Fields in the clim files for ISBA (in combination with PGD)

Martina Tudor, Stjepan Ivatek-Šahdan and Antonio Stanešić

1 Introduction

Configuration e923 is used to create fields that contain so called climatological or constant fields. Some of these fields vary during the year and other are constant. The result are 12 monthly climatological files. The configuration e923 is executed in 8 steps, numbered 1 to 9, while the step number 7 is omitted in the standard procedure (it is related to the aqua planet simulations). A climatological file is created in the following 8 steps:

step 1 - definition of numerous fields describing orography and land-sea mask, depending on the namelist, few fields that describe topography can be created from a PGD file (using one database - the same as for SURFEX) while other fields are computed from the usual database (another one), creates one output file

step 2 - definition of surface, soil and vegetation characteristics without annual cycle, creates one output file, uses fields computed in the previous step and input,

step 3 - definition of monthly climatological values of soil temperature and moisture, modification of albedo and emissivity according to the climatology sea-ice limit, creates 12 output files, uses fields computed in the first two steps and input,

step 4 - definition of the vegetation characteristics and modification of several surface characteristics, uses fields computed in the first three steps and input,

step 5 - modification of fields created by step 2 or 4 over land from high resolution datasets for each month, uses fields computed in steps 1, 2 and 4 and input,

step 6 - modification of climatological values for soil temperature and moisture using "new" climatology, uses fields computed in steps 1 and 3 and input,

step 7 - modification of fields over the water surfaces (not run for usual e923)

step 8 - computes monthly fields of A, B and C coefficients for profiles of ozone

step 9 - computes monthly fields of aerosols (sea, land, soot, desert).

Steps 4 to 9 have to be run separately for each monthly file. Each step (except the first one) uses some of the fields created in previous steps as input. Additionally, there is Step 10, that is also run for the aqua planet and not used for common clim files.

2 Layout

Each step of the configuration e923 uses a number of input files (possibly more than 15 years old?) that contain different fields in different resolutions, some of the input files cover the whole globe, while other cover a smaller area and most of them use the output fields from the previous step. The default values for the covered area and resolution of the input files are set in incli0.F90, these default values are listed in Table 1, but can be changed in the namelist NAMCLI. Each step requires input files named in a prescribed way (the names are hardcoded

Table 1: Parameters change according to N923 value (step of 923). Finally, the values for NGLOBX/Y are set equal to NDATX/Y, and the resolution of input data EDLON/LAT is computed from NDATX/Y for datasets 1-4, 6, 8 and 9. The values for step 6 are modified in the namelist. The rest are using these default values.

N923	1	2	3	4	5	6	8	9
LIEEE	T	T	T	T	T	T	F	F
NDATX	8640	360	432	360	860	240	144	72
NDATY	4320	180	216	180	420	120	73	45
coverage	global	global	global	global	SW(-25,30)	global	global	global
Resolution (degrees)	0.042	1	0.83	1	0.1	1.5	2.5	5

in the subroutines) so the input files are copied from the source directories to the working directory with the required name before executing computations. Some steps would work (well, execute something) even without the input files (using only output from the previous step) and write the output file. Such steps simply check for the existence of the input files and execute particular computations only if the input file exists. The only indication of the missing input files would be in the NODE file. So some variables change and others do not, depending on the existence of the input files. Currently there are several high resolution files missing/not used in different steps. The computations related to all steps can be done using a single script. The only thing that changes is the namelist and mostly in a minimum way since each step requires different N923 in the namelist. The only exception is Step 6, where an alternative data set is used for input and the resolution of the input increased from 1.5 to 1 degree (longitude and latitude).

2.1 Step1 - topography

The novelty in e923 is the usage of PGD (fields from the SURFEX file). This allows using new topography from the new database. A PGD file is created using a separate script that has to be run before the step 1. Using the topography and land sea mask from the new file is invoked by setting LNORO=T in the namelist NAMCLA. If one wants to use new (alternative) land sea mask (LNLSM=T), one also needs to use the new topography file. If PGD topography is imported (LIPGD=T) in the Step 1 of e923, envelope is added to the topography using multiplication factor FENVN and the topography variance from the old database (topography variance is used from the different database than the database used for the topography in the PGD file).

The resulting clim files are created as a combinationi of topographies from several databases. As a consequence land-sea mask and height of topography are taken from one database (used for SURFEX), but proportion of land, standard deviation of orography and other parameters describing topography are taken from another database.

SURFIND.TERREMER is the land sea mask, can have only 2 values, values over land are fixed to 1, and 0 for water surfaces if the percentage of water surface over the area of the grid cell is greater than the SMASK parameter that can be controlled via namelist NAMCLI, and was set to 0.5. The "old" land sea mask is applied to correct the roughness length and compute the fraction of land, and the new percentage of water is read from the new file afterwards and used to compute the new land sea mask. But the contents of this new file is not used for the field describing the percentage of water (or land) in the grid cell nor to correct the fields that should have certain default values above the sea surface.

SURFPROP.TERRE is the field that describes the fraction of land in the gridbox. It is equal to 1 for purely land points, 0 for the sea points, and varies from 0 to 1 over the coastlines, land with small lakes and rivers. It should match the land sea mask field, but in the Step 1 it is taken from the old database, even if the land sea mask is taken from the new one. This field can have substantially different values. The proportion of land is used in the subsequent steps of the configuration e923. The values should be computed from the new database and put into the clim file before the subsequent steps of the configuration e923.

SURFGEOPOTENTIEL - terrain height as geopotential (height in meters multiplied by 9.81 m/s2) as a grid-point field and SPECSURFGEOPOTEN as its spectral counterpart. This field can include the effect of envelope, controlled by the parameter FENVN in namelist NAMCLA, and the height of surface H_s is computed according to:

$$H_s = H_{mean} + FENVN * H_{stdev} * (1 - P_{water}) \tag{1}$$

where P_{water} is the percentage of water in the grid cell (from the old database!) and H_{stdev} is standard deviation of topography described below, H_{mean} is the mean topography in the grid cell.

SURFET.GEOPOTENT is the standard deviation of sub-grid topography multiplied by g=9.81m/s2. This field is taken from the old database by the standard Step 1 of the configuration e923. It is computed as:

$$H_{stdev} = \sqrt{\sigma_H^2 + \sigma_h^2 + \frac{(H_{max} - H)(H - H_{min})}{4}} \tag{2}$$

where σ_H s the terrain variance resolved in the input file but not in the output topography (rather questionable what this is once the output resolution approaches the resolution of the input file), σ_h is the unresolved variance read from the Sigma input file, and $\frac{(H_{max}-H)(H-H_{min})}{4}$ is simly contents of the file Hmax-HxH-Hmin_ov4.

SURFVAR.GEOP.ANI is the anisotropy coefficient, it is equal to 1 for isotropic surfaces (sea) and varies from 0 to 1, where lower values mean that the terrain is particularly varying in one direction, but not in another. This field is computed using the fields taken from the old database by the standard Step 1 of the configuration e923. The output of eganiso is the square of the anisotropy coefficient. But in acdrag it is used as anisotropy (not the square value). The anisotropy γ and direction θ are computed as

$$\gamma^2 = \frac{P_1 + P_2 - \sqrt{(P_1 - P_2)^2 + 4P_3^2}}{P_1 + P_2 + \sqrt{(P_1 - P_2)^2 + 4P_3^2}} \tag{3}$$

$$\theta = atan\left(\frac{-(P_1 - P_2) + \sqrt{(P_1 - P_2)^2 + 4P_3^2}}{-2P_3}\right) - atan(\frac{gnordl}{gnordm}) \tag{4}$$

where

$$P_1 = \frac{\left(\frac{\partial H}{\partial x}\right)^2 \sigma_H^2}{\left(\frac{\partial H}{\partial x}\right)^2 + \left(\frac{\partial H}{\partial y}\right)^2} + \frac{\left(\frac{\partial h}{\partial x}\right)^2 \sigma_h^2}{\left(\frac{\partial h}{\partial x}\right)^2 + \left(\frac{\partial h}{\partial y}\right)^2} \tag{5}$$

$$P_2 = \frac{\left(\frac{\partial H}{\partial y}\right)^2 \sigma_H^2}{\left(\frac{\partial H}{\partial x}\right)^2 + \left(\frac{\partial H}{\partial y}\right)^2} + \frac{\left(\frac{\partial h}{\partial y}\right)^2 \sigma_h^2}{\left(\frac{\partial h}{\partial x}\right)^2 + \left(\frac{\partial h}{\partial y}\right)^2} \tag{6}$$

$$P_3 = \frac{\frac{\partial H}{\partial x}\frac{\partial H}{\partial y} \sigma_H^2}{\left(\frac{\partial H}{\partial x}\right)^2 + \left(\frac{\partial H}{\partial y}\right)^2} + \frac{\frac{\partial h}{\partial x}\frac{\partial h}{\partial y} \sigma_h^2}{\left(\frac{\partial h}{\partial x}\right)^2 + \left(\frac{\partial h}{\partial y}\right)^2} \tag{7}$$

SURFVAR.GEOP.DIR is the direction of the principal axis of topography (in radian). This field is computed using the fields taken from the old database by the standard Step 1 of the configuration e923. The angle of topography is computed from the components of the tensor and then the angle of the grid orientation is added so the final angle θ is not restricted to the range from $-\pi/2$ to $\pi/2$.

SURFZ0REL.FOIS.G is the roughness length of the bare surface multiplied by g=9.81m/s2, it can be scaled using an arbitrary parameter FACZ0 in the namelist NAMCLA, the experiments shown here used FACZ0=1. This field is computed using the fields taken from the old database by the standard Step 1 of the configuration e923. In e923, the surface roughness is computed as a combination of standard deviation and square root of the density of the number of peaks from both resolved and unresolved topography:

$$Z_{0ter} = \sigma_H \sqrt{\frac{N}{S}} + \sigma_h \sqrt{\frac{n}{S}} \tag{8}$$

where N is the number of resolved peaks (in the topography file), n is the number of peaks in the NB_peaks input file, and S is the surface of the grid cell.

2.2 Inserting fields from the new database to the clim file (after Step 1 is finished)

As mentioned before, only two of the fields describing topography are taken from the new database, and other fields are taken from the old one. Since the proportion of land had several strange features over the Adriatic after the Step 1 and not corrected in the subsequent steps so these features remained in the final clim files (Figure 1a, not-existent peninsulas along Italian coastline, rather messy Croatian coastline).

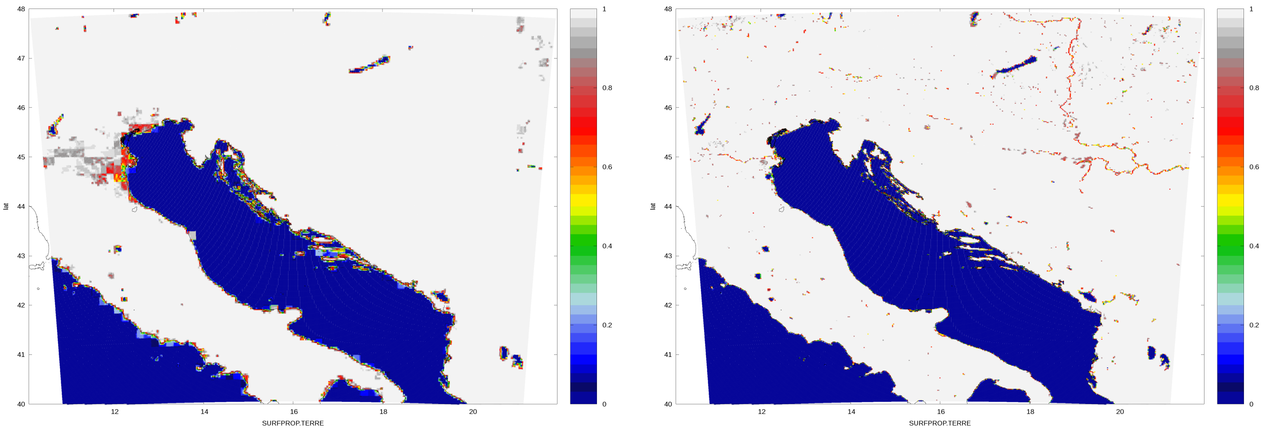

Figure 1: Proportion of land after the Step1 (a) and computed from the SURFEX PGD file (b). These figures show data for 2 km resolution domain.

Therefore an FA file was created from the SURFEX PGD file that had the same geometry as the Const.clim file and then the percentage of land was computed as:

$$P_{land} = 1 - P_{sea} - P_{water} \tag{9}$$

where P_{sea} and P_{water} are SFX.FRAC_SEA and SFX.FRAC_WATER. This field was inserted into the Const.clim file overwriting the old SURFPROP.TERRE field.

Furthermore, surface roughness for the bare land exhibited a chessboard pattern over the Alps and other mountains (Figure 2a, this feature became apparent only when the value of the roughness length was plotted as a small square on the position of the grid point), this was considered unnatural and could affect the forecast quality there.

As a first guess, this parameter was taken from the new database as the square root of the standard deviation of topography times g and the resulting field is shown in Figure 2b. One can immediately see much higher values above the mountains such as the Alps, but even more so above the mountains along the Croatian coastline that were rather smooth in the old clim files. The z0 field can be tuned together with the turbulence scheme. The Figures 2a and 2b show the roughness length in the clim file from the old database and the new field, the range of values in the new file is the same as the range in the old files.

Fields describing the anisotropy of topography and angle to the main axis were taken from the SURFEX PGD file. The anisotropy γ and the angle θ are computed in SURFEX as:

$$K = \frac{1}{2}\left(\left(\frac{\partial h}{\partial x}\right)^2 + \left(\frac{\partial h}{\partial y}\right)^2\right) \qquad L = \frac{1}{2}\left(\left(\frac{\partial h}{\partial x}\right)^2 - \left(\frac{\partial h}{\partial y}\right)^2\right) \qquad M = \frac{\partial h}{\partial x}\frac{\partial h}{\partial y} \tag{10}$$

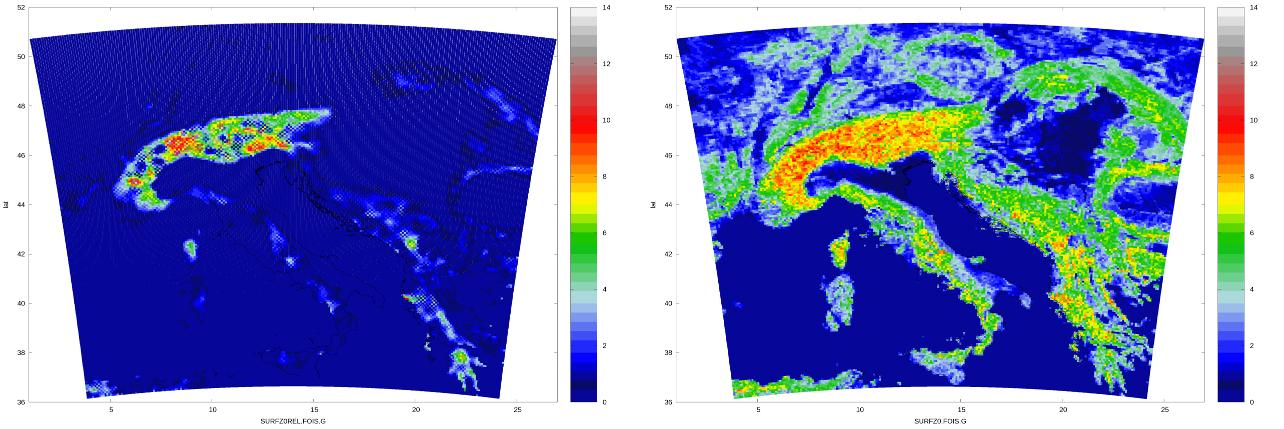

Figure 2: Surface roughness (a) and corrected field (b) in 8 km resolution (the values in the figures were divided by 9.81).

$$\theta = \frac{1}{2} atan\left(\frac{M}{L}\right) \qquad \gamma = \sqrt{\frac{K - \sqrt{L^2 + M^2}}{K + \sqrt{L^2 + M^2}}} \tag{11}$$

One can immediately see that the output is γ, not γ^2 as in e923. The anisotropy from e923 is shown in Figure 3a and from SURFEX in Figure 3b. Larger values means that the unresolved topography is more isotropic. Low values indicate that terrain is changing dominantly in one direction and the values above the sea should be 1 (isotropic surface). Since γ varies from 0 to 1, square of this field should yield lower values. This is why γ has higher values in Figure 3b than in 3a.

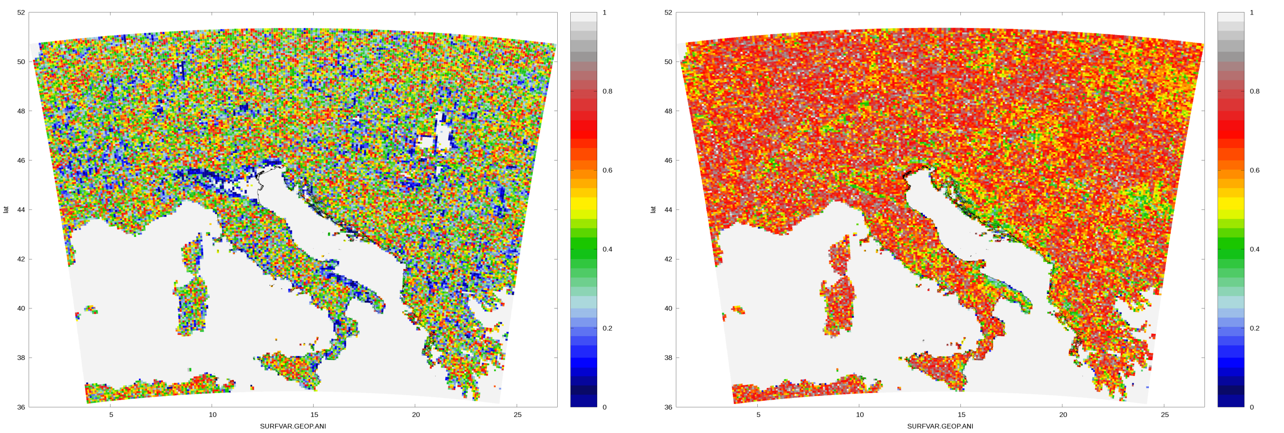

Figure 3: Anisotropy of unresolved topography in 8 km resolution, when computed by e923 from the old database (a) and taken from SURFEX (b).

In SURFEX θ is (according to the available documentation) defined as an angle to the x axis, positive northward and varies from -90 to 90. In code, θ is multiplied by 180/pi. Depending on the sign of L, the above θ is modified so that 90 degrees are added if L is negative and in the end, if the resulting angle is larger than 90 degrees, θ is reduced by 180 degrees. The link between the two θs (the one from e923 and another from SURFEX) is less transparent. Let's assume that one can identify the following:

$$K = \frac{1}{2}(P_1 + P_2) \qquad L = \frac{1}{2}(P_1 - P_2) \qquad M = P_3 \tag{12}$$

Then we start from the computations of θ in e923, how it is computed in eganiso, and insert the relations as defined above.

$$\theta = atan(\frac{-(P_1 - P_2) + \sqrt{(P_1 - P_2)^2 + 4P_3^2}}{-2P_3}) \tag{13}$$

$$\theta = atan(\frac{-2L + \sqrt{4L^2 + 4M^2}}{-2M}) = atan(\frac{L - \sqrt{L^2 + M^2}}{M}) \tag{14}$$

Since in SURFEX the angle θ is defined as one half of the arcus tangens function, one has to go to some basic trigonometic transformations. It is valid that:

$$atan(x) = \frac{1}{2}atan\frac{2x}{1-x^2} \qquad for \qquad |x| < 1 \tag{15}$$

$$atan(x) = \frac{\pi}{2} + \frac{1}{2}atan\frac{2x}{1-x^2} \qquad for \qquad x > 1 \tag{16}$$

$$atan(x) = -\frac{\pi}{2} + \frac{1}{2}atan\frac{2x}{1-x^2} \qquad for \qquad x < -1 \tag{17}$$

inserting this property (well the first line) into the above formula for θ, one gets:

$$\theta = \frac{1}{2}atan\frac{2\frac{L-\sqrt{L^2+M^2}}{M}}{1-\left(\frac{L-\sqrt{L^2+M^2}}{M}\right)^2} = \frac{1}{2}atan\frac{2\frac{L-\sqrt{L^2+M^2}}{M}}{\frac{M^2-(L^2-2L\sqrt{L^2+M^2}+L^2+M^2)}{M^2}} \tag{18}$$

$$\theta = \frac{1}{2}atan\frac{2M(L-\sqrt{L^2+M^2})}{-2L^2+2L\sqrt{L^2+M^2}} = \frac{1}{2}atan\frac{2M(L-\sqrt{L^2+M^2})}{-2L(L-\sqrt{L^2+M^2})} \tag{19}$$

$$\theta = -\frac{1}{2}atan\frac{M}{L} \tag{20}$$

Apparently the two angles are not defined the same way (the above derivation is valid if the absolute value of the argument of the arcus tangens function is less than unity). Let's see if it is possible to start from the SURFEX definition of θ and try to go back:

$$\theta = \frac{1}{2}atan\frac{M}{L} \qquad means \qquad \frac{M}{L} = \frac{2x}{1-x^2} \tag{21}$$

$$M - Mx^2 = 2Lx \qquad Mx^2 + 2Lx - M = 0 \tag{22}$$

$$x_{1,2} = \frac{-2L + -\sqrt{4L^2 + 4M^2}}{2M} = \frac{-L \pm \sqrt{L^2 + M^2}}{M} \tag{23}$$

The quadratic equation has two solutions. The one with a plus sign would correspond to the minus of the argument of the arcus tangens function got when starting from e923. Finally

$$\theta_{e923} = \theta_{surfex} \tag{24}$$

2.3 Step 2: Sand and Clay

This step calculates the following fields: dominant land use type, bare ground albedo (used in 3 fields), emissivity, maximum and useful depth of the soil column, percentages of clay and sand and maximum vegetation fraction.

SURFPROP.ARGILE - percentage of clay, varies from 3 (above the sea surface!) to 58, the field appears unnatural (Figure 5a).

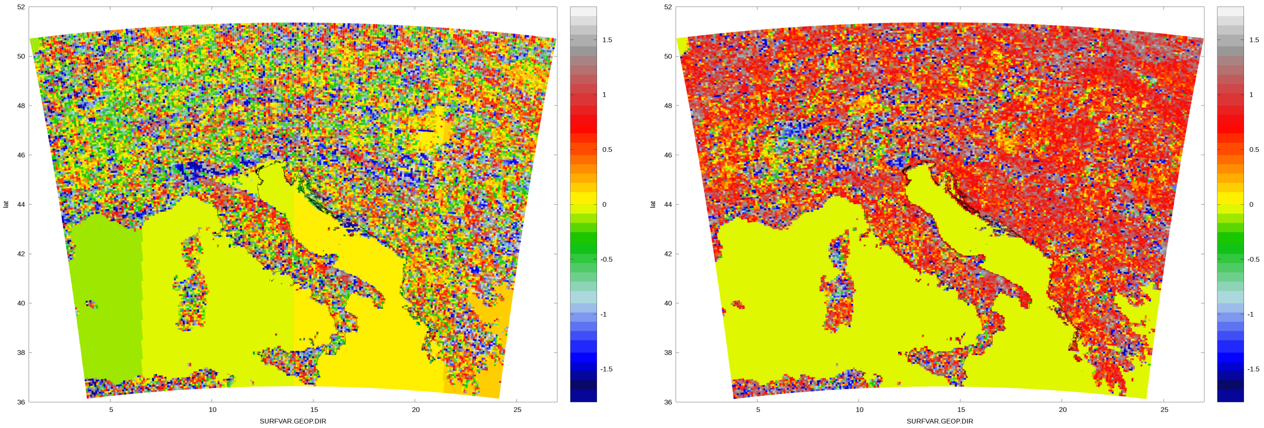

Figure 4: The angle of the main axis of topography with the x axis, θ in ISBA (a) and in SURFEX (b) recomputed to be in radians (but not multiplied by -1).

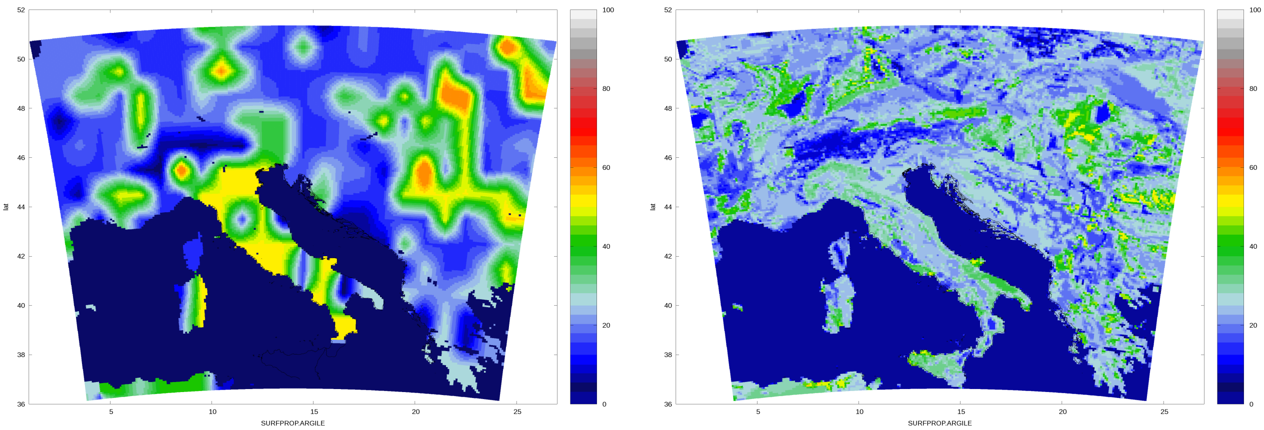

Figure 5: Proportion of clay in the clim file (a) and after the correction using data from the SURFEX PGD file (b).

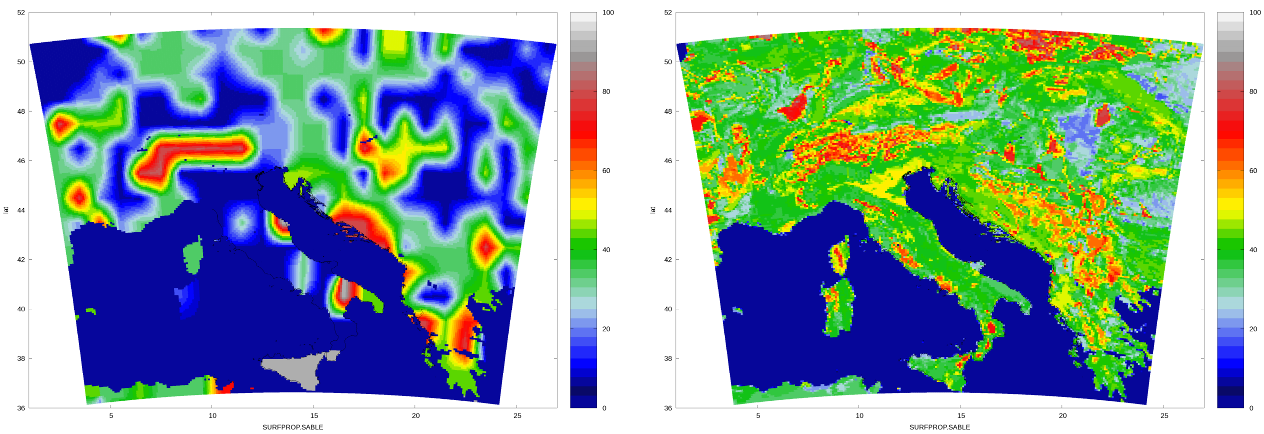

Figure 6: Proportion of sand in the clim file (a) and after the correction using data from the SURFEX PGD file (b).

SURFPROP.SABLE - percentage of sand, varies from 6 (above the sea surface!) to 92, the field appears unnatural (Figure 6a).

Both can be computed from the percentages of clay and sand from the SURFEX PGD file after correcting for the values above the sea (from 10^{20} to 0), limiting with the proportion of land and scaling with 100, the resulting fields are shown in Figureis 5b and 6b. These field could be modified by high resolution data in Step 5, but there are no input files.

3 Testing

The impact of modified roungness length was tested by running 31 forecasts in 8 and 2 km resolutions starting from 00 UTC for March 2016. The forecast of wind at 10m above fround depends on the roughness length. The introduction of new, rougher surface reduced the wind speed in cases with strong to severe bura wind (that blows fron northeast therefore from land to sea). The reduction in wind speed varies from place to place.

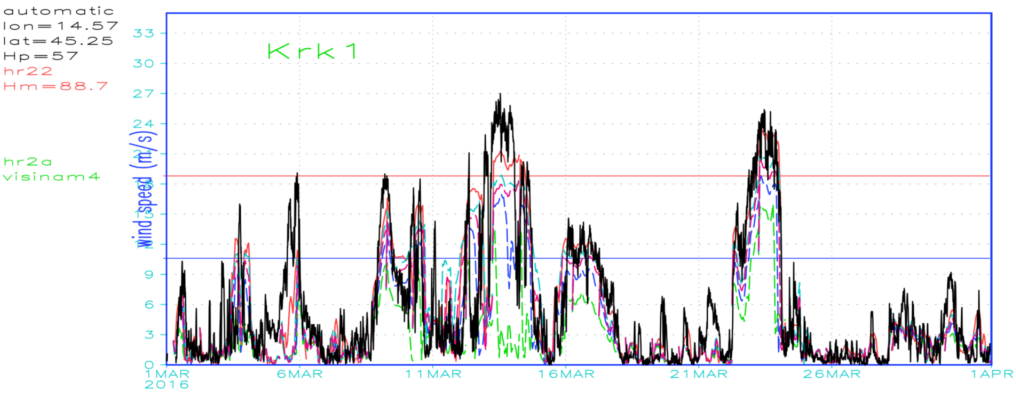

*Figure 7: Wind speed at 10m: measured (black), operational 2km NH forecast (red), using new z0 (green), new z0*0.5 (dark blue), new z=*0.25 (light blue) and new z0*0.33 (purple) for March 2016 station Krk bridge 1.*

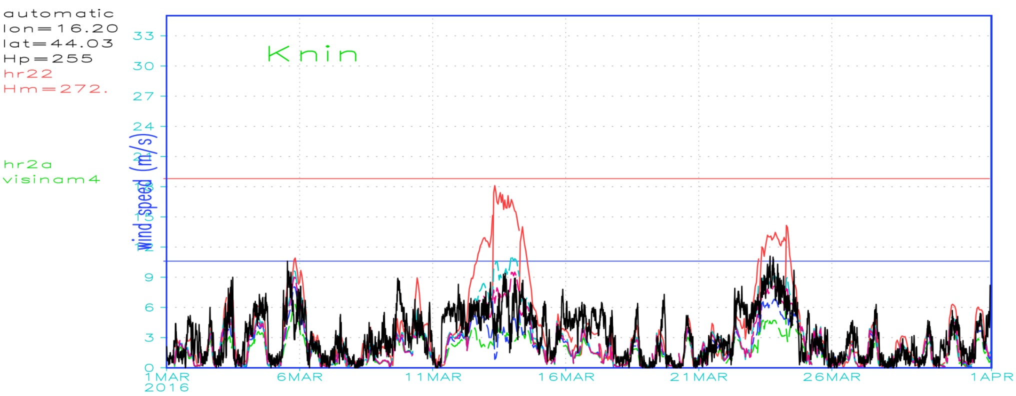

*Figure 8: Wind speed at 10m: measured (black), operational 2km NH forecast (red), using new z0 (green), new z0*0.5 (dark blue), new z=*0.25 (light blue) and new z0*0.33 (purple) for March 2016 station Knin.*

4 References

http://radar.dhz.hr/ tudor/clim/clim_vars.pdf http://radar.dhz.hr/ tudor/clim/e923_v2016.pdf