A SOFTWARE OF ULTRASONIC METEOROLOGICAL STATIONS FOR INVESTIGATION OF THE ATMOSPHERIC TURBULENCE

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Received October 30, 1998

A specialized METEO 2.0 software for ultrasonic meteorological stations is described. The software operates in the Microsoft Windows operating system; it can be easily modified for a particular measuring equipment connected to a computer through COM1–COM4 or LPT1 standard port. METEO 2.0 Windows Application allows one to measure instantaneous values of meteorological parameters and process them in order to study the atmospheric turbulence.

Ultrasonic meteorological stations are a unique instrument for research into the atmospheric turbulence.[1–7] They allow one to estimate instantaneous values of the air temperature and three wind velocity components with the time constant of the order of 10^{-3} s and a sensitivity about 0.01–0.02 (°q or m/s) at 0.1 s or longer intervals. Using these data and specialized algorithms, it is possible to calculate numerical characteristics of the atmospheric turbulence.

We have developed the specialized software for ultrasonic meteorological stations, which is described below as METEO 2.0 Application. The software can be easily modified to fit any particular meteorological equipment connected to a computer through standard COM1–COM4 or LPT1 port. METEO 2.0 Application is a multiwindow 16-bit application running in Microsoft Windows 3.1 or Windows 95 operating system. It requires about 2 Mb of hard disk space. The distinctive feature of the METEO 2.0 Application is its capability to perform secondary processing of measurements along with estimation of meteorological parameters.

METEO 2.0 Application is designed for performing the following functions:

– automatic check of errors in external devices attached to the computer and failures in their operation;

– organization of measurements of instantaneous values of the air temperature and three wind velocity components, as well as mean values of the air pressure and relative air humidity, including round-the-clock unattended measurements;

– calibration of the device–application system (in automatic and manual modes) to achieve the maximum measurement accuracy;

– automatic correction of wind velocity for orientation of the measuring system at the meteorological mast (via measurement of angles of its inclination in the orthogonal planes), as well as for shading the wind flow with ultrasonic transducers;

– automatic storing of all measured instantaneous values of the meteorological parameters on the computer hard disk;

– generation of a specialized report file including the information about measurements performed (date, time, the amount of data, etc.) as well as mean values of the measured meteorological parameters and their statistical characteristics and numerical values of some standard parameters of the atmospheric turbulence (altogether about 70 quantities);

– prediction, based on the Monin–Obukhov similarity theory and video pictures, of mean altitude profiles of the air temperature, horizontal wind velocity, structured constants of the temperature C_T^2 and wind C_V^2 fluctuations, turbulent exchange coefficients for heat and wind velocity, dissipation rate of turbulent energy for temperature and wind, the Richardson gradient number Ri, and the outer scale of the turbulence;

– calculation of the structured functions of temperature DT and wind velocity fluctuations (for longitudinal Drr and transverse Dtt components of wind velocity with respect to the direction of the mean vector of wind velocity);

– calculation of the probability distributions (histograms of the probability density) of fluctuations of the temperature T′, modulus V'_h, and direction F′ of the horizontal wind, longitudinal u′ and transverse v′ components (with respect to the direction of the mean horizontal wind), as well as vertical w′ fluctuations of the wind velocity;

– calculation of autocorrelation and intercorrelation functions for turbulent pulsations of T', V'_h, F', u', v', and w';

– calculation of power spectra of turbulent pulsations of T', V'_h, F', u', v', and w';

– graphical presentation of the results.

0235-6880/99/02 170-05 $02.00

METEO 2.0 provides user-friendliness typical of Windows applications. It has a standard graphic interface including the well-developed system of menus, context-sensitive Help, menu-driven access by shortcut and hot keys (through icons). Any calculated data, both text (numerical) or graphical, can be printed out or stored in text files.

Figure 1 shows the architecture of METEO 2.0 Windows Application. Upon loading, Application displays the main window with menus, which is seen while Application is running. The user can change the parameters of an active problem by selecting needed commands in the dialog boxes. Besides, the user can select a set of dynamically loaded libraries (DLL) corresponding to particular devices and a set of active windows for visual control of execution of basic operations in different tasks.

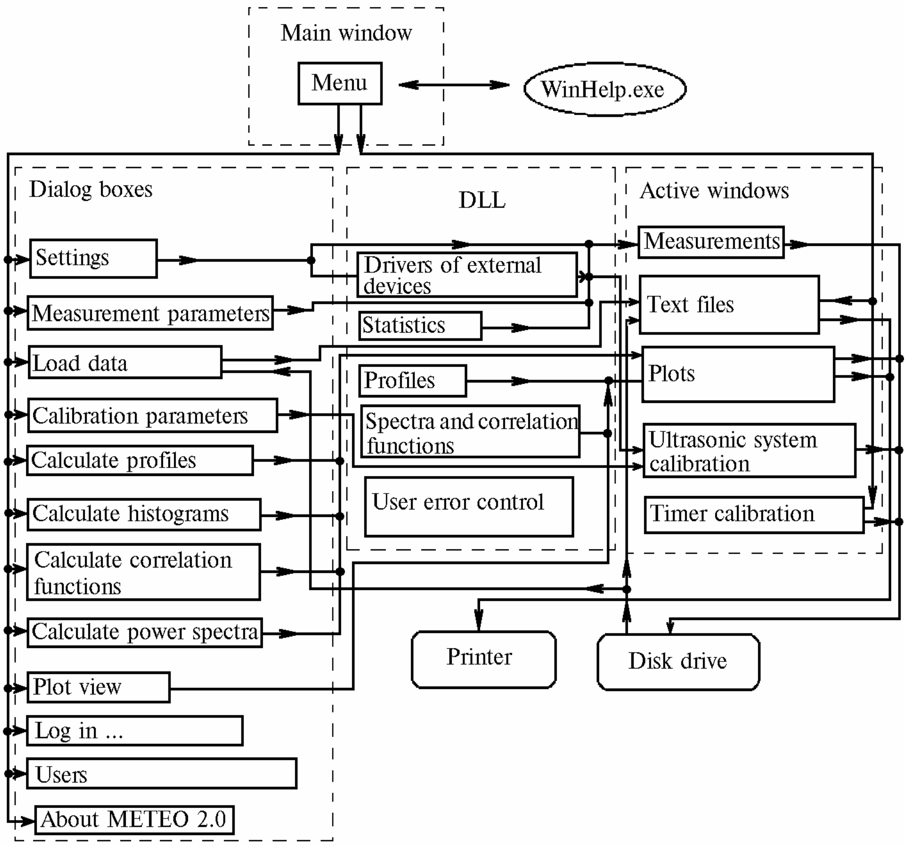

FIG. 1. Structure of the METEO 2.0 software.

Note that METEO 2.0 provides a capability to work with different instrumentation of ultrasonic meteorological stations through DLL with drivers for different external devices. It allows different protocols to be used for communication between the computer and different external devices supported by Application. To change an external device, the user applies to the Settings dialog box. Through this dialog box the executable program can also be allowed or prohibited to poll the additional sensors, which may be a part of a meteorological station (sensors of atmospheric pressure, air humidity, and inclination angle of the meteorological mast).

Figure 2 shows the METEO 2.0 menu system. The Measurement submenu includes the commands for organizing the meteorological measurements and viewing their results, as well as settings for the Application running and its termination. The Calibration submenu includes the commands for control of the ultrasonic system connected to the computer, as well as the commands for automatic calibration of the system and the timer used. The Processing submenu includes the commands for secondary processing of the measured data. The Tools submenu contains auxiliary service commands; the Help submenu provides an access to the Help system.

Upon loaded in the measurement mode, the Application displays the dialog box Measurement parameters, where the user can change the duration $T_{\rm meas}$ of a continuous measurement cycle, the interval Δt between measurements of instantaneous values of the meteorological parameters ($0.1\,{\rm s} \le \Delta t \le 10$ min), and the azimuthal orientation of the ultrasonic system against the north. Besides, the user can set a type of the underlying surface (from the list of models) to be taken into account, save instantaneous values of meteorological parameters and a report containing results of measurements on the hard disk, or reject saving. The maximum value of $T_{\rm meas}$ is restricted by the

PC capability to store up to 16382 instantaneous values of each of the eight measured meteorological parameters (512 Kb). Once this limit is achieved, the measurement process stops, and the data are saved on a computer hard disk. For example, at the maximum measurement rate $F_d = 1/\Delta t = 10$ Hz the value of T_{meas} cannot exceed 27 min. In this dialog, the user can put the ultrasonic station in the mode of automatic round-the-clock operation starting from a preset time. In this case, Application automatically forms the names of the stored files from the date and the starting time of the current measurement cycle.

In the measurement mode, Application displays the specialized window (Fig. 3), which allows real-time monitoring of instantaneous values of the air temperature and three orthogonal components of wind velocity (southward, eastward, and vertical ones) in both numerical and graphical forms. Current values of atmospheric pressure, relative and absolute air humidity, meteorological mast inclination angles, as well as the speed and the direction of horizontal wind are also shown here. Once a measurement cycle is completed, average values of the meteorological parameters are calculated and displayed.

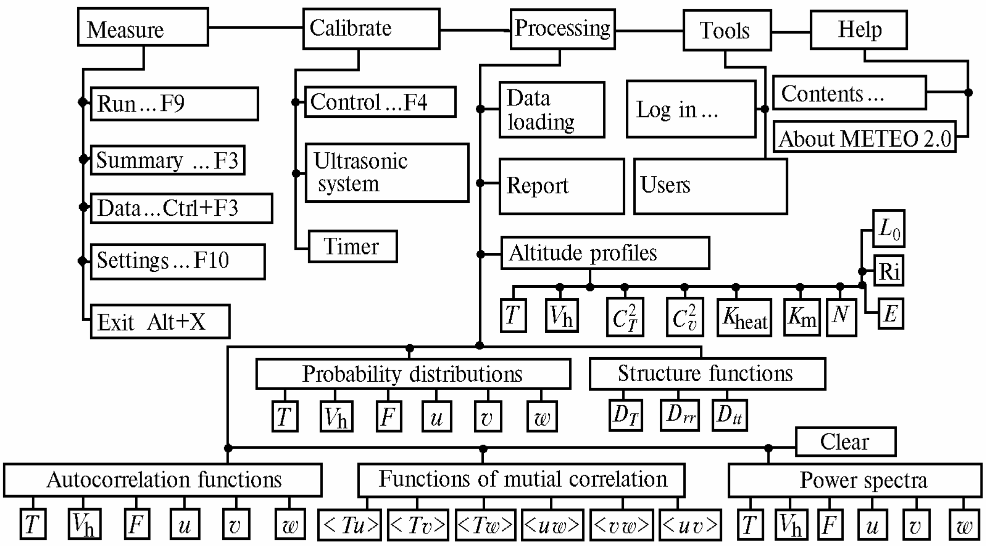

FIG. 2. Menu system of the METEO 2.0 Windows Application.

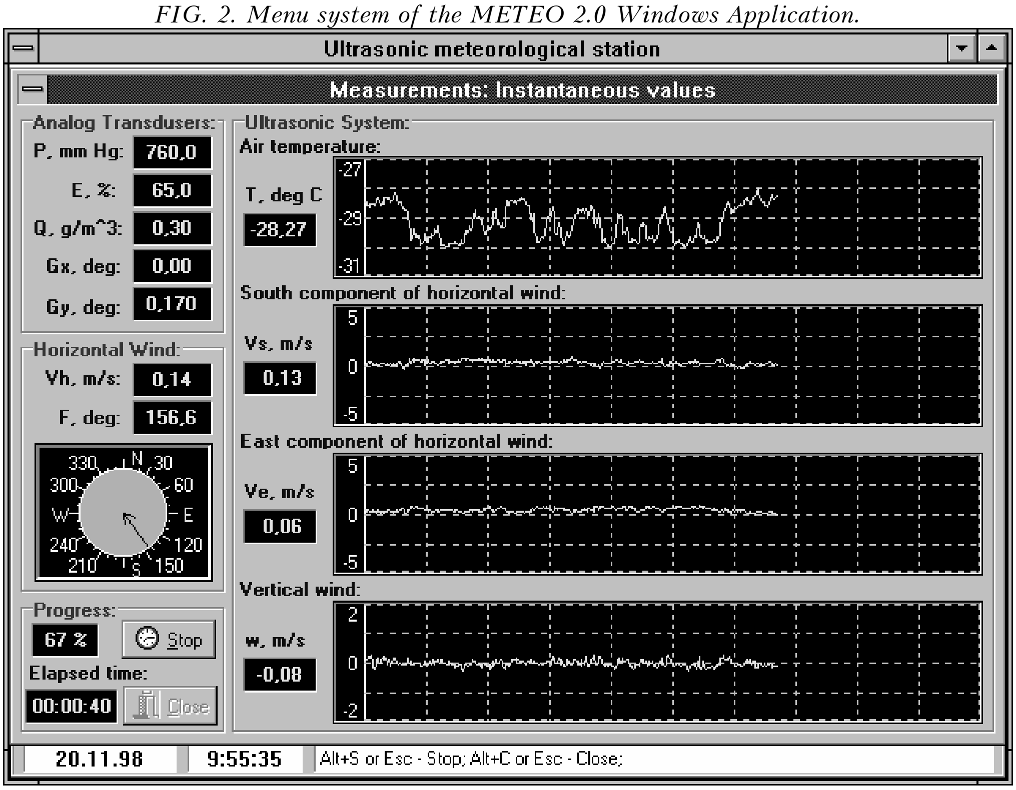

FIG. 3. METEO 2.0 Windows Application: the window for current measured data.

The calibration of the ultrasonic system is in accurately estimating the distances between ultrasonic sensors. For that, Application first asks for the true value of the air temperature measured by a control thermometer. Then it organizes measurements of the distances with regard for this value. The ultrasonic system in this case is used as an acoustic meter of distances. The results of calibration are stored in meteo2.ini initialization file.

For accurate estimation of the atmospheric turbulence parameters, it is important to measure instantaneous values of meteorological parameters at strictly synchronized intervals Δt. At the same time, the minimum controllable interval in the Windows operating system is equal to 1 ms. Therefore, METEO 2.0 Application performs reprogramming of the computer timer, which allows synchronization of time processes with 1 μs resolution.

During secondary processing of data, Application uses the files containing instantaneous values of meteorological parameters. The user can select one such file on the computer hard disk. In the computer RAM, Application forms samples of instantaneous values of the air temperature, vertical, longitudinal, and transverse wind components (with respect to the direction of the mean horizontal wind) with the given initial point and the number of points. Then these samples can be processed by different methods selected using the corresponding commands from the menu. The numerical results of data processing are graphically displayed in separate windows (Fig. 4). The windows differ only by the data displayed, while being identical in the general view and the control means. Here the user can view numerical data corresponding to plot points by scanning the plot with the mouse pointer. He (or she) can also store the data into a new file, change the view of a plot, and print it out. The number of windows, which can be opened simultaneously, is restricted in practice only by the available computer resources.

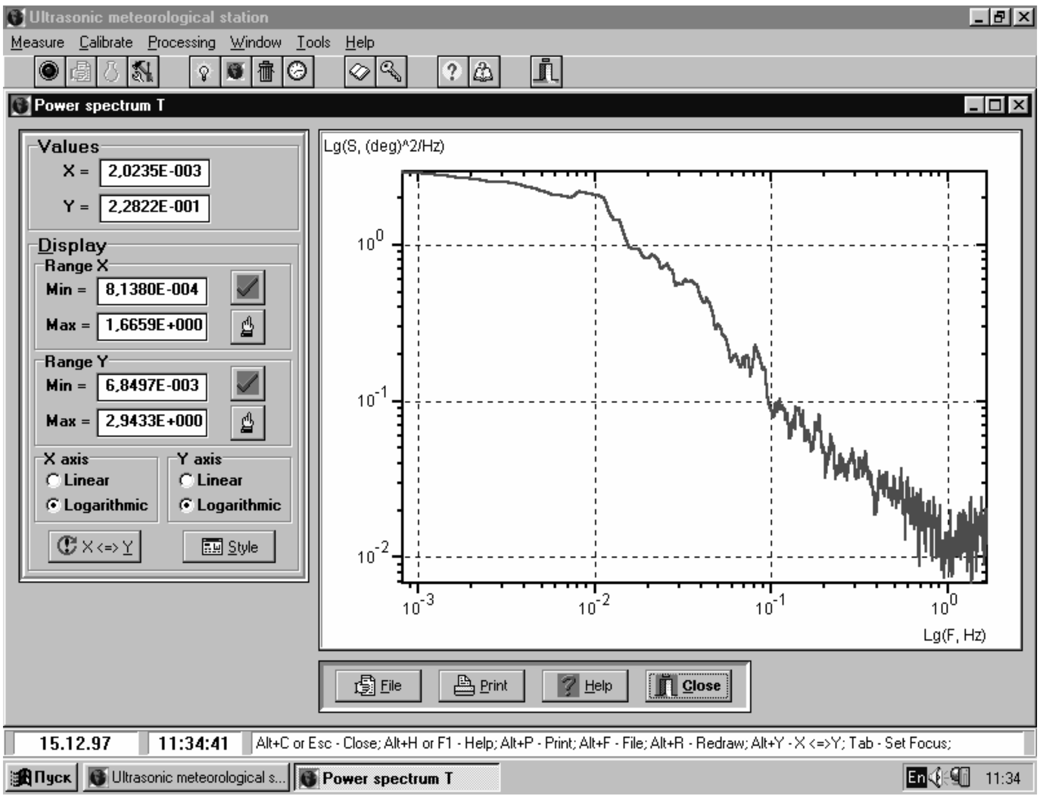

FIG. 4. METEO 2.0 Windows Application: the window for graphical data obtained at secondary processing of the measured results (the window displays the power spectrum of turbulent fluctuations of air temperature).

It should be noted in conclusion that the architecture of METEO 2.0 Application allows its functional capabilities to be further extended with minimum expenses. The library of drivers can be supplemented, if necessary, with drivers of other devices connected to a computer and co-operating with Application. Besides, new algorithms for secondary processing of the measured data can be implemented. For optimal performance, METEO 2.0 Application requires 486DX2 PC with RAM of 8 Mb or higher. For Windows 3.1 operation METEO 2.0 requires 386 PC with at least 4 Mb RAM. However, the maximum rate of obtaining the meteorological data cannot be achieved in the latter case, because it is restricted by the value of $F_d \approx 3 - 4$ Hz.

ACKNOWLEDGMENTS

The work was partially supported by the Russian Foundation for Basic Research, Project No. 98–05–03177.

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