CRITICAL PERIODS AND CRITICAL VALUES EXPLAINING FLUXES INTER-ANNUAL VARIABILITY IN A TEMPERATE MIXED FOREST

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1. Introduction

- In order to explain inter-annual variability of Net Ecosystem CO_2 Exchange (NEE) above a mixed temperate forest, two approaches were followed:
  - Detection of **critical periods** using the R-squared of the regression between annual NEE and cumulated NEE on a mobile window.
  - Identification of **critical values** of a threshold used to decompose annual and seasonal NEE in two components.

2. Site description

- Data are from the Vielsalm Terrestrial Observatory (VTO, ICOS Belgium), a mixed mature temperate forest located in East Belgium (altitude 450 -500 m).
- 12 years (1997–2008) of gap filled daily eddy covariance (EC) data were used.
- Forest is composed of beech, spruce, Douglas fir and silver fir. In the wind direction from 330 to 90° (from the North), the forest is dominated by coniferous. The other sector (from 90 to 330°) is dominated by beeches.

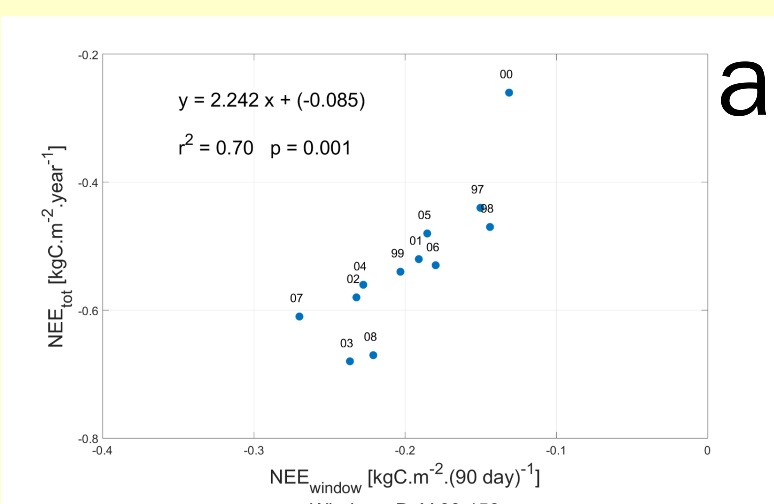
3. Critical period detection at seasonal scale

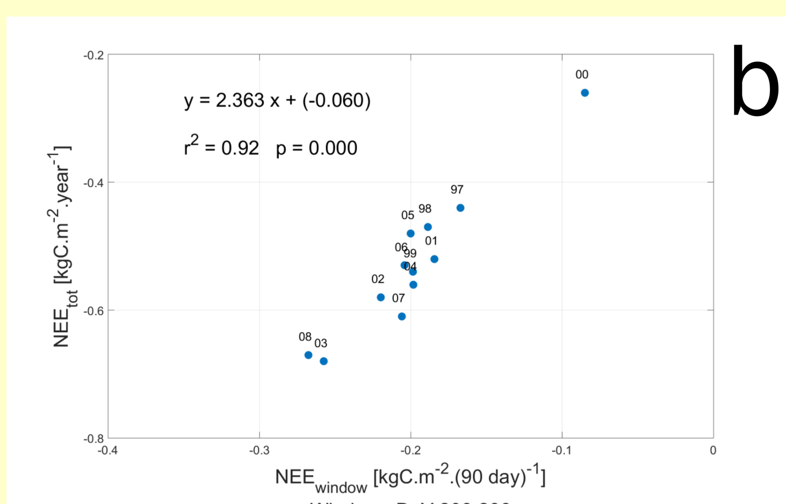
Method

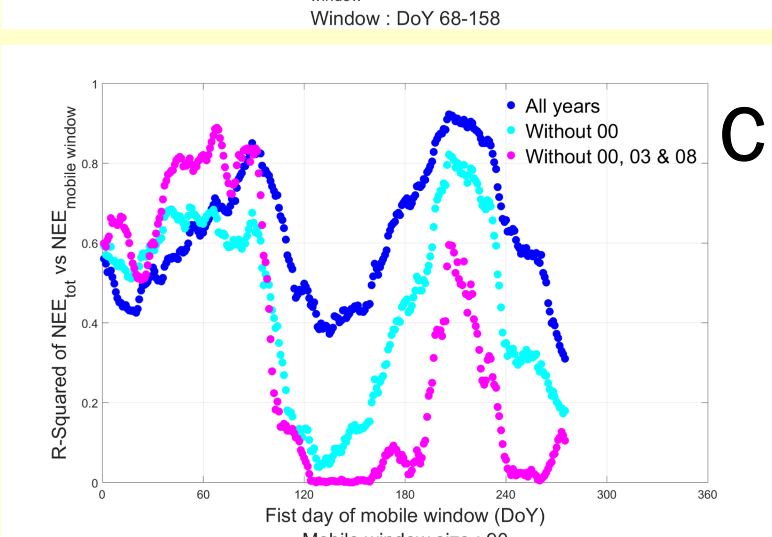
- A "critical period" is a relatively short period that can explain a significant part of the variability observed in the long-term fluxes (le Maire et al., 2010)[1].
- Critical periods were defined as the periods where the slope of the regression between annual NEE (NEE_{tot}) and NEE in a window of the year (NEE_{window}) was significant ($p < 0.01$, corresponding to a R-squared above around 0.5).
- They were detected at seasonal scale by using a 90 days mobile window.

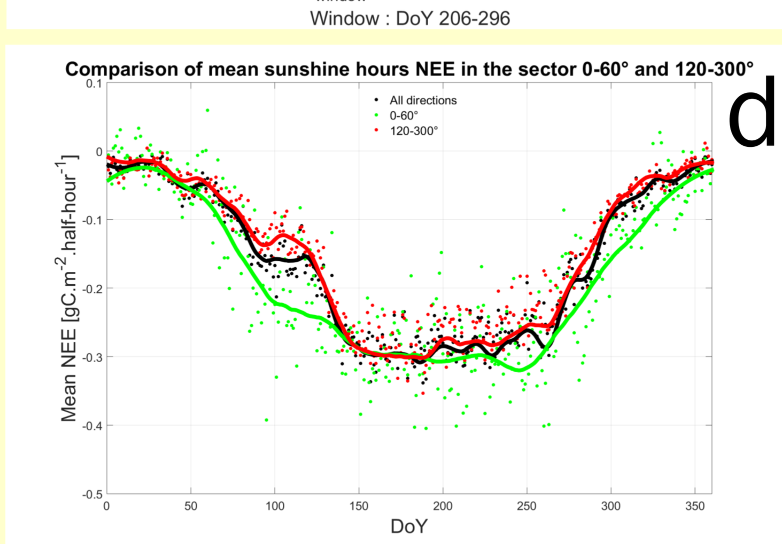
Results

- Two periods for which a significant relation appeared were identified:
  - One without taking into account the years 2000, 2003 and 2008: from March to May (start around Day of Year 60, Fig. a)
  - One taking into account all the years: from August to October (start around Day of Year 206, Fig. b).
- The regressions are highly influenced by the years 2000, 2003 and 2008 (Fig. c). 2000 was the year with the lowest annual mean global radiation and the highest precipitation. 2003 was characterized by a summer drought and 2008 by an exceptionally mild winter and spring.
- During the two identified critical periods, mean sunshine hours NEE differ between the two forest sectors (Fig. d), highlighting the difference between beech and coniferous physiological activity.









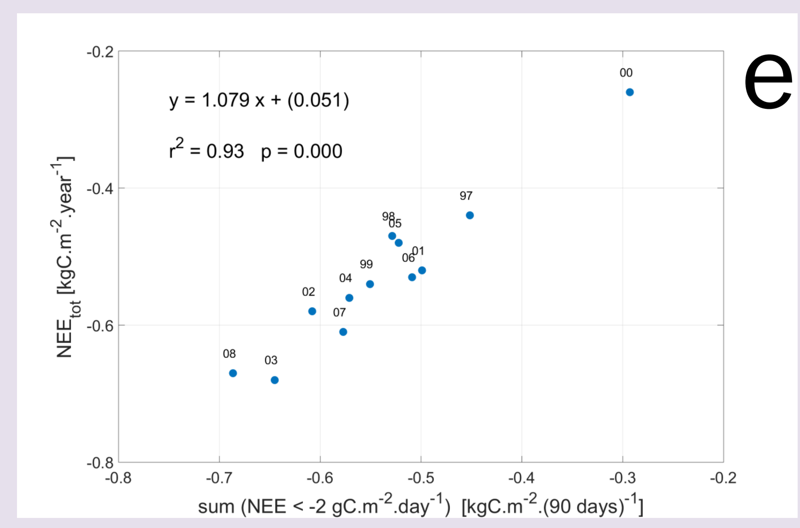
4. Critical value detection at annual and seasonal scale:

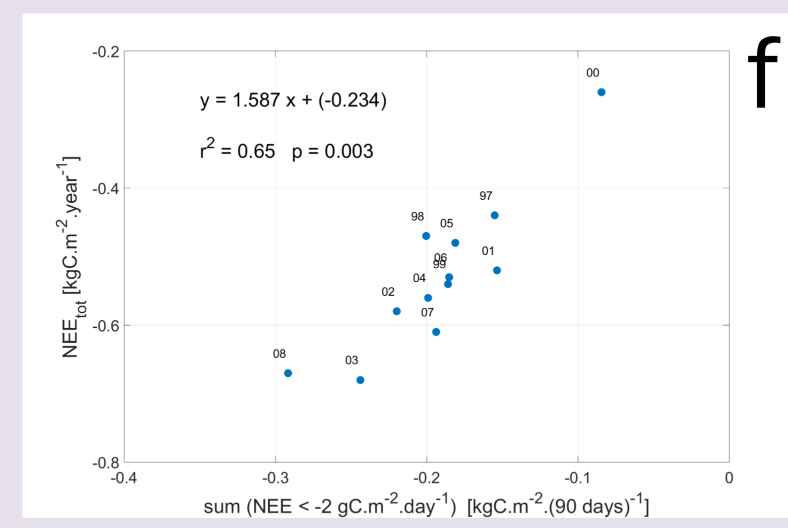
Method

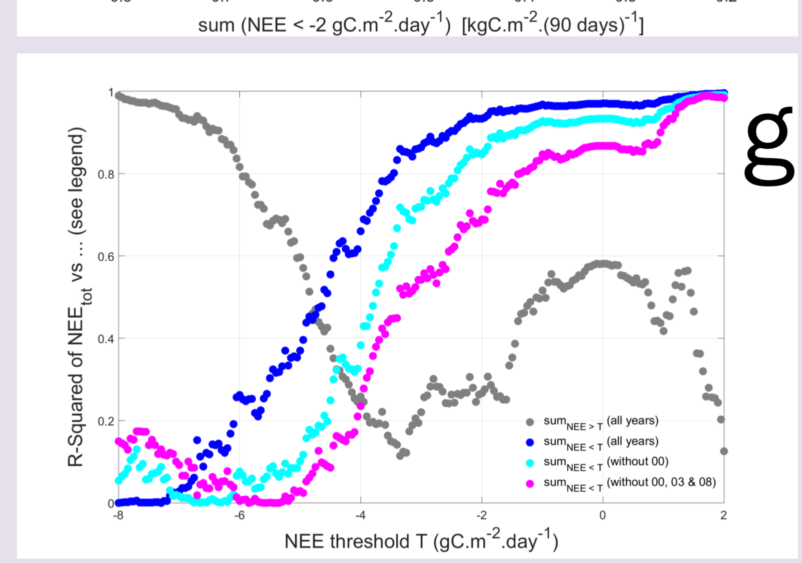
- For each year, annual NEE (NEE_{tot}) was decomposed in two terms: the sum of the daily NEE below ($sum_{NEE<T}$) and above ($sum_{NEE>T}$) a given threshold T:
  - $NEE_{tot} = sum_{NEE<T} + sum_{NEE>T}$
- The threshold T was varied in order to determine the critical values defined as the threshold values for which the slope of the regression between NEE_{tot} and $sum_{NEE<T}$ was significant ($p < 0.01$, corresponding to a R-squared above around 0.6).
- By combining variable threshold T and mobile temporal window (90 days), we assessed if there was a combination of critical periods and critical values that explained inter-annual variability.
  - R-squared of the regression between NEE_{tot} and $sum_{NEE<T}$ in each temporal window was used to check the regression.

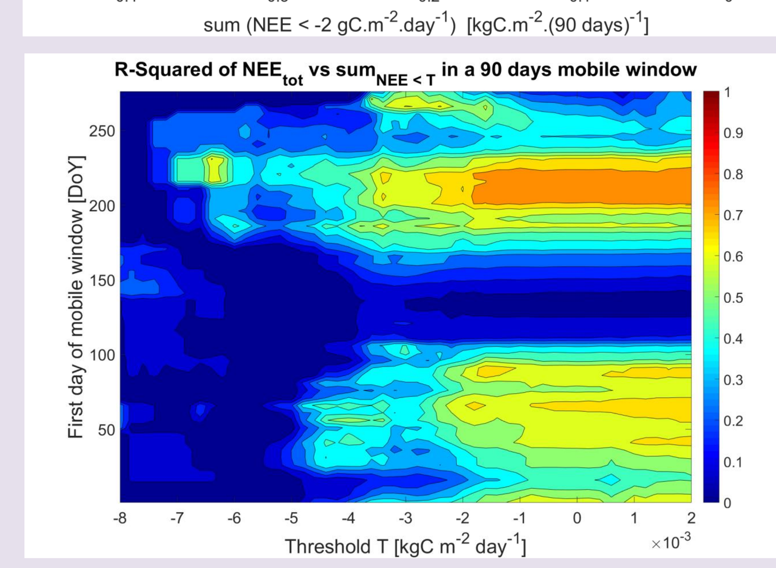
Results

- At a yearly scale, $sum_{NEE<T}$ with T above around -2 gC m^{-2}.day^{-1} is highly correlated to NEE_{tot} (Fig. e). Even when removing the most influential years (Fig. g). In contrast, $sum_{NEE>T}$ is not a good indicator of NEE_{tot} (except if the threshold is low, obviously).
- The combination of a variable threshold T and a mobile temporal window (without taking into account the year 2000) confirmed (Fig. h) that the most critical periods are the beginning and the end (Fig. f) of the vegetation period. In addition, we can see that, during the critical periods, $sum_{NEE<T}$ with T between around -3.5 and -0.5 gC m^{-2}.day^{-1} is correlated to NEE_{tot}.









5. Conclusion

- The low correlation observed between annual NEE and cumulated NEE from May to August (Fig. c) suggest that inter-annual flux variability is hardly due to a variability of fluxes during the full vegetation season.
- At the opposite, the high correlations observed in early spring (Fig. a) and late summer (Fig. b) suggest annual fluxes are more influenced by these periods.
- No significant relations were found between the cumulated fluxes during these critical periods and climatic variables (results not shown). These fluxes could be related to forest heterogeneity as these periods correspond to the periods with the highest difference between the fluxes from the two forest sectors (Fig. d). Further investigations must be made.
- Furthermore, we illustrated that the same rules may not apply to all the years as the results differ when exceptional years are included or not.
- The cumulated fluxes below a threshold around -2 gC.m^{-2}.day^{-1} contribute significantly to annual NEE (Fig. g). The slope of 1 observed in Fig. e seems to indicate there is a compensation between the days with a NEE above this threshold. More specifically, the sum of daily NEE below this threshold during the previously identified critical periods is correlated to annual fluxes (Fig. f & Fig. h).
- The results stress the impact of the days with low NEE (especially during critical periods) and suggest focusing on these days to study inter-annual variability.

[1]le Maire, G., et al. (2010), Detecting the critical periods that underpin interannual fluctuations in the carbon balance of European forests, J. Geophys. Res., 115, G00H03, doi:10.1029/2009JG001244.
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