Answers from the SRNWP ET on surface processes to the SRNWP interoperability programme regarding surface issues

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Document written by J.-F. Mahfouf

Introduction : This document is the result of a number of discussions and information exchanges on current practices that took place during the first half of 2009, through email exchanges, during a NetFAM working week in Oslo (15-20 March) and during a working day of the SRNWP ET on surface processes (12^{th} June).

General recommendations : First, a number of general recommendations regarding the conversion of surface variables from one model (source) to be used in another model (target) are provided :

- The complexity of this conversion has been recognized together with its dependency with the surface physics described in both source and target models. The more different the surface physics is between the two models, the more difficult (and arbitrary) the conversion will be. Currently the surface parameterization schemes in SRNWP LAM models (+ECMWF global model) have important similar features that make "physical conversions" possible. However, it has been mentioned that this situation may evolve unfavourably in the future when more sophisticated surface parameterization schemes are included in SRNWP models.
- A consequence of the previous item ("model dependency" of the conversion), it that, when it is possible, the surface from the target model should be kept and that only atmospheric fields from the source model should be interpolated to the target model. This "blending technique" is already used by a number of consortia. However, it is not always possible to have surface initial fields in the target model (e.g. cold start runs over old reanalysis periods). The present document provides advices for such cases.
- The number of intermediate steps (interpolations) from the source grid to the target grid should be reduced as much as possible (e.g. the interpolation of the target climatological fields on the source grid as done in the ALADIN consortium with the so-called configuration "E901" is not recommended)
- The importance of ancillary data in addition to orography and land/sea mask on both target and source grids has been stressed (e.g. soil and vegetation properties) in order to allow "physical conversion" of the variables that need to be spatially interpolated.

Request 1 : Surface parameters and surface characteristics required to run the model

Three main categories :

Primary physiographic parameters that are provided from high resolution data bases

1. Land cover use
2. Orography
3. Soil types (textural classes)

Secondary soil and vegetation parameters that are deduced from the primary ones and averaged (different techniques: e.g. "flux-preserving" method) at model resolution

1. Land sea mask
2. Lake fraction / urban fraction
3. Soil depth

4. Vegetation properties (LAI, fractional cover, albedo, minimum stomatal resistance, root profile, ...)
5. Surface roughness, variance of orography, ...

Remarks : Some surface parameters can now be derived from (real-time) satellite products (e.g. LandSAF). Currently, these products are mostly used to derive monthly climatologies (slowly varying fields) but should be included in land data assimilation schemes in the near future (see discussion about that in the third point of the request). What is also important to mention is that the secondary parameters are very much "model dependent" and their use in a model where the land surface scheme is very different from the source model could be rather dangerous (see general recommendations). Instead, differences in surface parameters between source and target models can be accounted for by an appropriate scaling of the prognostic variables that drive the fluxes between the surface and the atmosphere.

Prognostic variables

1. Surface temperature (all types)
2. Soil temperatures and liquid/solid water contents
3. Sea-ice temperatures
4. Snow water equivalent
5. Interception reservoir

Request 2 : Appropriate way to initialise LAMs

The importance of the initialisation lies in the time scale of the relevant variables : the longer the time scale of a given prognostic variable with respect to short range forecasts (few days) is, the more necessary its initialisation will be. It is important to stress that the complexity of surface schemes is increasing and that the number of variables to initialize (and/or to prescribe) increases accordingly.

Usually the source grid is assumed to be at coarser resolution than the target grid, which is the "normal" configuration of a limited area model initialized from a global model, but it may be different for other applications envisaged in the SRNWP interoperability programme.

Definition of interpolated fields :

Surface fields that need to be interpolated from the native to the target grid :
1. Land sea-mask (0/1)
2. Surface orography
3. Surface temperature
4. Soil temperatures and liquid/ice water contents
5. Sea-ice temperatures
6. Snow water equivalent

Remark : Units of soil water contents are of importance : when considering (kg/m2) or (mm), the actual *depth of the soil* is accounted for. In order to avoid discrepancies in terms of soil depths between the source and target models it is recommended to use volumetric units (m3/m3). However, this "normalization" by the soil depth is not sufficient, since *soil textures* can also differ between the source and target models. An additional "normalization" has to be done by accounting for soil textural differences. Three main soil water content thresholds are usually defined in land surface schemes : *w_sat* (value at saturation : maximum amout of water a given soil can hold), *w_fc* (value

at field capacity : value above which evaporation is at potential rate), *w_wilt* (value at wilting point : value below which plant transpiration is assumed negligible).
Two scaling are possible : either with the saturation fraction *w/w_sat* or with the “soil wetness index” 'SWI defined as (*w*-*w_wilt*)/(*w_fc* -*w_wilt*). Since the SWI is more directly linked to evapotranspiration processes, using such variable for interpolation should lead to more similar evaporation fluxes between the source and target grids (but recognizing that during winter periods such scaling is less relevant).

Therefore, it is recommended not to use the soil moisture contents (either in volumetric units or in depths) for horizontal interpolation but to use the SWI that accounts for textural information and does not depend explictly upon the soil depth of the layer of interest. Once the SWI has been interpolated it can be transformed in a soil moisture content using the textural properties of the target grid. It is worth mentioning that the SWI is more relevant for the root-zone soil moisture and that other (more sophisticaled) scalings could be used for the deep soil layers or for the surface one using other surface properties such as the vegetation fraction or the ratio “R_smin/LAI” (minimum canopy resistance over leaf area index).

The snow can be interpolated in water equivalent (kg/m2)

Recommended variables for spatial interpolation :

1. Land sea mask
2. Surface orography
3. Surface temperature
4. Soil temperatures (several layers)
5. Sea-ice temperatures (several layers)
6. Soil wetness index (several layers) [ice/liquid or ice+liquid]
7. Snow water equivalent

The interpolation needs to be performed horizontally and vertically.

Vertical interpolation on fine intermediate grid

Since the vertical discretization of the soil (sea-ice) scheme can be different between the source and target grids, a vertical interpolation on a finer intermediate grid can be used (cruder techniques can also be applied since currently the number of vertical layers in most surface models is small). It is important to mention that for land surface schemes based on the “force-restore” method, no explicit model layers are assigned for soil temperature and superficial soil moisture. Arbitrary levels have to be specified in order to make a physical vertical interpolation when one of the schemes is not based in the “force-restore” method.

Horizontal interpolation

The horizontal interpolation needs to consider the land sea mask on the source and target grids in order to interpolate points of the same nature. For points that cannot be correctly interpolated by the standard method, the nearest data point of the same type has to be considered. The distinction between land and sea could be extended to other surfaces (urban areas, lakes, sea-ice, ...) : this should be appropriate when source and target grids have similar resolutions.

Vertical interpolation on the target grid

Once the horizontal interpolation is performed, the variables can be vertically interpolated from the fine intermediate grid to the soil (sea-ice) layers of the target grid.

Vertical adjustment to orography

The interpolated quantities are converted back into the actual prognostic variables needed by the land surface scheme of the target model. An adjustment to orography has to be performed in order take into account the difference between the orography on the source grid (interpolated on the target grid) and on the target grid.

This is important for :

1. soil temperatures that can be corrected according to a standard vertical gradient
2. snow water when the corrected surface temperature is above zero (melting required or decrease of surface temperature to maintain the snow mantle)
3. the partition between liquid and soil water contents that needs to be consistent with the soil temperature corrections (partial melting or freezing). Another possible approach : perform the interpolation on liquid+frozen soil amounts and split them empirically when corrected soil temperatures are known.

The current proposal by-passes the interception reservoir that can be considered as a very fast evolving prognostic variable (initialization to zero should be satisfactory).

It is worth mentioning the level of arbitrariness for some parts of these final consistency adjustments (e.g. definition of vertical gradients and thresholds).

Remark : The present approach only needs the interpolation of the orography from the source grid on the target grid.

Request 3 :Surface climatologies

A number of surface climatologies are used in SRNWP LAMs:

- surface temperature
- deep soil tempearture
- deep soil moisture content
- snow water equivalent

These fields are generally monthly values available at a rather coarse resolution (and with poor quality). They are used in order to prevent the deep soil variables evolving with long time scales from drifting. When possible their usage should be avoided through data assimilation.

Climatological fields such as (snow free) surface albedo or surface emissivity could be considered as relevant to this request. However, a number of features associated to these fields are “scheme dependent” (separation between bare soil and vegetation types; spectral dependency) for which it is difficult to provide general recommendations for interoperability.

In a not so distant future one can reasonably assume that real-time satellite products will be used for SRNWP :

- surface albedo
- leaf area index
- fractional vegetation coverage
- snow cover

As mentioned earlier, such satellite data have to be-processed to make them compatible with parameters required by the surface schemes, but their common origin would insure a rather high level of compatibility between models.