Non-linear aggregation of subgrid-scale orography roughness

Kai Sattler, DMI

1 Introduction

Since the HIRLAM reference version 6.1.1 (HIRLAM, 2003), a new method for the aggregation of subgrid-scale orography roughness $z_{0,\mathrm{SSO}}$ was introduced into the climate generation. The method aims at determination of $z_{0,\mathrm{SSO}}$ in accordance with the target grid size (model grid). This means that the calculation of $z_{0,\mathrm{SSO}}$ includes only information from within the actual target grid square. The method may be regarded as to retain consistency with the target grid, and it was implemented at DMI several years ago (Sattler, 1999). This implementation was, however, not very practical, because it necessitated the creation of special HDF files (input files for the climate generation) for each target grid. A climate generation production could therefore only make use of the method, if the appropriate HDF files were available. As a consequence of this, the old approach, which makes use of a constant subgrid-scale orographic variance (Undén, 2002, Eq. (5.12)), persisted for quite a long time in the reference system.

During the work on subgrid-scale orographic effects by Rontu et. al. (2002) the concept of the grid consistent aggregation for $z_{0,\mathrm{SSO}}$ was taken up again and a more practical procedure was developed, which works with a general set of HDF files (Sattler, 2001). The new procedure was implemented in a simplified version into HIRLAM reference version 6.1.1 (HIRLAM, 2003). This simplification included an approximation in the determination of the subgrid-scale orographic variance, which treated the calculation procedure as if it was a linear process. The simplification reduced the number of necessary data fields from five to three and thus helped to limit the HDF file sizes.

Tests performed with the linearized aggregation method as it is implemented in HIRLAM reference version 6.1.1 show, however, that $z_{0,\mathrm{SSO}}$ may often be estimated inaccurately, especially when variance on the source grid is inhomogeneous (see below).

The following section describes the issues of the aggregation of $z_{0,\mathrm{SSO}}$, the linear approach from HIRLAM reference version 6.1.1, as well as the non-linear approach. A specific example is given in the following section, and it shows the differences between the two methods, which become especially clear over Greenland. The final section draws some conclusions.

2 Subgrid-scale orography roughness aggregation

2.1 General formulation

The general form for the determination of the subgrid scale orographic roughness $z_{0,\mathrm{SSO}}$ in HIRLAM is

$$z_{0,SSO} = a \left[\frac{1}{2} \sqrt{\frac{n_0 + n_{p,T}}{A_T}}\, \sigma_{so}^2 \right]^B . \qquad (1)$$

This formulation is partially adopted from Tibaldi and Geleyn(1981). In (1) σ_{so}^2 is the variance in height of the original data base (GTOPO30) within the grid area A_T of the target grid (model grid). The number of peaks $n_{p,T}$ counts the number of relative maxima in a 3×3 grid pixel vicinity, which fall into the area A_T. A constant minimum for the denominator under the square root in (1), n_0 has been introduced in order to avoid unsteady behavior where $n_{p,T}$ varies between zero and one. It has been set to 0.001 in older versions, but was changed to 1 in the latest versions of the formulation (Sattler, 2004). The scaling parameters a and B make it possible to tune $z_{0,SSO}$ for use in HIRLAM.

The variance σ_{so}^2 is determined by

$$\sigma_{so}^2 = \frac{1}{N}\sum_{i=1}^{N} h_i^2 - \left(\frac{1}{N}\sum_{i=1}^{N} h_i\right)^2 , \tag{2}$$

where h_i denotes height values from the original data base, and N is their number within a target grid pixel. Because of the different grid projections used in the original data and in the targt grid, N is not a constant.

The aggregation of $z_{0,\mathrm{SSO}}$ onto the desired target grid is completely described by (1) and (2). In practice, however, this aggregation cannot be performed in one step. The reason for this is that the original data base GTOPO30 for the digital elevation model (DEM) cannot be directly processed by the HIRLAM climate generation, and this has in turn two reasons. Firstly, there are different data bases, one of which represents the DEM. These data bases are represented in different data formats and grid representations. Secondly, these original data bases do not contain all the fields requested by the HIRLAM climate generation, which means that a preprocessing has to take place. The solution is the use of the HDF files. The HDF files are a data base, where original data as well as preprocessed data is collected in a uniform data format (in Undén (2002), the HDF file data base is also refered to as climate data base (CDB)). The use of the HDF files as input data to the HIRLAM climate generation renders the latter much more transparent with respect to coding as well as usage. On the other hand, the HIRLAM climate generation does not have any knowledge about the grid representation, in which the original data was given. Instead, all aggregation done during the climate generation is performed by reading data from the uniform grid given in the HDF files. So the source grid for the climate generation is not a grid from the original data bases, but the uniform grid of the HDF files (Fig. 1).

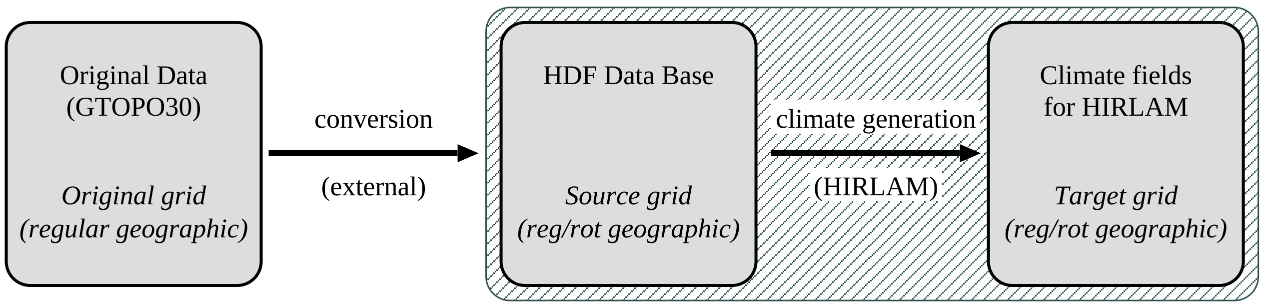


Figure 1: Simplified sketch of the data flow from the original DEM data to the HIRLAM climate generation. The original data is not available for the climate generation. Instead, HDF files that represent the data in a uniform data format are employed. Note that the HIRLAM climate generation only comprises the part on the right hand side of the sketch, which is outlined by the hatched area.

2.2 Split variance determination

As a consequence from using the HDF files as data source in the HIRLAM climate generation instead of the original data, the aggregation of $z_{0,\mathrm{SSO}}$ cannot be performed by just applying (1). Especially the determination of the variance is not possible in a straightforward way. The problem can be resolved, however, if the aggregation is split into two steps. The first step can be performed when the HDF files are created. At this stage, information about the original data base is available, but no information about the target grid. The second step can be performed during the climate generation, and at this stage, information about the target grid is prescribed, but direct information about the grid of the original data base is not available. When splitting the determination of the variance into two such steps Eq. (2) reads

$$\sigma_{so}^2 = \frac{1}{\sum\limits_{j=1}^{J} K_j} \sum_{j=1}^{J} \sum_{k=1}^{K_j} h_{j,k}^2 - \left(\frac{1}{\sum\limits_{j=1}^{J} K_j} \sum_{j=1}^{J} \sum_{k=1}^{K_j} h_{j,k} \right)^2 , \tag{3}$$

where $\sum_{k=1}^{K_j}$ is the sum over the original grid pixels whithin source grid pixel j. Note that for this sum only knowledge about the original grid is necessary, and no information about the target grid. Note also that the number K_j of original grid pixels within a source grid pixel is not a constant. The outer sum in (3), $\sum_{j=1}^{J}$, is the sum over the source grid pixels within a target grid pixel, where J denotes the number of source grid pixels within the target grid pixel. In this second sum only information about the target grid pixel is necessary. When comparing (3) with (2), it can be imediately recognized that the original sum over the original grid pixels whithin the target grid pixel is replaced by a double sum:

$$\sum_{i=1}^{N} \dots \quad \longrightarrow \quad \sum_{j=1}^{J} \sum_{k=1}^{K_j} \dots = \tag{4}$$

and where

$$N = \sum_{j=1}^{J} K_j . \tag{5}$$

So the generic step of building one single sum is split into two steps, each of which with a sum over a part of the original sum.

2.3 The linearized aggregation of $z_{0,\mathrm{SSO}}$

As mentioned in Sec. 1, the new aggregation method for $z_{0,\mathrm{SSO}}$ was implemented as a linearized approximation since HIRLAM version 6.1.1. This implementation does not exploit the split determination of the variance, but uses an approximation instead. It works as follows. During the production of the HDF files four fields are created, which have relevance for the aggregation of $z_{0,\mathrm{SSO}}$. These fields are listed in Table 1.

As the mean height $\overline{h}$ is necessary also for the determination of the surface geopotential, there are only three supplementary fields necessary in order to aggregate $z_{0,\mathrm{SSO}}$. The mean height and the mean squared height are determined during the preprocessing step of the HDF file creation by

Table 1: Fields expected from the HDF files by the linearized aggregation method for $z_{0,\mathrm{SSO}}$. They are given on the soucre grid, which is different from the grid of the original data base.

Parameter	Description
$n_{p,j}$	number of relative height maxima within source grid pixel j
$\overline{h}_j$	mean height in the source grid pixel j
$\overline{h^2}_j$	mean squared height in the source grid pixel j
A_j	area for source grid pixel j

$$\begin{aligned} \overline{h}_j &= \tfrac{1}{K_j} \sum_{k=1}^{K_j} \overline{h_k} \\ \overline{h^2}_j &= \tfrac{1}{K_j} \sum_{k=1}^{K_j} \overline{h_k^2} \end{aligned} \tag{6}$$

for all source grid pixels $j = 1, J$.

The fields listed in Table 1 are used then during the climate generation to determine $z_{0,\mathrm{SSO}}$ in the following way:

$$\begin{aligned} n_{p,T} &= \sum_{j=1}^{J} n_{p,j} \\ A_T &= \sum_{j=1}^{J} A_j \\ \sigma_{so}^2 &= \tfrac{1}{J} \sum_{j=1}^{J} \overline{h^2}_j - \left(\tfrac{1}{J} \sum_{j=1}^{J} \overline{h}_j \right)^2 \end{aligned} \tag{7}$$

In the last equation of (7), the sums make use of mean values of height and squared height. This is an approximation, which treats the determination of the variance as a linear and homogeneous calculation process. It is not only for the squared height, where an approximation is made. The mean of the height, see first formulation in (6), is also approximate because of the fact that K_j may vary from source grid pixel to source grid pixel.

2.4 The non-linear aggregation of $z_{0,\mathrm{SSO}}$

The split determination of the orographic variance described in Sec. 2.2 does not need to be approximated actually. Thus, the approximations from Sec. 2.3 in the $z_{0,\mathrm{SSO}}$ aggregation during the climate generation can be avoided. The number of HDF fields, which the climate generation then expects, however, increases from three to five (Table 2).

In the climate generation process the variance is then detremined by

$$\sigma_{so}^2 = \frac{1}{\sum_{j=1}^{J} K_j} \sum_{j=1}^{J} \sum_{k=1}^{K_j} h_{j,k}^2 - \left(\frac{1}{\sum_{j=1}^{J} K_j} \sum_{j=1}^{J} \sum_{k=1}^{K_j} h_{j,k} \right)^2 , \tag{8}$$

Table 2: Fields expected from the HDF files by the non-linear aggregation method for $z_{0,\mathrm{SSO}}$. They are given on the soucre grid, which is different from the grid of the original data base.

Parameter	Description
K_j	number of original grid pixels within source grid pixel j
$n_{p,j}$	number of relative height maxima within source grid pixel j
$\sum_{k=1}^{K_j} h_{j,k}$	height sum in the source grid pixel j
$\sum_{k=1}^{K_j} h_{j,k}^2$	squared height sum in the source grid pixel j
A_j	area for source grid pixel j

and the subgrid orographic roughness becomes

$$z_{0,SSO} = a \left[\frac{1}{2} \sqrt{\frac{n_0 + \sum_{j=1}^{J} n_{p,j}}{\sum_{j=1}^{J} A_j}} \, \sigma_{so}^2 \right]^B . \tag{9}$$

In this approach, mean values are avoided and the original formulation for $z_{0,\mathrm{SSO}}$, Eq. (1), is retained, because of the equivalences

$$\begin{aligned} n_{p,T} &= \sum_{j=1}^{J} n_{p,j} \\ A_T &= \sum_{j=1}^{J} A_j \\ N &= \sum_{j=1}^{J} K_j \\ \sum_i h_i &= \sum_{j=1}^{J} \sum_{k=1}^{K_j} h_{j,k} \\ \sum_i h_i^2 &= \sum_{j=1}^{J} \sum_{k=1}^{K_j} h_{j,k}^2 . \end{aligned} \tag{10}$$

3 An Example

The following example shall make the actual differences between the linear and the non-linear $z_{0,\mathrm{SSO}}$ aggregation clear. The HIRLAM climate generation was run for a large area, which includes Europe, the North pole, North Asia and North America to some extend. The grid spacing is 0.15 degrees on a rotated grid, where the south pole position is at 80° longitude and 0° latitude.

Fig. 2 shows the $z_{0,\mathrm{SSO}}$ field as it was aggregated by the climate generation as of reference system version 6.2.1. This field was aggregated using the linearly approximated method as described in Sec. 2.3. There are some features in this field that are striking. Firstly, there are discontinuities in the structure of $z_{0,\mathrm{SSO}}$ visible over Northern Asia, North America, and Northern Europe. Another less distinct discontinuity appears over Greenland. Furthermore, rougness length over the inner

Greenland seems rather large, and $z_{0,\text{SSO}}$ is very large over Spitsbergen and Ellesmere Island west of Greenland. The first effect is to some extent related to the fact that the HDF file for the North Pole area is represented in a polar stereographic grid, whereas all the other HDF files are represented in a rotated geographic grid. Combination of different grid projections may be permissible for many parameters like mean orography or surface type. For the aggregation of parameters, which depend on the aggregation area, use of different projections should, however, be avoided. The same is probably true for parameters with anisotropic properties. The second effect seems to be related to the linearly approximated calculation of $z_{0,\text{SSO}}$.

In order to get a better estimate for the differences between the linear and the non-linear $z_{0,\text{SSO}}$ aggregation method, a second aggregation using the linear approximation was performed. It is shown in Fig. 3. This time, the HDF files were replaced by a set that includes the North Pole area in a rotated geographic grid representation. The creation of these HDF files has been done using the same procedure as for the HDF files used in the non-linear method below. As the field in Fig. 3 indicates, $z_{0,\text{SSO}}$ looks more realistic over Northern Asia, North America, and Northern Europe, although a slight influence of the border of the HDF file coverage remains (see e.g. Northern Russia in Fig. 3). This confirms the presumption from above that the use of the polar stereographic projection cannot be employed here. Where the discontinuity over Greenland is concerned, it is more distinct now than before. The use of the different HDF file set has also some influence on the estimation of $z_{0,\text{SSO}}$ over flat terrain as for example Eastern Europe, were $z_{0,\text{SSO}}$ is smaller in the second case.

The $z_{0,\text{SSO}}$ field as determined by the non-linear method is given in Fig. 4. The most striking differences appear over Greenland, were the contrast between the inner area and the coast is increased significantly. Also the discontinuities over Greenland have disappeared, and there are no other discontinuities within the shown area either. The estimates for $z_{0,\text{SSO}}$ exhibit stronger contrast, showing smaller values over flat terrain and larger values over the mountainous regions. As a result, the given example shows that applying the unapproximated procedure to aggregate $z_{0,\text{SSO}}$ is necessary in order to get better estimates for $z_{0,\text{SSO}}$ and to diminish spurious effects in the structure of the field.

4 Conclusions

This work presented the formulation and method for the aggregation for subgrid-scale orographic roughness length and argued for an improved implementation of the method in the HIRLAM reference system. The shown example reveals the major differences between an approximated calculation, that treats the determination as if it was linear, and the unapproximated calculation, which is based on a split determination of the subgrid variance of the height field.

When determining $z_{0,\text{SSO}}$ with the linearly approximated method, values tend to be overestimated over flat areas, and underestimated over mountainous areas. Furthermore, the linear method can lead to discontinuities in the $z_{0,\text{SSO}}$ field, some of which are related to boundaries in the underlying data sets from the HDF files. The unapproximated method avoids these effects in the structure of the $z_{0,\text{SSO}}$ field. The cost in computer resources in form of additional storage capacity of additional data sets in the HDF files seems to be justified by the improvements.

There are different opinions about what values $z_{0,\text{SSO}}$ actually should take, and this certainly depends on the model that is to use the $z_{0,\text{SSO}}$ field. This work does not try to argue for or against a certain choice on how large $z_{0,\text{SSO}}$ should be over a certain area. The results in this work actually do not depend on the choice of the scaling parameters. The scaling applied for $z_{0,\text{SSO}}$ in the HIRLAM climate generation (parameters a and B of Eq. (1)) is such that it resembles the values over mountainous areas from earlier climate generation versions in HIRLAM. If the modeller thinks that $z_{0,\text{SSO}}$

should resemble a different range of values, she/he has the opportunity to change the scaling and is encouraged to so by adjusting the two scaling parameters a and B of Eq. (1).

The approximated method for the aggregation of $z_{0,\mathrm{SSO}}$ was implemented in the HIRLAM reference system since version 6.1.1. It is planned that the unapproximated method is fully available in the next stable release of the reference system. As the new method necessitates the presence of different data sets in the HDF files, the implementation comes together with new sets of HDF files. They are described in more detail by Sattler (2004).

The questiion on how usefull the use of orographic roughness as such is not treated here. As Rontu (2001) indicated, the size of the $z_{0,\mathrm{SSO}}$ values may not have as much an effect on the surface fluxes as expected. In the future the concept of the effective subgrid-scale orographic roughness length may be abandoned in favor of new methods. However, as long as subgrid-scale orographic roughness is utilized in HIRLAM, it should be aggregated in a reasonable way, that represents a structure free of spurious effects.

References

HIRLAM, 2003: Release notes of HIRLAM 6.1.1. Available from the HeXnet.

Rontu, L., 2001: Notes on roughness in HIRLAM. *Hirlam Newsletter*, **38**, 135–136.

Rontu, L., Sattler, K., Sigg, R., 2002: Parametrization of subgrid-scale orography effects in HIRLAM. *Hirlam Tech. Rep.*, **56**, 49pp.

Sattler, K., 1999: New high resolution physiographic data and climate generation for the HIRLAM forecasting system. *DMI Tech. Rep.*, **99-11**, 1999, 41pp.

Sattler, K.; 2001: Aggregation of Subgrid Orography Parameters in the HIRLAM climate system. *Hirlam Newsletter*, **38**, 122–126.

Sattler, K.; 2004: Climate generation developments for high resolution: A technical note on the new HDF sets. *Hirlam Newsletter*, **45**, 134–140.

Sigg, R., Rontu, L., Sattler, K., 2001: Subgrid-scale orography parametrization for HIRLAM – first experiments. *HIRLAM Newsletter*, **37**, 20–34.

Tibaldi, S., Geleyn, J.-F., 1981: The Production of a new Orography, Land-Sea Mask and associated Climatological Surface Fields for Operational Purposes. it ECMWF Research Department Tech. Memorandum, **40**, 13 pp + Appendices and Figures.

The, H., 1998: Revised routines for pre-processing the HIRLAM physiographic data sets (script Preps). *KNMI internal note*, 11pp.

Undén, P., Rontu, L., Järvinen, H., Lynch, P., Calvo, J., Cats, G., 2002: HIRLAM-5 scientific documentation. HIRLAM-5 project SMHI Norrköping, 144pp.

USGS 1998: GTOPO30, Global 30 Arc Second Elevation Data Set. *U.S. Geological Survey*, http://edcdaac.usgs.gov/gtopo30/gtopo30.html.

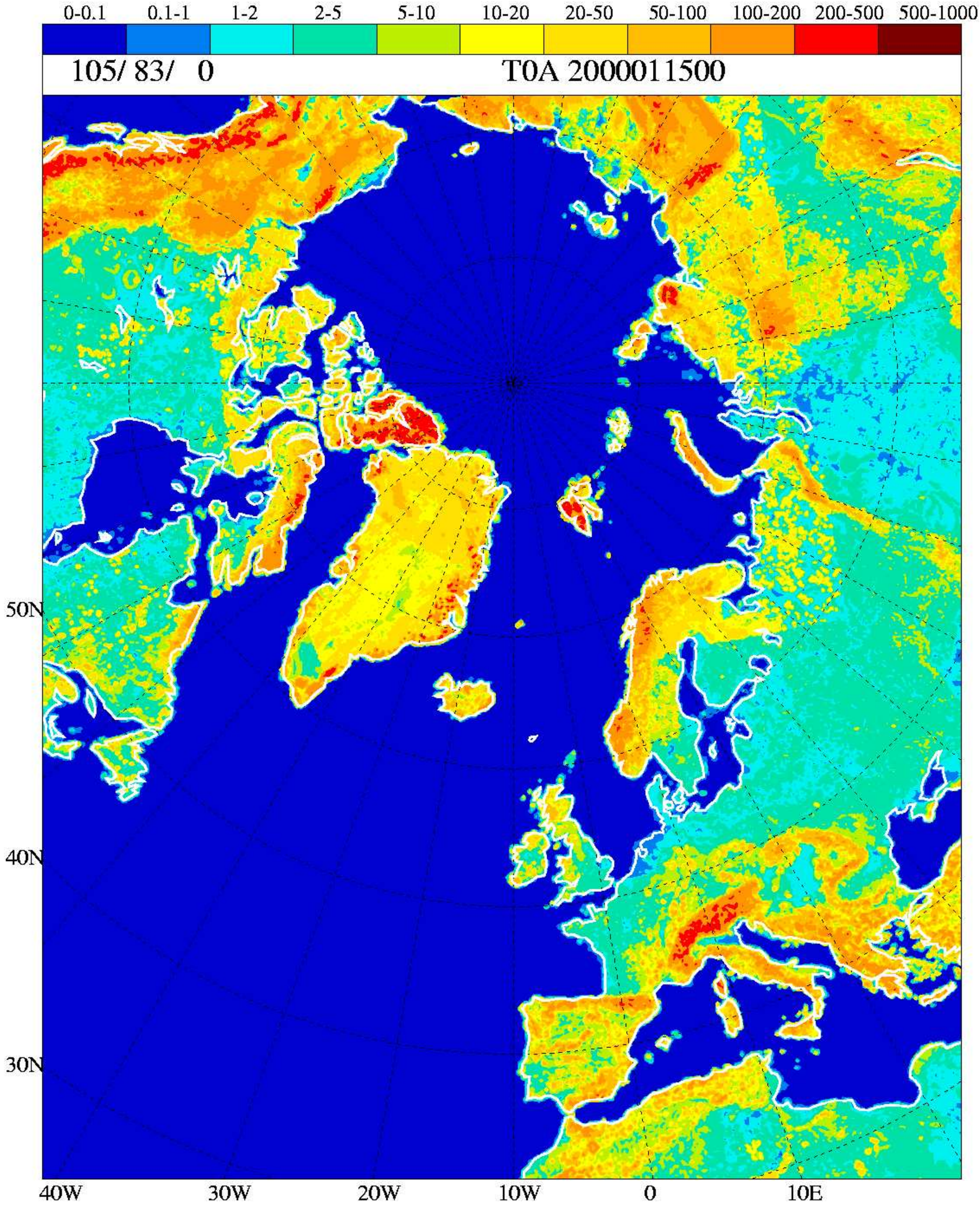


Figure 2: $z_{0,\mathrm{SSO}}$ in cm as aggregated by the standard reference system version 6.2.1. The aggregation method includes the linear approximation.

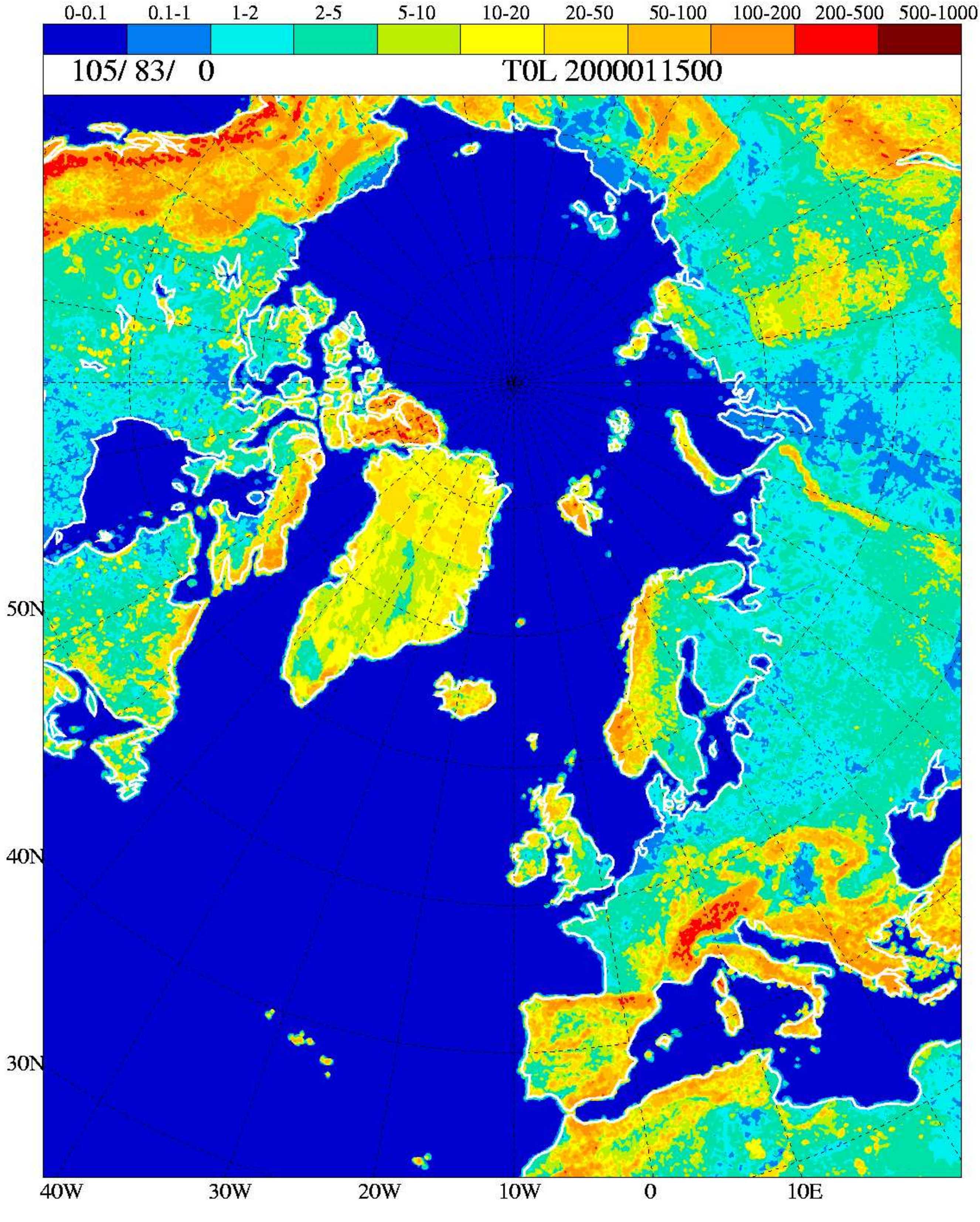


Figure 3: $z_{0,\mathrm{SSO}}$ in cm as aggregated by the standard reference system version 6.2.1 using HDF files that avoid data given in polar stereographic projection. The aggregation method includes the linear approximation.

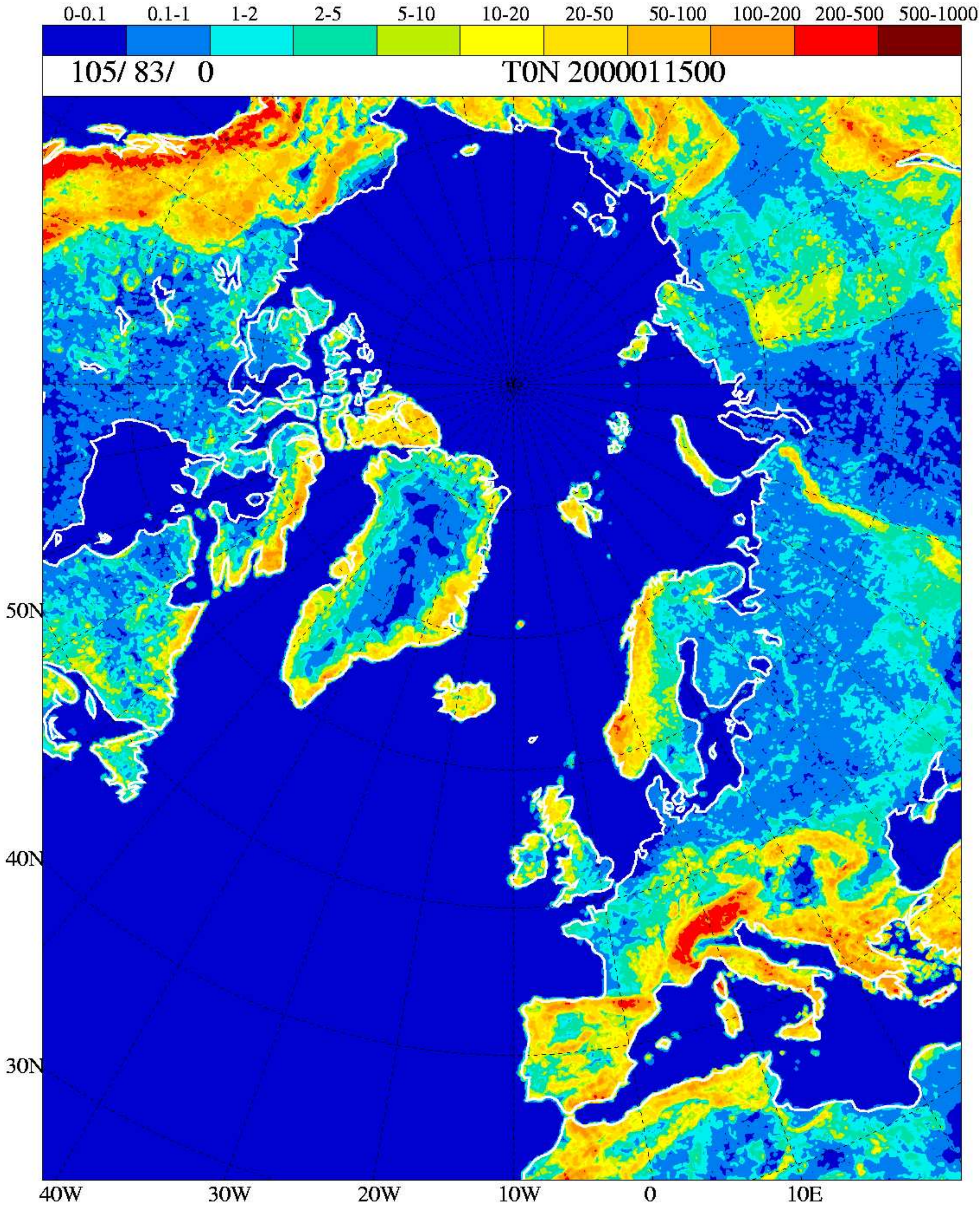


Figure 4: $z_{0,\mathrm{SSO}}$ in cm as aggregated using the non-linear method.

Climate generation developments for high resolution: A technical note on the new HDF sets

Kai Sattler, DMI

1 General

The HIRLAM climate generation makes use of topographic data from different data sources, which has been transformed to the Hierarchical Data Format (HDF, http://hdf.ncsa.uiuc.edu/). These topographic data are mainly based on the digital elevation model (DEM) of the GTOPO30 database (http://edcdaac.usgs.gov/gtopo30/gtopo30.asp) and the *Global Land Cover Characteristics* database GLCC (http://edcdaac.usgs.gov/glcc/glcc.asp). In addition, local data for the DEM and for the land cover may be added as HDF files. The idea behind using the HDF file format is to provide all data for the climate generation in a uniform format. This renders the climate generation itself much simpler. Another reason for introducing the HDF files is that the climate generation makes use of parameters, which are not directly available in the original data bases, and which have to be created in a preparational step. An overview on the HIRLAM climate generation can be found in Undén (2002), and The (1998) as well as The (2002) provide a technical description of the climate generation procedure.

With the release of the HIRLAM reference version 6.2.3 new HDF files are to be introduced (HIRLAM, 2004). These HDF files are collected in different sets (HDF sets) in order to facilitate ease of their use. The new HDF sets introduce the following new features:

- facilitate the non-linear calculation of the subgrid-scale orographic roughnes length (Sattler, 2004)
- support of surface type *ocean*
- almost global data coverage with a grid mesh size of 0.025°
- Europe is covered with a grid of mesh size of 0.0125°

The following sections give a technical description on the HDF sets and provide an overview over the data coverage as well as the data contents.

2 The HDF sets

The new HDF sets are based on the GTOPO30 elevation data and the GLCC land cover data version 2.1. There are three HDF sets available:

REG-0250 The regular set with 0.025° mesh size. This set represents the data on the regular geographic lat-lon grid with. The data covers the whole globe, but distortion becomes large towards the poles.

9000-0250 This set represents the data on a rotated grid, on which the south pole is located at the location 90° longitude and 0° latitude. The mesh size is 0.025°. The globe is almost completely covered, except the Galapagos Islands and a region in the Indian ocean. Grid distortion increases towards these two singularities.

9000-0125 This set represents the data on the same rotated grid as **9000-0250**. The mesh size is 0.0125°, however, and the covered area is restricted to Europe, Iceland and Greenland.

The data in each of the HDF sets is split into contiguous tiles, and the two HDF sets **REG-0250** and **9000-0250** contain similar data, but they differ in grid representation. The reason for employing two HDF sets for the global coverage is that the used grid representation is based on the georgraphic grid, which leads to growing distortions towards the two singularities at the repective poles. While the HDF set **REG-0250** is usefull over equatorial regions and low latitudes, the set **9000-0250** is more suitable in the polar regions and around the Greenwich meridian as well as over the date border.

The special HDF set **9000-0125** fully exploits the information content of the original data bases GTOPO30 and GLCC. Currently, only the most important areas related to the usual HIRLAM usage are supported in this high resolution.

Figs. 5, 6 and 7 show the coverage of the tiles for the three HDF sets, respectively. The labels within the tiles indicate a HDF set identifier, the approximate geographical coordinates of the tile centre and an indication of the mesh size. The labels are used within the file name structure for the respective HDF set.

3 HDF set contents

As already mentioned above the data in the HDF sets are split into contiguous tiles. For each tile there exist two HDF files: The first one includes data sets derived from the DEM (GTOPO30), and the other one includes data sets derived from the surface characterisics from GLCC. The data sets included in the HDF file for the DEM are listed in Table 3, and the data sets included in the HDF file for GLCC are listed in Table 4.

Table 3: Available data sets in the HDF file of the DEM.

Data set name	range	unit	Description
`landseamask`	$0-100$	%	fraction of land, no rivers or lakes
`height`	$\lesseqqgtr 0$	m	elevation
`dx2`	>0	1	(dh/dx)*(dh/dx)
`dy2`	>0	1	(dh/dy)*(dh/dy)
`dxdy`	>0	1	(dh/dx)*(dh/dy)
`points`	>0	1	number of subgrid points in grid pixel
`peaks`	≥ 0	1	number of subgrid elevation peaks in grid pixel
`sumheight`	≥ 0	m	elevation sum over all subgrid pixels
`sumsqheight`	≥ 0	m^2	squared elevation sum over all subgrid pixels
`area`	>0	m^2	grid pixel area

It should be noted that the data sets `landseamask` from the DEM and `landmask` from GLCC are derived from different data bases and by different criteria. While the first one is determined on basis of the *no data* indication of GTOPO30, the second is determined by summarizing the surface types for land from the underlying classification. Therefore there may occur differences at the coasts.

The data sets `dx2`, `dy2` and `dxdy` are for utilization in the derivation of the orography variables for the MSO scheme (Undén, 2002, ch. 3.7.4). The rest of the data sets from the DEM are utilized by the grid-consistent aggregation method for subgrid-scale orographic roughness length (Sattler, 2004).

The data sets in the HDF file of the surface characterisics from GLCC include an entry for each class of the *reduced Wilson and Henderson-Sellers surface types* (Bringfelt, 1996). The final data set `bats` represents the predominant surface type in terms of this classification.

Table 4: Available data sets in the HDF file of the GLCC.

Data set name	range	unit	Description
`landmask`	0-100	%	fraction of land, rivers and lakes identified
`cropland`	0-100	%	fraction of agricultural land cover
`grassland_short`	0-100	%	fraction of short grass land cover
`evergrn_needle`	0-100	%	fraction of evergreen neddle tree land cover
`decid_needle`	0-100	%	fraction of deciduous neddle tree land cover
`decid_broadleaf`	0-100	%	fraction of deciduous broadleaf tree land cover
`evergrn_broadleaf`	0-100	%	fraction of evergreen broadleaf tree land cover
`grassland_tall`	0-100	%	fraction of tall grass land cover
`desert`	0-100	%	fraction of desert land cover
`tundra/wetland`	0-100	%	fraction of tundra land cover
`cropland_irrig`	0-100	%	fraction of irrigated agricultural land cover
`semi-desert`	0-100	%	fraction of emi-desert land cover
`bogs`	0-100	%	fraction of bog land cover
`inland_water`	0-100	%	fraction of lake/river land cover
`ocean`	0-100	%	fraction of ocean cover
`evergrn_shrubs`	0-100	%	fraction of evergreen shrub land cover
`decid_shrubs`	0-100	%	fraction of deciduous shrub land cover
`forest_mixed`	0-100	%	fraction of mixed forest land cover
`forest/fields`	0-100	%	fraction of mixed open land and forest
`urban`	0-100	%	fraction of urban land cover
`bats`	1-20/99	1	index of predominant land cover class

4 Final Remarks

A description on how to utilize the new HDF sets is given in the HIRLAM release notes (HIRLAM, 2004). It should be noted that the new HDF sets demand significant resources in terms of disk space as well as memory when running the climate generation. Even though the data sets supply a contiguous coverage, it is highly recommended to allways check the produced climate files and to control whether the climate records include what is expected.

References

Bringfelt, B., 1996: Tests of a new Land Surface Treatment in HIRLAM. *Hirlam Tech. Rep.*, **23**, 72pp.

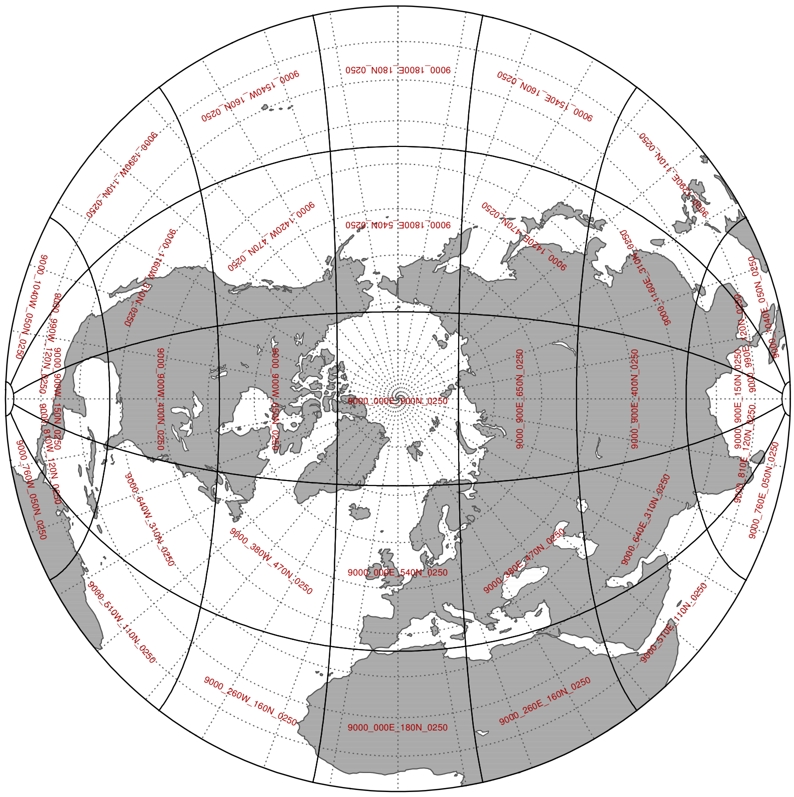
HIRLAM, 2004: Release notes of HIRLAM 6.2.3. Available from the HeXnet.

Sattler, K.; 2004: Non-linear aggregation of subgrid-scale orography roughness. *Hirlam Newsletter*, **45**, 124–133.

The, H., 1998: Revised routines for pre-processing the HIRLAM physiographic data sets (script Preps). *KNMI internal note*, 11pp.

The, H., 2002: Description of the Hirlam Climate system and CTOPO. Available from the HeXnet.

Undén, P., Rontu, L., Järvinen, H., Lynch, P., Calvo, J., Cats, G., 2002: HIRLAM-5 scientific documentation. HIRLAM-5 project SMHI Norrköping, 144pp.



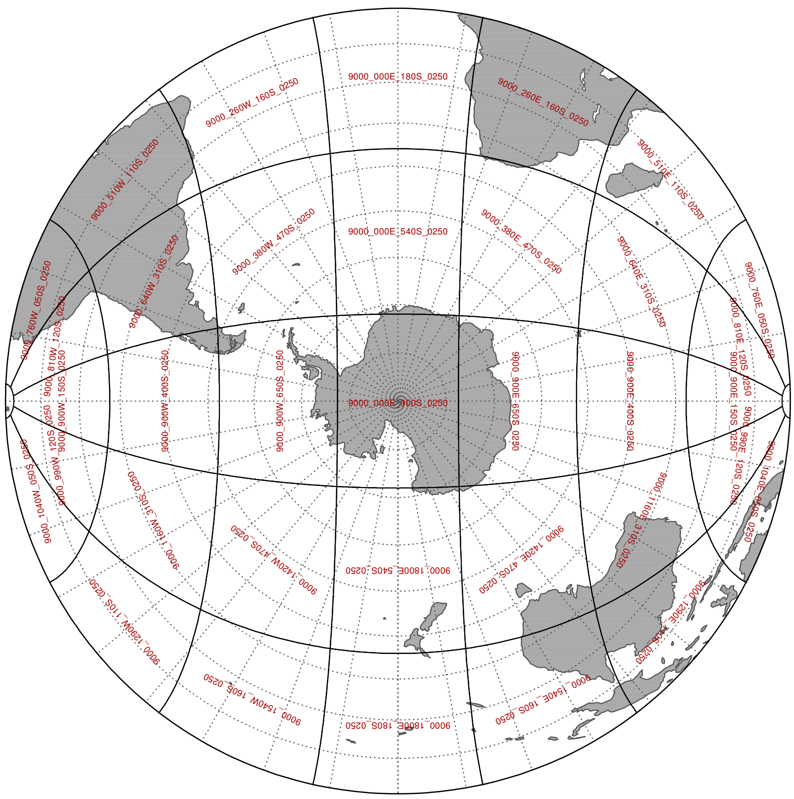


Figure 5: Areal coverage of the tiles from the HDF set **9000-0250** for the Northern hemisphere and the Southern hemsphere.

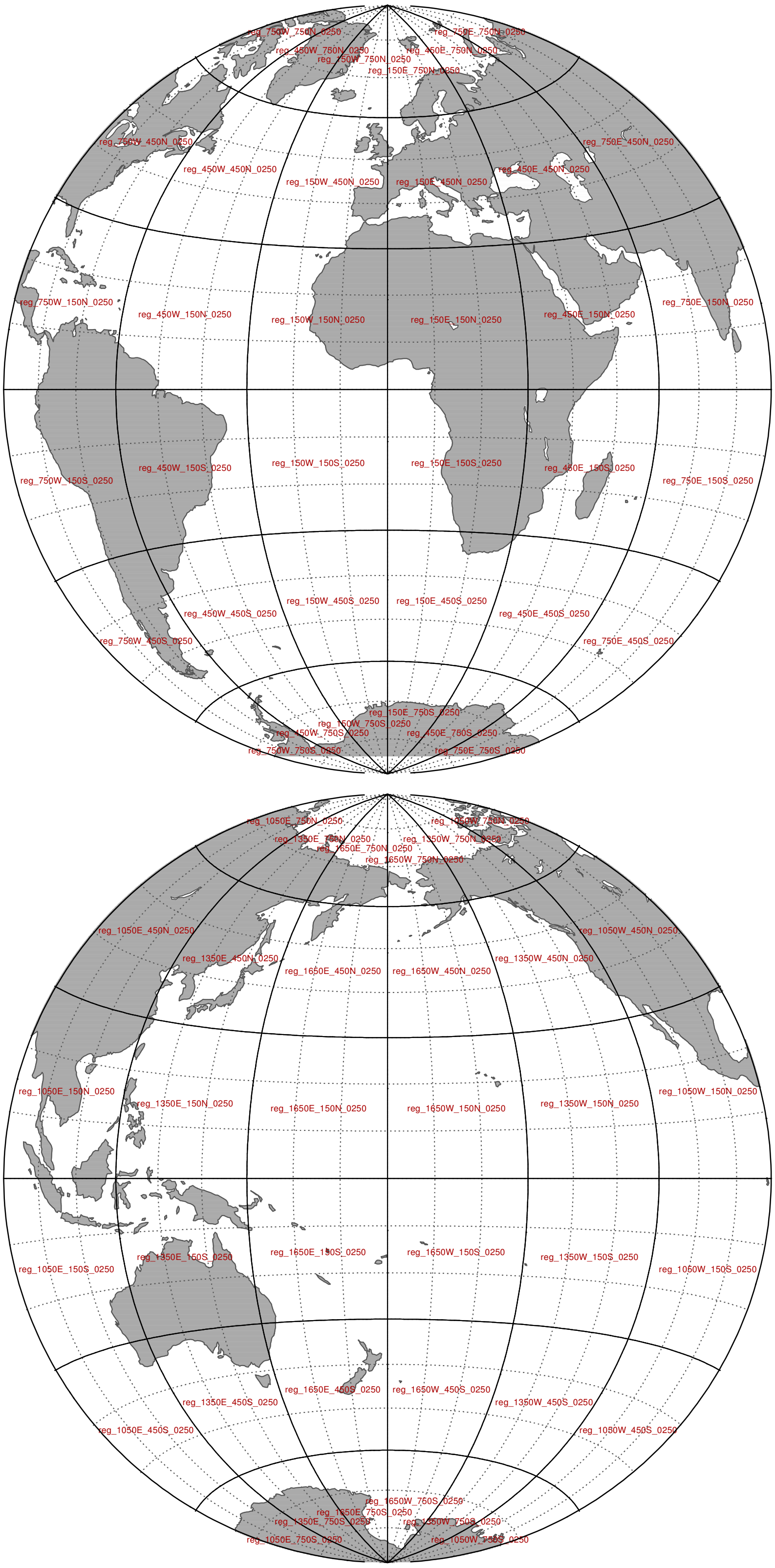


Figure 6: Areal coverage of the tiles from the HDF set **REG-0250** for the Atlantic and for the Pacific Ocean, respectively.

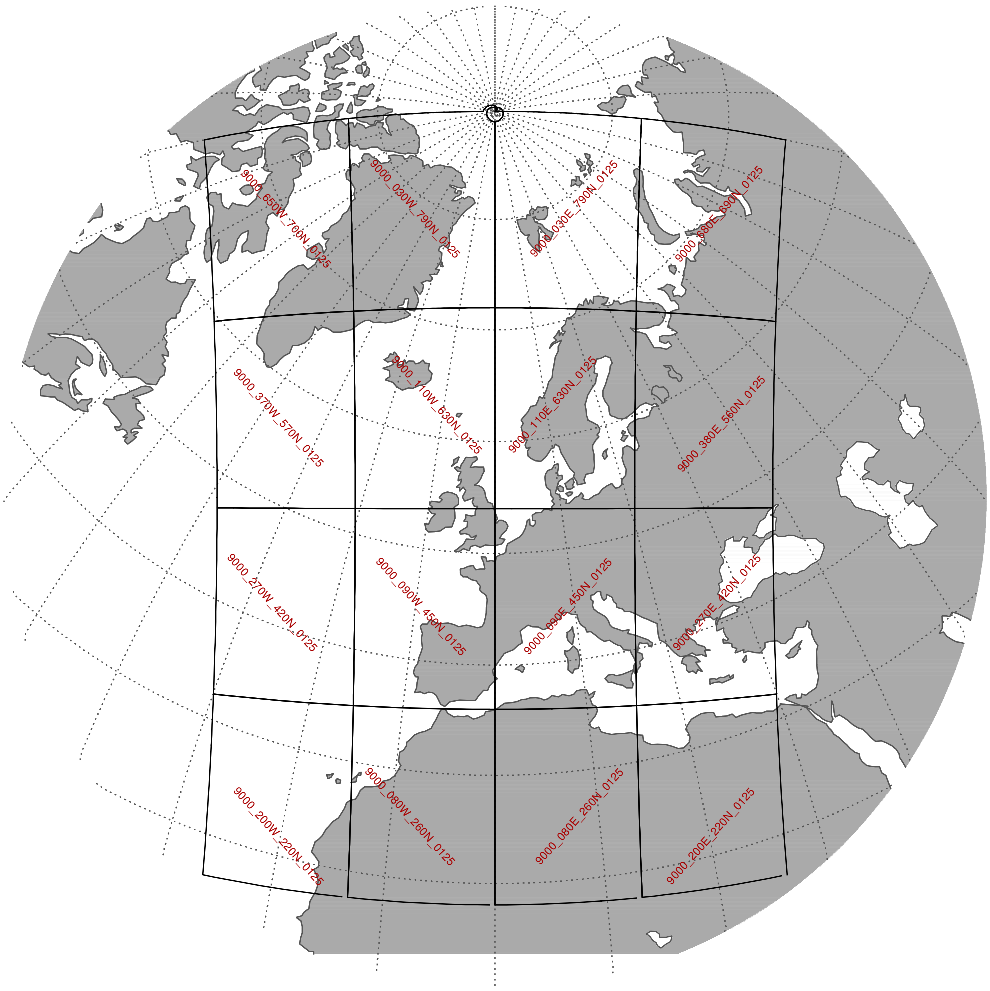


Figure 7: Areal coverage of the tiles from the HDF set **9000-0125**.