DETERMINATION OF METEOROLOGICAL PREPROCESSORS FOR AIR QUALITY MODELS IN THE NEW HUNGARIAN STANDARDS

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Abstract: Using data measured at the central station of the Hungarian baseline climate network meteorological preprocessors of air quality models has been determined. Calculation method of each parameter has been described in the New Hungarian Meteorological Standard. The final aim is to establish a long-term dataset with high temporal resolution for investigation of meteorological preprocessors for air quality dispersion models and for detecting the effects of global climate change on the local dispersion climate.

Key words: *meteorological preprocessor, baseline climate network, meteorological standards, air pollutant dispersion parameters.*

1. INTRODUCTION

This Meteorological information provided with required space and temporal resolution has an impact on the accuracy of the model results. Meteorological input data and preprocessors to dispersion models produced by the climate reference network have high accuracy and quality assured data.

At the Hungarian Meteorological Service, originally, a baseline climate network has been established to describe the local effect of the global climate change. The network meets the requirement of the Global Climate Observing System. These data will be used also for air quality research. The main goal of the establishment of the baseline climate network and the standardization of meteorological measurements and calculation methods is the same, namely, to provide high quality meteorological dataset for climate and dispersion modelling.

2. BASELINE CLIMATE NETWORK IN HUNGARY

The aim of establishing a high precision baseline climate network is to describe the surface layer characteristics (profiles, energy budget components, etc.) for detection of local effects of the global climate change with the highest possible accuracy and reliability. Four background climate stations have been integrated into the automatic synoptical and climate network of the Hungarian Meteorological Service; each of them represents different characteristic sites of the country. The central station located at the Agrometeorological Observatory in Debrecen (northeast of Hungary) is operationally working from April 2008. The quality control of data provided by the Meteorological Service, state of the art measurements and data processing techniques used in the research programs are unified.

The measurement program of the central station (with a 10 m tower) and another baseline climate station consists of: (i) detection of long term changes in basic climate parameters with the highest accuracy (for all elements measured at standard synoptic stations), (ii) besides the conventional 2 m measurements, profile measurements (wind speed, temperature and moisture on the levels $z = 1$ m, 2 m, 4 m and 10 m) and calculation of stratification, (iii) high accuracy radiation budget measurements, (iv) soil temperature and moisture profiles, soil energy budget measurements, (v) determination of energy budget components using the eddy covariance and/or the Bowen ratio methodologies. The first results from the central station are already available and they will be presented below.

3. METEOROLOGICAL STANDARDS FOR DESCRIBING DISPERSION

In the past years a new meteorological pre-processor for use in dispersion models was designed and standardised in Hungary.

The Hungarian Meteorological Standards for dispersion models were updated with the goal of standardising and improving methods for the calculation of meteorological parameters used as inputs in air quality dispersion models. The new Hungarian Meteorological Standards contain the following parts: (i) definitions of meteorological parameters, (ii) description of meteorological measurements in the near-surface layer and in the atmospheric boundary layer, (iii) calculation of dynamical parameters of the surface layer, (iv) wind speed, direction and temperature profile and (v) determination of air pollutant dispersion parameters. The structure of the Hungarian Meteorological Standard is shown in Figure 1.

During the standard development in the meteorological measurements segment, more generic supplemental measurements discussion, sensor accuracy definitions, atmospheric stability class definitions, revised specifications for winds, solar and net radiation, and barometric pressure were added, and a method for accuracy calculations was introduced.

Based on hourly standard meteorological measurements, parameterizations of the global radiation and the radiation budget components and the surface energy budget components (sensible and latent heat fluxes) were developed using the Penman-Monteith methodology (De Bruin, 1983; Holtslag and Van Ulden, 1983; Ács, 1994; Lagzi et al., 2006). The modified Pristley-Taylor parameter was used on the basis of meteorological and agroclimatological information

(Szász and T kei, 1997). Surface layer parameters, such as friction velocity, dynamic temperature and Monin-Obukhov length were calculated from wind speed and sensible heat flux using the Monin-Obukhov similarity theory knowing the roughness length and displacement height (Weidinger et al., 2000; Ács and Kovács, 2001). Finally, ambient turbulence for use in the calculation of dispersion and buoyancy induced dispersion components were also estimated.

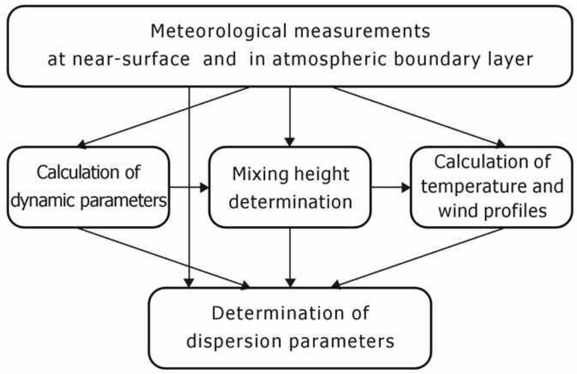

Figure 1. Structure of the Hungarian Meteorological Standard for describing dispersion of air pollutants (arrows represent input data flow between boxes).

In the knowledge of radiation budget components and energy balance measurements (gradient measurements of humidity and wind speed, radiation balance, soil temperature, water content, heat flux) friction velocity, dynamic temperature and the Monin-Obukhov length can be calculated. After that the next step is the determination of mixing height, which involves a method for nocturnal and daytime conditions and for the case of mechanical and thermal turbulence. It is also necessary to calculate the wind speed, the wind direction and the temperature profiles between the surface and the 850 hPa pressure level. Finally, determination of dispersion parameters has been carried out. Additional results of the determination of dispersion parameters are the producing of the height of the plume centreline and the variation of standard deviation of the horizontal and vertical wind speed components with altitude and the determination of vertically averaged meteorological parameters in the mixing layer. Finally the vertical and horizontal components of the dispersion parameters in the Gaussian type dispersion models were also estimated (Cimorelli et al., 1998 and Fisher et al., 1998).

The mean result of the standardizing activity is that the calculation procedures of the meteorological parameters for preprocessors of air quality models and their detailed using criteria are already summarized in the New Hungarian Meteorological Standards (Hungarian Standard Istitution, 2002).

4. SOME QUANTITIES CHARACTERIZING AIR POLLUTANT DISPERSION

The evaluation of data provided by the baseline climate network gives us possibility

- to verify the standardized calculation method of meteorological prepocessor for dispersion models,
- to estimate meteorological quantities more accurately because of using high temporal resolution measured data passed over the quality control procedure.

Preliminary results of the data processing is presented below. The data are available at the central station of the climate network from 28 April, 2008.

Determination of the energy budget components is crucial for further dispersion parameter calculations. Energy budget components include radiation budget (*Rn*), sensible heat flux, (*H*), latent heat flux (*LE*) and surface heat flux into the soil (*Gs*). An additional quantity, the residual term should be introduced (*Res*), which represents the closing error of energy budget measurements:

$$\mathrm{Re}s = Rn - Gs - H - LE \qquad (1)$$

Average daily variation of the energy budget components based on measurements on 1-31 May 2008 at the central station (Debrecen) of the baseline climate network is shown in Figure 2.

The energy budget components could be determined by using the Bowen ratio methodologies. The Bowen ratio (*Bow*) can be calculated from the sensible (*H*) and latent (*LE*) heat fluxes:

$$Bow = \frac{\mathrm{H}}{LE} \qquad (2)$$

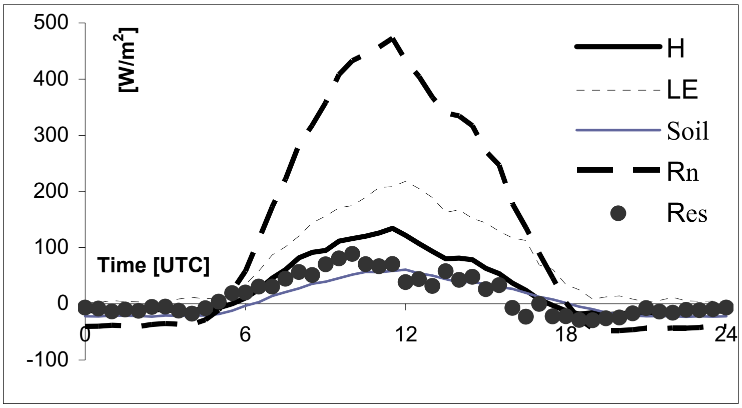

Figure 2. The average daily variation of the energy budget components over the period of 1-31 May, 2008 at the central station (Debrecen).

After the application, some filtering criteria (to eliminate the extreme values as suggested by Ohmura, (1982), and data grouped as $0 < Bow < 2$, and $-2 < Bow < 2$) the medians of the Bowen ratio over the period 1-31 May 2008 are shown in Figure 3. It can be seen that during the daytime the difference between the medians of the different methods of averaging can be neglected.

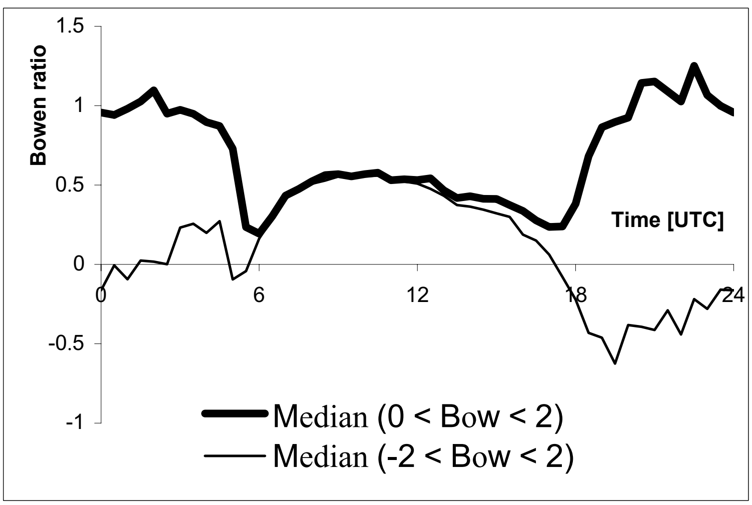

Figure 3. Average daily variation of the Bowen ration over the period of 1-31 May 2008.

Figure 4 shows the comparison of three different methods for determination of the Bowen ratio. In the figure the circles represent Bowen ratio values calculated from direct flux measurements (eddy covariance). During daytime there is not a big difference between the methods, while during the night big fluctuation of direct measurement was found. It shows that measurements are more or less reliable because of weak turbulence during the night.

To characterize the atmospheric stability, the Richardson number (Ri) has been calculated by the following equation between four layers of the measuring tower:

$$Ri = \beta \frac{\Delta\Theta_v}{(\Delta U)^2} \Delta z \,, \tag{3}$$

where ΔU is the difference of wind speeds, $\Delta\Theta_v$ – the difference of virtual potential temperatures, Δz – the difference of altitudes, β is a stability parameter, depending on the rate of gravity acceleration and average virtual potential temperature of the mixing height ($\beta = g / \overline{\Theta_v}$). Figure 5 shows that the typical daily variation of atmospheric stability and the Ri values of four different layers have similar course.

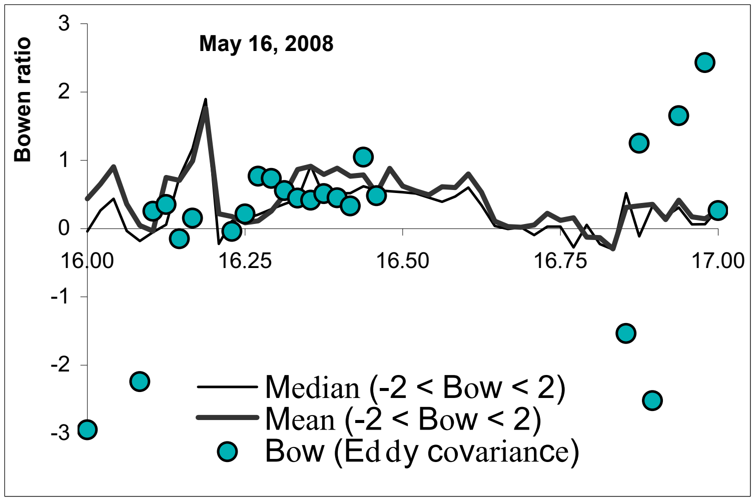

Figure 4. Relationship between the Bowen ratio method (with two averaging techniques) and the eddy covariance method.

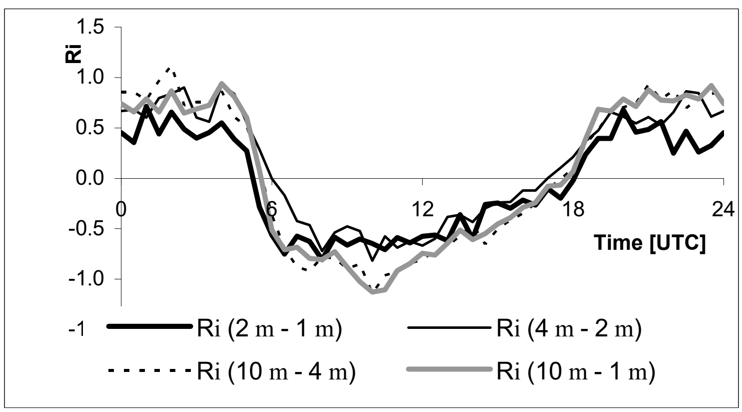

Figure 5. Average daily variation of the Richardson number during the period 1-31 May, 2008.

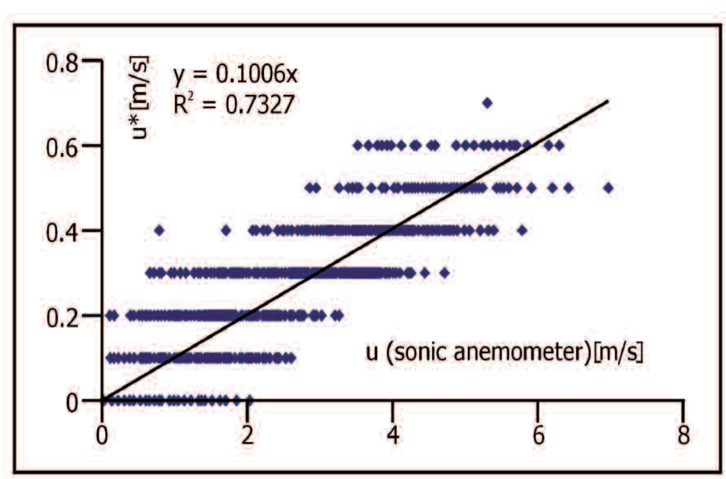

Figure 6. The relationship between friction velocity and wind speed measured by sonic anemometer.

The friction velocity can be calculated on the basis of sonic anemometer measurements. The relationship between the friction velocity and the wind speed (see Figure 6.) indicates the reliability of the measurements. The friction velocity is one tenth of the wind speed, which corresponds to the results found in literature.

Going further on this way, the final goal is to create a long-term database containing all meteorological parameters used by preprocessors. This database is also useful for

- comparison of dispersion models results
- detection of the effect of climate change on dispersion climate.

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REFERENCES

Ács, F., 1994: A coupled soil–vegetation scheme: description, parameters, validation, and sensitivity studies. *J. Appl. Meteor.,* **33**, 268–284.

Ács, F. and M. Kovács, 2001: The surface aerodynamic transfer parameterization method SAPA: description and performance analyses. *Idöjárás* **105**, 165–182.

Cimorelli, A.J., Perry, S.G., Venkatram, A., Weil, J.C., Paine, R.J., Wilson, R.B., Lee, R.F. and Peters, W.D., 1998: AERMOD – Description of Model Formulation. *Version 98315 (AERMOD and AERMET) and 98022 (AERMAP)/ EPA document*, Posted on EPA Web site. http://www.epa.gov.scram001.

De Bruin, H.A.R., 1983: A model for the Priestley–Taylor parameter . *J. Clim. Appl. Meteorol.* **22**, 572–578.

Fisher, B., Erbrink, J., Jeannet, P., Joffre, S., Morselli, M., Pechinger, U., Seibert, P. and Thomson, D. (eds.), 1998: Harmonisation in the preprocessing of meteorological data for atmospheric dispersion models COST Action 710 Final Report. *EC-DG Science, Research and Development, EUR 18195 EN*, Luxembourg.

Holtslag, A.A.M. and Van Ulden, A.P., 1983: A simple scheme for daytime estimates of the surface fluxes from routine weather data. *J. Clim. Appl. Meteor.* **22**, 517–529.

Hungarian Standard Institution, 2002: Meteorological Quatities Characterizing the Transmission of Air Pollutants No. MSZ-21457-1–7. Posted on HSI Web site. http://www.mszt.hu/ (in Hungarian)

Lagzi, I., Mészáros, R., Ács, F., Tomlin, A.S., Haszpra, L., and Turányi, T., 2006: Description and evaluation of a coupled Eulerian transport-exchange model. Part I. Model development. *Idöjárás* ***110***, 349–364.

Ohmura, A., 1982: Objective criteria for rejecting data for Bowen ratio flux calculations. *J. Appl. Meteorol.* **21**, 595–598.

Szász, G. and Tökei, L., 1997: Meteorology for agronomists, horticulturists and foresters. Mezögazda Kiadó. (In Hungarian).

Weidinger, T., Pinto, J. and Horváth, L., 2000: Effects of uncertainties in universal functions, roughness length, and displacement height on the calculation of surface layer fluxes. *Meteorologische Zeitschrift* **9**, No. 3, 139–154.