Gap-filling strategy for net ecosystem exchange of carbon dioxide at agro-ecosystems in Korea

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Challenges

Observation ↔ Simulation

Short growing periods

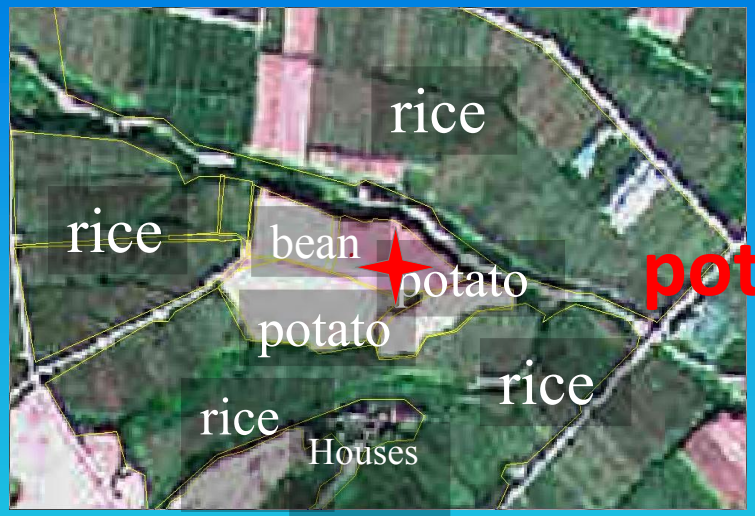
Seasonal response

Human activities

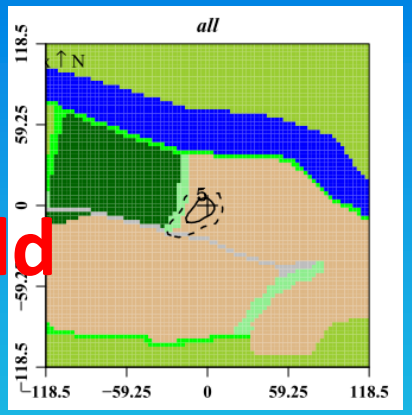
Patchy

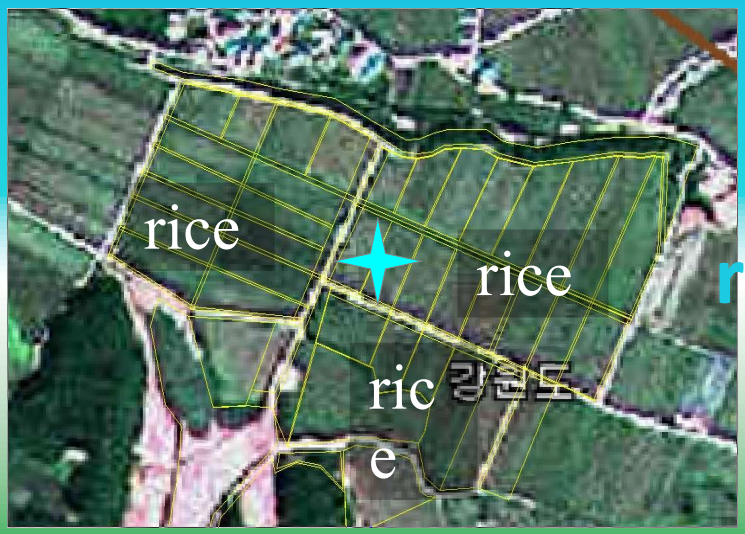
Monsoon

Patchy farmlands

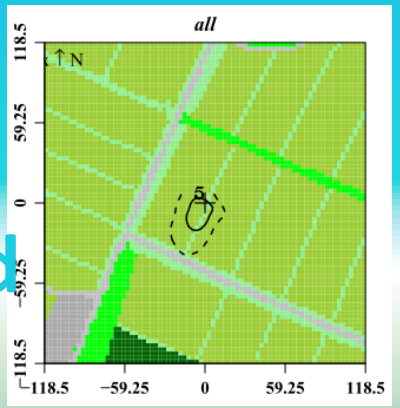


potato field



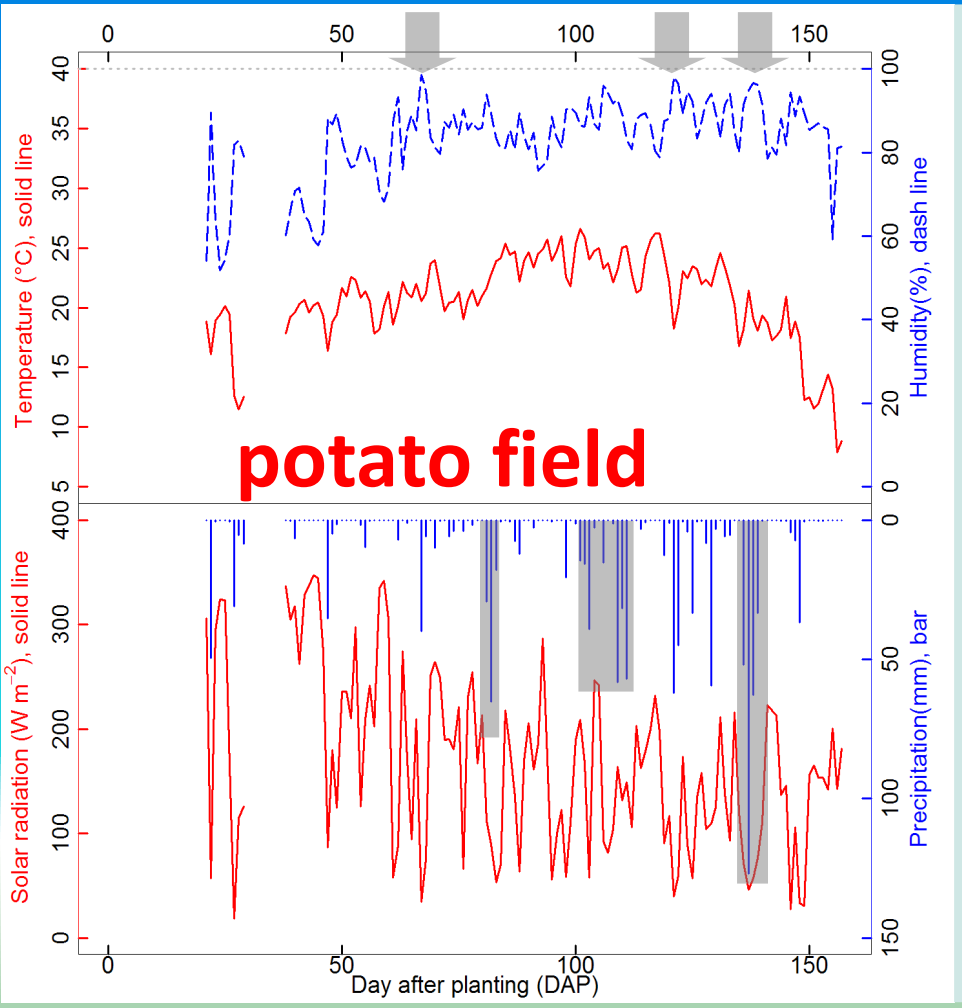


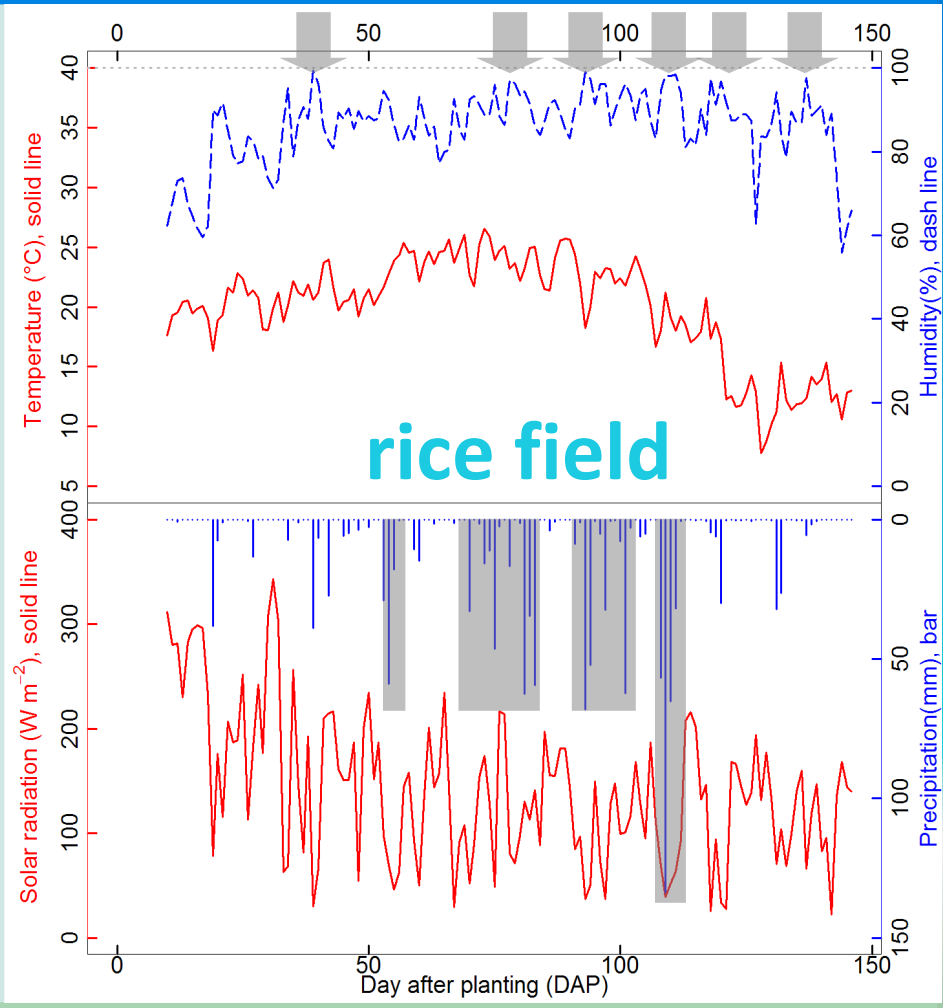
rice field



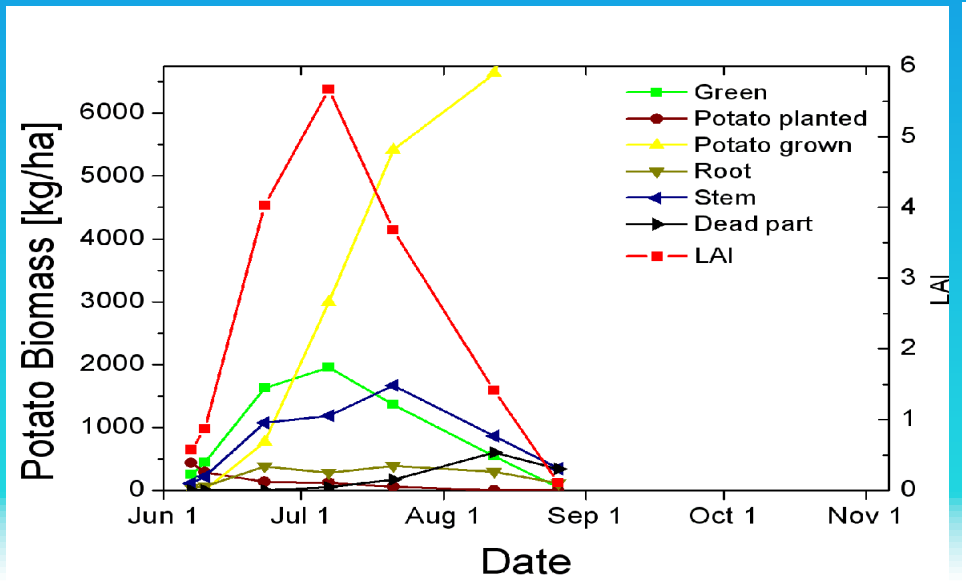
 # after Göckede et al. (2008)

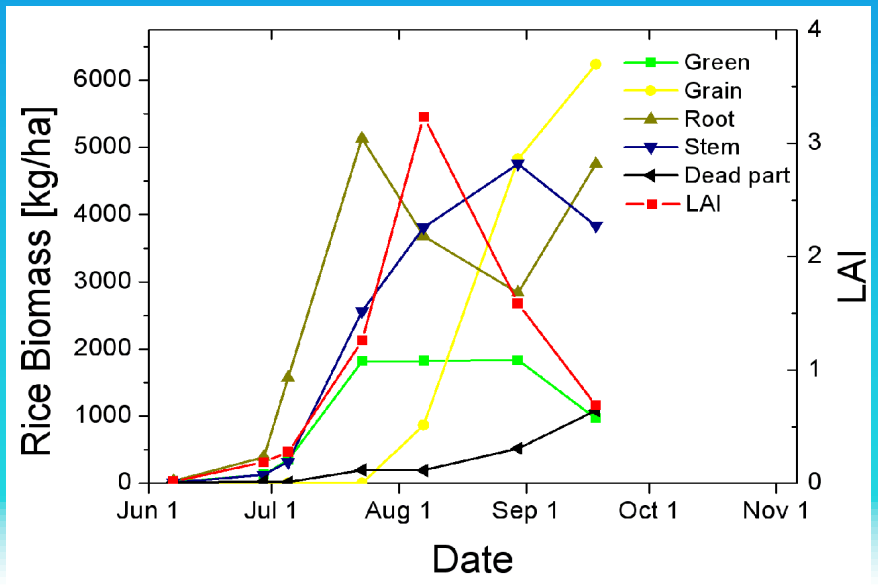
Monsoon


potato field
Temperature (°C), solid line
Humidity(%), dash line
Solar radiation (W m^{-2}), solid line
Precipitation(mm), bar
Day after planting (DAP)


rice field
Temperature (°C), solid line
Humidity(%), dash line
Solar radiation (W m^{-2}), solid line
Precipitation(mm), bar
Day after planting (DAP)

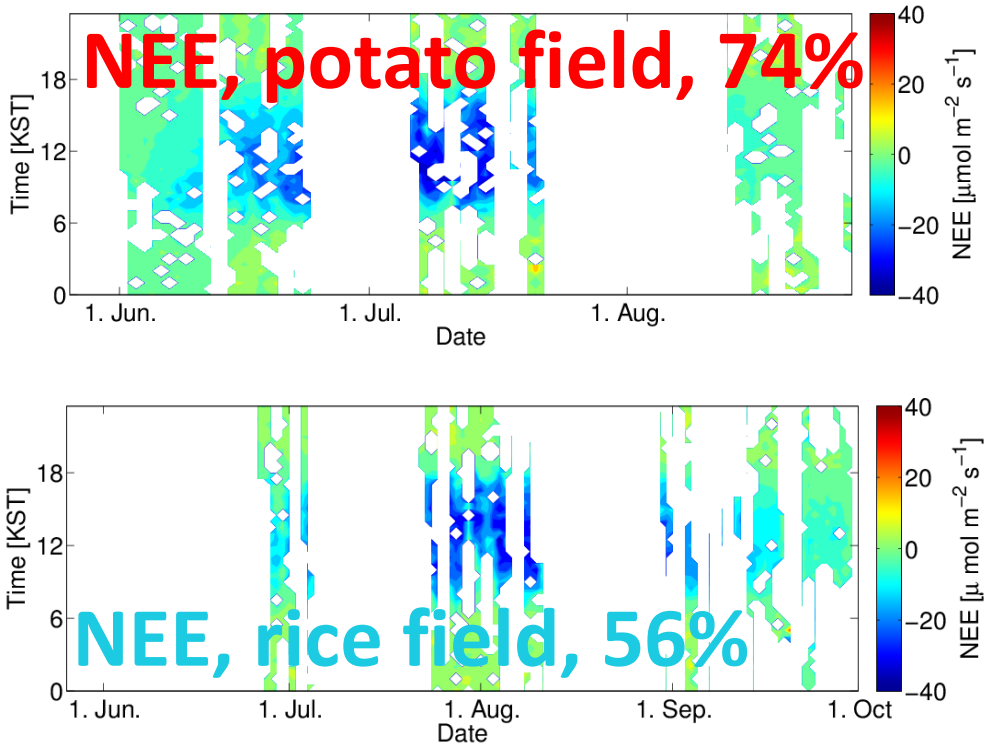
Fast-growing





Gaps in data-set

Data acquisition after overall quality control (*Foken et al., 2004*) and outlier check



Gap-filling methods

- Mean Diurnal Variation
- Look-Up Table
- Non-linear regression
- Other methods, e.g. artificial neural networks

 # Aubinet et al. 2000
 # Falge et al., 2001
 # Moffat et al. 2007

Driving factors of NEE

$$\beta^* = \begin{cases} \beta_0^* e^{-k(\mathrm{VPD}-\mathrm{VPD}_0)} & , \mathrm{VPD} > \mathrm{VPD}_0 \\ \beta_0^* & , \mathrm{VPD} \le \mathrm{VPD}_0 \end{cases}$$

 # Lasslop et al., 2010

Q: dry and irrigated farmland?

Vapor pressure deficit (VPD)

Seasonal

other

NEE

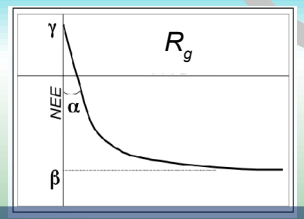
Temperature

Light

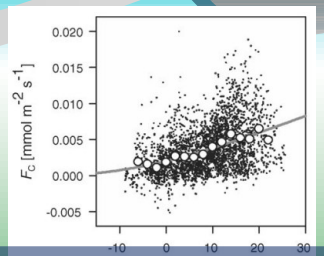
- Temporal groups

Q: 16 days, 8 days, 4 days, 2 days?

- When no observation available

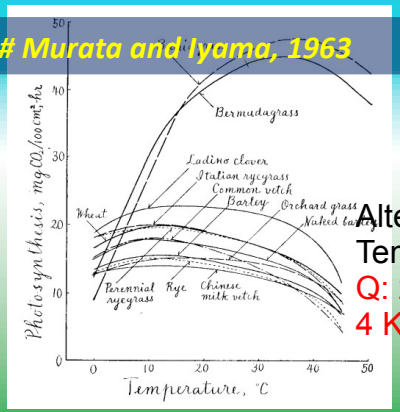


 # Michaelis and Menten, 1913
 # Falge et al., 2001



 # Lloyd and Taylor, 1994

 # Murata and Iyama, 1963



Alternative: Temperature groups

Q: 28 K, 14 K, 8 K, 4 K or 2 K?

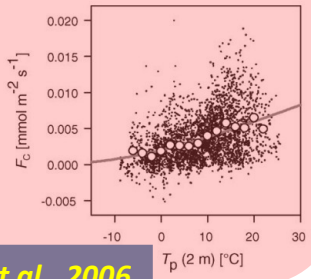
Gap-filling strategy for CO_2 flux

	Nighttime	Daytime
Ecosystem respiration (R_{eco})	Measured with gaps	gaps
Net ecosystem exchange (NEE)	NEE = R_{eco}	Measured with gaps
Gross primary production (GPP)	0	GPP = NEE - R_{eco}

 # Lloyd and Taylor, 1994

$$R_{eco} = R_{ref} e^{E_0\left(\frac{1}{T_{ref}-T_0}-\frac{1}{T-T_0}\right)}$$

T_{ref}: reference temperature, 10 °C
R_{ref}: R_{eco} at T_{ref}
E_0: temperature sensitivity
T: air temperature
T_0: constant value, -46.02 °C



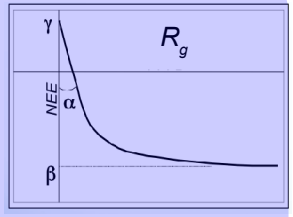
 # Ruppert et al., 2006

 # Michaelis and Menten, 1913
 # Falge et al., 2001

$$NEE = \frac{\alpha R_g \beta}{\alpha R_g + \beta} + R_{eco}$$

$$NEE = GPP + R_{eco}$$

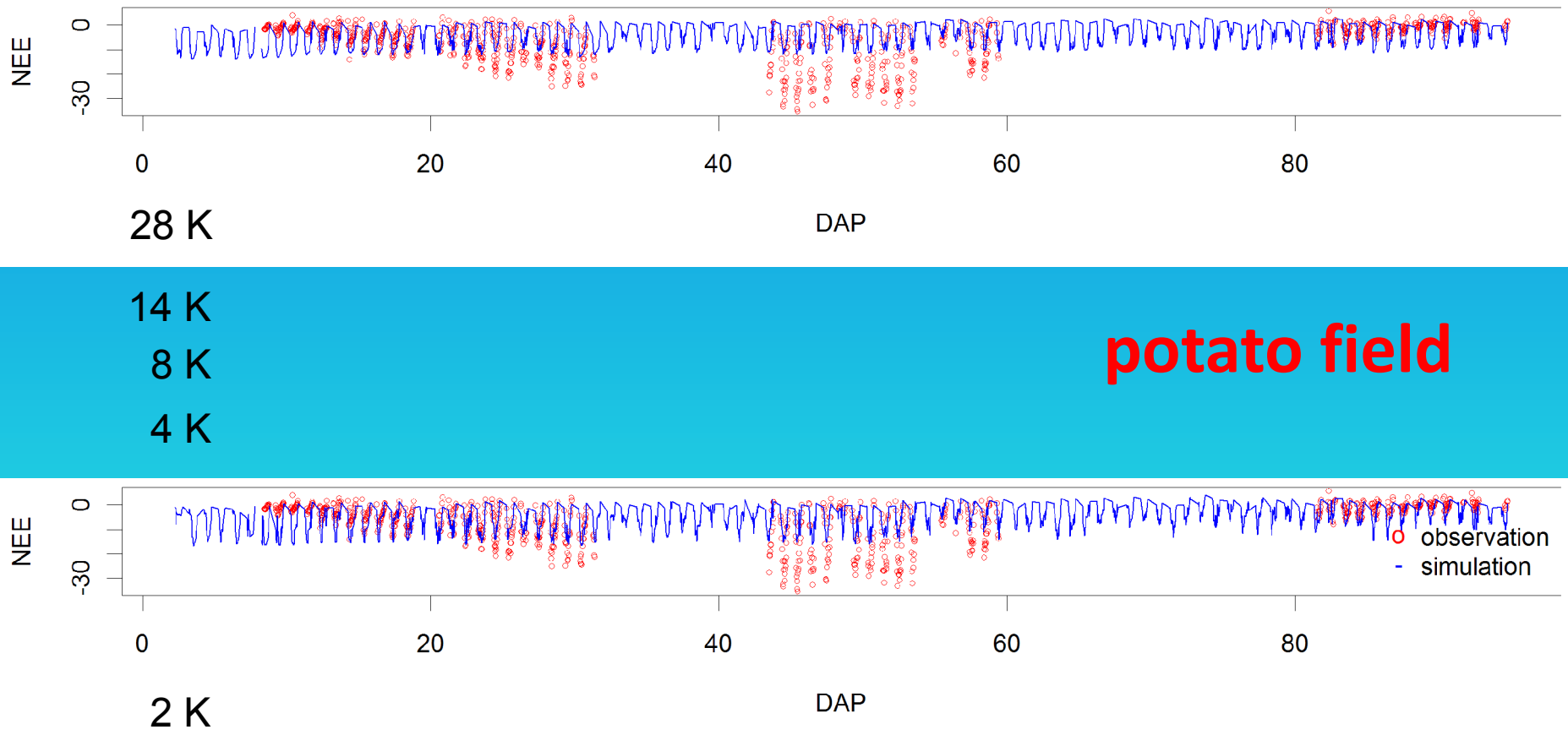
$$GPP = \frac{\alpha R_g \beta}{\alpha R_g + \beta}$$



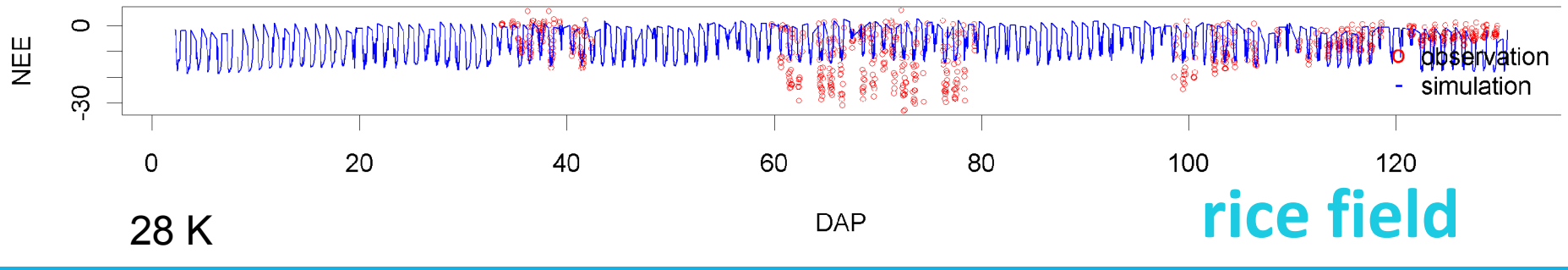
R_g: global radiation
α: initial slope
β: saturated NEE

seasonal temperature VPD

Temperature dependency



Temperature dependency



28 K

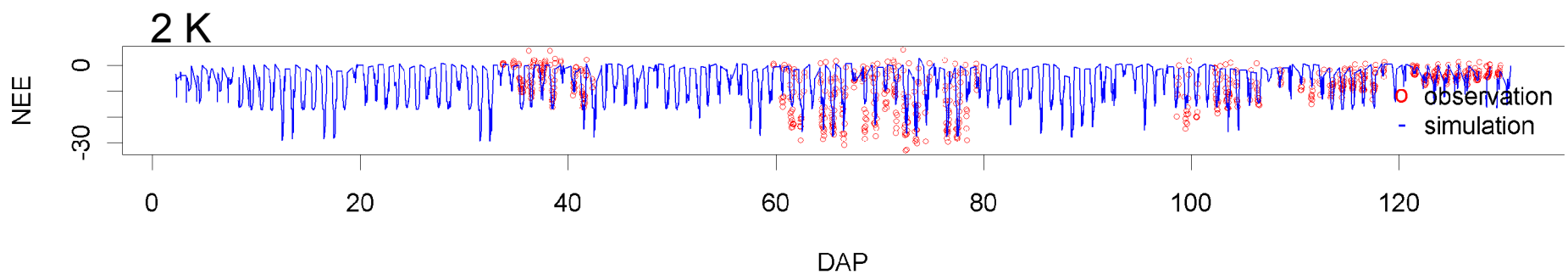
rice field

14 K

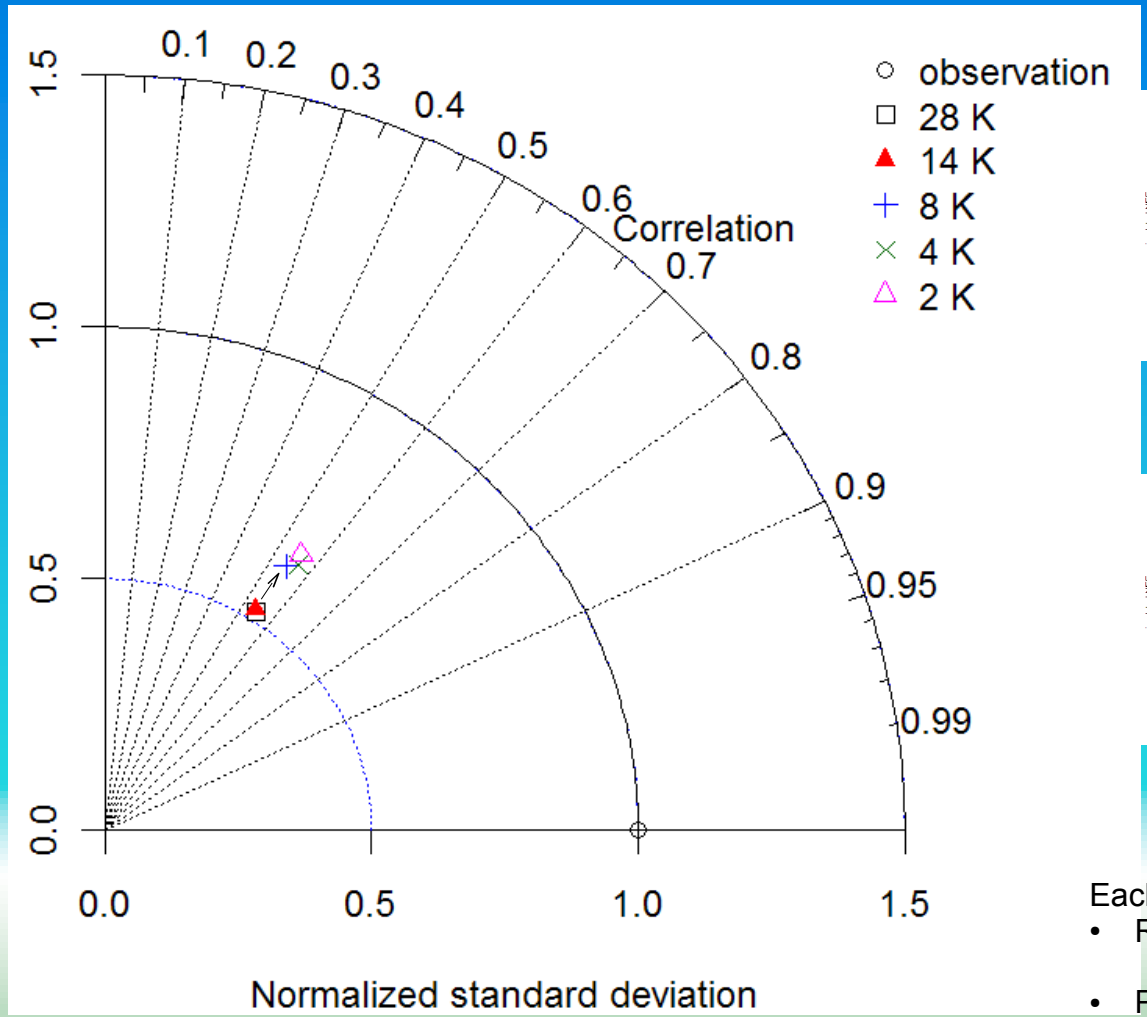
8 K

4 K

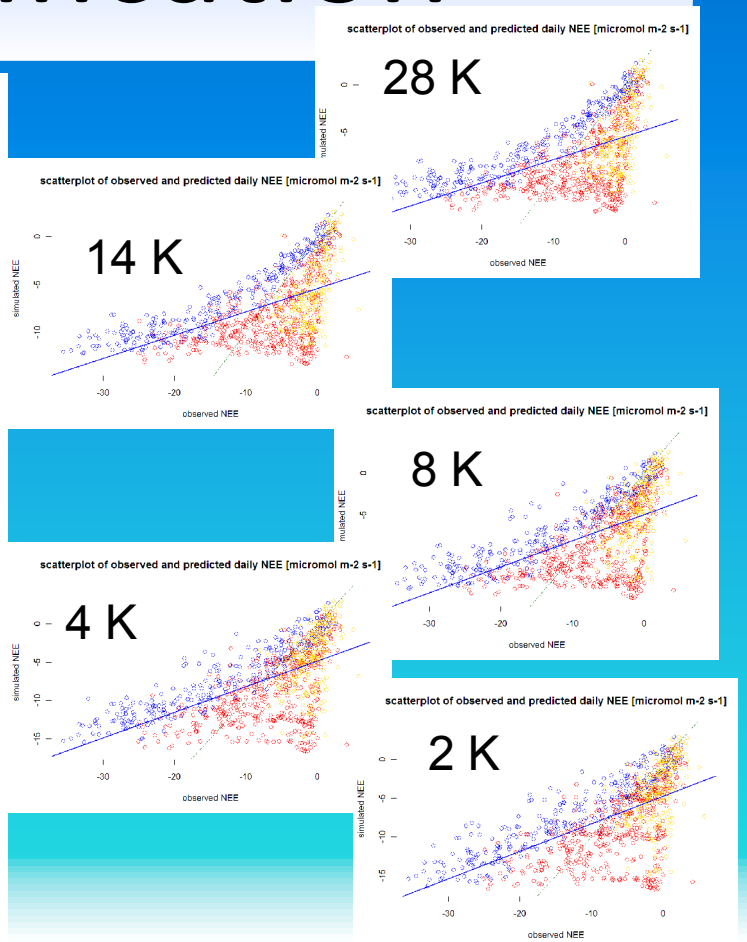
2 K



Temperature classification



potato field

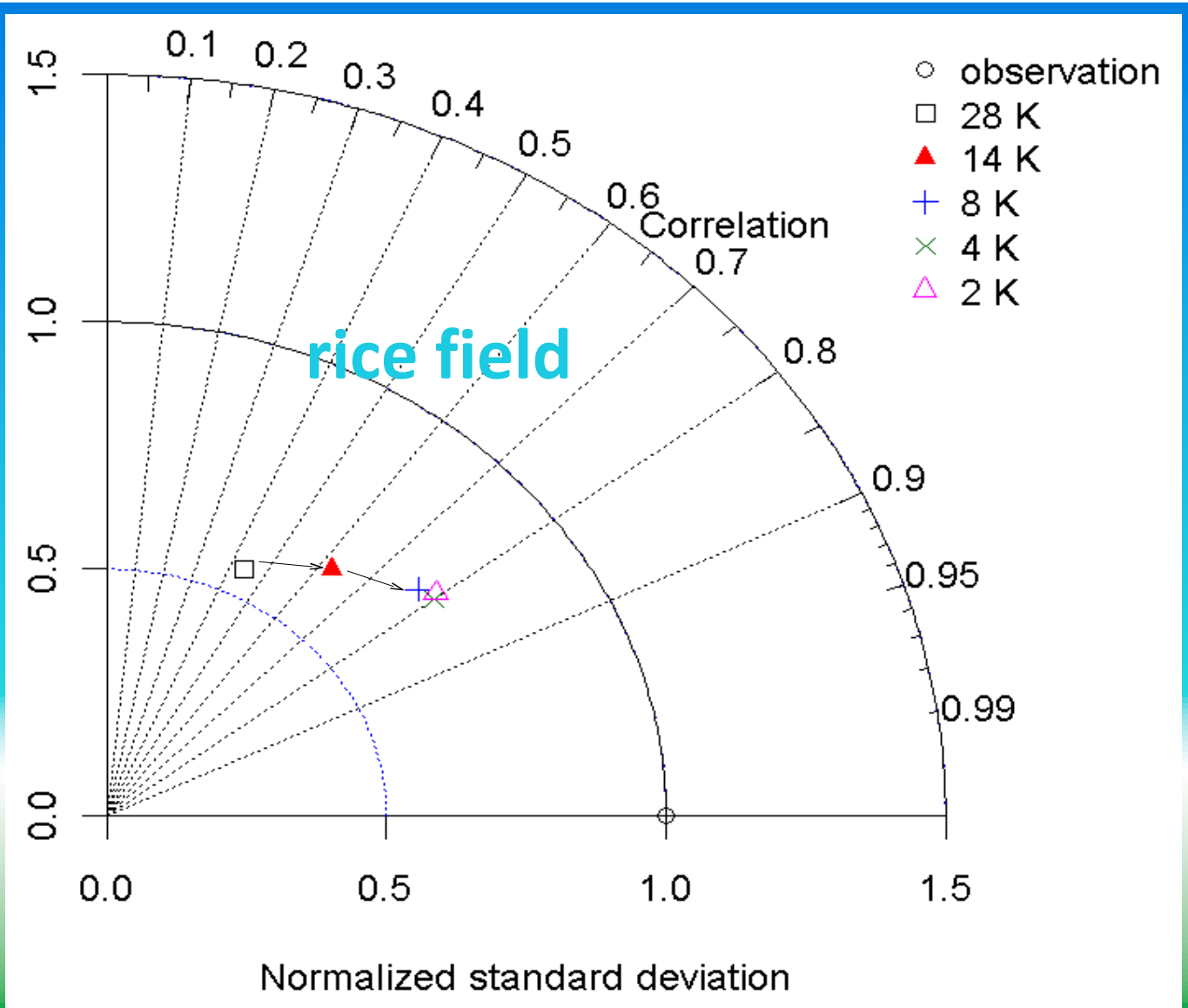


Each single point specify the performance of one model.

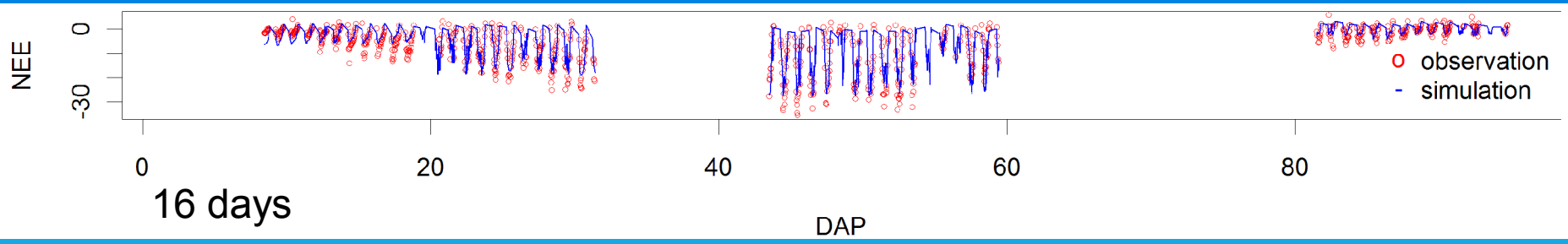
- Radial distance:
  Normalized standard deviation,
- Polar angle:
  correlation coefficient,
- Distance to observation point (○):
  root mean square error.

 # Taylor (2001)

Temperature classification



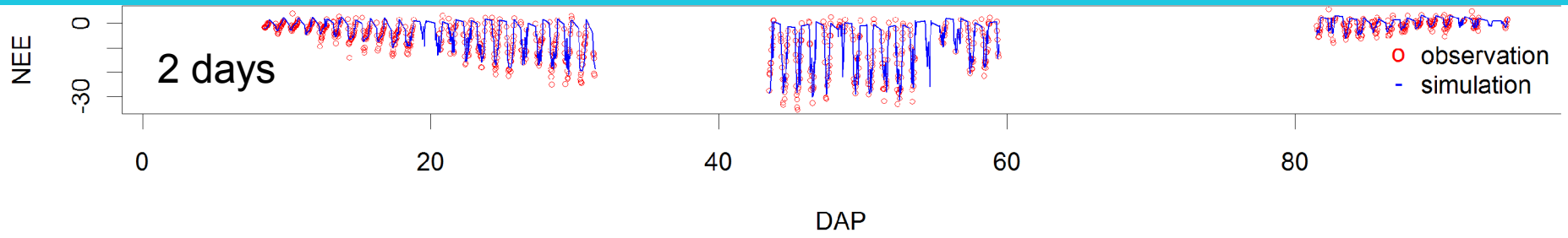
Temporal classification



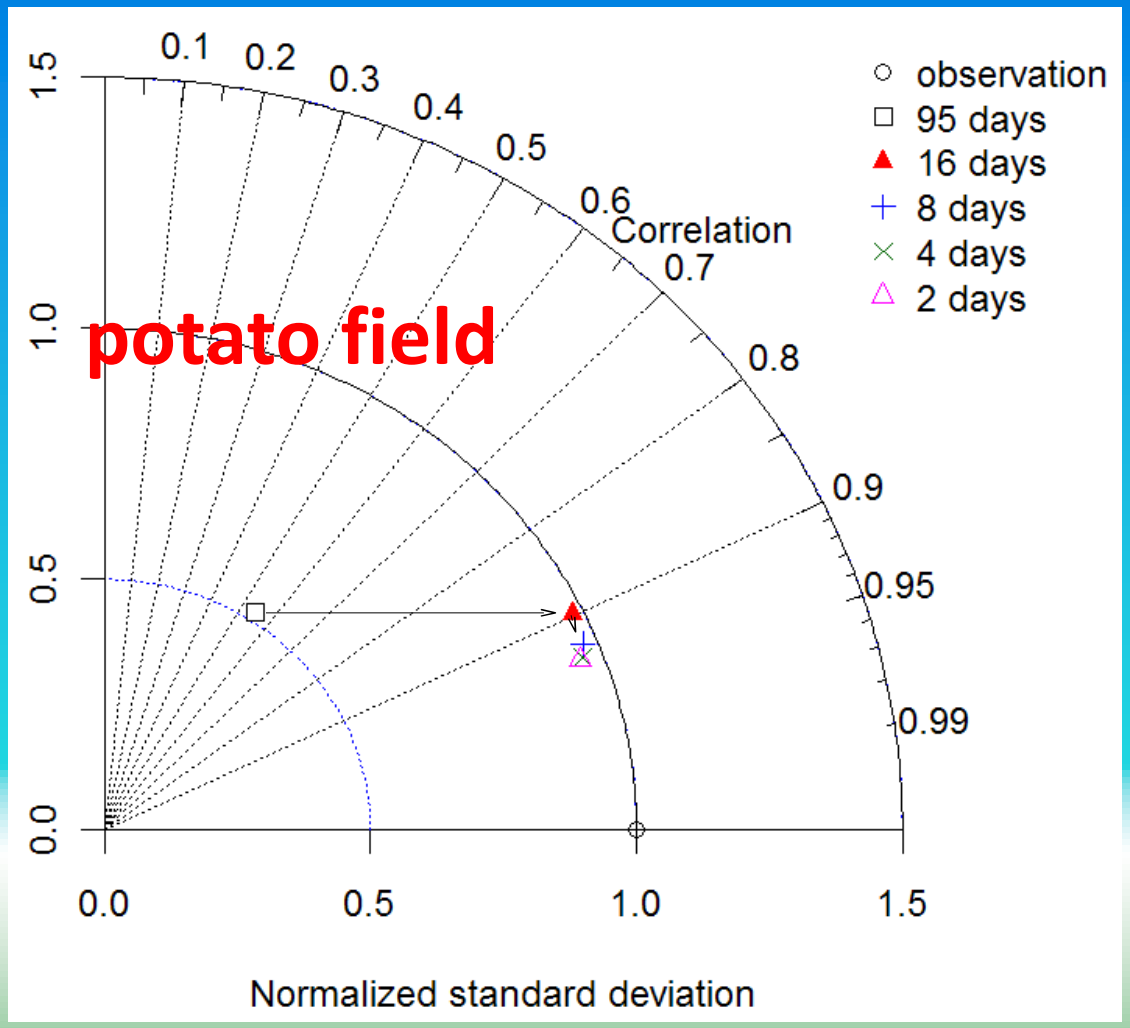
8 days

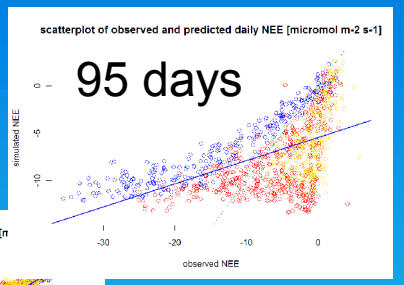
4 days

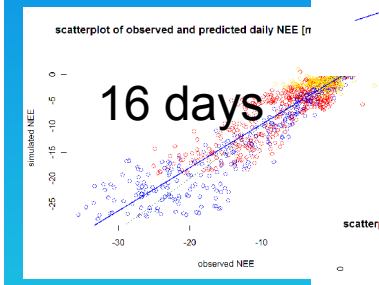
potato field

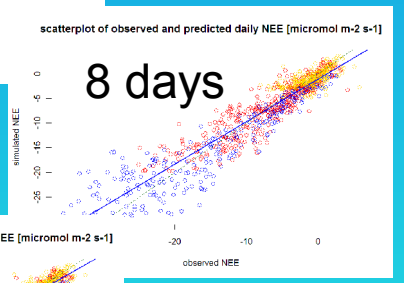


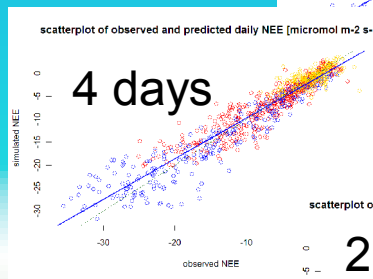
Temporal classification

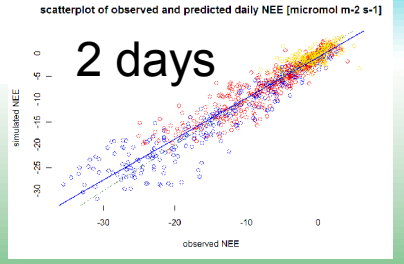




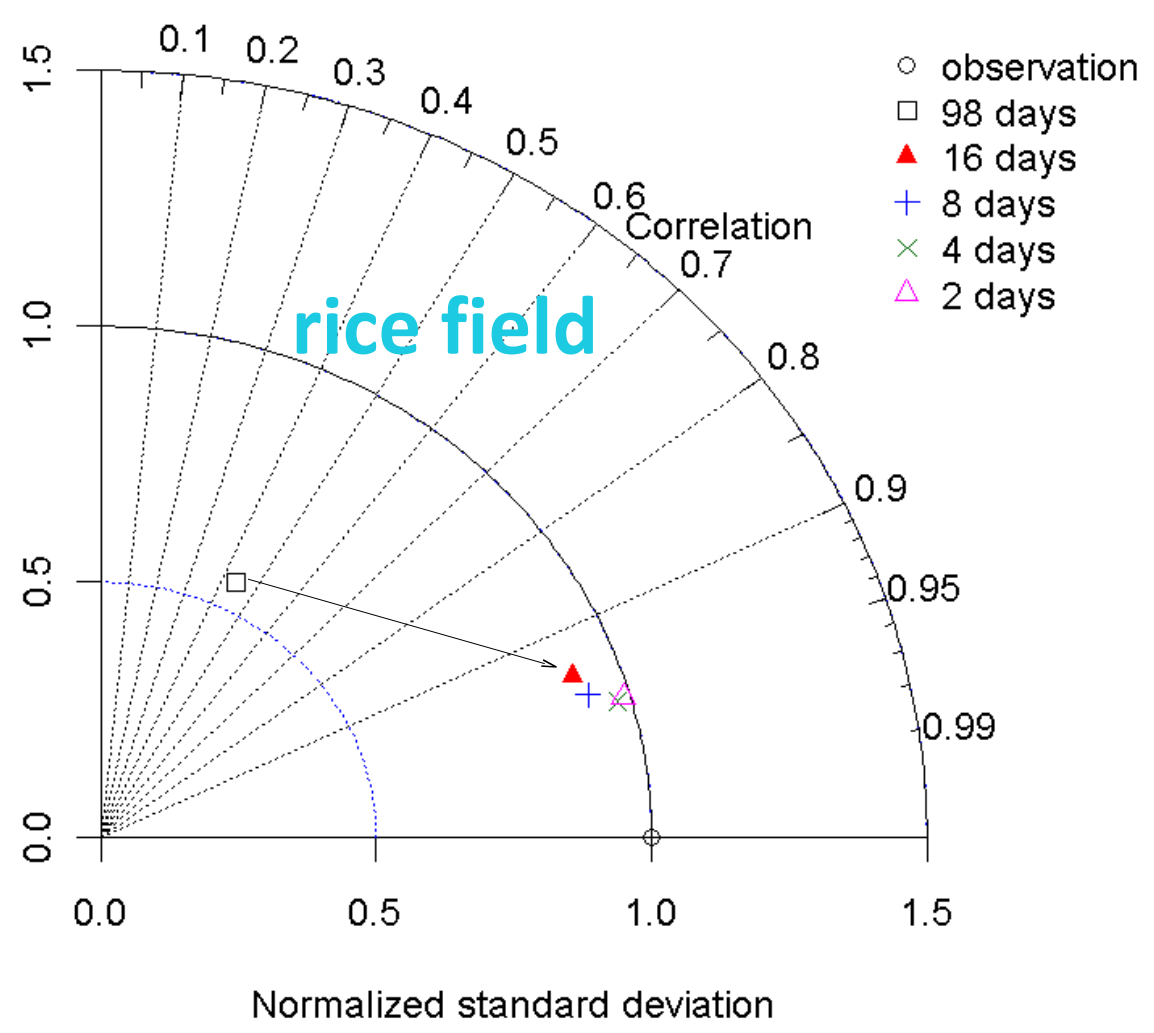




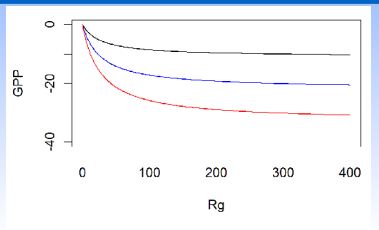




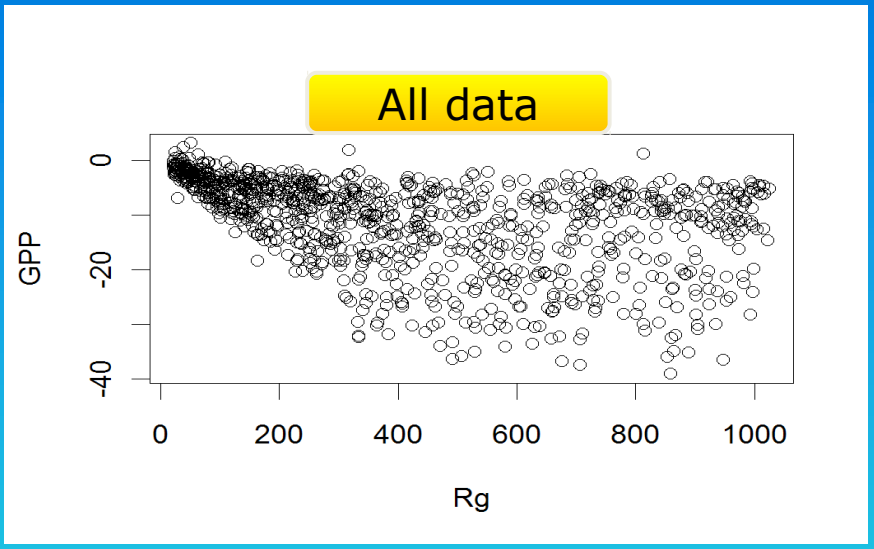
Temporal classification



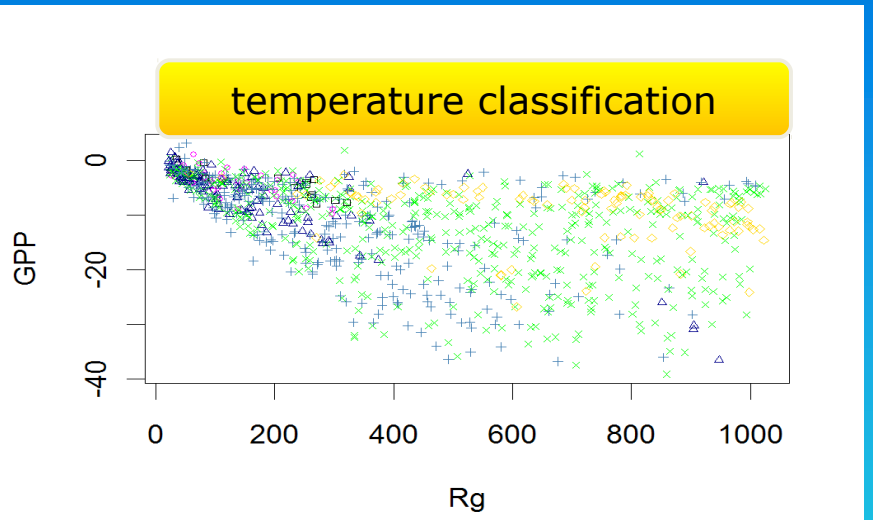
Data classification



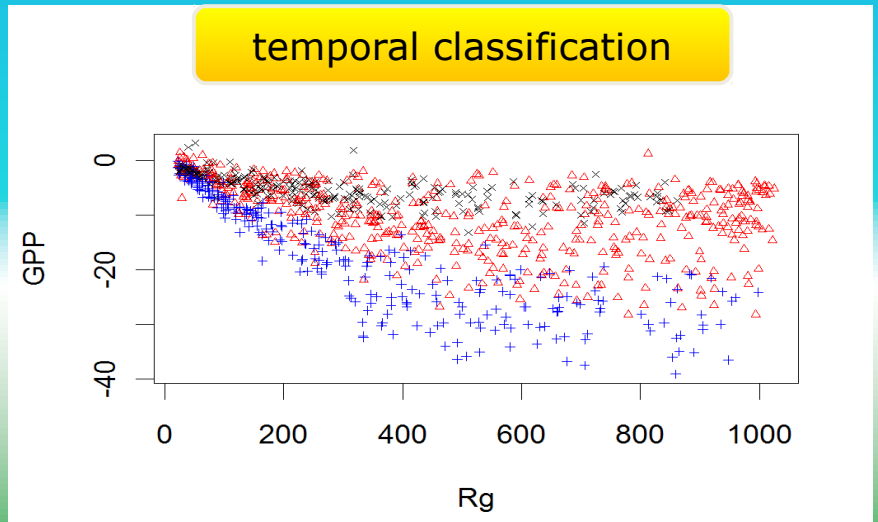
All data



temperature classification



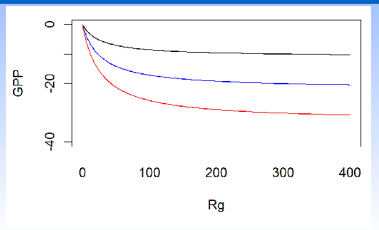
temporal classification



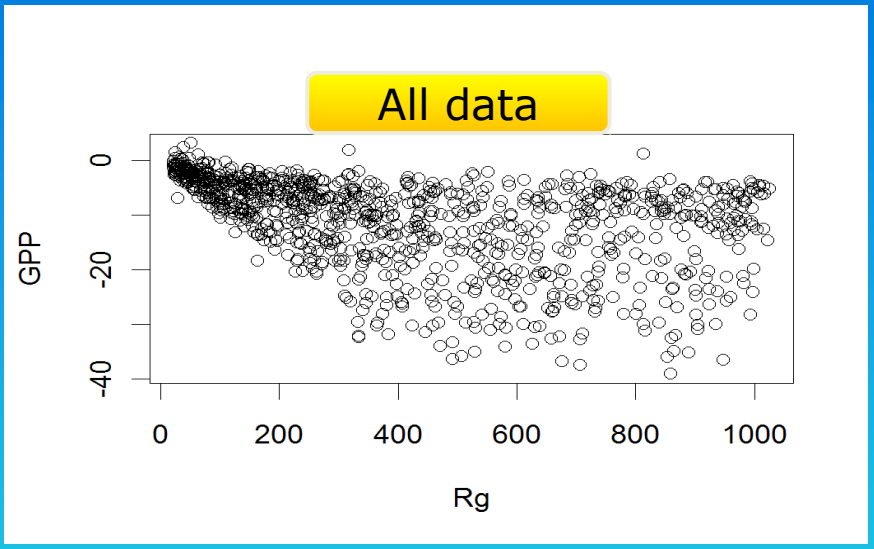
?

Other classification?

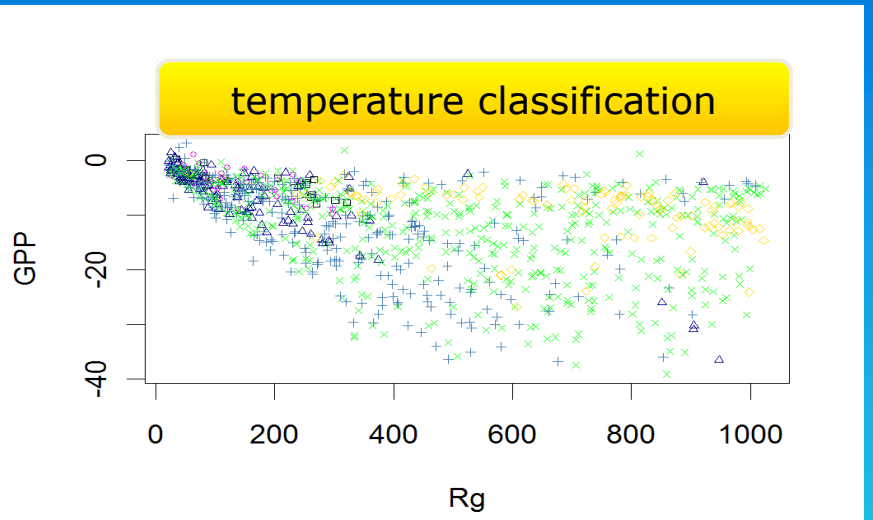
Data classification



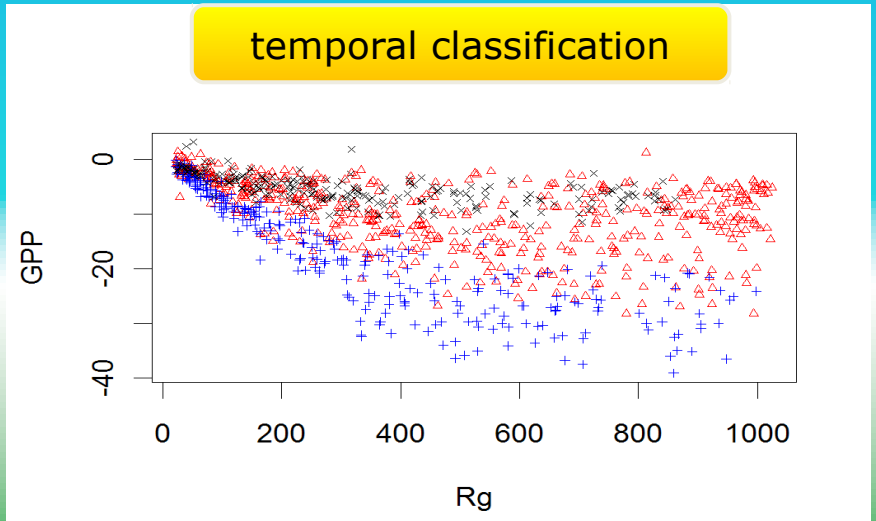
All data



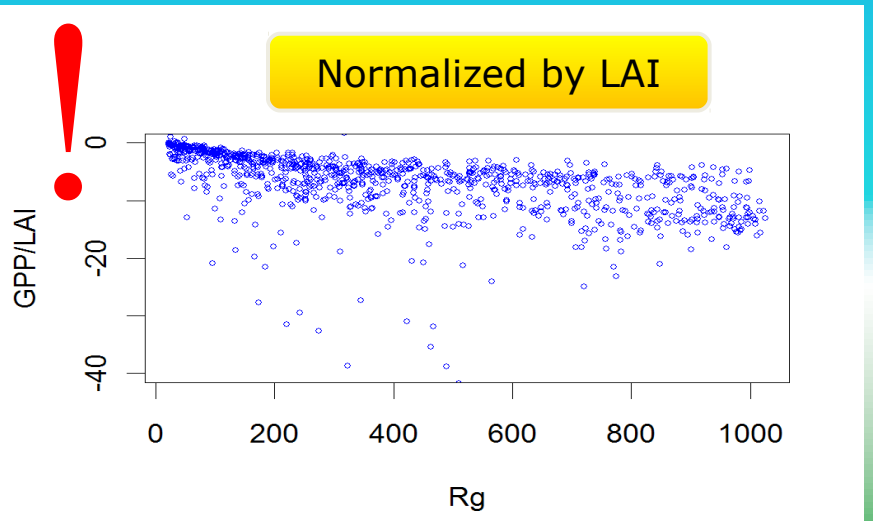
temperature classification



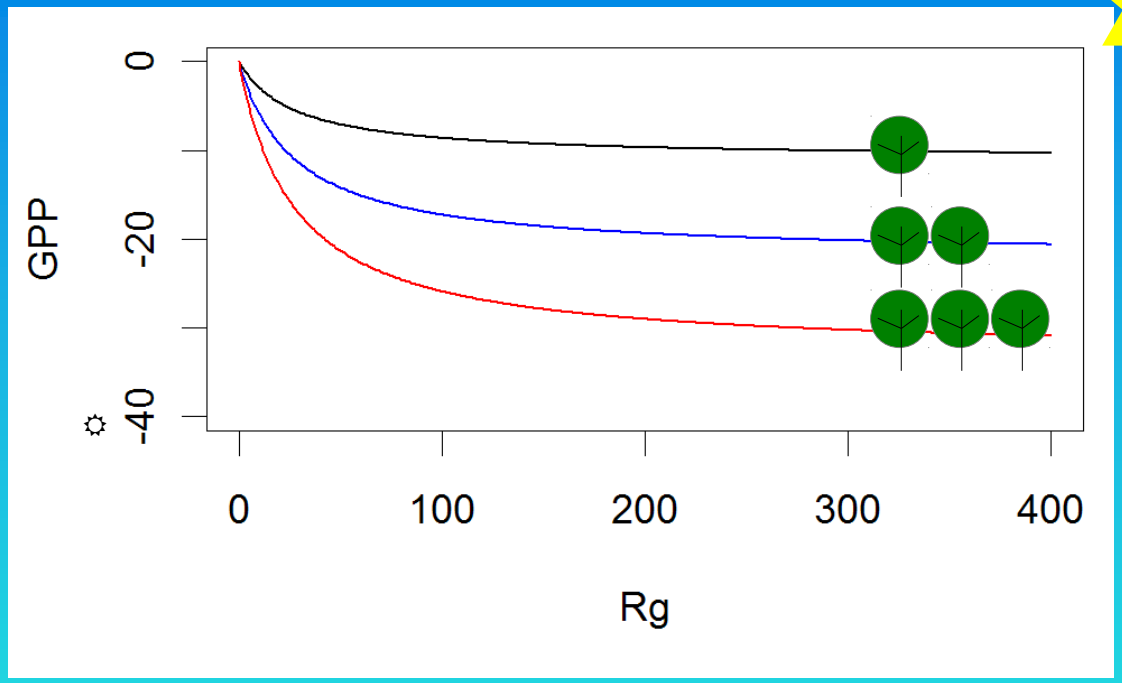
temporal classification



Normalized by LAI



LAI factor



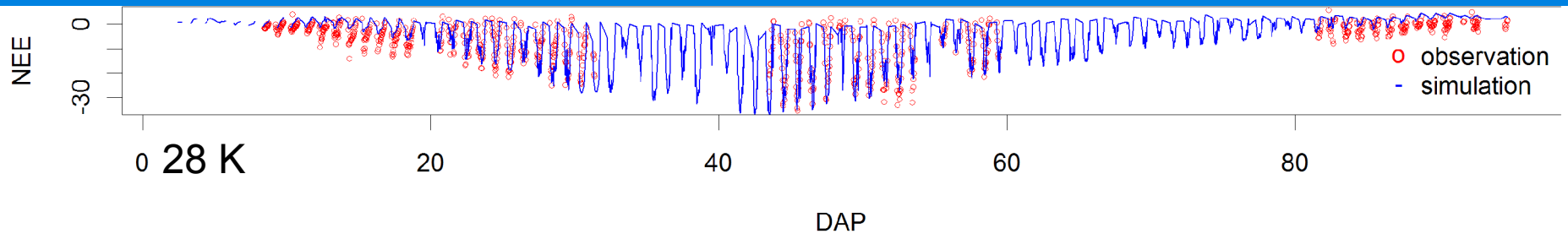
$$GPP = \frac{\alpha R_g \beta}{\alpha R_g + \beta}$$

$$\frac{GPP}{LAI} = \frac{\frac{\alpha}{LAI} R_g \frac{\beta}{LAI}}{\frac{\alpha}{LAI} R_g + \frac{\beta}{LAI}}$$

GPP´ = GPP / LAI
α´ = α / LAI
β´ = β / LAI

$$GPP' = \frac{\alpha' R_g \beta'}{\alpha' R_g + \beta'}$$

LAI factor + temperature class.

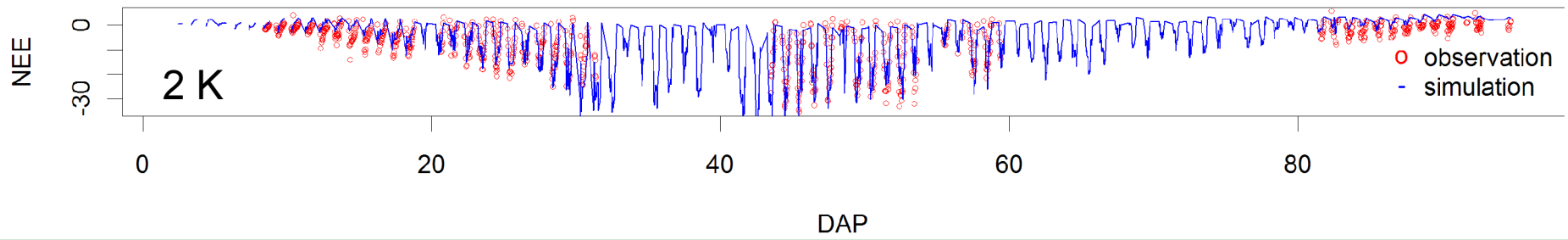


14 K

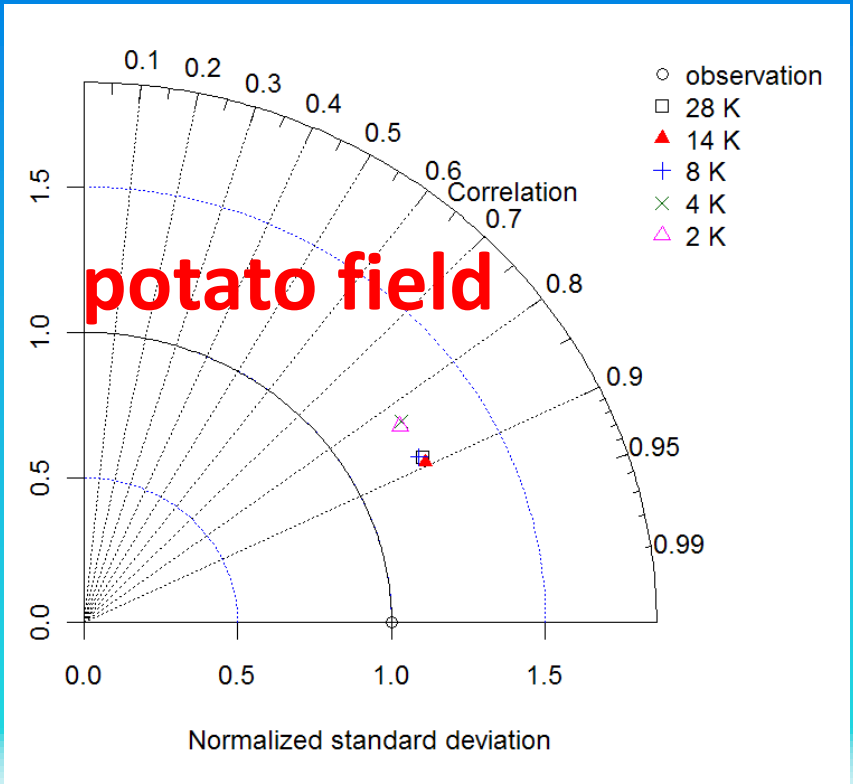
8 K

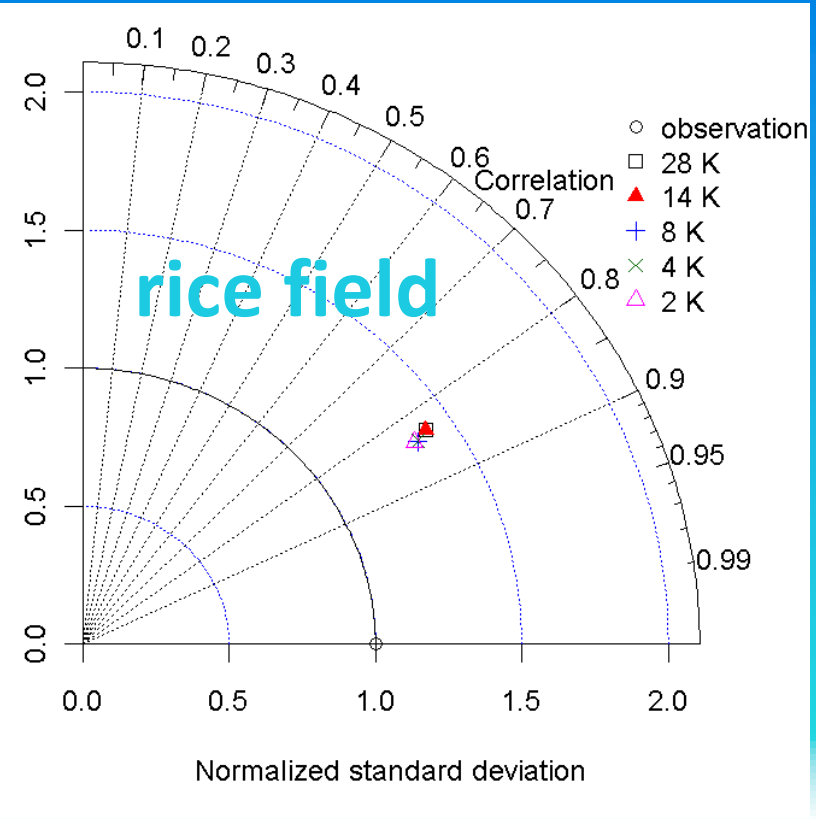
4 K

potato field

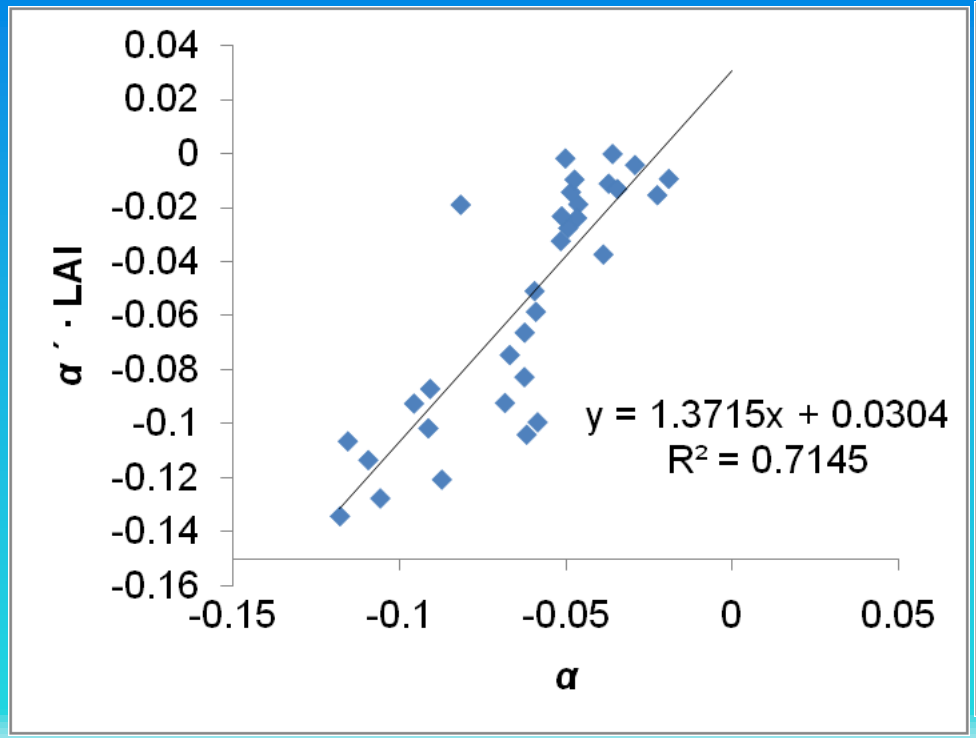


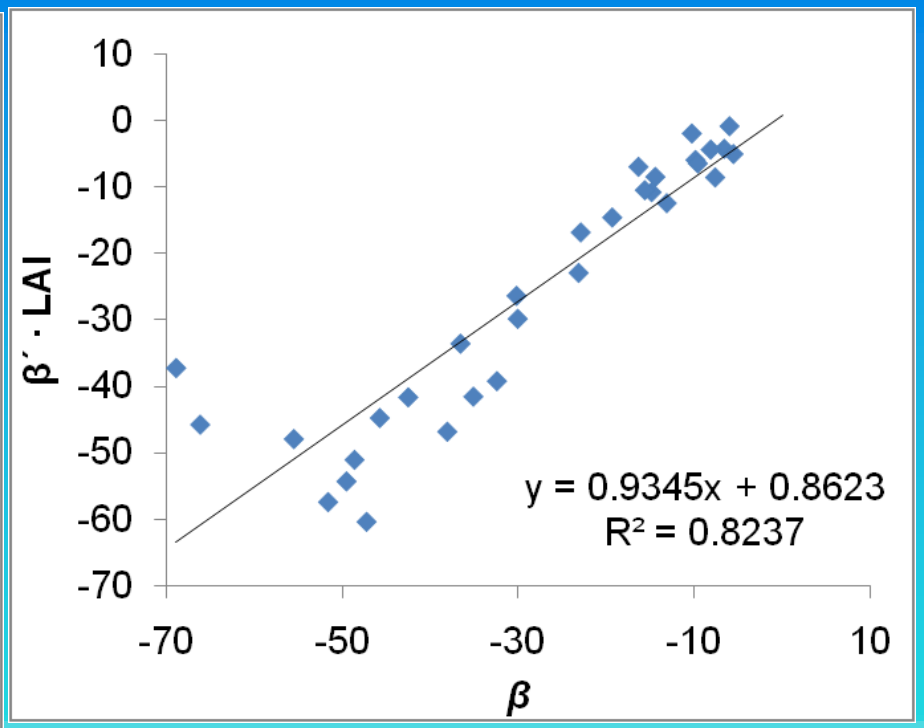
LAI factor + temperature class.





LAI factor VS temporal class.

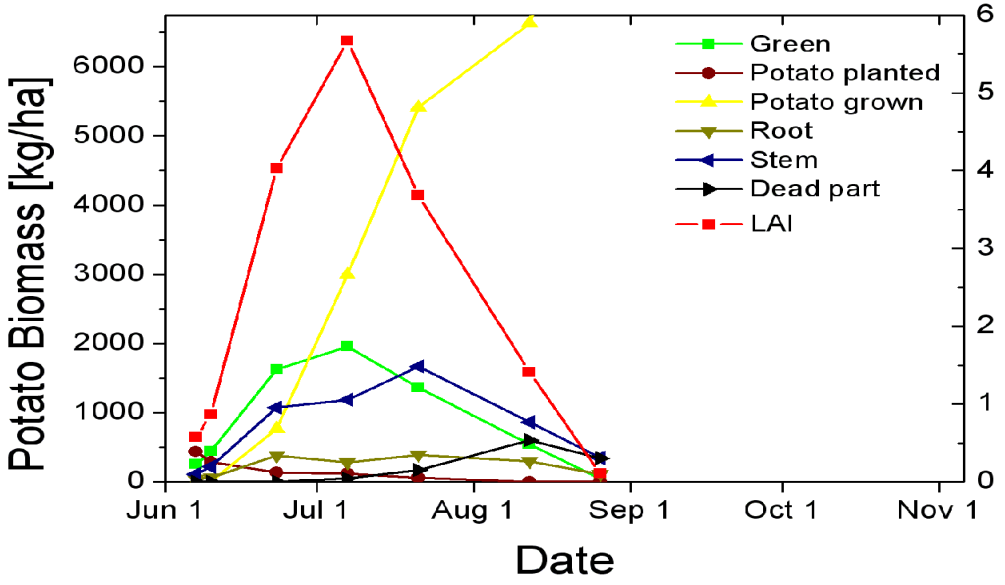




$$GPP' = \frac{\alpha' R_g \beta'}{\alpha' R_g + \beta'}$$

$\alpha' = \alpha / LAI$ $\beta' = \beta / LAI$

Errors



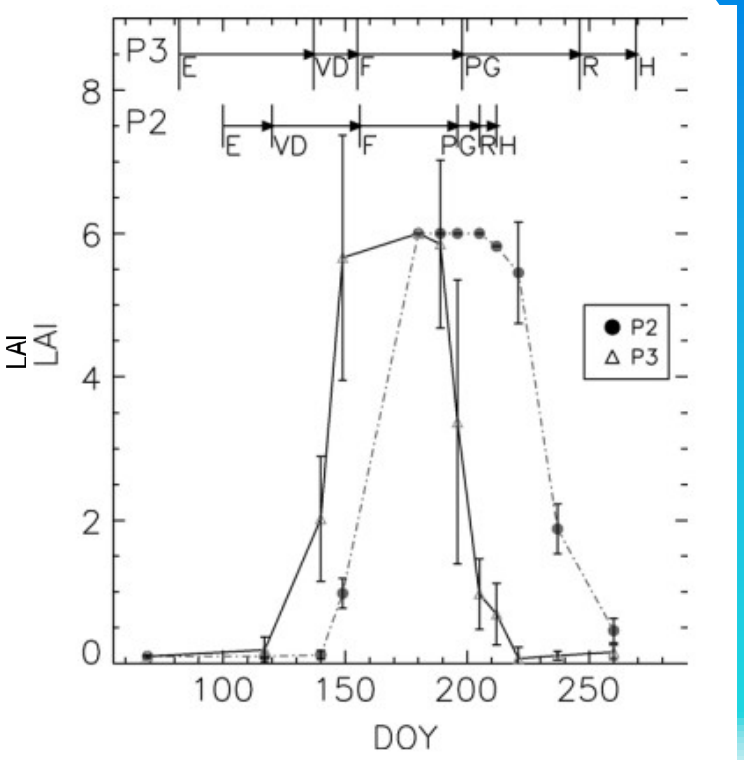


Fig. 5. Retrieved LAI for two potato fields (P2 and P3) with different calendar. Phenological observations are indicated on top. P2 has a longer cycle than P3: emergence is earlier and harvest is later than for P2. E stands for Emergence, VD for Vegetation Development, F for Flowering, PG for Potato Growing, R for Ripening an H for Harvest.

 # González-Sanpedro et al. (2008)

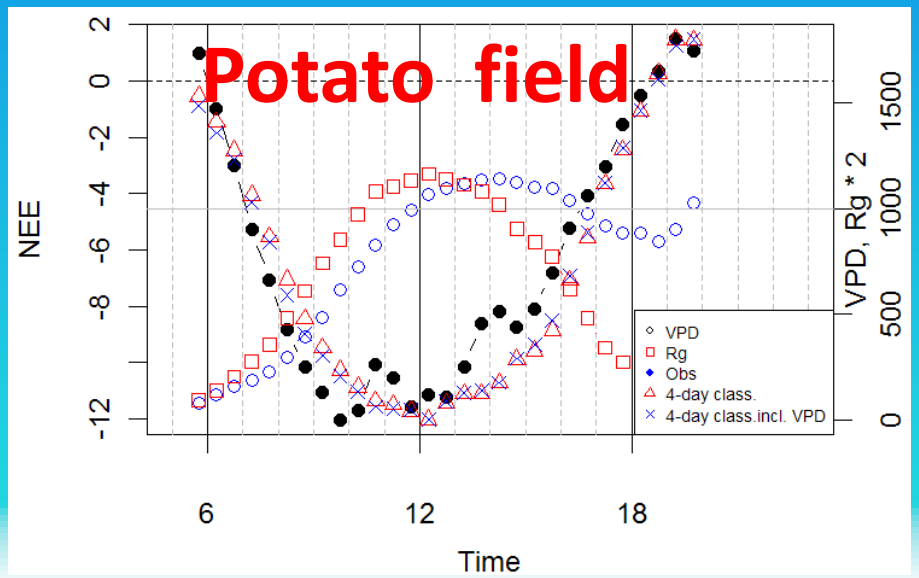
VPD factor

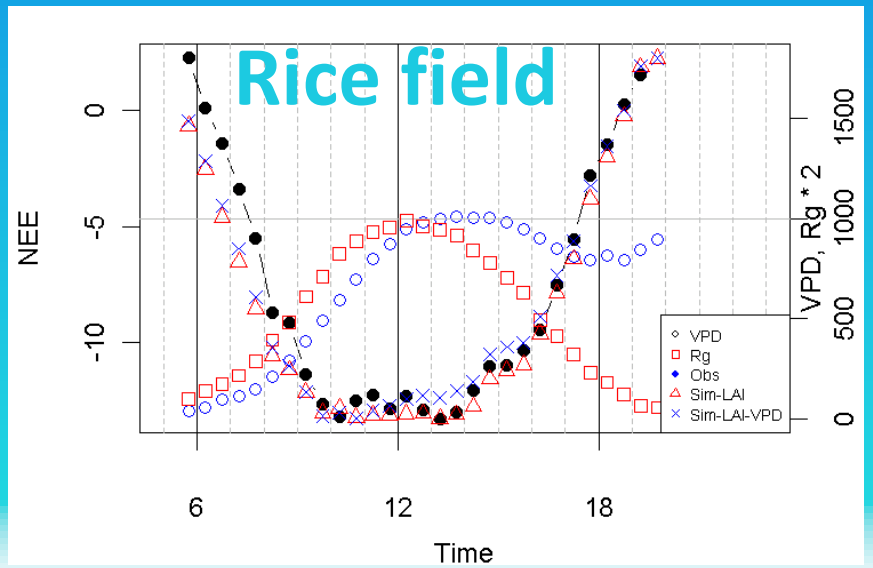
$$GPP = \frac{\alpha R_g \beta}{\alpha R_g + \beta}$$

$$\beta^* = \begin{cases} \beta_0^* e^{-k(\mathrm{VPD}-\mathrm{VPD}_0)} & , \mathrm{VPD} > \mathrm{VPD}_0 \\ \beta_0^* & , \mathrm{VPD} \leq \mathrm{VPD}_0 \end{cases}$$

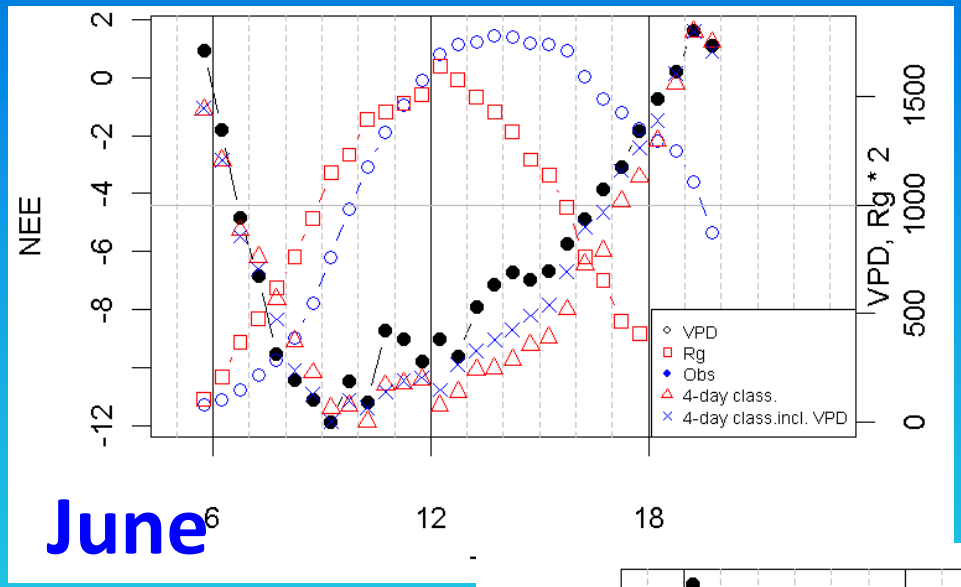
VPD_0 = 10 hPa

 # Körner, 1995
 # Lasslop et al., 2010

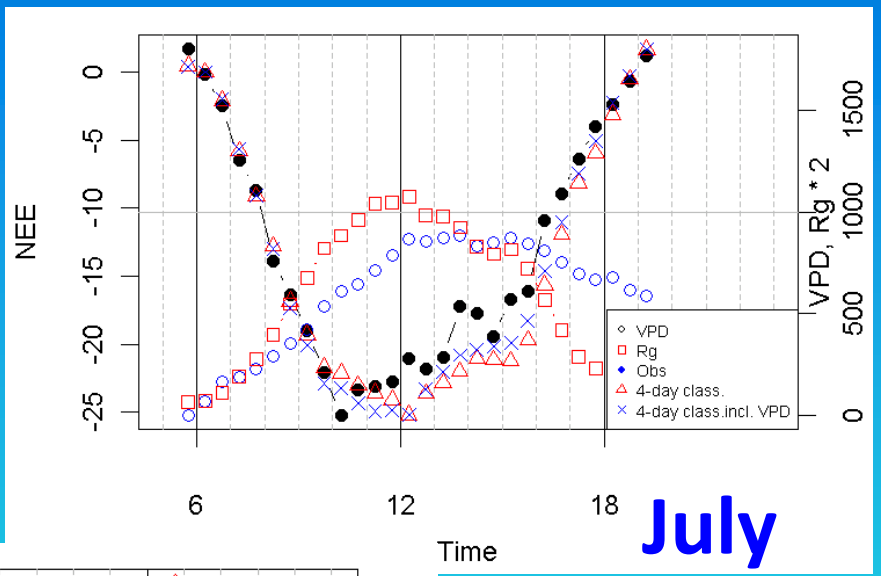




VPD factor

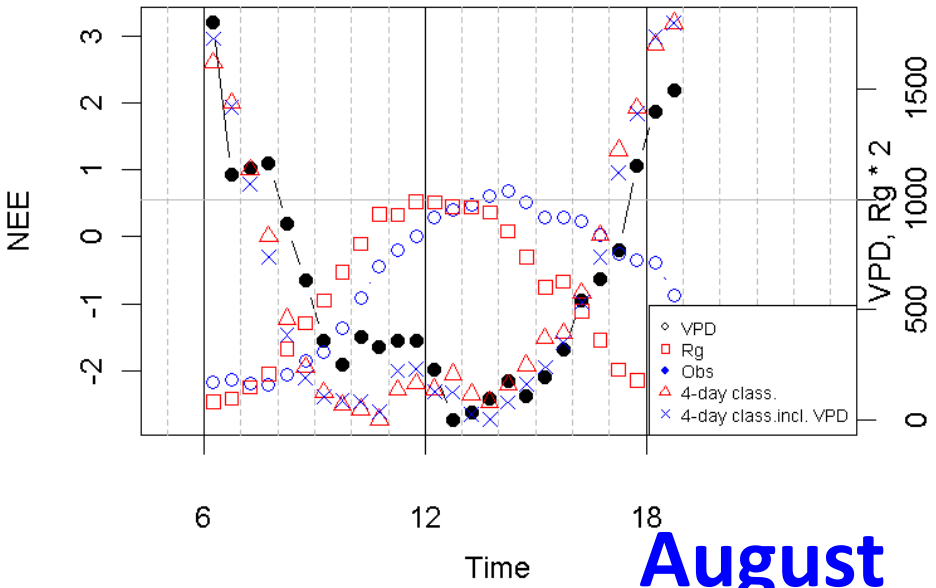


June



July

Potato field



August

Conclusion

- 4-day and 8-day classification is sufficient for daytime NEE gap-filling for the potato and rice fields, respectively.
- As the seasonal response plays a more important role than temperature response, temperature classification for NEE gap-filling could be ignored for both the potato and rice fields if temporal classification is applied.
- The approach of Introducing a LAI factor can be used for filling large gaps of NEE.
- VPD response is an unimportant factor for both the rice field and the potato field except the early growing stage of potato.