

Inferring ecosystem-level rates of gross primary productivity, respiration, and evapotranspiration with automatic light-dark measurement chambers

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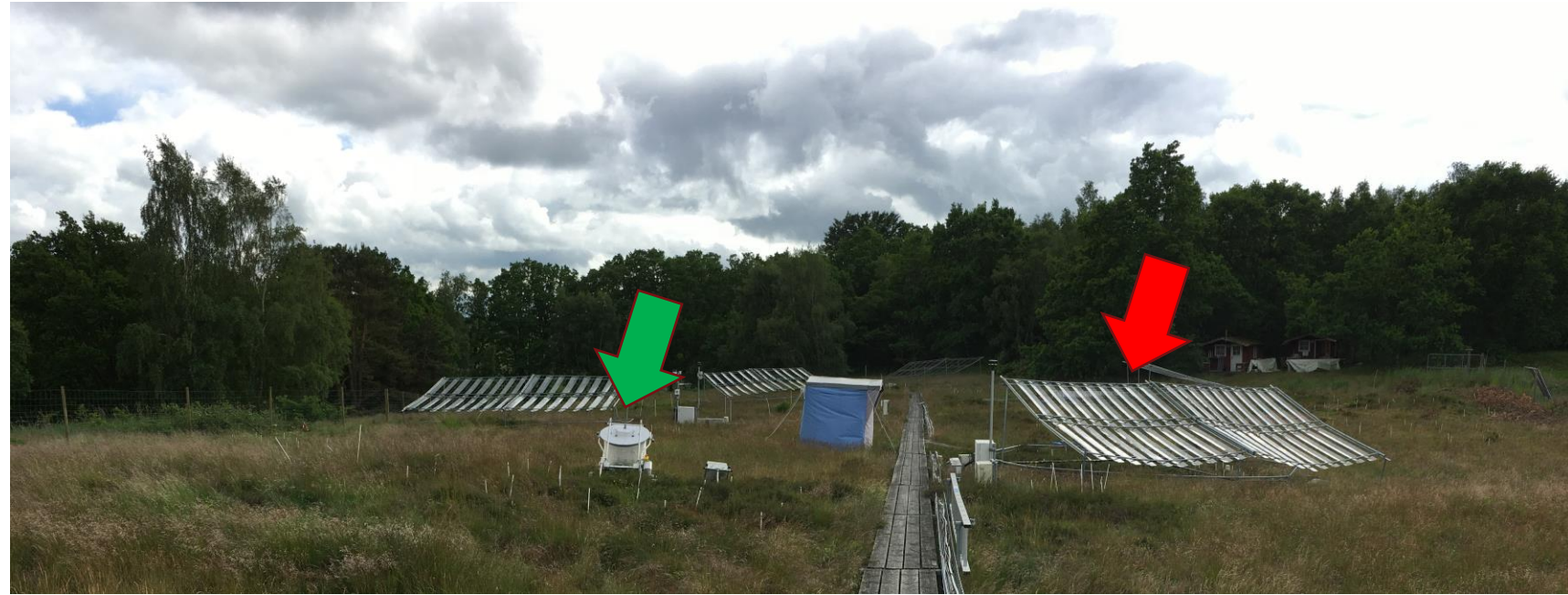
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Question: How do we best estimate ecosystem Gross Primary Productivity (GPP), Ecosystem Respiration (R_{eco}) and Net Ecosystem Exchange (NEE) in climate experiments?

In experimental ecosystem research, plot sizes are often too small to apply eddy covariance techniques for estimating ecosystem gas exchange rates.

In low-stature vegetation, we can perform measurements at the ecosystem level with closed chamber technologies.

We here present data from measurements with large, automatic light/dark chambers.



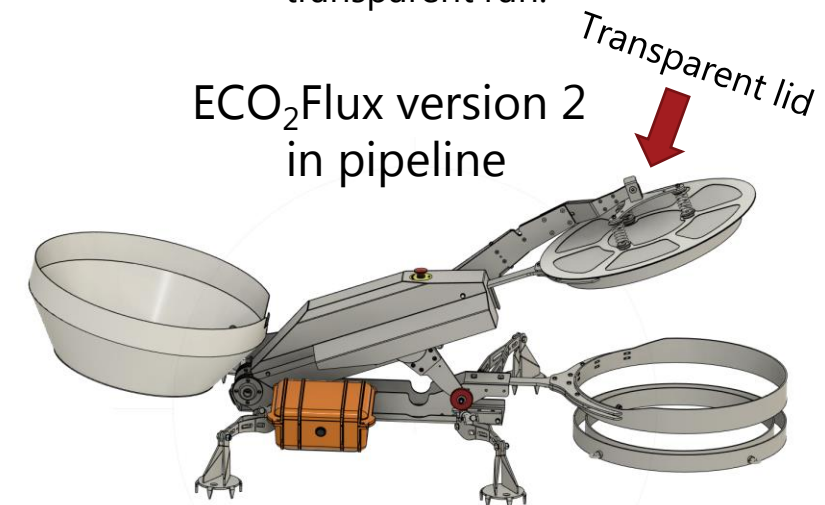
In the CLIMAITE climate experiment in a Danish heathland ecosystem (anaee.dk/platforms/climaite), each plot is 9 m² and gas measurements must rely on chamber technologies. Permanent rainout shelters (red arrow) and an automatic light/dark measurement chamber can be seen (green arrow).

The ECO₂FluX chamber is a large, automatic light/dark chamber for measuring NEE, R_{eco} and GPP in low-stature vegetation



The chamber is 63 cm in diameter and 80 cm tall = 250L. It is controlled by a LI8150 LI-COR system. It has two tubes – the inner transparent and the outer opaque. The outer tube is on every second run, i.e., the chamber is first transparent, then darkened.

An updated version is under development with improvements, e.g. a transparent lid for the transparent run.



The chamber runs with a LI-8150 system (www.licor.com)

Example data from the field

First run: **transparent** = **NEE**



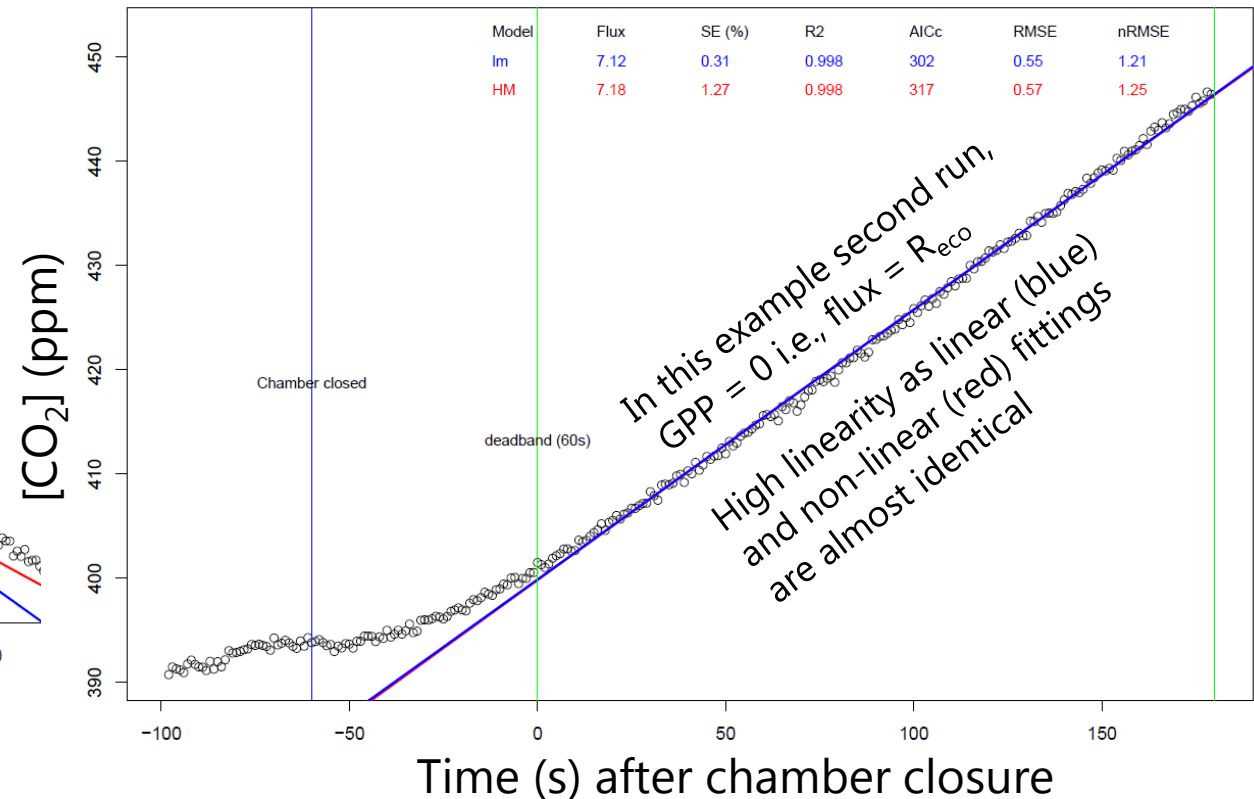
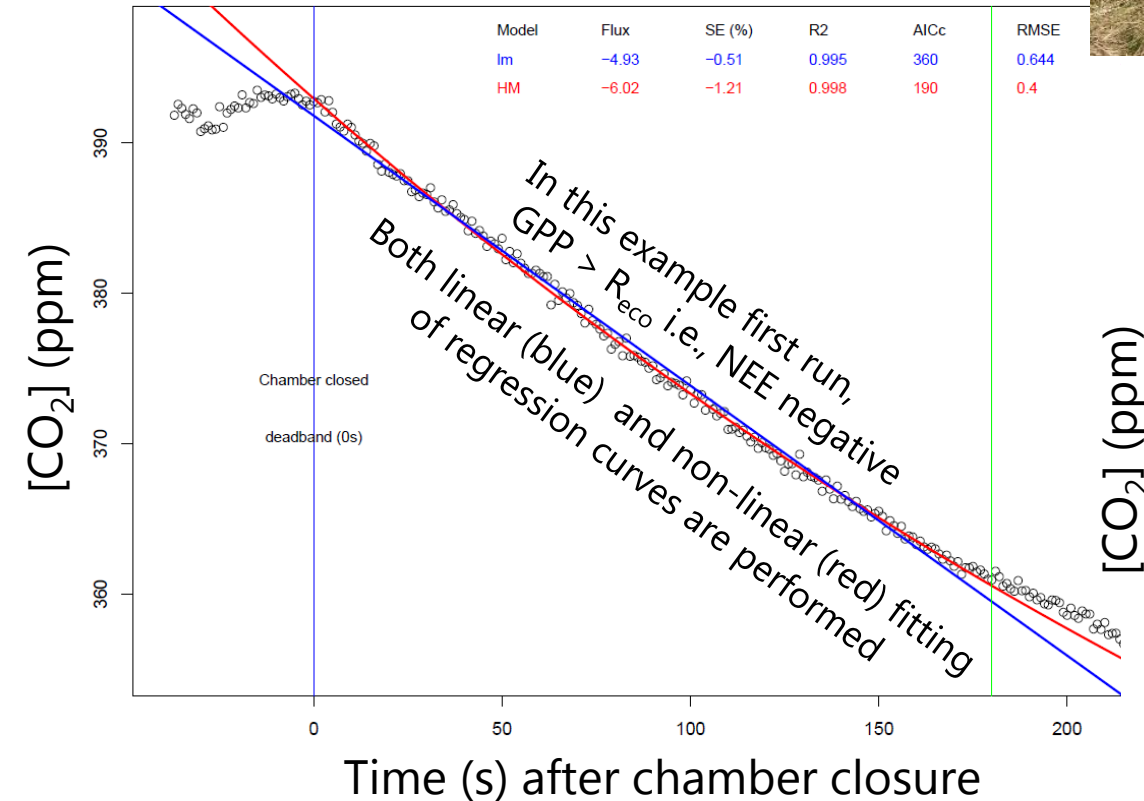
Second run: **darkened** = **R_{eco}**



The major advantage of being able to darken the chamber is, that NEE is obtained in the transparent mode and R_{eco} in the darkened mode during the daytime. **In this way, GPP can be estimated directly as:**

$$\text{GPP} = \text{NEE} - \text{R}_{\text{eco}}$$

↑
First run
↑
Second run



Currently, 28 ECO₂FluX chambers are active at 5 different sites and ecosystem types in Denmark, Iceland and Norway



6 at Foulum, Denmark (CO₂, N₂O)

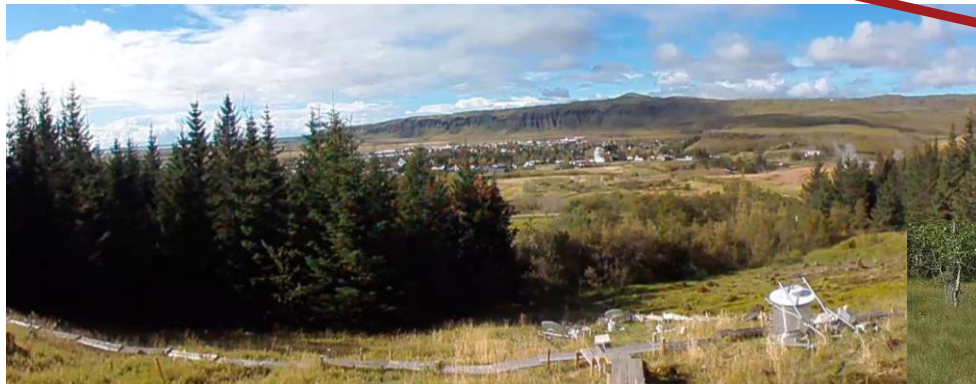
2 at Brandbjerg, Denmark (CLIMAITE, CO₂, CH₄)



6 at Højbakkegård, Denmark
(CO₂, CH₄, N₂O)



These sites are part of anaee.dk



4 at ForHot (FutureArctic), Iceland (CO₂, CH₄)

10 at Mire Restoration project,
Norway (CO₂, CH₄, N₂O)



Other presentations at EGU 2021 give more examples of chamber application in other systems:

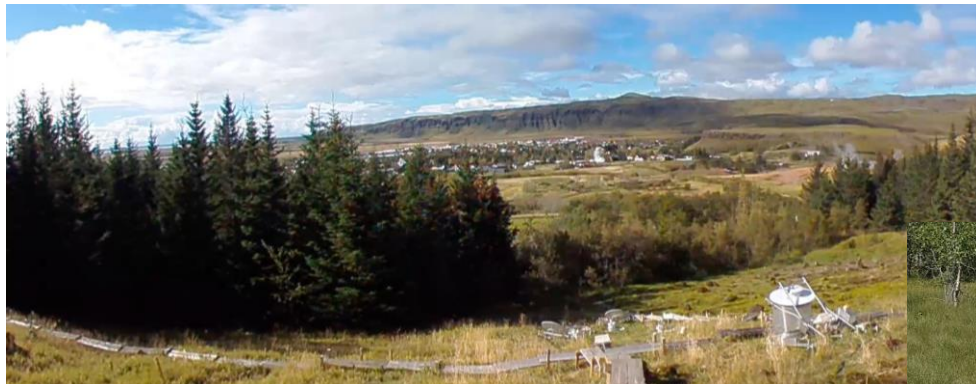


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This talk!



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Linsey Avila, UCPH

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Andreas Ibrom, DTU



In this presentation, I will focus on data from the CLIMAITE experiment in a Danish heathland ecosystem



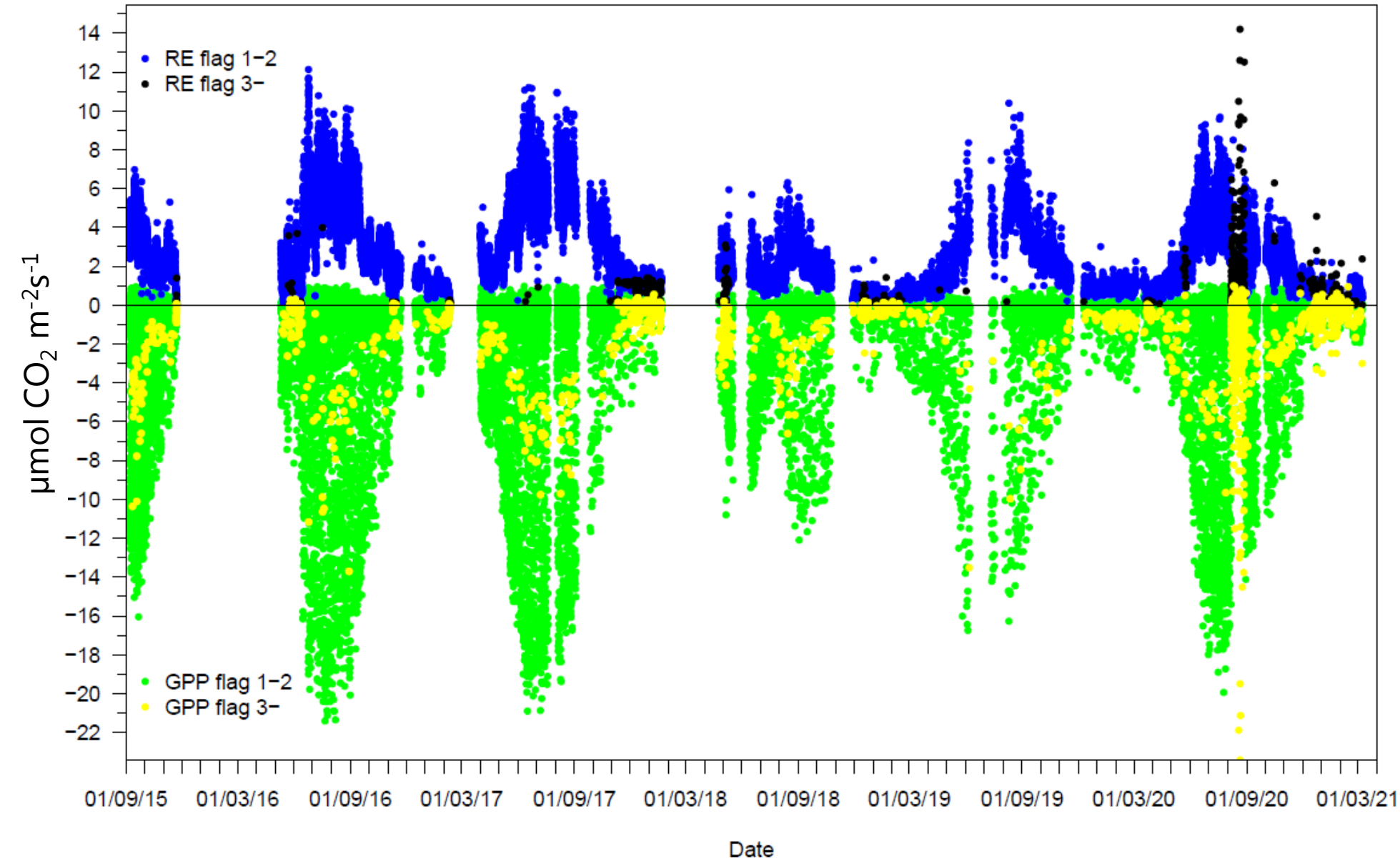
Chamber 1 vegetation is dominated by *Calluna vulgaris*, with some *Deschampsia flexuosa* and mosses sp.

I will focus in data from Chamber 1 (also called 'Ch1 Calluna'), which was the first edition of the chamber installed in Sept. 2015.



These two chambers runs in drought-stressed plots (since 2018) where 50% of the precipitation is removed by permanent rainout shelters.

Data from Chamber 1 at CLIMAITÉ 2015-2021



Chamber 1 has been running since Sept. 2015.

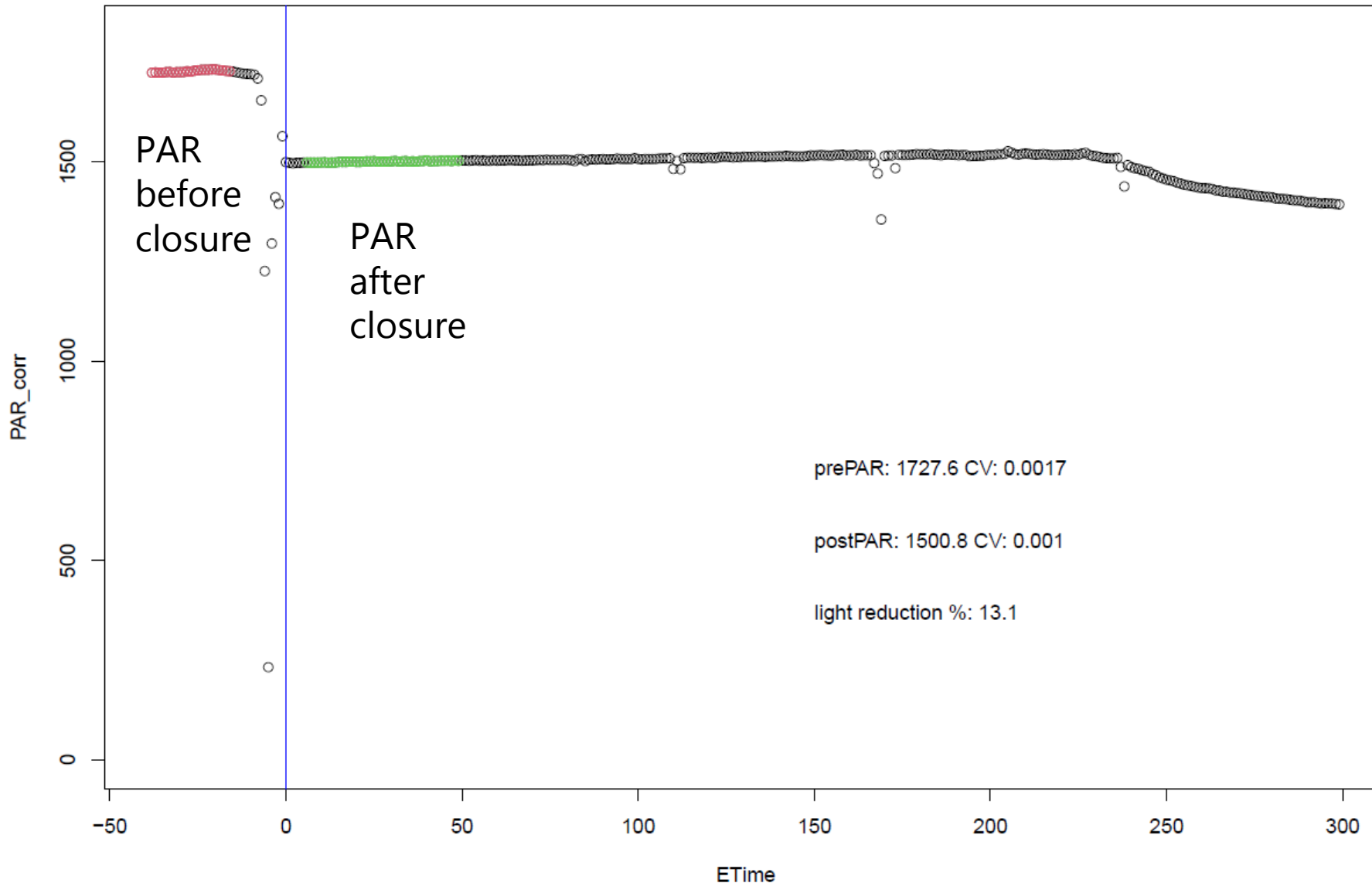
Here, R_{eco} is in blue (R^2 of linear fit > 0.95) and black ($R^2 < 0.95$) while GPP is shown in green ($R^2 > 0.95$) and yellow ($R^2 < 0.95$).

The GPP rates shown here are before correction for light reduction of the transparent chamber material during measurements ($\sim 27\%$ on average).

In total, measurements cover $\sim 54,100$ measurements performed (12,820 in 2020). Half is NEE measurements, the other half is R_{eco} measurements.

Light reduction during NEE measurements

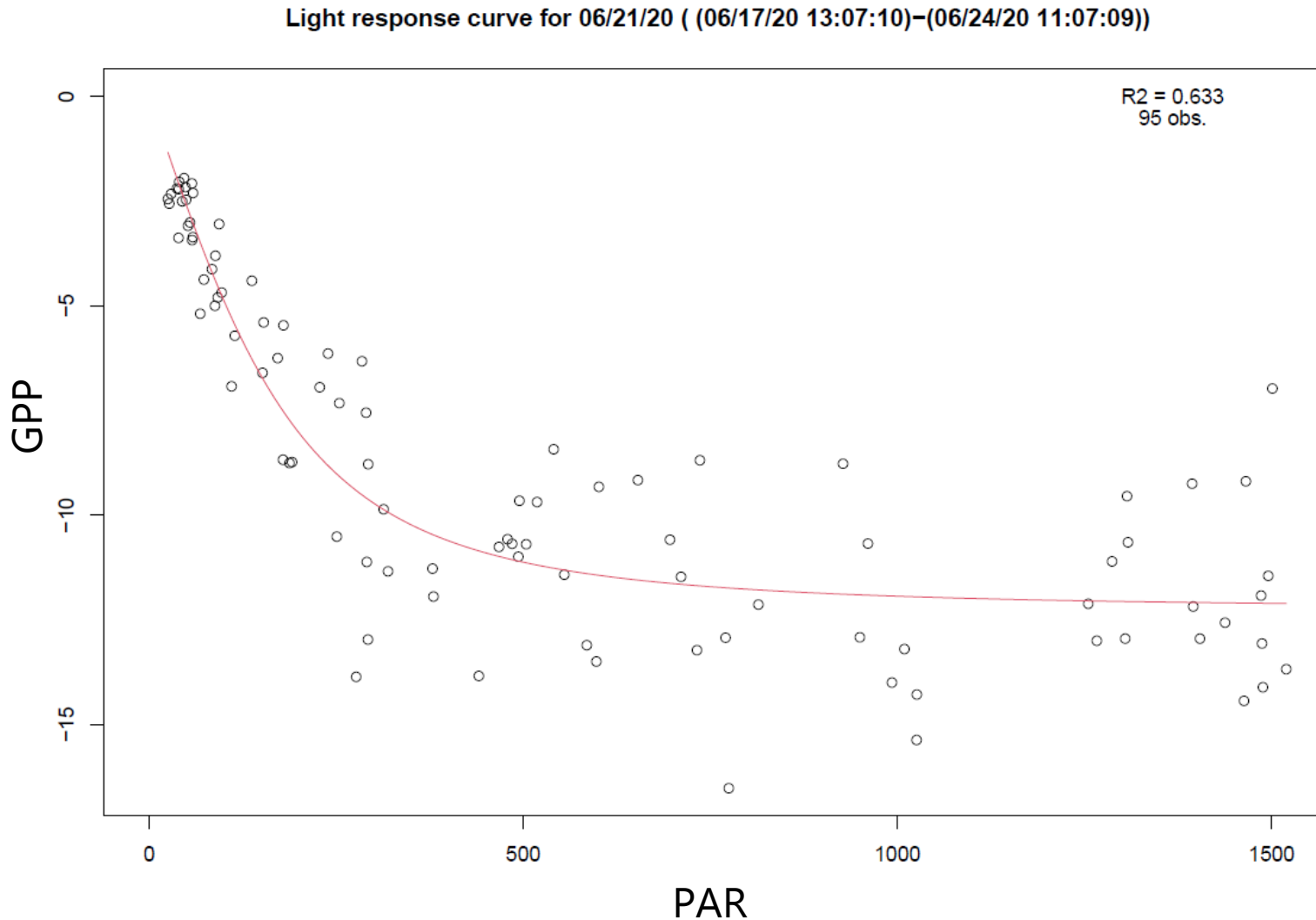
Obs: 1 Ch1_Calluna 2020-06-17 13:05:22



Here is an example of the light reduction of the transparent chamber material after chamber closure.

When GPP has been calculated (at the reduced light level – estimated as the mean of the green dots), it is corrected for this light reduction by estimating what it would have been at the light level measured before chamber closure (the mean of the red dots).

Correction of observed GPP based on a running window light response curve



A running 7-day (min.) window with nearest min. 30 NEE measurements with $R^2 > 0.95$ of the regression are used to fit light response curves.

The light response curves are used to correct for the reduction of light by the transparent chamber material (see PAR before and after chamber closure in previous slide).

In this example, the window is 7 days and the curve is used to correct GPP rates measured for the day 21 June 2020. NEE was then corrected with the same correction as GPP.

NEE was then run through gapfilling and flux partitioning using the R package REddyProc (Wutzler et al., 2018)*.

*Wutzler T, Lucas-Moffat A, Migliavacca M, Knauer J, Sickel K, Sigut, Menzer O & Reichstein M (2018) Basic and extensible post-processing of eddy covariance flux data with REddyProc. Biogeosciences, Copernicus, 15, doi: 10.5194/bg-15-5015-2018

Chamber 1 NEE data before and after gapfilling for the years 2018 - 2020 (R package REdDyProc)

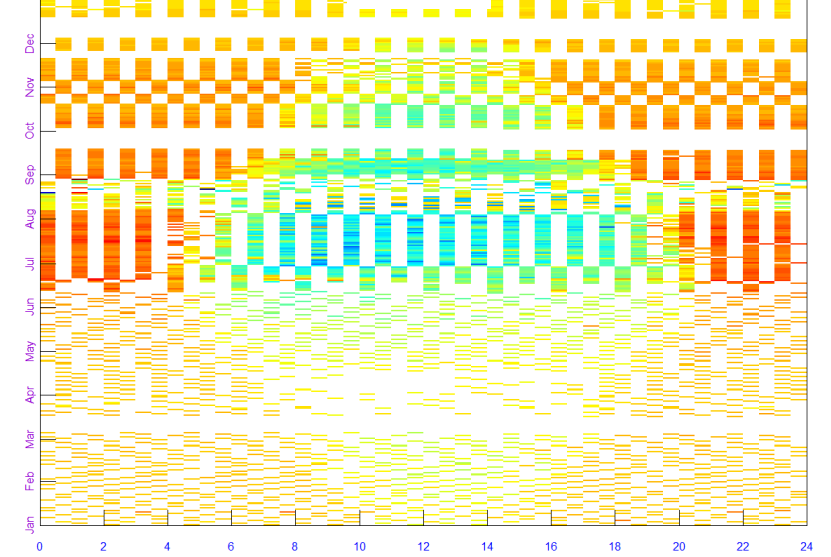
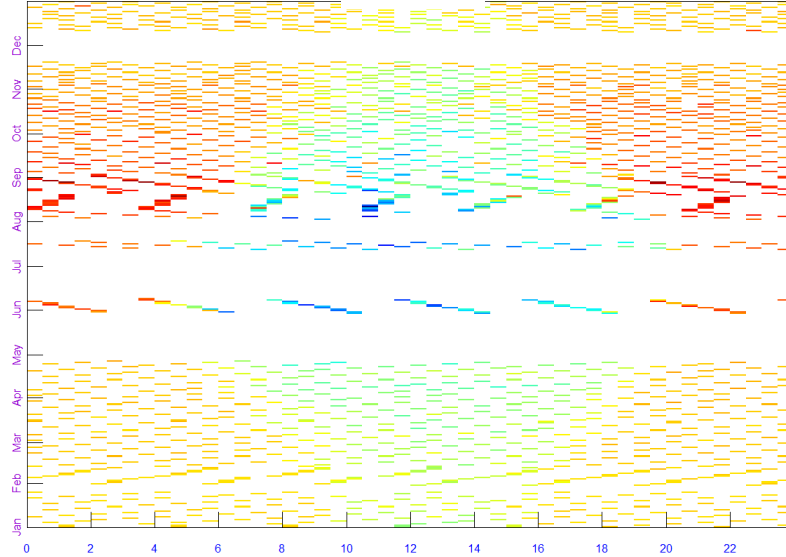
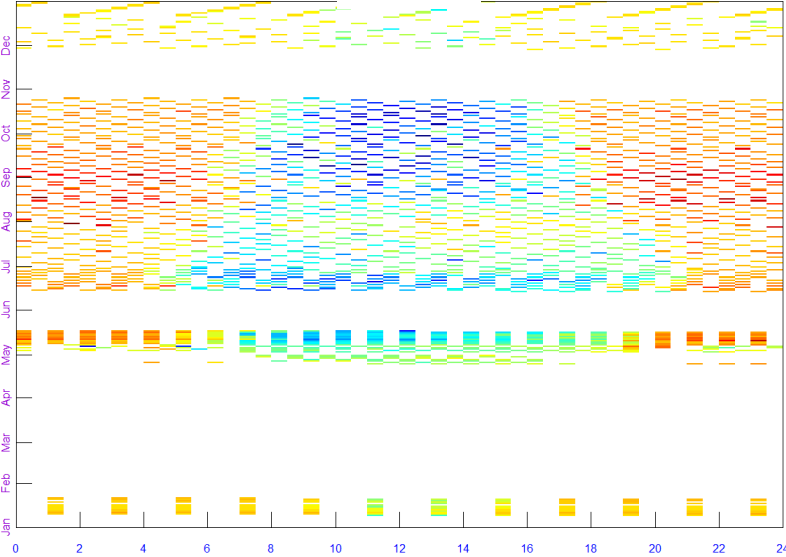
Before

2018

2019

2020

Month of year



Time of day

Time of day

Time of day

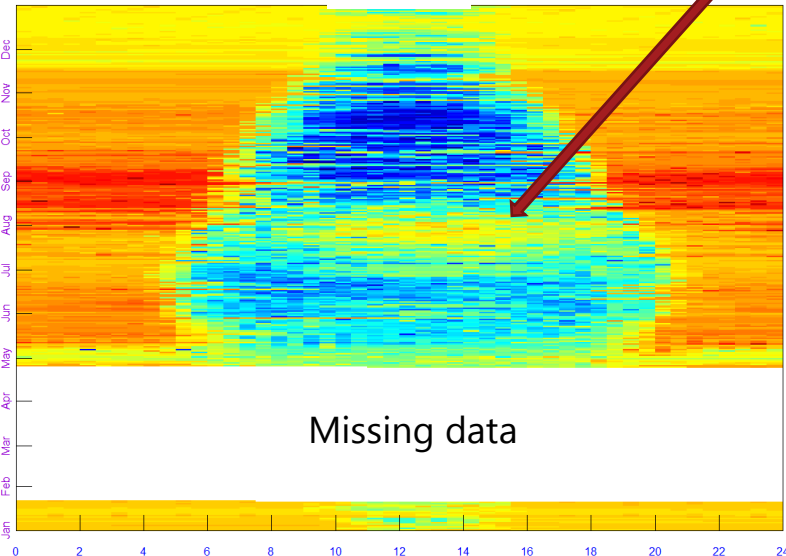
After

2018

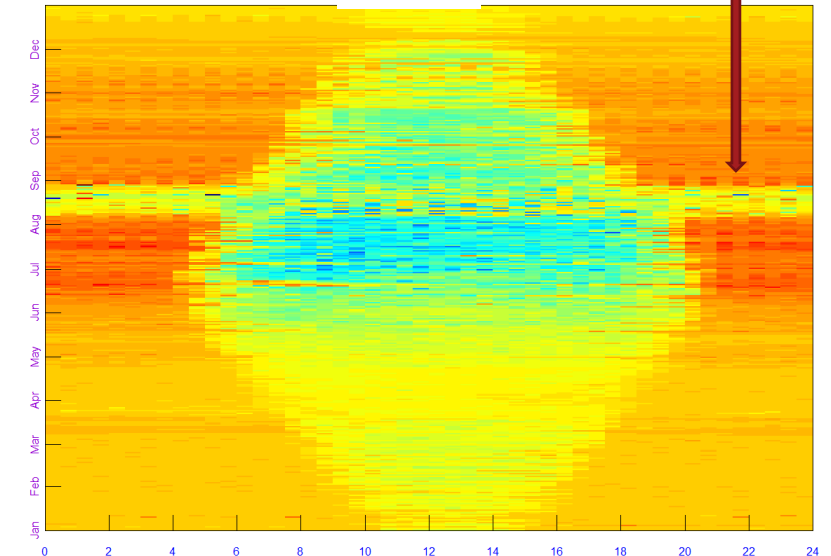
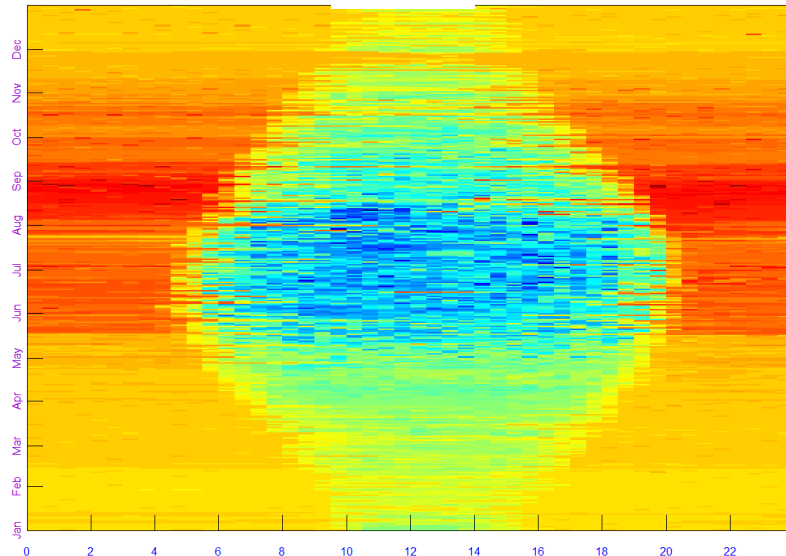
2019

2020

Month of year



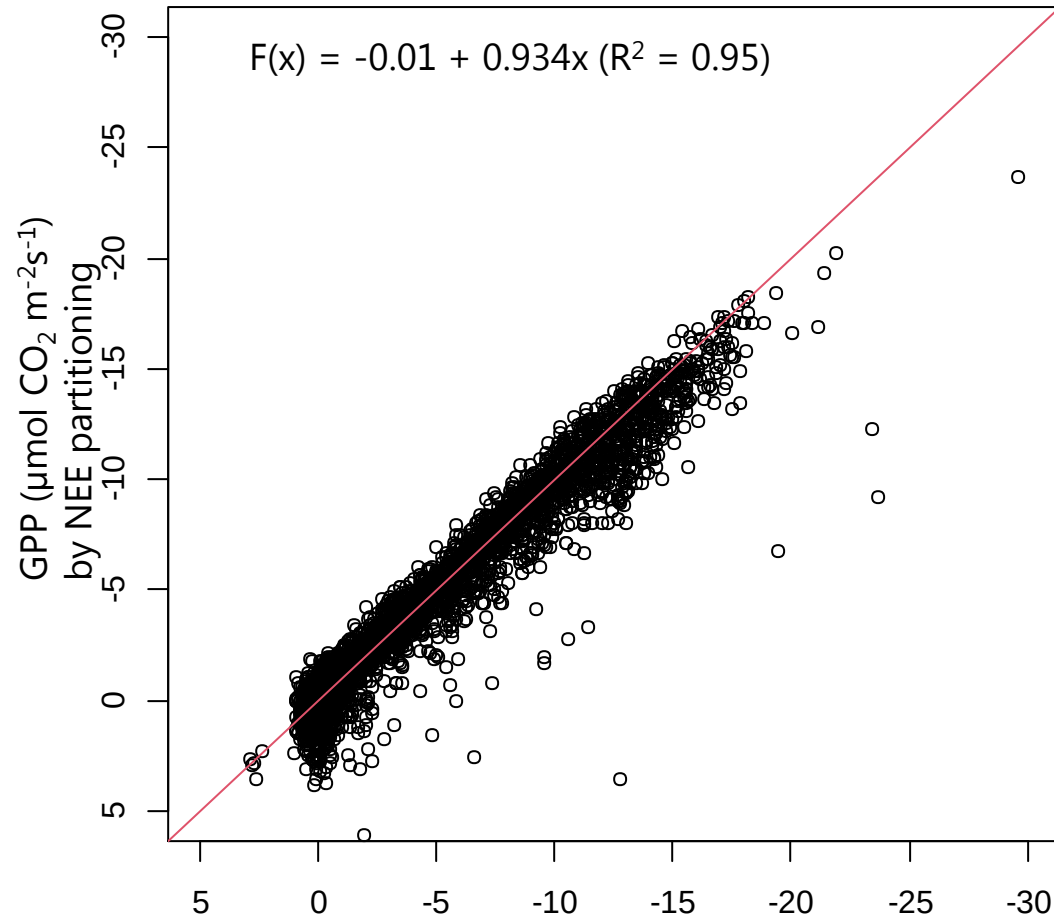
2018 severe drought
is seen here



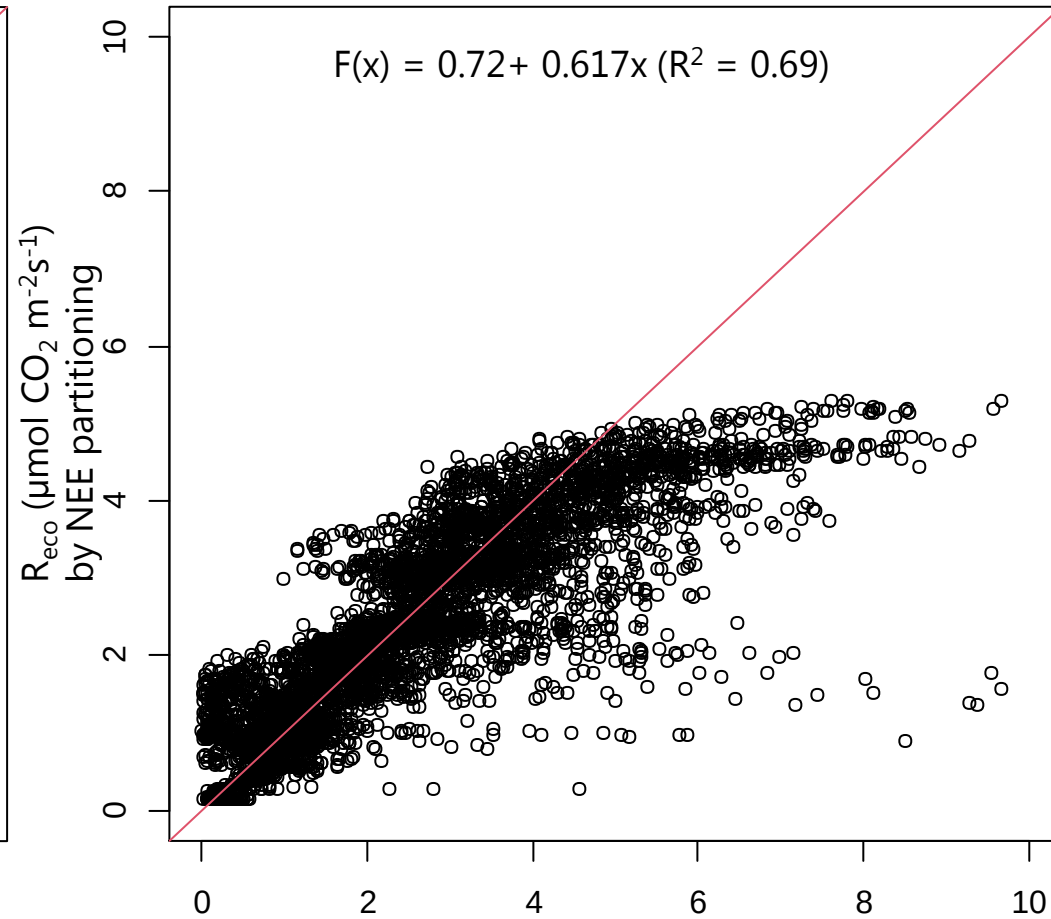
August data needs
further analysis

Missing data

After gapfilling, partitioning was performed using the nighttime method – and the NEE partitioning result compared with the direct chamber measurements (data from Chamber 1 – 2020)



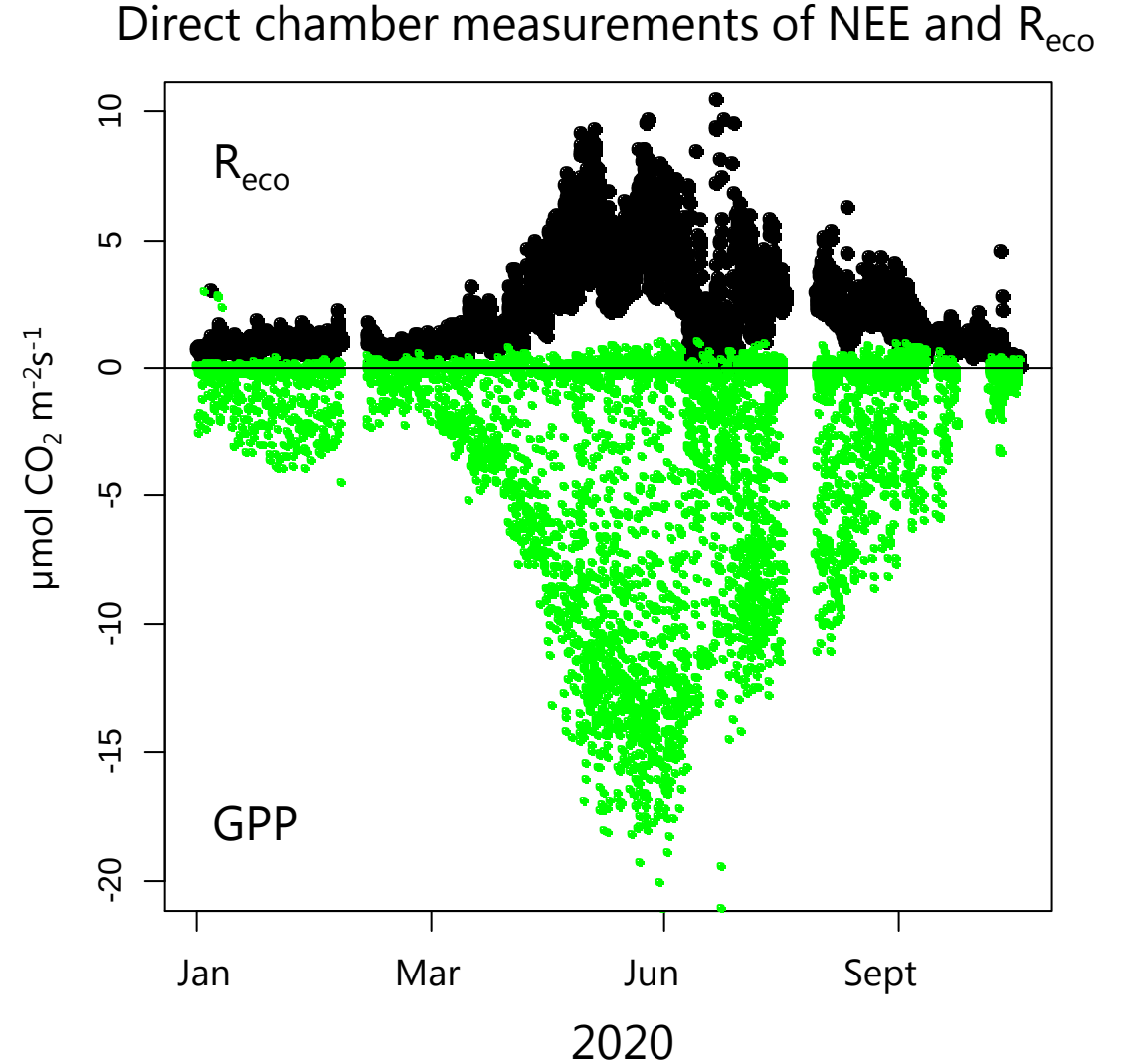
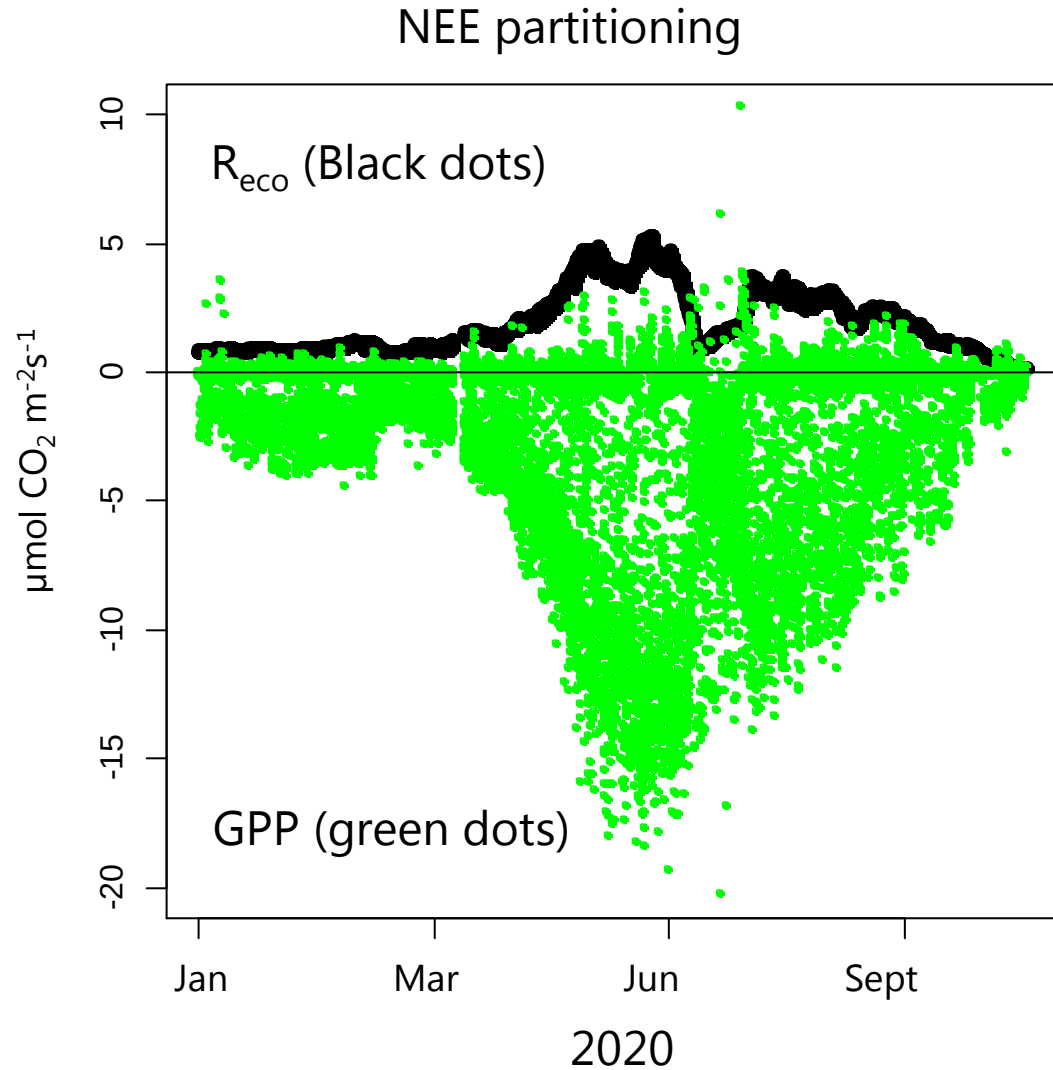
GPP ($\mu\text{mol CO}_2 \text{ m}^{-2}\text{s}^{-1}$) by chamber measurement (NEE – R_{eco})



R_{eco} ($\mu\text{mol CO}_2 \text{ m}^{-2}\text{s}^{-1}$) by chamber measurement (NEE – R_{eco})

The slopes of 0.934 for GPP and 0.617 for R_{eco} indicate that both GPP rates and R_{eco} rates are lower after NEE partitioning than by direct estimating with the light/dark chamber.

Larger scatter and sometimes higher rates of Reco measured than estimated by partitioning of NEE (data from Chamber 1 – 2020)



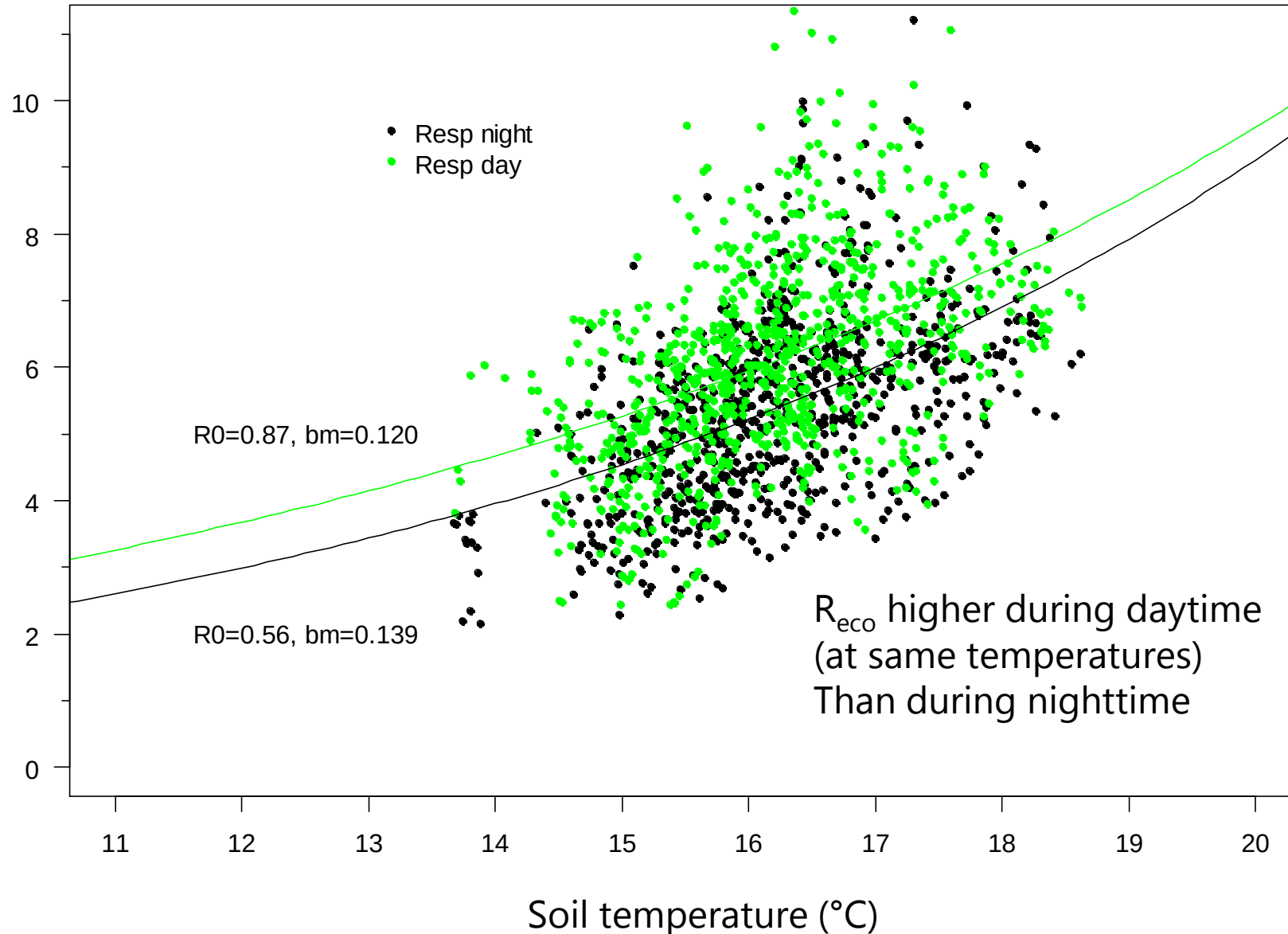
Mean rates of NEE, GPP, and R_{eco} during measurements compared to values at these times from NEE partitioning

Comparison of overall mean and standard deviation (sd) for NEE, GPP and R_{eco} from NEE partitioning (nighttime method, see Wutzler et al., 2018*) with the direct chamber measurements of NEE and R_{eco} (and GPP by their difference) only at times when chamber data points exists in 2020 (12,820 measurements in total, i.e. 6,410 NEE measurements and 6,410 R_{eco} measurements).

Method	NEE (mean±sd) $\mu\text{mol CO}_2 \text{ m}^{-2}\text{s}^{-1}$	GPP (mean±sd) $\mu\text{mol CO}_2 \text{ m}^{-2}\text{s}^{-1}$	R_{eco} (mean±sd) $\mu\text{mol CO}_2 \text{ m}^{-2}\text{s}^{-1}$
NEE partitioning	-0.761±3.60	-0.304±4.41	2.268±1.30
Chamber NEE + R_{eco}	-0.762±3.89	-0.322±4.60	2.390±1.78

NEE rates were similar, but GPP and R_{eco} rates were higher when measured directly than when estimated by NEE partitioning.

Example data from chamber measurements of R_{eco} during night and day at mid summer – at similar soil temperatures, R_{eco} is higher during day than night



Conclusion on partitioning NEE:

Our analysis showed generally good correlation between the direct chamber estimates and NEE partitioning, BUT with overall higher rates of GPP and R_{eco} when using the direct chamber method.

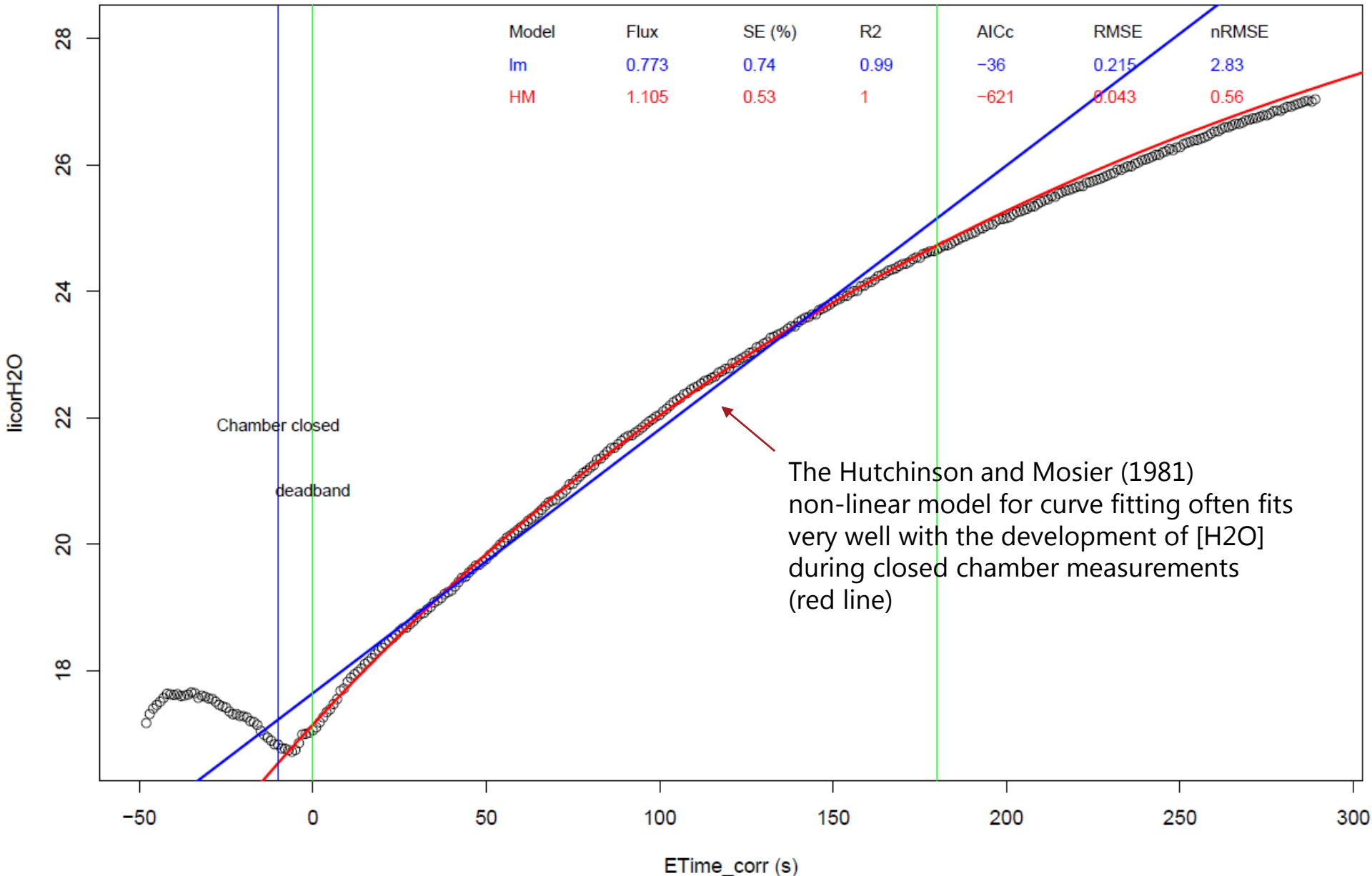
This suggests that other parameters than temperatures may affect daytime R_{eco} .

We hypothesize, that this additional R_{eco} activity during daytime may be connected to GPP (see e.g., Larsen et al., 2007*) and carbon flow to plant tissue, above- and belowground, and potentially also to the rhizosphere microbial community, where it may cause enhanced rates of respiration.

A potential bias in the direct measurements of R_{eco} during daytime by darkening also needs further scrutiny. Next step is to also compare with the daytime partitioning method (Wutzler et al., 2018).

*Larsen, K.S., Ibrom, A., Beier, C., Jonasson, S. and Michelsen, A., 2007. Ecosystem respiration depends strongly on photosynthesis in a temperate heath. *Biogeochemistry*, 85(2): 201-213.

Additional question: Can we use closed chambers to estimate evapotranspiration rates (ET)?

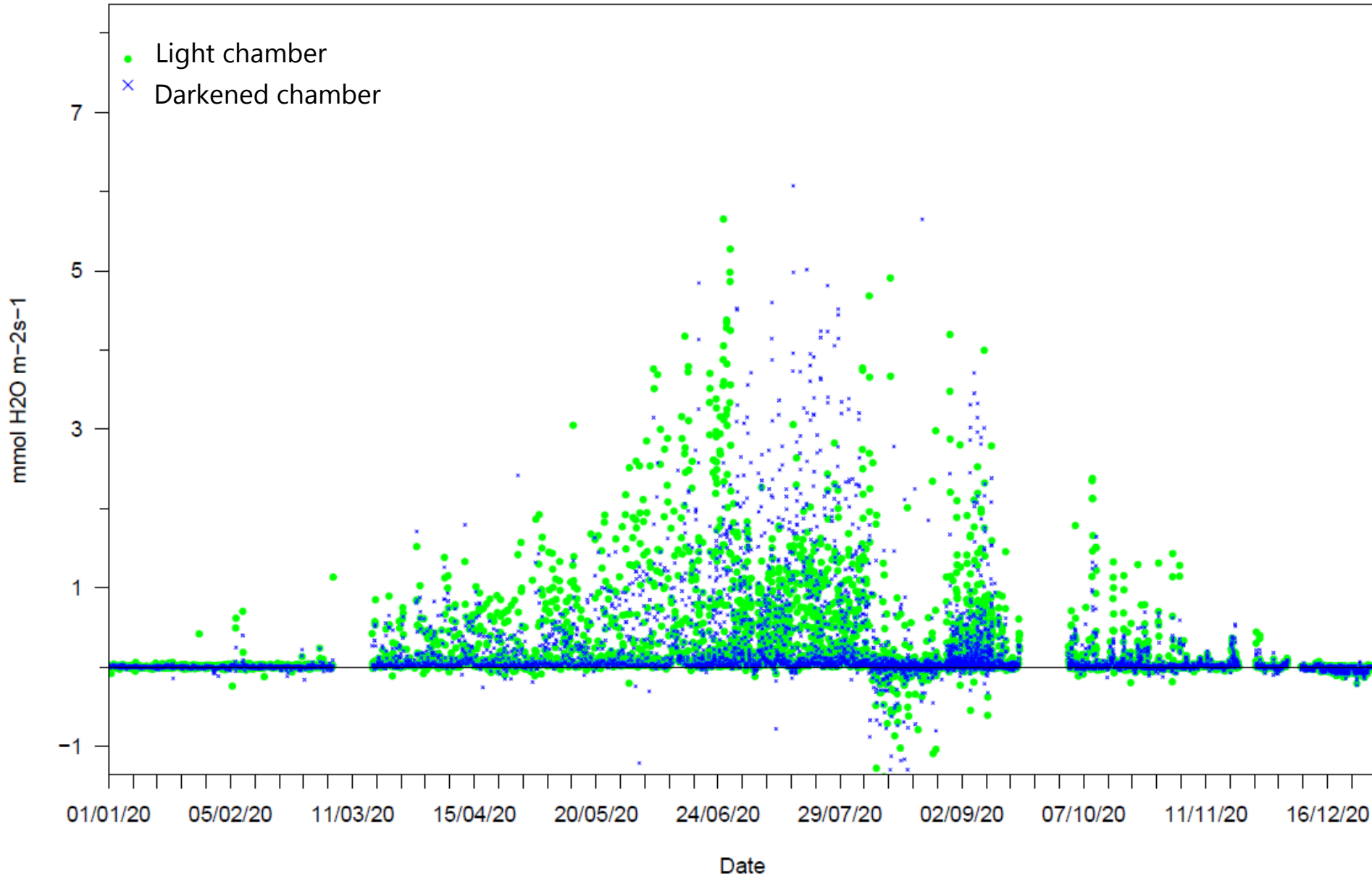


The closed chamber measurement technology shows a good potential for estimating ET rates but because of the size of the ET flux, non-linear methods with minimal deadband after chamber closure is needed in order to avoid potential underestimation of the flux.

As seen in this graph, the non-linear method by Hutchinson & Mosier (1981)* can be used to estimate slope in time zero of chamber closure.

*G. L. Hutchinson GL and Mosier AR (1981) Improved Soil Cover Method for Field Measurement of Nitrous Oxide Fluxes. Soil Science Society of America Journal 45, 311-315.

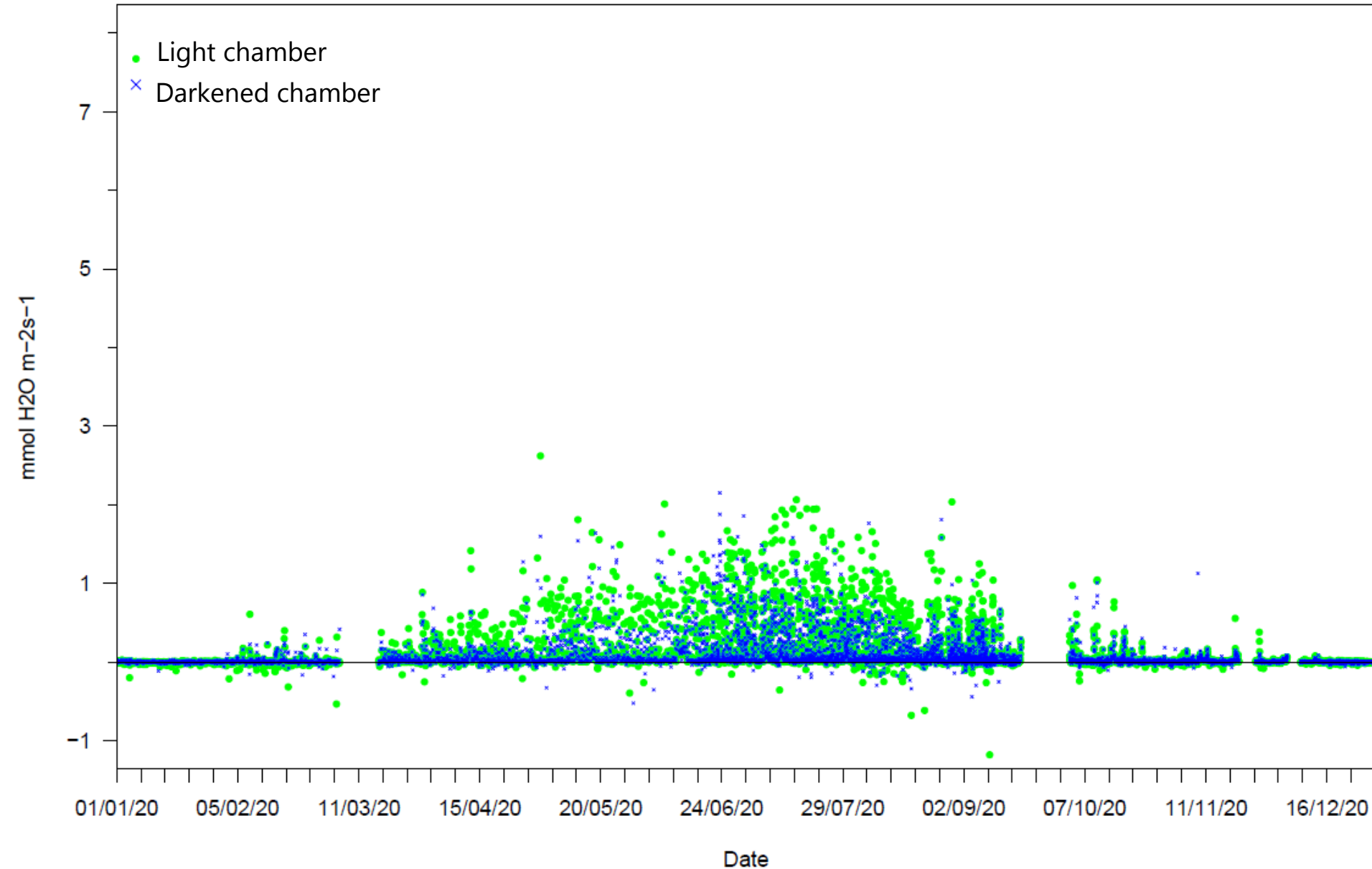
Brandbjerg LI8100 H₂O fluxes – CH1 Calluna control



The two next slides shows ET rates from 2020 in the CLIMAITE experiment – in a control plot (this slide) and then in a plot exposed to precipitation removal (next slide).

As seen in this graph, in Chamber 1, which is a control plot, ET rates during mid day in June/July, peak at 5-6 mmol H₂O m⁻² s⁻¹ (~ 7-9 mm m⁻² d⁻¹).

Brandbjerg LI8100 H₂O fluxes – CH5 Calluna Drought (32)



In Chamber 5, a precipitation removal plot with similar vegetation cover as in Chamber 1 (control), ET rates during mid day, peak at around 2 mmol H₂O m⁻² s⁻¹ (~ 3 mm m⁻² d⁻¹) during mid-summer. The treatment therefore seems to clearly reduce the ET rates.

Conclusion on measuring ET with closed, automated chambers:

The closed chamber method shows good potential for estimating ET. If potentially biased, the relative differences in different treatment plots in field experiments are still interesting. This can be valuable for evaluating the potential changes in ET e.g. in climate experiments.

If you are interested, please see the other presentations at EGU 2021 with data from the ECO₂FluX chambers. Thanks for your attention!

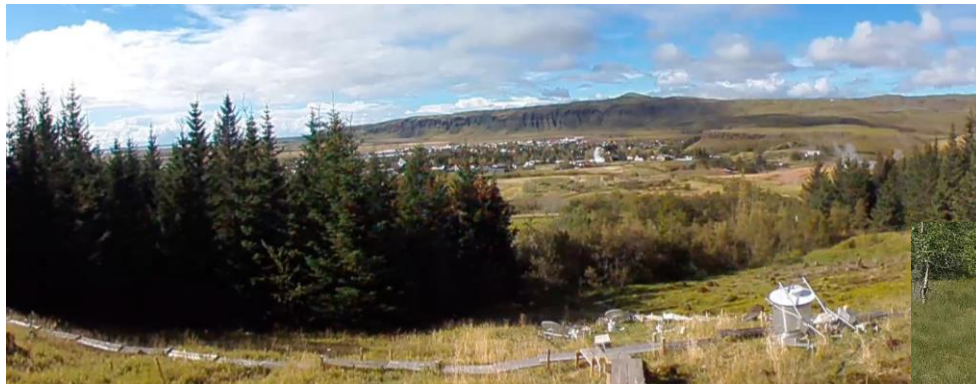


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Want to know more or
interested in collaboration?
Contact Klaus S Larsen
(ksl@ign.ku.dk).

If you want a quote on new
chambers, contact Preben
Jørgensen (pj@dmr.dk).