Verification of ALADIN/LACE pseudo-TEMPs for Ljubljana

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1. INTRODUCTION

The verification of pseudo-TEMPs by ALADIN/LACE prognostic model for temperature and dew point temperature in comparison to radiosonde measurements was studied for Ljubljana. In the period between 1 January 2000 and 31 August 2001 radiosonde measurements and pseudo-TEMPs were archived for most of the days. Only in temperature analysis certain days were subsequently excluded due to uncompleted measurements. In Slovenia, radiosonde measurement is carried out only in Ljubljana at 6 UTC. The release of radiosonde takes place at approximately 5 UTC, the duration of measurement is approximately one hour. Since ALADIN forecasts by 00 UTC run valid at 6 UTC are available only a few hours before 6 UTC, we decided to verify the forecasts by 12 UTC run, valid at 6 UTC following day.

2. VERIFICATION OF TEMPERATURE PROFILE

The comparison between the forecasted temperature and the radiosonde measurement of temperature for one selected day is shown in Figure 1. The forecasted profile is defined by the values of temperature for 31 layers and the temperature at 2 m above model surface. Such profile is much smoother than measured temperature profile.

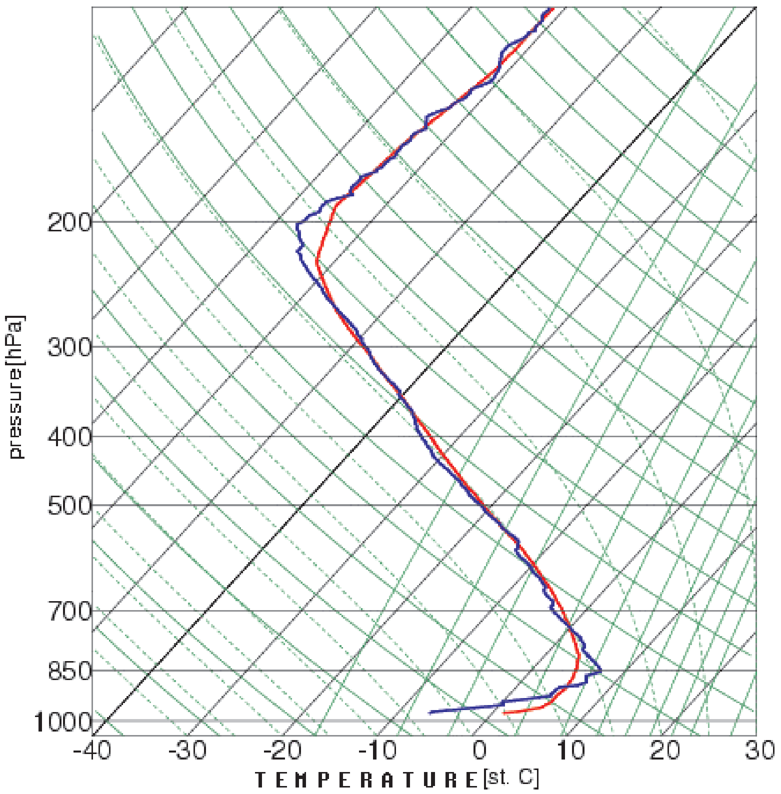

Figure 1: The emagram with ALADIN forecast (3 January 2000, 12 UTC +18 h) of temperature (red) and radiosonde measurements of temperature (blue) in Ljubljana, 4 January 2000 at 6 UTC.

The repetition time of radiosonde measurements is 10 s, which means that the measurements take place on more than 300 levels, which vary from one to the other measurement. The comparison of the forecasted and the measured temperatures was evaluated at the measured pressure levels. A linear interpolation was used to obtain forecasted temperatures at measured pressure levels (TAL12).

Figure 2 shows a scatter plot of the measured temperatures (T) and the forecasted temperatures (TAL12), for which linear interpolation to the levels of measurements was made. In the parts, where deviation from the odd quadrant line is sharper, the error is bigger. As evident in Figure 2, the deviation is the slightest in the middle interval for the temperature between 260 and 240 K.

The verification of temperature was made up to 100 hPa. Figure 3 demonstrates errors at standard pressure levels. The error is defined with median, lower quartile, upper quartile and extreme values of the T-TAL12 difference. The levels with narrower inter-quartile display better forecasts, which is between 850 hPa to 300 hPa. Differences were bigger around tropopause and also in lower layers, where the forecasted temperatures were usually overestimated.

Three mean vertical errors were calculated for every day: mean error (ME), mean absolute error (MAE), root mean square error (RMSE), which are shown in Figure 4. The poorest forecast of the temperature was at the beginning of February (Fig. 4 around day 350), which was a consequence of error more than 20 K in the part around 200 hPa.

Linear interpolation from the forecasted levels to measured levels was made, but to be sure that this interpolation was good enough, some additional interpolations were tested, i.e. spline interpolation with polynomial of third degree and Hermite splines; furthermore a very simple method, which does not involve interpolation but takes the nearest value, was employed. The method of interpolation did not have significant influence on mean errors.

Mean errors in temperature up to 100 hPa and up to 850 hPa, when method of linear interpolation was used, are shown in Table 1. Forecasts of temperature in lower atmosphere (up to 850 hPa) were poorer than forecasts of temperature up to 100 hPa. The mean error up to 100 hPa was negative, which means that forecasts were too warm on average. That was even more obvious when evaluating the lower part up to 850 hPa. On average, the errors were bigger in the lower part (up to 850 hPa) in comparison to errors in the part up to 100 hPa. That can be seen when comparing RMSE and RMSE 850 in Table 1.

days	number	ME	MAE	RMSE	ME850	MAE850	RMSE850
all	463	-0,19	1,10	1,46	-1,30	1,59	1,93
strong inversion	26	-0,22	1,17	1,64	-1,53	1,94	2,37

Table 1: Comparison of average errors in forecasted temperatures up to 100 hPa (ME, MAE, RMSE) and up to 850 hPa (ME 850, MAE, 850, RMSE 850) in Kelvin.

Daily errors (Figure 4) demonstrate that in certain periods the errors were more dispersed than in the others. Our forecasters stressed that the forecast of temperatures at the ground is usually wrong if temperature inversion is present. That is the reason why the cases with inversion were separated and errors calculated. All days, when the measured temperature increase between two measured levels exceeded 2 K, were separated. The criteria was limited to only up to 400 hPa, so that temperature inversion on tropopause was excluded. The number of days, which satisfied this demand, was 26. The forecasts with the specified temperature inversion were poorer than others. This is evident in Table 1 and it was true in the lower part of the atmosphere or when the temperatures up to 100 hPa were treated. It can be seen that average forecasts of temperature profiles in the cases of specified inversion were poorer than in all other cases.

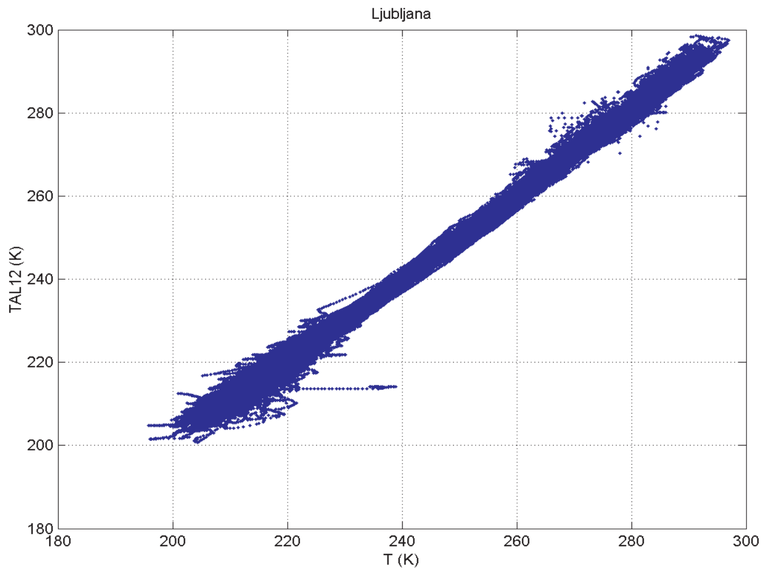

Figure 2: Scatter plot of the measured temperatures (T) and the forecasted temperatures (TAL12), for which linear interpolation was made to the levels of measurements between 1 January 2000 and 31 August 2001.

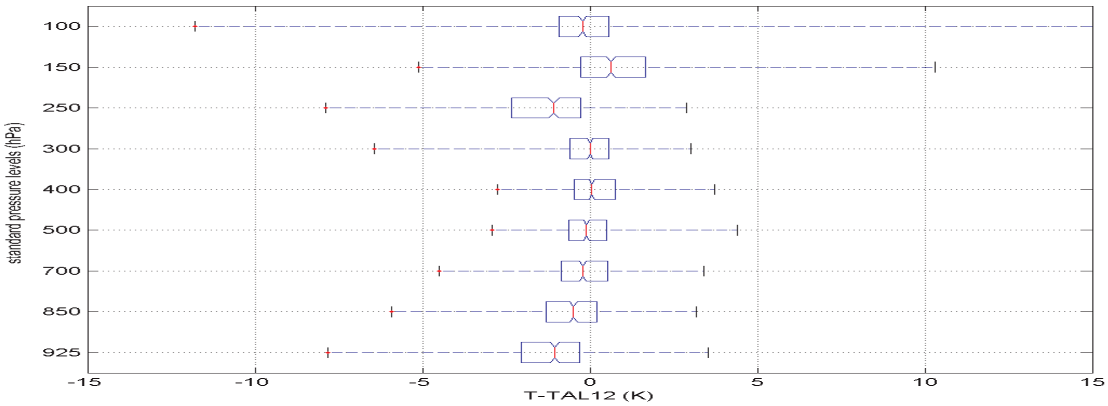

Figure 3: Distribution of temperature difference between measured (T) and forecasted (TAL12) at standard pressure levels. Red vertical lines mark median, blue vertical lines mark lower quartile (left) and upper quartile (right). Minimum and maximum errors are also indicated. Period as in Figure 2.

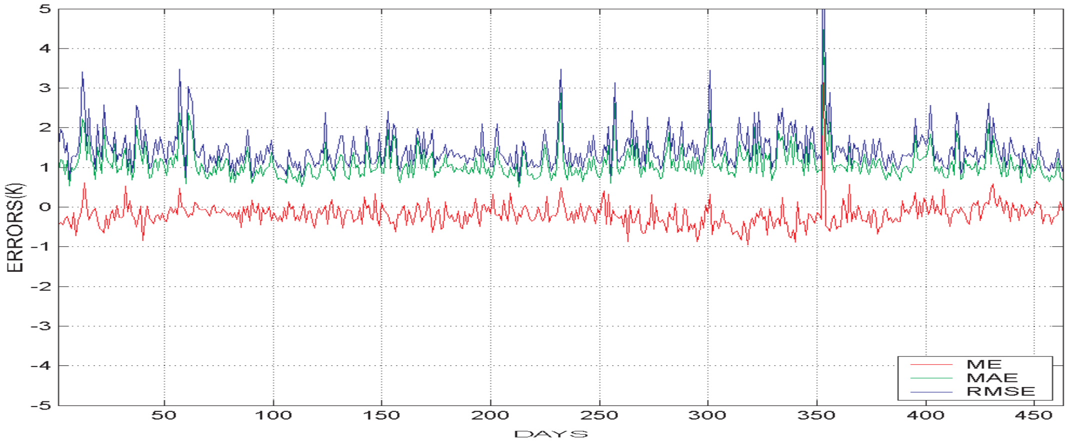

Figure 4: Errors in forecasted temperatures for 463 days between 1 January 2000 and 31 August 2001. ME in blue, MAE in green and RMSE in red.

3. VERIFICATION OF DEW POINT TEMPERATURE PROFILE

Comparisons for dew point temperature profiles were made using the same methods of evaluation. In the atmosphere, a thin dry or very moist layer of air can be present in comparison to the surroundings, which can be seen on the measured profiles, but cannot be predicted by the model limited by its resolution. So the forecasted dew point temperature profiles were expected to be poorer than the forecasted temperature profiles.

This evaluation took into account only the measurements and the forecasts for dew point up to 400 hPa. The reason for this is that the measurements, which are higher in the atmosphere, are not very reliable with sensor Vaisala RS 80.

Figure 5 demonstrates the scatter plot of measured (Td) and forecasted (Td AL12) dew point temperatures. The width of scatter is particularly large for lower temperatures. Figure 6 demonstrates errors at standard pressure levels. The distributions of errors at each standard pressure level are presented with median, lower quartile, upper quartile and extreme values. Forecasts at 925 hPa were generally better than forecasts at 500 hPa. Figure 7 demonstrates three errors for each day. The comparison between dew point temperature errors (Figure 7) and temperature errors (Figure 4) shows that dew point errors occur in larger intervals. Figure 8 presents mean errors for a chosen period up to two different pressure levels. MAE and RMSE for dew point temperature were much bigger for values up to 400 hPa than in the lower part (up to 850 hPa). ME was slighter when considering the atmosphere up to 400 hPa than when considering only the lower part up to 850 hPa. The reason for this was the fact that between 850 hPa and 400 hPa, ME was negative. There was a difference of more than 1 K between RMSE and MAE when considering the atmosphere up to 400 hPa (Figure 8), which means that some errors were very big. The same is evident in Figure 6 with some cases even exceeding -20 K at levels 700 and 500 hPa.

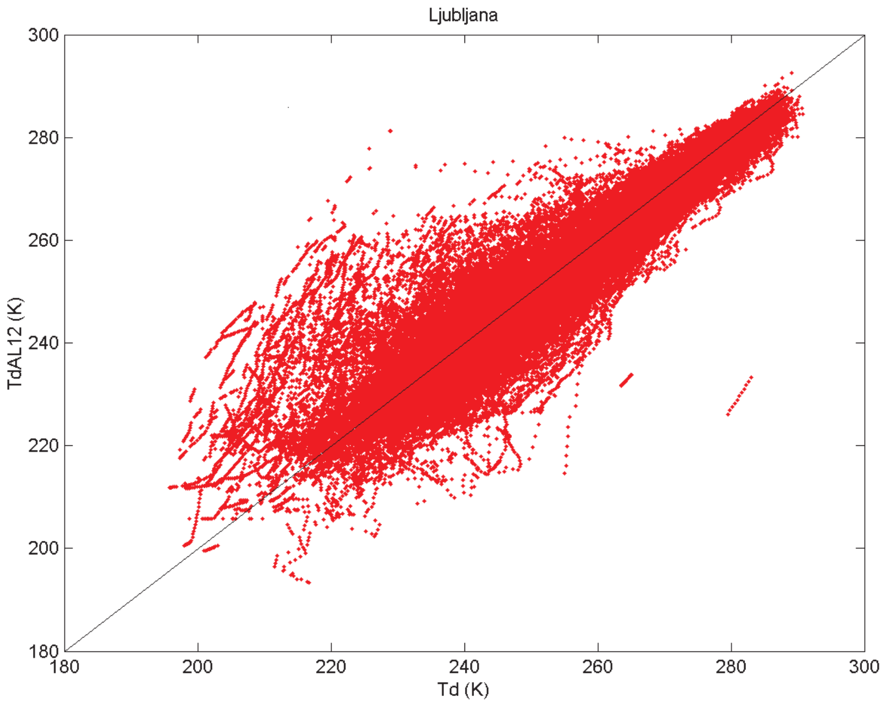

Figure 5: Scatter plot of measured dew point temperatures (Td) and forecasted temperatures (Td AL12), for which linear interpolation to the levels of measurements was made for days between 1 January 2000 and 31 August 2001.

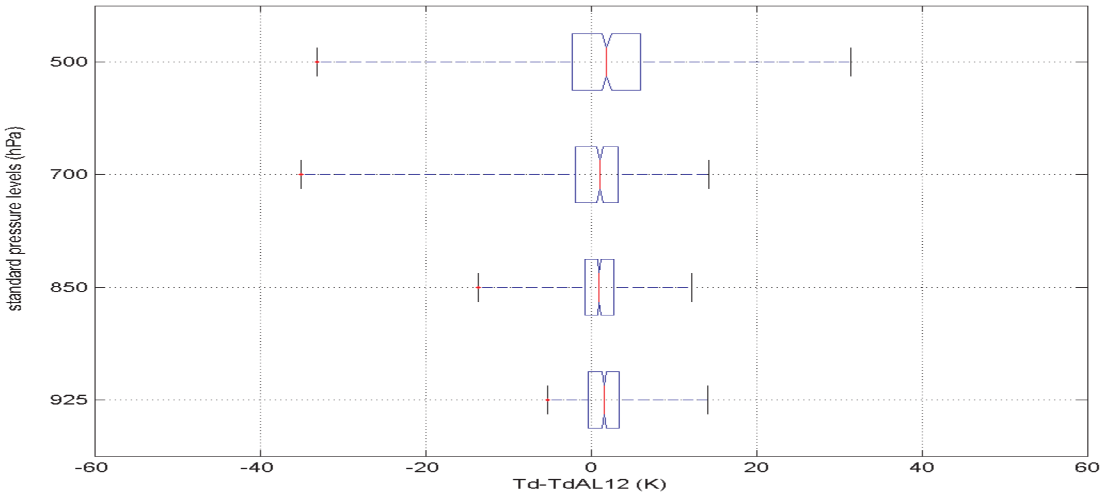

Figure 6: Distribution of dew point temperature error (Td- Td AL12) at standard pressure levels. Red vertical lines mark median, blue vertical lines mark lower quartile (left) and upper quartile (right). Minimum and maximum errors are also indicated.

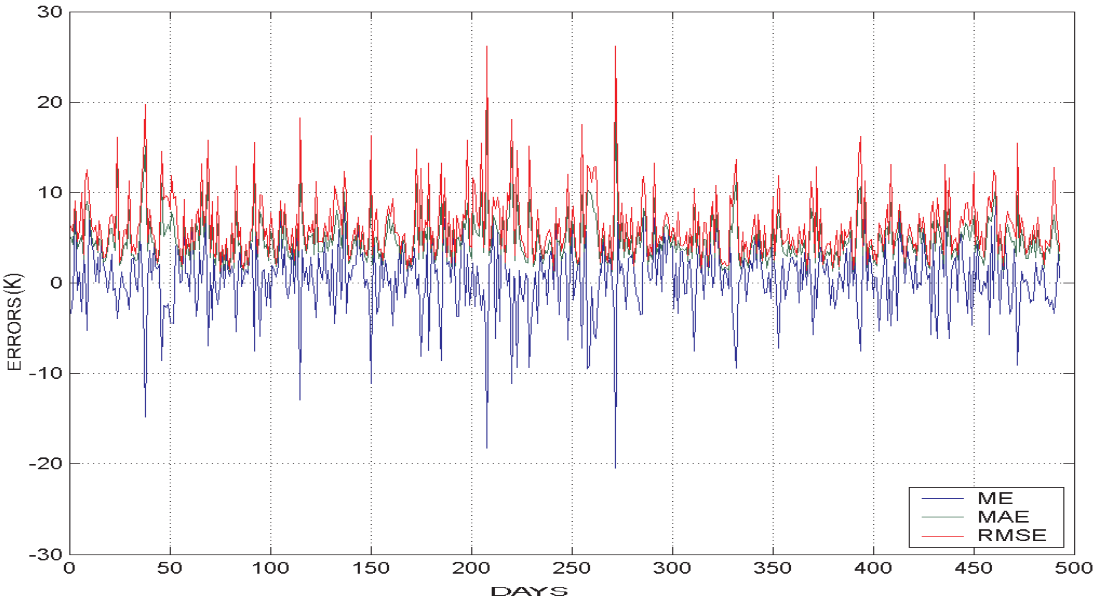

Figure 7: Errors in forecasted dew point temperatures for 493 days between 1 January 2000 and 31 August 2001 up to 400 hPa. ME in blue, MAE in green and RMSE in red.

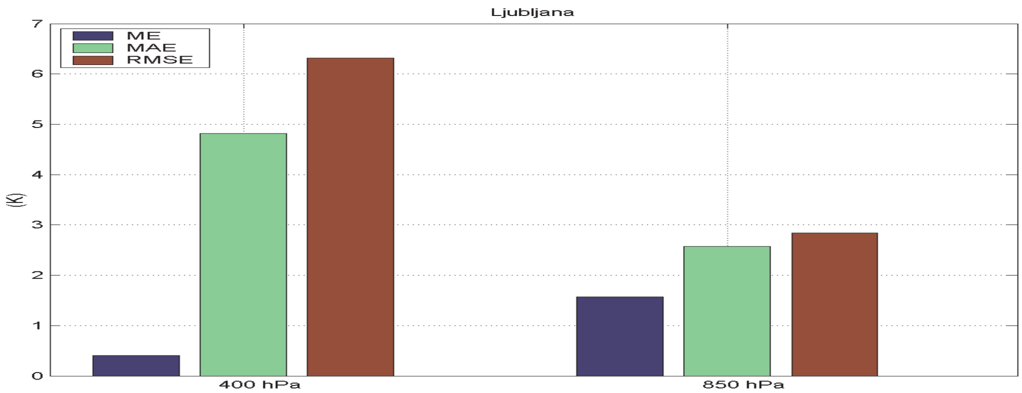

Figure 8: Errors in dew point temperatures up to 400 hPa and up to 850 hPa for the period as in Figure 7.

4. CONCLUSION

This article presents the objective verification of temperature and dew point temperature profiles by ALADIN/LACE forecasts for Ljubljana. Vertical profiles in the period between January 2000 and August 2001 at 6 UTC were compared with forecasts by run 12 UTC previous day, valid for 6 UTC next day. The forecasted temperatures from the ground up to 100 hPa and the forecasted dew point temperatures from the ground up to 400 hPa were linearly interpolated to measured pressure levels and compared with the radiosonde measurements.

The biggest errors in temperature forecasts occurred in the lower part up to 850 hPa and in the upper part above 300 hPa. The reason for this included a rapidly changing gradient in the lower atmosphere in comparison to that in the middle atmosphere (between 850 hPa and 300 hPa) and variation in tropopause height. The forecasted temperature profiles were slightly warmer on average, which was demonstrated by negative ME. The biggest part of errors was a consequence of poor forecasts in the cases of inversion in the lower part of the atmosphere.

The forecasted profiles of dew point temperature were on average colder, since ME was positive. Consequently, the atmosphere up to the 400 hPa would be, according to forecast, on average too dry for the chosen period. In the lower part of the atmosphere (up to 850 hPa), the forecasts of dew point temperatures were more accurately predicted (smaller MAE and RMSE) than in the part above it. This was due to expressive gradients of dew point temperature in the part higher than 850 hPa, which were changing from negative to positive and vice versa.

This study did not take into account that the duration of radiosonde measurements is approx. 1 hour, we treated it as if it were carried out at 6 UTC. Furthermore, it was taken into account that radiosonde measurements were advected by horizontal wind, and the horizontal shift can be bigger than model horizontal resolution. In that case, we should take into consideration the lower forecast of one model point and the forecast of the upper part of the model point beside it. Consequently, not only one column in the forecast model would have impact on verification results of the upper troposphere.

The forecasts of dew point temperatures were much poorer than the forecasts of temperatures, which was expected since moisture field is in general more variable as temperature field.

This study is important for our future work. The known correctness is particularly important when using forecasted profiles as a first guess in reconstructing measured vertical profiles of temperature and dew point temperature by polar - orbital satellites. In this study it was shown that the days when temperature inversion is present should be treated with more carefulness, especially in the lower part of the atmosphere and at the ground. On the other hand the forecasts of dew point temperature above 850 hPa are very insecure. When calculating the height of cloud tops based on satellite measurements, the conversion from temperatures to pressure levels is the most reliable for middle clouds.