Romul.exe

Uncertainties in the model of soil organic matter pools dynamics ROMUL

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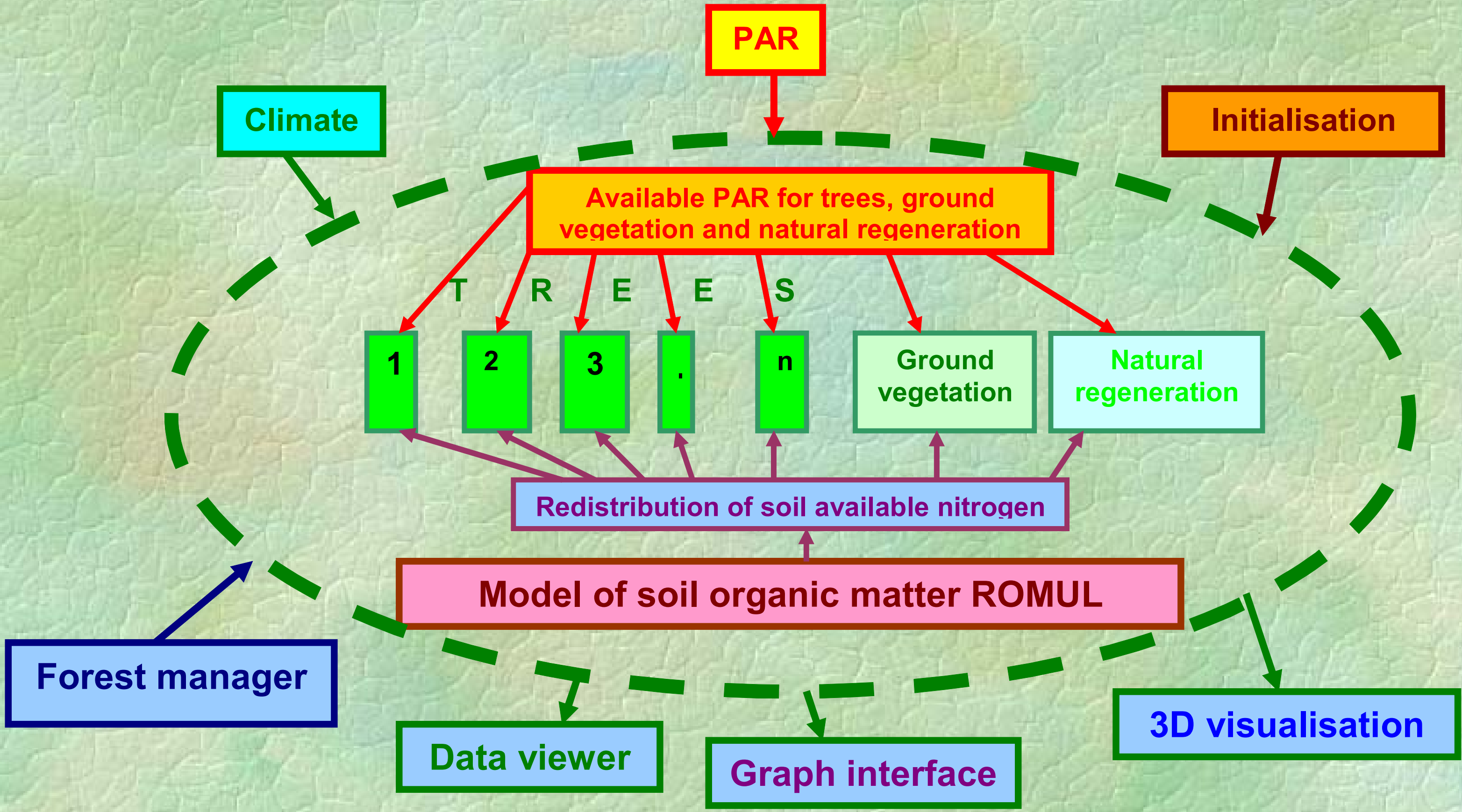
4/20/2006

Flow chart of the EFIMOD – system of models of forest growth and elements cycling



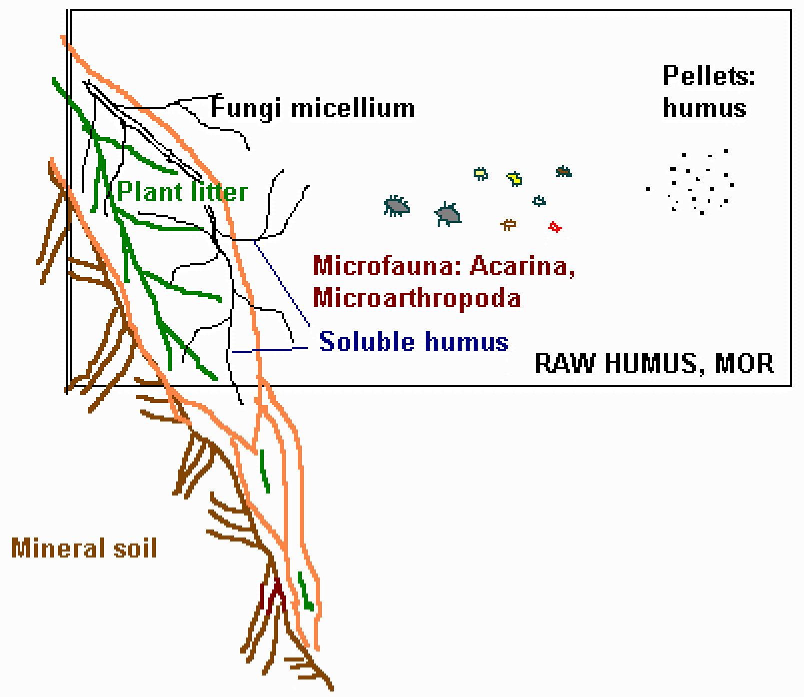
Modelling soil as a decomposing part of biological turnover in forest ecosystem : main problems

- How to split the soil organic matter into different pools, which are decomposing and humifying with different rates?
- How to evaluate the decomposition and humification rates for those fractions?
- How to assess the robustness of these coefficients concerning the accuracy of evaluation?
- What uncertainties arise at initialization of the model in relation to the suggested pools?

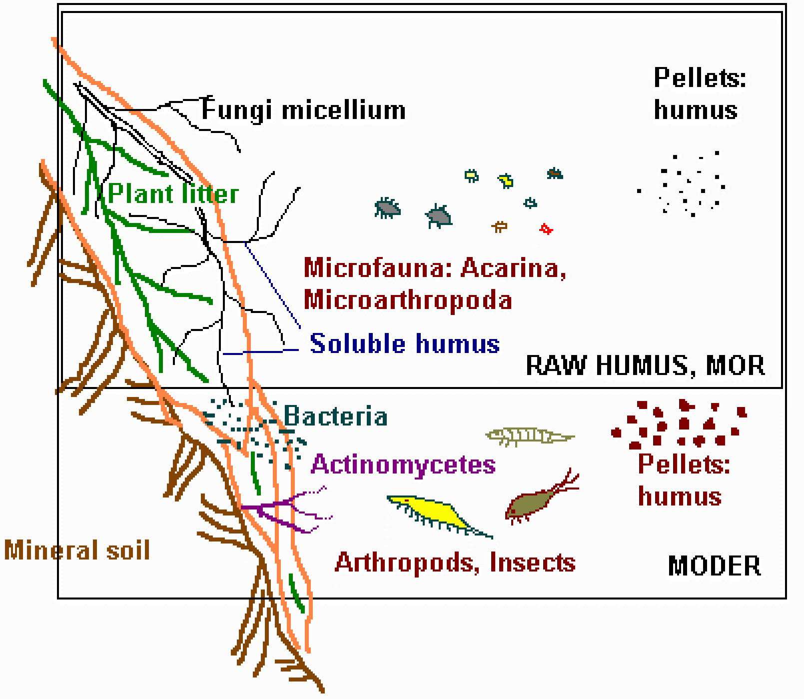
Theoretical basis of the ROMUL model

- Formalization of the classical concept of "humus type (Humusform)"
- The idea of three complexes of organisms-destructors influencing decomposition
- organic matter mineralisation and humification in dependence of soil temperature, soil moisture, litter nitrogen and ash content, C/N ratio in mineral topsoil
- specification of rate variables for above and below ground litter cohorts
- calculation of dynamics of organic matter and nitrogen during the decomposition with gross CO_2 and available N evaluation

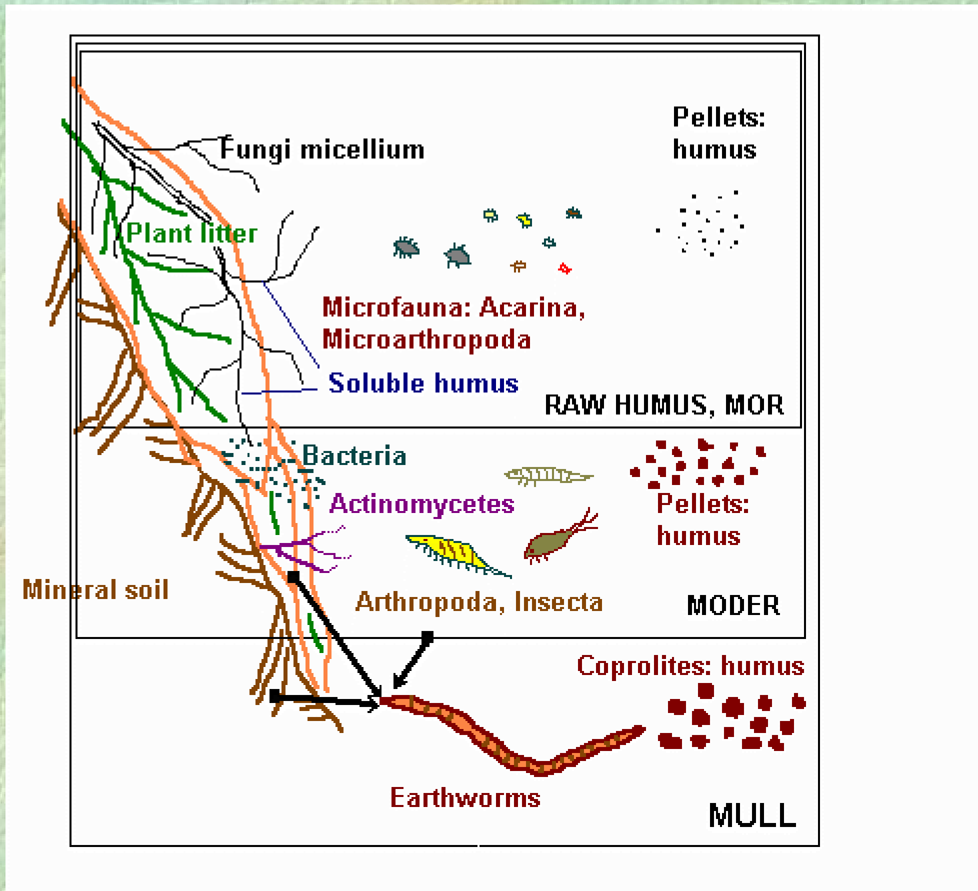
Humus types formation



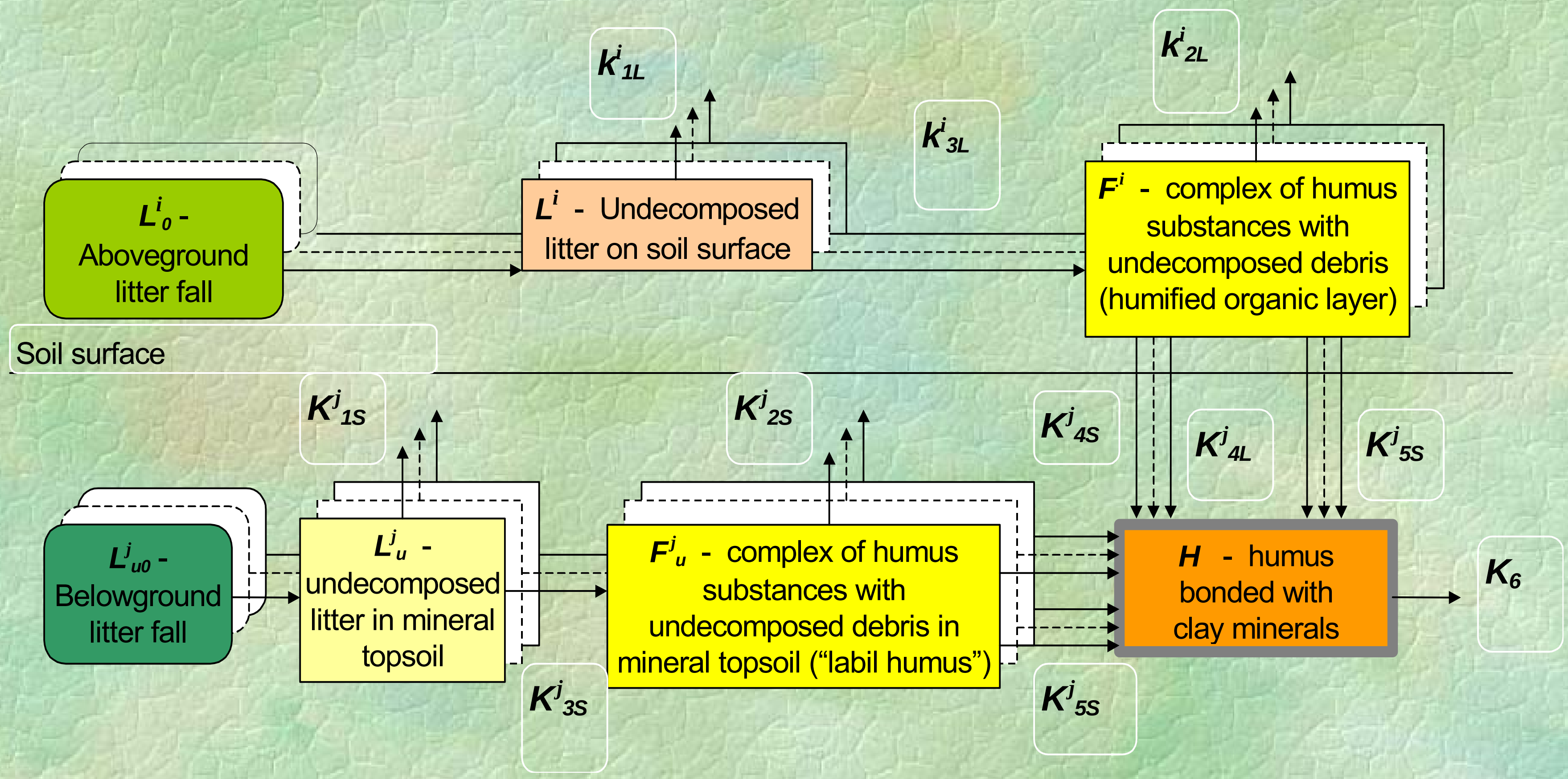
Humus types formation



Humus types formation



ROMUL flow chart



ROMUL input parameters:

- Above ground and belowground litter fractions (including CWD) - amount (by time step), nitrogen and ash concentrations
- Soil temperature and soil moisture (in mass per cent)
- Soil hydrological characteristics
- Pools of soil organic matter and soil nitrogen in organic horizons and mineral topsoil (100 cm layer): SOM of forest floor, labile SOM in mineral soil, stable SOM (humus) in mineral soil

Model realisation

$$dL^i/dt = L^i_0 - (k^i_{1L} + k^i_{3L})L^i,$$

$$dL^j_u/dt = L^j_{u0} - (k^j_{1S} + k^j_{3S})L^j_u,$$

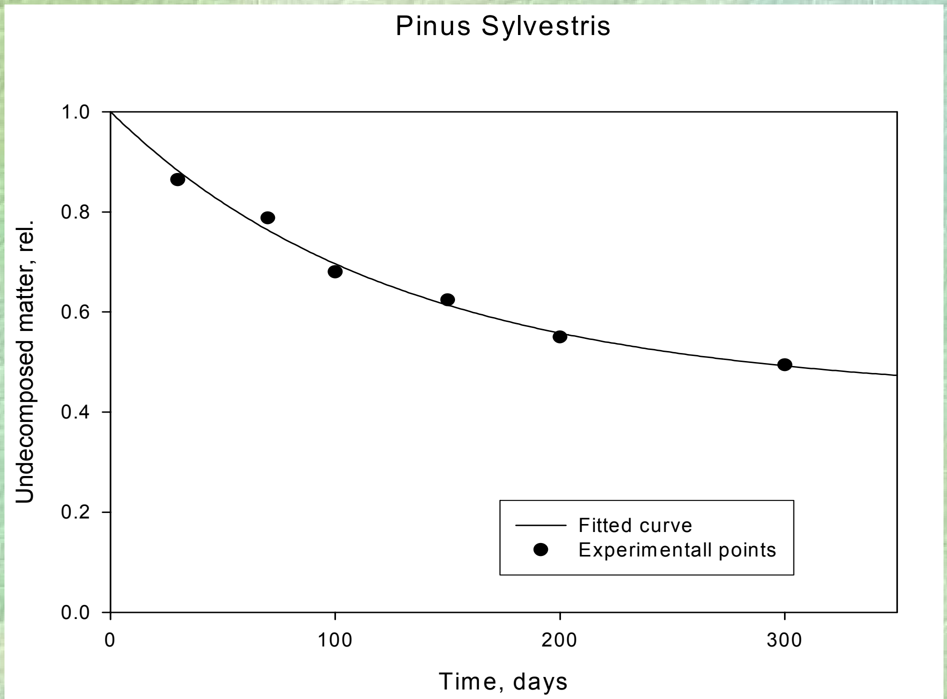
$$dF^i/dt = k^i_{3L}L^i - (k^i_{2L} + k^i_{4L} + k^i_{5S})F^i,$$

$$dF^j_u/dt = k^j_{3S}L^j_u - (k^j_{2S}(H) + k^j_{4S} + k^j_{5S})F^j_u,,$$

$$dH/dt = \delta_{Bact}(\Sigma^m k^i_{4L}N^i_F + \Sigma^n k^j_{4S}N^j_{Fu}) +$$
$$\delta_{Lumb}(\Sigma^m k^i_{5S}N^i_F + \Sigma^n k^j_{5S}N^j_{Fu}) - k_6H$$

Experimental basis of the model

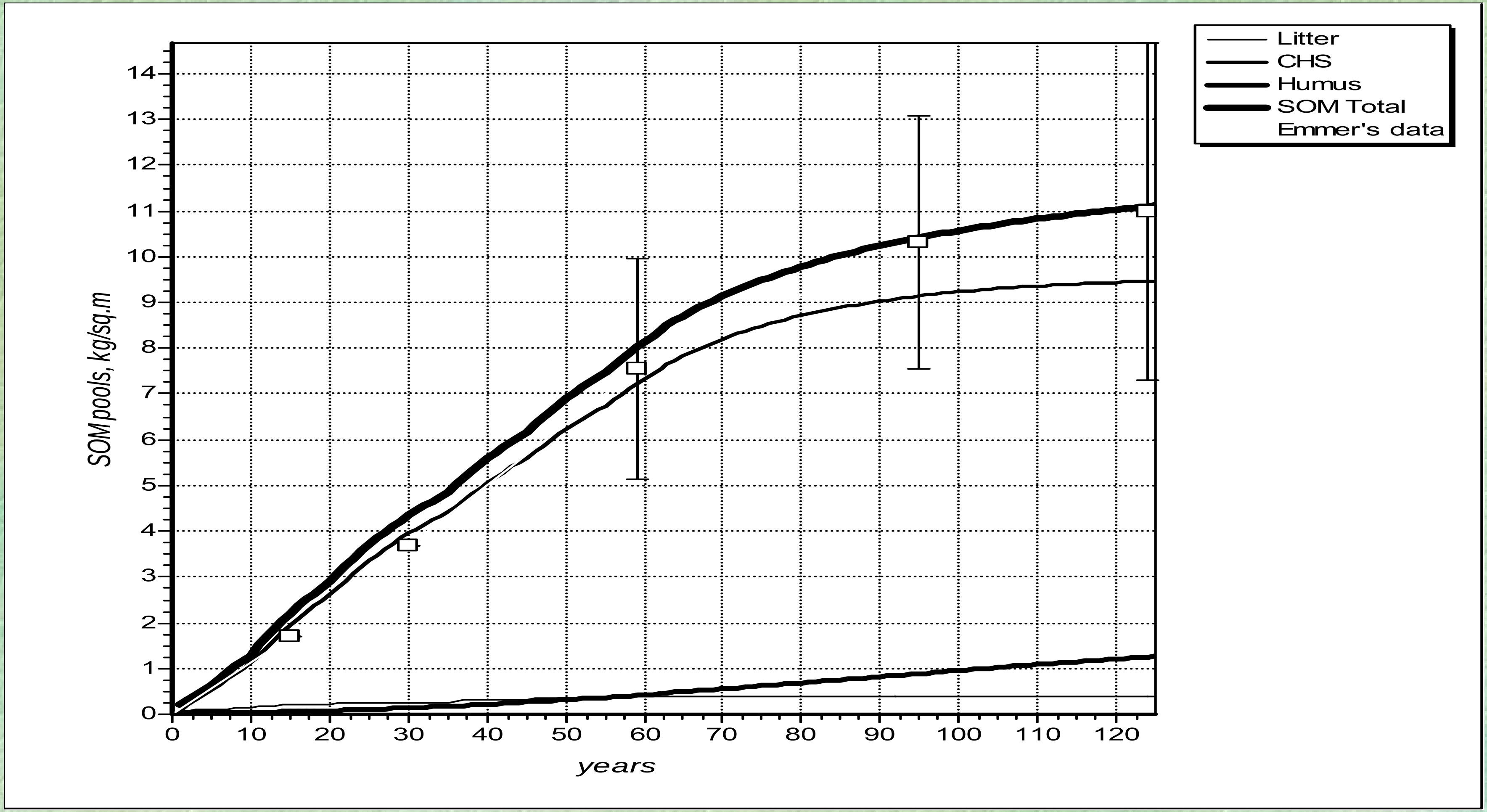
A set of laboratory experiments on the rate of decomposition of plant debris and soil organic matter of definite chemical composition in controlled conditions: previously published data and results of specially performed experiments in the Lab of Soil Biochemistry, St. Petersburg State University



The coefficients have been evaluated using exact solution of the system of differential equations and Markquart method

Then dependencies of the coefficients on nitrogen and ash contents, soil temperature and moisture have been found and inserted into the ROMUL model

Verification example: comparison of experimental data (Emmer, 1995) with ROMUL simulation



Inputs: parameters and initial values

We distinguish **model parameters** and **state variables**. In terms of computer code model parameters and initial values of state variables represent inputs of a model, whereas outputs consist of values of state variables at final and some intermediate state of the modeled system.

<u>Calibration</u> is an adjustment (often determined by statistical estimation techniques) of parameter values so that the model output estimates are close to the measured system output values. Additional problem is to find minimal number of parameters for calibration of initial data and reducing uncertainties. Their number must be small to avoid formal regression approximations. The calibration parameters usually are external in relation to the model and cannot be evaluated inside the model. In ROMUL they are proportion of labile and stable SOM in mineral soil and rate of decomposition of stable humus.

Mentioned parameters could be evaluated in more comprehensive model, in our case in the model of carbon and nitrogen turnover in the forest-soil system EFIMOD.

Sources of uncertainties at simulation:

Ambiguous splitting of SOM into pools

Imperfect model structure

Errors at coefficients' and their dependencies evaluation

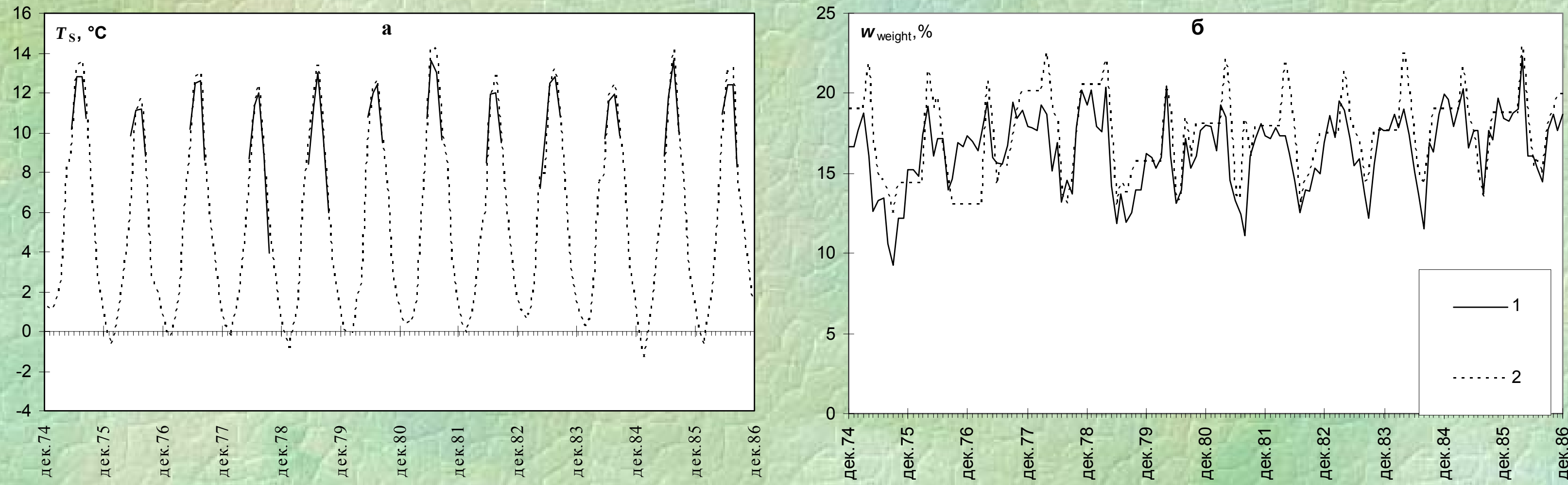
Variability and uncertainty of initial soil data

Variability of soil climate

Variability and uncertainty of litter fall data: amount and quality, including fine roots production and litter

A soil climate generator is used in the ROMUL model for two purposes:

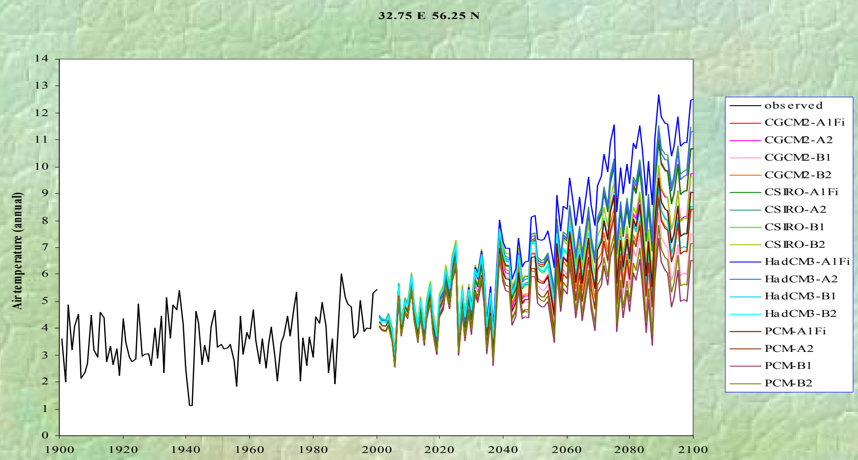
- as a method of evaluation of soil temperature and moisture using measured standard meteorological long-term data;
- For statistical simulation of realisations of long-term series of necessary input climate data with known statistical properties.



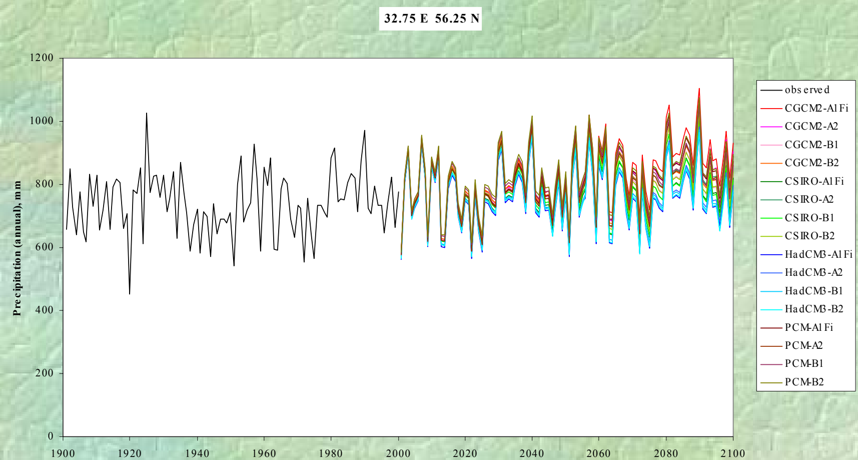
LONG-TERM DYNAMICS OF MEASURED (1) AND CALCULATED (2) SOIL TEMPERATURE (a) AND GRAVIMETRIC MOISTURE (б)

Central Forest Reserve
Climate change scenarios from different models

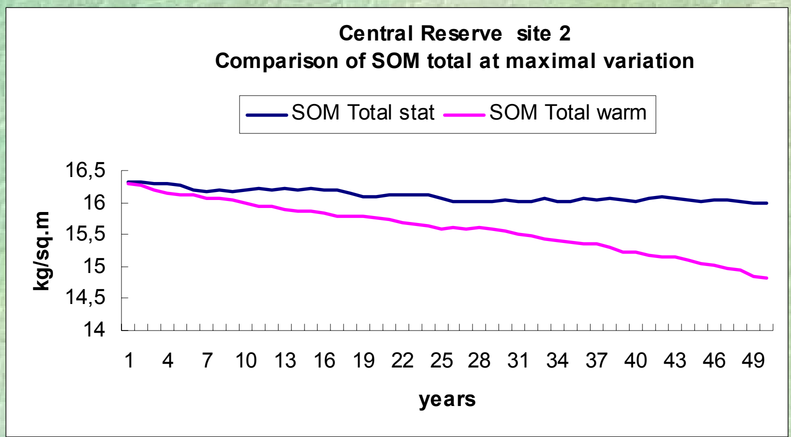
Air temperature

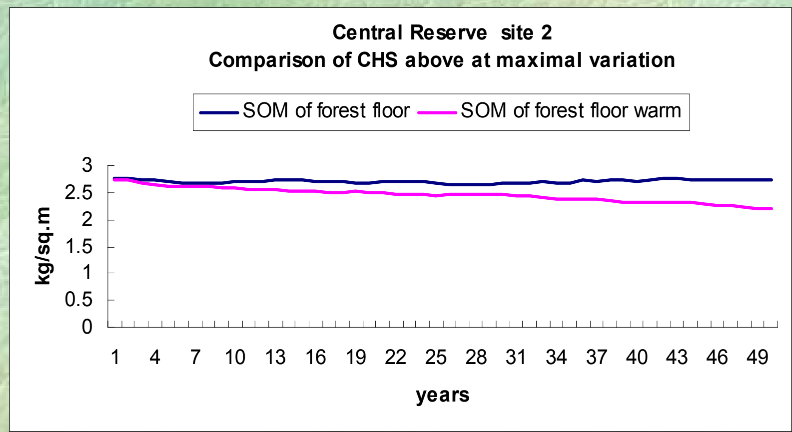


Precipitation

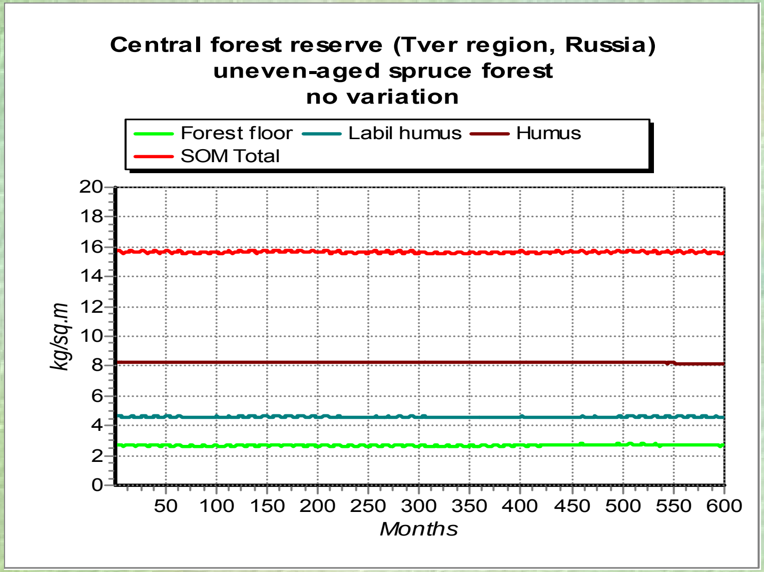


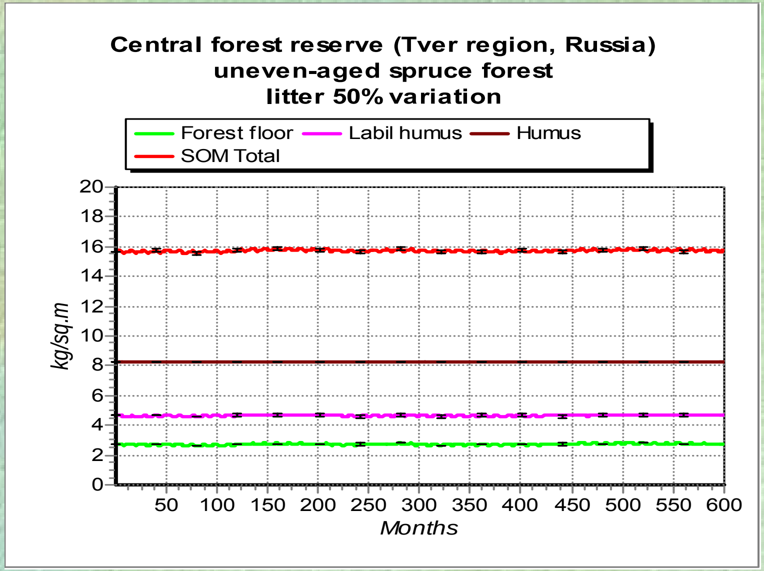
Comparison of stable climate and HADCM3 scenario



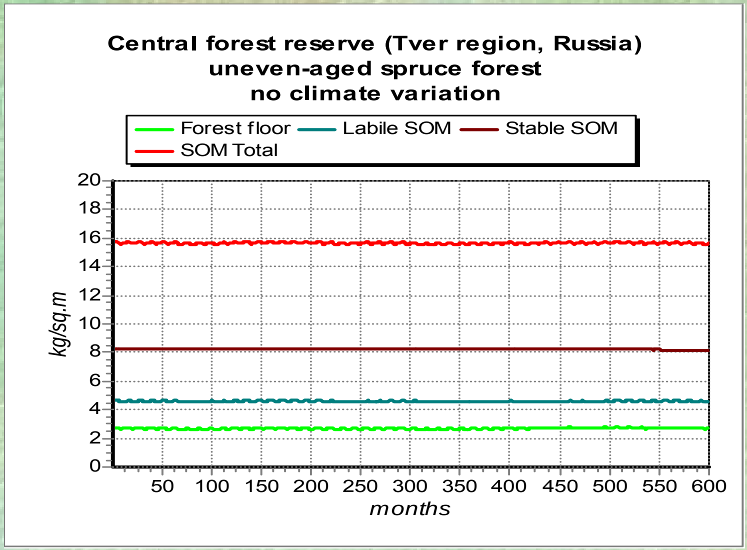


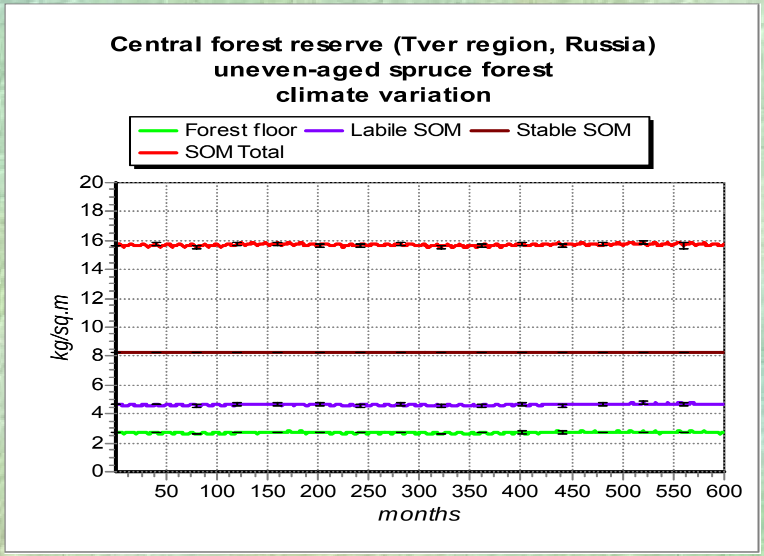
Uncertainties of litter fall data



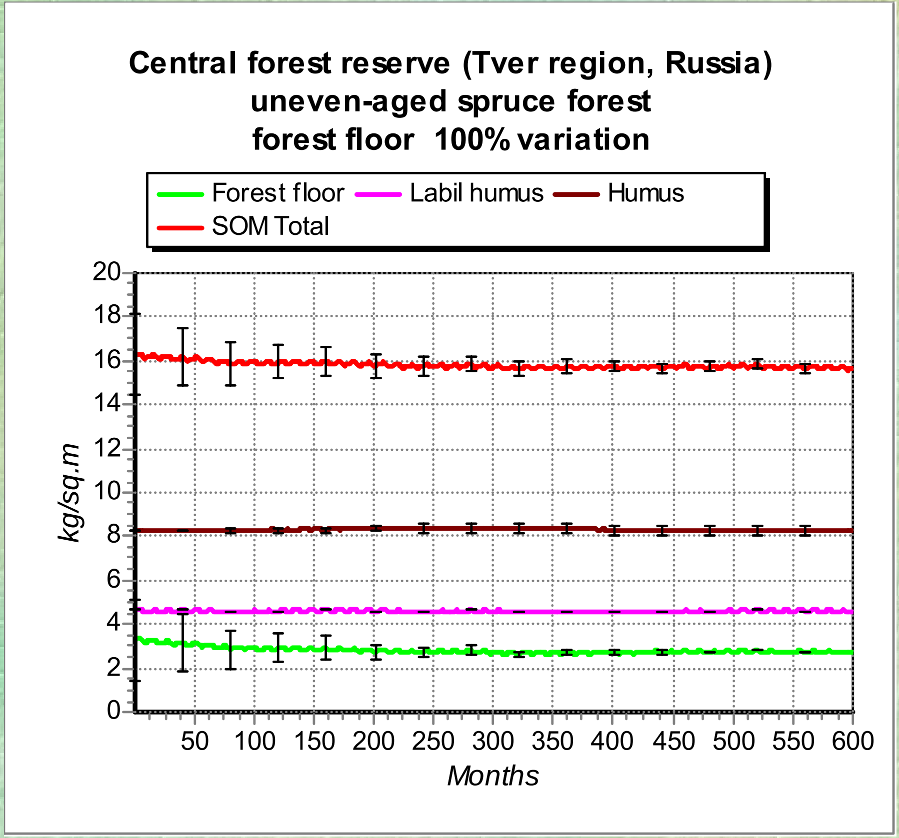


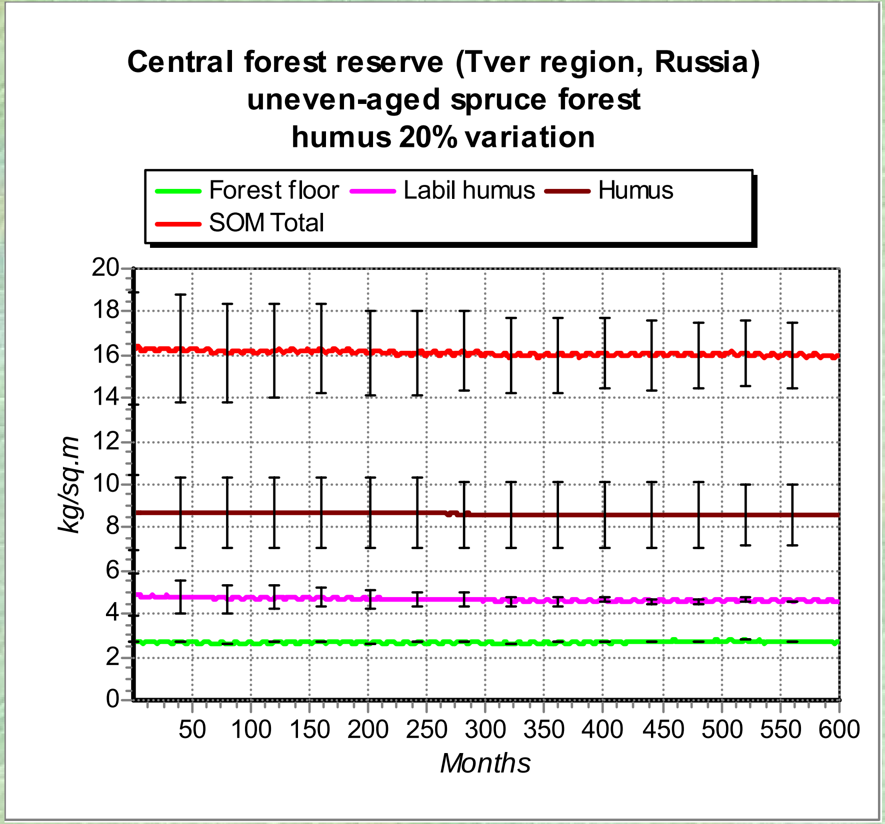
Uncertainties of climate variation



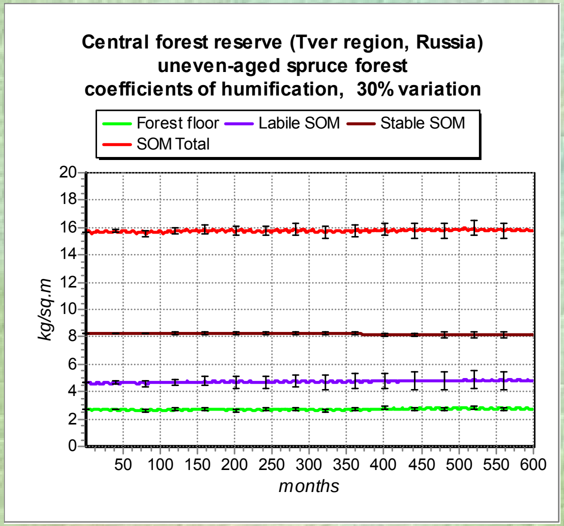


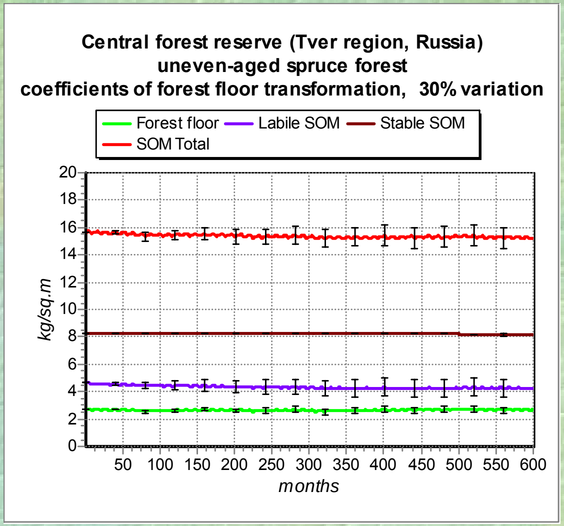
Variability and uncertainty of initial soil data

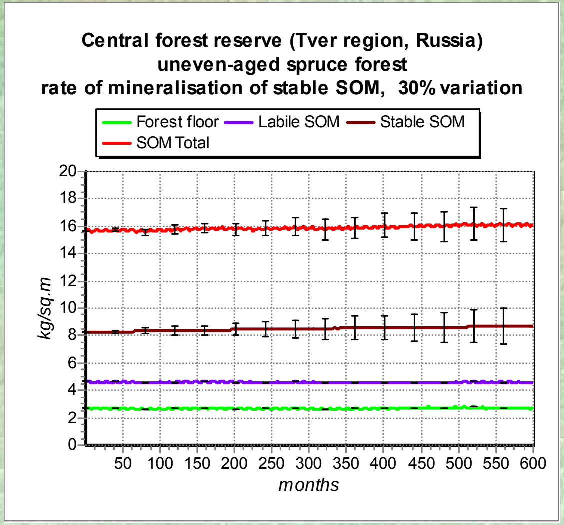


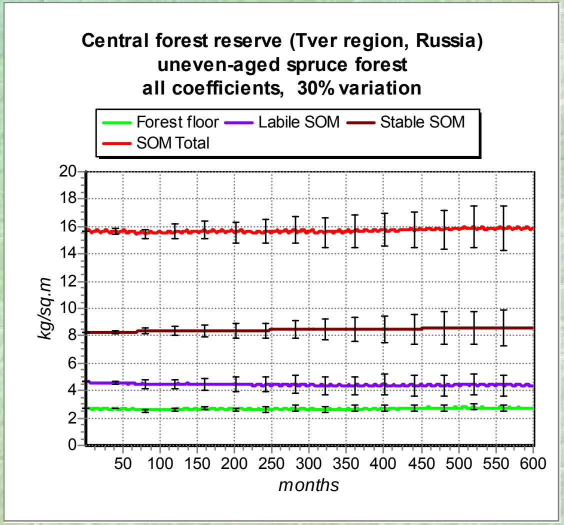


Variability of the model coefficients of mineralisation and humification









Conclusions:

- From ecosystem point of view soil is an exponential filter, which smoothes outliers and forced oscillations at different scales
- Ordinary climatic and litter input variations do not affect model output
- The initialization of mineral soil variables and evaluation of rates of humification and mineralization of pool of stable SOM are main sources of uncertainties in model output
- Initial values of pools of SOM in forest floor and mineral soil could be evaluated on data for forest types (prehistory of a plot could be a crucial point in uncertainties arising)
- The relation between labile and stable SOM in mineral soil can be evaluated from data about coarse and fine roots productivity (or by Bayesian estimation)
- The rate of mineralization of stable SOM can be used as a calibrating parameter at forest ecosystem level: it must control rate of stable humus accumulation at early successive stages of forest ecosystem development and lead to steady state at climax stage, it could be done using known durations of stages of succession

Thank you
for your attention!