Application of a generalized likelihood function for parameter inference of a carbon balance model using multiple, joint constraints

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(1) Background

Parameter estimation is usually done by minimizing a simple least squares objective function with respect to the model parameters – presuming Gaussian, independent and homoscedastic errors (formal SLS approach). Very often residual errors are non-Gaussian, correlated and heteroscedastic. Thus, these error sources have to be considered and residual-errors have to be described in a statistically correct fashion order to draw statistically sound conclusions about parameter- and model predictive-uncertainties.

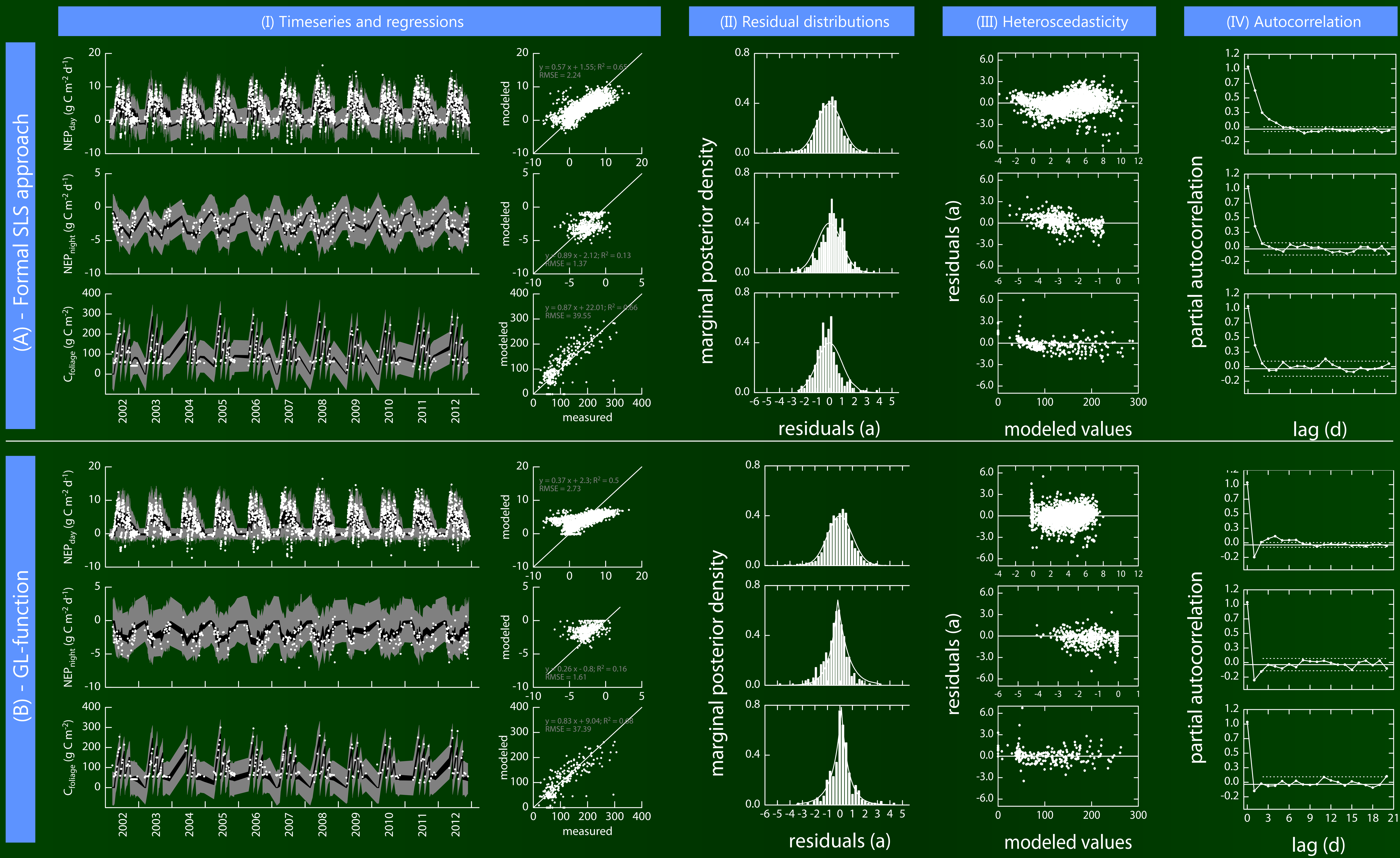
We examined the effects of a generalized likelihood (GL) function[1] for parameter estimation of a carbon balance model. Compared with the formal approach, the GL function allows for correlation, non-stationarity and non-normality of model residuals.

(2) Results

While Fig. A I shows a reasonable model performance, Fig. A II-IV reveal that the SLS assumptions do not hold for the three datasets used for constraining the model parameters.

Fig. B II shows, that the GL-function is able to reproduce the residual distribution very well, with a Laplace distribution for the dataset NEP_{night} and $C_{foliage}$, allowing for heavy tailed outliers. Fig. B III & IV show that the GL function accounted for heteroskedasticity and autocorrelation of residuals.

These results show evidence for heavy-tailed errors and reveal model structural deficits.



white dots: measured data | black shaded areas: parameter uncertainty | grey shaded area: predicitive uncertainty

assumed (line) and actual (bars) residuals

(3) Conclusions

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Explicitly modeling residual distributions of 3 datasets for constraining model parameters revealed violations of SLS assumptions and indicated model structural deficits. The GL function is thus recommended over the SLS approach or Box-Cox transformations, as they typically do not account for heavy tailed residuals, as presented here. Furthermore, this method is seen as a pragmatatic approach treating measurement, input data and model structural errors in a lumped manner.

[1] Schoups, G. and Vrugt, J.A., 2010. A formal likelihood function for parameter and predictive inference of hydrologic models with correlated, heteroscedastic, and non-Gaussian errors. Water Resour Res, 46: 10531-10531