REddyProc for Eddy Covariance Data Analysis

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Acknowledgements

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Prerequisites

Knowledge

It would be easier for you to follow the talk if you have brief backgrounds on: 1. R language 2. Eddy covariance 3. Net Ecosystem Exchange

Software

You would need the software below to perform the steps discussed in the talk.

1. R
2. RStudio
3. Packages: REddyProc

Introduction to the REddyProc Package: When Do We Use It?

The REddyProc package is used after the pre-processing of the raw, high-frequency eddy covariance data. Using software, such as EddyPro, the data was checked using quality-control protocols, e.g., Mauder and Foken (2004), Foken (2003), etc., to discard low-quality fluxes.

We use the package to:

1. Post-process the Net Ecosystem Exchange (NEE) data.
2. Estimate the NEE, e.g., the annual sum of NEE.
3. Determine the contributions of processes in the NEE, e.g., productivity and respiration.

There are three main steps in a typical REddyProc analysis workflow.

1. The REddyProc package is utilized after the pre-processing step in which the fluxes are checked further for under-developed turbulence or low friction velocity (u_*).

    - The package can suggest threshold values of u_* and calculate uncertainties in different scenarios.
2. Gaps introduced due to the discarding of fluxes below the thresholds can later be filled.
3. The fluxes can then be separated into groups of Gross Primary Productivity (GPP) and Ecosystem Resipiration (R_{eco}).

You can view more details about the package at https://bgc.iwww.mpg.de/5622399/REddyProc.

Learning Outcomes

At the end of the talk, you would be able to:

1. List the capabilities of the REddyProc package.
2. Explain the analysis steps of the package.

Step 0: Preliminary Work

Install the Package

The package needs to be installed prior to use. You might also need to install other package dependencies to run REddyProc. You can do so by using the `install.package` command on the missing package.

```
#install.packages("REddyProc", repos = "http://cran.us.r-project.org")
```

You will need to load the package after a successful installation.

```
library(REddyProc)
```

Step 1: Prepare the Data

Step 1-1: Import the Data

The eddy covariance data that will be used in this walk-through are included in the package. They are for demo purposes.

1. `DEGebExample`, the Gebesee, Germany, data from 2004 to 2006.
2. `Example_DETha98`, the Tharandt, Germany, data for the year 1998.

The full data is downloadable at http://www.europe-fluxdata.eu/home/ after registration.

Load the Gebesee data.

```
data(DEGebExample)
```

Load the Tharandt data.

```r
data(Example_DETha98)
```

Get an overview of the data. Look at the data parameters and take note of missing data or `NA`.

The Gebesee, Germany, Data

Characteristics

- Surface: Agriculture
- Time zone: +1 GMT
- Latitude, Longitude: 51.1N, 10.9E

Notice that VPD is not in the dataset.

```r
summary(DEGebExample)
```

```
##     DateTime                          NEE              Ustar
##  Min.   :2004-01-01 00:30:00   Min.   :-49.919   Min.   :0.0000
##  1st Qu.:2004-10-01 00:22:30   1st Qu.: -1.864   1st Qu.:0.0640
##  Median :2005-07-02 00:15:00   Median :  0.635   Median :0.1490
##  Mean   :2005-07-02 00:15:00   Mean   : -1.935   Mean   :0.1884
##  3rd Qu.:2006-04-02 00:07:30   3rd Qu.:  1.834   3rd Qu.:0.2800
##  Max.   :2007-01-01 00:00:00   Max.   : 19.008   Max.   :2.0450
##                                NA's   :21849     NA's   :1149
##       Tair              rH               Rg
##  Min.   :-16.710   Min.   : 15.87   Min.   :   0.00
##  1st Qu.:  3.360   1st Qu.: 66.61   1st Qu.:   0.00
##  Median :  9.970   Median : 79.10   Median :   2.04
##  Mean   :  9.664   Mean   : 75.24   Mean   : 124.71
##  3rd Qu.: 15.520   3rd Qu.: 87.07   3rd Qu.: 176.03
##  Max.   : 34.680   Max.   :100.00   Max.   :1046.03
##                    NA's   :1
```

The Tharandt, Germany, Data

Characteristics

- Surface: Forest
- Time zone: +2 GMT
- Latitude, Longitude: 51.0N, 13.6E

Note that the timestamp is not in REddyProc-usable format.

```r
summary(Example_DETha98)
```

```
##       Year           DoY            Hour             NEE
##  Min.   :1998   Min.   :  1   Min.   : 0.000   Min.   :-34.900
##  1st Qu.:1998   1st Qu.: 92   1st Qu.: 5.875   1st Qu.: -5.250
##  Median :1998   Median :183   Median :11.750   Median :  0.360
##  Mean   :1998   Mean   :183   Mean   :11.750   Mean   : -2.165
```

```
##  3rd Qu.:1998   3rd Qu.:274   3rd Qu.:17.625   3rd Qu.:  2.270
##  Max.   :1998   Max.   :366   Max.   :23.500   Max.   : 24.700
##                                                NA's   :6257
##        LE              H                 Rg             Tair
##  Min.   :-99.38   Min.   :-199.60   Min.   :  0.0   Min.   :-13.600
##  1st Qu.:  2.80   1st Qu.: -20.22   1st Qu.:  0.0   1st Qu.:  3.400
##  Median : 14.22   Median :  -7.66   Median :  0.0   Median :  8.800
##  Mean   : 36.42   Mean   :  22.32   Mean   :116.5   Mean   :  8.573
##  3rd Qu.: 48.11   3rd Qu.:  31.07   3rd Qu.:159.5   3rd Qu.: 13.900
##  Max.   :503.16   Max.   : 590.02   Max.   :996.6   Max.   : 32.800
##  NA's   :2456     NA's   :2500      NA's   :157     NA's   :85
##      Tsoil              rH            VPD             Ustar
##  Min.   :-0.280   Min.   :22.39   Min.   : 0.000   Min.   :0.0100
##  1st Qu.: 3.970   1st Qu.:63.83   1st Qu.: 0.900   1st Qu.:0.3400
##  Median : 7.430   Median :78.25   Median : 2.400   Median :0.5600
##  Mean   : 7.679   Mean   :75.16   Mean   : 3.784   Mean   :0.6107
##  3rd Qu.:11.775   3rd Qu.:90.45   3rd Qu.: 5.100   3rd Qu.:0.7900
##  Max.   :19.060   Max.   :99.43   Max.   :34.200   Max.   :8.0300
##  NA's   :85       NA's   :117
```

Important Parameters

Parameters required for the package to run are:

1. `DateTime` in the POSIX format.
2. `NEE` or carbon dioxide flux.
3. `Ustar` or friction velocity
4. `Rg`, `Tair`, `rH`, and or `VPD` for the gap-filling and partitioning steps.

Note that: `Rg` is global solar radiation. `Tair` is air temperature. `rH` is relative humidity. `VPD` is vapor pressure deficit.

Step 1-2: Calculate Needed Parameters

Essential parameters can be calculated from existing parameters using functions built in REddyProc.

Some useful functions are:

1. `fConvertTimeToPosix`. We will use this in the demo.
2. `fCalcVPDfromRHandTair`. We will use this in the demo.
3. `fCalcETfromLE`
4. `fConvertCtoK`

There are other functions in the package and the function name begins with an `f`.

Step 1-3-1: Tharandt Dataset: Unsupported Timestamp Format

In the Tharandt dataset, the date-time columns are not suitable for analysis in REddyProc. It needs to be converted to the POSIX format.

```r
head(Example_DETha98)
```

```
##   Year DoY Hour   NEE   LE      H Rg Tair Tsoil    rH VPD Ustar
## 1 1998   1  0.5 -1.21 1.49 -11.77  0  7.4  4.19 55.27 4.6  0.72
## 2 1998   1  1.0  1.72 3.80 -13.50  0  7.5  4.20 55.95 4.6  0.52
## 3 1998   1  1.5    NA 1.52 -18.30  0  7.1  4.22 57.75 4.3  0.22
## 4 1998   1  2.0    NA 3.94 -17.47  0  6.6  4.23 60.20 3.9  0.20
## 5 1998   1  2.5  2.55 8.30 -21.42  0  6.6  4.22 59.94 3.9  0.33
## 6 1998   1  3.0    NA 1.33 -20.55  0  6.5  4.21 59.25 4.0  0.15
```

We can convert the timestamp using the `fConvertTimeToPosix` function. It will add the `DateTime` column into the data frame.

The `'YDH'` means Year-Day-Hour, and the `Year`, `Day`, and `Hour` arguments require the columns that contains the Year, DoY, and Hour information.

You can find other valid time configurations in the documentation by running the command `?fConvertTimeToPosix`.

```r
Example_DETha98V1 <- fConvertTimeToPosix(Example_DETha98, TFormat = c('YDH'),
                    Year = 'Year',
                    Day = 'DoY',
                    Hour = 'Hour')
```

```
## Converted time format 'YDH' to POSIX with column name 'DateTime'.
```

```r
head(Example_DETha98V1)
```

```
##              DateTime Year DoY Hour   NEE   LE      H Rg Tair Tsoil    rH VPD
## 1 1998-01-01 00:30:00 1998   1  0.5 -1.21 1.49 -11.77  0  7.4  4.19 55.27 4.6
## 2 1998-01-01 01:00:00 1998   1  1.0  1.72 3.80 -13.50  0  7.5  4.20 55.95 4.6
## 3 1998-01-01 01:30:00 1998   1  1.5    NA 1.52 -18.30  0  7.1  4.22 57.75 4.3
## 4 1998-01-01 02:00:00 1998   1  2.0    NA 3.94 -17.47  0  6.6  4.23 60.20 3.9
## 5 1998-01-01 02:30:00 1998   1  2.5  2.55 8.30 -21.42  0  6.6  4.22 59.94 3.9
## 6 1998-01-01 03:00:00 1998   1  3.0    NA 1.33 -20.55  0  6.5  4.21 59.25 4.0
##   Ustar
## 1  0.72
## 2  0.52
## 3  0.22
## 4  0.20
## 5  0.33
## 6  0.15
```

Step 1-3-2: Missing VPD in the Gebesee Data

The Gebesee dataset does not have the VPD parameter, which could be useful for gap-filling and partitioning.

```r
head(DEGebExample)
```

```
##                  DateTime NEE Ustar  Tair    rH Rg
## 35041 2004-01-01 00:30:00  NA 0.092 -0.06 96.13  0
## 35042 2004-01-01 01:00:00  NA 0.090 -0.14 96.10  0
```

```
## 35043 2004-01-01 01:30:00  NA 0.023 -0.16 95.93  0
## 35044 2004-01-01 02:00:00  NA 0.038 -0.17 95.80  0
## 35045 2004-01-01 02:30:00  NA 0.077 -0.19 95.67  0
## 35046 2004-01-01 03:00:00  NA 0.025 -0.23 95.47  0
```

We can calculate VPD using the function `fCalcVPDfromRHandTair`. The input arguments' units are stated in the documentation, `?fCalcVPDfromRHandTair`

```r
VPD <- fCalcVPDfromRHandTair(DEGebExample$rH, DEGebExample$Tair)
DEGebExampleV1 <- cbind(DEGebExample,VPD)
rm(VPD) # A house-keeping step.
head(DEGebExampleV1)
```

```
##                  DateTime NEE Ustar  Tair    rH Rg       VPD
## 35041 2004-01-01 00:30:00  NA 0.092 -0.06 96.13  0 0.2353394
## 35042 2004-01-01 01:00:00  NA 0.090 -0.14 96.10  0 0.2357827
## 35043 2004-01-01 01:30:00  NA 0.023 -0.16 95.93  0 0.2457012
## 35044 2004-01-01 02:00:00  NA 0.038 -0.17 95.80  0 0.2533640
## 35045 2004-01-01 02:30:00  NA 0.077 -0.19 95.67  0 0.2608249
## 35046 2004-01-01 03:00:00  NA 0.025 -0.23 95.47  0 0.2720758
```

Step 2: Create REddyProc Object Class

Before REddyProc can work on your data, the data has to be converted to an REddyProc object.

Gebesee

Create the class for the Gebesee data. The ID is `DE-Geb` and the parameters are:

1. `NEE`
2. `Rg`
3. `Tair`
4. `VPD`
5. `Ustar`

```r
# Gebesee Data
EProcDEGeb <- sEddyProc$new('DE-Geb', DEGebExampleV1, c('NEE','Rg','Tair','VPD','Ustar'))
```

```
## New sEddyProc class for site 'DE-Geb'
```

Check the additional info of the data.

```r
EProcDEGeb$sLOCATION
```

```
## $LatDeg
## [1] NA
##
## $LongDeg
## [1] NA
##
## $TimeZoneHour
## [1] NA
```

Add the location information. This is important for the daytime-nighttime partitioning analysis because it requires the time to be accurate.

```
## Location of Gebesee
EProcDEGeb$sSetLocationInfo(LatDeg = 51.1, LongDeg = 10.9, TimeZoneHour = 1)
EProcDEGeb$sLOCATION
```

```
## $LatDeg
## [1] 51.1
##
## $LongDeg
## [1] 10.9
##
## $TimeZoneHour
## [1] 1
```

Tharandt

Create the class for the Gebesee data. The ID is `DE-Tha` and the parameters are:

1. `NEE`
2. `Rg`
3. `Tair`
4. `VPD`
5. `Ustar`

```
# Tharandt Data
EProcDETha <- sEddyProc$new('DE-Tha', Example_DETha98V1, c('NEE','Rg','Tair','VPD','Ustar'))
```

```
## New sEddyProc class for site 'DE-Tha'
```

Check the additional info of the data.

```
EProcDETha$sLOCATION
```

```
## $LatDeg
## [1] NA
##
## $LongDeg
## [1] NA
##
## $TimeZoneHour
## [1] NA
```

Add the location information.

```
## Location of Tharandt
EProcDETha$sSetLocationInfo(LatDeg = 51.0, LongDeg = 13.6, TimeZoneHour = 2)
EProcDETha$sLOCATION
```

```
## $LatDeg
## [1] 51
##
## $LongDeg
## [1] 13.6
##
## $TimeZoneHour
## [1] 2
```

Step 3: u*-Threshold Estimation

Friction velocity, or (u_*), changes seasonally at Gebesee. Thus, the (u_*)-threshold needs to be estimated in each season. We do this because (u_*) changes with the surface cover change. A previous study determined the days on which the seasons and (u_*) change. It can be determined by visual inspection of the data.

Year	Start Day
2004	70, 210, 320
2005	70, 180, 320
2006	120, 350

Step 3-1-2: Adding the Start Days for the Gebesee Data.

Create a data frame for the start days.

```
df_startDays <- data.frame(day=c(70,210,320,70,180,320,120,305),
                           year=c(2004,2004,2004,2005,2005,2005,2006,2006))
df_startDays
```

```
##   day year
## 1  70 2004
## 2 210 2004
## 3 320 2004
## 4  70 2005
## 5 180 2005
## 6 320 2005
## 7 120 2006
## 8 305 2006
```

Change the start days into the POSIX format.

We can use `usCreateSeasonFactorYdayYear` to change the `df_startDays` data frame to a factor vector that contains values that tag each rows to their respective seasons.

Create the factor vector. Note that the product `15*60` is used to make the time be between 00:00 and 00:30. The `summary` shows that there are 3312 observations for season `2004001`, i.e., between days 1 and 70, etc.

```
seasonFactor <- usCreateSeasonFactorYdayYear(DEGebExampleV1$DateTime - 15*60,
                                             starts = df_startDays)
summary(seasonFactor)
```

```
## 2004001 2004070 2004210 2004320 2005070 2005180 2005320 2006120 2006305
##    3312    6720    5280    5568    5280    6720    7920    8880    2928
```

Optional: View the Season Demarcation

Create timestamps in the POSIX format from `df_startDays`. Here, we embed a new data frame with the additional column `Hour` into the `fConvertTimeToPosix` function call. The hour is set at `0.25` to be between 00:00 and 00:30, i.e., 00:15.

```
seasonStartsDate <- fConvertTimeToPosix(data.frame(Year = df_startDays$year,
                                                    DoY = df_startDays$day,
                                                    Hour = 0.25),
                                         TFormat = 'YDH',
                                         Year = "Year",
                                         Day = "DoY",
                                         Hour = "Hour")
```

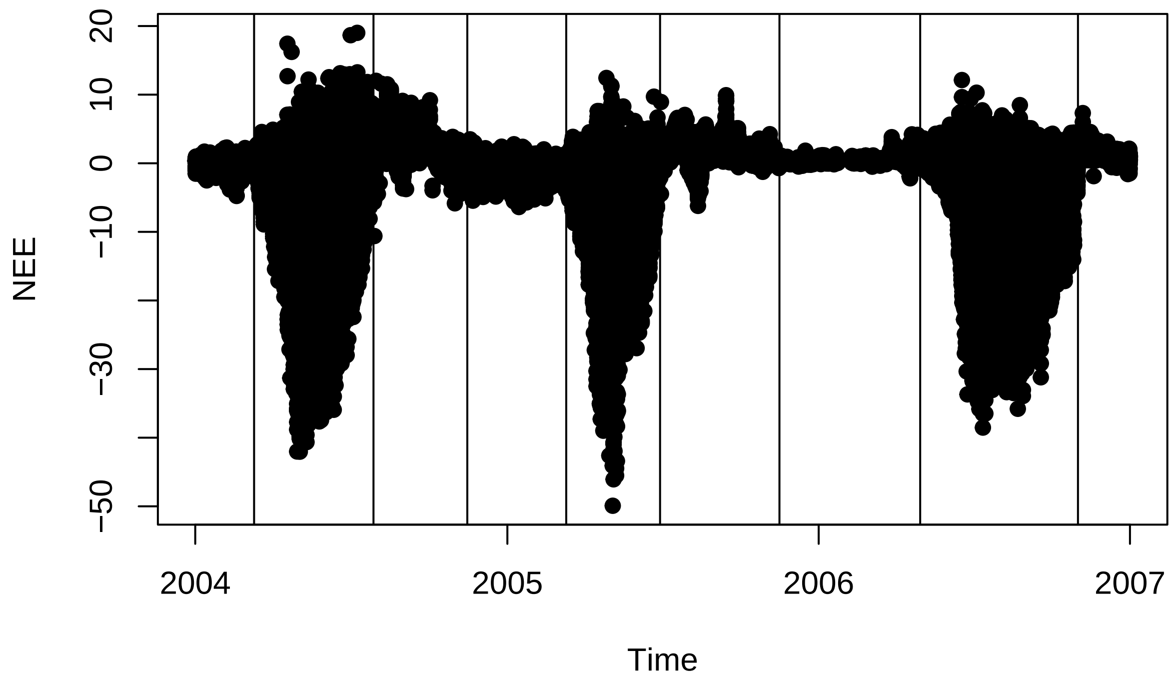
```
## Converted time format 'YDH' to POSIX with column name 'DateTime'.
```

```
seasonStartsDate
```

```
##              DateTime Year DoY Hour
## 1 2004-03-10 00:15:00 2004  70 0.25
## 2 2004-07-28 00:15:00 2004 210 0.25
## 3 2004-11-15 00:15:00 2004 320 0.25
## 4 2005-03-11 00:15:00 2005  70 0.25
## 5 2005-06-29 00:15:00 2005 180 0.25
## 6 2005-11-16 00:15:00 2005 320 0.25
## 7 2006-04-30 00:15:00 2006 120 0.25
## 8 2006-11-01 00:15:00 2006 305 0.25
```

You can check the dates by plotting them on the time series.

```
plot(DEGebExample$DateTime, DEGebExample$NEE, pch=19, xlab = "Time", ylab = 'NEE')
abline( v = seasonStartsDate$DateTime)
```



Step 3-2-2: Calculate the (u_*)-Thresholds Distributions

We will estimate the (u_*) limits using the `sEstimateUstarScenarios` function. The function will write to the data object. The `seasonFactor` is needed here to tell `REddyProc` the season intervals that it must estimate the (u_*) thresholds.

Note that the (u_*) threshold estimation uses the `usEstUstarThreshold` function, which requires the `NEE`, `Tair`, and `seasonFactor`. It returns the median value.

In this example, the (u_*) threshold is estimated, using the `usEstUstarThreshold` function, 30 times, and the (u_*) limits are reported using the default quantiles of 5%, 50%, and 95%: The low, median, and high values of (u_*).

The function `sGetEstimatedUstarThresholdDistribution` displays the results.

Note that you can create the plots of NEE versus (u_*) by using the function `sPlotNEEVersusUStarForSeason`.

```
EProcDEGeb$sEstimateUstarScenarios(seasonFactor = seasonFactor,
                                   nSample = 30,
                                   probs = c(0.05,0.50,0.95))
```

```
##
```

```
## Estimated UStar distribution of:
##        uStar       5%       50%       95%
```

```
## 1 0.1604118 0.126475 0.1554611 0.2109851
## by using  30 bootstrap samples and controls:
##                        taClasses                      UstarClasses
##                                7                                20
##                            swThr              minRecordsWithinTemp
##                               10                               100
##           minRecordsWithinSeason              minRecordsWithinYear
##                              160                              3000
## isUsingOneBigSeasonOnFewRecords
##                                1
```

```r
EProcDEGeb$sGetEstimatedUstarThresholdDistribution()
```

```
##    aggregationMode seasonYear  season      uStar         5%        50%
## 1           single         NA    <NA> 0.16041176 0.12647500 0.15546111
## 2             year       2004    <NA> 0.13500000 0.12126111 0.14961257
## 3             year       2005    <NA> 0.16041176 0.10931429 0.15046538
## 4             year       2006    <NA> 0.25094444 0.07029851 0.20400000
## 5           season       2004 2004001 0.13500000 0.09471000 0.13117500
## 6           season       2004 2004070 0.12037500 0.09057750 0.10763889
## 7           season       2004 2004210 0.08925000 0.08819583 0.13120833
## 8           season       2005 2004320 0.16041176 0.07858750 0.12064522
## 9           season       2005 2005070 0.12533333 0.10976429 0.14600595
## 10          season       2005 2005180 0.13473214 0.07364375 0.10784787
## 11          season       2006 2005320 0.04842361 0.04770478 0.06467647
## 12          season       2006 2006120 0.06966667 0.05960000 0.06916084
## 13          season       2006 2006305 0.25094444 0.13408889 0.22626768
##           95%
## 1  0.21098512
## 2  0.19629167
## 3  0.19025238
## 4  0.26995000
## 5  0.15395500
## 6  0.12544250
## 7  0.19629167
## 8  0.16925063
## 9  0.18280952
## 10 0.13949562
## 11 0.08885496
## 12 0.08652273
## 13 0.27476667
```

Step 4-1: Gap-Filling the Gebesee Data

Step 4-1-1: Check the Use of Seasonal (u_*) Thresholds

First, we have to ensure the use of seasonal (u_*) thresholds. If it is not set in the previous step, check that it is used now.

Show the default thresholds: annual

```
EProcDEGeb$sGetUstarScenarios()
```

```
##    season     uStar        U05       U50       U95
## 1 2004001 0.1350000 0.12126111 0.1496126 0.1962917
## 2 2004070 0.1350000 0.12126111 0.1496126 0.1962917
## 3 2004210 0.1350000 0.12126111 0.1496126 0.1962917
## 4 2004320 0.1604118 0.10931429 0.1504654 0.1902524
## 5 2005070 0.1604118 0.10931429 0.1504654 0.1902524
## 6 2005180 0.1604118 0.10931429 0.1504654 0.1902524
## 7 2005320 0.2509444 0.07029851 0.2040000 0.2699500
## 8 2006120 0.2509444 0.07029851 0.2040000 0.2699500
## 9 2006305 0.2509444 0.07029851 0.2040000 0.2699500
```

Instruct REddyProc to use the seasonal threholds.

```
EProcDEGeb$useSeaonsalUStarThresholds()
```

Confirm that the seasonal thresholds are used by displaying it.

```
EProcDEGeb$sGetUstarScenarios()
```

```
##     season      uStar        U05        U50        U95
## 5  2004001 0.13500000 0.09471000 0.13117500 0.15395500
## 6  2004070 0.12037500 0.09057750 0.10763889 0.12544250
## 7  2004210 0.08925000 0.08819583 0.13120833 0.19629167
## 8  2004320 0.16041176 0.07858750 0.12064522 0.16925063
## 9  2005070 0.12533333 0.10976429 0.14600595 0.18280952
## 10 2005180 0.13473214 0.07364375 0.10784787 0.13949562
## 11 2005320 0.04842361 0.04770478 0.06467647 0.08885496
## 12 2006120 0.06966667 0.05960000 0.06916084 0.08652273
## 13 2006305 0.25094444 0.13408889 0.22626768 0.27476667
```

Step 4-1-2: Gap-Fill the Gebesee Data

Gap-fill the data using the function `sMDSGapFillUStarScens`. It will filter the data using the (u_*) thresholds and gap-fill it.

`MDS` means Marginal Distribution Sampling, which combines the Look Up Table (LUT) and Mean Diurnal Course (MDC) to gap-fill the data.

Quality flags are created for the gap-filled data: 0, 1, and >1.

- 0 means original observations
- 1 gap-filled data with good quality (more parameters and shorter time window used)
- 1 low quality (less parameters and longer time window used)

The function also calculates the random error for non-gap records by replacing the original values with gap-filled values.

```r
EProcDEGeb$sMDSGapFillUStarScens("NEE", FillAll = TRUE)
```

Check the columns that were created.

Definitions * NEE_*f: gaps replaced by modeled values (gap-filled) * NEEfall: all NEE replaced by modeled values * NEE*_fqc: quality flag: 0 observations, 1 good quality of gap-filling

```r
colnames(EProcDEGeb$sExportResults())
```

```
##  [1] "season"            "Ustar_uStar_Thres" "Ustar_uStar_fqc"
##  [4] "NEE_uStar_orig"    "NEE_uStar_f"       "NEE_uStar_fqc"
##  [7] "NEE_uStar_fall"    "NEE_uStar_fall_qc" "NEE_uStar_fnum"
## [10] "NEE_uStar_fsd"     "NEE_uStar_fmeth"   "NEE_uStar_fwin"
## [13] "Ustar_U05_Thres"   "Ustar_U05_fqc"     "NEE_U05_orig"
## [16] "NEE_U05_f"         "NEE_U05_fqc"       "NEE_U05_fall"
## [19] "NEE_U05_fall_qc"   "NEE_U05_fnum"      "NEE_U05_fsd"
## [22] "NEE_U05_fmeth"     "NEE_U05_fwin"      "Ustar_U50_Thres"
## [25] "Ustar_U50_fqc"     "NEE_U50_orig"      "NEE_U50_f"
## [28] "NEE_U50_fqc"       "NEE_U50_fall"      "NEE_U50_fall_qc"
## [31] "NEE_U50_fnum"      "NEE_U50_fsd"       "NEE_U50_fmeth"
## [34] "NEE_U50_fwin"      "Ustar_U95_Thres"   "Ustar_U95_fqc"
## [37] "NEE_U95_orig"      "NEE_U95_f"         "NEE_U95_fqc"
## [40] "NEE_U95_fall"      "NEE_U95_fall_qc"   "NEE_U95_fnum"
## [43] "NEE_U95_fsd"       "NEE_U95_fmeth"     "NEE_U95_fwin"
```

Summarize the results.

```r
summary(EProcDEGeb$sExportResults())
```

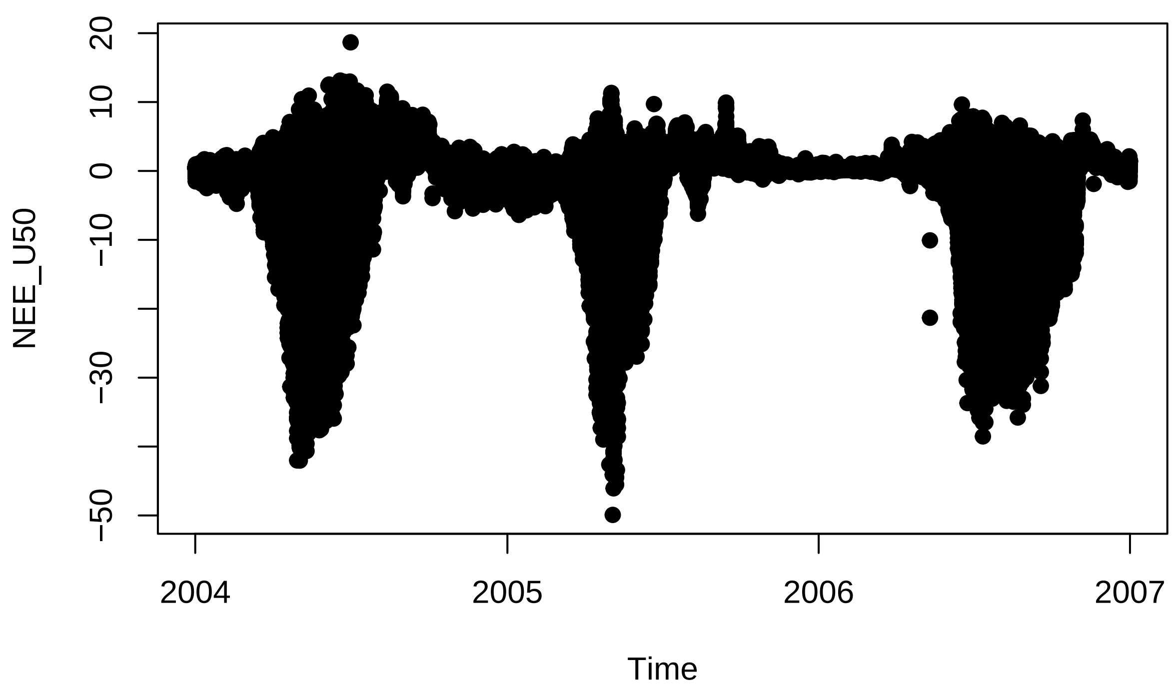
```
##      season      Ustar_uStar_Thres Ustar_uStar_fqc  NEE_uStar_orig
##  2006120: 8880   Min.   :0.04842   Min.   :0.0000   Min.   :-49.919
##  2005320: 7920   1st Qu.:0.06967   1st Qu.:0.0000   1st Qu.: -2.803
##  2004070: 6720   Median :0.12037   Median :0.0000   Median :  0.546
##  2005180: 6720   Mean   :0.11262   Mean   :0.3187   Mean   : -2.353
##  2004320: 5568   3rd Qu.:0.13473   3rd Qu.:1.0000   3rd Qu.:  1.794
##  2004210: 5280   Max.   :0.25094   Max.   :4.0000   Max.   : 18.668
##  (Other):11520                                      NA's   :25112
##   NEE_uStar_f        NEE_uStar_fqc    NEE_uStar_fall      NEE_uStar_fall_qc
##  Min.   :-49.91900   Min.   :0.0000   Min.   :-40.26775   Min.   :1.000
##  1st Qu.:  0.01475   1st Qu.:0.0000   1st Qu.:  0.06288   1st Qu.:1.000
##  Median :  0.79000   Median :0.0000   Median :  0.80624   Median :1.000
##  Mean   : -0.81318   Mean   :0.5071   Mean   : -0.80384   Mean   :1.032
##  3rd Qu.:  2.22525   3rd Qu.:1.0000   3rd Qu.:  2.28422   3rd Qu.:1.000
##  Max.   : 18.66800   Max.   :3.0000   Max.   : 10.45100   Max.   :3.000
##
##  NEE_uStar_fnum   NEE_uStar_fsd       NEE_uStar_fmeth NEE_uStar_fwin
##  Min.   :  2.00   Min.   : 0.005657   Min.   :1.000   Min.   : 1.00
##  1st Qu.: 12.00   1st Qu.: 0.302818   1st Qu.:1.000   1st Qu.:14.00
##  Median : 27.00   Median : 0.639365   Median :1.000   Median :14.00
##  Mean   : 46.96   Mean   : 1.089787   Mean   :1.024   Mean   :14.44
##  3rd Qu.: 65.00   3rd Qu.: 1.414365   3rd Qu.:1.000   3rd Qu.:14.00
##  Max.   :323.00   Max.   :14.470233   Max.   :3.000   Max.   :98.00
```

```
##
##  Ustar_U05_Thres   Ustar_U05_fqc     NEE_U05_orig       NEE_U05_f
##  Min.   :0.04770   Min.   :0.0000   Min.   :-49.919   Min.   :-49.9190
##  1st Qu.:0.05960   1st Qu.:0.0000   1st Qu.: -2.266   1st Qu.:  0.0116
##  Median :0.07859   Median :0.0000   Median :  0.602   Median :  0.7610
##  Mean   :0.07983   Mean   :0.2685   Mean   : -2.124   Mean   : -0.8372
##  3rd Qu.:0.09058   3rd Qu.:0.0000   3rd Qu.:  1.810   3rd Qu.:  2.1763
##  Max.   :0.13409   Max.   :4.0000   Max.   : 19.008   Max.   : 19.0080
##                                     NA's   :23370
##   NEE_U05_fqc      NEE_U05_fall       NEE_U05_fall_qc  NEE_U05_fnum
##  Min.   :0.0000   Min.   :-40.26775   Min.   :1.000   Min.   :  2.00
##  1st Qu.:0.0000   1st Qu.:  0.06245   1st Qu.:1.000   1st Qu.: 12.00
##  Median :0.0000   Median :  0.77427   Median :1.000   Median : 30.00
##  Mean   :0.4718   Mean   : -0.82721   Mean   :1.029   Mean   : 53.03
##  3rd Qu.:1.0000   3rd Qu.:  2.23871   3rd Qu.:1.000   3rd Qu.: 77.00
##  Max.   :3.0000   Max.   : 10.45100   Max.   :3.000   Max.   :368.00
##
##   NEE_U05_fsd        NEE_U05_fmeth   NEE_U05_fwin   Ustar_U50_Thres
##  Min.   : 0.005657   Min.   :1.00   Min.   : 1.00   Min.   :0.06468
##  1st Qu.: 0.307294   1st Qu.:1.00   1st Qu.:14.00   1st Qu.:0.06916
##  Median : 0.656494   Median :1.00   Median :14.00   Median :0.10785
##  Mean   : 1.102335   Mean   :1.02   Mean   :14.41   Mean   :0.11038
##  3rd Qu.: 1.449568   3rd Qu.:1.00   3rd Qu.:14.00   3rd Qu.:0.13121
##  Max.   :14.470233   Max.   :3.00   Max.   :98.00   Max.   :0.22627
##
##  Ustar_U50_fqc     NEE_U50_orig       NEE_U50_f        NEE_U50_fqc
##  Min.   :0.0000   Min.   :-49.919   Min.   :-49.919   Min.   :0.0000
##  1st Qu.:0.0000   1st Qu.: -2.711   1st Qu.:  0.013   1st Qu.:0.0000
##  Median :0.0000   Median :  0.563   Median :  0.773   Median :0.0000
##  Mean   :0.3193   Mean   : -2.312   Mean   : -0.819   Mean   :0.5016
##  3rd Qu.:1.0000   3rd Qu.:  1.780   3rd Qu.:  2.217   3rd Qu.:1.0000
##  Max.   :4.0000   Max.   : 18.668   Max.   : 18.668   Max.   :3.0000
##                   NA's   :24781
##   NEE_U50_fall       NEE_U50_fall_qc  NEE_U50_fnum     NEE_U50_fsd
##  Min.   :-40.26775   Min.   :1.000   Min.   :  2.00   Min.   : 0.000707
##  1st Qu.:  0.06426   1st Qu.:1.000   1st Qu.: 12.00   1st Qu.: 0.299619
##  Median :  0.78075   Median :1.000   Median : 27.00   Median : 0.639790
##  Mean   : -0.80964   Mean   :1.033   Mean   : 48.24   Mean   : 1.088904
##  3rd Qu.:  2.26818   3rd Qu.:1.000   3rd Qu.: 68.00   3rd Qu.: 1.434993
##  Max.   : 10.45100   Max.   :3.000   Max.   :348.00   Max.   :14.470233
##
##  NEE_U50_fmeth    NEE_U50_fwin   Ustar_U95_Thres   Ustar_U95_fqc
##  Min.   :1.000   Min.   : 1.00   Min.   :0.08652   Min.   :0.0000
##  1st Qu.:1.000   1st Qu.:14.00   1st Qu.:0.08885   1st Qu.:0.0000
##  Median :1.000   Median :14.00   Median :0.13950   Median :0.0000
##  Mean   :1.022   Mean   :14.45   Mean   :0.14277   Mean   :0.3648
##  3rd Qu.:1.000   3rd Qu.:14.00   3rd Qu.:0.18281   3rd Qu.:1.0000
##  Max.   :3.000   Max.   :98.00   Max.   :0.27477   Max.   :4.0000
##
##   NEE_U95_orig       NEE_U95_f         NEE_U95_fqc      NEE_U95_fall
##  Min.   :-49.919   Min.   :-49.919   Min.   :0.0000   Min.   :-40.26775
##  1st Qu.: -3.288   1st Qu.:  0.015   1st Qu.:0.0000   1st Qu.:  0.06076
##  Median :  0.498   Median :  0.782   Median :1.0000   Median :  0.78783
##  Mean   : -2.559   Mean   : -0.806   Mean   :0.5328   Mean   : -0.79717
```

```
##  3rd Qu.:  1.738   3rd Qu.:  2.232   3rd Qu.:1.0000   3rd Qu.:  2.28560
##  Max.   : 18.668   Max.   : 18.668   Max.   :3.0000   Max.   : 10.58200
##  NA's   :26384
##  NEE_U95_fall_qc  NEE_U95_fnum     NEE_U95_fsd         NEE_U95_fmeth
##  Min.   :1.000   Min.   :  2.00   Min.   : 0.000707   Min.   :1.000
##  1st Qu.:1.000   1st Qu.: 11.00   1st Qu.: 0.301369   1st Qu.:1.000
##  Median :1.000   Median : 24.00   Median : 0.621600   Median :1.000
##  Mean   :1.033   Mean   : 42.85   Mean   : 1.077977   Mean   :1.028
##  3rd Qu.:1.000   3rd Qu.: 59.00   3rd Qu.: 1.396538   3rd Qu.:1.000
##  Max.   :3.000   Max.   :315.00   Max.   :14.470233   Max.   :3.000
##
##   NEE_U95_fwin
##  Min.   : 1.00
##  1st Qu.:14.00
##  Median :14.00
##  Mean   :14.46
##  3rd Qu.:14.00
##  Max.   :98.00
##
```

Check one of the parameters by plotting

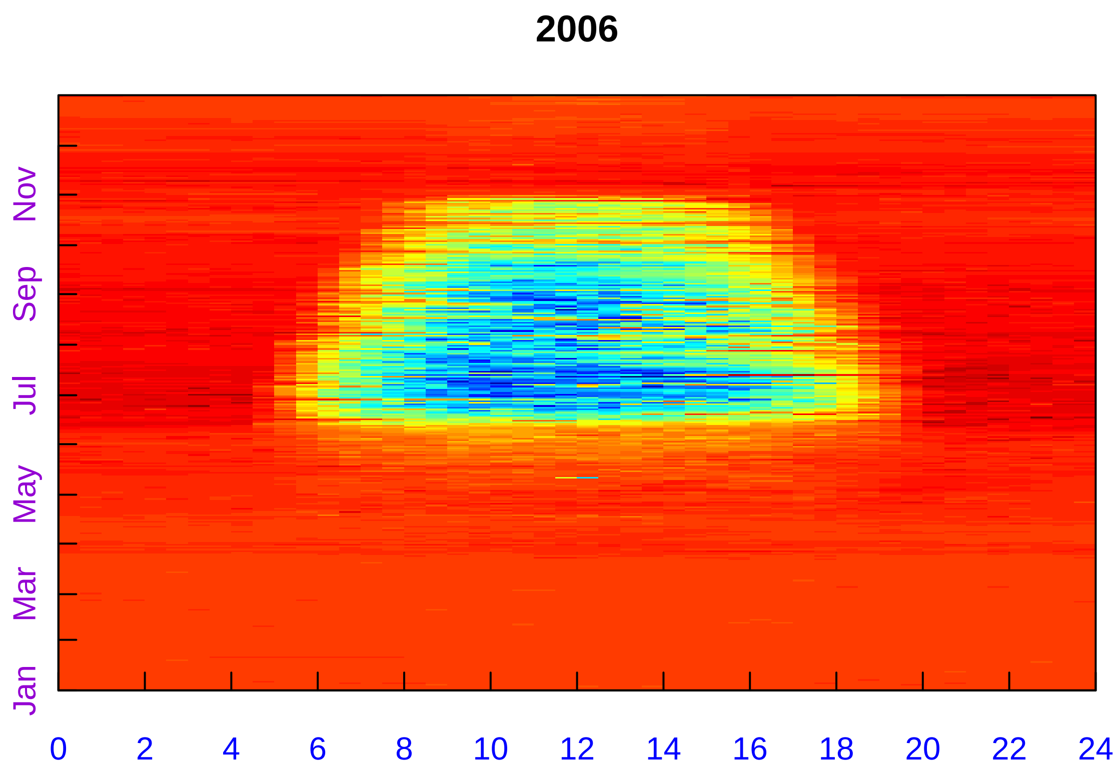
```r
plot(EProcDEGeb$sDATA$sDateTime, EProcDEGeb$sExportResults()$NEE_U50_f, pch = 19, xlab = 'Time',
     ylab = 'NEE_U50')
```



Step 4-1-3: Gebesee Fingerprint Plot

We can also generate a fingerprint plot using the function `sPlotFingerprintY`. This is for the `NEE_U95_f` parameter and the year 2004.

```
EProcDEGeb$sPlotFingerprintY('NEE_U50_f', Year = 2006)
```



We can also produce PDF files with legend for all years in sub-directory "figs."

```
EProcDEGeb$sPlotFingerprint('NEE_U50_f', Dir = "figs")
```

```
## sPlotFingerprint:::.self$.sxOpenPlot:::fSetFile::: Directory created: figs
```

```
## Saved plot to: figs/DE-Geb_04-06_FP_NEE_U50_f.pdf
```

Step 5-1: Gebesee Preparing the Data for Partitioning

This step requires the data to have location (lat lon) information and the time zone because it uses the time to estimate daytime and nighttime. We already did this in the Step 3-1-2.

There are some weather values that are missing and can be gap-filled here. However, we do not need to replace the original values with gap-filled values because we are not going to calculate random error.

```
EProcDEGeb$sMDSGapFill('Rg', FillAll = FALSE)
EProcDEGeb$sMDSGapFill('Tair', FillAll = FALSE)
EProcDEGeb$sMDSGapFill('VPD', FillAll = FALSE)
```

Step 5-1-1: Gebesee Reichstein Partitioning

Partitioning the data into the nighttime fractions of the Gross Primary Production (GPP) and ecosystem respiration (R_{eco}) using all (u_*) scenarios. This uses the 'sMRFluxPartitionUStarScens' function.

More details on the equations used can be found in the paper Reichstein et al. (2005).

```
EProcDEGeb$sMRFluxPartitionUStarScens()
```

Step 5-1-2: Plotting the GPP

Extract the result to the variable nightPart and summarize it.

```
ReichsteinPart <- EProcDEGeb$sExportResults()
summary(ReichsteinPart)
```

```
##      season      Ustar_uStar_Thres Ustar_uStar_fqc  NEE_uStar_orig
##  2006120: 8880   Min.   :0.04842   Min.   :0.0000   Min.   :-49.919
##  2005320: 7920   1st Qu.:0.06967   1st Qu.:0.0000   1st Qu.: -2.803
##  2004070: 6720   Median :0.12037   Median :0.0000   Median :  0.546
##  2005180: 6720   Mean   :0.11262   Mean   :0.3187   Mean   : -2.353
##  2004320: 5568   3rd Qu.:0.13473   3rd Qu.:1.0000   3rd Qu.:  1.794
##  2004210: 5280   Max.   :0.25094   Max.   :4.0000   Max.   : 18.668
##  (Other):11520                                      NA's   :25112
##   NEE_uStar_f         NEE_uStar_fqc    NEE_uStar_fall      NEE_uStar_fall_qc
##  Min.   :-49.91900   Min.   :0.0000   Min.   :-40.26775   Min.   :1.000
##  1st Qu.:  0.01475   1st Qu.:0.0000   1st Qu.:  0.06288   1st Qu.:1.000
##  Median :  0.79000   Median :0.0000   Median :  0.80624   Median :1.000
##  Mean   : -0.81318   Mean   :0.5071   Mean   : -0.80384   Mean   :1.032
##  3rd Qu.:  2.22525   3rd Qu.:1.0000   3rd Qu.:  2.28422   3rd Qu.:1.000
##  Max.   : 18.66800   Max.   :3.0000   Max.   : 10.45100   Max.   :3.000
##
##  NEE_uStar_fnum   NEE_uStar_fsd       NEE_uStar_fmeth NEE_uStar_fwin
##  Min.   :  2.00   Min.   : 0.005657   Min.   :1.000   Min.   : 1.00
##  1st Qu.: 12.00   1st Qu.: 0.302818   1st Qu.:1.000   1st Qu.:14.00
##  Median : 27.00   Median : 0.639365   Median :1.000   Median :14.00
##  Mean   : 46.96   Mean   : 1.089787   Mean   :1.024   Mean   :14.44
##  3rd Qu.: 65.00   3rd Qu.: 1.414365   3rd Qu.:1.000   3rd Qu.:14.00
##  Max.   :323.00   Max.   :14.470233   Max.   :3.000   Max.   :98.00
##
##  Ustar_U05_Thres   Ustar_U05_fqc     NEE_U05_orig       NEE_U05_f
##  Min.   :0.04770   Min.   :0.0000   Min.   :-49.919   Min.   :-49.9190
##  1st Qu.:0.05960   1st Qu.:0.0000   1st Qu.: -2.266   1st Qu.:  0.0116
##  Median :0.07859   Median :0.0000   Median :  0.602   Median :  0.7610
##  Mean   :0.07983   Mean   :0.2685   Mean   : -2.124   Mean   : -0.8372
##  3rd Qu.:0.09058   3rd Qu.:0.0000   3rd Qu.:  1.810   3rd Qu.:  2.1763
##  Max.   :0.13409   Max.   :4.0000   Max.   : 19.008   Max.   : 19.0080
##                                     NA's   :23370
##   NEE_U05_fqc      NEE_U05_fall       NEE_U05_fall_qc  NEE_U05_fnum
##  Min.   :0.0000   Min.   :-40.26775   Min.   :1.000   Min.   :  2.00
##  1st Qu.:0.0000   1st Qu.:  0.06245   1st Qu.:1.000   1st Qu.: 12.00
##  Median :0.0000   Median :  0.77427   Median :1.000   Median : 30.00
##  Mean   :0.4718   Mean   : -0.82721   Mean   :1.029   Mean   : 53.03
```

```
##  3rd Qu.:1.0000   3rd Qu.:  2.23871   3rd Qu.:1.000   3rd Qu.: 77.00
##  Max.   :3.0000   Max.   : 10.45100   Max.   :3.000   Max.   :368.00
##
##   NEE_U05_fsd        NEE_U05_fmeth   NEE_U05_fwin   Ustar_U50_Thres
##  Min.   : 0.005657   Min.   :1.00   Min.   : 1.00   Min.   :0.06468
##  1st Qu.: 0.307294   1st Qu.:1.00   1st Qu.:14.00   1st Qu.:0.06916
##  Median : 0.656494   Median :1.00   Median :14.00   Median :0.10785
##  Mean   : 1.102335   Mean   :1.02   Mean   :14.41   Mean   :0.11038
##  3rd Qu.: 1.449568   3rd Qu.:1.00   3rd Qu.:14.00   3rd Qu.:0.13121
##  Max.   :14.470233   Max.   :3.00   Max.   :98.00   Max.   :0.22627
##
##  Ustar_U50_fqc     NEE_U50_orig       NEE_U50_f        NEE_U50_fqc
##  Min.   :0.0000   Min.   :-49.919   Min.   :-49.919   Min.   :0.0000
##  1st Qu.:0.0000   1st Qu.: -2.711   1st Qu.:  0.013   1st Qu.:0.0000
##  Median :0.0000   Median :  0.563   Median :  0.773   Median :0.0000
##  Mean   :0.3193   Mean   : -2.312   Mean   : -0.819   Mean   :0.5016
##  3rd Qu.:1.0000   3rd Qu.:  1.780   3rd Qu.:  2.217   3rd Qu.:1.0000
##  Max.   :4.0000   Max.   : 18.668   Max.   : 18.668   Max.   :3.0000
##                   NA's   :24781
##   NEE_U50_fall       NEE_U50_fall_qc  NEE_U50_fnum     NEE_U50_fsd
##  Min.   :-40.26775   Min.   :1.000   Min.   :  2.00   Min.   : 0.000707
##  1st Qu.:  0.06426   1st Qu.:1.000   1st Qu.: 12.00   1st Qu.: 0.299619
##  Median :  0.78075   Median :1.000   Median : 27.00   Median : 0.639790
##  Mean   : -0.80964   Mean   :1.033   Mean   : 48.24   Mean   : 1.088904
##  3rd Qu.:  2.26818   3rd Qu.:1.000   3rd Qu.: 68.00   3rd Qu.: 1.434993
##  Max.   : 10.45100   Max.   :3.000   Max.   :348.00   Max.   :14.470233
##
##  NEE_U50_fmeth    NEE_U50_fwin   Ustar_U95_Thres   Ustar_U95_fqc
##  Min.   :1.000   Min.   : 1.00   Min.   :0.08652   Min.   :0.0000
##  1st Qu.:1.000   1st Qu.:14.00   1st Qu.:0.08885   1st Qu.:0.0000
##  Median :1.000   Median :14.00   Median :0.13950   Median :0.0000
##  Mean   :1.022   Mean   :14.45   Mean   :0.14277   Mean   :0.3648
##  3rd Qu.:1.000   3rd Qu.:14.00   3rd Qu.:0.18281   3rd Qu.:1.0000
##  Max.   :3.000   Max.   :98.00   Max.   :0.27477   Max.   :4.0000
##
##   NEE_U95_orig       NEE_U95_f        NEE_U95_fqc      NEE_U95_fall
##  Min.   :-49.919   Min.   :-49.919   Min.   :0.0000   Min.   :-40.26775
##  1st Qu.: -3.288   1st Qu.:  0.015   1st Qu.:0.0000   1st Qu.:  0.06076
##  Median :  0.498   Median :  0.782   Median :1.0000   Median :  0.78783
##  Mean   : -2.559   Mean   : -0.806   Mean   :0.5328   Mean   : -0.79717
##  3rd Qu.:  1.738   3rd Qu.:  2.232   3rd Qu.:1.0000   3rd Qu.:  2.28560
##  Max.   : 18.668   Max.   : 18.668   Max.   :3.0000   Max.   : 10.58200
##  NA's   :26384
##  NEE_U95_fall_qc  NEE_U95_fnum     NEE_U95_fsd       NEE_U95_fmeth
##  Min.   :1.000   Min.   :  2.00   Min.   : 0.000707   Min.   :1.000
##  1st Qu.:1.000   1st Qu.: 11.00   1st Qu.: 0.301369   1st Qu.:1.000
##  Median :1.000   Median : 24.00   Median : 0.621600   Median :1.000
##  Mean   :1.033   Mean   : 42.85   Mean   : 1.077977   Mean   :1.028
##  3rd Qu.:1.000   3rd Qu.: 59.00   3rd Qu.: 1.396538   3rd Qu.:1.000
##  Max.   :3.000   Max.   :315.00   Max.   :14.470233   Max.   :3.000
##
##   NEE_U95_fwin      Rg_orig             Rg_f              Rg_fqc
##  Min.   : 1.00   Min.   :   0.00   Min.   :   0.00   Min.   :0
##  1st Qu.:14.00   1st Qu.:   0.00   1st Qu.:   0.00   1st Qu.:0
```

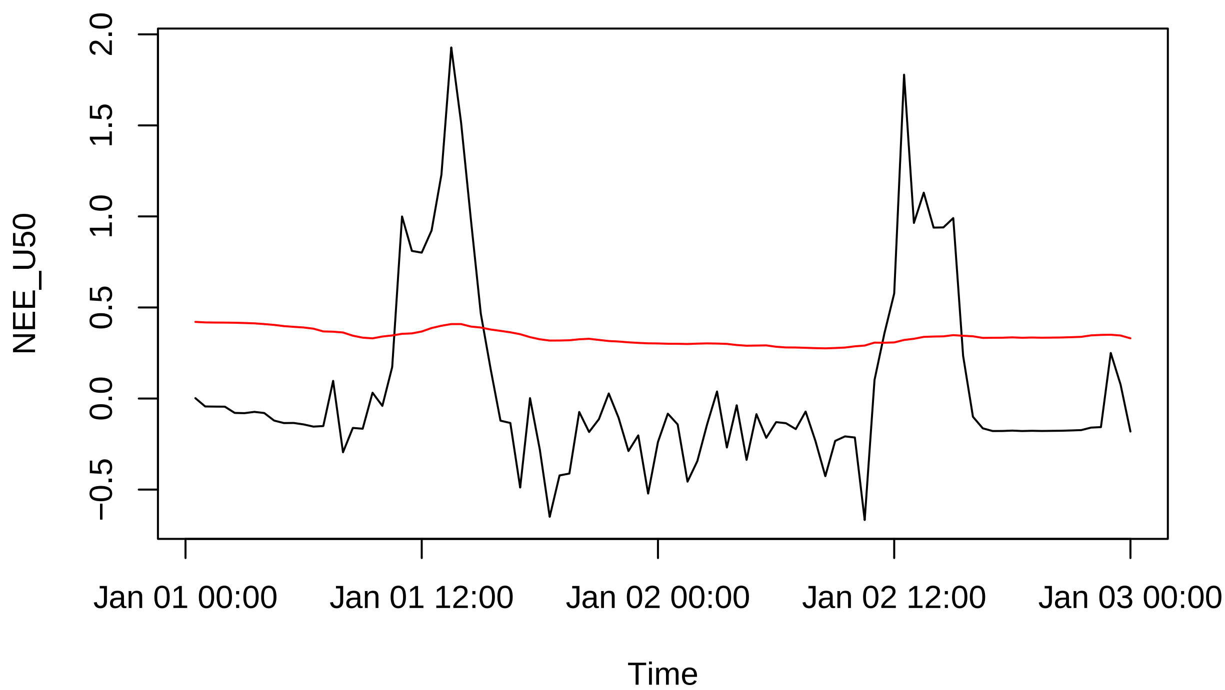
```
##  Median :14.00   Median :   2.04   Median :   2.04   Median :0
##  Mean   :14.46   Mean   : 124.71   Mean   : 124.71   Mean   :0
##  3rd Qu.:14.00   3rd Qu.: 176.03   3rd Qu.: 176.03   3rd Qu.:0
##  Max.   :98.00   Max.   :1046.03   Max.   :1046.03   Max.   :0
##
##     Rg_fall          Rg_fall_qc       Rg_fnum          Rg_fsd
##  Min.   :   0.00   Min.   : NA     Min.   : NA     Min.   : NA
##  1st Qu.:   0.00   1st Qu.: NA     1st Qu.: NA     1st Qu.: NA
##  Median :   2.04   Median : NA     Median : NA     Median : NA
##  Mean   : 124.71   Mean   :NaN     Mean   :NaN     Mean   :NaN
##  3rd Qu.: 176.03   3rd Qu.: NA     3rd Qu.: NA     3rd Qu.: NA
##  Max.   :1046.03   Max.   : NA     Max.   : NA     Max.   : NA
##                    NA's   :52608   NA's   :52608   NA's   :52608
##     Rg_fmeth        Rg_fwin        Tair_orig          Tair_f
##  Min.   : NA     Min.   : NA     Min.   :-16.710   Min.   :-16.710
##  1st Qu.: NA     1st Qu.: NA     1st Qu.:  3.360   1st Qu.:  3.360
##  Median : NA     Median : NA     Median :  9.970   Median :  9.970
##  Mean   :NaN     Mean   :NaN     Mean   :  9.664   Mean   :  9.664
##  3rd Qu.: NA     3rd Qu.: NA     3rd Qu.: 15.520   3rd Qu.: 15.520
##  Max.   : NA     Max.   : NA     Max.   : 34.680   Max.   : 34.680
##  NA's   :52608   NA's   :52608
##     Tair_fqc   Tair_fall        Tair_fall_qc     Tair_fnum        Tair_fsd
##  Min.   :0   Min.   :-16.710   Min.   : NA     Min.   : NA     Min.   : NA
##  1st Qu.:0   1st Qu.:  3.360   1st Qu.: NA     1st Qu.: NA     1st Qu.: NA
##  Median :0   Median :  9.970   Median : NA     Median : NA     Median : NA
##  Mean   :0   Mean   :  9.664   Mean   :NaN     Mean   :NaN     Mean   :NaN
##  3rd Qu.:0   3rd Qu.: 15.520   3rd Qu.: NA     3rd Qu.: NA     3rd Qu.: NA
##  Max.   :0   Max.   : 34.680   Max.   : NA     Max.   : NA     Max.   : NA
##                                NA's   :52608   NA's   :52608   NA's   :52608
##    Tair_fmeth      Tair_fwin        VPD_orig         VPD_f
##  Min.   : NA     Min.   : NA     Min.   : 0.000   Min.   : 0.000
##  1st Qu.: NA     1st Qu.: NA     1st Qu.: 1.106   1st Qu.: 1.106
##  Median : NA     Median : NA     Median : 2.246   Median : 2.246
##  Mean   :NaN     Mean   :NaN     Mean   : 4.136   Mean   : 4.135
##  3rd Qu.: NA     3rd Qu.: NA     3rd Qu.: 5.027   3rd Qu.: 5.026
##  Max.   : NA     Max.   : NA     Max.   :44.321   Max.   :44.321
##  NA's   :52608   NA's   :52608   NA's   :1
##     VPD_fqc           VPD_fall       VPD_fall_qc       VPD_fnum
##  Min.   :0.0e+00   Min.   : 0.000   Min.   :1       Min.   :372
##  1st Qu.:0.0e+00   1st Qu.: 1.106   1st Qu.:1       1st Qu.:372
##  Median :0.0e+00   Median : 2.246   Median :1       Median :372
##  Mean   :1.9e-05   Mean   : 4.135   Mean   :1       Mean   :372
##  3rd Qu.:0.0e+00   3rd Qu.: 5.026   3rd Qu.:1       3rd Qu.:372
##  Max.   :1.0e+00   Max.   :44.321   Max.   :1       Max.   :372
##                                     NA's   :52607   NA's   :52607
##     VPD_fsd        VPD_fmeth        VPD_fwin       PotRad_U05
##  Min.   :3.85    Min.   :2       Min.   :14      Min.   :   0.000
##  1st Qu.:3.85    1st Qu.:2       1st Qu.:14      1st Qu.:   0.000
##  Median :3.85    Median :2       Median :14      Median :   5.994
##  Mean   :3.85    Mean   :2       Mean   :14      Mean   : 279.417
##  3rd Qu.:3.85    3rd Qu.:2       3rd Qu.:14      3rd Qu.: 521.982
##  Max.   :3.85    Max.   :2       Max.   :14      Max.   :1170.471
##  NA's   :52607   NA's   :52607   NA's   :52607
##  FP_NEEnight_U05  FP_Temp_U05         E_0_U05        R_ref_U05
```

```
##  Min.   :-4.47   Min.   :-16.710   Min.   :186.2   Min.   :0.6146
##  1st Qu.: 0.66   1st Qu.:  3.360   1st Qu.:186.2   1st Qu.:1.7204
##  Median : 1.17   Median :  9.970   Median :186.2   Median :2.2758
##  Mean   : 1.82   Mean   :  9.664   Mean   :186.2   Mean   :2.9148
##  3rd Qu.: 2.53   3rd Qu.: 15.520   3rd Qu.:186.2   3rd Qu.:3.4756
##  Max.   :19.01   Max.   : 34.680   Max.   :186.2   Max.   :9.5245
##  NA's   :41552
##     Reco_U05          GPP_U05_f          GPP_U05_fqc       PotRad_U50
##  Min.   : 0.06148   Min.   :-11.06670   Min.   :0.0000   Min.   :   0.000
##  1st Qu.: 0.83666   1st Qu.: -0.06693   1st Qu.:0.0000   1st Qu.:   0.000
##  Median : 1.88022   Median :  0.20682   Median :0.0000   Median :   5.994
##  Mean   : 2.53468   Mean   :  3.37185   Mean   :0.4718   Mean   : 279.417
##  3rd Qu.: 3.58295   3rd Qu.:  2.16944   3rd Qu.:1.0000   3rd Qu.: 521.982
##  Max.   :13.20519   Max.   : 58.65293   Max.   :3.0000   Max.   :1170.471
##
##  FP_NEEnight_U50  FP_Temp_U50         E_0_U50        R_ref_U50
##  Min.   :-4.47   Min.   :-16.710   Min.   :182.5   Min.   :0.4881
##  1st Qu.: 0.66   1st Qu.:  3.360   1st Qu.:182.5   1st Qu.:1.7191
##  Median : 1.20   Median :  9.970   Median :182.5   Median :2.3374
##  Mean   : 1.85   Mean   :  9.664   Mean   :182.5   Mean   :2.9553
##  3rd Qu.: 2.60   3rd Qu.: 15.520   3rd Qu.:182.5   3rd Qu.:3.5793
##  Max.   :13.12   Max.   : 34.680   Max.   :182.5   Max.   :9.5301
##  NA's   :42872
##     Reco_U50          GPP_U50_f          GPP_U50_fqc       PotRad_U95
##  Min.   : 0.06353   Min.   :-10.88804   Min.   :0.0000   Min.   :   0.000
##  1st Qu.: 0.85010   1st Qu.: -0.05176   1st Qu.:0.0000   1st Qu.:   0.000
##  Median : 1.91661   Median :  0.21728   Median :0.0000   Median :   5.994
##  Mean   : 2.58240   Mean   :  3.40143   Mean   :0.5016   Mean   : 279.417
##  3rd Qu.: 3.63605   3rd Qu.:  2.20014   3rd Qu.:1.0000   3rd Qu.: 521.982
##  Max.   :13.11290   Max.   : 58.78027   Max.   :3.0000   Max.   :1170.471
##
##  FP_NEEnight_U95  FP_Temp_U95         E_0_U95        R_ref_U95
##  Min.   :-4.12   Min.   :-16.710   Min.   :180.3   Min.   :0.3506
##  1st Qu.: 0.67   1st Qu.:  3.360   1st Qu.:180.3   1st Qu.:1.7326
##  Median : 1.23   Median :  9.970   Median :180.3   Median :2.4772
##  Mean   : 1.88   Mean   :  9.664   Mean   :180.3   Mean   :3.0367
##  3rd Qu.: 2.65   3rd Qu.: 15.520   3rd Qu.:180.3   3rd Qu.:3.6609
##  Max.   :12.94   Max.   : 34.680   Max.   :180.3   Max.   :9.4606
##  NA's   :44369
##     Reco_U95          GPP_U95_f          GPP_U95_fqc      PotRad_uStar
##  Min.   : 0.06481   Min.   :-10.55077   Min.   :0.0000   Min.   :   0.000
##  1st Qu.: 0.87365   1st Qu.: -0.03933   1st Qu.:0.0000   1st Qu.:   0.000
##  Median : 2.00246   Median :  0.24752   Median :1.0000   Median :   5.994
##  Mean   : 2.66963   Mean   :  3.47560   Mean   :0.5328   Mean   : 279.417
##  3rd Qu.: 3.80156   3rd Qu.:  2.35855   3rd Qu.:1.0000   3rd Qu.: 521.982
##  Max.   :13.91746   Max.   : 58.78006   Max.   :3.0000   Max.   :1170.471
##
##  FP_NEEnight_uStar FP_Temp_uStar       E_0_uStar      R_ref_uStar
##  Min.   :-4.12     Min.   :-16.710   Min.   :181.8   Min.   :0.3515
##  1st Qu.: 0.67     1st Qu.:  3.360   1st Qu.:181.8   1st Qu.:1.7262
##  Median : 1.23     Median :  9.970   Median :181.8   Median :2.3994
##  Mean   : 1.88     Mean   :  9.664   Mean   :181.8   Mean   :2.9644
##  3rd Qu.: 2.66     3rd Qu.: 15.520   3rd Qu.:181.8   3rd Qu.:3.5957
##  Max.   :12.94     Max.   : 34.680   Max.   :181.8   Max.   :9.3886
```

```
##  NA's   :43188
##    Reco_uStar         GPP_uStar_f          GPP_uStar_fqc
##  Min.   : 0.06392   Min.   :-10.54515   Min.   :0.0000
##  1st Qu.: 0.86315   1st Qu.: -0.05545   1st Qu.:0.0000
##  Median : 1.95545   Median :  0.22373   Median :0.0000
##  Mean   : 2.59036   Mean   :  3.40354   Mean   :0.5071
##  3rd Qu.: 3.68605   3rd Qu.:  2.25411   3rd Qu.:1.0000
##  Max.   :14.08955   Max.   : 58.69400   Max.   :3.0000
##
```

Plot the GPP and Reco for `U50` scenario against time for two days (`48*2`).

```
nRec = 48*2
plot(head(DEGebExampleV1$DateTime, nRec), head(ReichsteinPart$GPP_U50_f,nRec), type = "l",
     xlab = 'Time', ylab = 'NEE_U50')
lines(head(DEGebExampleV1$DateTime, nRec), head(ReichsteinPart$Reco_U50,nRec), type = "l",
     col = 'red')
```



Step 5-1-3: Gebesee Lasslop Partitioning

Partitioning the data into the fractions of the Gross Primary Production (GPP) and ecosystem respiration (R_{eco}) using all (u_*) scenarios. This uses the 'sGLFluxPartitionUStarScens' function.

More details on the equations used can be found in the Lasslop et al. (2010).

```r
EProcDEGeb$sGLFluxPartitionUStarScens()
```

```
## Warning in sqrt(dsAssoc$wBefore^2 * varPred2[[1]][, "varGPP"] +
## dsAssoc$wAfter^2 * : NaNs produced

## Warning in sqrt(dsAssoc$wBefore^2 * varPred2[[1]][, "varGPP"] +
## dsAssoc$wAfter^2 * : NaNs produced
```

Export and summarize the results

```r
LasslopPart <- EProcDEGeb$sExportResults()
summary(LasslopPart)
```

```
##      season      Ustar_uStar_Thres Ustar_uStar_fqc  NEE_uStar_orig
##  2006120: 8880   Min.   :0.04842   Min.   :0.0000   Min.   :-49.919
##  2005320: 7920   1st Qu.:0.06967   1st Qu.:0.0000   1st Qu.: -2.803
##  2004070: 6720   Median :0.12037   Median :0.0000   Median :  0.546
##  2005180: 6720   Mean   :0.11262   Mean   :0.3187   Mean   : -2.353
##  2004320: 5568   3rd Qu.:0.13473   3rd Qu.:1.0000   3rd Qu.:  1.794
##  2004210: 5280   Max.   :0.25094   Max.   :4.0000   Max.   : 18.668
##  (Other):11520                                      NA's   :25112
##   NEE_uStar_f        NEE_uStar_fqc    NEE_uStar_fall      NEE_uStar_fall_qc
##  Min.   :-49.91900   Min.   :0.0000   Min.   :-40.26775   Min.   :1.000
##  1st Qu.:  0.01475   1st Qu.:0.0000   1st Qu.:  0.06288   1st Qu.:1.000
##  Median :  0.79000   Median :0.0000   Median :  0.80624   Median :1.000
##  Mean   : -0.81318   Mean   :0.5071   Mean   : -0.80384   Mean   :1.032
##  3rd Qu.:  2.22525   3rd Qu.:1.0000   3rd Qu.:  2.28422   3rd Qu.:1.000
##  Max.   : 18.66800   Max.   :3.0000   Max.   : 10.45100   Max.   :3.000
##
##  NEE_uStar_fnum   NEE_uStar_fsd       NEE_uStar_fmeth NEE_uStar_fwin
##  Min.   :  2.00   Min.   : 0.005657   Min.   :1.000   Min.   : 1.00
##  1st Qu.: 12.00   1st Qu.: 0.302818   1st Qu.:1.000   1st Qu.:14.00
##  Median : 27.00   Median : 0.639365   Median :1.000   Median :14.00
##  Mean   : 46.96   Mean   : 1.089787   Mean   :1.024   Mean   :14.44
##  3rd Qu.: 65.00   3rd Qu.: 1.414365   3rd Qu.:1.000   3rd Qu.:14.00
##  Max.   :323.00   Max.   :14.470233   Max.   :3.000   Max.   :98.00
##
##  Ustar_U05_Thres   Ustar_U05_fqc     NEE_U05_orig       NEE_U05_f
##  Min.   :0.04770   Min.   :0.0000   Min.   :-49.919   Min.   :-49.9190
##  1st Qu.:0.05960   1st Qu.:0.0000   1st Qu.: -2.266   1st Qu.:  0.0116
##  Median :0.07859   Median :0.0000   Median :  0.602   Median :  0.7610
##  Mean   :0.07983   Mean   :0.2685   Mean   : -2.124   Mean   : -0.8372
##  3rd Qu.:0.09058   3rd Qu.:0.0000   3rd Qu.:  1.810   3rd Qu.:  2.1763
##  Max.   :0.13409   Max.   :4.0000   Max.   : 19.008   Max.   : 19.0080
##                                     NA's   :23370
##   NEE_U05_fqc      NEE_U05_fall       NEE_U05_fall_qc  NEE_U05_fnum
##  Min.   :0.0000   Min.   :-40.26775   Min.   :1.000   Min.   :  2.00
##  1st Qu.:0.0000   1st Qu.:  0.06245   1st Qu.:1.000   1st Qu.: 12.00
##  Median :0.0000   Median :  0.77427   Median :1.000   Median : 30.00
##  Mean   :0.4718   Mean   : -0.82721   Mean   :1.029   Mean   : 53.03
##  3rd Qu.:1.0000   3rd Qu.:  2.23871   3rd Qu.:1.000   3rd Qu.: 77.00
##  Max.   :3.0000   Max.   : 10.45100   Max.   :3.000   Max.   :368.00
```

```
##
##   NEE_U05_fsd        NEE_U05_fmeth   NEE_U05_fwin   Ustar_U50_Thres
##  Min.   : 0.005657   Min.   :1.00   Min.   : 1.00   Min.   :0.06468
##  1st Qu.: 0.307294   1st Qu.:1.00   1st Qu.:14.00   1st Qu.:0.06916
##  Median : 0.656494   Median :1.00   Median :14.00   Median :0.10785
##  Mean   : 1.102335   Mean   :1.02   Mean   :14.41   Mean   :0.11038
##  3rd Qu.: 1.449568   3rd Qu.:1.00   3rd Qu.:14.00   3rd Qu.:0.13121
##  Max.   :14.470233   Max.   :3.00   Max.   :98.00   Max.   :0.22627
##
##  Ustar_U50_fqc     NEE_U50_orig       NEE_U50_f        NEE_U50_fqc
##  Min.   :0.0000   Min.   :-49.919   Min.   :-49.919   Min.   :0.0000
##  1st Qu.:0.0000   1st Qu.: -2.711   1st Qu.:  0.013   1st Qu.:0.0000
##  Median :0.0000   Median :  0.563   Median :  0.773   Median :0.0000
##  Mean   :0.3193   Mean   : -2.312   Mean   : -0.819   Mean   :0.5016
##  3rd Qu.:1.0000   3rd Qu.:  1.780   3rd Qu.:  2.217   3rd Qu.:1.0000
##  Max.   :4.0000   Max.   : 18.668   Max.   : 18.668   Max.   :3.0000
##                   NA's   :24781
##   NEE_U50_fall       NEE_U50_fall_qc  NEE_U50_fnum     NEE_U50_fsd
##  Min.   :-40.26775   Min.   :1.000   Min.   :  2.00   Min.   : 0.000707
##  1st Qu.:  0.06426   1st Qu.:1.000   1st Qu.: 12.00   1st Qu.: 0.299619
##  Median :  0.78075   Median :1.000   Median : 27.00   Median : 0.639790
##  Mean   : -0.80964   Mean   :1.033   Mean   : 48.24   Mean   : 1.088904
##  3rd Qu.:  2.26818   3rd Qu.:1.000   3rd Qu.: 68.00   3rd Qu.: 1.434993
##  Max.   : 10.45100   Max.   :3.000   Max.   :348.00   Max.   :14.470233
##
##  NEE_U50_fmeth    NEE_U50_fwin   Ustar_U95_Thres   Ustar_U95_fqc
##  Min.   :1.000   Min.   : 1.00   Min.   :0.08652   Min.   :0.0000
##  1st Qu.:1.000   1st Qu.:14.00   1st Qu.:0.08885   1st Qu.:0.0000
##  Median :1.000   Median :14.00   Median :0.13950   Median :0.0000
##  Mean   :1.022   Mean   :14.45   Mean   :0.14277   Mean   :0.3648
##  3rd Qu.:1.000   3rd Qu.:14.00   3rd Qu.:0.18281   3rd Qu.:1.0000
##  Max.   :3.000   Max.   :98.00   Max.   :0.27477   Max.   :4.0000
##
##   NEE_U95_orig       NEE_U95_f         NEE_U95_fqc      NEE_U95_fall
##  Min.   :-49.919   Min.   :-49.919   Min.   :0.0000   Min.   :-40.26775
##  1st Qu.: -3.288   1st Qu.:  0.015   1st Qu.:0.0000   1st Qu.:  0.06076
##  Median :  0.498   Median :  0.782   Median :1.0000   Median :  0.78783
##  Mean   : -2.559   Mean   : -0.806   Mean   :0.5328   Mean   : -0.79717
##  3rd Qu.:  1.738   3rd Qu.:  2.232   3rd Qu.:1.0000   3rd Qu.:  2.28560
##  Max.   : 18.668   Max.   : 18.668   Max.   :3.0000   Max.   : 10.58200
##  NA's   :26384
##  NEE_U95_fall_qc  NEE_U95_fnum     NEE_U95_fsd        NEE_U95_fmeth
##  Min.   :1.000   Min.   :  2.00   Min.   : 0.000707   Min.   :1.000
##  1st Qu.:1.000   1st Qu.: 11.00   1st Qu.: 0.301369   1st Qu.:1.000
##  Median :1.000   Median : 24.00   Median : 0.621600   Median :1.000
##  Mean   :1.033   Mean   : 42.85   Mean   : 1.077977   Mean   :1.028
##  3rd Qu.:1.000   3rd Qu.: 59.00   3rd Qu.: 1.396538   3rd Qu.:1.000
##  Max.   :3.000   Max.   :315.00   Max.   :14.470233   Max.   :3.000
##
##   NEE_U95_fwin      Rg_orig            Rg_f             Rg_fqc
##  Min.   : 1.00   Min.   :   0.00   Min.   :   0.00   Min.   :0
##  1st Qu.:14.00   1st Qu.:   0.00   1st Qu.:   0.00   1st Qu.:0
##  Median :14.00   Median :   2.04   Median :   2.04   Median :0
##  Mean   :14.46   Mean   : 124.71   Mean   : 124.71   Mean   :0
```

```
##  3rd Qu.:14.00   3rd Qu.: 176.03   3rd Qu.: 176.03   3rd Qu.:0
##  Max.   :98.00   Max.   :1046.03   Max.   :1046.03   Max.   :0
##
##     Rg_fall          Rg_fall_qc       Rg_fnum          Rg_fsd
##  Min.   :   0.00   Min.   : NA     Min.   : NA     Min.   : NA
##  1st Qu.:   0.00   1st Qu.: NA     1st Qu.: NA     1st Qu.: NA
##  Median :   2.04   Median : NA     Median : NA     Median : NA
##  Mean   : 124.71   Mean   :NaN     Mean   :NaN     Mean   :NaN
##  3rd Qu.: 176.03   3rd Qu.: NA     3rd Qu.: NA     3rd Qu.: NA
##  Max.   :1046.03   Max.   : NA     Max.   : NA     Max.   : NA
##                    NA's   :52608   NA's   :52608   NA's   :52608
##     Rg_fmeth        Rg_fwin        Tair_orig          Tair_f
##  Min.   : NA     Min.   : NA     Min.   :-16.710   Min.   :-16.710
##  1st Qu.: NA     1st Qu.: NA     1st Qu.:  3.360   1st Qu.:  3.360
##  Median : NA     Median : NA     Median :  9.970   Median :  9.970
##  Mean   :NaN     Mean   :NaN     Mean   :  9.664   Mean   :  9.664
##  3rd Qu.: NA     3rd Qu.: NA     3rd Qu.: 15.520   3rd Qu.: 15.520
##  Max.   : NA     Max.   : NA     Max.   : 34.680   Max.   : 34.680
##  NA's   :52608   NA's   :52608
##     Tair_fqc   Tair_fall        Tair_fall_qc     Tair_fnum        Tair_fsd
##  Min.   :0   Min.   :-16.710   Min.   : NA     Min.   : NA     Min.   : NA
##  1st Qu.:0   1st Qu.:  3.360   1st Qu.: NA     1st Qu.: NA     1st Qu.: NA
##  Median :0   Median :  9.970   Median : NA     Median : NA     Median : NA
##  Mean   :0   Mean   :  9.664   Mean   :NaN     Mean   :NaN     Mean   :NaN
##  3rd Qu.:0   3rd Qu.: 15.520   3rd Qu.: NA     3rd Qu.: NA     3rd Qu.: NA
##  Max.   :0   Max.   : 34.680   Max.   : NA     Max.   : NA     Max.   : NA
##                                NA's   :52608   NA's   :52608   NA's   :52608
##    Tair_fmeth      Tair_fwin        VPD_orig          VPD_f
##  Min.   : NA     Min.   : NA     Min.   : 0.000   Min.   : 0.000
##  1st Qu.: NA     1st Qu.: NA     1st Qu.: 1.106   1st Qu.: 1.106
##  Median : NA     Median : NA     Median : 2.246   Median : 2.246
##  Mean   :NaN     Mean   :NaN     Mean   : 4.136   Mean   : 4.135
##  3rd Qu.: NA     3rd Qu.: NA     3rd Qu.: 5.027   3rd Qu.: 5.026
##  Max.   : NA     Max.   : NA     Max.   :44.321   Max.   :44.321
##  NA's   :52608   NA's   :52608   NA's   :1
##     VPD_fqc          VPD_fall       VPD_fall_qc       VPD_fnum
##  Min.   :0.0e+00   Min.   : 0.000   Min.   :1       Min.   :372
##  1st Qu.:0.0e+00   1st Qu.: 1.106   1st Qu.:1       1st Qu.:372
##  Median :0.0e+00   Median : 2.246   Median :1       Median :372
##  Mean   :1.9e-05   Mean   : 4.135   Mean   :1       Mean   :372
##  3rd Qu.:0.0e+00   3rd Qu.: 5.026   3rd Qu.:1       3rd Qu.:372
##  Max.   :1.0e+00   Max.   :44.321   Max.   :1       Max.   :372
##                                     NA's   :52607   NA's   :52607
##     VPD_fsd        VPD_fmeth        VPD_fwin       PotRad_U05
##  Min.   :3.85    Min.   :2       Min.   :14      Min.   :   0.000
##  1st Qu.:3.85    1st Qu.:2       1st Qu.:14      1st Qu.:   0.000
##  Median :3.85    Median :2       Median :14      Median :   5.994
##  Mean   :3.85    Mean   :2       Mean   :14      Mean   : 279.417
##  3rd Qu.:3.85    3rd Qu.:2       3rd Qu.:14      3rd Qu.: 521.982
##  Max.   :3.85    Max.   :2       Max.   :14      Max.   :1170.471
##  NA's   :52607   NA's   :52607   NA's   :52607
##  FP_NEEnight_U05  FP_Temp_U05         E_0_U05        R_ref_U05
##  Min.   :-4.47   Min.   :-16.710   Min.   :186.2   Min.   :0.6146
##  1st Qu.: 0.66   1st Qu.:  3.360   1st Qu.:186.2   1st Qu.:1.7204
```

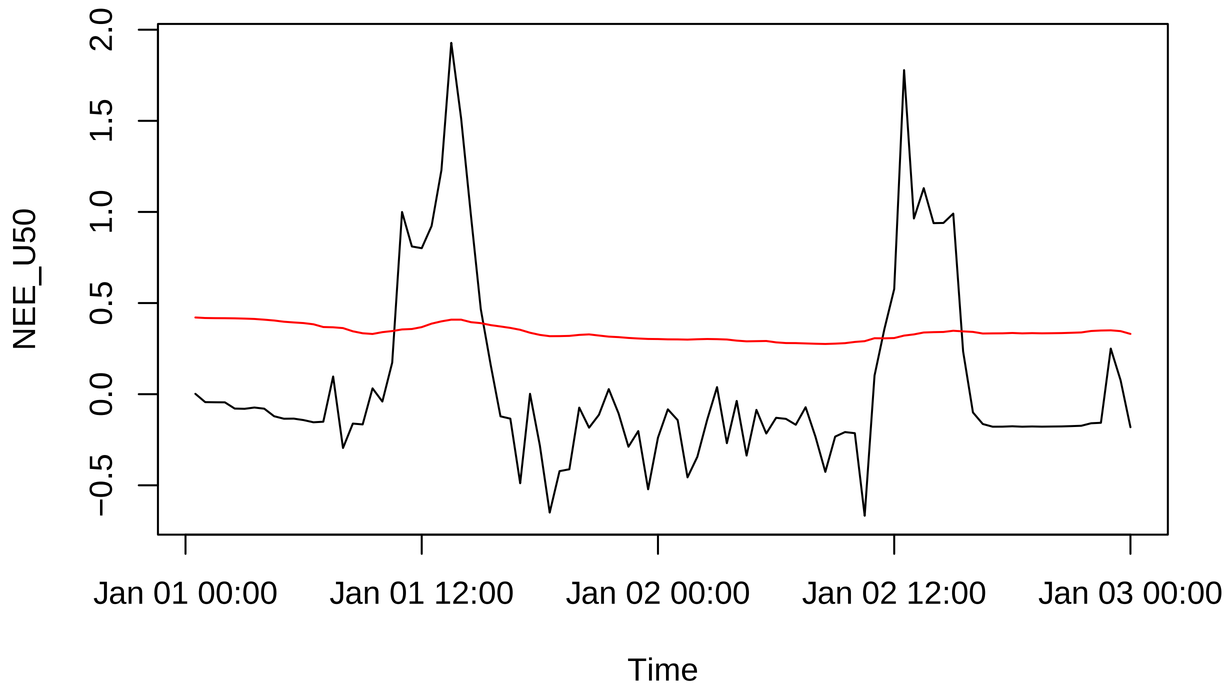
```
##  Median : 1.17   Median :  9.970   Median :186.2   Median :2.2758
##  Mean   : 1.82   Mean   :  9.664   Mean   :186.2   Mean   :2.9148
##  3rd Qu.: 2.53   3rd Qu.: 15.520   3rd Qu.:186.2   3rd Qu.:3.4756
##  Max.   :19.01   Max.   : 34.680   Max.   :186.2   Max.   :9.5245
##  NA's   :41552
##     Reco_U05          GPP_U05_f          GPP_U05_fqc       PotRad_U50
##  Min.   : 0.06148   Min.   :-11.06670   Min.   :0.0000   Min.   :   0.000
##  1st Qu.: 0.83666   1st Qu.: -0.06693   1st Qu.:0.0000   1st Qu.:   0.000
##  Median : 1.88022   Median :  0.20682   Median :0.0000   Median :   5.994
##  Mean   : 2.53468   Mean   :  3.37185   Mean   :0.4718   Mean   : 279.417
##  3rd Qu.: 3.58295   3rd Qu.:  2.16944   3rd Qu.:1.0000   3rd Qu.: 521.982
##  Max.   :13.20519   Max.   : 58.65293   Max.   :3.0000   Max.   :1170.471
##
##  FP_NEEnight_U50  FP_Temp_U50         E_0_U50        R_ref_U50
##  Min.   :-4.47   Min.   :-16.710   Min.   :182.5   Min.   :0.4881
##  1st Qu.: 0.66   1st Qu.:  3.360   1st Qu.:182.5   1st Qu.:1.7191
##  Median : 1.20   Median :  9.970   Median :182.5   Median :2.3374
##  Mean   : 1.85   Mean   :  9.664   Mean   :182.5   Mean   :2.9553
##  3rd Qu.: 2.60   3rd Qu.: 15.520   3rd Qu.:182.5   3rd Qu.:3.5793
##  Max.   :13.12   Max.   : 34.680   Max.   :182.5   Max.   :9.5301
##  NA's   :42872
##     Reco_U50          GPP_U50_f          GPP_U50_fqc       PotRad_U95
##  Min.   : 0.06353   Min.   :-10.88804   Min.   :0.0000   Min.   :   0.000
##  1st Qu.: 0.85010   1st Qu.: -0.05176   1st Qu.:0.0000   1st Qu.:   0.000
##  Median : 1.91661   Median :  0.21728   Median :0.0000   Median :   5.994
##  Mean   : 2.58240   Mean   :  3.40143   Mean   :0.5016   Mean   : 279.417
##  3rd Qu.: 3.63605   3rd Qu.:  2.20014   3rd Qu.:1.0000   3rd Qu.: 521.982
##  Max.   :13.11290   Max.   : 58.78027   Max.   :3.0000   Max.   :1170.471
##
##  FP_NEEnight_U95  FP_Temp_U95         E_0_U95        R_ref_U95
##  Min.   :-4.12   Min.   :-16.710   Min.   :180.3   Min.   :0.3506
##  1st Qu.: 0.67   1st Qu.:  3.360   1st Qu.:180.3   1st Qu.:1.7326
##  Median : 1.23   Median :  9.970   Median :180.3   Median :2.4772
##  Mean   : 1.88   Mean   :  9.664   Mean   :180.3   Mean   :3.0367
##  3rd Qu.: 2.65   3rd Qu.: 15.520   3rd Qu.:180.3   3rd Qu.:3.6609
##  Max.   :12.94   Max.   : 34.680   Max.   :180.3   Max.   :9.4606
##  NA's   :44369
##     Reco_U95          GPP_U95_f          GPP_U95_fqc      PotRad_uStar
##  Min.   : 0.06481   Min.   :-10.55077   Min.   :0.0000   Min.   :   0.000
##  1st Qu.: 0.87365   1st Qu.: -0.03933   1st Qu.:0.0000   1st Qu.:   0.000
##  Median : 2.00246   Median :  0.24752   Median :1.0000   Median :   5.994
##  Mean   : 2.66963   Mean   :  3.47560   Mean   :0.5328   Mean   : 279.417
##  3rd Qu.: 3.80156   3rd Qu.:  2.35855   3rd Qu.:1.0000   3rd Qu.: 521.982
##  Max.   :13.91746   Max.   : 58.78006   Max.   :3.0000   Max.   :1170.471
##
##  FP_NEEnight_uStar FP_Temp_uStar       E_0_uStar      R_ref_uStar
##  Min.   :-4.12     Min.   :-16.710   Min.   :181.8   Min.   :0.3515
##  1st Qu.: 0.67     1st Qu.:  3.360   1st Qu.:181.8   1st Qu.:1.7262
##  Median : 1.23     Median :  9.970   Median :181.8   Median :2.3994
##  Mean   : 1.88     Mean   :  9.664   Mean   :181.8   Mean   :2.9644
##  3rd Qu.: 2.66     3rd Qu.: 15.520   3rd Qu.:181.8   3rd Qu.:3.5957
##  Max.   :12.94     Max.   : 34.680   Max.   :181.8   Max.   :9.3886
##  NA's   :43188
##    Reco_uStar        GPP_uStar_f        GPP_uStar_fqc      PotRad_NEW
```

```
##  Min.   : 0.06392   Min.   :-10.54515   Min.   :0.0000   Min.   :   0.000
##  1st Qu.: 0.86315   1st Qu.: -0.05545   1st Qu.:0.0000   1st Qu.:   0.000
##  Median : 1.95545   Median :  0.22373   Median :0.0000   Median :   5.994
##  Mean   : 2.59036   Mean   :  3.40354   Mean   :0.5071   Mean   : 279.417
##  3rd Qu.: 3.68605   3rd Qu.:  2.25411   3rd Qu.:1.0000   3rd Qu.: 521.982
##  Max.   :14.08955   Max.   : 58.69400   Max.   :3.0000   Max.   :1170.471
##
##   Reco_DT_U05         GPP_DT_U05       Reco_DT_U05_SD    GPP_DT_U05_SD
##  Min.   : 0.001762   Min.   : 0.00000   Min.   :0.01606   Min.   :0.0000
##  1st Qu.: 0.590982   1st Qu.: 0.00000   1st Qu.:0.13788   1st Qu.:0.0000
##  Median : 1.613478   Median : 0.01532   Median :0.24237   Median :0.0000
##  Mean   : 2.338669   Mean   : 3.36451   Mean   :0.36851   Mean   :0.1659
##  3rd Qu.: 3.311402   3rd Qu.: 1.89190   3rd Qu.:0.50258   3rd Qu.:0.2160
##  Max.   :15.819516   Max.   :50.42574   Max.   :5.33172   Max.   :3.9723
##                                                           NA's   :216
##   Reco_DT_U50         GPP_DT_U50       Reco_DT_U50_SD    GPP_DT_U50_SD
##  Min.   : 0.006236   Min.   : 0.00000   Min.   :0.01693   Min.   :0.0000
##  1st Qu.: 0.575918   1st Qu.: 0.00000   1st Qu.:0.16548   1st Qu.:0.0000
##  Median : 1.638213   Median : 0.01853   Median :0.31819   Median :0.0000
##  Mean   : 2.353489   Mean   : 3.40110   Mean   :0.40569   Mean   :0.1848
##  3rd Qu.: 3.429624   3rd Qu.: 2.01745   3rd Qu.:0.55425   3rd Qu.:0.2933
##  Max.   :15.467986   Max.   :50.37063   Max.   :5.00099   Max.   :3.9556
##
##   Reco_DT_U95         GPP_DT_U95       Reco_DT_U95_SD    GPP_DT_U95_SD
##  Min.   : 0.004086   Min.   : 0.00000   Min.   :0.01896   Min.   :0.0000
##  1st Qu.: 0.622133   1st Qu.: 0.00000   1st Qu.:0.14425   1st Qu.:0.0000
##  Median : 1.644569   Median : 0.01958   Median :0.28096   Median :0.0000
##  Mean   : 2.360291   Mean   : 3.37777   Mean   :0.40658   Mean   :0.1766
##  3rd Qu.: 3.429336   3rd Qu.: 1.96480   3rd Qu.:0.56092   3rd Qu.:0.2347
##  Max.   :14.892974   Max.   :50.37084   Max.   :6.05250   Max.   :3.9749
##                                                           NA's   :58
##   FP_VARnight      FP_VARday       NEW_FP_Temp       NEW_FP_VPD
##  Min.   :-4.12   Min.   :-49.92   Min.   :-16.710   Min.   : 0.000
##  1st Qu.: 0.67   1st Qu.: -8.50   1st Qu.:  3.360   1st Qu.: 1.106
##  Median : 1.23   Median : -0.85   Median :  9.970   Median : 2.246
##  Mean   : 1.88   Mean   : -4.67   Mean   :  9.664   Mean   : 4.135
##  3rd Qu.: 2.66   3rd Qu.:  1.16   3rd Qu.: 15.520   3rd Qu.: 5.026
##  Max.   :12.94   Max.   : 18.67   Max.   : 34.680   Max.   :44.321
##  NA's   :43230   NA's   :34808
##  FP_RRef_Night       FP_qc          FP_dRecPar          FP_errorcode
##  Min.   :0.59    Min.   :0.0000   Min.   :-1001.0000   Min.   :   0.0
##  1st Qu.:1.75    1st Qu.:0.0000   1st Qu.:  -34.0000   1st Qu.:   0.0
##  Median :2.63    Median :1.0000   Median :    0.0000   Median :   0.0
##  Mean   :3.10    Mean   :0.7269   Mean   :    0.5638   Mean   : 289.6
##  3rd Qu.:3.75    3rd Qu.:1.0000   3rd Qu.:   34.0000   3rd Qu.:1002.0
##  Max.   :9.43    Max.   :2.0000   Max.   : 1001.0000   Max.   :1011.0
##  NA's   :52061                                         NA's   :52061
##    FP_GPP2000        FP_k          FP_beta         FP_alpha
##  Min.   : 0.00   Min.   :0.00    Min.   : 0.00   Min.   :0.00
##  1st Qu.: 3.12   1st Qu.:0.02    1st Qu.: 3.85   1st Qu.:0.02
##  Median : 9.39   Median :0.05    Median :10.47   Median :0.06
##  Mean   :19.25   Mean   :0.10    Mean   :24.16   Mean   :0.06
##  3rd Qu.:36.59   3rd Qu.:0.05    3rd Qu.:47.55   3rd Qu.:0.11
##  Max.   :66.75   Max.   :6.19    Max.   :95.84   Max.   :0.21
```

```
##  NA's   :52219   NA's   :52219   NA's   :52219   NA's   :52219
##     FP_RRef          FP_E0          FP_k_sd       FP_beta_sd
##  Min.   : 0.00   Min.   : 45.3   Min.   :0.00    Min.   : 0.00
##  1st Qu.: 1.57   1st Qu.:128.3   1st Qu.:0.01    1st Qu.: 0.64
##  Median : 2.52   Median :180.6   Median :0.03    Median : 1.64
##  Mean   : 3.14   Mean   :182.6   Mean   :0.15    Mean   : 2.40
##  3rd Qu.: 4.20   3rd Qu.:224.5   3rd Qu.:0.09    3rd Qu.: 3.22
##  Max.   :12.42   Max.   :371.3   Max.   :2.08    Max.   :16.12
##  NA's   :52219   NA's   :52061   NA's   :52466   NA's   :52219
##   FP_alpha_sd      FP_RRef_sd       FP_E0_sd      Reco_DT_uStar
##  Min.   :0.00    Min.   :0.05    Min.   : 14.17   Min.   : 0.000731
##  1st Qu.:0.01    1st Qu.:0.30    1st Qu.: 39.16   1st Qu.: 0.588511
##  Median :0.01    Median :0.47    Median : 58.59   Median : 1.567060
##  Mean   :0.16    Mean   :0.61    Mean   : 71.24   Mean   : 2.341419
##  3rd Qu.:0.02    3rd Qu.:0.80    3rd Qu.: 82.63   3rd Qu.: 3.455995
##  Max.   :6.08    Max.   :3.72    Max.   :463.59   Max.   :15.237787
##  NA's   :52247   NA's   :52219   NA's   :52061
##   GPP_DT_uStar      Reco_DT_uStar_SD  GPP_DT_uStar_SD
##  Min.   : 0.00000   Min.   :0.01289   Min.   :   0.0000
##  1st Qu.: 0.00000   1st Qu.:0.14561   1st Qu.:   0.0000
##  Median : 0.00863   Median :0.26700   Median :   0.0000
##  Mean   : 3.35264   Mean   :0.38150   Mean   :   4.4799
##  3rd Qu.: 1.80500   3rd Qu.:0.48936   3rd Qu.:   0.3239
##  Max.   :50.36409   Max.   :3.73757   Max.   :2729.1336
##
```

Plot the GPP and Reco for `U50` scenario against time for two days (`48*2`).

```r
nRec <- 48*2
plot(head(DEGebExampleV1$DateTime, nRec), head(LasslopPart$GPP_U50_f,nRec), type = 'l',
     xlab = 'Time', ylab = 'NEE_U50')
lines(head(DEGebExampleV1$DateTime, nRec), head(LasslopPart$Reco_U50,nRec), type = "l",
      col = 'red')
```



Step 5-1-4: Fingerprint Plots of GPP_DT and Reco_DT

PDFs that contain the fingerprint plots will be generated and placed in the folder `figs`.

- The non-bootstrapped data has the `uStar` suffix.
- The bootstrapped data has the scenario suffix, e.g., `U50`, `U95`, etc.

```
EProcDEGeb$sPlotFingerprint("GPP_DT_U50", Dir = "figs")
```

```
## Saved plot to: figs/DE-Geb_04-06_FP_GPP_DT_U50.pdf
```

```
EProcDEGeb$sPlotFingerprint("Reco_DT_U50", Dir = "figs")
```

```
## Saved plot to: figs/DE-Geb_04-06_FP_Reco_DT_U50.pdf
```

Step 5-1-5: Export the Gebesee Results

This part will produce a text file for analysis outside R. It will be placed in the folder `results`.

```
GebResults <- EProcDEGeb$sExportResults()
GebData <- EProcDEGeb$sExportData()
GebCombResults <- cbind(GebData, GebResults)
fWriteDataframeToFile(GebCombResults, "DE-Geb_Part.txt", Dir = "results")
```

```
## fWriteDataframeToFile:::fSetFile::: Directory created: results

## Number of NA convertered to '-9999': 1840545

## Wrote tab separated textfile: results/DE-Geb_Part.txt
```

Step 6-1: Gebesee Bias with u_{*Th}

Bias for the Year 2004

Create a subset data frame from the combined results.

```
GebCombResults$year <- as.POSIXlt(GebCombResults$DateTime)$year + 1900
Geb2004 <- subset(GebCombResults, year == 2004)
```

Step 6-1-1: Calculate the Annual Mean of NEE for each u_{*Th} scenario

We will use the gap-filled data of the difference scenarios.

```
GebScenarios <- c("uStar","U05","U50","U95")
NEE_UStar <- sapply(GebScenarios, function(suffix){
  colName = paste0("NEE_",suffix,"_f")
  mean(Geb2004[[colName]])
})
NEE_UStar
```

```
##      uStar        U05        U50        U95
## -0.5667606 -0.5780693 -0.5629376 -0.5470766
```

Step 6-1-2: Calculate the Statistics

Calculate the mean, standard deviation, and relative error.

```
c(mean(NEE_UStar), sd(NEE_UStar), sd(NEE_UStar)/abs(mean(NEE_UStar)))
```

```
## [1] -0.56371104  0.01281615  0.02273531
```

Step 7-1: Random Uncertainty Aggregation

Step 7-1-1: Gebesee Calculate Error Terms

To calculate the error, the replaced NEE using the gap-filling method or `NEE_uStar_fall` is subtracted from the original NEE values `NEE_ustar_orig`. The resulting value is the residual.

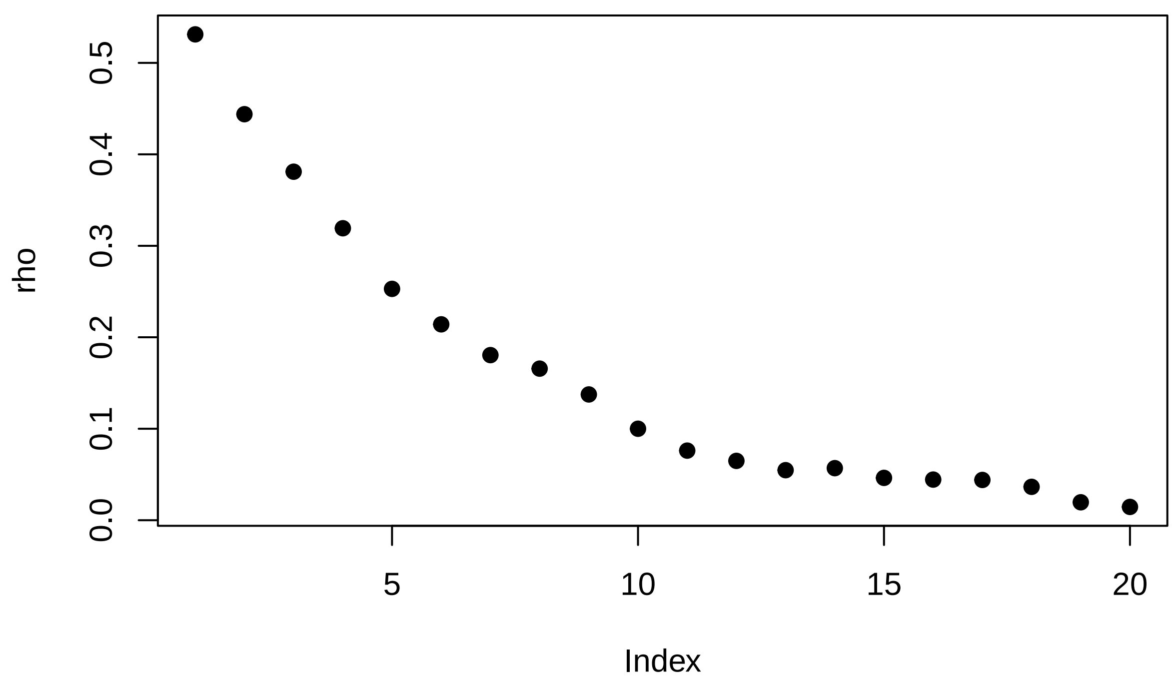
```r
n <- sum(GebCombResults$NEE_uStar_fqc == 0)

# All Results
GebCombResults$residual <- ifelse(GebCombResults$NEE_uStar_fqc == 0,
                                  GebCombResults$NEE_uStar_orig - GebCombResults$NEE_uStar_fall,
                                  NA)

# Gebesee 2004 Results for Future Analysis
Geb2004$residual <- ifelse(Geb2004$NEE_uStar_fqc == 0,
                           Geb2004$NEE_uStar_orig - Geb2004$NEE_uStar_fall,
                           NA)
```

Step 6-1-2: Calculate the Empirical Autocorrelation Function

```r
library(lognorm)
rho <- computeEffectiveAutoCorr(GebCombResults$residual)
plot(rho[-1], ylab = 'rho', pch = 19)
```



Step 6-1-3: Calculate the Effective Number of Observations Create the variable `nEff` and compare to the number of good observations `n`.

```r
nEff <- computeEffectiveNumObs(GebCombResults$residual, na.rm = TRUE)
c(nEff, n)
```

```
## [1]  4699.79 27496.00
```

Step 6-1-4: Calculate the Effective Number of Observation for 2004

We can calculate the number by using the autocorrelation function.

```
?computeEffectiveNumObs # note argument effAcf
### TO_COMPLETE
nEff <- computeEffectiveNumObs(Geb2004$residual, na.rm = TRUE, effAcf = rho)
```

Step 6-1-5: Calculate the Mean Annual NEE and its Standard Deviation for 2004

Using the non-gap-filled data (`NEE_Ustar_f`), the relative error can calculated. Do not use gap-filled records in uncertainty estimation. However, for the mean, the gap-filled values, e.g., `NEE_U50_f`, can be included in the calculation, but in this example, the non-gap-filled results are used.

```
sd_notGapFilled <- Geb2004$NEE_uStar_fsd[Geb2004$NEE_uStar_fqc == 0]

NEE_notGapFilled <- mean(Geb2004$NEE_uStar_f)

sdNEE_notGapFilled = sqrt(mean(sd_notGapFilled^2)) / sqrt(nEff - 1)

c(mean = NEE_notGapFilled, sd = sdNEE_notGapFilled,
  cv = sdNEE_notGapFilled/abs(NEE_notGapFilled))
```

```
##        mean          sd          cv
## -0.56676058  0.05009385  0.08838627
```

Step 6-1-6: Combined Uncertainty for the Random and u_{*Th}

Remember that standard deviation of independent variables adds in squares.

```
sdNEEUStar <- sd(NEE_UStar)
sdNEECombined <- sqrt(sdNEEUStar^2 + sdNEE_notGapFilled^2)
sdNEECombined
```

```
## [1] 0.05170733
```