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The performance of aviation forecasters as a consequence of major events

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Abstract: Aviation forecasters, recognized for their consistent professionalism and rigorous training, typically exhibit unwavering focus on their responsibilities. Despite this, acknowledging the human element, this research explores the potential impact of external social and psychological influences on their forecasting accuracy. Utilizing standard Terminal Aerodrome Forecasts (TAF) and Meteorological Aerodrome Reports (METAR) observations, the study assesses forecast quality, emphasizing significant events like the COVID-19 pandemic, Nordic storm, tornado, and ice hockey world cup finals. Instances of decreased forecast accuracy during these events prompt an investigation into the role of social and psychological factors. This paper introduces a novel approach, employing variance from the long-term average, to gauge the influence of social and psychological factors on professional performance. Beyond highlighting the daily impacts of the social environment on highly routinized and professional activities, the study underscores an often-overlooked prospect. It posits that professional and technical assessment metrics can robustly indicate the severity of social and natural events. The research thus contributes to a deeper understanding of the intricate interplay between meteorological expertise and external influences, emphasizing the potential for utilizing professional performance metrics as indicators of broader societal events.

1. Introduction

Aviation weather forecasting stands as one of the most esteemed and closely monitored segments of meteorology. The ramifications of inaccuracies extend beyond delayed flights, logistical challenges, and financial implications to encompass critical aspects such as airport services, expensive equipment, and, most crucially, human lives. The essence of forecasting lies in the remarkably consistent interpretation of diverse meteorological inputs, demanding a high level of proficiency in reading, understanding, analyzing, compiling, and evaluating data.

Forecasters in this domain undergo specialized training programs, aiming for excellence and precision in their tasks. Their mandate is to maintain consistency in their interpretations, avoiding undue caution while prioritizing vigilance over potential threats. This commitment is paramount given the significant responsibility placed on them to anticipate and respond to potentially dangerous weather events.

In the face of major sociological or natural events, the accuracy of forecasts in the affected regions may undergo changes due to external influences. These alterations have the potential to impact both partial and overall forecast performance. These events can be broadly categorized as:

1. Meteorological or climatic event (hurricane, intense rainfall, sudden weather change, etc.);

2. Disruptive social influences (social events, e. g. sporting, political or other events, pandemics, economic or social deterioration, etc.);
3. Local events at the airport (inspections, exhibitions, annual forecaster performance reviews, busy days, arrivals of VIPs, etc.);
4. Personal influences (understaffing, overtime, motivational issues, personal difficulties, etc.).

Points 3 and 4 present challenges in statistical representation due to the requirement for unusual or specialized data, and their effects are often confined to local or isolated contexts. While these points might not be thoroughly addressed through statistical analysis, points 1 and 2 will be scrutinized in greater detail.

Specifically focusing on weather events, the ability to adeptly navigate sudden changes stands as a critical competency within aviation forecasts, constituting a key aspect of their performance evaluation. This area of expertise is objectively significant, drawing attention from regulatory bodies such as the International Civil Aviation Organization (ICAO), as well as national air traffic control and meteorological services. The comprehensive examination of points 1 and 2 aims to contribute to a nuanced understanding of the factors influencing forecast accuracy in the aviation weather forecasting domain.

Despite media speculation that COVID-19 might decrease forecast accuracy due to reduced flight numbers, scientific studies, such as those examining ground observation data, revealed the opposite. Numerous studies investigated the accuracy of Numerical Weather Prediction (NWP) systems.

Ingelby et al. (2020) offer unbiased perspective on the absence of commercial flight data in weather forecasting during the COVID-19 pandemic. They note that while aviation meteorological observations were significantly impacted, satellite observations remained active, filling the gap left by aerial observations. The study also found that the most significant data drop occurred between 10-12 km altitude but did not result in a noticeable deterioration in forecasts.

Martinez (2020) explored the connection between weather forecast accuracy, hurricane strikes, and subsequent costs. The study sheds light on the considerable pressure forecasters face during major weather events.

It is crucial to recognize that global climate change can profoundly affect long-term statistics and forecaster experience. A study from Stockholm University (Scher and Messori, 2019) suggests that while temperature parameters may become more predictable in the future, predicting summer rainfall could be more challenging due to climate change. The paper also outlines avenues for further research, including identifying causes for the decline in summer precipitation predictability and exploring tropical contexts.

The aim of this study is therefore to identify some significant events and estimate their potential impact on the individual parts of the forecast. As the aeronautical forecasts are greatly professional and their quality is of a high standard, it will be possible to select moments when the forecast is too alarming or too inaccurate. The perspective of meteorology and the possibilities of forecasting given situations will be also commented on through a sensitive evaluation of individual cases.

2. Stations, data, and methods

Two stations in Finland were selected to be investigated (Jyväskylä – ICAO code: EFJY and Helsinki – ICAO code: EFHK) and one in the Czech Republic (Brno-Tuřany, ICAO code: LKTB). Forecasts from 2010-2019 were used to capture long-term average conditions. This provided a sufficient data set to estimate the standard performance of forecasters.

Worldwide used Terminal aerodrome forecasts (TAFs) were chosen as the main source of data. These forecasts are issued according to ICAO standards and are under constant strict quality control (International Civil Aviation Organization, 2018). Their

validity at all stations is 24 or 30 hours with an issuance period of 3 or 6 hours. Since intervals are not the same, it is not possible to compare performance between stations, but within a single station only. This is also reasonable given the nature of the weather, which would need to be accurately characterized for both stations to enable any comparative study to be made.

There are many technical details within the TAF terminology that could be explained, but for the purposes of this study we focused mainly on the nature and number of groups of changes. In principle, five types of change groups can be used in a TAF forecast to indicate the nature of change (Table 1).

Table 1. TAF change groups and their explanations

Code	Explanation
Main group	Prevailing conditions
BECMG	Gradual change of conditions
FM	Sudden change of conditions
TEMPO	Temporal change of conditions
PROB30	Change of conditions with probability of 30 %
PROB40	Change of conditions with probability of 40 %
PROB30 TEMPO	Temporal change of conditions with 30 % probability
PROB40 TEMPO	Temporal change of conditions with 40 % probability

The precise utilization of change groups is outlined in ICAO Annex 3 (International Civil Aviation Organization, 2018), though the intuitive interpretation of these groups is generally straightforward. Using an inadequate number of change groups can result in confusing predictions, hindering users from swiftly and clearly comprehending the forecast. Even if one value within the change groups is accurate, an unsettling level of uncertainty may persist. This uncertainty might signify discomfort for the forecaster. Furthermore, overuse of probability groups, especially in situations where certainty is warranted, may magnify the impact of external factors on the forecaster.

Horizontal visibility predominantly served as the metric for evaluation in most cases, given its precise expression in METAR observations (as a reference value) and TAF forecasts (as a compared value). Visibility, expressed as a number with no room for ambiguity, differs from parameters like wind direction or cloud base height, where considerations of cloud amount or type introduce subjectivity. Evaluating meteorological phenomena adds another layer of difficulty and subjectivity, although methodologies for these parameters have been explored in other research papers (Sládek, 2021; Mahringer, 2008; Novotný et. al, 2021).

Visibility's appropriateness for evaluation arises from its limited representation in numerical models. Forecasts for visibility require the forecaster's ingenuity and methodology, offering insights into potential inner challenges. Had parameters like temperature or wind direction been given greater emphasis, their success rates might closely align with numerical models. Wind speed, despite its crucial role in situations like the South Moravian tornado, received marginal attention.

While accuracy traditionally takes precedence in evaluating forecasters' performance, this study prioritizes a different metric. The quantity of values included in the forecast serves as a representative measure of the forecaster's confidence in the situation. A higher number of "temporary" options with a "30% probability" suggests a potential compromise in the forecaster's natural assertiveness. Although professionals like aviation forecasters are not presumed to be overtly influenced by social or meteorological events, critical predictions during critical times might exhibit unconscious biases.

2.1 Major event 1: COVID-19 Pandemic

The COVID-19 pandemic has affected most areas of human society (Tušl et al., 2021). Despite the reduction in the number of flights, and thus presumably a reduction in the ability of numerical models to predict the weather, the relevant studies (Ingleby, et al., 2020; Cardinalli, 2009) suggest that numerical predictions should have not reduced their success rate. This leads to the assumption that the inaccuracies caused during a pandemic are mainly due to the forecaster. The assumption was that the meteorologist may be adversely affected by, for example, overtime resulting from high numbers of isolations and sudden absences. His concentration may have been affected, for example, by reduced flight numbers at the airport (reduced demands due to reduced user numbers). But the influences could also be much more complex - for example, the illness itself, possibly many sick relatives, closed schools (childcare concerns) and other psychological influences.

The observations from March and April 2020 will be used to demonstrate how the forecast changed during the COVID-19 pandemic, namely during the period when the serious and quite sudden restrictions were imposed in Finland.

2.2 Major event 2: Nordic Storm Eino November 2013, Finland

Concerning major weather phenomena, one of the selected storms with a relatively typical course was the Nordic storm Eino. It hit Finland in November 2013, accompanied by strong wind gusts, snow and ice pellets showers, and warnings from the National Weather Service. The aim, however, was to see whether meteorologists - distracted by considerations of maximum wind gusts - had neglected to forecast visibility. This was quite difficult in mixed showers before the storm's arrival but seemed relatively easy to predict after it passed.

2.3 Major event 3: IIHF 2021 world cup final weekend

Very differently from the storm, as one of analyzed situations, final weekend of the 2021 Ice Hockey World Championship was chosen. It is undoubtedly one of the most watched events in Finland, especially since Finland reached the finals. The aim is to find out whether the viewership of such an event could cause a lack of concentration of either the meteorologist on duty or the forecast quality in the following hours. The parameter under investigation will also be some unusual uncertainty in the following day. It should be borne in mind that the meteorologist issues a forecast for a full 24 hours in advance and therefore some lack of concentration on Sunday could affect the meteorologist on Monday, as well as overall performance metrics of Monday observations.

2.4 Major event 4: Tornado in South Moravia

One of the most significant meteorological phenomena in the Czech Republic in recent years was a tornado in Moravia. It struck the area near Hodonín (**Error! Reference source not found.**) between Brno and Vienna in the evening of 24 June 2021, reaching F4 strength (Edwards et al., 2013).

This was an unprecedented case of such a strong phenomenon in a populated area. The topic resonated in the media (STT-APF, 2021; Hovet, 2021) and the entire public sphere, igniting a wave of solidarity, and the effects of the destructive element were talked about every day. It is therefore reasonable to assume that even the meteorologist at one of the nearest airports, Brno (approximately 50 km from the area), could have been influenced by such an environment in issuing forecasts for wind speeds in the future (presumably in the 'false alarming' way).

Figure 1. Supercell in Hodonín (Czech Republic), in vicinity of the Tornado strike (Bernátek, 2021)

3. Results

3.1. Helsinki Airport (EFHK)

Three time periods were commented on at Helsinki Airport. The first was the Nordic storm in 2013, the second was March 2020, the onset of the COVID-19 pandemic, and the third was April 2020, when staff shortages due to infections, isolations, etc., were likely to occur.

From a dataset of forecasts and observations from 2010 to 2019, average values of change group usage were generated. For correctness, average visibility values and their standard deviations are presented in the

Table **2**. In aviation forecasting, the assumption is that reduced visibility and sudden changes in visibility are difficult to predict. However, statistically, there are usually more hours with good visibility.

Table 2. Mean visibility and its standard deviation in years 2010-2019, in March 2020 and April 2020 (maximum value is 9999 standing for 'visibility over 10 km')

	Overall	**March 2020**	**April 2020**
Mean	9198 m	9472 m	9657 m
Std	2154 m	1688 m	1463 m

In terms of basic statistics, i.e., just the mean and standard deviation, it can be predicted that, given the standard deviation of values, the months of March 2020 and April 2020 should be easier to predict than the long-term average. The mean visibility values are higher, suggesting that more hours of unreduced visibility were registered. Also, the standard deviation suggests that the best results with forecast accuracy would be expected in April 2020.

The number of amended (abb. AMD) forecasts (

Table **3**) provided an overall view of how confident the overall forecasts dataset is. These are those forecasts that are objectively inaccurate at the time of validity (criteria are subject to ICAO regulations (International Civil Aviation Organization, 2018)) and the forecaster would issue an amended forecast himself. This simple indicator may reveal that the confidence and decisiveness of the forecaster was not as consistently strong as usual.

Table 3. Counts and percentage of amended forecasts for overall dataset (2010-2019) and for analyzed events for Helsinki airport

	EFHK
Overall	21067
AMD Overall	2490
% AMD	11.8 %
Storm Eino	82
AMD Storm Eino	5
% AMD	6.1 %
March 2020	305
AMD MAR2020	46
% AMD	15.1 %
April 2020	292
AMD Apr 2020	40
% AMD	13.7 %

The table shows that the average proportion of amended forecasts at the Helsinki station is approximately 11.8%. Only six per cent of forecasts were corrected during the days around the storm, which is below average. In contrast, the months of March and April 2020 had a higher-than-average proportion of corrected forecasts. This indicates either a complex and rapidly changing situation or some lack of meteorologist focus. It can be speculated that the effect of (a) difficult conditions in the society due to the pandemic (b) less concentration due to reduced flight numbers and staff numbers, may be partly to blame.

Analyzing the number of change groups as a next step, it was assumed that in the event of a storm, meteorologists would use a much larger number of change groups to create variety of values, i.e., room for error. In contrast, in the case of a pandemic, the assumption was that the meteorologist would overlook some obvious facts, even in relatively simple situations, and make an erroneous forecast.

It should be noted that in the following analysis (

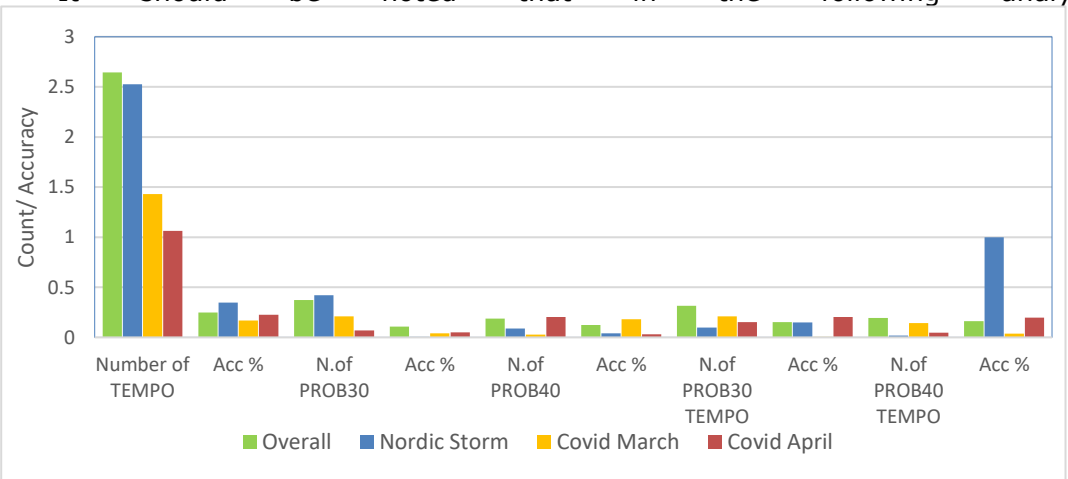

Figure **2**), we are only concerned here with change groups. This excludes some influence of the so-called persistent forecasts, i.e., the main groups that contain the prevailing weather values. In simplified terms, this review primarily considers the ability of the forecast to respond to change.

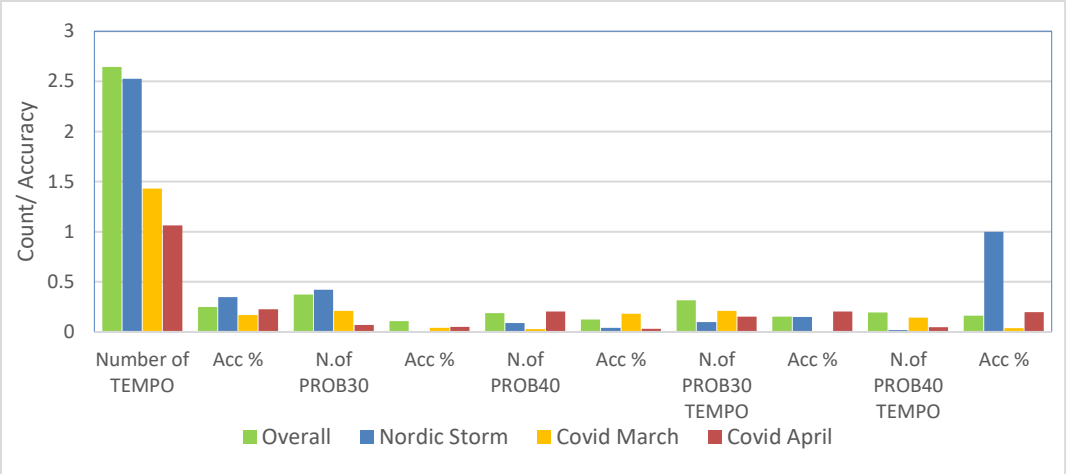

Figure 2. Count of change groups per observation and their accuracy overall and in all three tested situations at Helsinki Airport

The result shown in the graph indicates that in all cases fewer-than-average TEMPO groups were used. Even in the storm case, there were two and a half TEMPO groups per observation, which is not much. Their success rate was higher in the case of the storm, but below average in the case of both months of the COVID-19 pandemic. The use of the other groups is already quite marginal because they occur at very low values. It is definitely worth mentioning the 100% success rate in the case of the storm for the "PROB40 TEMPO" group, which could very easily be misinterpreted and considered impressive. This is only approximately one date when the group was valid. Therefore, no greater statistical significance can be attributed to this value.

Thus, the results suggest that in the case of a storm, the forecaster was able to capture the situation well without using too many change groups, which would have made the forecast unreadable. In March and April 2020, the forecasts showed a lower frequency of use of change groups, but also a generally lower success rate than average. Thus, it can be stated, without taking into account the uniqueness of the situation and its complexity, that there may have been some underestimation of the situation. What caused the results would have to be assessed for each situation separately.

3.2 Jyväskylä Airport (EFJY)

For Jyväskylä Airport, March 2020 and April 2020 were selected as months with significant COVID-19 influence. Further, the forecast accuracy for the final weekend of the Ice Hockey World Cup as a social event was analysed. The evaluation of the forecasts for March and April 2020 was the common for all airports. Statistics of amended forecasts rate is listed in the Table 4.

Table 4 Counts and percentage of amended forecasts for overall dataset (2011-2019) and for analyzed events for Jyväskylä airport

	EFJY
Overall	20973
AMD Overall	2485
% AMD	11.8 %
IIHF final weekend	23
AMD IIHF	0
% AMD	0
March 2020	290
AMD MAR2020	40
% AMD	13.8 %

April 2020	276
AMD Apr 2020	28
% AMD	10.1 %

Regarding at the table of corrected forecasts, it seems that the attention of forecasters was correct during the Ice Hockey World Cup final and semi-final weekend. Slightly more corrected forecasts were issued in March 2020, but the proportion was below average in April. Therefore, it cannot be said at this point that there is any indication that the quality of forecasts was worse during the selected months of COVID-19. For the final match of the IIHF World Cup, it was assumed that forecasts could be quite inaccurate (or too alarming) due to inattention of the forecaster (**Error! Not a valid bookmark self-reference.**).

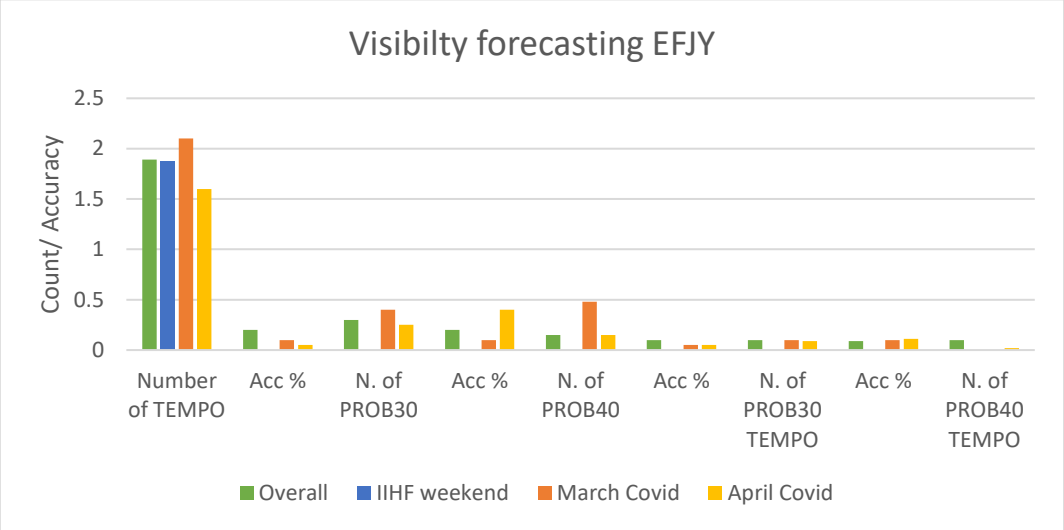

Figure 3. Accuracy assessment of Visibility forecasting EFJY of overall 2010-2019 conditions, during IIHF 2021 final weekend, and during March and April 2020 as representative months of the COVID-19 pandemic

For this airport, it is evident that the difference in the number of change groups was not significant. Even during the weekend of the final matches of the Ice Hockey World Championship there was no overuse of change groups. However, what is not a good sign of a professional performance is that not a single TEMPO type change group was observed. In other words, the prediction did not come true. We take a closer look at this inaccuracy in the Figure 4.

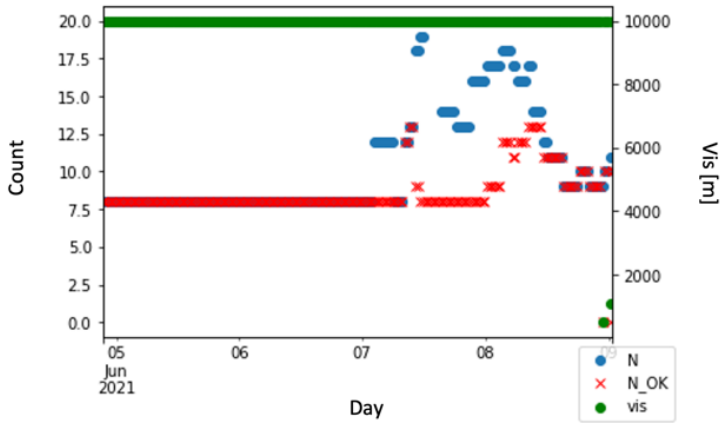

Figure 4. Visibility (green), number of all change groups per one observation (blue) and number of correct groups (red) from 5th June-9th June 2021 at the EFJY Airport

The plot shows that 7th to 8th June visibility did not decrease at all in either case, however the forecasters added more change groups, predicting a decrease in visibility. This did not

happen and so the forecast cannot be rated 100% positive. Here we can say that the meteorologist used an excessive number of groups when it was not necessary.

When analyzing the individual forecasts, it was found that the group predicting thunderstorms and reduced visibility was included approximately 24 hours before the storms arrived and was left unchanged until almost the arrival of the convective system. It is customary to continually correct and refine forecasts, and thus it is surprising that neither the visibility, phenomenon, nor cloud base for these forecasts were adjusted. It would not be presumptuous to suggest that the forecast could have been made more conscientiously. In the forecasters' defence, the system of issuing forecasts varies from one area to another and from one organisation to another. It may be central, it may be subject to various local agreements, there may be different rules on continuity, etc. However, it appears from the available data that the forecast, or the group concerned, may have been modified during its validity but it was not.

3.3 Brno-Tuřany Airport (LKTB)

Like in case of other airports, analysis of amended forecasts was performed (Table 5). It presents overall average (2011-2019) amended forecasts ratio in two months after tornado occurrence and two initial moths of COVID-19 pandemics.

Table 5. Counts and percentage of amended forecasts for overall dataset (2011-2019) and for analyzed events for Brno airport

	LKTB
Overall	10154
AMD Overall	560
% AMD	5.5 %
June 2021	127
AMD 6/21	5
% AMD	3.9 %
July 2021	127
AMD 7/21	3
% AMD	2.3 %
March 2020	129
AMD MAR2020	6
% AMD	4,6 %
April 2020	126
AMD Apr 2020	2
% AMD	1.5 %

When evaluating the effect of a tornado on the forecast output (Figure 5), it was assumed that the meteorologist would use a higher number of change groups to ensure that outliers would not remain unpredicted. It should be noted that from the perspective of government circles and the general public, there has been an increased interest in weather forecasting and thus also a greater focus on aviation forecasting. This may have imposed additional pressure on the forecaster.

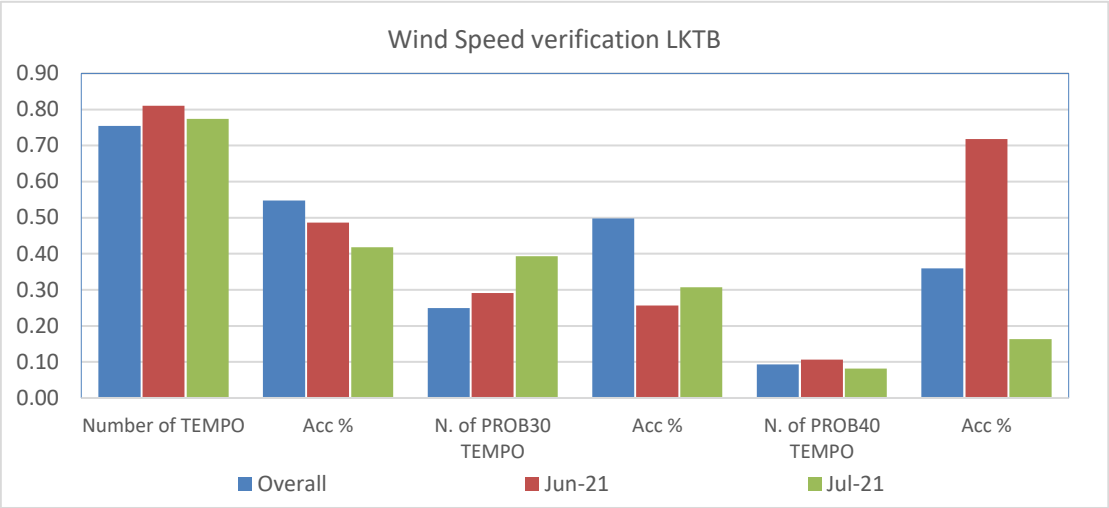

Figure 5. Use of change groups in Brno station, wind speed in June and July 2021 (average number of groups used per one observation

The wind speed graph shows some interesting facts. First, in both months TEMPO groups were used more than average, and their accuracy was lower. In terms of the other groups, uncertainty was evident. For the "PROB30 TEMPO" group, where the number of groups was higher, the accuracy was lower. For the "PROB40 TEMPO" groups, the counts were relatively similar, even lower in July. Interestingly, the precision in June is very high, even over 70%. In July the accuracy of these groups was the lowest. In terms of accuracy evaluation, the last group of columns is mentionable. The accuracy of the use of the "PROB40 TEMPO" groups looks acceptable, since the 70% accuracy is decent. However, it should be noted that the "PROB40 TEMPO" group says that "with a probability of 40% a certain phenomenon will occur temporarily". Therefore, if the forecasted phenomenon occurs in 70% of cases, we can say that the group is not being used correctly.

It is possible that in the very month when such a serious event as a tornado occurred, the meteorologist tried to be careful not to overestimate his forecasts. Therefore, for some extreme events he often used only the probability group "PROB30 TEMPO". In general, probability groups do not unnecessarily draw attention to extreme values that might not occur.

Although in 70% of cases these outliers did occur, it should be noted that in the case of the "PROB40 TEMPO" group it is not possible to generate statistics based on this indicator. The number of groups in this case was too small (only 2% of all change groups) to say that it caused some serious influence on the evaluation.

Visibility statistics were also created for the Brno-Tuřany station (
Figure **6**). In the months of March and April 2020 the use of change groups was reduced and at the same time the success rate of the TEMPO group was higher. Therefore, it can be said that the forecast quality was probably better. From the formal point of view, however, it is interesting to note that the PROB30 and PROB40 groups are basically not used at all for visibility. This is certainly due to the fact that most of the events that limited visibility in April were convective in nature, such as thunderstorms or showers. Fog was only predicted in two TEMPO groups, which is interesting. From a formal or practical point of view, fog is not an intermittent phenomenon, that is, for example, it is present for an hour and absent for half an hour.

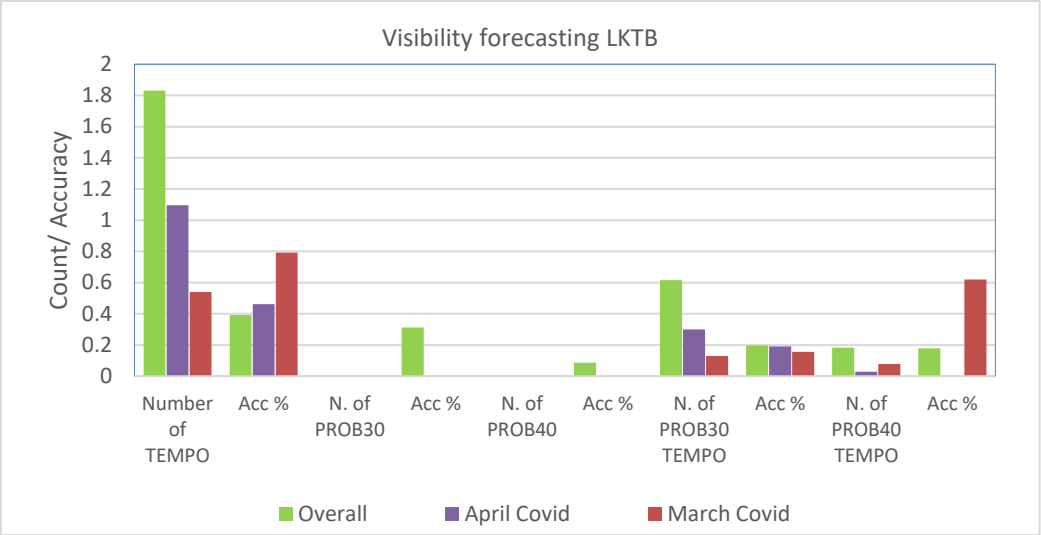

Figure 6. Statistics of overall (2010-2019), March and April 2020 visibility change groups counts and their accuracy

As far as the quality of the visibility forecast is concerned, the meteorologist produced a very high standard of forecast. In March and April, they reduced the number of groups and the success rate increased. If any shortcomings were to be found in the forecast, they would only be of a technical type.

5. Discussion

The article endeavours to establish a connection between routine skills, scientific methodologies, and significant events, recognizing the inherent reflection of socio-economic and personal occurrences in individuals' daily performance. Numerous dimensions exist where dataset quality can be critically assessed in light of social phenomena. Meteorology, in particular, presents a unique opportunity to employ technical indicators as reflections of major societal changes, professional considerations, and, to some extent, public pressures. Despite the progressive stance of certain organizations in this domain (Roberts, 2022; American Meteorological Society, 2014), the integration of sociology or psychology with meteorology remains relatively uncommon.

The utilization of prediction verification for assessing subordinates' performance or evaluating meteorological services is a well-established approach. However, the exploration of discernible patterns in forecast quality concerning significant events remains largely uncharted territory. Determining the precise factors influencing forecasters is challenging; yet, it is evident that, alongside the inherent complexity of situations, factors such as the forecaster's mental well-being, fatigue, or motivation can play pivotal roles. This holds true even for trained professionals, such as aviation forecasters.

As social and environmental changes escalate, both the scientific community and society must acknowledge the necessity of addressing factors that induce fluctuations in various realms of human activity. With climate change ushering in more extreme events, individuals working directly under the influence of weather are likely to experience significant impacts. Systemic effects may manifest in situations characterized by staff reductions, prolonged overtime, or enduring fatigue.

While meteorological services generally offer excellent data and professional support to aviation meteorologists, it is prudent to also consider their psychological well-being, work environment, and social background. Future advancements in quantifying the accuracy of numerical models, observations, and other influences in the forecasting process highlight the forecaster's increasing significance. The growing dependence on external social and psychological factors necessitates a nuanced understanding.

Additionally, the quality of forecast delivery is intrinsically tied to the meteorologist's communication skills, emphasizing the integral role of social, psychological, and material factors in the technical and scientific aspects of their work.

6. Conclusions

The case study implies that factors such as insufficient attention, staffing shortages, or distractions do not wield a substantial influence on professional performance. Conversely, the findings indicate that when confronted with a significant weather event, meteorologists exhibit heightened focus, resulting in an increased level of certainty in their forecasts.

In conclusion, the analysis of various airports and forecasting scenarios reveals that the multitude of factors contributing to inaccuracies precludes pinpointing a singular moment of misjudgment or optimal prediction. Instead, retrospective analysis allows for an examination of the appropriateness in both quantity and type of forecasting groups employed. From a formal perspective, debates may arise concerning the selection of group types, while considerations of forecast consistency involve scrutinizing the gradual adjustments and refinements, or the initial estimates of the situation.

Notably, these imperfections, deemed uncommon in forecasts executed by seasoned meteorologists, may serve as indicators of situations where external influences have impacted the forecasting process. A crucial prerequisite for advancing research in this domain is the establishment of a standardized methodology for assessing variability — encapsulating unpredictability and complexity in weather patterns. The ability to extract the meteorologist's average performance for a given situational complexity could unveil influences unrelated to weather patterns. This framework provides an opportunity to investigate the impact of excessive workload, distracting elements, and other external factors.

Such an evaluation, serving primarily the forecasters themselves, offers valuable feedback and potential avenues for enhancing forecasts in the face of varying external influences. Establishing a uniform methodology for assessing meteorological performance will not only contribute to the refinement of forecasting techniques but also foster a deeper understanding of the nuanced interplay between meteorological expertise and external factors.

Acknowledgements

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Code (Python notebook) used in this work is placed and maintained in the online repository: https://github.com/Sladekd/Terminal-Forecast-Python-Processing

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