Reducing uncertainty in global moisture flux estimates: Evaluation of long-term vegetation index products

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Drought Outlook 'Grim News'

Hot, Dry Weather To Go Until Fall

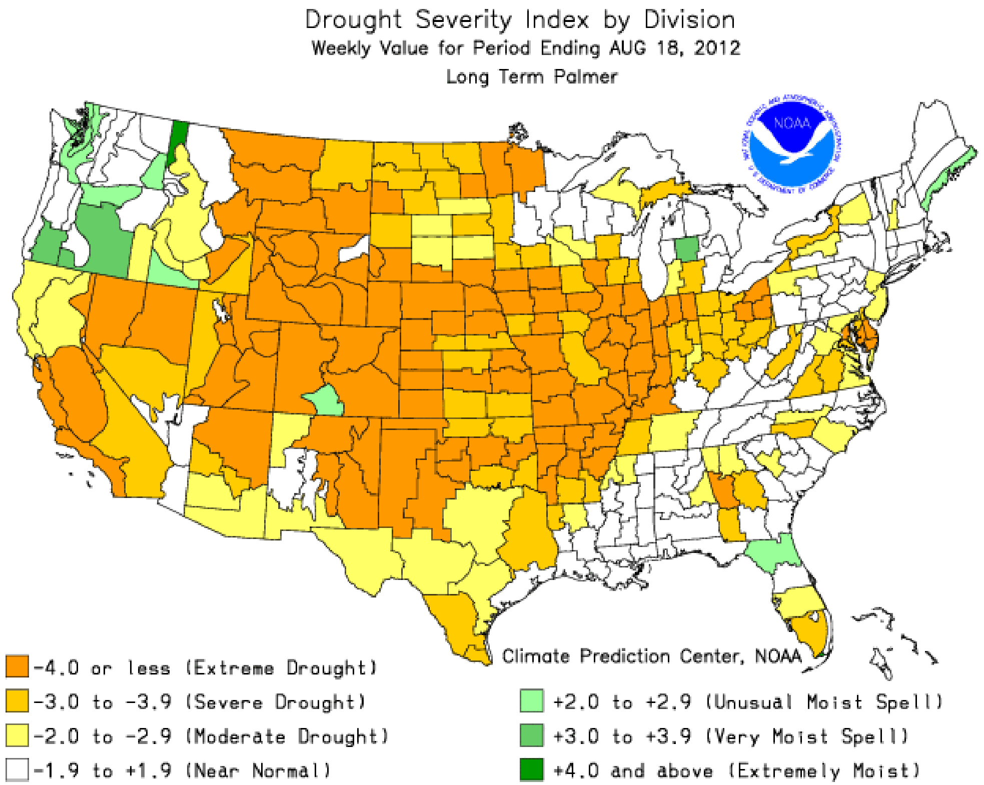
By Seth Borenstein
AP Science Writer

WASHINGTON — The unusually hot, dry weather that has gripped the nation will not let up its stranglehold over the next few months, federal weather forecasters said Thursday.

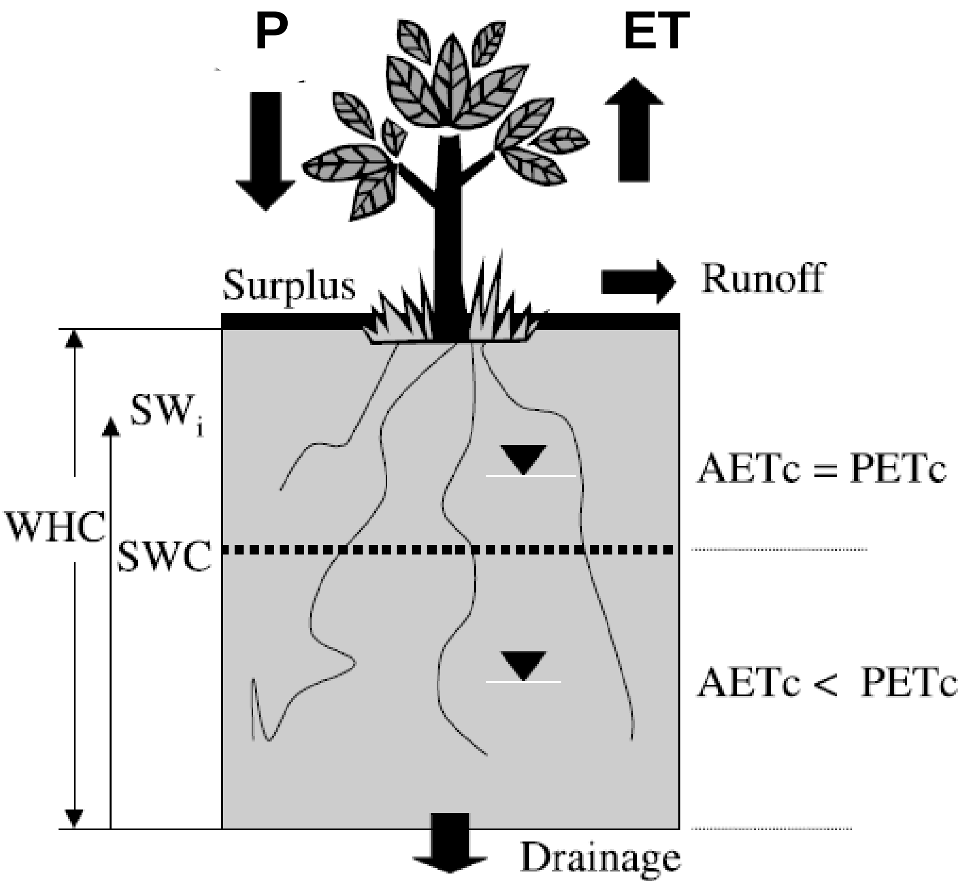
And that means the heartland's "flash drought" will linger at least until around Halloween and even spread a bit farther north and east.

The National Oceanic and Atmospheric Administration's outlook for August through October shows that nearly every state likely will

Friday, July 20, 2012, *Albuquerque Journal*



Evapotranspiration (latent heat)



Senay and Verdin (2003)

$$\overline{\frac{dS}{dt}} = \overline{P} - \overline{D} - \overline{ET} - \overline{Q}$$

$$\overline{\frac{dR_N}{dt}} = \overline{\lambda E_a} - \overline{G} - \overline{H}$$

Obstacles to Effectively Modeling ET

- Short residence time and diurnal variability
- Sparse and inconsistent station data
  - Roughness length (“fetch”)
  - Energy balance closure
- Too many models
- Remote sensing vs. land surface models
  - Land surface temperature uncertainty and scale dependencies
  - Evaporative fraction and persistent cloud-cover
  - Data assimilation
  - Vegetation climatology
  - Strong theoretical framework

Objective

Near real time ET estimates driven can be a powerful tool to promote early warning response to drought. Remote sensing-based and operational land surface modeling approaches utilize free and globally available data, but have unique drawbacks…

Model hybridization: NOAH’s sophisticated transpiration component driven by long-term average NDVI and surface climate reanalysis is substituted with PT-JPL’s simple transpiration scheme driven by a time series of NDVI and EVI and surface climate reanalysis.

PT-JPL

Parameter	Description	Equation	Reference
LE	Latent heat	$LE_s + LE_c + LE_I$	(*Fisher et al.*, 2008)
LE_c	Canopy LE	$(1-f_{WET})f_g f_T f_M \alpha \frac{\Delta}{\Delta+\gamma} R_{NC}$	(Fisher et al., 2008) ; (Priestley and Taylor, 1972)
LE_s	Soil LE	$(f_{WET} + f_{SM}(1-f_{WET}))\alpha \frac{\Delta}{\Delta+\gamma}(R_{NS} - G)$	(Fisher et al., 2008) ; (Priestley and Taylor, 1972)
LE_i	Wet canopy LE	$f_{WET}\alpha \frac{\Delta}{\Delta+\gamma} R_{NC}$	(Fisher et al., 2008) ; (Priestley and Taylor, 1972)
f_{wet}	Relative surface wetness	RH^{10}	(Fisher et al., 2008)
f_g	Green canopy fraction	f_{APAR} / f_{IPAR}	(Fisher et al., 2008)
f_T	Plant temperature constraint	$e^{-\left(\frac{T_{MAX} - T_{OPT}}{\lambda}\right)^2}$	(June et al., 2004)
f_M	Plant moisture constraint	$f_{APAR} / f_{APARmax}$	(Fisher et al., 2008)
f_{SM}	Soil moisture constraint	$RH^{VPD/\beta}$	(Fisher et al., 2008)
f_{APAR}	Fraction of PAR absorbed by green vegetation cover	$m_1 SAVI + b_1$	(Gao et al., 2000), (Huete, 2006)
f_{IPAR}	Fraction of PAR intercepted by total vegetation cover	$m_2 NDVI + b_2$	(Fisher et al., 2007)
f_c	Fractional total vegetation cover	f_{IPAR}	(Campbell and Norman, 1998)
T_{opt}	Optimum plant growth temperature	T_{max} @ $\max\{PAR f_{APAR} T_{max} / VPD\}$	(Fisher et al., 2007)

National Centers for Environmental Protection, Oregon State University, Air Force, and Hydrologic Research Lab (Noah)

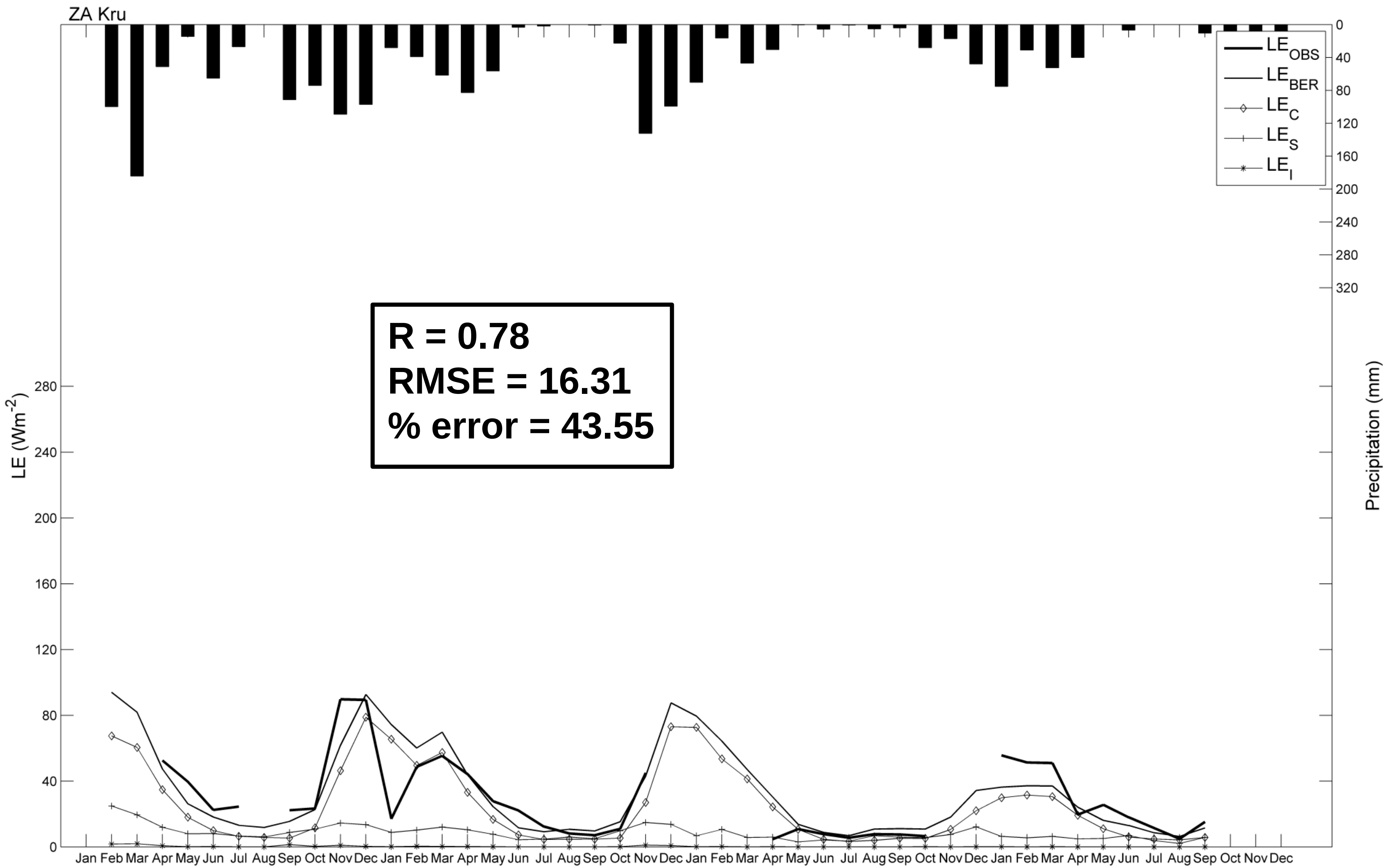
Parameter	Description	Equation	Reference
E_a	**Evapotranspiration**	$E_s + E_c + E_l$	**(Chen et al. 1996)**
E_c	**Canopy transpiration**	$f_g P_c \left[1 - \left(\frac{W_c}{S} \right)^{0.5} \right] \times Ep$	(Chen et al. 1996)
E_s	**Soil evaporation**	$(1 - f_g)\beta \times Ep$	(Mahfouf and Noilhan 1991)
E_i	**Interception evaporation**	$f_g \left(\frac{W_c}{S} \right)^{0.5} \times Ep$	(Chen et al. 1996)
β	**Soil moisture availability**	$\left(\frac{\Theta_1 - \Theta_w}{\Theta_{ref} - \Theta_w} \right)^f$	(Betts et al. 1997)
P_c	**Stomatal resistance**	$\frac{r + \Delta}{r(1 + C_h R_c) + \Delta}$	(Jacquemin and Noilhan 1990)

Data and Processing

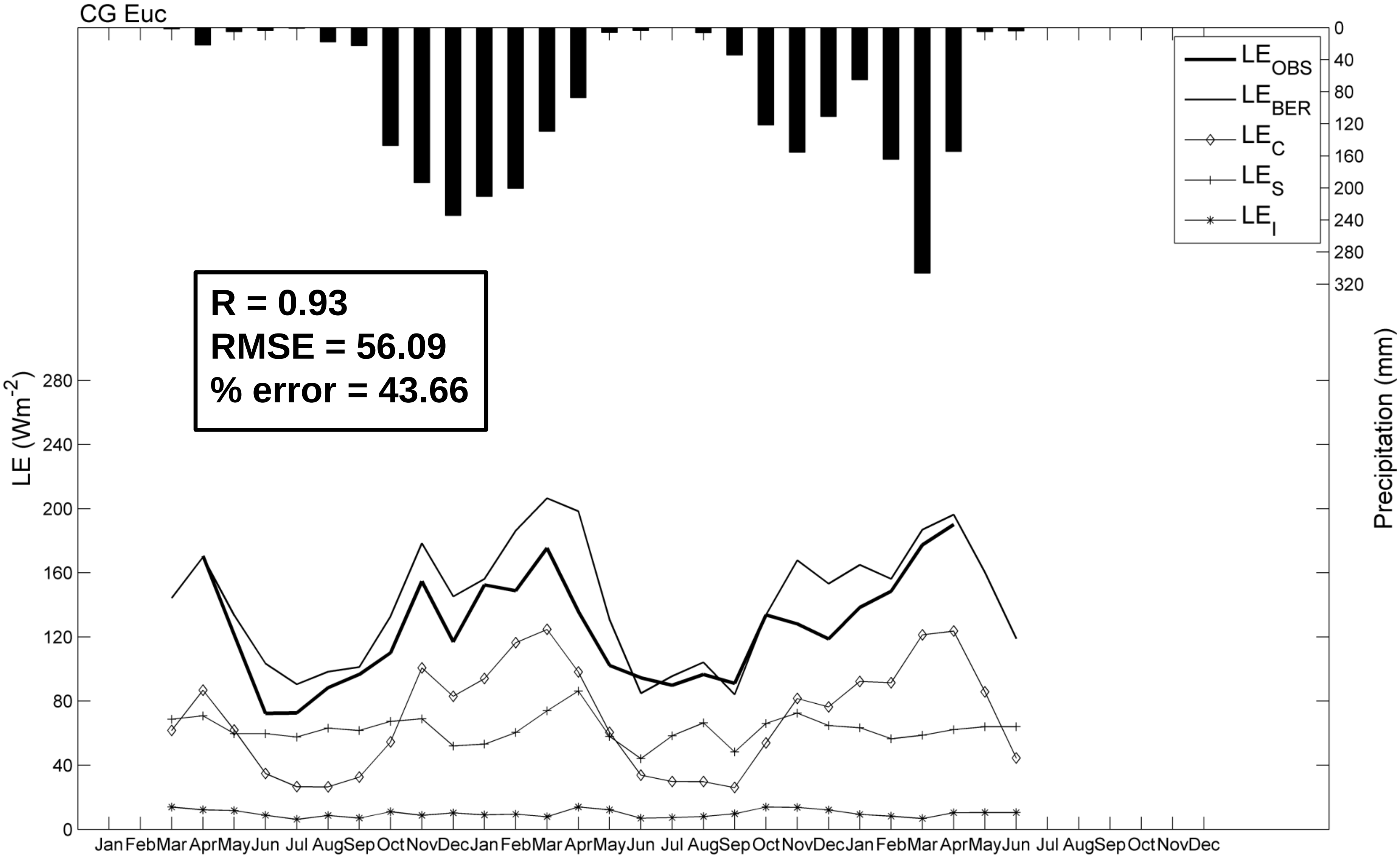
- (NDVI, EVI): MODIS/LTDR 16/15-day VI at 0.05° resolution
- (VPD_{MAX}, RH_{MIN}, R_N, T_{MAX}, PAR): GLDAS NOAH 3-hourly surface reanalysis at 0.25°/1.0° resolution
- (LE, met data): FLUXNET and CARBOAFRICA 30-minute flux tower data

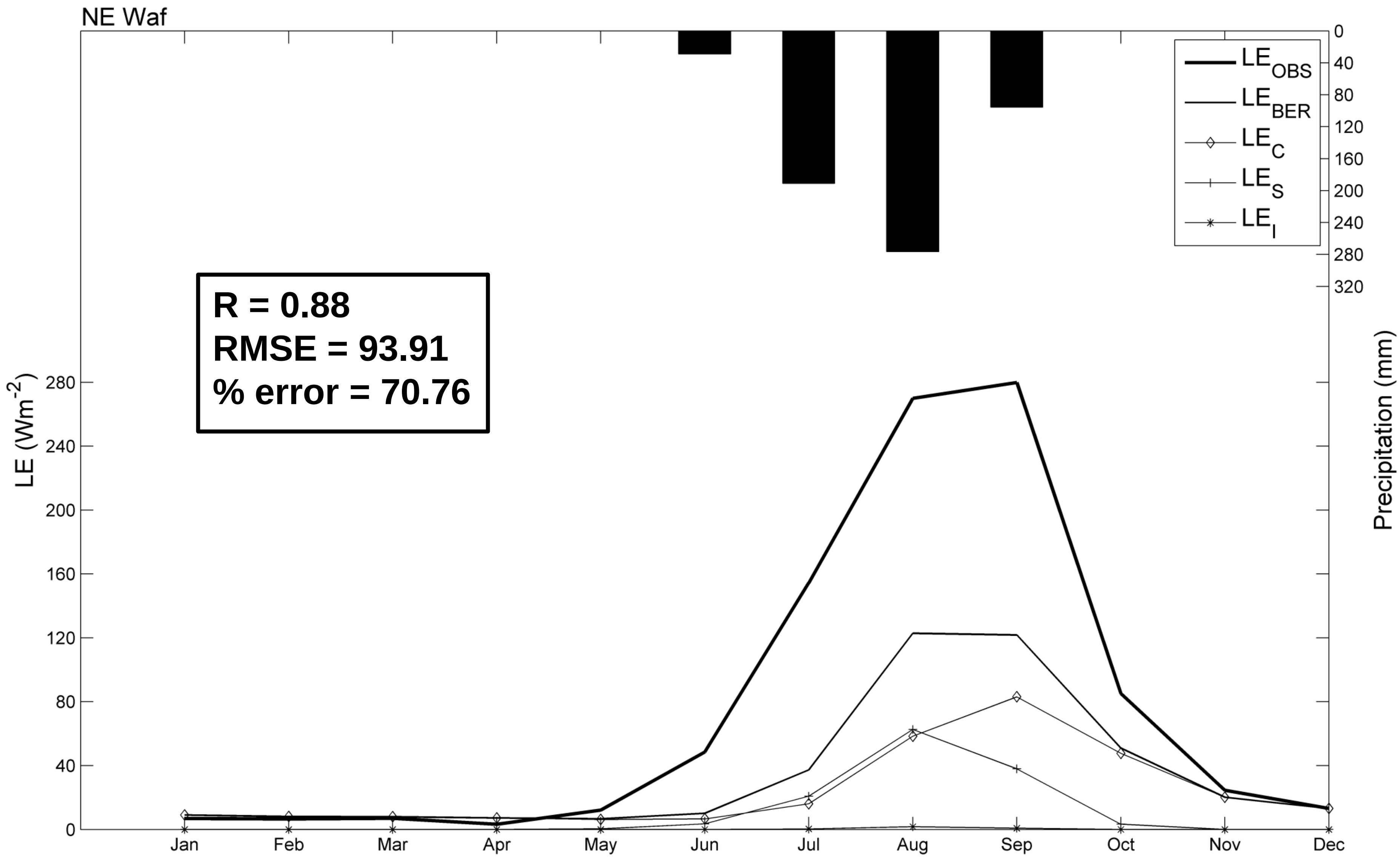
ID	Name	Country	Lat	Long	Period	IGBP	P (mm)	T_A (°C)	Source
BW-Ma1	Maun-Mopane Woodland	Botswana	-19.92	23.56	1999-2001	WSA	464	22.0	Fluxnet
CG-Euc	Kissoko Eucalyptus Plantation	Congo	-4.79	11.98	2004-2006	EBF	1274	23.5	CarboAfrica
CG-Tch	Tchizalamou	Congo	-4.29	11.66	2006-2008	OSH	1150	25.7	Fluxnet
NE-WaF	Wankama Fallow	Niger	13.65	2.63	2006	CRO	519	28.5	CarboAfrica
NE-WaM	Wankama Millet	Niger	13.64	2.63	2006	CRO	519	28.5	CarboAfrica
SD-Dem	Demokeya	Sudan	13.28	30.48	2007-2008	SAV	320	26.0	CarboAfrica
ZA-Kru	Skukuza	South Africa	-25.02	31.50	2001-2008	SAV	547	21.9	CarboAfrica
ZM-Mon	Mongu	Zambia	-15.44	23.25	2007-2008	EBF	945	25.0	Fluxnet

PT-JPL vs. Flux Tower Data



R = 0.78
RMSE = 16.31
% error = 43.55


CG Euc
R = 0.93
RMSE = 56.09
% error = 43.66
LE_{OBS}
LE_{BER}
LE_C
LE_S
LE_I
LE (Wm^{-2})
Precipitation (mm)
0
40
80
120
160
200
240
280
320
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec



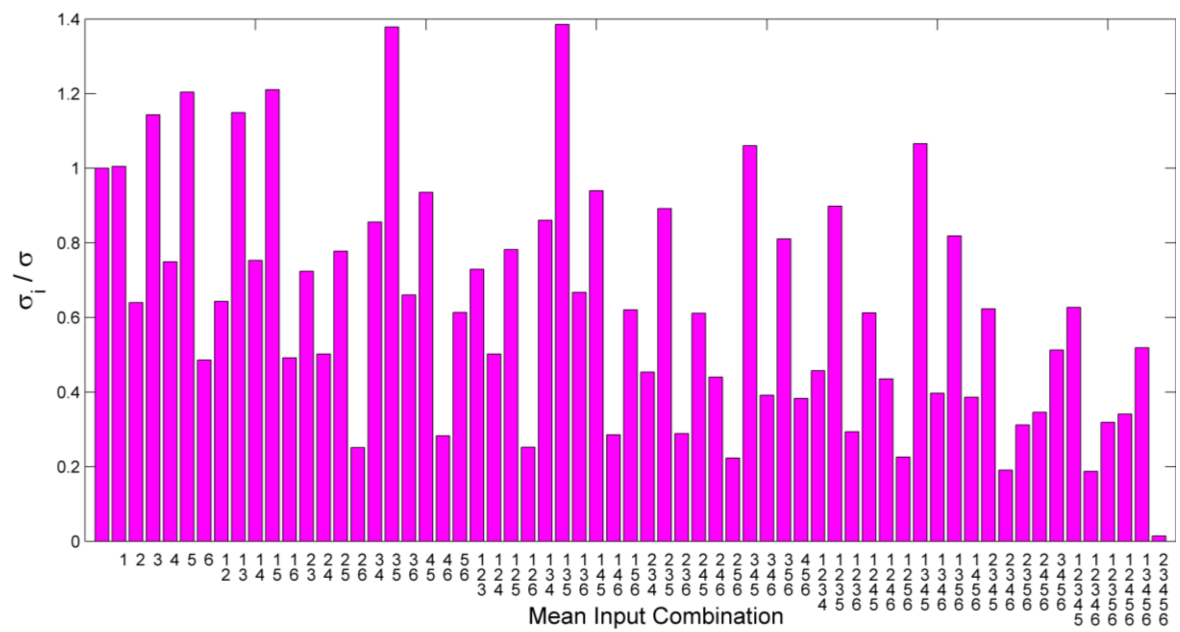
NE Waf
R = 0.88
RMSE = 93.91
% error = 70.76
LE_{OBS}
LE_{BER}
LE_C
LE_S
LE_I
LE (Wm^{-2})
Precipitation (mm)
0
40
80
120
160
200
240
280
320
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Sensitivity of PT-JPL to GLDAS

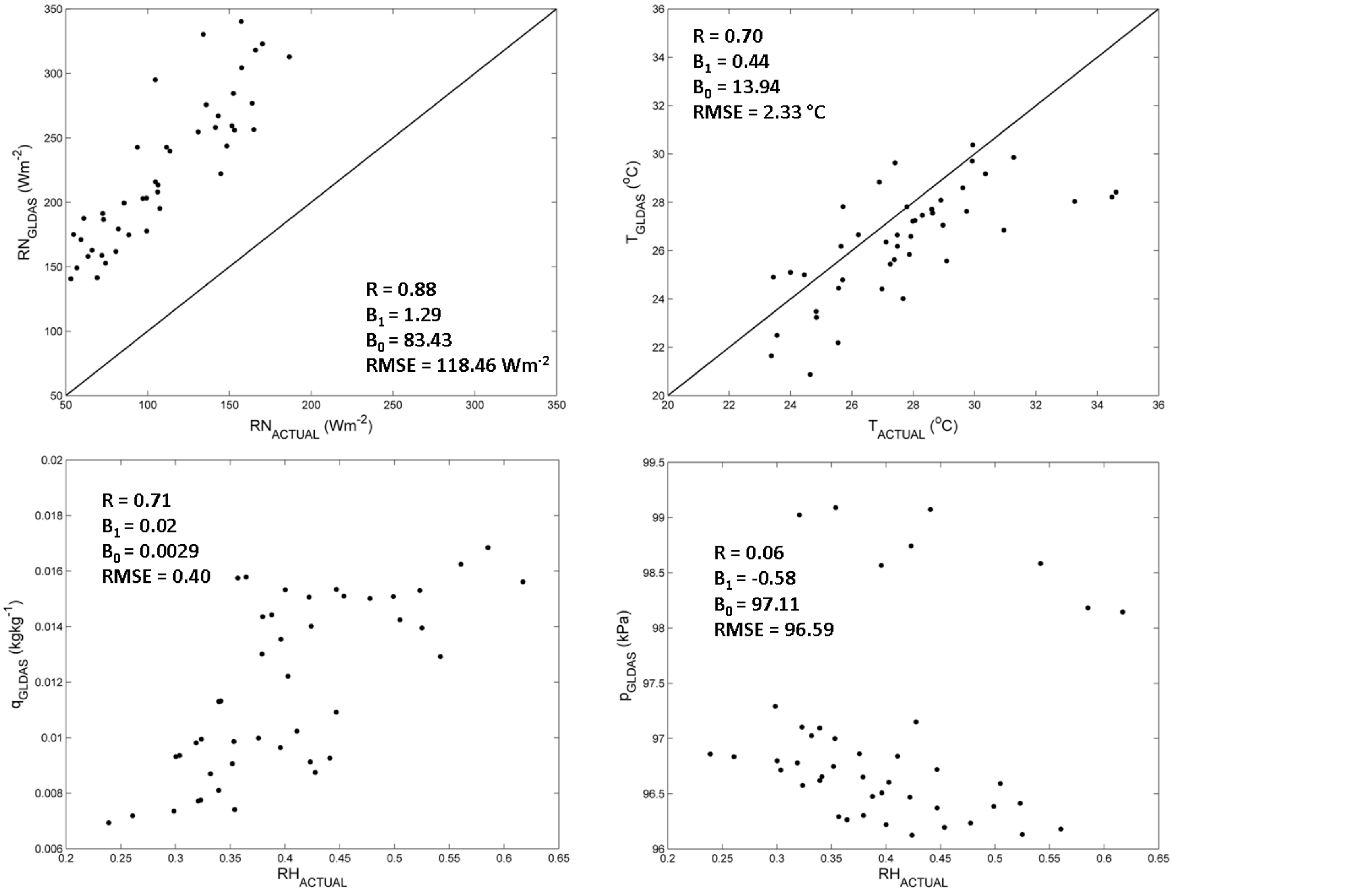
Unconditional case

Station (ZA Kru)	B_1 (Wm^{-2})	B_0 (Wm^{-2})
EVI	29.61	92.61
NDVI	-9.88	74.63
RN	16.77	74.63
T	-16.18	78.78
Press	0.73	74.64
SH	24.65	85.81

Conditional case

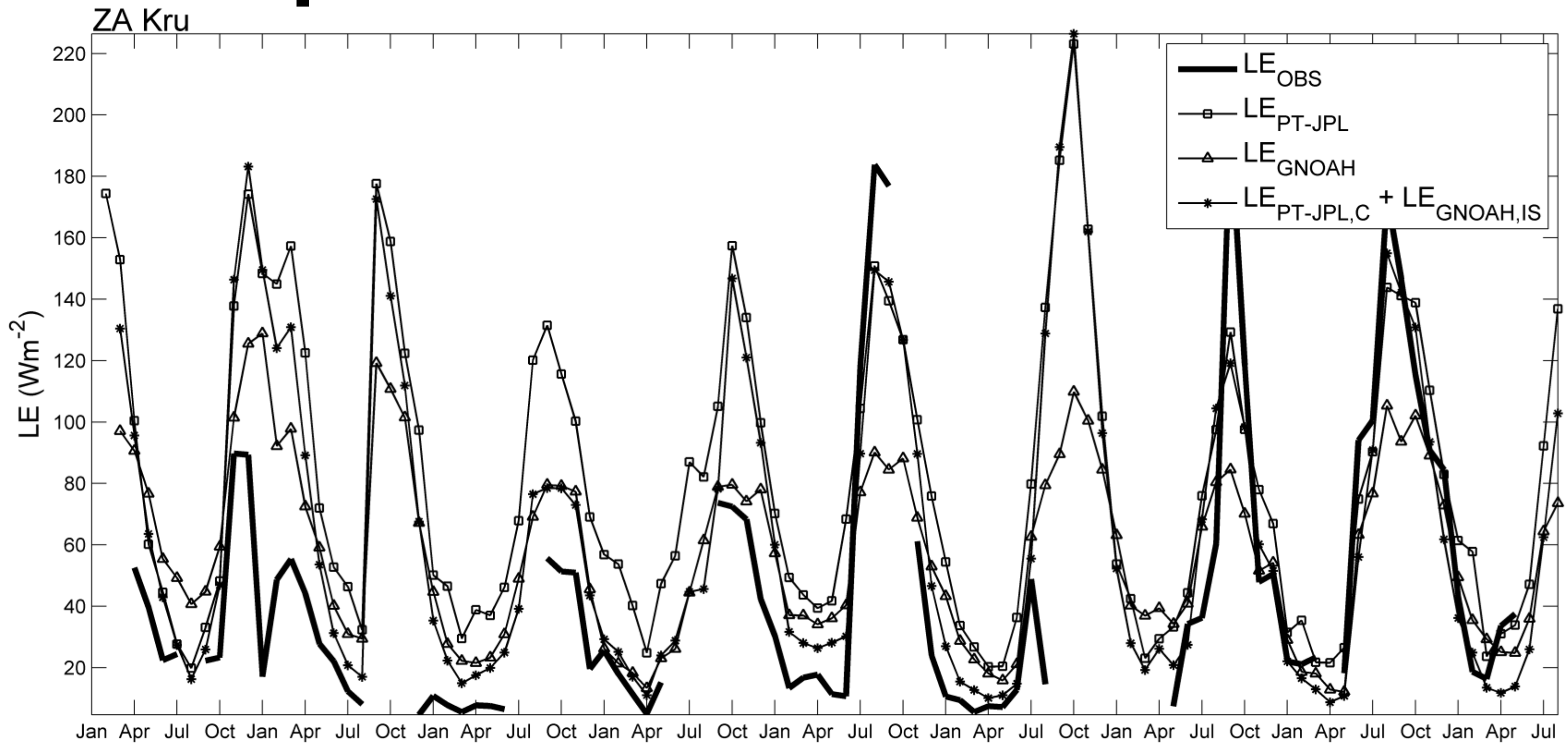


GLDAS vs. Flux Tower Data

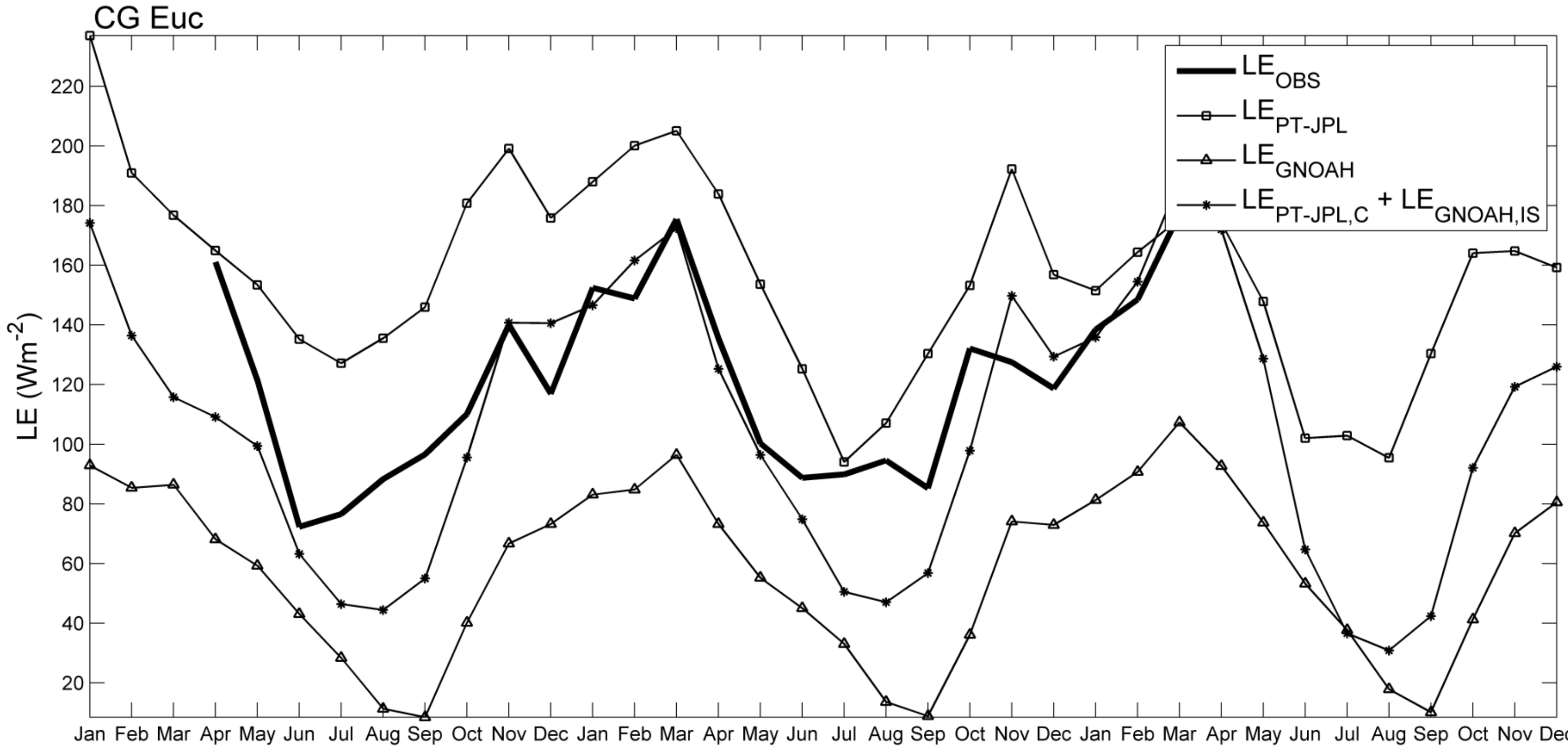


Station ID	R_N (Wm^{-2})	T (°C)	q ($kgkg^{-1}$)	p (kPa)
BW-Ma1 (N=23)				
R	0.06	0.85	0.50	-0.11
B_1	0.10	0.96	0.02	-0.33
B_0	211.78	0.19	0.0067	91.17
RMSE	88.71	2.20		
CG-Euc (N=30)				
R	0.72	0.72	-0.46	0.52
B_1	0.23	0.62	-0.04	4.02
B_0	169.17	11.24	0.04	97.92
RMSE	42.99	1.61		
NE-Waf (N=12)				
R	-0.38	0.97	0.94	0.29
B_1	-0.18	1.07	0.03	0.26
B_0	276.28	-0.90	0.002	98.23
RMSE	81.80	1.98		
NE-Wam (N=11)				
R	-0.17	0.93	0.98	0.27
B_1	0.0012	1.13	0.03	0.23
B_0	243.81	-2.28	0.0013	98.12
RMSE	109.52	2.71		
ZA-Kru (N=44)				
R	0.88	0.70	0.71	0.06
B_1	1.29	0.44	0.02	-0.58
B_0	83.43	13.94	0.0029	97.11
RMSE	118.46	2.33		

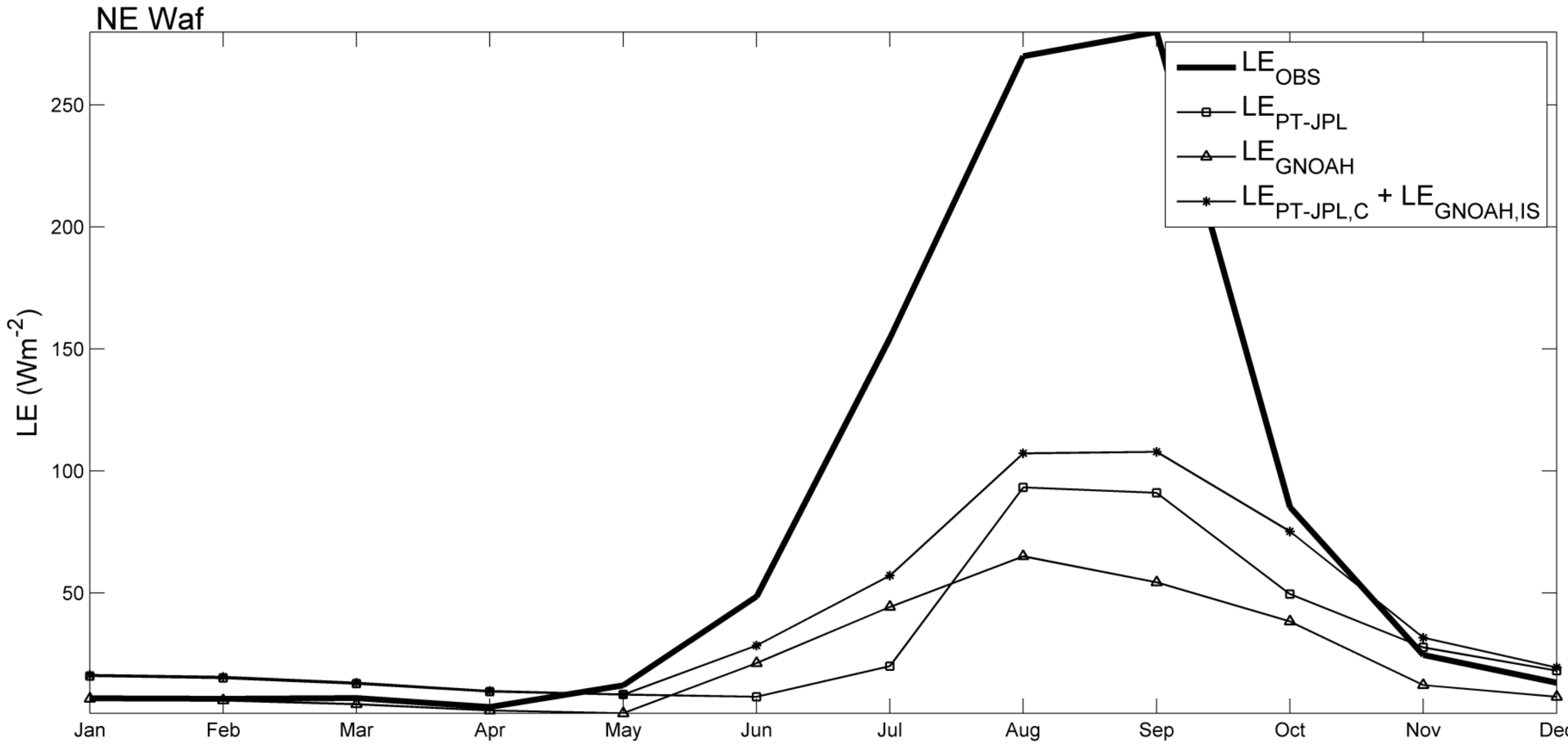
Development and Performance



Models	R^2	RMSE
Fish	0.44	48.40
GLDAS	0.45	34.80
Hybrid	0.55	36.00



Models	R^2	RMSE
PT-JPL	0.53	42.15
GLDAS	0.71	67.89
Hybrid	0.80	25.31



Models	R^2	RMSE
PT-JPL	0.82	85.71
GLDAS	0.91	94.97
Hybrid	0.91	74.38

Summary

- PT-JPL and NOAH hybridization improves correlations and reduces RMSE across all sites
  - Fractional cover
  - Long-term and continuous vegetation data
- Humid (light limited) and dry (water limited) sites
- Driest sites (NE-Waf and NE-Wam) large negative bias (R_N)
- Tower to coarser scale comparison errors persist

Next Step

- Focus on $\mathbf{f_c}$
- Compare $\mathbf{f_c}$ methods and data products
  - NASA GIMMS 3g NDVI with NASA MEaSUREs NDVI (EVI2)
  - mNDVI + b, $(NDVI\text{-}NDVI_{MIN})/(NDVI_{MAX}\text{-}NDVI_{MIN})$, $(EVI2\text{-}EVI2_{MIN})/(EVI2_{MAX}\text{-}EVI2_{MIN})$, *etc.*
  - 800+ LAI data points for agriculture areas across the globe
- Water balance evaluation: LIS-NOAH

Thank You