NATIONAL UNIVERSITY OF PUBLIC SERVICE
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Author's summary

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Development and validation of up-to-date analogy based forecasting methods for the meteorological support of military aviation

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IDENTIFICATION OF THE SCIENTIFIC PROBLEM

The impact of the physical environment and the weather on the military operations was already observed in the ancient times. In that time the military leaders could have operational benefits due to the accurate knowledge about the effects of atmospheric conditions or weather phenomena on the different dimensions of the physical environment or the contributing liveware and technical tools. It was well known that this kind of information has influence on the commander's decisions, or in other words, it has important role in the decision-making process. Obviously, in that time this information meant the results of visual observations and the application of the general knowledge of meteorology, rather than real measurements and forecast data. Nevertheless, considering this information could help decision-makers. Modern weather forecasting techniques could enhance these benefits by summarizing the mentioned effects for a future state of the atmosphere. It gives the opportunity to use the appropriate meteorological information during the planning phase of military operations. Easy to recognize, that the better and more efficient user of observational and forecast information in his decision-making process, will win of the opposing parties with equal military forces and resources. This is increasingly true nowadays when detailed measurement fields, remote sensing products and reliable forecast information available and when weather sensitive air force operations are carried out. Additionally, the most often limiting factors (e.g. visibility, ceiling) during the meteorological support of military aviation are only derived output of numerical weather prediction models. This uncertainty and the temporal and spatial scale of the physical processes behind these parameters result

that forecasting usual aviation meteorological variables, such as visibility, is one of the most challenging tasks for an aeronautical forecaster. Taking into account the duality above, we can conclude that the development of the predicting elements of meteorological support system, namely the working out and application of up-to-date forecasting techniques, the operational efficiency of military aviation and the level of flight safety can be increased. Its essential criterion that the future methods concern to meteorological parameters, which are relevant from the viewpoint of the military operations.

That is the main reason why I have chosen visibility forecasting as my major research field. Most of the weather minima are related to horizontal visibility which also confirm the available achivements in the challenging area of aviaton meteorology predictions.

This also means, that there could be the greatest impact in this narrow field by the success of the developed and applied forecasting methods. My decision on choosing this field was easy because of my experience as an operational forecaster. That time I met the challenges of visibility forecasting in aviation meteorology many times. The errors of the forecast were never covered, because I was confronted the errors every time by the end-users and they did not let my forecasts unverified. This is highlighted the importance of the continuous and comprehensive verification of the forecasts, which is also important in the field of validation of new prognostic methods beside the operational aspects. Due to this approach, the demonstration of applicability of the modern forecasting method is also a part of the scientific problem.

RESEARCH OBJECTIVES

Based on the scientific problem identified above I declare the following research objectives:

1. Review of the scientific publications and research papers related to my field. Choosing the appropriate visibility forecasting method which can give a possible solution to the scientific problem.
2. The creation, adaptation and potential development of the chosen forecasting method in the own military environment.
3. Creation of an appropriate verification approach to prove the applicability and efficiency of the visibility forecasting methods.
4. Implementation of a comprehensive verification, which is able to compare the different forecasting methods and able to prove their applicability by independent examinations.
5. Confirmation or rejection of my research hypotheses and then deducing the summarized conclusions and giving recommendations.

RESEARCH HYPOTHESES

Based on the scientific problem and my research objectives I would like to confirm the following hypotheses in my thesis:

1. I suppose that the application of the weight determined by Analytic Hierarchy Process increases the performance of analogue visibility forecast method.
2. I assume that the performance of hybrid forecasts does not decrease significantly comparing with analogue forecast despite of the increasing weight of the numerical part because of the weighting method of the initial category difference.
3. I suppose that the operational application of ultra-short term analogue and hybrid forecasts have great benefits in the meteorological support of military aviation.
4. I assume that the applicability of analogue and hybrid visibility forecasts is independent from the applied category limits in their range of interpretation.
5. I suppose that more accurate forecasts of the hazard of poor visibility can help to reduce the related risk and ensure safety flight operations.

RESEARCH METHODS

During my research I applied the following research methods:

- I have reviewed and analysed the relevant literatures in the topic of conditional climatology and the field of forecasting methods especially the theoretical background and operational tools of analogy based predictions. I also thoroughly reviewed the mathematical background of Analytic Hierarchy Process. I analysed the scientific papers related to meteorological verification methods, especially those publications

which are appropriate for the comparison of different type of aviation meteorology forecasts.

- Based on the knowledge of the reviewed publications I found correlations between the climatological frequencies of different meteorological variables by the means of analytic and synthetizing methods. These correlation were used to develope the analogue forecasts by the new weights. Based on my analysis I chose the appropriate synoptic situations for case studies, which helped to anticipate the efficiency of the examined methods.
- I modelled the forecasting process by mathematical means. Then I made a long-term simulation to produce the verification database which can help to confirm my hypotheses.
- I analysed the results of the comprehensive and comparative verification and based on it I confirmed my hypotheses using logical approaches.
- I participated in several domestic and international conferences, professional presentations. The experience gained were used during my research work.
- I made discussions with researchers, professionals of this topic during conferences. Their opinion, advices were combined with my own ideas and so I fine tuned my research directions and corrected my misleading conceptions.

BRIEF CHAPTER-BY-CHAPTER DESCRIPTION OF THE CONDUCTED ANALYSIS

I. METEOROLOGICAL SUPPORT SYSTEM OF MILITARY AVIATION

In this chapter, I introduced the meteorological support system of military aviation in details. The complexity of the legal background and the close connection between its meteorological and military part confirms the important role of meteorological support of military aviation. The operational support based on a multi-level hierarchy, which is able to adopt novel forecasting methods in practice.

The meteorological support provide relevant information in the decision-making process for the decision-makers. During the support, it takes into account the users' needs and the operational requirements while keeping the principles of the support systematically. As I explained in my thesis: in the decision-making process, the main goal is to choose that course of action, which best approaches the desired end state. That is why so important to the decision-makers to make the input data of this process as accurate as possible and therefore keep the potential uncertainties as low as possible.

The analogue visibility forecasting method is in accordance with the mentioned principles and not needed to transform the organizational structure in order to apply. Therefore, the new method easily integrable to the operational procedures of the meteorological groups of the military airports and the aviation forecast center.

II. LITERATURE REVIEW

In this chapter, I introduced the main steps and results of the development of visibility forecasting. At first, I dealt with the physical explanation of visibility. I showed the complexity of the physical processes behind visibility and I highlighted its importance in modelling. Beside this, I made the related phrases and expressions clear. I reviewed the research papers related to visibility forecasting from the early years of aviation meteorology in chronological order. The main goal was to introduce the reliable results rather than to give a complete description. I determined that visibility forecasting had central role in aviation meteorological research from the beginning. Nevertheless, the development of the applied forecasting methods went ahead very slowly, sometimes with decade-long pauses. Additionally, the up-to-date methods and solutions are not perfect yet, but the best forecasting performance related to statistical based procedures without exception. This fact led me to choose the appropriate forecasting method and to designate the optimal directions of the development.

In the final part of this chapter I reviewed some scientific papers related to the forecasting methods of hazardous weather phenomena. Beside this introduction I had a secondary goal too, I examined the question of applicability of analogy based forecasting methods with meteorological variables, other than visibility. I found that in ceiling and wind gust forecasting could be this type of method feasible, because of the importance of local impacts in case of these parameters.

III. SAFETY ASPECTS OF AVIATION METEOROLOGY

The field of meteorology and the horizontal visibility with some other parameters, have emphasized role in military flights. It was not only proved by scientific approaches and theoretical considerations but by the sad statistics of weather related accidents in aviation. Maybe this is the most cruel driver of those flight safety recommendations, which according to the strategic objectives of European Union Aviation Safety Agency (EASA) and International Civil Aviation Organization (ICAO) try to increase the level of flight safety by the means of different research projects and programs. Easy to notice that the objectives of the research and development in the field of aviation meteorology are only useful means to achive the declared goals in the field of safety. This synergistic system with the continuous feedbacks helps to realize the benefits of the more accurate forecasts to provide a higher level of safety.

The end users of forecast products have to understand that how predictions related to risk need to be mitigated and safety objectives. That is why the forecast should be used as tool, which can reduce uncertaities, rather than certain statement. This approach is similar to the risk mitigation procedures in methodology and help to understand the exact role of meteorological information in safety management system.

I determined by deductive reasoning that the application of more accurate forecasts of the hazards gives the opportunity to apply successful risk mitigation measures.

IV. APPLICATION OF ANALOGUE AND HYBRID METHODS IN FORECASTING OF HORIZONTAL VISIBILITY

In this chapter, I introduced the constructional background of the new methods, which were developed for the meteorological support of military aviation. I also detailed the methodological description of the applied tools.

I showed how the analogy based forecasting methods works and I gave a detailed description on the application of Analityc Hierarchy Process. By the linear combination of numerical and analogue predictions I introduced the phrase of hybrid forecast.

Finally, I dealt with the question of the data used, where I showed that the analogue forecasts requires only METAR reports as input, which means that if an appropriate observational database is available, then the forecasting method can be applied without any further development. It also makes this method easily adoptable and very useful, especially in operational environment, where the lack of reliable forecast information is overall.

V. COMPARATIVE VERIFICATION OF VISIBILITY FORECASTING METHODS

This chapter was divided into two major parts. In the first part I introduced the verification methodology and the data used, while in the second part I discussed the verification results produced by the methods.

After that I reviewed the related publications, I chose the verification method for categorical forecast to validate the examined forecast methods. As I mentioned earlier in aviation lot of limitations related to horizontal visibility and these minima often changes according to the different tasks.

This also draw the attention the importance of the category limits. The chosen verification method is in accordance with the validation principles and provides a comprehensive evaluation of the results. Initially, this evaluation could not be carried out in the case of TAF forecasts, therefore I created a novel method to solve this problem. This new method is going te be applied in the operational verification process of the aviation meteorological support of the military.

In the second part of this chapter I highlighted repeatedly the importance of the detailed, comprehensive verification. Based on the verification results I proved that the application of the weights of Analytic Hierarchy Process significantly increase the performance of the analogue forecast.

The analogue and hybrid forecast has much better results compared with TAF forecast, therefore their application could give real value added in meterological support. Additionally, the results also proved that the applicability of analogue and hybrid forecasts do not depend on category limits.

Based on the stable results of hybrid forecasts, I declared that hybrid and analogue forecasts had similar performance despite the increasing numerical part in hybrid, because the numerical forecasts were filtered by the initial category difference between observation and numerical forecast.

SCIENTIFIC NOVELTIES

1. I have carried out a comprehensive and very detailed research on the publication background of visibility forecasting. This resulted a thorough summary of this field and it can be a good theoretical starting point for the future researches working on this field.
2. Using unprejudiced verification methods, I proved that the application of AHP weights increases the performance of analogue visibility forecasts.
3. I created a complex TAF verification method that keeps the validation principles and allows comparing the verification of the different forecast methods. Based on this method I showed that the ultra-short term analogue and hybrid forecasts beat the TAF independently from the category limit.
4. Based on the verification results I proved that the performance of the hybrid forecast is similar to the analogue's performance due to the filtering by the initial category difference between observations and numerical forecast outputs.
5. I determined by deductive reasoning that the application of more accurate forecasts of the hazards gives the opportunity to apply successful risk mitigation measures to achive safer aviation tasks.

RECOMMENDATIONS

I propose the operational application of the introduced TAF verification method at the prescribed evaluation of aviation meteorological forecasts.

I suggest using the analogue and hybrid forecasting methods in the operational meteorological support of military aviation in order to mitigate risk and to increase the operational efficiency. I also suggest producing numerical model outputs at the HDF in case of using hybrid forecast, without external help to keep this kind of dependency as low as possible.

I propose to build the scientific novelties and summarized conclusions of my thesis in to the thematics of the preparation of meteorological officers.

LIST OF PUBLICATIONS ON THE TOPIC OF THE THESIS

PEER REVIEWED PUBLICATIONS IN HUNGARIAN

1. **Tuba Zoltán**, Wantuch Ferenc, Bottyán Zsolt, Hadobács Katalin, Jámbor Krisztián: Repülésmeteorológiai klíma adatok felhasználásának lehetséges aspektusai pilóta nélküli repülőeszközök (uav-k) meteorológiai támogatásában. SZOLNOKI TUDOMÁNYOS KÖZLEMÉNYEK 16: pp. 192-197. (2012)
2. Bottyán Zsolt, Wantuch Ferenc, **Tuba Zoltán**, Hadobács Katalin, Jámbor Krisztián: Repülésmeteorológiai klíma adatbázis kialakítása az UAV–k komplex meteorológiai támogató rendszeréhez. REPÜLÉSTUDOMÁNYI KÖZLEMÉNYEK 24:(3) pp. 11-18. (2012)
3. **Tuba Zoltán**, Bottyán Zsolt, Wantuch Ferenc, Vidnyánszky Zoltán, Hadobács Katalin: Javaslat katonai műveletek tervezésének meteorológiai támogatási modelljére. HADMÉRNÖK 8:(3) pp. 294-304. (2013)
4. Hadobács Katalin, **Tuba Zoltán**, Wantuch Ferenc, Bottyán Zsolt, Vidnyánszky Zoltán: A pilóta nélküli légijárművek meteorológiai támogató rendszerének kialakítása és alkalmazhatóságának bemutatása esettanulmányokon keresztül. REPÜLÉSTUDOMÁNYI KÖZLEMÉNYEK 25:(2) pp. 405-421. (2013)
5. **Tuba Zoltán:** Pilótanélküli repülőeszközök (UAV-k) és a látástávolság egyes kérdései. REPÜLÉSTUDOMÁNYI KÖZLEMÉNYEK 26:(2) pp. 94-105. (2014)
6. **Tuba Zoltán:** Merevszárnyú repülőgépek felületi jegesedésének alternatív csökkentési módszerei. REPÜLÉSTUDOMÁNYI KÖZLEMÉNYEK 1: pp. 46-58. (2014)
7. **Tuba Zoltán:** A repülésmeteorológia biztonságtechnikai vonatkozásai. HONVÉDSÉGI SZEMLE: A MAGYAR HONVÉDSÉG KÖZPONTI FOLYÓIRATA (2008-) 143: pp. 90-96. (2015)
8. **Tuba Zoltán**, Bottyán Zsolt: Analógiás elven alapuló repülésmeteorológiai előrejelzések és a makroszinoptikus időjárási szituációk kapcsolatának vizsgálata. REPÜLÉSTUDOMÁNYI KÖZLEMÉNYEK 27:(2) pp. 162-168. (2015)

9. **Tuba Zoltán**, Kardos Péter, Szabó Péter: AMDAR adatok lehetséges felhasználása a repülésmeteorológiai előrejelzésben. REPÜLÉSTUDOMÁNYI KÖZLEMÉNYEK 28:(2) pp. 165-178. (2016)
10. **Tuba Zoltán**, Bottyán Zsolt: Analóg és hibrid módszerek alkalmazása a horizontális látástávolság előrejelzésében. REPÜLÉSTUDOMÁNYI KÖZLEMÉNYEK 29:(2) pp. 211-224. (2017)

PEER REVIEWED PUBLICATIONS IN ENGLISH

1. **Tuba Z**, Vidnyánszky Z, Bottyán Z, Wantuch F, Hadobács K: Application of Analytic Hierarchy Process in fuzzy logic-based meteorological support system of unmanned aerial vehicles ACADEMIC AND APPLIED RESEARCH IN MILITARY SCIENCE (AARMS) 12:(2) pp. 221-228. (2013)
2. Bottyán Z, Gyöngyösi A Z, Wantuch F, **Tuba Z**, Kurunczi R, Kardos P, Istenes Z, Weidinger T, Hadobács K, Szabó Z, Balczó M, Varga Á, Bíróné Kircsi A, Horváth Gy: Measuring and Modeling of Hazardous Weather Phenomena to Aviation Using the Hungarian Unmanned Meteorological Aircraft System (HUMAS) IDŐJÁRÁS / QUARTERLY JOURNAL OF THE HUNGARIAN METEOROLOGICAL SERVICE 119 (3) pp. 307-335. (2015)
3. **Tuba Z**, Bottyán Z: Fuzzy Logic-Based Analogue Forecasting and Hybrid Modeling of Horizontal Visibility METEOROLOGY AND ATMOSPHERIC PHYSICS 130:(2) pp. 265-277. (2018)

CONFERENCE PRESENTATIONS

1. Complex weather support system for Unmanned Aerial Vehicle (UAV) mission planning and execution In: Proceedings of Annual meeting of European Meteorological Society. Place and date of conference: Reading, UK, 09-13. September 2013. p. 1.
2. Application of Analogue Ensemble in Horizontal Visibility Forecasting In: Proceedings of Annual meeting of European Meteorological Society. EMS Annual Meeting Abstracts Vol. 14, EMS2017-208 Place and date of conference: Dublin, Ireland 04-07. September 2017.

PROFESSIONAL AND SCIENTIFIC CURRICULUM VITAE

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Job/assignments:

2017-	**senior officer**, **meteorological expert**, Ministry of Defence, State Aviation Department, Aviation Supervisory Division
2014-2016	**meteorological senior officer**, HDF Geoinformation Service, Meteorological Support Division
2007-2014	**group commander**, MH 86. Szolnok Helicopter Base, Meteorological group
2004-2007	**weather officer, deputy group commander,** HDF 86. Szolnok Helicopter Wing, Meteorological group
2003-2004	**weather officer**, HDF 87. Bakony Combat Helicopter Wing

Education:

2012-2015	National University of Public Service, **Doctoral School of Military Engineering**
1997-2003	Loránd Eötvös Science University, **meteorologist**
1993-1997	Bercsényi Miklós Grammar School, Győr, Hungary

Membership:

2019-	Hungarian Meteorological Society, **secretary of aviation meteorology division**
1998-	Hungarian Meteorological Society

Professional courses:

2018	Oversight of Provision of MET Information, Institute of Air Navigation, Luxemburg
2016	GIS courses (basic, intermediate, advanced)
2011	NATO METOC Orientation Course, NATO School, Oberammergau, Germany
2007	Weather Officer Course, Biloxi, Mississippi, USA

Other professional activity:

2016-	GINOP 2.3.2-15-2016-00007, "Increasing and integrating the interdisciplinary scientific potential relating to aviation safety into the international research network at the National University of Public Service - VOLARE" project researcher
2012-2013	TÁMOP-4.2.1.B-11/2/KMR-2011-0001 „Development of complex meteorological support system for unmanned aerial vehicles" (UAV_MET) project researcher
2010	Meteorological assistant course, presentation module, lecturer
2010	Loránd Eötvös Science University, thesis concultant
2009	Meteorological assistant course, remote sensing module, lecturer
2009-2014	Contribution of the training of meteorolocical officers as lecturer
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Language skills:

English C1 level (STANAG 3.3.3.3), Russian B1 level

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