

REPORT

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Part 7: Data assimilation, Variational computations

1 Introduction

During our stay we learned how to use the externalized surface scheme in offline mode. In the first week we read a big amount of article written about the different parts of the scheme (isba, teb, snow scheme, etc.) Then we learned how to run the code in offline mode (i.e. without coupling it to an atmospheric model). In the remaining time we did some experiments in order to get familiar with the code and to study the model's behavior in case of the different options that can be set, e.g. type of snow scheme, number of layers used in isba, etc.

2 Offline-mode run

The model can be run in offline mode which means that during the run the surface scheme gets forcing from the atmosphere -- which is prescribed before starting the model -- but the surface scheme is not coupled back to atmosphere.

To run the model in offline mode one has to go through the following steps (for a more detailed description see the documentation of Valery Masson):

■ Determination of physiographic fields (PGD executable)

Input: files describing surface cover, orography etc; namelist (OPTIONS.nam)

Output: SURFOUT.txt in ascii format. This contains the different cover types.

■ Initial conditions (PREP executable)

Input: SURFOUT.txt (output of PGD). Binary file (GRIB or MESONH format) containing the initial values. Namelist (OPTIONS.nam)

Output: PREP.txt in ascii format, which contains the initial field values (e.g. temperature of first layer) together with the result of the previous step (PGD).

■ Creating the forcing (prep_forcing)

Input: Reads an ascii file containing the atmospheric fields for every forcing time step, and every horizontal point.

Output: Netcdf file (FORCING.nc) containing the forcing fields as well as the forcing time step.

■ Input parameters (prep_parameters_netcdf)

This executable creates 2 netcdf files (ISBA_CONF.DAT.nc, PARA.DAT.nc) which contain some parameter values needed by the offline run: number of points, maximum snow layers, maximum soil layers, isba time step, output time step, etc. These values should be in accord with the values in PREP.txt file.

■ Offline run (OFFLINE)

Input: PREP.txt, OPTIONS.nam, FORCING.nc, ISBA_CONF.DAT.nc, PARA.DAT.nc

Output: Netcdf files --different files for each land type (vegetation, town, sea, inland water)-- containing the result.

3 Experiments

In order to get familiar with the code, to have some exercise to run the offline-model and to study the model behavior in case of different options we made some experiments. The following

subsections describe the different experiments we made.

The first experiment was the reproduction of the Hapex experiment.

In case of all the remaining experiments the forcing was created by an ALADIN forecast (date: 12/02/2003, 00 UTC, 48h forecast), on a horizontal area over Hungary of 30 points. (The number of points was limited by a bug in the code, for more than 35 points the model aborted after the second time step. Now this bug was corrected by Patrick Lemoigne.) In fact 2 different horizontal areas was chosen. For the study of the sensitivity on forcing time step we chose the area:

$A_1 \rightarrow$ Lon = [17.04-17.68], Lat = [47.20-47.95]. When studying the different snow schemes it turned out that there is an other area where much more snow is present, so we also studied this area: A Lon = [19.68-20.32], Lat = [47.20-47.95]\$. There was no precipitation (unfortunately) in neither of the 2 domains during this integration period.

3.1 Reproduction of Hapex experiment

For this run Patrick Lemoigne prepared all the initial conditions and forcing, so we only had to run the OFFLINE executable. This is a single point experiments, the total integration time is one year. Only nature land type is present. The forcing time step is 1800s and the ISBA time step is 300s. Fig 1. shows the temperature evolution.

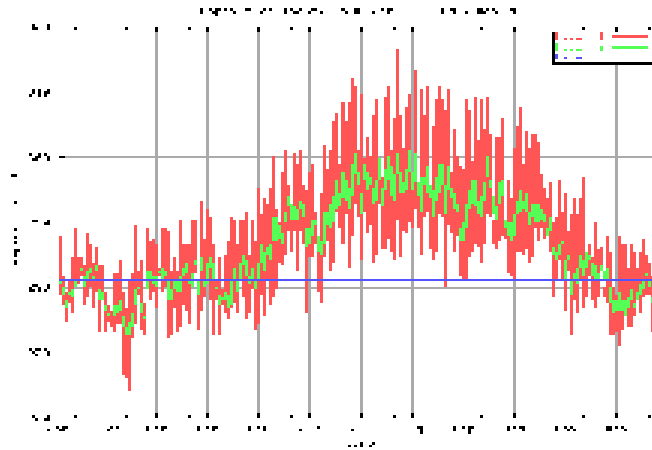


Fig. 1. Time evolution of soil layer temperatures.

3.2 Sensitivity on forcing time step

We studied the sensitivity of the surface scheme on the forcing time step. We chose 3 different forcing time steps, Δt_f 1 hour, 3 hour, 12 hour. The output time step was the same for each experiment, $\Delta t_{out} = 1h$, as well as the isba time step, $\Delta t_{isba} = 300s$.

Fig 2. represents the time evolution of the first soil layer temperature in case of different forcing time steps. Also the 2m temperature forcings are indicated. While there is no big difference between the results corresponding to $\Delta t_f = 1h$ and $\Delta t_f = 3h$, the result belonging to $\Delta t_f = 12h$ is far away from these. The evolution of temperature in case of $\Delta t_f = 12h$ is linear between the two proceeding forcing time steps, because in the model the surface scheme gets forcing data for every isba time step, and this is calculated by linear interpolation from the two nearest neighbor forcing time steps.

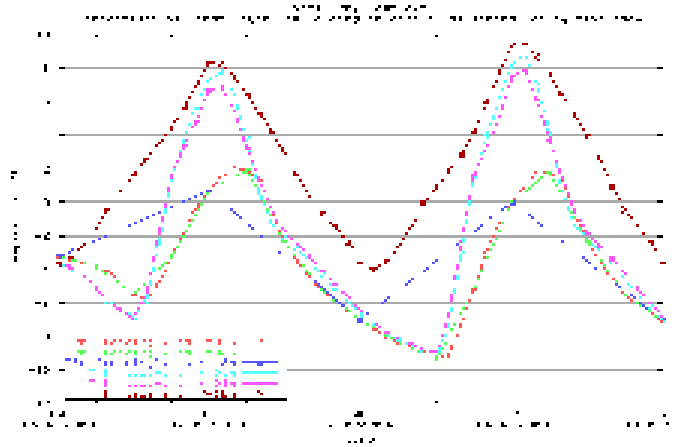


Fig. 2. First layer temperature evolution in case of different forcing

One problem in the code is that the total integration time, T , depends on the choice of Δt_f , because the integration time is calculated (in `ol_read_atm_conf.f90`) as: $T = \Delta t_f N_f$, where N_f is the number of forcing steps and this value is read from `FORCING.nc` file (`NB_TIMESTP`). The calculation of total integration time, T , is however wrong since the model needs forcing also at the initial time, so the number of forcing time steps is $N_f = T / \Delta t_f + 1$, i.e. T should be calculated as: $T = (N_f - 1) \Delta t_f$.

3.3 Different snow schemes

We studied the behavior of the different snow scheme options of the ISBA scheme: Douville scheme (only 1 snow layer exists) and a more sophisticated 3-L scheme (3 snow layers are present).

Figure 3. shows the time evolution of the total snow depth ($d = w / \rho_s$ where w [kg/m²] is the water equivalent snow, and ρ_s [kg/m³] is the snow density), for both snow schemes for two different location point. The Douville scheme gives less snow depth. It is interesting that in case of the left hand side picture, in the 3-L scheme all snow is melted after 12 hour, while in Douville case there is still snow remaining.

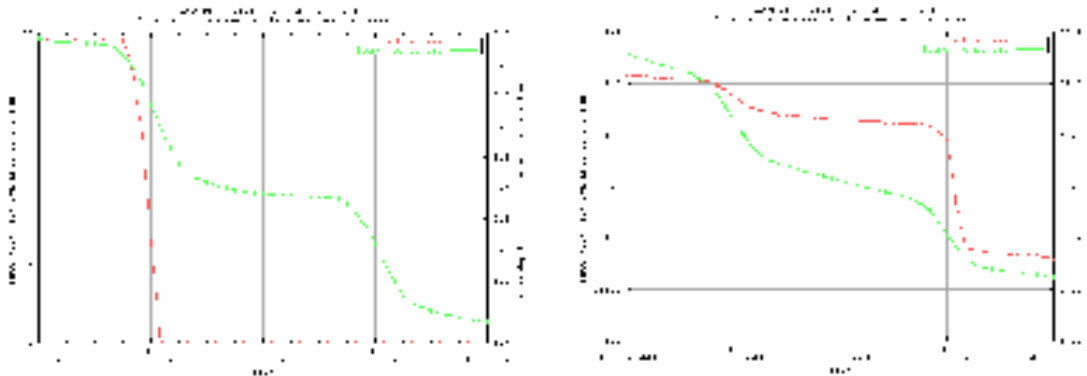


Fig. 3. Total snow depth for the two different snow schemes (Douville, 3-L). The 2 figures differs in the location. Mark the difference in the y axis range in case of the two schemes.

There is a small bug in the code, that although there should be a possibility to write out the snow temperature, `TSNOW_VEGi`, of different snow layers (in case of 3-L snow scheme) the values does not appear in the netcdf file.

3.4 Number of Isba layers

We studied here the effect of the number of ISBA layers. The original ISBA scheme (2-L) had 2 layers: surface and deep soil. The 3-L scheme has also a root zone layer. In case of the Diffusion scheme any number of layer can be set. There was a bug in the code. If one sets the ISBA scheme to CISBA = 'DIF': i) the number of layer will be minimized to 3 and ii) the program will stop. See lines 176-181 in the subroutine: *pgd_isba.f90*.

After correcting the bug we run the diffusion scheme with layer number $N=10$. The results were quite disappointing. Fig. 4. shows the time evolution of different soil layer temperatures in case of 3-L and in case of Diffusion scheme. (The result of 2-L scheme is not present, but it is almost the same as the 3-L scheme.) In case of diffusion scheme at the beginning of integration there is an unrealistic temperature decrease for the first 4 layer.

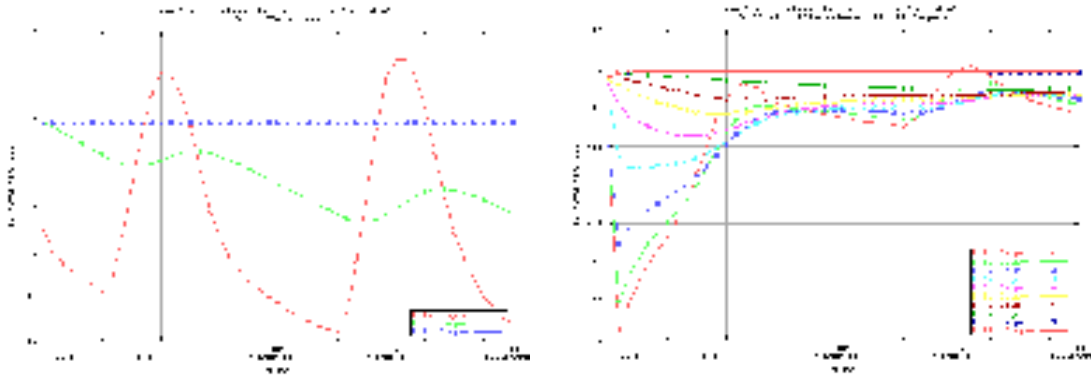


Fig. 4. The layer temperatures in case of 3-L and Diffusion ISBA scheme.

In order to check whether the problem comes from the calculation of the diffusion scheme (perhaps some bug in the code) or only from the number of layers, we also run the diffusion scheme for different number of layers. The result is presented in Fig. 5. It shows that the unrealistic temperature decrease is only present for $N=10$ layer.

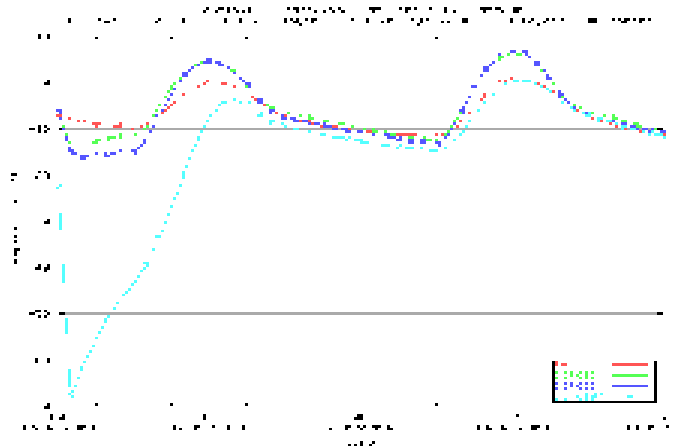


Fig. 5. The first layer temperature in case of 3-L ISBA scheme and Diffusion scheme with different number of layers (3, 5, 10).

An other idea was to rerun the model with smaller time step (originally we used $\Delta t_{isba} = 300s$, because it may happen that due to the small layer depths the model is unstable. We tried with Δt_{isba}

= 5s, but the result did not change.

The temperature behavior may come from the big temperature gradient between the layers. So we run the model with constant initial vertical temperature profile, but the problem remained the same.

Finally it turned out the the problem comes from the ice content in the soil. When we set the initial ice content to zero, the problem disappeared, as can be seen in Fig. 6, where we compare the time evolution of the first layer temperature in case of original ice content (created by using the PREP executable), and with ice content set to zero. The temperature behavior for zero initial ice content is very similar to the result of 3-L ISBA scheme (which is also present for comparison).

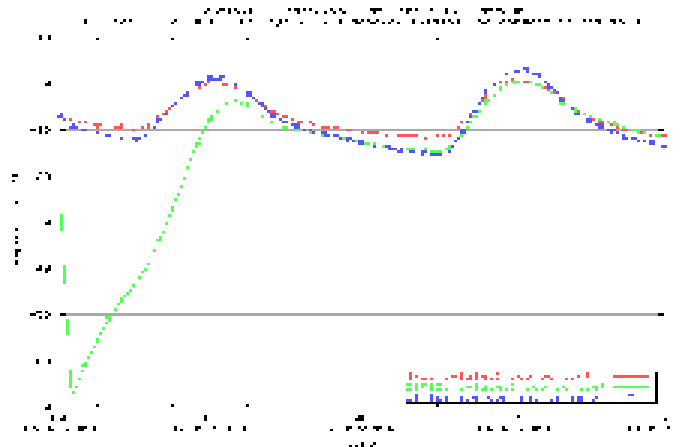


Fig. 6. Time evolution of the 1. layer's temperature in case of initial ice content given originally by running PREP and in case of manually setting it to zero. As a comparison the result of 3-L ISBA scheme is also presented (with initial ice content also given by PREP).

However the question remains open whether the problem is due to the initialization procedure (bad ice content value for 10 layer) or the calculation of the diffusion scheme. In Fig. 7. one can see the time evolution of the ice and water content of the first layer. After the first output time step the ice content is decreased while the water content increased dramatically due to melting, although the temperature of the first layer was below 0 °C. The same behavior can be seen for the layers 2 — 4, while for the remaining layers the water and ice content does not change dramatically.

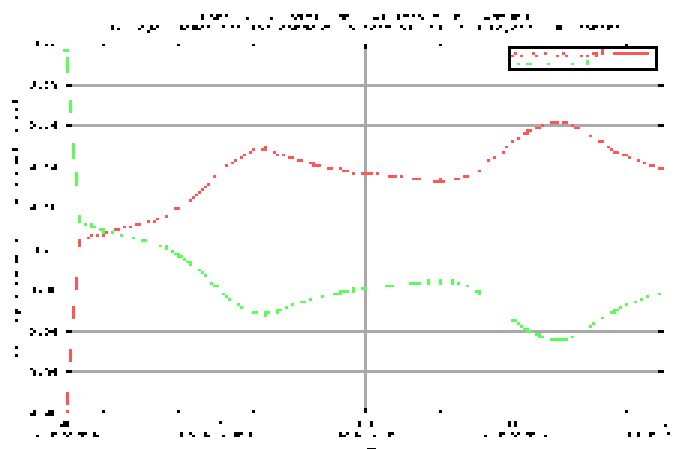


Fig. 7. Time evolution of the 1. layer's ice and water content.

In case of diffusion scheme the melting process as well as the temperature change due to melting is calculated in the subroutine *ice_soildiff90*.

$$\Delta T = T - T_{max}, \quad \text{where } T_{max} = \left(\frac{L_{melt} T_t}{L_{melt} - g \psi} \right) \quad (1)$$

In the equation above L_{melt} is the latent heat of melting, T_t is the triple point temperature and ψ is the matric potential, which is a function of saturation water content w_{sat} , and volumetric liquid water content, w :

$$\psi = \psi_{sat} \left(\frac{w}{w_{sat}} \right)^{-b} \quad (2)$$

The phase change due to melting is calculated as:

$$\phi_m = \frac{\Delta t}{\tau} \min \{ ZK \text{ ZEFFIC } c_i \rho_i \max(0, \Delta T), w_i L_{melt} \rho_w \} \quad (3)$$

where ZK and $ZEFFIC$ are some variables, the latter is depending on ice content, and saturation water content. Finally the temperature decrease due to melting is calculated as:

$$T(t) = T(t-1) - \phi_m C_T \quad (4)$$

The problem is that if the water content is small the value T_{max} is close to zero and so $\max(0, \Delta T) \approx T$ and it can happen that in Eq. (3) in the $\min\{\cdot\}$ expression the $w_i L_{melt} \rho_w$ term is smaller, i.e. there is melting. If there is a big amount of ice content, the temperature will decrease dramatically as was the case in Fig. 4.

4 Future Plans

We discussed with Patrick Lemoigne, Joel Noilhan, Claude Fischer and Gwenaëlle Hello how to proceed. The result of the discussion was:

- As a first step: install the externalized surface scheme in Hungary. All the source is available.
- Study and test the diffusion scheme of ISBA. Try to correct the bugs e.g. the one described in the previous section corresponding to temperature behavior and ice content.
- Work on the interface of the externalized surface scheme in ALADIN model. Before starting with this step further discussion is needed since there are a lot of open questions how to start.

CONTENTS

1 Introduction	2
2 Offline-mode run	2
3 Experiments	2
3.1 Reproduction of Hapex experiment	3
3.2 Sensitivity on forcing time step	3
3.3 Different snow schemes	4
3.4 Number of Isba layers	5
4 Future Plans	7