11.3 DOWNSCALING PRECIPITATION FIELDS OVER COMPLEX TERRAIN

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1. INTRODUCTION

Precipitation is a climate element which is not only more difficult to be measured accurately than other atmospheric parameters but is also more difficult to become temporally and spatially interpolated. These difficulties with precipitation are even more severe over complex terrain. Precipitation measurements on high elevated locations may become strongly affected by winds, especially if solid precipitation is present. Also the lack of areal representativity for single station data becomes more dramatic over complex terrain due to the hight dependence of precipitation and cross ridge gradients (upslope precipitation enhancement – downslope weakening). Therefore the uncertainty about the spatially averaged precipitation amount over mountains is still considerable and makes model validation quite difficult.

2. SCALE CONSIDERATIONS

If we neglect for the moment the measurement deficiency of ombrometers due to wind and evaporative processes, the measured precipitation amount is valid of the area of the sensor, e. g. 1/10 square meter. Even for convective precipitation and over complex terrain this value may be seen representative for an area of say 1/10 square kilometer. Over the Alpine region the fairly dense GTS-type observation network gives about one station per 1000 square kilometers. The additional, extremely dense Alpine non-GTS precipitation network reduces this value to approximately 1 station per 100 square kilometers. Even this is far beyond the necessary resolution of 10 stations per square kilometer.
Todays operational prognostic models have approached a horizontal resolution of a few kilometers. The precipitation amounts are hence representative of roughly 100 square kilometers, comparable of the mean area per observing station. Nevertheless, it is not justified to compare observations with model precipitation directly, due to the different representativity.
Radar information would give a much better spatio-temporal resolution than ombrometers but shading effects of mountains limit its application over mountainous terrain.
What can we do? We can make use of very high resolution topographical information to carry out a downscaling procedure.

3. TOPOGRAPHIC DOWNSCALING

We know that in general there exists an increase of precipitation with altitude in mid latitudes. Hence we can formulate:

$$P(x,y,z,t) = \hat{P}(x,y,z=0,t) + c_z(t)P'_z(x,y,z)\,, \quad (1)$$

where the first right hand term denotes the fictitious (unknown) "background" precipitation without topographic influence, the second part the (unknown) altitude effect. P'_z is now set numerically equal to the (known) altitude. We call the latter distribution "altitude fingerprint". Then c_z calibrates the altitude fingerprint.
Furhermore, we know that there exists an an upslope enhancement – downslope weakening of precipitation. In the same fashion like above (1) may be formulated:

$$P = \hat{P} + c_z P'_z + c_s P'_s, \quad (2)$$

P'_s is set numerically equal to e. g. the altitude gradient of the terrain in the direction of the flow, which we call the "slope fingerprint". Furher influences like precipitation advection or blocking effects, leading to an upward motion in some distance ahead of the topography, may be introduced in a similar way. It is now reasonable, that the background precipitation $\hat{P}$ is smoother than the fields of the primed quantities. If we reformulate (2) as:

$$\hat{P} = P - c_z P'_z - c_s P'_s \quad (3)$$

and apply the Laplacian we can formulate a cost functional which is being minimized:

$$J = \iint_A \left[\nabla^2 P - c_z \nabla^2 P'_z - c_s \nabla^2 P'_s\right]^2 dA \rightarrow Min \quad (4)$$

Then we get a solution for the coefficients c_z and c_s.
A model precipitation field P_M may be treated similarly to obtain the model coefficients $(c_z)_M$ and $(c_s)_M$. Then these coefficients may be used to downscale the model precipitation with respect to the high resolution topography, i. e. using (3). If a larger domain is considered the coefficients may be set as function of space as well and their variation is minimized in (4) too. An example on one dimension is given in fig. 1.

4. CONCLUSION AND OUTLOOK

The downscaling method outlined is very sensitive upon observational errors. Therefore a data quality control is essential. This can also be incorporated in the variational approach.
A necessary condition for the functioning of the method is a sufficient number of observations which contain the orographic signal. Over the Alps this criterion is usually fulfilled already with GTS stations.
In the future the method will also be tested upon its suitability to disaggregate precipitation fields with respect to time. An other idea is to incorporate radar information into the downscaling procedure.

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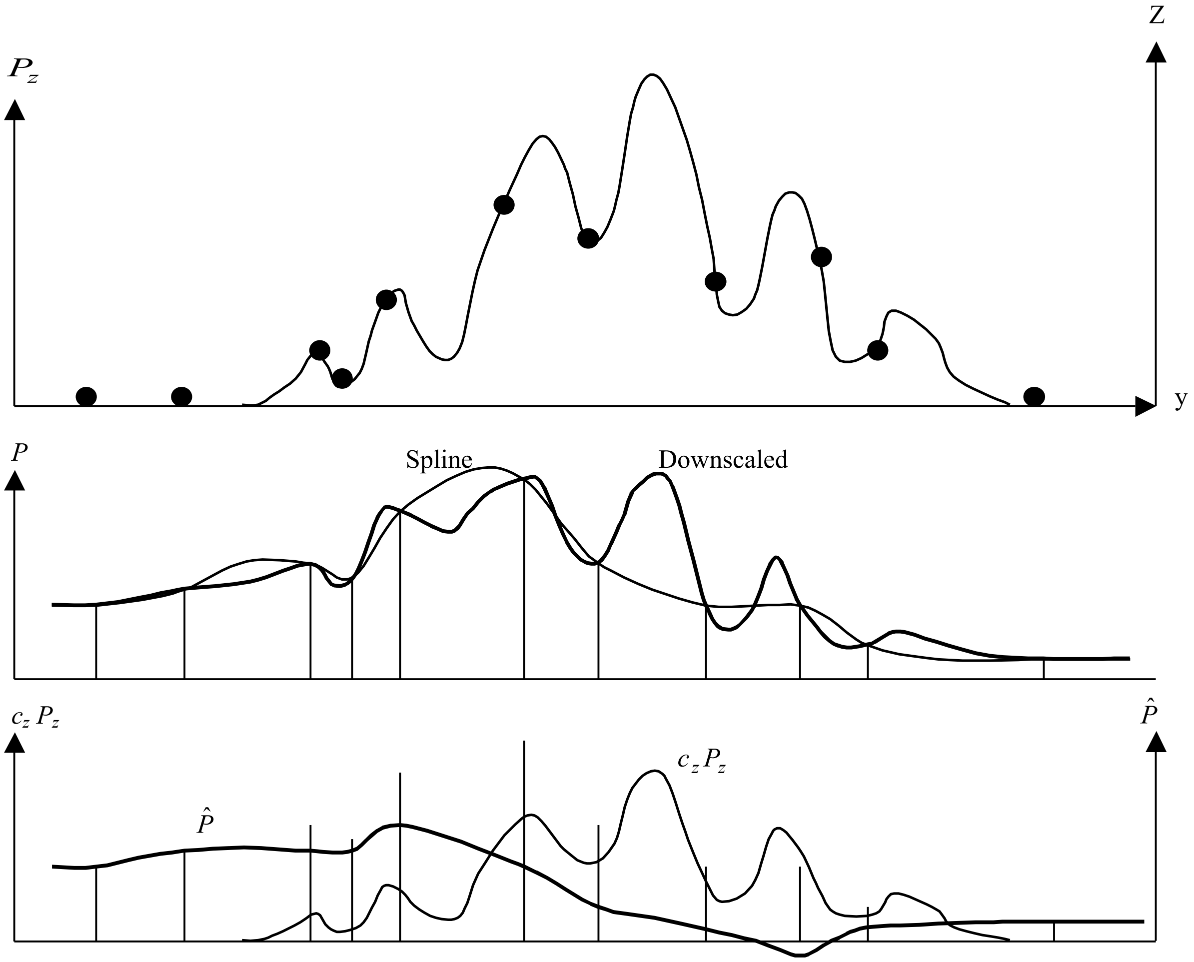

Fig.1: Schematic plot of the downscaling procedure. In the upper panel the topography and the location of stations (dots) is plotted. This curve represents also the altitude fingerprint. The center panel shows the interpolated precipitation profile due to a spline interpolation and the downscaled profile (bold). The lower panel shows the background precipitation profile (bold) and the calibrated altitude fingerprint, objectively defined by the variational approach of eq. (4). The superposition of both curves in the lower panel gives the downscaled precipitation profile of the center panel.