**VERIFYING MODELED PRECIPITATION
IN MOUNTANIOUS REGION FOR HEAVY PRECIPITATION CASES**

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1. INTRODUCTION

A prognostic model produces precipitation as an average over a model grid cell. Both explicit large scale precipitation and parameterized sub grid convection deal with a grid cell as a whole and it is not possible to asses -within the model framework- a sub grid cell variation. Model precipitation are represented in a form of two-dimensional field with a finite resolution, pixel has the dimensions of a grid cell. The precipitation in a model cell is representing a whole area of the cell and not just its center.
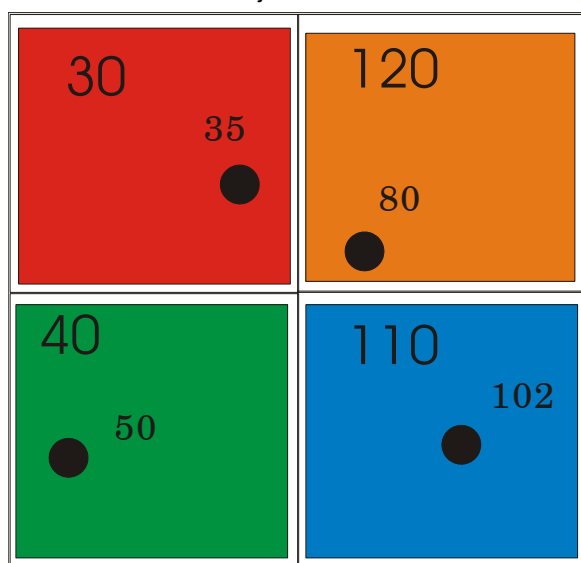

Figure 1. Model grid cells with precipitation values and precipitation at stations in case of great precipitation gradient.

When calculating the precipitation amount in a selected point – for instance a meteorological station- (a zero dimensional entity) from model precipitation (a two dimensional entity) it is often erroneously assumed that model precipitation is representing precipitation in the center of model cell. So the distances between the centers of cells and selected points are used in the interpolation procedure. When comparing such interpolated model values with measured ones the model results are disqualified "ab initio" as model is not forecasting point values but spatial means over a whole cell.

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2. VERIFYING THE MODEL PRECIPITATION WITH SURFACE DATA

To get an honest verification of model precipitation it is necessary to establish a common level where neither model precipitation (mean area values for regularly spaced grid cells) neither surface measurements (point values, irregular and often spatially inhomogeneous, different sampling interval) are initially disqualified. Taking into account the spatial density of surface networks 24-hour accumulation is the best choice also regarding the spatial homogeneity and the data quality.
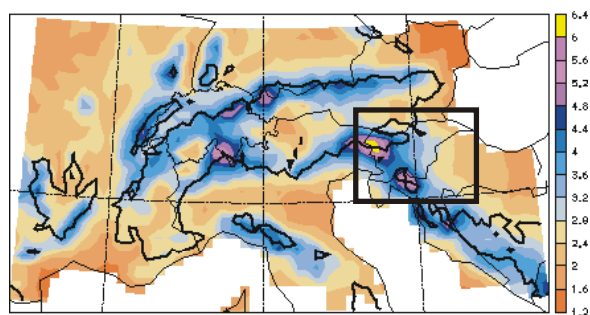

Figure 2. The area of analysis and verification in the Alps (square). Background map: precipitation climatology of the Alps (Frei and Schaer 1998)
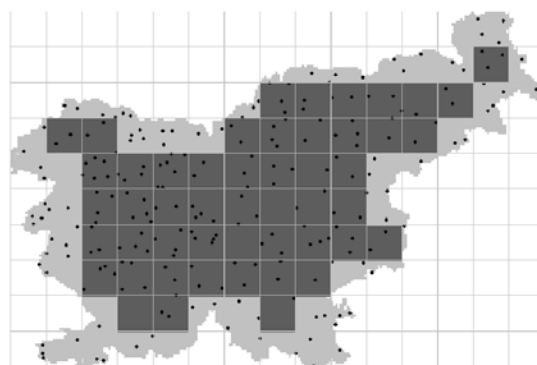

Figure 3. The grid cells (16 km squares) that are completely within the area of analysis. Dots denote the location of rain gauges. (50 cells, covering area of 12 800 km^2),

As the model results are area values and surface data are point values it is sensible to use point data to produce spatial averages of daily precipitation in manner that climatologists (Tveito and Schoener

2002) do it for long period means. Thus the process of verifying the model results reduces to the problem of comparing two sets of precipitation maps: one produced from a model, the other produced by spatial interpolation of point values from rain gauges. Of course the geometrical structure of both rasterized maps should be the same and a logical choice is producing a measured precipitation map in a grid that corresponds to the model grid. Various interpolation techniques can be used and various GIS software can be utilized.

2.1 *Heavy precipitation cases*

In cases of weak and homogenous precipitation the problems of spatial interpolation of precipitation are not great and various spatial interpolation methods produce useful maps of measured precipitation. With a heavy precipitation cases the problems of the interpolation techniques are increased, especially if the precipitation fields are spatially inhomogeneous (Vrhovec et al. 2001, Kastelec and Vrhovec 2000). The heavy precipitation cases are expected to be not only the most difficult to verify but they are also of the highest importance in short range hydrological forecasting and they add a considerable fraction to monthly, seasonal and yearly totals.

To test several methods for preparing the 24 hours surface precipitation maps five days with precipitation exceeding 200 mm were chosen out of ARSO archives (Archives of Met. Service of Slovenia). The spatial structure of precipitation field of these selected cases is very diverse. Three chosen cases are barotropic cyclonic days with precipitation mostly controlled by topography. The other two cases are baroclinic days with extensive convection activity.

2.2 *Surface data interpolations*

For all selected days we made several sets of interpolations:
   a. We used several different interpolation schemes: **mathematical interpolations** with inverse squared distances, varying the number of data points used for interpolation (1, 2, 5, 10, 20, 100, 200 nearest stations) and **statistical interpolations** (ordinary kriging and universal kriging) varying the area of influence 10 and 20 km. Universal kriging was done with two different supporting fields: climatologically mean precipitation and topography.
   b. We varied the spatial resolution (cell size) of afore mentioned **direct interpolations**, starting from 1 to 2, 4, 8 and 16 km (square grid cells).
   c. We computed **aggregated interpolations** (calculated a mean for a grid cell) for combinations:
   in 2 km out of 1 km;
   in 4 km out of 2 km and 1 km;

in 8 km out of 1 km, 2 km and 4 km;
in 16 km out of 1 km, 2 km, 4 km and 8 km. Altogether there were 120 mathematical and 50 statistical interpolations calculated for the selected day and these maps were compared to 5 model precipitation interpolations
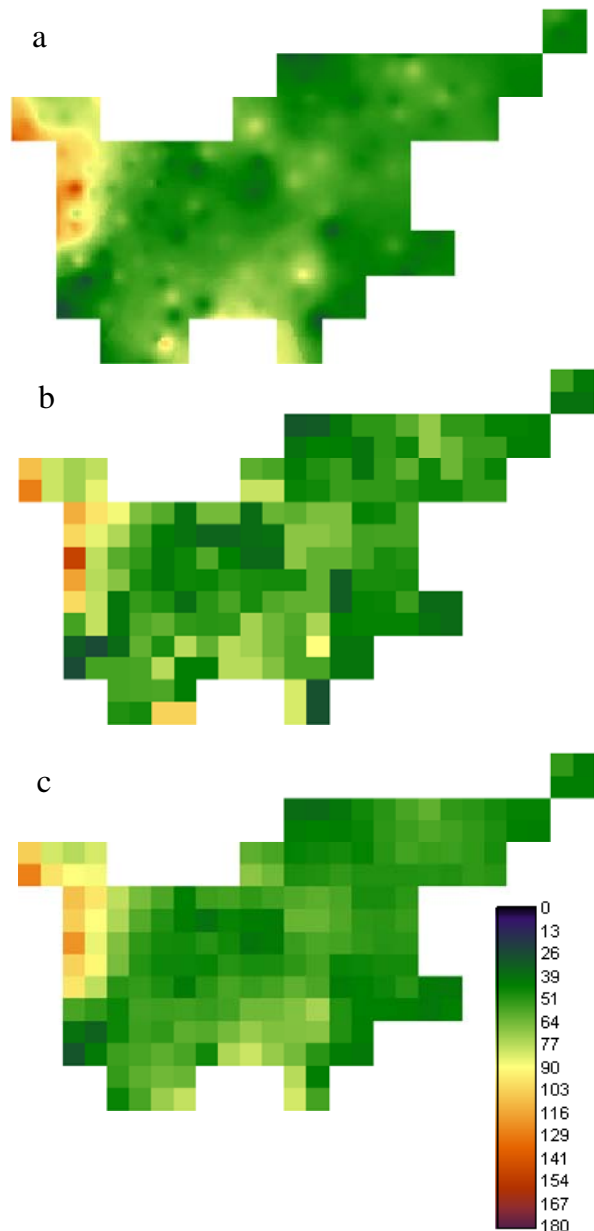

Figure 4.Results of different spatial interpolations: direct mathematical interpolations using IWD with different number of observed data point used. (a) 1km grid, 10 points; (b) into 8 km grid from 1 point; (c) into 8 km grid from 10 points. (Nov. 6. 1998)

Mathematical IWD interpolations gave precipitation field with a lot of small-scale details that are hard to justify (circles around the data points) Fig 4 a., as precipitation is normally spatially more homogenous.
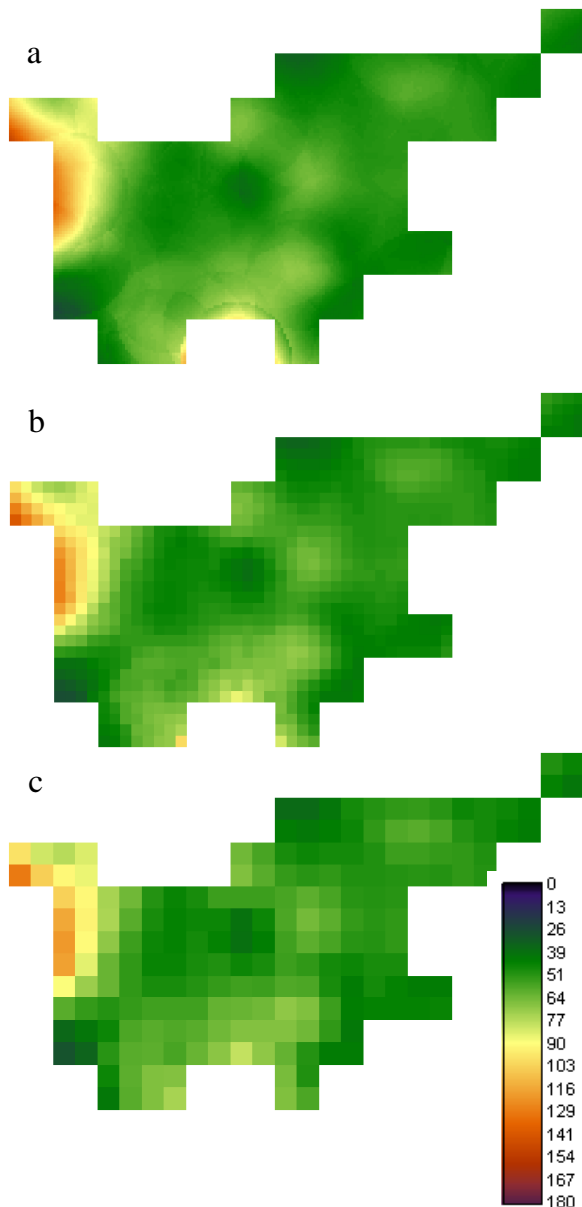
a

b

c

Figure 5. Results of statistical interpolations using ordinary kriging. a) into 1 km grid, b) 4 km grid, c) 8 km grid (gaussian variogram, the area of influence is 20 km) (Nov. 6. 1998)

Interpolations with ordinary kriging gave smoother precipitation fields and the results are less sensitive to the grid cell size. When aggregating precipitation from small grid cells to large ones the precipitation fields created with statistical interpolations were more conservative – directly interpolated and aggregated maps into same grid cell size – has smaller differences as when using IWD methods.

Ordinary kriging was used to spatially interpolate point precipitation data into regular grids with 1, 2, 4, 8, and
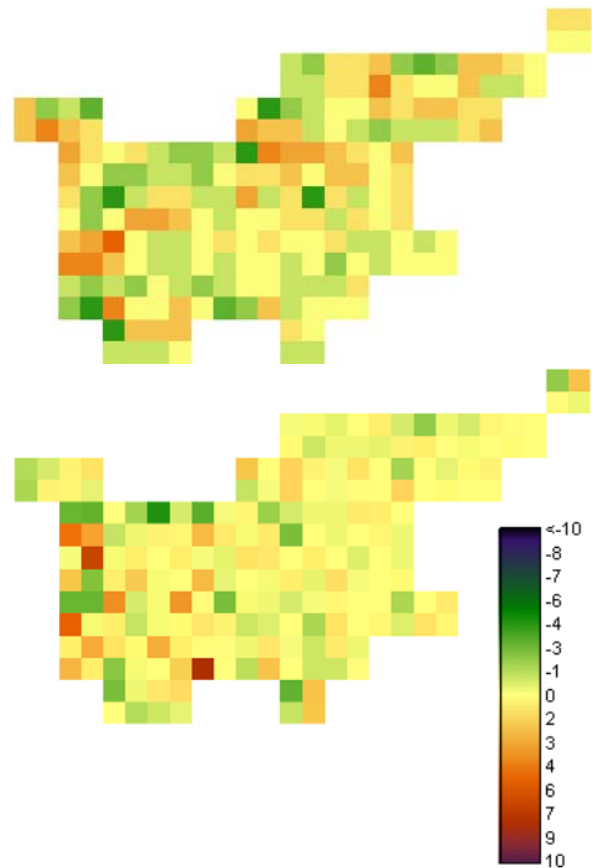
Figure 6. The differences between directly interpolated and aggregated precipitation 8 km maps for (Nov. 6. 1998). Upper panel: IWD; lower panel kriging.

16 km grid cell size. Variogram is calculated over whole domain. The area of influence was limited to 20 km initially. Mean over whole domain is conserved for all the cases and is consistent with the mean derived out of mathematical interpolation.

We were using universal kriging with 30- years precipitation mean and separately with the topography heights averaged over grid cell size.

2.3 *Interpolation of model precipitation*

For the selected day (Nov. 6. 1998 – cyclonic barotropic day) forecasted and observed precipitation is compared. The forecasted precipitation (24 j accumulation) was created with ALADIN (Bubnova et al. 1995) mesoscale limited area model using ERA-40 reanalysis as boundary and initial conditions. The model resolution was about 11 km. The simulated precipitation was interpolated in 1 km grid using the method of the nearest neighbor: each 1 km grid cell got the precipitation value of the nearest model's grid point. Precipitation maps with coarser grid (2 km, 4 km, 8 km, 16 km) were calculated with aggregation from 1 km grid.
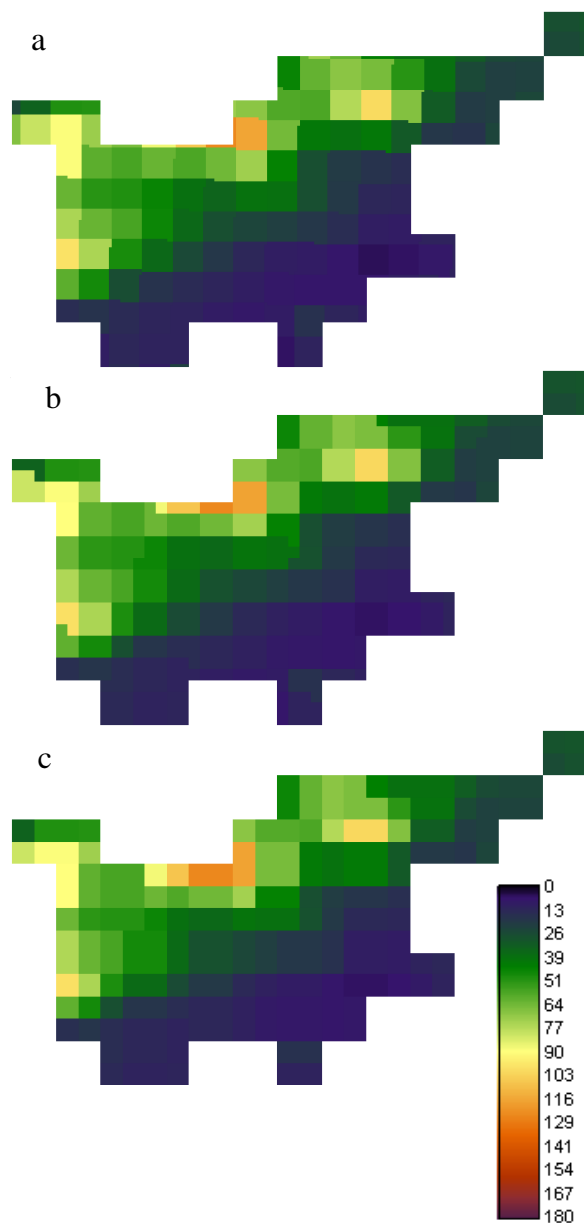
Figure 7. Model precipitation data interpolated into a) 1 km grid b) 4 km grid c) 8 km grid with the method of the nearest neighbor. (Accumulation period Nov. 5. 1998 06.00 UTC - Nov. 6. 1998 06.00 UTC)

3. RESULTS

3.1 *Mathematical interpolations of measured data*

For all the direct and aggregated interpolations the mean over whole domain is between 56.88 to 57.73 mm. The interpolation procedure is not changing the total mean (total precipitation is conserved. The total mean increases just slightly with increase of the number of stations included into mathematical interpolation.

For the **direct interpolations** there are great differences in minimum and maximum values of 24-

hours gauge precipitation interpolated into different grids: with the increase of the points (stations) included maxima decrease. For 1 km cell maximum changes from 172 mm for 1 point to 145 mm for 200 included points. Minima increase inversely but less: from 24.9 to 26.3 mm. Similar behavior is observed for all different cell sizes.

Change of cell size has a significant effect upon both maxima and minima: with the change of cell size from 2 km to 16 km, the maxima decrease from 172 to 102 mm (by 40 %) and minima increase from 24.9 to 30.25 mm (by 15 %) The highest maximum is obtained by few points' interpolation and smallest grid cell size (172.6 mm) and the lowest by 200 points and 16 km cell size (95.46 mm). The effect of changing the number of points included in interpolation is by order of magnitude smaller than the effect of cell size.
The change of variability is illustrated also by the changes of standard deviation of the whole map: it decreases with increase of number of points into interpolation and it decreases with increasing grid cell size.

With the **aggregated interpolations** the mean of precipitation is conserved, the maximum and the variability of precipitation field decrease significantly and the minimum increases. Aggregated maps with the same resolution (e.g. 16 km) generated from starting maps with different resolution (1, 2, 4 km) show little difference in mean, maximum, minimum and standard deviation. Aggregated interpolations give slightly lower maxima and higher minima comparing to direct interpolations (up to 5%), standard deviation is decreased. The influence of the number of points included in interpolation is evident: more points included, smaller maxima and higher minima (up to 10%). If we subtract the two maps with the same cell size the differences between the maps are significant.

3.2 *Statistical interpolations of measured data*

Ordinary and universal kriging were used to spatially interpolate point precipitation data into regular grids with 1, 2, 4, 8, and 16 km grid cell size. Variograms were calculated over the whole domain. The area of influence was 20 km and 10 km. Maps calculated with **ordinary kriging** with the 20 km area of influence show that mean over whole domain are conserved for all the cases.

The maximum and variability increases with the decreasing of cell size. The results of interpolations with variogram derived over whole domain corresponds to the results with mathematical interpolation with a large number of data points used.

Changing the area of influence to just 10 km (being almost at the limit of ordinary kriging validity) the mean is still conserved regardless of grid cell size but the maximum is increased when using small grid sizes. With greater grid size nothing changes.

Aggregating kriging fields into coarser grid it does not change the values of maxima and variability more then 0.1 mm, the procedure is completely linear.

Universal kriging was made with 30- years precipitation mean and separately with the topography heights averaged over grid cell size as an auxiliary variable. With climatological precipitation (Kastelec, 1999) we get a significant increase of the maximum with the smallest grid cells, (from 158 mm to 204 mm) and a slight increase in variability compared to ordinary kriging, while mean is conserved. Again the increase of grid cell size decreases maximum and variability. It is important to stress that the spatial structure of selected daily precipitation is not very similar to the climatological one.

With topography heights as auxiliary variable (e.g. Daly et al 1994) we get with small grid cell size completely different results: the maximum increases for more the 100% compared to the ordinary kriging. This is due to the fact that in 1 km grid the relief has very high peak values and the deterministic part of universal kriging then assumes, that precipitation should be very high if the topography is high. The approach with topography is useful with the climatological data, where the extremes average out but in the case of daily precipitation it gives bad results.

3.3 *Interpolation of model data*

Precipitation map calculated from model data into 1 km grid with the method of the nearest neighbor is rather different from maps interpolated from measured data (Fig. 7). Maximum of that model precipitation field is 124.3 mm, mean 36.9 mm and standard deviation 25.6 mm. Aggregating that field into coarser grids decreases maximum (89.6 mm for 16 km grid) and standard deviation (23.4 mm for 16 km grid) but conserves mean.

4. CONCLUSION

Precipitation maps calculated with various direct mathematical interpolations have the same mean but their variability changes: smaller grid cell, higher variability, and higher maxima. With increase of the number of closest data points used in interpolation the variability decreases. The aggregated fields are not dependant on aggregation method used. The process of interpolation is so linear that just about 1 - 5 % of changes can be attributed to the different methods of averaging. This is especially true (very small changes) for the interpolations with a large number of data

points used, while for the interpolation with few data points (local interpolations) the differences are bigger.

Out of kriging procedures one would suggest that the most useful statistical interpolation method is ordinary kriging. It is the least sensitive to the aggregation method and it derives the interpolation function by evaluating a variogram, specific to the data interpolated. Further it has more conservative spatial structure but is less applicable to highly variable fields.

Figure 8. Differences in 24 hours precipitation accumulation between the forecasted and meassured (interpolated with ordinary kriging) in 8 km grid (Accumulation period Nov. 5. 1998 06.00 UTC - Nov. 6. 1998 06.00 UTC).

The comparison of various maps interpolated from measured precipitation with maps interpolated from model output shows disagreement between the model and measurements for the selected day. Figure 8. presents the map of differences between the forecasted and interpolated (with ordinayi kriging) precipitation maps. Based on our research we can conclude that in this case the disagreement is more due to problems with the model than due to interpolation scheme used to calculate measured and simulated precipitation fields. Our approach in comparing forecasested and observed precipitation can give an objective and spatially referenced value of the model precipitation quality.

5. REFERENCES

Bubnova et al. 1995, Integration of the fully elastic equations cast into the hydrostatic pressure terrain following coordinate in the framework of the ARPEGE/ALAdin NWP System. – *Monthly Wea. Rev.* **123**, 515-535.

Daly, C., R. P. Neilson, and D. L. Phillips, 1994: A Statistical-Topographic Model for Mapping Climatological Precipitation over Mountainous Terrain, J. Appl. Meteor., 33, 140-158.

Kastelec, D. 1999: Geostatistical approach for spatial interpolation of climatological variables. Fourth Meeting of Austrian, Slovenian, Italian and Hungarian Young Statisticians, 8. - 10. October 1999, Pecs, Hungary, 25 pp.

Tveito, O.E., Schoener 2002: Applications of spatial interpolation of climatological and meteorological elements by the use of geographical information systems (GIS). *met.no* REPORT 28/2 ISSN 0805-9918

Vrhovec, T., Gregorič, G., Rakovec, J. and Žagar, M. 2001: Observed versus forecasted precipitation in the South-east Alps. *Meteorol. Z.*, 10, 17-27