Making Thermal Activity Forecast at the Hungarian Meteorological Service

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Abstract

At the Division for Aviation and Severe Weather Forecasting of the Hungarian Meteorological Service, thermal activity forecasts are made for soaring flight. In the last 20-25 years, the numerical weather prediction models have developed so quickly that our old statistical method could have been replaced with an automatic forecast. However, the method for the calculation is the same. Our thermal activity forecasting method is based on a statistical method, which was developed in the 80's by János Szalma, András Kerekes, Bertalan Katkó and Valéria Sándor. We automated their old method in the last ten-fifteen years. Most input data come from the ALADIN.HU numerical weather prediction model, but some predictors still are determined by the synoptic meteorologist. Using the input data, the program makes automatic forecasts for wind, maximum temperature, visibility range, starting time of thermals, end of thermal activity, lifting in thermals and height of 0 degree centigrade. Of course, the weather forecaster can modify these automatic thermal activity forecasts, and he/she may compliment them with warnings or different comments. Furthermore, our thermal activity forecasts have been verified since 1995.

Introduction

At the Division of Aviation and Severe Weather Forecasting of Hungarian Meteorological Service, we make thermal activity forecasts from April through September. These forecasts are used by pilots of gliders, hanggliders and paragliders. Of course, paragliders need much better wind forecasts than gliders or hanggliders. In this study we will show the method which is used for the prediction of thermal activity.[1, 5, 7, 14]

Types of thermals

In a sunny weather situation, due to the different ground conditions, the sun can warm each type of ground differently. As a consequence, the air above the ground will heat up at different rates.

When the air is warm enough to become absolutely unstable, it can rise from the surface cooling at the dry adiabatic lapse rate.[26, 27] If the rising air is hot enough to reach the convective condensation level (CCL), then cumulus clouds will form. In Hungary, we define a flyable thermal if the air is able to lift a glider to at least 1000 m above the ground level (AGL).

Two different types of thermals can be differentiated: bubble thermals and chimney thermals. In the first case the lifting is not stable, but turbulent. This type of thermals appears when the temperature is close to the starting temperature of thermals, a strong wind blows and an inversion layer is situated between 1500-2000 m AGL. The lifetime of this type of thermal is usually 5-20 minutes. In the case of chimney type thermals, the lifting is not turbulent. In addition, lifting increases by moving to the centre of thermal. This type of thermal appears when the temperature is much higher than the starting temperature of thermals, a weak wind blows and there is no inversion. The lifetime of chimney thermals is usually 15-30 minutes.

Methods

Our method is based on a statistical method developed in the 1970's, 1980's.[30, 31] This method was developed further by us using new weather prediction model data and our new global radiation and temperature forecasting methods. Using these methods, we have attempted to predict the real strength of lifting.

To make forecasts, the new method uses the data of 10 radiosonde stations measured at 00 UTC (Viena, Graz, Prostejov, Poprad, Zagreb, Belgrade, Budapest, Szeged, Uzhgorod, Cluj Napoca), data of 6 SYNOP stations measured at 04 UTC (Baja, Békéscsaba, Budapest, Győr, Nagykanizsa, Nyíregyháza) and the data of ALADIN.HU mesoscale weather prediction model.

Using radiosonde and SYNOP data, we can calculate the average gradient between the inversion and 2000 m height, the starting temperature of thermal, the CCL and the cumulus condensation temperature. To calculate the above mentioned predictors, the following equations were used.

Height difference between 'breaking points' in the temperature lapse rate

$$H_2 - H_1 \cong \frac{R\cdot(T_2+T_1)}{2\cdot g}\cdot \ln\left(\frac{P_1}{P_2}\right)$$

$$g = 9.78529472\frac{m}{s^2} \quad (1)$$

$$R = 286.8\frac{J}{kg\cdot K}$$

Gradient of the isogram (iso-mixing ratio)

$$\Gamma_i = -0.16541\frac{\mathrm{K}}{100\mathrm{m}} \quad (2)$$

Dry adiabatic lapse rate

$$\Gamma_a = -0.974\frac{\mathrm{K}}{100\mathrm{m}} \quad (3)$$

The error of the above mentioned equations is -2, +10 meters between the surface and 700 hPa level. The error of calculating the CCL is -5 to -10 meters. Using ALADIN.HU results, we determine the height of 0°C level, the wind speed and wind direction at 10 m AGL, 500 m, 1000 m, 1500 m and 2000 m height AMSL and the base of the stable or inversion layer if one exists.

It seems that the height of 0°C level and the wind direction are predicted well by the model, but the wind speed is a little bit underestimated. Additionally, the inversion layer sometimes is predicted insufficiently by the model, so we need to correct it using observed radiosonde data. We calculate these sets of data for six Hungarian cities (Baja, Békéscsaba, Budapest, Győr, Nagykanizsa, Nyíregyháza).

We use the predictors listed in Table 1 for calculating strength of thermals. Two predictors – surface condition (3) and synoptic situation (11) are determined by the aviation forecaster. The other 9 predictors are calculated from the model and radiosonde data. But, the forecaster can modify the predicted global radiation (1) and visibility range (2) data.

Surface condition categories:

1. Inundated Area
2. Very wet and dense forest
3. Very wet and straggling forest
4. Very wet steppe
5. Wet and dense forest
6. Wet and straggling forest
7. Wet steppe
8. Wet sand
9. Dry and dense forest
10. Dry and straggling forest
11. Dry steppe
12. Dry sand
13. Droughty steppe

The above mentioned surface condition categories determine the evapotranspiration heat. In the case of categories 1-3, the biggest part of global radiation evaporates water from the surface, so the air will not become warmer. In the case of categories 11-13, the biggest part of the incoming global radiation heats the air. To estimate the wettness of the ground the synoptic meteorologist can use the 72-96 hours precipitation data of 110 Hungarian precipitation measuring stations which data can be found in the "INDA" system. Of course, the 13 categories can not cover every available surface condition in Hungary, but the forecaster is able to estimate the real evapotranspiration heat and the program makes a linear interpolation between category 1 and category 13.

The following synoptic situations have been identified:

1. Slowly moving, wavy frontal zone
2. Cyclone centre or Mediterranean cold front
3. Strong warm sector
4. Foreside of a cyclone with southerly wind
5. High level low
6. "Old" anticyclone or backside of an anticyclone
7. South part of an anticyclone
8. Flat pressure situation
9. "Middle age" anticyclone
10. Westerly streaming
11. Short life high pressure area
12. Foreside of an anticyclone
13. "Young" anticyclone
14. Quick cold front or backside of a cyclone (wet)
15. Backside of a cyclone (dry)

In the case of a wavy frontal zone or cyclone centre situations, the sky is covered by clouds and the weather is rainy or thunderstormy. Understandably, these situations are not suitable for thermal activity. In the case of foreside of an anticyclone or backside of a cyclone, cool and relatively dry air is streaming above Hungary, so these situations are good for thermal activity. Of course, the 15 categories are not good for all kinds of synoptic situations, but the forecaster is able to decide that the real weather situation is suitable or unsuitable for thermal activity, and the program makes a linear interpolation between category 1 and category 15.

Furthermore, 11 additional predictors are considered: 1) dew point, 2, 3) the sum of dew point depression (850, 700 hPa), 4) the height of the CCL, 5) the advection at 850 hPa level, 6) the Laplace of pressure in a 300 km radius circle and the 7) average gradient are calculated automatically from the ALADIN.HU model and TEMP data using different program algorithms. Using special algorithms the program calculates 8) the visibility range at 12 UTC, 9) the amount of global radiation between sunrise and 15 UTC, 10) the maximum temperature and 11) the starting time of thermals using ALADIN.HU model data, 4 UTC SYNOP data and 00 UTC TEMP data.[6, 10, 11, 12, 17, 18, 23, 25, 28, 29]. If the forecaster wants to modify these sets of data, then he/she can do it.

Using the 11 above mentioned predictors, the program makes an automatic thermal activity forecast for 5 regions of Hungary using the average of the 11 predictors. The lifting (rate of climb of the glider) is dependent on the glide ratio, so the calculated lifting is valid at glide ratios between 15/1 and 30/1 (Pirate and Jantar type gliders). In cases, when the glide ratio is greater than 30/1, the lifting is underestimated (Nimbus 3, Nimbus 4 type gliders).

The calculated thermal activity data are saved in MS-DOS text file format by the program, and we can modify them or we can complete them by warnings, different comments of special weather phenomena or general weather forecasts using WinWord. Between May and September the calculated lifting data are usually sufficient, but in some weather situation they are overestimated. In the case of strong wind or medium level (1500-2200 m) inversion, the lifting is overestimated, so the weather forecaster needs to reduce the values of the results. In March and April the lifting is usually overestimated because of the low dew points.

To estimate the amount of cumuli, we use different methods. We get the cloud data of the ALADIN.HU model, or we can calculate cloud cover using a statistical method based on relative humidity forecast data. Furthermore, if the maximum temperature is lower than the cumulus condensation temperature then any cumulus clouds do not appear in the sky, only blue thermals will be possible.

Using a statistical method connected to the vertical profile of relative humidity, we can estimate the amount of medium level (Ac, As) and high level (Ci, Cc, Cs) clouds.

Using model data and our maximum temperature forecast, we can determine the base of Cumuli. Using our maximum temperature forecast the Cumulus base forecast is a little bit better than the model forecast.

Using the different stability indices (SSI, K-Index, Total Totals, CAPE, etc.) of the numerical weather prediction models and further parameters (vorticity advection, windshear, convergence, etc.), we can determine the probability of appearance of cumulonimbus clouds and thunderstorms.[2, 4, 26, 27]

Using model data we can determine the special phenomena (warm advection, appearance of inversion, etc.) and severe weather phenomena (hailstorm, torrential rain, stormy windgusts, etc.).

The detailed subscription of our thermal activity forecast can be found on the FTP server of Hungarian Meteorological Service and you can see it in Fig. 1.

Results

Every weather forecaster would like to know whether his/her prognosis was good or bad. This is the reason why we developed an automatic verifying method. Between 1996 and 2008, we verified the meteorological elements of our thermal activity forecasts[3, 8, 9, 13, 15, 16, 19, 20, 21, 22, 24] (Figs 2, 3, 4, 5, 6, 7, 8, 9, 10.). At first, we verified our forecasts using the data of those synoptic stations where human observers were. Unfortunately, the number of these stations has decreased in the last 15 years, so we needed to use radar, lightning detector data and temperature data of automatic weather stations. The greatest problem is the verification of the amount of cumuli because of the decreased number of meteorological observers.

Between 1996 and 2006 we made thermal activity forecasts from April through September, but in 2007 and 2008 the length of time of making forecasts shortened to those three weeks when gliding championships were conducted in Hungary. This is the reason of great deviation of precipitation and cumulonimbus existence data of the years 2007 and 2008. Although, we have gathered the GPS data of Hungarian gliding championships in the last 3 years, so in the future we will attempt to build them into our method, so we are going to continue our work to elaborate on our method onto a higher level.

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Table 1

The decision scheme and used predictors of thermal activity program

Average Lifting (m/s)	0.2	0.3-1.3	1.3-1.8	1.8-2.3	2.3-2.8
Maximal Lifting (m/s)	0.3	0.7–1.7	1.75–2.25	2.3–2.8	2.85–3.35
1. Global Radiation between sunrise and 15 UTC (J/cm^2)	<700	700-1300	1300-1600	1600-2000	>2000
2. Visibility Range at 12 UTC (km)	<=5	5–10	10–15	15–20	>20
3. Surface Condition (evapotranspiration heat)		Categories 1–4	Categories 5–8	Categories 9–10	Categories 11–13
4. Average gradient at 00 UTC (°C/100m)	>–0.4	-0.40, -0.45	-0.45, -0.55	-0.55, -0.65	<-0.65
5. Starting Time of Thermals (UTC)		>11	10–11	9–10	<9
6. Dew Point at 05 UTC (°C)		>15	12.5–15	10–12.5	<10
7. $D_{850}+D_{700}$ (°C)	<5	5–8	8–10	>14	10–14
8. Height of CCL (m)	<700	700-1200	1200-1400	1400-1800	>1800
9. Advection at 850 hPa Level (00-12 UTC) (°C/12h)	> +6	+6 – +3	+3 – +1	+1 – -1 < -3	-1 – -3
10. ∇^2 (P) (10^{-5}hPa/km^2)		<-10 >+10	-10–-7 +6–+10	-7–-3 +2–+6	-3–+2
11. Synoptic Situation		Categories 1-6	Categories 7-10	Categories 11-13	Categories 14-15

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Thermal activity forecast for Hungary

Valid:10-07-2010

General forecast: Weather of Hungary is determined by an anticyclone. The sky will
usually be clear, only few Cu clouds will appear in the sky. Late afternoon in NE
part of Hungary temporarily will increase the amount of clouds, and there will be a
small chance of showers or thunderstorms. Moderate northerly wind will usually blow,
but in E part of Hungary fresh or strong gusts will be possible in some places. In
Transdanubia afternoon will an inversion layer develop between 1800-2000 m height, so
the thermal activity will become weaker after 16.00 HLT.

Warnings: Gusts exceeding 25 KT in E part of Hungary. Isolated Cb or thunderstorm
will be possible in NE part of Hungary. Probability of thunderstorm: 5-10%.

Special effects: Inversion in Transdanubia. Mainly in W part of Hungary only blue
thermals will develop.

Outlook: Wetter and more unstable air will arrive to Hungary from E direction, so the
inversion layer will disappear, and locally showers or thunderstorms will develop.

Made by: Attila Fövényi

:::Observed vertical gradients at 00 UTC
::Height [m]; Gradient [ C/100m]
;        Budapest;           Viena;           Zagreb;         Uzhgorod;         Szeged
; 139- 225; 3.954; 209- 252;11.566; 128- 266; 4.351;         ;        ;  83- 168; 9.896
; 225- 499;-0.146; 252- 296; 3.188; 266-1822;-0.668;         ;        ; 168- 431;-0.380
; 499-2146;-0.813; 296- 385; 0.225;1822-1976; 0.779;         ;        ; 431-1472;-0.903
;2146-2368; 0.541; 385-1019;-0.694;1976-2576;-0.567;         ;        ;1472-1709; 0.253
;2368-2695;-0.367;1019-1085; 0.000;2576-3004;-0.560;         ;        ;1709-1994;-0.491
;2695-3723;-0.681;1085-1268;-0.986;         ;       ;         ;        ;1994-2288;-0.545
;         ;       ;1268-1316; 1.235;         ;       ;         ;        ;2288-2470;-0.438
;         ;       ;1316-1375;-1.023;         ;       ;         ;        ;2470-2612;-0.846
;         ;       ;1375-1434; 0.339;         ;       ;         ;        ;2612-2868;-0.704
;         ;       ;1434-1724;-0.827;         ;       ;         ;        ;2868-3366;-0.321
;         ;       ;1724-1857; 0.151;         ;       ;         ;        ;         ;
;         ;       ;1857-2278;-0.428;         ;       ;         ;        ;         ;

:::::Thermal activity
::Starting/end of thermals [HLT]
;NW-Hun.   ;Budapest   ;NE-Hun.    ;SW-Hun.    ;SE-Hun.
;11.30-18.00;10.30-19.00;10.30-18.30;11.30-18.30;11.00-19.00
::Trigger temperature/ maximum temperature [ C]
;NW-Hun.   ;Budapest   ;NE-Hun.    ;SW-Hun.    ;SE-Hun.
;   28/30-33;   26/30-32;   24/27-31;   25/30-32;   25/28-31

:::Top of Cu cloud [m]
:::Base of Cu cloud [m]
:::Top of blue thermals [m]
:::Amount of Cu clouds [octas]

::In the afternoon hours:
;NW-Hun.   ;Budapest   ;NE-Hun.    ;SW-Hun.    ;SE-Hun.
; 1800-1900 ; 2200-2400 ;Above 2500 ; 1800-1900 ; 2400-2500
; 1700-1800 ; 2100-2200 ; 1900-2100 ; 1700-1800 ; 2200-2300
; 1700-1800 ; xxxx-xxxx ; xxxx-xxxx ; 1700-1800 ; xxxx-xxxx
; 0-1/8     ; 1-2/8     ; 2-4/8     ; 0-1/8     ; 2-4/8

::Average lifting at starting of thermals [m/s]
::Type of thermals
;NW-Hun.   ;Budapest  ;NE-Hun.   ;SW-Hun.   ;SE-Hun.
;   0.4-0.9;   1.0-1.4;   0.6-1.1;   0.2-0.7;   0.6-1.1
;bubble    ;bubble    ;bubble    ;bubble    ;bubble

::Average lifting at the time of maximum [m/s]
::Type of thermals
;NW-Hun.  ;Budapest  ;NE-Hun.   ;SW-Hun.   ;SE-Hun.
;   2.1-2.6;   2.2-2.6;   2.2-2.7;   2.1-2.6;   2.2-2.7
;bub-chimney;bub-chimney;   chimney ;bub-chimney;   chimney

:::::Other weather phenomena

:::Height of 0 °C isotherm [m]
:::Base of inversion or stable layer [m]

::10071009 UTC
;Győr    ;Budapest;Miskolc ;Pécs    ;Szeged
;    4210;    4200;    4150;    4250;    4110
;    1720;    2200;     NIL;    1820;    1420

::10071015 UTC
;Győr    ;Budapest;Miskolc ;Pécs    ;Szeged
;    4270;    4180;    4230;    4240;    4060
;    1820;    2100;     NIL;    1750;     NIL

:::Visibility [km]
::Observation at 05 UTC
;NW-Hun. ;Budapest ;NE-Hun.  ;SW-Hun.  ;SE-Hun.
;20.0-40.0;10.0-50.0;25.0-30.0;20.0-50.0; 8.0-20.0

::Predicted visibility for 12 UTC [km]
;NW-Hun.;Budapest;NE-Hun. ;SW-Hun. ;SE-Hun.
;36      ;34      ;32      ;38      ;32

:::Other clouds
::Predicted for afternoon hours:

;NW-Hun.        ;Budapest       ;NE-Hun.        ;SW-Hun.        ;SE-Hun.
;0-2/8 Ci        ;0-2/8 Ci        ;1-4/8 Ci        ;0-2/8 Ci        ;0-2/8 Ci
;xxxx            ;xxxx            ;2-4/8 Cu, Cb   ;xxxx            ;xxxx

::::Wind
:::Predicted wind direction and windspeed [degree, m/s]
:::2000 m
:::1500 m
:::1000 m
::: 500 m
::: Surface

::10071009 UTC
;Győr    ;Budapest;Miskolc ;Pécs    ;Szeged
;   25/ 4;   15/ 6;   35/ 9;   30/ 6;   25/ 8
;   20/ 3;   15/ 5;   40/ 8;   15/ 4;   25/ 8
;   25/ 1;   10/ 2;   25/ 6;   10/ 2;   20/ 7
;   55/ 1;    5/ 2;   20/ 5;   30/ 1;   15/ 6
;   55/ 1;  360/ 1;   15/ 3;   55/ 1;   15/ 4

::10071015 UTC
;Győr    ;Budapest;Miskolc ;Pécs    ;Szeged
;   45/ 4;   40/11;   35/ 9;   10/ 5;   40/ 7
;   20/ 3;   45/ 7;   40/ 8;   15/ 3;   20/ 7
;   15/ 2;   30/ 4;   40/ 8;   20/ 3;    5/ 7
;   15/ 2;    5/ 3;   35/ 7;   30/ 3;    5/ 6
;   20/ 2;  360/ 2;   35/ 4;   40/ 2;  360/ 4
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Figure 1 The Thermal Activity Forecast on FTP Server

Editors comment: the gray shades in the figures that follow are defined in the color images at journals.sfu.ca/ts/.

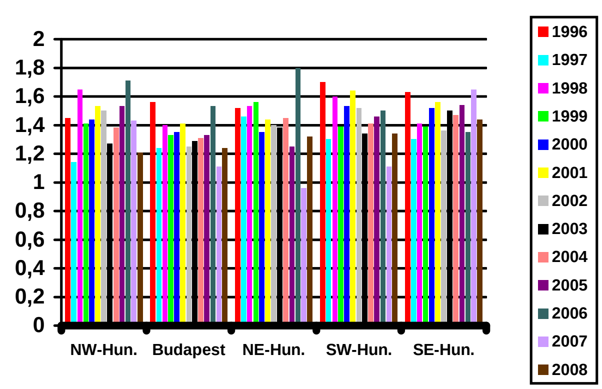

Figure 2 Root-mean-square-error (RMSE) of forecasts of minimum amount of Cu clouds 1996-2008 (octas)

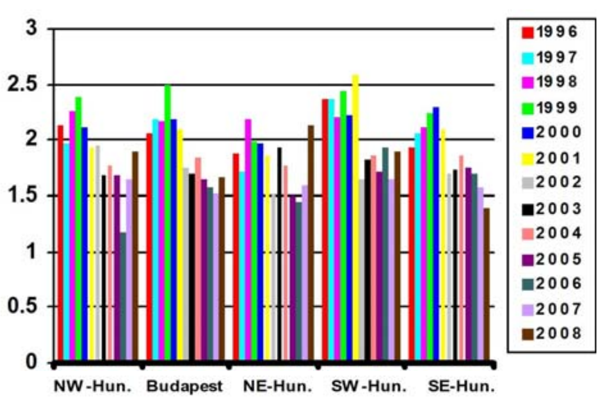

Figure 3 RMSE of forecasts of maximum amount of Cu clouds 1996-2008 (octas)

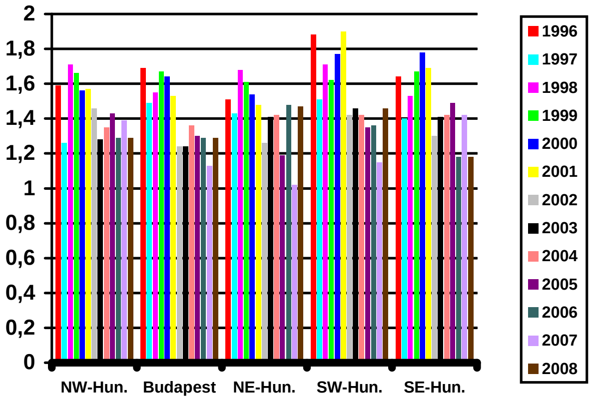

Figure 4 RMSE of forecasts of average amount of Cu Clouds 1996-2008 (octas)

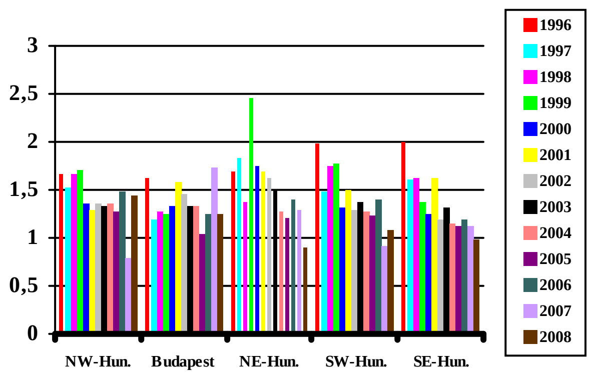

Figure 5 RMSE of maximum temperature forecasts 1996-2008 (°C)

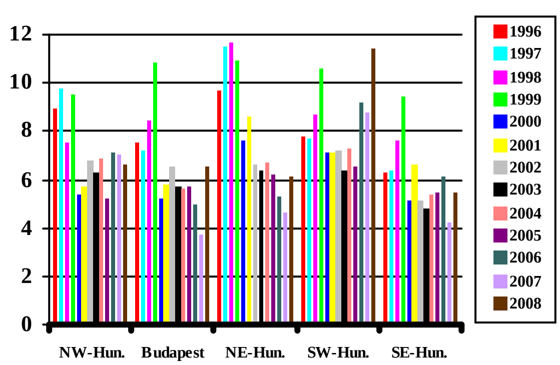

Figure 6 RMSE of visibility range forecasts 1996-2008 (km)

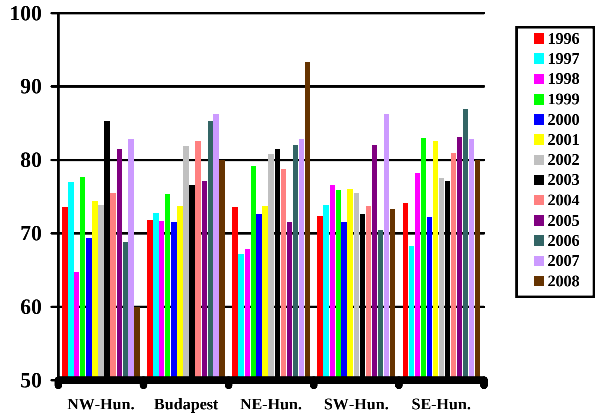

Figure 7 Cumulonimbus cloud existence 1996-2008 (%)

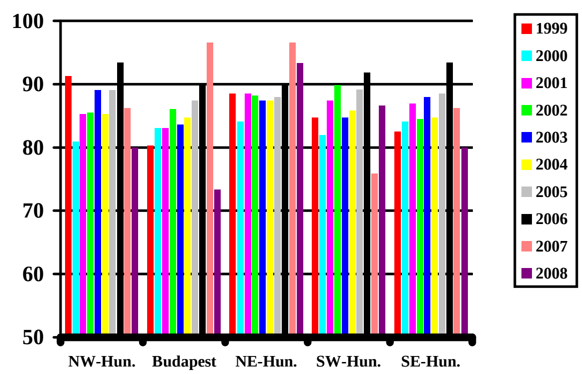

Figure 8 Precipitation existence 1999-2008 (%)

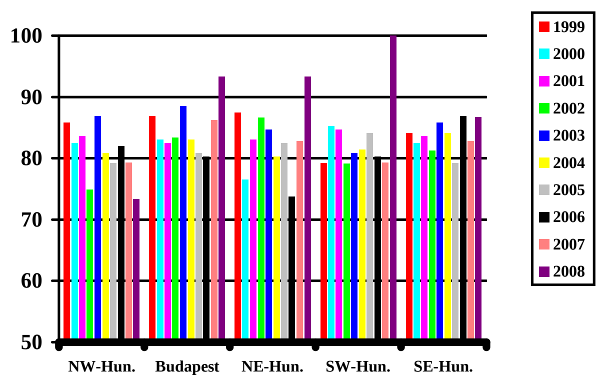

Figure 9 Thunderstorm existence 1999-2008 (%)

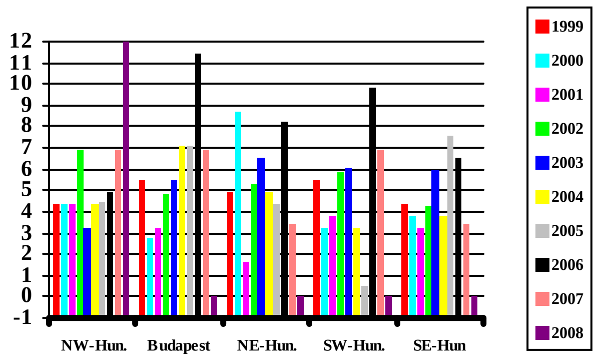

Figure 10 Thunderstorm was observed and it was not predicted 1999-2008 (%)