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JÜLICH
FORSCHUNGSZENTRUM

MODIS Land Surface Temperature Assimilation and Verification at Rur Catchment

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Evapotranspiration Uncertainties

Atmosphere

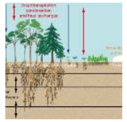
- Rainfall
- Radiation
- Wind
- Temperature
- …

Soil

- Moisture
- Temperature
- Hydraulic Properties
- …

Vegetation

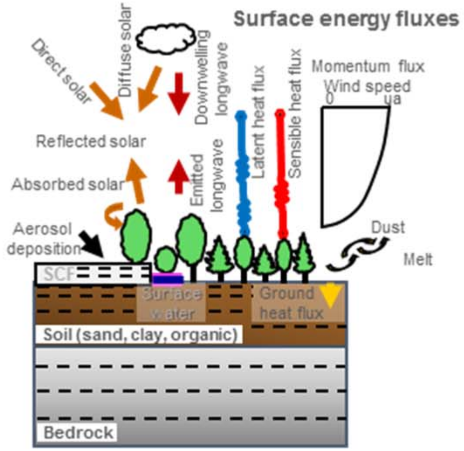
- Temperature
- Photosynthesis
- Root Uptake
- Leaf Area Index
- …

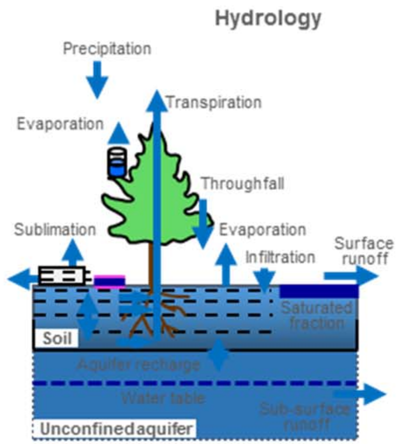


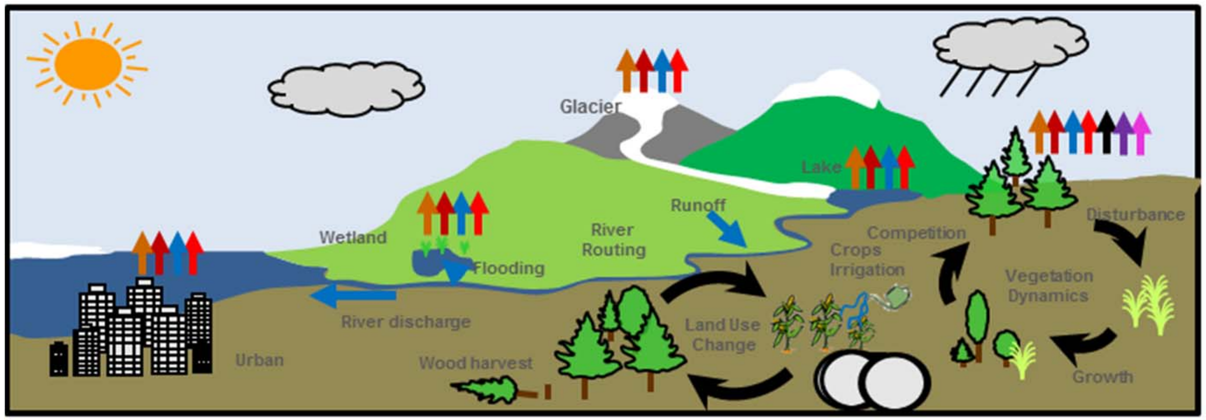
Model

- Model Structure
- …

Community Land Model (CLM 4.5)
- Surface energy and water balance

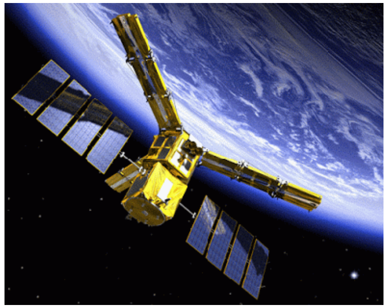




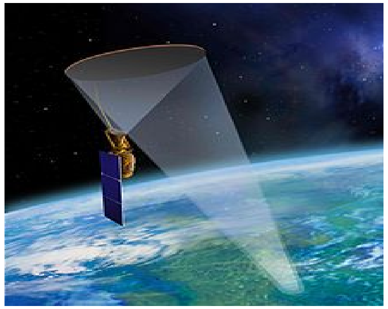


http://www.cesm.ucar.edu/models/clm

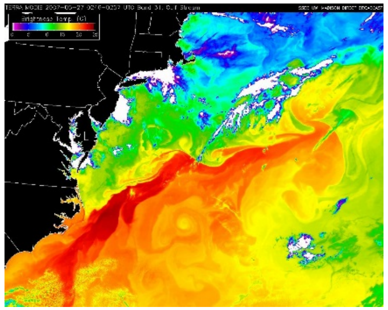
Remote Sensing of Land Surface



SMOS
40 KM



SMAP
10 KM



MODIS
1 KM

GOES
4 KM

Surface Soil Moisture

Land Surface Temperature

Land Surface Temperature (LST) Assimilation

- Advantages
  - High spatial resolution (~4 km)
  - High temporal resolution (hourly ~ daily)
  - High accuracy

- Disadvantages
  - No memory of LST
  - Diurnal cycle

Background

$$\Delta T_{soil} = f(h)/-\lambda \quad (1)$$

The heat flux into the soil surface from the overlying atmosphere

$$h = \vec{S}_{soil} + \vec{L}_{soil} - H_{soil} - \lambda E_{soil} \quad (2)$$

$\vec{S}_{soil}$ is the solar radiation absorbed by top soil, H_{soil} is the sensible heat flux from soil
$\vec{L}_{soil}$ is the longwave radiation absorbed by soil, λE_{soil} is the latent heat flux from soil

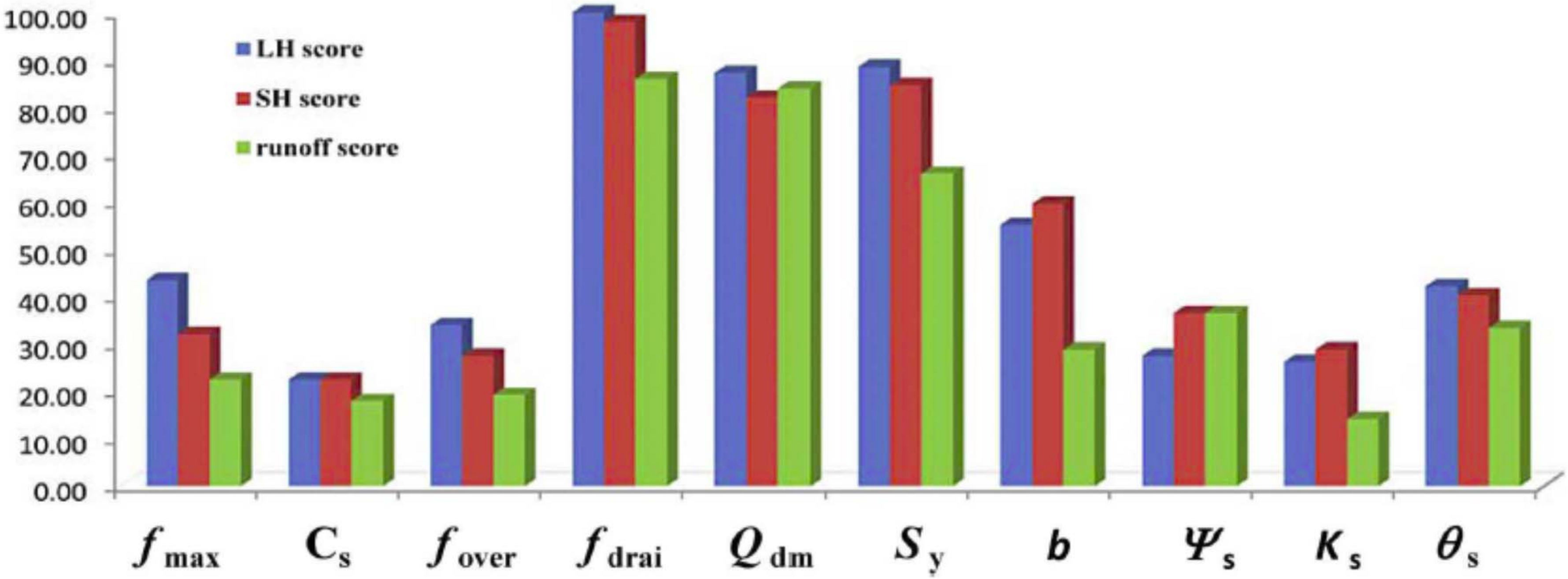
$$\Delta T_v = \frac{\vec{S}_v - \vec{L}_v - H_v - \lambda_{vap} E_v}{\frac{\partial \vec{L}_v}{\partial T_v} + \frac{\partial \overrightarrow{H_v}}{\partial T_v} + \frac{\partial \overrightarrow{\lambda E_v}}{\partial T_v}} \quad (3)$$

$\vec{S}_v$ is the solar radiation absorbed by the vegetation

$\vec{L}_v$ is the net longwave radiation absorbed by vegetation

H_v, $\lambda_{vap} E_v$ are the sensible and latent heat fluxes from vegetation

Sensitivity of Sensible and Latent Heat Flux



- Schwinger, J., et al. (2010). "Sensitivity of Latent Heat Fluxes to Initial Values and Parameters of a Land-Surface Model." Vadose Zone Journal **9**(4): 984-1001.

Objective

- Assimilate the MODIS LST products to improve predictions with the land surface model CLM through updating the following variables:
  - Leaf Area Index - LAI
  - Stem Area Index - SAI
  - $Vcmax$ - maximum rate of carboxylation
  - $Fdrai$ – decay factor of subsurface runoff
  - $Qdrai$ - maximum drainage when the water table depth is at the surface
  - Soil Moisture

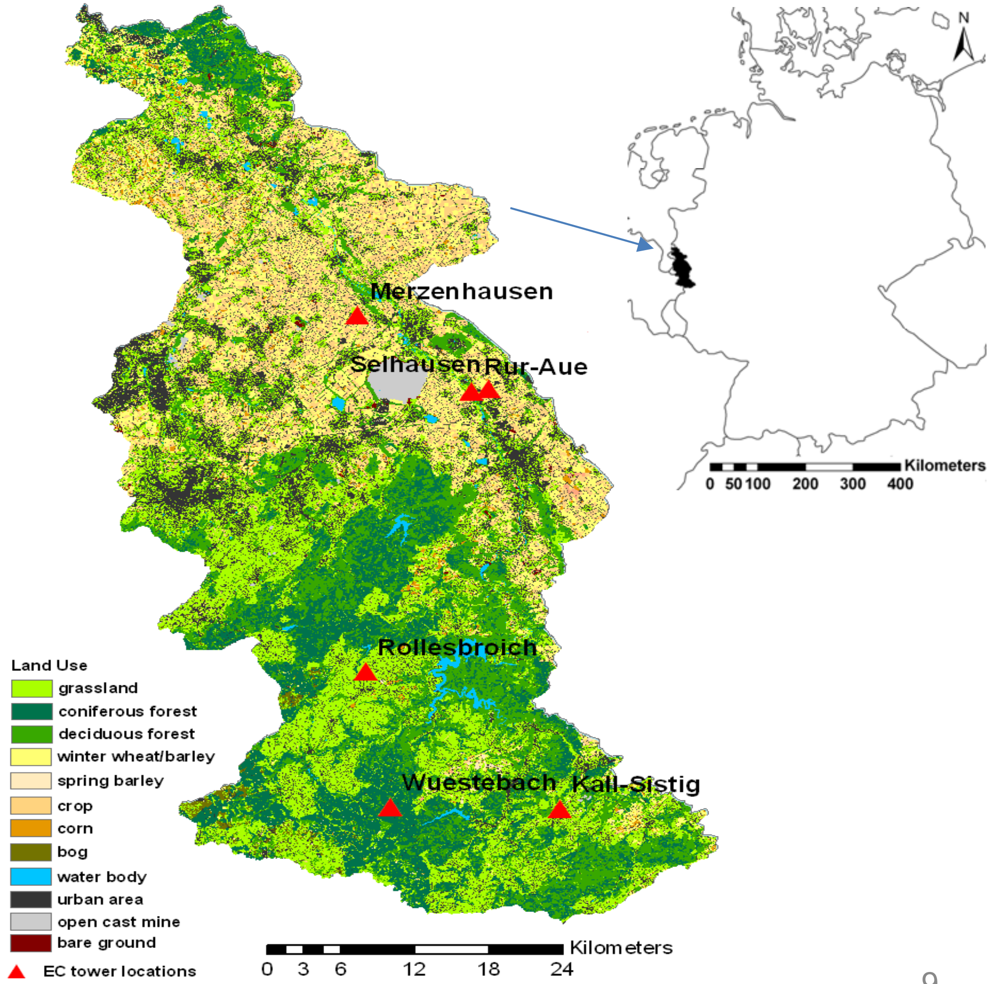
Study Area - Rur-catchment

Location:
Belgian–Dutch–German border region

Area:
2454km^2

Lowland, northern part:
PREC: 650–850 mm/a
PET: 580–600 mm/a
Loess soils with high silt content
mainly agriculture

Mountainous Eifel region, south:
PREC: 850-1300mm/a
PET: 450–550 mm/a
sedimentary rocks, shallow soils
mainly forests and grassland



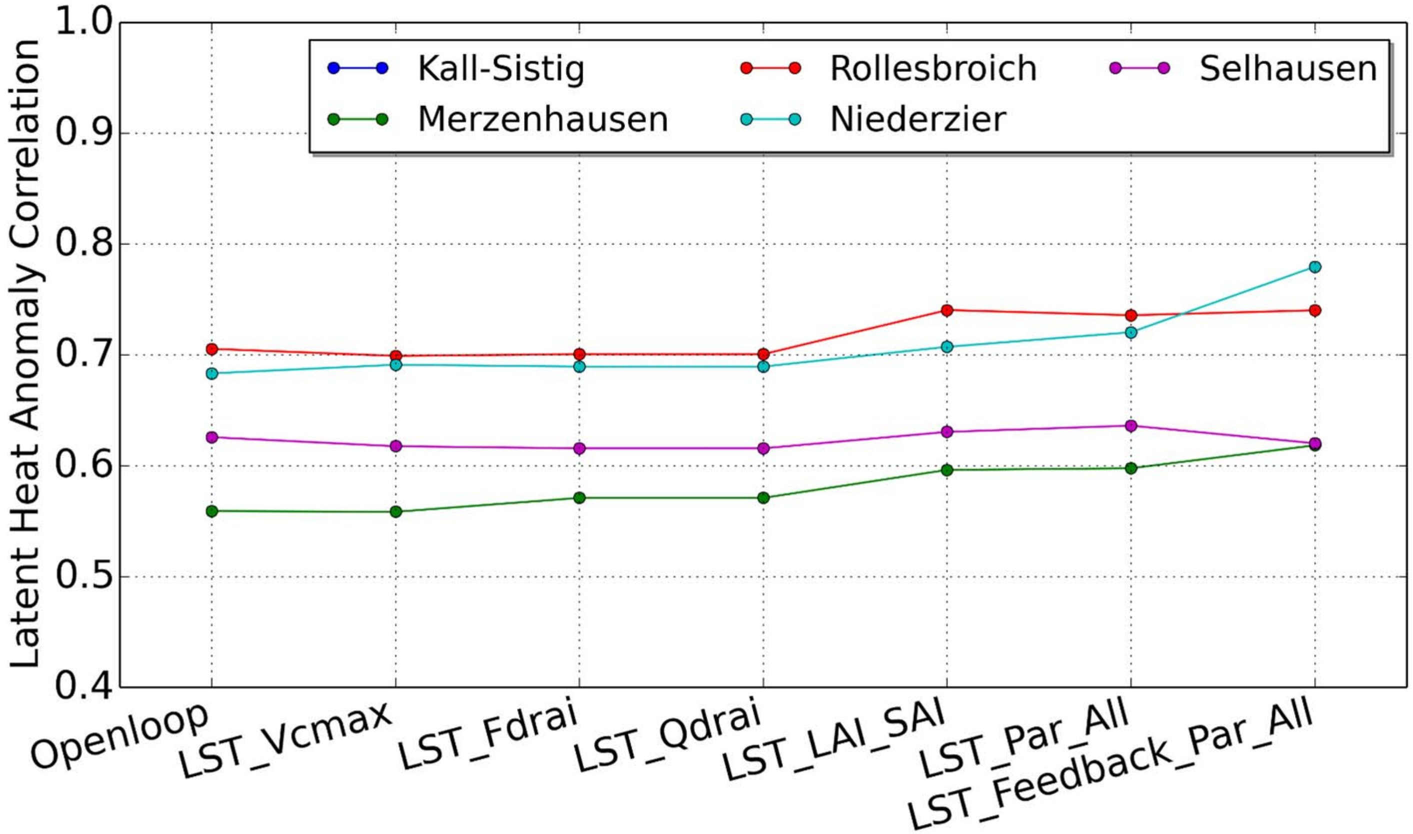
Experiment Design

- 10 years spinup, 2 years assimilation: 2011 (dry year) and 2012 (wet year)
- Compare different scenarios:
  - Open loop
  - LST_LAI_SAI – update LAI and SAI with LST
  - LST_Fdrai – update $Fdrai$ with LST
  - LST_Qdrai – update $Qdrai$ with LST
  - LST_Vcmax – update $Vcmax$ with LST
  - LST_All – update LAI, SAI, $Fdrai$, $Qdrai$ and $Vcmax$ with LST
  - LST_Feedback_All – update LAI, SAI, $Fdrai$, $Qdrai, Vcmax$ and soil moisture with LST

Data Assimilation

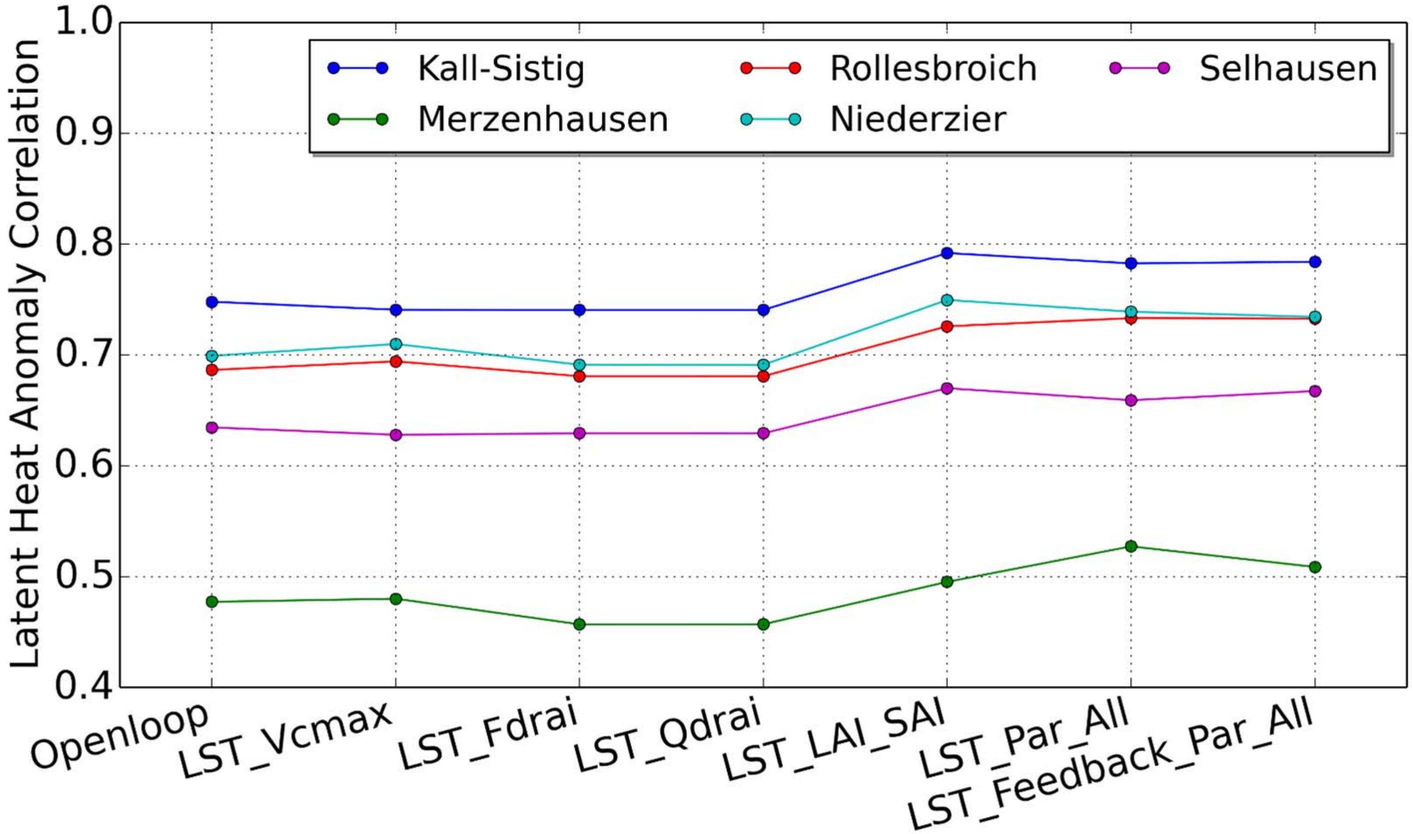
- Community Land Model – 4.5
- Local Ensemble Transform Kalman Filter (**LETKF**) with state augmentation
- Two source formulation as the observation operator
- GLDAS forcing and HWSD soil data
- 20 ensemble members with perturbed:
  - Atmospheric forcing
  - Sand faction, clay fraction and organic matter density
  - LAI, SAI, $Vcmax$, $Fdrai$, $Qdrai$

Anomaly Correlation – Latent Heat Flux (2011)

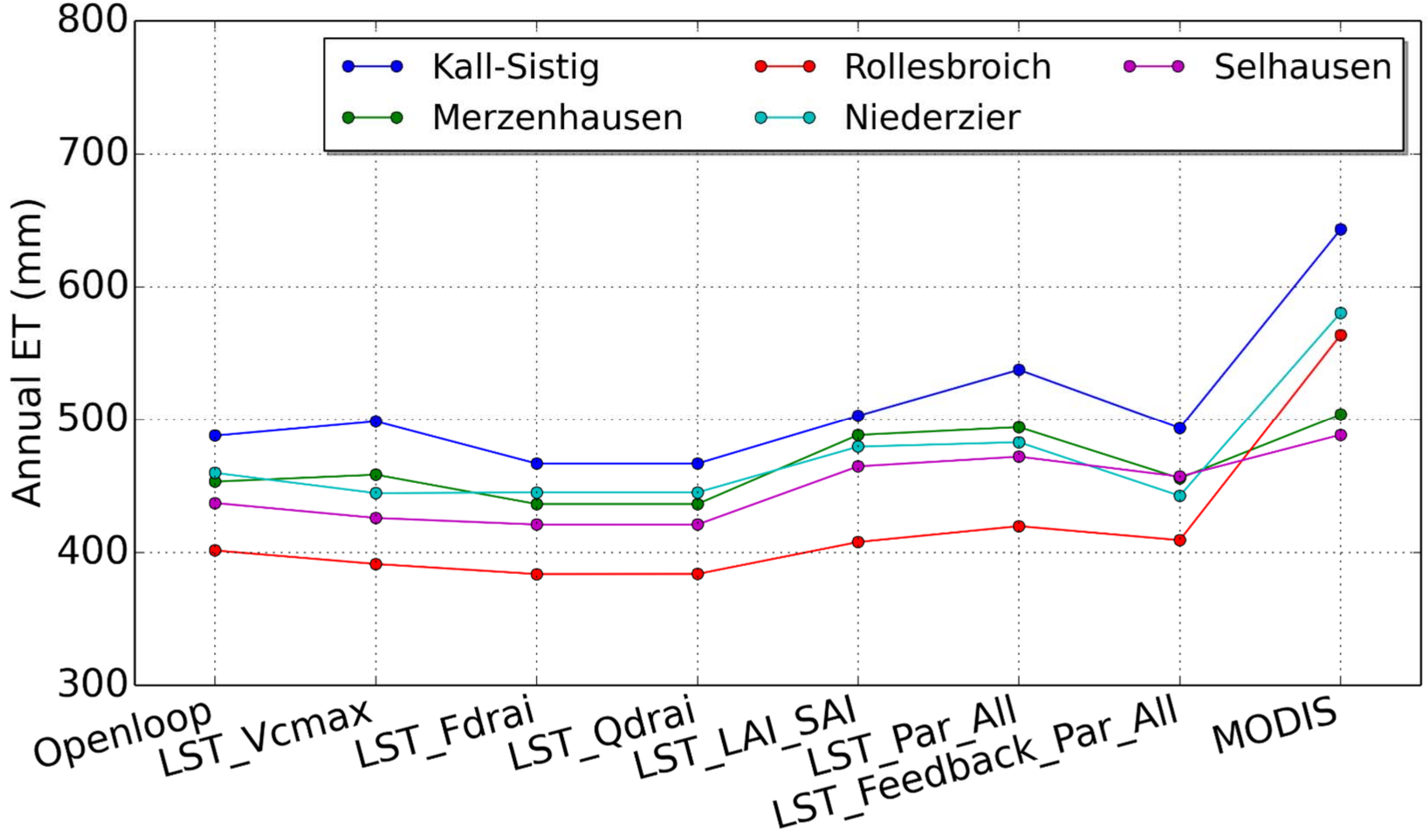


WMO Definition: $$ACC = \frac{\overline{\left[(f-c)-\overline{(f-c)}\right]\left[(obs-c)-\overline{(obs-c)}\right]}}{\sqrt{\overline{\left((f-c)-\overline{(f-c)}\right)^2\left((obs-c)-\overline{(obs-c)}\right)^2}}}$$

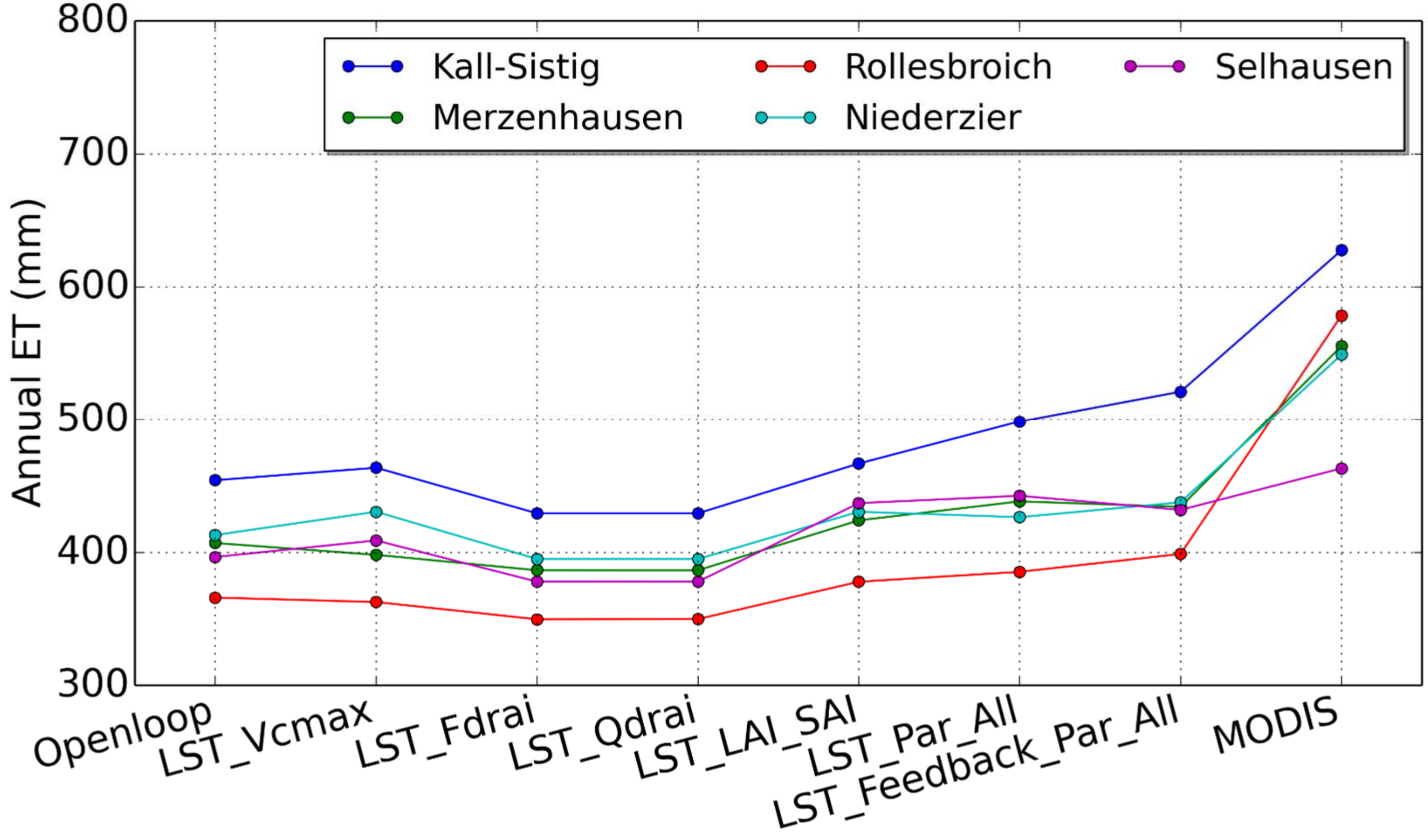
Anomaly Correlation – Latent Heat Flux (2012)



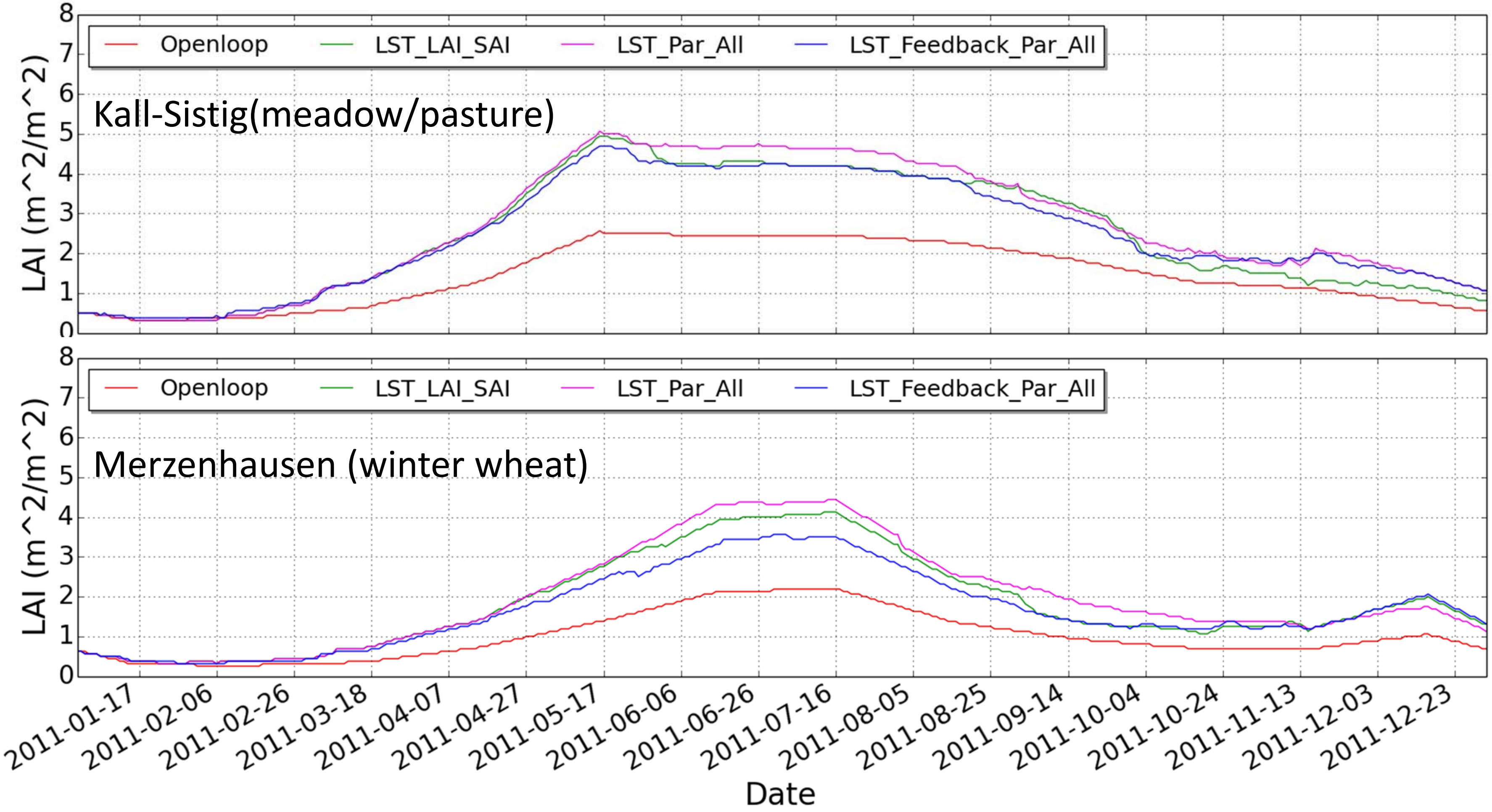
Annual ET (2011)



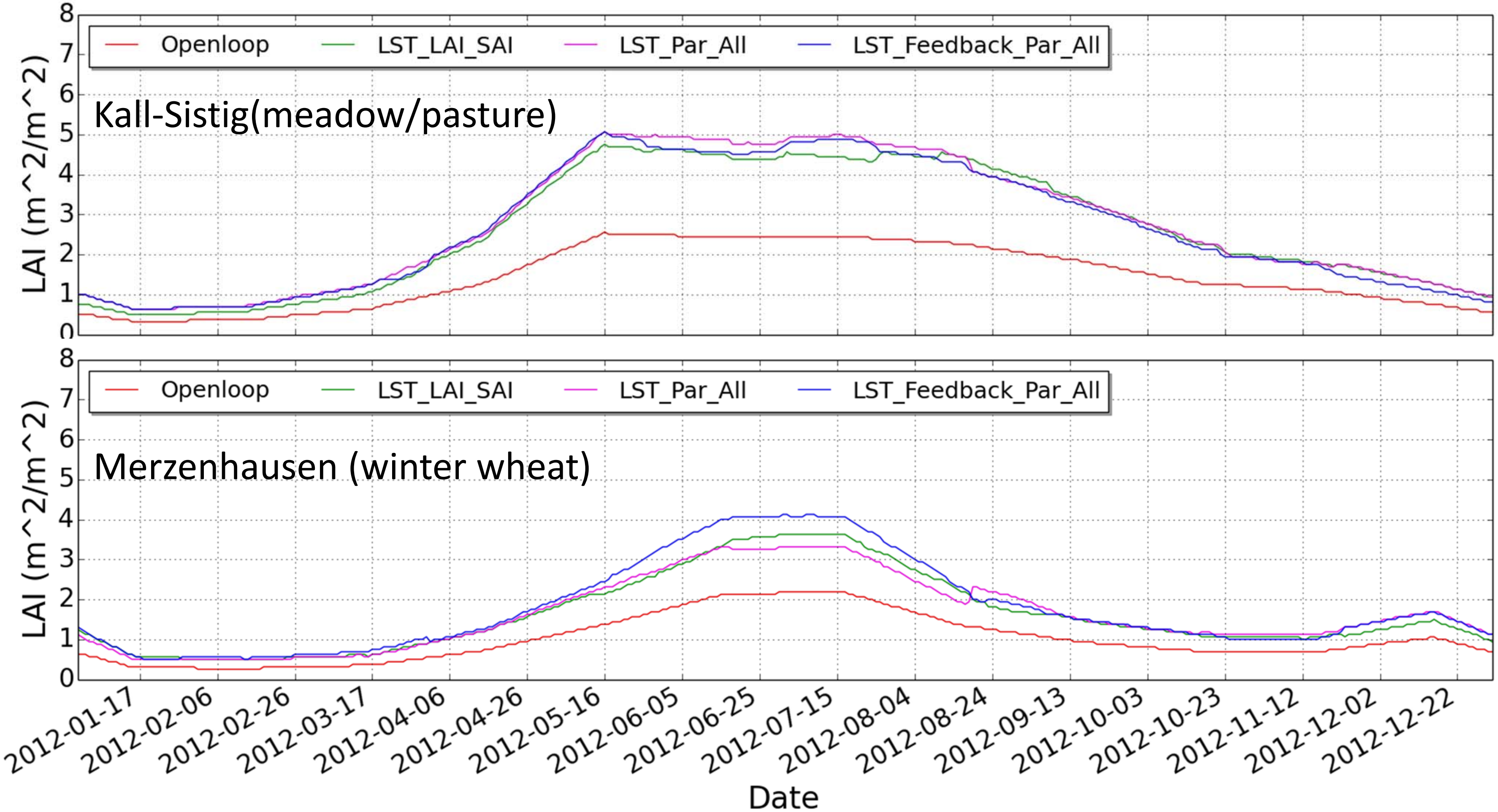
Annual ET (2012)



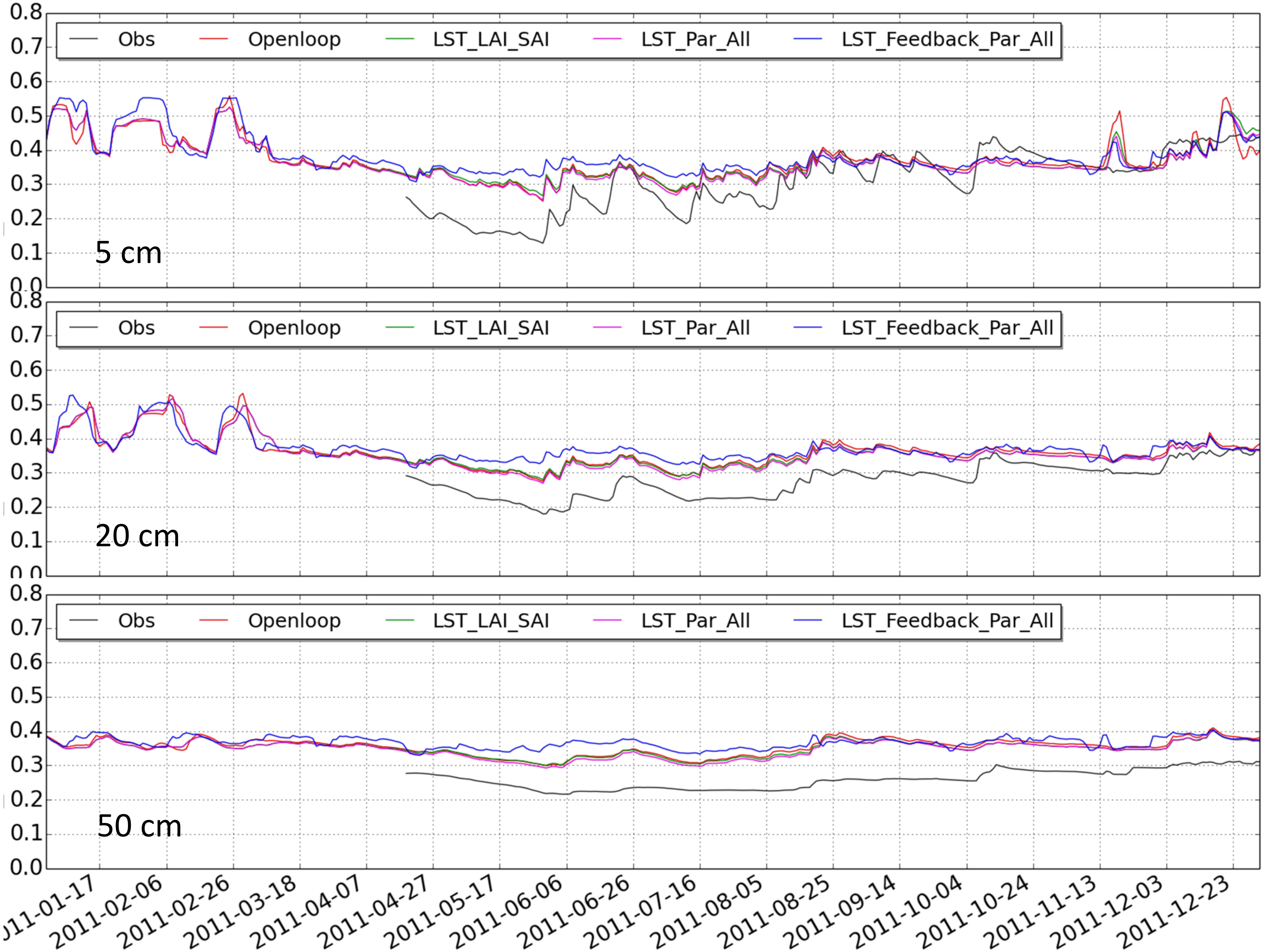
Updated Leaf Area Index (2011)



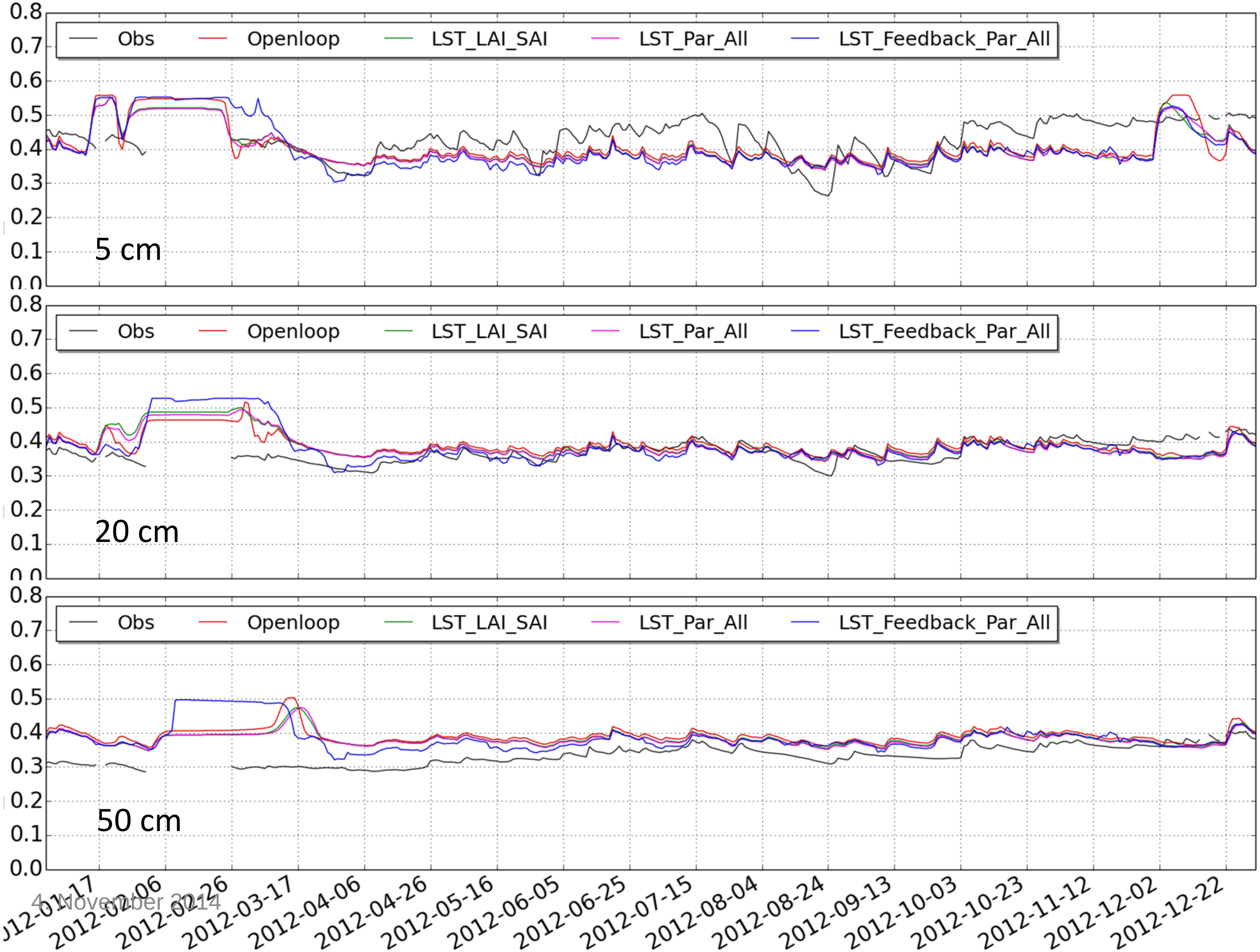
Updated Leaf Area Index (2012)



5 cm, 20 cm and 50 cm Soil Moisture (2011)



5 cm, 20 cm and 50 cm Soil Moisture (2012)



Summary

- Assimilating the MODIS land surface temperature product improves the estimation of sensible heat and latent heat estimation in CLM, but slightly
- The underestimation of leaf area index from MODIS sensors can be improved by assimilating land surface temperature with state augmentation method
- 5 sensitive parameters/states (LAI, SAI, $Fdrai$, $Qdrai, Vcmax$ and soil moisture) were selected, and only updating of LAI and SAI can improve the assimilation results

HH9

Thanks for your attention

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Folie 21

HH9 Please summarize the main conclusions.
Harrie-Jan Hendricks-Franssen; 29.09.2014