CENTRO EURO-MEDITERRANEO
PER I CAMBIAMENTI CLIMATICI

Technical Reports

ISC – Impacts on ground and coast

Terra-LM sensitivity tests: Falkenberg 2006

Guido Rianna
Centro Euro-Mediterraneo per i Cambiamenti Climatici(CMCC)

Centro Euro-Mediterraneo
per i Cambiamenti Climatici
www.cmcc.it

January 2008 ■ TR17

Terra-LM sensitivity tests: Falkenberg 2006

Summary

In this work, are shown the results of sensitivity tests carried out on 1D version of TERRA-LM code (for further details about physical parameterization and code of TERRA-LM, see Technical Reports “Descrizione del soil-module TERRA-LM” and “Studio e valutazione dei possibili miglioramenti apportabili a Terra-LM tramite il confronto con altri modelli SVAT”).

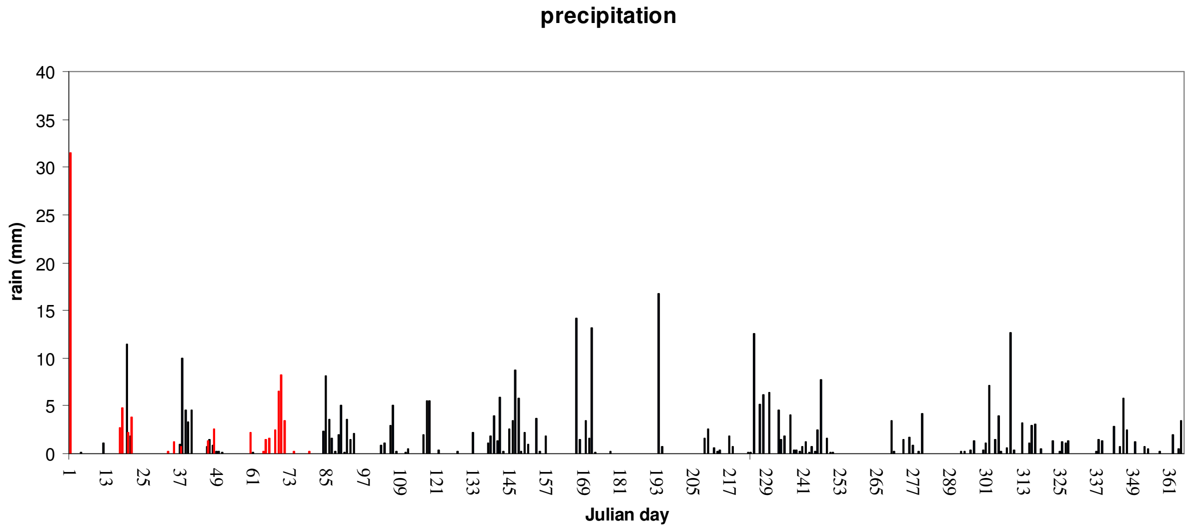
Keywords: SVAT, water content, soil temperature

.

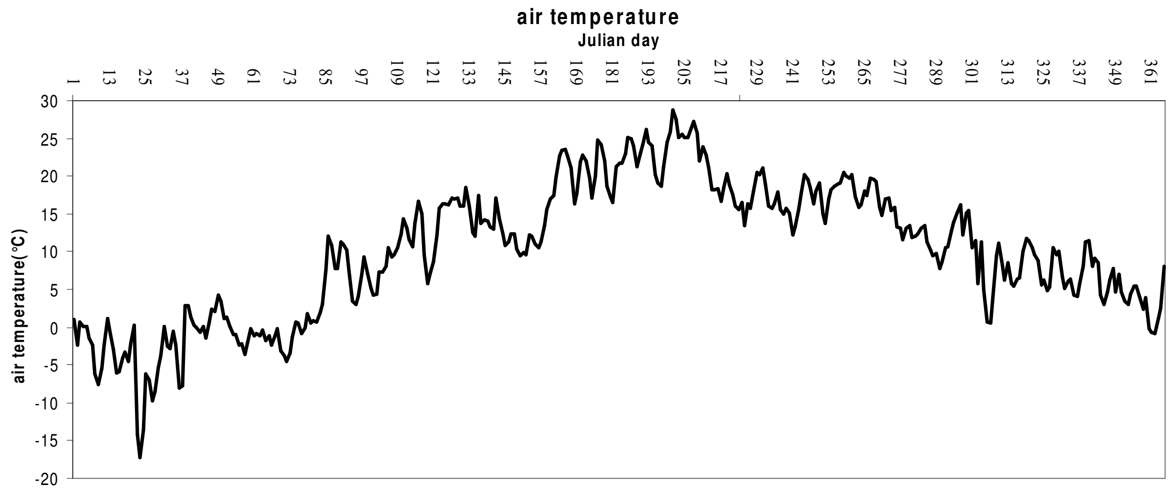
Address for correspondence:
Guido Rianna
E-mail: guido.rianna@unina.it

1.1 Introduction

In this Technical Report are shown the results of sensitivity tests carried out on 1D version of TERRA-LM code (for further details about physical parameterization and code of TERRA-LM, see Technical Reports “Descrizione del soil-module TERRA-LM” and “Studio e valutazione dei possibili miglioramenti apportabili a Terra-LM tramite il confronto con altri modelli SVAT”).
About the code, the input of initial and atmospheric boundary conditions, it is possible to see the Technical Report “Terra-LM sensitivity tests:Falkenberg 2005”.
While in this report were shown the results related to sensitivity tests carried out, using as atmospheric boundary conditions, monitored data from Falkenberg site for year 2005, in this work the atmospheric boundary conditions are from same site but for year 2006.
Between two datasets, the more important difference is for precipitation data; in fact, for year 2005, the presence of snow was simulated via temperature data (if, at the same time, precipitation and air temperature below zero is registered, snow presence is simulated); instead, now, the snow events are monitored and are reported in data set via minus sign.
The daily precipitation and air temperature trends are in **graph 1** and **2:**



graph 1: red bar represents snow precipitation, while the black one the rain precipitation for the 2006 year.



graph 2: the black curve represents air temperature for the 2006 year.

1.2 Sensitivity tests

1.2.1 Different soil types

To test the code sensitivity varying soil type, are carried out some simulations; in these, are used usual settings, but all different soil type are tested.

Some results are shown in **graphs 3-8** (they are water content and soil temperature trends for three layers).

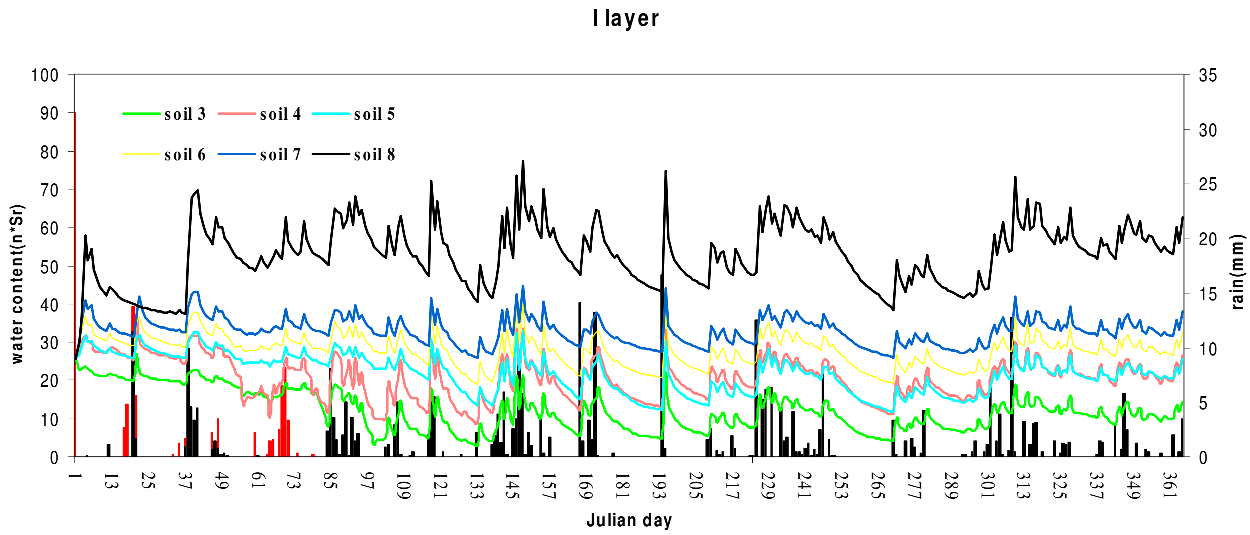
For the precipitation hystograms, black bar represents rain event and red bar represents snow event; in soil temperature graphs, the curve with crosses represents the air temperature.

First of all, some remarks for year 2005 can be repeated: the water content trends are heavily influenced by volume of voids and hydraulic conductivity; increasing these parameters, in the soil increases water content; as it is expected, the influence of atmospheric boundary conditions (especially rain and air temperature) on the water content and temperature profiles are gradually subsiding along the soil column

For soil type with intermediate properties, final conditions seem to be congruent with initial conditions, while for other soil type, they aren't congruent with initial conditions.

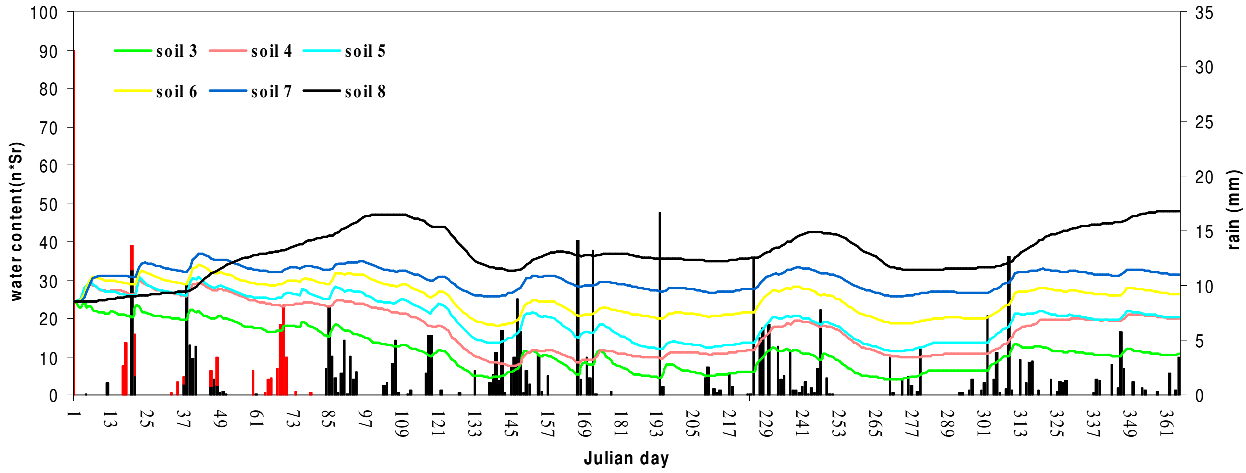
In these analysis, the trends are not affected by anomal peaks in spin-off time (on the contrary, see graphs **15-16** "Terra-LM sensitivity tests:Falkenberg 2005"); after a first time, the water content trends run parallel (especially, the soil types 4 and 5 are superimposed); because of high volume of voids, the soil type "peat" presents high water holding capacity.

In spite of great difference between the hydraulic conductivity values, in the soil, after a rain event, are not great lags between the water content peaks of the soils with very different permeability while, along the soil column, all the peaks result to be delayed as regard rainfalls.



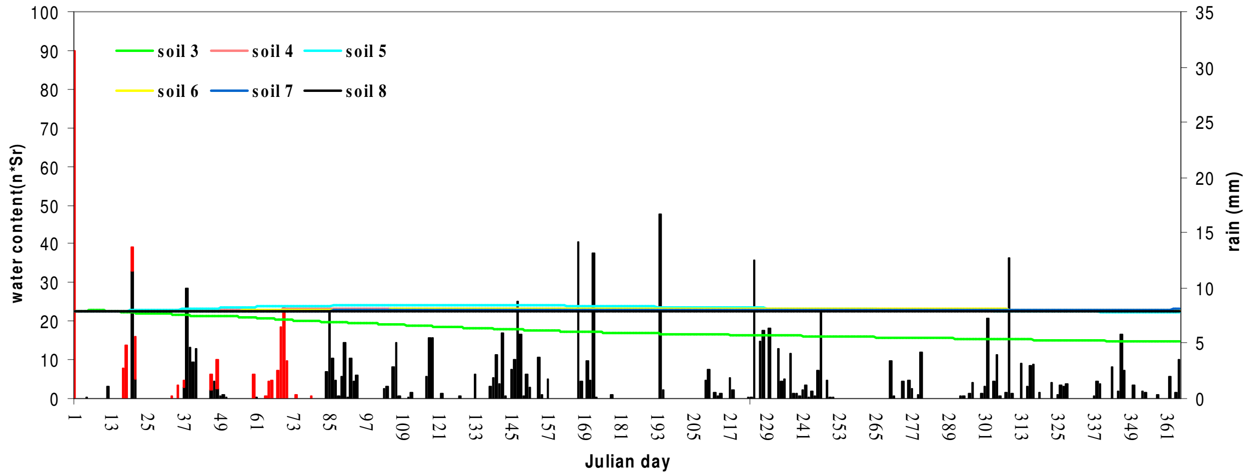
graph 3: the black bar represents the cumulated daily precipitations and the red bar represents snow precipitation; the others curves are the water content curves in the first soil level varying the soil type

IV layer



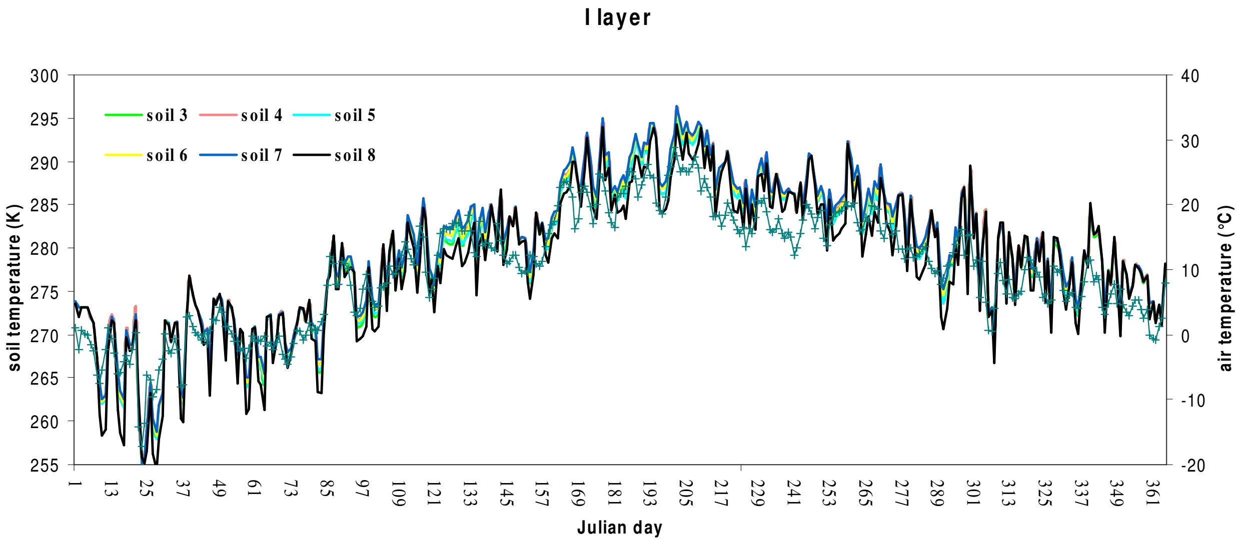
graph 4: : the black bar represents the cumulated daily precipitations and the red bar represents snow precipitation; the others curves are the water content curves in the IV soil level varying the soil type

VIII layer

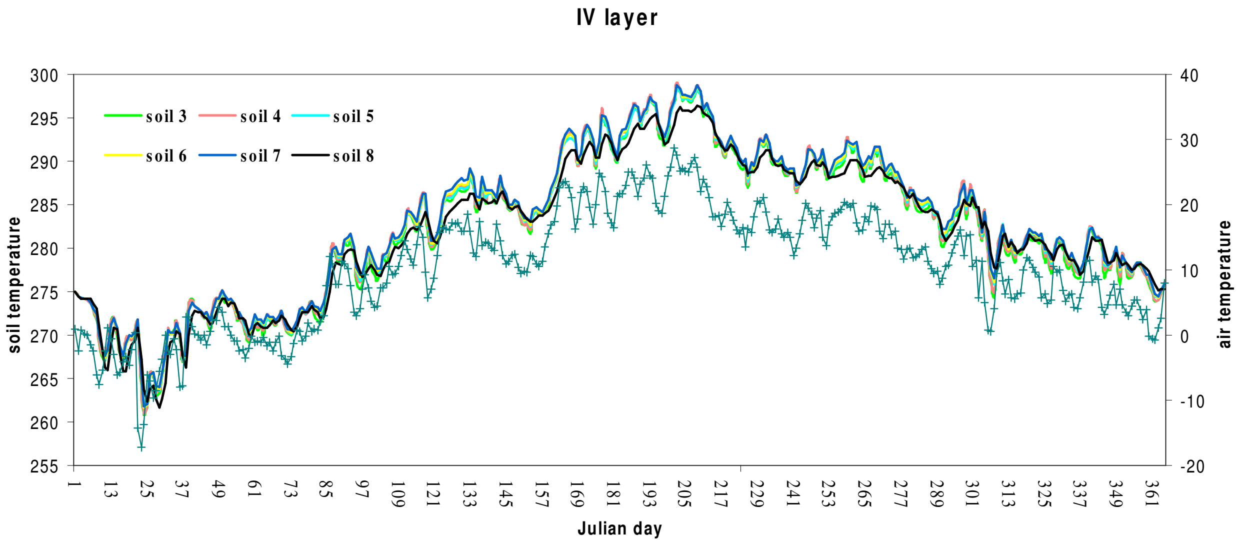


graph 5: : the black bar represents the cumulated daily precipitations and the red bar represents snow precipitation; the others curves are the water content curves in the VIII soil level varying the soil type

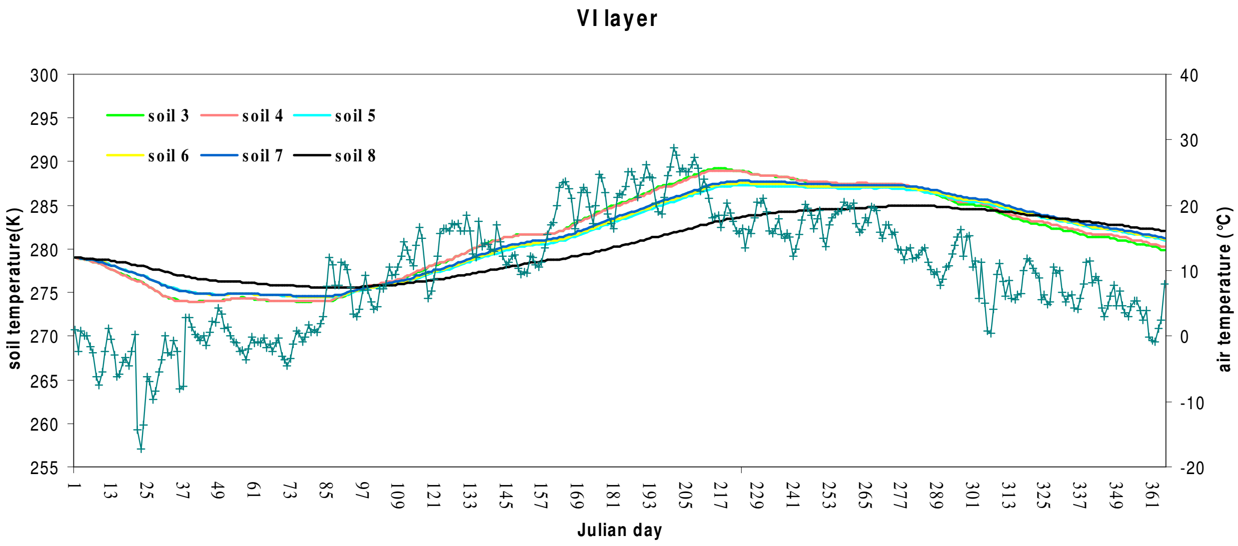
For surface layer, the soil temperature trends, because of similar thermal parameters, are superimposed; in the intermediate layers, anomalous soil temperature trends are simulated; in fact, (**graph 7**) all the curves of soil temperature are above the air temperature trend; on the contrary, because of low thermal conductivity properties, a different behaviour is expected; soil temperature higher than air temperature in cold season and lower in warm season (see **graph 8**).



graph 6: the grey curve with the crosses represents the air temperature; the others curves are the soil temperature curves in the first soil level varying the soil type

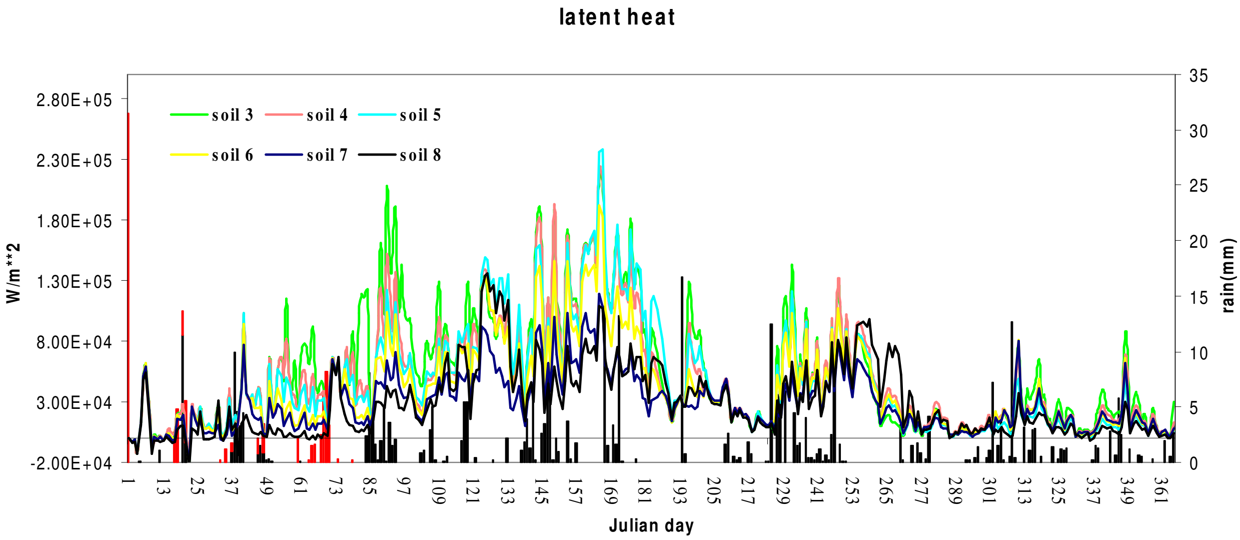


graph 7 : the grey curve with the crosses represents the air temperature; the others curves are the soil temperature curves in the IVsoil level varying the soil type



graph 8: the grey curve with the crosses represents the air temperature; the others curves are the soil temperature curves in the VI soil level varying the soil type

In **9**, there is latent heat graph; it is possible to note that the latent heat flux increases accordance to soil pore size; the soil type "peat" shows delayed peaks because of high water holding capacity.



graph 9: : the black bar represents the cumulated daily precipitations and the red bar represents snow precipitation; the others curves are the latent heat curves varying the soil type

In graph 8, are shown the solar radiation curves; while for 2005 year, the trends were superimposed, now , in presence of snow, different values are simulated; at the ground, the solar radiation has the form:

$sobs = so\_down\_bd[1 - alsoil]$ **eq. 1**

- *sobs: solar radiation at the ground*
- *so_down_bd: boundary field of downwelling solar radiation*

where $alsoil$ is:

$alsoil = csalb - csalbw * depth * w\_so$ **eq. 2**

- $alsoil$: solar albedo for soils:

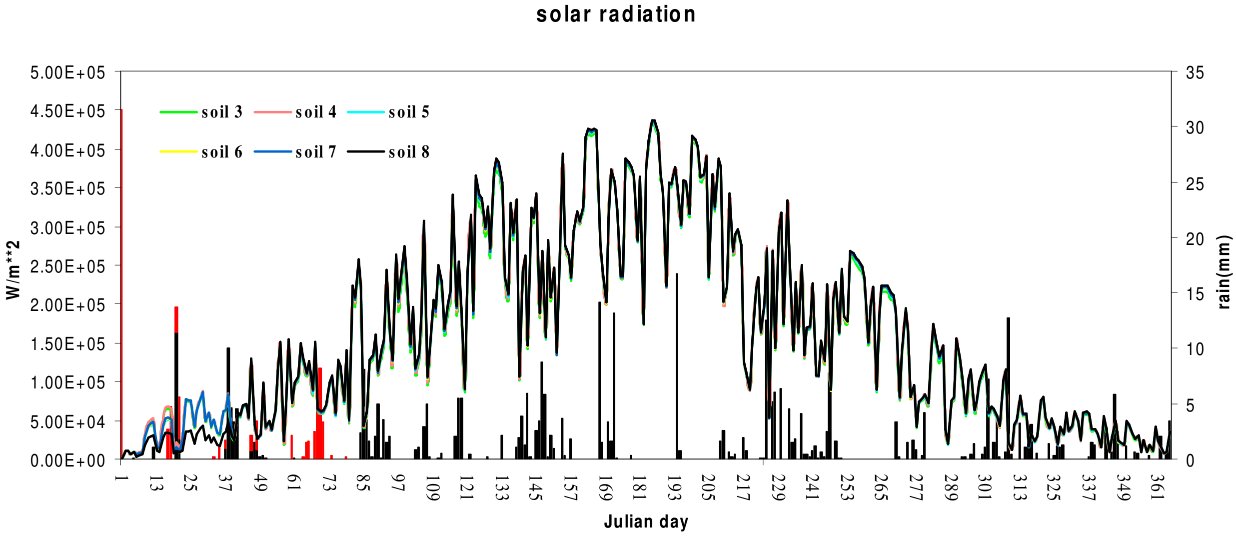
- $csalb$: solar albedo for dry soils
- $csalbw$: gradient of albedo vs water content
- w_so : water content

if there is snow cover:

$$also = zsnow + csalb\_snow + (1 - zsnow)(pl\cov * csalb\_p + (1 - plco * alsoil))$$

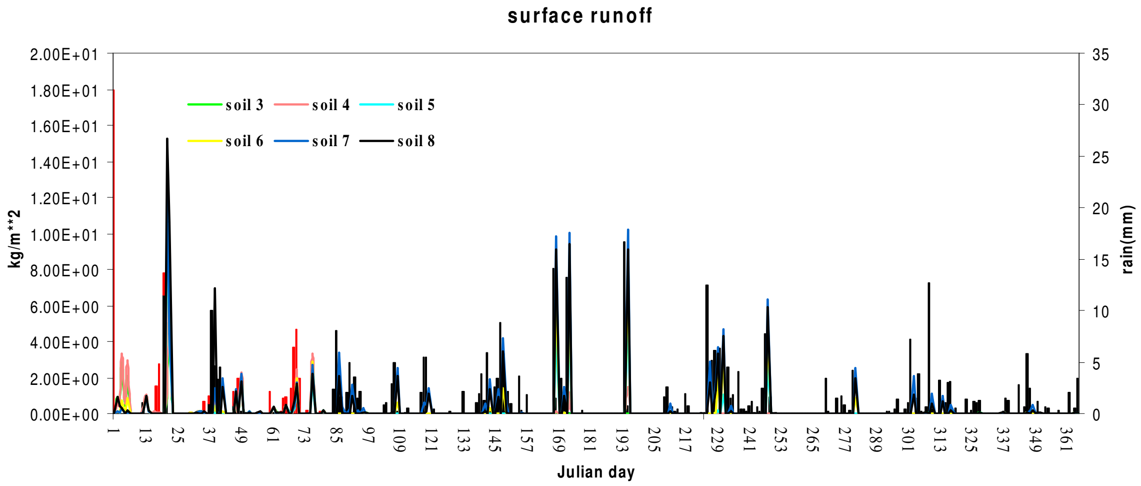
- $zsnow$: snow depth
- $csalb\_snow$: solar albedo for snow
- $plco$: plant cover
- $csalb\_p$: solar albedo for vegetation cover

then, in the first part of graph, the differences are due to snow cover on the soil and vegetation



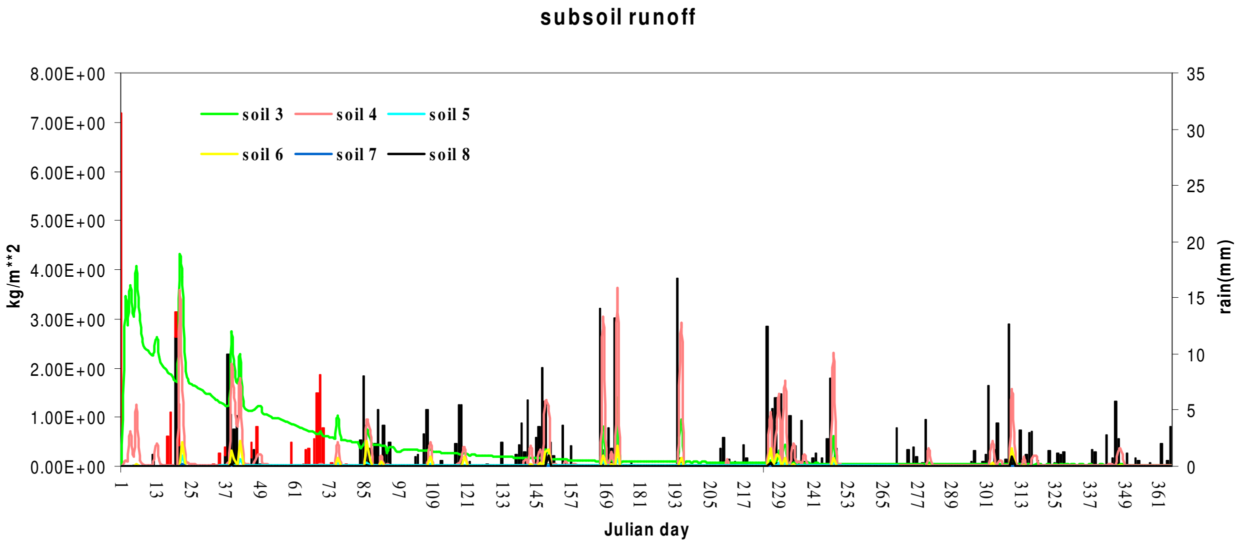
graph 10: the black bar represents the cumulated daily precipitations and the red bar represents snow precipitation; the others curves are the solar radiation curves varying the soil type

In surface runoff graph (**graph 11**), properly the surface runoff values are higher for the soils with very low permeability.



graph 11: the black bar represents the cumulated daily precipitations and the red bar represents snow precipitation; the others curves are the surface runoff curves varying the soil type

on the other hand, subsoil runoff values increase for permeable soils, because, at the soil column bottom, the water flows quickly; like for 2005 year, the soil type "sand" shows an unforeseen trend: in the first time, too high values that influence the entire subsoil runoff curve while, in the following time, the subsoil runoff curve of soil type "sand" is very below that one of soil type "sandy loam" (less permeable).



graph 12: the black bar represents the cumulated daily precipitations and the red bar represents snow precipitation; the others curves are the subsoil runoff curves varying the soil type

1.2.2 Type of bare soil evaporation model

Usually, for operative purpose, to estimate evaporation flux, BATS model is used.
In TERRA-LM stand alone version, it is possible to utilize other two evaporation models:

- **Bucket-Model**: a simplified experimental model; in this approach, in absence of water in the soil, potential evaporation E_p is reduced by β^2 factor:

$$E_b = (1 - f_i)(1 - f_{snow})(1 - f_{p\ln t})\beta_{E_b}{}^2\left(-E_{pot}(T_{sfc})\right) \quad \textbf{eq. 3}$$

with[1] β_{E_b}
$$\begin{cases} 0; \eta_1 < \eta_{adp} \\ \dfrac{\eta_1 - \eta_{adp}}{\eta_{fc} - \eta_{adp}}; \eta_{adp} < \eta_1 < \eta_{fc} \\ 1; \eta_1 \geq \eta_{fc} \end{cases} \quad \textbf{eq. 4}$$

- **Noilhan-Planton:** experimental in TERRA-LM code; in this approach , reducing factor has the following form:

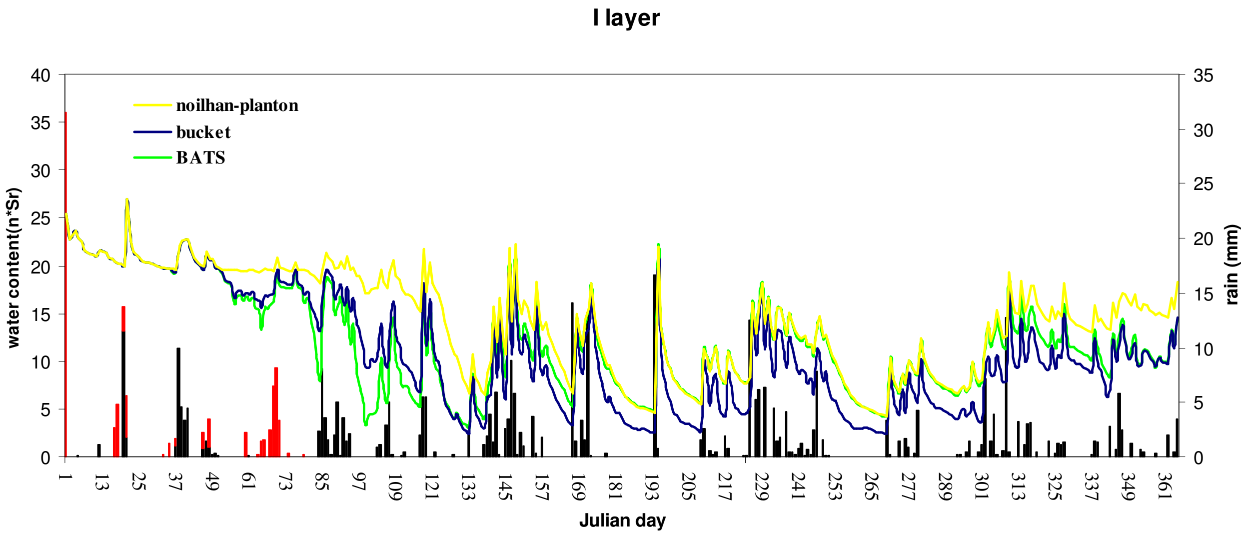
$$\beta_{E_b} = 1 \text{ if } \eta_1 > \eta_{fc} \quad \textbf{eq. 5}$$

$$\beta_{E_b} = 0.5\left(1 - \cos\left(0.5\pi\left(\frac{\eta_1 - \eta_{adp}}{\eta_{fc} - \eta_{adp}}\right)\right)\right) \quad \textbf{eq. 6}$$

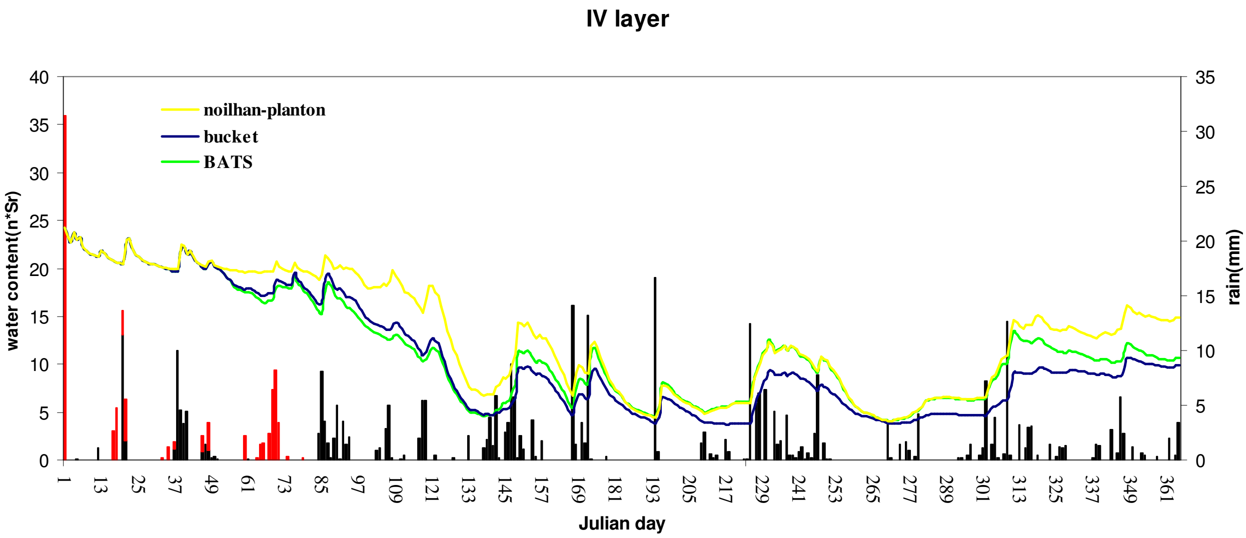
$$E_b = \min\left(0.0; \rho g\left(q_v - \beta_{E_b} q_{sfc}\right)\right) \quad \textbf{eq. 7}$$

Using the three evaporation models on the same area e with egual atmospheric inputs, some behaviour differences are evident (in **graph 13-16** are shown water content trends for three layers and soil temperature for upper layer).
It is necessary to underline that monitored data of water content and soil temperature are not available and then it is not possible to verify which model simulates better the real distributions of water content and temperature.

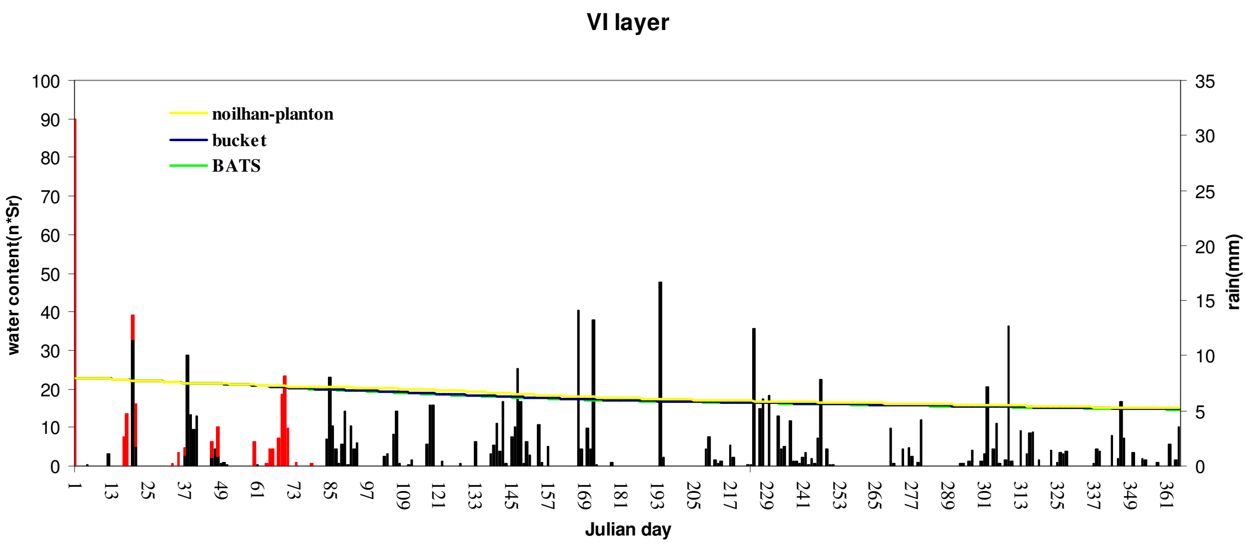
1 η_1 soil water content in upper layer
η_{adp} water content for air dryness point
η_{fc} water content for field capacity



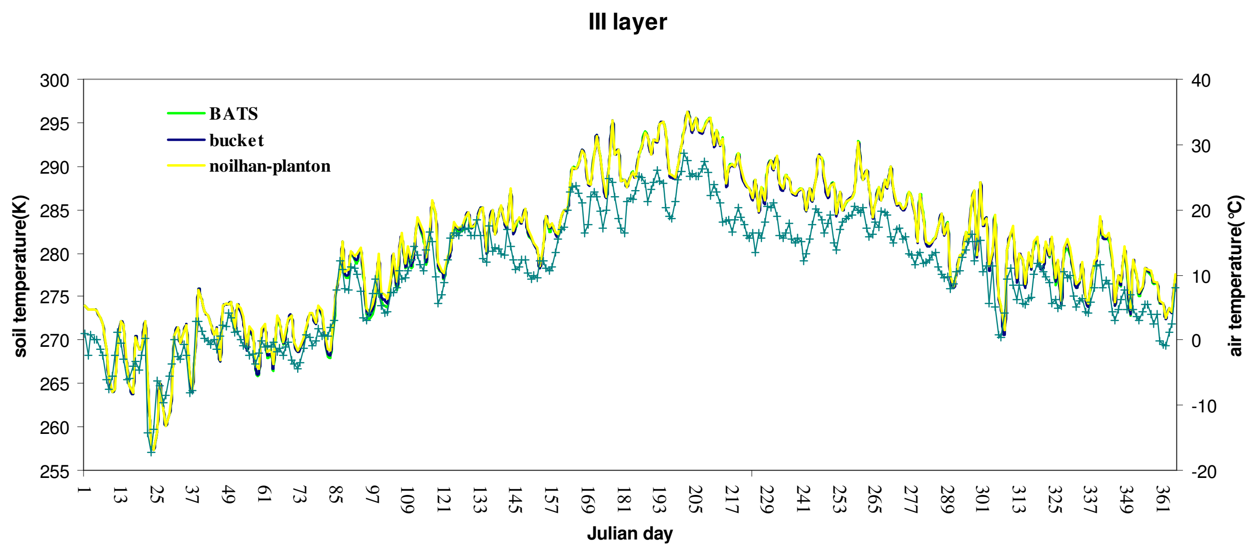
graph 13: the black bar represents the cumulated daily precipitations,the red bar represents the snow precipitation; the others bars are the soil moisture curves in the Ilayer varying the evaporation model (green line for BATS model, yellow line for Noilhan-Planton model and blue for bucket model)



graph 14: the black bar represents the cumulated daily precipitations,the red bar represents the snow precipitation; the others bars are the soil moisture curves in the IVlayer varying the evaporation model (green line for BATS model, yellow line for Noilhan-Planton model and blue for bucket model)



graph 15: the black bar represents the cumulated daily precipitations,the red bar represents the snow precipitation; the others bars are the soil moisture curves in the VI layer varying the evaporation model (green line for BATS model, yellow line for Noilhan-Planton model and blue for bucket model)



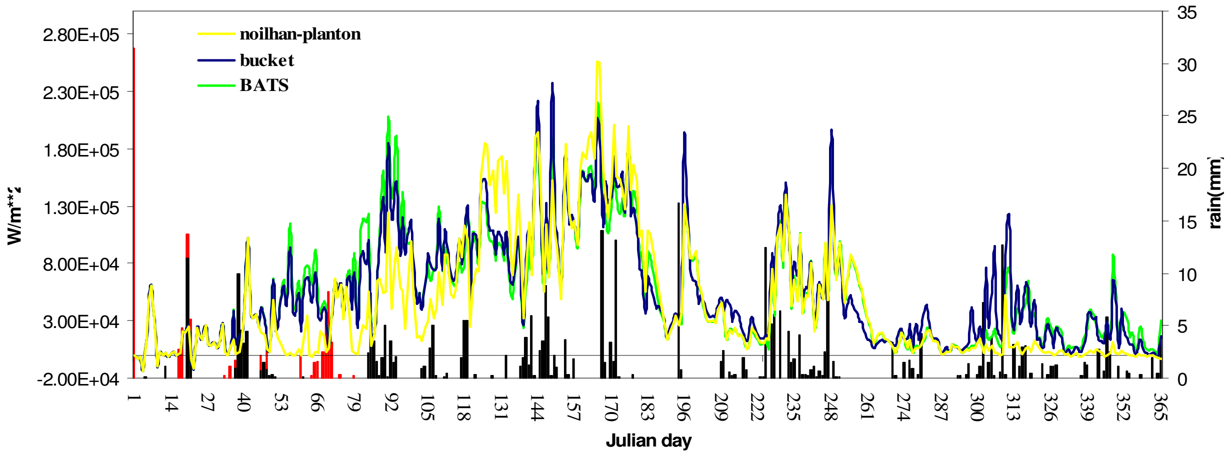
graph 16: the grey curve with the crosses represents the air temperature, the others bars are the soil temperaturecurves in the IIIlayer varying the evaporation model (green line for BATS model, yellow line for Noilhan-Planton model and blue for bucket model)

It is possible to reply some remarks expounded for 2005 sensitivity tests ("Terra-LM sensitivity tests:Falkenberg 2005"):

- In every layer, water content curves, estimated with Noilhan-Planton method are above the others; then, it simulates lower water losses caused by evaporation. This undervaluing is higher in cold season rather than in warm season when three curves are superimposed.
- Using bucket model, water content curves are above the curves obtained using BATS in first part of the simulation and are below these in the following (for 2005, in the last part of the year, the green and blue curves became superimposed);

In the warm season, the greater disagreement between the models are not related to wetting stage (in presence of rain) but related to drying stage, when the water content decreases and especially the bucket model simulates more water content losses.
Along the soil column, the water content distribution show traces of evaporation effect down to $80-90cm$; then, in the lower layers, the trends are superimposed.
Soil temperature trends aren't influenced by the utilized evaporation model; then, only the graph for upper layer is given.
.

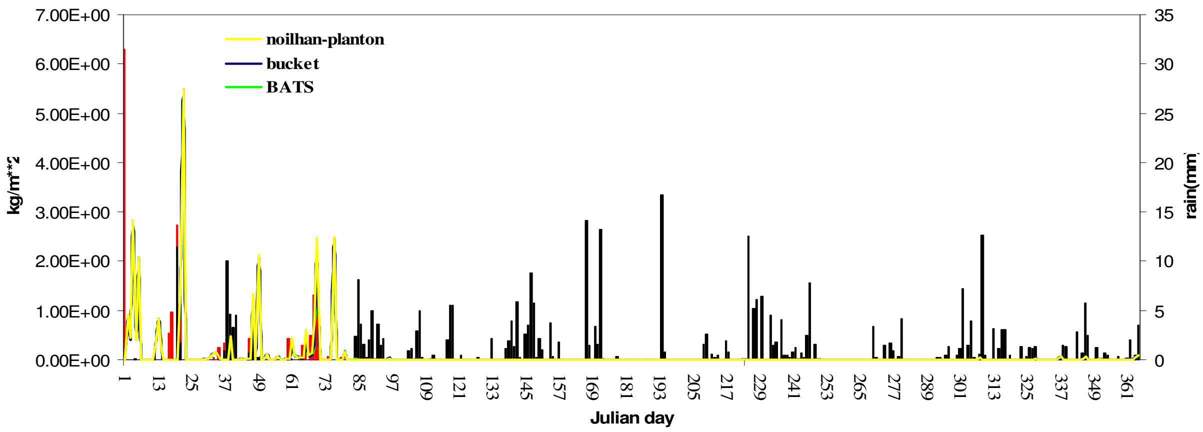
latent heat



graph 17: the black bar represents the cumulated daily precipitations,the red bar represents the snow precipitation; the others bars are the latent heat curves varying the evaporation model (green line for BATS model, yellow line for Noilhan-Planton model and blue for bucket model)

Looking at **graph17**, it is clear the link between the latent heat and water content (in upper layer) trends; actually, on the 92nd day , in latent heat graph, to a peak value, for BATS model corresponds a minimum in the water content graph; the same happens for the bucket model on the 248th day, while it is the opposite for the Noilhan-Planton approach on the 53rd day.

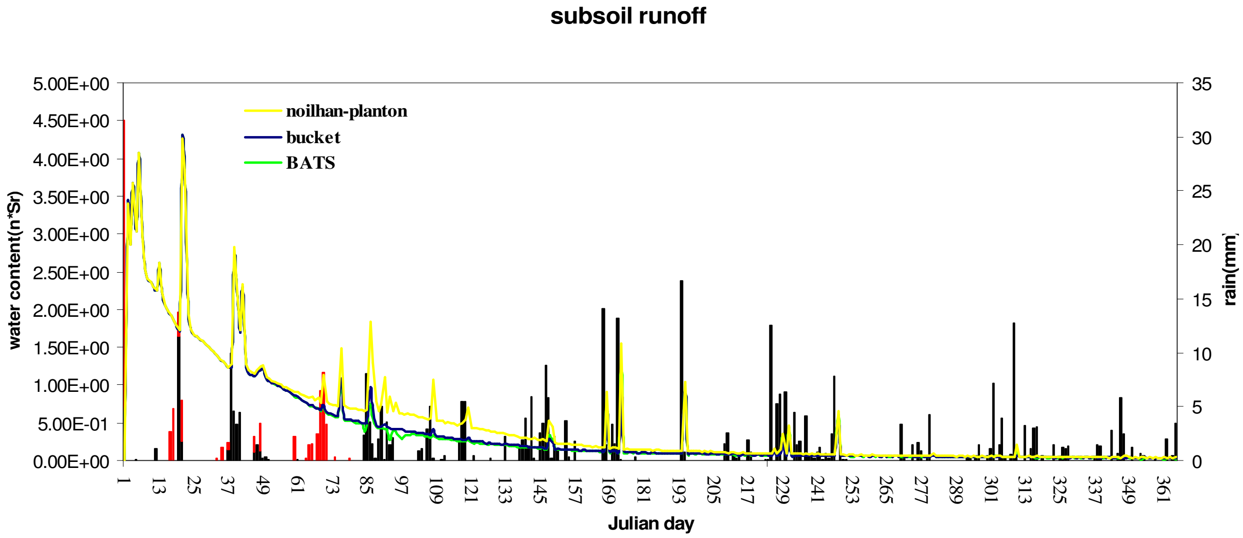
surface runoff



graph 18: the black bar represents the cumulated daily precipitations,the red bar represents the snow precipitation; the others bars are the surface runoff curves varying the evaporation model (green line for BATS model, yellow line for Noilhan-Planton model and blue for bucket model)

About the surface runoff graph (**graph 18**) and subsoil runoff (**graph 19**), it is possible to make some remarks:

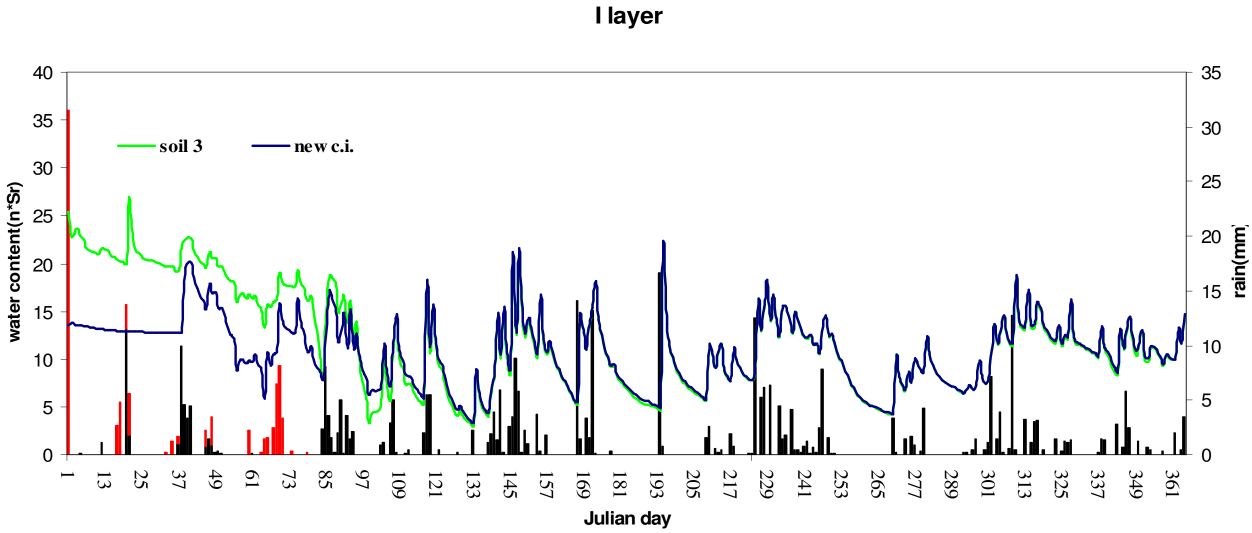
- Properly, the trends are not influenced by the used evaporation model; contrarily, in wrong way, in the 2005 trends, the three curves show different values.
- In **graph 18,** from the 85th day, the three curves vanish or reach very low values ; because of the lack of experimental data, it is not possible to know the real trends but it seems unlikely that there is not runoff in spite of many rainfall events.
- Like for 2005 subsoil runoff trends, using all three approaches, in the first time, very high values are simulated; a large part of trends is then affected by these anomalous values



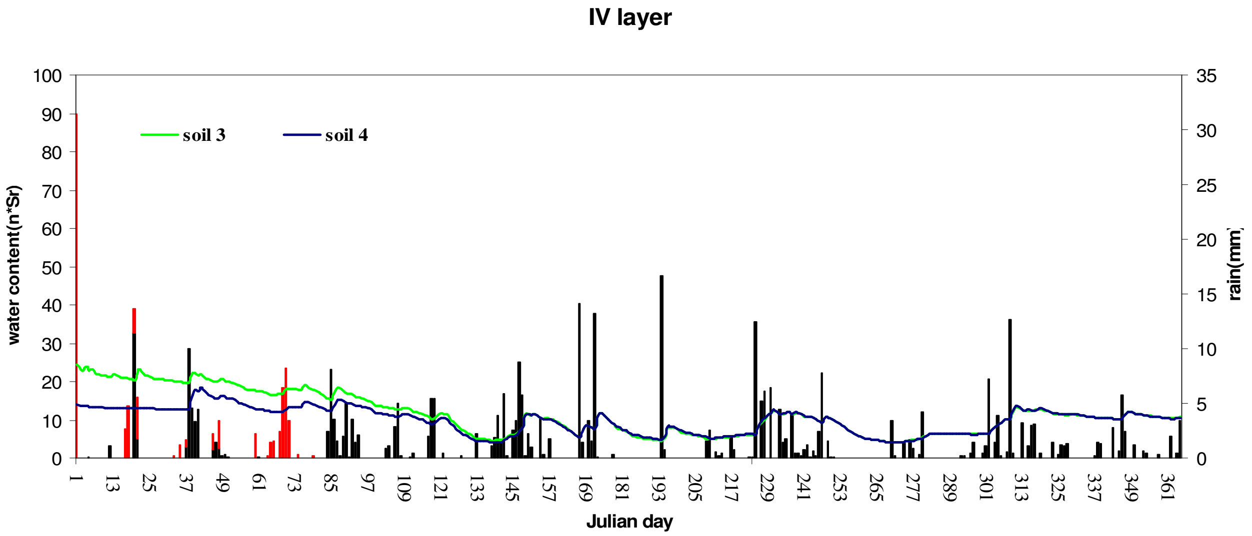
graph 19: the black bar represents the cumulated daily precipitations,the red bar represents the snow precipitation; the others bars are the subsoil runoff curves varying the evaporation model (green line for BATS model, yellow line for Noilhan-Planton model and blue for bucket model)

1.3.3 Changing the initial conditions

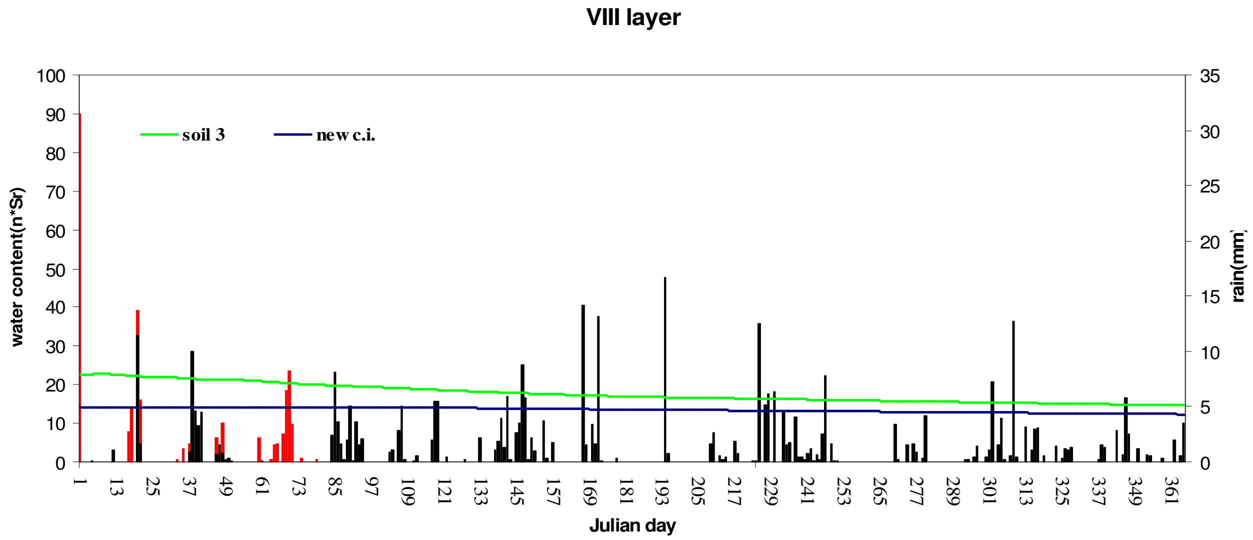
It is very interesting to verify how the initial conditions influence the entire yearly trends.
For this sensitivity test, as initial conditions are used the final values obtained by the 2005 simulation ("Terra-LM sensitivity tests:Falkenberg 2005"),besides the usual conditions.
The time, in which the trends are influenced by the initial conditions, changes varying the variables or along the soil column.
The principle results are shown in **graph 20-28**:



graph 20: the black bar represents the cumulated daily precipitations,the red bar represents the snow precipitation; the others bars are soil moisture curves in the I layer varying the initial conditions (green line for old i.c., blue for new i.c)

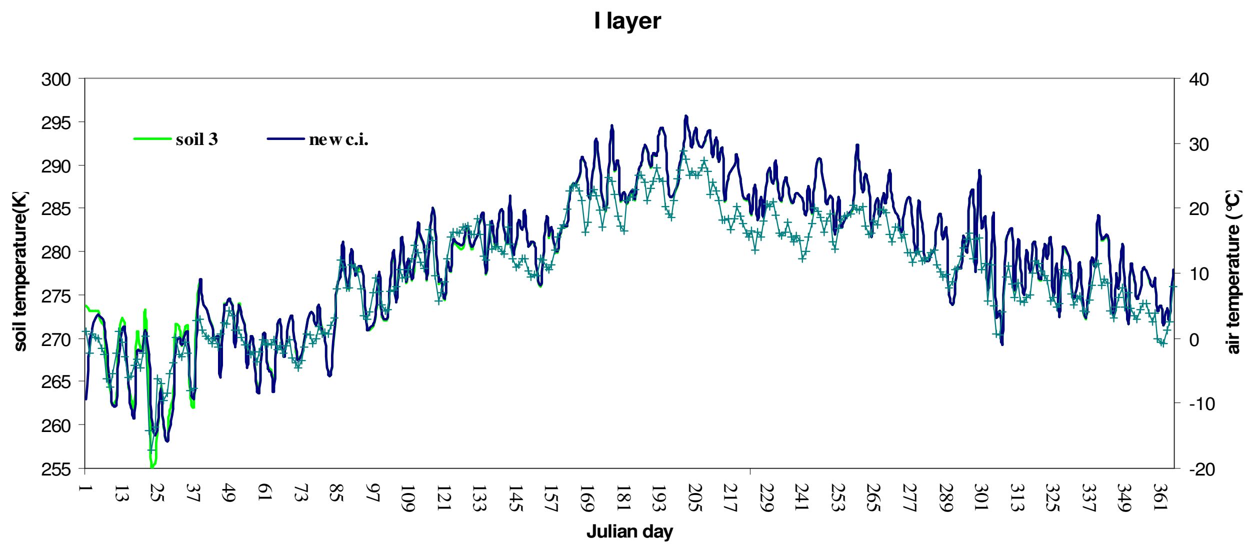


graph 21 : the black bar represents the cumulated daily precipitations,the red bar represents the snow precipitation; the others bars are soil moisture curves in the IV layer varying the initial conditions (green line for old i.c., blue for new i.c)

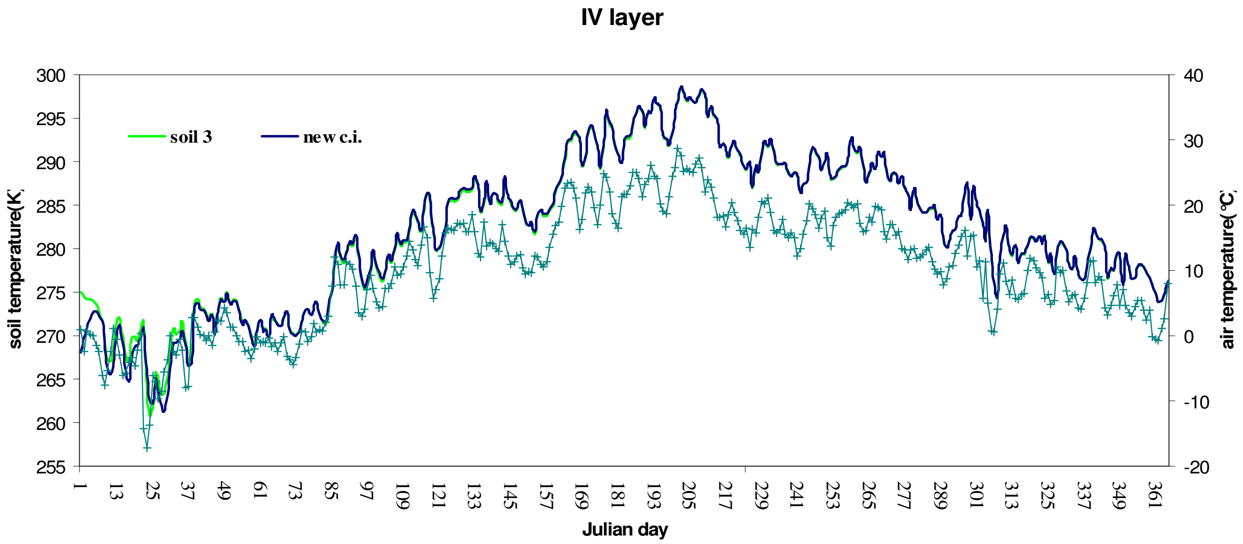


graph 22: the black bar represents the cumulated daily precipitations,the red bar represents the snow precipitation; the others bars are soil moisture curves in the VIII layer varying the initial conditions (green line for old i.c., blue for new i.c)

For the water content curves, the trends are influenced by the initial conditions about 4 months, in the upper layers; then, using the new initial conditions, during the entire year, the water content values are in a definied values range; contrarily, using the old conditions, during the entire year, the initial values are not ever reached; on the other hand, in the lower layers (**graph 22**), the two curves are not able to overlap; by the **graph 22**, it is clear that, using better initial conditions, in the lower layers, the water content remains unchanged.

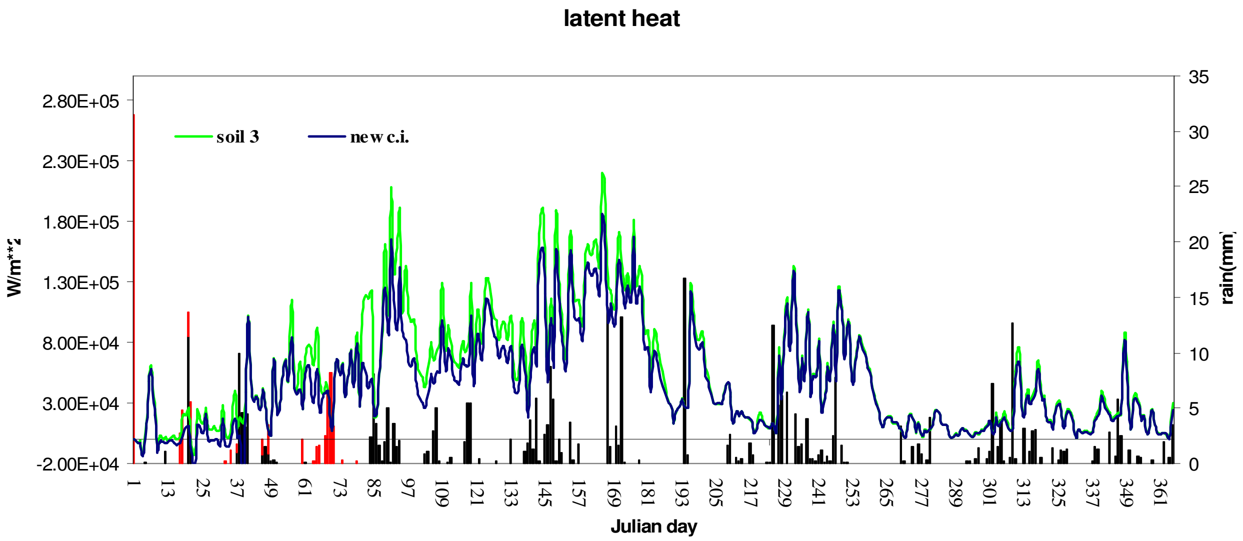


graph 23: the grey curve with the crosses represents the air temperature; the others bars are the soil temperature curves in the I layer varying the initial conditions (green line for old i.c., blue for new i.c)

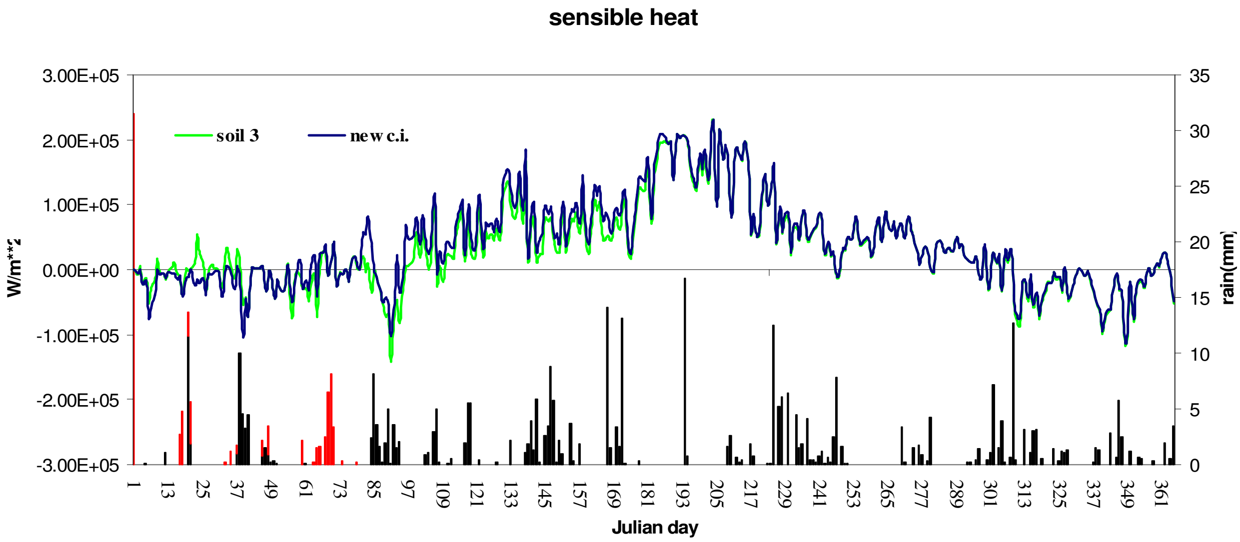


graph 24: the grey curve with the crosses represents the air temperature; the others bars are the soil temperature curves in the IV layer varying the initial conditions (green line for old i.c., blue for new i.c)

For the temperature curves, the influence of the initial conditions is not so much marked; in fact, the two trends have different values only during the first 40 days (approximately, this is the range for the all layers)

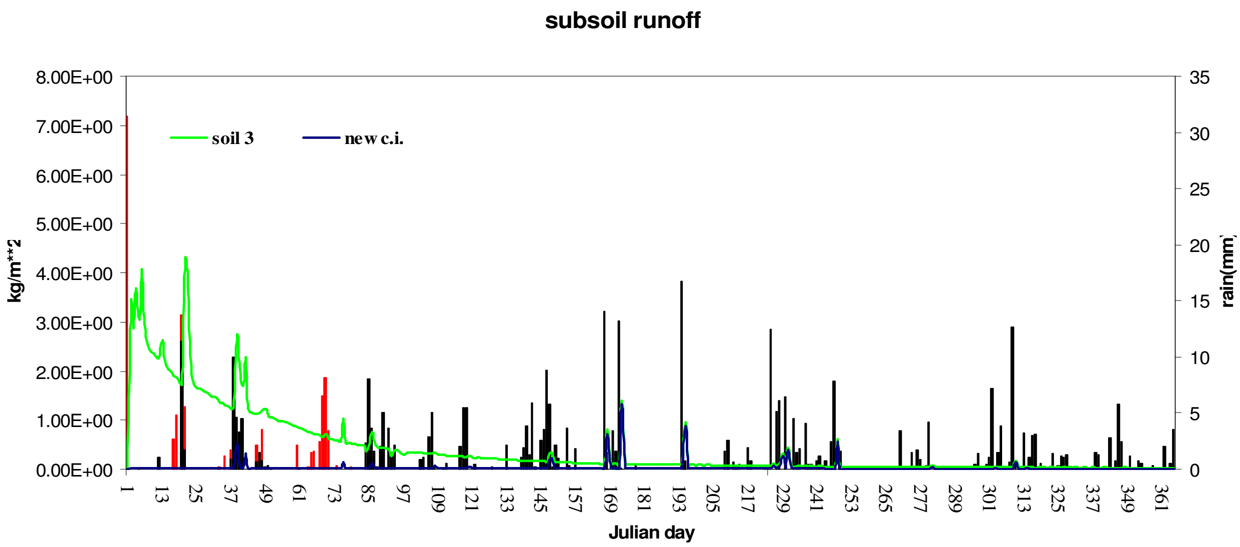


graph 25 : the black bar represents the cumulated daily precipitations,the red bar represents the snow precipitation; the others bars are the latent heat curves varying the initial conditions (green line for old i.c., blue for new i.c)



graph 26: the black bar represents the cumulated daily precipitations,the red bar represents the snow precipitation; the others bars are the sensible heat curves varying the initial conditions (green line for old i.c., blue for new i.c)

In the **graph 25** and **26**, are shown the results for latent and sensible heat; they seem to be influenced by the initial conditions for a long time (about 6 months); it is interesting to note that, in sensible heat graph, the differences are such as to cause the inversion of the heat flux (on 25th day and85thday).



graph 27: the black bar represents the cumulated daily precipitations,the red bar represents the snow precipitation; the others bars are the subsoil runoff curves varying the initial conditions (green line for old i.c., blue for new i.c)

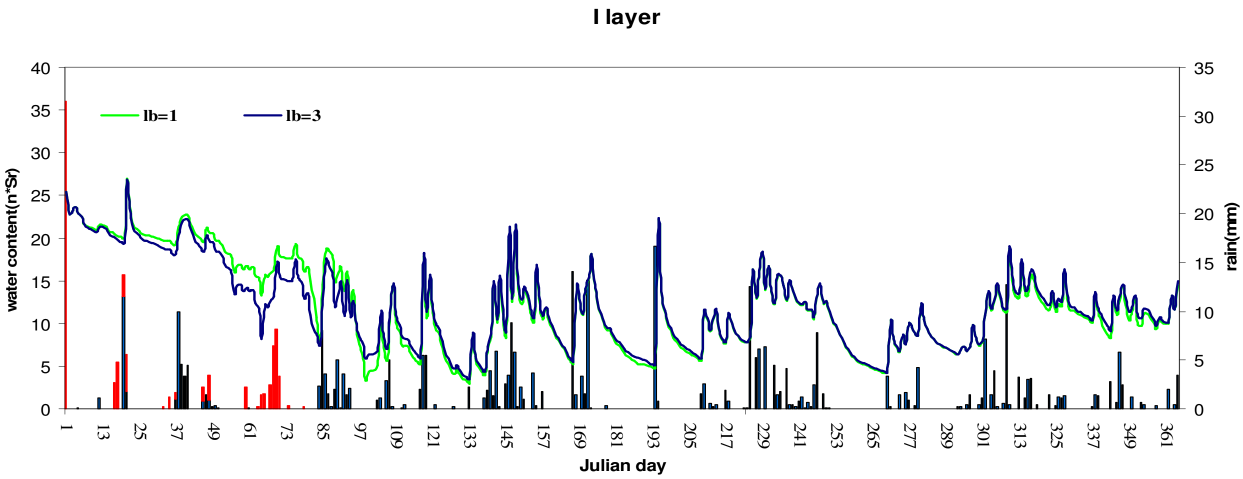
Looking at **graph 27**, it's evident that, using the new initial conditions, in the first period, there are not anomal values affecting the entire trend but, probably,values close to real data (there is the same problem for 2005 subsoil runoff trend).

1.3.3 Lower boundary

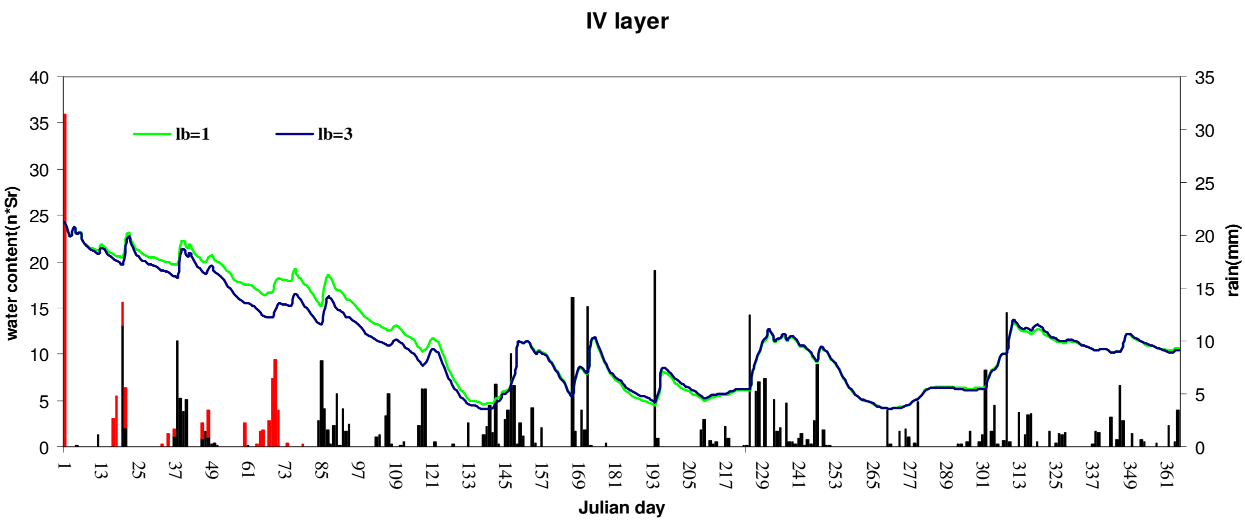
As lower boundary is usually utilized a flux boundary condition(in the following graphs **lb=1**); at a depth of 2.43m only the downward gravitational transport is considered (capillary transport is neglected); to test new settings, in TERRA-LM stand alone code other two experimental conditions are added:

- **Rigid lid :**impermeable bottom of soil column (at the moment, not available)
- **Constant ground water:** this condition assumes water table presence at the bottom of soil column and then ,water pressure equal to zero at this depth (now available; in the following graphs **lb=3**).

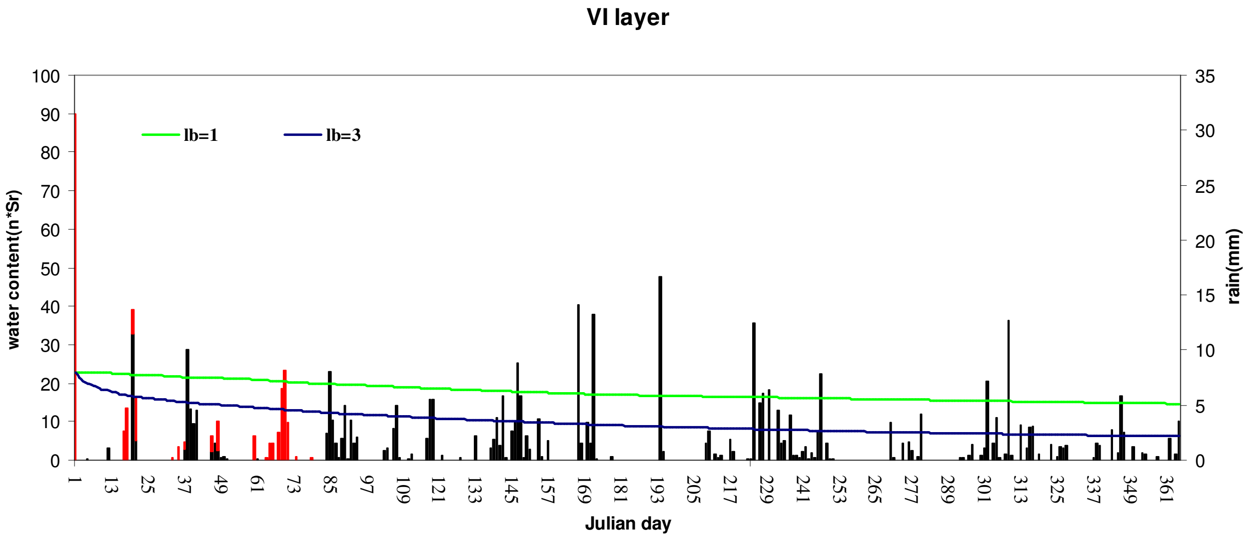
In these sensitivity tests, the outputs proved to be like 2005 runs, posing again the same problems;
In the following graphs (**graphs 28-31**) are shown the results obtained, for water content, with flux boundary condition (usually used) and constant ground water condition.



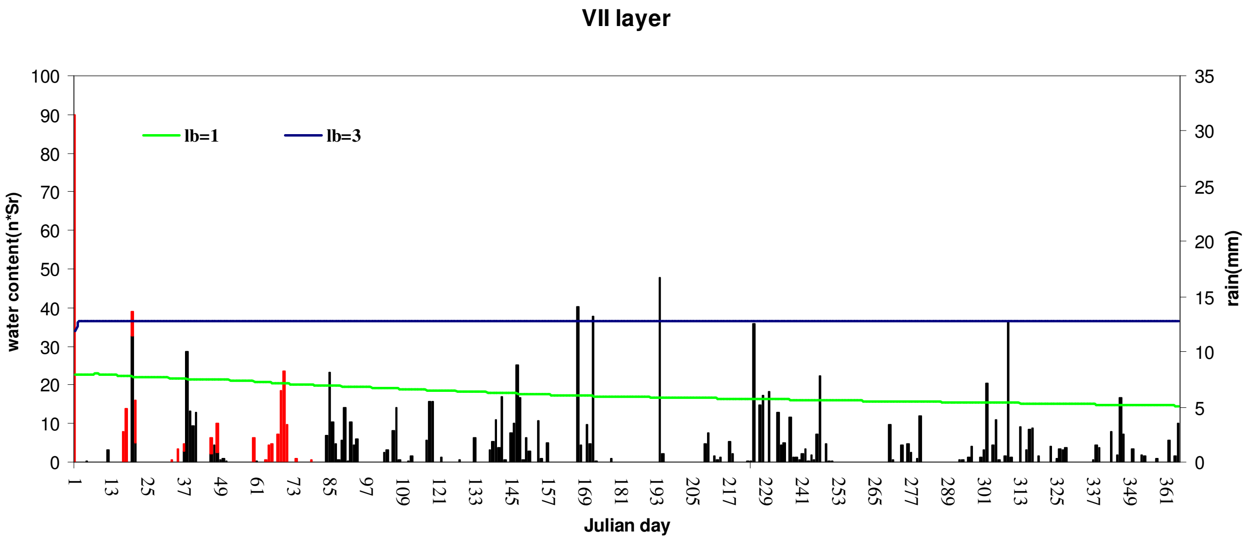
graph 28: the black bar represents the cumulated daily precipitations; the red bar represents the snow precipitation; the others bars are the soil moisture curves in the first layer varying the lower boundary (green line for the unit gradient condition and blue for constant groundwater condition)



graph 29: the black bar represents the cumulated daily precipitations; the red bar represents the snow precipitation; the others bars are the soil moisture curves in the IV layer varying the lower boundary (green line for the unit gradient condition and blue for constant groundwater condition)

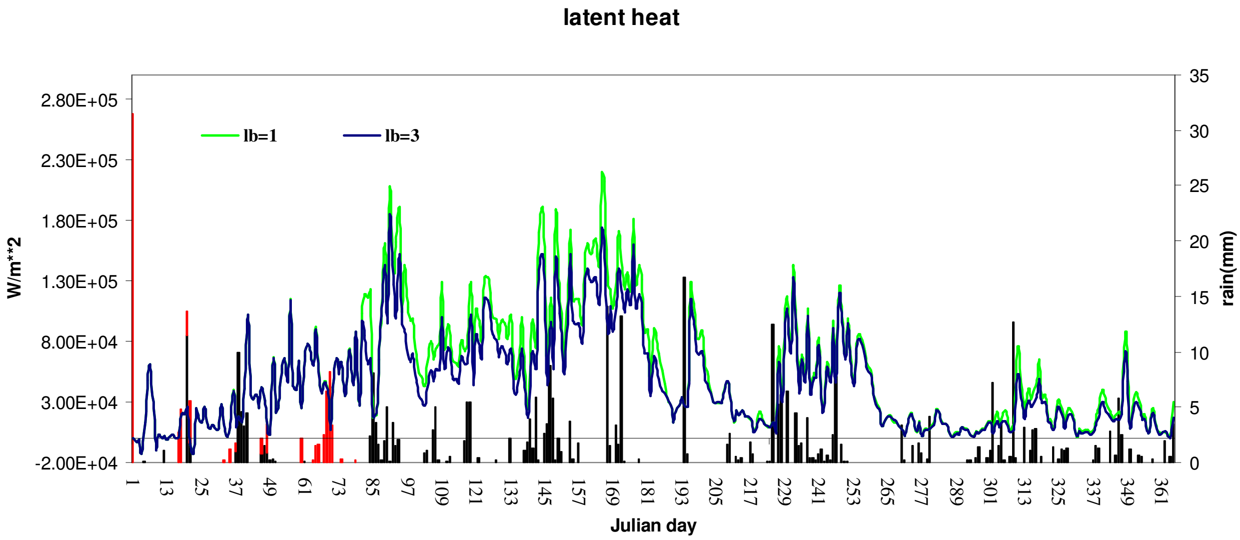


graph 30: the black bar represents the cumulated daily precipitations; the red bar represents the snow precipitation; the others bars are the soil moisture curves in the VI layer varying the lower boundary (green line for the unit gradient condition and blue for constant groundwater condition)



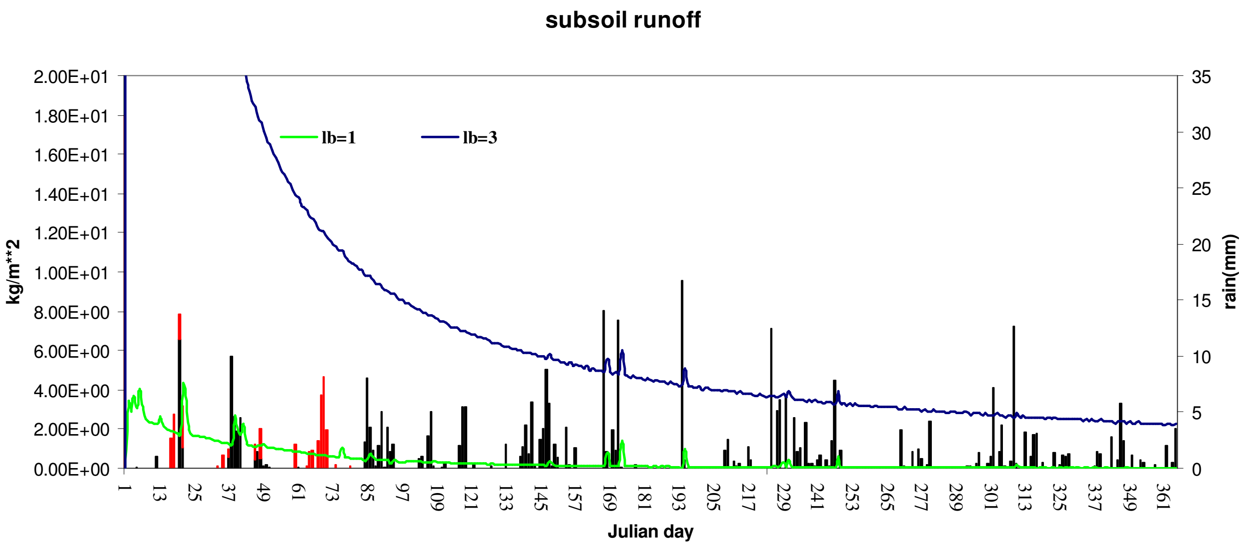
graph 31: the black bar represents the cumulated daily precipitations; the red bar represents the snow precipitation; the others bars are the soil moisture curves in the VII layer varying the lower boundary (green line for the unit gradient condition and blue for constant groundwater condition)

For four upper layers, between two curves the differences are mainly in cold season (until 140th day and the last part of the year; for 2005 year, this period was slightly shorter); after this period, they are superimposed; on the contrary, for three lower layers, constant ground water presence influnces heavily the trends; in fact, for lower boundary 3, water content tends to porosity value while the green curve tends to an equilibrium value (probably for better initial condition, it should tend to horizontal line). Between 6th and 7th layer, the sudden variation of water content doesn’t seem to be likely; the effect of constant groundwater on upper layers should be strictly marked;



graph 32 the black bar represents the cumulated daily precipitations; the red bar represents the snow precipitation; the others bars are latent heat curves varying the lower boundary (green line for the unit gradient condition and blue for constant groundwater condition)

The fluxes of water or heat are not much influenced by the boundary conditions variation; in the intermediate months there are some differences but they don't modify strictly the water balance. The soil temperature distribution in the soil remains unchanged; then, owing to the results of the other simulations, it is possible to observe that the thermal conduction seem to be not much influenced by the water content in the soil.



graph 33: the black bar represents the cumulated daily precipitations; the red bar represents the snow precipitation; the others bars are the subsoil runoff trends varying the lower boundary (green line for the unit gradient condition and blue for constant groundwater condition)

For subsoil runoff (**graph 33)** the lower boundary condition to test, furnishes more higher values (about three order of magnitude); these values seem to be incorrect; furthermore after a peak in the first time, trend slopes down apart from rain history.

1.3.4 Different numerical treatment of drainage

In TERRA-LM module, between two next layers water flux is expressed by Richards equation:

$$\frac{\partial(\eta)}{\partial t} = \frac{\partial}{\partial z}\left[D(\eta)\frac{\partial \eta}{\partial z} + k(\eta)\right] = \frac{\partial F}{\partial z} \qquad \textbf{eq. 8}$$

Permability $k(\eta)$ and hydraulic diffusivity $D(\eta)$ are expressed using *Rijtema (1969)* formulation:

$$D(\eta) = D_o e^{\frac{D_1(n-\eta_{m,l})}{n-\eta_{adp}}} \qquad \textbf{eq. 9}$$

$$k(\eta) = k_o e^{\frac{k_1(n-\eta_{m,l})}{n-\eta_{adp}}} \qquad \textbf{eq. 10}$$[2]

the term $\eta_{m,l}$ is calculated implementing an arithmetic mean between water content of two next layers; in TERRA-LM stand alone-version is introducted an experimental value for $\eta_{m,l}$; is used water content of layer receiving the flux.

Implementing this variation in the simulations, for this case-study, any variation is noted.

---

2 k_0, k_1, D_0, D_1 constants (see Table 1)
n volume of voids (see Table 1)

Remarks

First of all, it is possible to reply some remarks, exposed in “Terra-LM sensitivity tests:Falkenberg 2005”:

- The stand-alone version 1D of TERRA-LM proved to be an useful tool to test the “soil module”; forcing the SVAT model via monitored atmospheric conditions, error sources are reduced.
- Calculation time are very short (few seconds to simulate 1 year on the scalar parallel machine NEC TX7 using the sequential version of the code); in this way, it is possible to calculate a large number of sensitivity runs.
- Some terms of hydric balance, like subsoil runoff and surface runoff, need to be verified on other case-histories.
- Because of long spin-off time, it should be better to simulate a very long time to reduce spin-off effects.
- It is not possible to verify the outputs due to lack of experimental data in the soil.
- The simulation of thermal processes shows very little sensitivity to variations of soil properties, boundary condition or evaporation models.
- It should be very useful to carry out some tests on the Mediterranean area to understand how the model behaviour varies.
- It should be very useful to compare the outputs of other SVAT models using the same input data.

But it is possible to add:

- For the both years (2005 and 2006), varying the evaporation model, the lower boundary or the soil properties similar trends are obtained; then, the modifications implemented in the code give coherent outputs
- Some anomal trends arise again; for instance, subsoil runoff for constant groundwater lower boundary;
- Using monitored snow data, an error source is deleted;
- It is necessary to test the different numerical treatment of drainage on the other cases to understand how this modification can affect the trends;