1. Model algorithms for climate generator SCLISS

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1.1. General description

The SCLISS model (Soil CLImate Statistical Simulator) is intended for an assessment of average monthly values of temperature and moisture of organic layer (forest floor) and mineral soil in different forest stands with different dominants, grasslands and agricultural fields on the base of standard meteorological observations: air temperature, precipitation and, in a presence of data, soil temperature under the grass, measured at meteorological stations.

The SCLISS model plays an important role at work with the ROMUL model for evaluating of soil organic matter dynamics. Coefficients in ROMUL depend on temperature and moisture of forest floor and mineral soil. So it is necessary to have scenarios with average monthly temperatures and moisture of forest floor and mineral soil as input files. In this program we calculate climatic characteristics for forest floor as a whole without its breakdown into horizons. We consider also aggregation of all horizons of mineral topsoil into one horizon. It is a notorious roughening, however in this version referring mostly to boreal soils and at monthly time step we consider such division sufficient for modification of coefficients of organic matter transformation in ROMUL.

Air temperature and precipitation are usually measured at numerous meteorological stations. Sometimes soil temperature under grass vegetation is also measured. But, forest soil and especially forest floor temperature and moisture are seldom measured and, moreover, these data are mostly a result of short-term scientific forest studies, but not long-term monitoring. Therefore, the procedure of simulating the necessary monthly input data should be linked with the soil organic matter model. We developed a simple statistical model for the simulations of these data. A more detailed description of this soil climate generator and its verification is done by Bykhovets and Komarov (2002).

A soil climate generator can be used for two purposes:

- statistical simulation (generation) of realizations of long-term series of input climate data with known statistical properties (if necessary);
- evaluation of soil temperature and moisture using measured or simulated input meteorological data.

1.2. Simulation of air temperature and precipitation

The model can either use climate data series obtained from outer sources (measured data from meteorological stations or any simulated time series), or simulate them using some assumptions based on climatological investigations, and verified by the analysis of measured long-term monthly series from several stations. These assumptions are as follows:

- air temperature is normally distributed with a monthly average $\overline{T_{a,m}}$ and the standard deviation $\sigma_{T_{a,m}}$;
- monthly precipitation r_m is distributed normally logarithmically;
- autocorrelation in the monthly average temperature series is significant as opposed to the precipitation series;
- cross-correlation between air temperature and precipitation is significant, moreover, in the boreal zone it is positive in winter and negative in summer.

Assuming that the distribution of monthly precipitation (r_m) is lognormal, we obtained

$$r_m = \exp\left(\mu_{r,m} + \nu_{r,m} \cdot n_1\right) \qquad (1),$$

where $\mu_{r,m} = \overline{\ln r_m}$ and $\nu_{r,m} = \sigma_{\ln r_m}$ are the parameters of lognormal distribution. They can be expressed using traditionally published data, i.e., the long-term average $\overline{r_m}$ and coefficient of variation $Cv_{r,m} = \sigma_{r.m} / \overline{r_m}$ of monthly precipitation, as follows

$$\mu_{r,m} = \ln\left(\overline{r_m} \Big/ \sqrt{1 + Cv_{r,m}^2}\right), \qquad \nu_{r,m} = \sqrt{\ln\left(1 + Cv_{r,m}^2\right)} \qquad (2),$$

n_1 is the normally distributed random variable $N(0, 1)$.

The simulation of air temperature takes into account autocorrelation with a monthly lag and the correlation between air temperature and precipitation (logarithm of monthly total precipitation is used as “normalized” characteristic of precipitation).

Thus the monthly average air temperature (denoted as $T_{a,m}$) is simulated as

$$T_{a,m} = \overline{T_{a,m}} + B_{aa,m} \cdot \left(T_{a,m-1} - \overline{T_{a,m-1}}\right) + B_{ar,m} \cdot \left(\ln r_m - \overline{\ln r_m}\right) + n_1 \cdot S_{Ta,m} \qquad (3),$$

where $\overline{T_{a,m}}$ is the long-term monthly average air temperature of m-th month, which has usually been published in regional reference books; $B_{aa,m}$ and $B_{ar,m}$, the corresponding regression coefficients, obtained separately on the basis of long-term climatic data, and $S_{Ta,m}$, residual deviation, n_1 is the normally distributed random variable $N(0, 1)$.

1.3. Simulation of soil temperature

The soil temperature (denoted as $T_{s,m}$) may be simulated on the basis of the Gauss distribution accounting both for autocorrelation and correlation with air temperature. The corresponding statistical model is

$$T_{s,m} = \overline{T_{s,m}} + B_{ss,m} \cdot \left(T_{s,m-1} - \overline{T_{s,m-1}}\right) + B_{sa,m} \cdot \left(T_{a,m} - \overline{T_{a,m}}\right) + n_m \cdot S_{T_{s,m}} \qquad (4),$$

where $T_{s,m}$ is the long-term monthly average soil temperature; $B_{ss,m}$ and $B_{sa,m}$, the corresponding regression coefficients and $S_{T_{s,m}}$, the residual deviation.

As it was mentioned before there are usually no forest data available for this statistical model of soil temperature. One has enough data measured at standard conditions under grass at meteorological stations in Russia. Conversely, data on evaluating the difference between the soil temperature under grass at standard meteorological stations and under the forest are known. It may be seen in Fig. 1 that the differences between soil temperature under grass and forest are significant and relatively stable for a large geographical region. It allows one to assume as the first approximation that this difference does not depend on other factors.

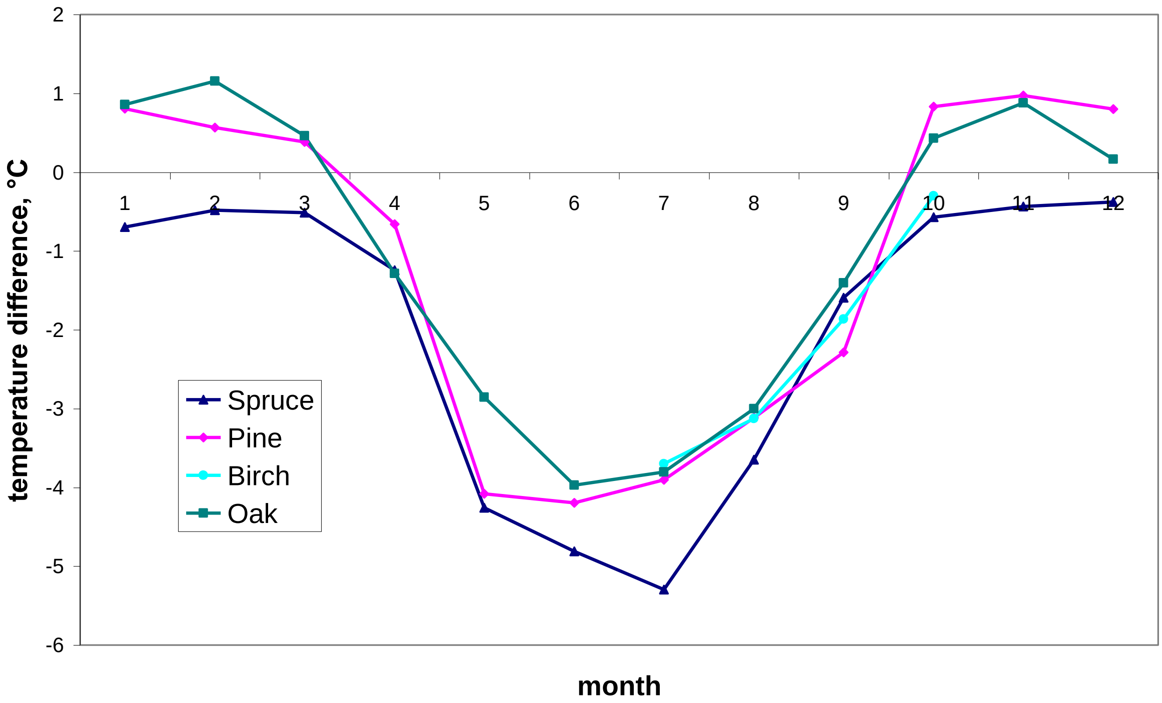


Figure 1. The annual course of the difference between soil temperatures at the depth of 0.20 m under a forest and under a standard grass cover at meteorological stations (data for birch forest was available for several months only, during the rest of year it supposed to be the same as for pine).

Consequently, the main scheme of evaluation of soil temperature using a statistical model includes:

(1) statistical simulation of soil temperature under “standard” conditions (grass vegetation) using the model described above (Eq. 4) if necessary;

(2) an account of the corresponding differences between forest conditions and standard conditions:

$$T_{FS,m} = T_{s,m} + \Delta T_{FS,m} \qquad (5);$$

and

(3) estimation of the forest floor temperature T_{FF}, supposed to be as follows:

$$T_{FF} = \begin{cases} T_{air} & \text{at } T_{air} > 0 \text{ and } T_{soil} > 0; \\ T_{soil} & \text{at } T_{air} < 0 \text{ and } T_{soil} < 0; \\ 0 & \text{in all other cases.} \end{cases} \tag{6}$$

1.4. Soil moisture

The construction of a strictly statistical model for the evaluation of soil moisture is possible in principle, but there is not enough measured data. Therefore quite simple balance equations can be used. It is clear that a change in the water content of the active soil layer $\Delta W=W_2-W_1$ may be defined as

$$\Delta W = W_2 - W_1 = r - E - f \tag{7}$$

where r is the precipitation, E is the evapotranspiration, f is the total runoff, W_1 and W_2 are soil water contents at the beginning and at the end of the month, respectively. The method of evaluation of evapotranspiration based on accounting of the components of water balance and their dependencies on soil moisture (Budyko, 1974) was used.

Evapotranspiration E is defined as

$$E = \begin{cases} E_0 & \text{at } W > W_0 \quad (\text{or } W^{(P)} > W_0^{(P)}) \\ E_0 \dfrac{W^{(P)}}{W_0^{(P)}} = E_0 \dfrac{W - W_{WP}}{W_0 - W_{WP}} & \text{at } W < W_0 \quad (\text{or } W^{(P)} < W_0^{(P)}) \end{cases} \tag{8}$$

where W is the water content in the root zone, $W^{(P)}=W-W_{WP}$; W_{WP} is the value of W at the permanent wilting point W_0 is the critical value of W (the value $W_0^{(P)}=W-W_{WP}$ changed from $W_{FC}^{(P)}=W_{FC}-W_{WP}$ during cold seasons to 0.75 $W_{FC}^{(P)}$ at midsummer).

Runoff is defined as

$$f = \mu \cdot r \cdot \frac{W^{(P)}}{W_k^{(P)}} = \mu \cdot r \cdot \frac{W - W_{WP}}{W_k - W_{WP}} \tag{9}$$

Where

$$\mu = \begin{cases} \alpha & \text{at } r < E_0 \\ \sqrt{\alpha^2 \left[1 - \left(1 - \dfrac{E_0}{r}\right)^2\right] + \left(1 - \dfrac{E_0}{r}\right)^2} & \text{at } r > E_0 \end{cases} \tag{10}$$

$\alpha \approx 0.2$ (for latitudes larger than 45°), empirical coefficient;

$$W_k = \begin{cases} W_{FC} & \text{(field capacity) for well - drained soils,} \\ W_S & \text{(saturation) if ground water is close to surface.} \end{cases}$$

The evaluation of potential evapotranspiration by this method requires additional input data: air humidity, net radiation, etc. Therefore, the authors have restricted themselves in this version to the simple empirical equation of Blaney and Criddle (1950), which allows one to evaluate potential evapotranspiration using air temperature only:

$$E_0 = 25.4 \cdot k_m \cdot p_m \cdot (1.8 \cdot T_{a,m} + 32), \qquad (11)$$

where: p_m is the percentage sum of light duration per month in relation to its annual sum, which is a function of latitude and may easily be computed; k_m is a coefficient reflecting seasons and the vegetation type. The k_m values were adjusted for the boreal forest zone conditions. It was found that k_m=0.5 during the growth period and k_m=0.2 during winter gives the result corresponding with the potential evapotranspiration estimated with the Budyko - Zubenok method.

After substituting Eqs. (8) and (9) into Eq. (7) and setting $W=(W_1+W_2)/2$ the equation for W_2 was solved.

$$W_2 = \begin{cases} W_{WP} + \dfrac{r + (W_1 - W_{WP}) \cdot \left(1 - \dfrac{E_0}{2(W_0 - W_{WP})} - \dfrac{\mu \cdot r}{2(W_k - W_{WP})}\right)}{\left(1 + \dfrac{E_0}{2(W_0 - W_{WP})} + \dfrac{\mu \cdot r}{2(W_k - W_{WP})}\right)} & \text{at } W < W_0 \\ W_{WP} + \dfrac{r - E_0 + (W_1 - W_{WP}) \cdot \left(1 - \dfrac{\mu \cdot r}{2(W_k - W_{WP})}\right)}{\left(1 + \dfrac{\mu \cdot r}{2(W_k - W_{WP})}\right)} & \text{at } W > W_0 \end{cases}$$

But the value $W=(W_1+W_2)/2$ is unknown before the calculation. Therefore, W_2 at first is calculated using one version of the equation and, after testing the condition, if necessary, it should be recalculated using another one.

Calculations were done for the period using positive air temperature. During winter, with negative temperatures, soil moisture is set as constant. Precipitation (without evaporation), are added and entered into the soil in the first month with positive air temperatures (including this month's precipitation). For transition to moisture (mass%) w_{mass}, the following expression was used:

Then we we "dividing" calculated water storage between two layers (forest floor and mineral soil) $W = W_{FF} + W_S$, supposing the ratio of their volumetric water contents $w_{FF,vol} / w_{S,vol} = C_f$ to be constant for each certain site. In this case:

$$W_{FF} = W \cdot L_{FF} \cdot C_f / (L_S + L_{FF} \cdot C_f),$$

$$W_S = W - W_{FF} = W \cdot Ls / (L_S + L_{FF} \cdot C_f);$$

or

$$w_{FF,vol} = 0.1 \cdot W \cdot C_f / (L_S + L_{FF} \cdot C_f)$$

$$w_{S,vol} = 0.1 \cdot W / (L_S + L_{FF} \cdot C_f)$$

and for water content in mass % ($w_{FF,mass}$ and $w_{S,mass}$),

$$w_{FF,mass} = w_{FF,vol} / D_{b,FF} \ ,$$

$$w_{S,mass} = w_{S,vol} / D_{b,S}$$

Where W is total water storage in soil, including forest floor (mm); L_{FF} is the thickness of organic layer (forest floor), m (estimated as forest floor organic matter pool divided per forest floor bulk density); L_S is the thickness of mineral soil layer in simulation (1 m by default);

$w_{FF,vol}$ and $w_{S,vol}$ are forest floor and mineral soil layer water contents (vol.%),

$w_{FF,mass}$ and $w_{S,mass}$ are forest floor and mineral soil layer water contents (mass.%)

$D_{b,FF}$ and $D_{b,S}$ are forest floor and mineral soil layer bulk densities (g/cm^3 = 10^{-3} kg/m^3);

C_f is the parameter specifying ($w_{FF,vol}$ / $w_{S,vol}$) ratio, dependent on site conditions. By default (for mesic sites) its value is set to be 0.5.

2. Description and preparation of input files

2.1. Introductory notes

Two modes of modeling are possible:

1. ***"Weather from file"*** – evaluation of temperature and moisture of forest floor and mineral soil according to input meteorological data (air temperature and precipitation); thus soil temperature under a grass can be set in the input file, as well as be calculated independently in the program (see item 2.2) .

2. ***"Simulated weather"*** – statistical generating of "input" meteorological data with the subsequent assessment of temperature and moisture of forest floor and mineral soil in different forest types.

The SCLISS model usually needs three input files (in some cases only two of them):

***.wed** contains series of monthly meteorological data which are necessary for modeling of temperature and moisture of forest floor and mineral soil in dependence on site parameters;

.cld** contains statistical parameters of climate, it is necessary for the ***"simulated weather" mode; for the ***"weather from file"*** mode it is needed only at total or partial absence of soil temperature data in ***.wed** file;

***.sit** contains data on site characteristics (mainly soil hydrological parameters) and is necessary in all cases.

All three input files are in text format with comma separators (CSV format), and can be prepared in any text editor. But it is necessary to check their expansions because text editors assign their own default expansions (.txt or .csv). The most convenient way to achieve right name of the file to put it in quotes together with his special expansion (for example, "spb.wed") in a window of saving of data of the appropriate program. The name of the file has to be written down without spaces, it is possible to use underlining and figures.

> ***Warning***
>
> ***At the preparation of input files with your own data create backup copies, please don't change values in the initial test files of the project, let these files-prototypes be always stored in the folder: SCLISS→test***

For preparation of the input files in the NOTEPAD editor:

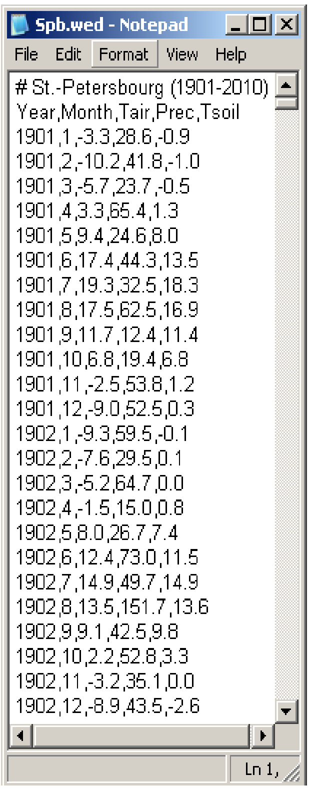
1) open the test file which is placed in the ***SCLISS→test*** folder with the corresponding expansion in the Notepad;
2) save the file under other name, be attentive with its name (see above),

Preparation of files (*.sit) and (*.cld) is also possible by facilities of the user interface of SCLISS.

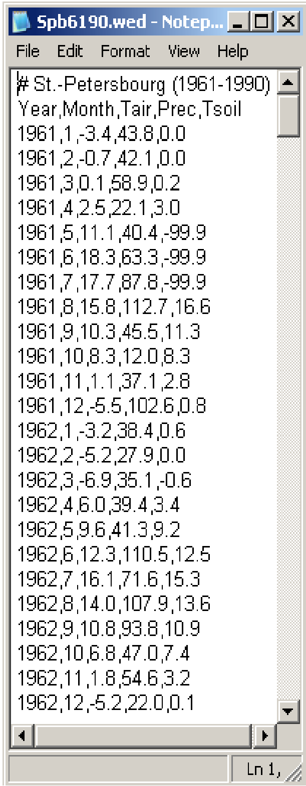
> ***Warning***
>
> ***File *.wed can be rather big; it includes meteorological series which often already exist in a digital form. Therefore, it is more convenient to prepare this file in a spreadsheet (for example, MS Excel) and to save it in .csv format, but with .wed expansion (see comments earlier). Besides, in this case in regional settings of Windows decimal point has to be installed as a separator of the whole and fractional part, and comma as a separator of elements in the list. Check correctness of separators! It can be done by Notepad.***

*2.2. Monthly meteorological data, *.wed file*

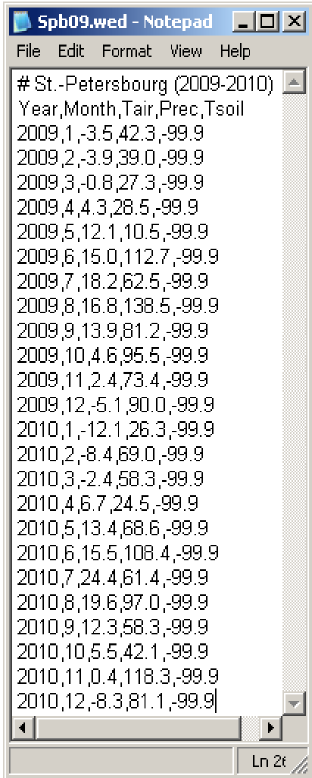
This file is necessary for modeling of dynamics of soil conditions in the presence of data on the ambient weather conditions for a certain time interval or for the data obtained from computer experiments with global climatic models (for example, during the work with climate change scenarios). The example of data recording is given in Fig. 2.



```
Spb.wed - Notepad
File Edit Format View Help
# St.-Petersbourg (1901-2010)
Year,Month,Tair,Prec,Tsoil
1901,1,-3.3,28.6,-0.9
1901,2,-10.2,41.8,-1.0
1901,3,-5.7,23.7,-0.5
1901,4,3.3,65.4,1.3
1901,5,9.4,24.6,8.0
1901,6,17.4,44.3,13.5
1901,7,19.3,32.5,18.3
1901,8,17.5,62.5,16.9
1901,9,11.7,12.4,11.4
1901,10,6.8,19.4,6.8
1901,11,-2.5,53.8,1.2
1901,12,-9.0,52.5,0.3
1902,1,-9.3,59.5,-0.1
1902,2,-7.6,29.5,0.1
1902,3,-5.2,64.7,0.0
1902,4,-1.5,15.0,0.8
1902,5,8.0,26.7,7.4
1902,6,12.4,73.0,11.5
1902,7,14.9,49.7,14.9
1902,8,13.5,151.7,13.6
1902,9,9.1,42.5,9.8
1902,10,2.2,52.8,3.3
1902,11,-3.2,35.1,0.0
1902,12,-8.9,43.5,-2.6
Ln 1,
```



```
Spb6190.wed - Notep...
File Edit Format View Help
# St.-Petersbourg (1961-1990)
Year,Month,Tair,Prec,Tsoil
1961,1,-3.4,43.8,0.0
1961,2,-0.7,42.1,0.0
1961,3,0.1,58.9,0.2
1961,4,2.5,22.1,3.0
1961,5,11.1,40.4,-99.9
1961,6,18.3,63.3,-99.9
1961,7,17.7,87.8,-99.9
1961,8,15.8,112.7,16.6
1961,9,10.3,45.5,11.3
1961,10,8.3,12.0,8.3
1961,11,1.1,37.1,2.8
1961,12,-5.5,102.6,0.8
1962,1,-3.2,38.4,0.6
1962,2,-5.2,27.9,0.0
1962,3,-6.9,35.1,-0.6
1962,4,6.0,39.4,3.4
1962,5,9.6,41.3,9.2
1962,6,12.3,110.5,12.5
1962,7,16.1,71.6,15.3
1962,8,14.0,107.9,13.6
1962,9,10.8,93.8,10.9
1962,10,6.8,47.0,7.4
1962,11,1.8,54.6,3.2
1962,12,-5.2,22.0,0.1
Ln 1,
```



```
Spb09.wed - Notepad
File Edit Format View Help
# St.-Petersbourg (2009-2010)
Year,Month,Tair,Prec,Tsoil
2009,1,-3.5,42.3,-99.9
2009,2,-3.9,39.0,-99.9
2009,3,-0.8,27.3,-99.9
2009,4,4.3,28.5,-99.9
2009,5,12.1,10.5,-99.9
2009,6,15.0,112.7,-99.9
2009,7,18.2,62.5,-99.9
2009,8,16.8,138.5,-99.9
2009,9,13.9,81.2,-99.9
2009,10,4.6,95.5,-99.9
2009,11,2.4,73.4,-99.9
2009,12,-5.1,90.0,-99.9
2010,1,-12.1,26.3,-99.9
2010,2,-8.4,69.0,-99.9
2010,3,-2.4,58.3,-99.9
2010,4,6.7,24.5,-99.9
2010,5,13.4,68.6,-99.9
2010,6,15.5,108.4,-99.9
2010,7,24.4,61.4,-99.9
2010,8,19.6,97.0,-99.9
2010,9,12.3,58.3,-99.9
2010,10,5.5,42.1,-99.9
2010,11,0.4,118.3,-99.9
2010,12,-8.3,81.1,-99.9
Ln 2(
```

1. complete data without missing values	2. with missing values in soil temperature series	3. without data on soil temperature

Figure 2. Example of data recording in ***.wed** file

File format:

1st line. Row containing the name of a site (meteorological station) and/or other text described data. The line has to be commented out (to begin with a symbol "#"). It will not be read by the program, but this information is useful to identification of file contents. The line can have length up to 250 characters and should not contain symbols of the end of row in the text (it arise when pressing a key [Enter]);

2nd line. Headings of columns: "Year, month, Tair, Prec, Tsoil";

3d and following lines. Actual monthly meteorological data:

Sequence of data in a line (columns):

Year : Number of year (actual or conditional);

Month : Number of month (1-12);

Tair : Average monthly air temperature, °C;

Prec : Monthly precipitation, mm;

Tsoil : Average monthly soil temperature at the depth of 0,2 m under "a natural surface" (grass) at meteorological station, °C. ***If these data are absent, in all fields without data there has to be a figure: -99.9 .***

> ***Warning***
>
> ***Values of month and year have to be written down as integers, for example: 1,2,3,4, other values as real numbers, with decimal point as a separator of the whole and fractional part (including zero), for example: -3.4, 0.0 .***
>
> ***A row of months has to contain integer number of years, beginning from January and until December.***
>
> ***The file shouldn't contain excess spaces and empty lines, including end of the file.***

This file with meteorological data consists of series of the actual observations in a certain place for a certain interval of time, as well as data of some estimated climatic scenarios (modelled climate changes, etc.).

Data on air temperature and precipitation are often available on Internet pages of national hydrometeorological services or their meteorological institutes, and also the international climatic centers (http://www.ncdc.noaa.gov, http://eca.knmi.nl, etc.). Soil temperature has often measured at meteorological stations, but is still seldom available online. Apparently, these data can be available in local or national meteorological institutions.

Such the data for the territory of Russia are partially available online on the RIHMI-WDC Internet page: http://meteo.ru/english/climate/cl_data.php.

Scenarios of climate changes can be found on a site of the Center of distribution of data of IPCC (IPCC DDC), and also on sites of global climatic models, but usually they represent huge files of data all around the globe, and receiving from them local scenarios needs separate description.

*2.3. Statistical parameters of climate *.cld file*

This file contains the climatic data necessary for statistical generating of input meteorological series, as well as for calculation of absent values of soil temperature by air temperature data.

```
VAR VALUE
# St.-Petersbourg (from data of 1961-1990)
av_Ta,-7.72,-6.83,-2.17,3.93,10.49,15.00,17.12,15.64,10.71,5.46,0.05,-4.44
# Average air temperature, deg.C
std_Ta,4.80,4.03,2.78,1.89,2.71,3.38,3.61,3.21,2.59,1.98,1.90,3.05
# Standard deviation of air temperature, deg.C
av_P,36.65,30.05,32.99,32.55,36.73,55.80,76.53,77.52,67.86,66.50,54.61,47.42
# Average precipitation
Cv_P,0.44,0.52,0.57,0.62,0.47,0.60,0.50,0.49,0.49,0.54,0.33,0.53
# coefficient of variation
av_Ts,-0.35,-0.68,-0.43,2.16,9.65,14.45,16.83,16.03,11.79,6.56,2.36,0.47
# Average soil temperature at 0.2 m depth under grass, deg.C
std_Ts,0.88,0.93,0.80,1.72,2.19,3.15,3.72,3.41,2.50,1.85,1.11,0.68
#Standard deviation of soil temperature at 0.2 m depth under grass, deg.C
Baa,0.57,0.37,0.25,0.16,0.26,-0.01,0.38,0.26,0.20,0.43,0.09,-0.31
# regression coefficient...
Bap,2.99,2.01,0.41,-0.60,-0.10,-0.79,-0.72,-0.40,-1.44,-0.05,-0.35,-0.19
# regression coefficient...
Sa,4.13,3.51,2.59,1.69,1.92,1.85,1.39,1.19,1.45,1.75,1.94,2.88
# residual deviation of air temperature, deg.C
Bss,0.59,0.90,0.63,0.81,0.21,0.29,0.46,0.43,0.34,0.31,0.36,0.22
# regression coefficient...
Bsa,0.05,0.05,0.10,0.66,0.51,0.68,0.80,0.59,0.57,0.67,0.30,0.10
# regression coefficient...
Ss,0.77,0.31,0.33,0.76,0.54,0.89,0.96,0.80,0.42,0.51,0.67,0.58
# residual deviation of soil temperature, deg.C
```

Figure 3. Example of data recording in ***.cld** file

File format (Figure 3):

1st line: VAR VALUE (it is written for compatibility with a format of the input DLES files).

2nd line. Row containing the name of a site (meteorological station) and/or other text described data. The line has to be commented out (to begin with symbol "#"). It will not be read by the program, but this information is useful to identification of file contents. The line can have length up to 250 characters and should not contain symbols of the end of row in the text.

3d line and next lines contain statistical characteristics of climate. Each readable line begins with the identifier designating this parameter and containing 12 values of this parameter (for January – December respectively), and after these values a commented out (beginning with symbol "#") line is placed containing the detailed comment to the corresponding variable.

List of variables:

av_Ta : long-term average monthly air temperature, °C;

std_Ta : standard deviation of average monthly air temperature, °C;

av_P : average monthly precipitation, mm;
Cv_P : coefficient of variation of the monthly precipitation;
av_Ts : the long-term average monthly soil temperature at 0.2 m depth under standard "natural surface" (grass) at meteorological station, °C;
std_Ts : standard deviation of average monthly soil temperature, °C;

Baa : regression coefficient $B_{aa,m}$,

Bap : regression coefficient $B_{ar,m}$. and

Sa : a residual deviation of air temperature $S_{T_{a,m}}$ in regression model for generating of air temperature (The equation 3 in Model Description);

Bss : regression coefficient $B_{ss.m}$,

Bsa : regression coefficient $B_{sa,m}$, and

Ss : a residual deviation of soil temperature $S_{T_{s,m}}$ in regression model for generating of a series of soil temperature(equation 4 in Model Description).

Where

$$B_{aa,m} = \frac{\sigma_{T_{a,m}}}{\sigma_{T_{a,m-1}}} \cdot \frac{\rho_{(T_{a,m},T_{a,m-1})} - \rho_{(T_{a,m},\ln r_m)} \cdot \rho_{(\ln r_m,T_{a,m-1})}}{1-\rho^2{}_{(\ln r_m,T_{a,m-1})}}$$

$$B_{ar,m} = \frac{\sigma_{T_{a,m}}}{\sigma_{\ln r_m}} \cdot \frac{\rho_{(T_{a,m},\ln r_m)} - \rho_{(T_{a,m},T_{a,m-1})} \cdot \rho_{(\ln r_m,T_{a,m-1})}}{1-\rho^2{}_{(\ln r_m,T_{a,m-1})}}$$

$$S_{T_{a,m}} = \sigma_{T_{a,m}} \cdot \sqrt{\frac{1-\rho^2_{(T_{a,m},\ln r_m)} - \rho^2_{(T_{a,m},T_{a,m-1})} - \rho^2_{(\ln r_m,T_{a,m-1})} + 2\cdot\rho_{(T_{a,m},\ln r_m)} \cdot \rho_{(T_{a,m},T_{a,m-1})} \cdot \rho_{(\ln r_m,T_{a,m-1})}}{1-\rho^2_{(\ln r_m,T_{a,m-1})}}}$$

and

$$B_{ss.m} = \frac{\sigma_{T_{s,m}}}{\sigma_{T_{s,m-1}}} \cdot \frac{\rho_{(T_{s,m},T_{s,m-1})} - \rho_{(T_{s,m},T_{a,m})} \cdot \rho_{(T_{a,m},T_{s,m-1})}}{1-\rho^2{}_{(T_{a,m},T_{s,m-1})}}$$

$$B_{sa,m} = \frac{\sigma_{T_{s,m}}}{\sigma_{T_{a,m}}} \cdot \frac{\rho_{(T_{s,m},T_{a,m})} - \rho_{(T_{s,m},T_{s,m-1})} \cdot \rho_{(T_{a,m},T_{s,m-1})}}{1-\rho^2{}_{(T_{a,m},T_{s,m-1})}}$$

$$S_{T_{s,m}} = \sigma_{T_{s,m}} \cdot \sqrt{\frac{1-\rho^2_{(T_{s,m},T_{a,m})} - \rho^2_{(T_{s,m},T_{s,m-1})} - \rho^2_{(T_{a,m},T_{s,m-1})} + 2\cdot\rho_{(T_{s,m},T_{a,m})} \cdot \rho_{(T_{s,m},T_{s,m-1})} \cdot \rho_{(T_{a,m},T_{s,m-1})}}{1-\rho^2_{(T_{a,m},T_{s,m-1})}}}$$

$\sigma_{T_{a,m}}$, $\sigma_{T_{s,m}}$, $\sigma_{\ln r_m}$ are standard deviations of air temperature, soil temperature and logarithm of the sum of a precipitation, $\rho_{(x, y)}$ are the corresponding coefficients of correlation (more detailed descriptions are in (Bykhovets, Komarov, 2002)).

All these parameters can be estimated on the basis of 20-30-year-long (and longer) series of monthly average values of air temperature, precipitation and soil temperature from any meteorological station close on climatic conditions to modeling site.

They can be estimated using any statistical software or a spreadsheet. It is convenient to use for this purpose facilities of SCLISS for calculation of climatic parameters ***(*.cld** file)* from initial meteorological series ***(*.wed** file)* – the option ***"Generate file"*** of the ***Climatology*** tab. For this purpose, please do the following after program start (before loading of input files for the program run) or after key  pressing (if after start any other task was already carried out):

1. choose the ***Climatology*** tab (the table of climatic parameters has to be empty);
2. press the ***Generate file*** button in the bottom of a tab. There will be a menu in which it is necessary to choose the file of meteorological data ***(*.wed)*** and to load it. Climatic parameters will be thus calculated and the ***Climatology*** tab table will be completed. Data in the table can be edited (generally speaking, it can be filled manually with the data calculated independently, but it is less convenient). Possibility of editing (filling) of data in the table can be needed, for example, if the ****.wed*** file doesn't contain data on soil temperature. Then these parameters should be taken from other ****.cld*** file or have to be estimated separately.
3 . press the ***Save file*** button in the bottom of tab and save obtained parameters in the climatic file ***"*.cld".***

Warning

1) if the file of meteorological data of "*.wed" format is intended for a calculation of climatic parameters only (generation of the file of climatic data "*.cld") then it can contain some missing values in the series of all meteorological elements where missed values have to be replaced with values-99.9);

2) such "*. wed" file with missed values in series of air temperature and precipitation is impossible to use as input data for the "Weather from file" simulation mode. For work in this mode all meteorological data in format "*. wed" have to take place (missed values are admissible only in series of soil temperature);.

3) there can be no complete data on soil temperature rather often at meteorological stations (and consequently, in the *.wed file). In this case the corresponding parameters (av_Ts, std_Ts, Bss, Bsa, and Ss) can't be estimated directly (see text below).

If data on soil temperature at the nearest meteorological stations are absent, the corresponding parameters (perhaps except average values of temperature) can be estimated on any station with available data from the region with similar climatic conditions, whereas long-term average values of average monthly temperature (at a depth of 0,2 m under grass) can be estimated, using simple approximation of its dependence on air temperature [Bykhovets, in preparation]:

$$t_s = \begin{cases} a_0 + a_1 t_a & npu \quad t_a \geq 0 \\ a_0 + a_2 t_a & '' \quad t_a < 0 \end{cases} \qquad (\ldots)$$

with coefficients

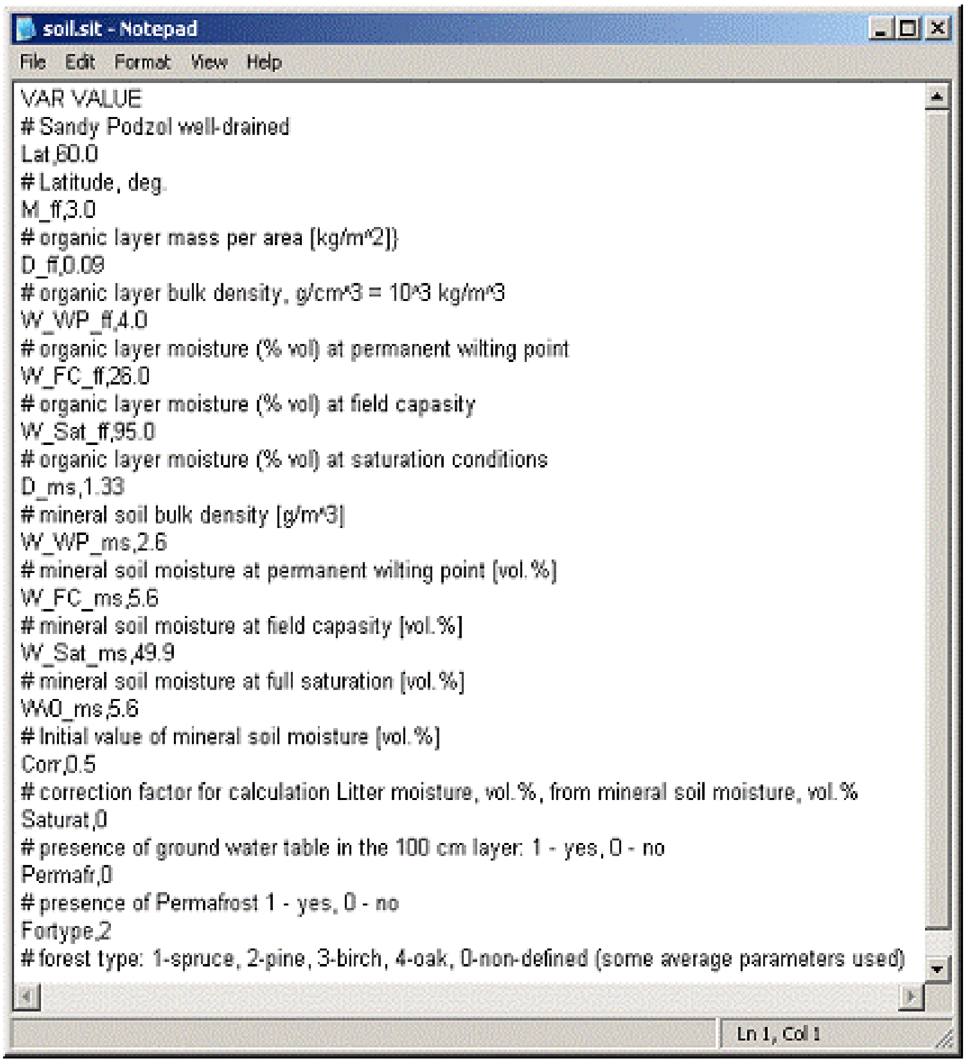
Table 1

Equation coefficients

month	a_0	a_1	a_2	R^2	SEE
I	2.53	0.57	0.45	0.753	2.48
II	2.55	0.69	0.51	0.791	2.35
III	1.66	0.86	0.59	0.894	1.68
IV	-0.69	1.10	0.69	0.951	1.28
V	-2.95	1.21	-	0.925	1.65
VI	-4.26	1.26	-	0.861	2.02
VII	-4.34	1.25	-	0.868	1.85
VIII	-2.25	1.20	-	0.919	1.47
IX	0.41	1.14	-	0.951	1.15
X	2.80	0.97	0.43	0.958	1.04
XI	2.77	0.90	0.41	0.914	1.37
XII	2.26	0.76	0.40	0.802	2.04

2.4. Site data (.sit)*

This file contains values of bulk density and hydro-physical constants of forest floor and mineral soil, and also some other characteristics of the site. The file can be built and edited in a text editor, for example, Notepad.



soil.sit - Notepad

File Edit Format View Help

```
VAR VALUE
# Sandy Podzol well-drained
Lat,60.0
# Latitude, deg.
M_ff,3.0
# organic layer mass per area [kg/m^2])
D_ff,0.09
# organic layer bulk density, g/cm^3 = 10^3 kg/m^3
W_WP_ff,4.0
# organic layer moisture (% vol) at permanent wilting point
W_FC_ff,26.0
# organic layer moisture (% vol) at field capasity
W_Sat_ff,95.0
# organic layer moisture (% vol) at saturation conditions
D_ms,1.33
# mineral soil bulk density [g/m^3]
W_WP_ms,2.6
# mineral soil moisture at permanent wilting point [vol.%]
W_FC_ms,5.6
# mineral soil moisture at field capasity [vol.%]
W_Sat_ms,49.9
# mineral soil moisture at full saturation [vol.%]
W0_ms,5.6
# Initial value of mineral soil moisture [vol.%]
Corr,0.5
# correction factor for calculation Litter moisture, vol.%, from mineral soil moisture, vol.%
Saturat,0
# presence of ground water table in the 100 cm layer: 1 - yes, 0 - no
Permafr,0
# presence of Permafrost 1 - yes, 0 - no
Fortype,2
# forest type: 1-spruce, 2-pine, 3-birch, 4-oak, 0-non-defined (some average parameters used)
```

Ln 1, Col 1

Figure 3. Example of data recording in ***.sit** file

File format (Figure 3)

The file contains the detailed comments to each variable in the commented-out lines (beginning with a symbol "#"). They have to be placed after a line with a corresponding variable. These lines can have length up to 250 characters, and shouldn't contain symbols of the end of a line in the text and will not be read by the program. Variables:

1st line: VAR VALUE (for compatibility with other programs based on the DLES format. See the ROMUL model description).

2nd line contains text description of site and/or soil; the line has to be commented out (with symbol "#")

3d line and next lines: actual values of parameters. Each readable line has to begin with the identifier designating this parameter, contains the corresponding values, and it follows by commented line (beginning with a symbol "#") containing a detailed comment for corresponding variable.

List of variables:

Lat : geographic latitude of site, degree;

M_ff : a pool of organic layer (forest floor), kg/sq.m;

D_ff : bulk density of forest floor, g/cm3 = 10-3 kg/m3;

W_WP_ff : forest floor moisture content at the permanent wilting point , volume %;

W_FC_ff : forest floor moisture content at field capacity, volume %;

W_Sat_ff : forest floor moisture content at saturation (the total porosity), volume %.

D_ms – bulk density of mineral soil, g/cm3 = 10-3 kg/m3;

W_WP_ms : mineral soil moisture content at the permanent wilting point, volume %;

W_FC_ms : mineral soil moisture content at field capacity, volume %;

W_Sat_ms ; mineral soil moisture content at saturation (the general porosity), volume %;

Wv0_ms : initial value of moisture content of mineral soil, volume %. If it isn't known, it is possible to accept the value close to ***W_FC_ms*** for well-drained soils, or between ***W_FC_ms*** and ***W_Sat_ms*** for the poor drained. Even if it will not be true, in the winter influence of possible errors of moisture on main processes is not so great, and in half a year the influence of initial value on result will be not so essential. One more reliable way is to exclude influence of initial conditions on result is to begin calculations of the climatic scenario in a year prior to the main modeling, and to exclude the first year from the SCLISS final scenario for the ROMUL model;

Corr : a correction multiplier for an assessment of moisture of forest floor using moisture of mineral soil (the average ratio of their volume moisture), usually is accepted for 0.5 for mesic moisture conditions, it is bigger for the wet sites, and less for dry ones (it can be used as calibration parameter);

Saturat : presence of ground waters at a 1-meter soil layer or its poor drainage: 1: yes, 0: is not present;

Permafr : existence of permafrost 1: yes, 0: is not present;

Fortype : dominant tree species of a forest stand: 1: spruce, 2: pine, 3: birch, 4: oak, 0: other (other look for which the corresponding parameters are not determined or the mixed forest, etc.) .

Soil bulk density is usually known if any quantitative researches of this soil were carried out. Unknown hydro-physical constants for a concrete site can be taken from adjoining sites (if the type of the soil and its texture are close), or are estimated by other known soil properties, in particular, using soil texture and the content of organic matter (Saxton et al. 1986).

W_WP_ms (%vol.) = 0.0260+0.0050*C+0.0158*H,

W_FC_ms (%vol.) = 0.2576-0.0020*S+0.0036*C+0.0299*H,

W_Sat_ms (%vol.) = 0.3320-0.0007251*S+0.1276*log10C, where C is clay content (<0.002мм), S is sand content (0.05-2.0MM), H – content of organic matter (all in mass %).

Physical properties of forest floor are known worse. It is possible to estimate them on the basis of some experimental data. We collected and analyzed literature data on hydro-physical properties of forest floor, and approximated physical properties by simple functions of bulk density, D_ff (g/cm3):

W_WP_ff *(%vol.)* = 51.54* D_ff ($R^2 = 0.72$)

W_FC_ff *(%vol.)* = 78.48* $(D\_ff)^{0.5003} \approx 78.48 * \sqrt{D\_ff}$ ($R^2 = 0.21$)

W_Sat_ff *(%vol.)* = 100 - 55.19*D_ff ($R^2 = 0.79$).

Bulk density of a forest floor D_ff (g/cm3) varies usually within 0.03 – 0.24 g/cm^3, on the average about 0.10 g/cm^3. For a certain site it can be estimated on forest floor stock and its thickness. If such data are inaccessible, then a rough approach it is possible to accept average density (0.10 g/cm^3) and the corresponding values of water and physical constants (W_WP_ff *(%vol.)* ≈ 5, W_FC_ff *(%vol.)* ≈ 25, W_Sat_ff *(%vol.)* ≈ 95).

For a preparation of a new ***.sit** file in SCLISS program, you have to do the following operations:

Please open the ***Site params*** tab only after program start (before loading of input files for runs) or after pressing button  (if after start any other task was already carried out), then fill all numerical values of parameters in the table, and choose ***Saturat, Permafr*** and ***Fortype*** values- Then you need to save file using ***Save file*** button in the bottom of the tab

2.5. Format of the output file (the climatic scenario for ROMUL)

This file in CSV format (commas as separators) contains 5 columns of data (the first line contains "headings" of columns);

step –: number of a step,

t_lit –: average monthly forest floor temperatures in C° (in designations above as T_ff),

t_soil –: average monthly soil temperatures in C° (T_ms),

m_lit –: average monthly moisture of forest floor in volume % (W_ff),

m_soil –: average monthly moisture of mineral soil in volume % (W_ms).

Warning

In the present version of the program, soil moisture is presented in volume percent (in old versions of the ROMUL model were used mass percent). For a

correct work of the ROMUL program (Init_values file), it is necessary to use the same values of water and physical constants (in volume percent!) as its input data, which were used for calculation of the corresponding scenario (for this site). These values are in our file of input data *.sit:

W_WP_ff : moisture content at the permanent wilting point of forest floor, volume %;

W_FC_ff : moisture content at field capacity of forest floor, volume %;

W_Sat_ff moisture content at saturation (the general porosity) of forest floor, volume %.

W_WP_ms : moisture content at the permanent wilting point of mineral soil, volume %;

W_FC_ms :moisture content at field capacity of mineral soil, volume %;

W_Sat_ms : moisture content at saturation (general porosity) of mineral soil, volume %.

The use of uncompatible values of these parameters in SCLISS and ROMUL (furthermore values with different dimensions) can lead to mistakes in an assessment of influence of soil moisture to rate of transformation of organic matter.

3. The user interface – the instruction on application

3.1 Installation and program start

The program doesn't require installation. It starts by opening of the executed SCLISS.exe file.

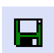
Warning.

View of separate elements of the graphic interface can be different during the work in various versions of Windows OS.

SCLISS works in operational environment of Microsoft Windows (versions must be not earlier than XP).

3.2 General view of the interface

In heading of the main window (Fig. 4), the name of the program (SCLISS) is displayed, the toolbar is located below. It includes the following options:

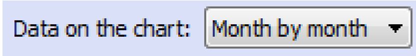
- Saving the modeling results in file: ;

- Iinitialization of the program: ;

- Choice of modeling interval (advanced in years): 

;

- Start of modelling: ;

- Menu of choice of data, which will be presented on graphics: 

;

- Auxiliary menu of year choice which data will be presented on graphics: 

;

- Exit from the program: .

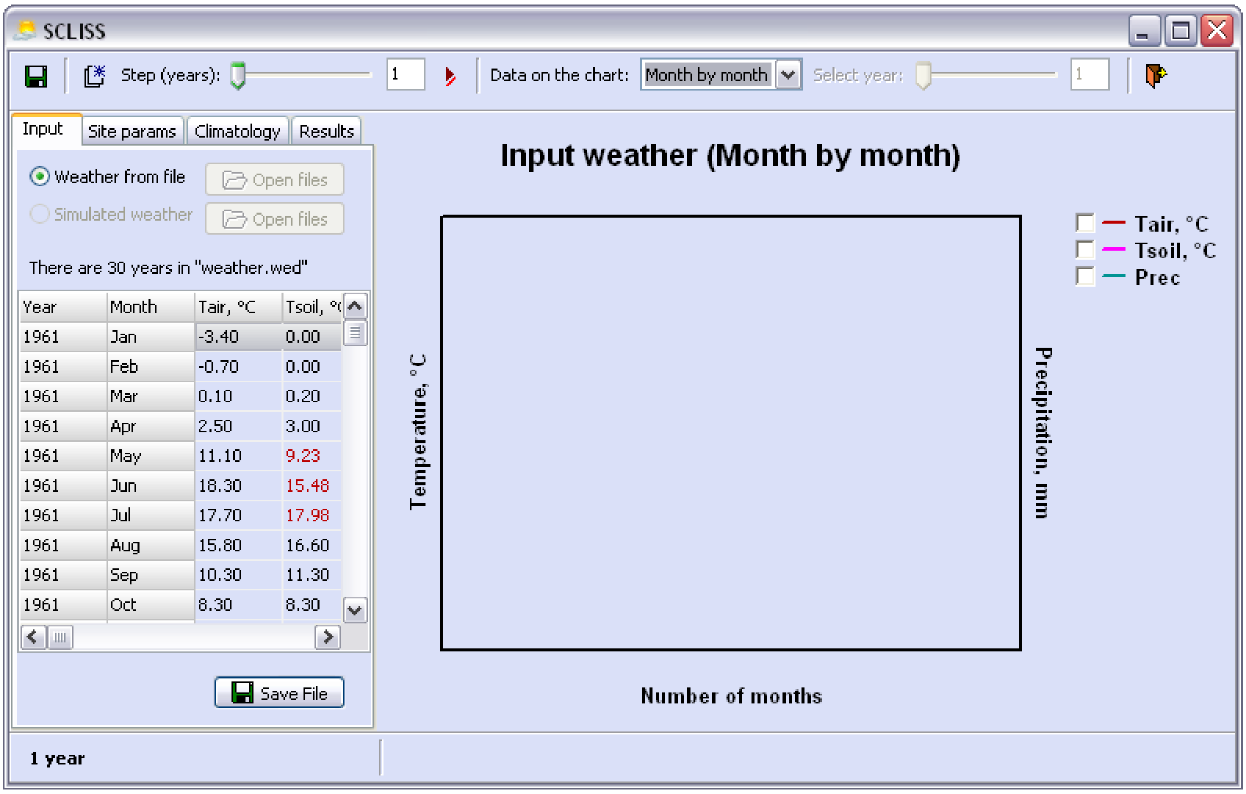


Figure 4. General view of the program interface

In the left part of the main window there are four tabs ***("Input"***, ***"Site params"***, ***"Climatology"***, ***"Results"***), which manage data. In its right part, charts window will be activated after carrying out the simulation. The number of years of modeling will be displayed in information line under working area of the main window.

Input tab (Fig. 5) is used for a choice of mode of modeling, loading input data from files and viewing of input meteorological series (in the table, and also on graphics at charts window).

At a choice of the first mode ***"Weather from file"***, you shall open for loading three input files for calculation of input meteorological data, and after choice of the option ***"Open files"*** sequentially catalogs: file of site data ****.sit,*** file of input meteorological data ****.wed*** and file of climatic ***.cld*** characteristics. The last in this mode is necessary only for calculation of missed values of soil temperature under grass, and it is not required in the presence of these data.

Input meteorological data are displayed in the ***Input*** tab, and also in window of charts (at the open ***Input*** tab). Values of soil temperature, which are missed in the input file, are estimated by model and displayed in the table by a font of red color. In the ***Input*** tab, a longevity of the entered data series (advanced in years) is also displayed.

Two files are loaded at a choice of the second mode ***("Simulated weather")***: file of site data ***(*.sit)*** and file of climatic parameters ***(*.cld).*** Meteorological series are generated after the run start in this case, and they are displayed in the table in the left part of a window by a font of red color.

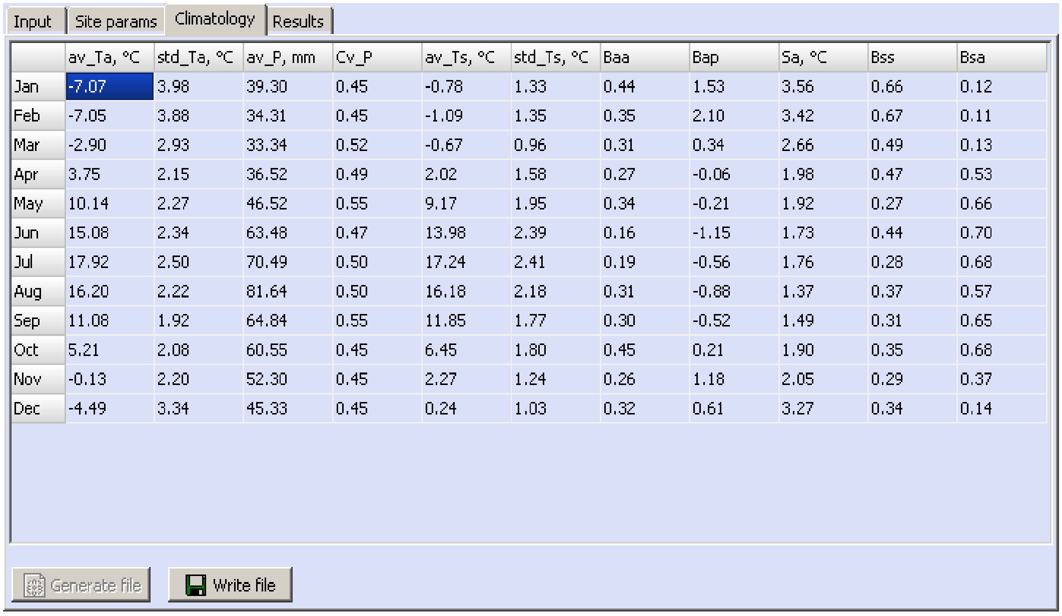
Generated ranks of meteorological data can be saved in new ****.wed*** file. For this purpose it is necessary after the end of simulation open the ***Input*** tab and execute the ***Write file*** command.

Figure 5. ***Input*** tab

Site params tab (Fig. 6) is used for viewing, editing and saving of the site data file ***(*.sit)*** (see file description in 2.3). The quantitative parameters characterizing physical properties of the soil and forest floor are displayed in the table, allowing for their editing. The "***Saturation"*** parameters (remoistening), "***Permafrost***" (permafrost presence/absence) and a choice of a dominating type of a forest stand ***"Select Forest type"*** are located in the bottom of the tab options (existence - 1/absence – 0). The last is necessary for the accounting of temperature corrections according to forest stand composition. In the program, the accounting of the following dominant tree species is possible: 1: Norway spruce, 2: Scots pine, 3: Silver birch, 4: pedunculate (English, French) oak, 0: other (for which the parameters are not determined, or the mixed forest, etc.). For grasslands and for crops not corrections needed (if there are no additional information), The changed data can be saved in the file by the option *"Save file*.

Figure 6. ***"Site params"*** tab

"Climatology" tab (Fig. 7) is used for preparation, viewing, editing and saving of the climatic file ****.cld*** (see the file description). The ****.cld*** file can be generated from the file of meteorological data ****.wed*** (option ***"Generate file"***) independently by means of the SCLISS program. This operation should be carried out separately, instead of loading all files at the start of the main run. If file does not contain data on soil temperature for calculation of climatic data "****.wed"*** then the corresponding parameters will not be calculated, and they will need to be estimated additionally (see the file description above). The climatic data from ****.cld*** file or generated from data of ****.wed*** file can be edited manually. The generated or edited file can be saved (option ***"Save file***").



	av_Ta, °C	std_Ta, °C	av_P, mm	Cv_P	av_Ts, °C	std_Ts, °C	Baa	Bap	Sa, °C	Bss	Bsa
Jan	-7.07	3.98	39.30	0.45	-0.78	1.33	0.44	1.53	3.56	0.66	0.12
Feb	-7.05	3.88	34.31	0.45	-1.09	1.35	0.35	2.10	3.42	0.67	0.11
Mar	-2.90	2.93	33.34	0.52	-0.67	0.96	0.31	0.34	2.66	0.49	0.13
Apr	3.75	2.15	36.52	0.49	2.02	1.58	0.27	-0.06	1.98	0.47	0.53
May	10.14	2.27	46.52	0.55	9.17	1.95	0.34	-0.21	1.92	0.27	0.66
Jun	15.08	2.34	63.48	0.47	13.98	2.39	0.16	-1.15	1.73	0.44	0.70
Jul	17.92	2.50	70.49	0.50	17.24	2.41	0.19	-0.56	1.76	0.28	0.68
Aug	16.20	2.22	81.64	0.50	16.18	2.18	0.31	-0.88	1.37	0.37	0.57
Sep	11.08	1.92	64.84	0.55	11.85	1.77	0.30	-0.52	1.49	0.31	0.65
Oct	5.21	2.08	60.55	0.45	6.45	1.80	0.45	0.21	1.90	0.35	0.68
Nov	-0.13	2.20	52.30	0.45	2.27	1.24	0.26	1.18	2.05	0.29	0.37
Dec	-4.49	3.34	45.33	0.45	0.24	1.03	0.32	0.61	3.27	0.34	0.14

Figure 7. ***"Climatology"*** tab

3.3 . Performance of calculations

The program requires correct sequence of loading files with different expansions. Firstly, open the ***.sit**, then ***.wed** and finaly ***.cld** file in the window for loading these files.

A. Calculation of parameters for already existing input meteorological data:

1. Load input files: choose ***"Weather from file"*** in the ***Input*** menu; this option opens access to folders with input files. Choose the "***Test"*** folder ticking by cursor and load file of soil data ***"soil.sit"*** (Figure 8).

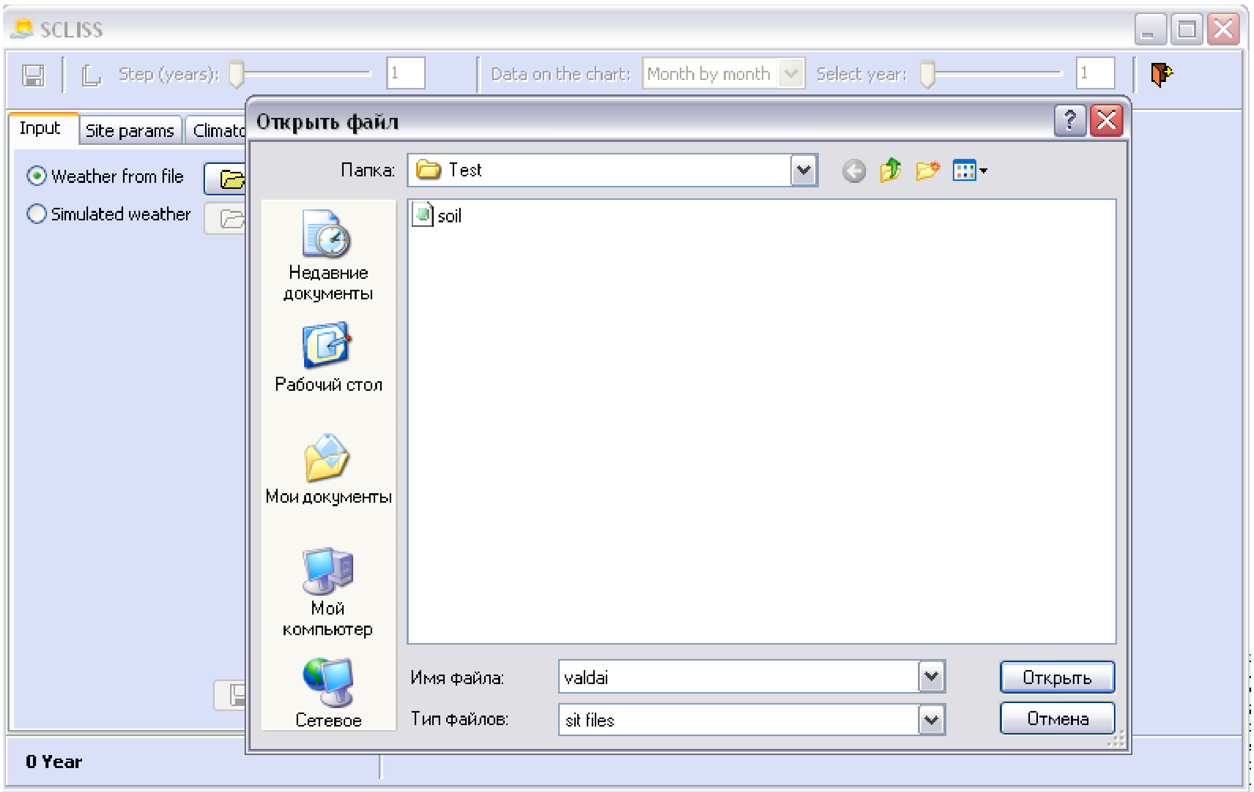


Figure 8. Loading of input files. Catalog of input files

Load test files: ***weather.wed***, and ***climate.cld.*** During work with own data, you will be able to choose the file of each type from the list of the files prepared by you. After loading of data in ***Input*** tab, the table with meteorological data (in our example it is output from the loaded ***weather.wed*** file) will be displayed. The size of window can be regulated.

2. Initialization is carried out by the button . Execute it after loading input data. Initialization is also necessary before loading new input data or when it is necessary to start model experiment from a zero step.

3. In the form with duration of modeling Step (years):, you can set a number of years for calculation at a single run of the program (default number is 1 year).

4 . Make active calculations by the button .

Warning

Repeated pressing the button increasethe interval of running the program for the same number of years. The number of years for which calculation is already executed is shown in information line in the bottom of the main window. The entire period, which has been set in the input *.wed-file, will be displayed in warning line on the right side of window below.

5. After carrying out the calculations, you can mark on the right side of a charts window what parameters you want to be shown on chart (Fig. 9). At open ***Input*** tab, the input data are displayed (Fig. 10); at the open ***Results*** tab - results of modeling (Fig. 11). Modeling results are displayed also in the table in the ***Results*** tab (Fig. 11).

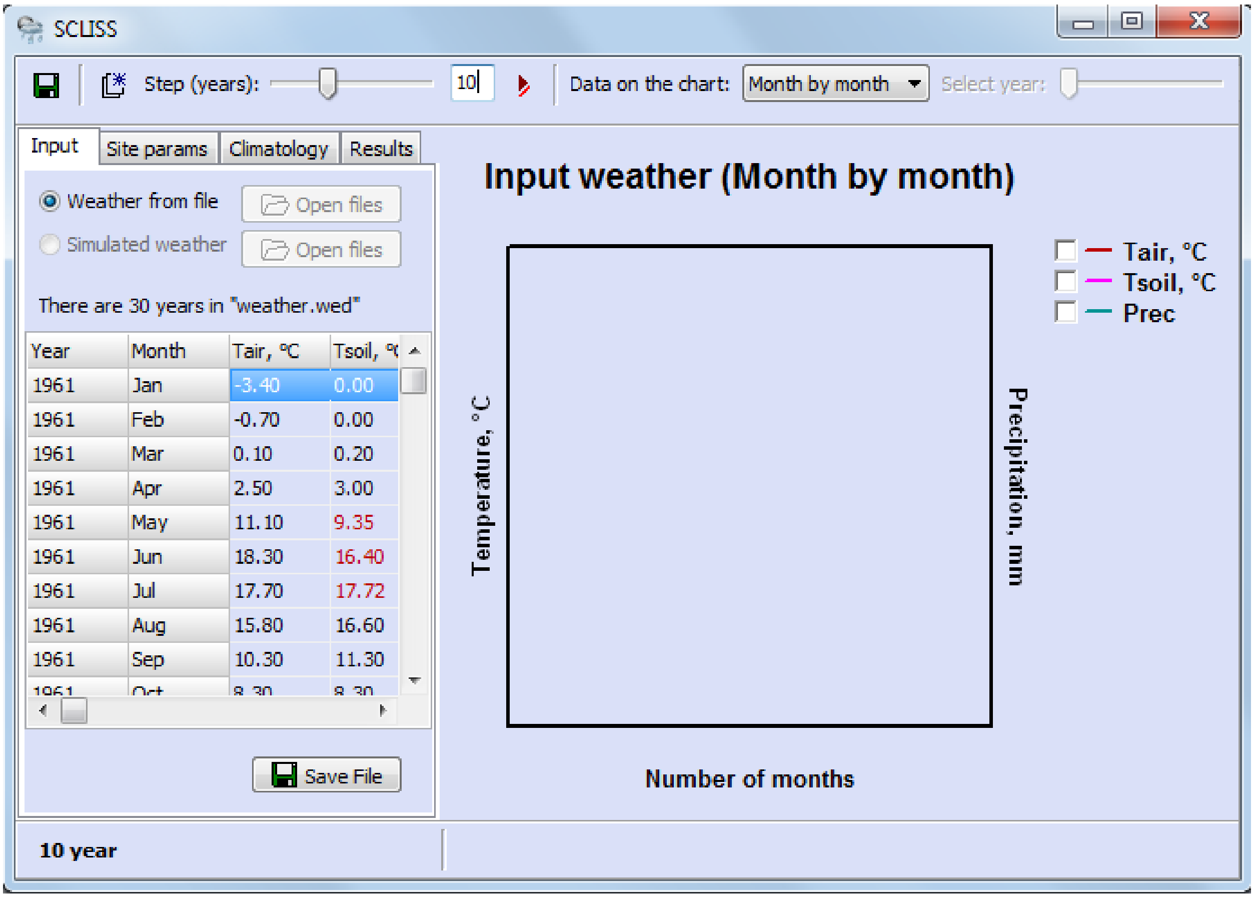


Figure 9. Choice of parameters for demonstration on graphics in a charts window

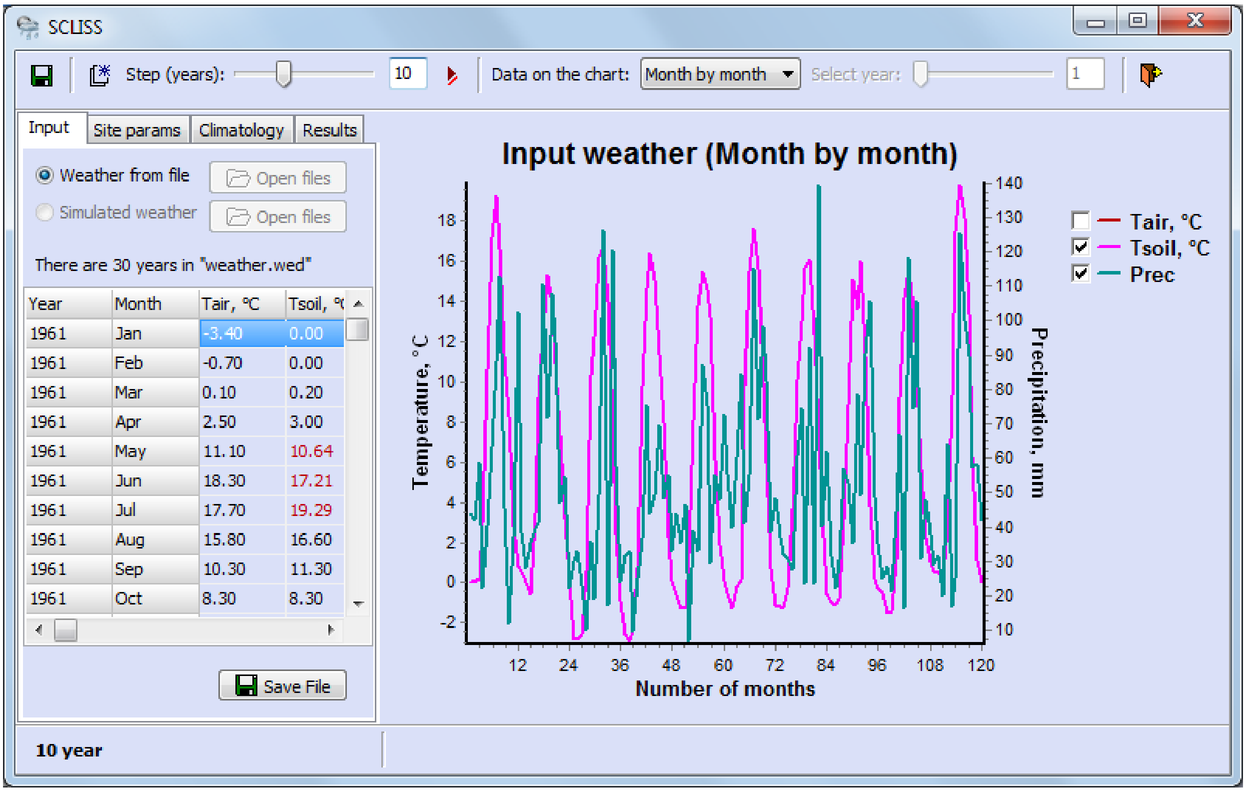


Figure 10. Display of input data of modeling

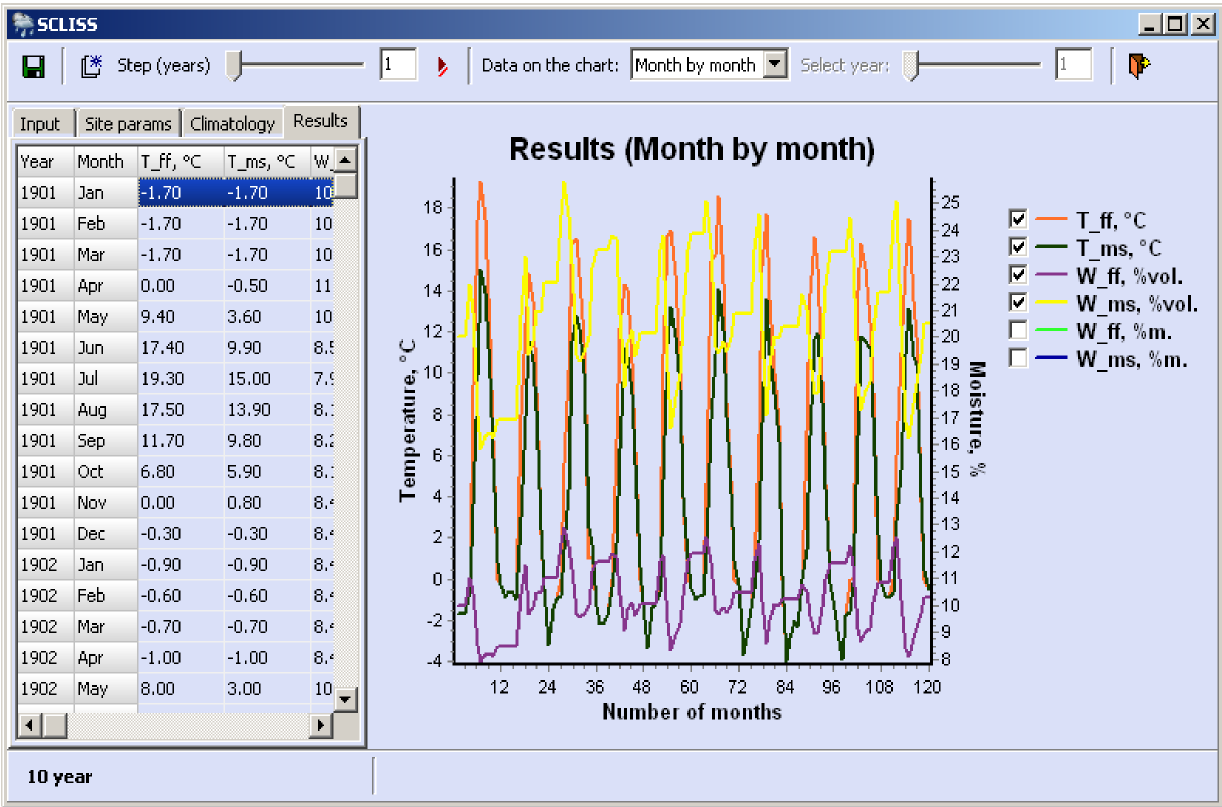


Figure 11. Display of modeling results

The annual course (*"Annual course"*) is displayed for one year. The year, which data are displayed on graphics could be chosen in a window 

at a toolbar. This window of a submenu is activated at a choice of an annual course (*"Annual course").* Actual years with data are displayed on the graphics for the ***"Weather from file"*** mode. Calculated years during the modeling displayed in the "S***imulated weather***" mode (Fig. 12).

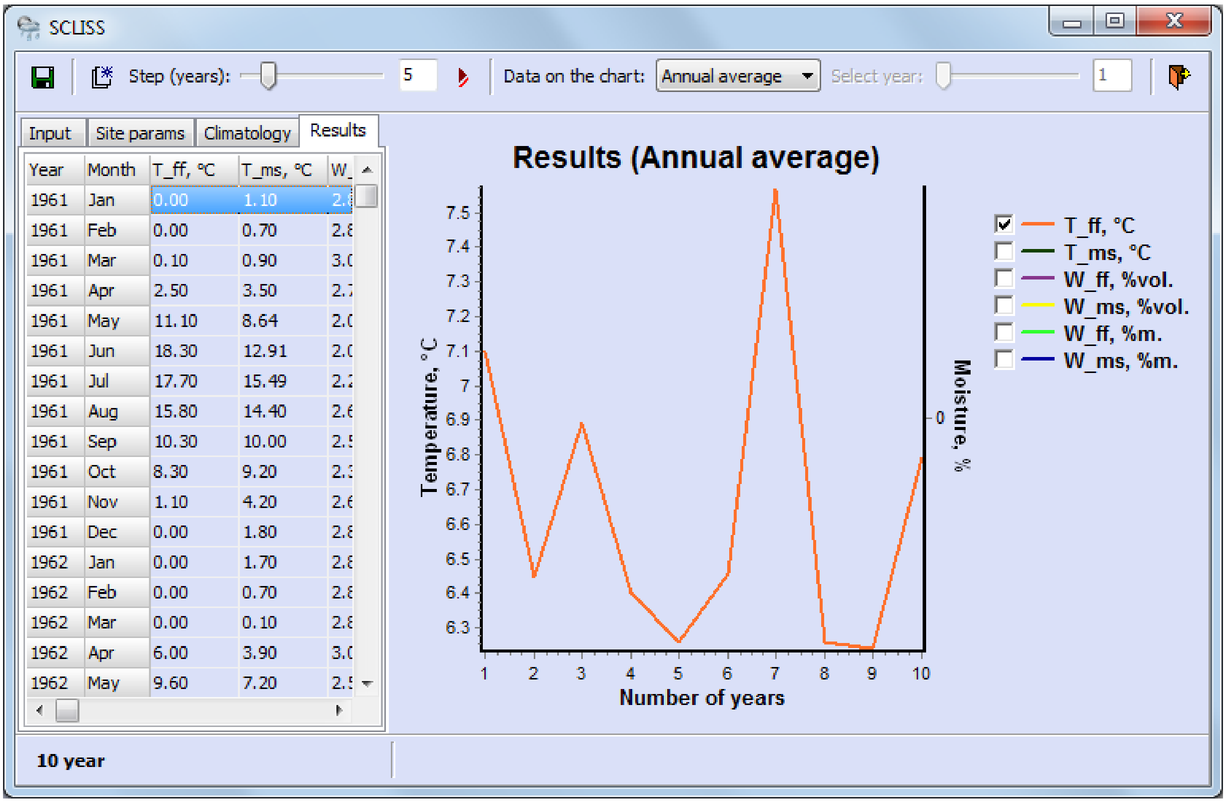
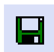


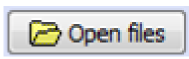
Figure 12. Display of results of modeling year by year

Modelling results can be saved by pressing the button of the main menu: . Saving of results is made in the ***climate.csv*** file, which can be used as the input file for the ROMUL model.

Saving or printing of graphic is possible to the file of the Windows Metafile format (*.wmf) or BitMap (*.bmp) as well as through a pop-up menu caused by the right button. The name of the file appropriated by default contains time of its creation (subsequently you can rename it).

Exit from the program is served by button , for repeated runs (with the same or other data) you may press .

B. Calculation by statistically generated input files of meteorological data.

1 . Load input files: choose in ***Input*** menu ***"Simulated weather"*** by option 

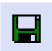
. Then go to folders with input files (Fig. 3) and load files ****.sit*** and climatic ****.cld*** (for example, soil.sit and climat.cld). The ****.wed*** file in this case isn't required.

2 . The subsequent actions are similar to the *"weather from file"* mode.

Warning

A duration of the simulation period can reach no more 500 years in this version in a mode of statistical generating "Simulated weather".

Meteorological series will be generated after the beginning of the main calculations and be displayed by a font of red color. Generated series of meteorological data can be saved in a new ***.wed*** file. It may be useful, if you need to calculate scenarios for several forest sites under the same simulated meteorological conditions. For this purpose, it is necessary to open the ***Input*** tab and to execute the ***Save file*** command after the completing of calculations.

In any case, the main result of the simulation will be the “climate.csv” file, saved by «***Save file***» () button. It contains results of the simulation of forest soil hydrothermal conditions, and it can be used as an input climate scenario for ROMUL model and bridging gaps between standard meteorological data and soil organic matter dynamic model requirements.

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