Problem with diffusion scheme

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In the following document we describe the problem found when running the offline version of the externalized surface code with diffusion scheme over nature. A possible solution is given however more analysis is needed to complete the work.

The problem appears if one runs the code with diffusion scheme and the ice content of the ground is high. In this case the temperature drops too much (near -60 degree of Celsius) in the beginning of integration and grows to the observed value just after the ice was melted. This behavior was not observed when the 3 layer force-restore scheme was used, see fig. 1.

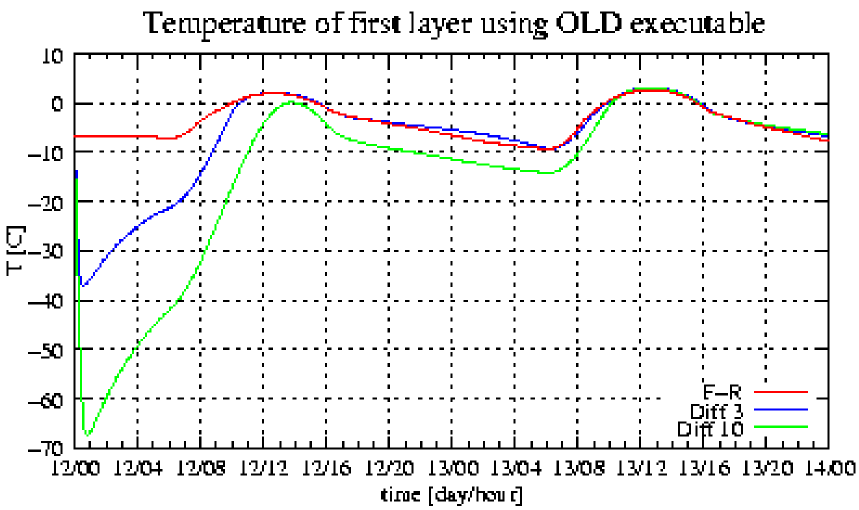

Figure 1: Time evolution of first layer temperatures for FR scheme (red), diffusion scheme with 3 layers (blue) and diffusion scheme with 10 layers (green).

The origin of the problem comes from the initialization of the water and ice content. The initialization procedure is the same for force-restore and for diffusion scheme but for diffusion scheme this seems to be inconsistent with the calculation used for melting/freezing procedures. So in case of diffusion surface scheme one should recalculate the water and water equivalent ice content to be consistent with the calculation used in *ice_soildif* routine.

The best place for the recalculation is in routine *init_isban.f90*. The water content is initialized by the **PREP** executable. This initialization process is not changed. When running the **OFFLINE** the XWG and XWGI arrays (water and water equivalent ice content respectively) are read from file PREP.txt and should be recalculated as following:

$$
\begin{aligned}
w_{tot} &= w_l + w_i \\
\psi_{max} &= \frac{L_f(T - T_f)}{gT}, \text{ and } \psi_{max} < \psi_{sat} \\
w_{l,max} &= w_{sat}\left(\frac{\psi_{max}}{\psi_{sat}}\right)^{-1/b} \\
w_l &= \max\left\{w_{l,max}, w_{l,init}\right\}, \text{ and } w_l \le w_{tot} \\
w_i &= w_{tot} - w_l
\end{aligned}
$$

Which is done in the code in routine *init_isban.f90* as follows:

```
!*       8.     Prognostic and semi-prognostic fields
!               -----------------------------------
!
CALL READ_ISBAn(HPROGRAM)
!the recalculation is inserted after this line
IF (CISBA=='DIF') THEN
   ALLOCATE( ZWGTOT (ILU,NGROUND_LAYER))
   ALLOCATE( ZPSIMAX(ILU,NGROUND_LAYER))
   ALLOCATE( ZWGMAX (ILU,NGROUND_LAYER))
   DO JPATCH=1,NPATCH
      DO JLAYER=1,NGROUND_LAYER
        ZWGTOT (:,JLAYER) = XWG(:,JLAYER,JPATCH) + XWGI(:,JLAYER,JPATCH)
        ZPSIMAX(:,JLAYER) = MIN( XMPOTSAT(:,JLAYER), &
                       &    XLMTT*(XTG(:,JLAYER,JPATCH)-XTT)/(XG*XTG(:,JLAYER,JPATCH)) )
        ZWGMAX (:,JLAYER) = XWSAT(:,JLAYER)* &
                       &   ((ZPSIMAX(:,JLAYER)/XMPOTSAT(:,JLAYER))**(-1./XBCOEF(:,JLAYER)))
        XWG (:,JLAYER,JPATCH) = MIN( MAX( XWG(:,JLAYER,JPATCH), ZWGMAX(:,JLAYER) ), &
                       &        ZWGTOT(:,JLAYER) )
        XWGI(:,JLAYER,JPATCH) = ZWGTOT(:,JLAYER) - XWG (:,JLAYER,JPATCH )
      END DO
   END DO
   DEALLOCATE(ZWGTOT)
   DEALLOCATE(ZPSIMAX)
   DEALLOCATE(ZWGMAX)
END IF
```

When running with the new executable (modified *init_isban.f90*) the time evolution of the first layer temperatures in case of diffusion scheme are much closer to the force-restore scheme's result. (3 layer and 10 layer diffusion scheme were used). At the beginning of the integration however there is still some kind of transient behavior especially in case of 3 layer diffusion scheme, see fig. 2.

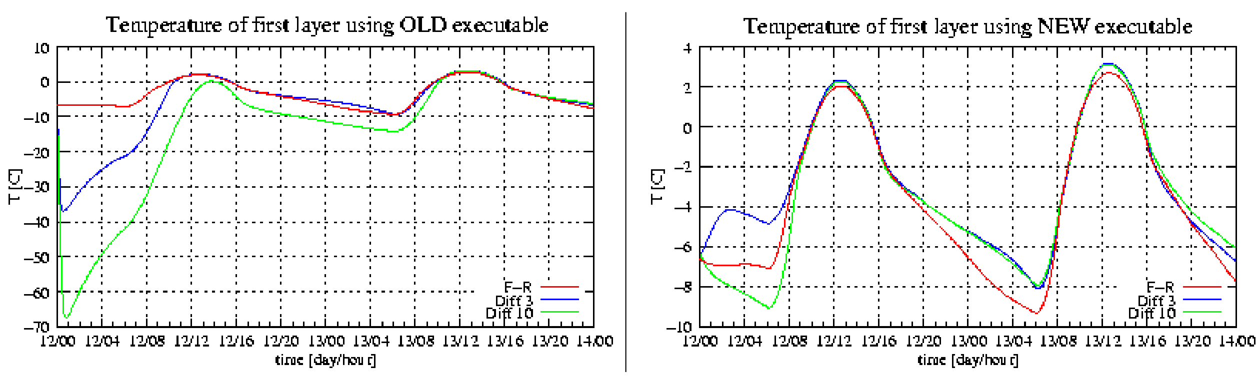

Figure 2: Time evolution of first layer temperatures for original (left panel) and modified (right panel) code.

In case of water and water equivalent ice content of the first layer one can see (fig. 3) that for the original code version a fast phase-transition occurs (ice is melted) at the beginning of the integration although the temperature is far below zero (see fig. 1). This behavior is missing when the modified executable is applied (right panel of fig. 3).

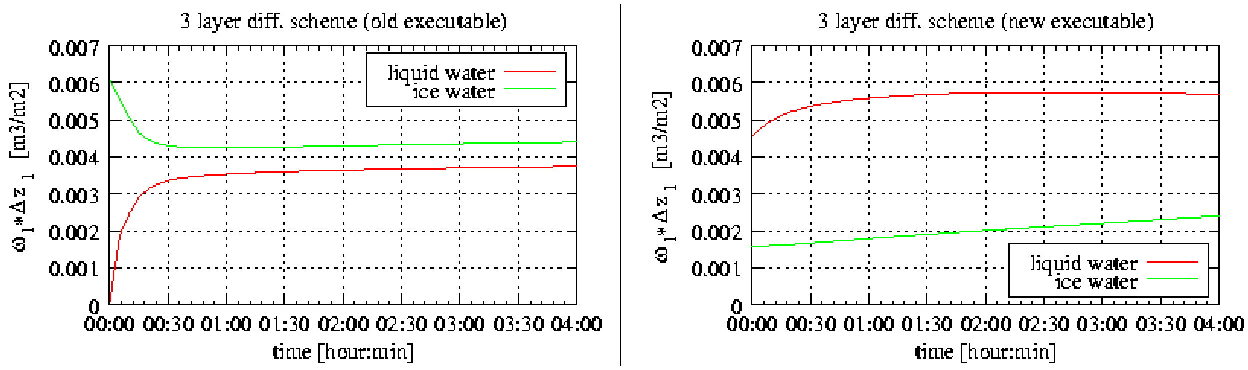

Figure 3: Time evolution of first layer water (red line) and water equivalent ice content (green line) multiplied by the first layer thickness for 3 layer diffusion scheme in case of old executable (left panel) and modified executable (right panel).

When comparing the 3 different scheme: FR, DIF 3 layer and DIF 10 layer (fig. 4) one can again observe that in case of 3 layer diffusion scheme some strange behavior occurs for the water content at the beginning of integration. (The water content $[m^3/m^3]$ * first layer depth $[m]$ is plotted, since the first layer depth is different for FR and DIFF scheme.)

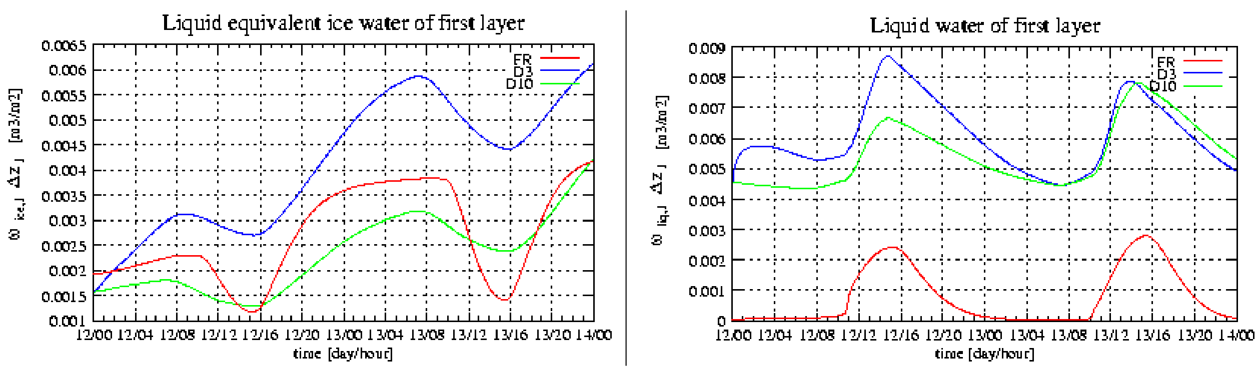

Figure 4: Time evolution of first layer water and water equivalent ice content multiplied by the first layer thickness. (New executable is used).

The conclusion is that the above modification can cure the observed problem for diffusion surface scheme however still some strange behavior remain. More analysis is needed to study these features, e.g. to compare the forecast with observations. An other plan is to compare the different surface schemes not only in the OFFLINE version but in the coupled surface-atmosphere model AROME.