Comprehensive System of Intense Convective Precipitation Forecasts for Regional Crisis Management

David Šaur, Lucia Ďuricová
Tomas Baťa University in Zlín
Faculty of Applied Informatics
Zlín, Czech Republic
e-mail: saur@fai.utb.cz, duricova@fai.utb.cz

***Abstract*— This paper focuses on the contemporary possibilities of predicting intense convective precipitation and the utilization of this information in Crisis Management procedures of the Zlin Region in the Czech Republic. The first part describes the Information, Notification and Warning System of the Zlin Region, which ensures comprehensive forecasts of convective precipitation. The outputs from the convective precipitation forecast system and the mobile meteorological radar (MMR50) are part of a comprehensive forecast. Both of these predictive tools are analyzed in this paper. The first principles of complex prediction are demonstrated in a case-based study involving the local flash floods that affected the Zlin Region on July 24th, 2015. The main contribution of the paper is unique information on the use of mobile meteorological radar (MMR50) to forecast thunderstorms and flash floods formation in the Zlín Region.**

Keywords-Flash Floods; Weather Forecast; Thunderstorms; Crisis Management

I. Introduction

In the last decade, flash floods have been one of the most abundant types of flooding in the Czech Republic. Despite the fact that large sum of money are being spent on flood prevention measures, effective protection against this type of flooding is almost nonexistent.

The main reason for this situation is the character of torrential floods and the possibility of their prediction. Flash floods are caused by intense convective precipitation over a very small area - in the order of kms^2 in a relatively short time (several dozen of minutes). The consequence of flash floods is a very steep rise in the level of the affected watercourse [1].

The main problem is the insufficient amount of ground meteorological stations including aerological stations that provide input data for Numerical Weather Prediction (NWP) models. Another shortcoming is insufficient resolution, which cannot affect the size of the convective cells. The use of NWP models for the prediction of intense convective precipitation has been investigated in many studies [2][3][4].

The second system used for predicting convective precipitation is “nowcasting” which calculates the shift of precipitation fields in the order of 30-60 minutes in advance. However, nowcasting systems cannot predict the dynamic development of convective precipitation in time. Nowcasting is combined with the outputs of NWP models [5][6][7].

The forecasting of intense convective precipitation is implemented by expert meteorological systems that combine the characteristics of NWP models, meteorological radars and satellites; including meteorological nowcasting in foreign meteorological services. The disadvantages of expert systems result from the forecasting systems´ deficiencies [8][9].

The fundamental problems reside in forecasting for a specific location and time of occurrence of intense convective precipitation; including sufficient lead-time ahead of the forecast.

The Czech Hydrometeorological Institute is the only institution in the Czech Republic that provides forecasts and warning information on the occurrence of dangerous atmospheric phenomena. However, this information is not of sufficient quality and accuracy - precisely because of the complicated temporal and spatial occurrence of these phenomena. Therefore, the Zlín Region is the only region in the Czech Republic that has decided to create its own complex system for forecasting torrential rainfall. One justifying reason for the design of this system is to provide another alternative that would support the decision-making processes of the regional crisis management of the administrative authorities before the occurrence and while finding a solution for flash floods.

In Section 3, the graphical and tabular expression of the probability of occurrence of convective precipitation will be the output for individual Municipalities with Extended Powers (MEP) in the Zlin Region. The information will be available, not only for the region, but also for MEP mayors including other municipalities and institutions.

The main objective of the comprehensive forecasting system will be to provide timely and high-quality information on the occurrence and development of future weather for crisis management and civil protection purposes. This information will then be used for preventive measures against the occurrence of flooding; for example, preventive inspections control of flood defenses, material and other resources.

II. The Complex forecasting of convective precipitation

The complex of forecasting of convective precipitation is based on a sequence of activities necessary to ensure timely and high-quality information regarding the likely formation of flash floods:

- Monitoring of forecasting and warning information from the Czech Hydrometeorological Institute.
- Information from the convective precipitation forecast system outputs for the next 24 hours.
- Very short prediction times (i.e., nowcasting) by the mobile meteorological radar (MMR50) for 30 to 60 minutes.
- Verification of radar data through an observation network of professional and amateur meteorologists in the Zlín Region.

The comprehensive forecast implementation tool is the Information, Notification and Warning System of the Zlin Region (further only INWS ZR), which consists of information support for crisis management and population protection for extraordinary events, for example, floods, technological accidents, etc.

As can be seen in Figure 1, the backbone of the system is a robust and secure communication infrastructure (a fiber optic cable), which interconnects 11 municipalities with extended powers and other municipalities with the Zlín Region Crisis Staff regional controlling centre. The Zlín Region´s Information, Notification and Warning System is also used to communicate with the public administration sector, the Fire Rescue Services of the Zlín Region and the other municipalities' warning information systems [10][11].

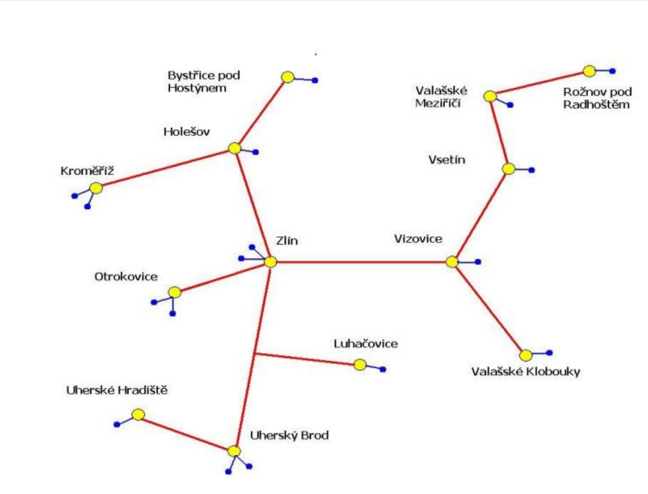

Figure 1. Structure of the INWS ZR [10].

INWS ZR consists of the following major components:

- Central Dispatch.
- Warning Information Systems (WIS).
- WIS Server.
- Videoconferencing systems.
- Municipal Closed-Circuits Television (CCTV) surveillance systems.
- Meteorological sensors and stations.
- Information and bulletin boards.
- Environmental and chemical detection elements.
- Mobile meteorological radar (MMR50).
- Alternative energy resources [12].

The forecasting of dangerous atmospheric phenomena has become a part of this system. The main component of this system is the control application of the INWS ZR. Simultaneously, control applications include outputs from:

- Convective precipitation forecasting system.
- Mobile meteorological radar (MMR50)

The comprehensive prediction of convective precipitation is comprised of the output control application of the INWS ZR that distributes data from radar measurements as well as the convective precipitation forecast system for authorities and other crisis management participants.

A. The INWS ZR control application

The INWS ZR control application is a user interface that enables the collection, analysis and evaluation of data for crisis management purposes in the Zlin Region. This application consists of two software components:

- The INWS ZR server application, connected to the data network with the individual clients of the INWS ZR under one municipality of extended powers.
- The INWS ZR applications client that runs on PCs in the individual departments and MEPs of the Zlin Region.

Access to the control applications of the INWS ZR is secured by logging into the INWS server. If the user is logged in, then they get permission to read and modify individual work sheets. The work sheets contain crisis management data and information about objects, documents, history, traffic, water courses, radar outputs from the mobile meteorological radar (MMR50) and other forecasting information [11].

B. The convective precipitation forecasting system

The core of the convective precipitation forecast system is an algorithm based on the principle of analyzing and evaluating the output of meteorological variables and the parameters of numerical weather prediction models; especially regional NWP model ALADIN [13]. The main research hypothesis is to assess the impact of the relief of the terrain on the development of convective precipitation in the target area. Because of this, one has to use an analysis of historical weather events and selected floods caused by torrential rainfall in order to produce supplementary, more accurate, warning information from the Czech Hydrometeorological Institute.

The main outcomes of the report are:

- The spatial and temporal occurrence of convective precipitation.
- The lead-time ahead of forecasts for the next 6-24 hours.

The "Place of occurrence" means the territory of the municipality with extended powers. The time occurrence forecast is set at the three-hour time interval.

The main method is a Multi-Criteria Assessment (MCA) whose basis is the selection criteria of the meteorological variables and the setting of the weights for these criteria.

The criteria weights were determined by analyzing the aerological data of 70 meteorological situations in 2007-2015.

The Convective Precipitation Forecast Algorithm (CPFA) operates in seven phases:

I. General characteristics of the predicted weather situation.
II. The forecasted time of the convective precipitation occurrence.
III. The air masses forecast conditions.
IV. The forecasted probability of dangerous accompanying phenomena (e.g., torrential rainfall, hail, strong wind gusts and tornadoes).
V. The forecasting of local conditions between the surface and the lift condensation level.
VI. The comparison of air masses´ forecast conditions and the local conditions with historical weather situations statistics.
VII. The main output of the forecast.

The first phase shows the basic characteristics of predicted weather conditions; such as date, flow direction at 700 hPa (i.e., precipitation movement direction), the type of weather situation, the triggering factor of convection and warning information by the Czech Hydrometeorological Institute. The second phase is focused on the prediction time occurrence of convective precipitation (i.e., 3-hour period). The forecast is based on the penetration of the NWP models ALADIN CHMU, ALADIN SHMU, GFS, GEM, UKMET, EURO4 outputs. The selection of these NWP models is based on an analysis of 50 weather situations with which these models have achieved the highest success rate of forecasting of convective precipitation.

Table I provides information about the weather conditions of air masses and the corresponding meteorological elements and convection indices:

TABLE I. AIR MASS CONDITIONS.

Meteorological condition	Meteorological elements, convection indices
Atmospheric instability	CAPE, Lifted Index, Showalter Index, K-Index, TT index, temperature gradient 2m-925,850, 500-850 hPa, Wetbulb temperature 0-1 km, Mixing ratio 1000 hPa
Triggering convection factors	Convective Inhibition, Relative Humidity 1000-500 hPa, Precipitable Water, Relative voriticity 850 hPa, Moisture Convergence, Frontogeneze 850 hPa, Temperature 850 hPa, Orographic Lift and Changing wind direction
Wind shear	Deep Layer Shear 0-6 km, Low Layer Shear 0-1 km, Storm Relative Helicity 0-3 a 0-1 km, SWEAT index
The organization and movement of storms	Jet Stream (300 hPa), Low Level Jet (850 hPa), Motion Convective Storm Propagation Vector, Wind 700 hPa

Each criterion (meteorological element, index convection) is classified according to the degree of intensity and probability of occurrence of convective precipitation clouds:

TABLE II. COEFFICIENTS OF THE INTENSITY AND PROBABILITY OF THE OCCURRENCE OF CONVECTIVE PRECIPITATION.

Coefficients	0	1	2	3
Thunderstorm instensity	Weak	Strong	Very strong	Extremely strong
Rainfall intensity (mm/hours)	0-29	30-49	50-89	>90
Propability of occurrence (%)	0-24	25-49	50-74	75-100

Tables II implies that the intensity of precipitation coefficients is related to the instability of the atmosphere, wind shear and the organization of the storms. The convective precipitation probability coefficients are used to trigger convection factors.

The intensity or probability of the convective precipitation occurrence is calculated according to this equation:

$$(\Sigma n/\Sigma m*3)*100(\%) = P . \quad (1)$$

where *n* is the sum of the forecast coefficients, e.g. forecasts of atmospheric instability, and *m* is the total number of predicted meteorological variables.

Fourthly, the probability of occurrence of dangerous atmospheric phenomena is defined as an intersection of selected meteorological variables defining the conditions of air masses.

In the fifth phase, the forecast of local conditions was calculated as the intersection of ALADIN meteograms meteorological variables and the morphometrical characteristics of relief:

- The air temperature at 2 meters above ground.
- The relative humidity 2 meters above ground.
- The difference of mean sea level pressure.
- The wind direction and speed at 10 meters above ground.
- The degree of cloud cover.
- The characteristics of terrain relief affecting the thermal conditions, e.g. orientation and slope of the terrain, the degree of vegetation coverage, the heat contrast of the Earth's surface, the Z-factor and the altitude and ridge parameters.
- The characteristics terrain relief influencing windy conditions; for example, settlement, valley parameters and wrapping obstacles.

In the sixth phase, the outputs of the first to third stages forecasts are compared with the historical statistics of meteorological situations. The main criteria are the direction of the precipitation movement, the synoptic situation and selected meteorological elements. The aim of this phase is to determine the degree of similarity between the predicted and historical meteorological situations.

The last phase is the final forecast of future occurrences of convective precipitation, which will include maps of the Zlin Region, including municipalities with extended powers for forecast purposes:

- The probability of time and place occurrence of precipitation for 6 to 24 hours in advance.
- The intensity of convective precipitation.
- The probability of the occurrence of dangerous atmospheric phenomena (e.g., heavy rainfall, hail, strong gusts and tornadoes).

This predictive information will be important in terms of its preventive nature for the region´s Crisis Management authorities and other participants.

C. The MMR50 Meteorological Rradar

The mobile meteorological radar (MMR50) is a device for detecting precipitation and other nonmeteorological targets within a radius of 60 km.

TABLE III. PARAMETETRS OF THE MMR50 METEOROLOGICAL RADAR.

Technical parameters	**The MMR 50 Mobile Meteorological Radar**
Location	The town Holešov Industrial Zone in the Zlín Region
Frequency	9,41 GHz
Wavelength/band	3 cm/ X-band
Transmitter power peak	50 kW
Maximum theoretical range	100 km

Table III presents the technical specification of the mobile meteorological radar (MMR50), which provides detailed information and the current state of precipitation through six radar products (i.e., Plan Position Indicator, Constant Altitude Plan Position Indicator, Range height indicator, ECHO TOP, Vertically Integrated Liquid). Very short-term forecast (Nowcasting) is secured by means of the Nowcasting TITAN forecasting software with forecasts for 30-60 minutes.

The fundamental radar quantity is the Radar Reflectivity Z in the dBz unit, which is converted from the rainfall intensity I:

$$10\text{^}(Z-10\log(a)/10b) = I. \qquad (2)$$

where the values of a and b are experimentally determined constants (a = 16, b = 200) [1].

III. CASE STUDY OF THE FLASH FLOOD ON 24.7.2015

The principle of the complex forecast of convective precipitation is shown with a case study of the flash flood that occurred on July 24th, 2015.

The main cause of the flash floods was a cold front, which ensured the emergence of sufficient atmospheric instability, combined with a moderate wind shear. This situation was characterized by the continuous emergence of new precipitation – and, its stationary movement.

This torrential rainfall, in combination with hail and strong wind gusts, caused material damage amounting to tens of millions Czech crowns. The most affected villages were Slušovice and Fryšták in the central part of the Zlin Region, where cellars and houses were flooded.

A. Convective Precipitation Forecasting System

The weather situation forecast was very complicated due to the uniqueness of the formation and development of the intensive convective precipitation.

In the previous section, the convective precipitation forecast was dealt with in several stages. The outcomes of a brief analysis of the predicted weather conditions were:

- The direction of precipitation movement from the southwest, with a speed of 9 m / s.
- The type of weather situation - an area of low pressure associated with a cold front over western Slovakia.
- Warning information from the Czech Hydrometeorological Institute was not released.

The Czech Hydrometeorological Institute did not issue predictive warning information on thunderstorms for the entire Czech Republic. Nevertheless, the forecast was calculated for 24 hours in advance, which found the likely occurrence of intense convective precipitation.

Subsequently, the interval occurrence of intense convective precipitation was determined - based on the outputs of the NWP models for 24 hours in advance:

TABLE IV. FORECAST OF PRECIPITATION TIME OCCURRENCE.

NWP models	**Time period (3 hours)**
ALADIN CHMU	12:00-15:00, **15:00-18:00**
ALADIN SHMU	12:00-15:00, **15:00-18:00**, **18:00-21:00**
GFS	**15:00-18:00, 18:00-21:00**
GEM	06:00-09:00, 09:00-12:00, 12:00-15:00, **15:00-18:00, 18:00-21:00,** 21:00-24:00
UKMET	12:00-15:00, **15:00-18:00, 18:00-21:00**, 21:00-24:00
EURO4	**15:00-18:00**

As shown in Table IV, times in bold typeface indicate those time intervals for which the predictions were calculated. The interval 15:00-18:00 is identified as 15 hours. The interval 18:00-21:00 is 18 hours.

The third phase involves the calculation of air mass conditions. Air mass includes the part of the atmosphere which is defined by the difference between the lift condensation level and the lower boundary of the troposphere.

The formation of strong and very strong thunderstorms was caused by a combination of sufficient atmospheric instability and a moderate wind shear in the central and northeastern parts of the Zlin Region.

TABLE V. AIR MASS FORECAST CONDITIONS.

Municipality with Extended Powers in the Zlin Region	Atmospheric instability		Convection trigger		Wind shear		Organization and motion of storm	
	15	***18***	***15***	***18***	***15***	***18***	***15***	***18***
Uherské Hradiště	1	2	2	2	0	1	1	1
Otrokovice	1	2	2	2	0	1	1	1
Kroměříž	1	2	2	2	0	**1**	1	1
Holešov	1	2	2	2	0	**1**	1	1
Zlín	1	2	2	2	0	**1**	1	1
Bystřice	1	2	2	2	0	**1**	1	1
Val. Meziříčí	1	2	2	2	0	**0**	1	1
Rožnov	1	2	2	2	0	**0**	1	1
Vsetín	1	2	2	2	0	**0**	1	1
Vizovice	1	2	2	2	0	**1**	1	1
Val. Klobouky	1	2	2	2	0	**1**	1	1
Luhačovice	1	2	2	2	0	**1**	1	1
Uherský Brod	1	2	2	2	0	**1**	1	1

Table V shows that the air mass conditions were more favorable after 18:00 hours.

TABLE VI. FORECAST OF LOCAL CONDITIONS.

Municipality with Extended Powers in the Zlin Region	Orographic effect		Thermal effect		Convergence effect		Resulting forecast	
	15	***18***	***15***	***18***	***15***	***18***	***15***	***18***
Uherské Hradiště	0	0	2	2	1	1	1	1
Otrokovice	0	0	1	1	2	2	1	1
Kroměříž	1	1	2	2	1	1	1	1
Holešov	1	0	2	2	2	2	2	1
Zlín	1	1	2	2	2	2	2	2
Bystřice	1	1	2	2	1	1	1	1
Val. Meziříčí	1	1	2	2	2	2	2	2
Rožnov	1	1	2	2	2	2	2	2
Vsetín	1	1	2	2	2	2	2	2
Vizovice	1	1	2	2	2	2	2	2
Val. Klobouky	1	1	1	1	2	2	1	1
Luhačovice	1	0	2	2	2	2	2	1
Uherský Brod	1	1	2	2	2	2	2	2

Table VI demonstrates the probability of formation of convection affected by the local weather conditions which are orographic, thermal and wind conditions of terrain relief for a specific time interval. The most favorable conditions for the initial formation of convection above the Earth's surface were predicted for the northeastern and central parts of the Zlin Region.

The sixth and seventh phases were consolidated for the clarity of the main output. The resulting forecast is a combination of air mass conditions and the local conditions, combined and compared with selected historical weather precipitation statistics.

TABLE VII. RESULTING FORECAST.

Municipality with Extended Powers in the Zlin Region	6th and 7th phases of predicted convective precipitation			
	23.7	***11.7.2011***	***7.8.2011***	***Resulting forecast***
Uherské Hradiště	0	0	0	0
Otrokovice	0	0	0	0
Kroměříž	1	0	2	**1**
Holešov	1	0	1	**1**
Zlín	1	1	0	**1**
Bystřice	1	2	1	**1**
Val. Meziříčí	1	0	1	**1**
Rožnov	1	0	0	**1**
Vsetín	1	0	0	**1**
Vizovice	1	0	0	**1**
Val. Klobouky	0	0	0	**0**
Luhačovice	0	0	0	**0**
Uherský Brod	0	0	0	**0**

Table VII summarizes the facts the outputs from statistics only confirm or complement the new convective precipitation locations. The resulting forecast only changes if the statistics concur on the occurrence of precipitation outside the forecast of conditions of air masses and the local conditions. In this case, the resulting forecast remains unchanged.

B. Nowcasting by the mobile meteorological radar (MMR50)

Very short-term forecasting was performed using the mobile meteorological radar (MMR50).

TABLE VIII. OUTPUTS OF NOWCASTING ON 24.7.2015.

Locations	**Time**	**Intensity (mm)**	**Air flow direction/ nowcasting**
Vsetín-Huslenky	17:15	25	SW/Vsetín-Cáb, Uherský Brod

Locations	Time	Intensity (mm)	Air flow direction/ nowcasting
Vsetín	17:30	30	SE/Vsetín-Hošťálková
Vsetín-Hošťálková	17:45	40	SE/Zlín-Fryšták
Zlín-Fryšták	18:00	50	SE/Holešov

As revealed in Table VIII, the most intense rainfall occurred in the village of Fryšták between 17:00 and 18:00 hours, at an average intensity of 37 mm / hour. Residents of Fryšták registered the occurrence of severe hail, combined with torrential rainfall, which caused considerable damage to property. The nowcasting method provided accurate predictions in terms of the place of occurrence of convective precipitation.

C. Verification of the forecast on 7/24/2015

Verification of comprehensive convective precipitation forecasts was performed using the outputs of ground –based meteorological stations.

The most intense rainfall occurred at stations:

- Zlín-Štípa - with 43 mm (Zlín); forecast 30-50 mm
- Huslenky - with 34 mm (Vsetín); forecast 30-50 mm
- Hošťálková - with 33 mm (Vsetín); forecast 30-50mm

The success of the prediction of precipitation locations is 81% for Municipalities with Extended Powers in the Zlin Region for both time periods. The success rate of forecasted precipitation occurrence time was 100%.

IV. CONCLUSION

The aim of this article was to provide information about the comprehensive forecasting of convective precipitation in the Zlín Region. The first section mentioned the importance of the Information, Notification and Warning System of the Zlín Region; and, especially in the Crisis Management field. The main focus was on the outputs of the convective precipitation forecast system.

The principle of complex predictions was described in the case study of 7/24/2015, when there was a local flash flood in the central part of the Zlin Region. The success rate of comprehensive predictions reached 81%, whereby, it met the condition predictions of success rate by more than 50%.

Future research will focus on optimizing the limits of the meteorological elements and the search for similar historical events. The main objective will be to continually refine and improve predictions of the place and time of occurrence of convective precipitation in order to provide preventive measures and improve the preparedness of Crisis Management authorities against the occurrence of flash floods.

ACKNOWLEDGMENT

This article was supported by the Department of Security Engineering under TBU in Zlín´s Internal Grant No.: IGA/FAI/2016/023 "Optimization of the System of Convective Precipitation Forecasts for Increase its Success Rate".

REFERENCES

[1] D. Řezacová, et al. "Physics of clouds and precipitation". Prague: Academia, 2007. 574 pp. with. Fig.Gerstner; sv. 2. ISBN 978-80-200-1505-1.

[2] M. Kaspar. "Analyses of gust fronts by means of limited area NWP model outputs". [cit. 2016-04-05]. doi: 10.1016/S0169-8095(03)00066-8.

[3] K. Lagouvardos, V. Kotroni, E. Defer and O. Bousquet. "Study of a heavy precipitation event over southern France, in the frame of HYMEX project: Observational analysis and model results using assimilation of lightning". [cit. 2016-04-05]. doi: 10.1016/j.atmosres.2013.07.003.

[4] G. Wang, W. Wai-Kin, Y. Hong, L. Liu and J. Dong. "Improvement of forecast skill for severe weather by merging radar-based extrapolation and storm-scale NWP corrected forecast: Observational analysis and model results using assimilation of lightning". [cit. 2016-04-05]. doi: 10.1016/j.atmosres.2014.10.021.

[5] P. Novak. "The Czech Hydrometeorological Institute's severe storm nowcasting system". [cit. 2016-04-05]. doi: 10.1016/j.atmosres.2005.09.014.

[6] S. Kolios and H. Feidas. "An automated nowcasting system of mesoscale convective systems for the Mediterranean basin using Meteosat imagery". [cit. 2016-04-05]. doi: 10.1002/met.1282.

[7] C. E. Pierce, P. J. Hardaker, C. G. Collier and C. M. Haggett. "GANDOLF: a system for generating automated nowcasts of convective precipitation". [cit. 2016-04-05]. doi: 10.1017/S135048270000164X.

[8] L. Panziera, U. Germann, M. Gabella and P. V. Mandpaka. "NORA-Nowcasting of Orographic Rainfall by means of Analogues: the COALITION approach. Quarterly" Journal of the Royal Meteorological Society" 2011, [cit. 2016-04-05]. s. 2106-2123 doi: 10.1002/qj.878.

[9] R. Lee and a J. E. Passner. "The development and verification of TIPS: An Expert System to Forecast Thunderstorm Occurrence". [cit. 2016-04-05]. Avalaible at: http://journals.ametsoc.org/doi/pdf/10.1175/1520-0434%281993%29008%3C0271%3ATDAVOT%3E2.0.CO%3B2

[10] M. Kucera. "Information, Notification and Warning System of the Zlin Region and MEP Uherské Hradiště". [cit. 2016-04-04]. Avalaible at: https://digilib.k.utb.cz/bitstream/handle/10563/34416/ku%C4%8Dera_2015_dp.pdf?sequence=1&isAllowed=y

[11] "Information, Notification a Warning System of the Zlín Region", Integrated project, Zlín Region [online]. 2012 [2014-03-31]. [cit. 2016-04-04]. Available: http://www.kr-zlinsky.cz/-informacni-vyrozumivaci-a-varovaci-system-zlinskeho-kraje-integrovany-projekt-cl-1392.html

[12] INWS Zlín Region - Information, Notification and Warning System". [cit. 2016-04-04]. Avalaible at: http://www.colsys.cz/novinky/detail/ivvs-zlinskeho-kraje.htm

[13] Czech Hydrometeorological Institute - Model predictions ALADIN. [cit. 2016-04-04]. Available at: http://portal.chmi.cz/files/portal/docs/meteo/ov/aladin/results/ala.html#nebul