Exploitation of Mode-S data at SHMU

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Abstract

Preliminary experiments on Mode-S data application in NWP were accomplished at SHMU. This poster reviews the work on quality control of Mode-S temperature, wind speed and wind direction data. The objective of the selection criteria applied was to select only reliable data. These were further subject to data assimilation experiments. The impact of the analysed sample was tested in a DFS study. The potential benefit of Mode-S data on data assimilation was confirmed in a case study with a limited area model AROME/SHMU.

Methodology

In preparation of Mode-S data sample for meteorological experiments, the raw dataset was first quality controlled. The OMG (observation minus first guess) departures method [5] was chosen for quality check. The departures were calculated as differences between observations and model variables interpolated into observation locations. For the OMG departures calculation, the AROME/SHMU model of 2km/L73 resolution experimentally used at SHMU [3] was utilized.

The quality control was performed in 2 steps. First the gross errors were eliminated by truncation of the data according to thresholds from Table 1. A similar approach was used by Trojakova [7]. Then the resulting dataset was trimmed by <$-2\sigma;2\sigma$> interval.

To further improve the Mode-S data statistics, the whitelist approach [6],[7] was opted for. This technique is based on selection of aircrafts reporting reliable data fulfilling the whitelisting criteria listed in Table 1. The identification of aircrafts is based on ICAO address which is a unique aircraft identifier.

Table 1: Statistical thresholds and whitelistng criteria

	OMG statistical thresholds		whitelisting criteria		
			No. of OBS	mean value	σ
temperature	± 10 K	2σ	1000	1 K	2 K
wind speed	± 20 m/s	2σ	1000	1 m/s	5 m/s
wind direction	± 45 deg	2σ	1000	10 deg	100 deg

Verification

The verification principle is to compare the reference observation dataset (SYNOP, TEMP) to the model variables interpolated into observation locations. The experiment shown in Figure 1 represents the observation minus analysis departures along the vertical profile for wind direction. The positive impact of Mode-S data (green) around 500 hPa level is influenced by the uneven distribution of model level which is sparser with increasing height.

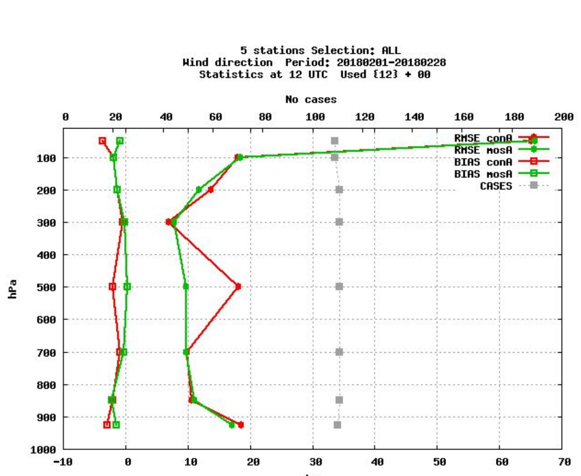


Fig. 1

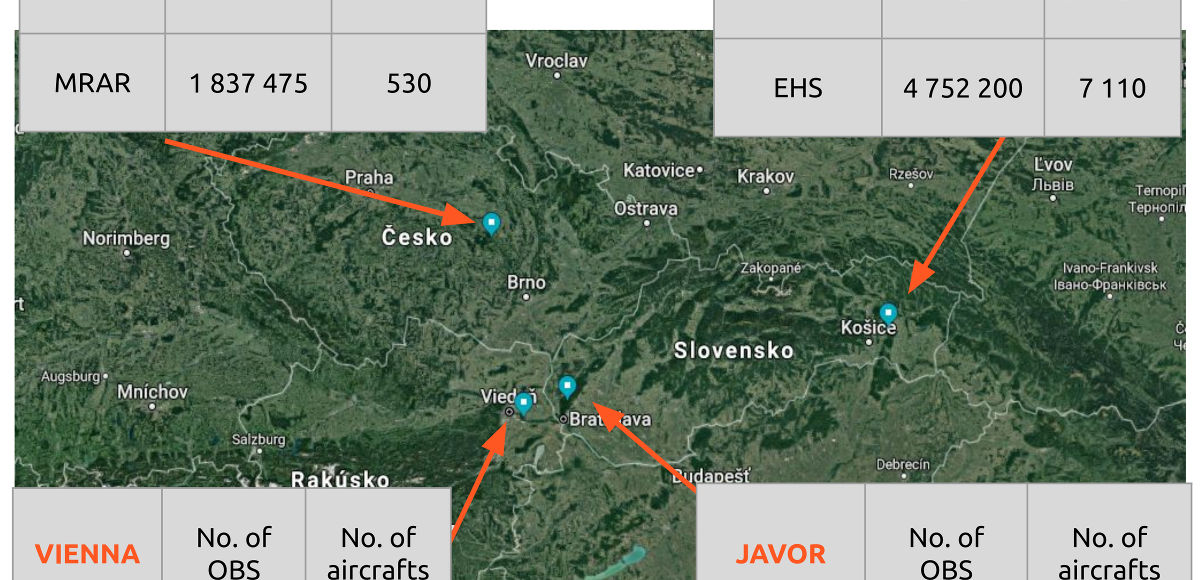
A validation of analyses with Mode-S data on temperature and geopotential was also examined (not shown) but the impact was neutral. A degradation was observed in relative humidity profiles because Mode-S data do not currently contain humidity measurements.

Data description

A 2-month (Jan-Feb 2018) sample of Mode-S data (EHS & MRAR) was provided by LPS SR (Air Traffic Services of Slovak republic) to SHMU. Meteorological parameters can be only derived [2] from EHS while MRAR data contain direct meteorological measurements. The amounts of data received by 4 tracking and ranging radars is listed in Figure 2 below. The lower number of MRAR data compared to EHS is due to additional radar settings to obtain MRAR. AMDAR dataset (215 577 measurements, 1 807 aircrafts) was provided from OPLACE [8] and served as a reference for Mode-S data analysis.

BUKOP	No. of OBS	No. of aircrafts
MRAR	1 837 475	530

MOSNIK	No. of OBS	No. of aircrafts
EHS	4 752 200	7 110



VIENNA	No. of OBS	No. of aircrafts
MRAR	95 758	401

JAVOR	No. of OBS	No. of aircrafts
EHS	9 898 618	8 428

Fig. 2

Statistical analysis

Temperature, wind speed and wind direction data retrieved from Mode-S EHS and Mode-S MRAR dataset were statistically analysed and compared to the reference AMDAR dataset. The importance was placed on mean value and standard deviation of the Mode-S data subsets.

Histogram in Figure 3 depicts MRAR temperature OMG departures after gross error check (white) and after whitelist (red). The distribution remained slightly positively asymmetric even after the whitelist, however the studied statistical parameters improved. The same dataset was analysed when the data were aggregated by aircraft and the output is plotted in Figure 4. The whitelist caused significant improvement. The large difference in the relative amount of remaining data after whitelist in Figure 3 (85% measurements) and in Figure 4 (30% aircrafts) can be explained either by occurence of a big number of aircrafts reporting biased measurements or a big number of aircrafts that executed only a few flights during the studied period. Here the criterion for number of measurements played an important role.

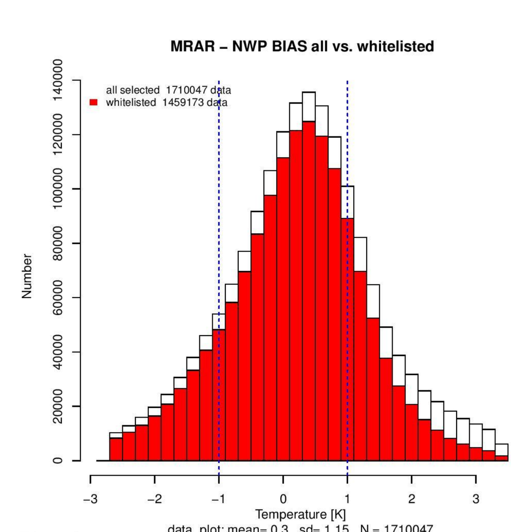


Fig. 3

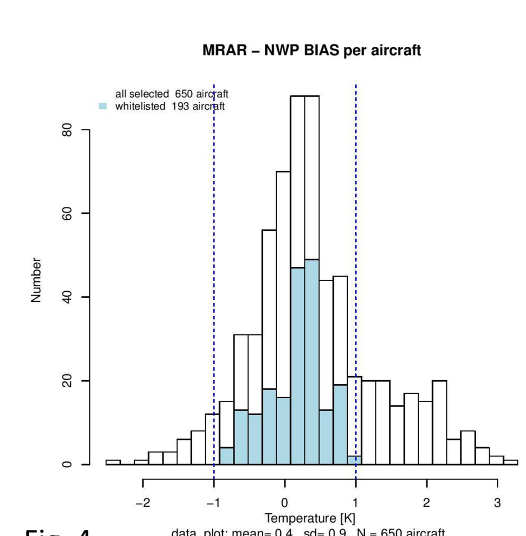


Fig. 4

The positive impact of whitelisting is noticeable along the whole profile for OMG departures computed from MRAR temperature dataset depicted in Figure 6. The mean value and standard deviation are consistent over all vertical layers. The number of measurements showed on the barplot is in accordance with the fact that the biggest part of measurements are taken during the en-route flight. Similar outcomes were observed for EHS temperature dataset depicted in Figure 5 although the general statistics are of lower quality which corresponds to the findings from literature [7].

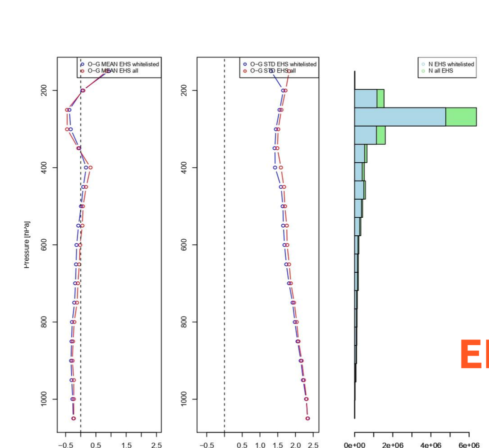


Fig. 5

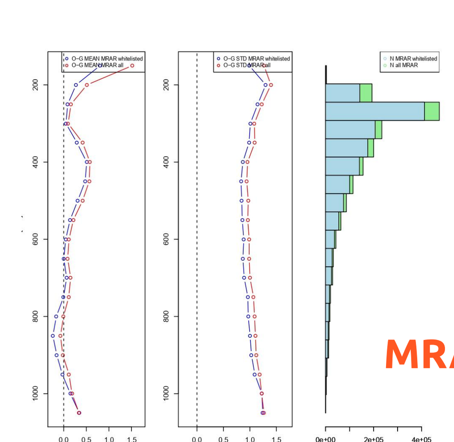


Fig. 6

Degrees of Freedom for Signal (DFS)

A validation of the impact of Mode-S (EHS and MRAR together) against other data types (SYNOP, TEMP, AMDAR) was executed exploiting DFS method [1]. The analysed data sample was divided in 4 datasets according to the synoptic hour and absolute as well as relative DFS were computed. The results in Figure 7 are plotted per each data type and variable separately.

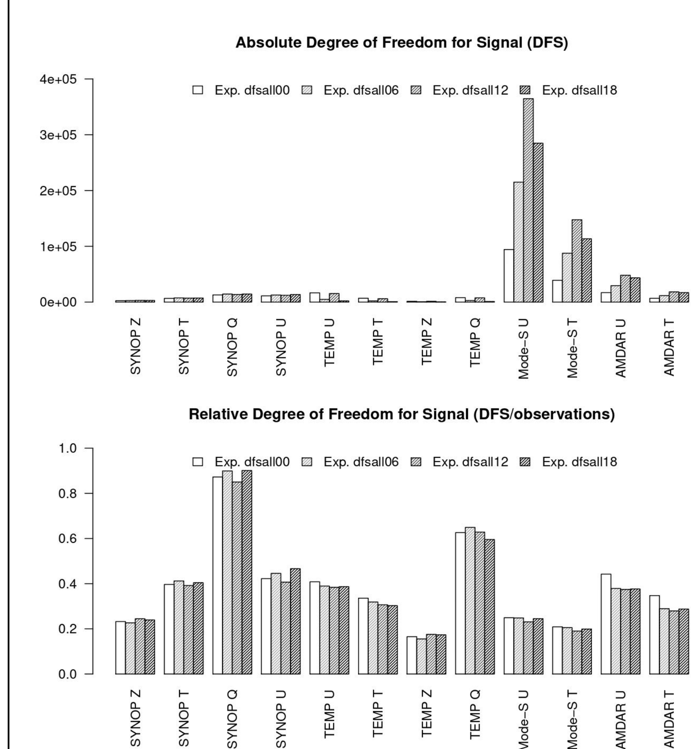


Fig. 7

The counts of TEMP and Mode-S data are subject to radiosonde launching frequency and air traffic peak hours. The immense number of Mode-S measurements causes the high absolute impact of Mode-S. In spite of that, Mode-S data scored a slightly lower relative impact than AMDAR. A wider availability of humidity data in MRAR (relative humidity reporting generally not used) measurements would increase the influence of Mode-S.

Case study

The purpose of the case study was to test the feasibility of Mode-S data assimilation into AROME/SHMU model and to investigate the impact of Mode-S on the forecast.

The selection of synoptic situation was motivated by succsessful outcomes from literature [6]. A winter situation of cold front passage over Slovakia on the 2 of February 2018 was chosen and the precipitation totals were analysed.

The experiment was prepared in 2 setups. First only conventional data were assimilated and forecast valid for 2018-02-02 at 18 UTC was computed. Second the same experiment with MRAR data added was executed. The 3h accumulated precipitation totals plotted in Figure 8 (with MRAR) and 9 (without MRAR) were compared. The differences between the 2 setups depicted in Figure 11 show correct redistribution of modelled precipitation due to MRAR data inclusion. The above mentioned AROME/SHMU forecasts were then confronted with the INCA [4] analysis depicted in Figure 10. The maximum of precipitation from AROME with MRAR is more concentrated though shifted and false precipitation maxima from north-east Slovakia from AROME without MRAR is reduced after MRAR assimilation.

Fig. 8

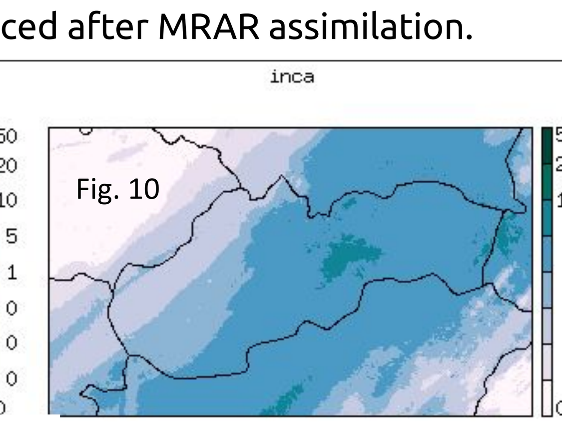


Fig. 10

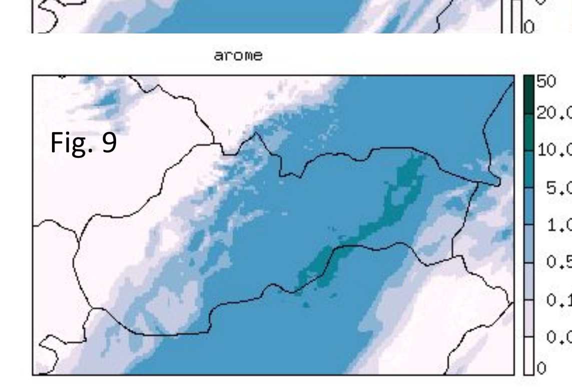


Fig. 9

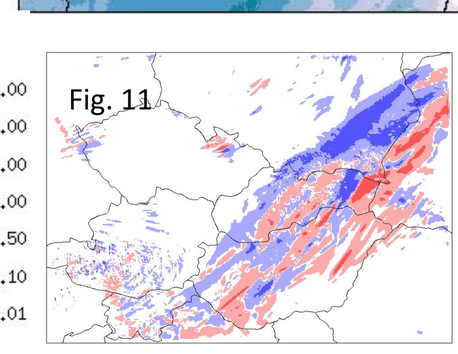


Fig. 11

Conclusions

The experiments presented here showed the importance of Mode-S data which indicate a potential benefit of their wider usage at SHMU.

- The statistical analysis of raw data revealed a necessity for gross error correction, mainly for EHS dataset.
- The whitelist method ensured improvement of the statistical parameters of studied dataset.
- The case study confirmed considerable impact of Mode-S data on the precipitation forecast.
- The outcomes Mode-S verification showed up positive or neutral influence on analyses.
- Mode-S data scored very high absolute impact and slightly lower impact than AMDAR data in the DFS study.

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