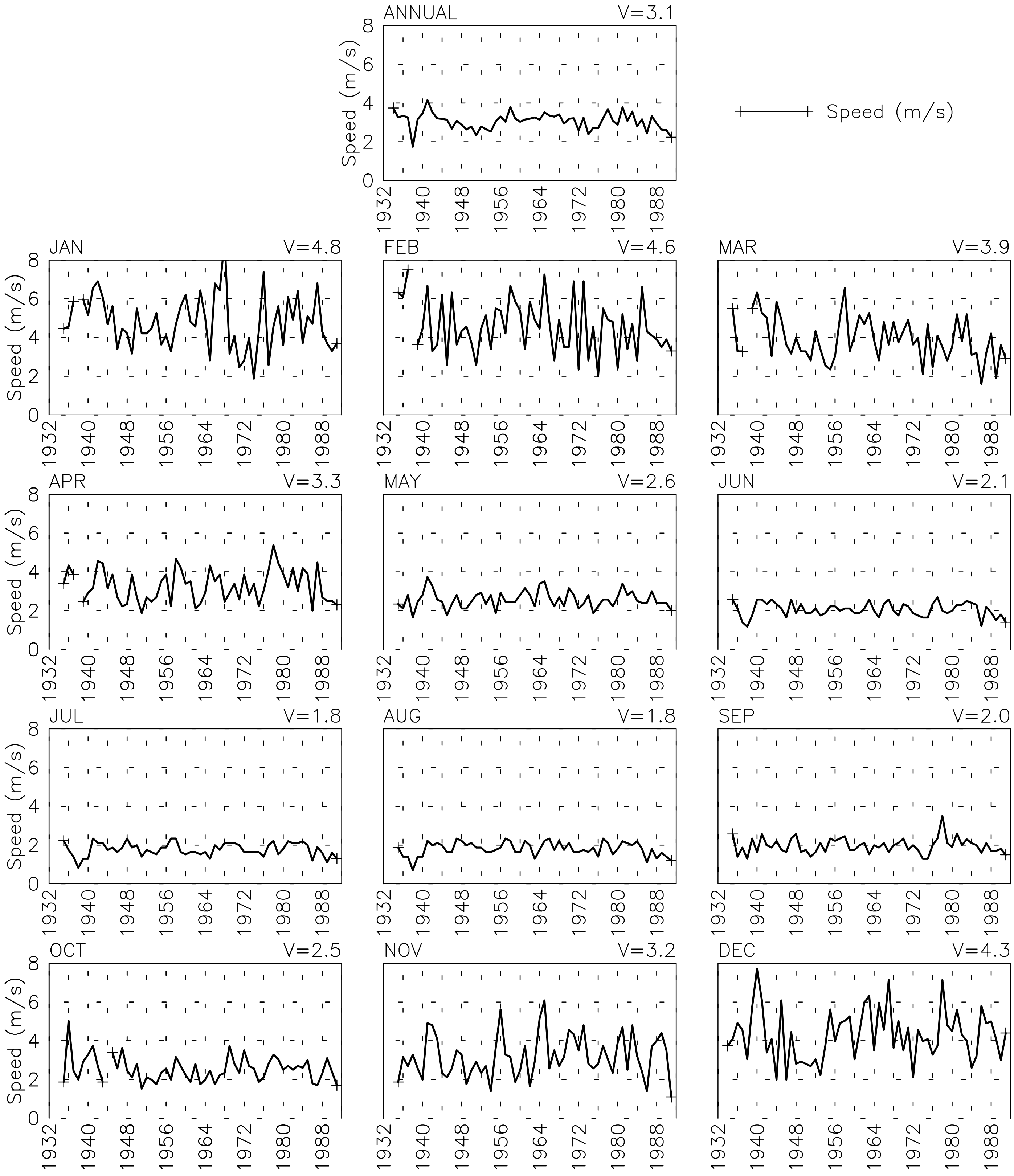
Mon Mar 24 11:38:55 2003

SPEED BY YEAR

Chambarak Krasnoselsk – 000016

40° 36' N 45° 22' E – Elev 1853m LST=GMT+99 hours *NT= +3

12/34–12/91



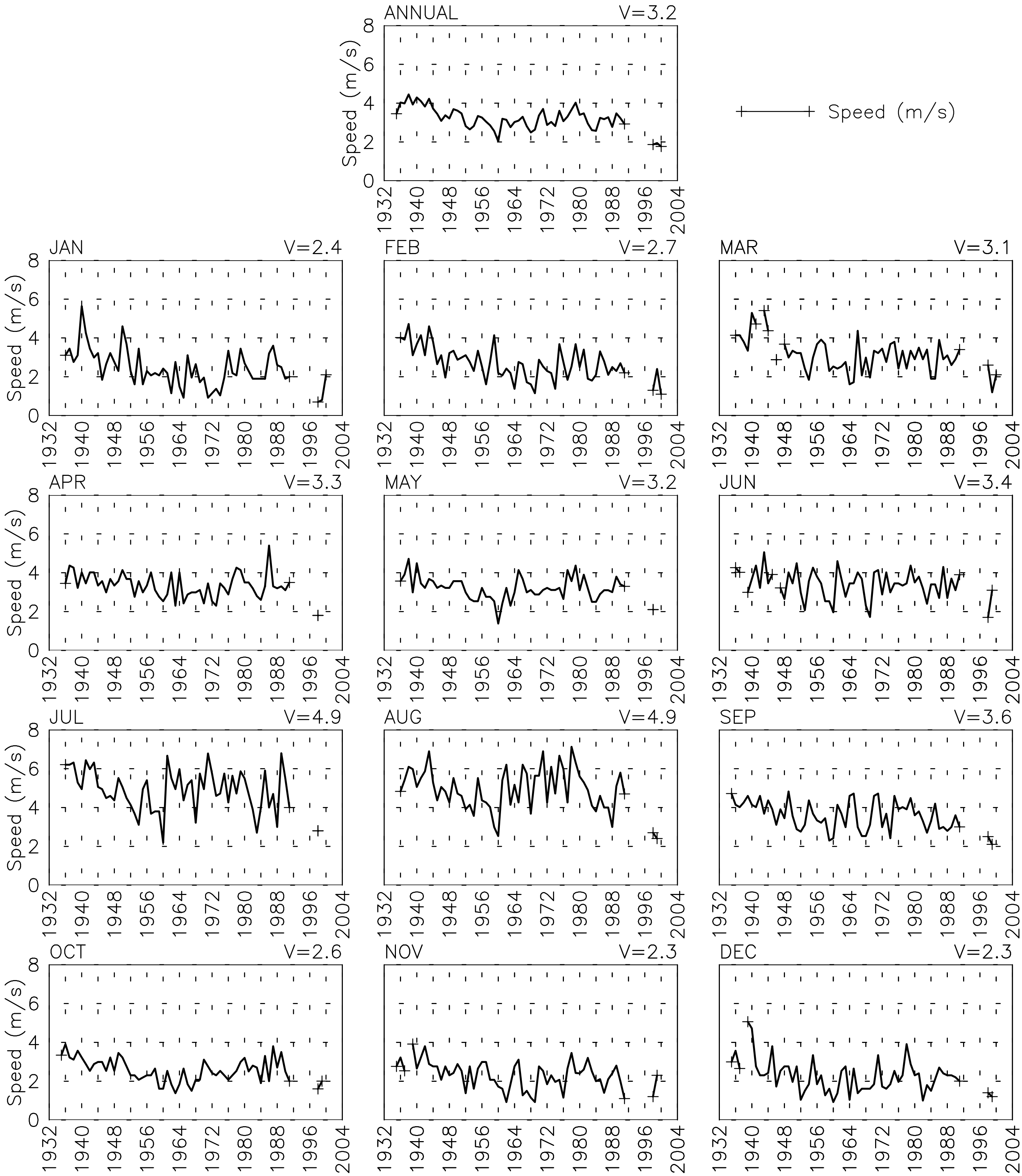
Mon Mar 24 11:38:56 2003

SPEED BY YEAR

Fontan – 000018

40° 24' N 44° 41' E – Elev 1800m LST=GMT+99 hours *NT= +3

09/35–12/91 01/98–03/00



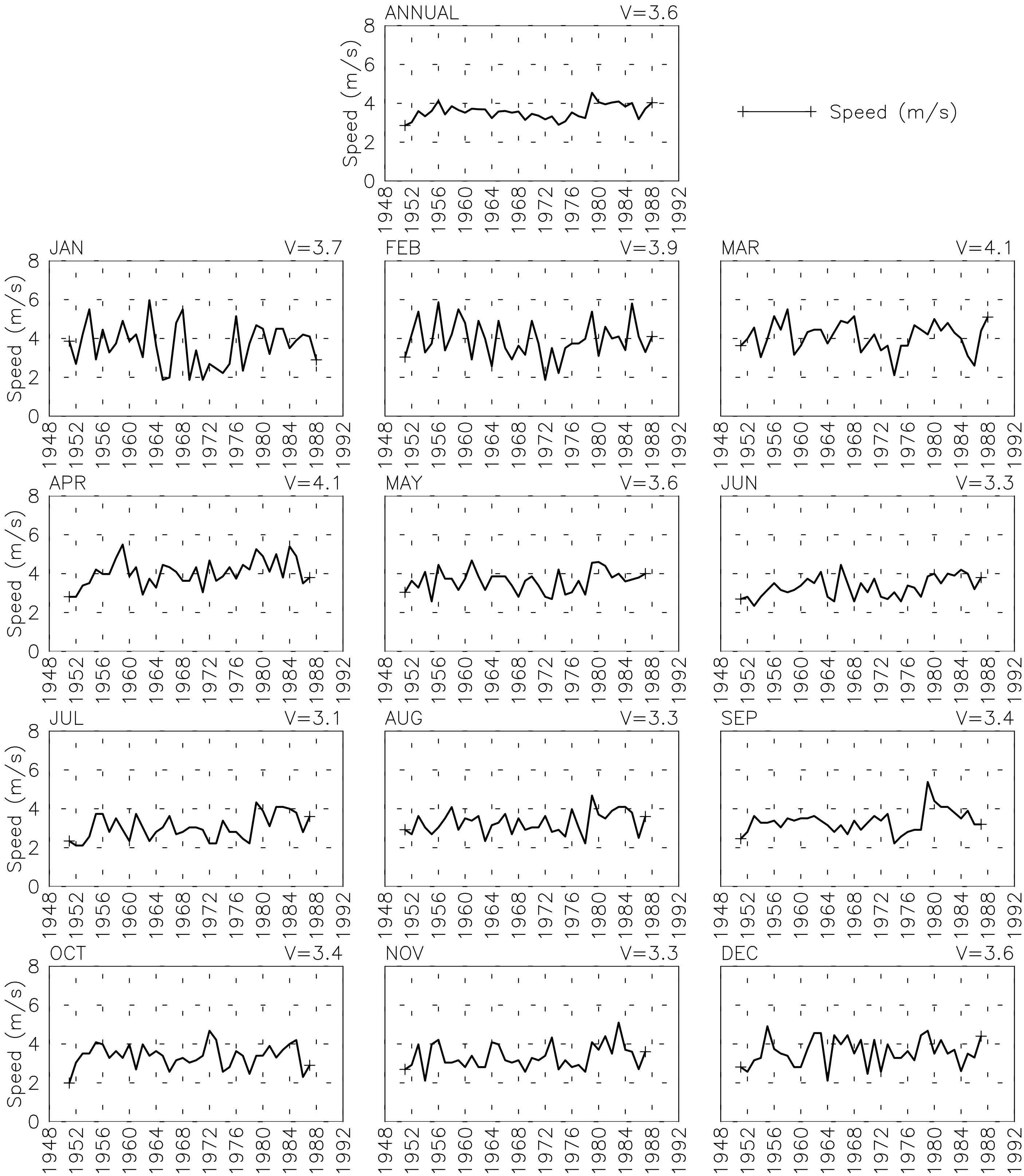
Mon Mar 24 11:38:58 2003

SPEED BY YEAR

Garnhovit - 000020

40° 30' N 43° 57' E - Elev 2166m LST=GMT+99 hours *NT= +3

01/51-03/88



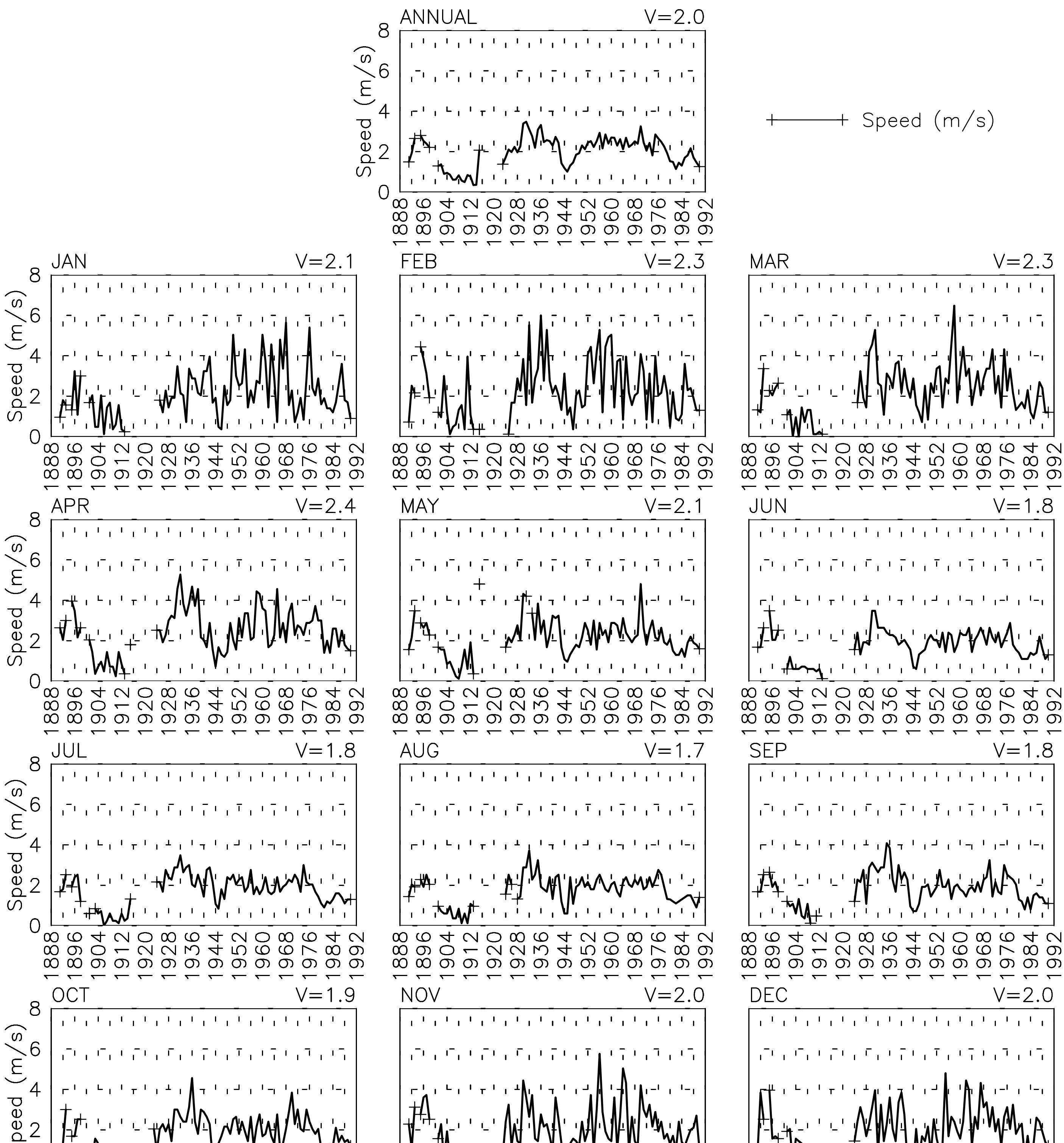
Mon Mar 24 11:38:59 2003

SPEED BY YEAR

Gavar (Kamo) – 000021

40° 21' N 45° 08' E – Elev 1960m LST=GMT+99 hours *NT= +3

01/91–12/93 01/95–12/98 01/01–07/15 10/23–12/90



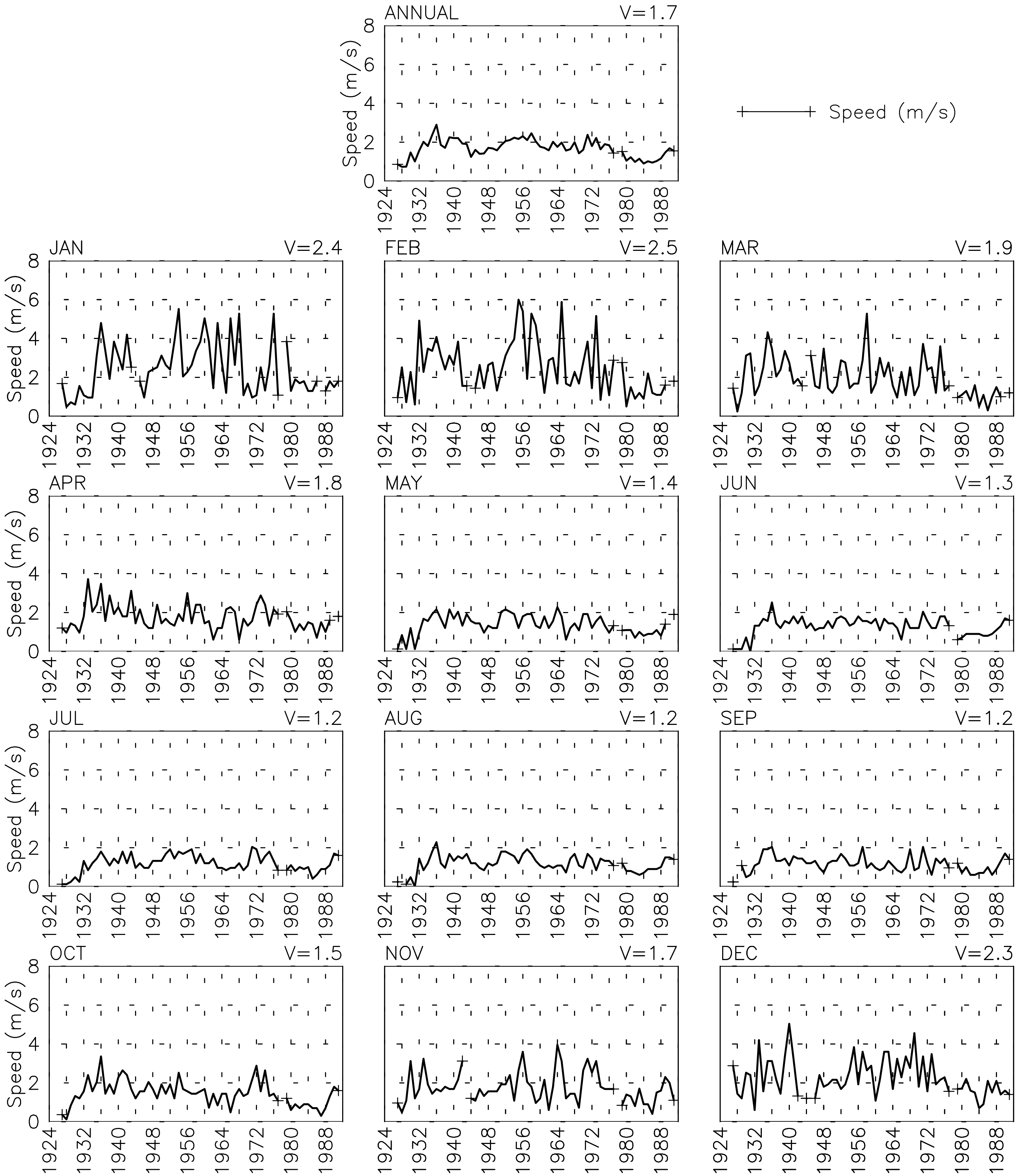
Mon Mar 24 11:39:01 2003

SPEED BY YEAR

Goris Hydro – 000022

39° 30' N 46° 20' E – Elev 1307m LST=GMT+99 hours *NT= +3

01/27–12/77 01/79–12/91



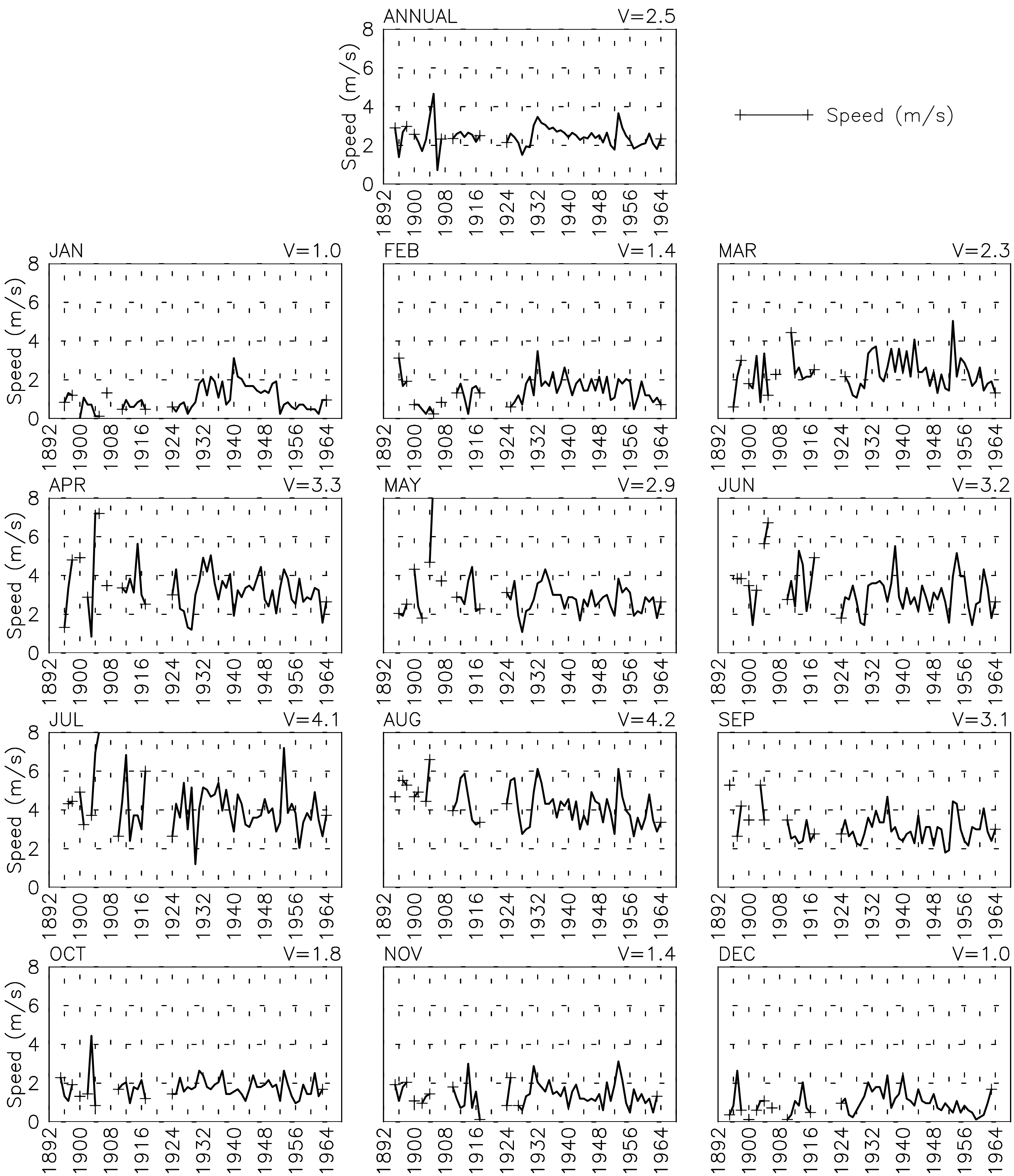
Mon Mar 24 11:39:03 2003

SPEED BY YEAR

Gyumri (Leninakan) – 000023

40° 48' N 43° 52' E – Elev 1528m LST=GMT+99 hours *NT= +3

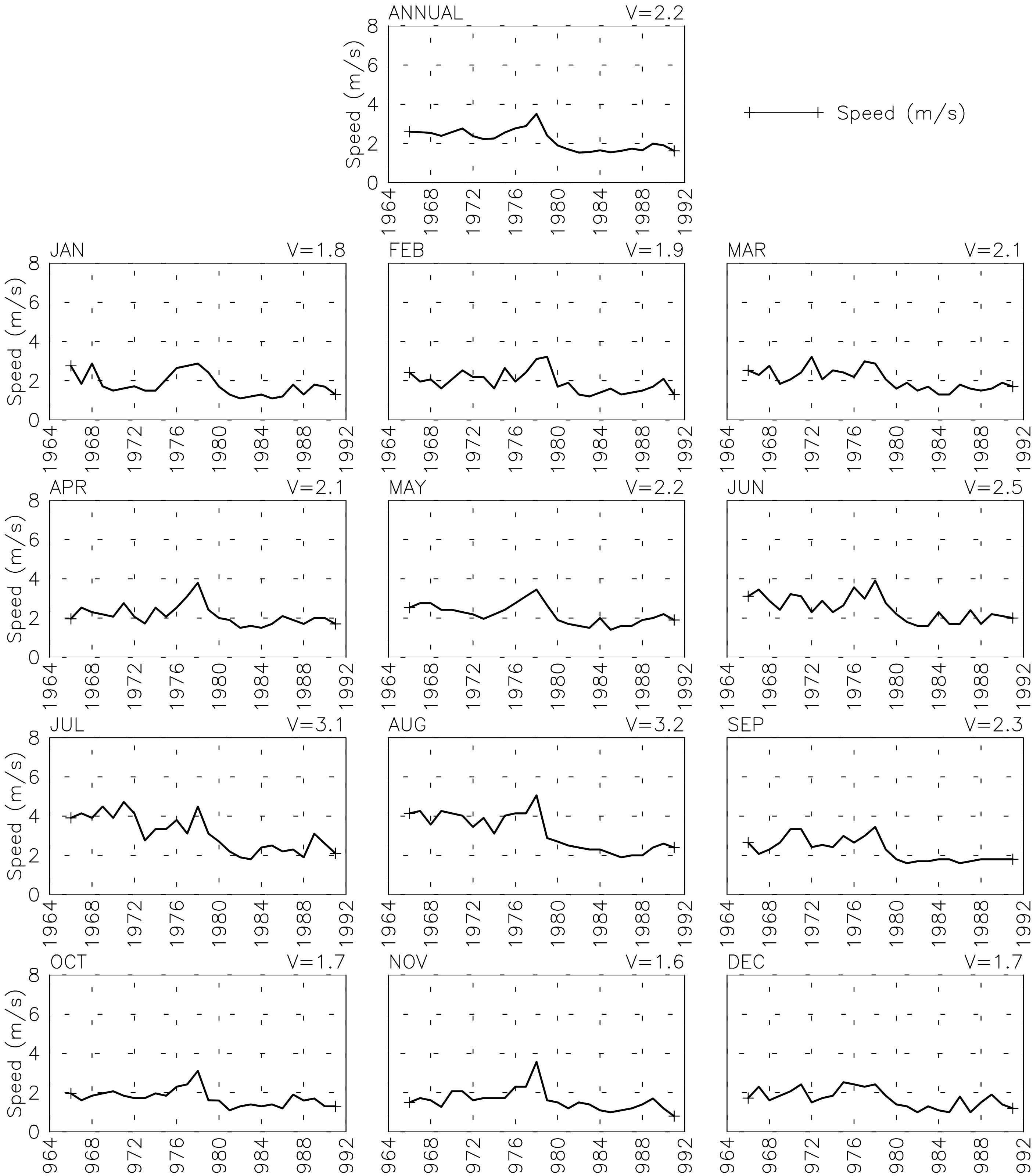
08/95–12/98 01/00–05/07 06/10–11/17 01/24–09/64



Mon Mar 24 11:39:05 2003

SPEED BY YEAR

Hrazdan – 000026
40° 30' N 44° 46' E – Elev 1765m LST=GMT+99 hours *NT= +3
01/66–12/91



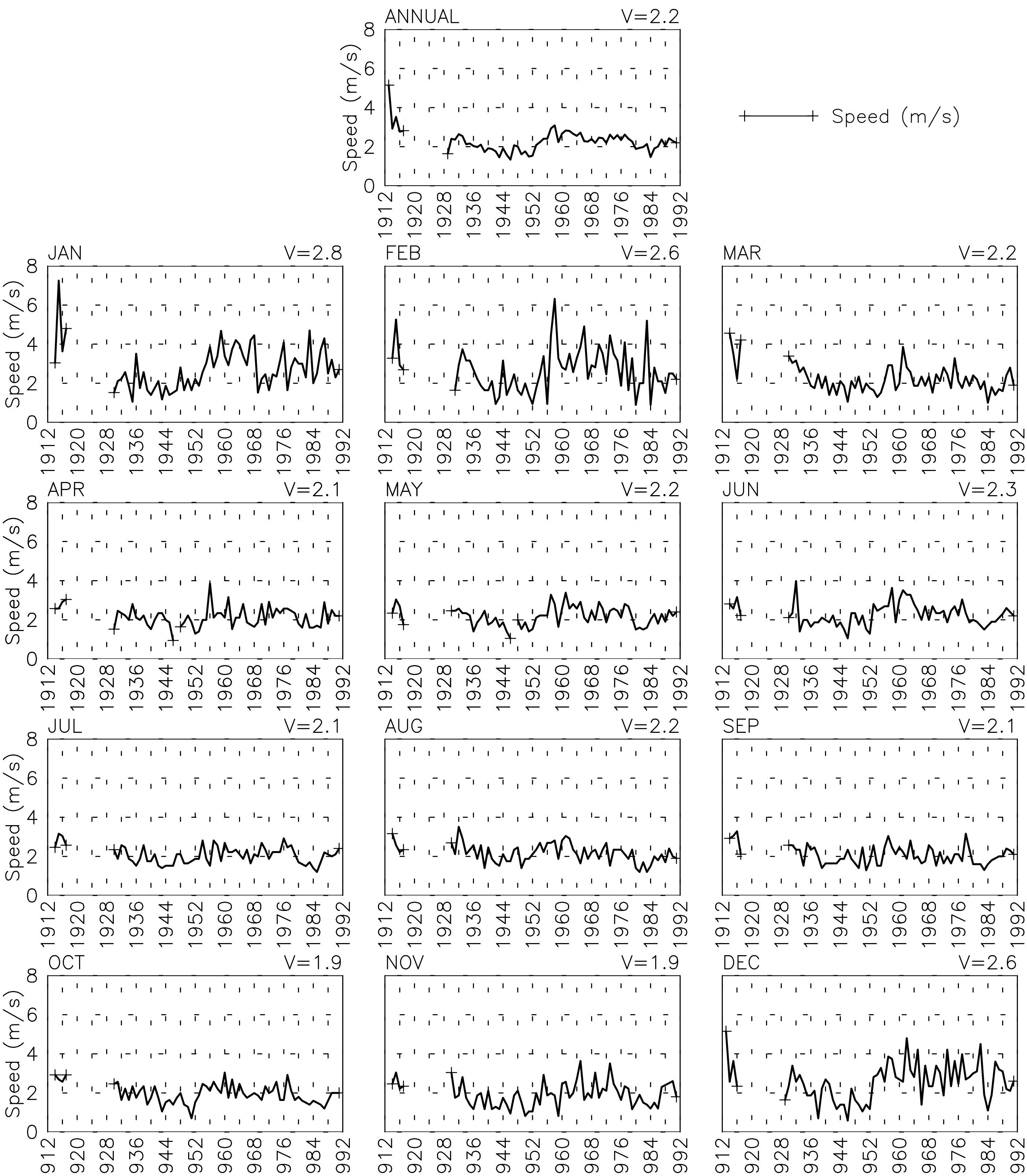
Mon Mar 24 11:39:07 2003

SPEED BY YEAR

Ijevan − 000027

40° 52' N 45° 09' E − Elev 732m LST=GMT+99 hours *NT= +3

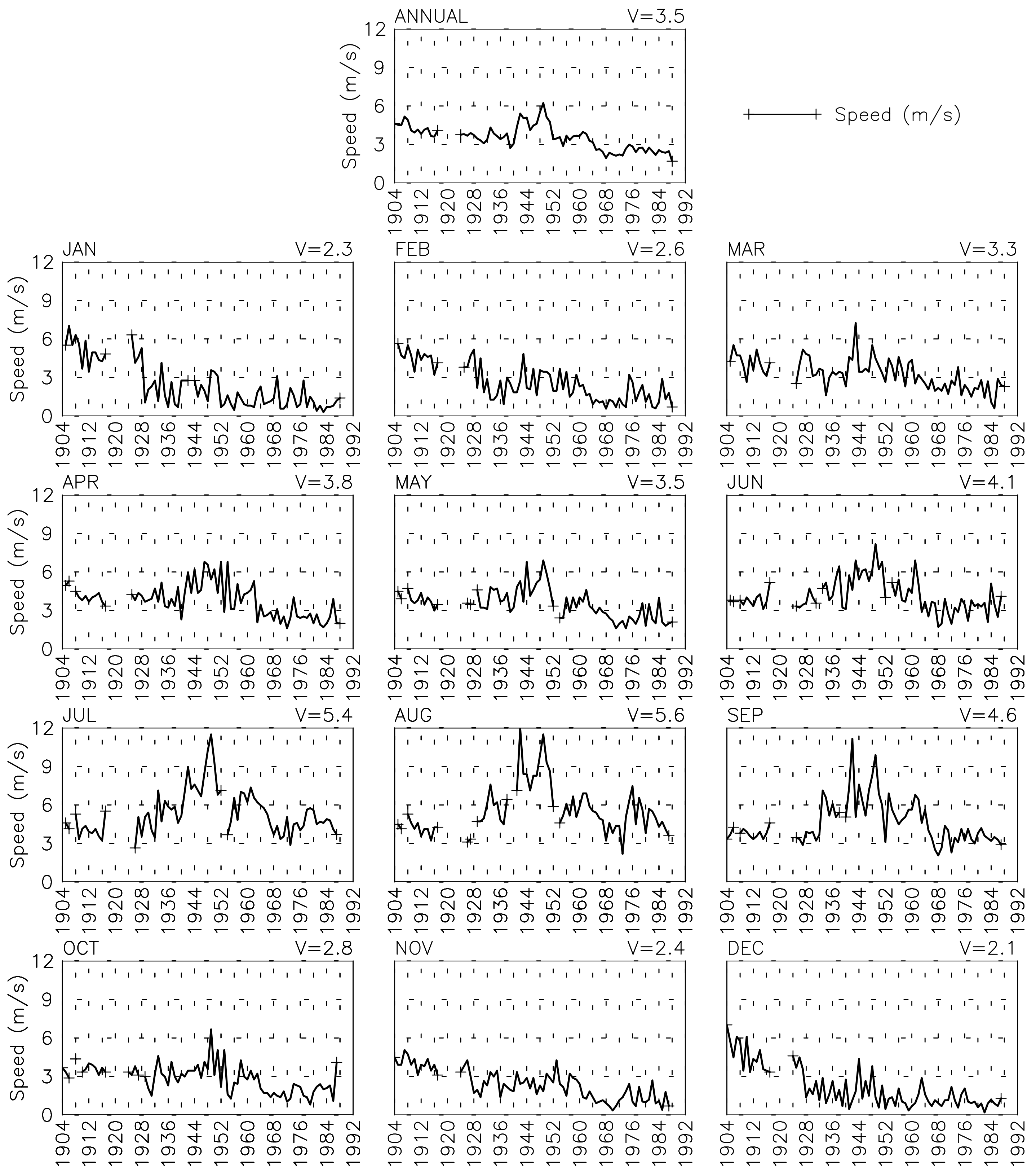
12/13−11/17 12/29−12/91



Mon Mar 24 11:39:08 2003

SPEED BY YEAR

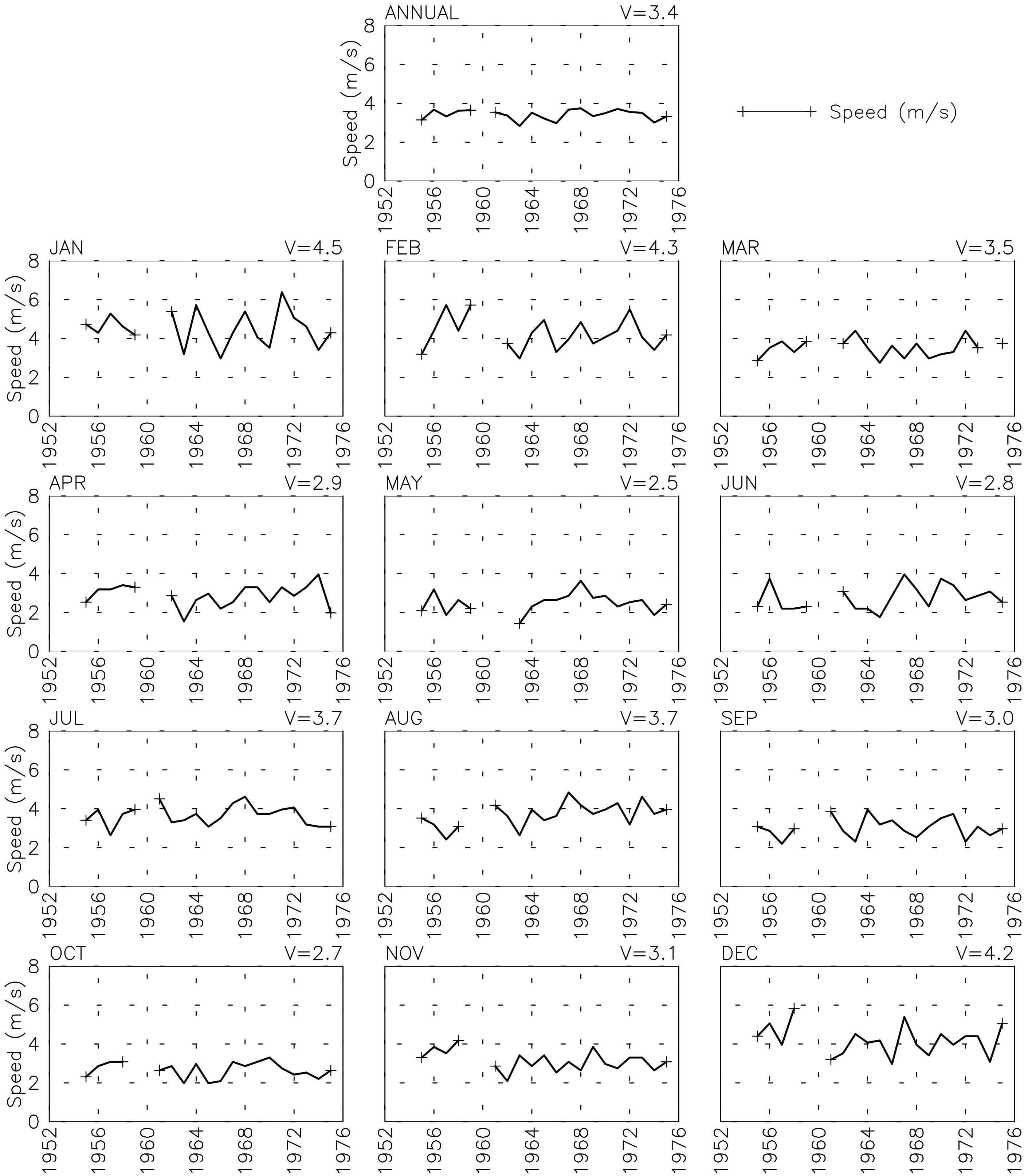
Jajur r/r st. - 000028
40° 52' N   43° 57' E - Elev 1792m   LST=GMT+99 hours   *NT= +3
09/04-12/17 10/24-05/88



Mon Mar 24 11:40:24 2003

SPEED BY YEAR

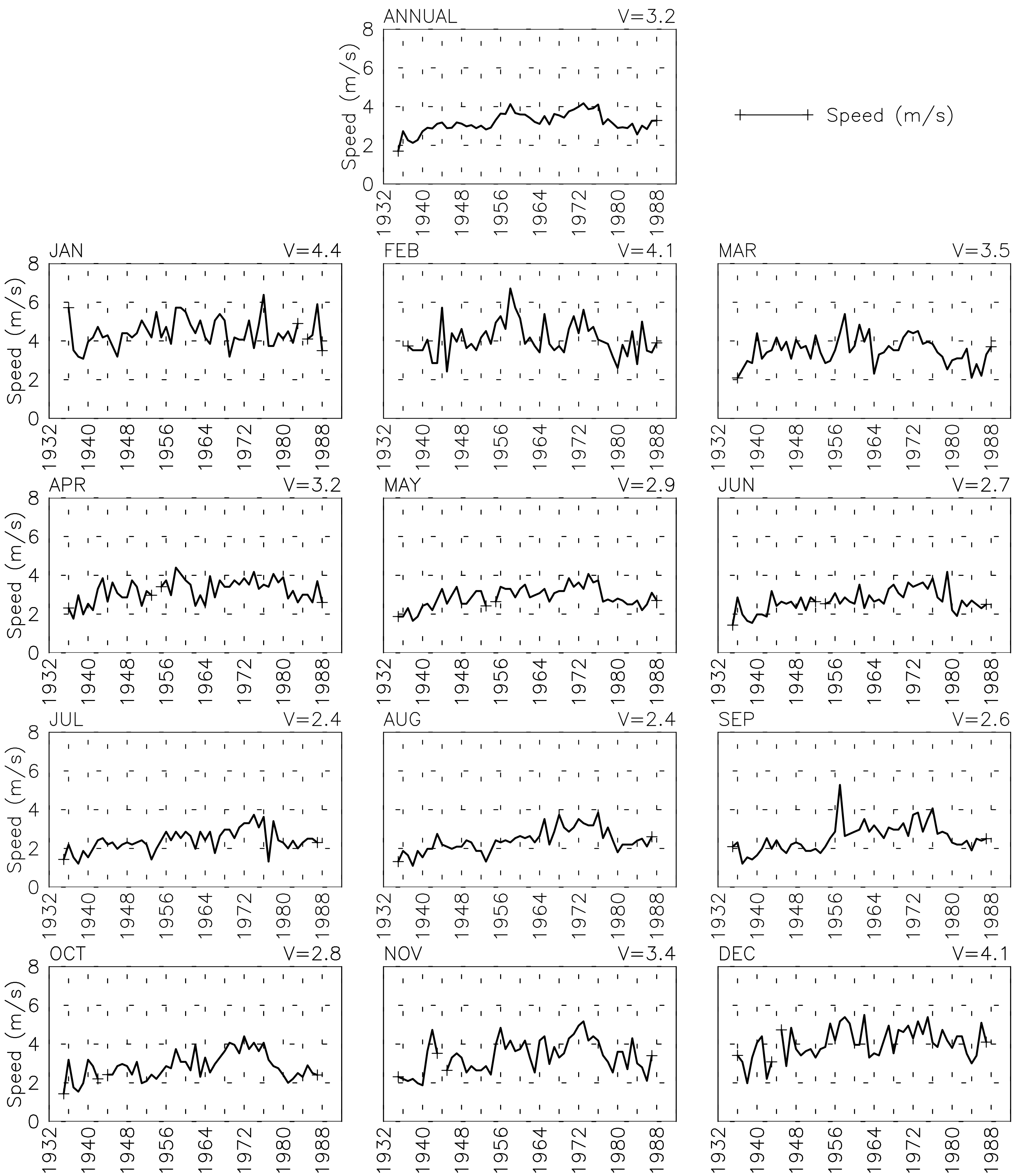
Kaltakhchi – 000030
40° 52' N 44° 01' E – Elev 1833m LST=GMT+99 hours *NT= +3
01/55–07/59 07/61–12/75



Mon Mar 24 11:39:09 2003

SPEED BY YEAR

Lermontovo – 000034
40° 46' N   44° 38' E – Elev 1798m   LST=GMT+99 hours   *NT= +3
05/35–05/88



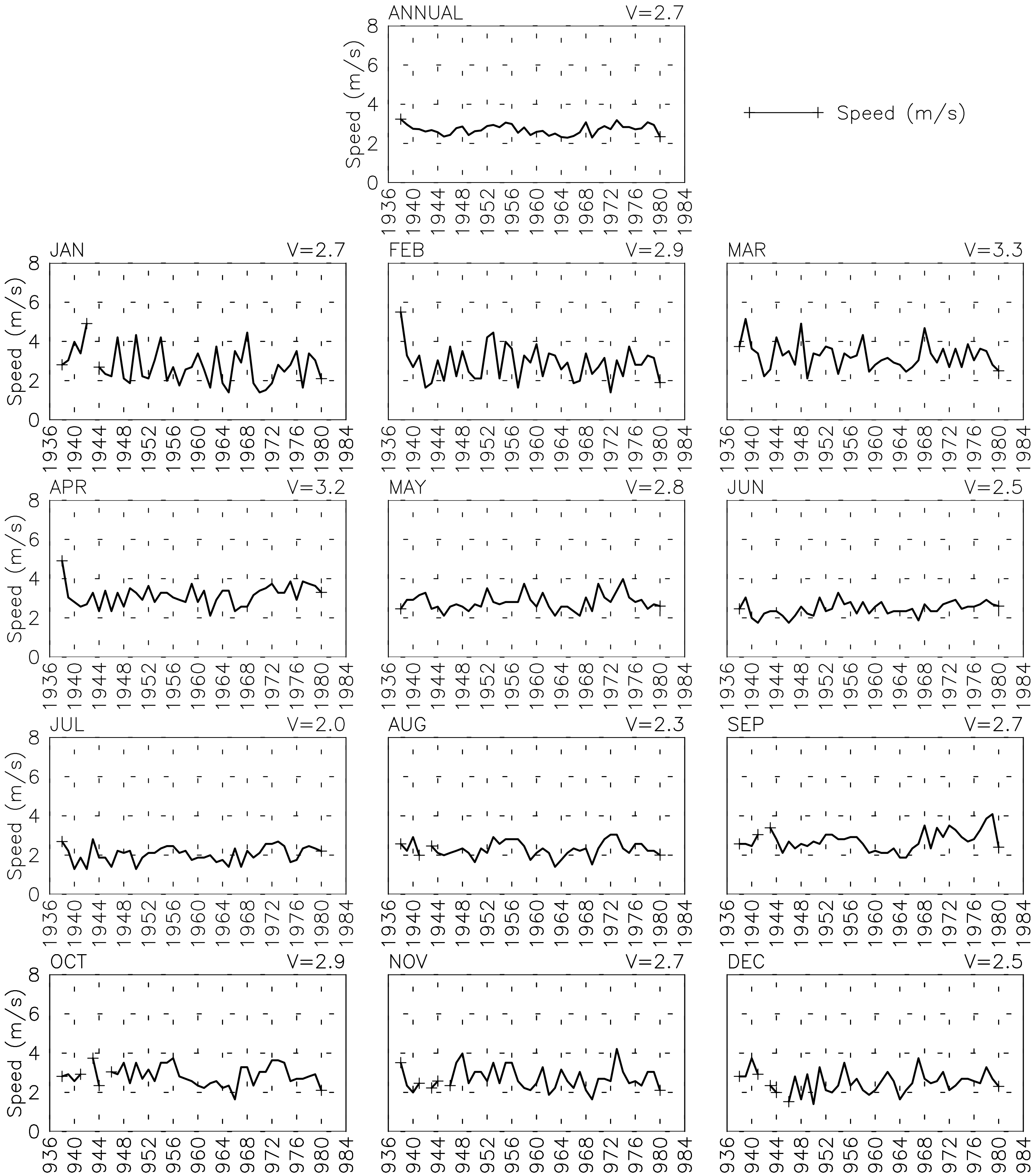
Mon Mar 24 11:39:11 2003

SPEED BY YEAR

Martiros – 000035

39° 36' N   45° 30' E – Elev 1957m   LST=GMT+99 hours   *NT= +3

01/38–12/80



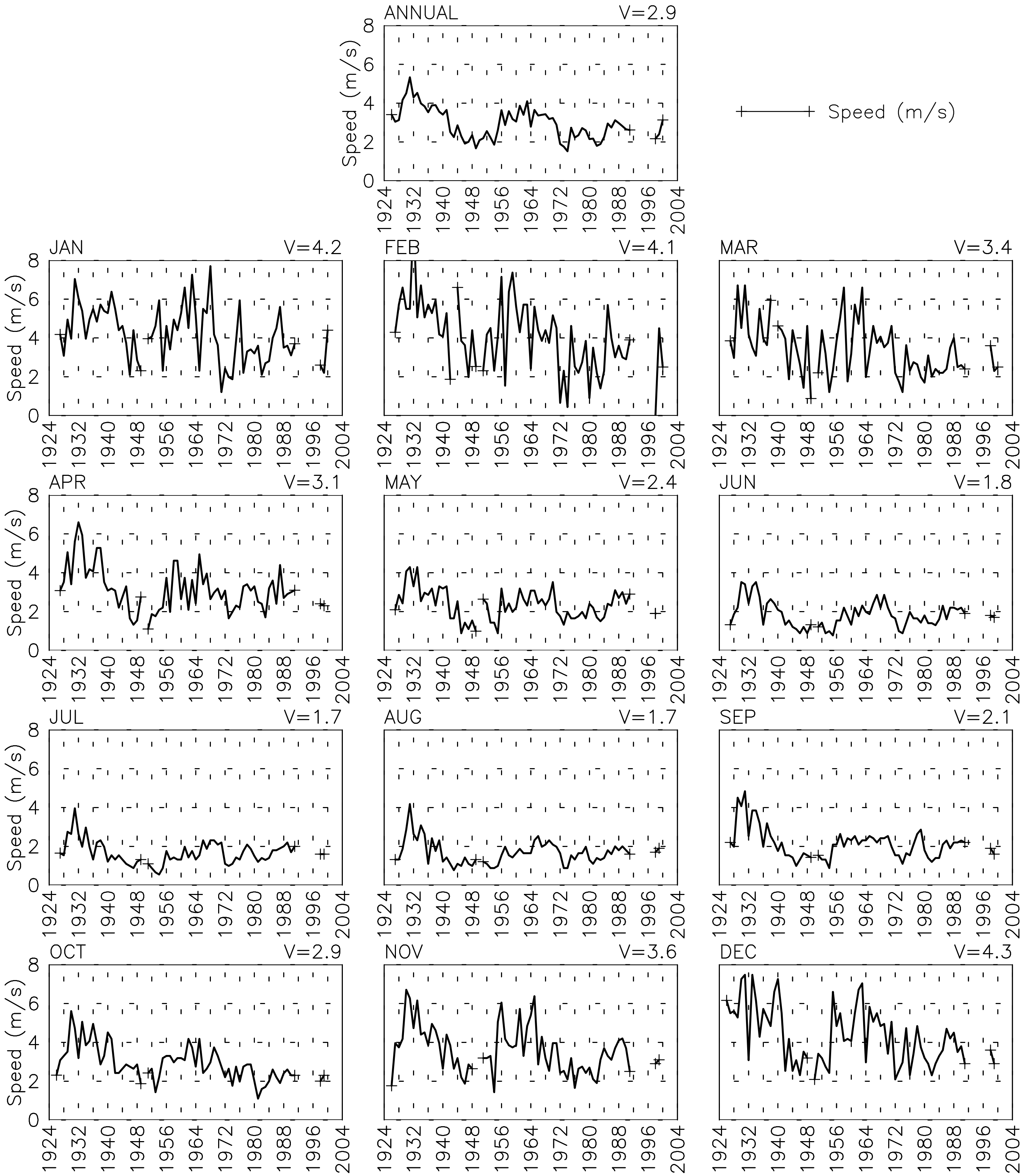
Mon Mar 24 11:39:12 2003

SPEED BY YEAR

Martuni - 000036

40° 08' N 45° 18' E - Elev 1943m LST=GMT+99 hours *NT= +3

10/26-12/91 01/98-03/00



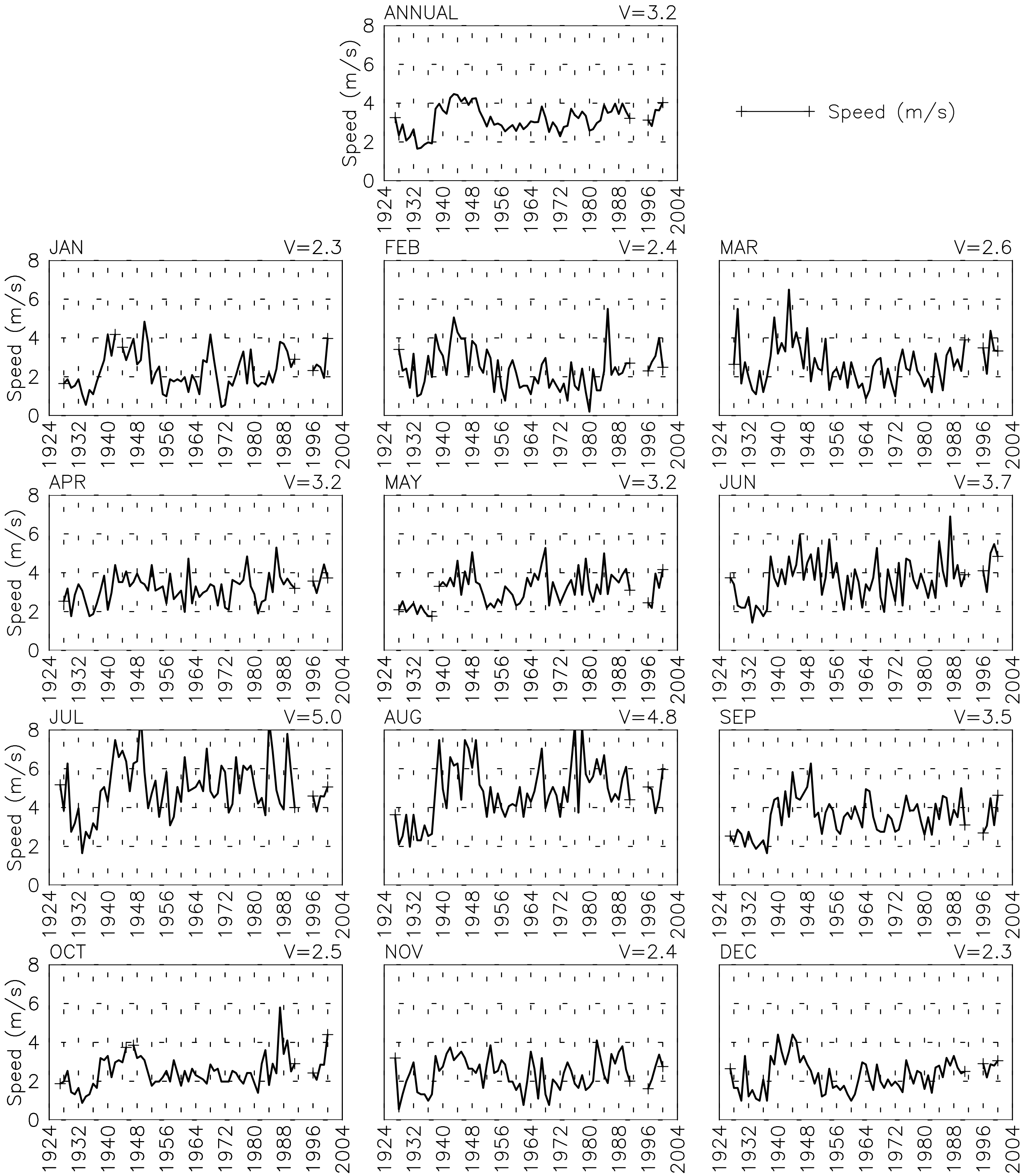
Mon Mar 24 11:39:14 2003

SPEED BY YEAR

Masrik (Mazra) – 000037

40° 14' N 45° 45' E – Elev 1939m LST=GMT+99 hours *NT= +3

06/27–12/91 01/96–12/00



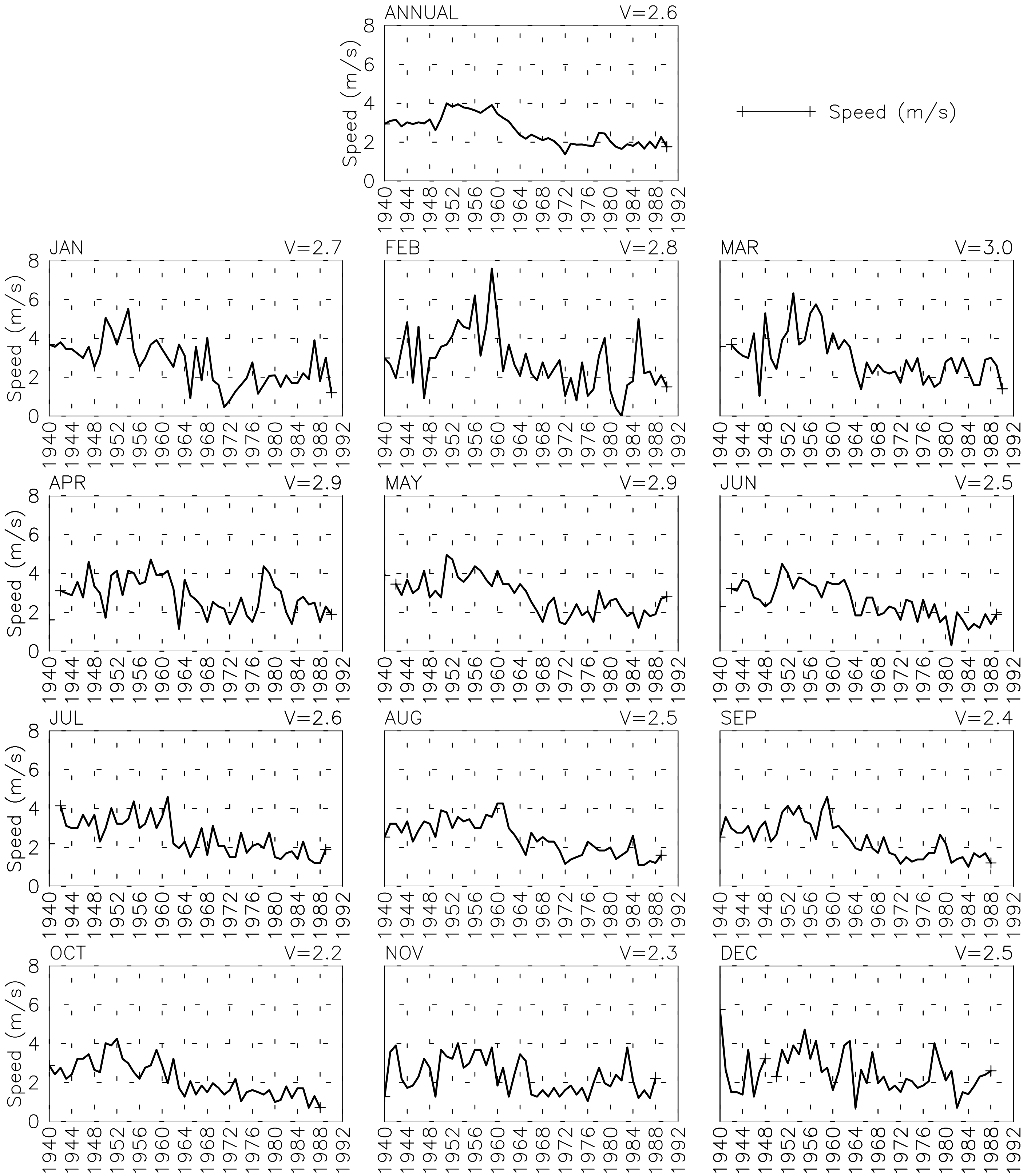
Mon Mar 24 11:39:16 2003

SPEED BY YEAR

Paghakn (Shurabad) – 000041

41° 04' N 43° 39' E – Elev 2005m LST=GMT+99 hours *NT= +3

01/40–05/90



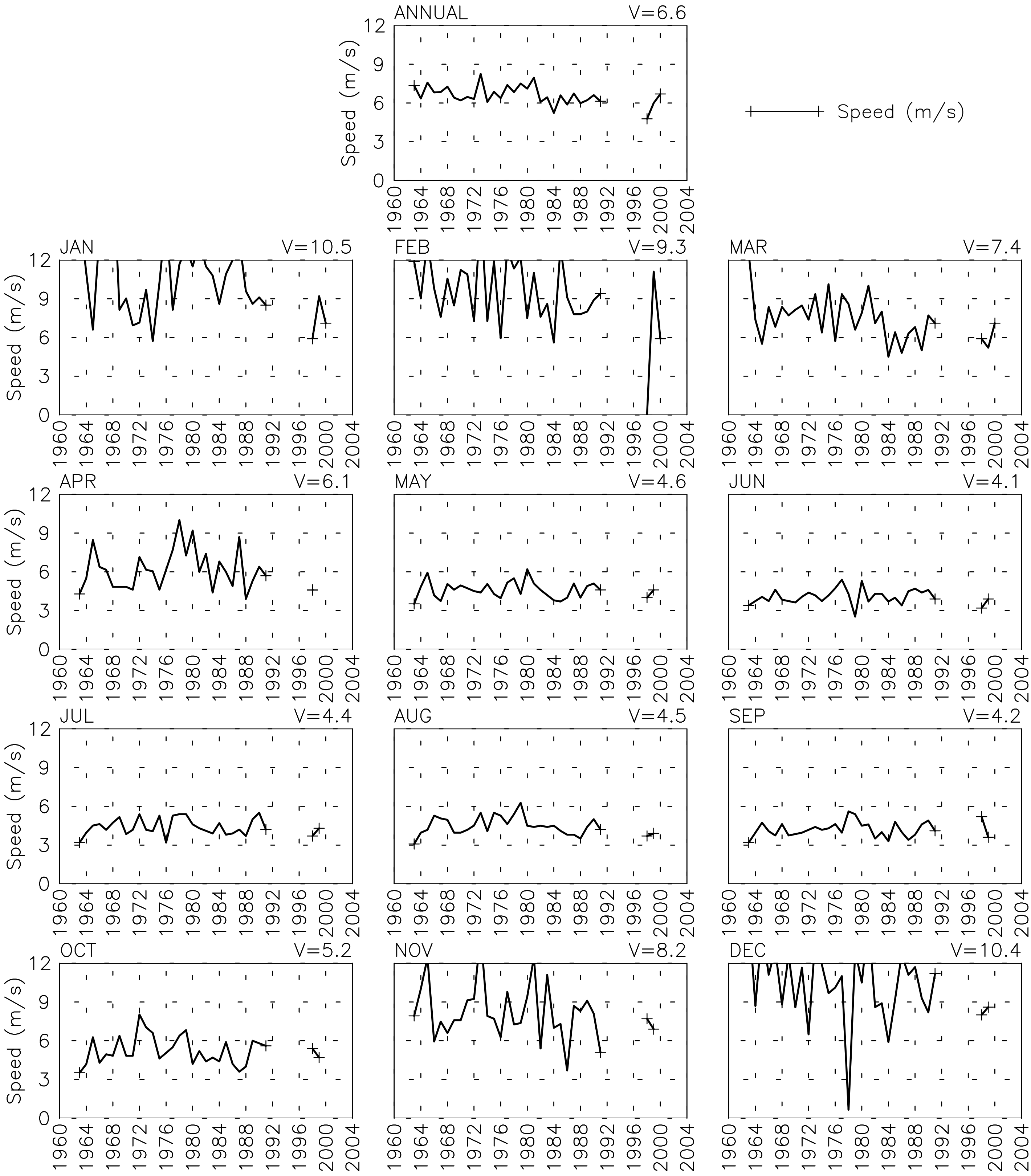
Mon Mar 24 11:39:17 2003

SPEED BY YEAR

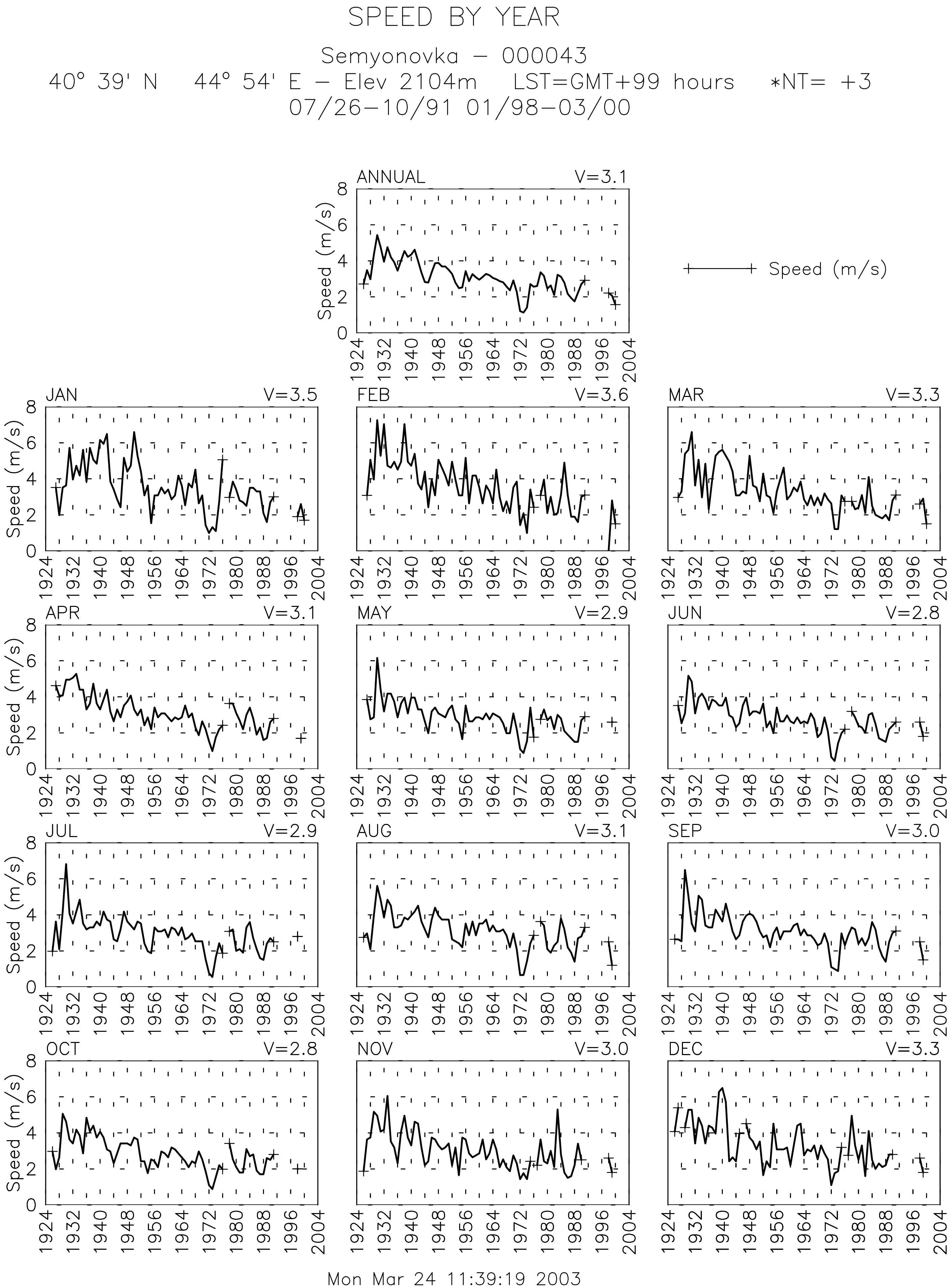
Pushkin Pass – 000042

40° 55' N 44° 26' E – Elev 2066m LST=GMT+99 hours *NT= +3

01/63–12/91 01/98–03/00



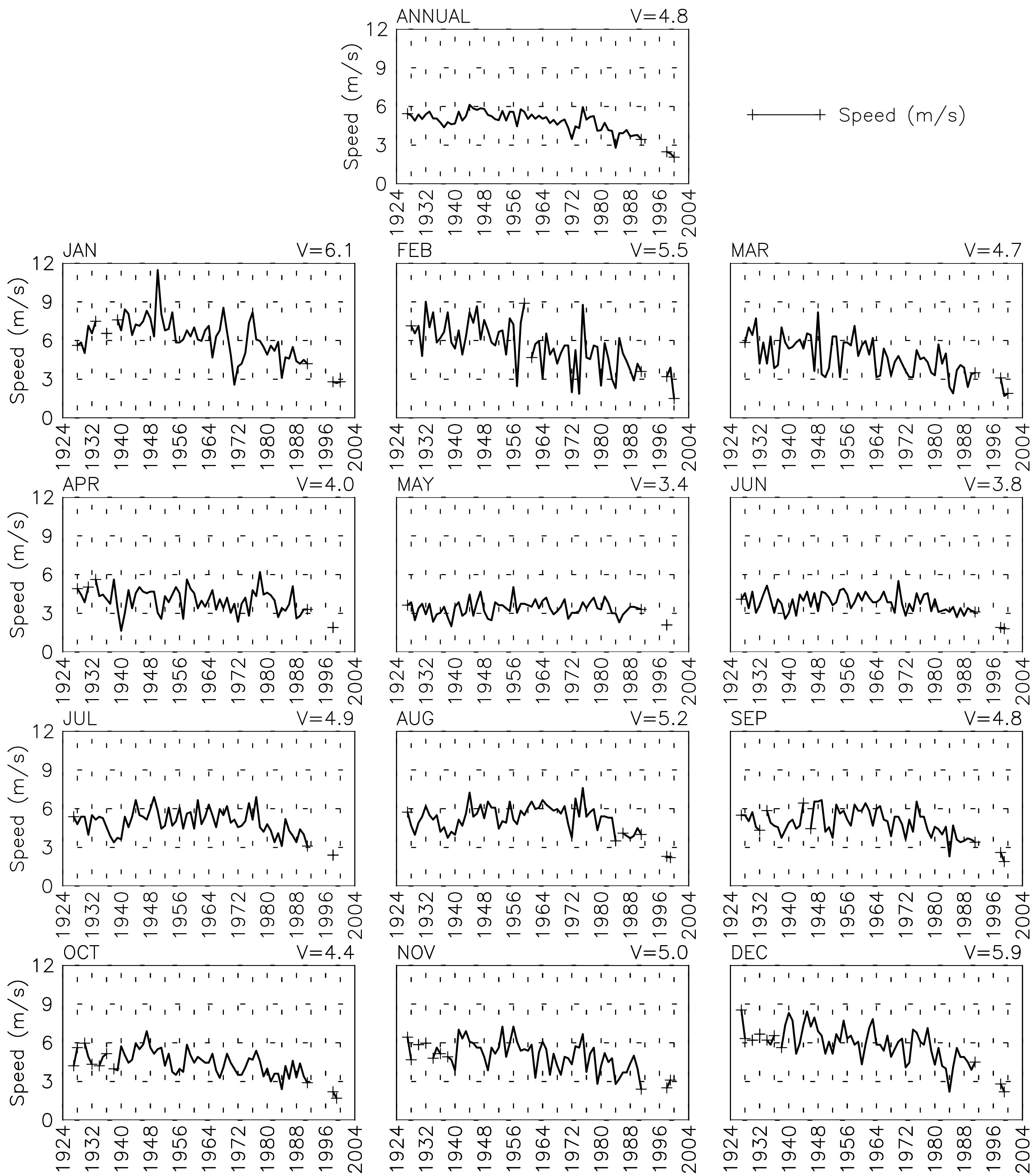
Mon Mar 24 11:40:25 2003



SPEED BY YEAR
Semyonovka - 000043
40° 39' N 44° 54' E - Elev 2104m LST=GMT+99 hours *NT= +3
07/26-10/91 01/98-03/00
ANNUAL V=3.1
Speed (m/s)
JAN V=3.5
FEB V=3.6
MAR V=3.3
APR V=3.1
MAY V=2.9
JUN V=2.8
JUL V=2.9
AUG V=3.1
SEP V=3.0
OCT V=2.8
NOV V=3.0
DEC V=3.3
1924 1932 1940 1948 1956 1964 1972 1980 1988 1996 2004
Mon Mar 24 11:39:19 2003

SPEED BY YEAR

Sevan Lake GMO – 000044
40° 34' N   45° 00' E – Elev 1917m   LST=GMT+99 hours   *NT= +3
05/27–12/91 01/98–03/00



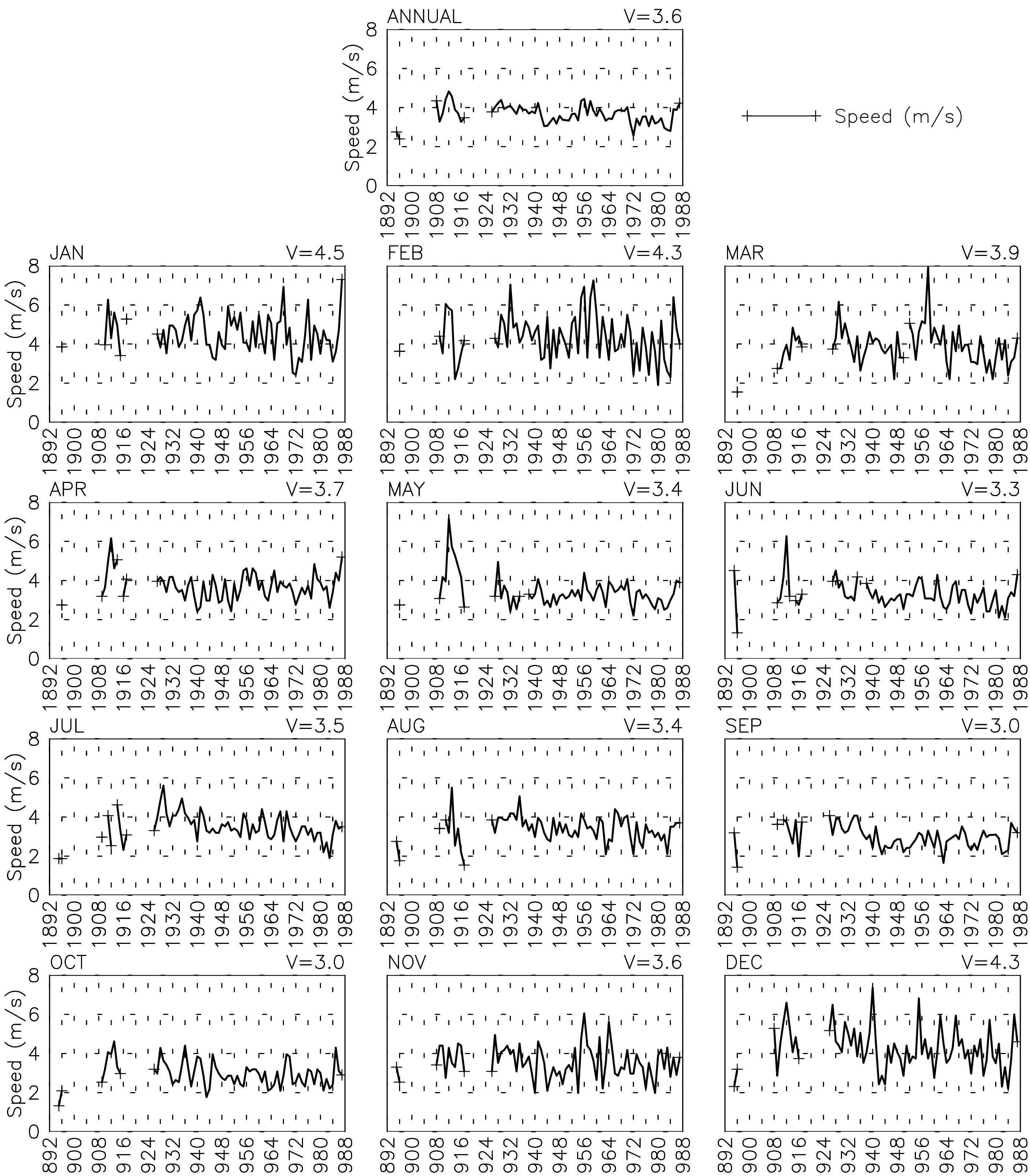
Mon Mar 24 11:40:27 2003

SPEED BY YEAR

Sevan AMSG - 000045

40° 33' N 44° 56' E - Elev 1936m LST=GMT+99 hours *NT= +3

06/95-12/96 11/08-11/17 07/26-12/87



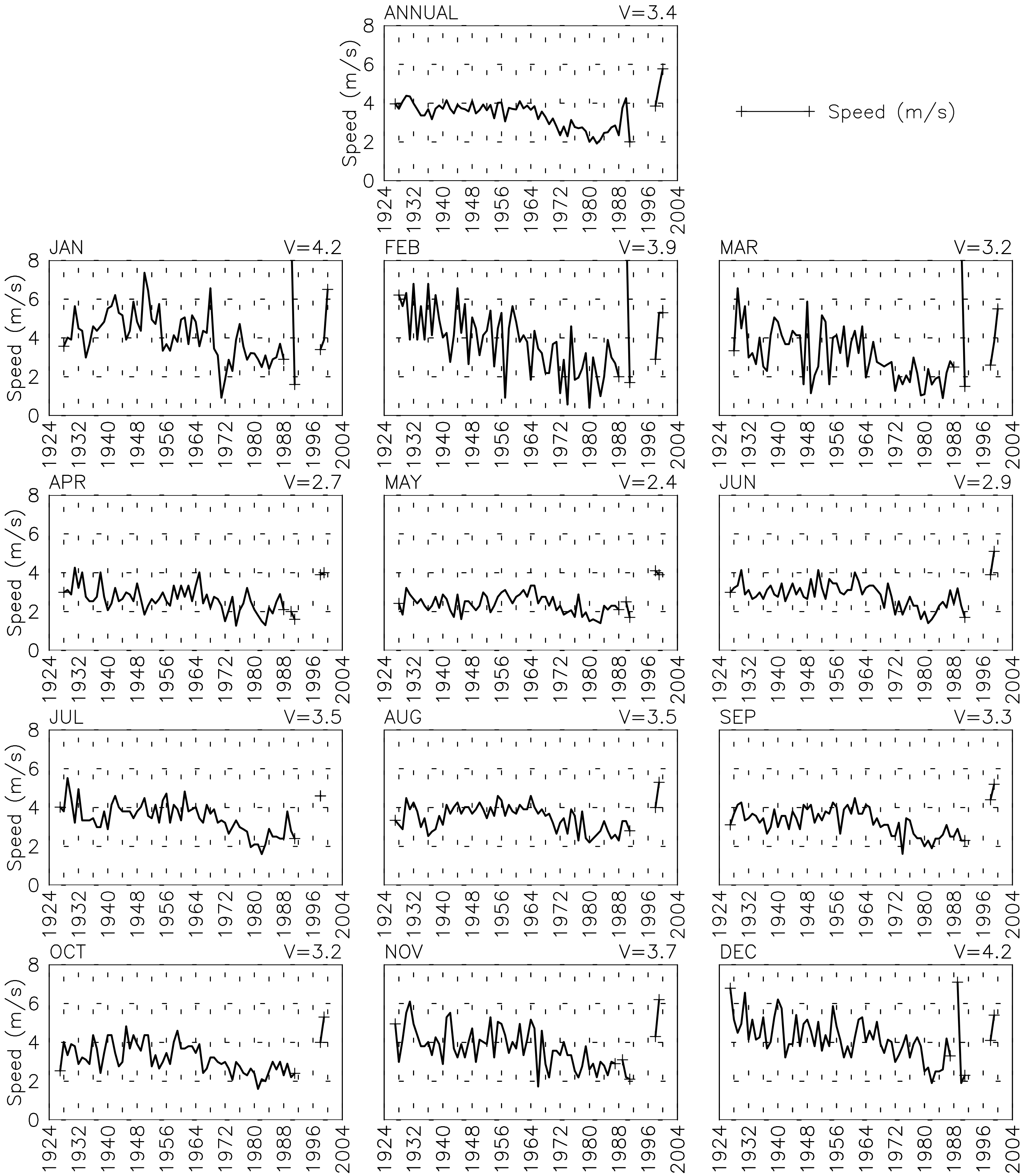
Mon Mar 24 11:39:21 2003

SPEED BY YEAR

Shorzha - 000049

40° 30' N 45° 16' E - Elev 1917m LST=GMT+99 hours *NT= +3

06/27-12/91 01/98-03/00



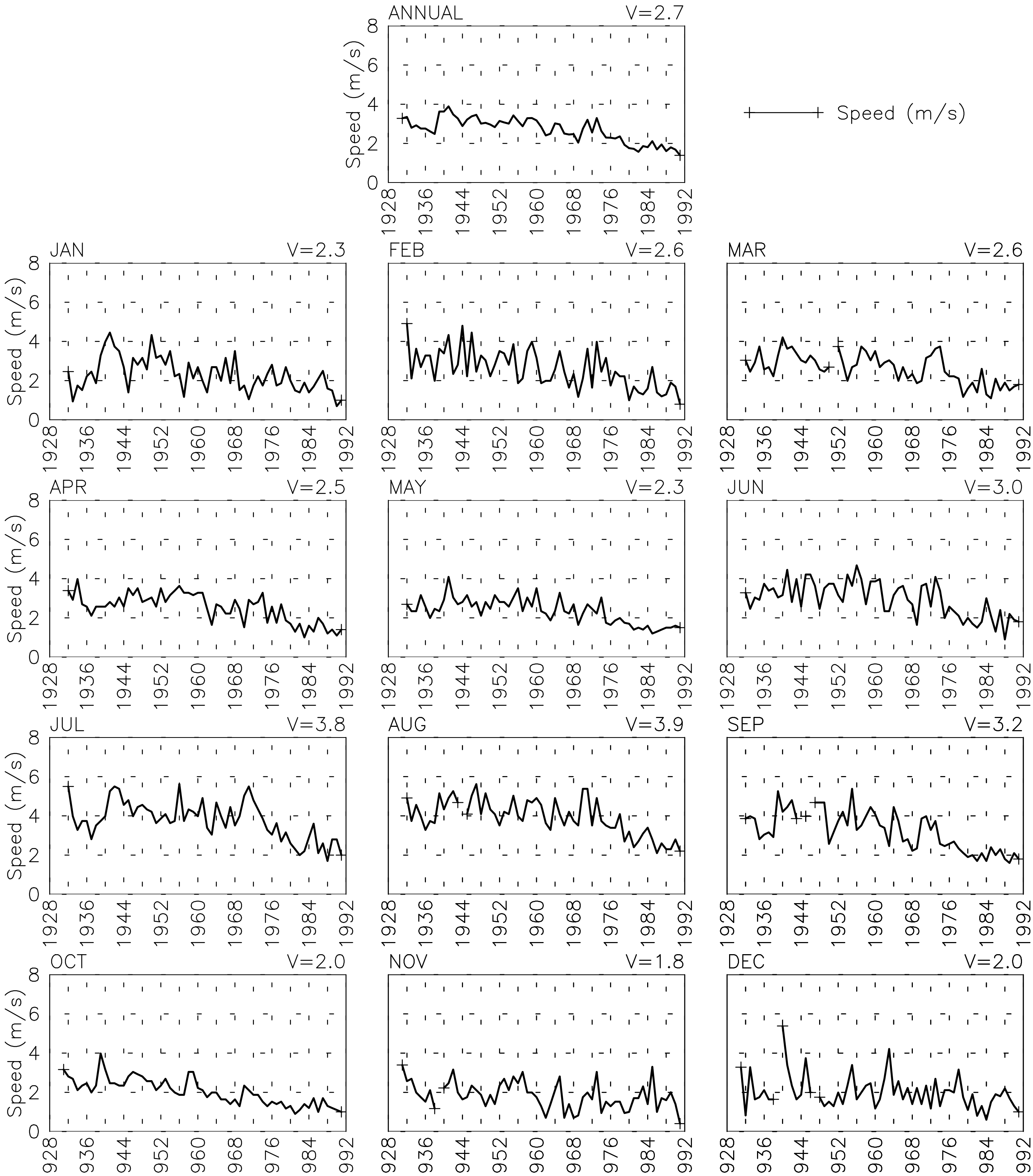
Mon Mar 24 11:39:23 2003

SPEED BY YEAR

Sisian - 000050

39° 32' N 46° 01' E - Elev 1580m LST=GMT+99 hours *NT= +3

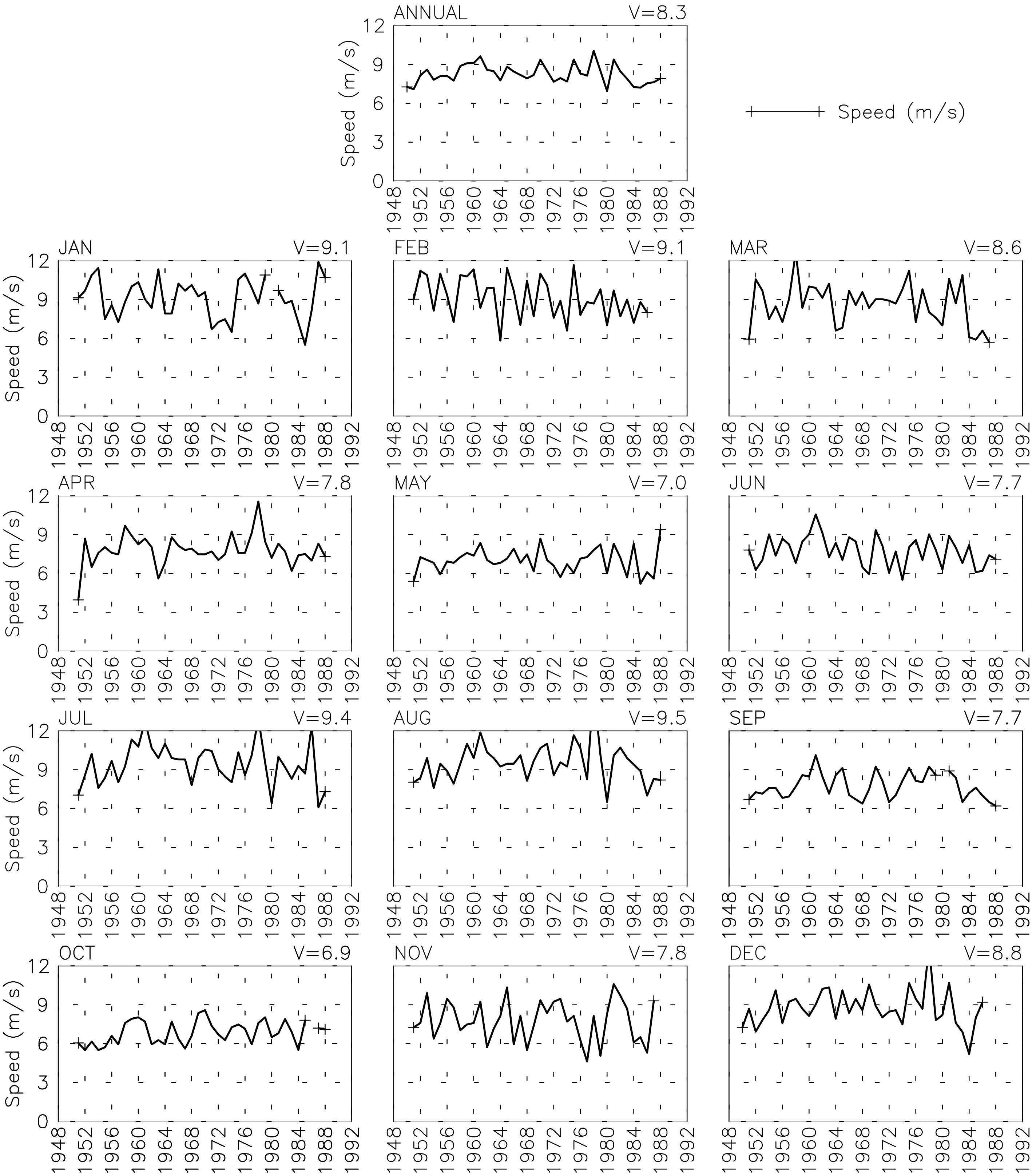
10/31-12/91



Mon Mar 24 11:39:25 2003

SPEED BY YEAR

Sisian Pass – 000051
39° 32' N 45° 50' E – Elev 2380m LST=GMT+99 hours *NT= +3
12/50–10/88



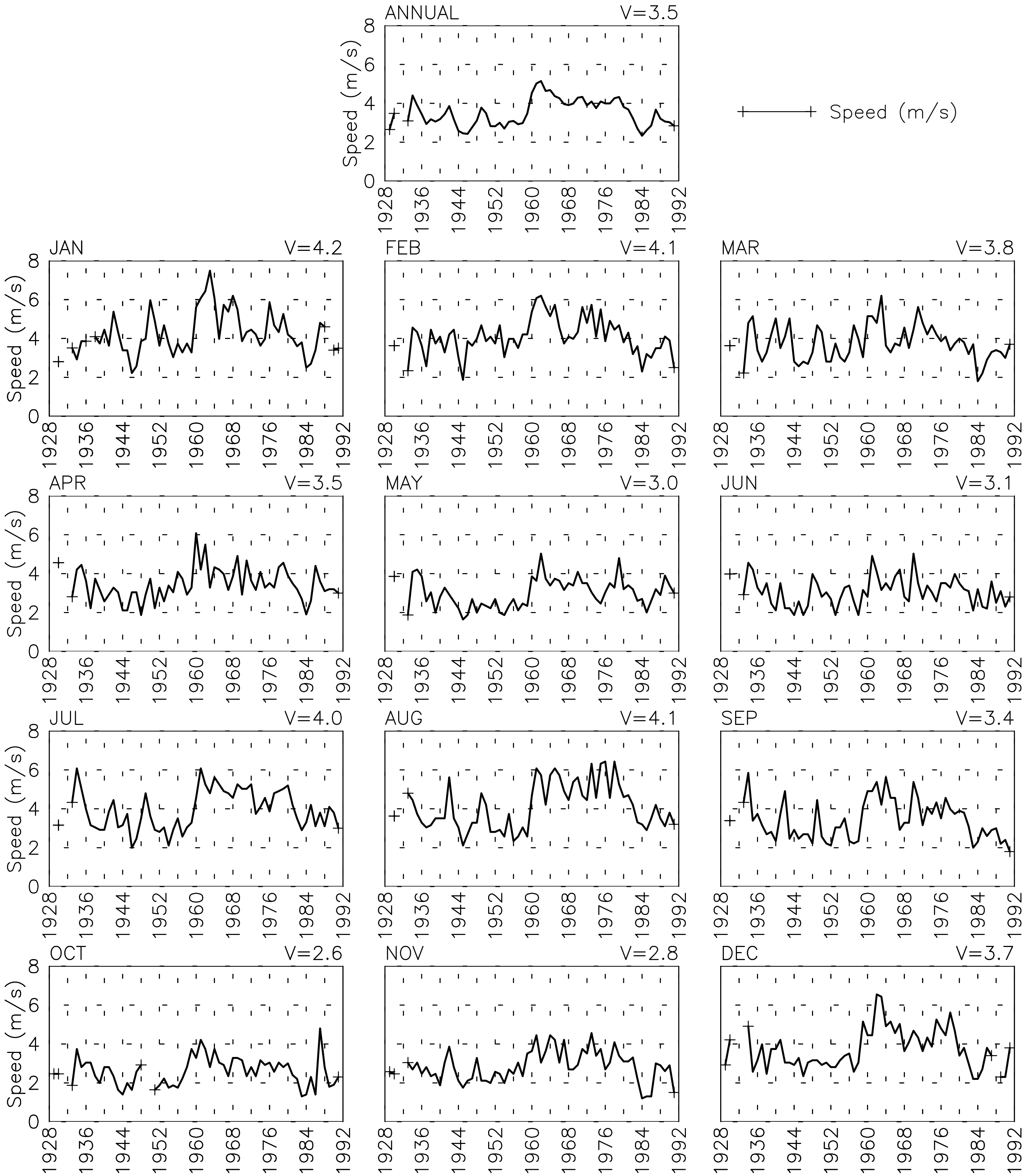
Mon Mar 24 11:40:29 2003

SPEED BY YEAR

Spitak – 000052

40° 50' N 44° 16' E – Elev 1552m LST=GMT+99 hours *NT= +3

10/29–12/30 01/33–12/91



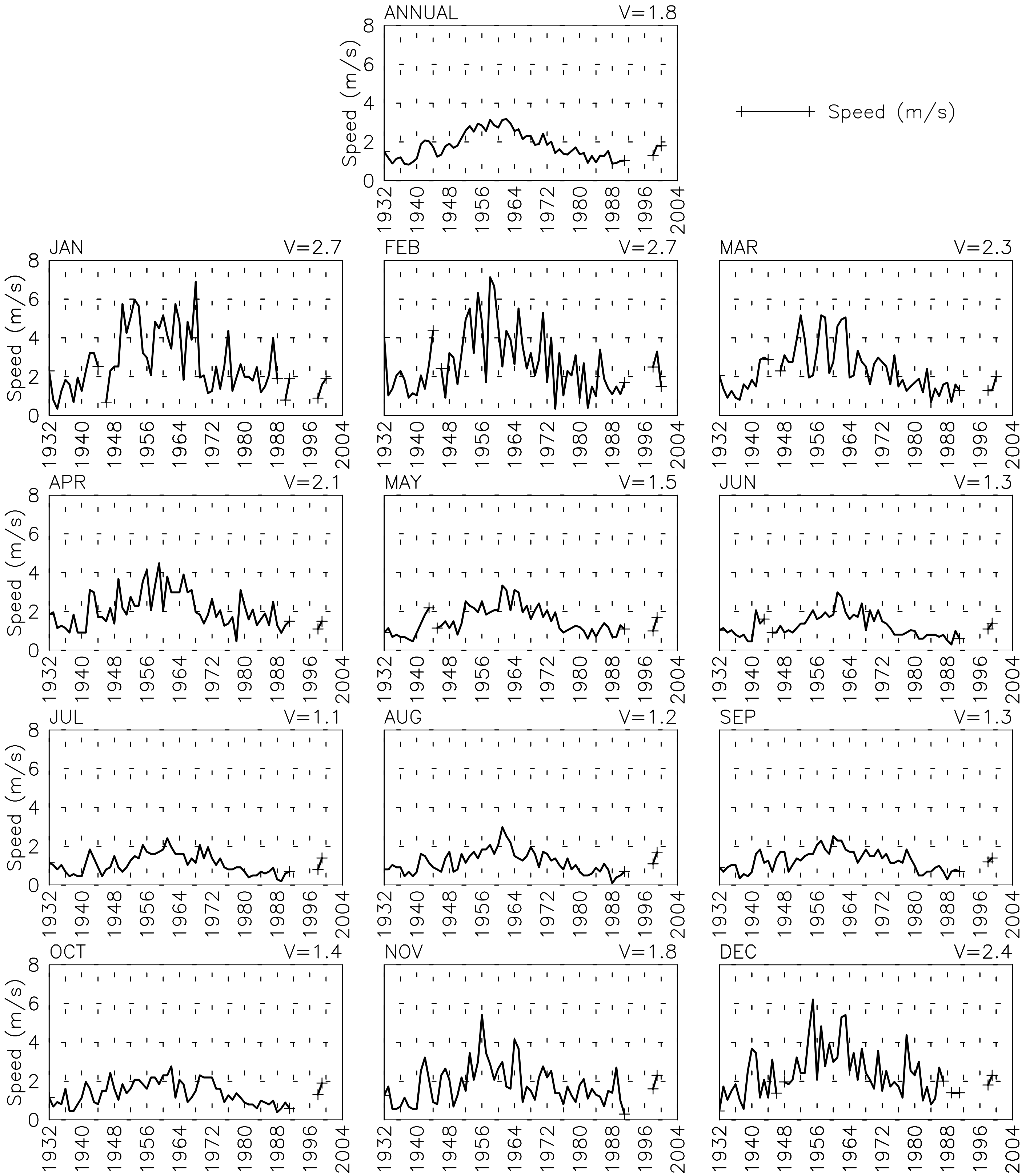
Mon Mar 24 11:39:26 2003

SPEED BY YEAR

Stepanavan – 000053

41° 00' N 44° 22' E – Elev 1397m LST=GMT+99 hours *NT= +3

01/32–12/91 01/98–03/00



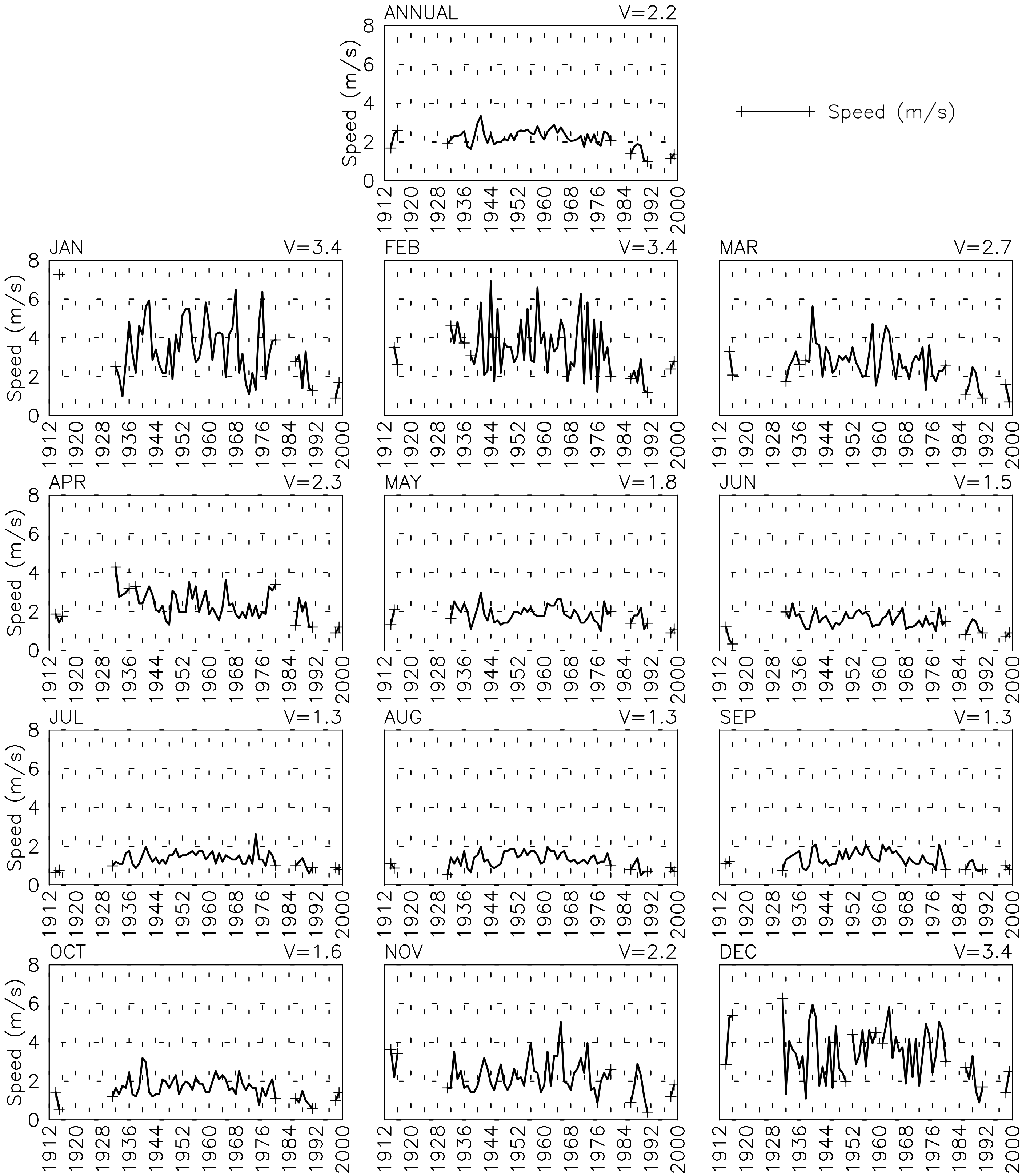
Mon Mar 24 11:39:28 2003

SPEED BY YEAR

Tashir (Kalinino) – 000055

41° 07' N 44° 17' E – Elev 1507m LST=GMT+99 hours *NT= +3

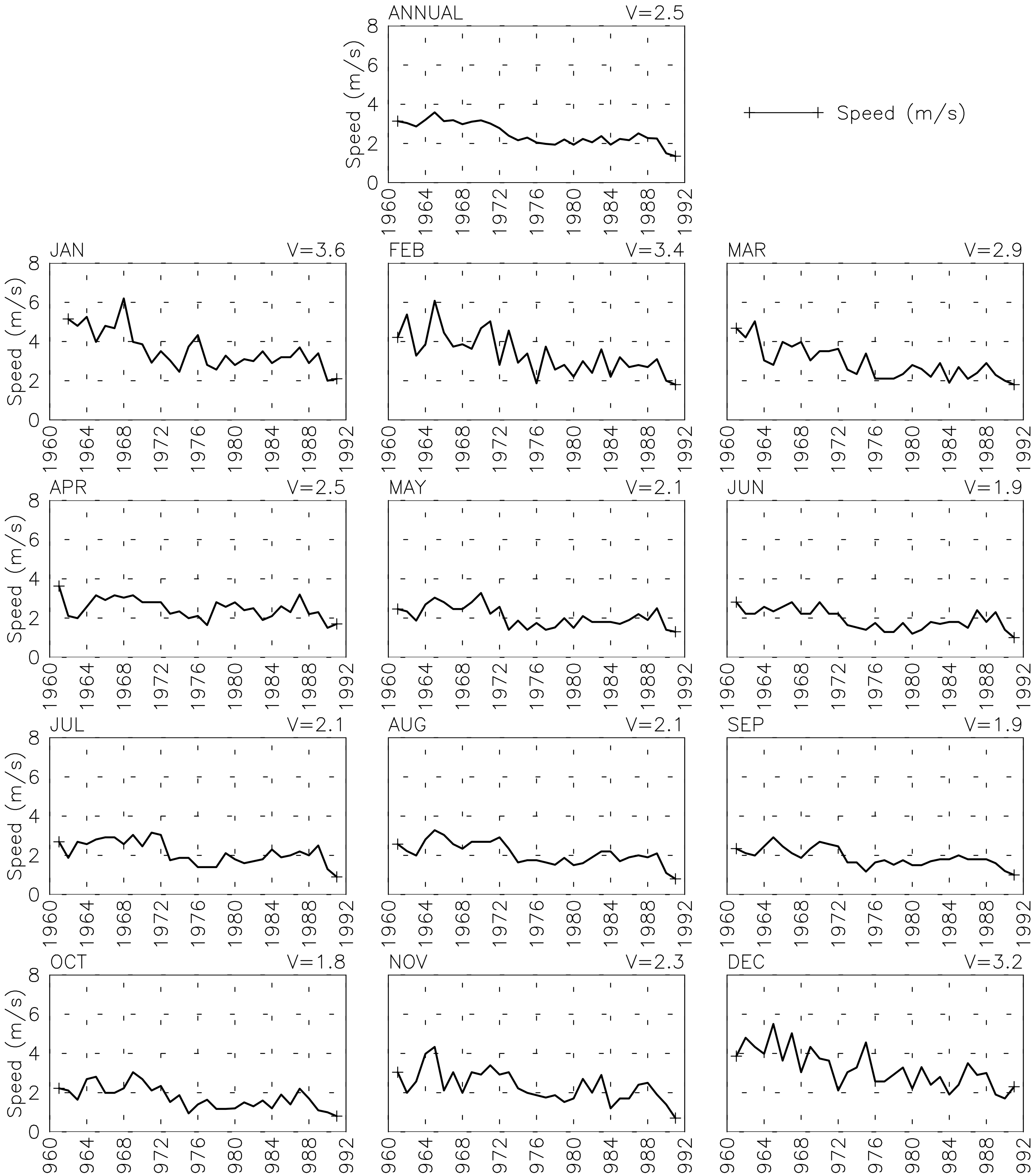
04/14–12/16 07/31–12/80 01/86–12/91 01/98–12/99



Mon Mar 24 11:39:30 2003

SPEED BY YEAR

Vanadzor AMSG – 000058
40° 49' N   44° 27' E – Elev 1376m   LST=GMT+99 hours   *NT= +3
02/61–12/91



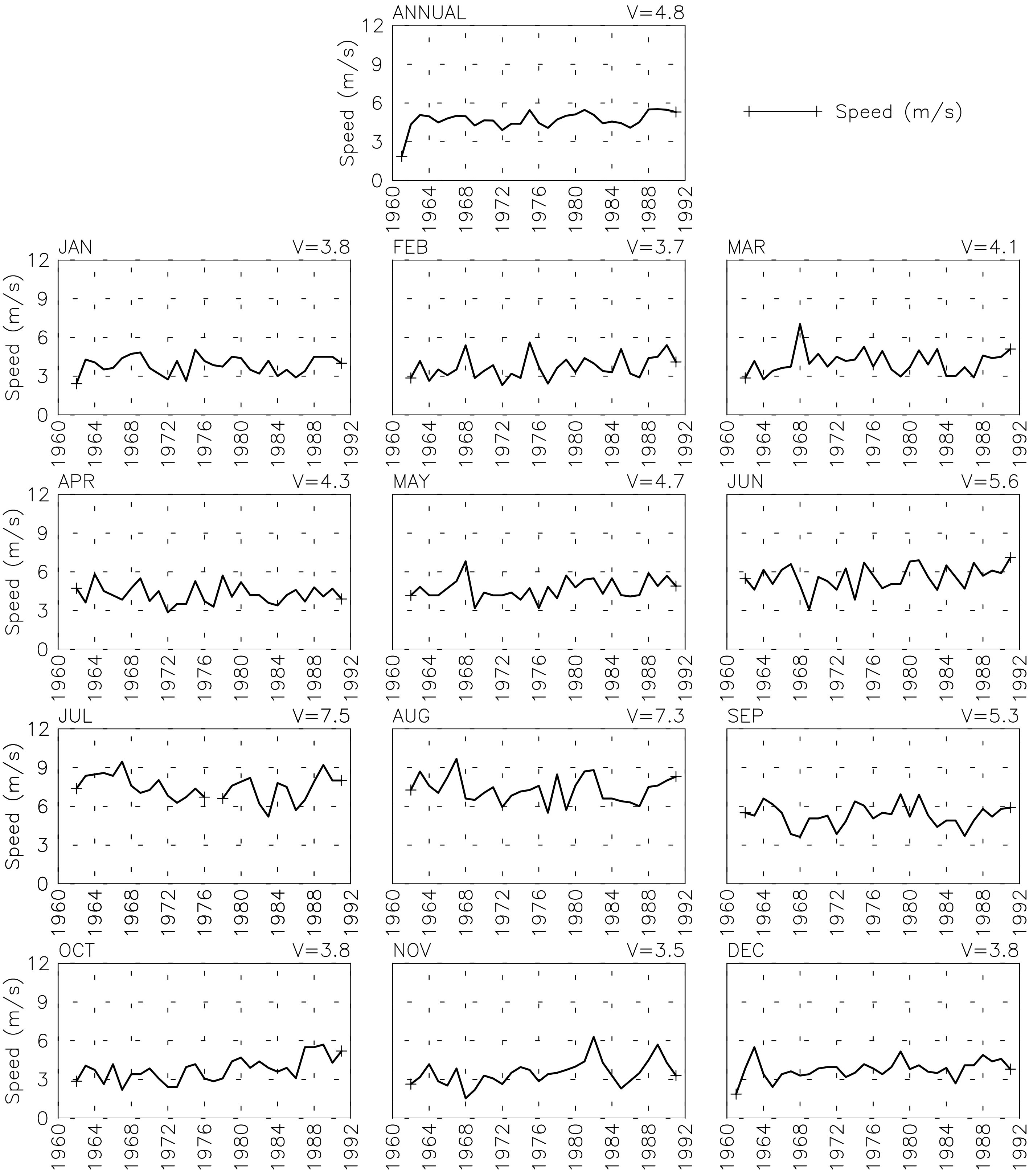
Mon Mar 24 11:39:32 2003

SPEED BY YEAR

Vorotan Pass (Kochbek - 000059

39° 41' N 45° 43' E - Elev 2387m LST=GMT+99 hours *NT= +3

12/61-12/91



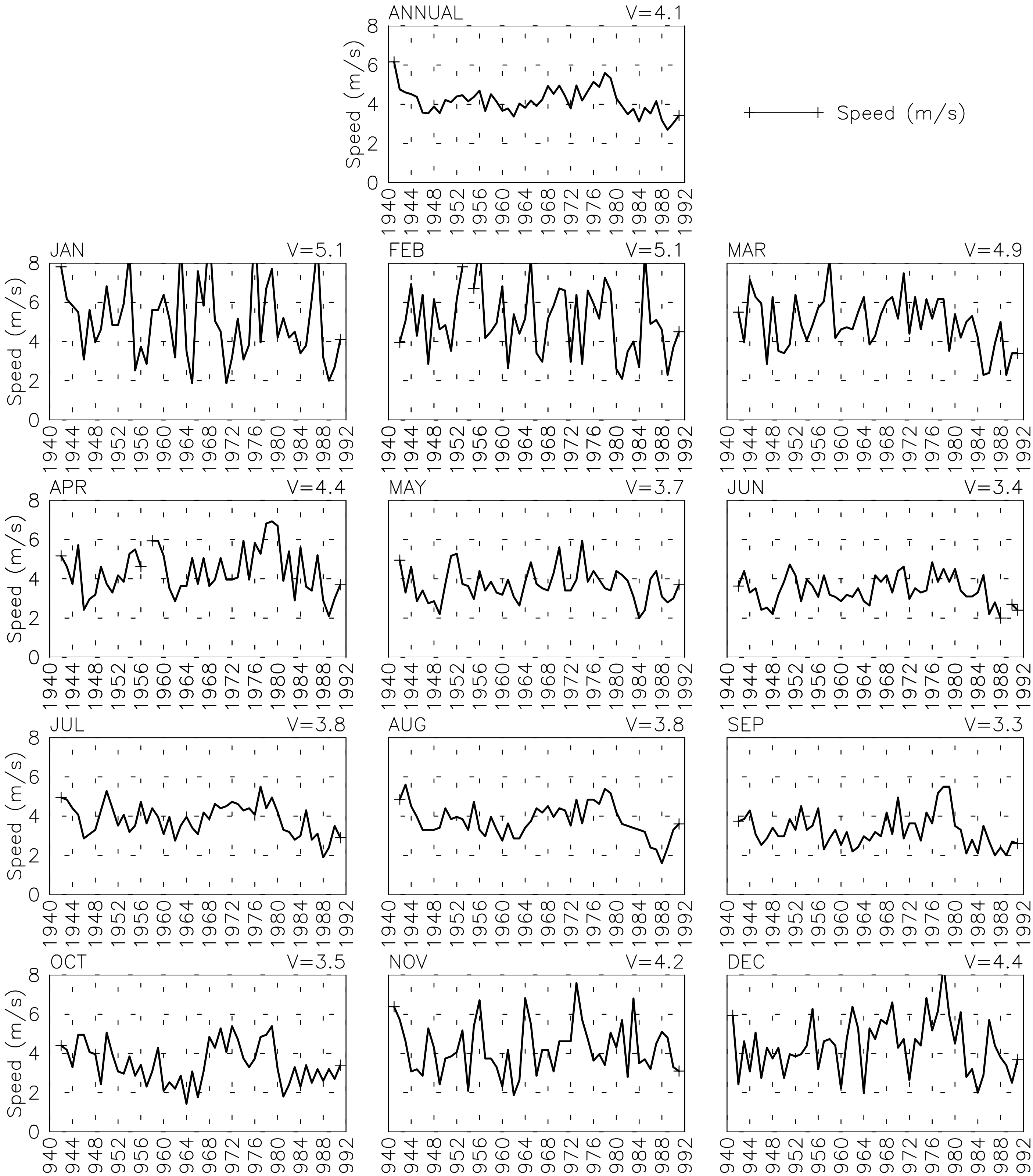
Mon Mar 24 11:40:30 2003

SPEED BY YEAR

Yanikh – 000060

40° 00' N 45° 14' E – Elev 2334m LST=GMT+99 hours *NT= +3

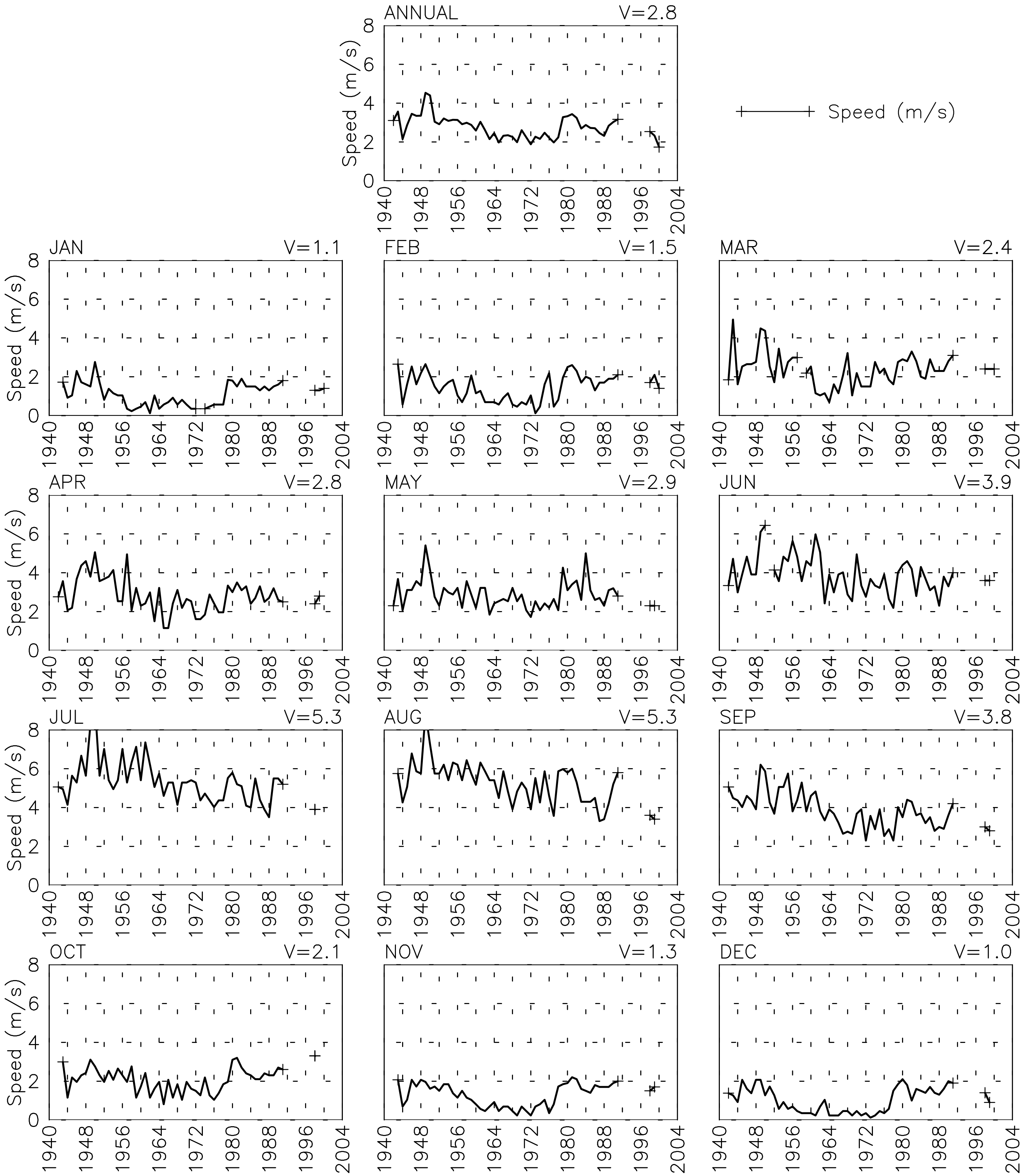
11/41–12/91



Mon Mar 24 11:39:33 2003

SPEED BY YEAR

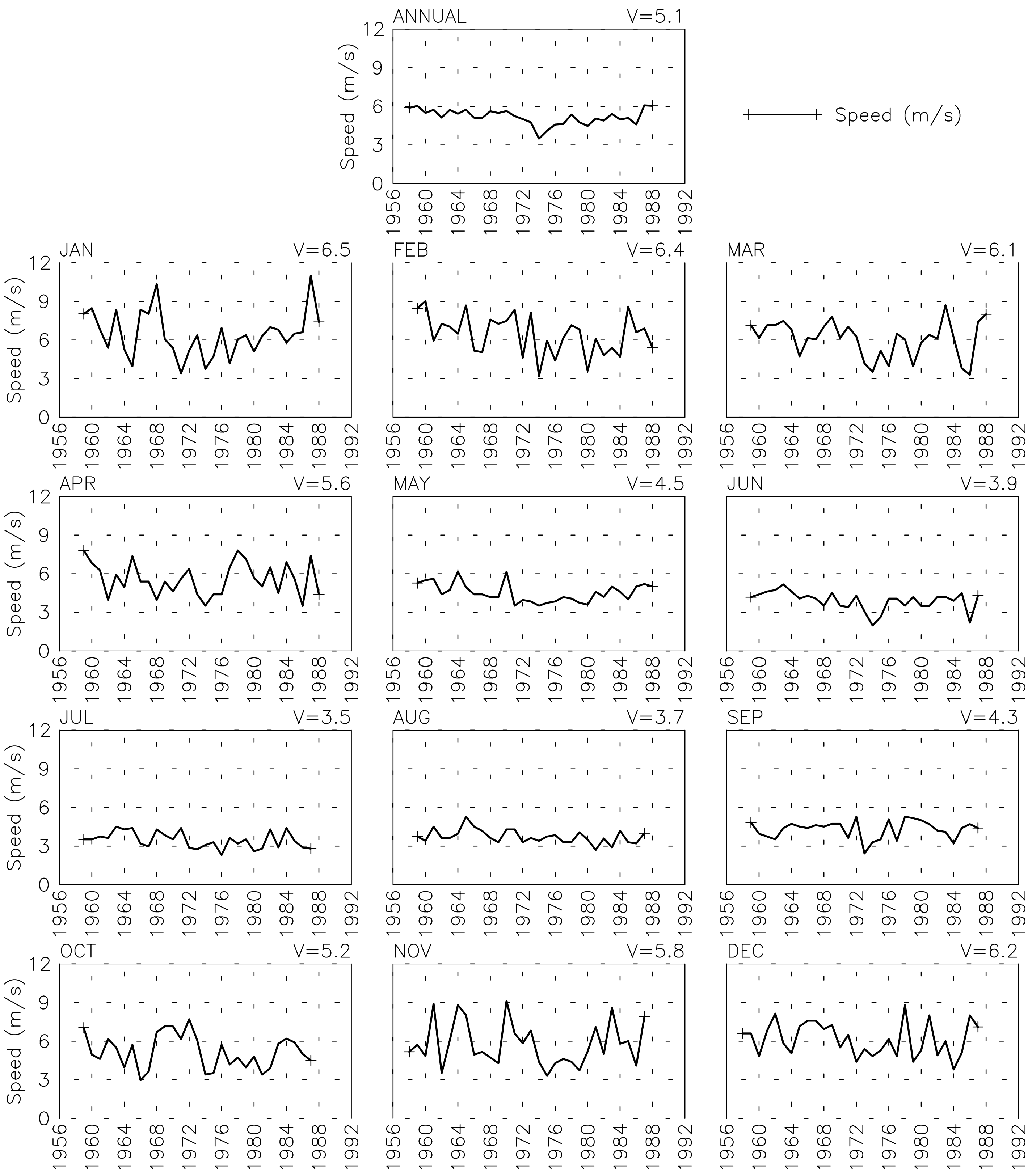
Yeghvard − 000062
40° 19' N   44° 29' E − Elev 1337m   LST=GMT+99 hours   *NT= +3
03/42−12/91 01/98−03/00



Mon Mar 24 11:39:34 2003

SPEED BY YEAR

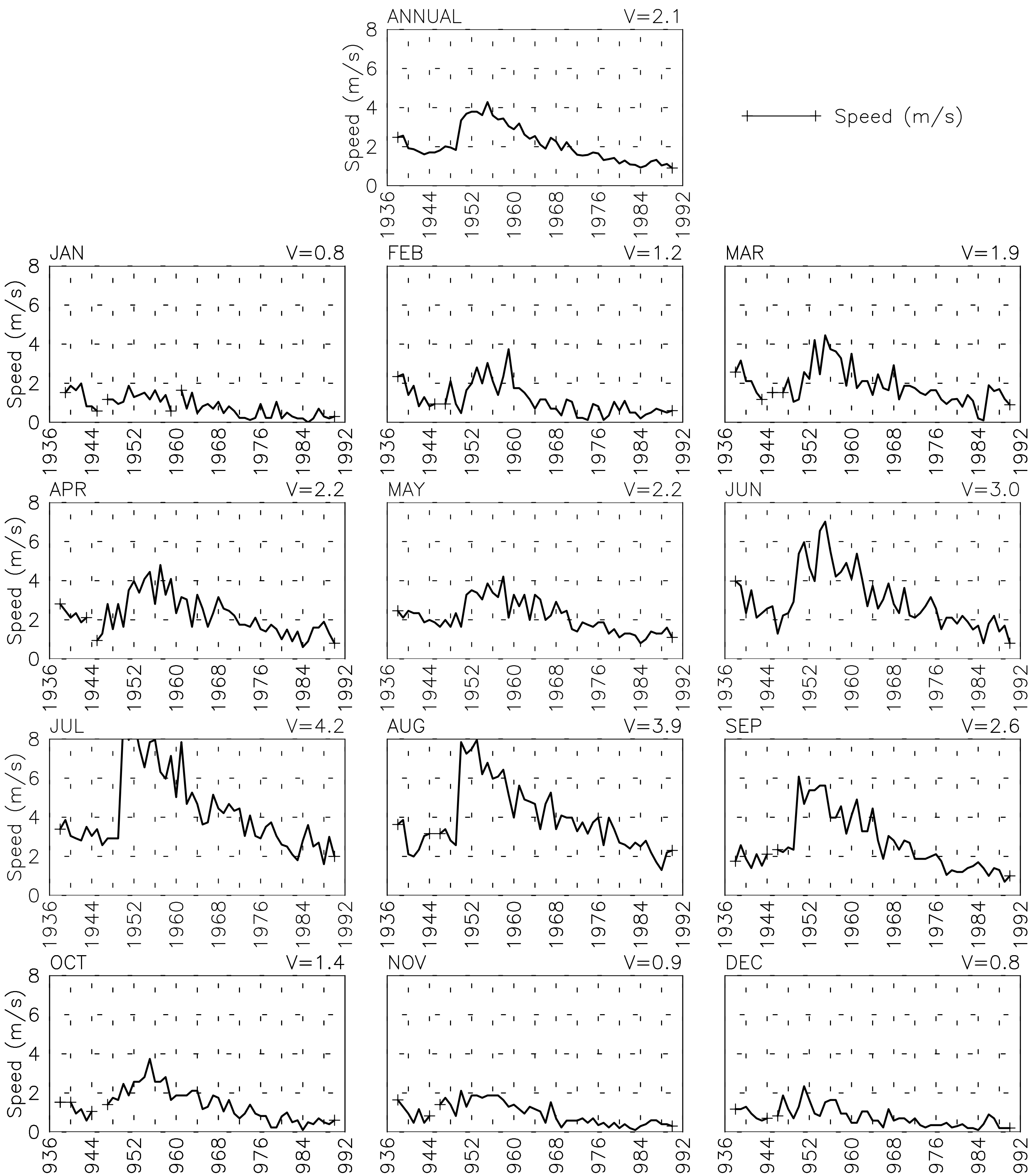
Yeratumber – 000063
40° 17' N 44° 56' E – Elev 3101m LST=GMT+99 hours *NT= +3
11/58–05/88



Mon Mar 24 11:40:31 2003

SPEED BY YEAR

Yerevan Argo – 000064
40° 11' N 44° 24' E – Elev 942m LST=GMT+99 hours *NT= +3
02/38–12/90



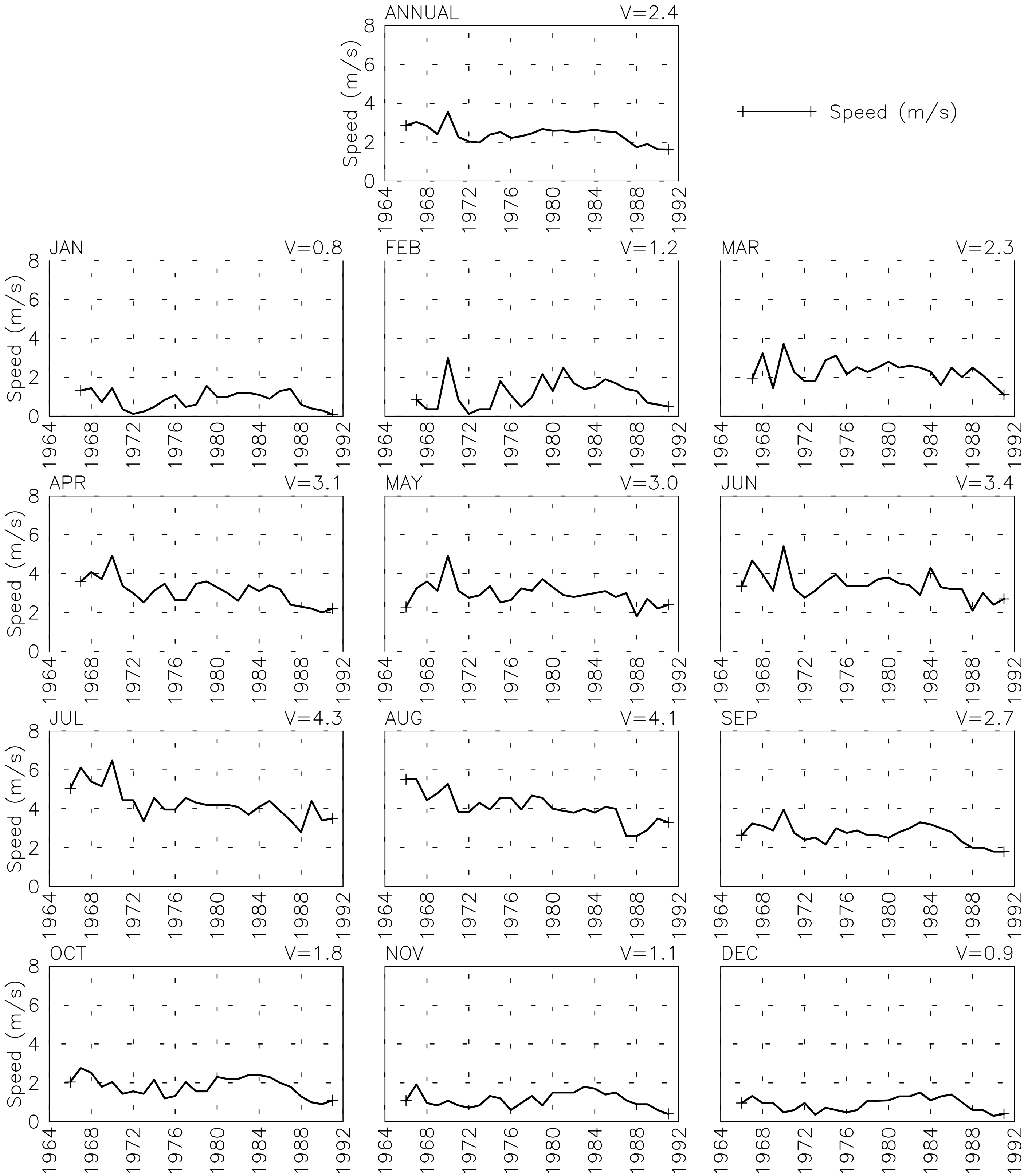
Mon Mar 24 11:39:36 2003

SPEED BY YEAR

Yerevan Zvartnots new – 000066

40° 09' N 44° 23' E – Elev 865m LST=GMT+99 hours *NT= +3

05/66–12/91



Mon Mar 24 11:39:37 2003

Appendix B

Surface Meteorological Stations
Tables and Analysis Summaries of Selected Stations

DATSAV2 Stations

Table B.1
DATSAV2 Stations in Armenia

Num	Name	Lat	Lon	Elev	From	To	NObs	WS	WP	Calm
376180	KALININO	41 7	44 16	1506	1959/01	1984/05	2400	2.08	88.1	50%
376270	UZUNLAR	41 4	44 37	1127	1961/02	1979/03	1592	1.41	21	43%
376820	AMASIJA	40 57	43 46	1878	1959/01	1996/05	5724	1.76	33.9	47%
376860	LENINAKAN	40 46	43 49	1529	1948/01	1990/08	60794	1.26	33.5	71%
376930	STEPANAVAN	41 1	44 22	1397	1973/01	1994/01	16989	1.29	35.7	61%
376950	SPITAK	40 49	44 13	1552	1959/01	1980/03	3844	3.52	92.7	25%
376990	APARAN	40 34	44 21	1891	1959/01	1994/09	18935	1.98	31.2	36%
377040	KIROVAKAN	40 49	44 30	1379	1959/08	1994/03	16643	2.06	32	28%
377060	DILIZAN	40 45	44 52	1255	1959/01	1978/06	4908	1.79	31.9	44%
377080	SEVAN	40 32	44 55	1937	1959/01	1995/11	16372	2.44	33	27%
377090	SEVAN	40 32	44 55	1937	1959/01	1996/08	55858	3.36	77.8	16%
377110	IDZEVAN	40 52	45 8	733	1959/01	1996/11	17919	2.2	57.4	24%
377130	BERD	40 52	45 22	900	1961/02	1981/04	1908	2.22	38	18%
377190	KRASNOSEL'SK	40 36	45 21	1834	1959/01	1995/04	18913	2.82	77.4	31%
377740	ARAGATS	40 19	43 40	1255	1959/01	1989/12	13736	2.2	39.5	29%
377870	OKTEMBERYAN	40 8	44 1	866	1959/01	1996/08	17830	0.77	14.7	75%
377890	YEREVAN / ZVARTNOTS	40 7	44 28	890	1932/01	1996/12	117459	1.68	36.2	52%
377910	LUSAVAN / CHARENTSAVA	40 23	44 37	1792	1973/01	1994/06	16851	3.18	69.8	24%
377920	RAZDAN	40 30	44 46	1761	1959/01	1978/07	4847	2.52	32.2	12%
378010	KAMO	40 21	45 7	1951	1959/01	1980/01	2961	2.39	87.5	42%
378080	MARTUNI (NO.2)	40 7	45 19	1945	1959/01	1995/11	18553	2.51	45.1	18%
378150	MEC MAZRA	40 13	45 46	1940	1959/01	1996/07	15370	3.07	112.3	41%
378740	ARTASHAT	39 57	44 32	822	1959/01	1993/09	16164	1.95	34.3	34%
378760	ARARAT	39 49	44 42	818	1959/01	1995/09	19237	1.24	18.9	53%
378970	SISIAN (STREAM)	39 31	46 1	1615	1959/01	1994/02	16297	1.93	35.8	57%
379530	GORIS (STREAM)	39 30	46 21	1367	1959/01	1996/11	14147	2.12	107.8	51%
379580	MEGRI	38 53	46 15	629	1959/01	1994/08	19606	1.36	19	49%
379590	KAFAN	39 12	46 25	704	1959/01	1994/09	23452	1.38	19.6	53%

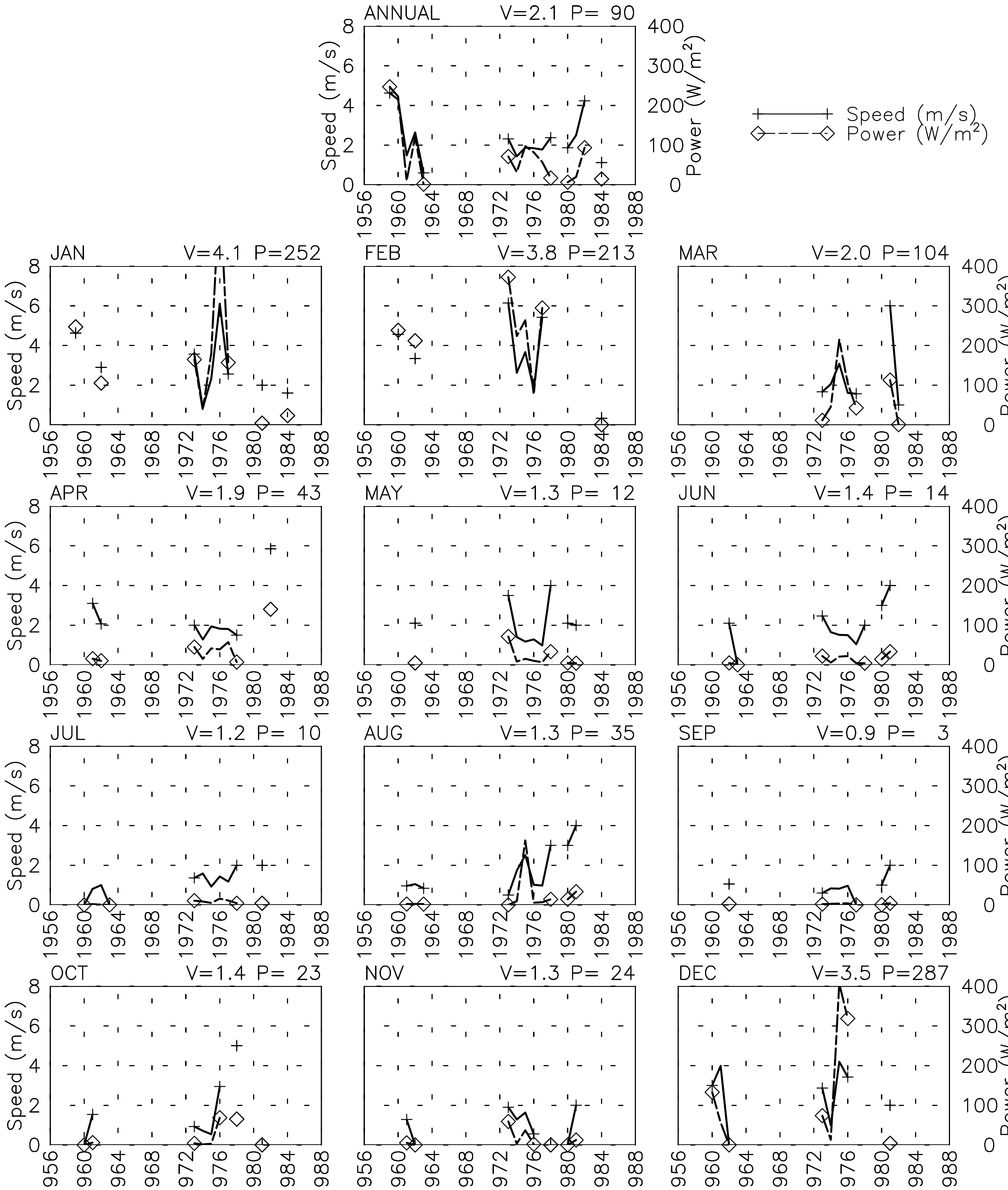
NOTES:
1) Latitudes (Lat) are in deg/min N, longitudes (Lon) in deg/min E. Elevations (Elev) are in meters above sea level. From/To is the period of record in yr/mo. Number of observations (NObs) are the number of records. Wind speeds (WS) are in meters/sec and wind power densities (WP) are in W/m^2. Percent calm is defined as the percentage of observations with wind speeds less than 1.0 meter/sec.

SPEED AND POWER BY YEAR

KALININO AM – 376180

41° 07' N 44° 16' E – Elev 1506m *LST=GMT +3 hours NT= +3

01/59–08/63 01/73–11/78 05/80–04/82 01/84–02/84



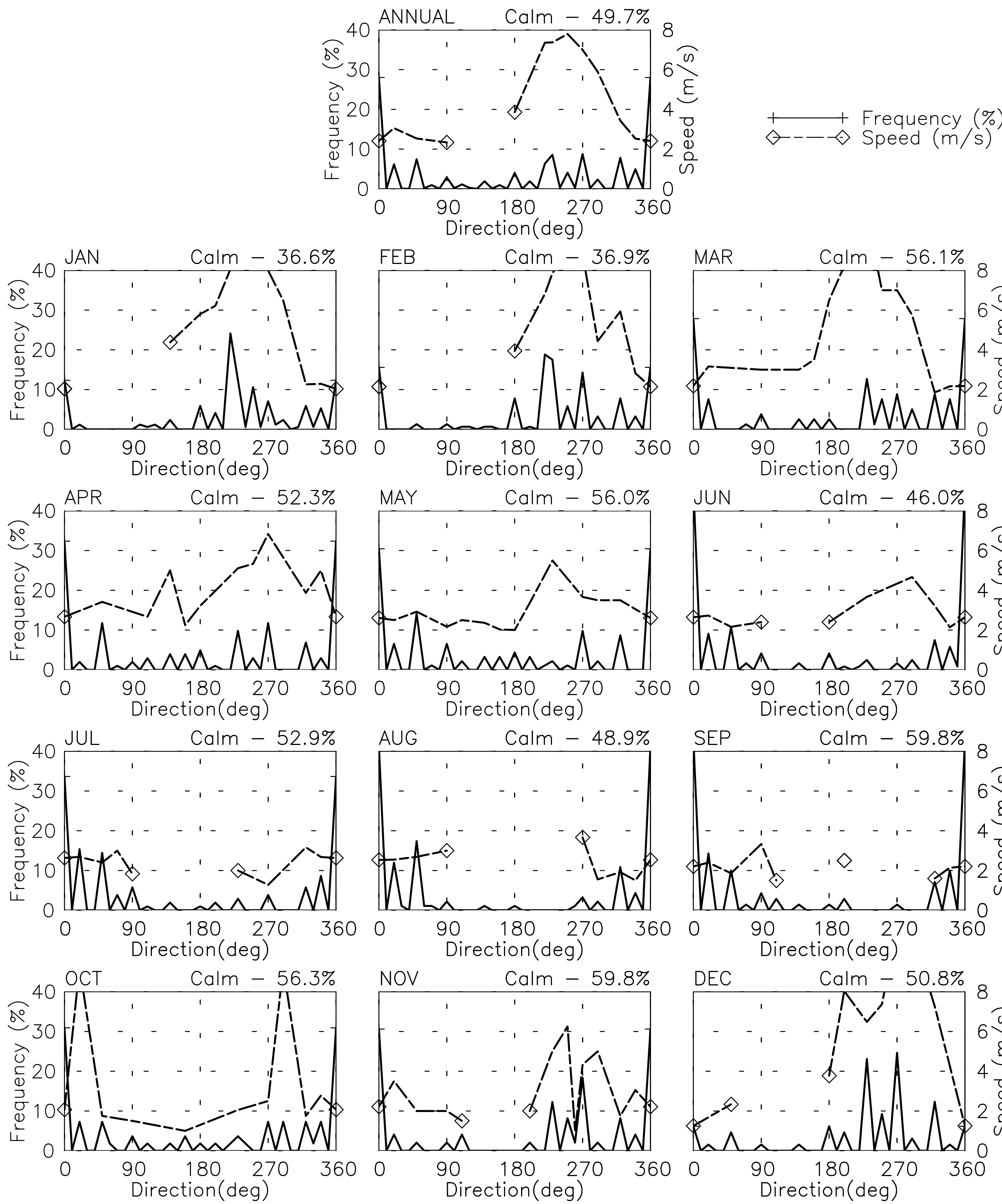
Mon Mar 24 13:38:02 2003

FREQUENCY AND SPEED BY DIRECTION

KALININO AM – 376180

41° 07' N 44° 16' E – Elev 1506m *LST=GMT +3 hours NT= +3

01/59–08/63 01/73–11/78 05/80–04/82 01/84–02/84



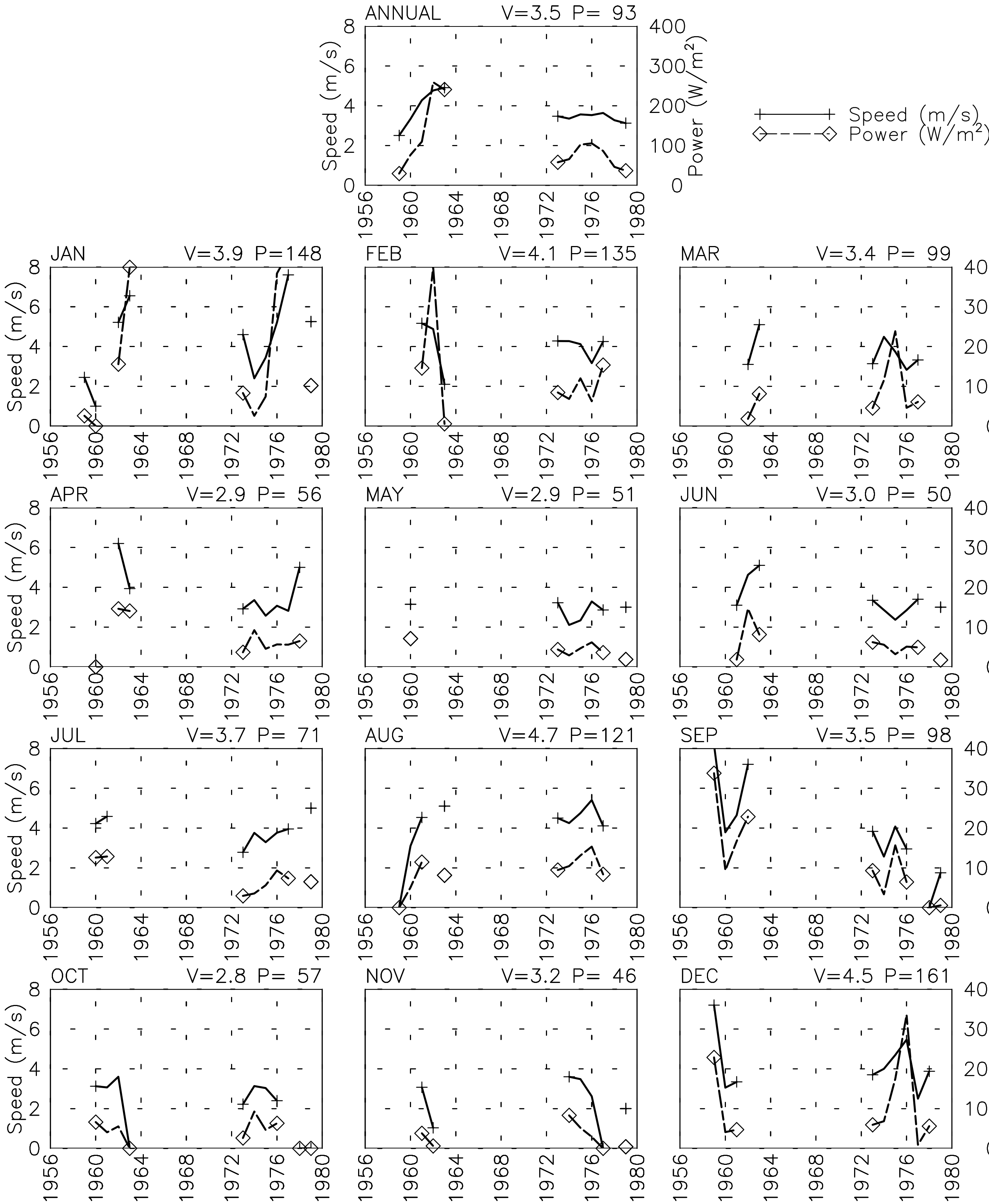
Mon Mar 24 13:38:04 2003

SPEED AND POWER BY YEAR

SPITAK AM – 376950

40° 49' N 44° 13' E – Elev 1552m *LST=GMT +3 hours NT= +3

01/59–10/63 01/73–11/79



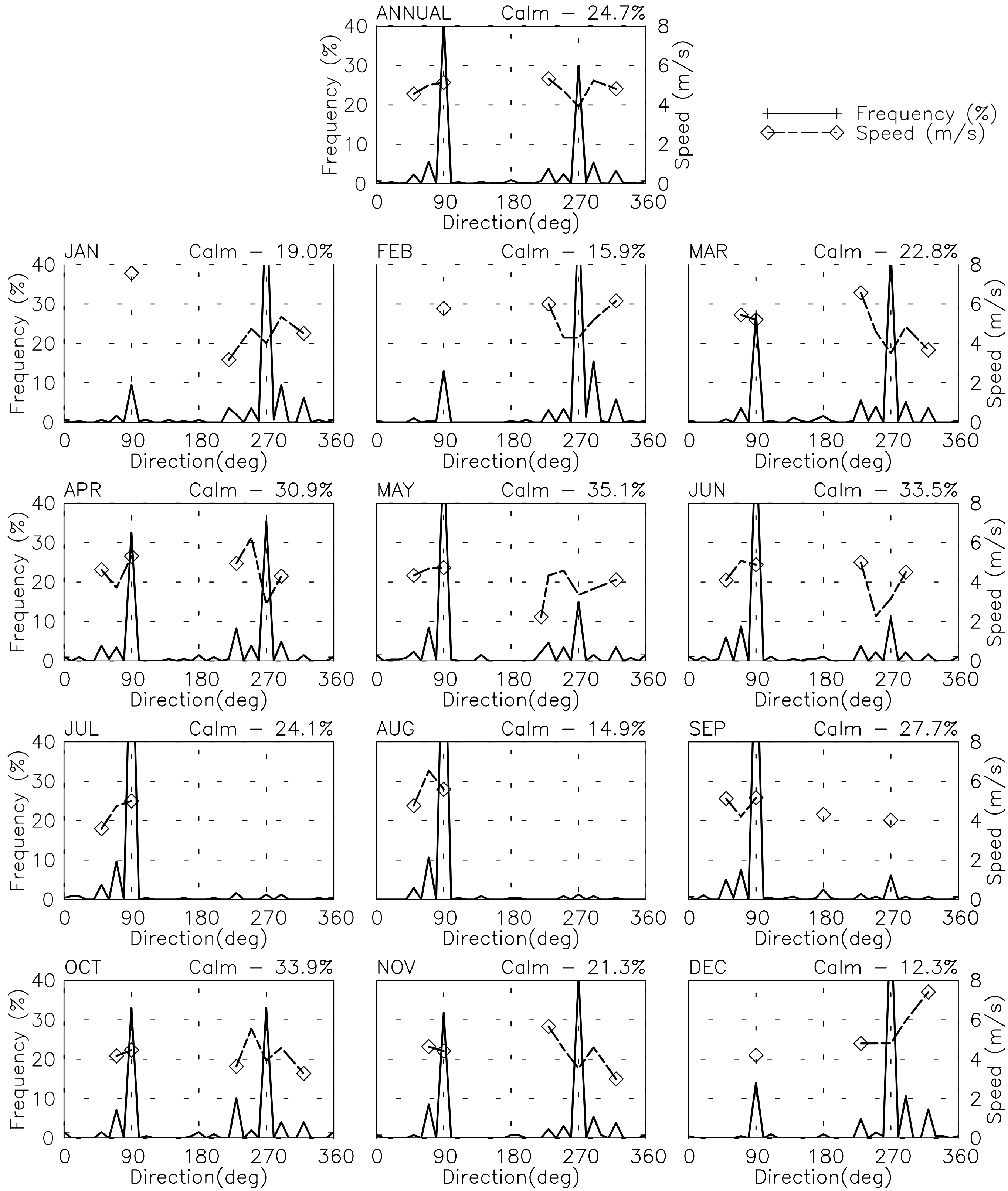
Mon Mar 24 13:38:05 2003

FREQUENCY AND SPEED BY DIRECTION

SPITAK AM – 376950

40° 49' N 44° 13' E – Elev 1552m *LST=GMT +3 hours NT= +3

01/59–10/63 01/73–11/79



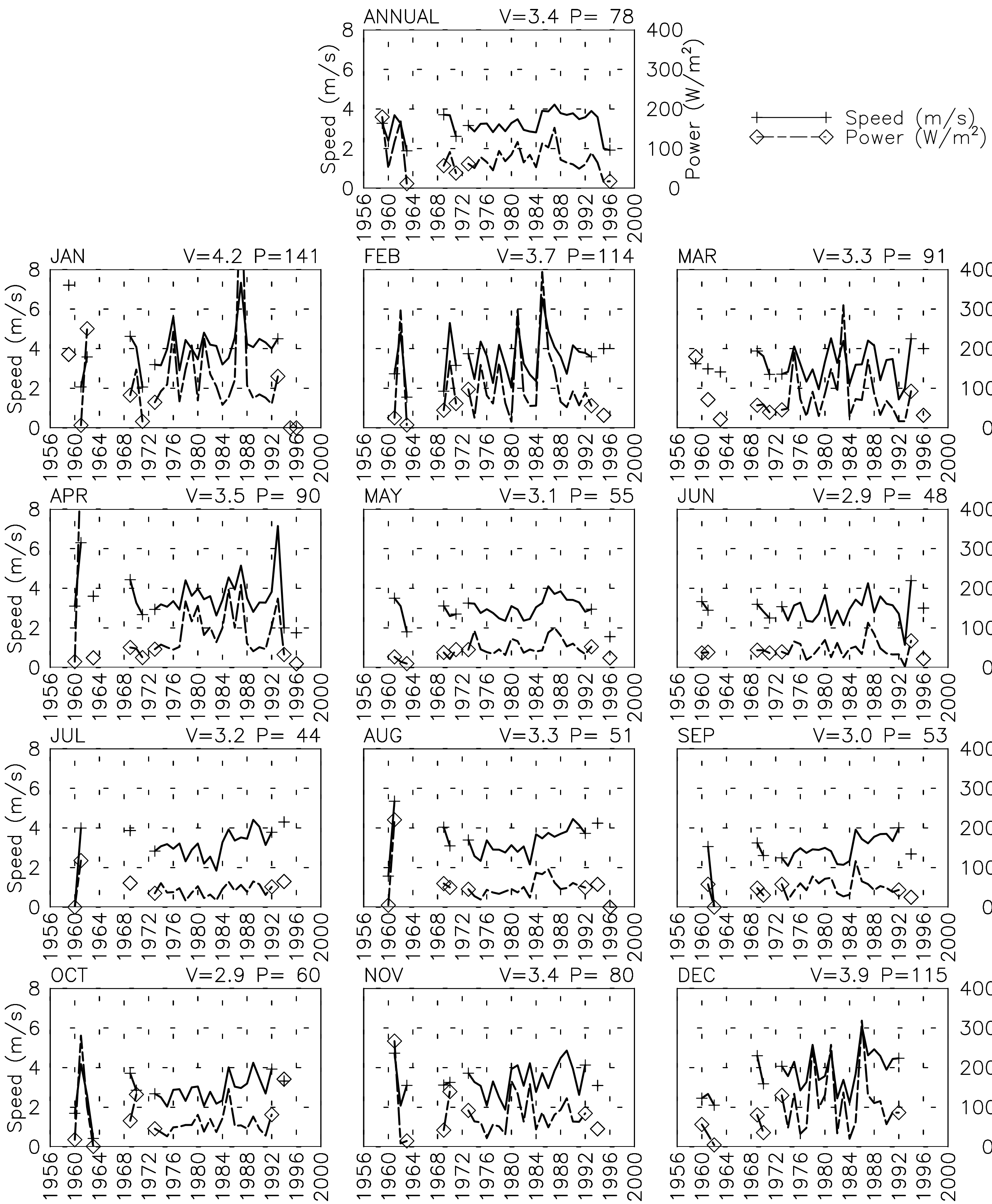
Mon Mar 24 13:38:06 2003

SPEED AND POWER BY YEAR

SEVAN AM – 377090

40° 32' N 44° 55' E – Elev 1937m *LST=GMT +3 hours NT= +3

01/59–11/63 01/69–06/71 01/73–08/96



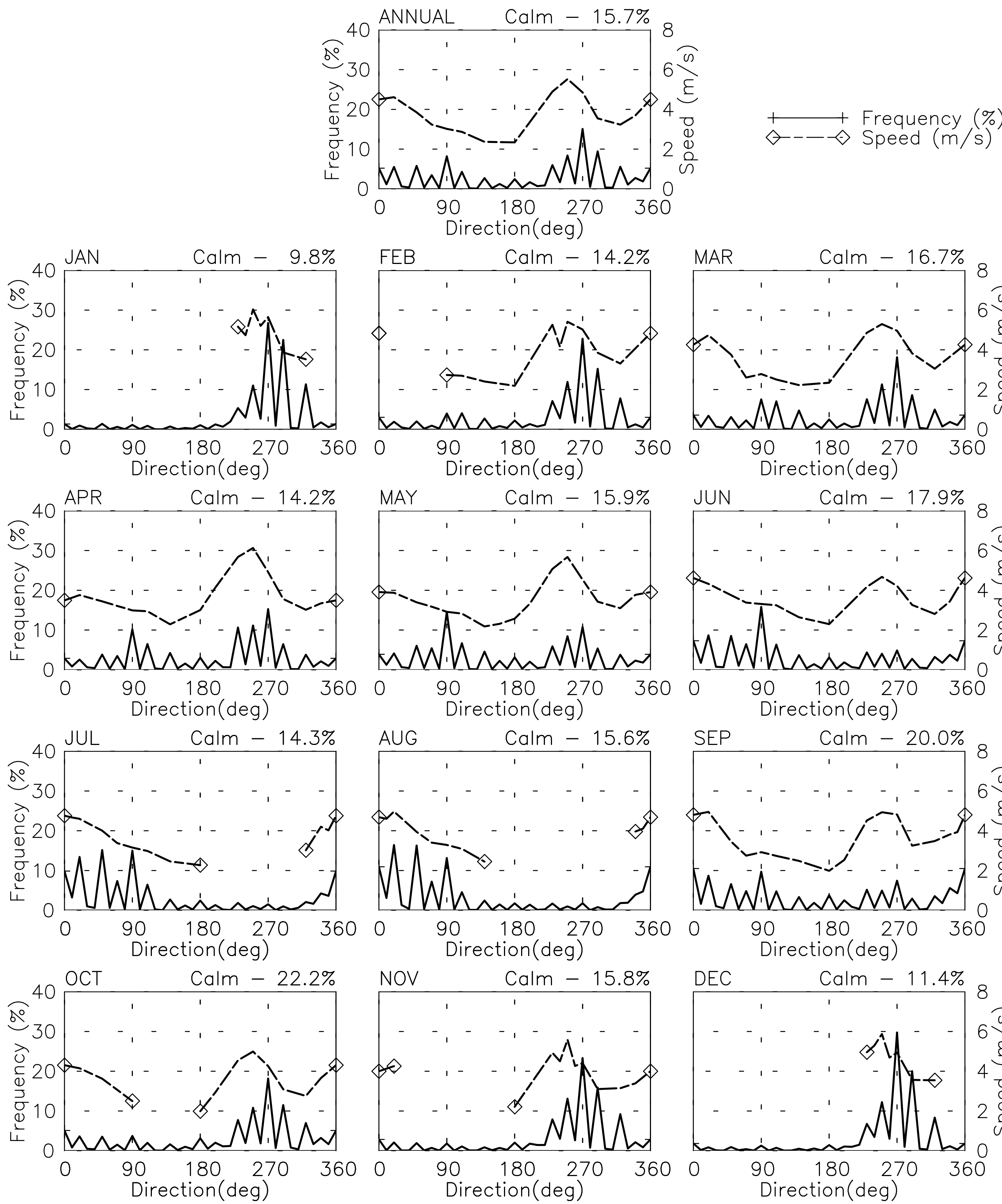
Mon Mar 24 13:38:09 2003

FREQUENCY AND SPEED BY DIRECTION

SEVAN AM – 377090

40° 32' N 44° 55' E – Elev 1937m *LST=GMT +3 hours NT= +3

01/59–11/63 01/69–06/71 01/73–08/96



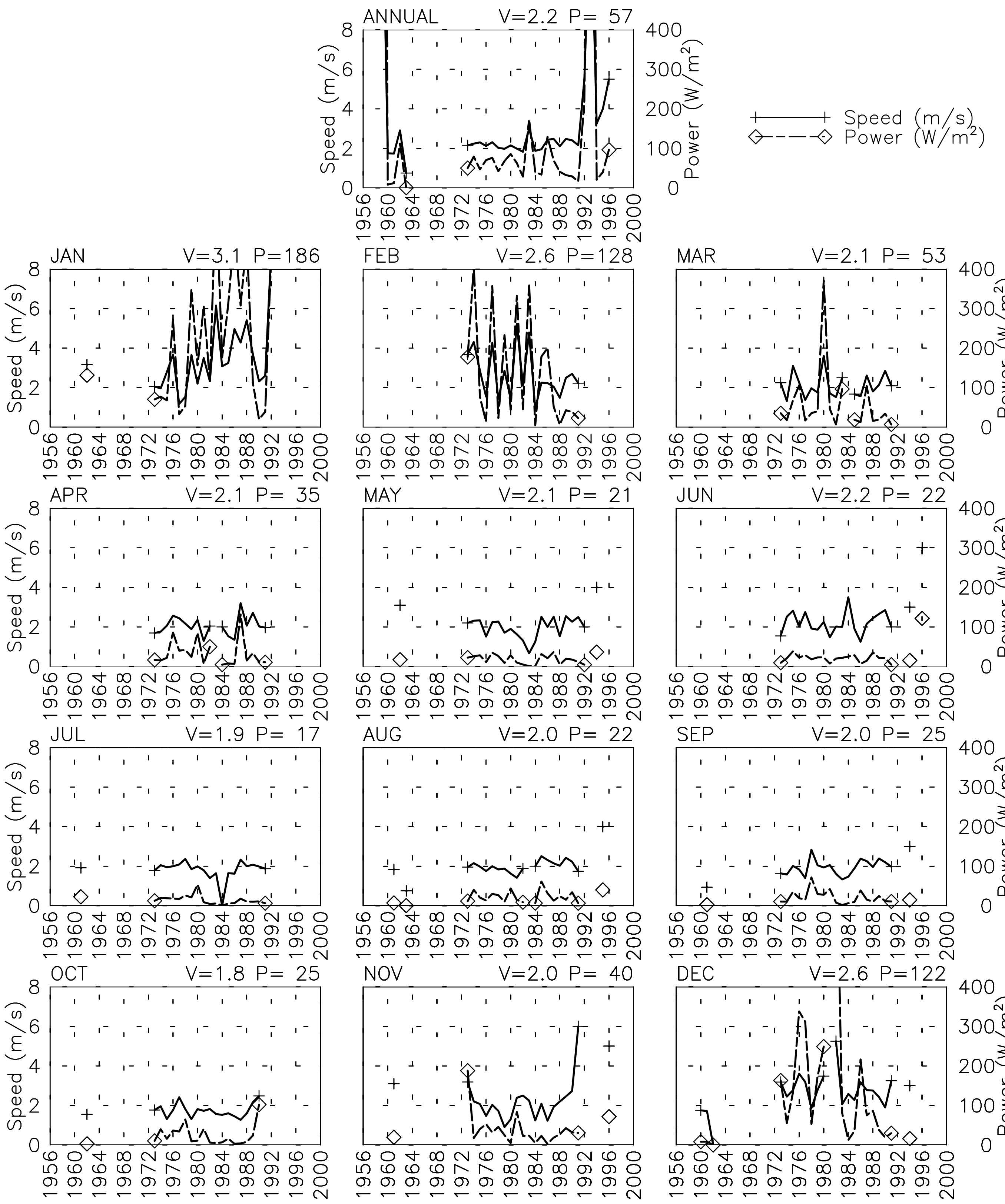
Mon Mar 24 13:38:12 2003

SPEED AND POWER BY YEAR

IDZEVAN AM – 377110

40° 52' N 45° 08' E – Elev 733m *LST=GMT +3 hours NT= +3

01/59–08/63 01/73–11/96



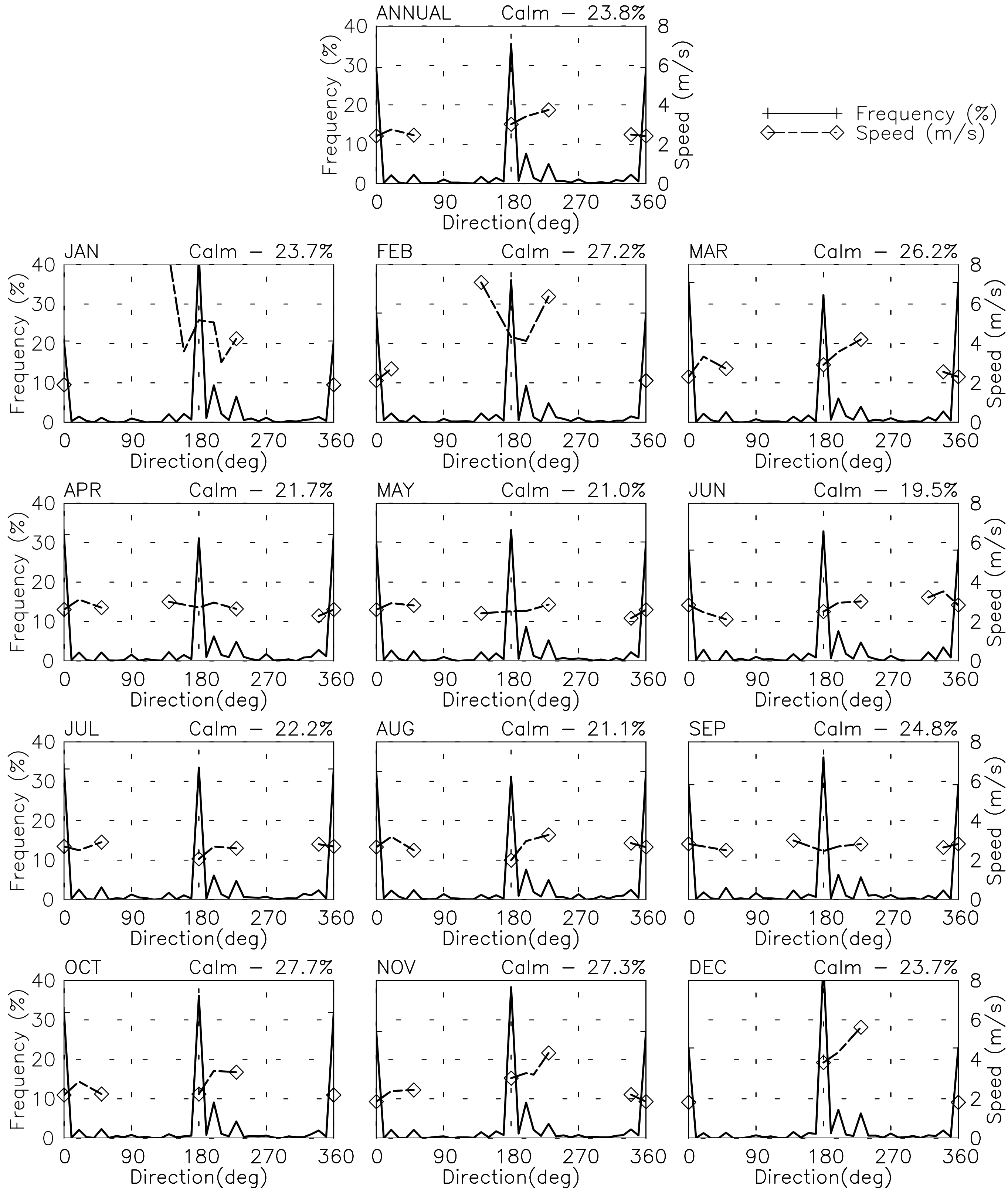
Mon Mar 24 13:38:14 2003

FREQUENCY AND SPEED BY DIRECTION

IDZEVAN AM – 377110

40° 52' N 45° 08' E – Elev 733m *LST=GMT +3 hours NT= +3

01/59–08/63 01/73–11/96



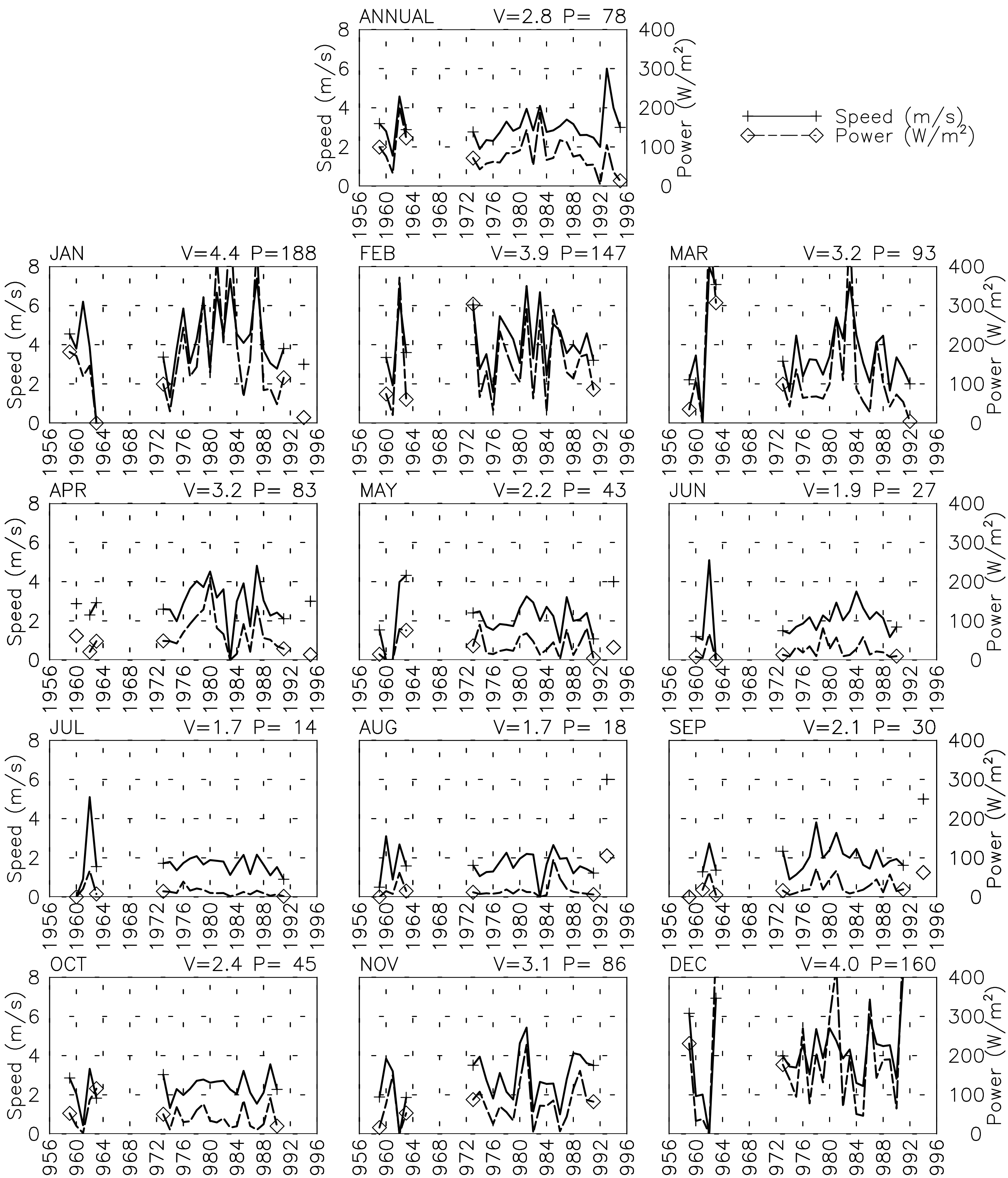
Mon Mar 24 13:38:16 2003

SPEED AND POWER BY YEAR

KRASNOSEL'SK AM – 377190

40° 36' N 45° 21' E – Elev 1834m *LST=GMT +3 hours NT= +3

01/59–12/63 01/73–04/95



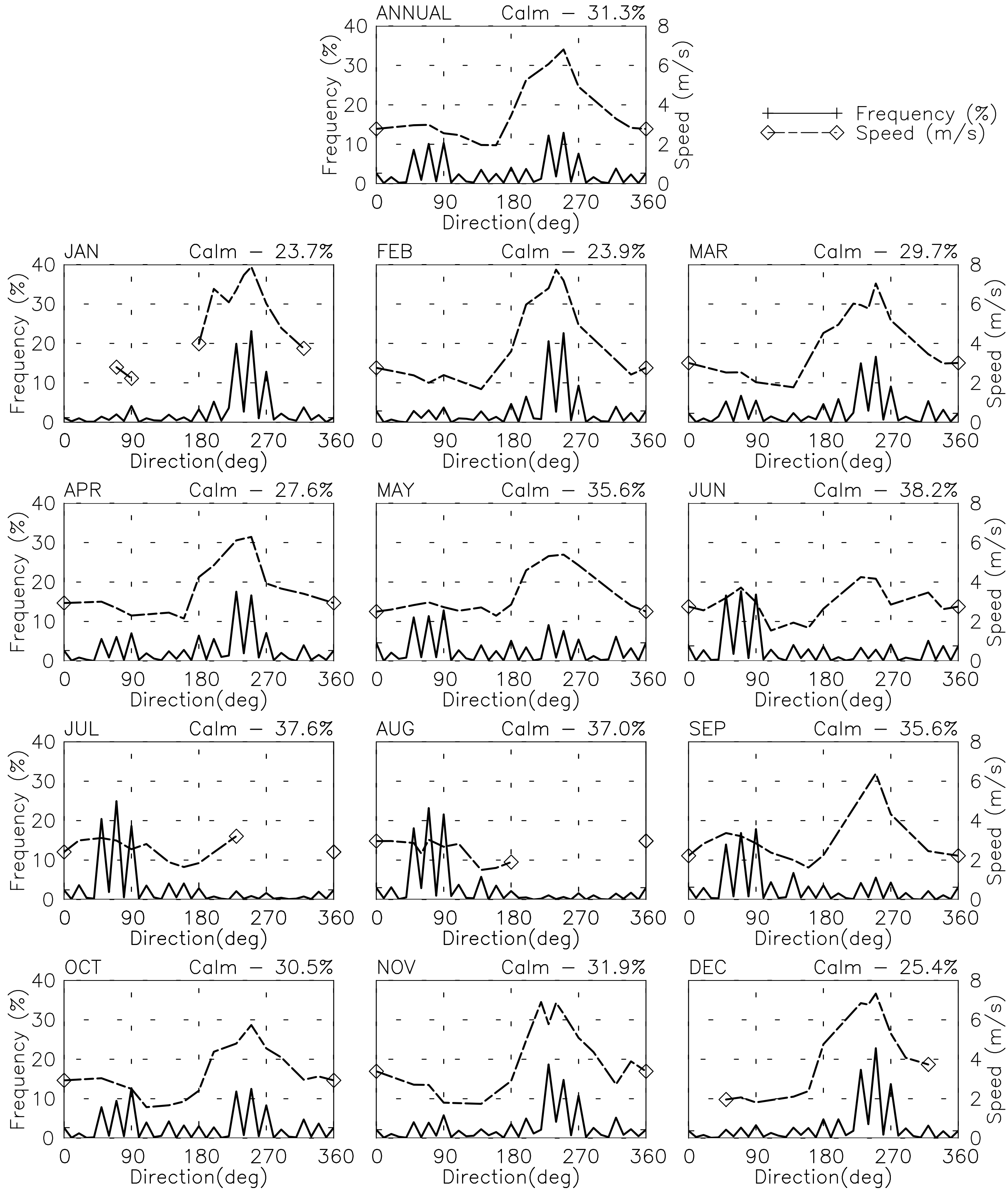
Mon Mar 24 13:38:18 2003

FREQUENCY AND SPEED BY DIRECTION

KRASNOSEL'SK AM – 377190

40° 36' N 45° 21' E – Elev 1834m *LST=GMT +3 hours NT= +3

01/59–12/63 01/73–04/95



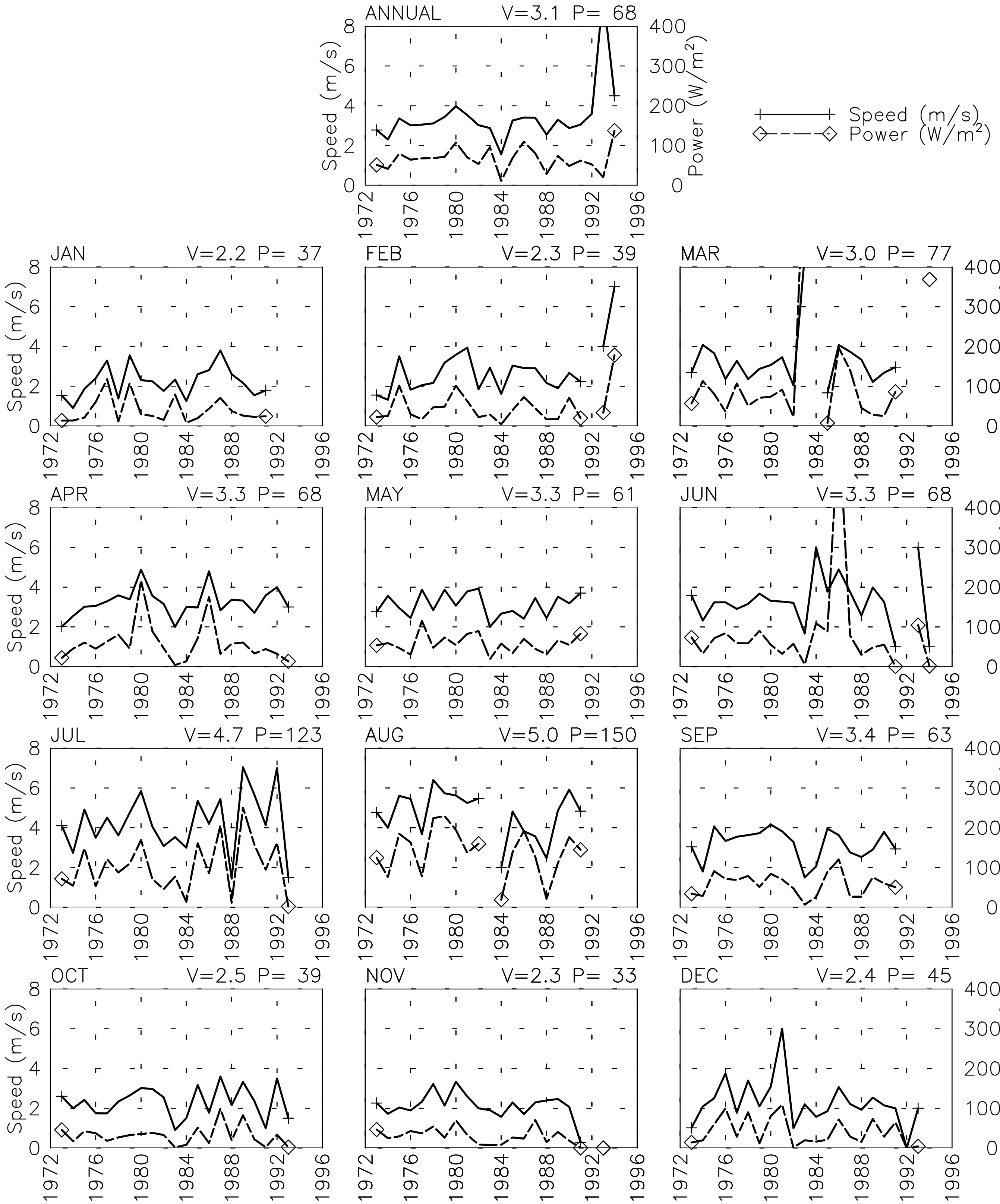
Mon Mar 24 13:38:20 2003

SPEED AND POWER BY YEAR

LUSAVAN/CHARENTSAVA AM – 377910

40° 23' N 44° 37' E – Elev 1792m *LST=GMT +3 hours NT= +3

01/73–06/94



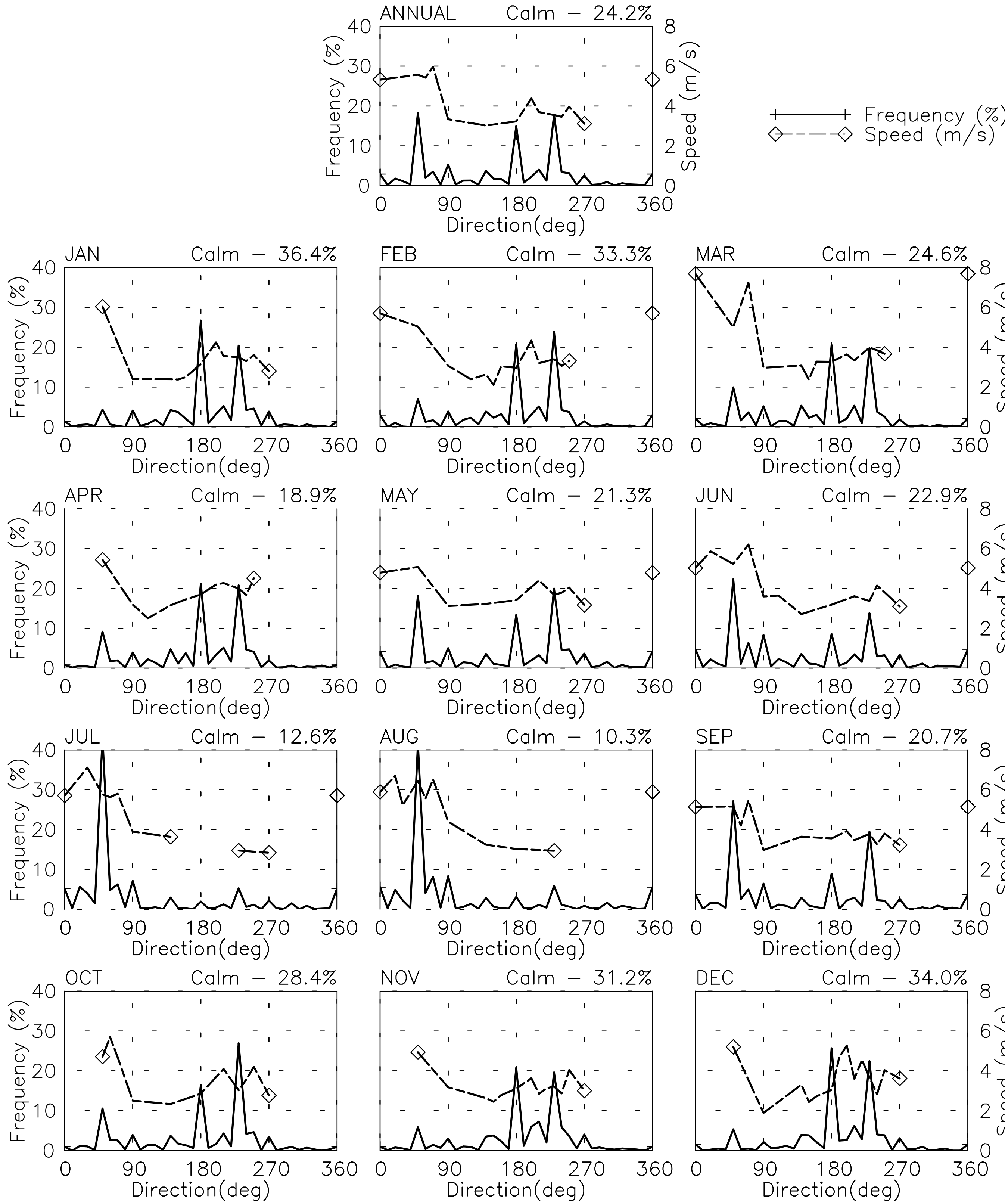
Mon Mar 24 13:38:22 2003

FREQUENCY AND SPEED BY DIRECTION

LUSAVAN/CHARENTSAVA AM – 377910

40° 23' N 44° 37' E – Elev 1792m *LST=GMT +3 hours NT= +3

01/73–06/94



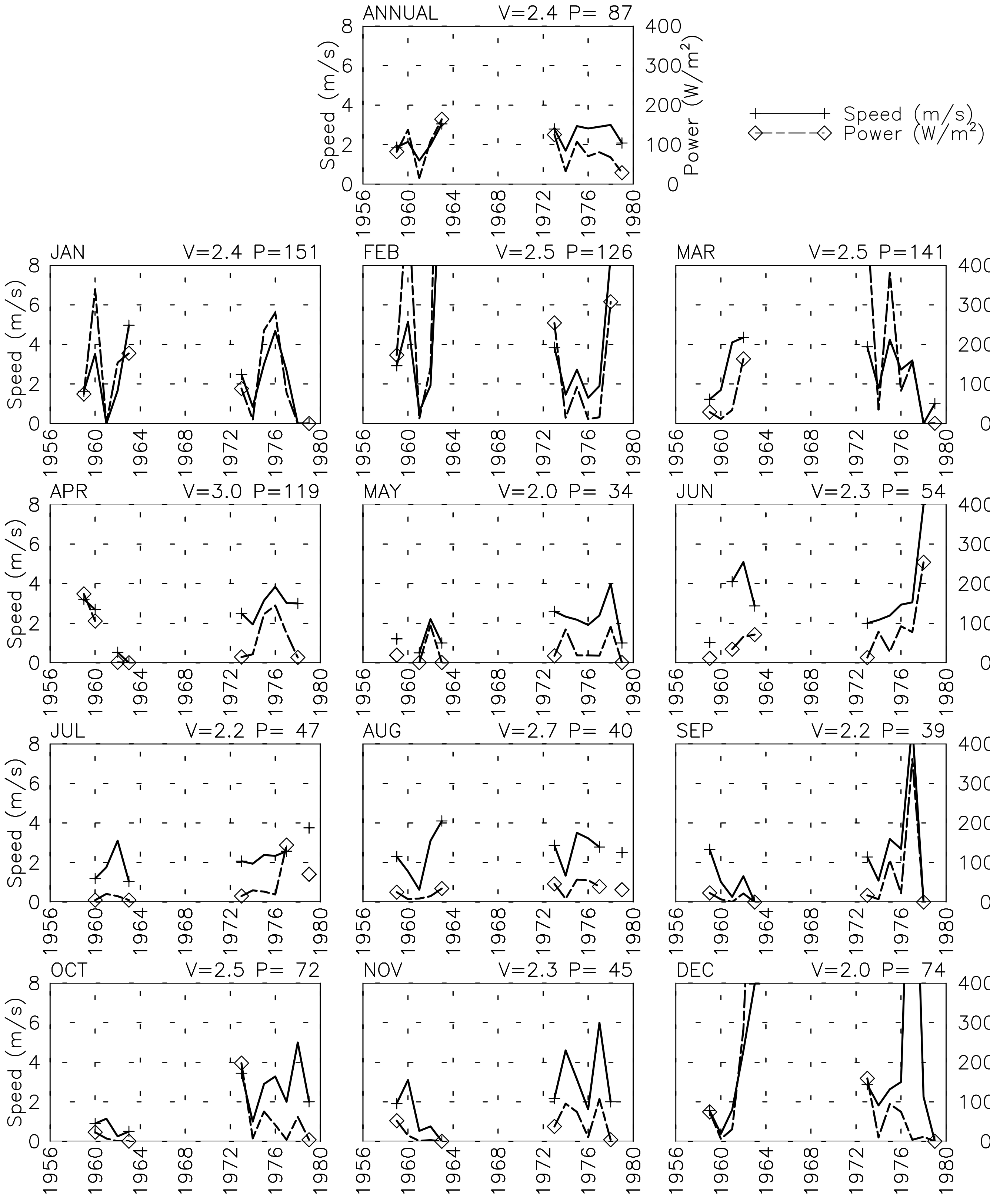
Mon Mar 24 13:38:23 2003

SPEED AND POWER BY YEAR

KAMO AM – 378010

40° 21' N 45° 07' E – Elev 1951m *LST=GMT +3 hours NT= +3

01/59–12/63 01/73–12/79



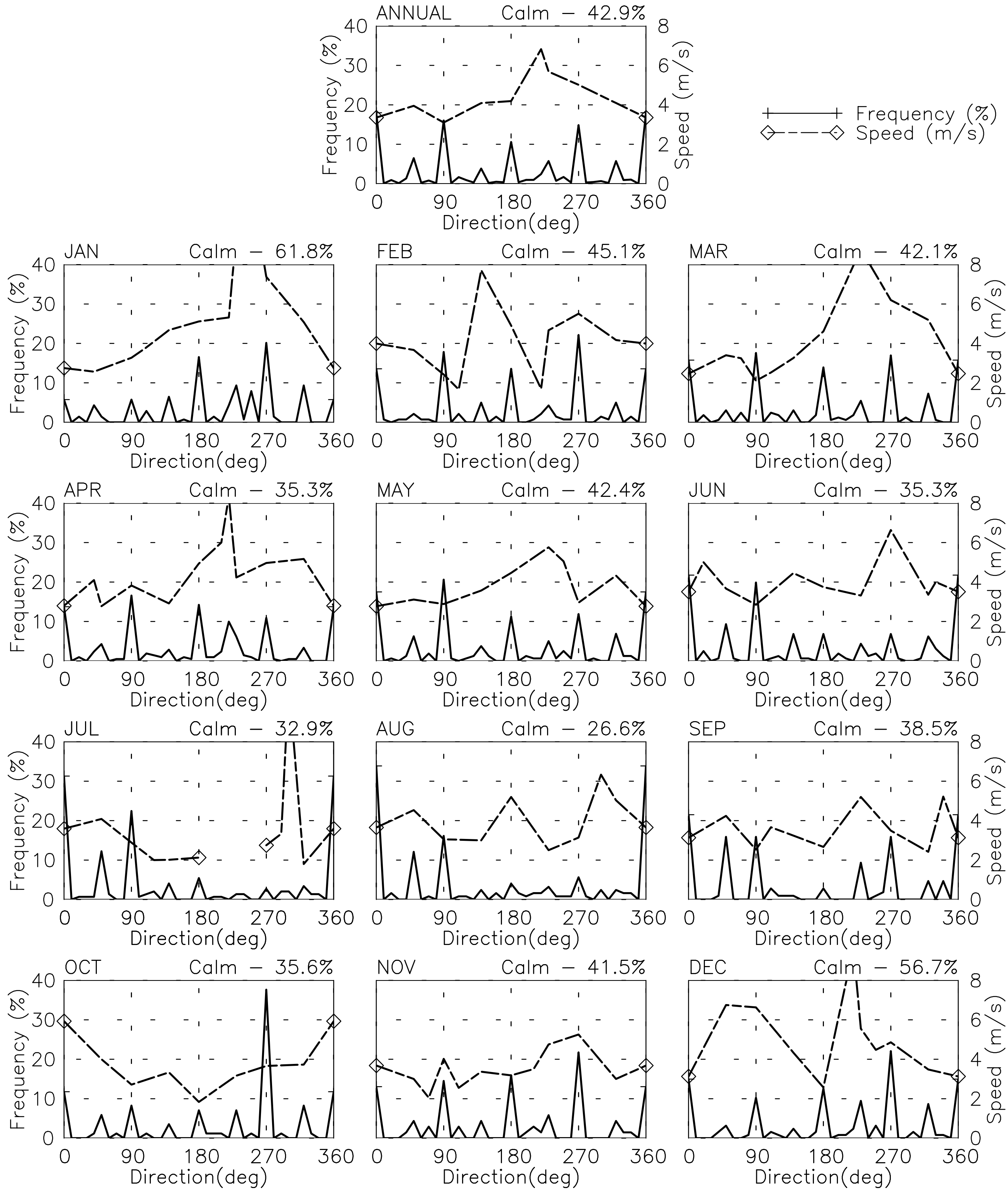
Mon Mar 24 13:38:25 2003

FREQUENCY AND SPEED BY DIRECTION

KAMO AM – 378010

40° 21' N 45° 07' E – Elev 1951m *LST=GMT +3 hours NT= +3

01/59–12/63 01/73–12/79



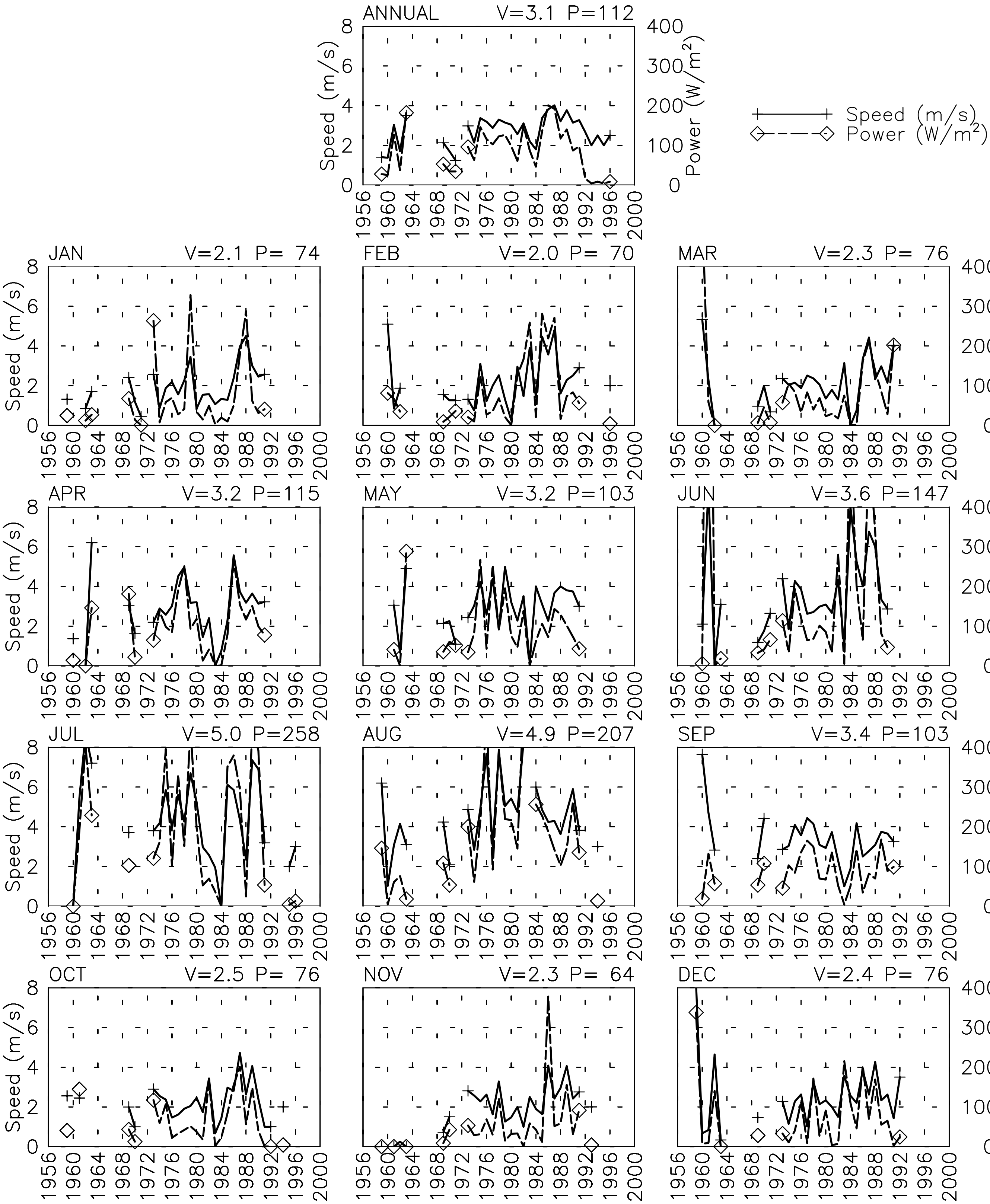
Mon Mar 24 13:38:26 2003

SPEED AND POWER BY YEAR

MEC MAZRA AM – 378150

40° 13' N 45° 46' E – Elev 1940m ∗LST=GMT +3 hours NT= +3

01/59–12/63 01/69–06/71 01/73–07/96



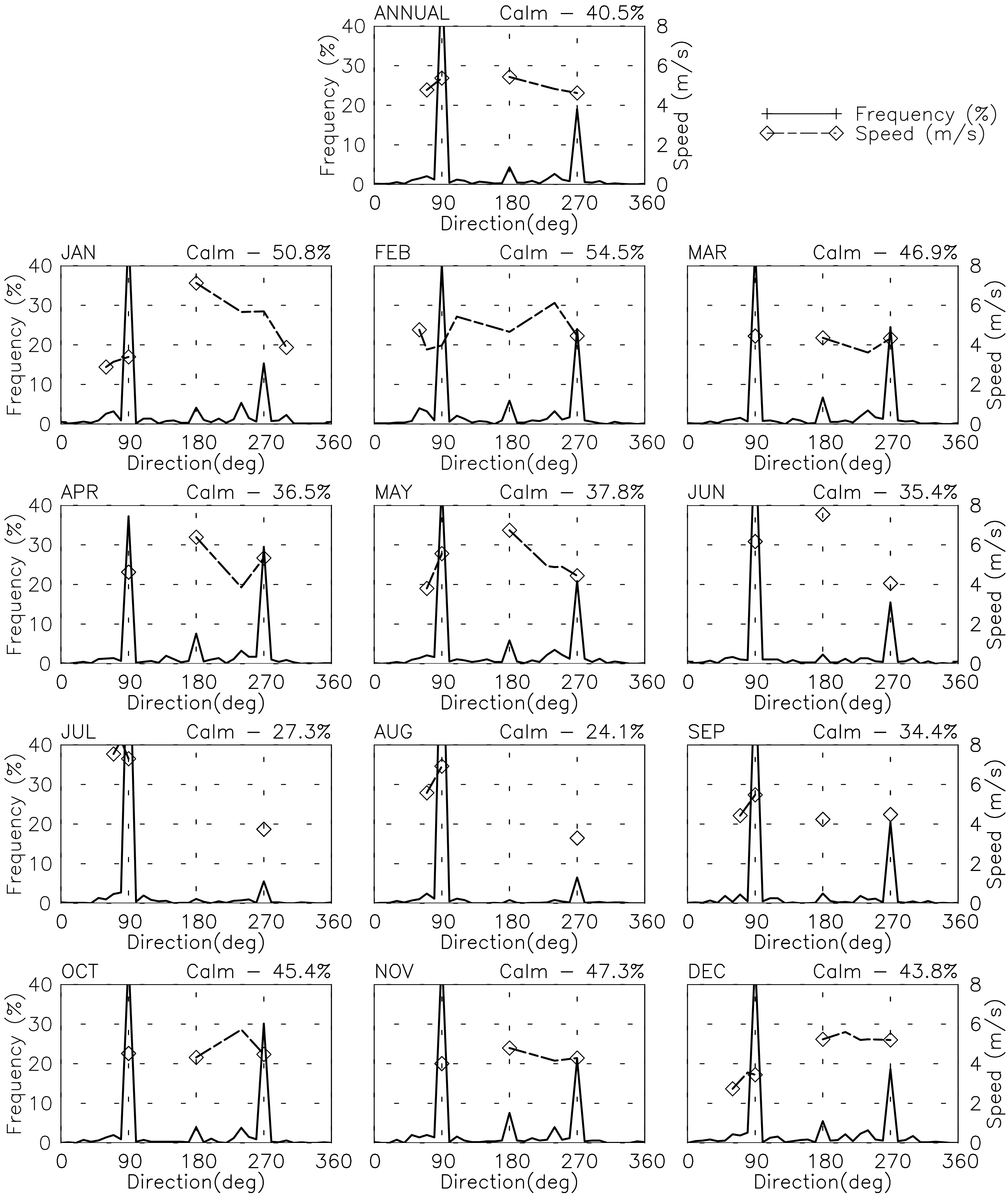
Mon Mar 24 13:38:28 2003

FREQUENCY AND SPEED BY DIRECTION

MEC MAZRA AM - 378150

40° 13' N 45° 46' E - Elev 1940m *LST=GMT +3 hours NT= +3

01/59-12/63 01/69-06/71 01/73-07/96



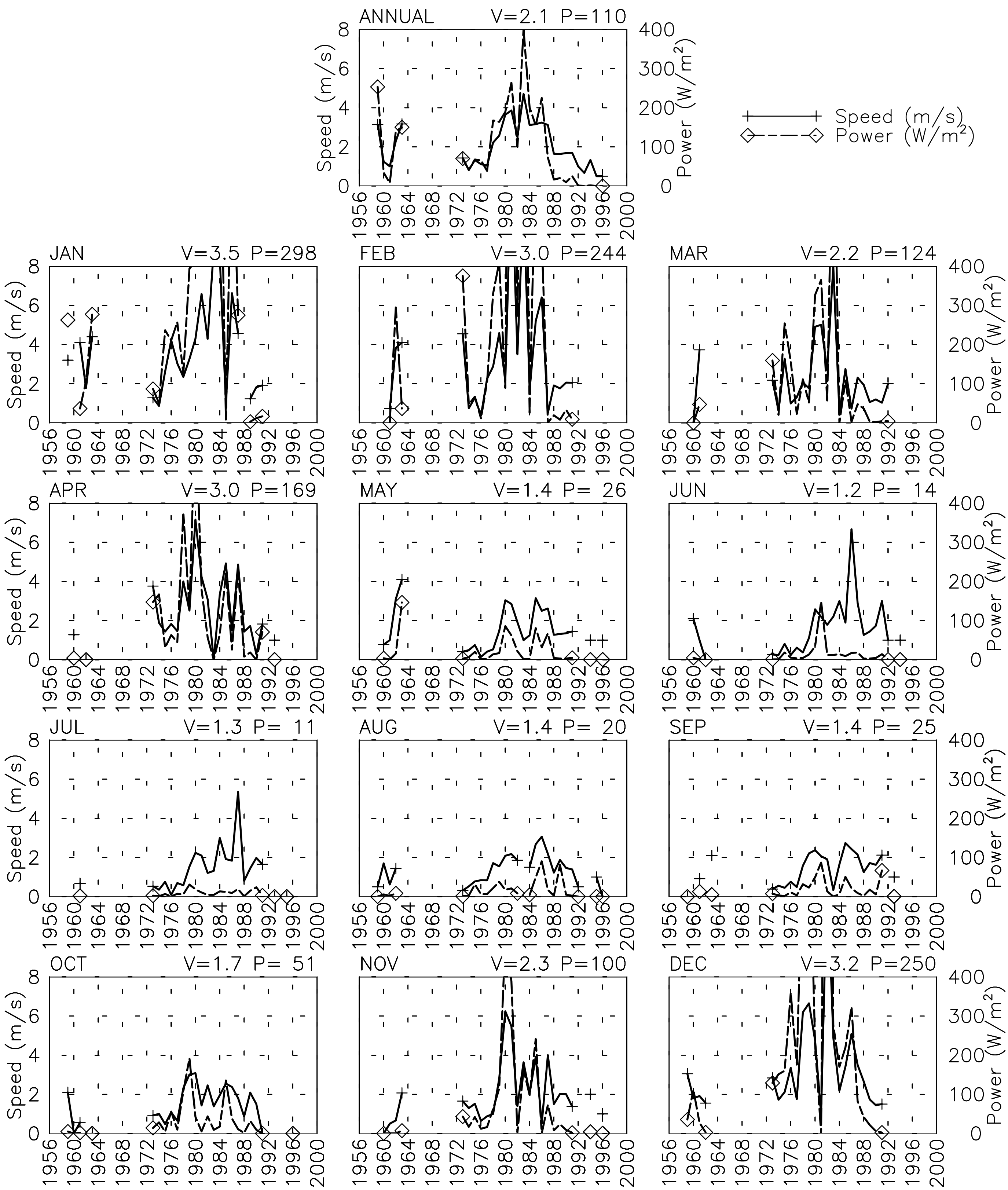
Mon Mar 24 13:38:30 2003

SPEED AND POWER BY YEAR

GORIS (STREAM) AM – 379530

39° 30' N 46° 21' E – Elev 1367m *LST=GMT +3 hours NT= +3

01/59–11/63 01/73–11/96



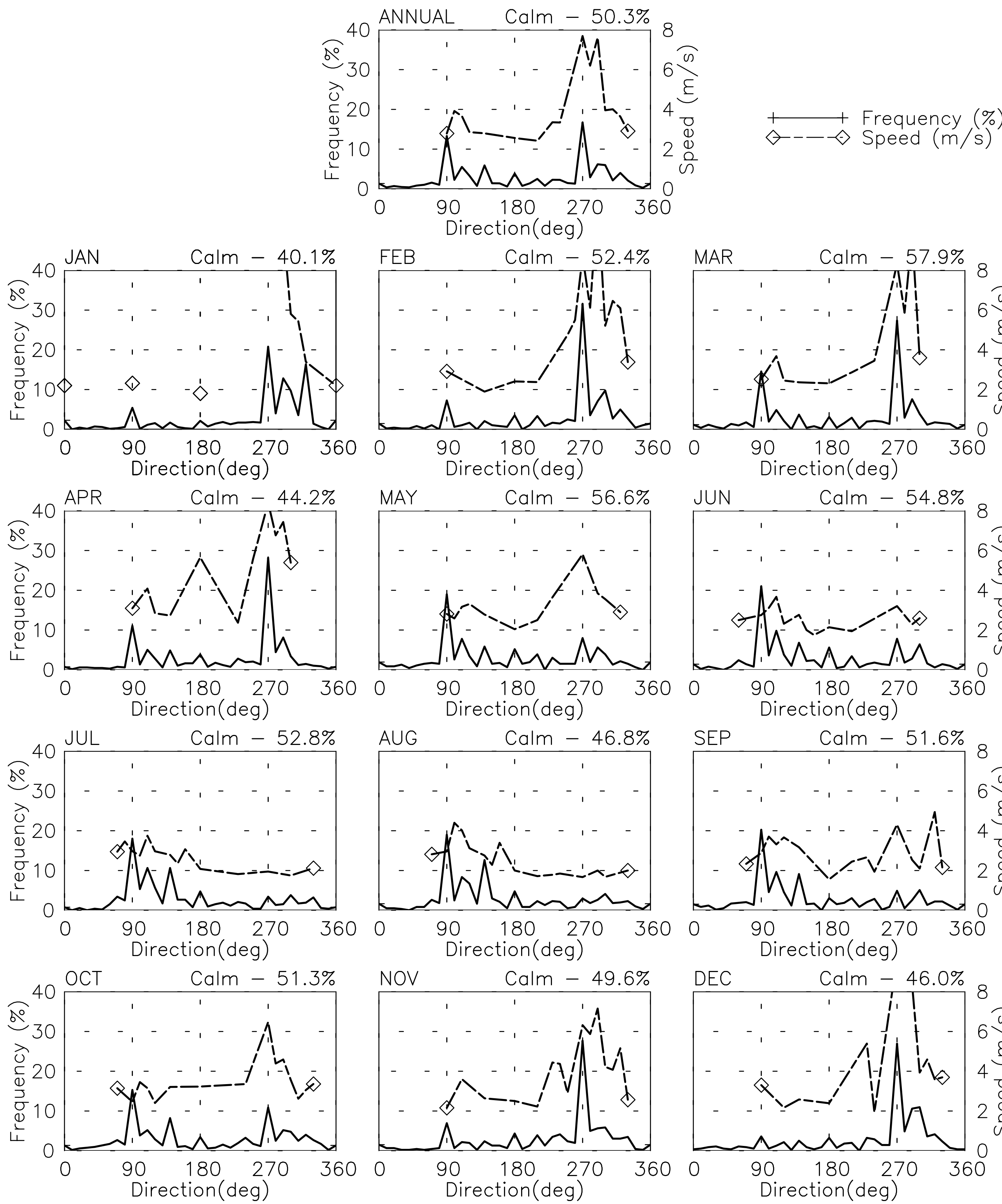
Mon Mar 24 13:38:32 2003

FREQUENCY AND SPEED BY DIRECTION

GORIS (STREAM)   AM - 379530

39° 30' N   46° 21' E - Elev 1367m *LST=GMT +3 hours   NT= +3

01/59-11/63 01/73-11/96



Mon Mar 24 13:38:35 2003

Appendix C

Wind Measurement Stations
Tables and Analysis Summaries of Selected Stations

NREL/SolarEn Stations

Table C.1 – Mean Wind Speeds by Month at NREL Stations
(wind speeds in meters/sec)

		Karakhach			Aparan			Aparan 2			Gagarin			Vorotan Pass		
Ht		**40m**	**20m**	**10m**	**40m**	**20m**	**10m**	**40m**	**20m**	**10m**	**40m**	**20m**	**10m**	**40m**	**20m**	**10m**
Yr	**Mo**															
2001	8	7.69	7.18	6.68												
2001	9	7.29	6.86	6.41												
2001	10	6.68	6.26	5.78												
2001	11	7.34	6.88	6.4	3.61	3.16	2.67				5.08	4.64	4.28	4.69	4.33	4.04
2001	12	7.07	6.99	6.09	5.13	4.42	3.74				6.02	5.28	5.04	4.64	4.27	3.96
2002	1	6.44	6.05	5.55	3.51	3.13	2.69				4.01	3.5	3.39	4.4	3.99	3.74
2002	2	7.55	7.02	6.39	3.76	3.24	2.73				5.62	4.98	4.76	5.05	4.65	4.47
2002	3	6.89	6.42	5.82	3.85	3.27	2.83				4.68	4.27	4.09	4.79	4.35	4.3
2002	4	7.03	6.39	5.87	4.11	3.43	2.94				5.01	4.53	4.28	4.38	4.33	4.1
2002	5		5.92	5.43	3.56	3.02	2.58				4.85	4.35	4.23	5.19	5.1	4.83
2002	6		6.28	5.51	4.14	3.48	2.88	5.25	5.1	5.04	4.92	4.35	4.1	7.48	7.15	6.74
2002	7		7.17	6.32				5.95	5.85	5.68	5.34	4.65	4.29	9.82	9.48	8.91
2002	8		7.06	6.16				5.01	4.98	4.85	5.13	4.57	4.28	9.1	8.8	8.26
2002	9		5.95	5.15				4.77	4.6	4.4	4.25	3.75	3.57	7.02	6.79	6.34
2002	10		5.46	4.77				5.11	4.97	4.7	4.07	3.72	3.57	5.15	4.84	4.48
2002	11		4.77	4.13				4.52	4.38	4.18	4.23	3.77	3.64			
2002	12		2.68	1.97				3.47	3.87	3.9						

Table C.2 – Mean Wind Power Densities by Month at NREL Stations
(WP in W/m^2)

		Karakhach			Aparan			Aparan 2			Gagarin			Vorotan Pass		
Ht		**40m**	**20m**	**10m**	**40m**	**20m**	**10m**	**40m**	**20m**	**10m**	**40m**	**20m**	**10m**	**40m**	**20m**	**10m**
Yr	**Mo**															
2001	8	317	258	206												
2001	9	295	240	198												
2001	10	276	222	176												
2001	11	364	300	240	136	85	54				209	153	123	110	95	76
2001	12	331	287	217	238	152	98				284	206	180	128	107	91
2002	1	346	287	225	186	122	76				180	133	113	120	104	91
2002	2	543	457	370	127	79	46				274	200	171	157	132	118
2002	3	381	313	228	149	91	56				163	121	102	173	138	129
2002	4	367	265	216	119	71	44				156	120	103	112	104	94
2002	5		217	179	68	40	25				122	93	81	172	160	140
2002	6		197	141	98	58	33	112	107	102	120	87	71	290	255	217
2002	7		243	175				145	137	126	119	80	63	572	514	431
2002	8		221	152				103	99	92	113	86	71	492	446	375
2002	9		171	123				95	88	78	96	73	62	264	241	203
2002	10		161	127				141	135	118	139	106	90	161	134	112
2002	11		125	95				90	84	75	159	117	97			
2002	12		28	15				29	43	42						

Table C.3 – Number of Observations by Month at NREL Stations

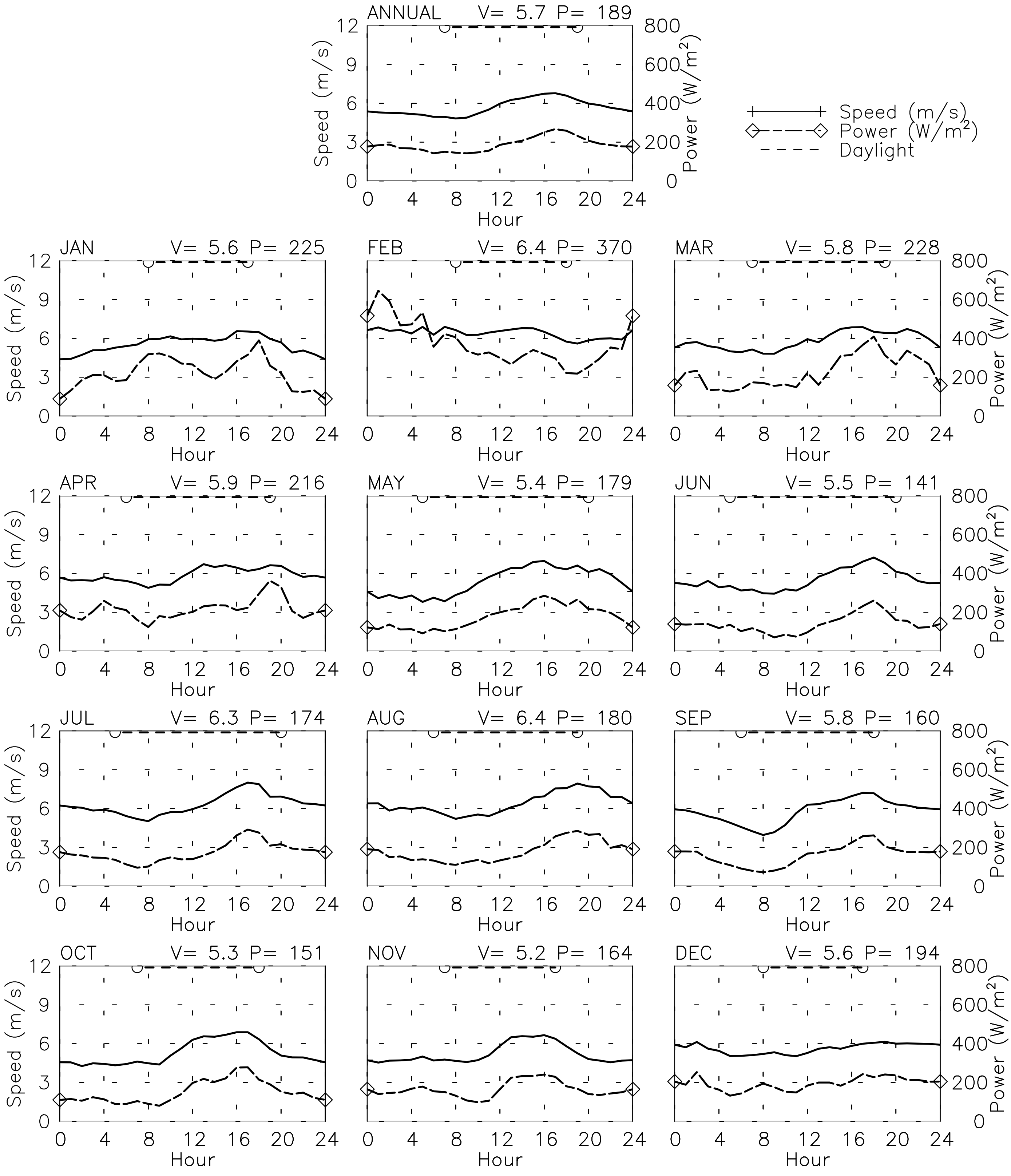
		Karakhach			Aparan			Aparan 2			Gagarin			Vorotan Pass		
Ht		**40m**	**20m**	**10m**	**40m**	**20m**	**10m**	**40m**	**20m**	**10m**	**40m**	**20m**	**10m**	**40m**	**20m**	**10m**
Yr	**Mo**															
2001	8	2071	2071	2071												
2001	9	4320	4320	4320												
2001	10	4464	4464	4464												
2001	11	3981	3981	3981	1634	1634	1634				4217	4151	4217	3334	3442	3502
2001	12	3510	3216	4002	4464	4464	4464				4230	4326	4224	3917	3999	4053
2002	1	4093	4092	4094	4138	4054	4204				4298	4297	4297	4338	4200	4110
2002	2	3744	3672	3708	3978	4032	3966				4032	4032	4032	4024	4027	3971
2002	3	3407	3448	3865	4461	4459	4461				4127	4126	4126	4456	4459	4457
2002	4	2370	4008	4098	4317	4315	4317				4210	4210	4210	4320	4320	4320
2002	5		4060	3960	4464	4464	4464				3508	3507	3507	4456	4459	4457
2002	6		4320	4320	1761	1761	1761	333	333	333	4319	4318	4318	4320	4320	4320
2002	7		3954	3955				4464	4464	4464	4463	4462	4462	4417	4420	4418
2002	8		1966	1968				4313	4313	4313	4463	4462	4462	4464	4464	4464
2002	9		4320	4320				4320	4320	4320	4320	4320	4320	4091	4094	4092
2002	10		4453	4454				4464	4464	4464	4121	4120	4120	2379	2379	2379
2002	11		4320	4320				4320	4320	4320	2664	2664	2664			
2002	12		507	507				162	162	162						

SPEED AND POWER BY HOUR

Karakhach 10m – 002012

41° 01' N 43° 59' E – Elev 2316m LST=GMT+99 hours *NT= +3

08/01–12/02



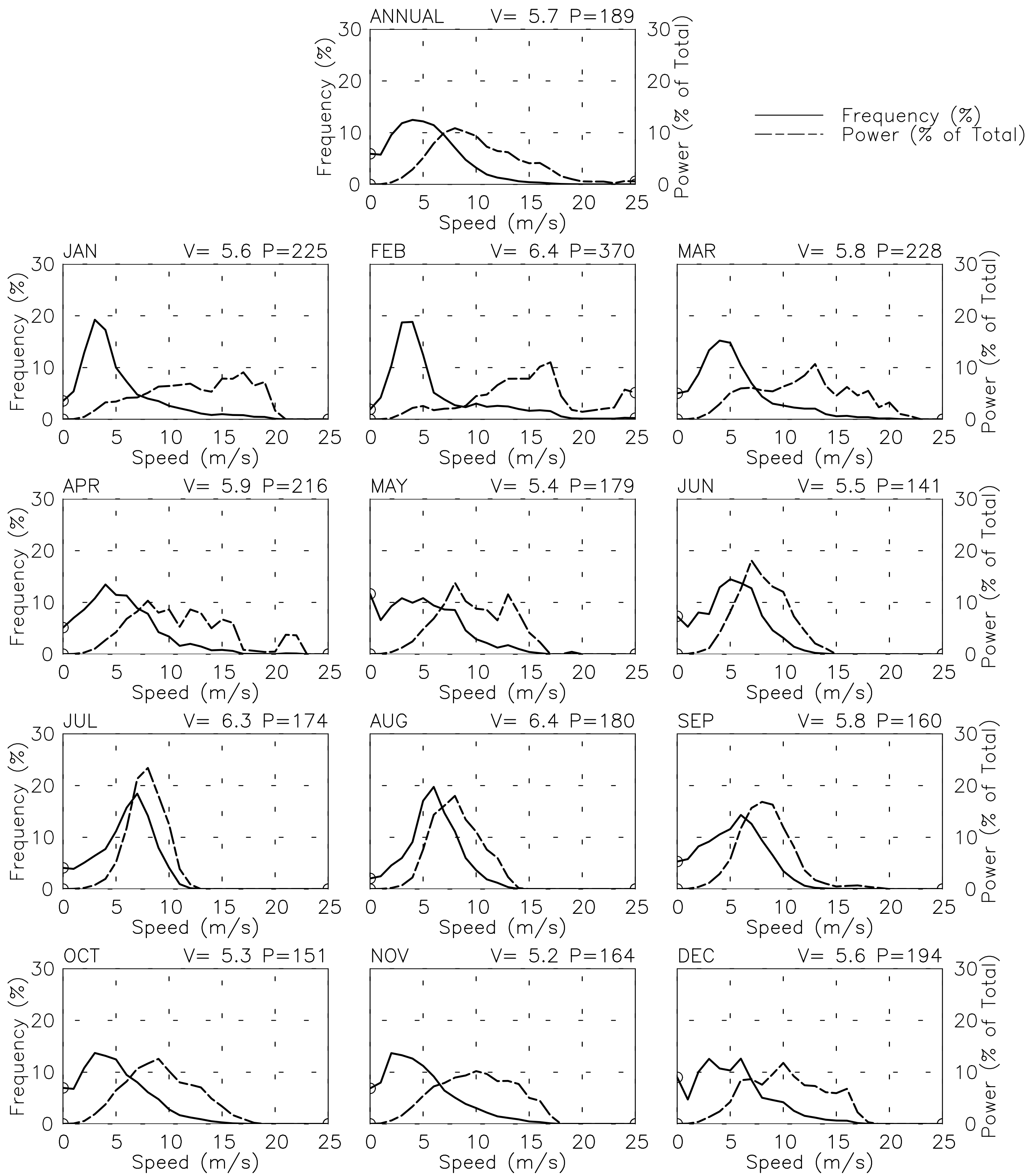
Mon Mar 17 10:00:17 2003

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

Karakhach 10m – 002012

41° 01' N 43° 59' E – Elev 2316m LST=GMT+99 hours *NT= +3

08/01–12/02



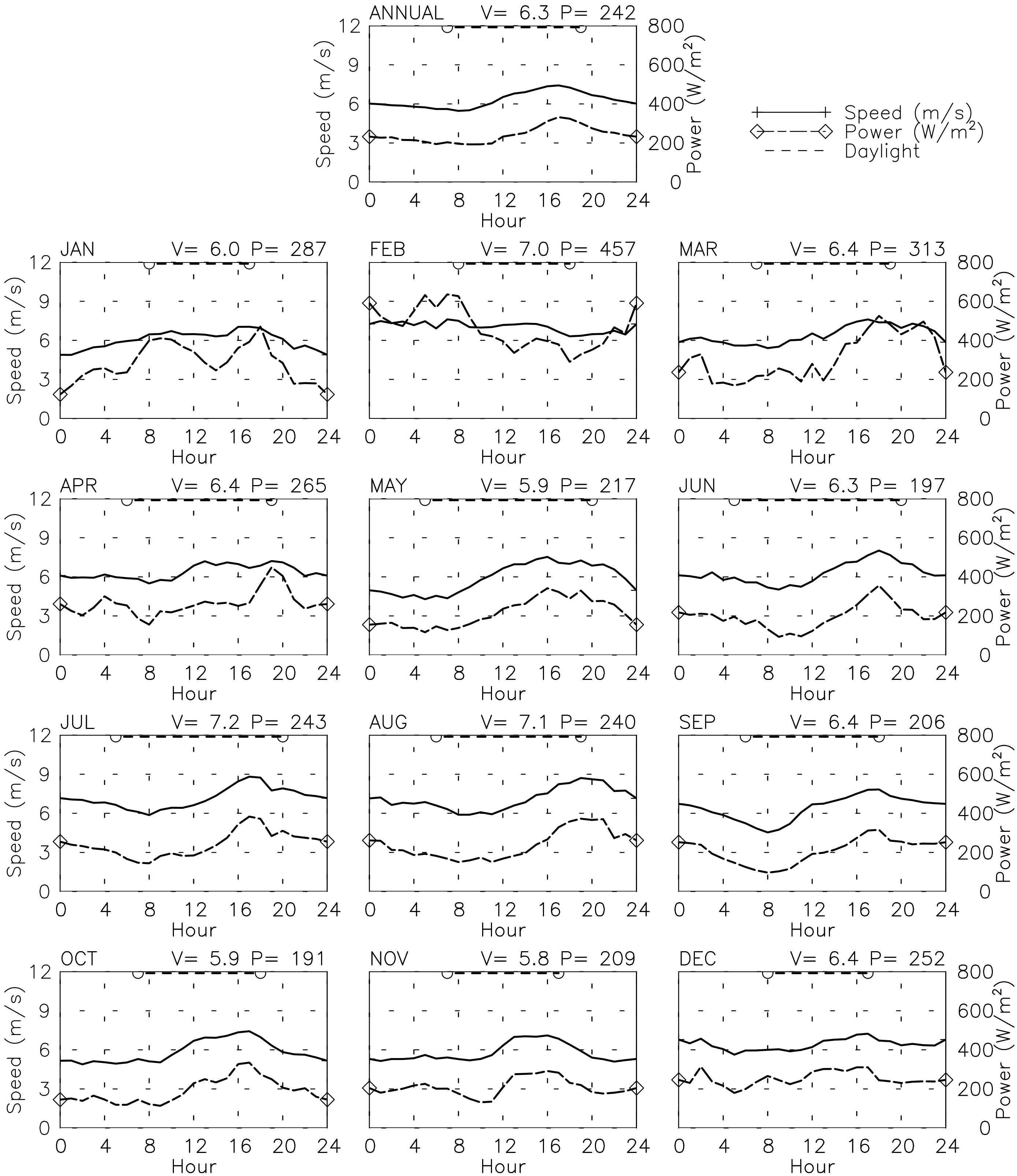
Mon Mar 17 10:00:18 2003

SPEED AND POWER BY HOUR

Karakhach 20m – 002011

41° 01' N   43° 59' E – Elev 2316m   LST=GMT+99 hours   *NT= +3

08/01–12/02



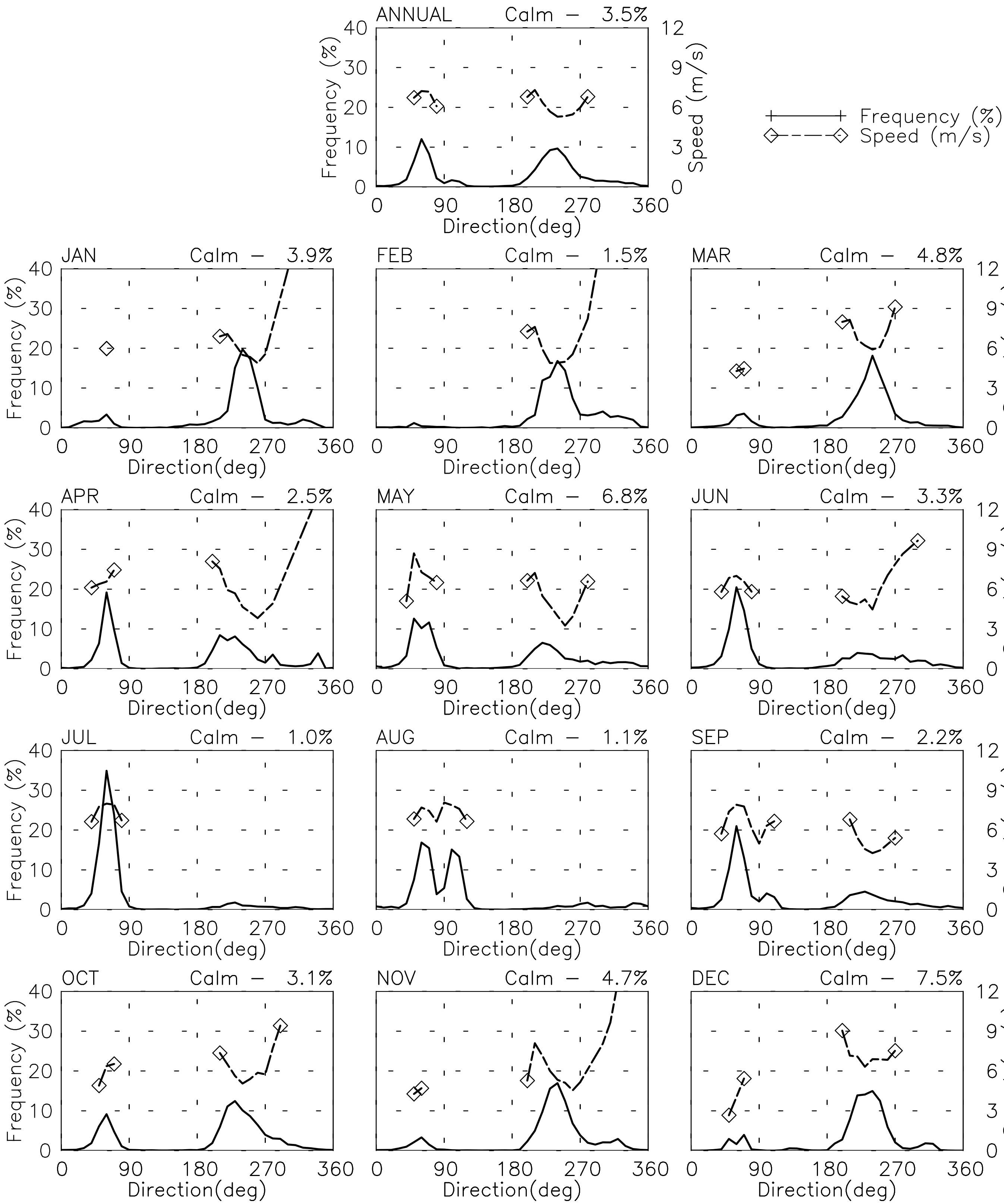
Mon Mar 17 10:00:13 2003

FREQUENCY AND SPEED BY DIRECTION

Karakhach 20m – 002011

41° 01' N 43° 59' E – Elev 2316m LST=GMT+99 hours *NT= +3

08/01–12/02



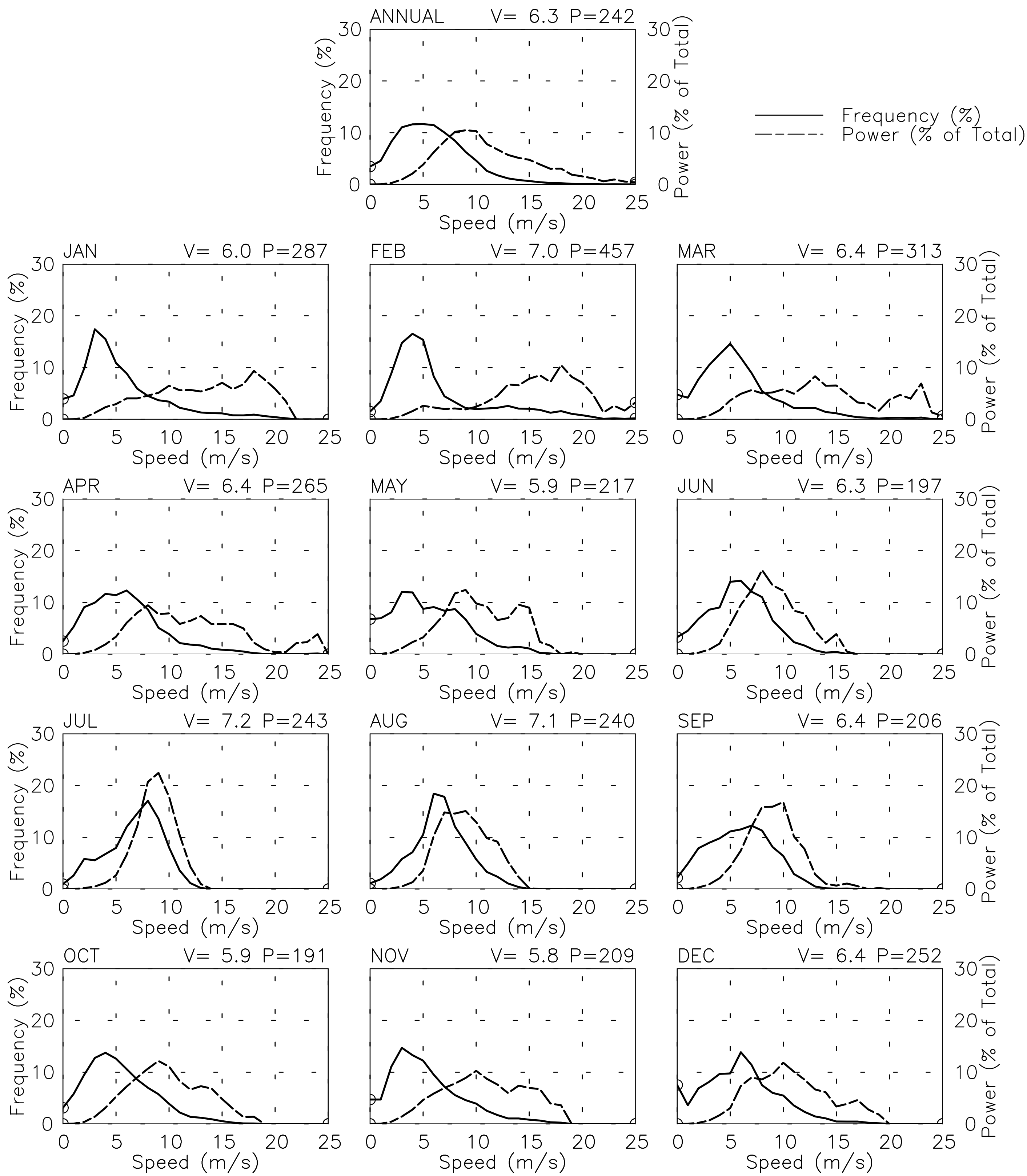
Mon Mar 17 10:00:14 2003

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

Karakhach 20m – 002011

41° 01' N   43° 59' E – Elev 2316m   LST=GMT+99 hours   *NT= +3

08/01–12/02



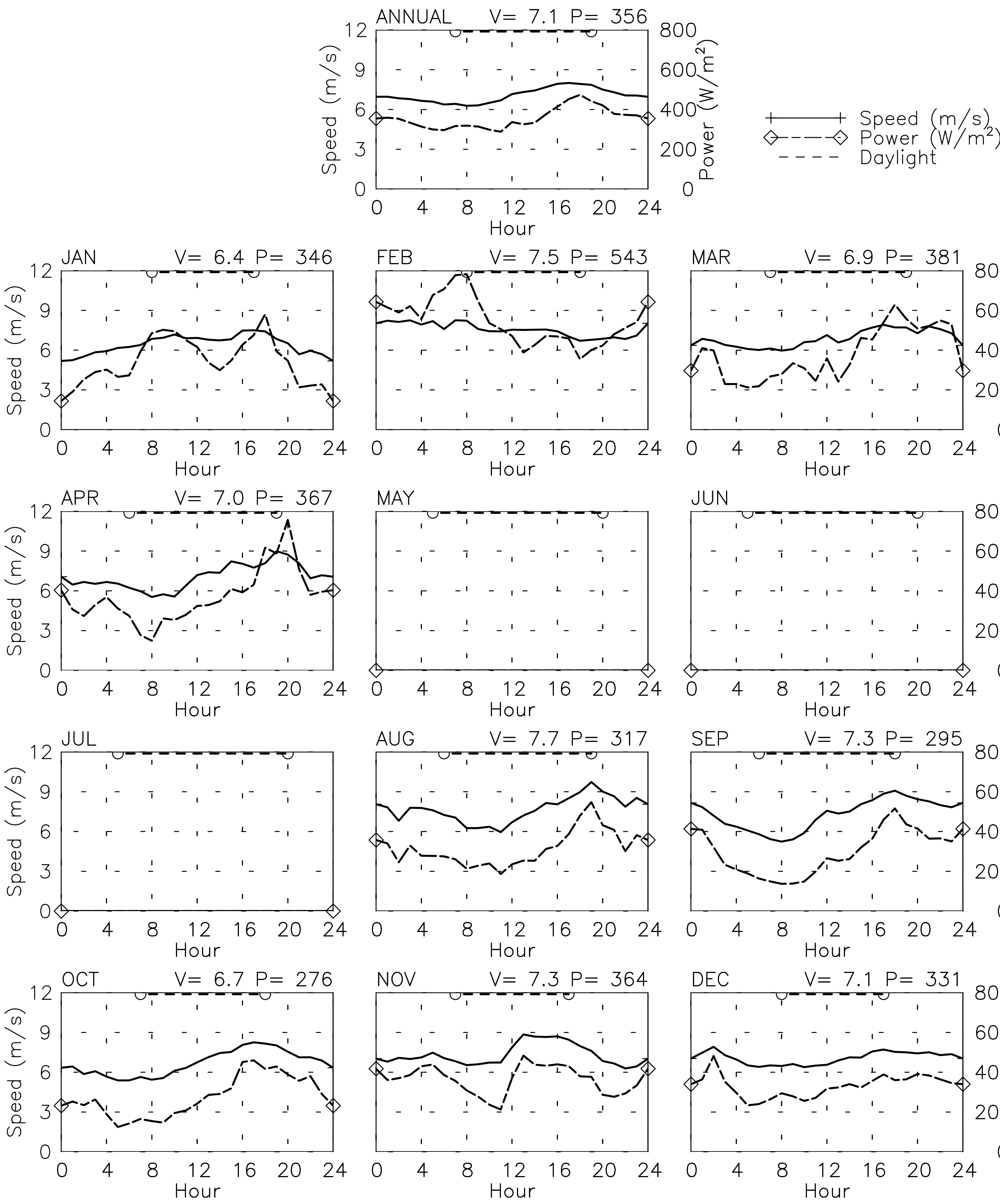
Mon Mar 17 10:00:15 2003

SPEED AND POWER BY HOUR

Karakhach 40m - 002010

41° 01' N 43° 59' E - Elev 2316m LST=GMT+99 hours *NT= +3

08/01-04/02



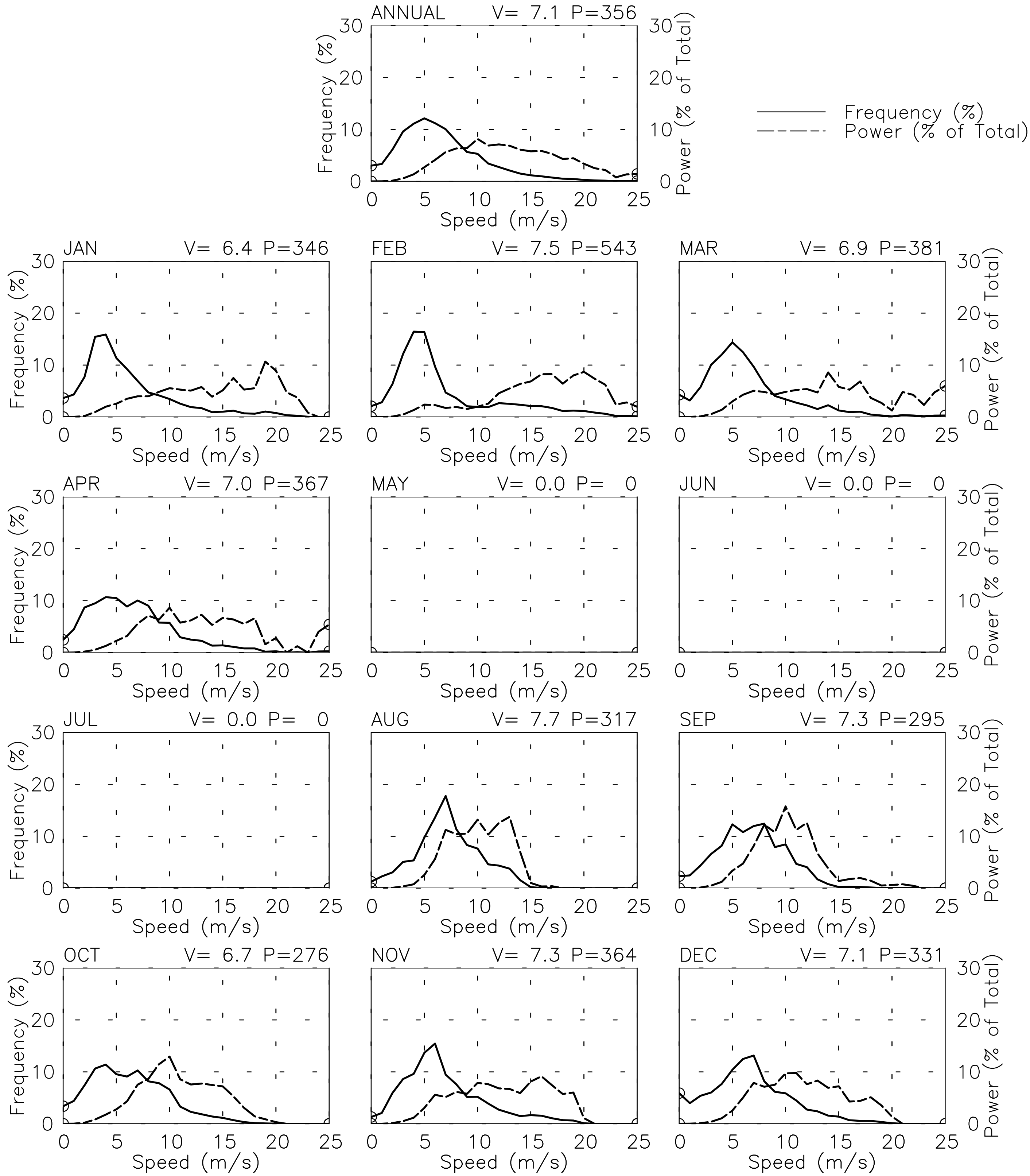
Mon Mar 17 10:00:10 2003

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

Karakhach 40m - 002010

41° 01' N 43° 59' E - Elev 2316m LST=GMT+99 hours *NT= +3

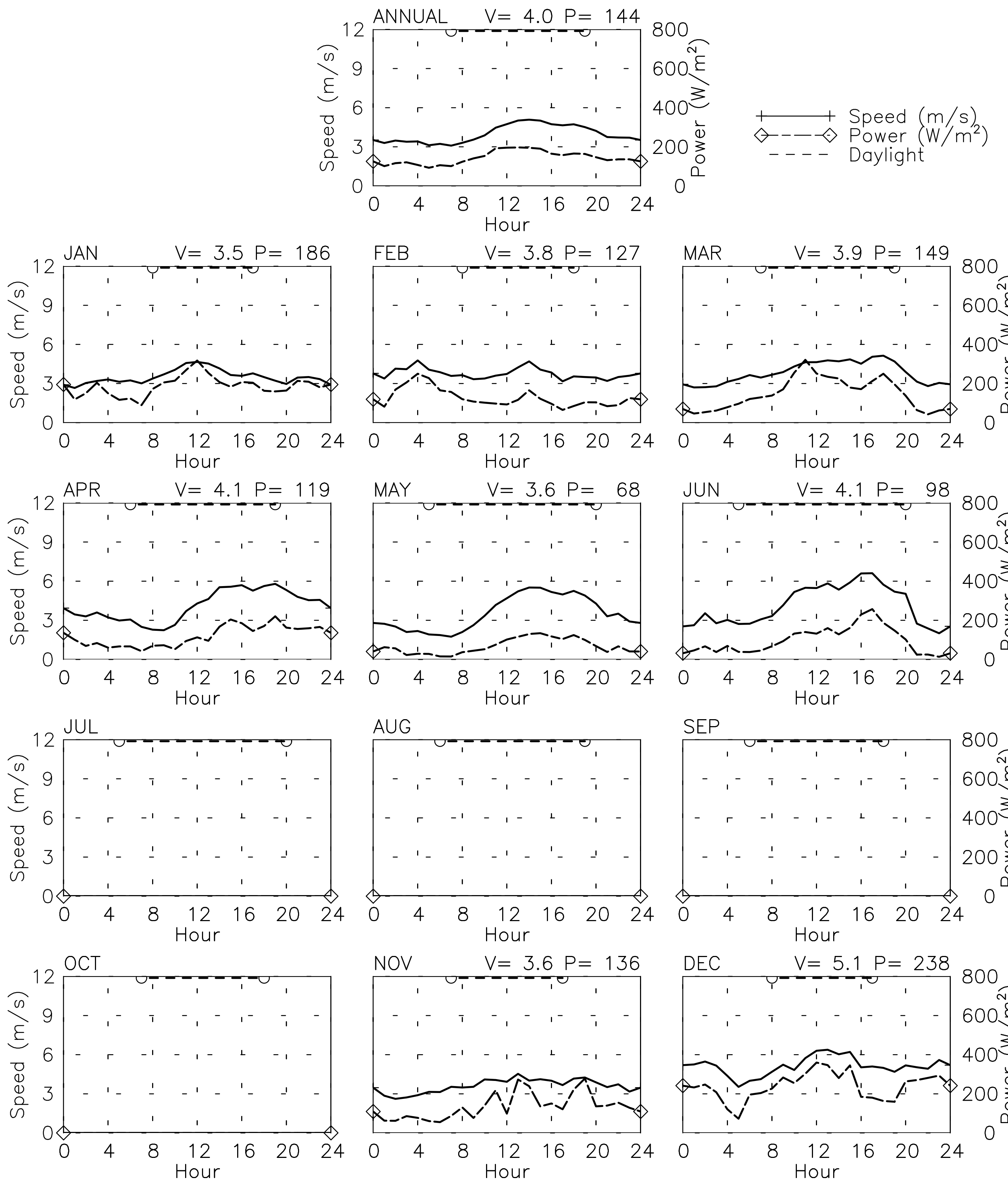
08/01-04/02



Mon Mar 17 10:00:11 2003

SPEED AND POWER BY HOUR

Aparan 40m – 003010
40° 40' N 44° 21' E – Elev 2098m LST=GMT+99 hours *NT= +3
11/01–06/02



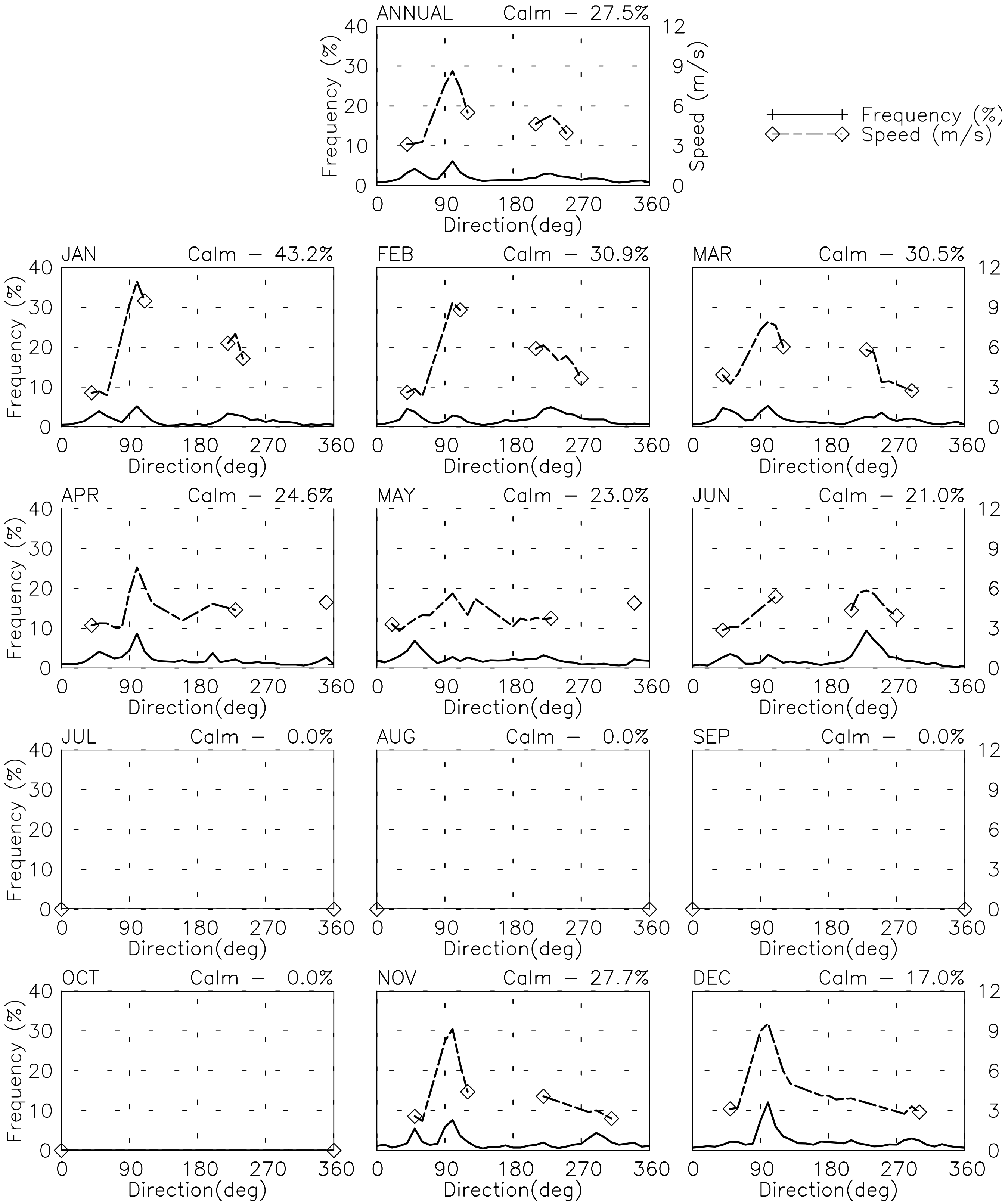
Mon Mar 17 10:00:19 2003

FREQUENCY AND SPEED BY DIRECTION

Aparan 20m – 003011

40° 40' N 44° 21' E – Elev 2098m LST=GMT+99 hours *NT= +3

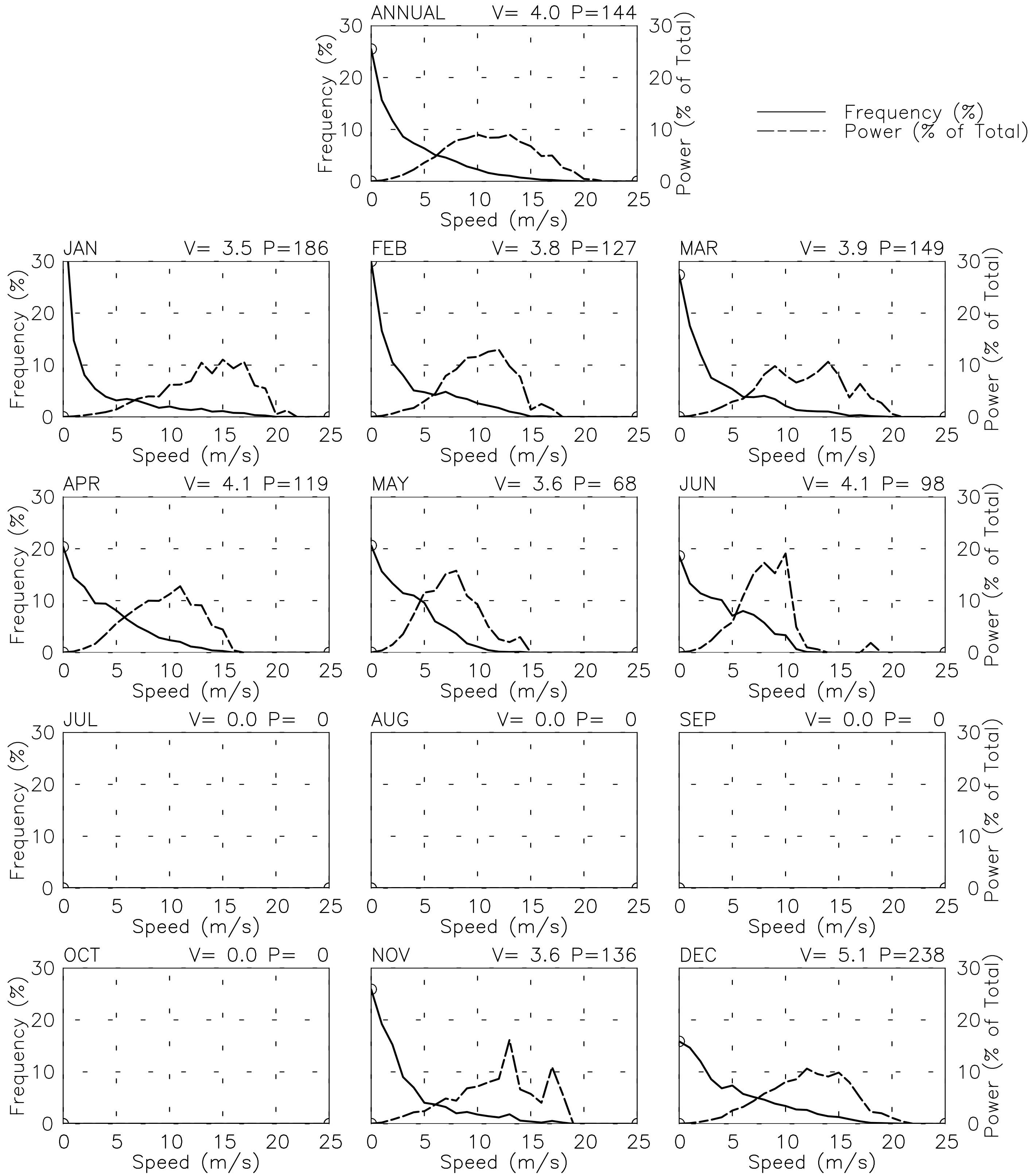
11/01–06/02



Mon Mar 17 10:00:23 2003

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

Aparan 40m – 003010
40° 40' N 44° 21' E – Elev 2098m LST=GMT+99 hours *NT= +3
11/01–06/02



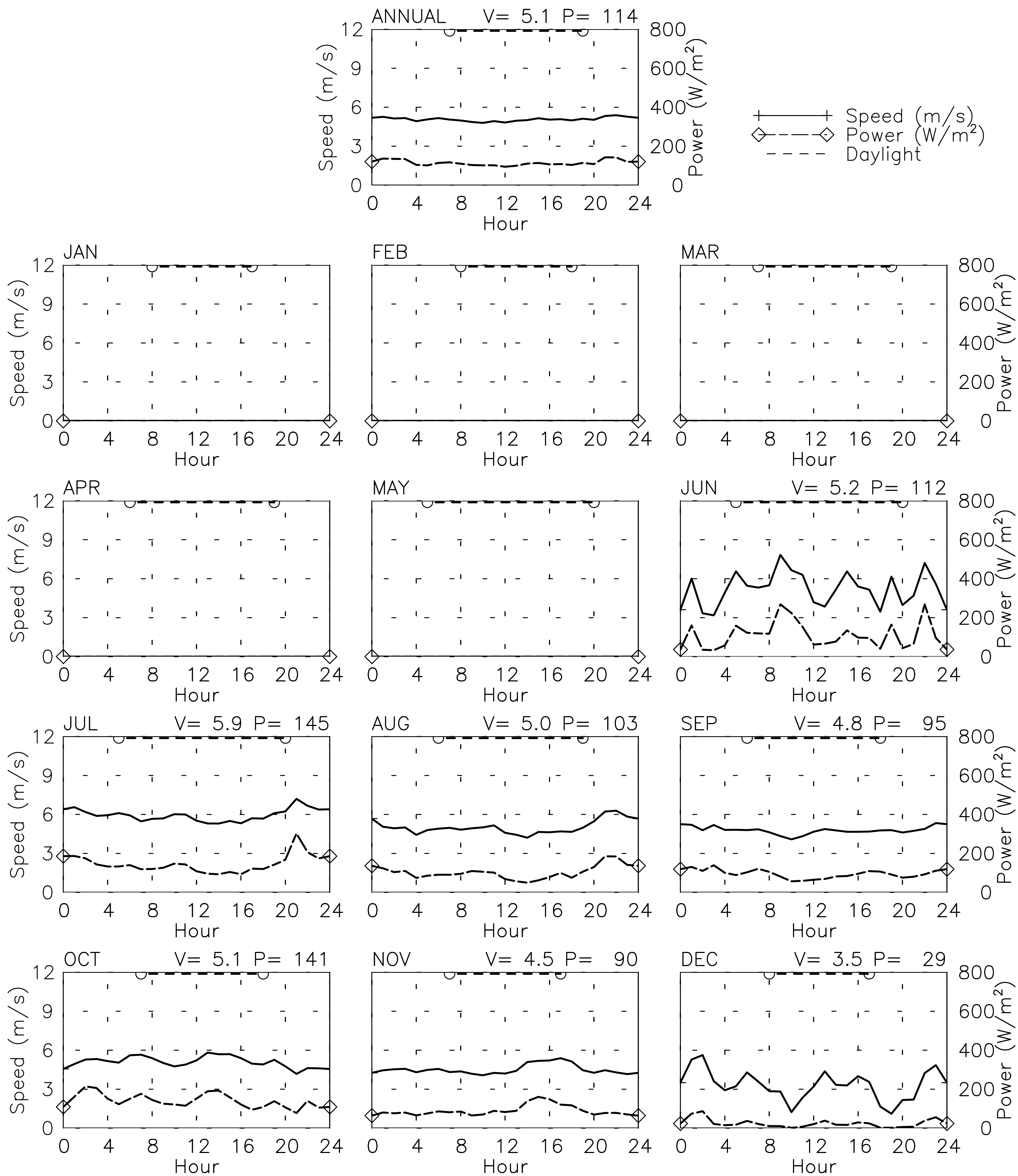
Mon Mar 17 10:00:21 2003

SPEED AND POWER BY HOUR

Aparan 40m site 2 – 003020

40° 39' N   44° 24' E – Elev 2685m   LST=GMT+99 hours   *NT= +3

06/02–12/02



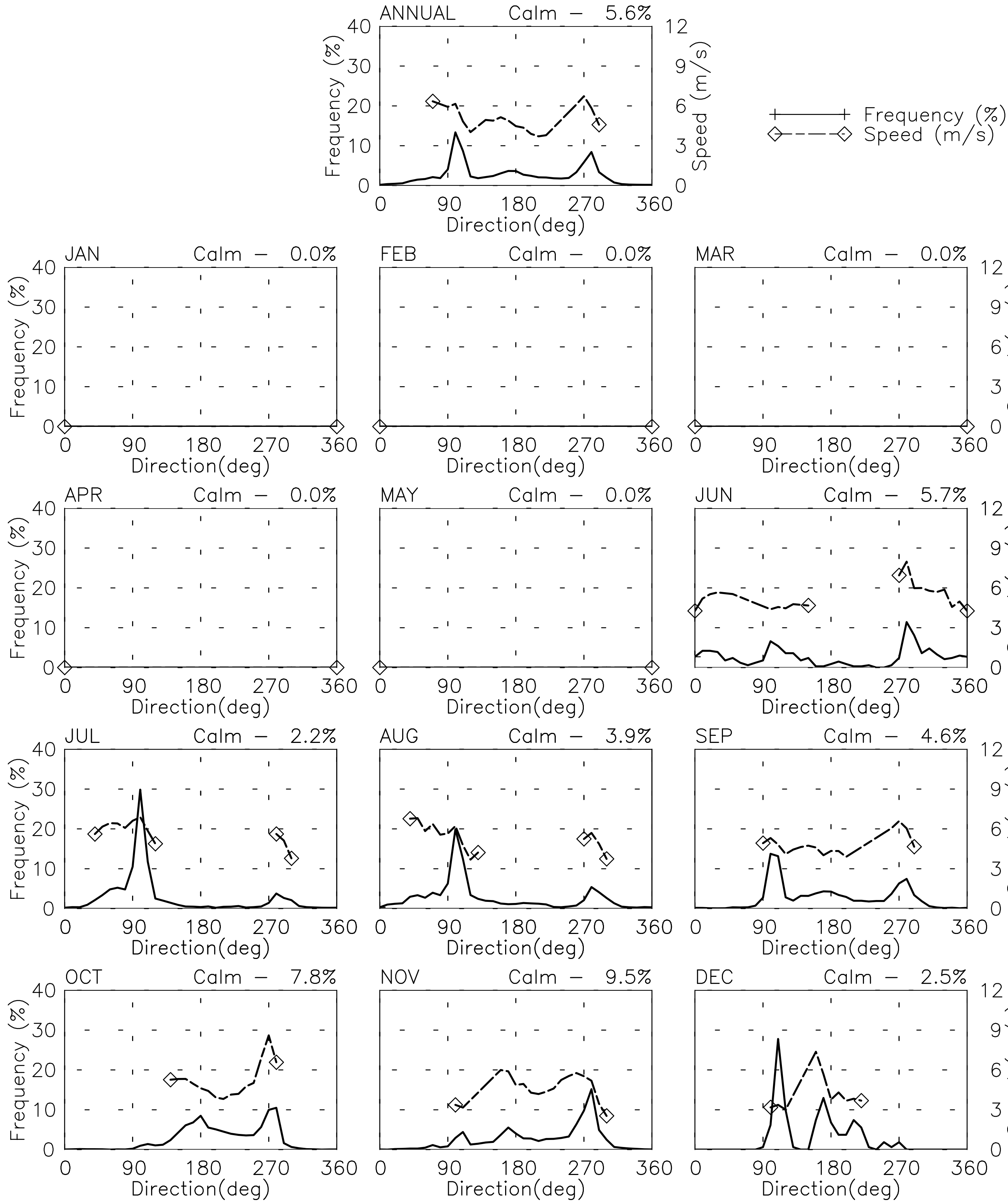
Mon Mar 17 10:00:28 2003

FREQUENCY AND SPEED BY DIRECTION

Aparan 20m site 2 – 003021

40° 39' N 44° 24' E – Elev 2685m LST=GMT+99 hours *NT= +3

06/02–12/02



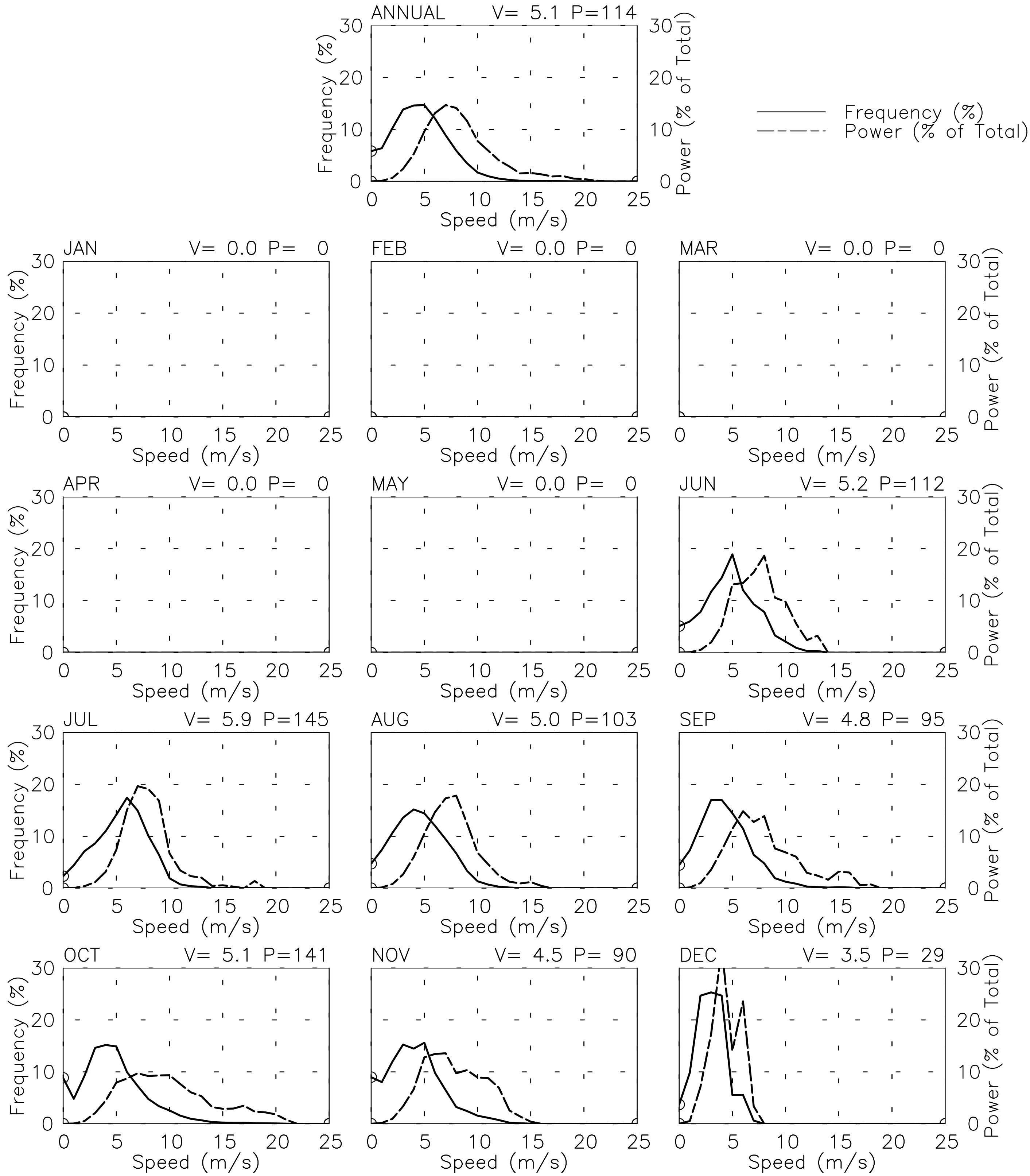
Mon Mar 17 10:00:31 2003

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

Aparan 40m site 2 – 003020

40° 39' N 44° 24' E – Elev 2685m LST=GMT+99 hours *NT= +3

06/02–12/02



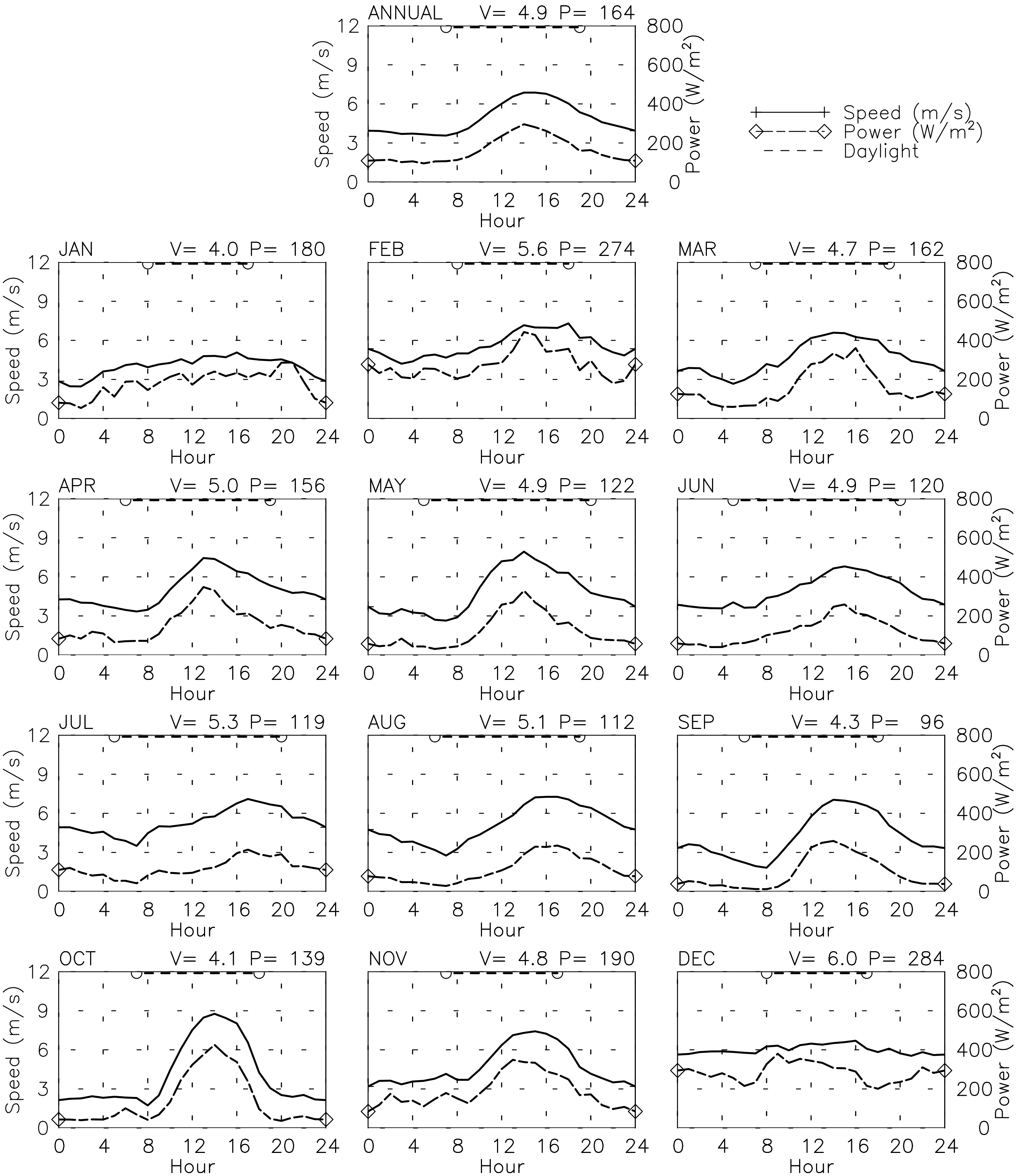
Mon Mar 17 10:00:29 2003

SPEED AND POWER BY HOUR

Gagarin 40m – 004010

40° 32' N   44° 51' E – Elev 1921m   LST=GMT+99 hours   *NT= +3

11/01–11/02



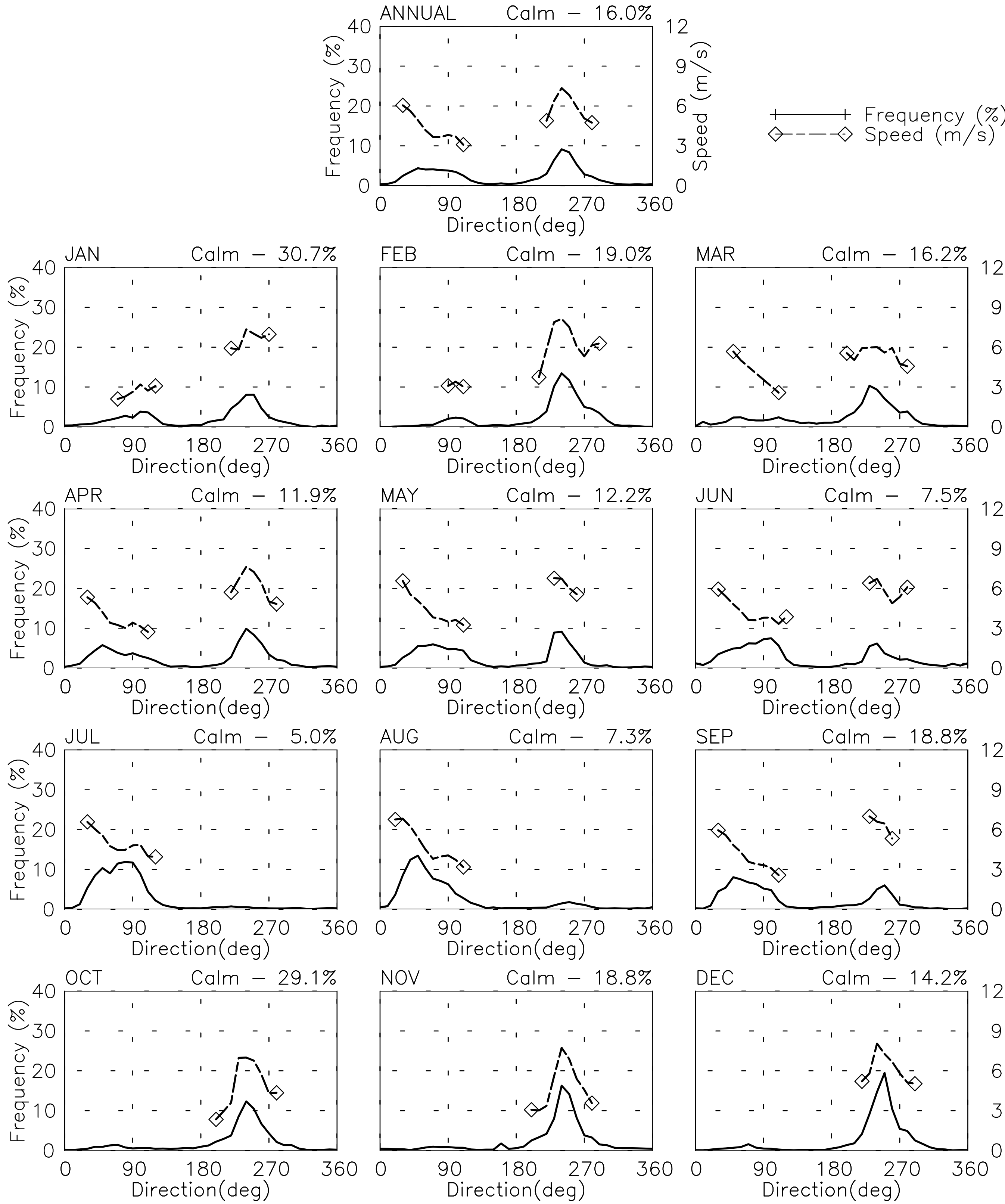
Mon Mar 17 10:00:36 2003

FREQUENCY AND SPEED BY DIRECTION

Gagarin 20m – 004011

40° 32' N 44° 51' E – Elev 1921m LST=GMT+99 hours *NT= +3

11/01–11/02



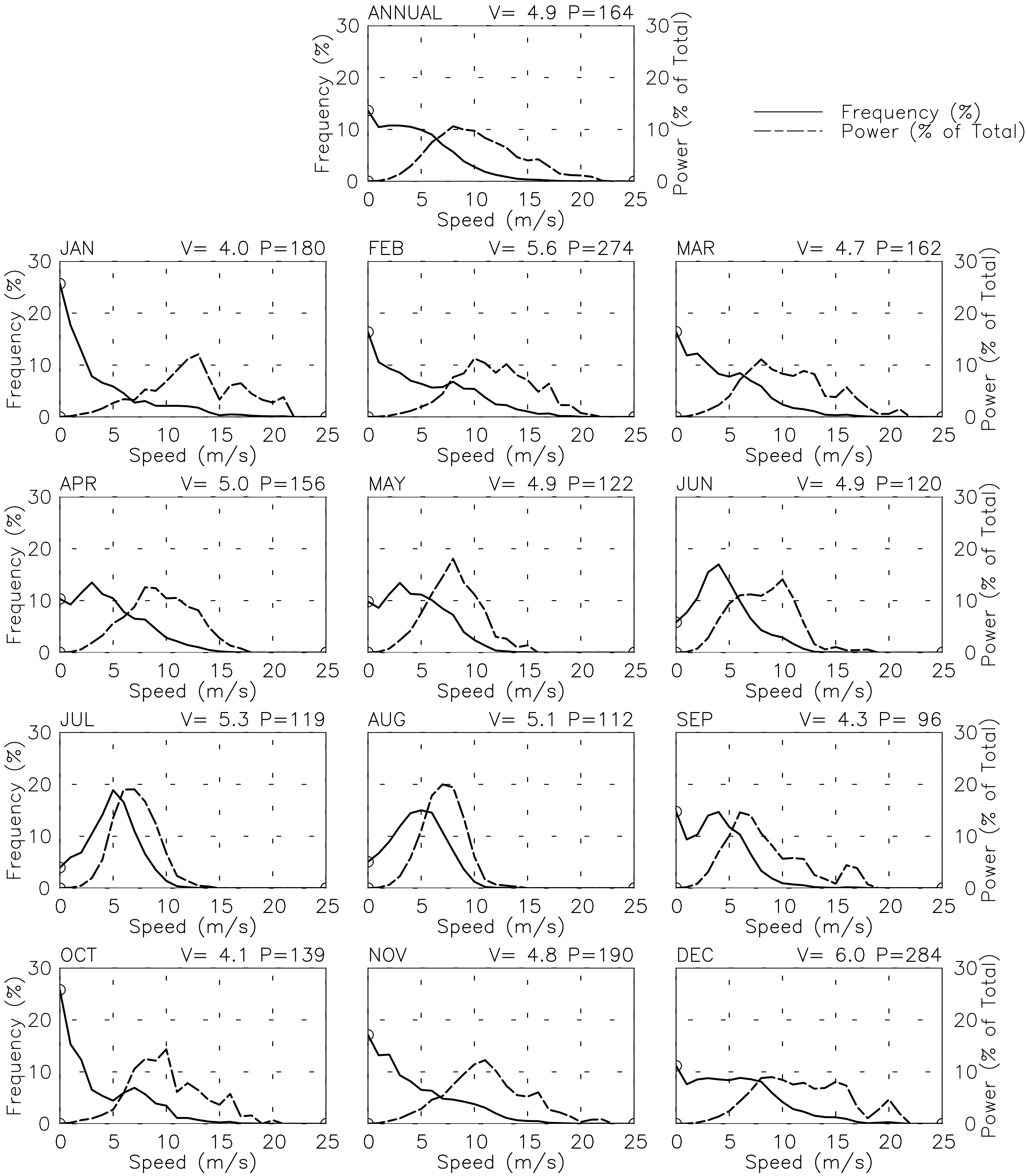
Mon Mar 17 10:00:41 2003

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

Gagarin 40m – 004010

40° 32' N 44° 51' E – Elev 1921m LST=GMT+99 hours *NT= +3

11/01–11/02



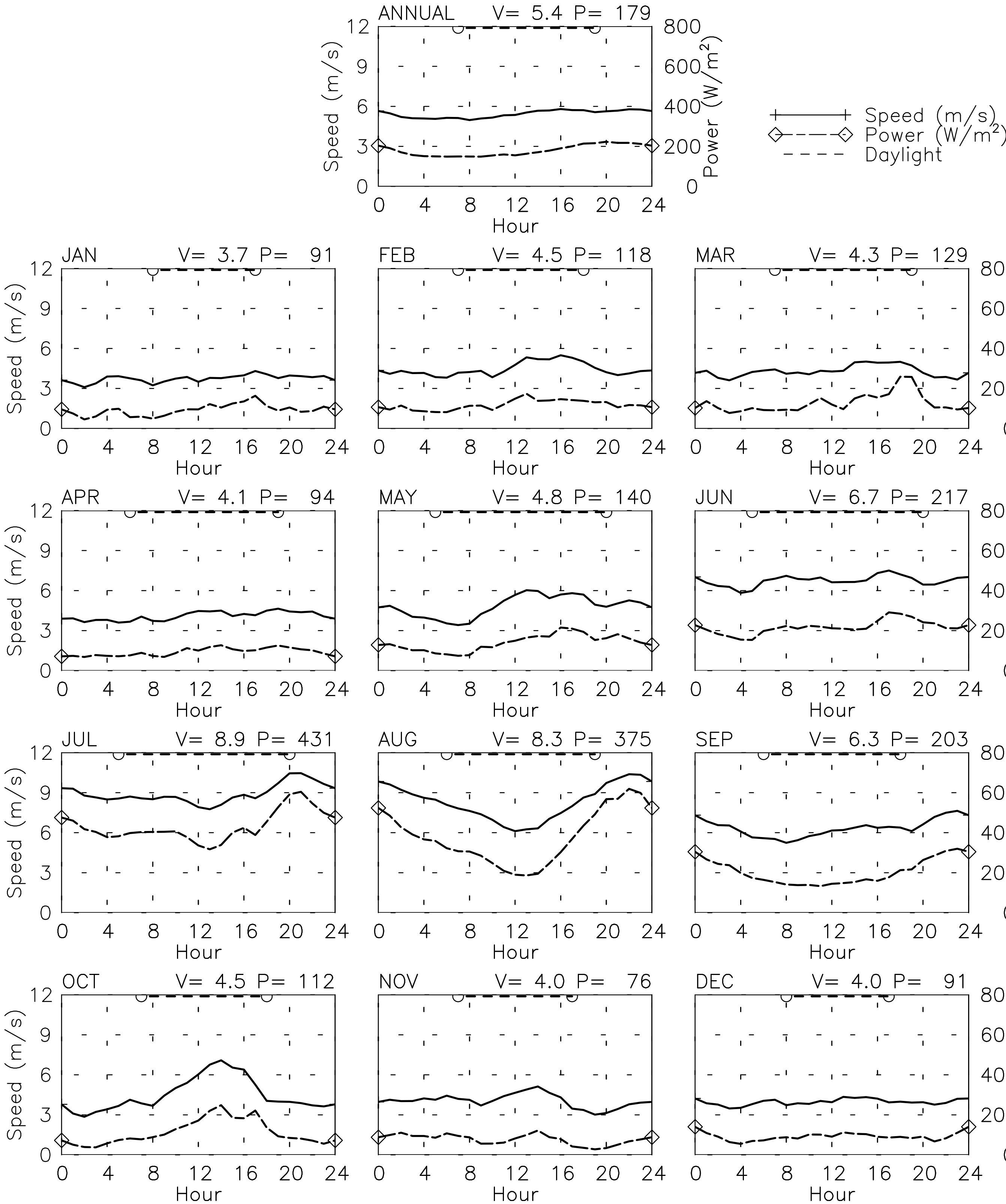
Mon Mar 17 10:00:38 2003

SPEED AND POWER BY HOUR

Vorotan Pass 10m - 005012

39° 42' N 45° 43' E - Elev 2408m LST=GMT+99 hours *NT= +3

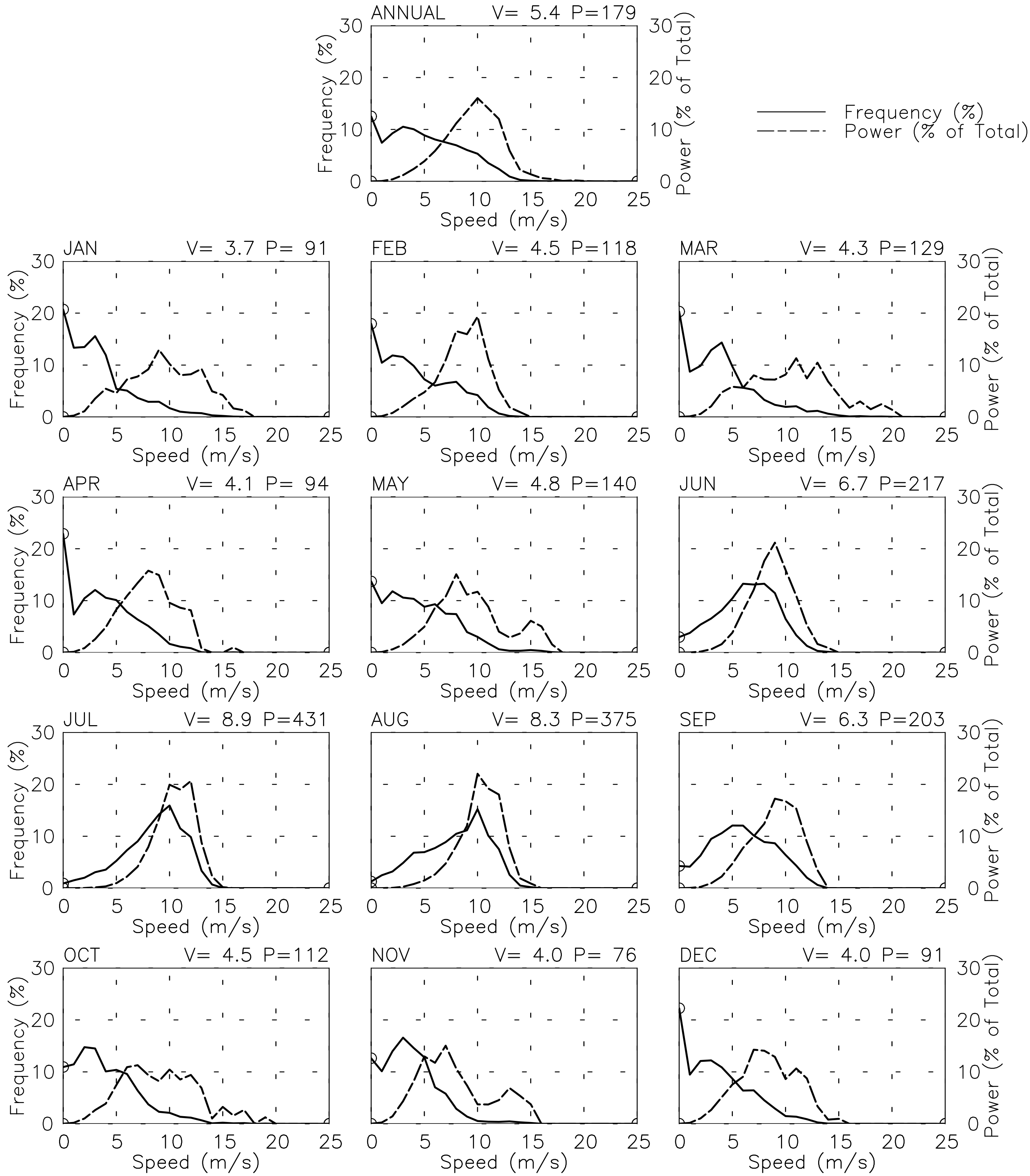
11/01-10/02



Mon Mar 17 10:00:53 2003

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

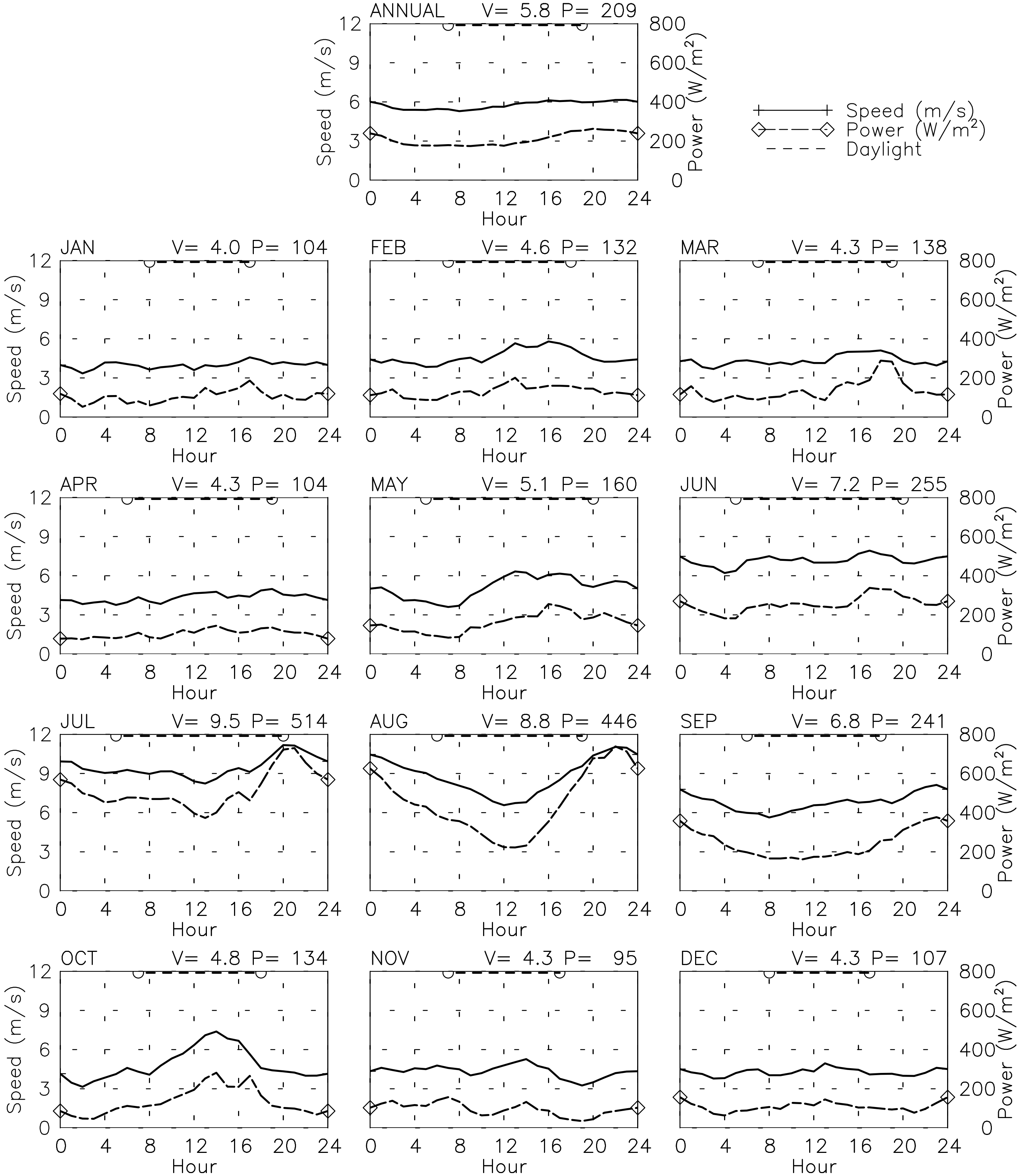
Vorotan Pass 10m – 005012
39° 42' N 45° 43' E – Elev 2408m LST=GMT+99 hours *NT= +3
11/01–10/02



Mon Mar 17 10:00:54 2003

SPEED AND POWER BY HOUR

Vorotan Pass 20m – 005011
39° 42' N   45° 43' E – Elev 2408m   LST=GMT+99 hours   *NT= +3
11/01–10/02



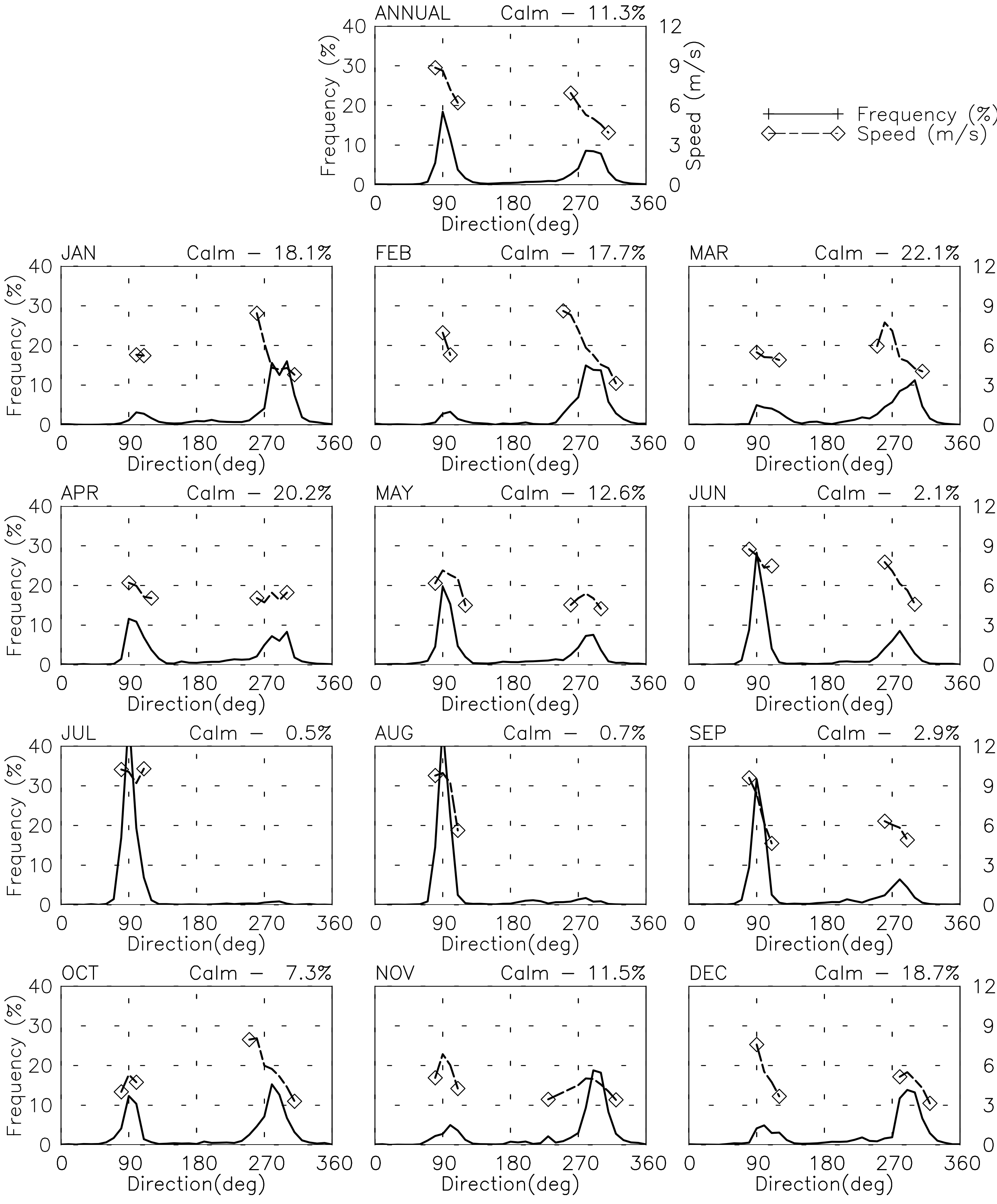
Mon Mar 17 10:00:49 2003

FREQUENCY AND SPEED BY DIRECTION

Vorotan Pass 20m − 005011

39° 42' N   45° 43' E − Elev 2408m   LST=GMT+99 hours   *NT= +3

11/01−10/02



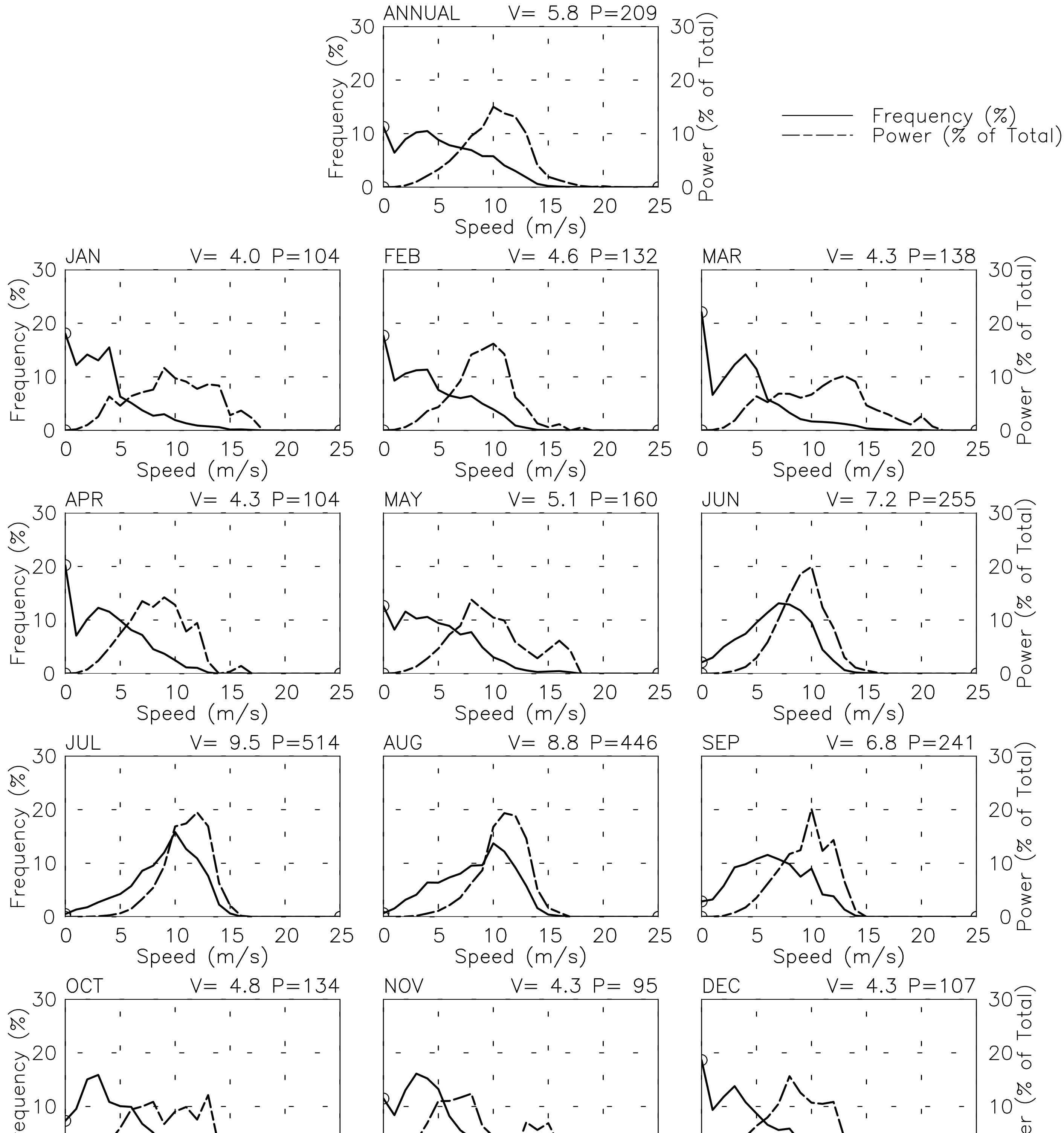
Mon Mar 17 10:00:50 2003

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

Vorotan Pass 20m – 005011

39° 42' N 45° 43' E – Elev 2408m LST=GMT+99 hours *NT= +3

11/01–10/02



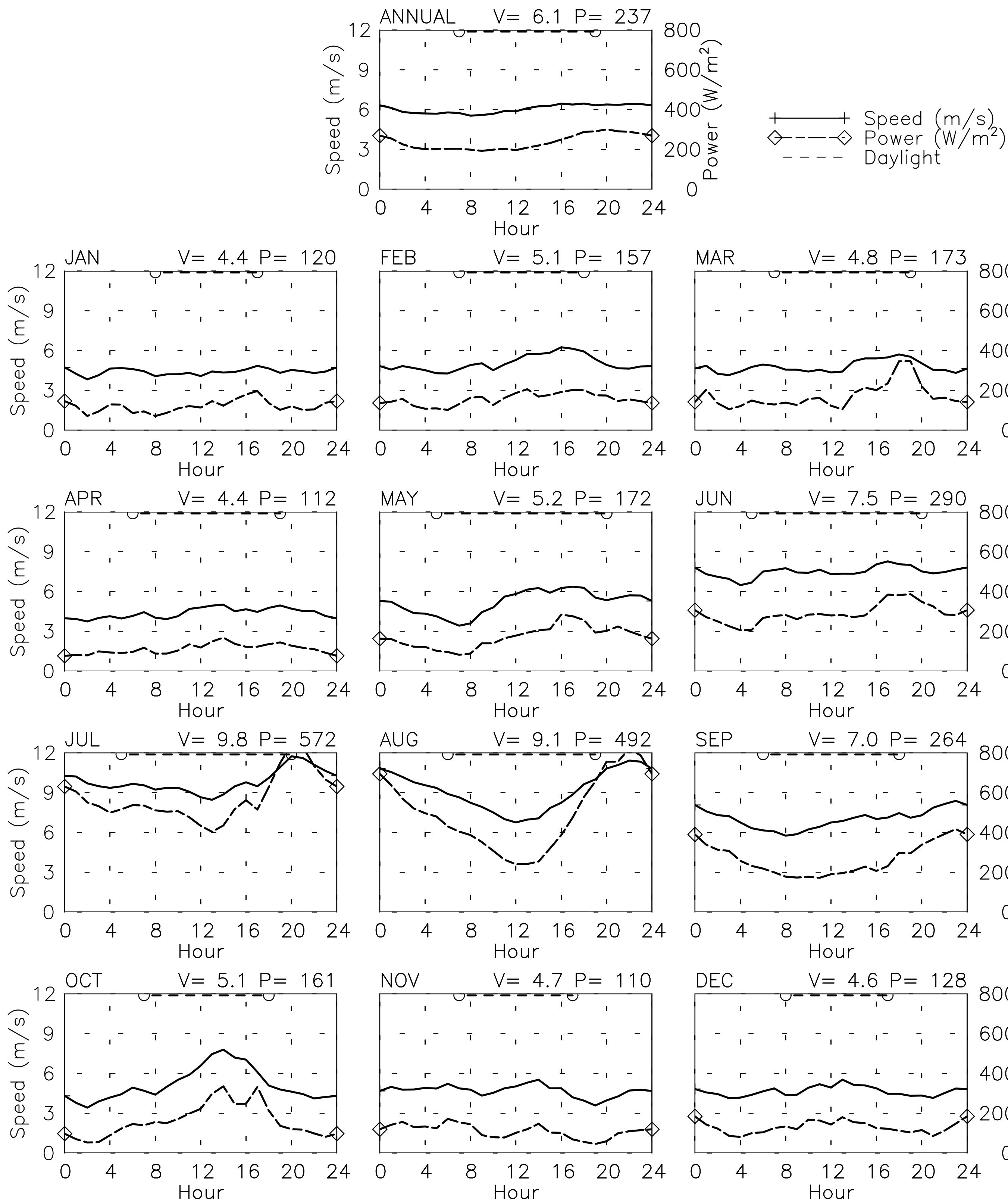
Mon Mar 17 10:00:51 2003

SPEED AND POWER BY HOUR

Vorotan Pass 40m - 005010

39° 42' N   45° 43' E - Elev 2408m   LST=GMT+99 hours   *NT= +3

11/01-10/02



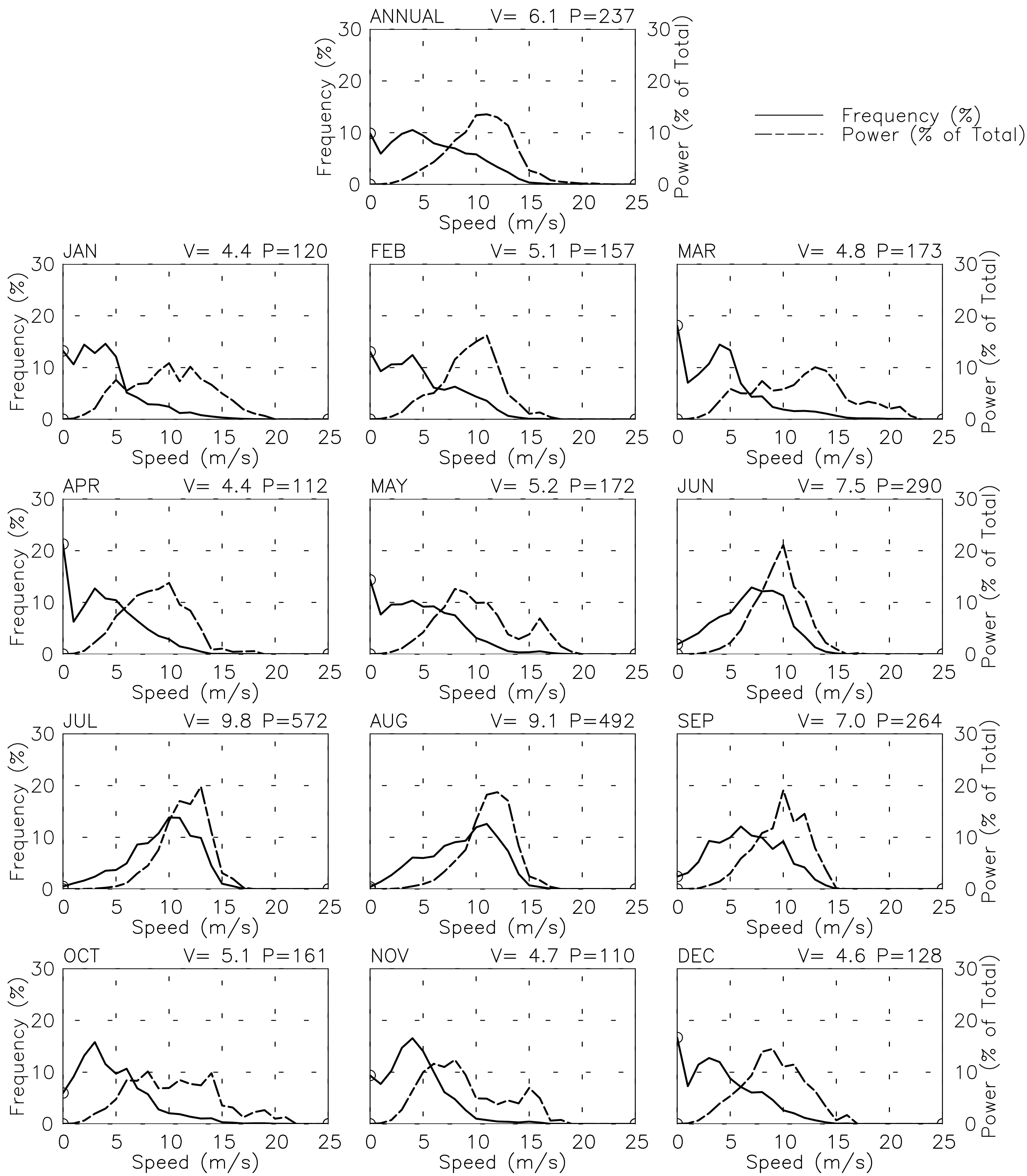
Mon Mar 17 10:00:46 2003

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

Vorotan Pass 40m – 005010

39° 42' N 45° 43' E – Elev 2408m LST=GMT+99 hours *NT= +3

11/01–10/02



Mon Mar 17 10:00:48 2003

Appendix D

Wind Measurement Stations
Tables and Analysis Summaries of Selected Stations

SolarEn Zod Area Stations

Table D.1
SolarEn Zod Measurement Program Data Summary

Site	Ht	Lat	Lon	Elev	From	To	NObs	WS	WP
1	10			2343	1999/11	2000/11	7772	6.7	285
2	40			2105	1999/09	2000/06	6903	4.8	181
2	30			2105	1999/09	2000/06	6903	4.6	156
2	20			2105	1999/09	2000/06	6903	4.4	143
3	10	40 13.24	45 58.40	2460	1999/09	2002/07	33035	8.2	584
4	20	40 13.15	45 58.39	2450	1999/09	2000/10	9128	8.3	573
4	10	40 13.15	45 58.39	2450	1999/09	2000/10	9191	8.1	528
5	20			2205	1999/09	2000/08	7703	5.7	194
5	10			2205	1999/09	2000/08	7703	5.4	169
6	20			2245	1999/09	2000/08	7675	5.5	198
6	10			2245	1999/09	2000/08	7675	5.3	176
8	40	40 12.57	45 58.40	2421	2000/08	2002/08	14920	7.6	533
8	30	40 12.57	45 58.40	2421	2000/08	2002/08	12943	7.7	485
8	20	40 12.57	45 58.40	2421	2000/08	2002/08	15093	7.8	475
9	20	40 13.31	45 58.35	2496	2000/08	2002/09	15568	7.4	495
9	10	40 13.31	45 58.35	2496	2000/08	2002/09	15630	7.9	489
11	20			2343	2000/08	2001/05	5937	6.7	296
11	10			2343	2000/08	2001/05	5937	6.4	268
12	10			2403	2000/10	2001/05	5187	6.0	273
33	40	40 13.24	45 58.41	2458	2000/08	2000/10	11144	7.3	306
33	30	40 13.24	45 58.41	2458	2000/08	2000/11	13760	6.6	262
33	20	40 13.24	45 58.41	2458	2000/08	2000/10	11252	6.9	261
42	30	40 13.15	45 58.39	2450	2000/11	2002/03	37068	8.7	606
42	20	40 13.15	45 58.39	2450	2000/11	2002/03	46860	8.4	556
42	10	40 13.15	45 58.39	2450	2000/11	2002/03	46968	8.6	586
77	40			2034	1999/10	2000/07	39548	4.9	164
77	30			2034	1999/10	2000/07	39548	4.6	135
77	20			2034	1999/10	2000/07	39548	4.4	110
101	10	40 12.24	45 58.28	2614	2001/05	2002/10	29930	7.3	568
102	20	40 12.31	45 58.35	2526	2001/05	2002/09	9112	7.9	454
102	10	40 12.31	45 58.35	2526	2001/05	2002/09	9112	7.3	358
103	40	40 12.35	45 58.38	2518	2001/06	2002/09	40303	5.8	279
103	20	40 12.35	45 58.38	2518	2001/06	2002/09	40297	6.1	251
103	10	40 12.35	45 58.38	2518	2001/06	2002/09	40236	6.1	232
104	10	40 12.39	45 58.43	2543	2001/06	2002/01	18060	9.0	635
105	10	40 12.52	45 58.43	2427	2001/06	2002/03	5370	9.1	656

NOTES:

1) Heights (Ht) are in meters above ground. Latitudes (Lat) are in deg/decimal min N, longitudes (Lon) are in deg/decimal min E. (Missing values were not supplied by SolarEn.) The period of record (From/To) is in yr/mo. Elevations (Elev) are in meters above sea level. NObs is the number of valid observations. Wind speeds (WS) are in meters/sec and wind power densities are in W/m^2. Observation interval at all stations is 10 minutes.
2) 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).

Table D.2
Mean Wind Speeds by Month at SolarEn Zod Stations
(speeds in meters/sec)

Station		**1**	**2**			**3**	**4**		**5**		**6**		**8**		
Ht		**10m**	**40m**	**30m**	**20m**	**10m**	**20m**	**10m**	**20m**	**10m**	**20m**	**10m**	**40m**	**30m**	**20m**
Year	**Month**														
1999	9		5.2	5.0	4.9	6.4	5.7	5.4	3.1	3.1	3.2	3.1			
1999	10		4.5	4.2	4.1	7.2	7.2	6.9	4.8	4.5	4.4	4.2			
1999	11	6.7	5.2	4.9	4.6	10.8	10.8	10.3	5.8	5.4	5.1	4.5			
1999	12	6.1	2.6	2.6	2.4	9.9	9.9	9.5	5.1	4.9	3.6	3.5			
2000	1	6.7	5.1	4.9	4.7	7.9	7.7	7.5	5.8	5.6	5.7	5.5			
2000	2	5.5	2.8	2.6	2.6	8.7	8.6	8.4	4.9	4.8	3.7	3.6			
2000	3	5.4	4.1	4.0	3.8	5.7	8.2	8.8	4.9	4.9	4.7	4.6			
2000	4	6.1	4.3	4.1	4.0	8.1	8.0	7.9	5.0	4.9	4.6	4.5			
2000	5	6.7	6.2	5.9	5.8	7.6	7.6	7.5	6.0	5.8	6.2	6.0			
2000	6	7.9	7.8	7.5	7.2	8.5	8.2	8.1	7.2	6.8	7.6	7.4			
2000	7	8.5				8.6	8.4	8.3	7.6	7.1	8.4	8.1			
2000	8	8.9				9.4	9.0	8.9	7.9	7.4	8.3	8.0	8.6	8.3	8.4
2000	9	6.8				7.1	7.0	6.9					6.7	6.4	6.5
2000	10	5.6				5.9	6.6	6.5					6.5	6.2	6.2
2000	11					6.3							7.0	6.6	6.6
2000	12					7.0							8.5	6.5	6.8
2001	1					7.8							7.9	7.5	7.5
2001	2					11.0							11.3	10.7	10.6
2001	3					8.5							8.9	8.7	8.3
2001	4					7.5							7.6		7.1
2001	5					7.8							7.6		7.2
2001	6					7.5							6.9	6.7	6.8
2001	7					9.5							8.5	8.7	8.7
2001	8					8.5							7.8	7.8	7.9
2001	9					7.4							7.0	7.0	7.0
2001	10					6.9							7.4	7.1	7.0
2001	11					8.5							8.8	8.2	7.9
2001	12					14.5							14.9	14.2	13.8
2002	1					9.2							9.4	8.9	8.7
2002	2					12.2							12.1	11.6	11.4
2002	3					13.1							12.9	12.4	12.1
2002	4					4.0							4.5	4.2	4.6
2002	5					6.5							6.3	6.2	6.1
2002	6					8.1							8.4	8.1	8.0
2002	7					10.0								8.2	8.1
2002	8													6.8	6.9
2002	9					6.2									
2002	10					8.6									

Table D.2 (continued)

Station		9		11		12	33			42			77		
Ht		**20m**	**10m**	**20m**	**10m**	**10m**	**40m**	**30m**	**20m**	**30m**	**20m**	**10m**	**40m**	**30m**	**20m**
Year	**Month**														
1999	9														
1999	10												4.6	4.3	4.0
1999	11												4.8	4.5	4.1
1999	12												3.1	3.1	3.0
2000	1												4.9	4.7	4.4
2000	2												2.7	2.6	2.7
2000	3												3.7	3.5	3.4
2000	4												4.3	4.1	3.9
2000	5												5.8	5.5	5.2
2000	6												7.4	6.9	6.5
2000	7												7.5	7.1	6.5
2000	8	8.8	8.7	9.3	9.0		9.0	8.4	8.7						
2000	9	6.8	6.7	7.3	7.0		6.9	6.4	6.5						
2000	10	6.6	6.5	6.0	5.8	6.1	6.1	5.6	5.5						
2000	11	7.8	7.6	5.4	4.4	4.9		5.8		7.3	7.0	7.1			
2000	12	7.6	8.0	5.4	5.2	5.1				7.7	7.2	7.4			
2001	1	7.9	7.5	5.8	5.6	5.2				7.1	6.9	7.0			
2001	2	11.0	10.5	8.0	7.8	7.6				11.2	10.3	11.0			
2001	3	8.6	8.4	6.5	6.2	6.3				10.3	9.4	9.6			
2001	4	7.2	7.2	6.1	6.1	6.0				8.2	7.4	7.7			
2001	5	7.5	7.4	6.7	6.6	6.8				7.4	7.4	7.7			
2001	6	7.0	7.0							7.2	7.1	7.3			
2001	7	8.7	8.9							9.0	9.1	9.1			
2001	8	7.9	7.9							8.5	8.6	8.6			
2001	9	6.9	7.0							8.0	7.9	7.9			
2001	10	7.1	6.8							7.8	7.8	7.7			
2001	11	8.6	8.3							8.8	8.5	8.4			
2001	12	14.5	14.2												
2002	1	9.4	9.2							18.4	18.5	18.5			
2002	2	12.0	11.7							11.9	11.9	11.9			
2002	3	8.8	9.8							13.0	12.8	12.7			
2002	4	5.9	6.4												
2002	5	6.1	6.0												
2002	6	3.2	7.6												
2002	7	1.6	8.3												
2002	8	4.2	7.4												
2002	9	0.8	8.6												
2002	10														

Table D.2 (continued)

Station		101	102		103			104	105
Ht		10m	20m	10m	40m	20m	10m	10m	10m
Year	Month								
1999	9								
1999	10								
1999	11								
1999	12								
2000	1								
2000	2								
2000	3								
2000	4								
2000	5								
2000	6								
2000	7								
2000	8								
2000	9								
2000	10								
2000	11								
2000	12								
2001	1								
2001	2								
2001	3								
2001	4								
2001	5	9.3	7.2	6.6					
2001	6	7.5	6.5	6.2	6.2	5.9	5.8	7.0	7.0
2001	7	9.1	8.4	8.0	7.9	7.8	7.4	8.4	7.8
2001	8	8.2	7.5	7.0	7.1	6.9	6.6	7.5	7.1
2001	9	7.7	6.4	6.1	6.4	6.1	6.0		6.5
2001	10	7.7	6.6	5.9	7.8	7.2	7.0	0.0	6.9
2001	11	10.4	7.8	7.0					8.2
2001	12	10.6	12.6	11.5					14.1
2002	1	9.5	7.5	6.9					8.9
2002	2	11.7	9.9	9.3					11.5
2002	3	10.6	11.2	10.3	5.7	5.9	5.0		12.9
2002	4	8.4	4.9	4.6	5.6	6.0	5.6		
2002	5	4.8	5.4	5.3	5.1	5.1	4.9		
2002	6	14.0	7.3	6.8	7.4	7.0	6.9		
2002	7		7.9	7.4	8.3	6.5	6.5		
2002	8		7.0	6.5		6.1	6.2		
2002	9	6.9	8.3	7.9		7.4	7.4		
2002	10	10.6							

Table D.3
Mean Wind Power Densities by Month at SolarEn Zod Stations
(WP in W/m^2)

Station		1	2			3	4		5		6		8		
Ht		**10m**	**40m**	**30m**	**20m**	**10m**	**20m**	**10m**	**20m**	**10m**	**20m**	**10m**	**40m**	**30m**	**20m**
Year	**Month**														
1999	9		182	166	154	186	152	138	45	39	46	42			
1999	10		148	123	112	432	476	431	135	116	134	116			
1999	11	288	259	208	189	1137	1195	1098	284	252	219	167			
1999	12	301	91	78	69	815	801	740	197	180	140	123			
2000	1	439	241	209	187	672	716	684	233	210	266	236			
2000	2	176	54	46	45	633	626	591	136	128	82	73			
2000	3	136	155	136	130	144	703	693	152	143	164	153			
2000	4	255	124	109	99	543	544	522	159	146	140	124			
2000	5	277	244	215	202	459	468	455	196	174	229	206			
2000	6	358	396	347	319	414	394	383	261	218	325	300			
2000	7	376				389	366	355	272	216	360	330			
2000	8	438				518	474	464	329	269	353	323	377	334	353
2000	9	251				277	261	255					214	188	194
2000	10	153				201	237	227					216	183	179
2000	11					335							338	283	278
2000	12					510							604	406	404
2001	1					506							502	425	418
2001	2					1223							1234	1085	1073
2001	3					716							776	690	641
2001	4					431							420		350
2001	5					420							387		323
2001	6					320							243	199	224
2001	7					505							351	366	379
2001	8					415							298	306	313
2001	9					339							279	267	263
2001	10					465							522	448	410
2001	11					649							699	601	544
2001	12					1866							1943	1748	1649
2002	1					571							666	583	549
2002	2					1344							1256	1141	1105
2002	3					1333							1181	1046	984
2002	4					99							111	102	130
2002	5					320							277	252	243
2002	6					557							638	530	500
2002	7					571								328	324
2002	8													198	206
2002	9					193									
2002	10					600									

Table D.3 (continued)

Station		9		11		12	33			42			77		
Ht		**20m**	**10m**	**20m**	**10m**	**10m**	**40m**	**30m**	**20m**	**30m**	**20m**	**10m**	**40m**	**30m**	**20m**
Year	**Month**														
1999	9														
1999	10												138	113	85
1999	11												175	137	106
1999	12												75	64	51
2000	1												195	166	140
2000	2												40	33	30
2000	3												109	89	74
2000	4												97	79	67
2000	5												192	160	133
2000	6												323	266	216
2000	7												298	244	197
2000	8	388	391	496	453		460	386	422						
2000	9	221	219	306	277		247	209	214						
2000	10	214	197	186	170	242	209	171	147						
2000	11	413	378	199	127	159		283		356	305	340			
2000	12	521	508	167	155	169				594	474	550			
2001	1	483	438	288	261	279				314	299	319			
2001	2	1184	1062	555	517	531				1240	1010	1195			
2001	3	700	614	320	292	315				941	761	833			
2001	4	360	327	237	227	249				498	370	421			
2001	5	342	319	294	288	328				428	347	390			
2001	6	245	250							236	253	289			
2001	7	377	407							413	429	441			
2001	8	315	333							389	403	415			
2001	9	261	265							385	377	378			
2001	10	439	398							535	529	512			
2001	11	623	586							675	645	628			
2001	12	1881	1772												
2002	1	611	574							2505	2498	2448			
2002	2	1190	1128							1240	1231	1244			
2002	3	691	769							1290	1242	1203			
2002	4	372	394												
2002	5	248	243												
2002	6	157	435												
2002	7	66	354												
2002	8	137	258												
2002	9	24	344												
2002	10														

Table D.3 (continued)

Station		**101**	**102**		**103**			**104**	**105**
Ht		**10m**	**20m**	**10m**	**40m**	**20m**	**10m**	**10m**	**10m**
Year	**Month**								
1999	9								
1999	10								
1999	11								
1999	12								
2000	1								
2000	2								
2000	3								
2000	4								
2000	5								
2000	6								
2000	7								
2000	8								
2000	9								
2000	10								
2000	11								
2000	12								
2001	1								
2001	2								
2001	3								
2001	4								
2001	5	740	362	257					
2001	6	317	203	172	155	142	130	214	204
2001	7	401	331	284	279	261	231	322	278
2001	8	349	265	219	231	210	189	262	240
2001	9	387	221	178	223	195	176		225
2001	10	676	376	263	485	384	340	0	426
2001	11	1008	480	358					586
2001	12	1189	1231	954					1669
2002	1	671	374	293					592
2002	2	1170	754	637					1096
2002	3	983	905	717	272	252	182		1238
2002	4	642	192	156	339	326	278		
2002	5	237	194	161	193	172	154		
2002	6	2421	402	305	479	408	377		
2002	7		290	242	308	178	168		
2002	8		204	168		146	146		
2002	9	242	312	268		221	220		
2002	10	592							

Table D.4
Number of Observations by Month at SolarEn Zod Stations

Station		1	2			3	4		5		6		8		
Ht		10m	40m	30m	20m	10m	20m	10m	20m	10m	20m	10m	40m	30m	20m
Year	Month														
1999	1														
1999	9		2793	2793	2793	2758	899	899	787	787	766	766			
1999	10		4464	4464	4464	4464	4464	4464	4464	4464	4464	4464			
1999	11	807	3709	3709	3709	3888	3942	3918	4320	4320	4320	4320			
1999	12	4464	4464	4464	4464	4464	4464	4464	4464	4464	4460	4460			
2000	1	4464	4463	4463	4463	4464	4469	4469	4469	4469	4463	4463			
2000	2	4032	4176	4176	4176	4032	4176	4176	4176	4176	4176	4176			
2000	3	524	4464	4464	4464	516	4464	3954	4464	4464	4464	4464			
2000	4	3238	4320	4320	4320	4239	4319	4319	4320	4320	4320	4320			
2000	5	4464	4464	4464	4464	4464	4464	4462	4464	4464	4464	4464			
2000	6	4320	4098	4098	4098	4320	4320	4318	4320	4320	4320	4320			
2000	7	4463				4464	4463	4461	4463	4463	4464	4464			
2000	8	4464				4464	4464	4462	1500	1500	1367	1367	3959	3959	3959
2000	9	4320				4320	4320	4318					4320	4320	4320
2000	10	1525				3942	1534	1532					1537	1537	1537
2000	11					4320							2081	2081	2081
2000	12					4464							3426	4464	4464
2001	1					4464							4464	4464	4464
2001	2					4032							4031	4031	4031
2001	3					4464							4464	4212	4464
2001	4					4320							4320		4320
2001	5					4464							4464		4464
2001	6					4320							4320	456	4320
2001	7					4464							4464	4464	4464
2001	8					4464							4464	4464	4464
2001	9					4320							4319	4319	4319
2001	10					4464							4464	4464	4464
2001	11					2249							2250	2250	2250
2001	12					1484							1483	1483	1483
2002	1					4464							4315	4315	4315
2002	2					4032							4032	4032	4032
2002	3					1661							1074	1074	1074
2002	4					1802							1795	1795	1795
2002	5					4464							4464	4464	4464
2002	6					4320							966	3298	3298
2002	7					2241								4464	4464
2002	8													3230	3230
2002	9					3777									
2002	10					949									

Table D.4 (continued)

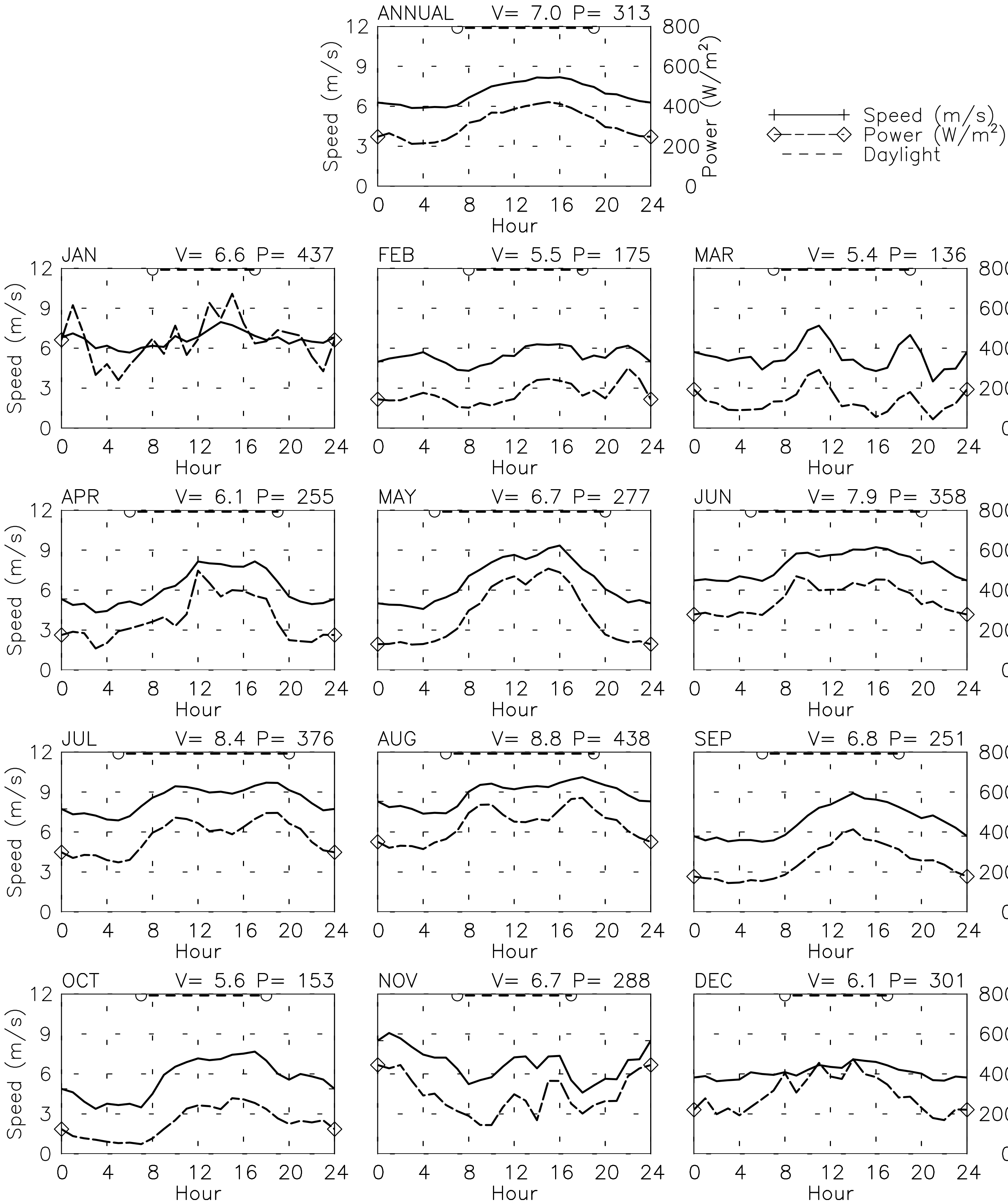
Station		**9**		**11**		**12**	**33**			**42**			**77**		
Ht		**20m**	**10m**	**20m**	**10m**	**10m**	**40m**	**30m**	**20m**	**30m**	**20m**	**10m**	**40m**	**30m**	**20m**
Year	**Month**														
1999	1														
1999	9														
1999	10												2491	2491	2491
1999	11												4320	4320	4320
1999	12												4464	4464	4464
2000	1												4464	4464	4464
2000	2												4176	4176	4176
2000	3												4464	4464	4464
2000	4												4320	4320	4320
2000	5												4464	4464	4464
2000	6												4320	4320	4320
2000	7												2065	2065	2065
2000	8	3062	3062	2952	2952		4214	4214	4214						
2000	9	4319	4319	4320	4320		4320	4320	4320						
2000	10	1543	1543	1532	1532	1929	2610	4026	2718						
2000	11	1080	1080	1951	1951	4320		1200		1930	1930	1930			
2000	12	4091	3521	4464	4464	4464				2234	2228	2348			
2001	1	4464	4464	4464	4464	4464				1927	1927	1927			
2001	2	4032	4032	4031	4031	4032				4031	4031	4031			
2001	3	4464	4464	4464	4464	4464				1352	1418	1418			
2001	4	4320	4320	4320	4320	4320				2598	4230	4206			
2001	5	4464	4464	3115	3115	3129				84	4464	4464			
2001	6	4320	4320							366	4320	4320			
2001	7	4464	4464							4464	4464	4464			
2001	8	4464	4464							2570	2570	2570			
2001	9	4320	4320							2939	2939	2939			
2001	10	4464	4464							4296	4062	4074			
2001	11	2248	2248							2244	2244	2244			
2001	12	1486	1486												
2002	1	4463	4463							343	343	343			
2002	2	4032	4032							4032	4032	4032			
2002	3	4463	3599							1658	1658	1658			
2002	4	4320	4320												
2002	5	4464	4464												
2002	6	4320	4320												
2002	7	942	4464												
2002	8	684	4464												
2002	9	543	543												
2002	10														

Table D.4 (continued)

Station		101	102		103			104	105
Ht		**10m**	**20m**	**10m**	**40m**	**20m**	**10m**	**10m**	**10m**
Year	**Month**								
1999	1								
1999	9								
1999	10								
1999	11								
1999	12								
2000	1								
2000	2								
2000	3								
2000	4								
2000	5								
2000	6								
2000	7								
2000	8								
2000	9								
2000	10								
2000	11								
2000	12								
2001	1								
2001	2								
2001	3								
2001	4								
2001	5	1226	1203	1203					
2001	6	4320	4320	4320	489	489	489	609	607
2001	7	4464	4464	4464	4464	4464	4464	4464	4464
2001	8	4464	4464	4464	4464	4464	4464	4158	4464
2001	9	4320	4320	4320	4320	4320	4320		4320
2001	10	4464	4464	4464	3699	3693	3633	2496	4463
2001	11	4320	2246	2246				2246	2248
2001	12	4464	1488	1488				1491	1485
2002	1	4464	4464	4464				2598	4464
2002	2	4032	4032	4032					4032
2002	3	3870	1673	1673	2796	1980	2796		1668
2002	4	3138	3022	3022	4320	4050	4320		
2002	5	2112	4464	4464	4464	4290	4464		
2002	6	666	4320	4320	3314	3314	3314		
2002	7	6	4464	4464	506	2973	2973		
2002	8		4464	4464		4464	4464		
2002	9	3793	533	533		536	536		
2002	10	971							

SPEED AND POWER BY HOUR

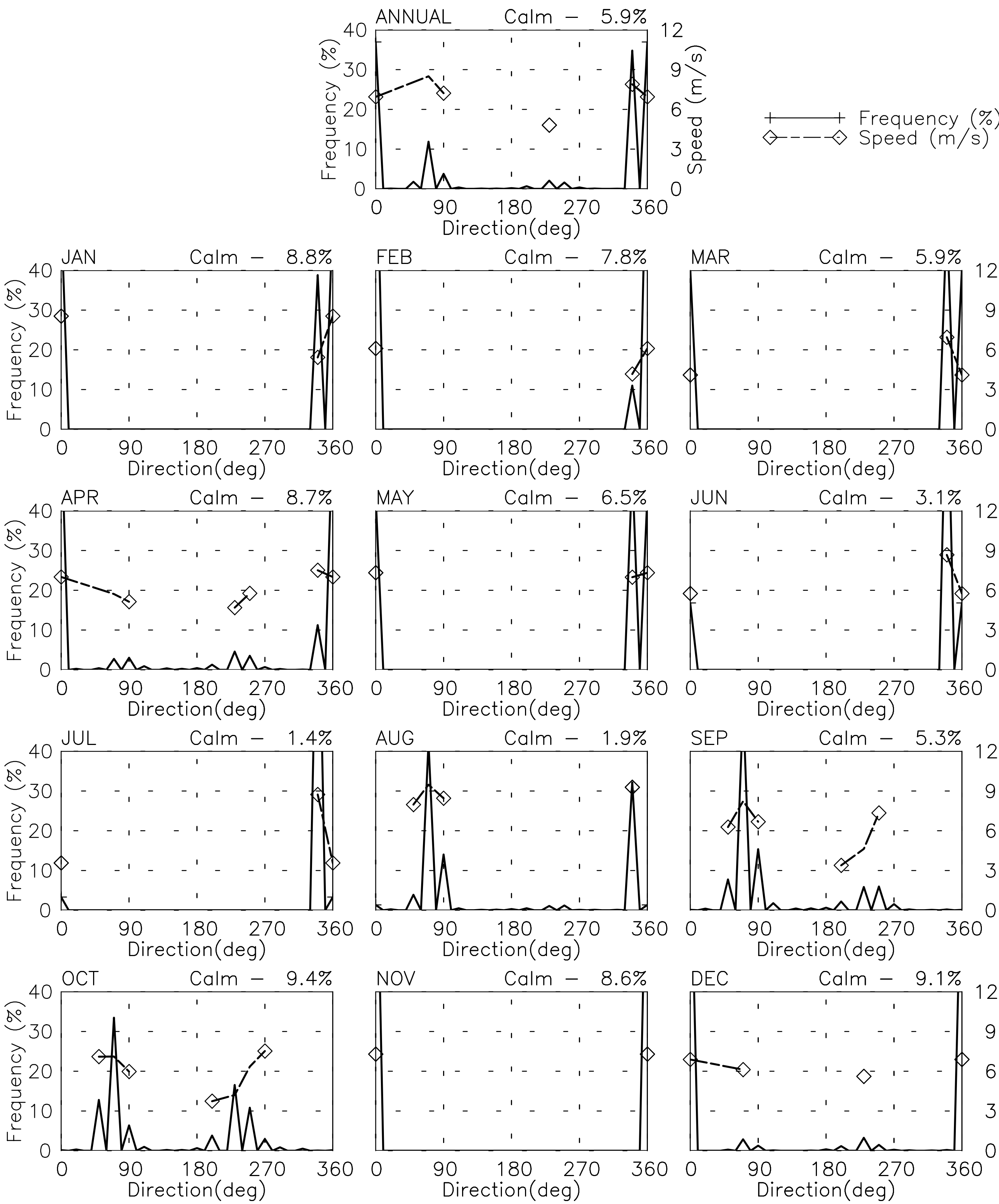
Zod Site 001 10m – 000001
40° 12' N 45° 52' E – Elev 2100m LST=GMT+99 hours *NT= +3
11/99–10/00



Wed Mar 26 16:21:36 2003

FREQUENCY AND SPEED BY DIRECTION

Zod Site 001 10m – 000001
40° 12' N   45° 52' E – Elev 2100m   LST=GMT+99 hours   *NT= +3
11/99–10/00



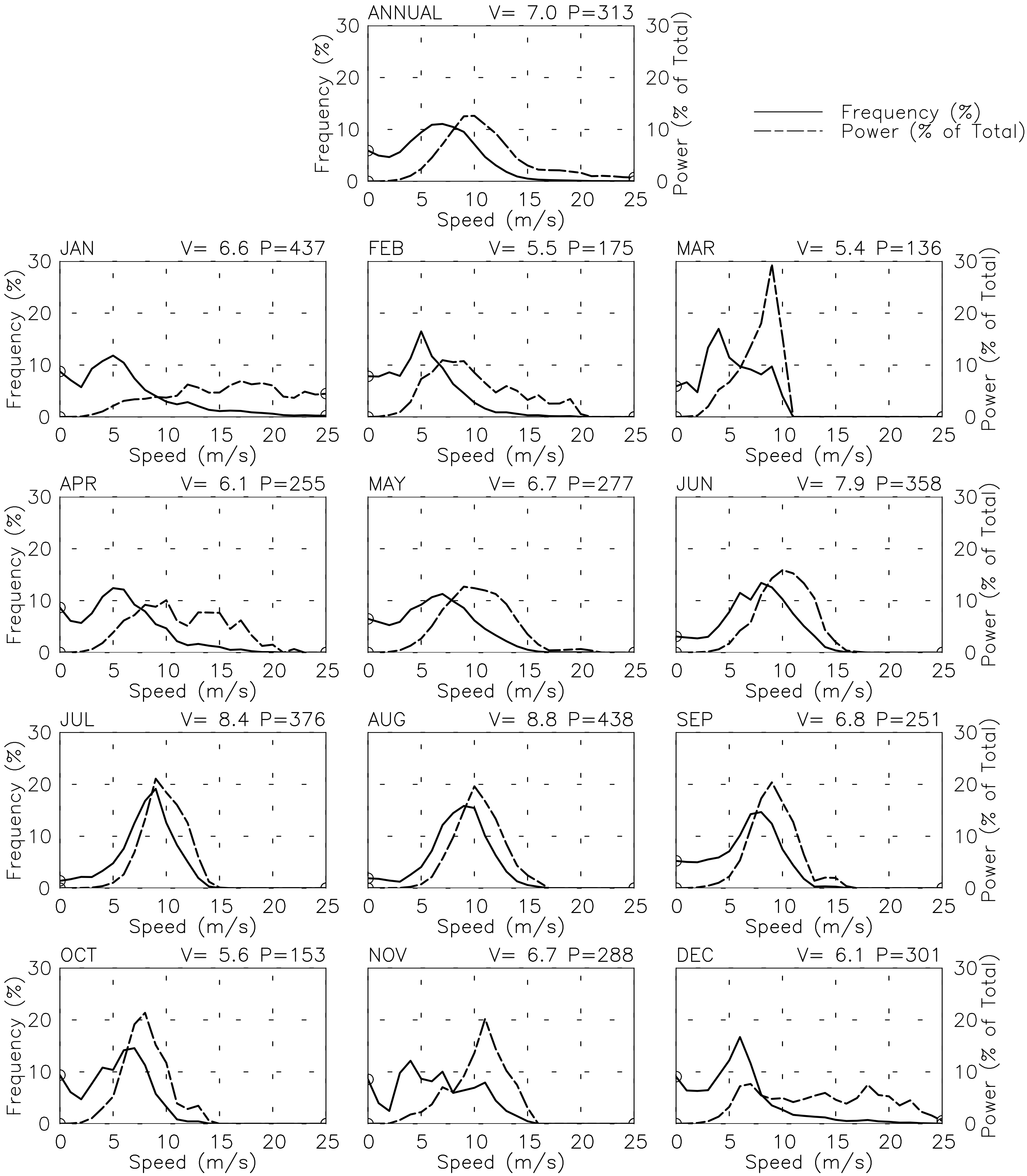
Wed Mar 26 16:21:37 2003

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

Zod Site 001 10m - 000001

40° 12' N 45° 52' E - Elev 2100m LST=GMT+99 hours *NT= +3

11/99-10/00



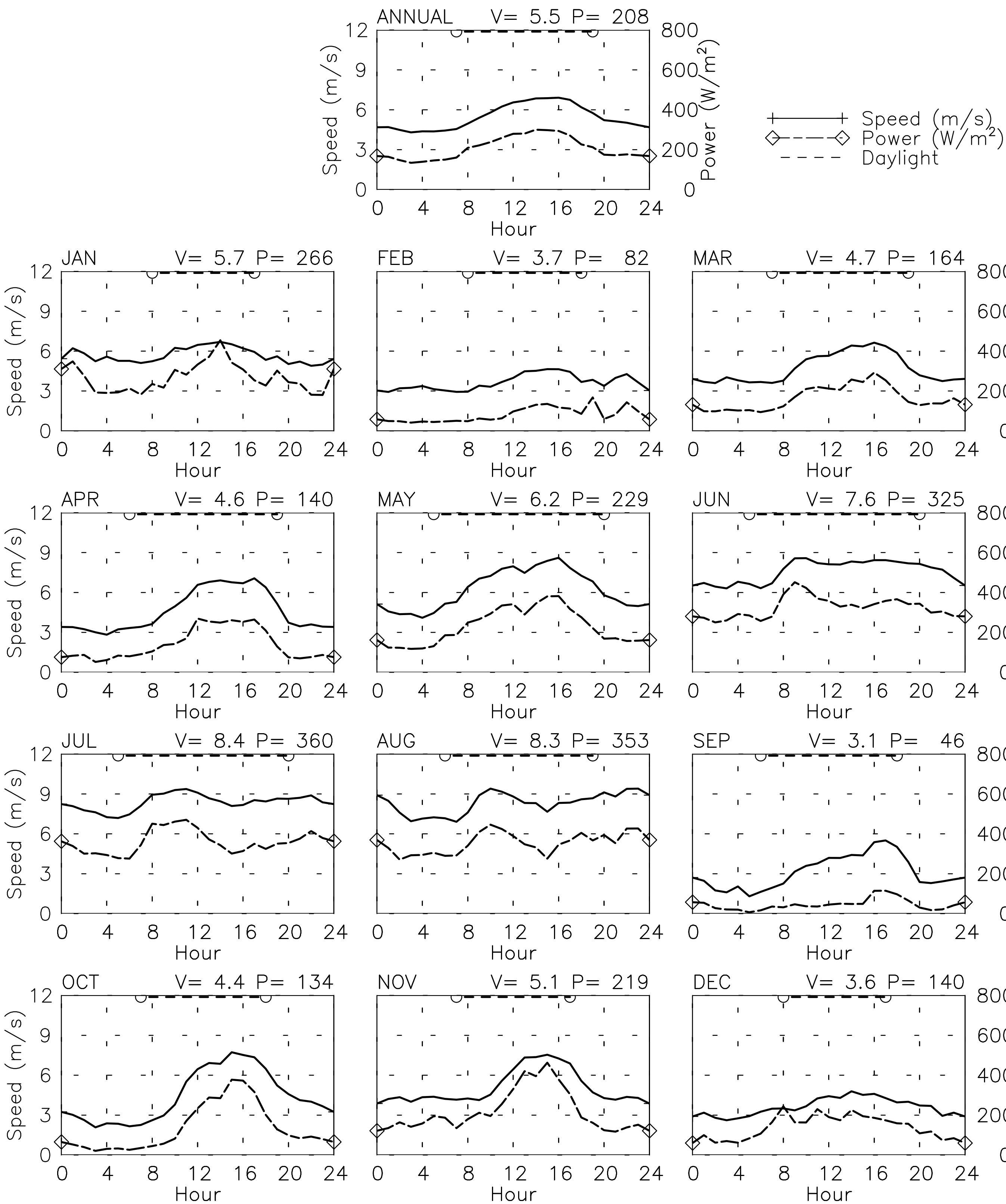
Wed Mar 26 16:21:38 2003

SPEED AND POWER BY HOUR

Zod Site 006 20m - 000006

40° 12' N 45° 52' E - Elev 2100m LST=GMT+99 hours *NT= +3

09/99-08/00



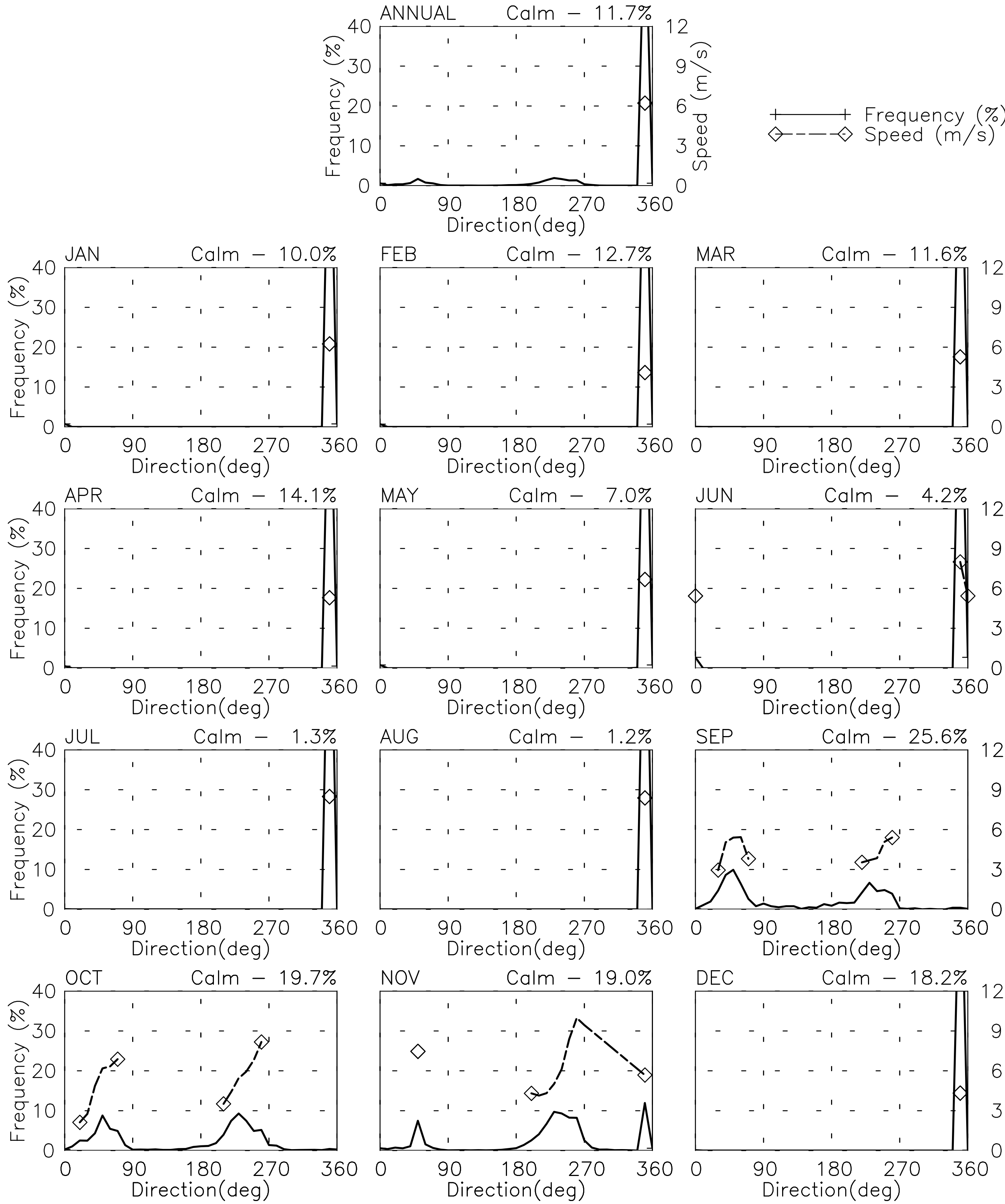
Thu Mar 27 10:16:41 2003

FREQUENCY AND SPEED BY DIRECTION

Zod Site 006 20m - 000006

40° 12' N   45° 52' E - Elev 2100m   LST=GMT+99 hours   *NT= +3

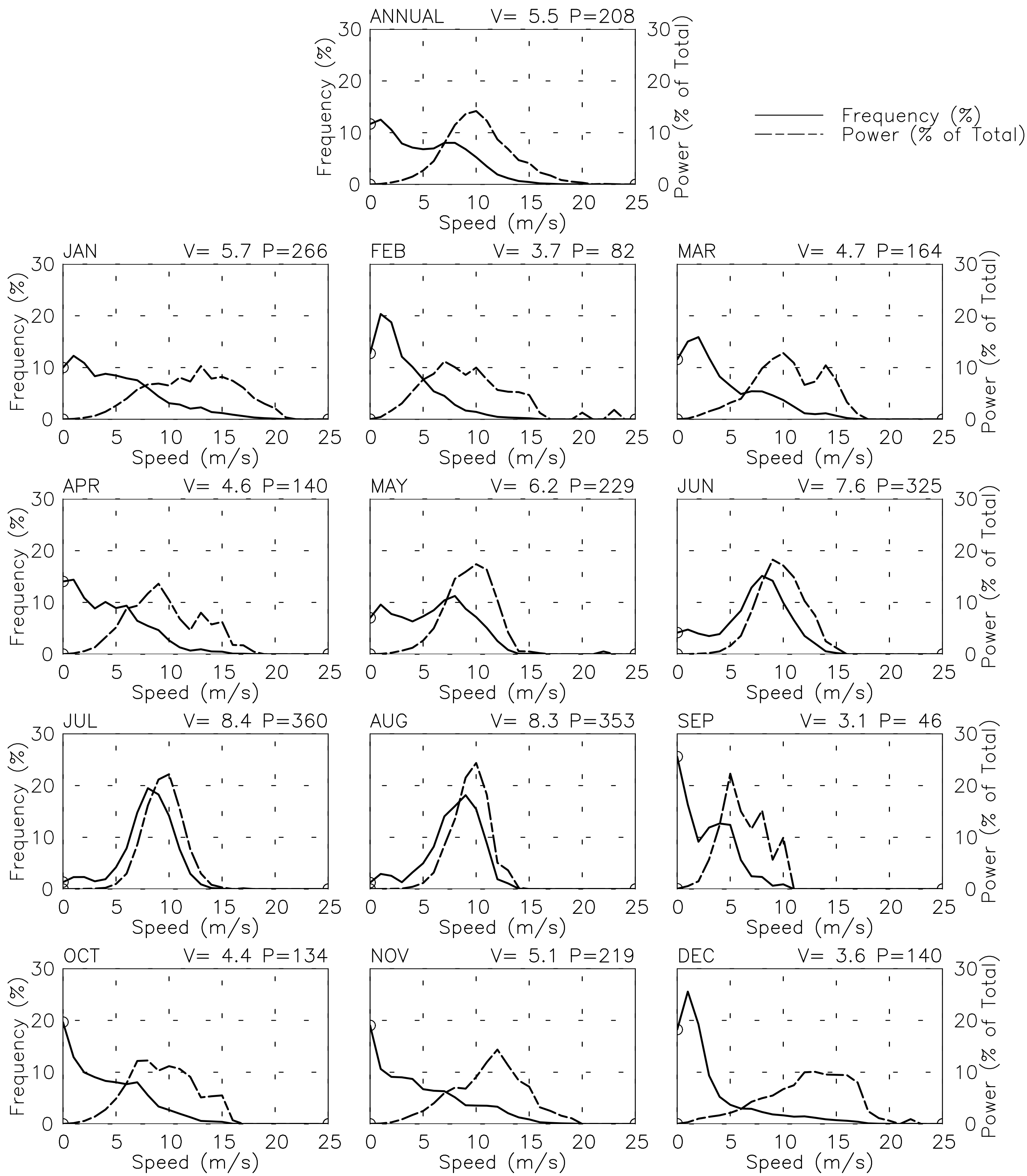
09/99-08/00



Wed Mar 26 16:21:52 2003

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

Zod Site 006 20m – 000006
40° 12' N 45° 52' E – Elev 2100m LST=GMT+99 hours *NT= +3
09/99–08/00



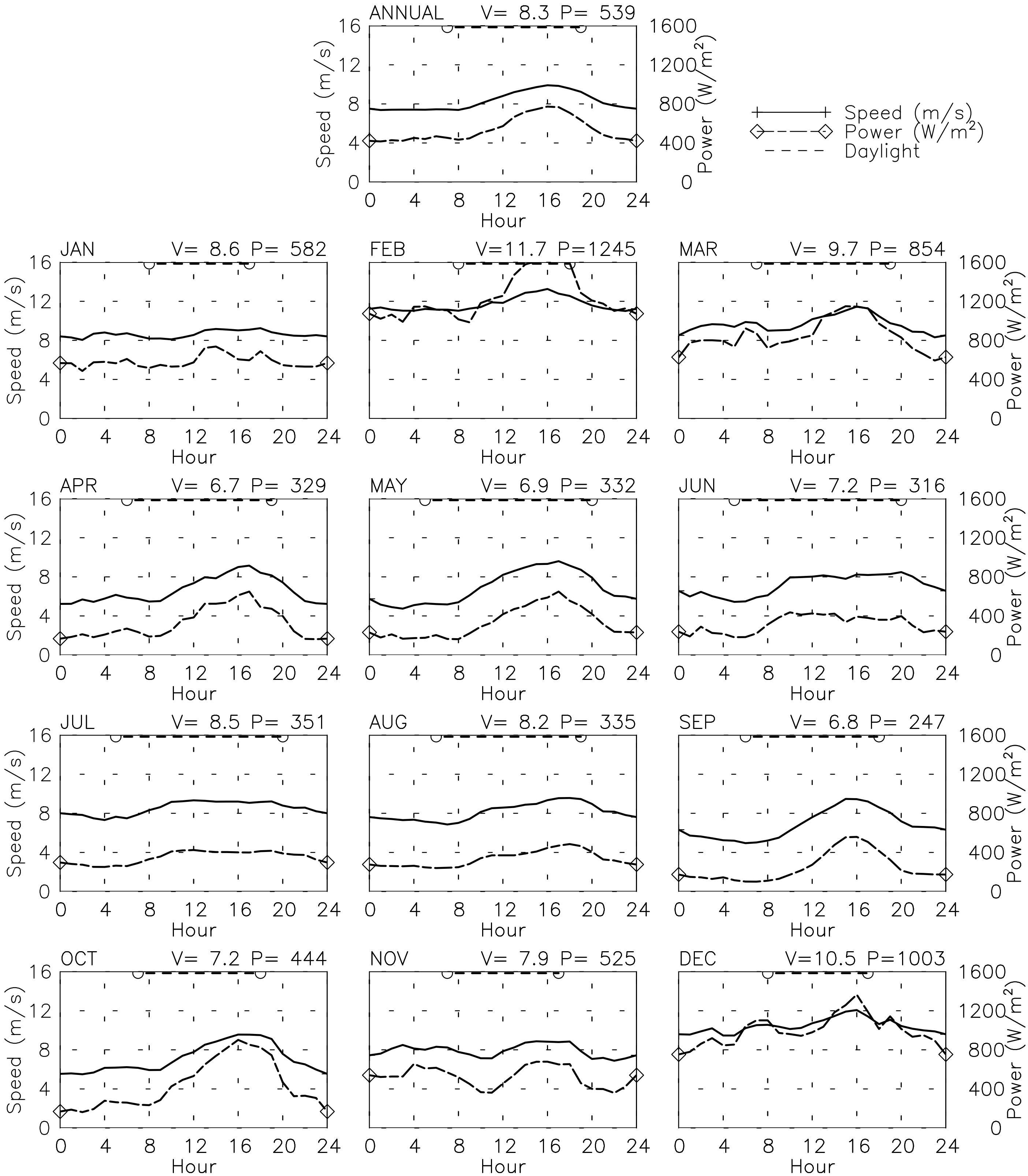
Wed Mar 26 16:21:52 2003

SPEED AND POWER BY HOUR

Zod Site 008 40m - 000008

40° 13' N 45° 59' E - Elev 2421m LST=GMT+99 hours *NT= +3

08/00-06/02



Wed May 14 11:04:12 2003

FREQUENCY AND SPEED BY DIRECTION

Zod Site 008 30m – 001008

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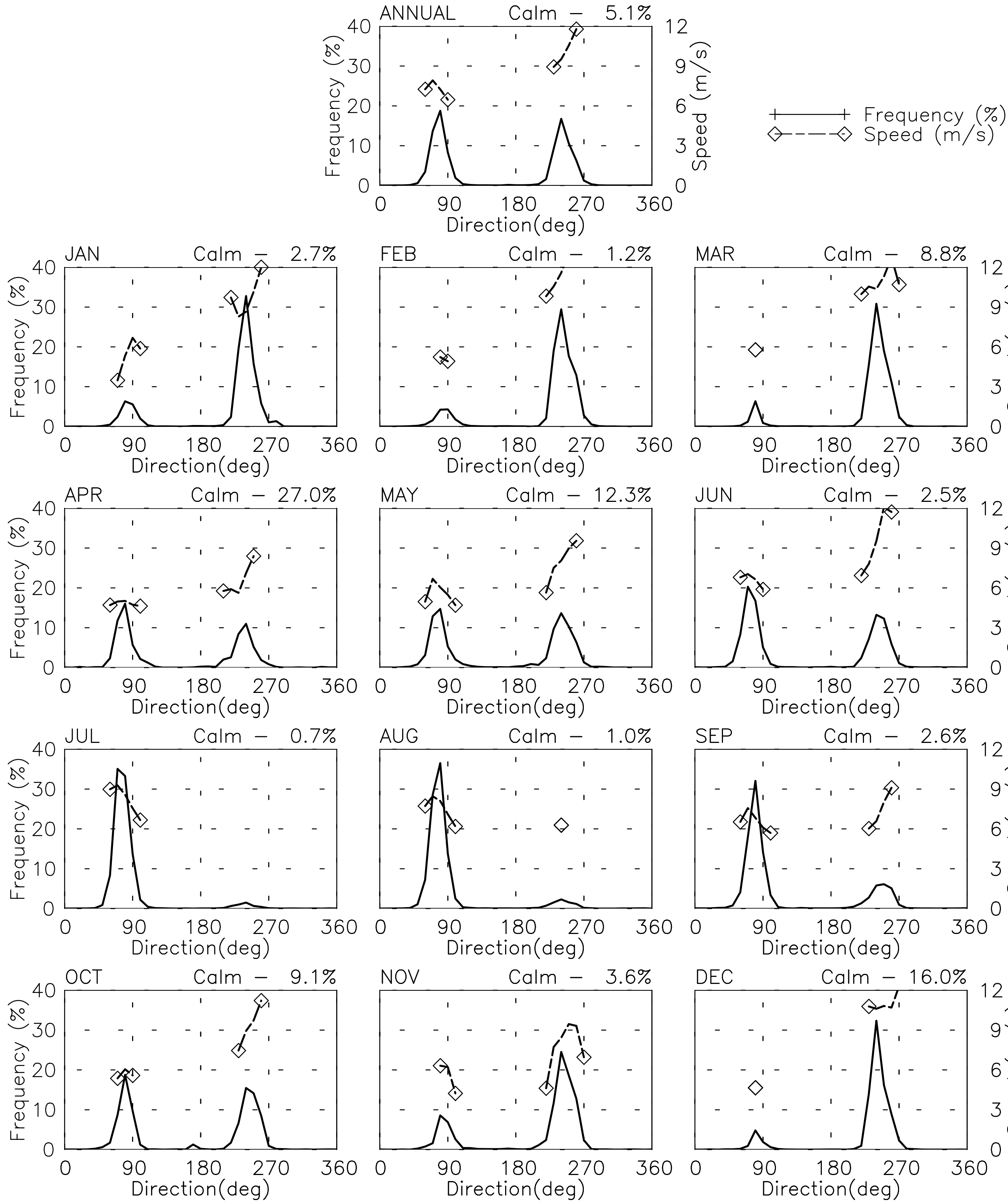
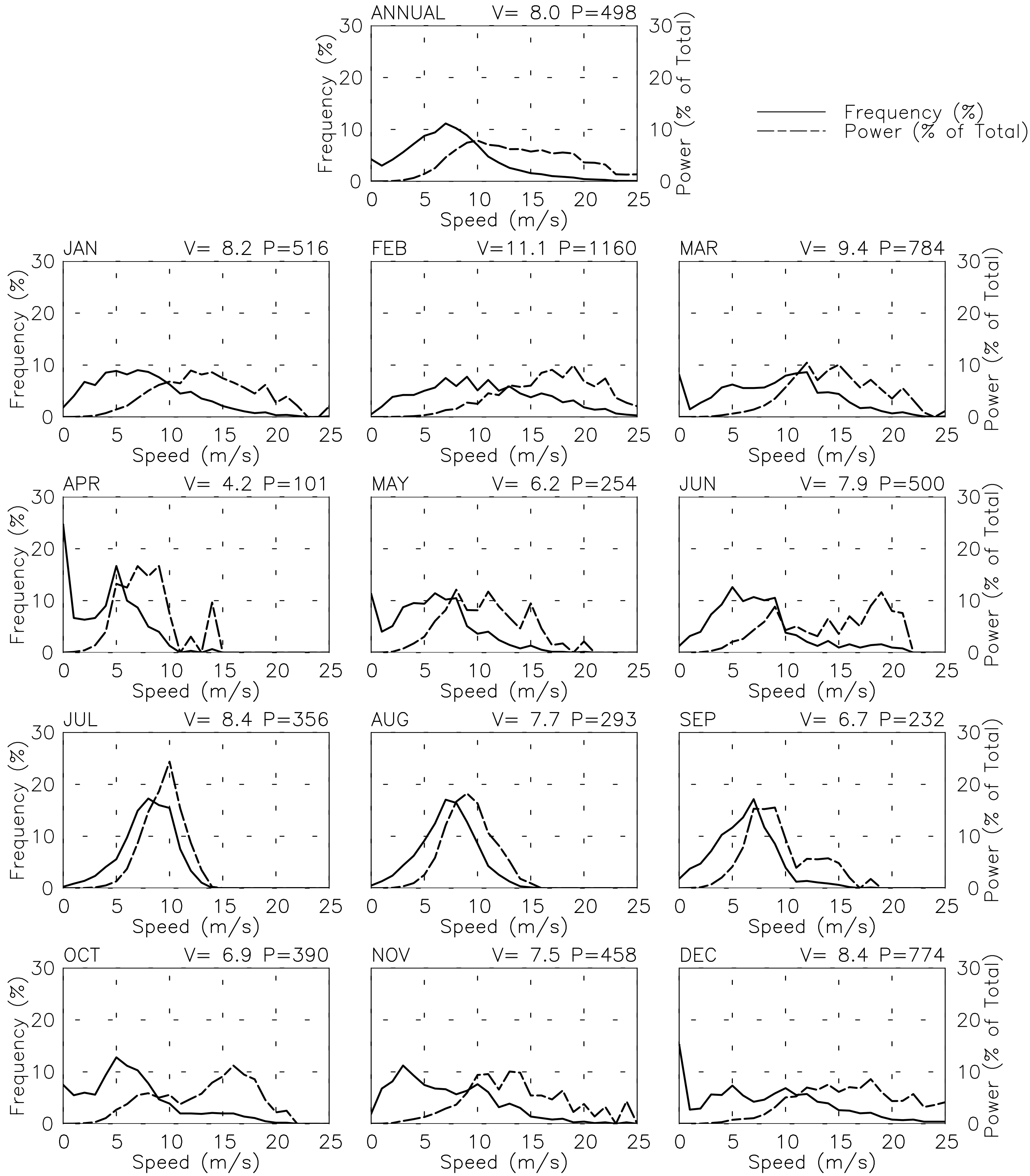
08/00–08/02



Wed May 14 10:55:12 2003

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

Zod Site 008 30m - 001008
40° 13' N 45° 59' E - Elev 2421m LST=GMT+99 hours *NT= +3
08/00-08/02



Thu May 29 14:21:21 2003

SPEED AND POWER BY HOUR

Zod Site 009 20m – 000009

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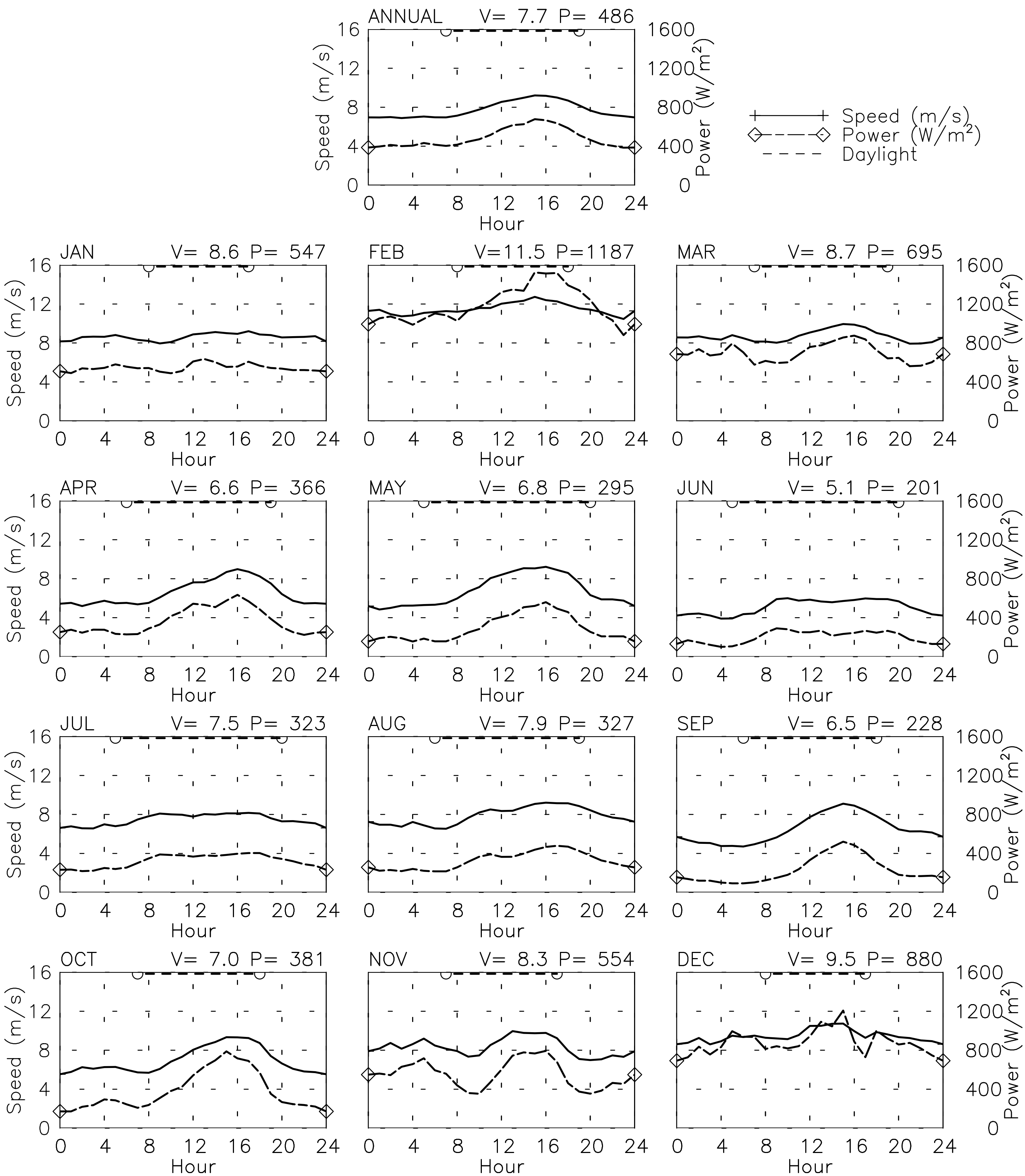
08/00–09/02



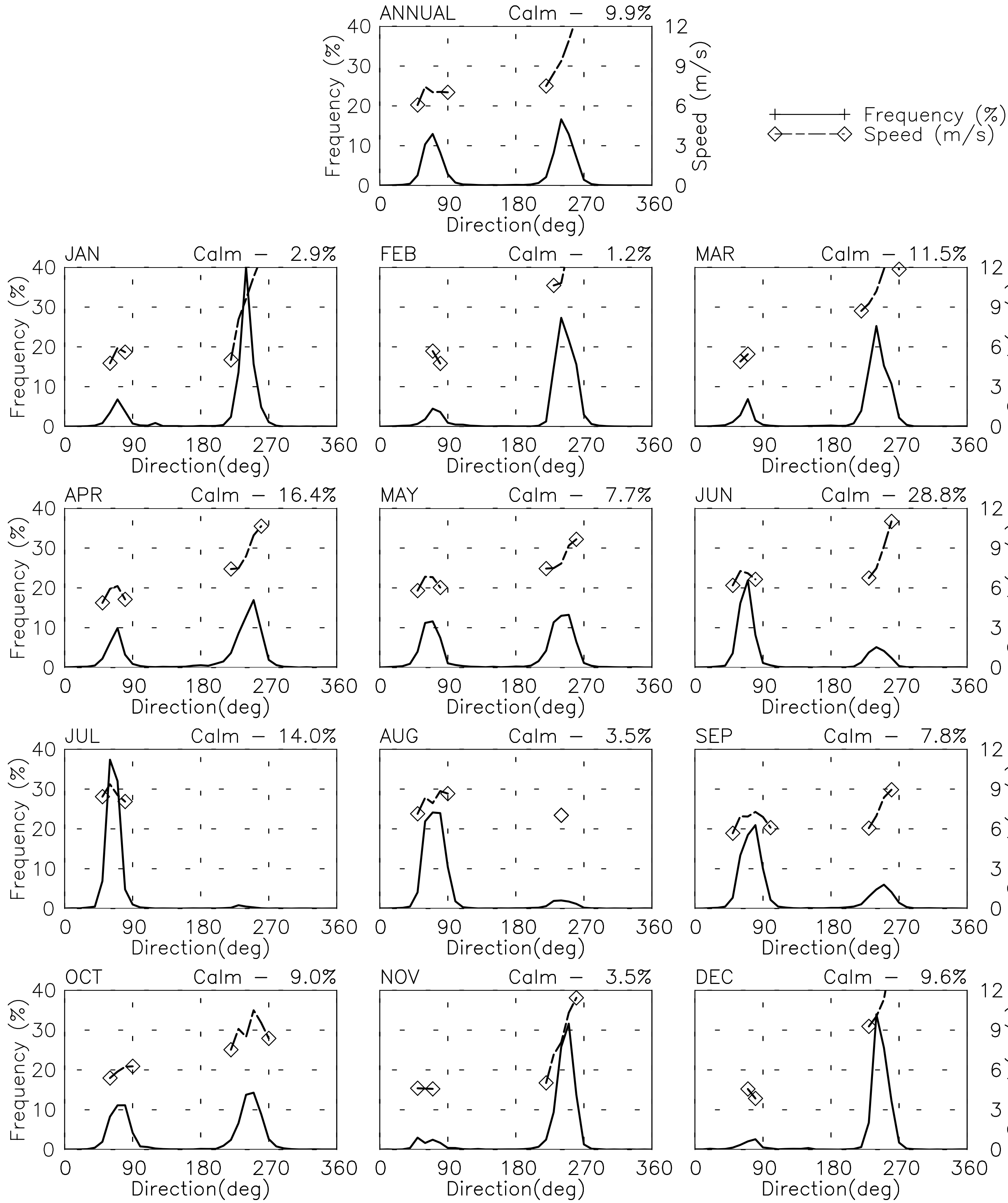
Thu Mar 27 10:17:30 2003

FREQUENCY AND SPEED BY DIRECTION

Zod Site 009 20m - 000009

40° 14' N   45° 59' E - Elev 2496m   LST=GMT+99 hours   *NT= +3

08/00-09/02



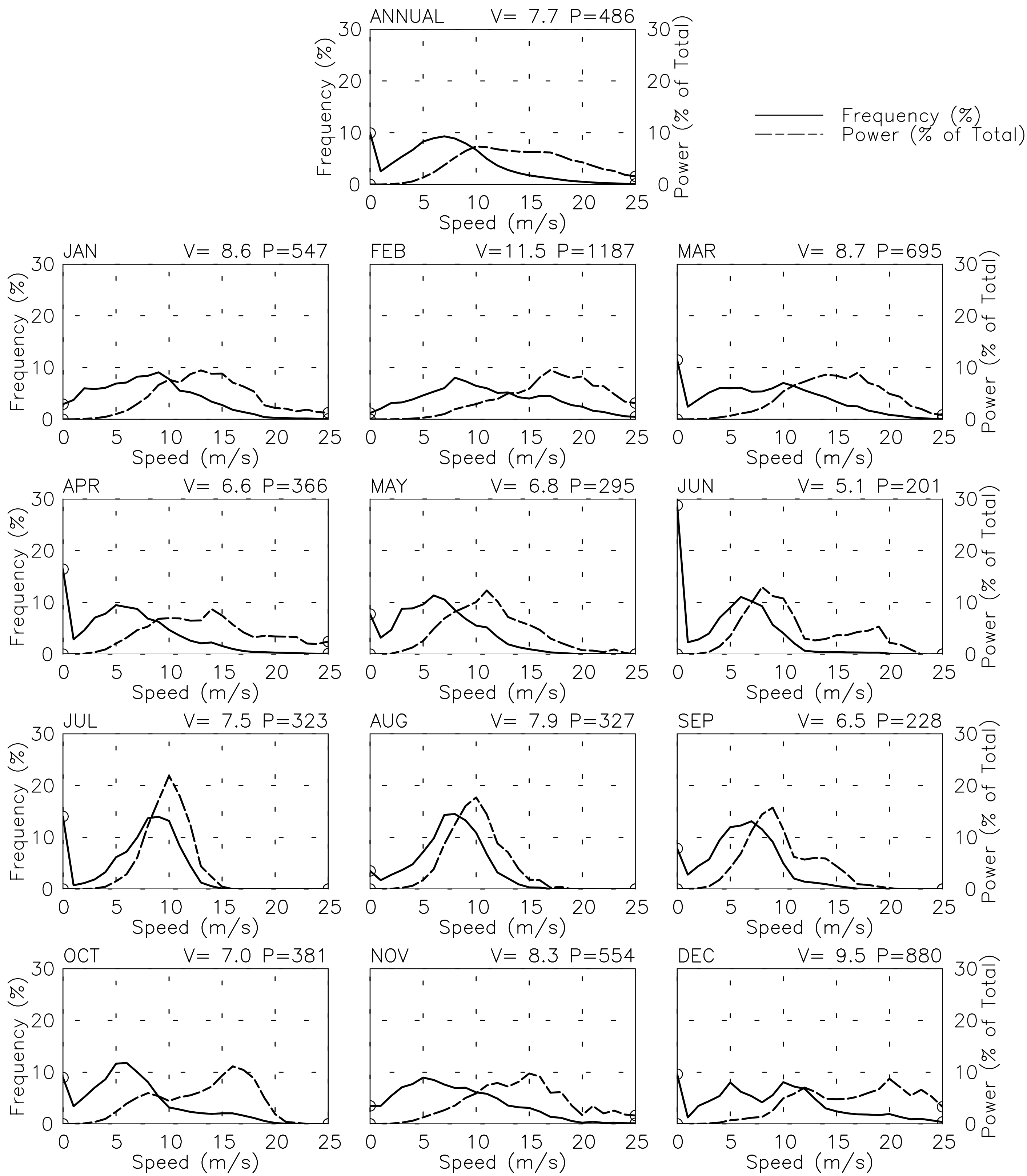
Wed Mar 26 16:21:59 2003

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

Zod Site 009 20m - 000009

40° 14' N 45° 59' E - Elev 2496m LST=GMT+99 hours *NT= +3

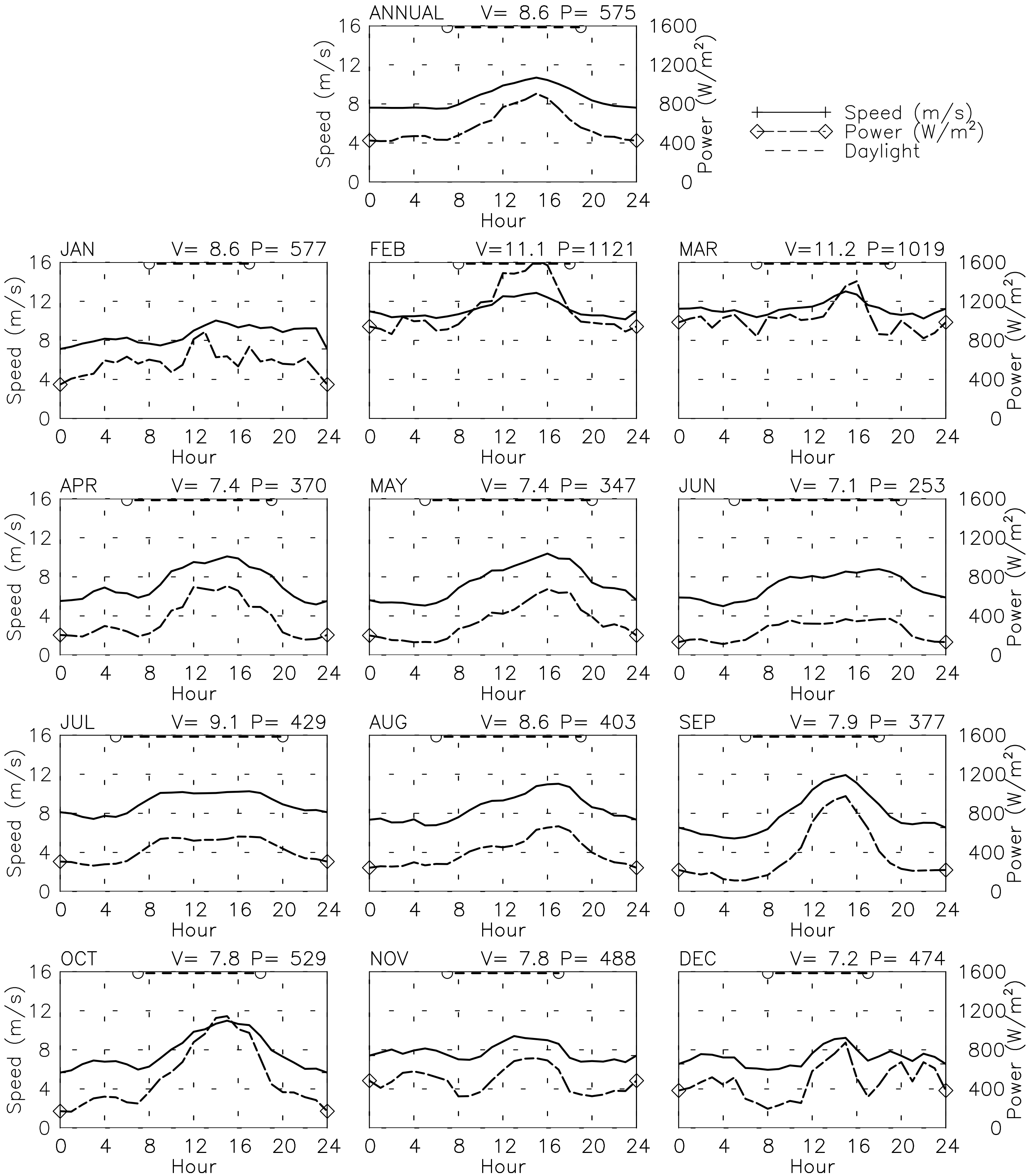
08/00-09/02



Wed Mar 26 16:22:00 2003

SPEED AND POWER BY HOUR

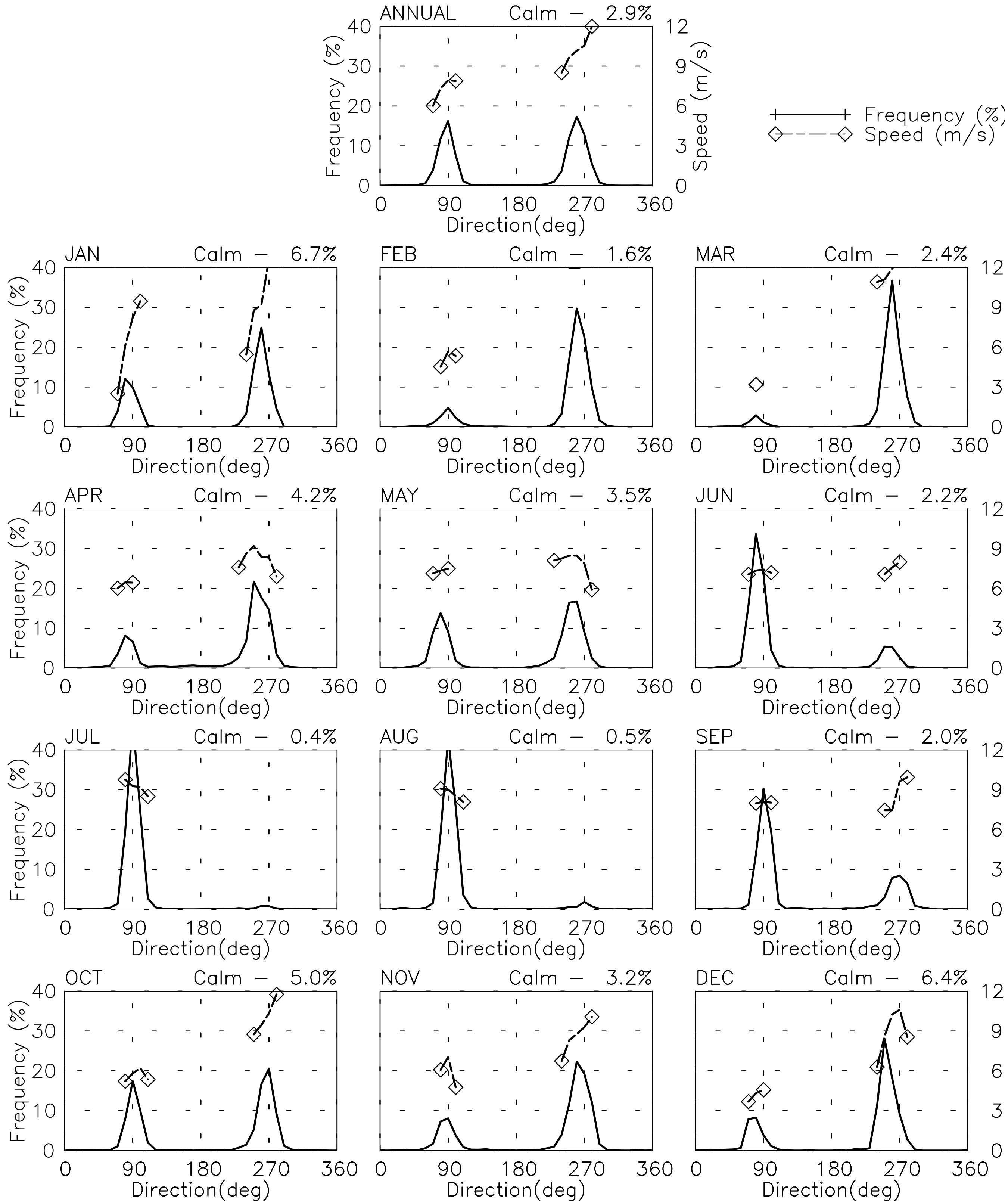
Zod Site 042 30m – 001042
40° 13' N 45° 59' E – Elev 2447m LST=GMT+99 hours *NT= +3
11/00–03/02



Wed May 14 11:00:36 2003

FREQUENCY AND SPEED BY DIRECTION

Zod Site 042 30m – 001042
40° 13' N 45° 59' E – Elev 2447m LST=GMT+99 hours *NT= +3
11/00–03/02



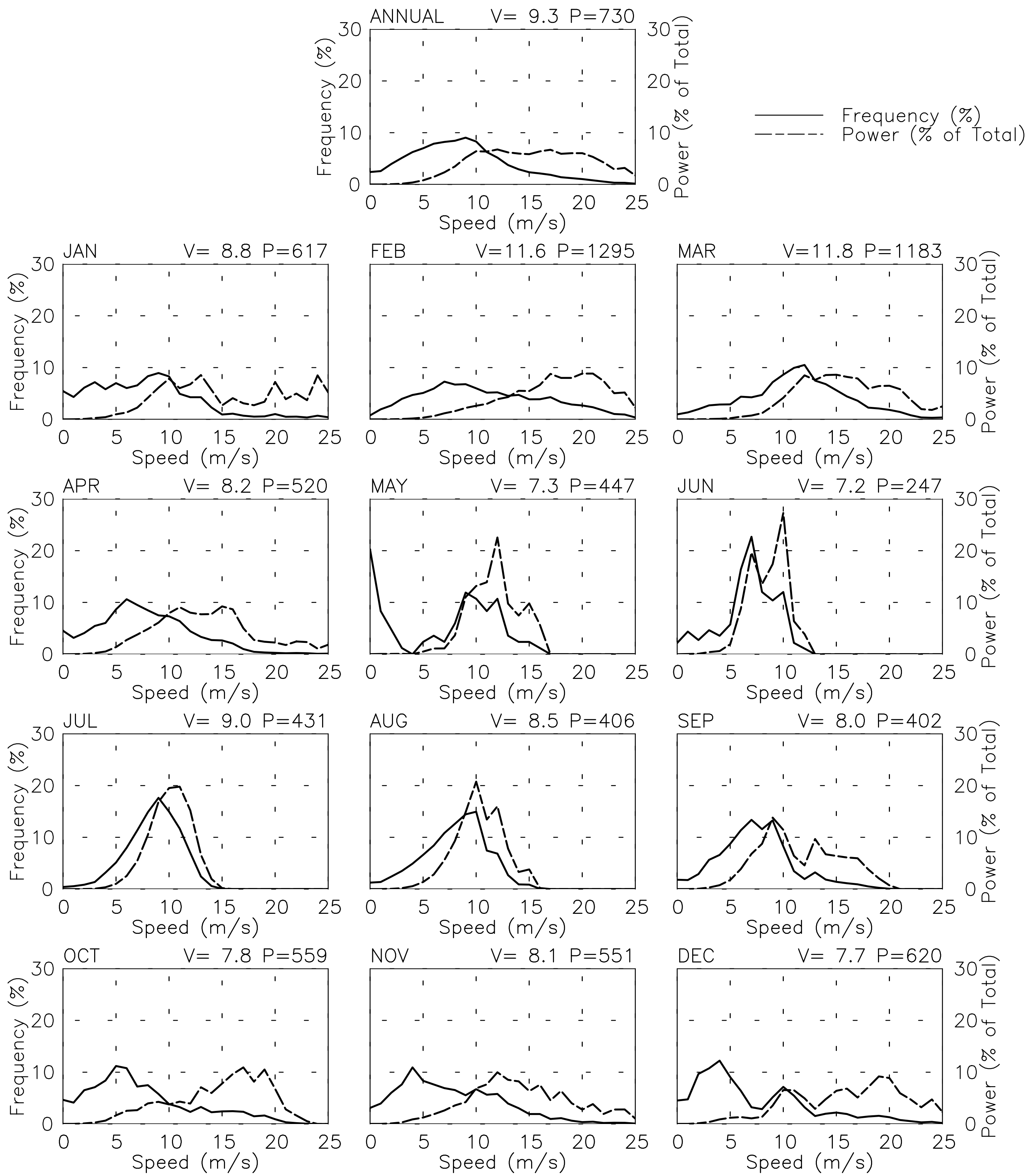
Wed Mar 26 16:40:58 2003

FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

Zod Site 042 40m - 000042

40° 13' N   45° 59' E - Elev 2447m   LST=GMT+99 hours   *NT= +3

11/00-03/02



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This wind energy resource atlas identifies the wind characteristics and distribution of the wind resource in the country of Armenia. The detailed wind resource maps and other information contained in the atlas facilitate the identification of prospective areas for use of wind energy technologies for utility-scale power generation and off-grid wind energy applications. The maps portray the wind resource with high-resolution (1-km^2) grids of wind power density at 50-m above ground. The wind maps were created at the National Renewable Energy Laboratory (NREL) using a computerized wind mapping system that uses Geographic Information System (GIS) software.

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