

The NEE-PAR relationship for a young spruce plantation



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Eddy covariance (EC) Measurements at Hoxmark

- An ICOS-compatible EC system was mounted on a 2 m tripod in a young Norway spruce plantation at the experimental farm Hoxmark, Viken county, Southeast Norway ($59^{\circ} 40' \text{ N}$, $10^{\circ} 43' \text{ E}$).
- NEE measurements were performed from July 2018 to January 2020
- Footprint analysis reveals that the majority of air masses reaching the EC station originates from inside the plantation (Figure)

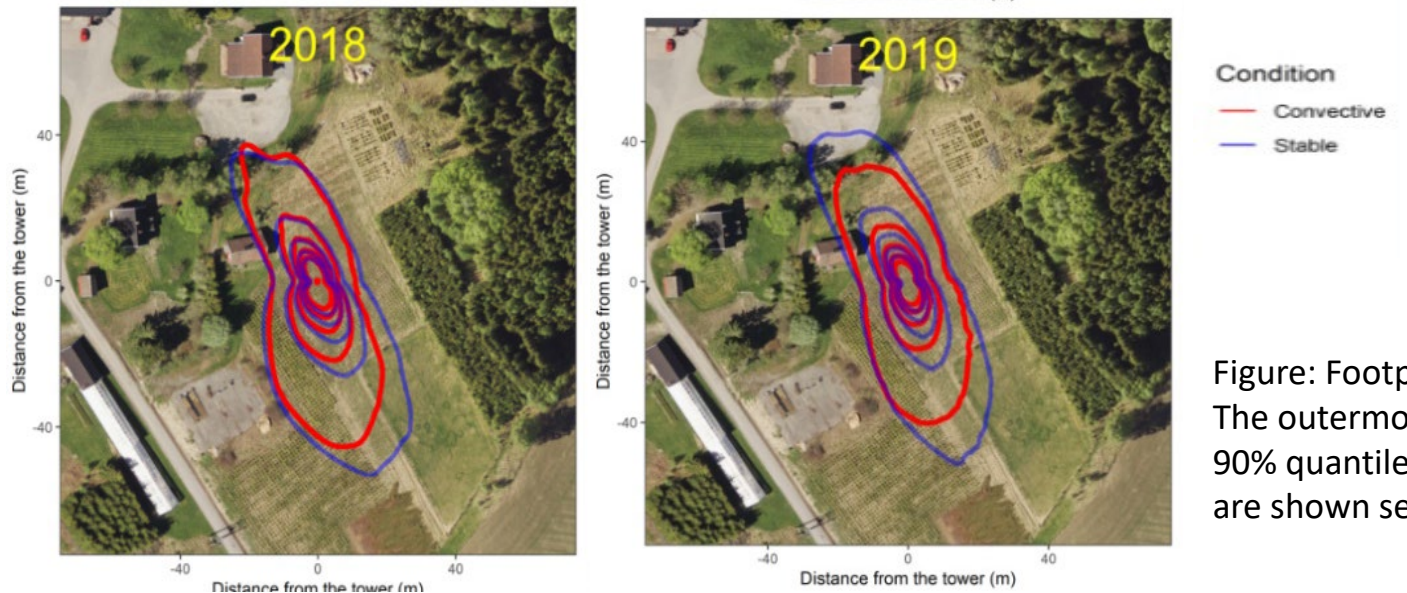
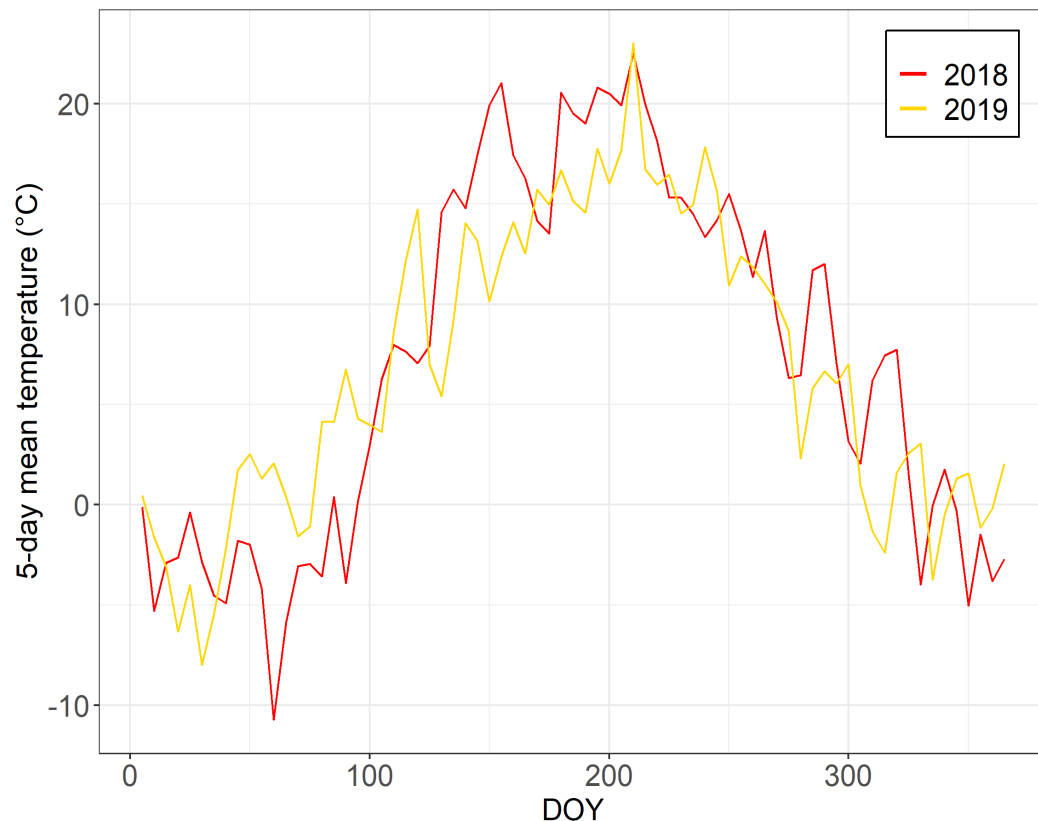


Figure: Footprint around the Hoxmark mast. The outermost polygon corresponds to the 90% quantile, and convective and stable conditions are shown separately.

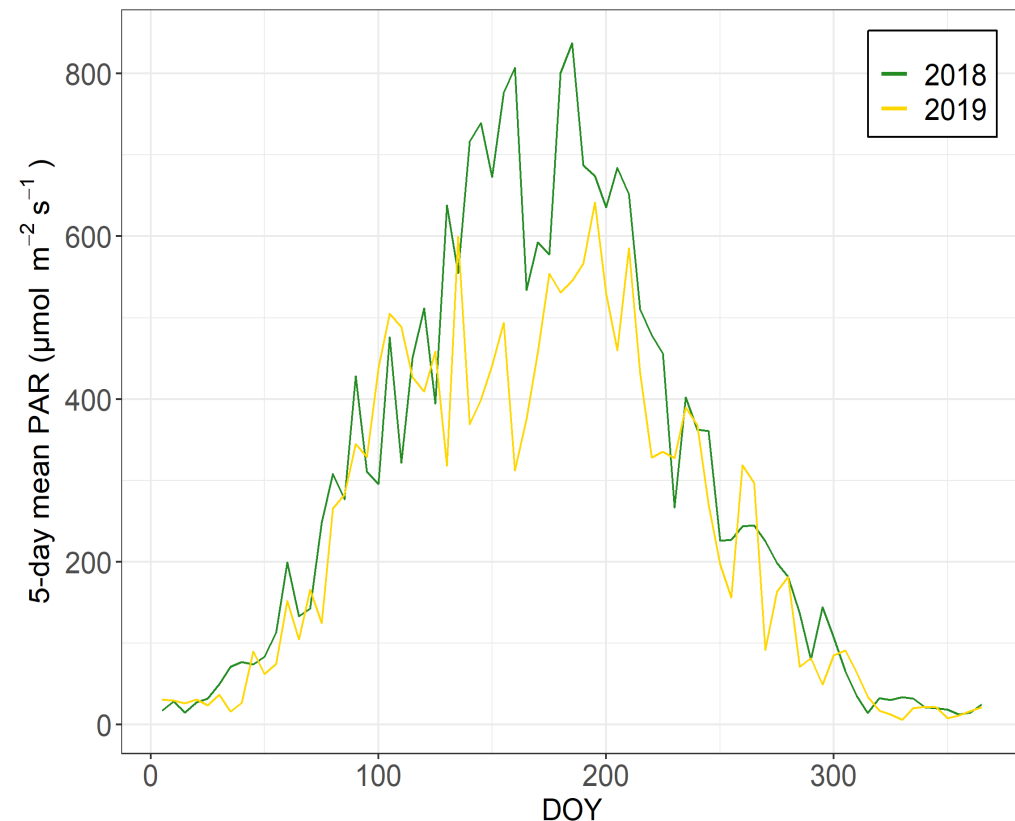
Local climate and radiation in 2018 and 2019 I

- Air temperature at 2 m height in 2018 was lower in spring, higher in summer, and overall quite comparable to that of 2019
- Radiation (PAR) was higher in the summer of 2018, indicating more cloud-free days than in 2019

5-day mean temperature in 2018 and 2019



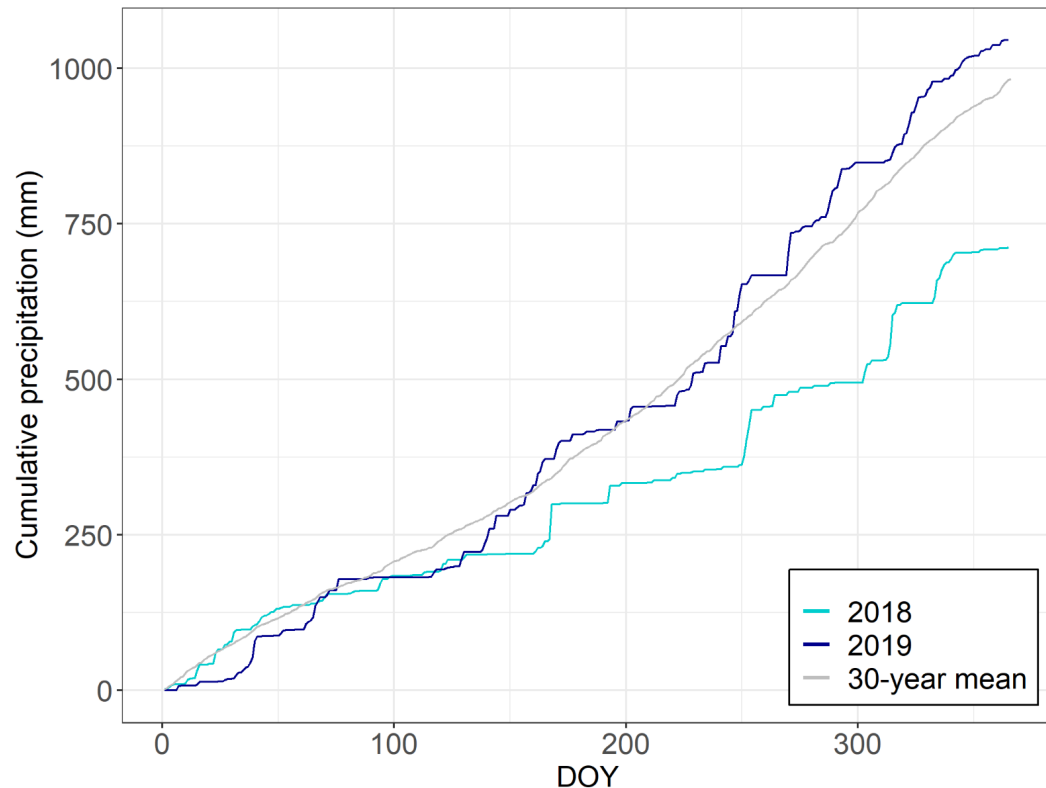
5-day mean PAR in 2018 and 2019



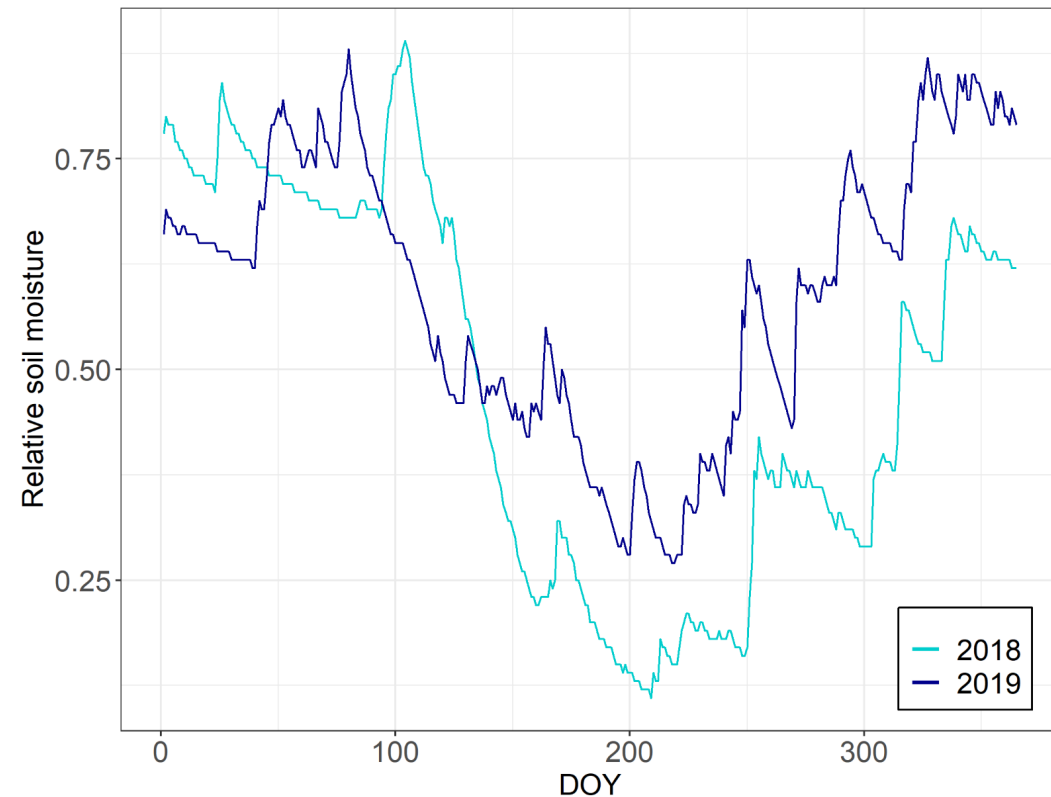
Local climate and radiation in 2018 and 2019 II

- In 2018, precipitation was much lower than the average in 1991-2020, whereas 2019 was close to an average year
- Soil moisture shows a strong decline in 2018 from April onwards, with a deep minimum in July

Cumulative precipitation in 2018 and 2019



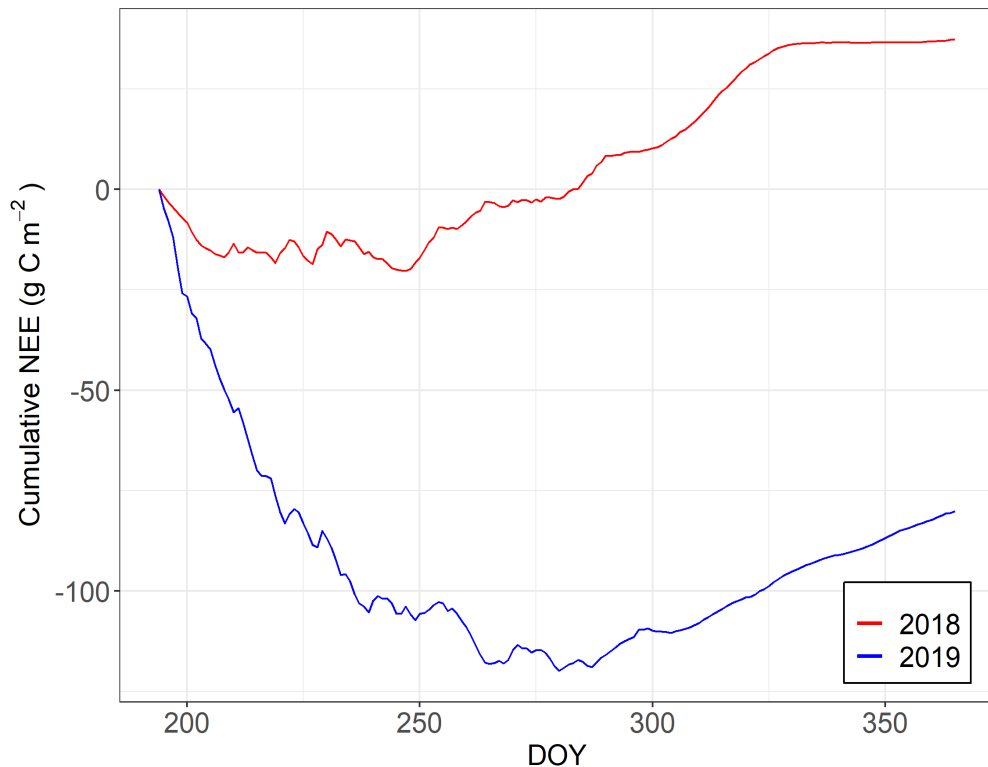
Relative soil moisture in 2018 and 2019



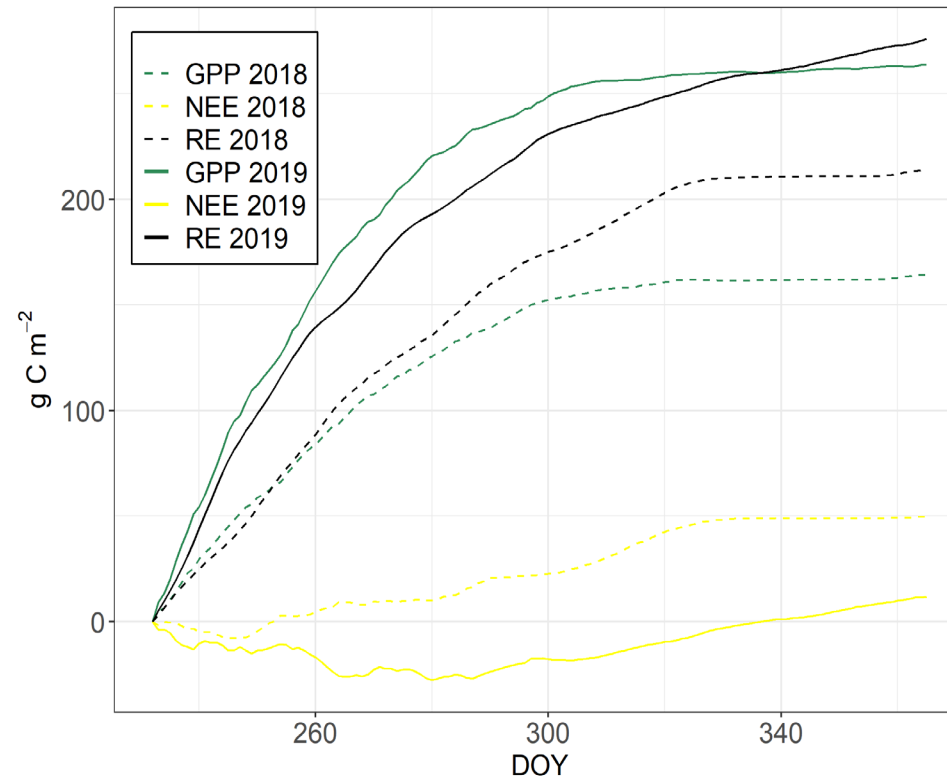
Net Ecosystem Exchange in 2018 and 2019

- NEE had very different courses in the two years. Setting cumulative NEE to the same value zero at the beginning of the measurements in 2018 (mid-July), a large difference develops from there. In 2019, Hoxmark was a net sink for carbon ($\text{NEE} = -308 \text{ g C m}^{-2}$).
- Gross Primary Productivity GPP and Ecosystem Respiration RE ($= \text{NEE} + \text{GPP}$) also show very different patterns. In 2018, respiration exceeded GPP throughout the summer and autumn

Cumulative NEE starting on 13th July



Cumulative NEE, GPP and RE (21/08 - 31/12)



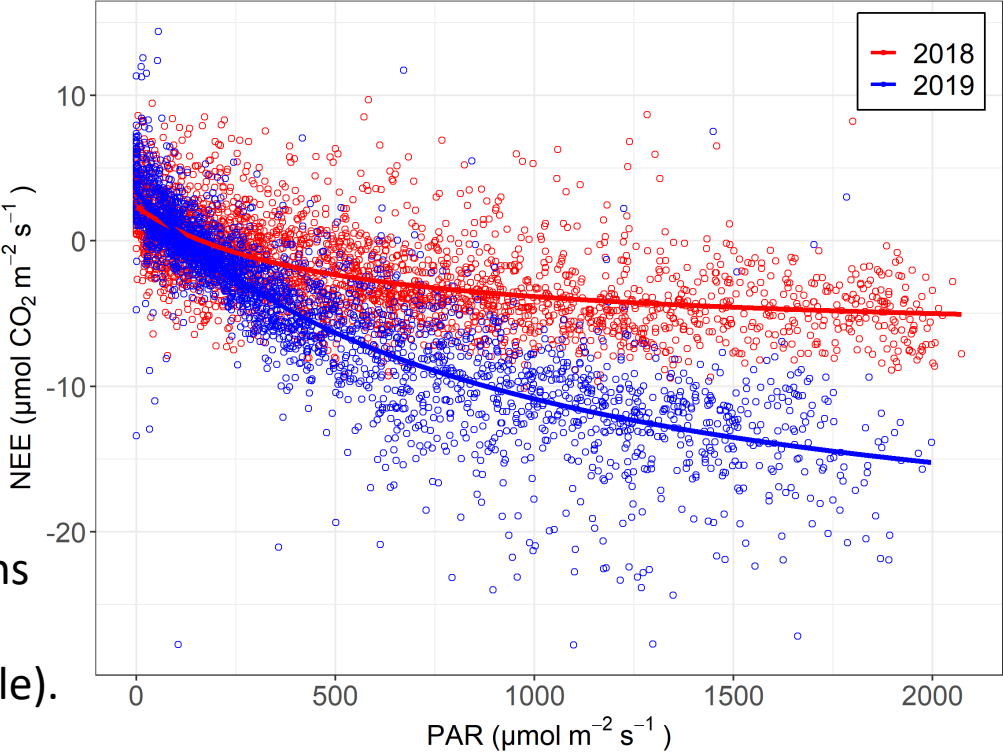
Modelling NEE with radiation I

The dependence of NEE on available radiation (PAR) was modelled with a simple Michaelis-Menten equation

$$NEE = -\frac{\alpha P_{max} PAR}{P_{max} + \alpha PAR} + R_d$$

where α is the initial quantum yield at low radiation, P_{max} is the photosynthesis capacity, and R_d is the dark respiration. Nonlinear regressions indicate a clear difference between 2018 and 2019 (Figure), and parameter estimates obtained are quite typical for 2019, but exceptional for 2018 (Table).

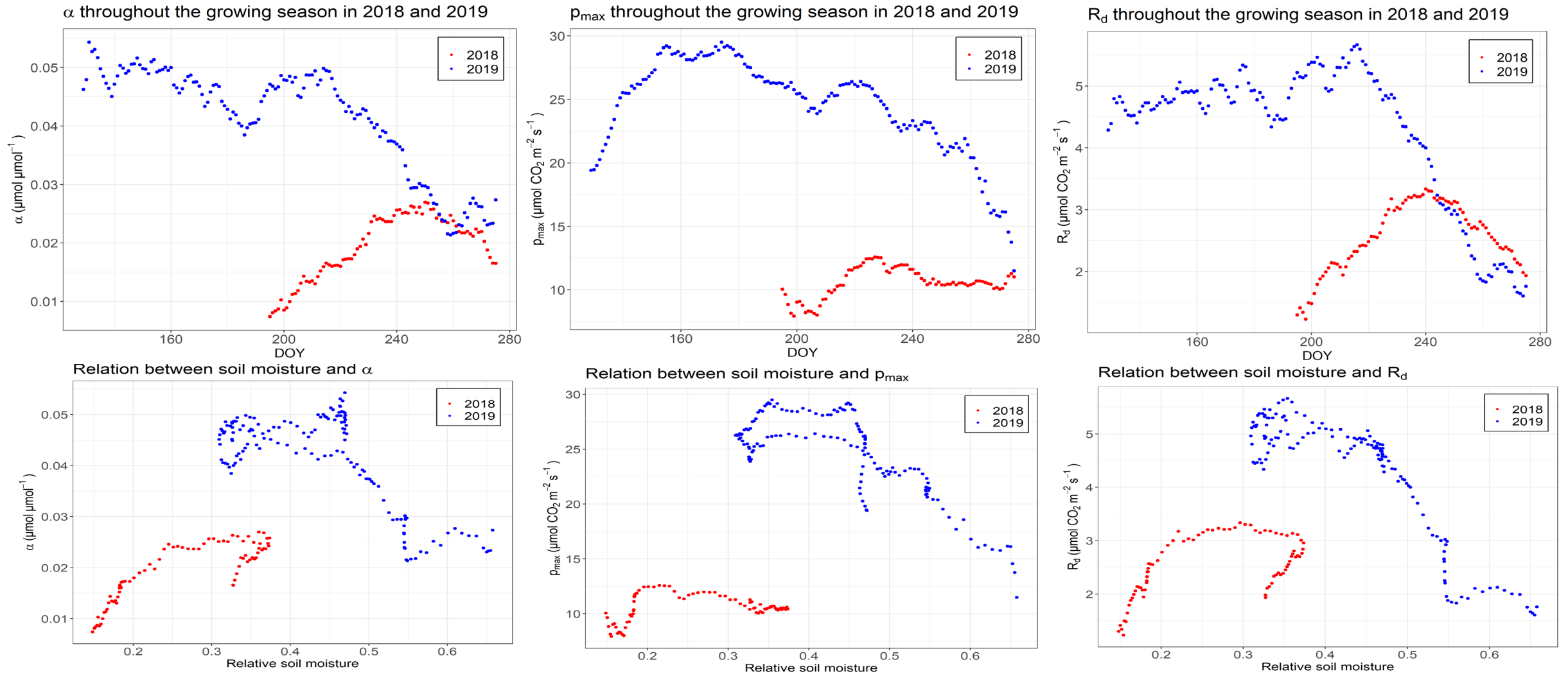
NEE - PAR relation in 2018 and 2019 (14/07 - 31/10)



Forest type	Period	α (µmol µmol ⁻¹)	p_{max} (µmol m ⁻² s ⁻¹)	R_d (µmol m ⁻² s ⁻¹)	Reference
Boreal black spruce	June – August (2001)	0.087 +/- 0.006	38.1 +/- 6.7	7.6 +/- 2.0	Griffis et al. 2003
Boreal Jack pine	June – August (2001)	0.040 +/- 0.01	13.1 +/- 4.7	3.4 +/- 1.5	Griffis et al. 2003
Boreal Scots Pine	June – September (1999 – 2002)	0.027 +/- 0.003	17.0 +/- 3.7	-	Zha et al. 2004
HOXMARK (Norway spruce)	Mid-July – September 2018	0.018 +/- 0.002	9.3 +/- 0.3	2.4 +/- 0.2	this study
HOXMARK (Norway spruce)	Mid-July – September 2019	0.038 +/- 0.002	26.1 +/- 0.6	4.4 +/- 0.2	this study

Modelling NEE with radiation II

Nonlinear fits for moving 30-day windows result in time series for the parameter estimates for the growing season. The two years are distinctively different, with 2019 being the much more productive year



Conclusions

- The Norway spruce plantation at Hoxmark acts as a C sink already at age 7 years (in 2019)
- The NEE-PAR relationship can be modelled by a Michaelis-Menten approach
- The two years 2018 and 2019 differ substantially in precipitation and soil moisture
- Carbon fluxes also differ largely for the two years, with much less uptake in the dry year 2018
- Parameter estimates for the NEE-PAR model are time-dependent and apparently dependent on environmental conditions (soil moisture in particular)