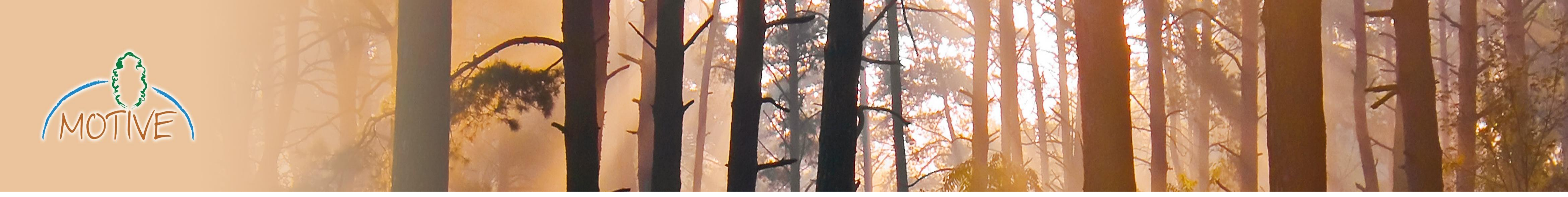

The forest growth model 4C – validation at nine European sites

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PIK, RD II: Climate Impacts and Vulnerabilities

Background

In the framework of the MOTIVE project the process-based forest growth model 4C is used to simulate the impact of climate change and elevated carbon dioxide concentration on forest productivity in Europe.

The main processes of the model that are relevant for simulating carbon and water fluxes were validated at nine climatically different sites in Europe.

The forest growth model 4C

The model 4C[1] simulates the water, carbon and nutrient budget of a forest stand depending on environmental conditions. This includes soil as well as stand dynamics described i.e. by litter fall, height and diameter growth. 4C was successfully validated and applied at several forest sites in Germany and other countries in northern and western Europe.

[1] Lasch, P., Badeck, F.W., Suckow, F., et al., 2005. Model-based analysis of management alternatives at stand and regional level in Brandenburg (Germany). Forest Ecology And Management 207, 59-74.

[2] Nash, J.E., Sutcliffe, J.V., 1970. River flow forecasting through conceptual models, Part I - A discussion of principles. J. Hydrol. 10, 282–290.

[3] $\bar{O}, \bar{P}$ mean of observed and simulated data respectively

Method

- The four most important tree species in Europe are investigated: pine, spruce, beech, and oak.
- Detailed measurement data from EUROFLUX/NORDFLUX and ICP Forests Level-II sites are used for validation.
- Model output variables P_i (soil temperature, soil water content, and water and carbon fluxes) were compared with measurements O_i using standard statistical measures described in Table 1.

Table 1 Description of statistical measures

Code	NMAE	NRMSE	MEFF	CC
Efficiency criteria	Normalised mean absolute error	Normalised root mean square error	Nash–Sutcliffe model efficiency coefficient[2]	Correlation coefficient
Formula[3]	$\frac{1}{N}\sum_{i=1}^{N}\frac{\lvert P_i-O_i\rvert}{\bar{O}}$	$\frac{1}{\bar{O}}\sqrt{\frac{1}{N}\sum_{i=1}^{N}(P_i-O_i)^2}$	$1-\frac{\sum_{i=1}^{N}(O_i-P_i)^2}{\sum_{i=1}^{N}(O_i-\bar{O})^2}$	$\frac{\sum_{i=1}^{N}(O_i-\bar{O})(P_i-\bar{P})}{\sqrt{\sum_{i=1}^{N}(O_i-\bar{O})^2\sum_{i=1}^{N}(P_i-\bar{P})^2}}$

Site and validation data

Nine climatically varying sites with stands of three different species were selected.

At these sites (Figure 1) detailed data of carbon and water fluxes, soil temperatures, and soil water content are available. The length of the data time series varies from 3 to 13 years (Table 2).

Table 2 Validation sites

	Site	Country	Altitude [m]	Climate	Species	Time period
1	**Brasschaat**	Belgium	16	maritime	pine	1997 – 1999
2	**Collelongo**	Italy	1560	maritime	beech	1997 – 2000
3	**Hesse**	France	300	maritime	beech	1996 – 2000
4	**Hyytiälä**	Finland	185	continental	pine/spruce	1997 – 2009
5	**Natteheide**	Germany	50	maritime	pine	1994 – 2004
6	**Neusorgefeld**	Germany	75	continental	pine	1994 – 2006
7	**Solling be**	Germany	504	maritime	beech	2000 – 2004
8	**Solling sp**	Germany	508	maritime	spruce	1995 – 2004
9	**Freising**	Germany	508	continental	beech	1999 – 2003

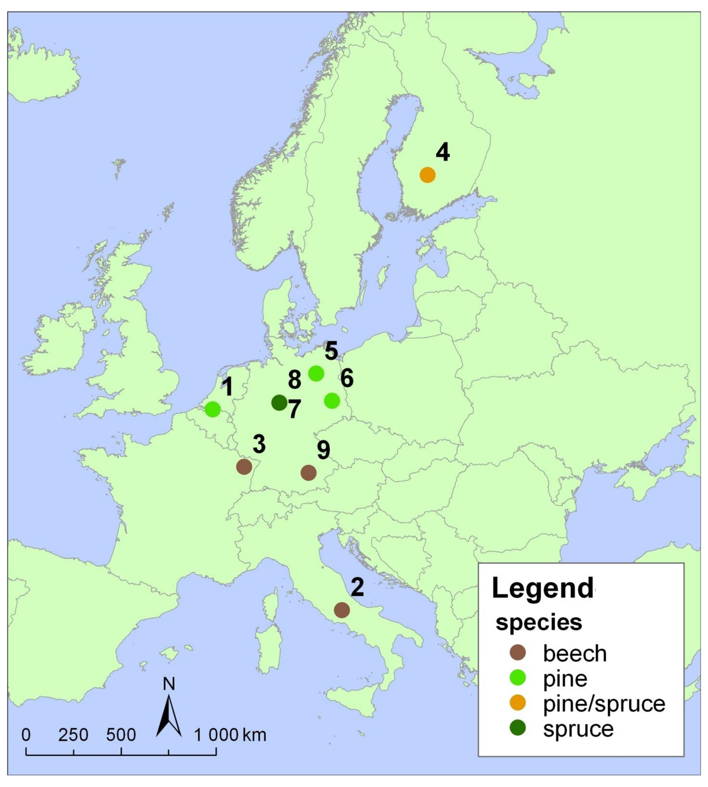

Figure 1 Location of validation sites

Statistical analysis of model results for all sites

The statistical results for individual sites can be quite different for each of the validation variable but generally the normalized errors are low and model efficiency and correlation coefficients are high (Figure 2, 3). High errors and low model efficiency for NEE in Brasschaat can be explained by management interventions in the understorey[4] which have altered the measured carbon flux but were not covered by 4C.

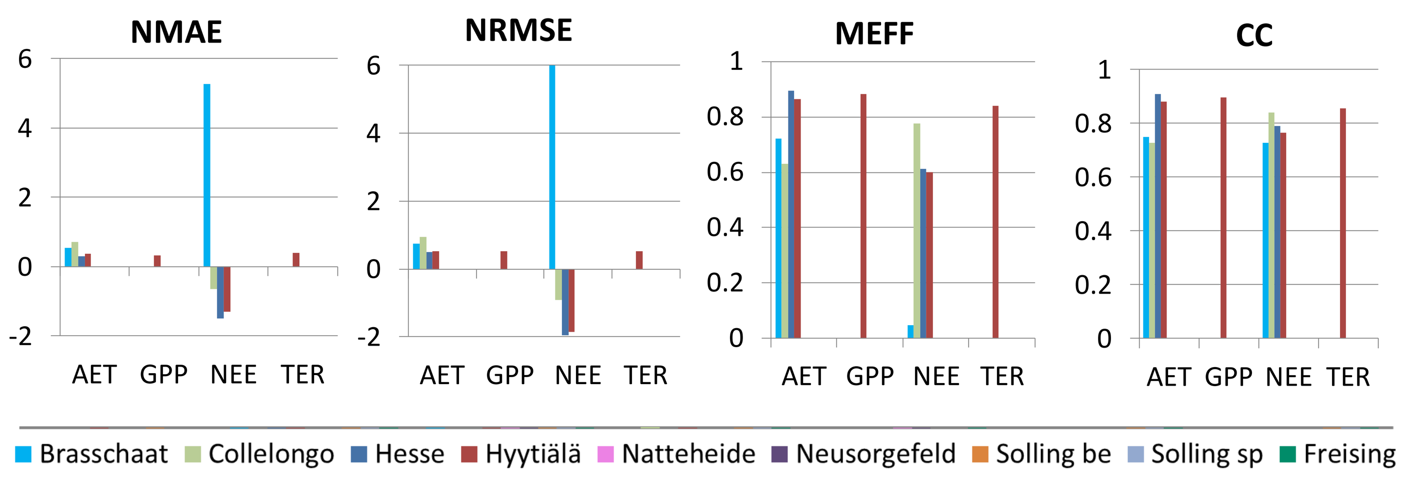

Figure 2 Statistical measures of actual evapotranspiration (AET), gross primary productivity (GPP), net ecosystem exchange (NEE), and total ecosystem respiration (TER) at the nine validation sites

For soil temperature, the NMAE at Collelongo is quite high and similar to Hyytiälä the MEFF and CC is lower than at the other sites (Figure 3). One reason is the insufficient description of snowfall and its heat isolation in 4C.

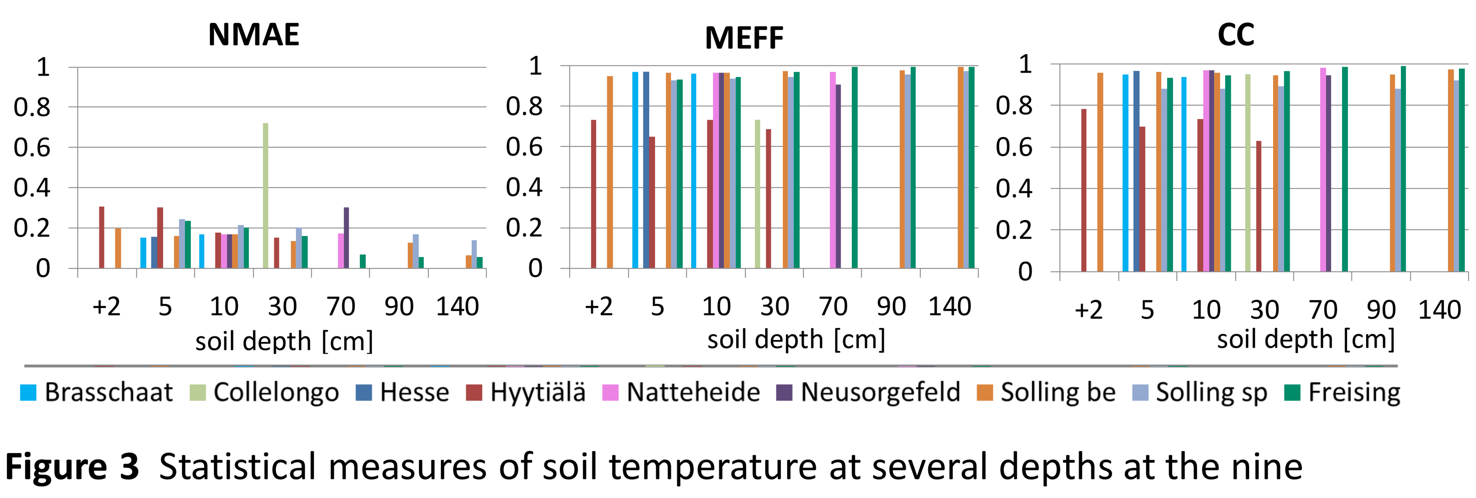

Figure 3 Statistical measures of soil temperature at several depths at the nine validation sites

[4] Carrara, A., A. S. Kowalski, et al. (2003). "Net ecosystem CO2 exchange of mixed forest in Belgium over 5 years." Agricultural and Forest Meteorology 119(3-4): 209-227.

Model validation at the Hyytiälä site

The largest and longest data set is available for the Hyytiälä site. Therefore, a graphical analysis of the annual course of soil temperature and net ecosystem exchange for this site is shown.

The simulated soil temperature follows the annual course of the measured values (Figure 4). Only the temperature peaks in summer and winter are sometimes overestimated. In the winter this may be related to a premature simulation of the first snow. In general, there is a good correspondence between simulated and observed values for all depths.

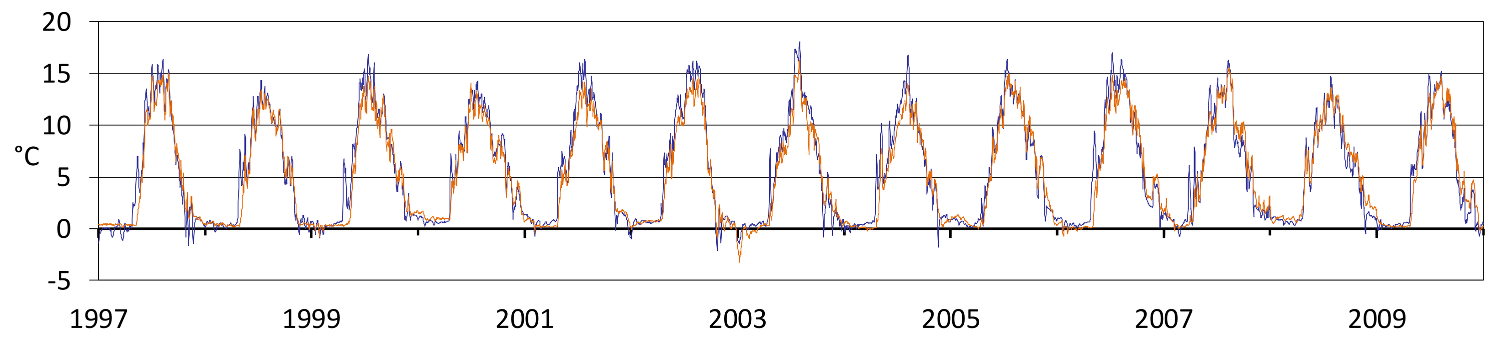

Figure 4 Annual course of observed ( ) and simulated ( ) soil temperature at 5 cm depth

The net ecosystem exchange calculated by 4C meets the annual pattern of the measured values (Figure 5) but it is systematically underestimated at low temperatures.

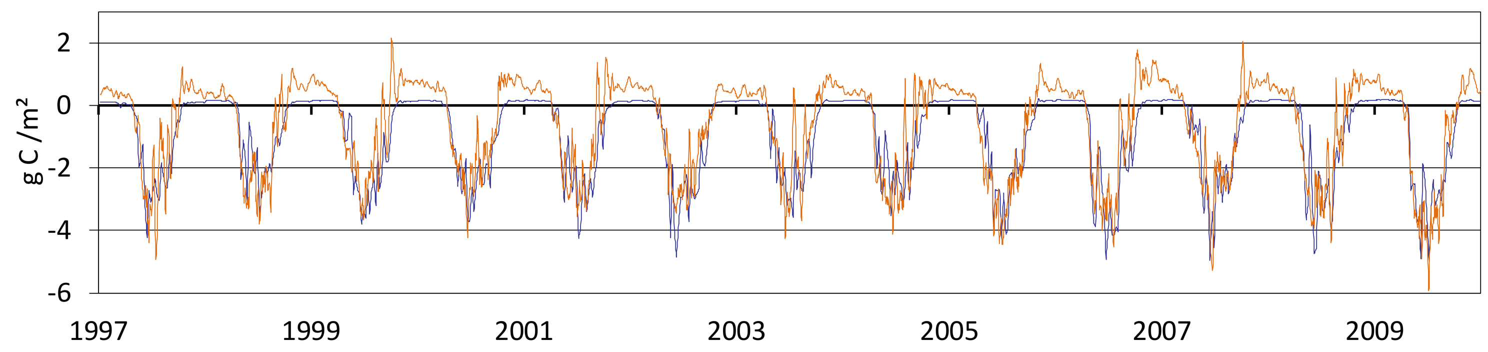

Figure 5 7-day moving average of observed ( ) and simulated ( ) net ecosystem exchange

Summary

The validation statistics of the main processes relevant for carbon and water fluxes as well as the graphical comparison of measured and simulated values of different parameters show satisfactory results. Thus, we assume that the model application will give plausible results at a great variety of sites for the considered species in Europe .

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Seventh Framework Programme