Supplemental Material for **Improvement of modelling plant responses to low soil moisture in JULESvn4.9 and evaluation against flux tower measurements**

Table SM1. Sites used in this study. Prescribed soil moisture levels are the 4 depths in default JULES soil (1=0-0.1m; 2=0.1-0.35m; 3=0.35-1.0m; 4=1-3m).

Site	Lat	Lon	Class	Run dates		Prescribed	
				start	end	LAI	SM
LBA-BAN	-9.82	-50.15	DecSav	2004-01-02	2006-10-31	y	y (1,2,3,4)
LBA-FNS	-10.76	-62.36	C4G	1999-01-02	2001-12-31		
LBA-K34	-2.61	-60.21	EBF	2003-01-02	2005-10-15	y	y (1,2,3,4)
LBA-K67	-2.85	-54.97	EBF	2002-01-02	2003-11-18	y	y (1,2)
LBA-K77	-3.02	-54.89	C4G	2001-01-02	2005-12-31		
LBA-K83	-3.05	-54.93	EBF	2001-01-02	2003-08-12	y	y (1,2)
LBA-PDG	-21.62	-47.63	DecSav	2002-01-02	2003-12-31		
LBA-RJA	-10.08	-62.36	EBF	2000-02-03	2002-09-13	y	y (1,2,3,4)
AT-Neu	47.12	11.32	GRA	2006-12-17	2012-12-30	y	y (1,2)
AU-Fog	-12.55	131.31	WET	2006-01-01	2008-12-31		
BE-Vie	50.31	6.00	MF	1996-07-18	2006-12-31	y	y (1,2,3)
CA-Oas	53.63	-106.20	DBF	1996-01-02	2010-12-31		
CG-Tch	-4.29	11.66	SAV	2006-01-01	2009-12-30		
CH-CHA	47.21	8.41	GRA	2006-01-01	2007-12-30	y	y (1,2,3)
CN-HaM	37.37	101.18	GRA	2002-01-01	2004-12-30		y (1)
DE-Tha	50.96	13.57	ENF	1996-01-01	2014-12-30		
FI-Hyy	61.85	24.30	ENF	1996-12-19	2014-12-30		y (1,2,3)
GF-Guy	5.28	-52.92	EBF	2007-01-02	2009-12-30	y	y (1,2,3,4)
IT-CA1	42.38	12.03	DBF	2012-02-16	2012-12-30	y	y (1,2,3)
IT-Col	41.85	13.59	DBF	1996-01-01	2014-12-30		
IT-Ren	46.59	11.43	ENF	1999-01-01	2013-12-30	y	y (1,2)
RU-Che	68.61	161.34	WET	2002-01-01	2005-12-30		
RU-SkP	62.26	129.17	DNF	2012-01-01	2014-12-30		
SD-Dem	13.28	30.48	SAV	2007-07-06	2009-12-30		y (1,2,3,4)
US-Ha1	42.54	-72.17	DBF	1991-01-02	2012-12-31		
US-MMS	39.32	-86.41	DBF	1999-01-02	2014-12-31		
US-Ne1	41.17	-96.48	CRO	2001-06-19	2012-12-31	y	y (1,2,3)
US-Ne2	41.16	-96.47	CRO	2001-06-19	2012-12-31	y	y (1,2,3)
US-Ne3	41.18	-96.44	CRO	2001-06-19	2012-12-31	y	y (1,2,3)
US-PFa	45.95	-90.27	MF	1995-01-02	2014-12-31		
US-SRG	31.79	-110.83	GRA	2008-03-08	2014-12-31		y (1,2,3)
US-SRM	31.82	-110.87	WSA	2004-01-02	2014-12-31		y (1,2,3,4)
US-Ton	38.43	-120.97	WSA	2001-01-02	2014-12-31		
US-UMB	45.56	-84.71	DBF	2009-08-17	2014-12-31		y (1,2,3,4)
US-Var	38.41	-120.95	GRA	2000-01-02	2014-12-31		
US-WCr	45.81	-90.08	DBF	1999-01-02	2014-12-31		
US-Whs	31.74	-110.05	OSH	2007-01-02	2014-12-31		
US-Wkg	31.74	-109.94	GRA	2004-01-02	2014-12-31		
ZA-Kru	-25.02	31.50	SAV	2000-04-01	2013-03-01		y (1,2,3)
ZM-Mon	-15.44	23.25	DBF	2000-01-01	2009-12-30		

Sites broken into climate and biome category (Fig 3-4 and SM Fig 1-3)

Tropics

Tropical evergreen forests:

LBA-K34, LBA-K67, LBA-K83, GF-Gui

Tropical grasslands:

LBA-K77, LBA-PDG, LBA-FNS, AU-Fog

Tropical dry forests:

LBA-BAN, LBA-RJA, ZM_Mon

Tropical savannahs:

SD-Dem, ZA-Kru

Boreal/Cold sites

Boreal forests:

FI-Hyy, RU-SkP, CA-Oas

Continental/high altitude grasslands:

AT-Neu, CH-Cha, CN-HaM, RU-Che

Temperate sites:

Temperate Mixed Forests:

BE-Vie, IT-CA1, IT-Col, IT-Ren, US-UMB, US-Wcr, US-Ha1, US-MMS, DE-Tha

Temperate grasslands:

US-SRG, US-Wkg, US-Var

Temperate savannahs:

US-SRM, US-Whs, US-Ton

Crops:

US-Ne1, US-Ne2, US-Ne3

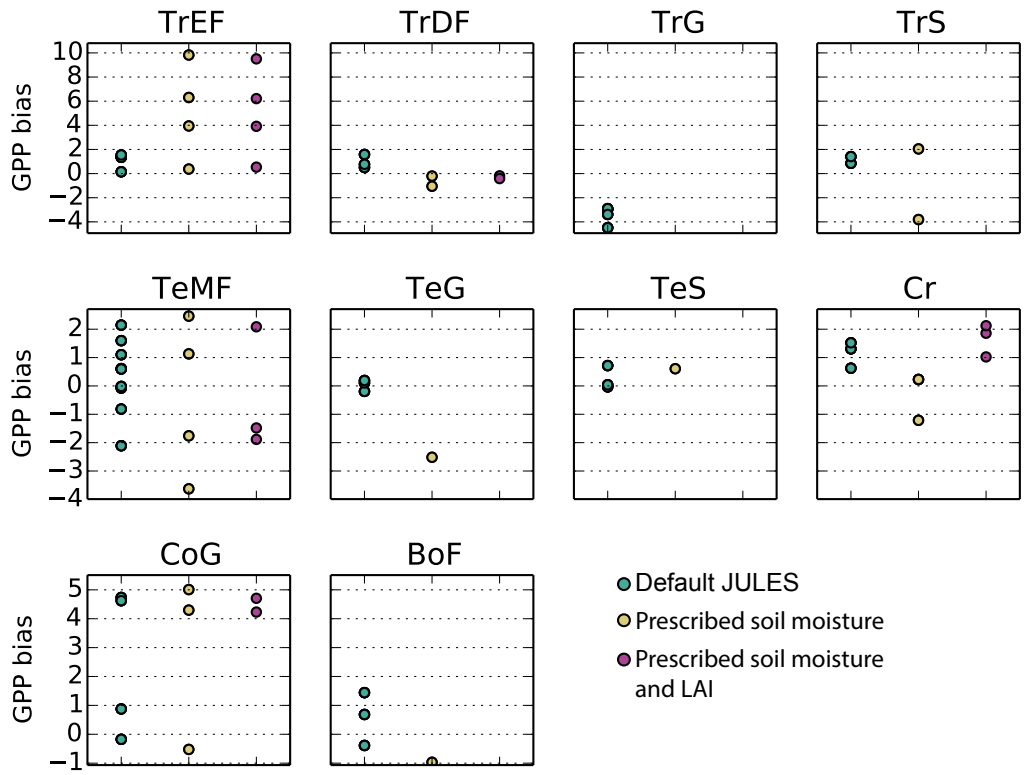


Figure SM1: Root mean bias for GPP per biome

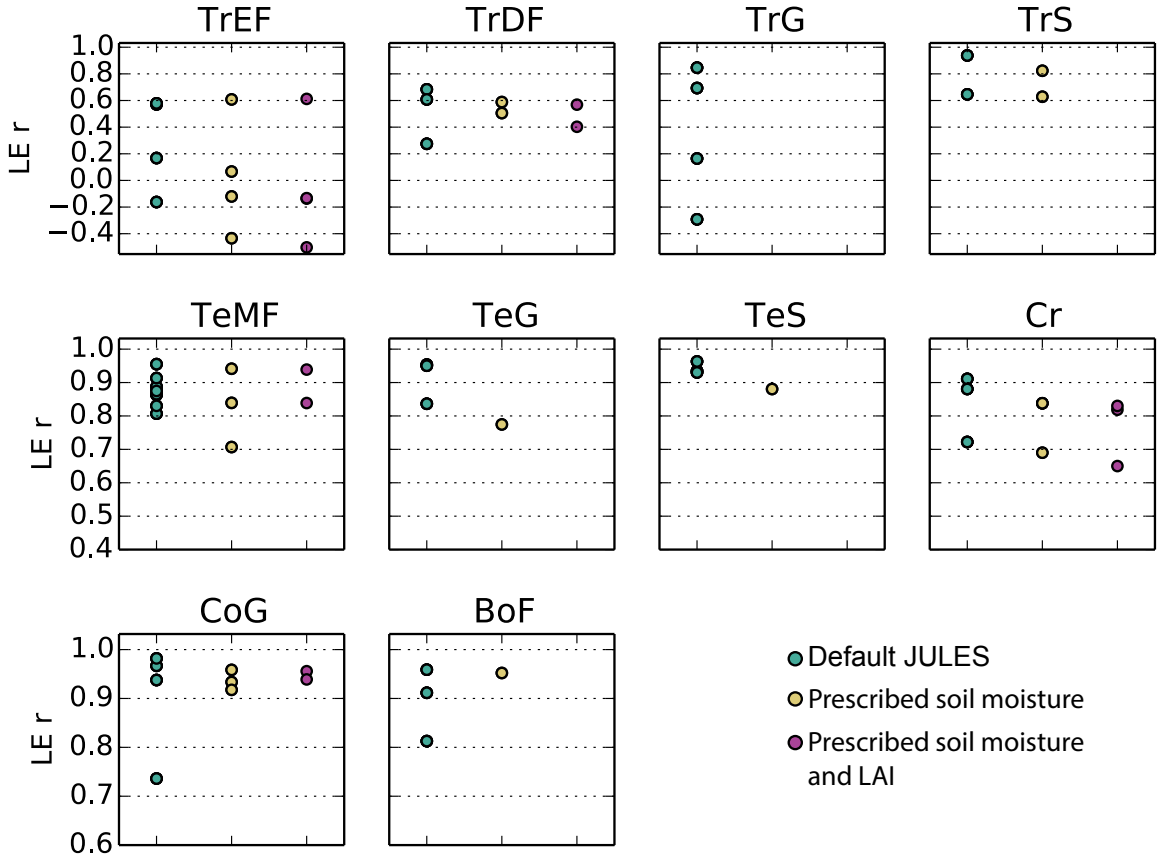


Figure SM2: r for LE per biome

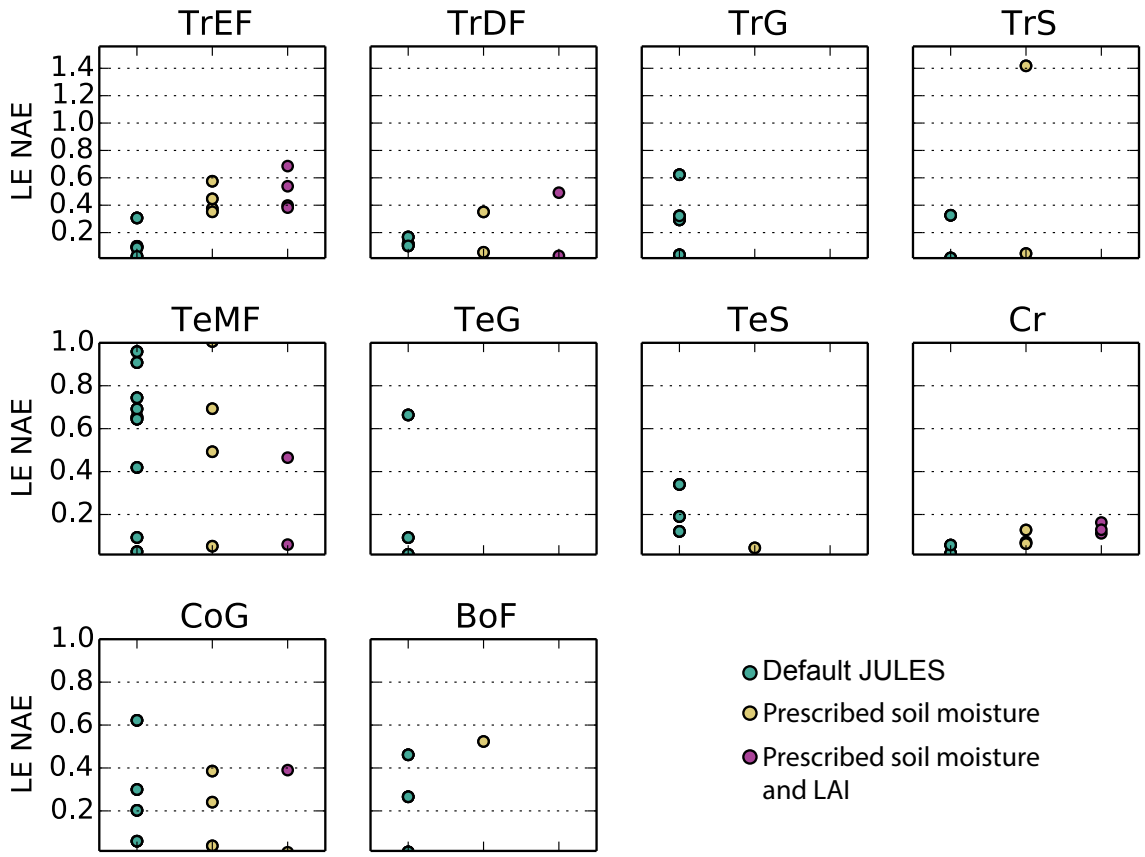


Figure SM3: NAE for LE per biome

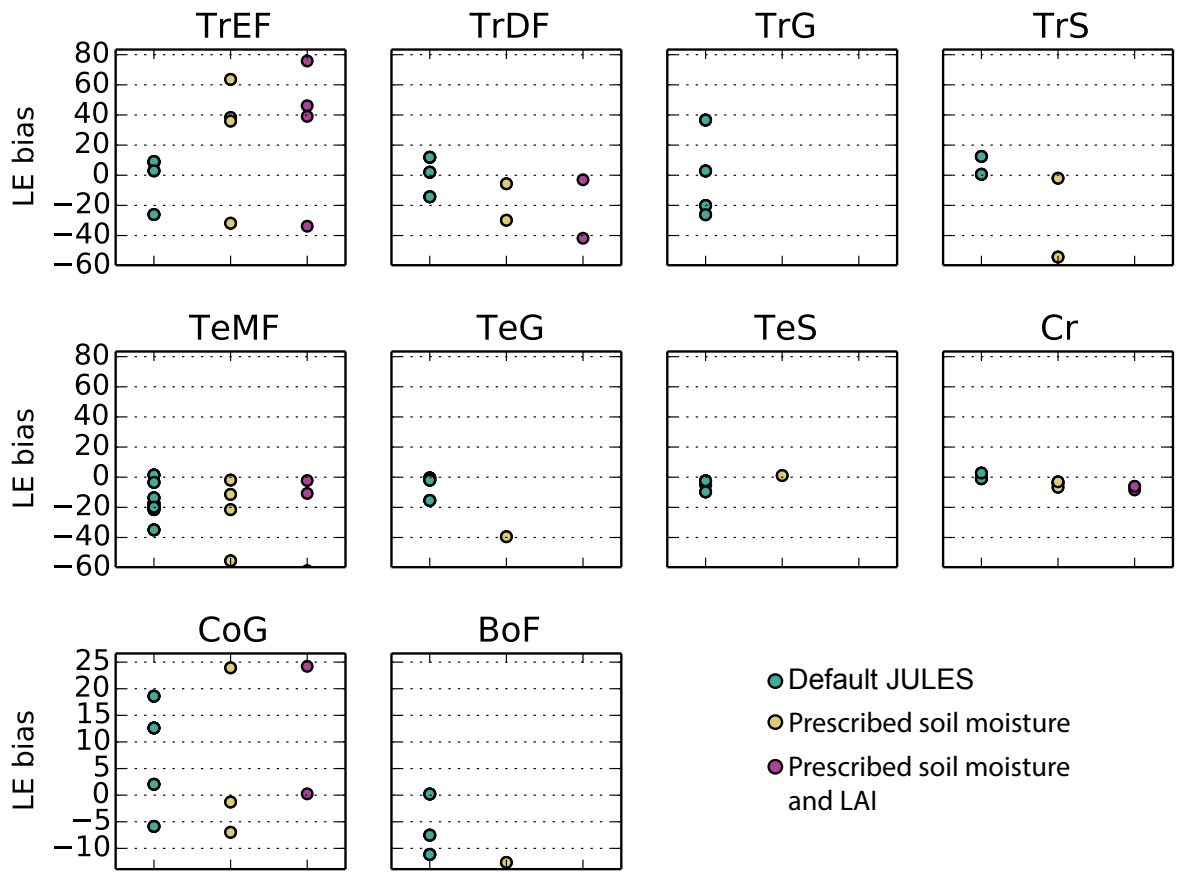
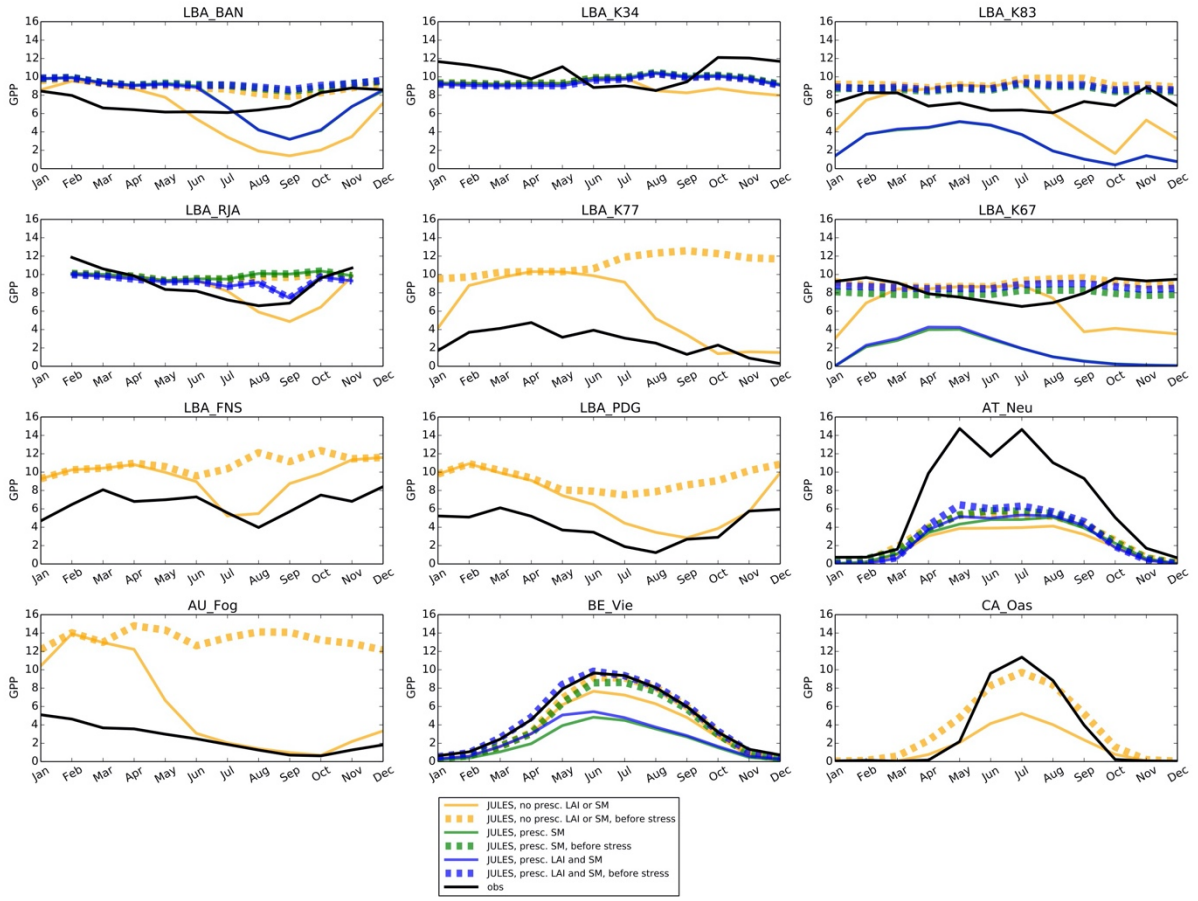
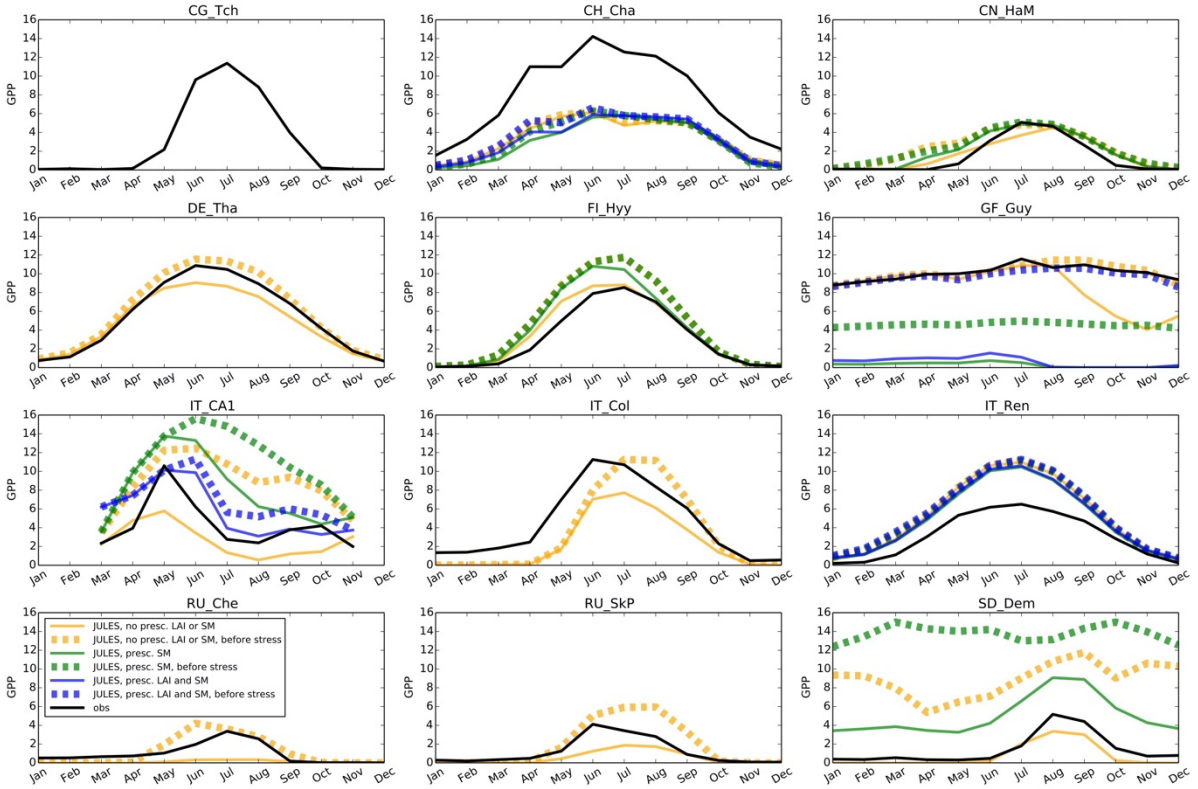


Figure SM4: Root mean bias for LE per biome


LBA_BAN
LBA_K34
LBA_K83
LBA_RJA
LBA_K77
LBA_K67
LBA_FNS
LBA_PDG
AT_Neu
AU_Fog
BE_Vie
CA_Oas
GPP
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
JULES, no presc. LAI or SM
JULES, no presc. LAI or SM, before stress
JULES, presc. SM
JULES, presc. SM, before stress
JULES, presc. LAI and SM
JULES, presc. LAI and SM, before stress
obs


CG_Tch
CH_Cha
CN_HaM
DE_Tha
FI_Hyy
GF_Guy
IT_CA1
IT_Col
IT_Ren
RU_Che
RU_SkP
SD_Dem
GPP
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
JULES, no presc. LAI or SM
JULES, no presc. LAI or SM, before stress
JULES, presc. SM
JULES, presc. SM, before stress
JULES, presc. LAI and SM
JULES, presc. LAI and SM, before stress
obs

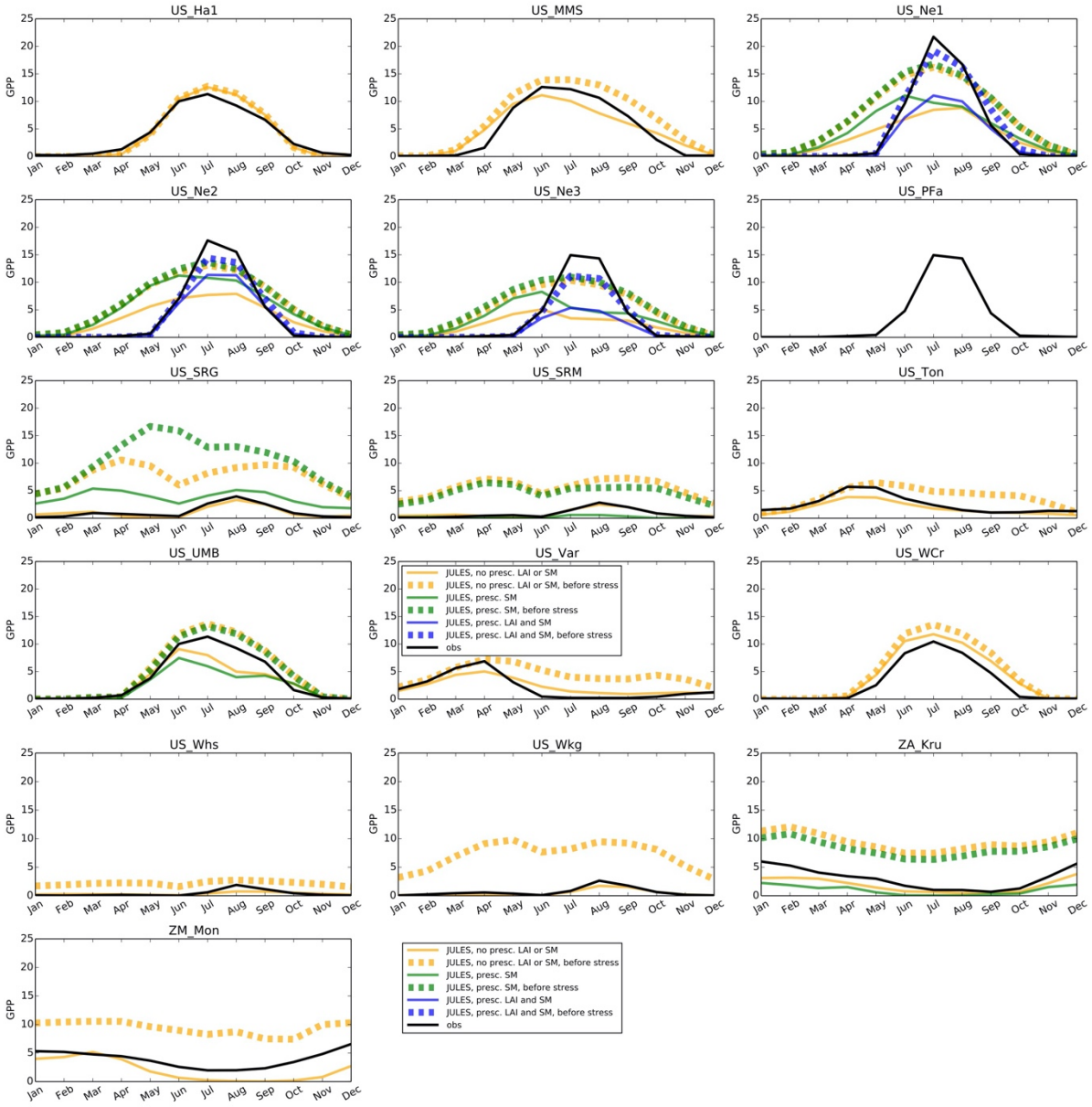
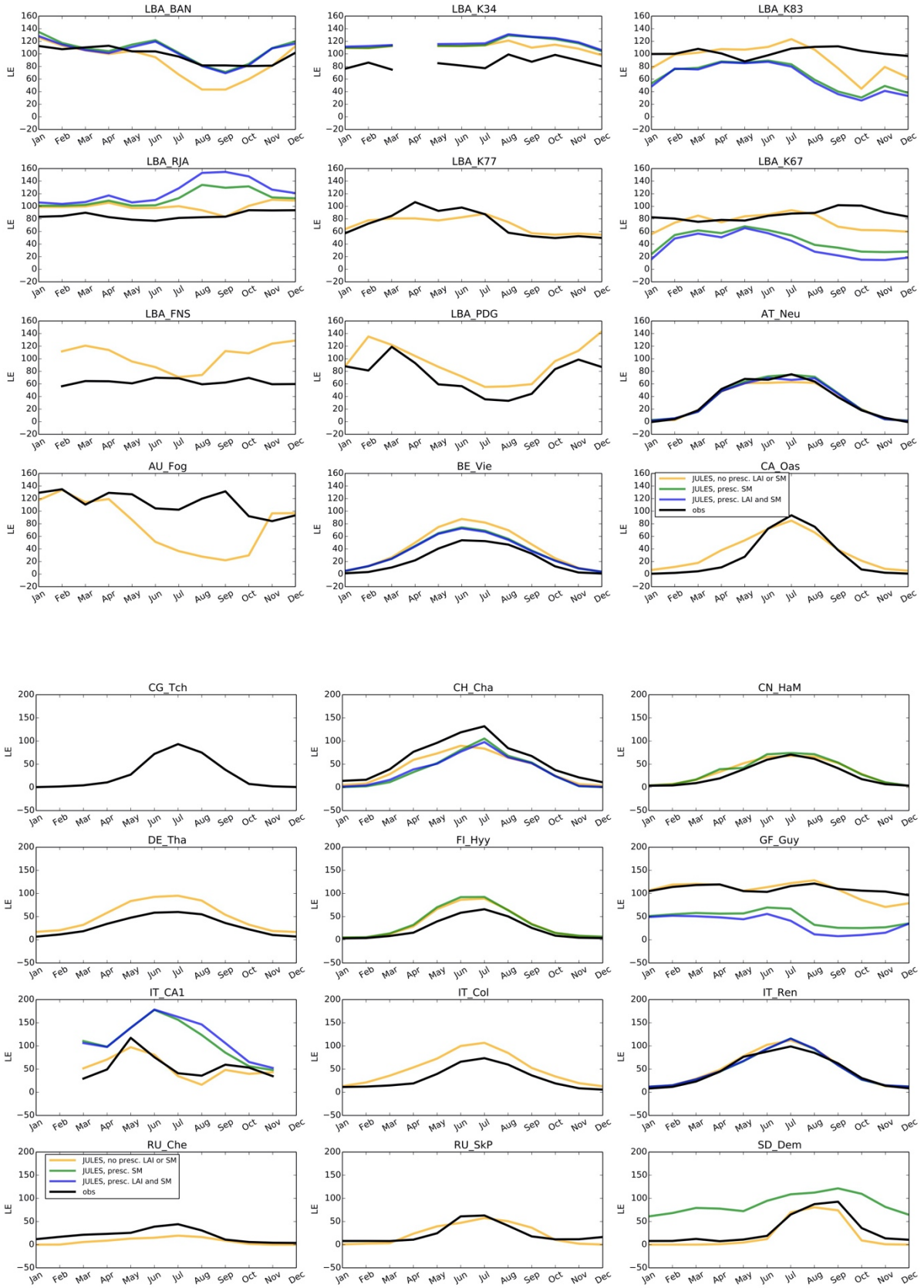


Figure SM5: GPP and unstressed GPP for all sites with and without prescribed data


LBA_BAN
LBA_K34
LBA_K83
LBA_RJA
LBA_K77
LBA_K67
LBA_FNS
LBA_PDG
AT_Neu
AU_Fog
BE_Vie
CA_Oas
CG_Tch
CH_Cha
CN_HaM
DE_Tha
FI_Hyy
GF_Guy
IT_CA1
IT_Col
IT_Ren
RU_Che
RU_SkP
SD_Dem
LE
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
JULES, no presc. LAI or SM
JULES, presc. SM
JULES, presc. LAI and SM
obs

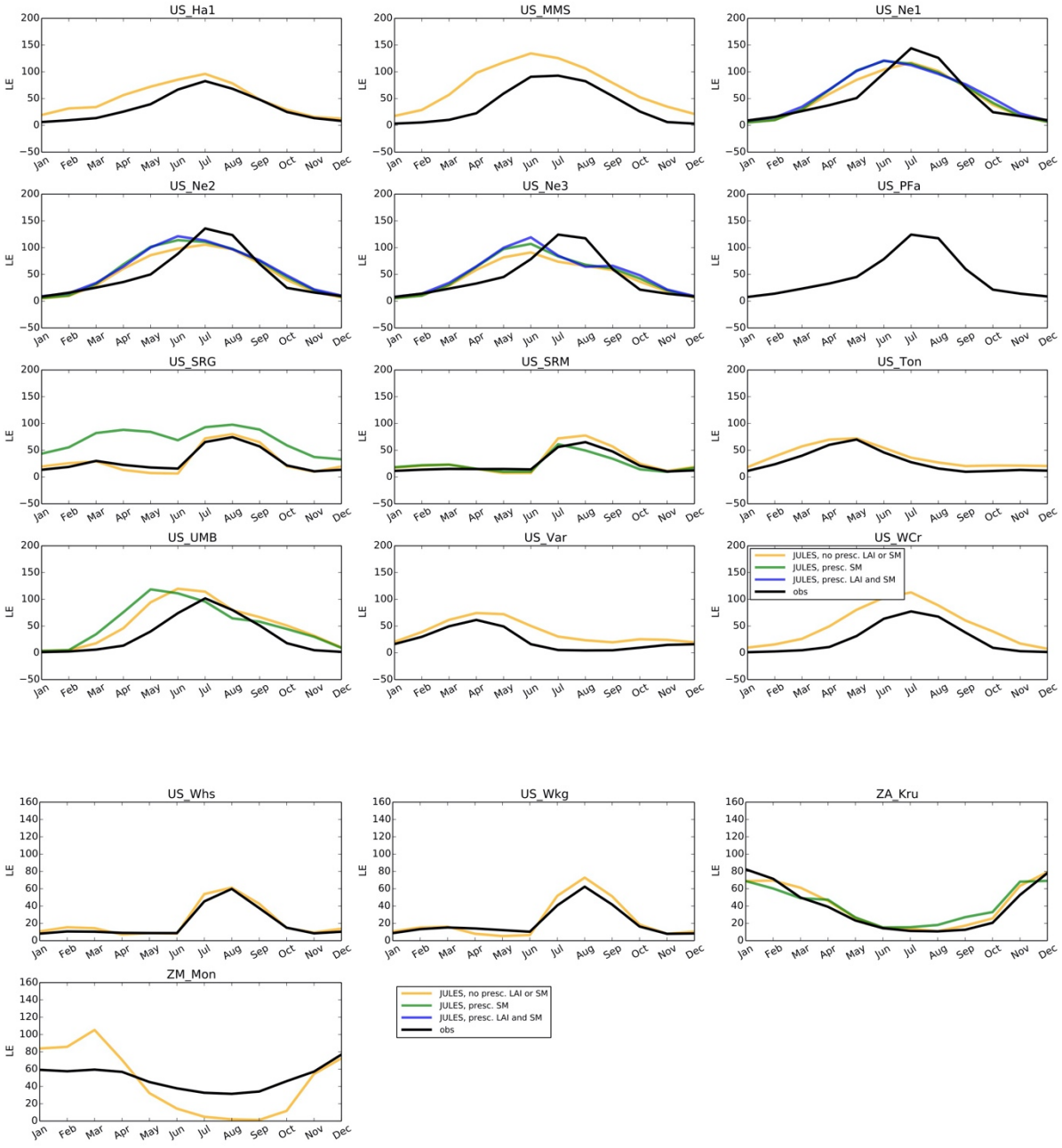


Figure SM6: LE for all sites with and without prescribed data

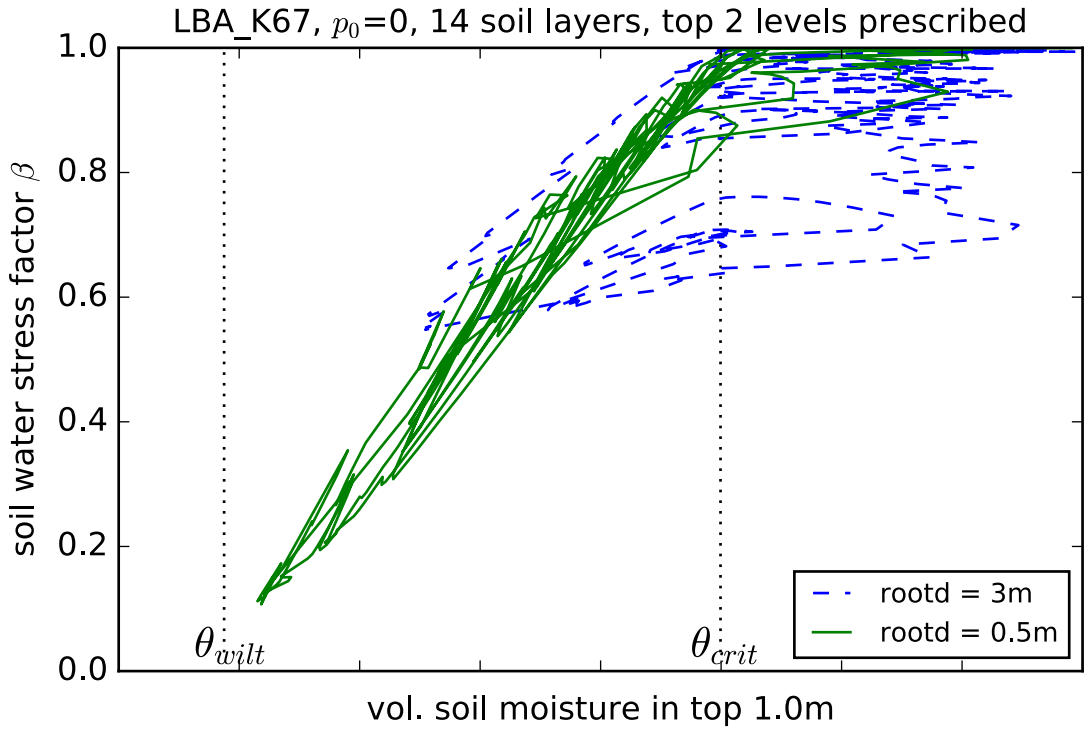
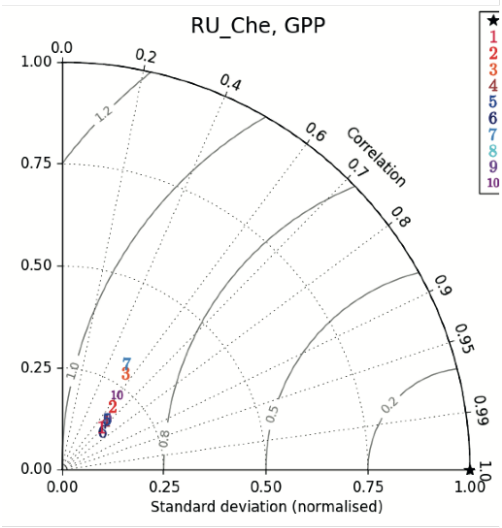
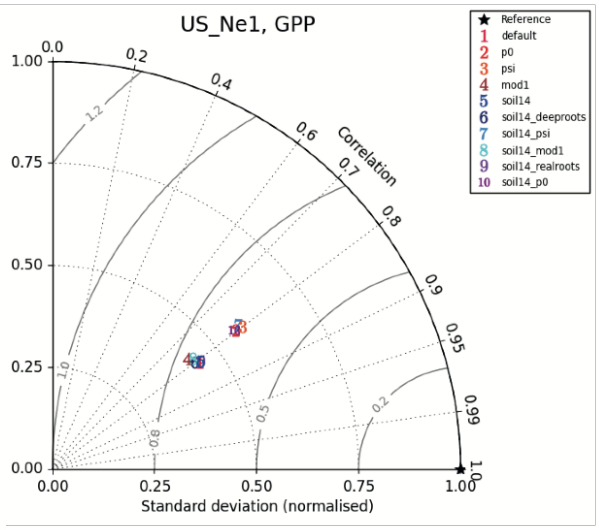
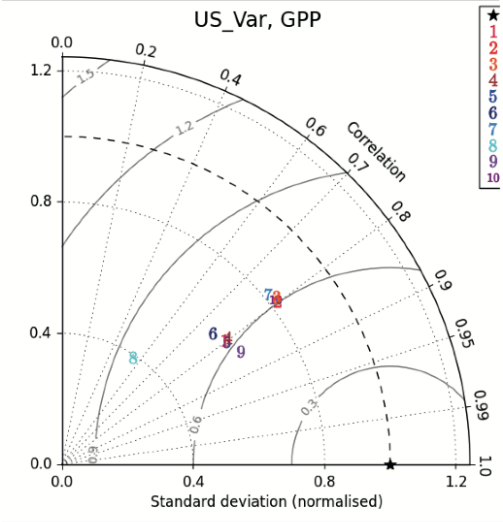
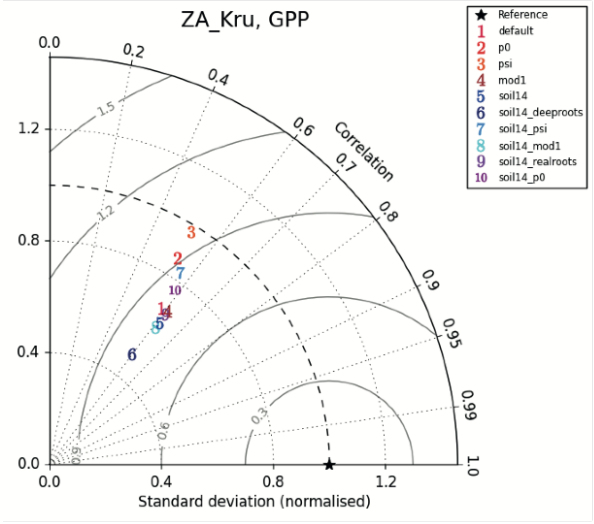


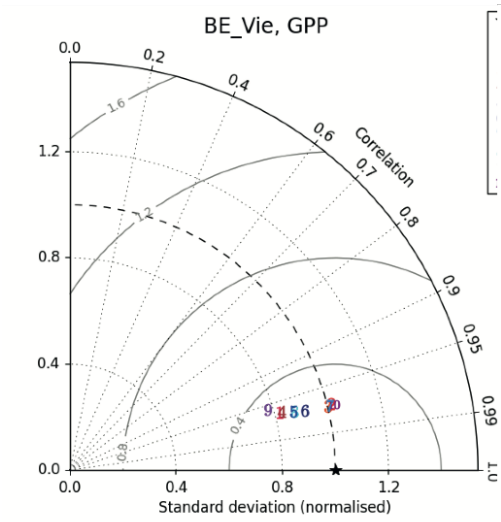
Figure SM7: LBA-K67 stress vs soil moisture

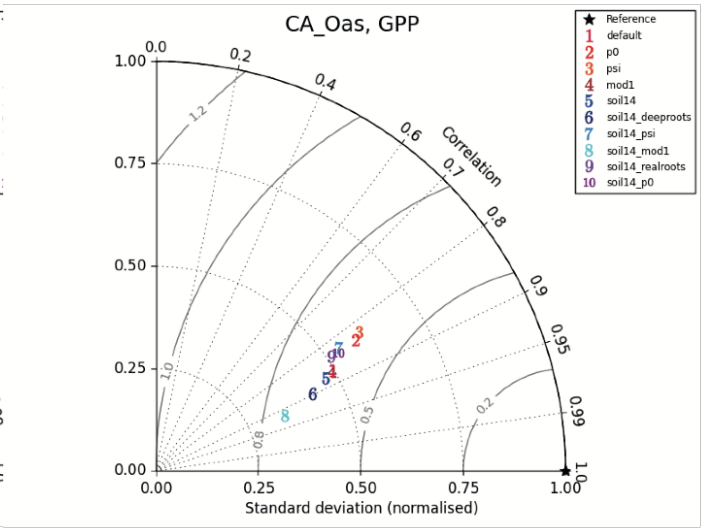

RU_Che, GPP
Correlation
Standard deviation (normalised)
Reference
1 default
2 p0
3 psi
4 mod1
5 soil14
6 soil14_deeproots
7 soil14_psi
8 soil14_mod1
9 soil14_realroots
10 soil14_p0

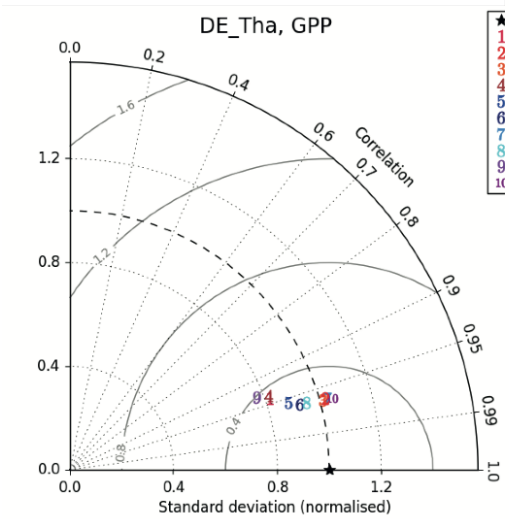

US_Ne1, GPP
Correlation
Standard deviation (normalised)
Reference
1 default
2 p0
3 psi
4 mod1
5 soil14
6 soil14_deeproots
7 soil14_psi
8 soil14_mod1
9 soil14_realroots
10 soil14_p0

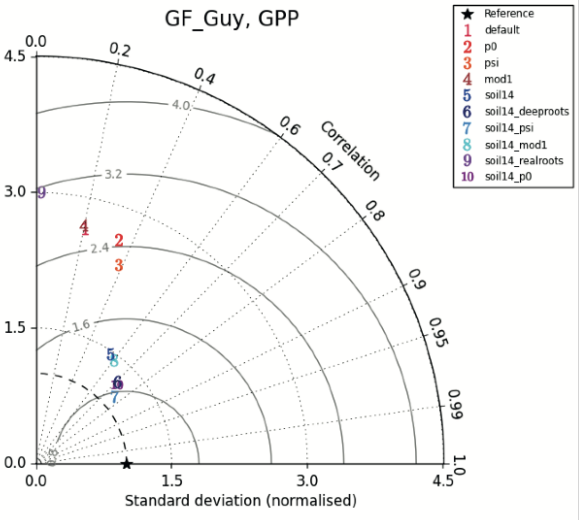

US_Var, GPP
Correlation
Standard deviation (normalised)

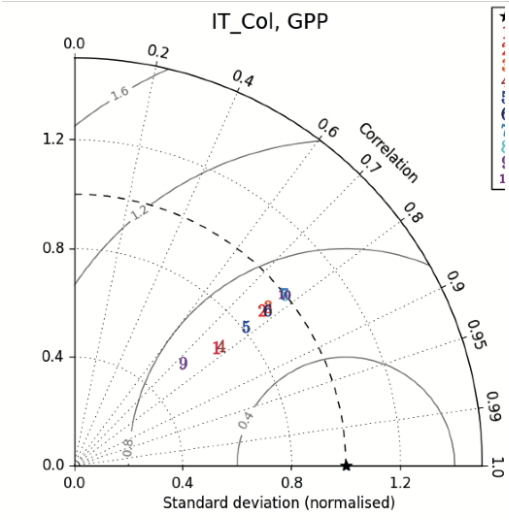

ZA_Kru, GPP
Correlation
Standard deviation (normalised)
Reference
1 default
2 p0
3 psi
4 mod1
5 soil14
6 soil14_deeproots
7 soil14_psi
8 soil14_mod1
9 soil14_realroots
10 soil14_p0

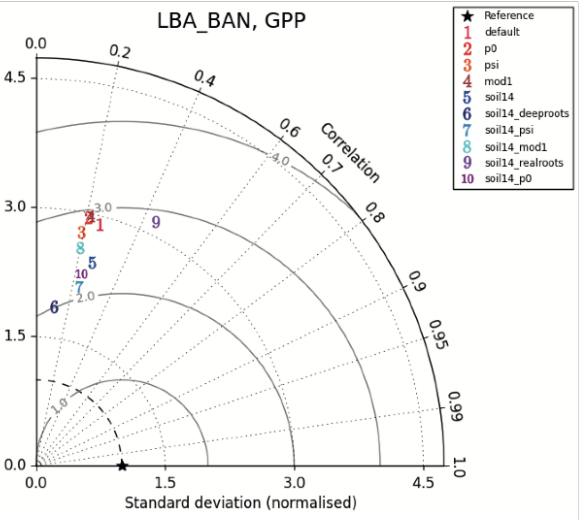

BE_Vie, GPP
Correlation
Standard deviation (normalised)


CA_Oas, GPP
Reference
1 default
2 p0
3 psi
4 mod1
5 soil14
6 soil14_deeproots
7 soil14_psi
8 soil14_mod1
9 soil14_realroots
10 soil14_p0
Correlation
Standard deviation (normalised)


DE_Tha, GPP
Correlation
Standard deviation (normalised)


GF_Guy, GPP
Reference
1 default
2 p0
3 psi
4 mod1
5 soil14
6 soil14_deeproots
7 soil14_psi
8 soil14_mod1
9 soil14_realroots
10 soil14_p0
Correlation
Standard deviation (normalised)


IT_Col, GPP
Correlation
Standard deviation (normalised)


LBA_BAN, GPP
Reference
1 default
2 p0
3 psi
4 mod1
5 soil14
6 soil14_deeproots
7 soil14_psi
8 soil14_mod1
9 soil14_realroots
10 soil14_p0
Correlation
Standard deviation (normalised)

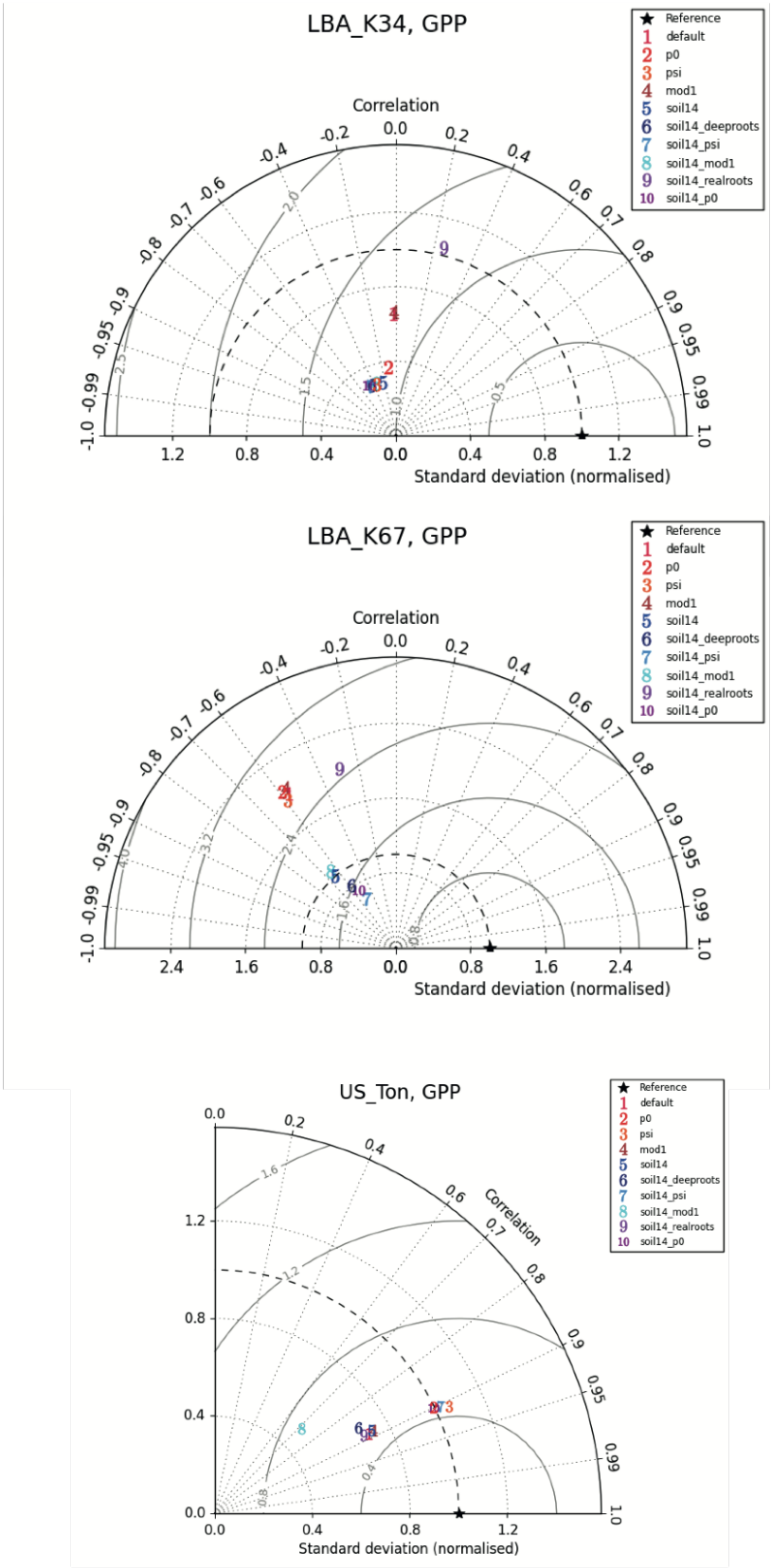
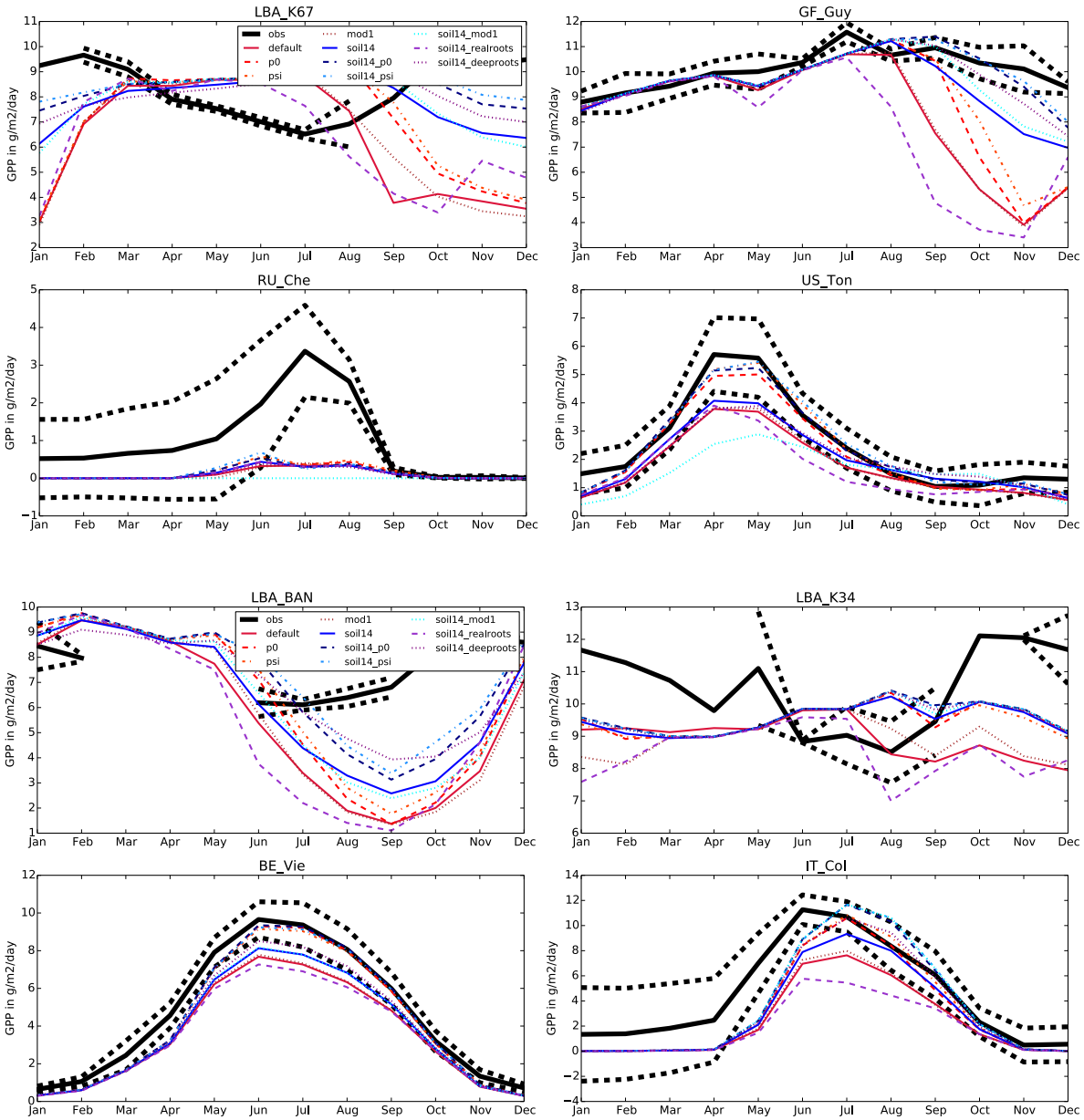


Figure SM8: Taylor Diagrams for all sites with soil experiments for GPP


LBA_K67
GF_Guy
RU_Che
US_Ton
LBA_BAN
LBA_K34
BE_Vie
IT_Col
obs
default
p0
psi
mod1
soil14
soil14_p0
soil14_psi
soil14_mod1
soil14_realroots
soil14_deeproots
GPP in g/m2/day
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

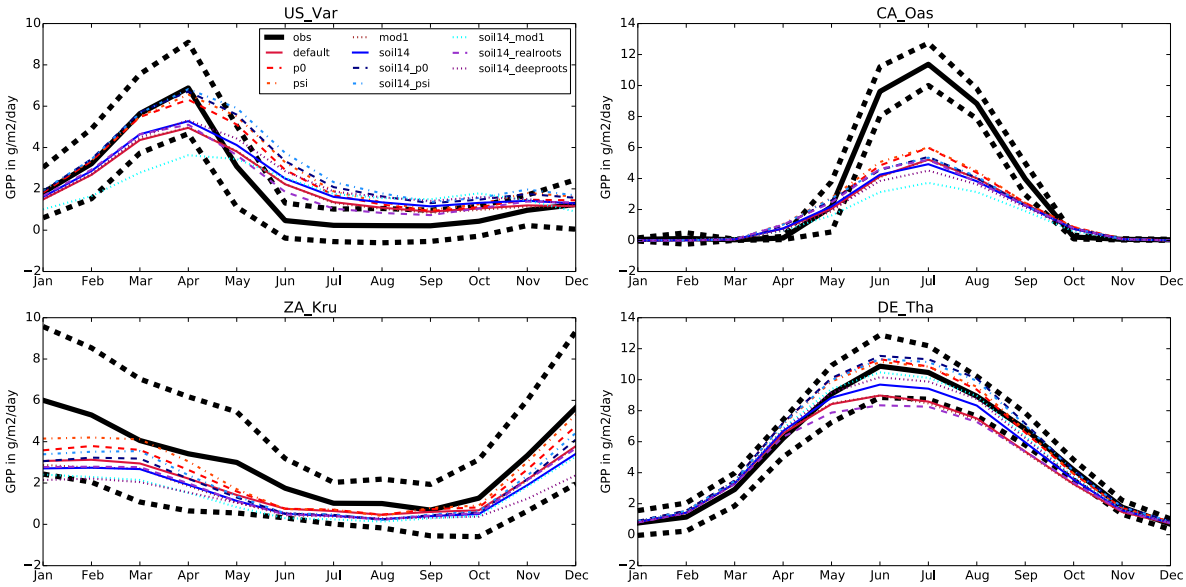
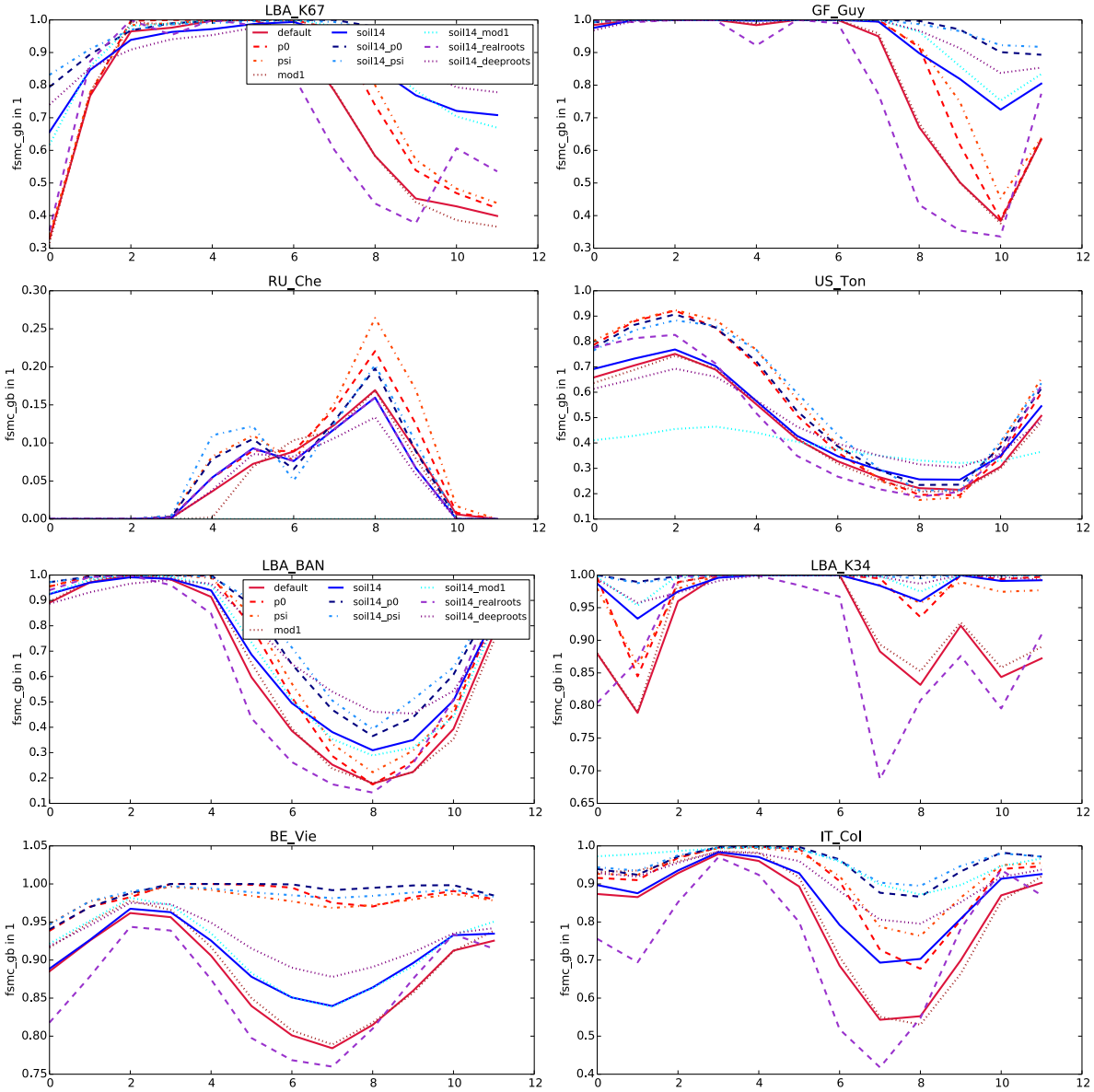


Figure SM9: Seasonal cycle of GPP for all sites with soil experiments


LBA_K67
GF_Guy
RU_Che
US_Ton
LBA_BAN
LBA_K34
BE_Vie
IT_Col
fsmc_gb in 1
default
p0
psi
mod1
soil14
soil14_p0
soil14_psi
soil14_mod1
soil14_realroots
soil14_deeproots

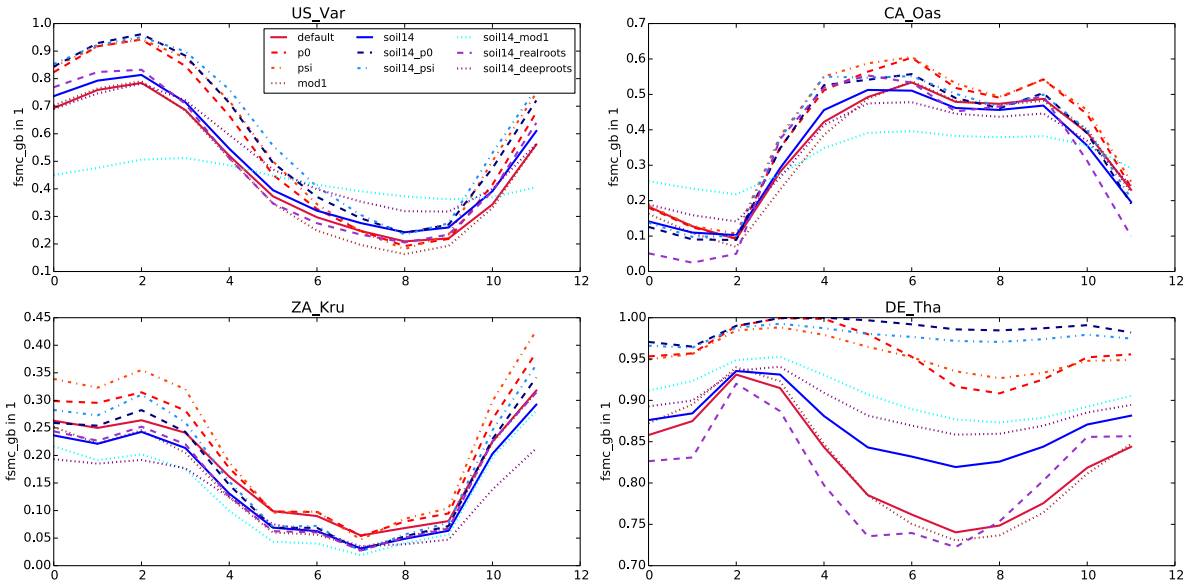
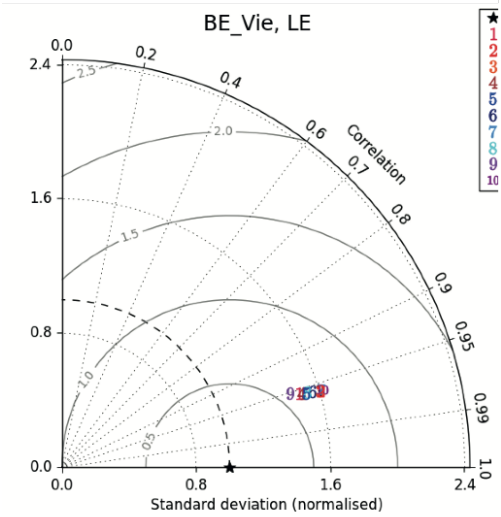
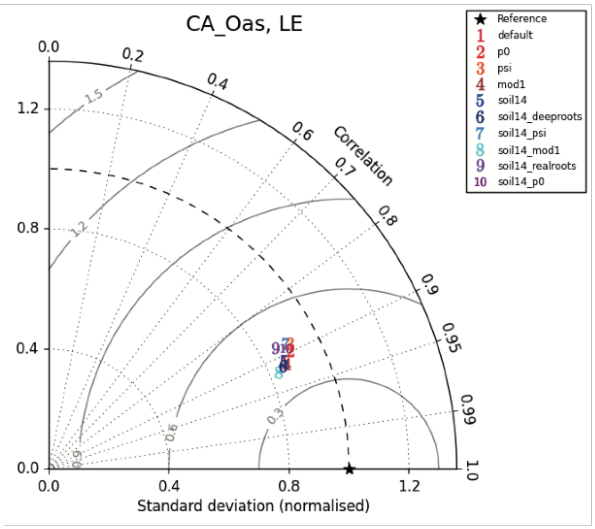
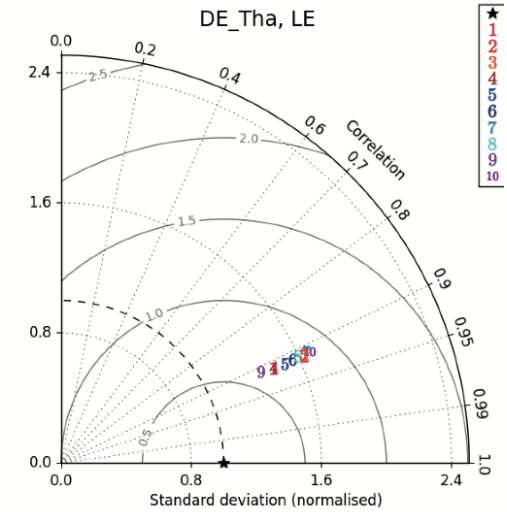
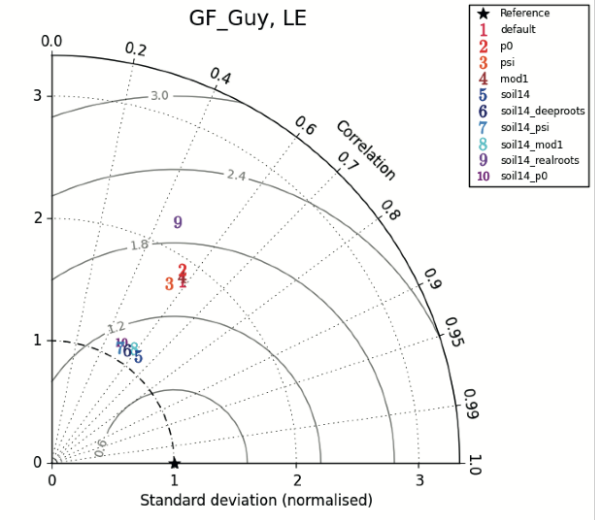


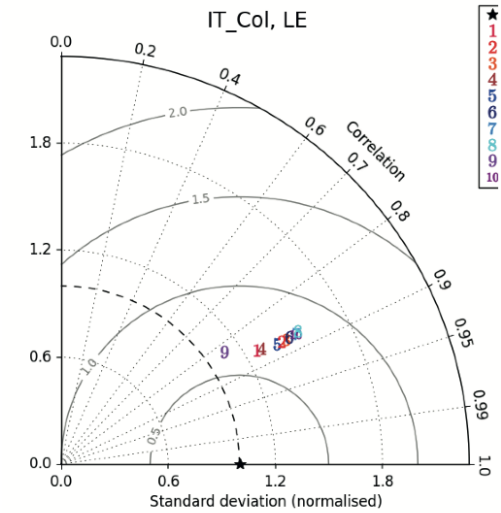
Figure SM10: Seasonal cycle of soil moisture stress factor for all sites with soil experiments.

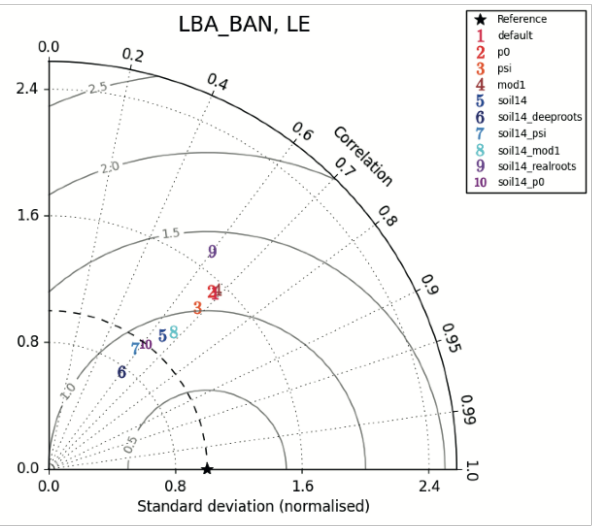

BE_Vie, LE
Correlation
Standard deviation (normalised)
Reference
1 default
2 p0
3 psi
4 mod1
5 soil14
6 soil14_deeproots
7 soil14_psi
8 soil14_mod1
9 soil14_realroots
10 soil14_p0

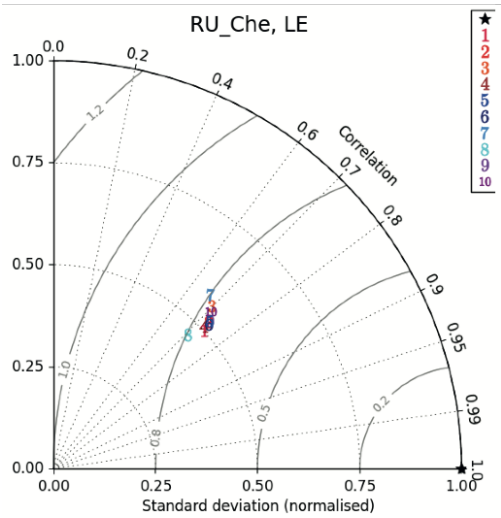

CA_Oas, LE
Correlation
Standard deviation (normalised)
Reference
1 default
2 p0
3 psi
4 mod1
5 soil14
6 soil14_deeproots
7 soil14_psi
8 soil14_mod1
9 soil14_realroots
10 soil14_p0

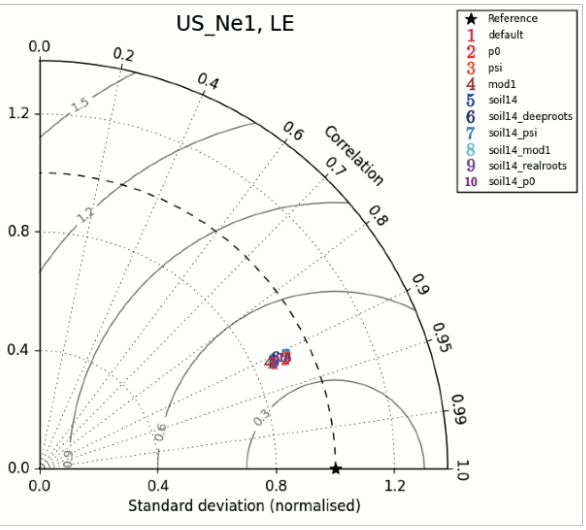

DE_Tha, LE
Correlation
Standard deviation (normalised)

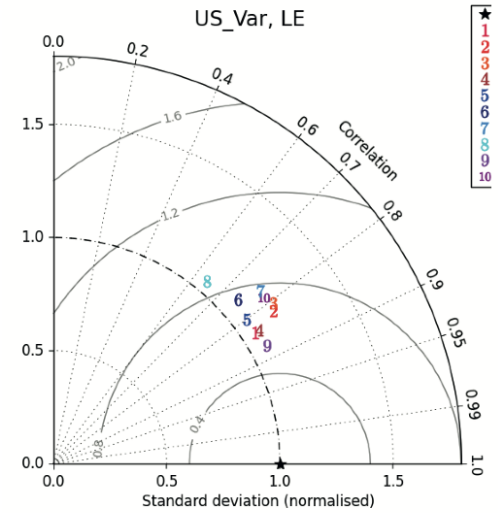

GF_Guy, LE
Correlation
Standard deviation (normalised)
Reference
1 default
2 p0
3 psi
4 mod1
5 soil14
6 soil14_deeproots
7 soil14_psi
8 soil14_mod1
9 soil14_realroots
10 soil14_p0

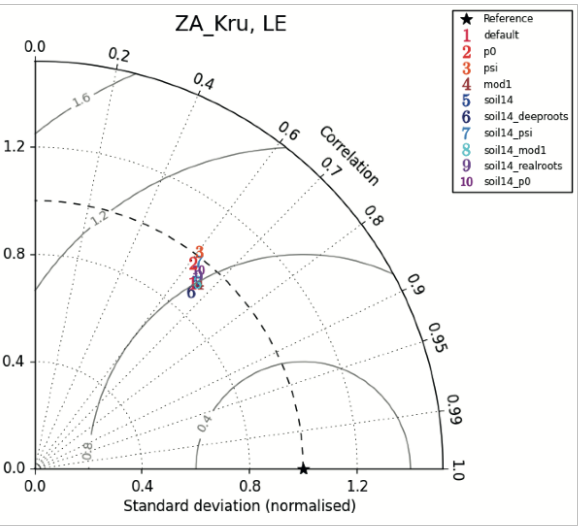

IT_Col, LE
Correlation
Standard deviation (normalised)

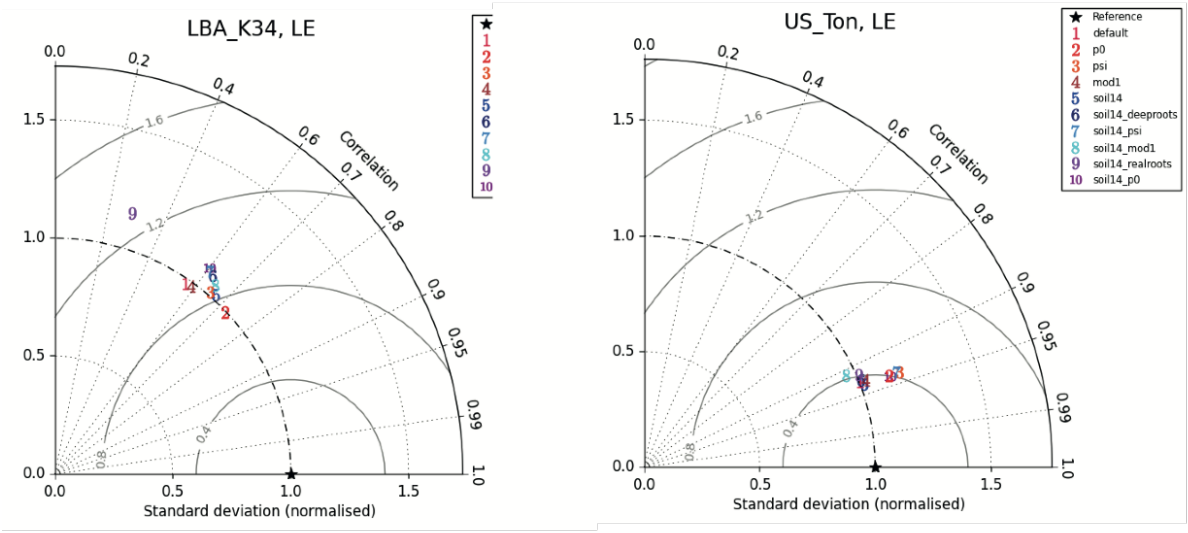

LBA_BAN, LE
Correlation
Standard deviation (normalised)
Reference
1 default
2 p0
3 psi
4 mod1
5 soil14
6 soil14_deeproots
7 soil14_psi
8 soil14_mod1
9 soil14_realroots
10 soil14_p0


RU_Che, LE
Correlation
Standard deviation (normalised)
Reference
1 default
2 p0
3 psi
4 mod1
5 soil14
6 soil14_deeproots
7 soil14_psi
8 soil14_mod1
9 soil14_realroots
10 soil14_p0


US_Ne1, LE
Correlation
Standard deviation (normalised)
Reference
1 default
2 p0
3 psi
4 mod1
5 soil14
6 soil14_deeproots
7 soil14_psi
8 soil14_mod1
9 soil14_realroots
10 soil14_p0


US_Var, LE
Correlation
Standard deviation (normalised)
Reference
1 default
2 p0
3 psi
4 mod1
5 soil14
6 soil14_deeproots
7 soil14_psi
8 soil14_mod1
9 soil14_realroots
10 soil14_p0


ZA_Kru, LE
Correlation
Standard deviation (normalised)
Reference
1 default
2 p0
3 psi
4 mod1
5 soil14
6 soil14_deeproots
7 soil14_psi
8 soil14_mod1
9 soil14_realroots
10 soil14_p0



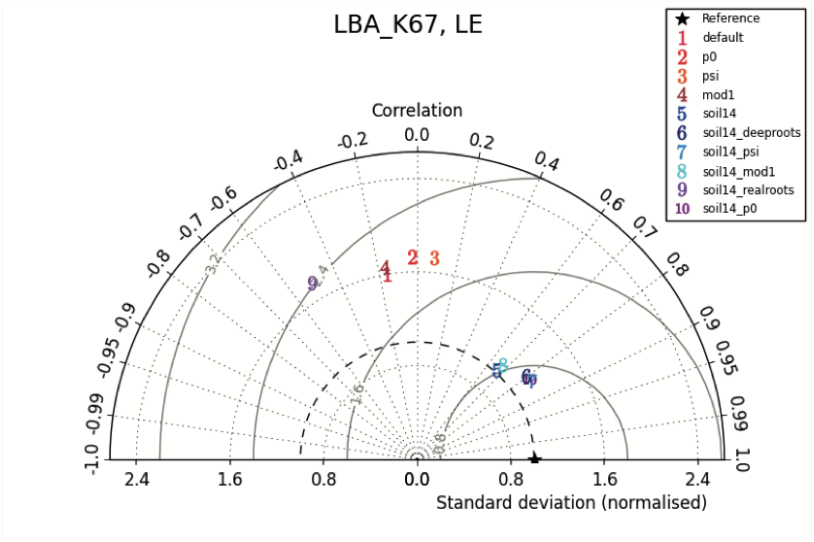
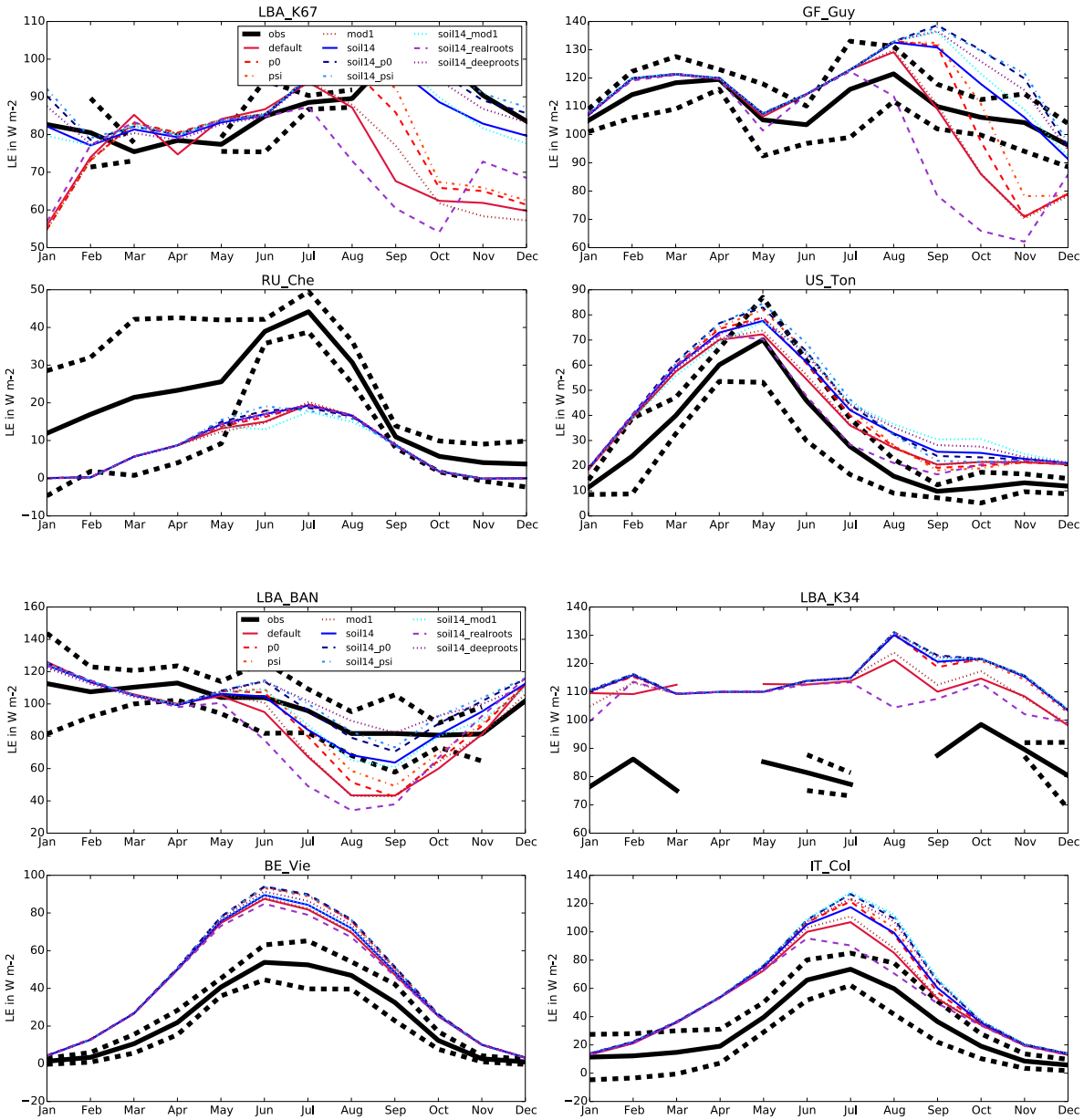


Figure SM11: Taylor Diagrams for all sites with soil experiments for LE


LBA_K67
GF_Guy
RU_Che
US_Ton
LBA_BAN
LBA_K34
BE_Vie
IT_Col
obs
default
p0
psi
mod1
soil14
soil14_p0
soil14_psi
soil14_mod1
soil14_realroots
soil14_deeproots
LE in W m-2
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

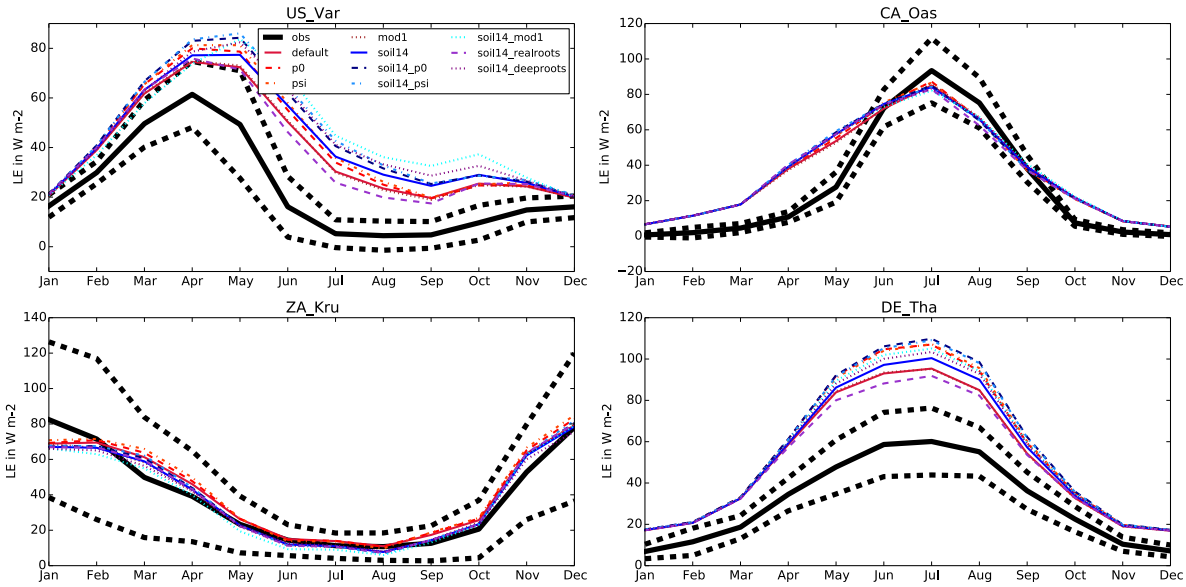


Figure SM12: Seasonal cycle of LE for all sites with soil experiments

References for each site:

Pastorello et al., 2020. The FLUXNET2015 dataset and the ONEFlux processing pipeline for eddy covariance data. Scientific data, 7:225; https://doi.org/10.1038/s41597-020-0534-3

AT-Nue: 10.18140/FLX/1440121
AU-Fog: 10.18140/FLX/1440124
BE-Vie: 10.18140/FLX/1440130
CA-OAs: 10.18140/FLX/1440043
CG-Tch: 10.18140/FLX/1440142
CH-Cha: 10.18140/FLX/1440131
CN-HaM 10.18140/FLX/1440190
DE-Tha: 10.18140/FLX/1440152
FI-Hyy: 10.18140/FLX/1440158
GF-Guy: 10.18140/FLX/1440165
IT-CA1: 10.18140/FLX/1440230
IT-Col: 10.18140/FLX/1440167
IT-Ren: 10.18140/FLX/1440173
RU-Che: 10.18140/FLX/1440181
RU-SkP: 10.18140/FLX/1440243
SD-Dem: 10.18140/FLX/1440186
US-Ha1: 10.18140/FLX/1440071
US-MMS: 10.18140/FLX/1440083
US-Ne1: 10.18140/FLX/1440084
US-PFa: 10.18140/FLX/1440089
US-SRG: 10.18140/FLX/1440114
US-SRM: 10.18140/FLX/1440090
US-Ton: 10.18140/FLX/1440092
US-Var: 10.18140/FLX/1440094
US-WCr: 10.18140/FLX/1440095
US-Whs: 10.18140/FLX/1440097
US-Wkg: 10.18140/FLX/1440096
ZA-Kru: 10.18140/FLX/1440188
ZM-Mon: 10.18140/FLX/1440189

Further list of site references:

SD-DEM

Ardö, J., Mölder, M., El-Tahir, B. A. and Elkhidir, H. A. M.: Seasonal variation of carbon fluxes in a sparse savanna in semi arid Sudan, Carbon Balance Manag., 3, 7, 2008.

http://www.fluxdata.org:8080/sitepages/siteInfo.aspx?SD-Dem

CG-Tch

1. Akkermans, T., Lauwaet, D., Demuzere, M., Vogel, G., Nouvellon, Y., Ardö, J., Caquet, B., De Grandcourt, A., Merbold, L., Kutsch, W. et al., 2012. Validation and comparison of two soil-vegetation-atmosphere transfer models for tropical Africa. Journal of Geophysical Research: Biogeosciences, 117(2), Doi 10.1029/2011JG001802

2. Caquet B., De Grandcourt A., Thongo M'bou A., Epron D., Kinana, A., Saint André L., Nouvellon Y., 2012. Soil carbon balance in a tropical grassland: estimation of soil respiration and its partitioning using a semi-empirical model. Agricultural and Forest Meteorology, 158– 159:71–79.
3. Zhang, Y., Xiao, X., Zhang, Y., Wolf, S., Zhou, S., Joiner, J., Guanter, L., Verma, M., Sun, Y., Yang, X., Paul-Limoges, E., Gough, C. M., Wohlfahrt, G., Gioli, B., van der Tol, C., Nouvellon, Y., Lund, M., de Grandcourt, A. (2018). On the relationship between sub-daily instantaneous and daily total gross primary production: Implications for interpreting satellite-based SIF retrievals. Remote Sensing of Environment 205: 276–289.

US-Ne sites:

Verma, S.B., A. Dobermann, K.G. Cassman, D.T. Walters, J.M. Knops, T.J. Arkebauer, A.E. Suyker, G.G. Burba, B. Amos, H. Yang. D. Ginting, K.G. Hubbard, A.A. Gitelson and E.A. Walter-Shea (2005) Annual carbon dioxide exchange in irrigated and rainfed maize-based agroecosystems. Agricultural and Forest Meteorology 131: 77-96.

CA-Oas:

Krishnan, P., Black, T.A., Grant, N.J., Barr, A.G., Hogg, E.H., Jassal, R.S., Morgenstern, K. (2006). Impact of changing soil moisture distribution on net ecosystem productivity of a boreal aspen forest during and following drought. Agric. For. Meteorol. 139: 208-223.

Stephens, J.J., Black, T.A., Jassal, R.S., Nesic, Z., Grant, N.J., Barr, A.G., Helgason, W., Richardson, A.D., Johnson, M.S., Christen, A. (2018). Effects of forest tent caterpillar defoliation on carbon and water fluxes in a boreal aspen stand. Agricultural and Forest Meteorology doi.org/10.1016/j.agrformet.2018.01.035.

US-UMB:

Gough C.M., Hardiman B.S., Nave L.E., Bohrer G., Maurer K.D., Vogel C.S., Nadelhoffer KJ, Curtis P.S. 2013. Sustained carbon uptake and storage following moderate disturbance in a Great Lakes forest. Ecological Applications, 23, 1202-1215.

US-UMB's Ameriflux DOI: http://ameriflux.lbl.gov/sites/siteinfo/US-UMB#doi.

CH-CHA:

Hörtnagl L, Barthel M, Buchmann N, Eugster W, Butterbach-Bahl K, Díaz-Pinés E, Zeeman M, Klumpp K, Kiese R, Burri S, Bahn M, Hammerle Albin, Ladreiter-Knauss T, Lu H, Merbold L (2018) Greenhouse

gas fluxes over managed grasslands in Central Europe. Global Change Biology 24:1843-1872, doi 10.1111/gch14079