On the estimation of monthly precipitation fields in Afghanistan

Jürgen Grieser, René Gommes, Stephen Cofield
The Agromet Group, SDRN
Food and Agriculture Organization of the UN (FAO),
Viale delle Terme di Caracalla, I- 00100 Rome, Italy

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Introduction

Among a variety of agrometeorological information Afghanistan's monthly agrometeorological Bulletin provides maps of the rainfall distribution of the previous month.

Here we shortly investigate how these maps may be improved by also using data from neighbouring countries and by the application of vertical gradients. Aside long term averages, precipitation of April 2006 is analyzed as a case study.

Data Availability

For the preparation of monthly precipitation maps for Afghanistan 40 Afghan precipitation stations are available. They are depicted in Fig.1a as black dots. If only these stations are being used for the interpolation of precipitation the resulting precipitation field is a true interpolation of surrounding stations for the green area of Fig.1a and an extrapolation in the red marked areas.

If the data from China and Pakistan are taken into account as well a great deal of the red area changes to green, i.e. the region for which precipitation has to be extrapolated shrinks considerably (Fig. 1b). Data from Pakistan are available via internet and can be used for regular interpolations. Data from China are only available for the experiment performed here.

No data were available for the other 4 neighbouring countries: Islamic Republic of Iran , Tajikistan, Turkmenistan, and Uzbekistan.

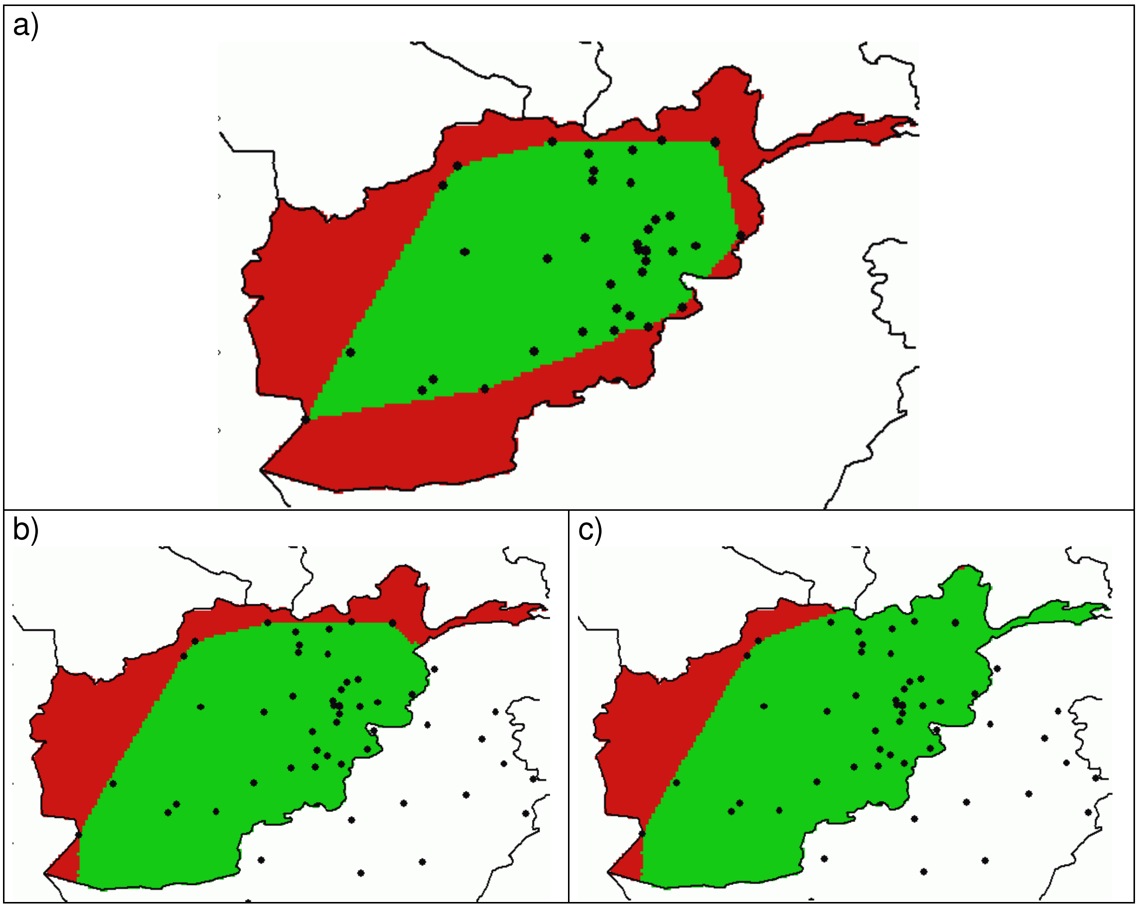


Fig 1: Gridpoints with neighbouring stations only on one halfsphere are marked in red. Green locations are surrounded by stations; a) Only Afghan stations, b) Afghan and Pakistan stations, and c) Afghan, Pakistan and Chinese stations. The use of stations from China and Pakistan adds information to the southern and eastern regions of Afghanistan.

Precipitation in Afghanistan

Precipitation in Afghanistan has a very pronounced annual cycle with a dry period in summer, generally from June to September, except for the western region where dry season starts earlier (May) and lasts longer (till October).

Annual precipitation sums are ranging from 50mm in the southwest to 700mm in the region of Salang and about 300mm in the capital Kabul. The area average annual precipitation is less than 300mm. In the far east of the country the annual precipitation sum is decreasing again to about 100mm.

Regarding the long term annual precipitation field of Afghanistan and the surrounding countries as shown in Fig. 2a it becomes obvious that the topography (Fig. 2b) has a marked influence on the precipitation pattern.

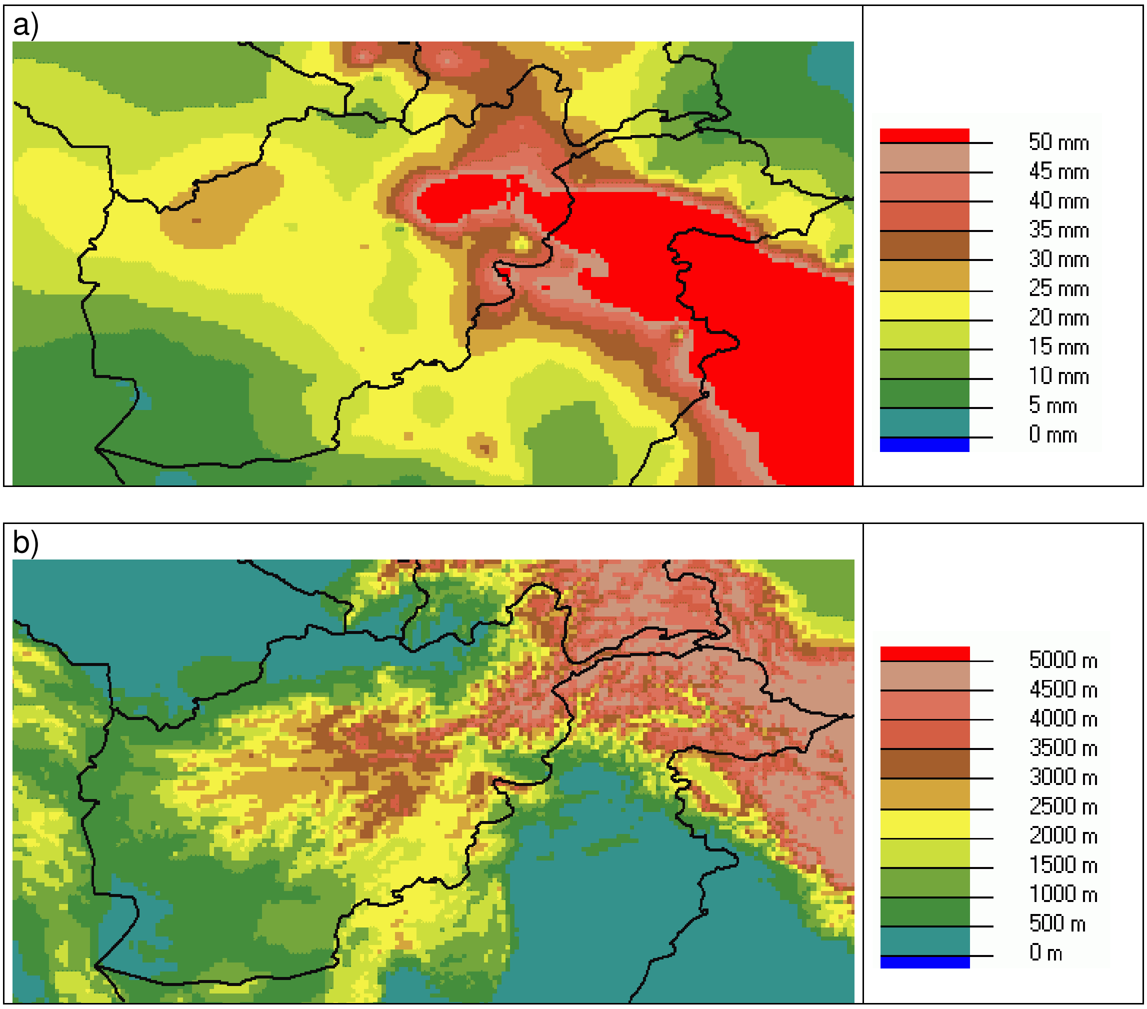


Fig. 2: a) Annual mean precipitation in mm/month and b) topographic map.

The influence of the interpolation method

For April, one of the "rainy" months, we study the influence of the interpolation method on the basis of the use of stations within and surrounding Afghanistan. Fig. 3a-c show the results of Kriging Interpolation, Inverse Distance Weighted Averaging Interpolation (IDWA) and IDWA plus Shadow Correction. We see that Kriging is smoothing too strongly. This can be seen clearly by the station observations which are marked by circles of the respective color. For some stations the interpolated precipitation does not fit to the observations. Fig. 3b demonstrates that IDWA is an exact method in the sense that at a station's location the interpolated value is exactly the same as the observation. However, in the case of strong gradients (as they occur in the very north of Pakistan and East of Afghanistan) IDWA may lead to island-like pattern. Another feature typical for exact interpolation methods are wave-like isoline patterns clearly visible in western Afghanistan. An easy way to deal with these effects is the so-called shadow correction which gives more influence to the closest stations and weakens the influence of stations behind (= in the shadow of) the closest stations. This allows to much better reproduce steep gradients as in the North of Pakistan. Observations of single stations which where smoothed out by Kriging and which appear only as small islands under IDWA become clearly visible as regionally representative if shadow correction is applied (see Fig. 3c).

Finally Fig. 3d shows the effect of neglecting the stations which are not within Afghanistan. If only the 35 Afghan stations are used the long term average precipitation in the East of the country gets heavily biased.

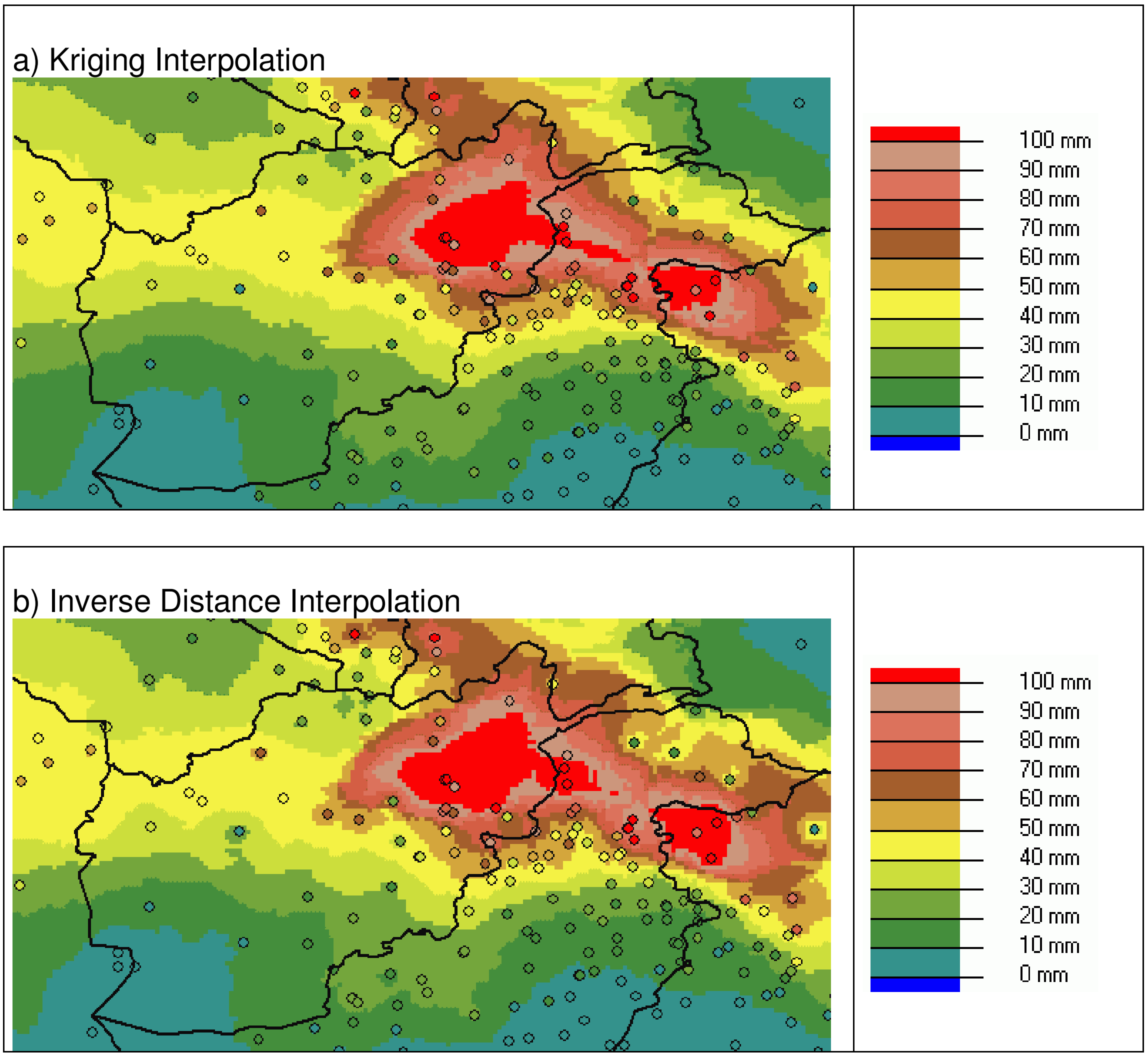
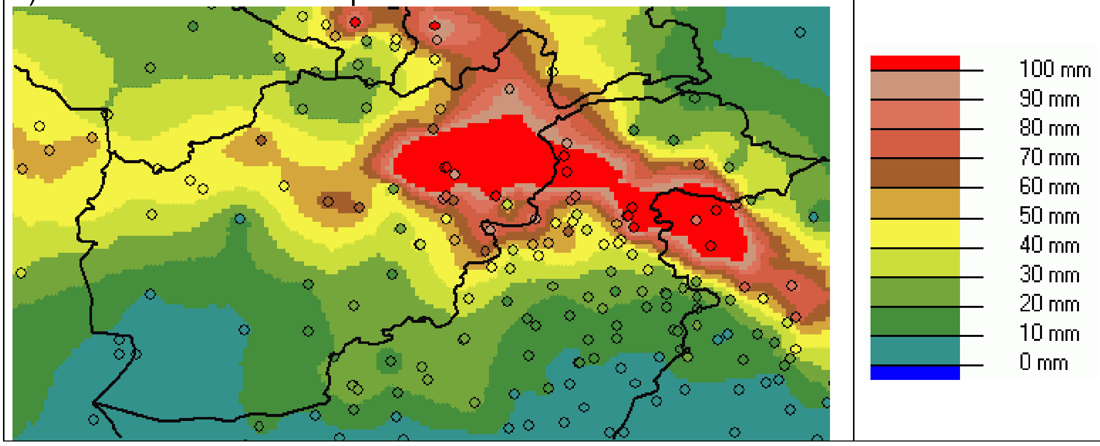


Fig. 3: Interpolated precipitation pattern as obtained by different methods; a) Kriging, b) Inverse Distance Weighted Averaging (IDWA), c) IDWA + shadow correction and d) as c) but only stations within Afghanistan.

c) Inverse Distance Interpolation with Shadow Correction



d) Inverse Distance Interpolation with Shadow Correction and only Afghan data

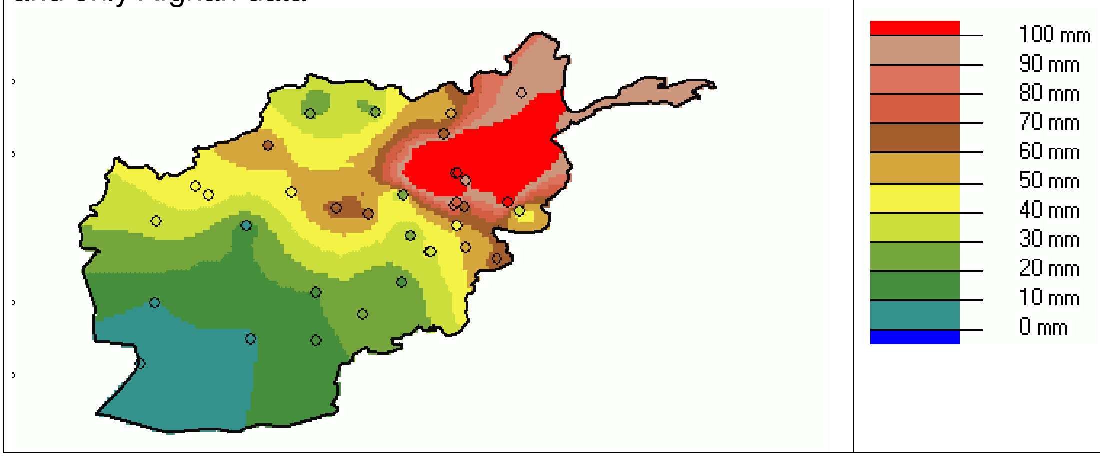


Fig. 3: continued.

Average Vertical Gradients

In order to get an impression of the strength of vertical precipitation gradients the nearest 40 stations to each grid point are used for a linear observation-altitude regression. The results for long-term averages are depicted in Fig.4. The vertical gradient of precipitation is always positive with small values (less than 1mm/100m) in the western part of the country and higher values of about 2 to 3 mm/100m in the central part. The average vertical gradient is 1.8mm/100m. It explains about 20% of the total variance of the spatial precipitation pattern.

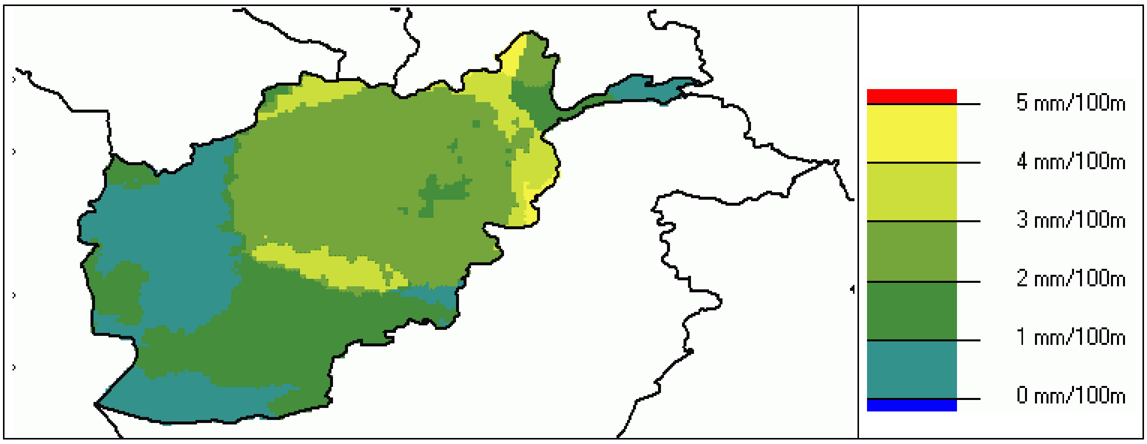


Fig. 4) Vertical gradients of April precipitation in Afghanistan.

Fig. 5 shows the mean April precipitation pattern if these vertical gradients are applied. A truncated regression is used. This means that the altitude regression is only used between the lowest and highest neighbouring stations. The gradient is not extrapolated above the highest and below the lowest neighbouring station. Some of the rain observed in central Afghanistan that is smoothed out by Kriging becomes attributed to the mountain ridges of this region. This reveals a much more structured precipitation pattern clearly in line with the observations.

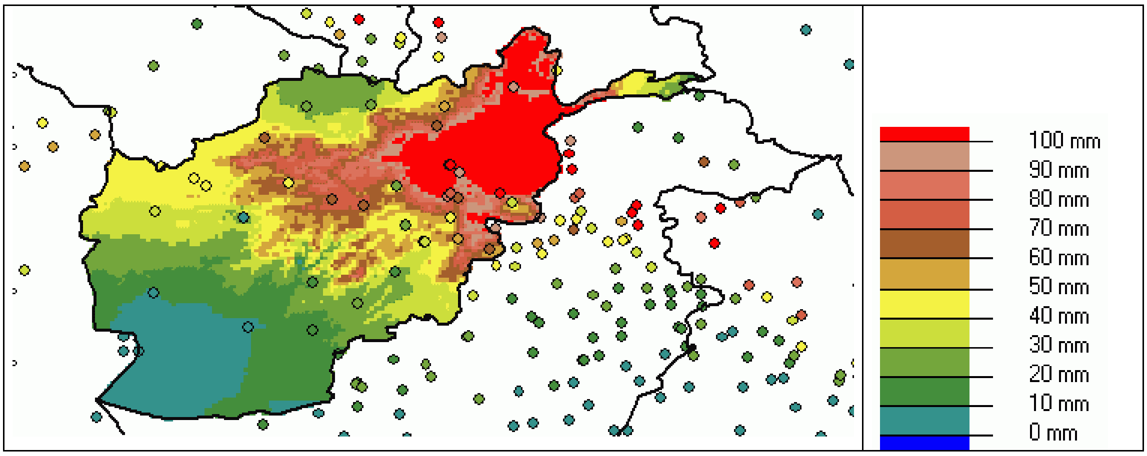


Fig. 5) Precipitation pattern including local vertical gradients.

April 2006, A Case Study

Fig. 6 shows the station distribution available for the estimation of the precipitation pattern of April 2006. Next to 40 stations within Afghanistan also stations from China and Pakistan are available.

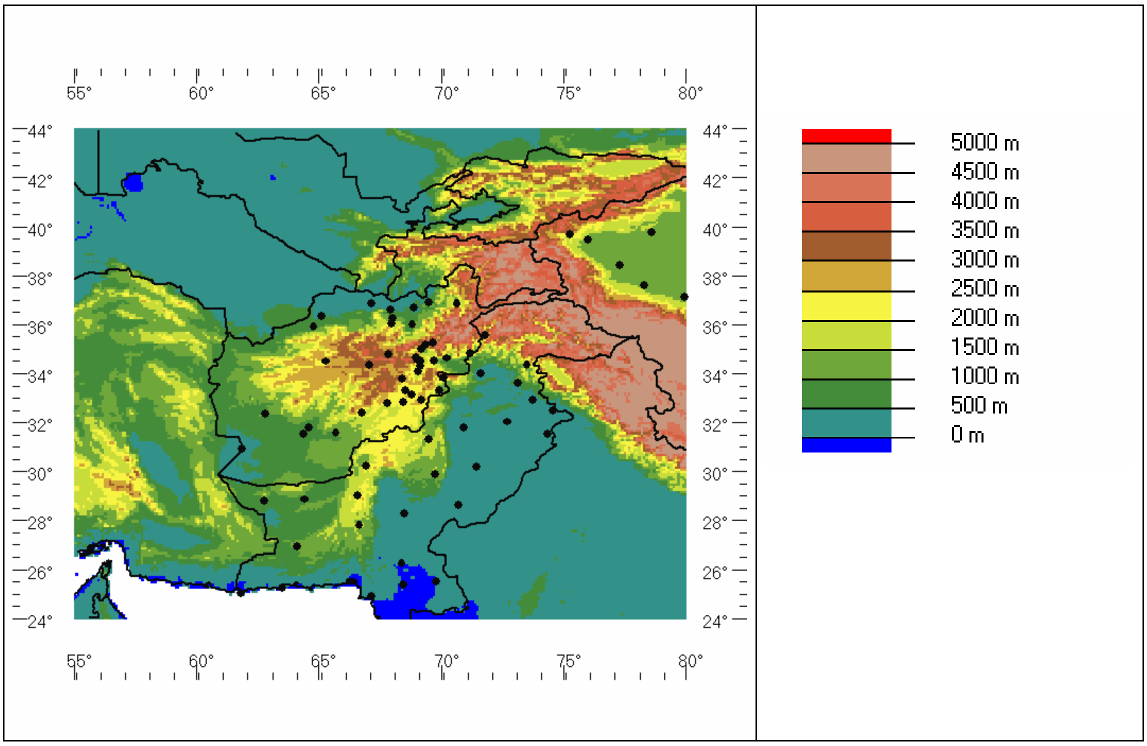
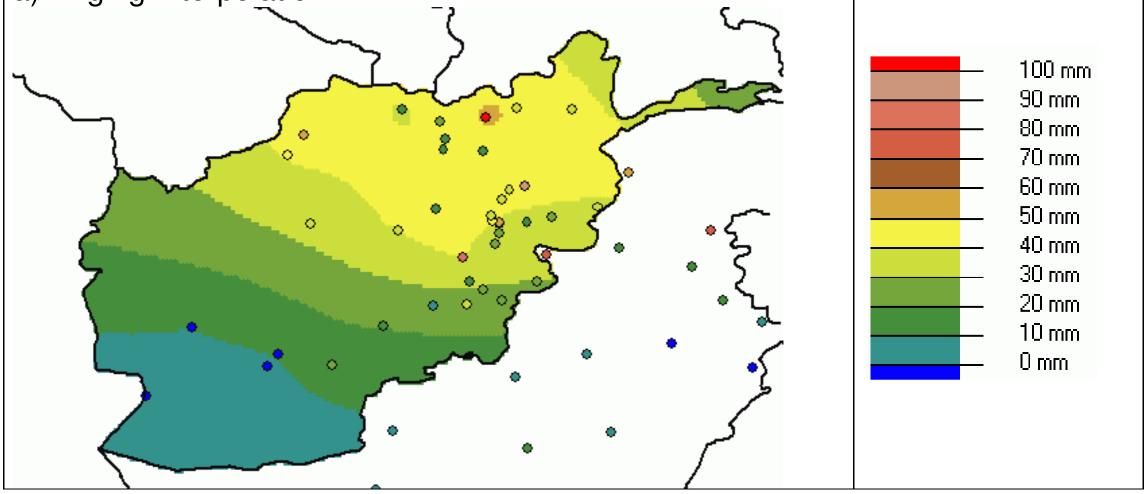


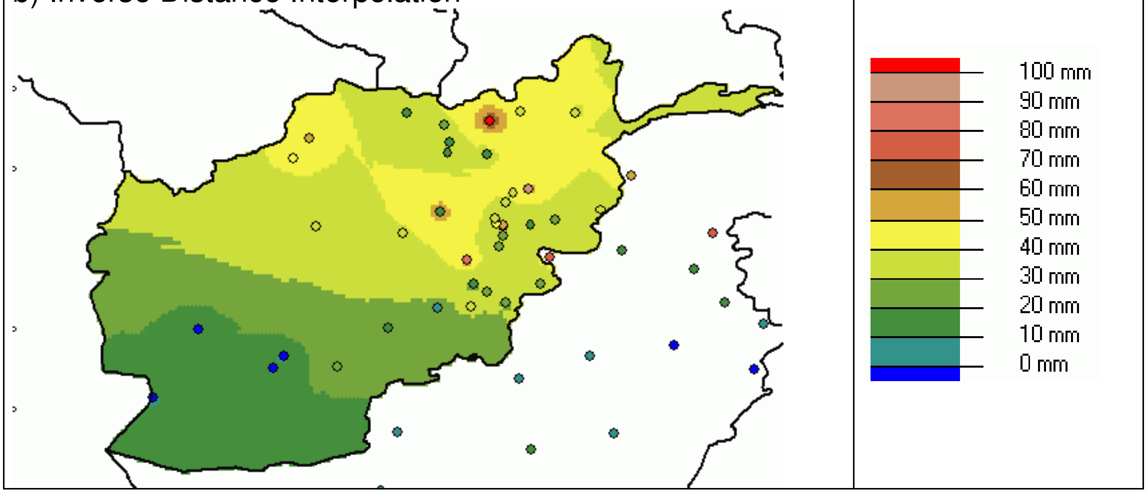
Fig. 6: Station distribution within Afghanistan and for neighbouring countries.

Fig. 7 shows the estimated precipitation pattern of Afghanistan as it results from the use of different interpolation routines. It is obvious that Kriging interpolation is smoothes to strong to provide acceptable estimates of the local conditions. IDWA produces too high precipitation in the dry Southwest. This effect can clearly be removed by the shadowing procedure. Finally the observation-altitude regression explains about 10% in this case and leads to a mean vertical gradient of .86mm/100m, which is about half the size of the usual vertical gradient of April. As a result, after application of the vertical gradients, the regional structures look much more reasonable except for a likely exaggeration in the very East of the country (see Fig. 7d).

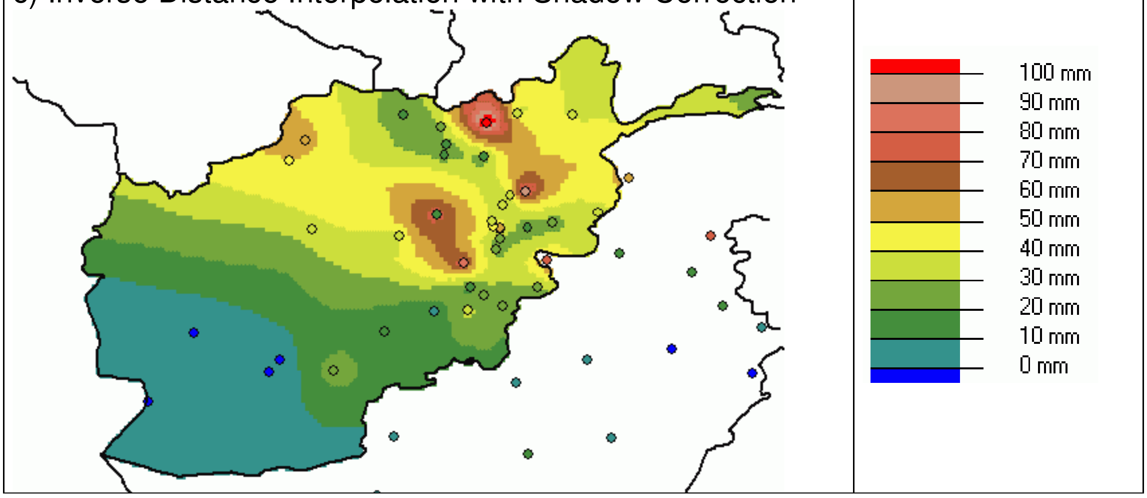
a) Kriging Interpolation



b) Inverse Distance Interpolation



c) Inverse Distance Interpolation with Shadow Correction



d) Inverse Distance Interpolation with Application of vertical gradients

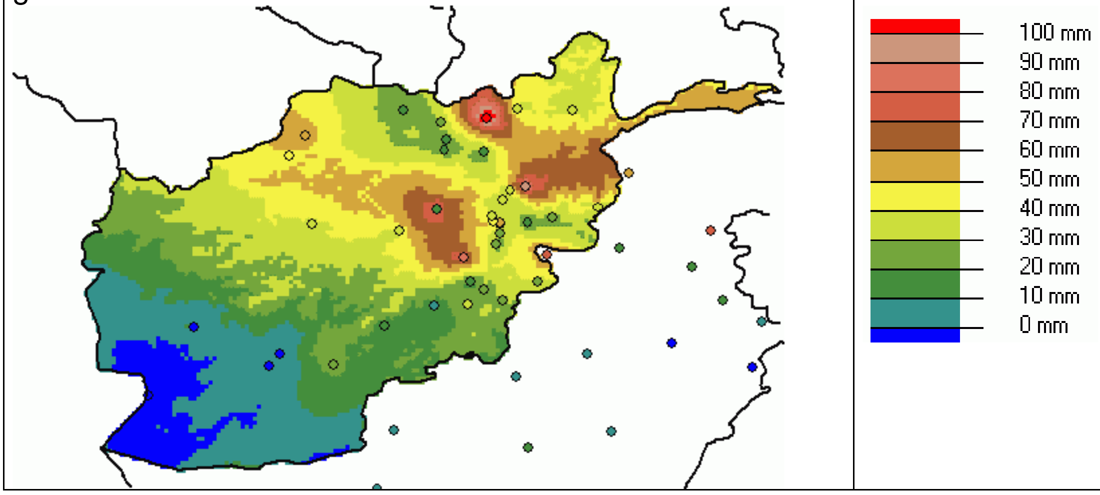
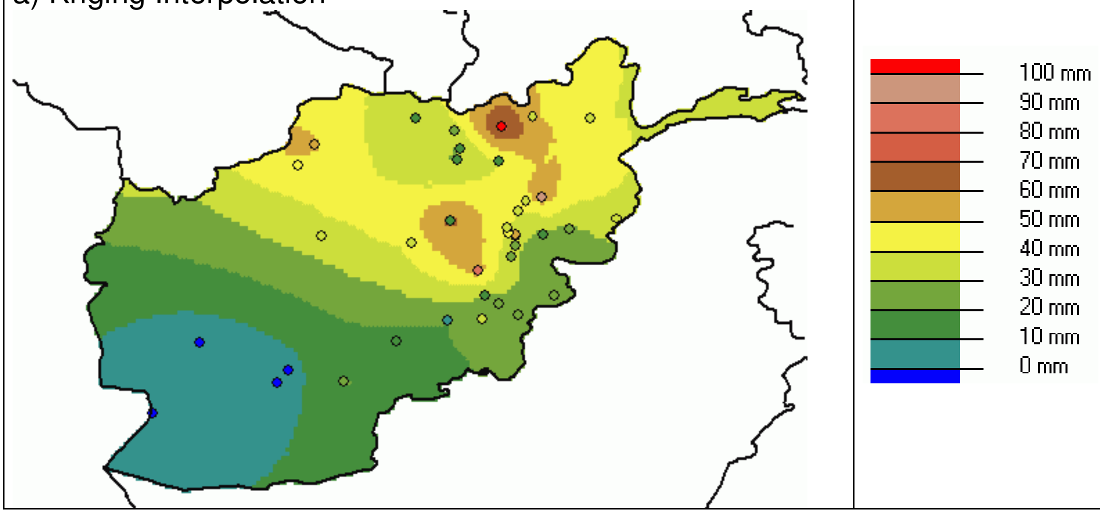


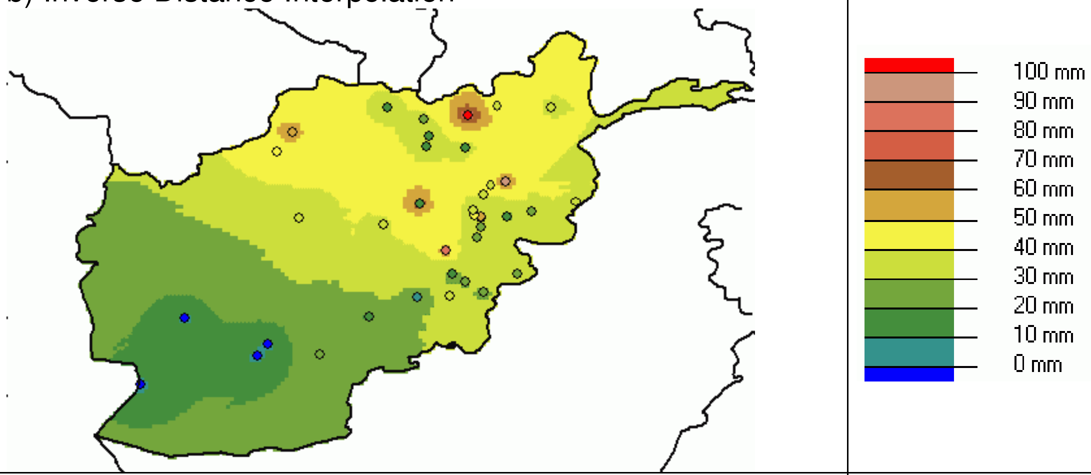
Fig. 7: Precipitation pattern of April 2006 over Afghanistan, calculated with several interpolation methods from Observations in Afghanistan, Pakistan and China.

Fig. 8 shows the interpolation results in case that only the stations within Afghanistan are used. In the test case of April 2006 this leads to very similar results as if the stations from neighbouring countries are used. Noteworthy differences however become visible in the very East of the country where the use of observations from neighbouring countries led to higher precipitation estimates.

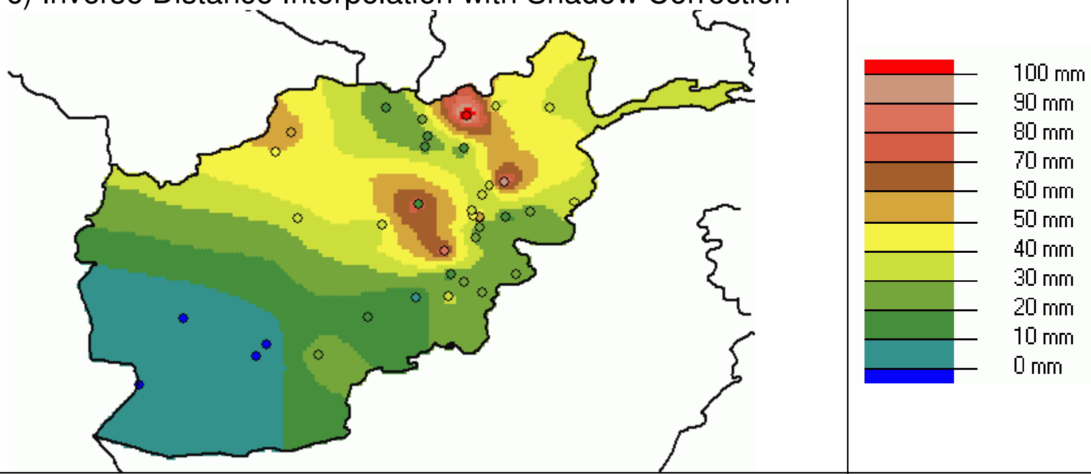
a) Kriging Interpolation



b) Inverse Distance Interpolation



c) Inverse Distance Interpolation with Shadow Correction



d) Inverse Distance Interpolation with Application of vertical gradients

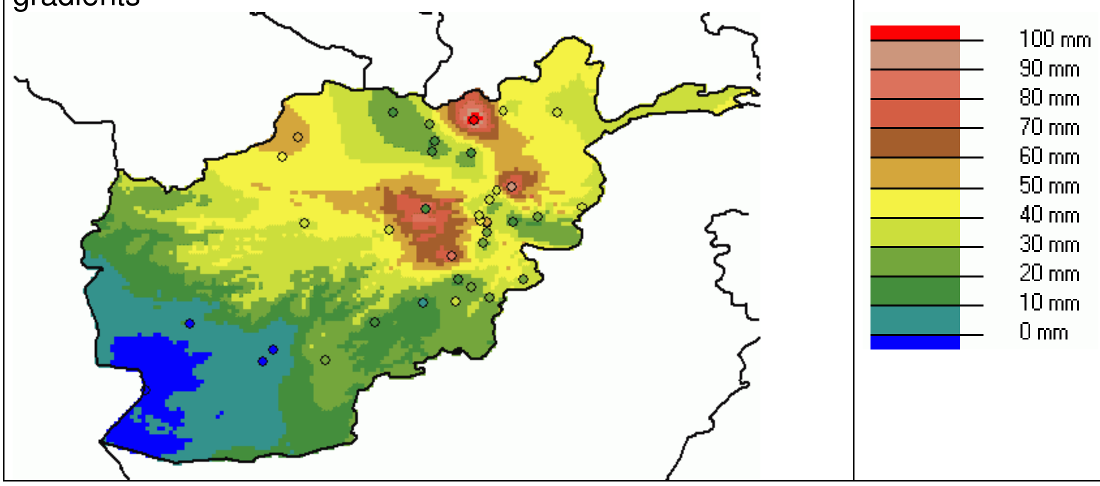


Fig. 8: Precipitation patter of April 2006 over Afghanistan calculated with several interpolation methods and the station data within Afghanistan.

Findings and Recommendations

According to the interpolation experiments performed in this work we recommend

1. using observations of stations from neighbouring countries in order to get more representative results at regions close to the borders,
2. considering local altitude gradients which are in the range of several mm precipitation increase per 100m altitude and explain about 10 to 20% of spatial variability, and
3. using inverse distance weighted averaging (IDWA) interpolation with a shadowing procedure in order to be exact on the one hand but avoid wavy and island-like isoline patterns on the other hand.

All interpolations and maps of this work are performed and prepared with New_LocClim (to be downloaded at ftp://ext-ftp.fao.org/SD/SDR/Agromet), the climate interpolation software of The Agromet Group of the Food and Agriculture Organization of the UN, FAO. The recommended New_LocClim method settings are as indicated in Fig. 9.

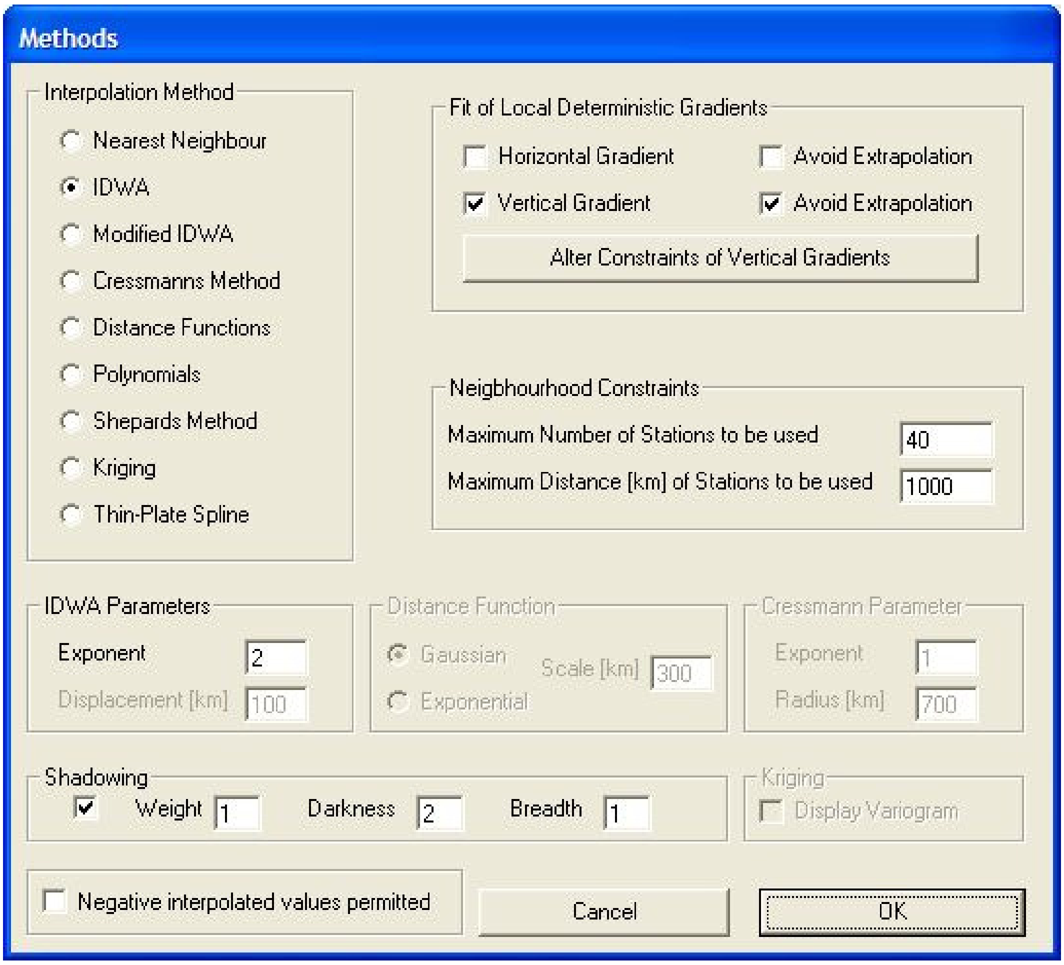


Fig. 9: Recommended method settings for the interpolation of monthly precipitation in Afghanistan during the “rainy” season.