Aggregation of Subgrid Orography Parameters in the HIRLAM climate system

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1 Introduction

The HIRLAM climate generation has recently been recoded (The, 1998) and new physiographic data bases were introduced (The, 1998; Sattler, 1999). These data bases originate from different sources. The new climate generation does not use the original data bases, because of their heterogeneity in data representation as well as in data format. Instead, the data from the various data bases is sampled into a climate data base (CDB) of uniform data format in a regular or rotated geographic coordinate representation, which serves as input to the climate generation.

Parameters for description of subgrid orography (SO) are aggregated during the climate generation and are based on fields from the CBD. The current climate generation only aggregates the isotropic subgrid orographic roughness length, which is utilized in the current HIRLAM to account for SO induced drag. With the introduction of the Météo-France subgrid-scale orography parametrization for mesoscale orographic effects (MSO–parametrization) into HIRLAM (Sigg et. al., 2001) the need for a more detailed description of SO arose. This led to a review of the current determination of the isotropic subgrid orographic variance and to the development of the aggregation of anisotropic SO parameters during climate generation.

The next section will describe the definitions of the isotropic and anisotropic SO parameters. Then the aggregation of these parameters, as realized in the climate generation, will be outlined. An outlook is given at the end.

2 Subgrid Orography Parameters

2.1 Source grid fields

The aggregation of the SO parameters during climate generation is based on fields from the CDB, which describe the important properties of SO. The grid representation in the CDB (source grid) is either a regular geographic grid or a rotated geographic grid.

The current field in the CDB of the HIRLAM reference system for the aggregation of the subgrid orographic roughness $z_{0,oro}$ is the subgrid-variance of height with respect to a regular geographic grid of 23×23 grid pixels of the GTOPO30 data (USGS, 1998): $\sigma^2_{so,23\times 23}$.

An alternative field has been utilized during the first experiments with the MSO–parametrization scheme (Sigg et. al., 2001). It utilizes an unscaled SO subgrid orographic roughness based on a variance field, which depends on the spacing of the target grid:

$$z_{0,oro,unsc} = \frac{1}{2}\sqrt{\frac{n_p + 0.001}{A}}\,\sigma^2_{so,A}. \quad (1)$$

$\sigma^2_{so,A}$ is the variance of height referring to the grid area A of the target grid, and n_p is the number of peaks within the area A. The formulation goes back to Tibaldi and Geleyn(1981).

For the purpose of the MSO–parametrization, a filtered elevation field is necessary in order to make it possible to aggregate the parameters for the scheme in a consistent way. This elevation field is band-pass filtered and refers to a rotated grid in order to assure improved area representation. The resolution of this source grid is $\approx$2.7 km (Sigg et. al., 2001).

2.2 Target grid aggregation

The aggregation of subgrid orography (SO) parameters can be separated into aggregation of isotropic SO-parameters and anisotropic SO-parameters. The two aggregations must be consistent, when the parameters are used within one scheme, as is the case for the MSO–parametrization. The following sub-sections describe the aggregation of the parameters.

2.2.1 Isotropic Parameters

The current climate generation aggregates subgrid orographic roughness length by applying the following scaling to $\sigma^2_{so,23\times 23}$:

$$z_{0,oro,ref} = c\left(\sigma^2_{so,23\times 23}\right)^D, \quad (2)$$

with $c = 0.4038$ and $D = 0.7767$. $\sigma^2_{so,23\times 23}$ is hereby determined as average on the target grid, see figure 1, where the grey circles denote the points from the aggregation grid, that contribute to the actual target grid point.

The aggregation of $z_{0,oro}$ for use in connection with the MSO–parametrization scheme is determined analogously, but based on the grid consistent $z_{0,oro,unsc}$ and using a different scaling:

$$z_{0,oro} = a\left(z_{0,oro,unsc}\right)^B, \quad (3)$$

where $a = 0.4038$ and $B = 0.7715$.

The MSO–parametrization scheme makes use of the SO standard deviation, which, contrary to the one used for $z_{0,oro}$, is based on the filtered elevation field from the CDB. The aggregation happens on the aggregation grid, where each aggregation grid pixel is subdivided into 4 pixels (figure 1, black crosses). This is done in order to be most consistent with the aggregation of the anisotropic parameters. The subdivision makes an enhanced aggregation close to the border of the target grid cell possible and assures appropriate weighting of the aggregation grid pixels.

2.2.2 Anisotropic Parameters

There are two anisotropic parameters in the MSO–parametrization scheme, which are defined on basis of the tensor of orographic gradient correlation. These are the coefficient of anisotropy

$$\gamma = \sqrt{\frac{|T-D|}{|T+D|}} \tag{4}$$

and the angle between the gradient of height and the x-axis of the target grid

$$\theta = \arctan\left(\frac{\frac{\partial h}{\partial x_j}\frac{\partial h}{\partial x_j} - \frac{\partial h}{\partial x_i}\frac{\partial h}{\partial x_i} + D}{2\frac{\partial h}{\partial x_i}\frac{\partial h}{\partial x_j}}\right). \tag{5}$$

T and D are defined:

$$\begin{aligned} T &= \frac{\partial h}{\partial x_i}\frac{\partial h}{\partial x_i} + \frac{\partial h}{\partial x_j}\frac{\partial h}{\partial x_j} \\ D &= \sqrt{\left(\frac{\partial h}{\partial x_i}\frac{\partial h}{\partial x_i} - \frac{\partial h}{\partial x_j}\frac{\partial h}{\partial x_j}\right)^2 + 4\left(\frac{\partial h}{\partial x_i}\frac{\partial h}{\partial x_j}\right)^2}. \end{aligned} \tag{6}$$

This means that the anisotropic parameters depend on the components of the first elevation derivatives only. The first derivatives are therefore the parameters to aggregate. They are determined for the filtered elevation field from the CDB. The aggregation is done using the subdivided aggregation grid (figure 1, black crosses), where a centered difference is determined on each subdivision pixel. The mean gradient for the target grid cell can then easily be determined. Appropriate weighting at the border of the target grid cell is included automatically by this procedure.

The first derivative components still refer to the aggregation grid, or equivalently, to the source grid. They are therefore rotated to the target grid coordinates using

$$\nabla_{\mathsf{xy}}\,\boldsymbol{h} \;=\; \boldsymbol{R}\,\nabla_{\mathsf{uv}}\,\boldsymbol{h}\,, \tag{7}$$

where

$$\boldsymbol{R} \;=\; \frac{1}{\sin(\omega_t)}\begin{pmatrix} \sin(\omega_t+\alpha_1) & \sin(\alpha_2) \\ -\sin(\alpha_1) & \sin(\omega_t-\alpha_2) \end{pmatrix} \tag{8}$$

describes the rotation between two oblique-angled coordinate systems. α_1 and α_2 denote the rotation angles and ω_t is the coordinate angle of the target grid. γ and θ are finally determined from $\nabla_{\mathsf{xy}}\,\boldsymbol{h}$.

3 Outlook

The previous sections described the major aspects of the aggregation of subgrid orography parameters. The aggregation of the anisotropic parameters is new in the climate generation, and the parameters have been applied in first experiments with the recently introduced Météo-France MSO–parametrization scheme in HIRLAM.

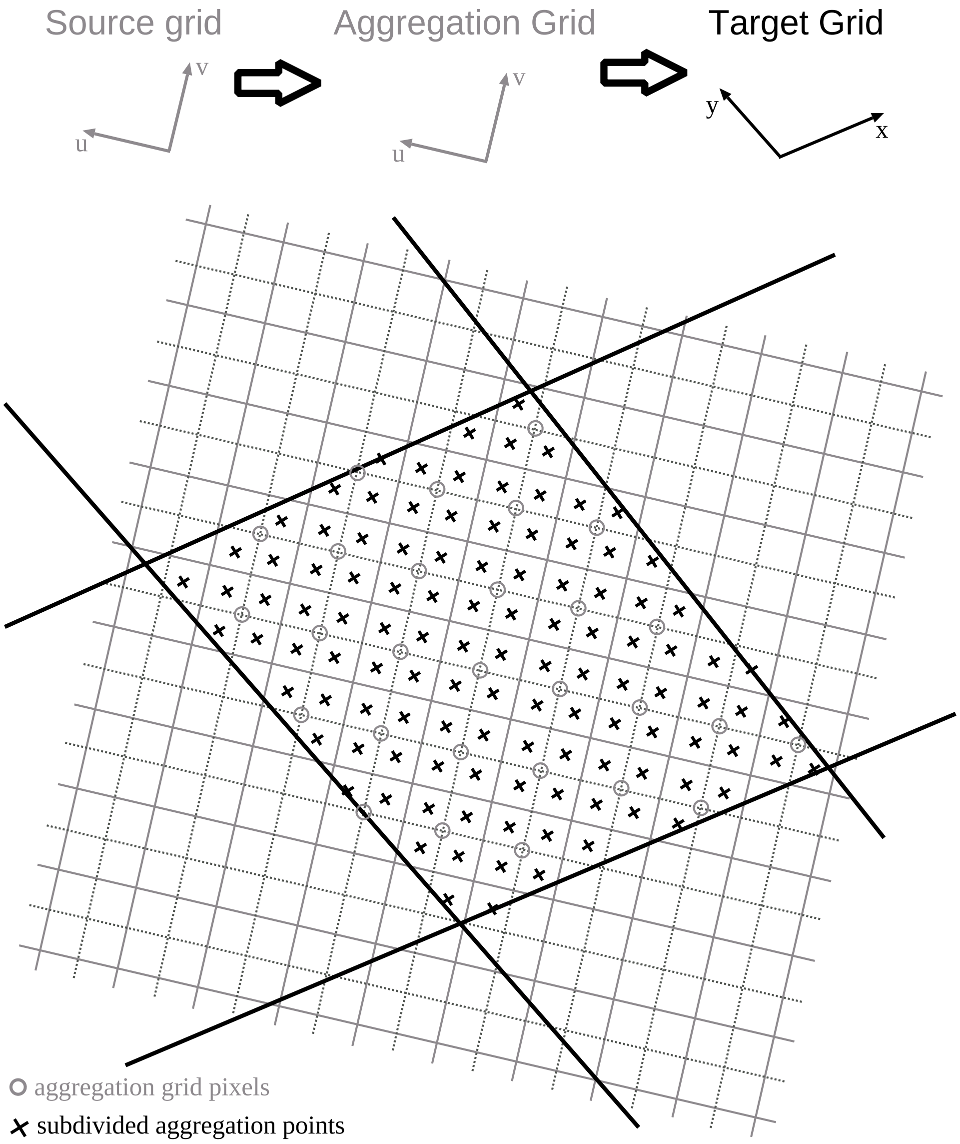

Figure 1: Sketch of the aggregation process of SO parameters during climate generation. The aggregation is performed on the aggregation grid (grey), which has the same rotation as the source grid (not shown), but which usually has a different resolution. The figure shows one grid pixel of the target grid (black), which usually has a different resolution and rotation from the aggregation grid. Further details are given in the text.

Future experiments with the MSO–parametrization scheme will beyond other purposes aim at finding the appropriately filtered source grid orography for the aggregation of both $z_{0,oro}$ and the MSO parameters.

The current aggregation of subgrid orographic roughness in the reference system is based on a fixed grid variance and should be replaced by a grid consistent method. The current grid consistent method using $z_{0,oro,unsc}$ from the CDB is, however, not practical and has to be implemented in a different way in order to keep the CDB independent from the target grid.

References

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