

# A Short Tutorial on Using the option ISBA-MEB for SURFEX-V8.1

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# 1 Setting up the namelist

## 1.1 Overview

This document provides a short tutorial on using the ISBA-MEB option within SURFEX. Currently, this document corresponds to SURFEX-v8. For a model description see Boone *et al.* (2017). For details on the forest litter parameterization and evaluation at the local scale see Napoly *et al.* (2017). All namelist references herein refer to the file OPTIONS.nam.

## 1.2 NAM\_MEB\_ISBA

For SURFEX-v8.1, MEB can only be activated for forest-type patches. Activation of MEB is controlled by setting the logical vector LMEB\_PATCH = T for each specific patch within NAM\_MEB\_ISBA.

Note again that MEB has been tested for forest patches only, so using MEB for any other vegetation covers should be considered as research or experimental. The code prevents one from using MEB for low covers, however, it is not difficult to modify slightly the code to use MEB for non-forest vegetation patches: as of 2019, several researchers and groups are testing MEB for low vegetation covers. Technically it should work, but some parameters in the model might need to be adapted for low covers. You have been warned!

For example, to activate MEB for forest patches only (the current recommendation unless you are researching using MEB for non-forest covers), if NPATCH=12, this corresponds to setting LMEB\_PATCH = T for patches 4, 5 and 6 (broadleaf deciduous, needleleaf evergreen, and broadleaf evergreen, respectively) and LMEB\_PATCH should be = F for all other patches. The same logic holds true for NPATCH=19. Here is an example namelist for a 12-patch configuration using MEB for class 5 (forest) and class 10 (grass):

```
&NAM_MEB_ISBA  LFORC_MEASURE = .TRUE.,  
  
  LMEB_PATCH    = .F., .F., .F., .F., .T., .F.,  
                .F., .F., .F., .T., .F., .F.,  
  
  LMEB_LITTER   = .T.,  
  
  LMEB_GNDRES   = .F.  
/
```

Note that litter has also been activated in the above example (NOTE currently one can activate either litter or the ground resistance, but not both at the same time). For the next version of SURFEX, LMEB\_LITTER and LMEB\_GNDRES will also be patch dependent (vectors). Thus, currently litter or the ground resistance, when activated, apply to all of the MEB patches.

For NPATCH=19, the forest classes have slightly different (more specific) definitions and correspond to patches 4-6 (temperate broadleaf cold-deciduous summergreen, Boreal needleleaf evergreen, and tropical broadleaf evergreen, respectively) as before, and also 13-17 (tropical broadleaf deciduous,

temperate broadleaf evergreen, temperate needleleaf evergreen, boreal broadleaf cold-deciduous summergreen, and boreal needleleaf cold-deciduous summergreen, respectively).

For NPATCH=20 (ECOCLIMAP-SG), the forest classes are different compared to the original ECOCLIMAP (above) and corresponds to patches 4-11 (boreal broadleaf cold-deciduous summergreen (TREE), temperate broadleaf cold-deciduous summergreen (TREE), tropical broadleaf deciduous (TREE), temperate broadleaf evergreen (TREE), tropical broadleaf evergreen (EVER), boreal needleleaf evergreen (CONI), temperate needleleaf evergreen (CONI), boreal needleleaf cold-deciduous summergreen (CONI), respectively, and 19 (flooded trees). Note that MEB has yet to be tested for ECOCLIMAP-SG.

### 1.2.1 Surface litter and additional ground resistance options

LMEB\_LITTER is also now (SFXv8.1) a logical vector used to activate the forest litter option (the current default is FALSE if unspecified). Litter currently is assumed to cover the entire patch in which it is activated. Thus, the below-forest energy budget is computed at the top of this layer (not the soil). It acts as a soil layer for thermal diffusion, and a bucket-type reservoir for hydrology (both with properties unique to litter). See Napoly *et al.* (2017). for more information. Despite the fact that it is set by default to FALSE., our tests indicate that for forests, it nearly always improves results, notably the sensible heat flux by improving/reducing the ground heat flux and for snow covered areas. Thus we strongly recommend that the user sets LMEB\_LITTER = T for forest patches.

LMEB\_GNDRES is also now (SFXv8.1) a logical vector used to activate the baresoil resistance. Ground evaporation becomes

$$E_g = \frac{\rho_a [h_u q_{sat}(T_{g,1}) - q_a]}{R_a + R_g} \quad (1)$$

where  $R_a = 1/(V_a C_H)$  and  $R_g$  is the soil resistance (Boone *et al.*, 2017). If LMEB\_GNDRES = F then  $R_g = 0$  and we obtain the ISBA classic soil evaporation (Noilhan and Planton, 1989). The current default is LMEB\_GNDRES = F if unspecified. Note that currently if LMEB\_LITTER = T, then since the soil is covered by litter this resistance is not used so that in pgd\_isba.F90 LMEB\_GNDRES = F (over-riding the user choice of T). As a general rule of thumb, the ground resistance has certain numerical advantages ( $E_g \rightarrow 0$  as  $R_g$  becomes large) and in this sense behaves like the stomatal resistance in the transpiration computation. Most LSMs use such a formulation alone (akin to  $h_u = 1$ ) or in combination with  $h_u$  (as here). In terms of physics, this formulation was developed for a site in the central US, and thus it's globality could be questioned (in terms of form but especially parameter values). But in the absence of a better method, an option for this standard method is included in MEB.

### 1.2.2 Forcing or reference level heights

LFORC\_MEASURE = T should be used for local scale offline tests. This implies that the forcing height provided at ZREF (defined in file Params\_config.txt or in the FORCING.nc file) is safely above the vegetation height XUNIF\_H\_VEG (defined in NAM\_DATA\_ISBA). Note that when LFORC\_MEASURE = T, ZREF corresponds to the height above the ground ( $z=0$ ).

LFORC\_MEASURE = F is generally reserved for fully coupled (with a host atmospheric model) usages of MEB. It can also be used when running in OFFLINE mode for many points using ECOCLIMAP as input. In this option, the effective surface corresponds to the displacement height (which is implicitly zero). It is somewhat analogous to the classic composite soil-vegetation approach in ISBA.

This is to avoid problems when the lowest atmospheric level (for prognostic variables) falls below the vegetation height.

A final option exists (in SURFEXv8.1): if LFORC\_MEASURE = T but the reference level is below the canopy height. If this is the case, the reference heights for heat (moisture) and momentum ( $z_{a,ref}$  and  $z_{u,ref}$ , respectively) for a given patch is adjusted locally for the turbulence computation:

$$z'_{a,ref} = H_{veg} + \delta z_{min} \quad (2)$$

$$z'_{u,ref} = H_{veg} + \delta z_{min} + (z_{u,ref} - z_{a,ref}) \quad (3)$$

if  $z_{a,ref} - H_{veg} \leq \delta z_{min}$ , and  $H_{veg}$  is the vegetation height. Note we have assumed that  $z_{u,ref} \geq z_{a,ref}$ . The factor  $\delta z_{min} = 2$  m (to ensure a safe distance between the reference and canopy top heights: this value is the usual reference height for heat). The last factor on the RHS of Eq. 3 is to conserve  $z_{a,ref}$  and  $z_{u,ref}$  differences in the original input data. Currently, this seems to be the preferred method for spatially distributed offline forcing. For example, this is essentially the method currently used in the Common Land Model (CLM) coupled to the NCAR GCM (Lawrence *et al.*, 2011: section 2.6.3). They argue that one advantage of this approach is that the atmospheric reference height be above  $z_0 + d$  for all patches, thus the fluxes are consistently determined over the same surface layer thickness. The second advantage is that there is no restriction on the thickness of the lowest model layer of the atmospheric model (it can be less than the tree height,  $H_{veg}$ ). This is one solution, almost any solution poses theoretical problems (such as conflicts with surface layer MO theory): this seems to be the best and most simple compromise currently.

### 1.3 NAM\_ISBA

Here we define variables which are specific to MEB. Variables not mentioned herein are assumed to have their usual meaning (although a few variables are mentioned here for emphasis).

The main activation flag for MEB is defined by LMEB = T (the default is LMEB = F). Please note that by default, MEB uses the TR\_ML radiation scheme (Carrer *et al.*, 2013), so that when LMEB = T, LTR\_ML = T automatically in SURFEX. When MEB is not in use, LTR\_ML = T only when one of the Ags options is activated (NAM\_ISBA:CPHOTO has any value other than NON). MEB can be used with CPHOTO=NON or AST (ISBA-Ags photosynthesis). Note that NIT is currently being tested (thus it is permitted and it has been coded, but evaluation is ongoing: You have been warned!). Note that other Ags (CPHOTO) and ISBA-CC options have yet to be tested, thus they currently should not be used with MEB. Work is ongoing to be able to use MEB with all of the CC options.

One can use CISBA = DIF or 3-L currently. Generally speaking, it is advised to use CISBA = DIF (since this is the general tendency moving forward: it permits a higher vertical resolution modeling of soil processes and freeze-thaw, a potentially deeper frozen soil, and a more realistic coupling with the explicit snow scheme (see the next section). But, the 3-L Force-Restore hydrology option is still valid.

A typical example for MEB+DIF+ES+AST (recommended options) might be (for a non-default 20-layer soil):

```
&NAM_ISBA
      XUNIF_CLAY      = 0.30      ,
      XUNIF_SAND      = 0.60      ,
      XUNIF_RUNOFFB   = 0.0       ,
```

```

XUNIF_WDRAIN = 0.000 ,
CPEDO_FUNCTION= 'CH78' ,
CALBEDO = "DRY" ,
CISBA = 'DIF' ,
CPHOTO = 'AST' ,
LTR_ML = .true. ,
NPATCH = 12 ,
LMEB = .true. ,
NGROUND_LAYER = 20 ,
XSOILGRID=
0.01,0.03,0.06,0.10,0.20,0.30,0.45,0.60,
0.80,1.00,1.25,1.50,2.00,2.50,3.00,4.00,
5.00,6.50,8.00,10.0

```

/

## 1.4 NAM\_SURF\_CSTS

For MEB, there is a single new parameter, XTAU\_LW. This controls the so-called viewing factor for longwave radiation transmission, and it is also used for snow interception (within the canopy). The default value is 0.4. A literature survey reveals a large range in values, but this is a seemingly general value so it is adopted here. Future work could be to possibly define this value. For example:

```

&NAM_SURF_CSTS XTAU_LW = 0.4
/

```

## 1.5 NAM\_PREP\_ISBA\_SNOW

Note that CSNOW must be set to 3-L currently. This means that MEB can only be used with the explicit snow scheme option (ISBA-ES). Details on the most recent version of ISBA-ES (typically used in evaluation of MEB) can be found in Decharme *et al.*, (2016). Because the canopy is now separate from the vegetation, the vegetation snow cover fraction from the composite soil-vegetation version of ISBA,  $p_{snv}$ , is not used within MEB (since MEB has an explicit canopy). Vegetation can only be buried if the vegetation height is literally below the snow depth (so generally for non-forest classes). One can also use use LSNOW\_FRAC\_TOT = T with MEB (indeed, it is more conceptually accurate for MEB than with the composite scheme for forests). Mthe best snow simulations tend to be realized with this option.

Note that work is ongoing to couple the CROCUS scheme to MEB (CISBA = CRO): the same coupling logic is used.

## 1.6 NAM\_DATA\_ISBA

Here are some recommended settings (based on testing thus far). It is recommended to set XUNIF\_Z0\_O\_Z0H = 2.7 (i.e.  $\ln(1)$  based on a literature review) for forest patches. For low vegetation covers, the best

value it yet to be known. The usual default value in SURFEX is 10., however, this was using the composite approach. In some preliminary tests for forest patches, it has been found that while not greatly impacting the turbulent fluxes, it has a significant impact on the LWnet, and generally improves it.

The MEB litter option currently has two namelist parameters. XUNIF\_GNDLITTER is the litter layer thickness (m). It can be USER-specified in the namelist, as a general rule of thumb, the litter should be 0.01 to 0.10 m thick. In the V8 release of SURFEX, the default is 0.03 m (if not specified in the namelist). Note that extremely thin litter layers might possibly pose numerical problems, thus it's probably a good idea to limit it at 0.01 m. One can potentially put a seasonal evolution into the namelist. Testing will continue.

XUNIF\_Z0LITTER is the sub-forest canopy litter layer roughness. This corresponds to the ground roughness when the litter option is activated. The litter roughness is similar in magnitude to a soil roughness, and is generally 0.025 m (default if not specified in the namelist). One can potentially put a seasonal evolution into the namelist.

One must set XUNIF\_VEGTYPE such that it corresponds with NAM\_MEB\_ISBA:LMEB\_PATCH (where the sum of XUNIF\_VEGTYPE for each grid point is equal to one). XUNIF\_H\_VEG must be set, and corresponds to the vegetation height within MEB.

In terms of albedo components, note that in MEB, currently only two spectral bands are considered for soil and vegetation albedos (NIR and VIS). Thus, the definition of UV is currently arbitrary.

XUNIF\_Z0 is the vegetation canopy roughness. It should be consistent with the definition of XUNIF\_H\_VEG (using the standard known empirical relationships...for many cases, one can assume

$$z_0 = 0.13 H_{veg} \quad (4)$$

i.e. XUNIF\_Z0 = 0.13 XUNIF\_H\_VEG for example.

When the litter option is activated, XUNIF\_ALBVIS\_SOIL and XUNIF\_ALBNIR\_SOIL correspond to the albedo of the litter layer. Finally, XUNIF\_GNDLITTER=0 corresponds to baresoil beneath the vegetation, thus the XUNIF\_ALBVIS\_SOIL and XUNIF\_ALBNIR\_SOIL values revert to their original soil definitions, and XUNIF\_Z0LITTER corresponds to a soil surface.

As a final note, the fractional vegetation concept in the composite ISBA model (using the vegetation fraction  $veg$ ) for splitting evaporation into the vegetation,  $E_v$ , and soil,  $E_g$ , components (in addition to other fluxes and for aggregating certain parameters, etc.) is not used in MEB. Thus, the value of XUNIF\_VEG is arbitrary (i.e. it is not used by MEB). Note however that currently there is a known bug so this parameter must be set to a non-zero (arbitrary) value for now so that the soil albedos are allocated and defined (in the non-MEB version of ISBA, if XUNIF\_VEG=0, then these variables are not allocated: they are always needed by MEB).

## 1.7 References

Boone, A., S. Samuelsson, S. Golvik, A. Napolly, L. Jarlan, E. Brun, and B. Decharme, 2017: The Interactions between Soil-Biosphere-Atmosphere (ISBA) land surface model with a multi-energy balance (MEB) option in SURFEXv8 - Part 1: Model description. *Geoscientific Model Development*, **10**, 1–30. doi:10.5194/gmd-10-1-2017

Decharme, B., E. Brun, A. Boone, C. Delire, P. Le Moigne and S. Morin, 2016: Impacts of snowpack properties and soil organic carbon content on snow characteristics and soil temperature profiles simulated by the ISBA land surface model. *The Cryosphere*, **10**, 853–877. doi:10.5194/tc-10-853-2016

Lawrence, D. M., K. W. Oleson, M. G. Flanner, P. E. Thornton, S. C. Swenson, P. J. Lawrence, Xubin Zeng, Z.-L. Yang, S. Levis, Koichi Sakaguchi, G. B. Bonan and A. G. Slater, 2011: Parameterization Improvements and Functional and Structural Advances in Version 4 of the Community Land Model, *J. Adv. Model. Earth Sys.*, **3**, doi:10.1029/2011MS00045

Napoly, A., Boone, A., P. Samuelsson, S. Gollvik, E. Martin, R. Seferian, D. Carrer, B. Decharme, L. Jarlan, 2017: The Interactions between Soil-Biosphere-Atmosphere (ISBA) land surface model Multi-Energy Balance (MEB) option in SURFEX - Part 2: Model evaluation for local scale forest sites. *Geoscientific Model Development*, **10**, 1621–1644. doi:10.5194/gmd-10-1621-2017

Noilhan, J. and S. Planton, 1989: A simple parameterization of land surface processes for meteorological models. *Mon. Wea. Rev.*, **117**, 536–549.