Modelling and monitoring forest evapotranspiration. Behaviour, concepts and parameters
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7. MODELLING AND MONITORING FOREST EVAPOTRANSPIRATION:

SOME FINAL REMARKS

From a scientific point of view, models can be used to improve the insight in processes, to extrapolate in time and space or to determine variables, which cannot be directly measured. To achieve these goals, confidence must be gained in the model concepts and model parameters. A model concept or values of model parameters can only be evaluated by comparing model results with measurements. As a consequence, the system behaviour must always be linked to the model behaviour. As shown in Figure 1.1, this confidence can be reached by improving the understanding of the model concepts by a focus on cause-effect relationships and by improving the interpretation of model parameters in terms of system properties. In this thesis, several methodologies were developed and used to improve the understanding of forest evapotranspiration model concepts and the interpretation of the model parameters. In this chapter, some final remarks for future research are given.

7.1 MODEL PARAMETERS

Nowadays, most hydrological and ecological models have several fit-parameters that cannot be measured independently. These fit-parameters are identified with optimisation algorithms. Due to increased computer power and standardisation of software, these optimisation algorithms are commonly used. However, as pointed out in this thesis, a wrong parameterisation can compensate systematic model errors. Due to these wrong parameterisations, fitted model-parameters can become unrealistic and it is difficult to trace the true causes of misfits between model results and measurements. With the methods developed and used in this thesis, as the Parameter Identification Method based on Localisation of Information (PLMIL) and the analysis of residuals with Artificial Neural Networks (ANN), the insight in the model errors caused by wrong parameterisations and wrong concepts is improved.

One way to improve the understanding of parameters and therefore the understanding of the system, is to link the parameter values to independently measured system properties with transfer functions. These functions will help to improve the interpretation of the model parameters, but only if the parameter estimates are unique.
Another way to improve the understanding of the model parameters is to avoid calibration by using, or re-using, the so-called ‘non-calibrated models’. In these models, parameters are directly assessed from the field, laboratory or from literature. With these models, the understanding of the parameters can be improved and the parameters are less dependent on the chosen model. Without fitting, the remaining residuals between measurement and model results are easier to interpret and the deviations between model results and observations become more realistic. However, we must realise that parameters from literature were often also derived from calibration.

The idea of the plant physiological model, as used in chapter 3, is that it is a more realistic model closer to the processes. Species dependent model parameters can be established and used without calibration for different situations at different sites. However, this type of model still contains several fit-parameters, which need to be calibrated and the stomatal conductance model is still empirical. Soil water stress, seasonal variations in LAI, fluctuations of nitrogen concentration in the leaf and adaptation due to global change cause all variations in the assimilation and transpiration rates at the leaf level. Direct cause-effect relationships of most of these processes are not known and the best until now is to use empirical relationships in the model concepts containing several fit-parameters, which need to be calibrated. Consequently, using the plant-physiological model does mean a use of a non-calibrated model. Future research should focus on linking the model parameters to system properties and including cause-effect relationships in the model concepts. For instance the seasonal variations of LAI should be linked to phenology (e.g. (Kramer et al., 1996)) and cause-effect relationships should be included in the model concepts between leaf nitrogen concentration and the photosynthetic coefficients (Kull and Jarvis, 1995).

7.2 MODEL CONCEPTS

Although the problems of parameter identification are impressive, little attention is often paid to it. The main cause is probably that most studies only focus on confirmation. In that case, problems with non-uniqueness of parameters are not an issue, because the model behaviour fits the system behaviour satisfactory. However, the insight in the processes is limited if interpretation of the parameters is missing. With confirmation, model results are compared to measurements by a subjective choice of the statistical measures, e.g. $R^2$, RMSE, $\chi^2$. These measures only highlight specific aspects in the time
series and models. As a result, confirmation gives little information on the behaviour of the system and may even give misleading information. The general approach to identify the parameters is to split the total data set in a calibration and confirmation data set. Due to this subjective splitting, the calibration data set can perform less than the confirmation data set. As shown in this thesis, every observation has its own information content with respect to a specific parameter. Therefore, the size of the data sets should not be the determining factor for constructing the calibration and confirmation data set, but it should contain an equal amount of information with respect to every parameter.

As shown in this thesis a focus on discrepancies gives more information, confidence and insight in the model concepts and parameters than a focus on confirmation. Model concepts were developed with different perceptions and therefore models perform differently during various conditions. With a focus on discrepancies, these different responses of models can be traced better. However, expected differences between models may disappear during calibration.

7.3 CONSEQUENCES FOR MEASUREMENT STRATEGIES

As stated clearly in this thesis, improvements in the understanding of the system in terms of concept and parameters can be achieved by the interaction between modelling and measuring.

As mentioned in chapter 1, there is no consensus about the model concepts of forest transpiration. In chapter 2 it was shown that several calibrated forest transpiration models could describe transpiration to an acceptable level. Main reasons that no consensus is established are that: (i) a linear regression with only global radiation gave good results; (ii) the standard deviation between model results and measurements is almost equal to the random error of the eddy-correlation measurements (chapter 2, 4 and 6); (iii) a mean response was easy to find due to the strong correlations between input variables, while short periods when these correlation were uncoupled are very rare and (iv) all models were calibrated and the values of these fit-parameters were not linked to system properties.

As a result, it means that further improvements in the understanding of cause-effect relationships of forest transpiration are not expected with the use of monitoring measurements as used in this thesis. As shown in chapter 4, more monitoring measurements will not increase the information content of the measurements. As long as
the accuracy of the eddy-correlation measurements is not increased, improvement in the understanding of the system is not expected.

In laboratory or manipulation experiments, experimental design increases the information of measurement. In this study, time series of monitoring measurements were used. These kinds of data have a limited amount of information to identify the parameters. By using PIMLI, this information is increased by selecting specific measurements. With PIMLI the most relevant periods to identify the parameters, to confirm the model behaviour or to falsify the model concepts can be calculated. It means that PIMLI can be used as a method for experimental design. However, using experimental design in monitoring research has some disadvantages. In practice, it is usually easier to measure the total period instead of specific conditions because of problems by setting up the instrumental equipment. A second disadvantage is that an efficient experimental design is inextricably bound up with the chosen model meaning that much confidence is given in the model concept. As a result of such a measuring strategy, new insights in processes will be limited.

Consequently, to further improve the understanding of the system, future research should focus on increasing the information of measurements by direct measurements of transpiration. With manipulation experiments, correlation between environmental variables can be uncoupled and only one part of the process is than examined. Examples of manipulation experiments are for instance (i) the HELOX experiments of Mott and Parkhurst (1991) to find out if stomata response directly to a change in humidity or indirectly as a consequence of a change of transpiration, (ii) the experiment of Musters (1998), who manipulated the soil water dynamics with the help of a roof that intercepted precipitation, (iii) or the free air carbon dioxide enrichment (FACE) experiments (Herrick and Thomas, 1999).

For rainfall interception it was concluded that the throughfall measurements, measured with funnels as used in the Douglas fir stand, have limited information. This limited information was caused by the large measurement errors affected by the spatial variability between the funnels. To increase the information of throughfall measurements, spatially correct area measurements with plastic sheets (Calder and Rosier, 1976) or troughs (Lundberg et al., 1997) can be used. However, with these types of measurements, as shown in chapter 5, the drainage parameter can still not be identified and the uncertainties of the evaporation and storage capacity parameter are still high. To improve the understanding of the canopy storage dynamics and evaporation rates of the canopy,
more attention should be paid on direct measurements of canopy storage and evaporation rates.

In current Soil Vegetation Atmosphere Transfer (SVAT) model development, the complexity and number of parameters is increased by incorporating plant-physiological processes and heterogeneity in sub-grids. This increase in model parameters would not be a problem, if these kinds of models were non-calibrated ones. However, in general, the parameters cannot be measured independently at the scale of interest. As a result, the majority of the parameters should always be calibrated and problems as non-uniqueness will be found. To assess the maximum complexity of the model with respect to the information of the available measurements is a major problem in these kinds of models. A next step for future research will be to use the knowledge from this thesis in research in SVAT models at a larger scale.

REFERENCES


