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USE OF FAIRMODE RECOMMENDATIONS FOR MODEL BENCHMARKING TO EVALUATE CAMX MODEL PERFORMANCE OVER THE CZECH REPUBLIC

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Abstract: In association with ongoing development of a capability to simulate atmospheric chemistry and air pollution transport over Europe, recent model results were evaluated against observations from the Czech Republic. The preliminary recommendations for model to observation comparison from FAIRMODE's model benchmarking working group were applied to evaluate the results. The comparison methods recommended by the group were used for an annual simulation. The results were generated by the air quality model CAMx v5.2 supplied with meteorological fields from the numerical weather prediction (NWP) model ALADIN/CE which is run operationally at the Czech Hydrometeorological Institute. Observations were gathered from Czech monitoring stations. The comparison focused on PM_{10} and gaseous species (NO_2, O_3, SO_2). Underestimation of PM_{10} was found and oppositely, overestimation of NO_2 and SO_2 was found. The high SO_2 concentrations were attributed to emissions being released at ground level in the model. A good fit was obtained for O_3. The main possibility for improving the model's results is in replacement of the EMEP-based emission inventory with emissions based on the Czech Republic's national emission inventory.

Key words: *FAIRMODE, CAMx, model evaluation, ALADIN, benchmark*

INTRODUCTION
Considerable improvement in ambient air pollution occurred in the Czech Republic between years 1989 and 1996. Currently, the main constituent of air quality pollution is particulate matter, especially during a bad dispersion conditions. The other main specie which negatively influences human health is ozone. Czech and EU limit values for ozone have been continually exceeded over a large area of the Czech Republic. In order to evaluate the pollution burden, and to forecast it, the chemical transport model CAMx is being implemented at the Czech Hyrdometeorological Institute (CHMI). Here we present results of a test case covering the period from January 2008 to December 2008.

MODEL SYSTEM AND INPUT DATA
Model system
The Eulerian photochemical dispersion model CAMx v5.2 (Environ, 2010) was used for modelling of the transport of gaseous and aerosol substances in the atmosphere and their reciprocal chemical reactions. The horizontal model domain was identical to the ALADIN (meteorological model) model domain. It was centred over the Czech Republic and consisted of 307x275 cells with a horizontal resolution 8977 m. Vertically, the CAMx model was configured to have 16 layers. Data from ALADIN's 34 lowest vertical layers were aggregated to suit the CAMx configuration.

Input data
Input data were prepared with a 1 hour time step. Meteorological data were obtained from NWP model ALADIN/CE (version CY35T1star) in which analysis followed by a 6-hour forecasts is carried out regularly at 0, 6, 12 and 18 h UTC. For upper air parameters, the analysis represents a sophisticated combination of the global analysis of the driving model ARPEGE with the mesoscale structures simulated by ALADIN and for the surface parameters, ground temperature and relative humidity is assimilated by the optimal interpolation method. Such a forecast represents the quality limit of the routine 54 hour forecast available at the CHMI.

Anthropogenic emissions based on the year 2006 were prepared using the emission model of B. Krüger from Universität für Bodenkultur Wien. This model stems from the EMEP emission inventory which has a 50x50 km horizontal resolution and includes emissions of non-methane volatile organic hydrocarbons (NMVOCs), oxides of nitrogen (NO_x), sulphur dioxide (SO_2), carbon monoxide (CO), ammonia (NH_3), particulate matter less than 2.5 microns ($PM_{2.5}$) and coarse particulate matter (PM_{crs}). For the Czech Republic, Hungary, Slovakia, and Austria a more detailed spatial and temporal structure of ozone precursor emissions with a 5x5 km resolution was used (Winiwarter and Zueger, 1996). Emissions were interpolated to the model grid.

Biogenic emissions of isoprene and terpene were prepared using the BEIS3 model which is a part of the model SMOKE. Detailed land cover categories based on AFOLOU and USGS databases were used (Zemánková and Brechler 2010).

Station data
Surface concentrations were compared to measured concentrations recorded in the ISKO data base which is maintained by the CHMI. 89 stations classified as 'background' were chosen.

EVALUATION METHOD
The results and the meteorological inputs were evaluated in general accordance with the recommendations of Thunis et al. (2011b). Statistical indicators and diagrams were produced using the DELTA tool (Thunis et al., 2011a). In this paper, due to space considerations, we focused on the target diagram and a summary statistics table for pollutant evaluation. The summary statistics table showed the following statistical measures: the target (RMSE normalized by the standard deviation of the observation), mean fractional bias (MFB), correlation coefficient (R), fraction of modelled values within a factor of two of observations (FAC2), relative directive error (RDE) and relative percentile error (RPE). The target indicator is proposed to be

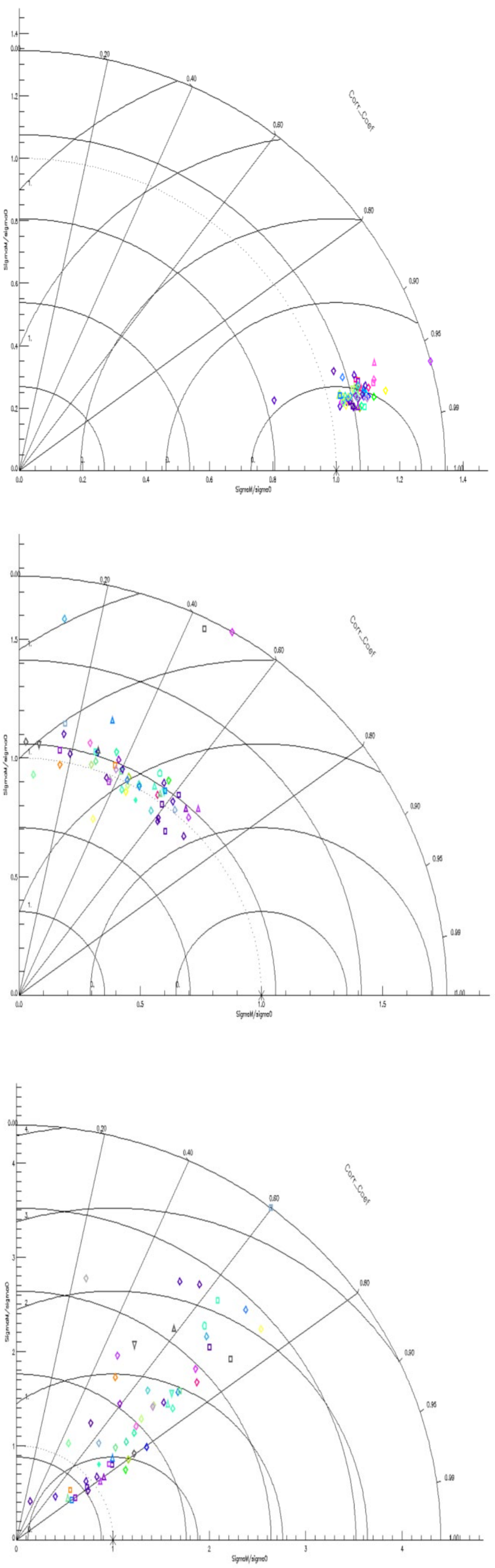


Figure 1. Taylor diagram for temperature (top), wind direction (centre) and wind speed (bottom). Each point represents one station.

used as main statistical indicator. In the target diagram it represents the distance from the origin. The performance criterion for the target indicator is set to unity and it is expected to be fulfilled for at least 90% of the available stations. Performance goal is set to 0.8.

These results were supplemented by time series plots at the selected stations. Taylor diagrams were also used to evaluate the meteorological data.

RESULTS

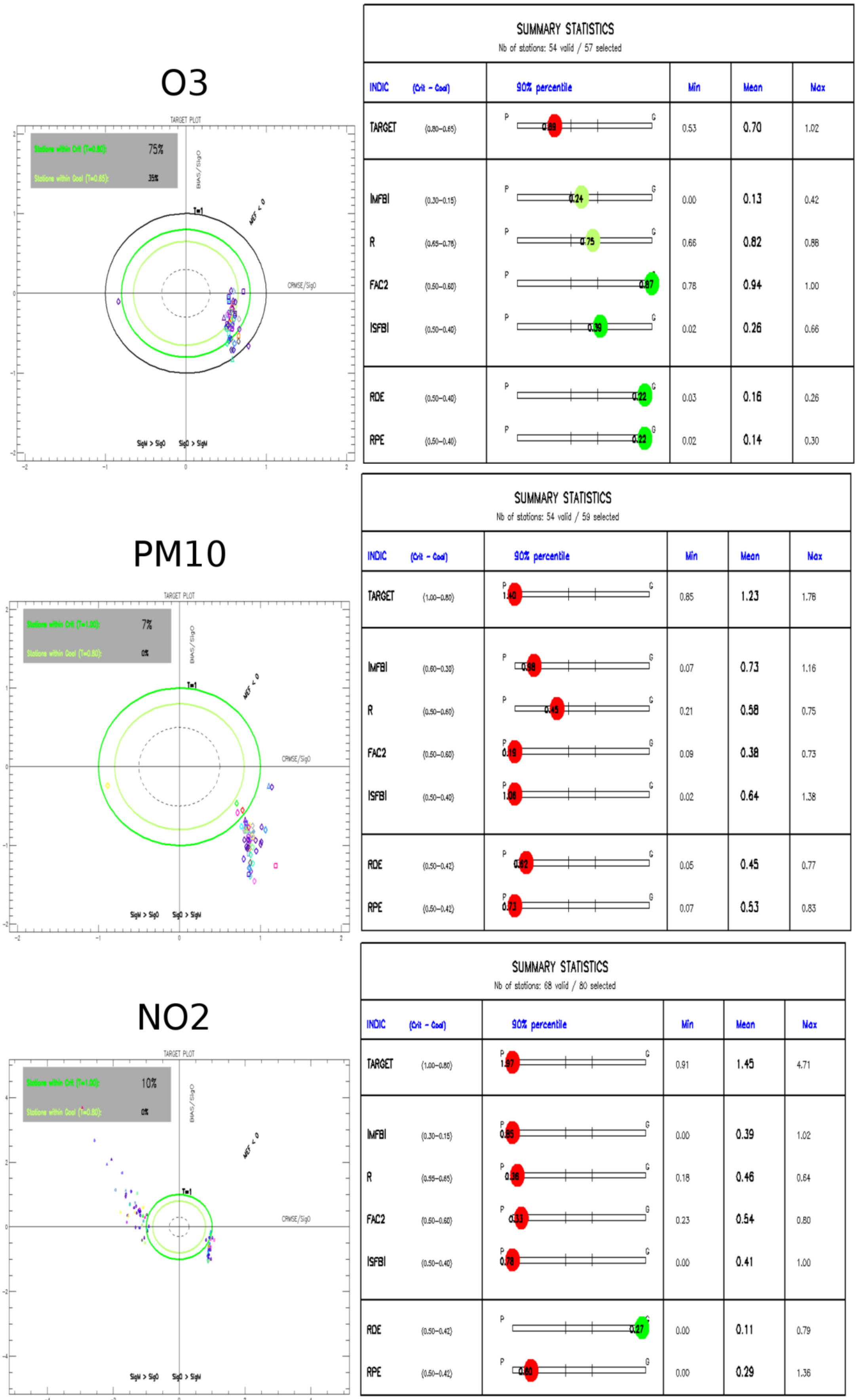
As a first step we evaluated the meteorology model. Taylor diagrams of temperature, wind speed and wind direction are displayed in Figure 1. Temperature was modelled the best amongst the assessed meteorological parameters. The root mean square error (rmse) was approximately 2.5 K for all stations except one and R values were approximately 0.96 indicating very good agreement with observations. The variance of modelled temperature was slightly larger than for the observations. The correlation coefficient of wind direction was less than 0.7 but the evaluation of wind direction on the basis of R and rmse is problematic due to its circular character. It was found that the wind speed agreement differed depending on station. Generally R was between 0.5 and 0.8 and the rmse was less than 2.2 ms^{-1} for all stations.

Figure 2 shows summary statistics for nitrogen dioxide (NO_2), ozone (O_3) and PM_{10}. For O_3, 75% of modelled stations met the target criteria (a score greater or equal to 1.0) and 35% were within the goal limit (0.8). The model underestimated measured O_3, but looking at the summary statistics table it can be concluded that the overall fit is quite good and the model can simulate O_3 well. This is supported by the grading of the statistical results; 90% of the stations met the criteria for all computed statistics except one – the target. While there is still opportunity for improvement, this was considered a good result.

The results of NO_2 and PM_{10} were found to be poor. The model considerably underestimated PM_{10} and frequently overestimated NO_2 concentrations. Only the NO_2 relative directive error (RDE) was found to be acceptable with a value of 0.27. The worst results were obtained for SO_2 (not shown) where very high overestimation occurred. It is suspected that the cause of this error was mostly due to the model releasing the SO_2 at ground level.

The time series of temperature, wind speed, wind direction, NO_2 and PM_{10} at Věřňovice is shown in Figure 3. We present here a 4-day time period (28-31.5.2008) where the meteorological model performed particularly well and as such we excluded meteorology as possible source of errors. The model underestimated PM_{10}. It overestimated NO_2 however the overall cycle was well described and only monitored peaks had bigger amplitudes than the modelled peaks.

The underestimation of PM10 concentrations was not specific to Věřňovice. It was suspected that emissions in the model did not represent the full load of particulate matter emitted into the atmosphere. Possible reasons for this require further investigation but might include re-suspended emissions from road ways and fugitive emissions such as wind-blown dust.



O3 — SUMMARY STATISTICS. Nb of stations: 54 valid / 57 selected

INDIC	(Crit – Goal)	90% percentile	Min	Mean	Max
TARGET	(0.80–0.65)	0.89	0.53	0.70	1.02
IMFBI	(0.30–0.15)	0.24	0.00	0.13	0.42
R	(0.65–0.78)	0.75	0.66	0.82	0.88
FAC2	(0.50–0.60)	0.87	0.78	0.94	1.00
ISFBI	(0.50–0.40)	0.39	0.02	0.26	0.66
RDE	(0.50–0.40)	0.22	0.03	0.16	0.26
RPE	(0.50–0.40)	0.22	0.02	0.14	0.30

PM10 — SUMMARY STATISTICS. Nb of stations: 54 valid / 59 selected

INDIC	(Crit – Goal)	90% percentile	Min	Mean	Max
TARGET	(1.00–0.80)	1.40	0.85	1.23	1.78
IMFBI	(0.60–0.30)	0.98	0.07	0.73	1.16
R	(0.50–0.60)	0.45	0.21	0.58	0.75
FAC2	(0.50–0.60)	0.19	0.09	0.38	0.73
ISFBI	(0.50–0.40)	1.08	0.02	0.64	1.38
RDE	(0.50–0.42)	0.82	0.05	0.45	0.77
RPE	(0.50–0.42)	0.73	0.07	0.53	0.83

NO2 — SUMMARY STATISTICS. Nb of stations: 68 valid / 80 selected

INDIC	(Crit – Goal)	90% percentile	Min	Mean	Max
TARGET	(1.00–0.80)	1.97	0.91	1.45	4.71
IMFBI	(0.30–0.15)	0.85	0.00	0.39	1.02
R	(0.55–0.65)	0.36	0.18	0.46	0.64
FAC2	(0.50–0.60)	0.33	0.23	0.54	0.80
ISFBI	(0.50–0.40)	0.78	0.00	0.41	1.00
RDE	(0.50–0.42)	0.27	0.00	0.11	0.79
RPE	(0.50–0.42)	0.80	0.00	0.29	1.36

Figure 2. Target plots and summary statistics for O_3, PM_{10}, NO_2.

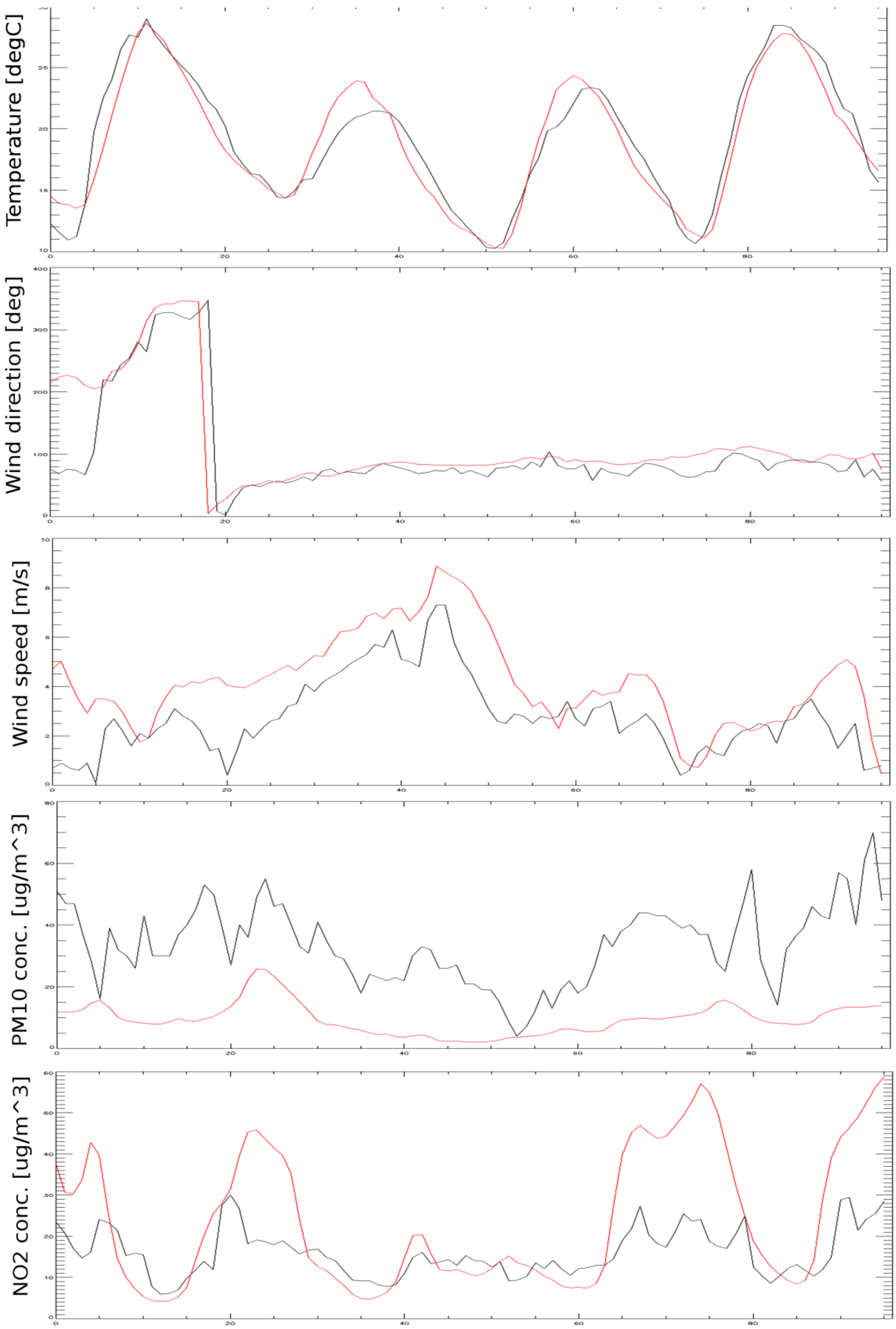


Figure 3. Time series (4 days) from Věřňovice station. Time units (on x-axis) are hours.

CONCLUSION

A good fit was obtained for O_3. Underestimation of PM_{10} was found and oppositely, overestimation of NO_2 and SO_2 was found. The high NO_2 and SO_2 concentrations are likely due to emissions being released at ground level in the model, as a significant proportion of the mass of these substances is released from elevated sources and is well mixed before reaching ground level. Also, the spatial resolution of the emission inventory should be improved and a future task is to utilise the national Czech emission inventory to derive anthropogenic emissions for the model. This should improve the temporal and spatial characteristics of the inventory and allow data from the actual simulation period to be used.

COMMENTS AND SUGGESTIONS ON THE DELTA TOOL

The DELTA tool was used under Linux (Ubuntu 10.04) and it was found that, overall, the software functioned as expected. This was very pleasant finding since the tool is yet to be tested under Linux. We found two areas for improvement of the tool which were:

1 Wind direction evaluation: A specific plot, perhaps a radial plot, to accommodate the circular nature of wind direction would be useful to visualise wind direction error or model agreement with wind direction observations.

2 Graphics produced by the tool: The graphics produced served well for on-screen assessment, but did not have optimum readability when exported for printed documents. One option to solve this might be to enable the tool to produce vector graphics.

ACKNOWLEDGEMENT

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