

Complex Terrain and Ecological Heterogeneity (TERRECO): Evaluating Ecosystem Services in Mountainous Landscapes

Energy and CO₂ exchange between agro-ecosystems and the atmosphere over a complex terrain in Korea



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Ökologie und Umweltforschung
Bayceer

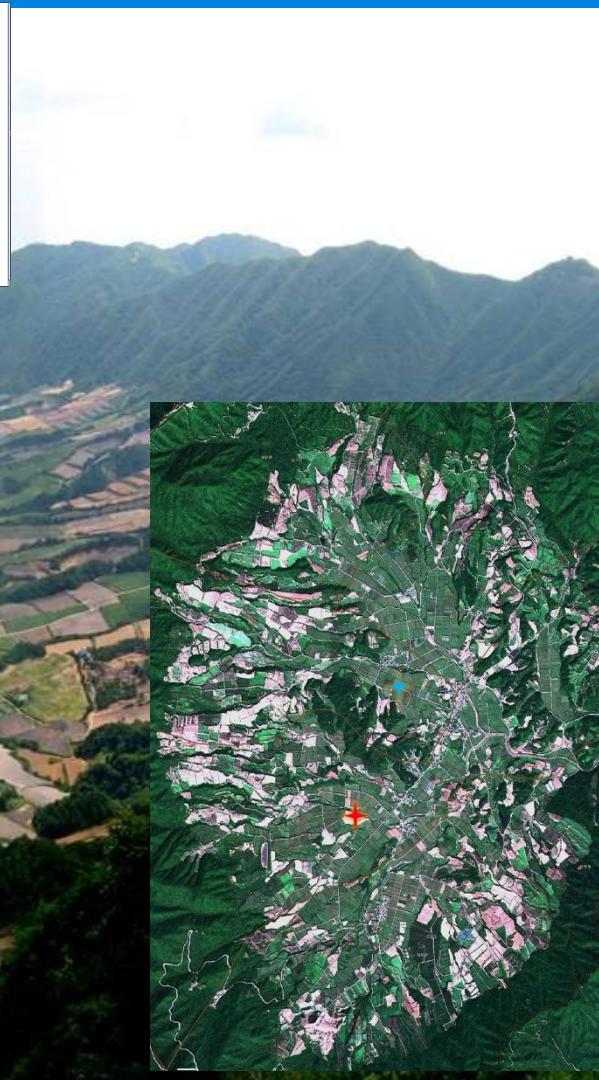
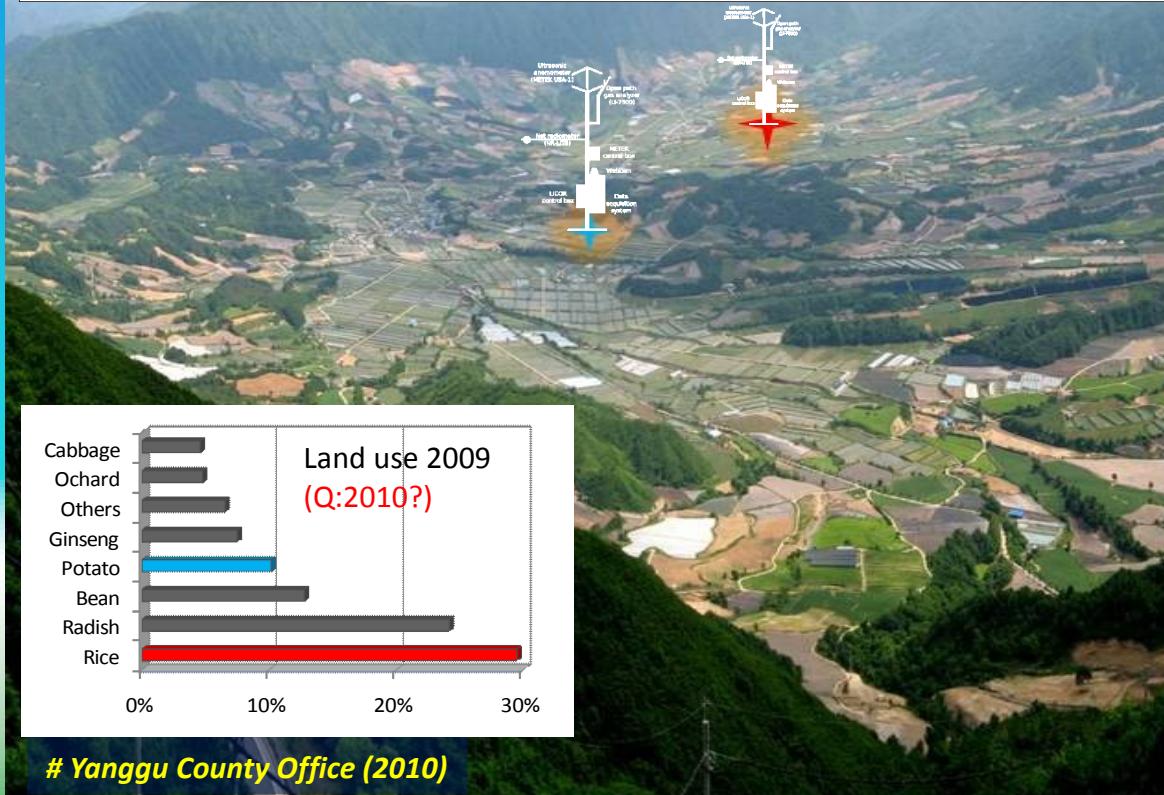
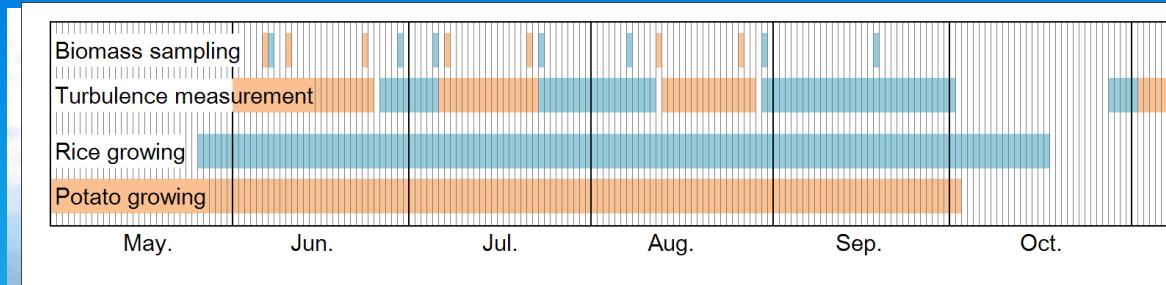


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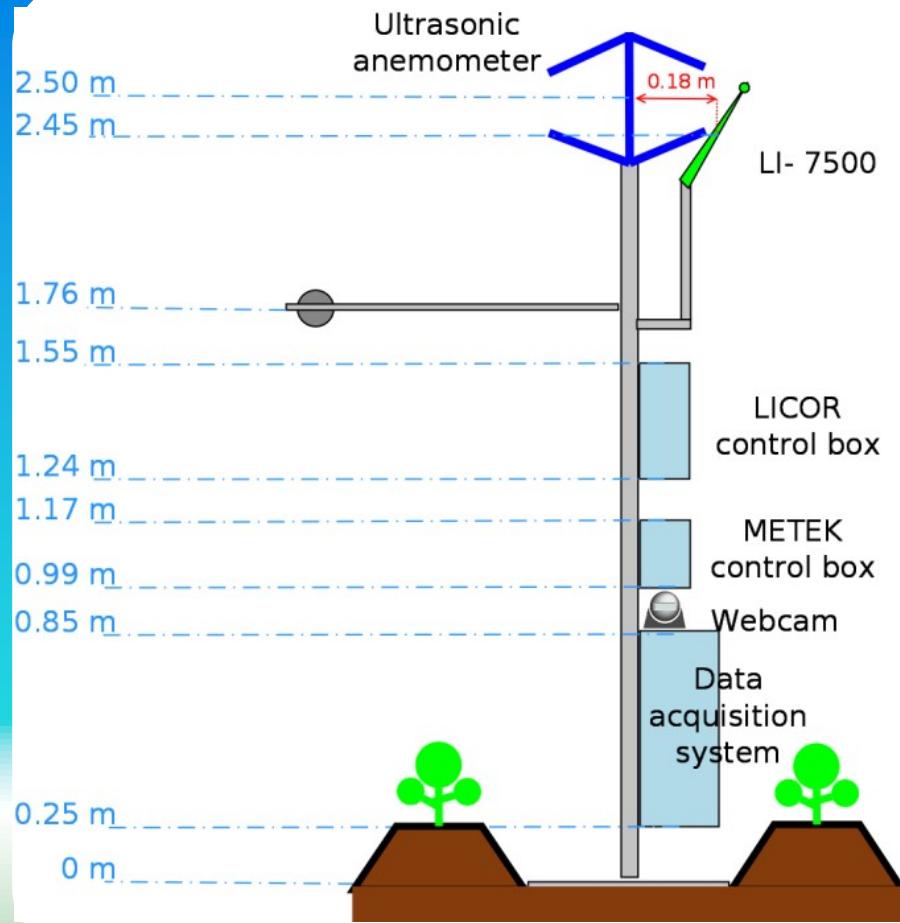
Objectives

- Eddy-covariance technique ~ complex terrain
 - Site selection and footprint analysis
 - Data quality control
 - Gap-filling
- Energy and CO₂ exchange over croplands at Haean
 - Monsoon
 - Length of growing season
- Input or validation for models

Field campaign 2010



Eddy-covariance

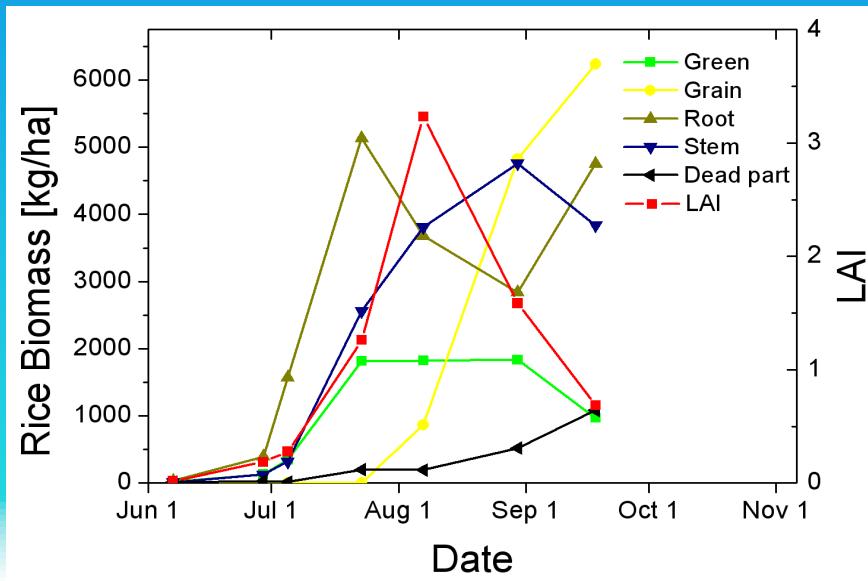
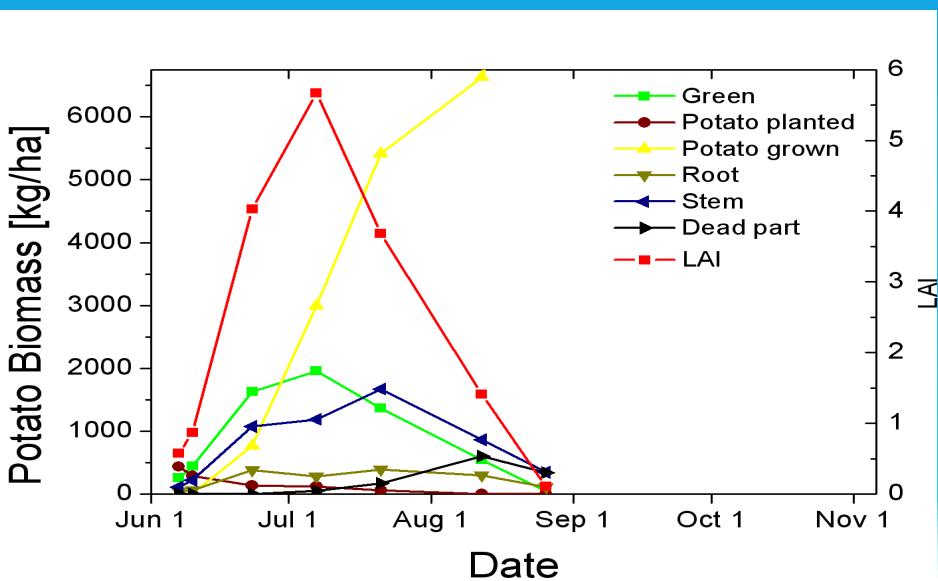


$$F = \overline{w'x'}$$

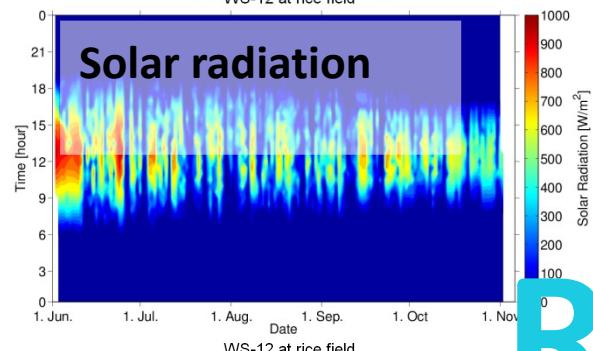


TK2 (Mauder and Foken, 2004)
TK3 (Mauder and Foken, 2011)

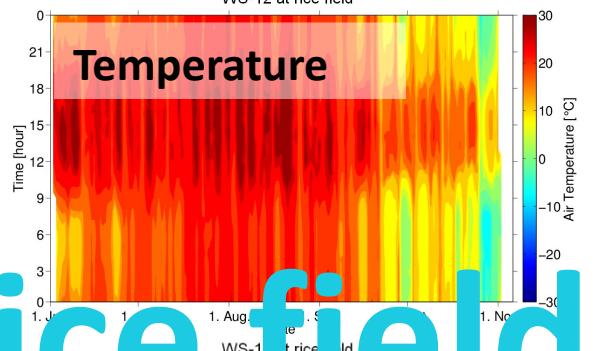
Biometric measurements



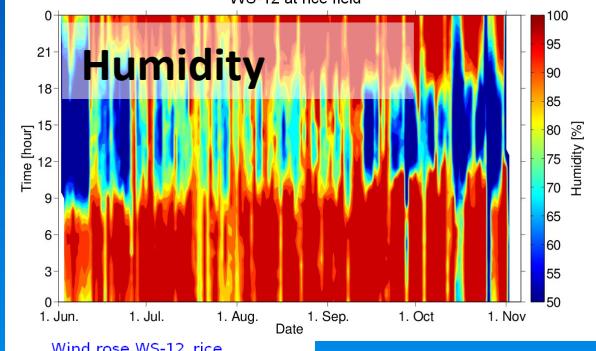
WS-12 at rice field



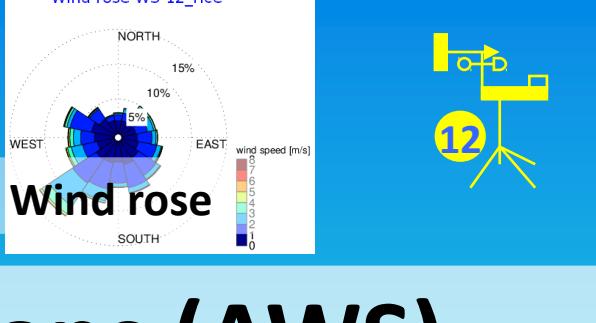
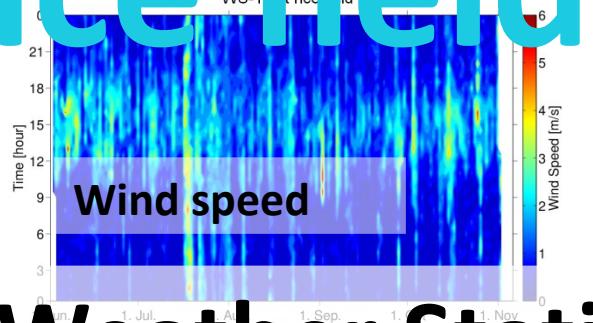
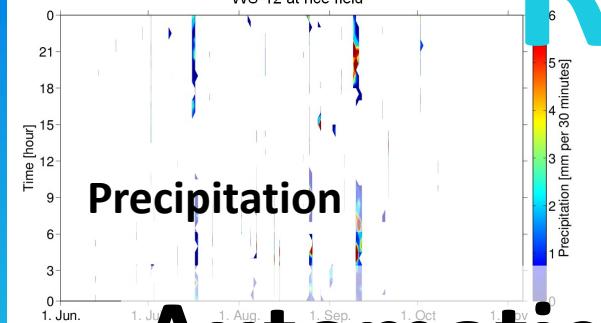
WS-12 at rice field



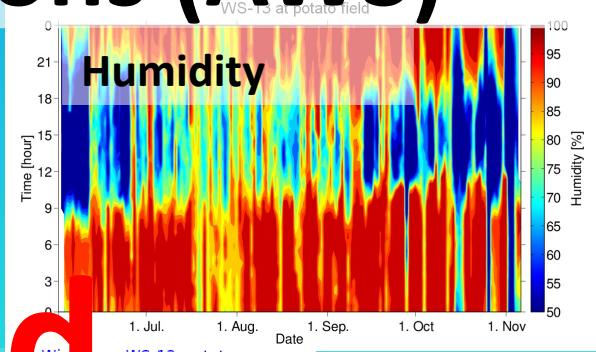
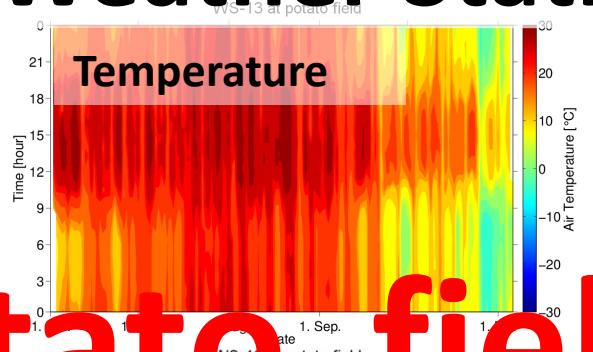
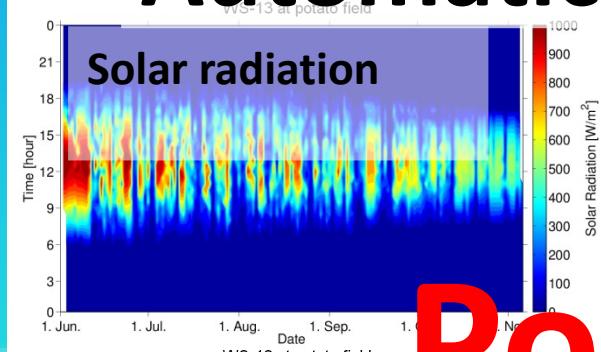
WS-12 at rice field



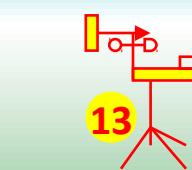
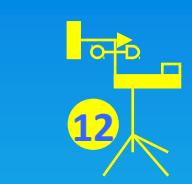
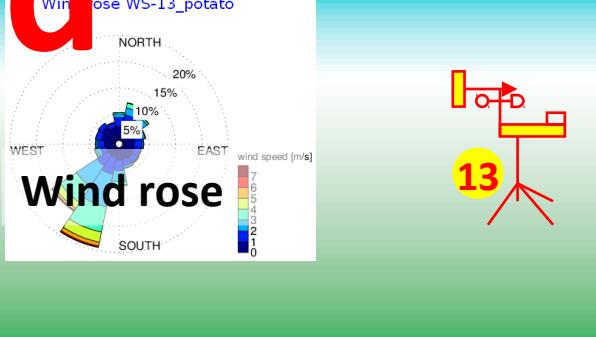
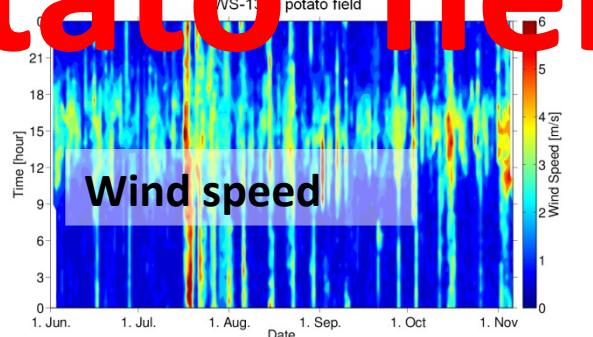
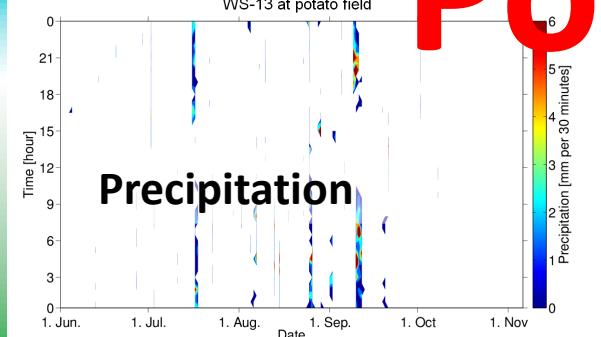
Rice field

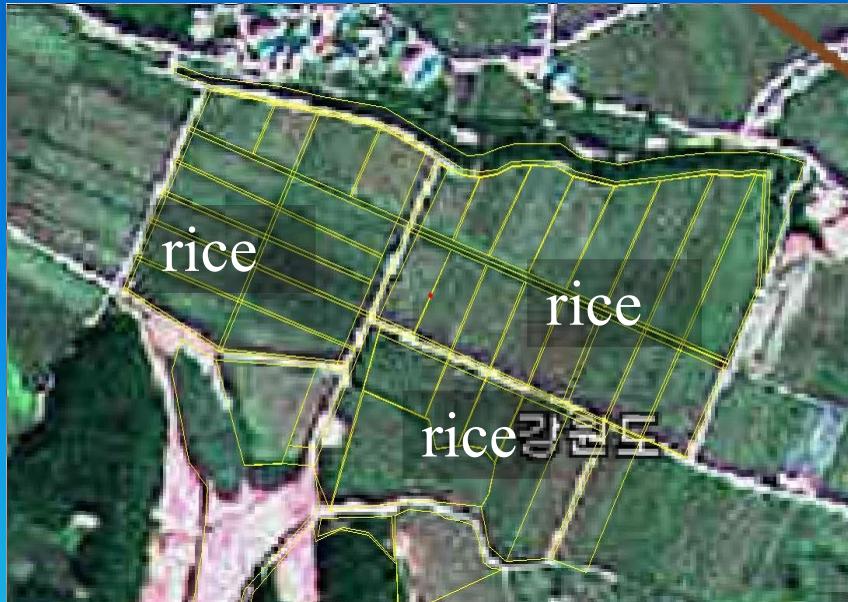


Automatic Weather Stations (AWS)

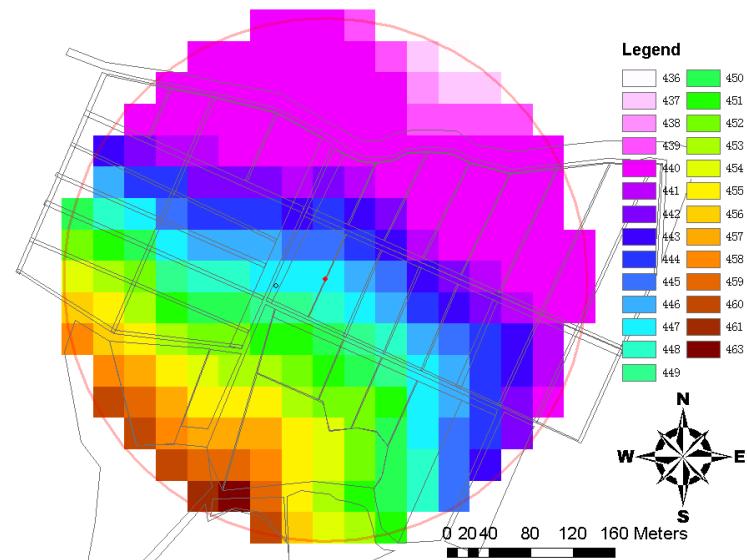


Potato field

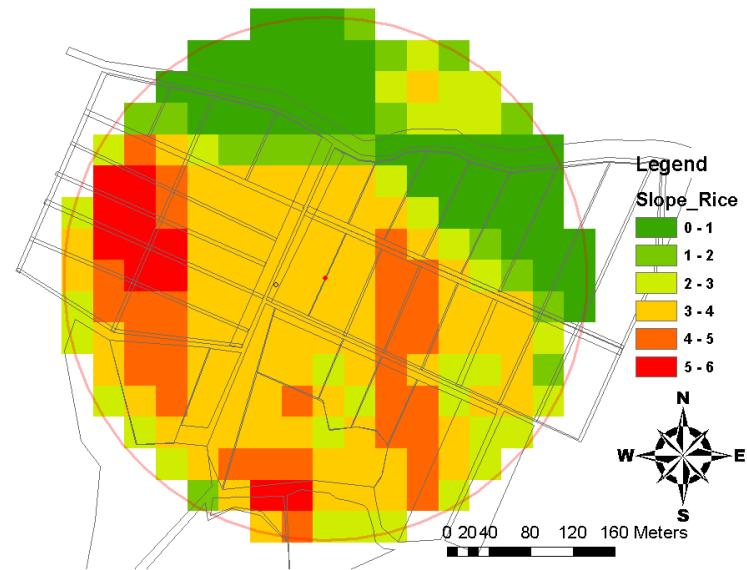




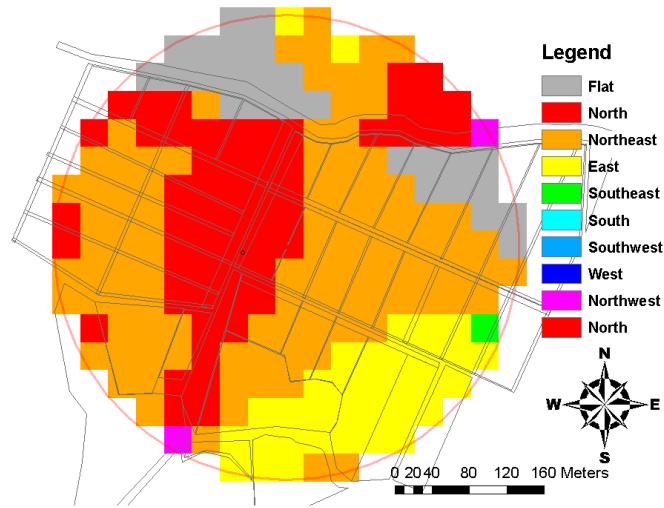
Altitude Rice Field, Haean, Korea

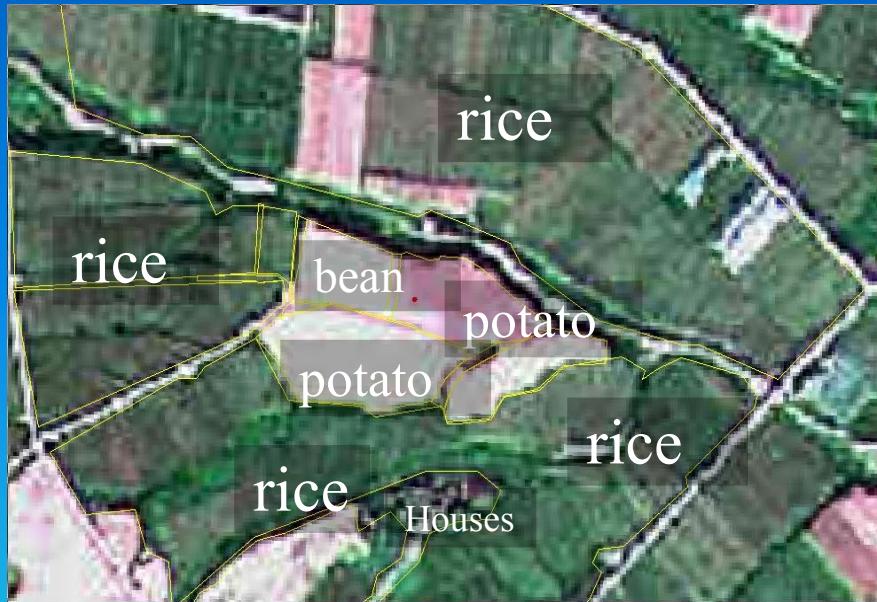


Slope Rice Field, Haean, Korea

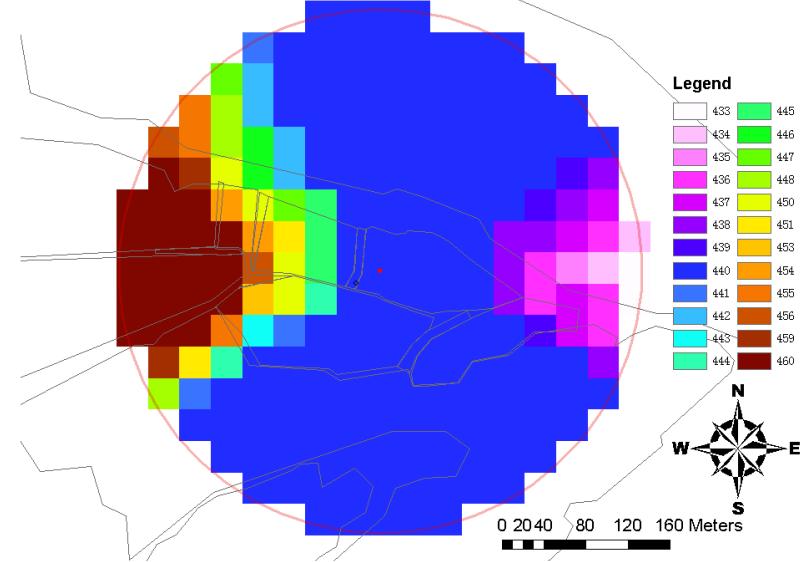


Aspect Rice Field, Haean, Korea

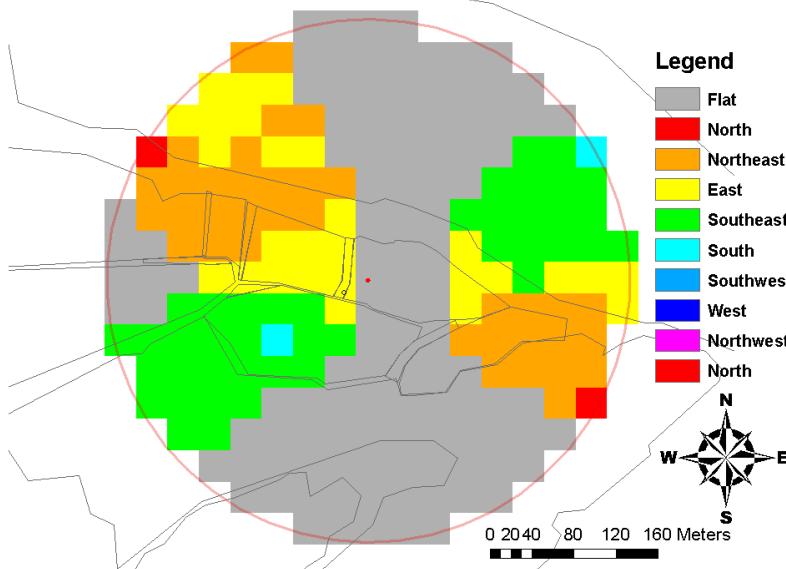




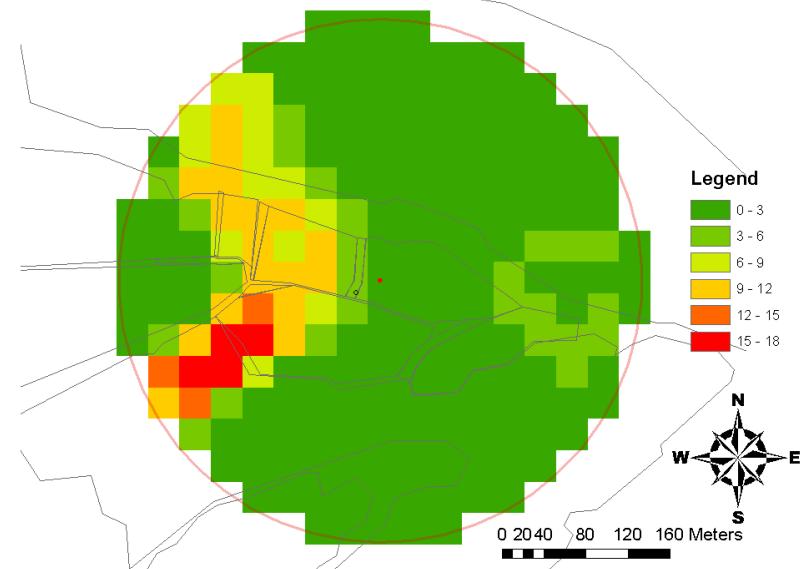
Altitude Potato Field, Haean, Korea



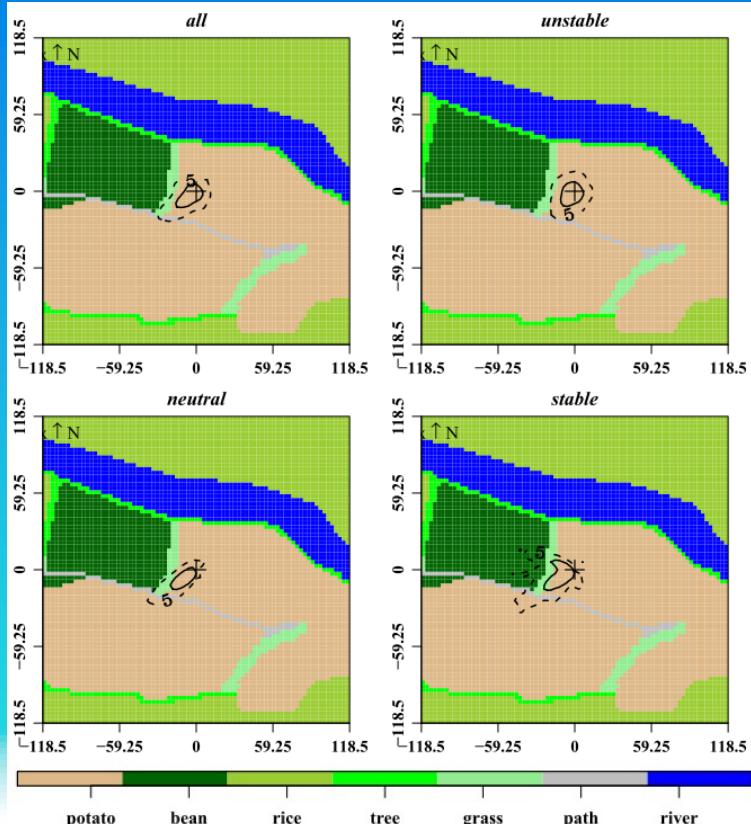
Aspect Potato Field, Haean, Korea



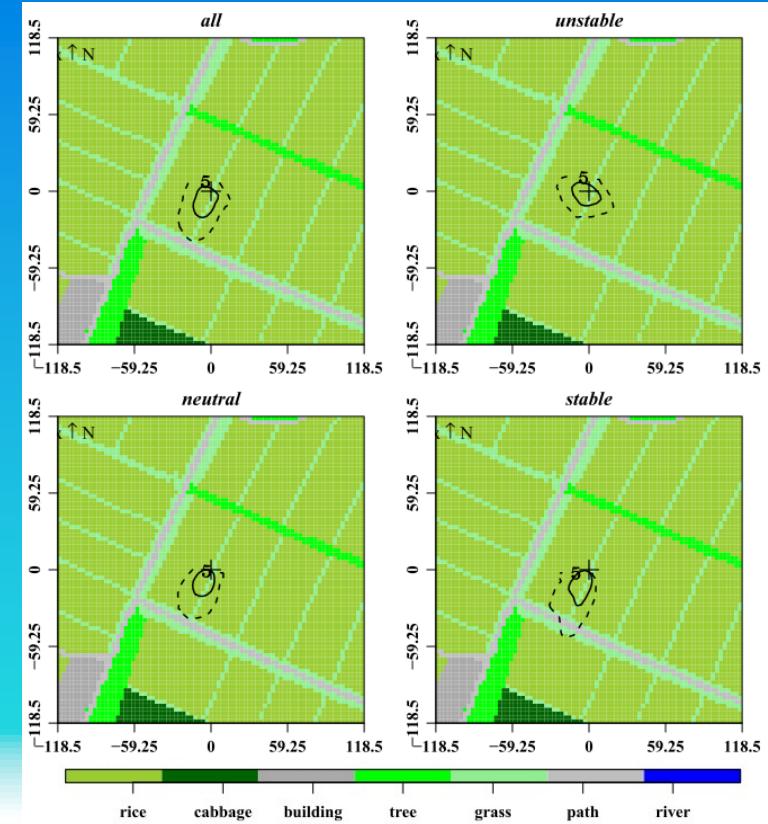
Slope Potato Field, Haean, Korea



Footprint

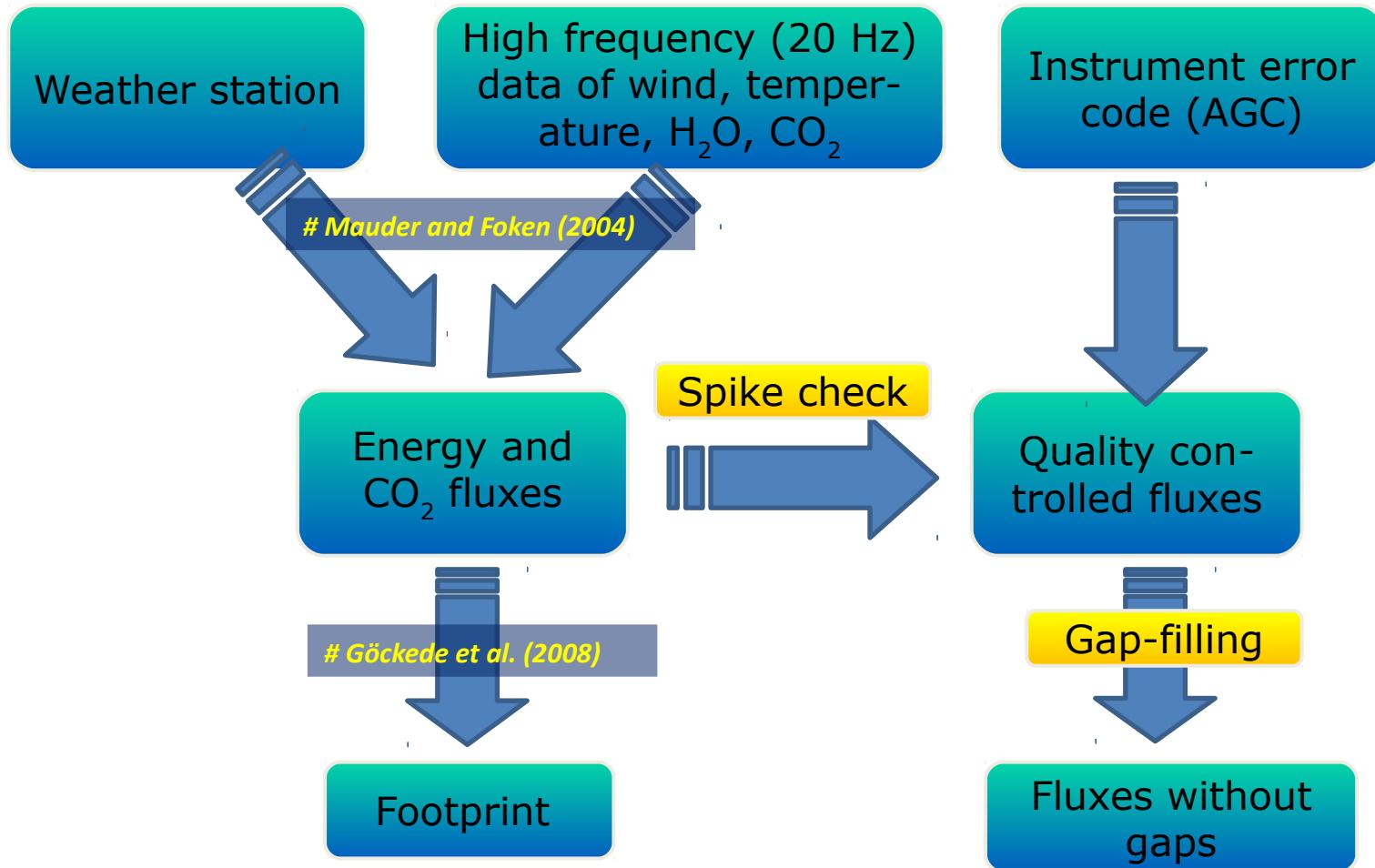


Potato field

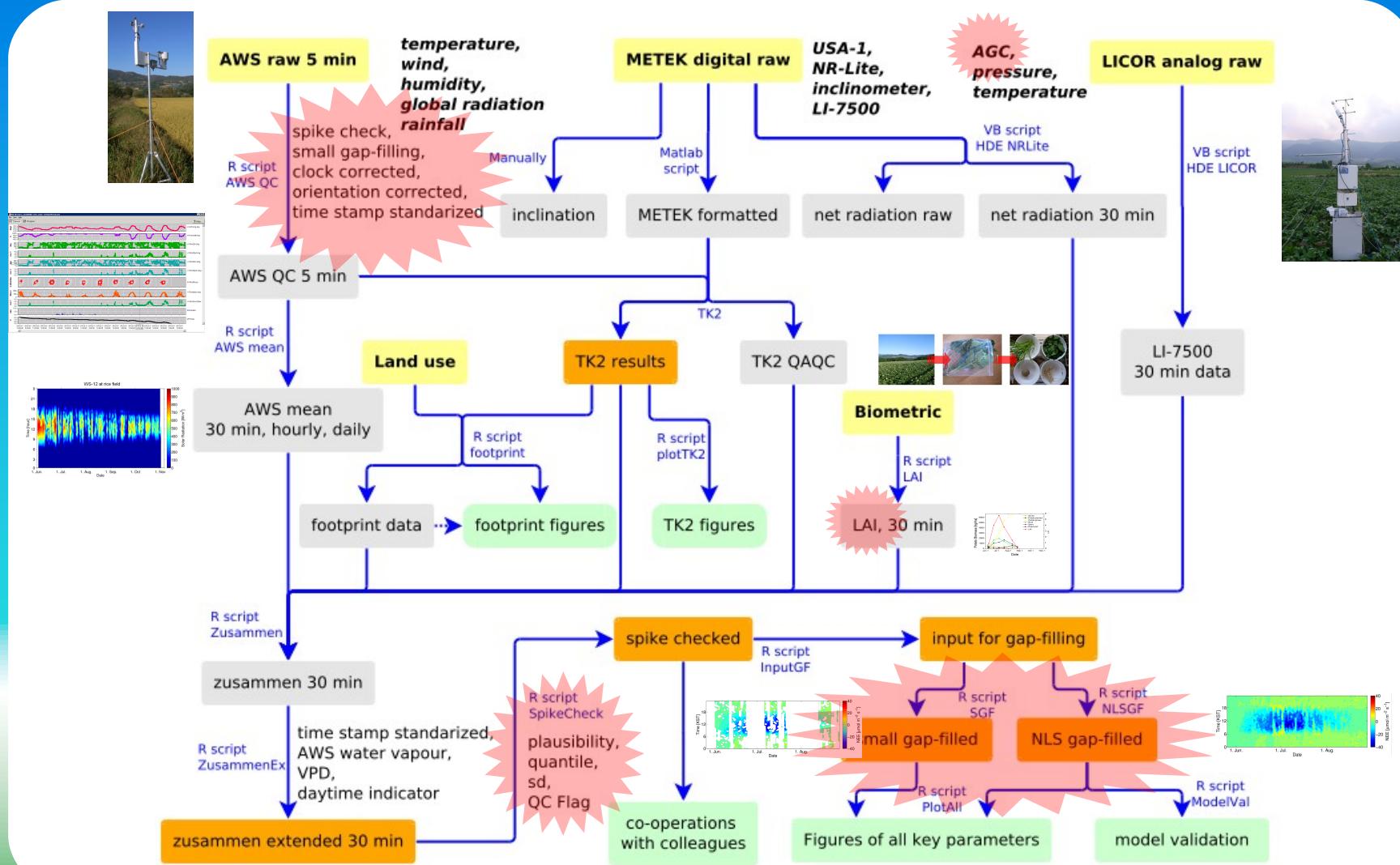


Rice field

Data flow



Data flow (what's new)

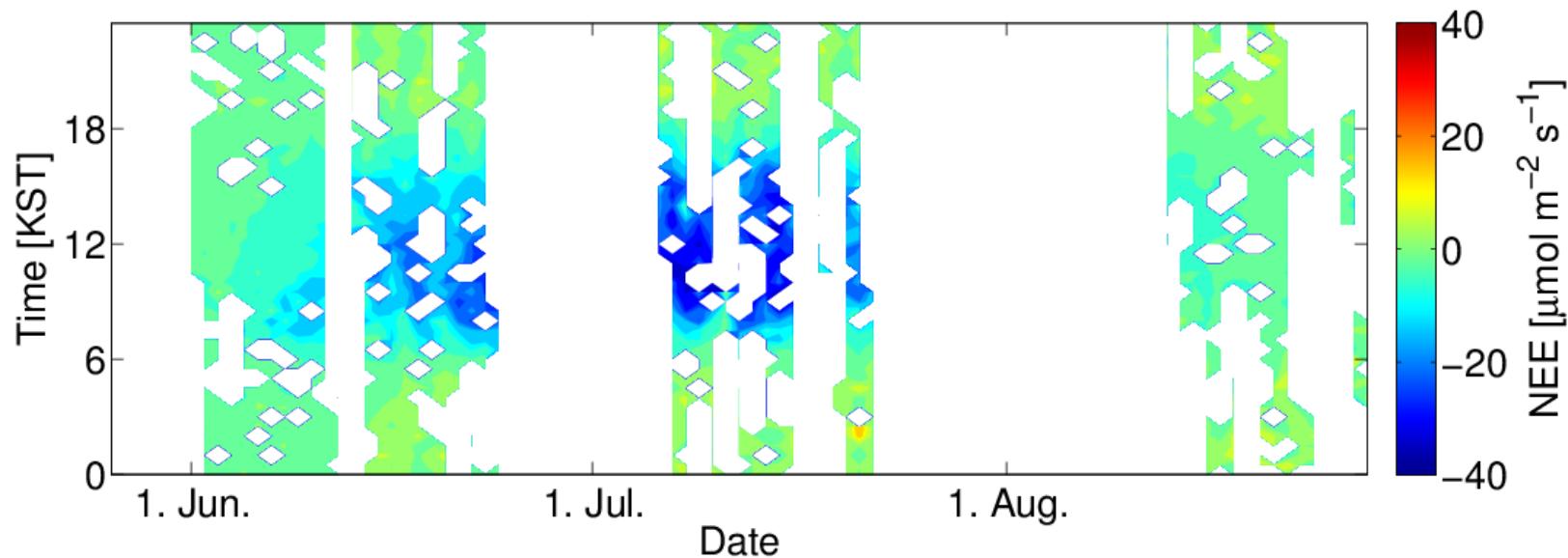


Quality control

Steps	Period 1	Period 2	Period 3	Overall
w/CO ₂ threshold check	99.6%	99.9%	99.7%	99.7%
Instrument error check	86.8%	70.9%	72.0%	78.0%
w/CO ₂ spike check	86.2%	68.9%	70.1%	76.6%
NEE Threshold check	86.2%	68.9%	70.1%	76.6%
NEE quality flag check*	82.1%	68.4%	68.0%	74.1%
NEE spike check	78.6%	65.1%	63.9%	70.5%

* data with quality flag of 7, 8, 9 were rejected (Foken and
Wichura, 1996; Foken et al., 2004).

Gaps



Gap-filling strategy for CO₂ flux

	Daytime	Nighttime
R _{eco}	gaps	Measured and gaps
NEE	Measured and gaps	NEE = R _{eco}
GPP	GPP = NEE-R _{eco}	0

Gap-filling strategy for CO₂ flux

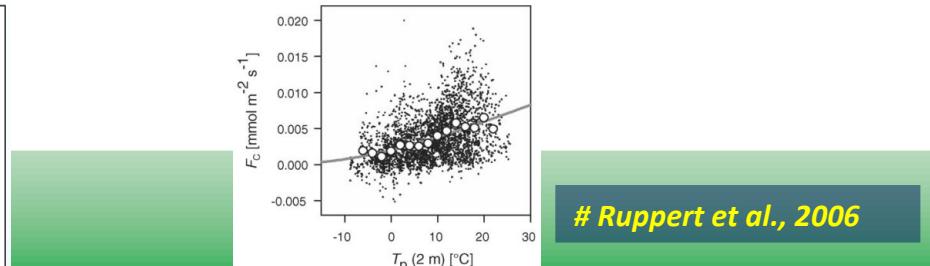
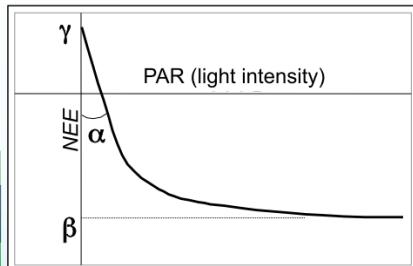
	Daytime	Nighttime
R _{eco}		gaps
NEE	Measured and gaps	Measured and gaps
GPP	GPP = NEE - R _{eco}	

$F_d = \frac{\alpha R_g \beta}{\alpha R_g + \beta} + \gamma$

*# Michaelis and Menton, 1913;
Falge et al., 2001*

$F_{R,eco} = F_{R,10} e^{E_0[(1/(283.15-T_0))-(1/(T-T_0))]}$

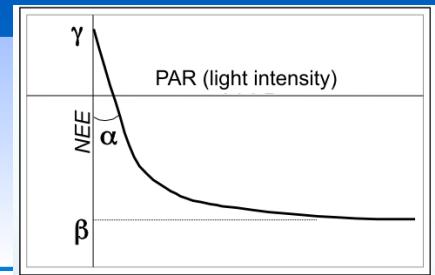
*# Lloyd and Taylor, 1994;
Falge et al., 2001*



Lindner, 2011

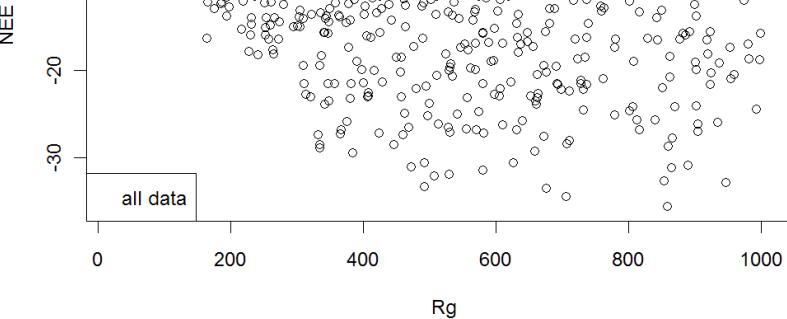
Ruppert et al., 2006

Light response curve



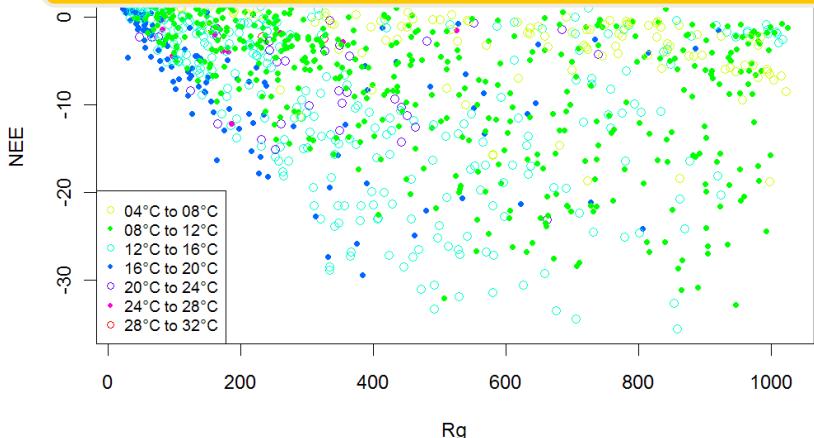
Daytime NEE [micromol/m² s] ~ Rg (global radiation) [W / m²]

All data

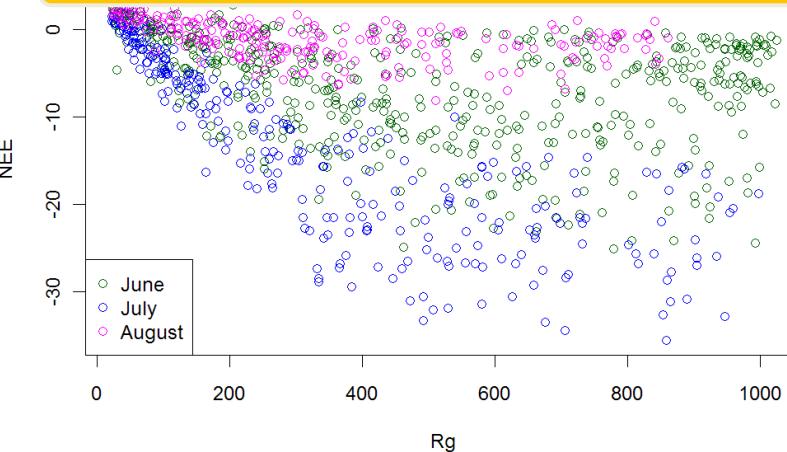


Daytime NEE [micromol/m² s] ~ Rg (global radiation) [W / m²]

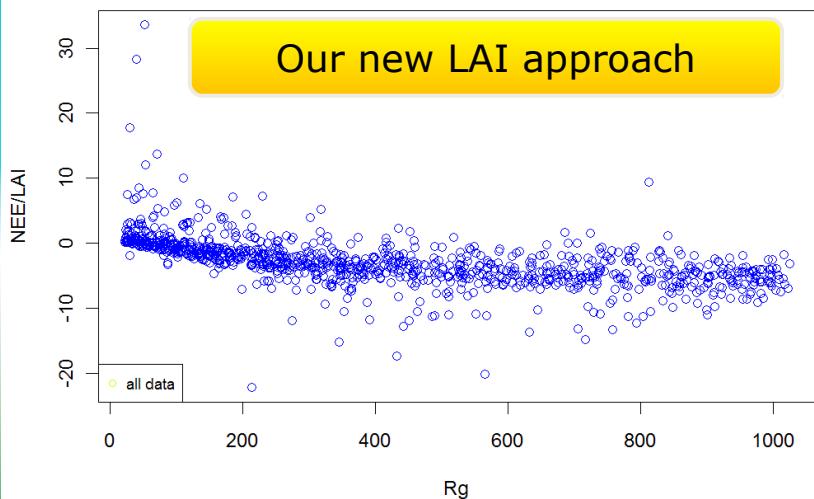
Conventional temperature classification



Conventional temporal classification



Our new LAI approach



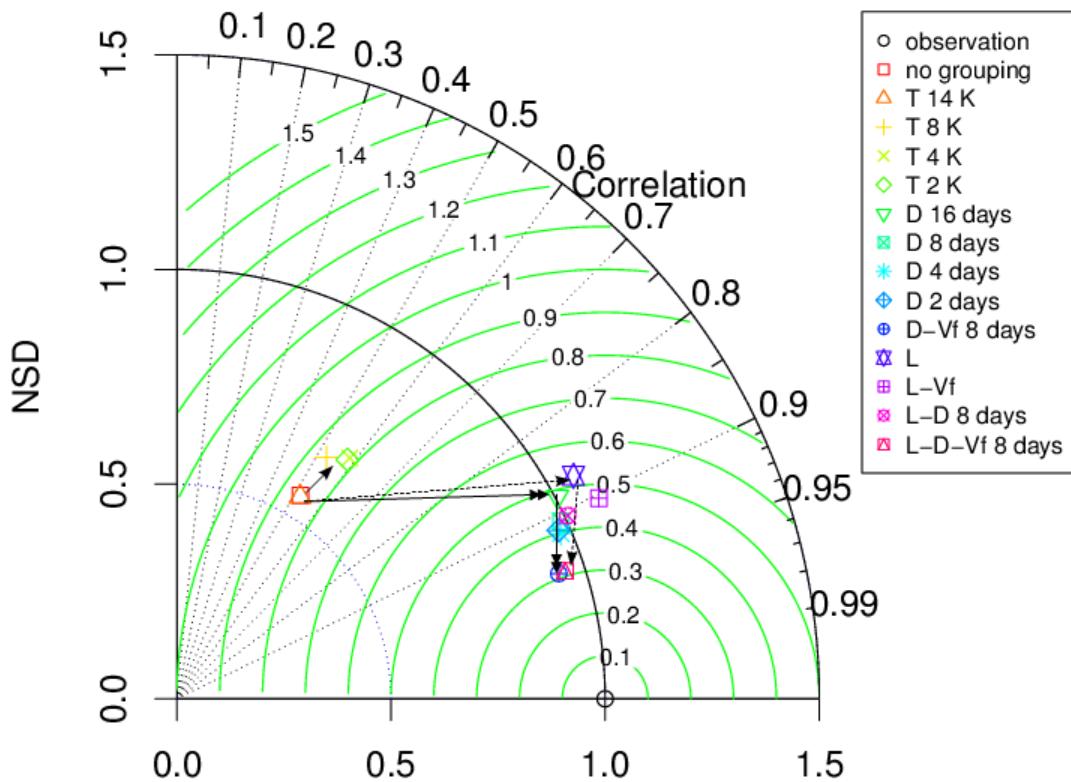
Gap-filling

Models	Temperature bins	LAI factor*	Day bins	VPD bins	VPD factor**
1-T	Yes	No	No	No	No
2-D	No	No	Yes	No	No
3-T-L	Yes	Yes	No	No	No
4-T-L-Vf	Yes	Yes	No	No	Yes
5-L-Vb	No	Yes	No	Yes	No
6-L-Vb-Vf	No	Yes	No	Yes	Yes
7-D-L-Vf	No	Yes	Yes	No	Yes

* F_d was replaced with $F_d^* = F_d / LAI$

** An exponential function was introduced (# Lasslop et al., 2010).

Performances of gap-filling models: daytime NEE



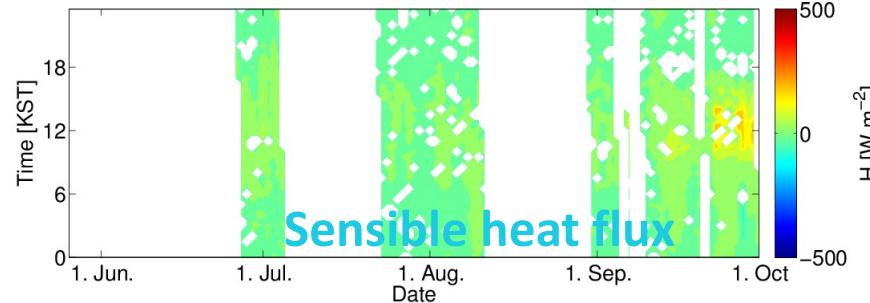
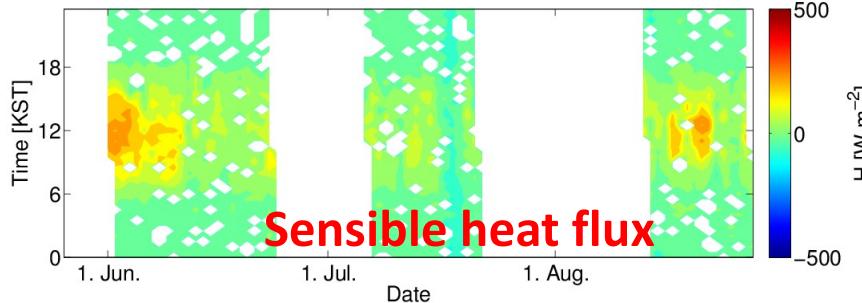
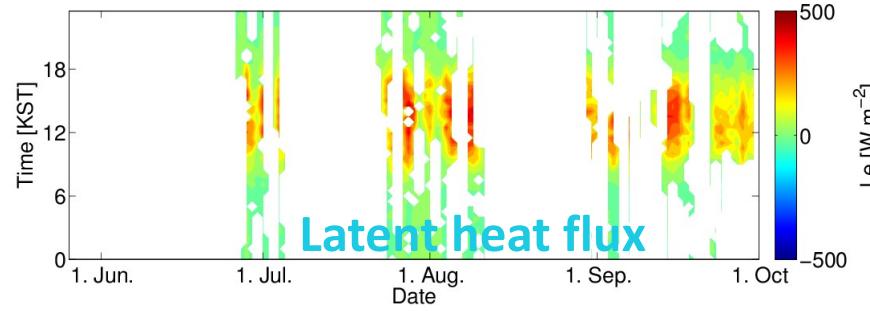
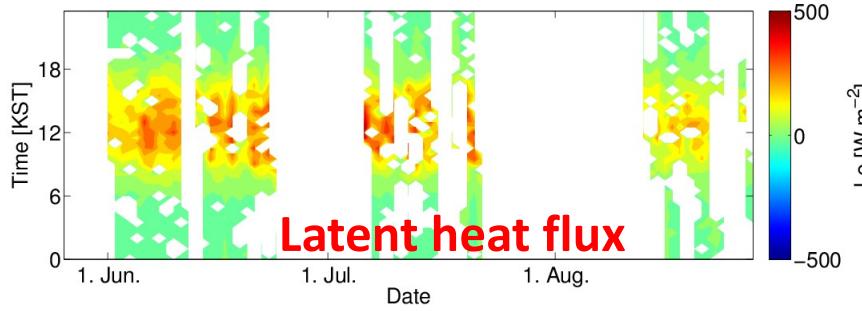
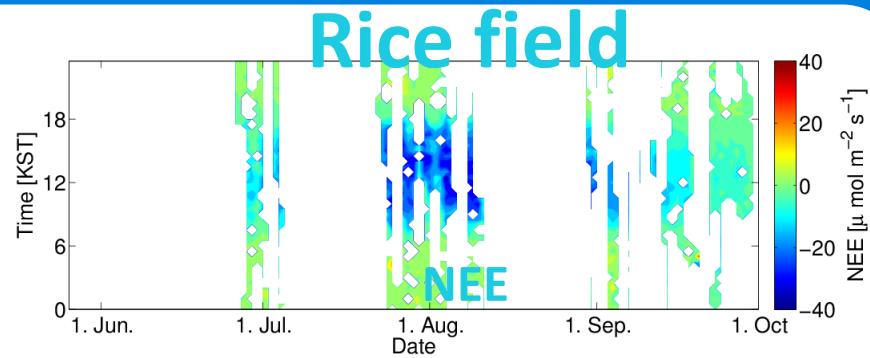
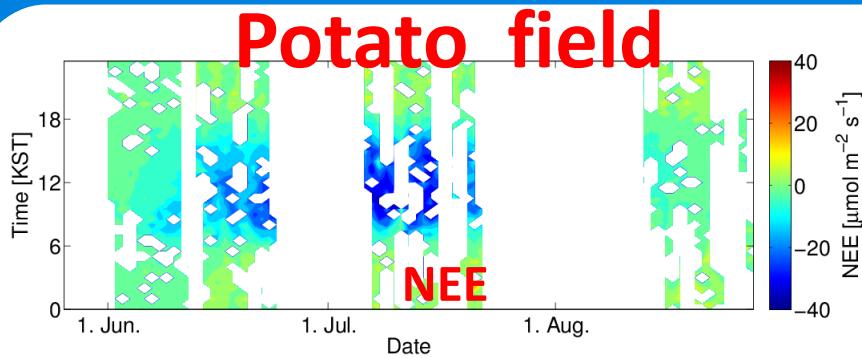
Methods	E	d
1-T_bin02	0.31	0.73
1-T_bin04	0.3	0.74
1-T_bin08	0.23	0.7
1-T_bin14	0.26	0.66
1-T_bin28	0.26	0.66
2-D_bin02	0.83	0.96
2-D_bin04	0.84	0.96
2-D_bin08	0.81	0.95
2-D_bin16	0.76	0.94
3-T-L_bin02	0.78	0.95
3-T-L_bin04	0.78	0.95
3-T-L_bin08	0.72	0.93
3-T-L_bin14	0.73	0.93
3-T-L_bin28	0.71	0.93
4-T-L-Vf_bin02	0.8	0.95
4-T-L-Vf_bin04	0.8	0.95
4-T-L-Vf_bin08	0.79	0.95
4-T-L-Vf_bin14	0.78	0.95
4-T-L-Vf_bin28	0.77	0.95
5-L-Vb_bin250	0.74	0.94
5-L-Vb_bin500	0.78	0.95
5-L-Vb_bin1000	0.76	0.94
5-L-Vb_bin2000	0.7	0.93
6-L-Vb-Vf_bin250	0.74	0.94
6-L-Vb-Vf_bin500	0.77	0.95
6-L-Vb-Vf_bin1000	0.77	0.95
6-L-Vb-Vf_bin2000	0.73	0.93

Taylor (2001)

E: Nash–Sutcliffe model efficiency coefficient

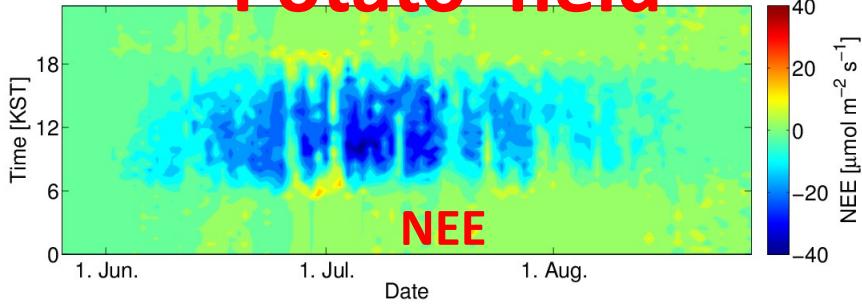
d: index of agreement

Fluxes: observed

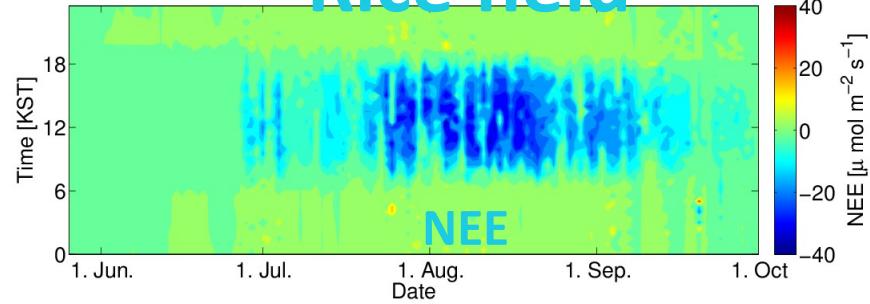


Fluxes: gap-filled

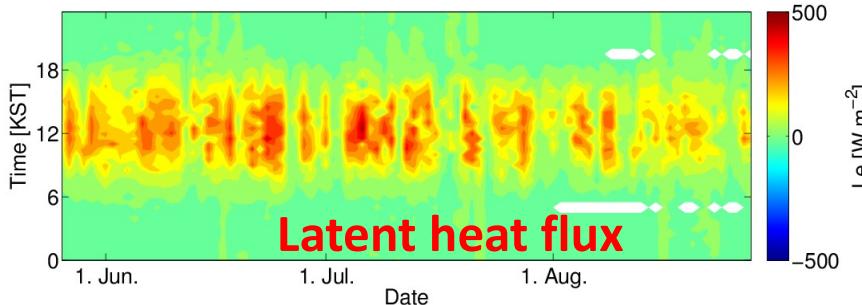
Potato field



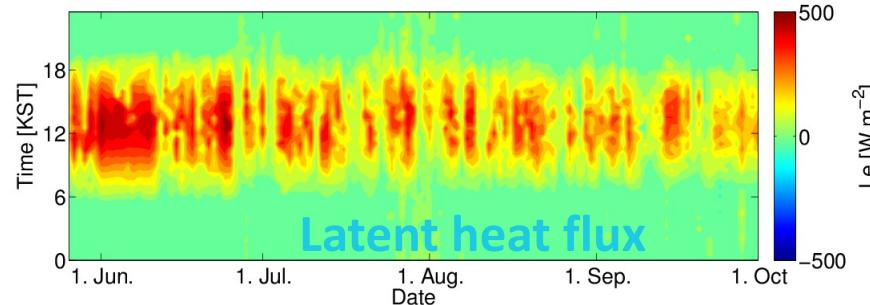
Rice field



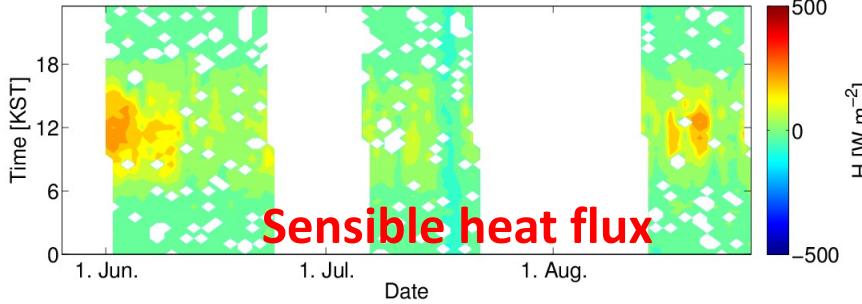
Latent heat flux



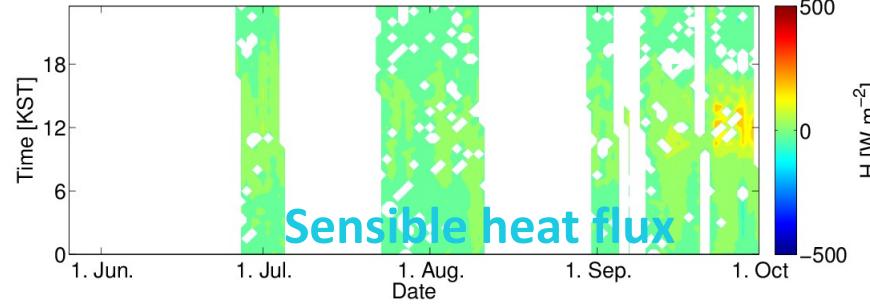
Latent heat flux



Sensible heat flux



Sensible heat flux



Residuals

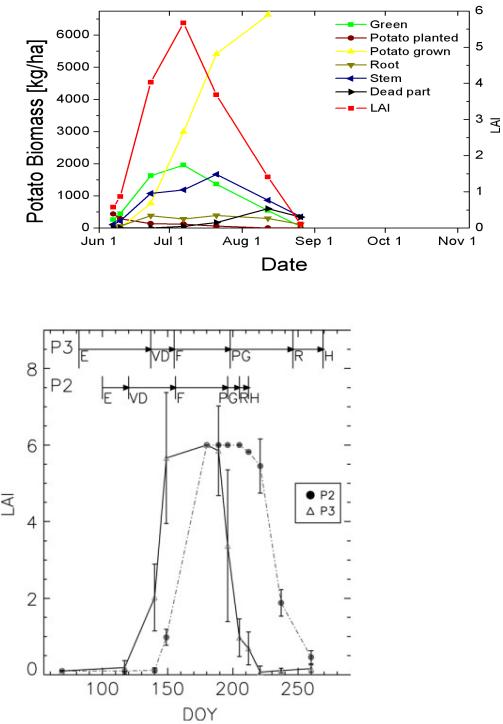
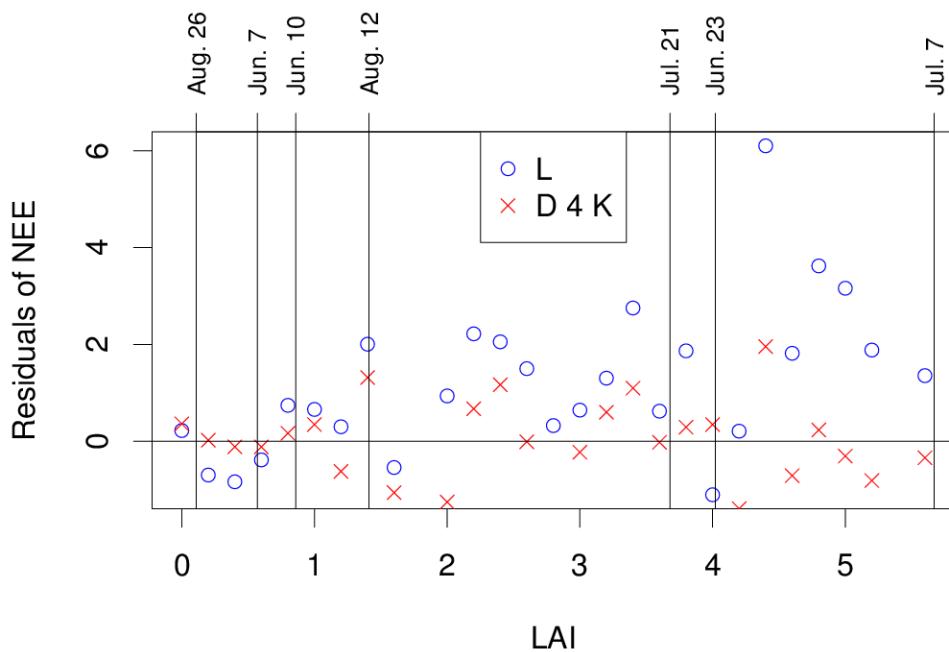
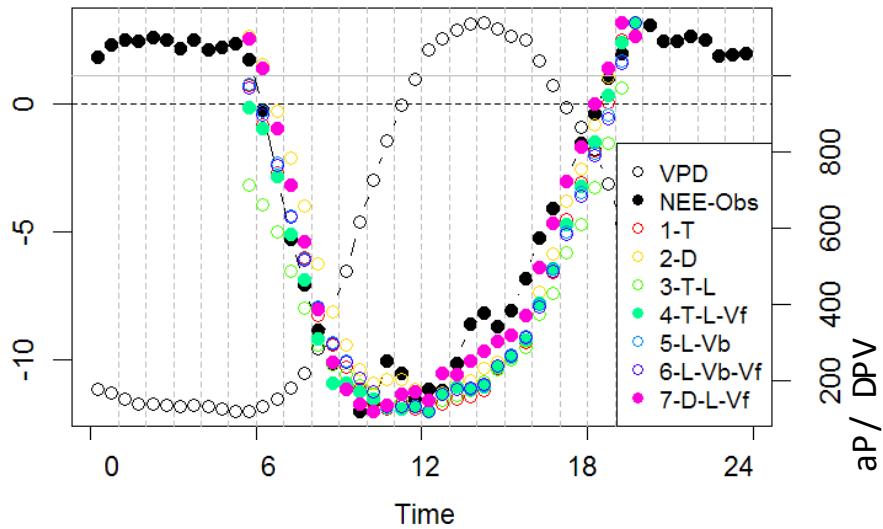


Fig. 5. Retrieved LAI for two potato fields (P2 and P3) with different calendar. Phenological observations are indicated on top. P2 has a longer cycle than P3: emergence is earlier and harvest is later than for P2. E stands for Emergence, VD for Vegetation Development, F for Flowering, PG for Potato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

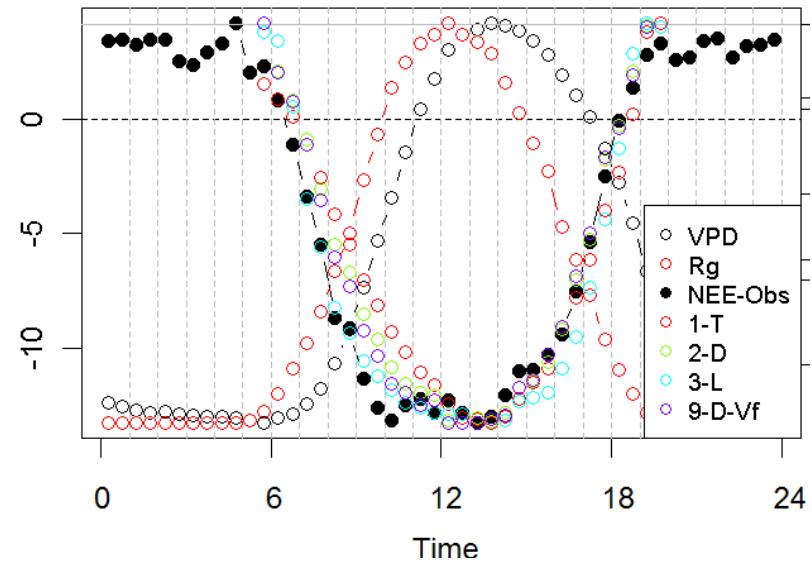
González-Sanpedro et al. (2008)

Mean diurnal cycle

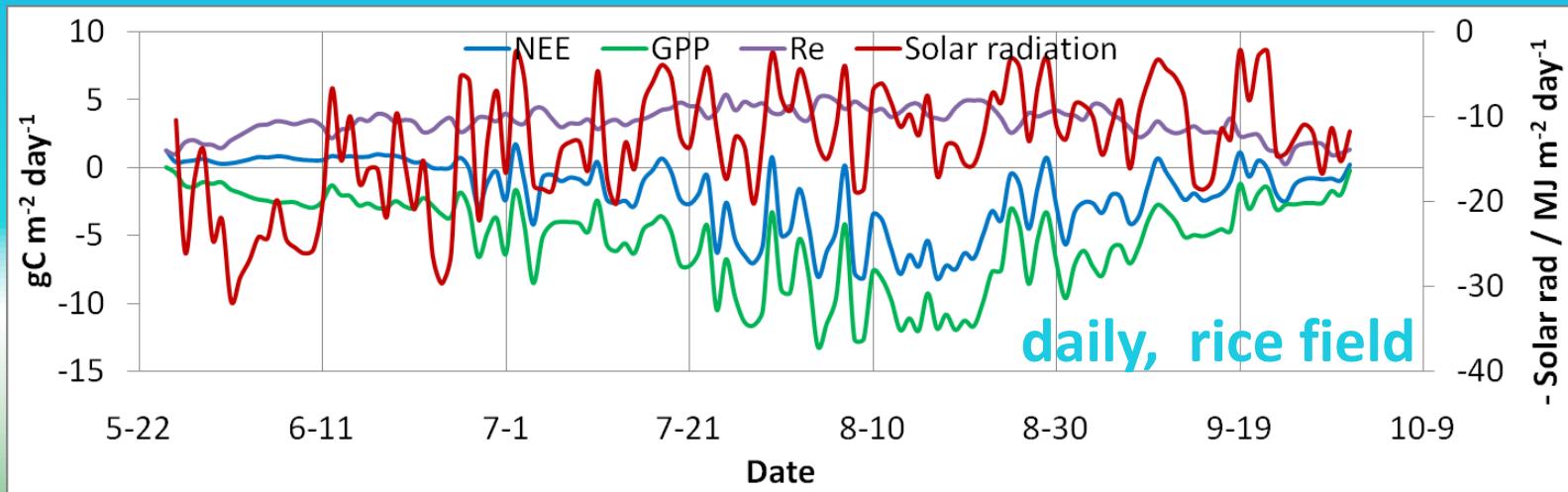
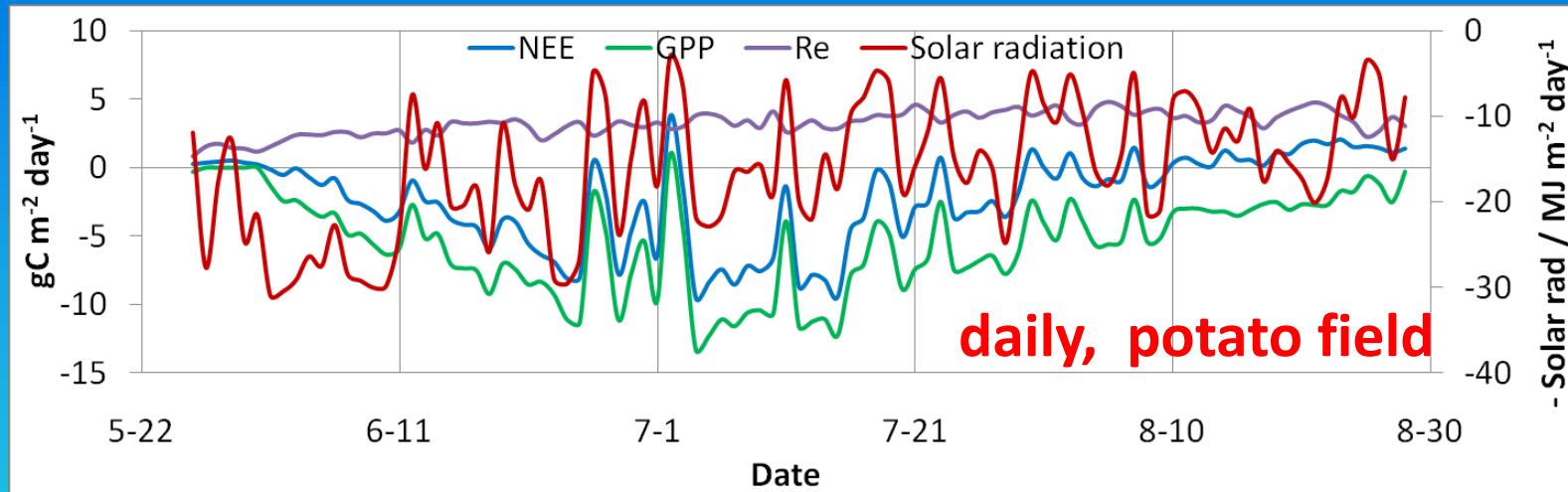
Potato field



Rice field

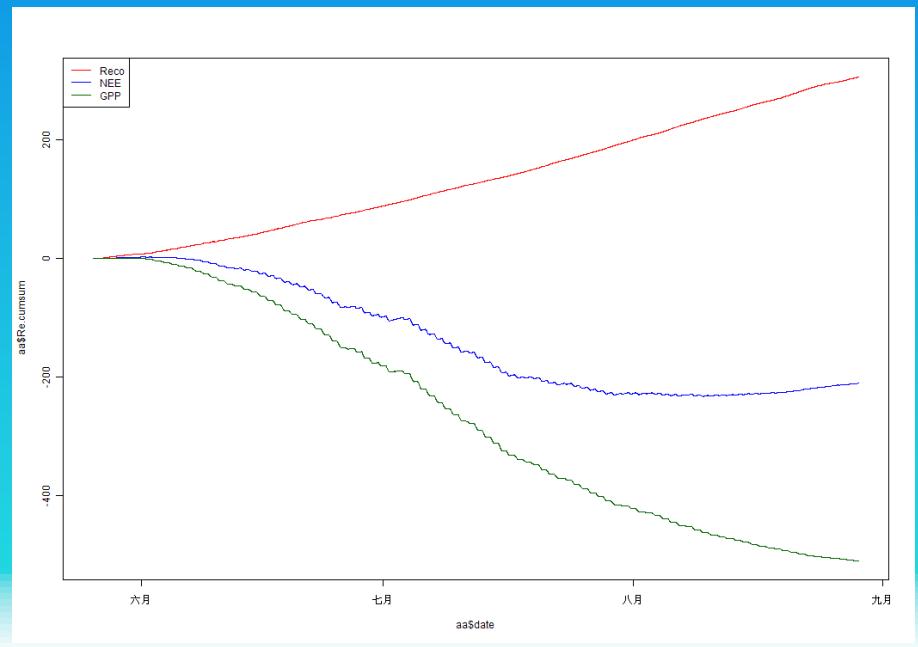


Daily mean

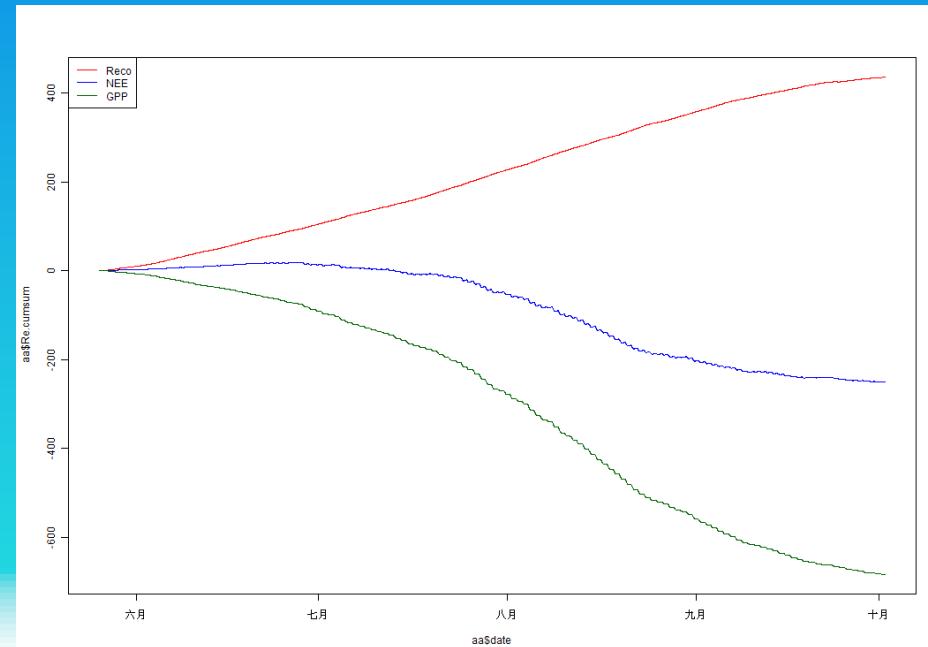


Cumulative

Potato field

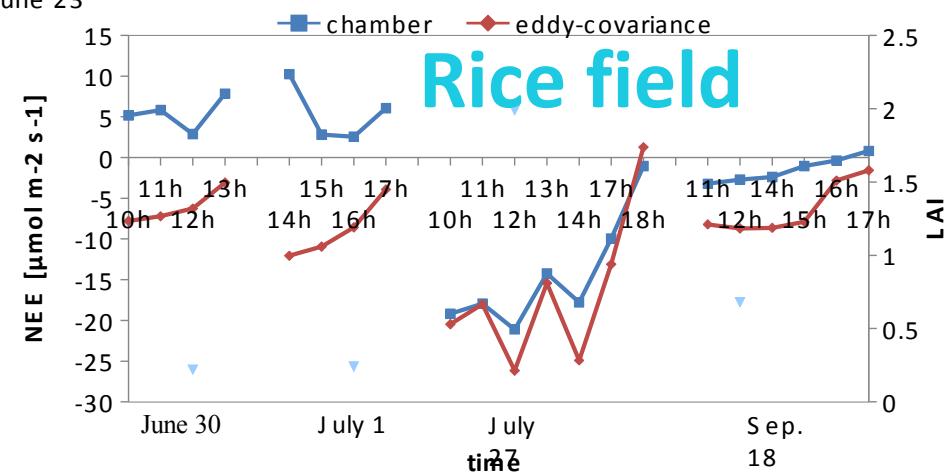
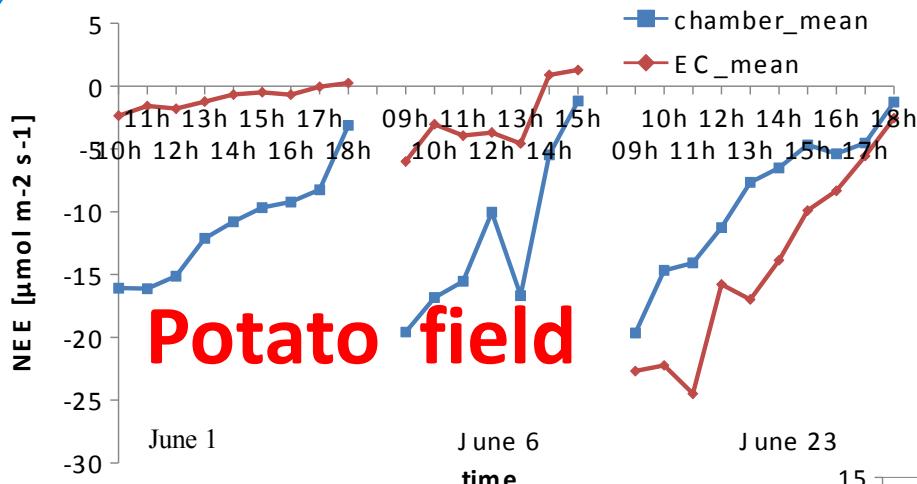


Rice field



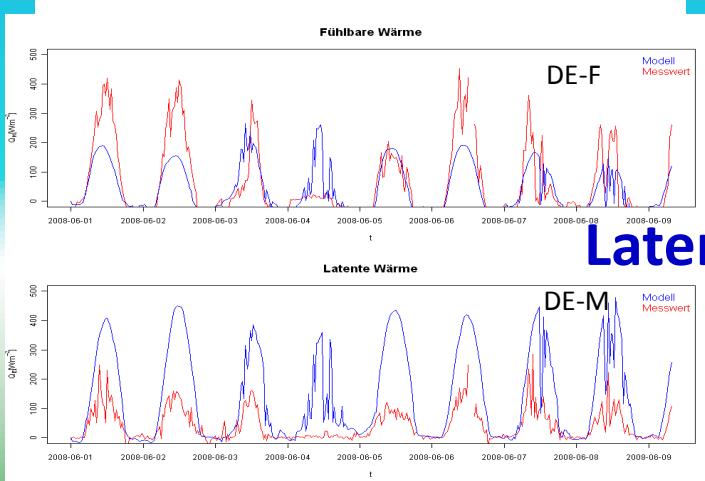
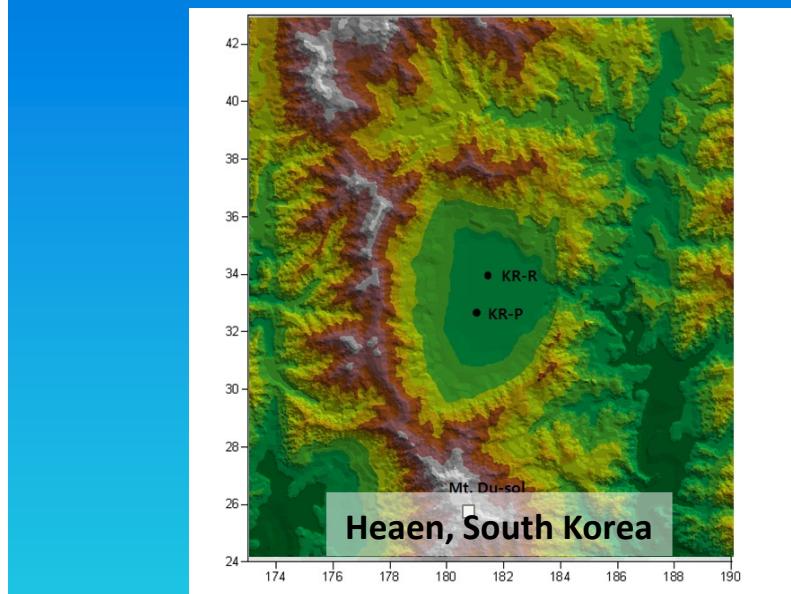
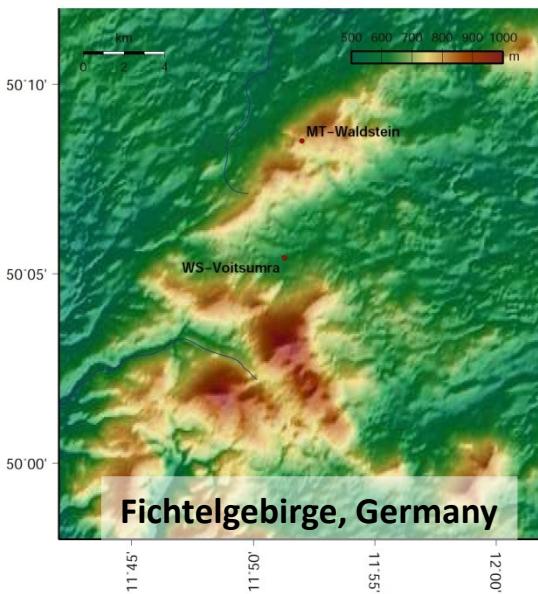
Comparison with chamber measurement

Co-worker: Steve Lindner

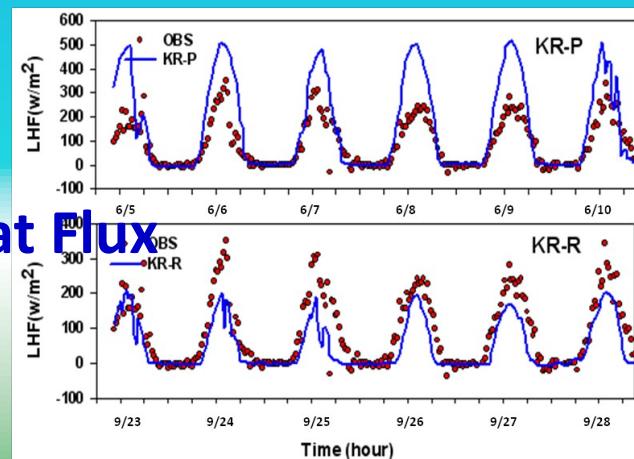


Comparison of WRF model with observations

Co-worker: Dr. Jea-Chul Kim, Dr. Andrei Serafimovich



Latent Heat Flux



Red : OBS
Blue : WRF

Conclusion

- Eddy-covariance technique ~ complex terrain
- Gap-filling
- CO₂ flux
 - Mid-season depression
 - Late-season source at potato farm
- Further co-operation work

Publications

- Zhao, P. et al., 2011. Documentation of the Observation Period, May 12th to Nov. 8th, 2010, Haean, South Korea, Universität Bayreuth, Abt. Mikrometeorologie, Print, ISSN 1614-8916, Arbeitsergebnisse 45.
- Zhao, P. and Lüers, J., *in progress*. Gap-filling strategy for net ecosystem exchange of carbon dioxide at a rapidly-growing cropland in South Korea.
- Kim J.-C., Zhao P., Serafimovich, A., Thieme, C., Lüers J., Lee C. B., Tenhunen J., Foken T., *in progress*: Analysis of meteorological features using observations and models in a basin area
- Zhao P., Lee B., Lindner S., Lüers J., Tenhunen J., Foken T., *in plan*: Influence of monsoon and crop management on CO₂ uptake over farmlands in South Korea

A scenic rural landscape featuring a dirt road leading through a lush green field towards distant mountains under a blue sky with scattered white clouds.

Thank you for your attention.