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Weather Forecast in Prague Using Different Prediction Models

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Abstrakt: *Předmětem práce, která vychází z bakalářské práce, je předpovídání počasí na území Letiště Václava Havla v Praze. Práce popisuje, jak fungují moderní předpovědi počasí. Téměř půlroku byly zaznamenávány konkrétní jednodenní předpovědi jednotlivých meteorologických prvků. Veškeré předpovědi byly odebrány z veřejně dostupných zdrojů. Praktická část se zaměřuje na vytvoření důvěryhodné statistiky z dat o skutečných předpovědích jednotlivých modelů a následného zhodnocení jejich přesnosti, stability a vzájemné závislosti. Na základě statistických výpočtů byly jednotlivé metody hodnoceny. Na základě výsledků lze doporučit konkrétní numerický model jak pro civilní, tak letecké uživatele.*

Klíčová slova: *předpověď počasí, meteorologická předpověď, predikční model, numerický model, meteorologický prvek*

Abstract: *The subject of this paper, which is based on a bachelor thesis, is the weather forecast at Václav Havel Airport, Prague. The paper describes how modern weather forecasts work. For almost half a year, there were recorded specific daytime predictions of individual meteorological elements. All forecasts have been taken from publicly available resources. The practical part focuses on the creation of reliable statistics from data that are based on real predictions of individual models and the following evaluation of their accuracy, stability and interdependence. Based on statistical calculations, the each method was evaluated by comparing with the other. Based on the results, it is possible to recommend specific numerical models for civil and aviation users.*

Keywords: *weather forecast, meteorological prognosis, prediction model, numerical model, meteorological element*

1. Introduction

Meteorological conditions are one of the most important factors that influence air traffic. It is important to monitor and evaluate the meteorological conditions correctly because of the safe flight and minimization of a probability of a collision with dangerous external conditions [2]. Meteorological forecasts do these points. There are many forecasts in the world. For instance, there are conventional climatological observations, measuring by probes, radars and satellites or modern forecasting methods using mathematical models [1]. This paper is about the forecasting methods using mathematical models.

The theoretical part of the research contains general familiarization with the methods and forecasting history. Then, there is a description of several publicly available numerical models

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and their principles in the paper. The practical part is about a basic research. The forecasts and real meteorological situations had been recorded for 90 days. Then, the statistical tests were used, evaluation of the results were done for each model and the results were compared.

2. Numerical Models

The authors worked with several publicly available meteorological numerical models. The models were subjects of an observation. The models were Czech-French Aladin, Swiss Meteoblue, Norwegian Yr, German global models ECMWF and ICON and American global model GFS. Though the cell phone application Klara is not the model, it was the subject too. The Klara gets information from the Norwegian Meteorological Institute. The Klara was included because of academic reasons for comparison with other forecasting tools. Each model uses different calculation method. However, some of them are very similar. In principle, it is always a way how an atmospheric model is created. Input for this model is actual weather conditions. Next step is that the model calculates several possible scenarios and compares them between themselves. Based on the calculation results, the model choses the most probable scenario and creates the forecast [3, 4, 6, 7].

3. Weather Forecast Recording

The weather forecast recoding was done by a smartphone. The authors used free mobile apps and websites of each forecasting model. It was a 24hours forecasts for an area of the Václav Havel Airport, Prague. The forecast from each model was recorded at the same time. The monitored elements were air temperature, total precipitation, clouds cover, wind speed and direction, atmospheric pressure, relative air humidity and dew point. A real weather was controlled and recorded next day at the same time. The real weather was controlled by information from the Czech Hydro-Meteorological Institute. The institute releases the weather conditions each hour and the source for this is professional climatological station at the Václav Havel Airport. The authors worked with 90 forecasts that had been collected during half a year. The forecasts and also the real conditions were placed into the Excel table. The Excel was used for calculation of absolute deviations from the real situation of each forecast. These deviations were used in the statistical models.

4. Application of Statistical Tests

The statistical programs Paleontological Statistics version 3.2.0 (PAST) and Scilab version 5.2.2 were used for processing the collected data. The programs were recommended by Mgr. Pavel Provinský from the Department of Applied Mathematics FTS, CTU in Prague. The goal of the statistics was to evaluate accuracy a stability of the forecasts. This was done by using mean values and variances statistical tests.

First, a conformity of the mean values for all meteorological elements was verified by ANOVA test in the PAST. This was done for all numerical models. The conformity was refuted at all cases. It meant that the mean values of the forecasts were not the same or very similar. This was the impulse for searching significant better and significant worse forecasts. The searching

was done by the PAST too. The PAST showed all mean values for all elements for each model. A table was created after comparing the results. The table 1 shows the forecasts accuracy of each model.

Tab. 1 *Accuracy comparison of numerical models*

	Temperature	Cloudiness	Precipitation	Windspeed	Humidity	Pressure	Dewpoint
Significantly more accurate	Meteoblue ICON Aladin	Yr	Aladin	Yr GFS Klara	Meteoblue ICON	ICON Klara	ICON
Significantly less acurate	ECMWF GFS	GFS	GFS	Meteoblue	ECMWF	Aladin	GFS

The stability of the forecasts was evaluated by variances prognosis of each model. So the bigger variance was, the deviations from the exact values more significant was. The test began by Levener's test of the variances conformity. It was found out that the variances were different at total precipitation, humidity, atmospheric pressure and dew point. It was necessary to compare each variances of all models for these elements. The PAST calculated specific values of each variance. Based on these results the significant better and significant worse forecast were determined. The stability results were summarized into the table 2.

Tab. 2 *Stability comparison of numerical models*

	Precipitation	Humidity	Pressure	Dewpoint
Significantly more stable	ICON Aladin Meteoblue	Meteoblue	ICON ECMWF	ICON
Significantly less stable	GFS	Aladin ECMWF	Aladin	Klara

A next criterion for the evaluation was mutual independence of forecasts models. This was done by a correlation function at the PAST. The correlation values between all models were available for all elements. The significantly stronger correlations meant that there were suspicion of a mutual linear dependency and the significantly weaker correlations meant a linear independency. With help of this test, it was found out that there was the mutual linear dependency almost for all meteorological elements for Yr, ECMWF and Klara. This confirmed that these models use similar sources. So it is not recommended to use more than one of these forecasts. It is because they will probably show the same data. It was confirmed or it was not refuted the linear independency for other links between models.

5. Alternate Wind Direction Processing

A wind direction was processed another way. It is because this element was predicted in values of the eight world sides. If the predicted world side coincided with the real wind direction, the forecast was evaluated as a correct. A percentage success of all 90 forecasts was calculated. This was done for all models. The results showed that the accuracy of the wind direction forecasts was approximately 50% for all models. The research did not provide more knowledges in this case. The table 3 shows the results of the wind direction research.

Tab. 3 *Alternate wind direction processing results*

	Aladin	Klara	Meteoblue	Yr	ICON	ECMWF	GFS
Number of correct predictions	45/90	47/90	44/90	50/90	47/90	49/90	49/90
Percentage success	50 %	52 %	49 %	56 %	52 %	54 %	54 %
Ranking	6.	4.-5.	7.	1.	4.-5.	2.-3.	2.-3.

6. Conclusion

It was possible to determinate the significantly more accurate and more stable forecast models based on the statistical tests and the results that are mentioned above. Very good meteorological models are ICON and Meteoblue. They had significantly better accuracy and stability. On the other hand, worse models are the global one, GFS and ECMWF. The research showed that the local numerical models have significantly better results than the models for very large areas. Based on mutual dependency, the link between Yr, ECMWF and Klara forecasts was proved.

Based on the results, it can be recommended Aladin and Yr models for civil user. It is assumed that the civil user want to know temperature, clouds cover, total precipitation or wind speed in the area of the Czech Republic. The Aladin and Yr have satisfactory accuracy for these elements.

It is not possible to give to a specific user, especially aviation one, an exact recommendation to exact numerical model. Only official source of the meteorological information for aviation in the Czech Republic is the Czech Hydro-Meteorological Institute and its affiliated model – Aladin. The results have only informative character because of this. They can be used as a supporting material for the Civil Aviation Authority of the Czech Republic for forecast improvement. The knowledge of all mentioned elements is substantial in the aviation. There are many reasons why it is suitable to have exact and reliable forecasts. For instance, the user have to be capable to create an idea about coming meteorological situation. For pilot, the temperature is important for an aircraft performance and an accuracy of barometric altimeters, the clouds cover is important for flight minimums, the total precipitation is important because of a visibility and icing, the wind speed and direction is important because of the wind drift and take-offs and landings limits, the air humidity and dew point indicate a probability of a cloud,

fog and precipitation creation, the atmospheric pressure affects flight levels system and so on [5]. The ICON and Meteoblue can be recommended for pilots but only as a supplementing source that supplement the mandatory source. The recommendation is based on the mentioned calculations. These two models have high accuracy and stable stability. This research worked with quite small volume of the data that were collected during one half a year. A longer data collection can show more accurate and authoritative results.

References

[1] BEDNÁŘ, Jan. *Meteorologie: Úvod do studia dějů v zemské atmosféře*. Praha: Portál, 2003. ISBN 80-717-8653-5.

[2] CAE Oxford Aviation Academy. *050 Meteorology: ATPL Ground Training Series*. Oxford: CAE Aviation Academy, 2014.

[3] DVOŘÁK, Petr. *Pozorování a předpovědi počasí*. Cheb: Svět křídel, 2012. ISBN 978-80-87567-20-3.

[4] ŠÁLEK, Milan. UBIMET. *Monitoring a předpověď počasí*. CZE, 2013, 175 p. Available from: https://is.muni.cz/el/1431/podzim2013/Z0076/um/Monitoring_a_predpoved_pocasi__dr._Salek.pdf

[5] FREI, J. Basic Evaluation of Meteorological Observation from Aircraft. In: *Zvyšovanie bezpečnosti a kvality v civilnom letectve 2016*. Zvyšovanie bezpečnosti a kvality v civilnom letectve 2016. Zuberec, 27.01.2016 - 29.01.2016. Žilina: Žilinská univerzita. 2016, pp. 16-21. ISBN 978-80-554-1143-9.

[6] WORLD METEROLOGICAL ORGANIZATION. *Guide to meteorological instruments and methods of observation* [online]. 6th ed. Geneva, Switzerland: Secretariat of the World Meteorological Organization, 1996, 716 p. [cit. 2018-09-25]. WMO (Series), no. 8. ISBN 92-631-6008-2. Available from: https://library.wmo.int/pmb_ged/wmo_8_en-2012.pdf

[7] SOBOTA, J. and KRÁČMAR, J. *Meteorologie.* 1. ed. Brno: Akademické nakladatelství CERM. 2002, ISBN 80-7204-238-6.