

Evaluating the effect of the 2018 drought on the NEE in the Sorø beech forest by means of trend analysis and mechanistic canopy modelling of GPP.

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Introduction



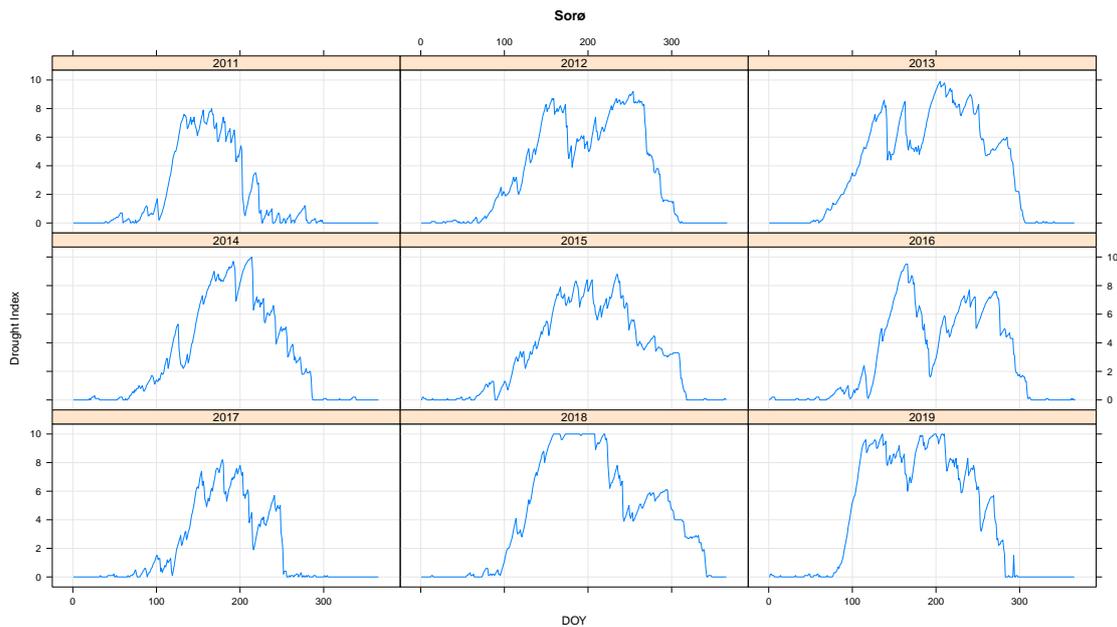
Denmark experienced a severe drought in 2018 lasting from the beginning of May to the end of August with very little rain during this period. The influence of drought on the net ecosystem CO₂ exchange (NEE) was analysed at the Danish ICOS DK-Sor site (a mature beech forest). The site has a very long continuous flux data set starting in June 1996. The annual NEE of the site has been increasing over the years, mainly due to a prolonged growing season in the autumn and CO₂ fertilisation (Pilegaard et al., 2011).

The effect of the summer drought in 2018 was analysed by means of linear trend estimation based on monthly trends during 1996-2017. The observed monthly NEE in 2018 was compared to the predicted values from the monthly time series.

In addition, we used the flux data set together with a mechanistic canopy model to examine the tree physiological nature of the photosynthesis limitation during drought.

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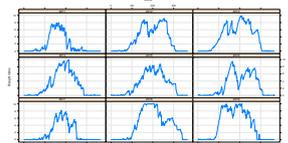
Drought index 2011-2019



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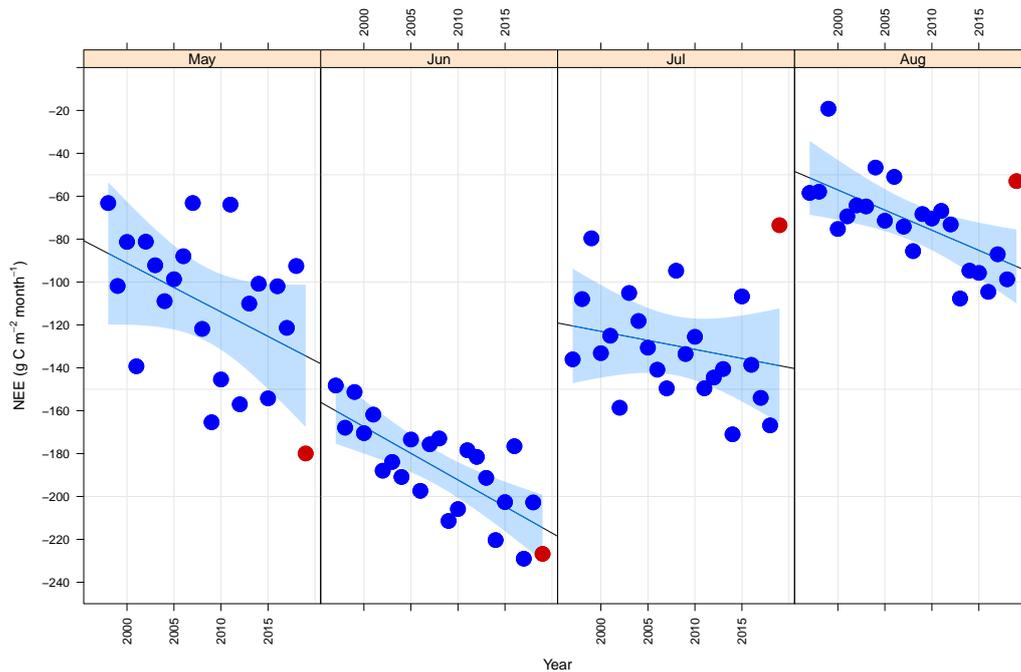
Drought index 2011-2019



Drought index 2011-2019

- The figure shows the annual course of the drought around our site during 2011-2019 based on data from the Danish Meteorological Institute.
- The drought index goes from 0 (no risk of drought) to 10 (high risk of drought).
- Summer drought occurs all years, but by far most severe in 2018.
- Maximum drought occurred from May through August 2018 with moderate precipitation in the beginning of August.

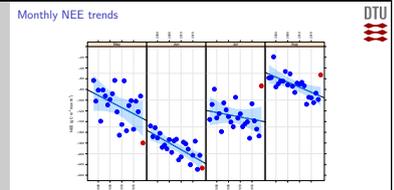
Monthly NEE trends



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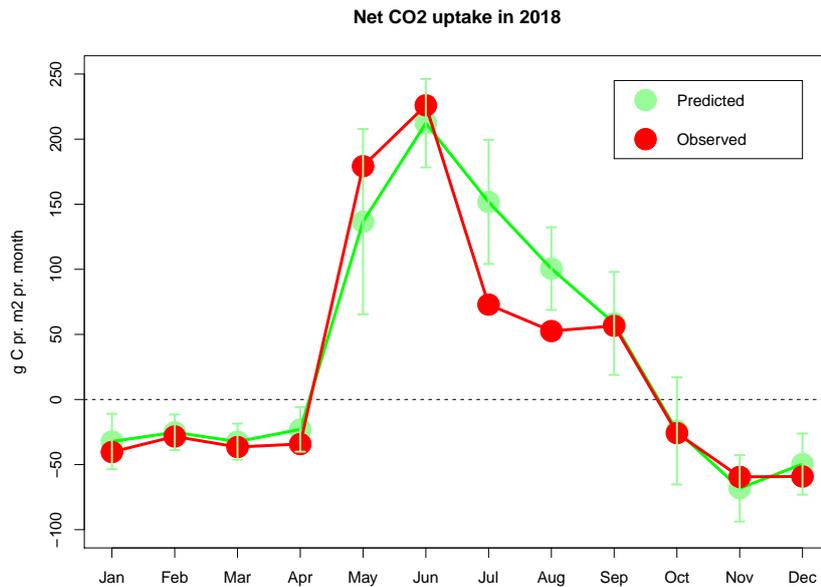
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Monthly NEE trends



- The long time-series makes it possible to explore trends within months.
- The figure shows monthly trends for May through August over 1996-2018.
- May and July show most scatter around the line due to timing of bud-break (May) and summer drought (July).
- The values for 2018 (red dots) show somewhat higher uptake in May and June and especially much lower uptake in July and August.

The anomaly due to the 2018 drought



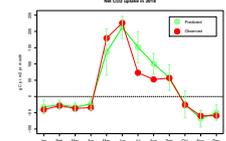
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The anomaly due to the 2018 drought

- The monthly trends of NEE over the years previous to 2018 were used to predict the monthly 2018 values; i.e. the likely values without effects of severe drought.
- The figure shows the measured monthly net CO₂ uptake (red marks and lines) and the predicted values with 95% prediction limits (green marks and lines).
- The predicted 2018 values for the months outside the summer period (May–August) fits extremely well with the measured values.
- The measured values shows somewhat higher values for May and June than predicted, and significant lower values for July and August.

The anomaly due to the 2018 drought



Understanding the decrease of GPP during drought

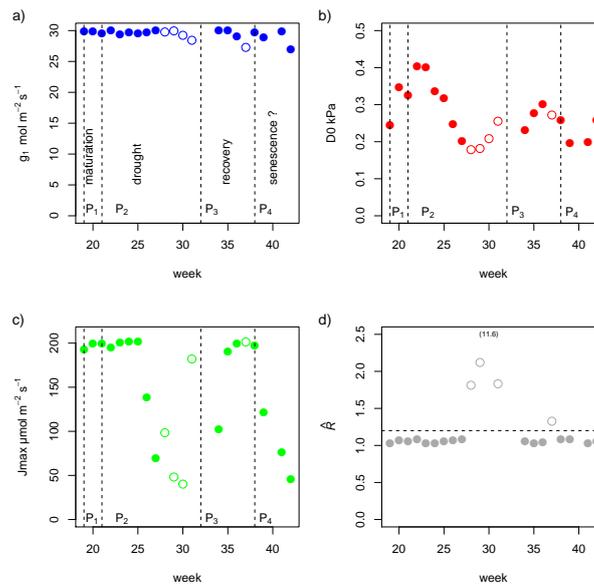
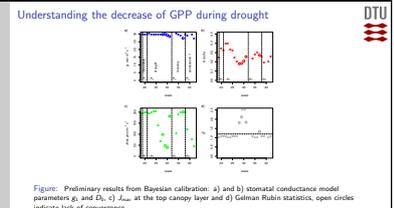


Figure: Preliminary results from Bayesian calibration: a) and b) stomatal conductance model parameters g_1 and D_0 , c) J_{max} at the top canopy layer and d) Gelman Rubin statistics, open circles indicate lack of convergence

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Understanding the decrease of GPP during drought



- Motivated by the pioneering work of Gourlez de la Motte et al. (2020, PTRS B, accepted), a mechanistic multi-layer canopy model based on the plantecophys R-package (Duursma et al., 2019) was used to together with CO_2 and water vapour flux data to fit parameters of Leuning's stomatal conductance model (g_1 and D_0) and the biochemical C_3 photosynthesis model (J_{max}). Data was prepared to minimise effects of rain and intercepted rain water. We used the Differential Evolution Markov Chain sampler provided by the R-package BayesianTools (F. Hartig et al. 2019) for every week of data during the vegetation period in 2018.
- The calibration converged in the majority of cases and simulations of both GPP and transpiration (ET) improved compared to the default parameter settings. Both GPP and ET were strongly reduced in the months July to August.
- The two parameters, g_1 and J_{max} reached unrealistic magnitudes but there was a meaningful seasonality of the parameter D_0 and J_{max} , initially increasing with leaf development and then declining under the drought.

- ▶ At the start of the drought in May and in the first part of June, there was a sufficient amount of water available and the GEE was high due to high solar radiation.
- ▶ From the late June to beginning of August, water was clearly a limiting factor resulting in a much lower GEE and a corresponding low NEE.
- ▶ The summer drought in 2018 resulted in an overall lower photosynthetic assimilation (GEE) than in a normal year. The NEE was moderately affected because of a reduction of RE by drought. The annual NEE in 2018 was about 100 g C lower (approx. 25%) than expected from the trend over the previous years (1996-2017).
- ▶ The modelling study showed a meaningful seasonality of the parameters in Leunings stomatal conductance model.

Acknowledgements:

The study was based on data from ICOS-Denmark.

References:

1. Duursma, R.A., 2015. Plantecophys - An R Package for Analysing and Modelling Leaf Gas Exchange Data. PLoS ONE 10, e0143346. doi:10.1371/journal.pone.0143346
2. Hartig, F. et al. (2019). BayesianTools: General-Purpose MCMC and SMC Samplers and Tools for Bayesian Statistics. R package version 0.1.7. <https://CRAN.R-project.org/package=BayesianTools>.
3. Kim Pilegaard, Andreas Ibrom, Michael S. Courtney, Poul Hummelshøj, Niels Otto Jensen. Increasing net CO₂ uptake by a Danish beech forest during the period from 1996 to 2009. Agricultural and Forest Meteorology 151 (2011) 934–946.