REddyProc: Process your Eddy data

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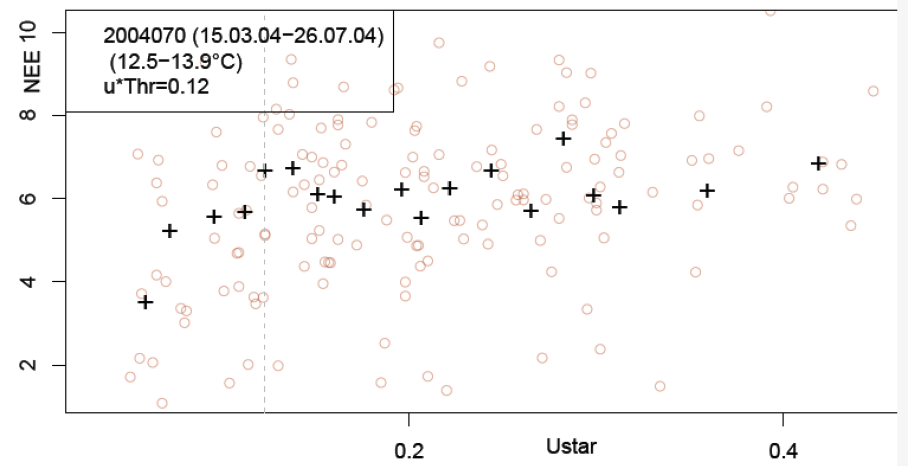
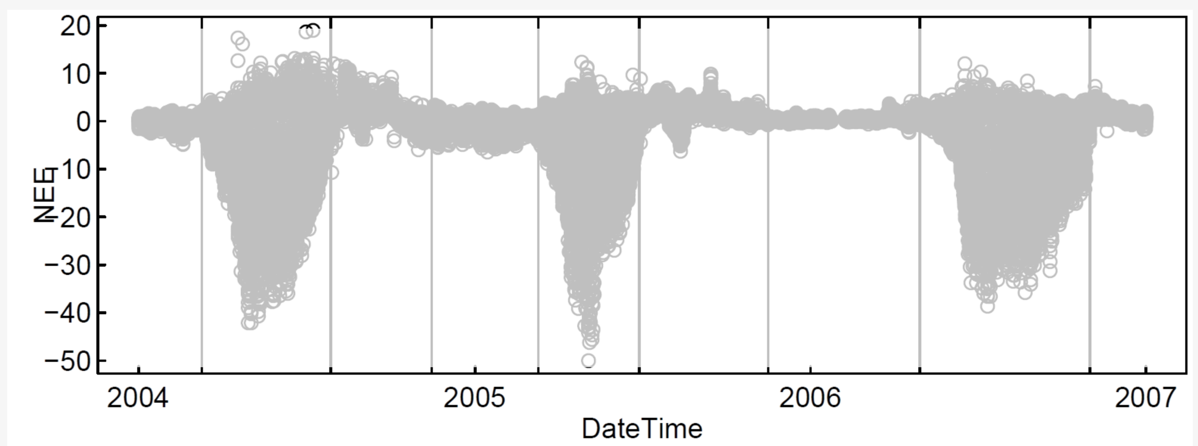
Ustar-Filtering

Underestimating NEE with low u*

At periods with low turbulence indicated by low friction velocity (u*) half-hourly NEE is under-estimated. Those data must be filtered and a threshold of u* for the filtering is estimated from data.



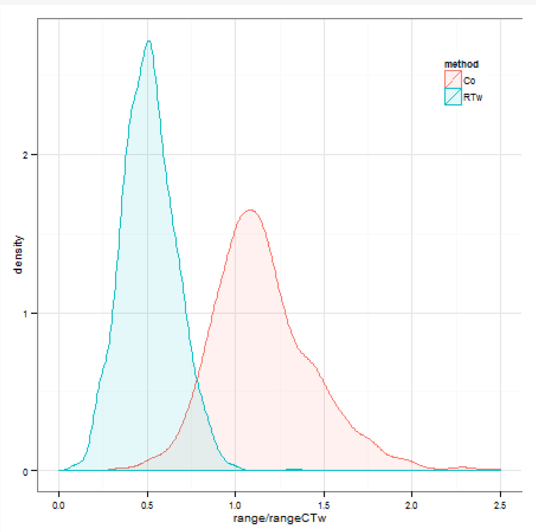
User-defined seasons



The u* threshold changes with surface roughness and canopy height at e.g. at harvest. Hence, specifying proper periods/seasons (which can span annual boundaries) improves the identification of bad conditions.

Performance

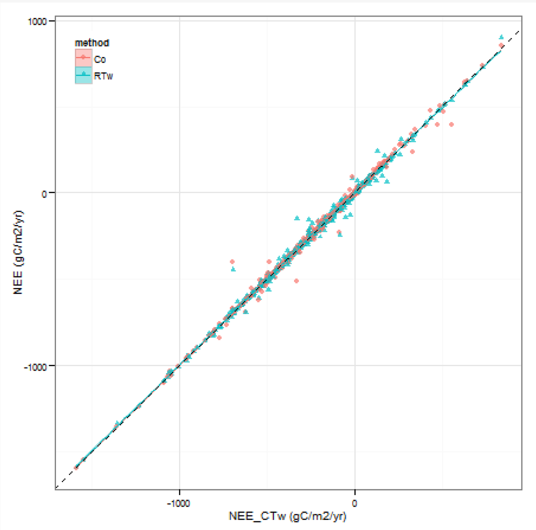
We used as benchmark the implementation used for the preparation of the FLUXNET database: C-version from Papale 2013 (Co)
And an adapted C-version version (Ctw)



Lower uncertainty estimate

by REddyProc (Rtw), because bootstrap is performed within seasons instead across the entire year.

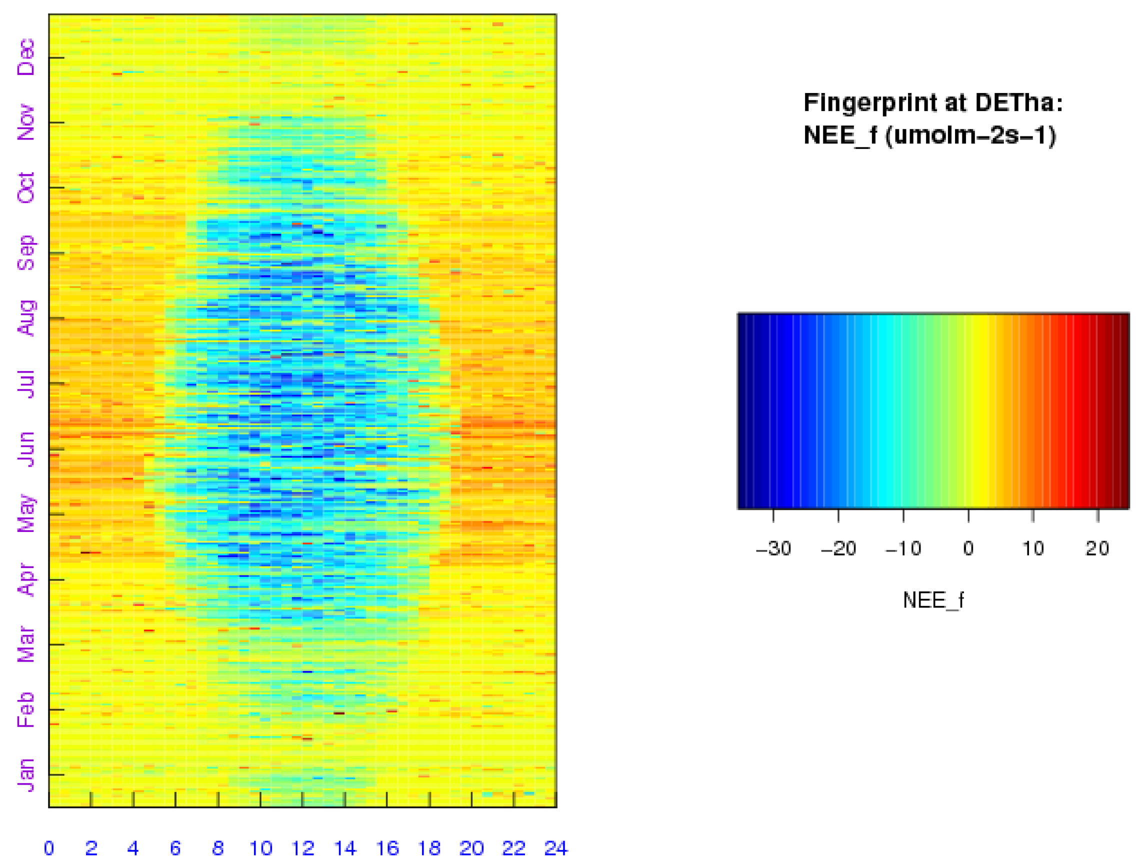
Same effect on gap-filled NEE



Estimates of u* threshold by different tools were used to filter low turbulence conditions. The cumulative annual NEE based on the gap-filled time series for site years from the LaThuille dataset.

- no consistent bias across sites
- small absolute differences (mostly < 20gC/m2/yr)
- Mostly within half the 10% to 90% confidence interval

Gapfilling

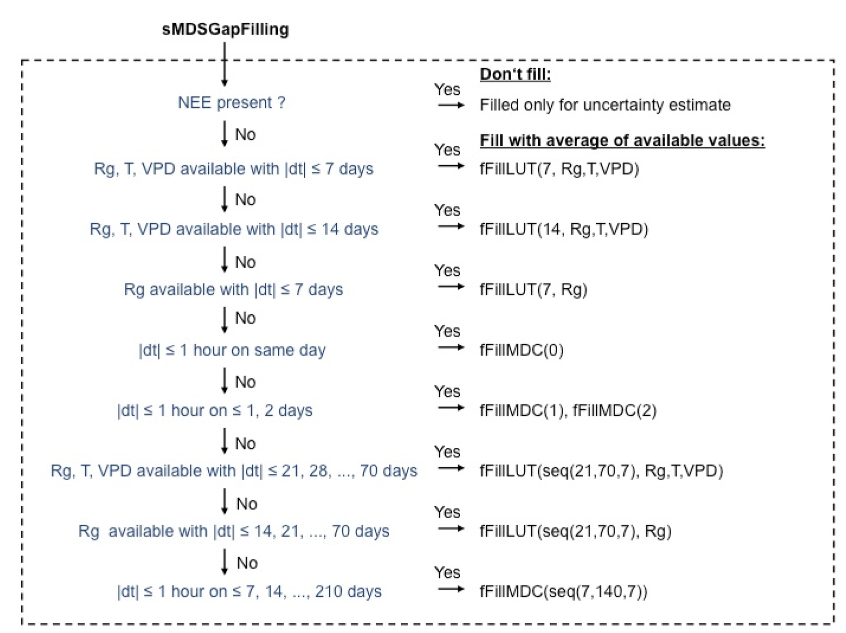


Filling gaps with different qualities

The method is based on Falge et al. (2001) but also considering the co-variation of fluxes with meteorological variables and the temporal auto-correlation of the fluxes (Reichstein et al. 2005).
Gaps of different conditions can be filled with quality 1 (good) to 3 (poor).

1. The meteorological data are available for radiation (Rg), air temperature (Tair), and vapor pressure deficit (VPD).
   -> Average value under similar meteorological conditions , i.e. with a look-up table (LUT), within a certain time window
2. Also Tair or VPD are missing, but Rg is available.
   -> Similar Rg
3. Also Rg is missing.
   -> the average value at the same time of the day (1 hour), i.e. the mean diurnal course (MDC)

If the values could not be filled, the procedure is repeated with increased window sizes.



Flux uncertainty

To estimate the flux uncertainties, the standard deviation of NEE records with similar conditions is computed. The same identification of conditions as with the gap-filling above is applied.

Flux partitioning

Night-time based

Ecosystem Respiration R_{eco} is modelled as a function of temperature, whose parameters are estimated from night-time NEE – temp relationship (Reichstein 2005)

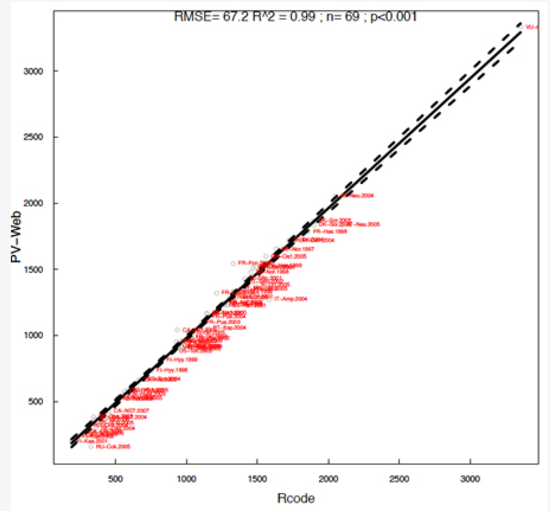
Lloyd and Taylor (1994): $R = R_{Ref}\, e^{E_0\left(\frac{1}{T_{Ref}-T_0} - \frac{1}{T-T_0}\right)}$

This relationship is then applied to daytime temperature.

While respiration at reference Temperature R_{Ref} is allowed to vary with time (linearly interpolated between windows of 7 days), whereas a single temperature sensitivity E_0 is applied throughout the year.

Performance:

Results for 69 site-years were consistent with PW-Wave based implementation by M. Reichstein. Lasslop. E.g. for annual R_{eco} values (R^2=0.99; RMSE=67.2 $gCm^{-2}yr^{-1}$, MEF=0.98).
Slight differences for half-hourly values for some sites were due to sensitivity of selecting night-time records (REddyProc using the exact solar time of location instead of only local time zone).



Day-time based

Based on Lasslop et al., 2010. NEE was modelled using the common rectangular hyperbolic light–response curve (Falge et al., 2001): $NEE = \frac{\alpha\beta R_g}{\alpha R_g + \beta} + R,$
where R is modelled by the Lloyd and Taylor above.

Saturation β is diminished at high VPD:

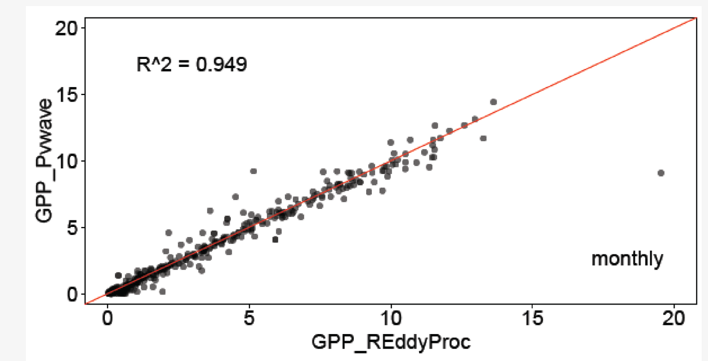
$$\beta = \begin{cases} \beta_0 \exp\left(-k(VPD - VPD_0)\right) & if\ VPD > VPD_0 \\ \beta_0\ otherwise & \end{cases}$$

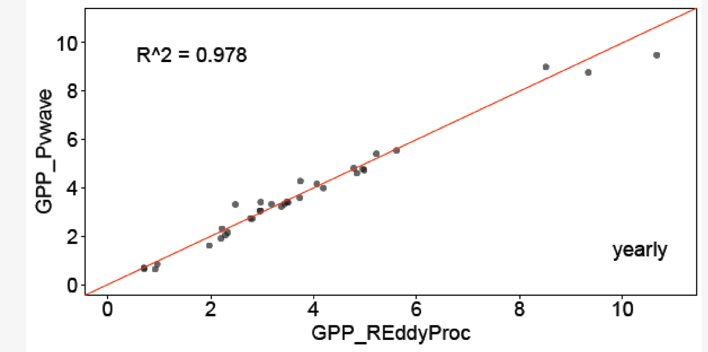
While temperature sensitivity is estimated from a moving window of night-time data, parameters $\alpha, \beta_0, k, R_{Ref}$ are estimated from the light response curve during day-time on a 4-day moving window.

Predictions for GPP and R are interpolated between predictions using the parameters estimated in the former window and the parameter estimated in the next window

Performance:

Across sites, REddyProc yields similar results as the PW-Wave based implementation by G. Lasslop. There are, however, significant differences for several sites.





Preliminary study of the differences at specific sites suggests that results from REddyProc are more reasonable because the parameters are better constrained.

Using the R package (www.bgc-jena.mpg.de/bgi/index.php/Services/REddyProcWebRPackage)

After installing the R-package (see website), vignettes and help are available: R> library(REddyProc); ?REddyProc

```
Dir.s <- system.file('examples', package='REddyProc')
eddyData <- fLoadTXTIntoDataframe('Example_DETha98.txt', Dir.s)

#+++ If not provided, calculate VPD from Tair and rH
eddyData$VPD <-
  CalcVPDfromRHandTair(EddyData.F$rH, EddyData.F$Tair)
#+++ Add time stamp in POSIX time format
eddyDataPosix<- fConvertTimeToPosix(EddyData.F, 'YDH',
   Year.s='Year', Day.s='DoY', Hour.s='Hour')

#+++ Initialize R5 reference class
EddyProc.C <- sEddyProc$new('DE-Tha', EddyDataWithPosix.F,
   c('NEE','Rg','Tair','VPD', 'Ustar'))
EddyProc.C$sSetLocationInfo(Lat_deg.n=51.0, Long_deg.n=13.6,
   TimeZone_h.n=1)  #Location of DE-Tharandt

#+++ Estimate uStar-Threshold
(uStarTh <- EddyProc.C$sEstUstarThreshold()$uStarTh)

#+++ Fill gaps in variables with MDS gap filling algorithm
EddyProc.C$sMDSGapFillAfterUstar('NEE')

#+++ Partition NEE into GPP and respiration
EddyProc.C$sMDSGapFill('Tair', FillAll.b=FALSE)
EddyProc.C$sMDSGapFill('VPD', FillAll.b=FALSE)
EddyProc.C$sMRFluxPartition() # night time  -> Reco, GPP

#+++ Export gap filled and partitioned data
FilledEddyData.F <- EddyProc.C$sExportResults()

#+++ Example plots of filled data to screen or to directory \plots
EddyProc.C$sPlotFingerprintY('NEE_f', Year.i=1998)
```

More information at www.bgc-jena.mpg.de/bgi/index.php/Services/REddyProcWebRPackage

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Wutzler et. al (in prep)
Reichstein M, Falge E, Baldocchi D et al. (2005) On the separation of net ecosystem exchange into assimilation and ecosystem respiration: review and improved algorithm. Global Change Biology, 11,
Lasslop G, et al. (2010) Separation of net ecosystem exchange into assimilation and respiration using a light response curve approach: critical issues and global evaluation. Global Change Biology 16

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