Simulating Surface Energy Budget and Evapotranspiration with RMEP

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Setting up the environment

Loading the *RMEP* library, which contains data and functions.

```
library(RMEP)
```

- The code below show the simple example in the RMEP package. The evapotranspiration(ETMEP, mm/day), sensible heat flux(HMEP, W/m^2), latent heat flux(EMEP, W/m^2), ground heat flux(GMEP, W/m^2) and effective numbers(ef_id) are given in the outputs list.

Usage

RMEP(Rn,RnL,qs,Ts,type,I,z,. . .)

Example

Calculate evapotranspiration(ET) and heat fluxes

Three variables are required at least in theory for the maximum entropy production (MEP) model inputs, including the net radiation (Rn), specific humidity (qs) and surface temperature (Ts). Net long wave radiation (RnL) variable is also introducing in the RMEP for the case of Water-snow-ice surface in the MEP formulations.

```
RMEP(Rn=300,RnL=100,qs=0.004,Ts=25,I=600,z=2.5,type=1)
#> $ETMEP
#>          [,1]
#> [1,] 2.546414
#>
#> $HMEP
#>          [,1]
#> [1,] 136.7877
```

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```
#>
#> $EMEP
#>          [,1]
#> [1,] 72.20737
#>
#> $GMEP
#>          [,1]
#> [1,] 91.00497
#>
#> $ef_id
#> [1] 1
```

- After calculating, the actual ET is 2.546416 (mm/day), the H, E and G are 136.7877, 72.20737, 91.00497 (W/m^2) respectively, and the effective number is 1. Parameter "Type" represents the condition of surface land cover, type 1 for bare soil surface or short canopy, 2 for dense canopy and 3 for Water-snow-ice surface, and the default is 1.Parameter "I" (constant) is the media thermal inertial (units:TIU),default is 600 TIU. Parameter "z" (constant) is the theoretical height above surface (unit:m), and default is 2.5 m.
- If you want to calculate potential evapotranspiration (PET), only the Rn and Ts two variables are needed.

```
RMEPPET(Rn=300,RnL=100,Ts=25,type=2)
#> [1] "RMEPPET completed!"
#> $PETMEP
#>          [,1]
#> [1,] 7.386154
#>
#> $HMEP
#>          [,1]
#> [1,] 90.55463
#>
#> $EMEP
#>          [,1]
#> [1,] 209.4454
#>
#> $GMEP
#>      [,1]
#> [1,]    0
#>
#> $ef_id
#> [1] 1
```

- The PET is 7.386154 mm/day.

Calculate the specific humidity for MEP model input

To calculate specific humidity(qs), three variables are needed, including: Air temperature(TA, unit: deg C), Relative humidity(RH, unit: percent), and Atmospheric pressure(PA, unit: kPa).

```
Shum(TA=20,PA=101,RH=50)
#> [1] 0.007311296
```

- The qs is 0.007311296 kg/kg.

Calculate the saturated specific humidity for MEP model input

Only one variable: surface temperature(Ts, unit: deg C) are required for calculating saturated specific humidity.

```
SShum(Ts=20)
#> [1] 0.01464032
```

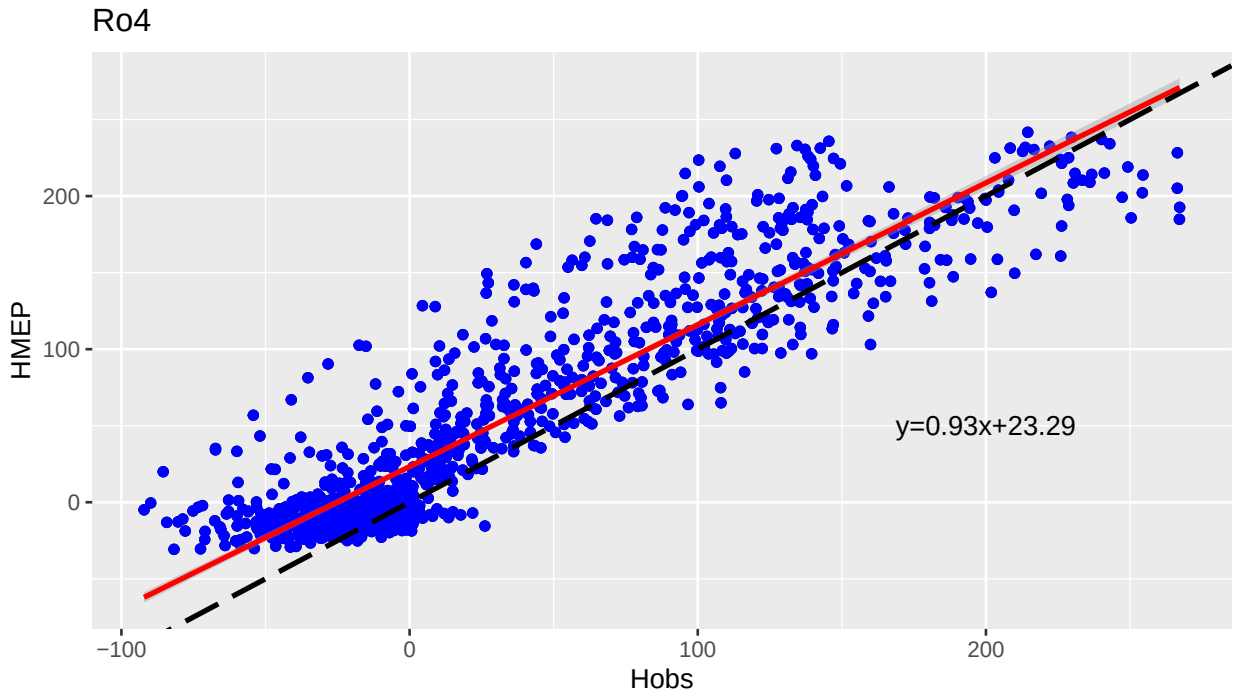
- The saturated specific humidity is 0.01464032 kg/kg.

Analysis of time series data

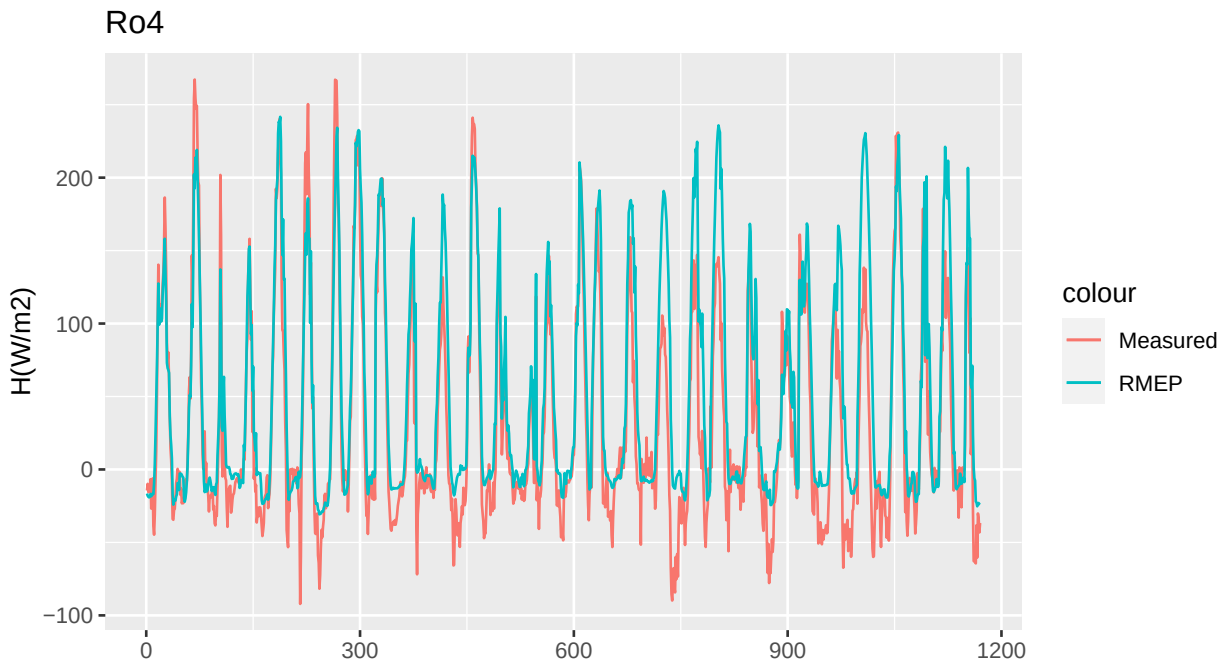
A time series based dataset "datademo" is used for analysis with RMEP, which contains 8 variables during 1-30, June 2016 with half-hourly time step.

```
#Load example data
data("datademo")
Data <- datademo
Data[1:10,] #View the data and variables
#>    year month day hour minute          H         LE       TA       TS    NETRAD
#> 1  2016     6   1    0      0 -14.407263  -9.934079 15.91093 14.49795 -54.32172
#> 2  2016     6   1    0     30  -9.859117  -6.935340 15.52109 14.33843 -58.48128
#> 3  2016     6   1    1      0 -15.518080 -13.240676 15.03826 14.01476 -60.22767
#> 4  2016     6   1    1     30 -13.139322  -5.780158 14.74430 13.72859 -60.86670
#> 5  2016     6   1    2      0 -15.072064  -6.821963 14.72106 13.55086 -58.36591
#> 6  2016     6   1    2     30  -6.674508  -2.759529 14.46212 13.32149 -52.79269
#> 7  2016     6   1    3      0 -26.796906   9.721723 14.39440 13.05945 -56.11091
#> 8  2016     6   1    3     30 -15.078698   1.255220 14.09641 12.91913 -53.41729
#> 9  2016     6   1    4      0  -6.142570  -0.385221 12.98811 12.62078 -49.64660
#> 10 2016     6   1    4     30 -38.875650   7.148115 13.33910 12.35124 -50.47627
#>          RH            G       PA
#> 1  91.30830  2.583116917 98.00363
#> 2  91.37280  1.452023583 97.95211
#> 3  91.55937  1.153016033 97.92966
#> 4  90.53987  0.008579167 97.93804
#> 5  88.27939 -1.558201833 97.95336
#> 6  87.87180 -2.510031500 97.95427
#> 7  81.75238 -3.411356833 97.96003
#> 8  80.25656 -4.911265167 97.97232
#> 9  84.57561 -5.193535083 97.99420
#> 10 80.68737 -6.143775583 98.03209
qs <- Shum(TA <- Data$TA,PA <- Data$PA,RH <- Data$RH) #Calculate specific humidity
Rn <- Data$NETRAD;RnL <- Data$NETRAD #RnL is not used in type=1 so let it equals to Rn
Ts <- Data$TS #Surface temperature
output <- RMEP(Rn,RnL,qs,Ts,type=1) #The results is obtained in the "output" list
simH <- t(output$HMEP);simE <- t(output$EMEP);simG <- t(output$GMEP)#The results of H, E and G as a vec
```

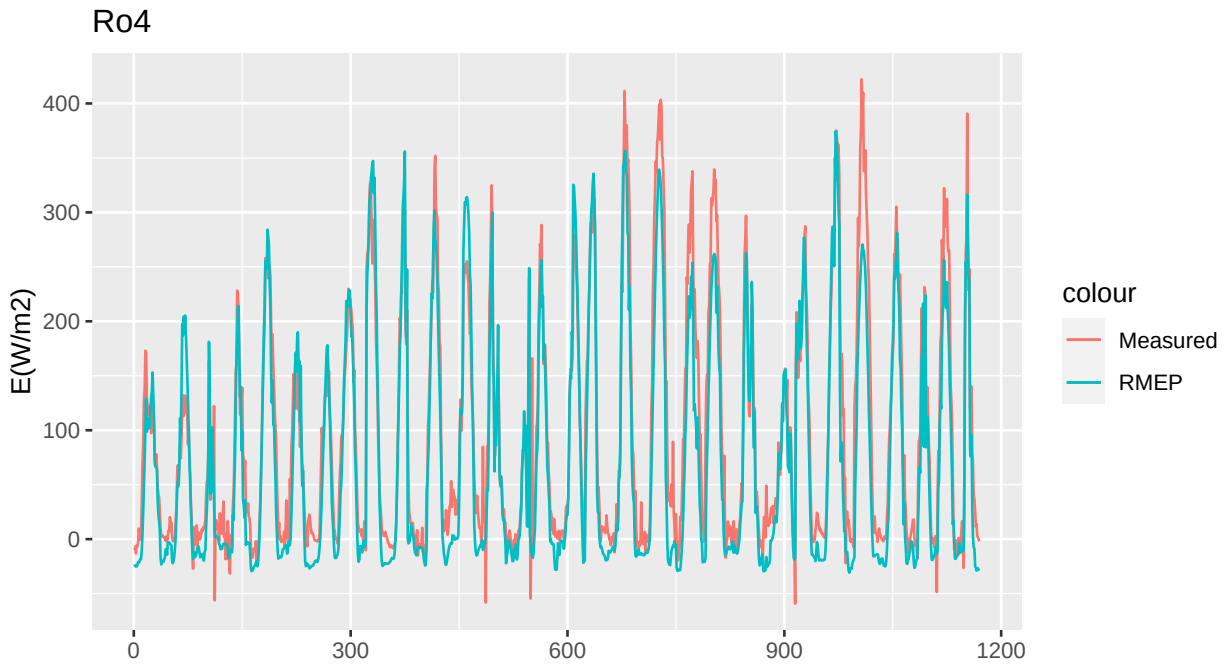
```r
#Package "ggplot2" is used to produce time series plot between RMEP results and observations
library(ggplot2)
lm(simH~Data$H) #Linear fit between calculated and observed H
#>
#> Call:
#> lm(formula = simH ~ Data$H)
#>
#> Coefficients:
#> (Intercept)       Data$H
#>     23.2872       0.9269
qplot(Data$H,simH)+geom_point(col="blue")+geom_smooth(method="lm",formula = y~x,col="red",lty=1)+
  geom_abline(intercept=0, slope=1,col="black",lty=5,lwd=1)+labs(x="Hobs",y="HMEP",title = "Ro4")+
  annotate("text",x=200,y=50,label="y=0.93x+23.29")  #Scatter plot of MEP estimated and observed H
```



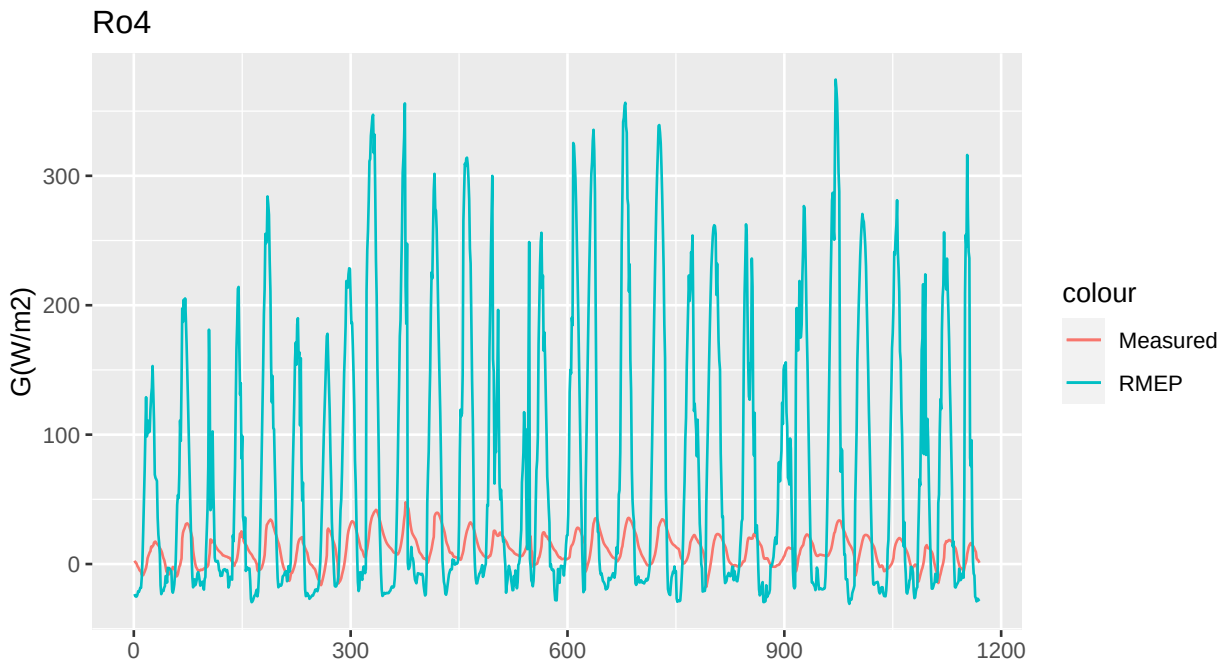

```r
# Time series change between RMEP calculations and measurements
xlab <- seq(1,length(Data$H),by=1)
timeseries <- data.frame(xlab,Data$H,simH)
fill=c("black","red")
Hplot <- ggplot(timeseries,aes(x=xalab))+geom_line(aes(x=xlab,y=Data$H,color="Measured"))+geom_line(aes
Hplot # Time series of calculated H and measured H
```




```
Eplot <- ggplot(timeseries,aes(x=xalab))+geom_line(aes(x=xlab,y=Data$LE,color="Measured"))+geom_line(aes
Eplot # Time series of calculated E and measured E
```




```
Gplot <- ggplot(timeseries,aes(x=xalab))+geom_line(aes(x=xlab,y=Data$G,color="Measured"))+geom_line(aes
Gplot # Time series of calculated G and measured G
```



Software details

This tutorial was built under:

```
#> [1] "x86_64-w64-mingw32/x64 (64-bit)"
#> [1] "R version 4.0.4 (2021-02-15)"
#> [1] "RMEP 2.0"
```

Version history

- v0.2: Feb 2021
- v0.1: Dec 2020