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Supplement of

Testing water fluxes and storage from two hydrology configurations within the ORCHIDEE land surface model across US semi-arid sites

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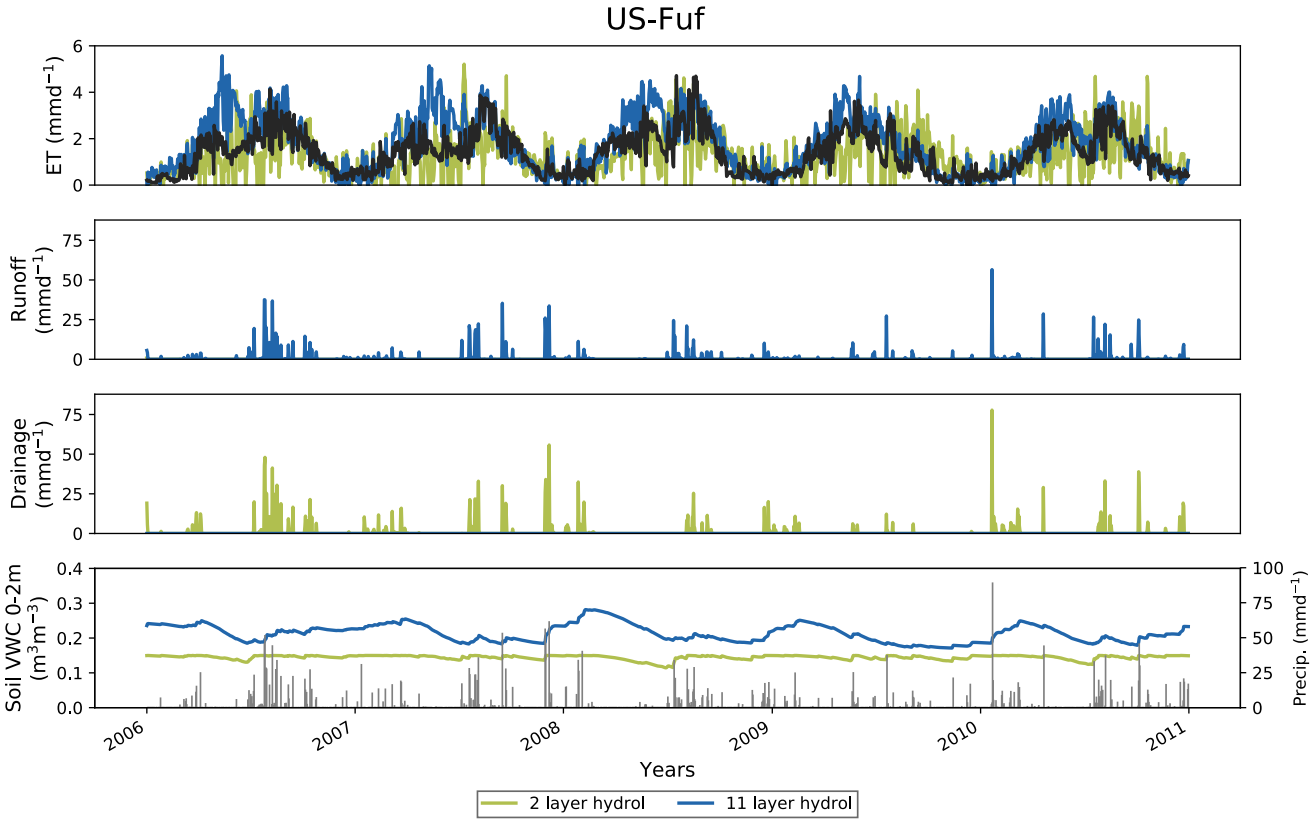
Table S1: Depths of the ORCHIDEE 11-layer discretized hydrology model

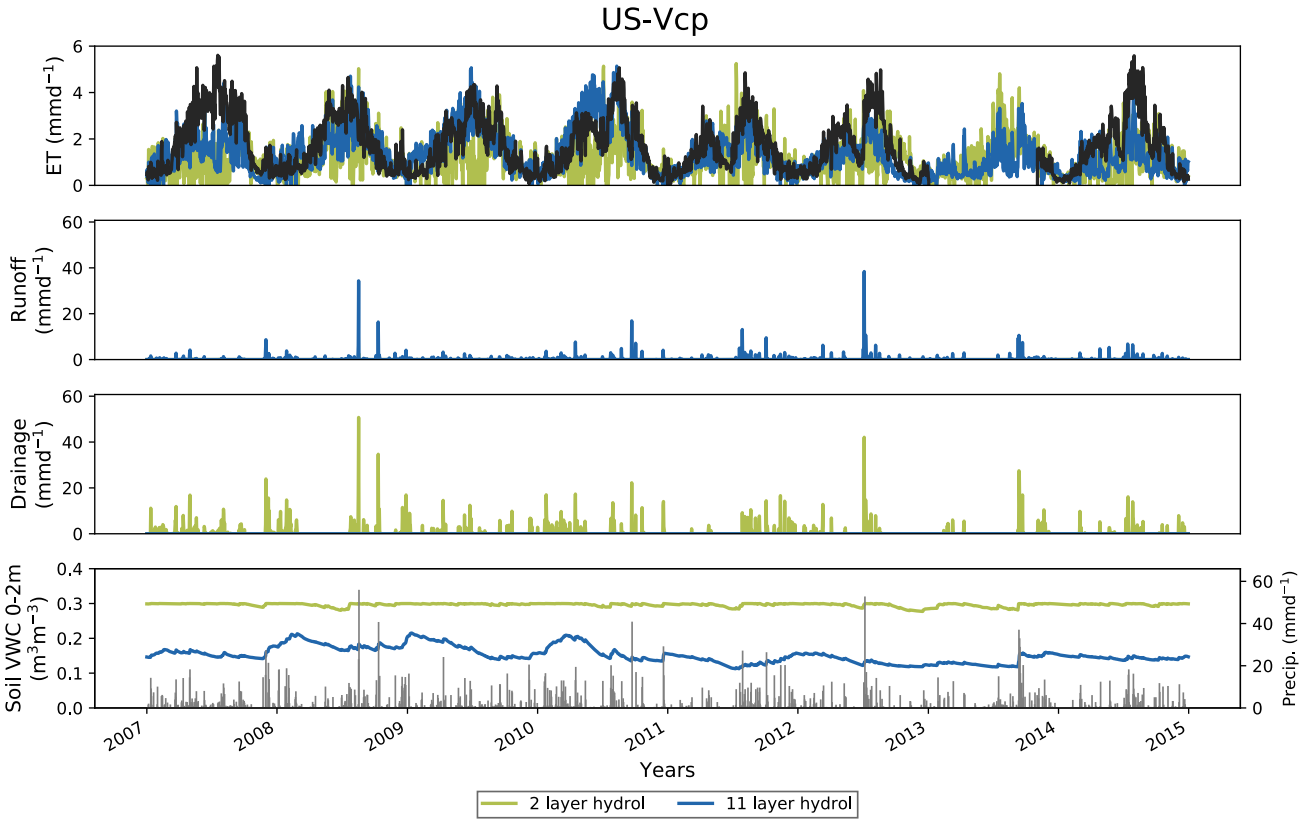
ORCHIDEE Layer	Layer thickness (m)	Cumulative Depth (m)
1	0.001	0.001
2	0.003	0.004
3	0.006	0.01
4	0.012	0.022
5	0.023	0.045
6	0.047	0.092
7	0.092	0.186
8	0.188	0.374
9	0.375	0.750
10	0.750	1.5
11	0.5	2.0

Figure S1: Complete daily time series comparing the 2LAY (green curve) and 11LAY (blue curve) simulations for the following hydrological variables: i) ET (top panel for each site) compared to observations (black curve); ii) surface runoff (2nd panel for each site); iii) drainage (3rd panel for each site); and iv) total 2m column volumetric soil water content (SWC) soil moisture (bottom panel for each site). Precipitation is shown in the grey bars in the bottom panel for each site. Sites in following order: a) US-Fuf; b) US-Vcp; c) US-SRM; d) US-Whs; e) US-SRG; f) US-Wkg. Precipitation is shown in the grey lines in the bottom panel for each site.

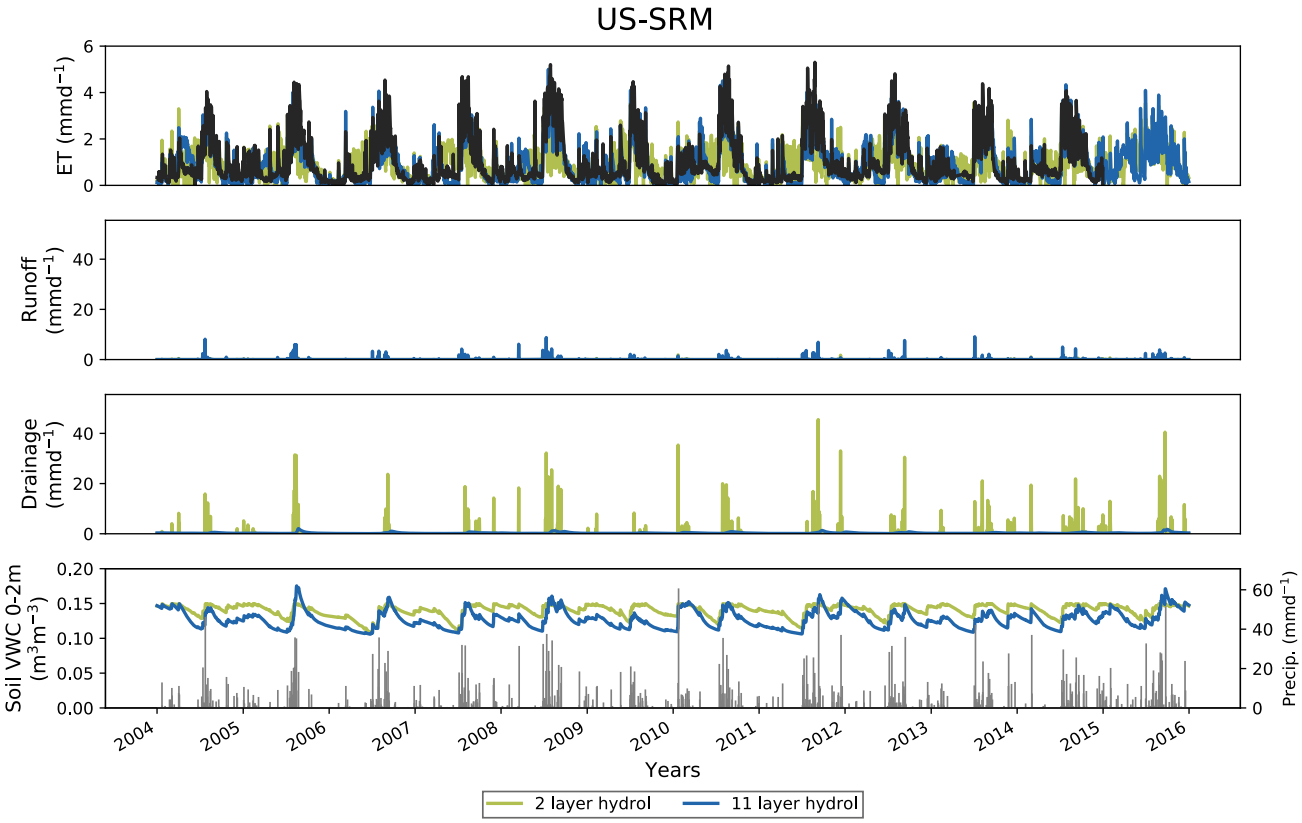
a) US-Fuf



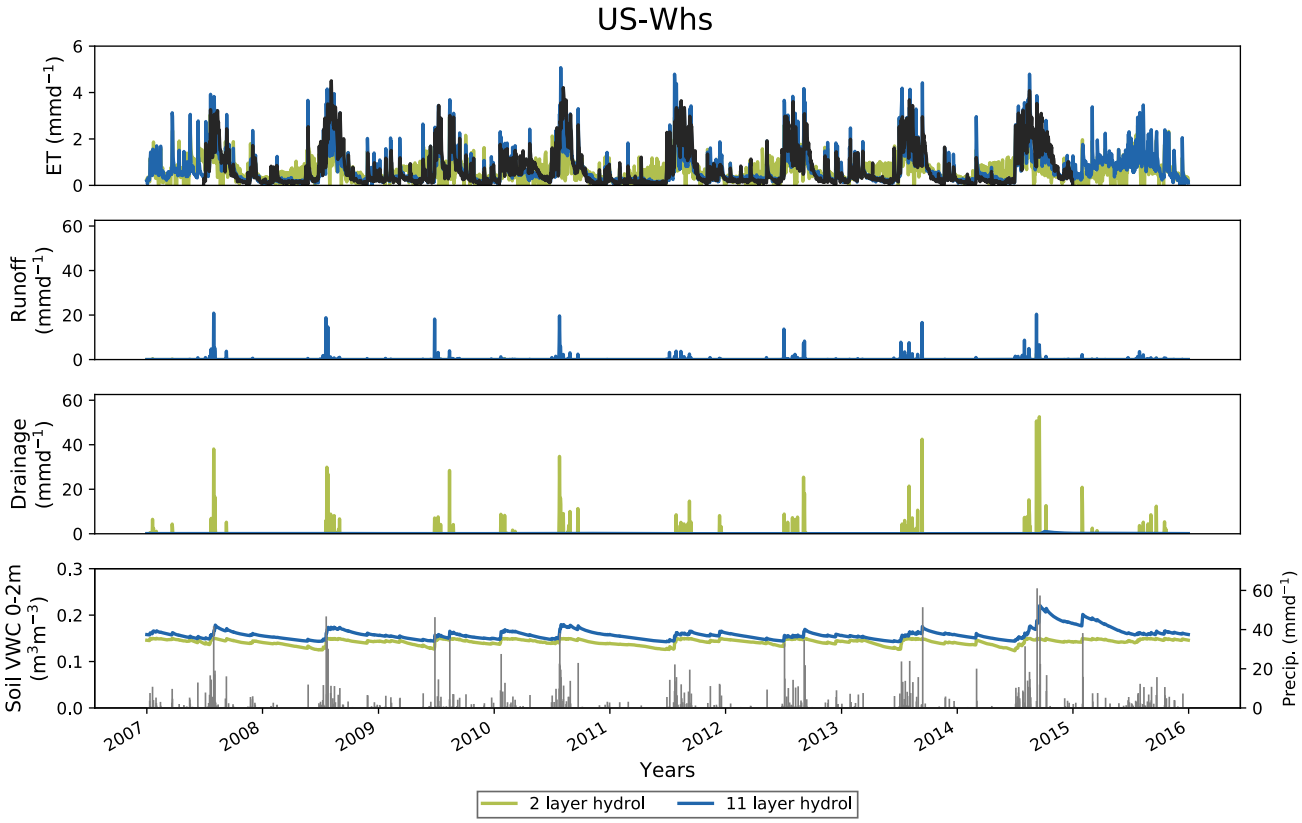
b) US-Vcp


US-Vcp
ET (mmd^{-1})
Runoff (mmd^{-1})
Drainage (mmd^{-1})
Soil VWC 0-2m (m^{3}m^{-3})
Precip. (mmd^{-1})
2007
2008
2009
2010
2011
2012
2013
2014
2015
Years
2 layer hydrol
11 layer hydrol

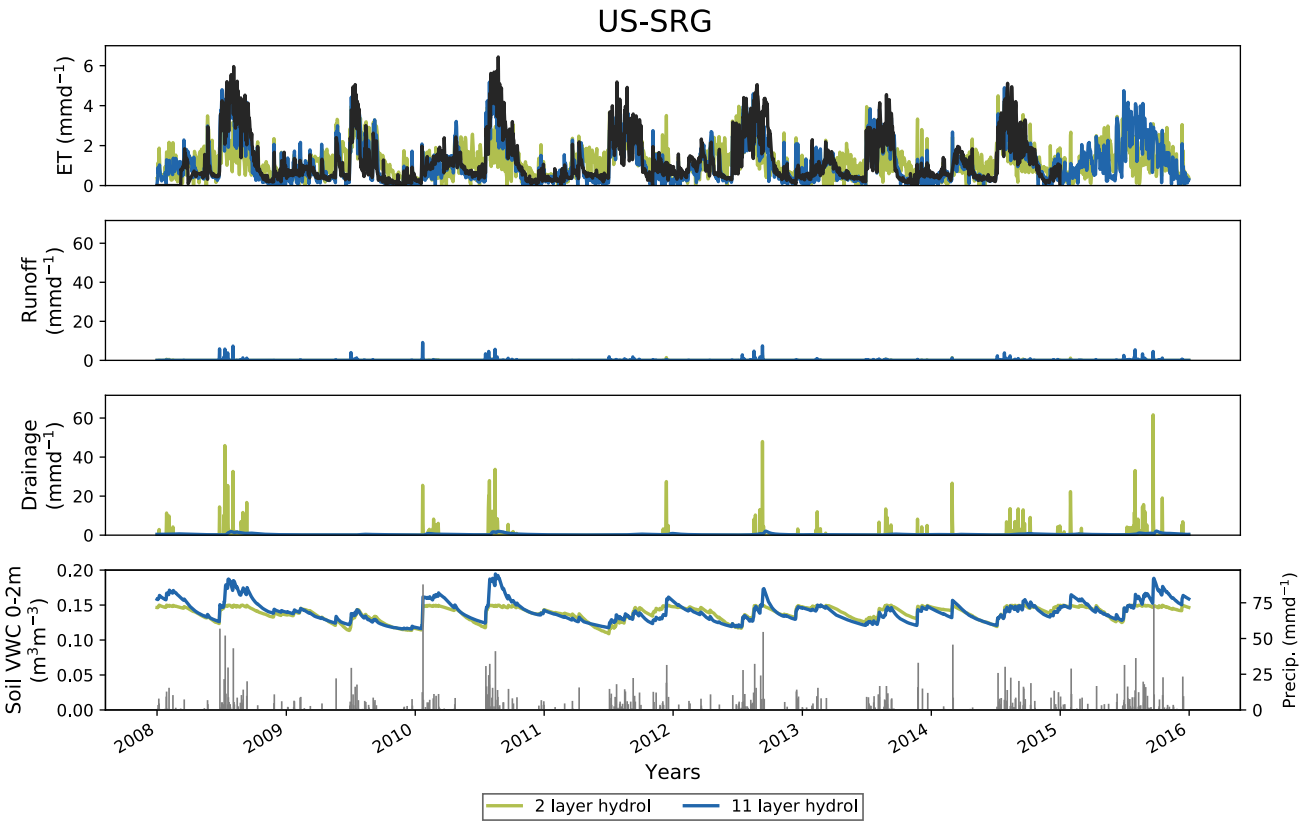
c) US-SRM


US-SRM
ET (mmd^{-1})
Runoff (mmd^{-1})
Drainage (mmd^{-1})
Soil VWC 0-2m (m^{3}m^{-3})
Precip. (mmd^{-1})
Years
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2 layer hydrol
11 layer hydrol

d) US-Whs


US-Whs
ET (mmd^{-1})
Runoff (mmd^{-1})
Drainage (mmd^{-1})
Soil VWC 0-2m (m^{3}m^{-3})
Precip. (mmd^{-1})
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Years
2 layer hydrol
11 layer hydrol

e) US-SRG


US-SRG
ET (mmd^{-1})
Runoff (mmd^{-1})
Drainage (mmd^{-1})
Soil VWC 0-2m (m^{3}m^{-3})
Precip. (mmd^{-1})
Years
2008
2009
2010
2011
2012
2013
2014
2015
2016
2 layer hydrol
11 layer hydrol

f) US-Wkg

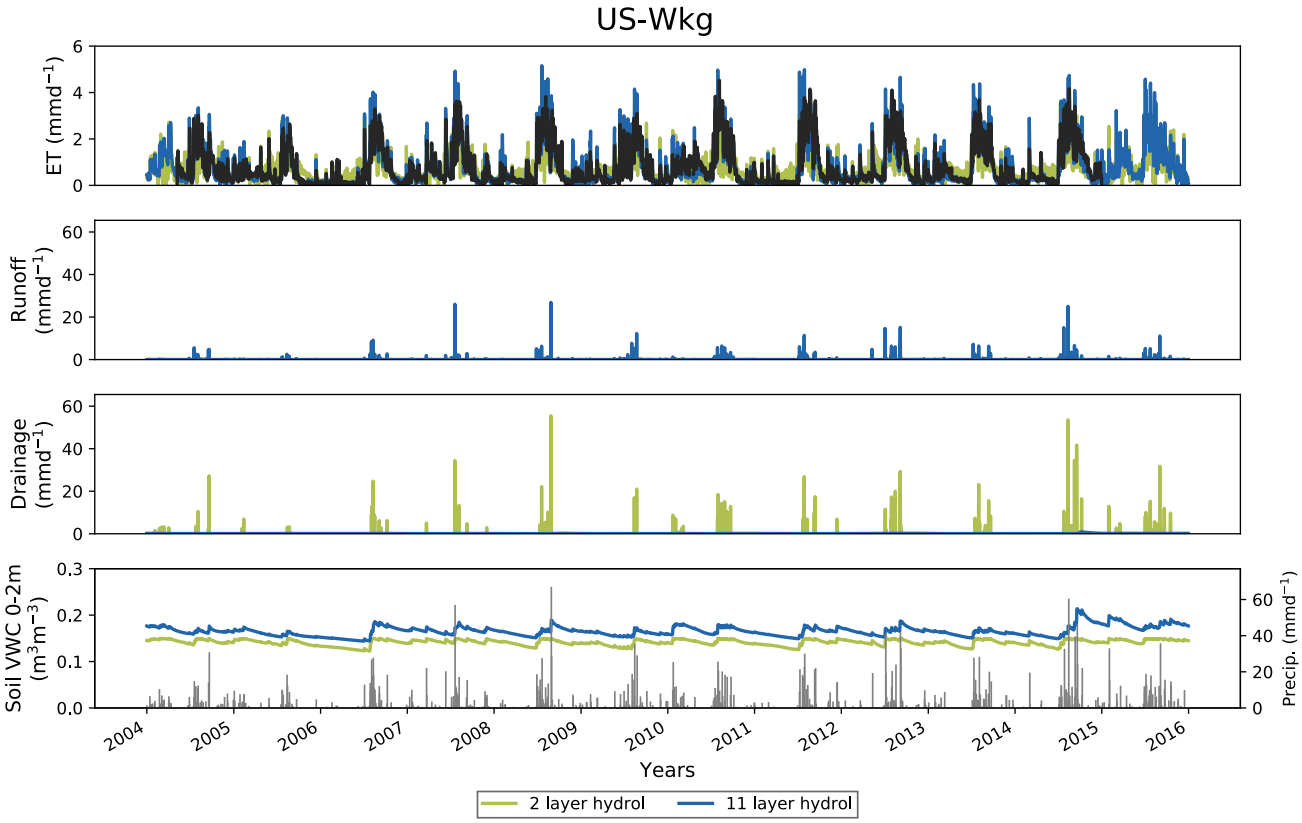
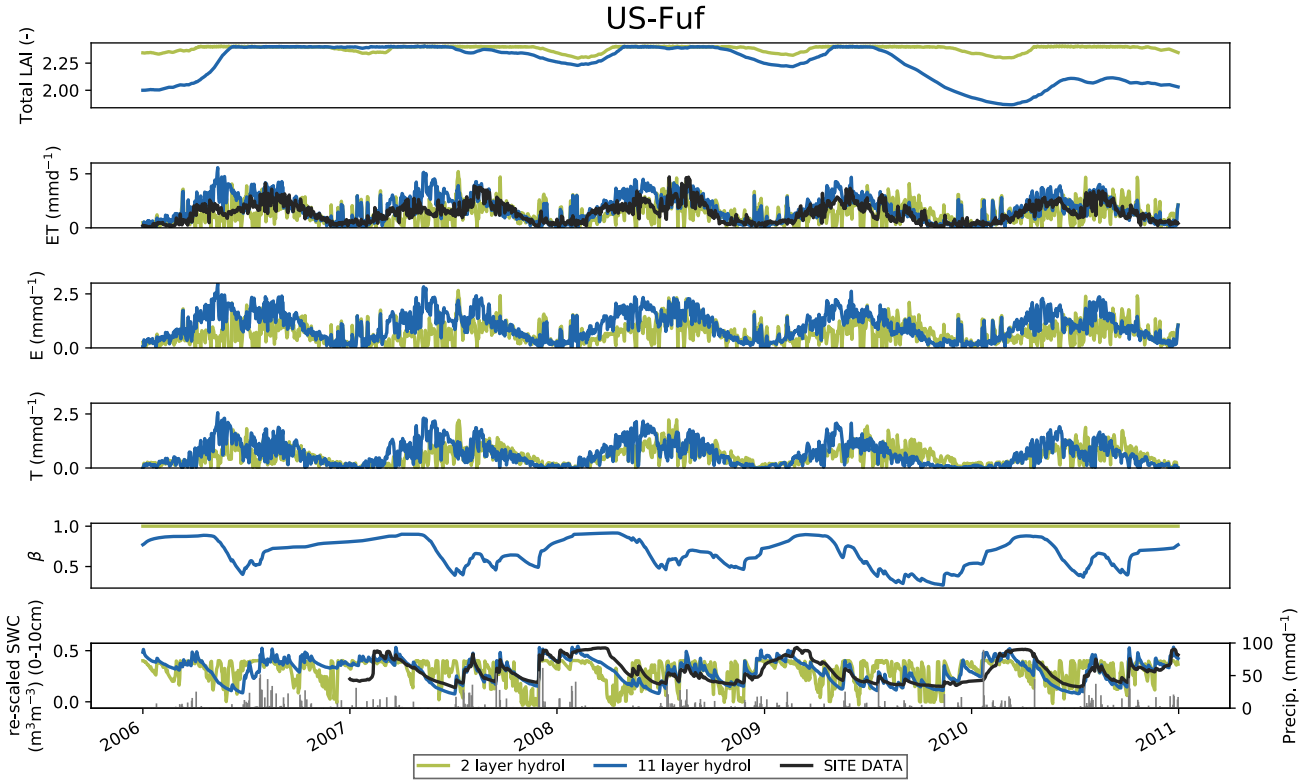
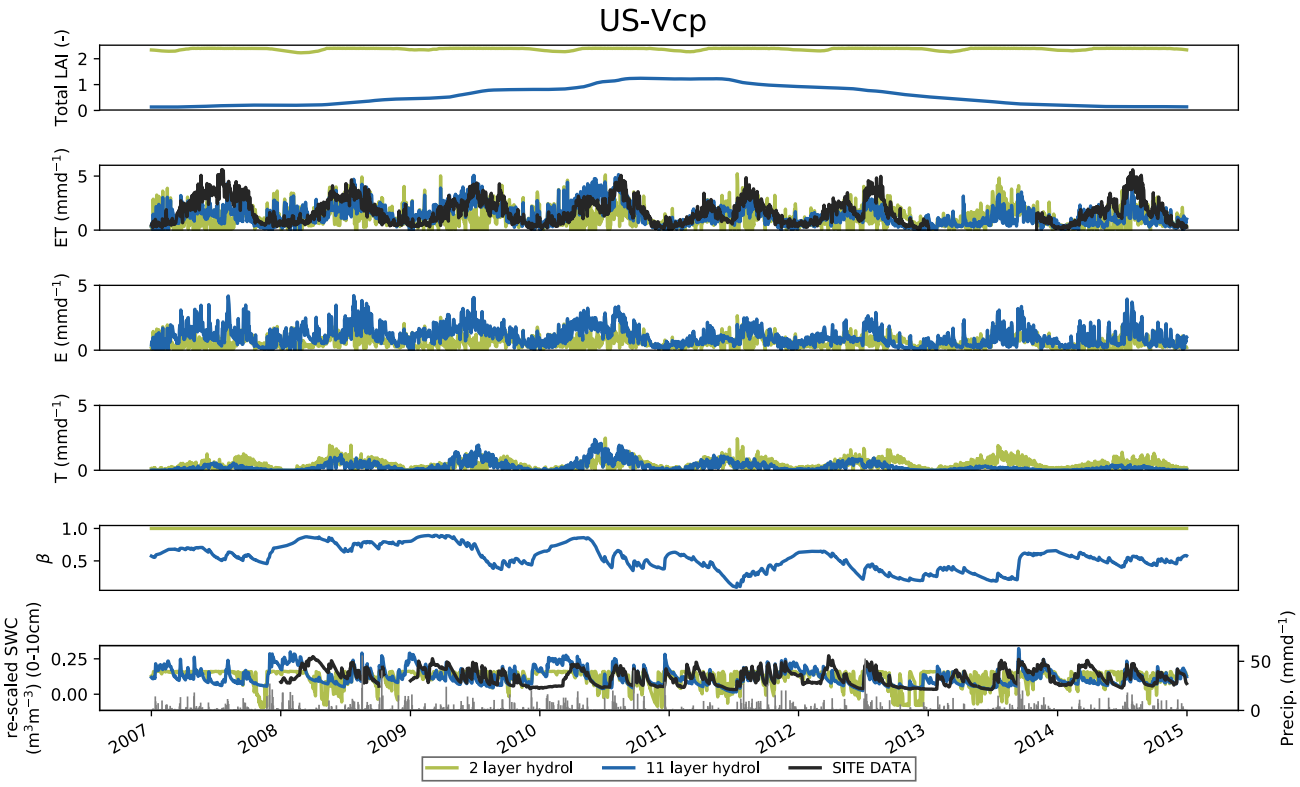

US-Wkg
ET (mmd^{-1})
Runoff (mmd^{-1})
Drainage (mmd^{-1})
Soil VWC 0-2m (m^{3}m^{-3})
Precip. (mmd^{-1})
Years
2 layer hydrol
11 layer hydrol

Figure S2: Complete daily time series of upper layer soil moisture, surface water fluxes and related variables between the 2LAY (green curve) and 11LAY (blue curve) simulations for all sites – equivalent to Fig. 2. At each site, top panel: LAI; 2nd panel: ET compared to observations (black curve); 3rd panel: bare soil evaporation; 4th panel: transpiration; 5th panel: empirical water limitation function (β) that scales photosynthesis and stomatal conductance; bottom panel: model soil moisture (re-scaled via linear CDF matching) expressed as volumetric soil water content (SWC) in the uppermost 10cm of the soil compared to observations (black curve). Precipitation is shown in the grey bars in the bottom panel for each site. Sites in following order: a) US-Fuf; b) US-Vcp; c) US-SRM; d) US-Whs; e) US-SRG; f) US-Wkg. Precipitation is shown in the grey lines in the bottom panel for each site.

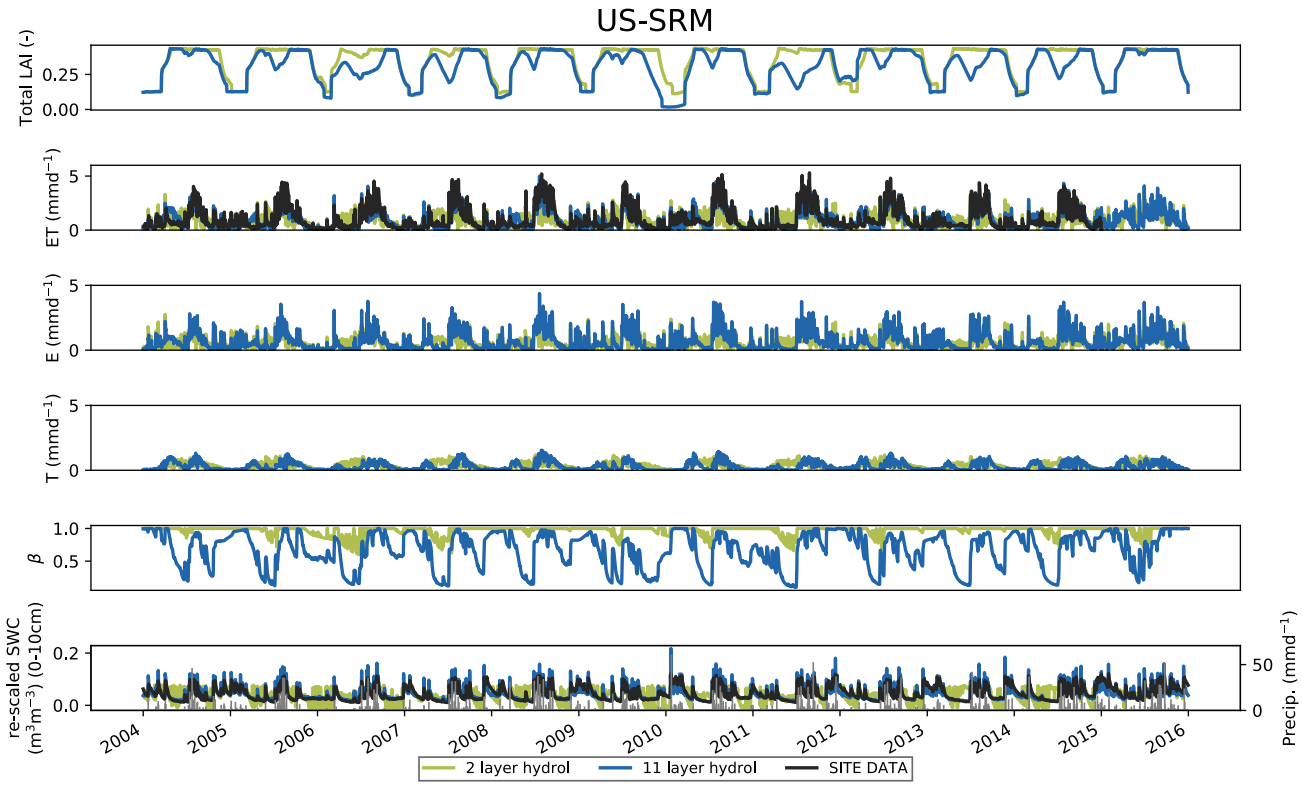
a) US-Fuf



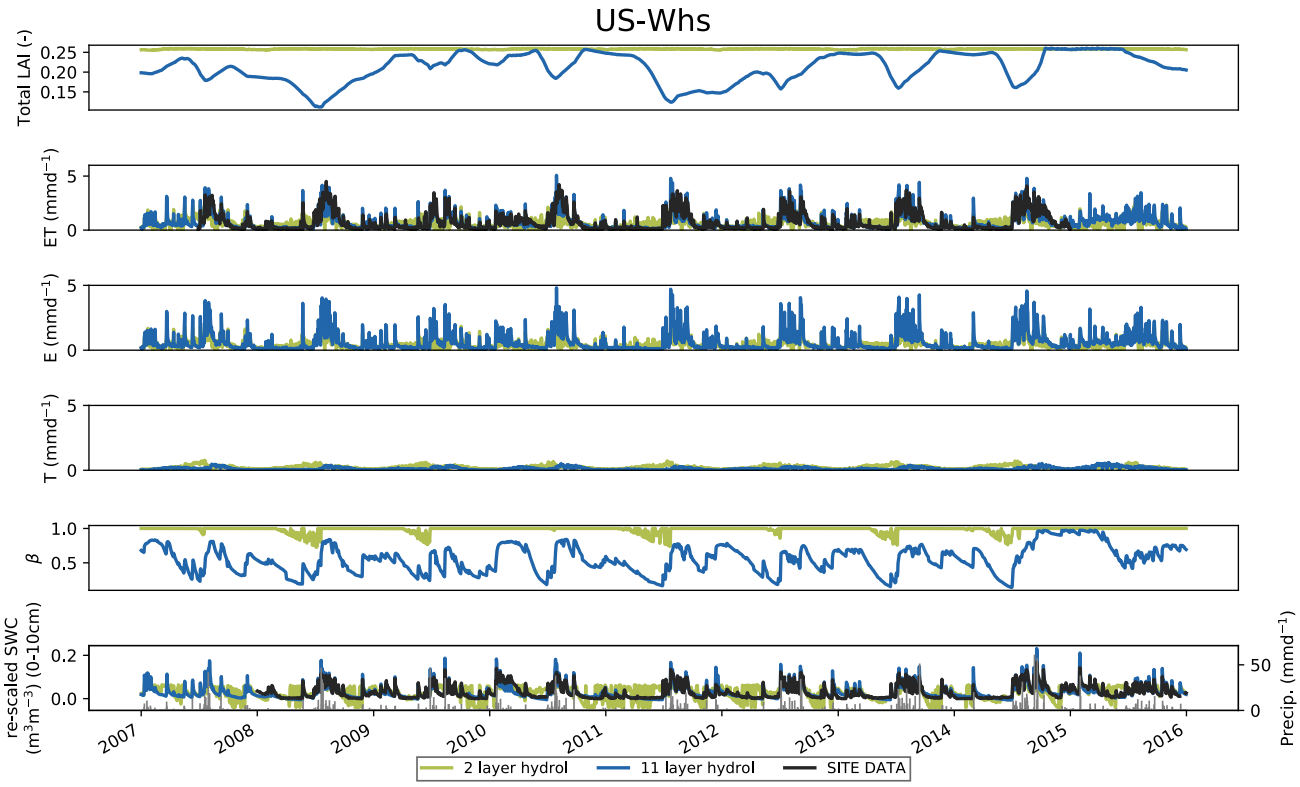
b) US-Vcp


US-Vcp
Total LAI (-)
ET (mmd^{-1})
E (mmd^{-1})
T (mmd^{-1})
β
re-scaled SWC (m^{3}m^{-3}) (0-10cm)
Precip. (mmd^{-1})
2007
2008
2009
2010
2011
2012
2013
2014
2015
2 layer hydrol
11 layer hydrol
SITE DATA

c) US-SRM


US-SRM
Total LAI (-)
0.25
0.00
ET (mmd^{-1})
E (mmd^{-1})
T (mmd^{-1})
5
0
β
1.0
0.5
re-scaled SWC (m^{3}m^{-3}) (0-10cm)
0.2
0.0
Precip. (mmd^{-1})
50
0
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2 layer hydrol
11 layer hydrol
SITE DATA

d) US-Whs

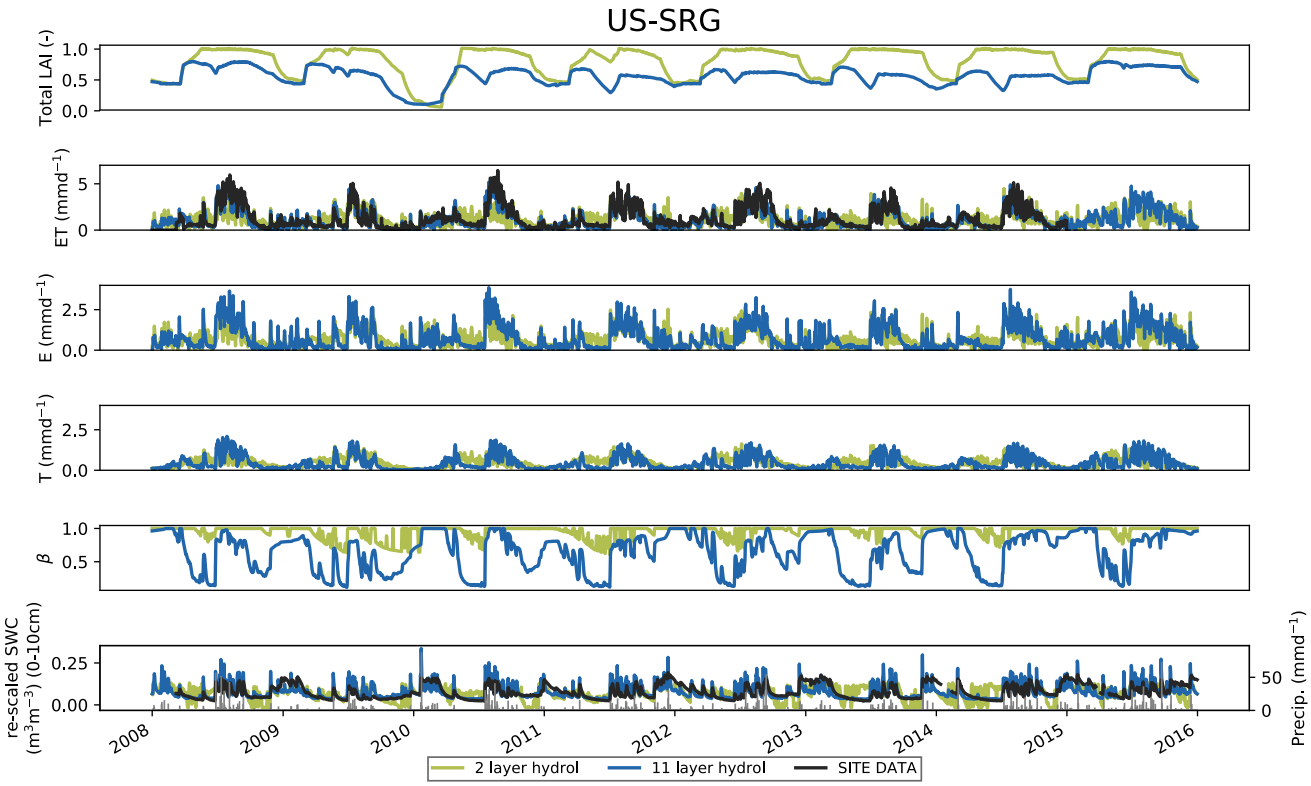


155

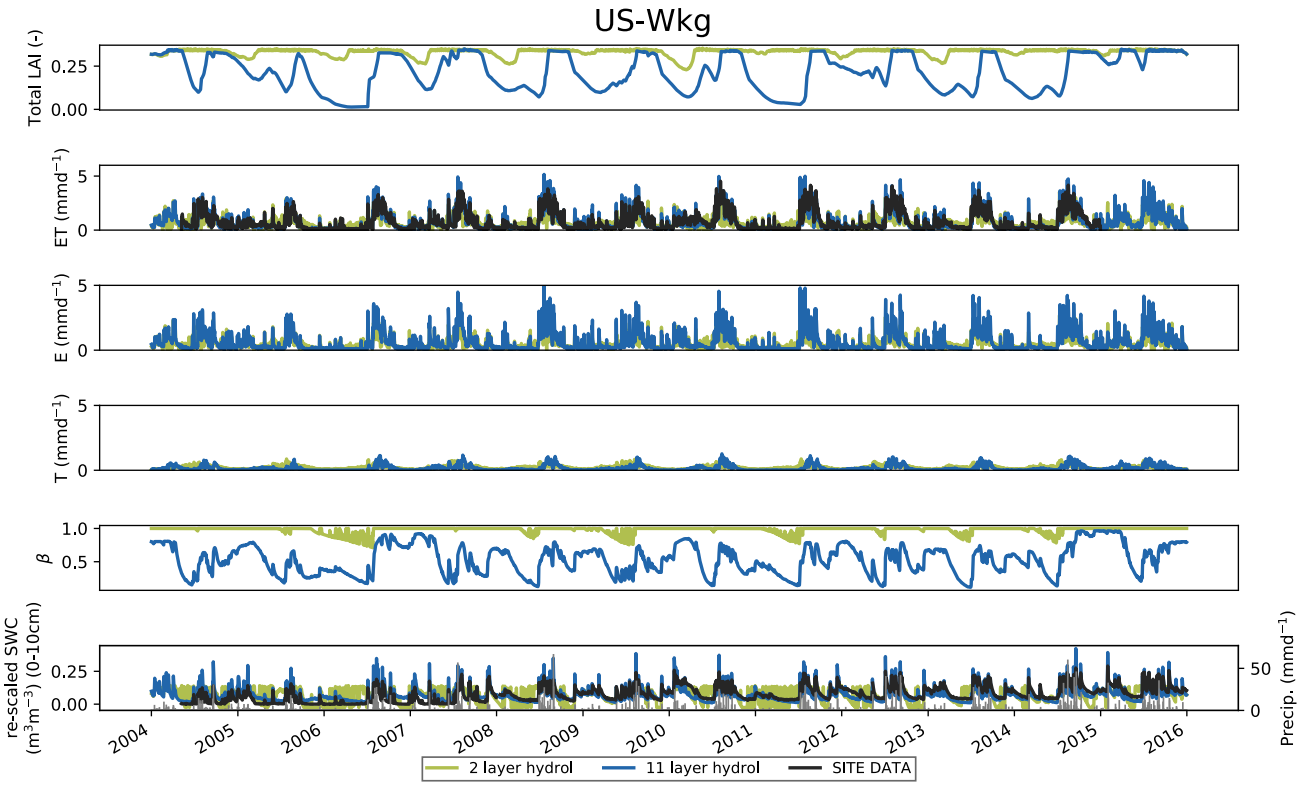
160

165

e) US-SRG


US-SRG
Total LAI (-)
ET (mmd^{-1})
E (mmd^{-1})
T (mmd^{-1})
β
re-scaled SWC (m^{3}m^{-3}) (0-10cm)
Precip. (mmd^{-1})
2008
2009
2010
2011
2012
2013
2014
2015
2016
2 layer hydrol
11 layer hydrol
SITE DATA

f) US-Wkg



185

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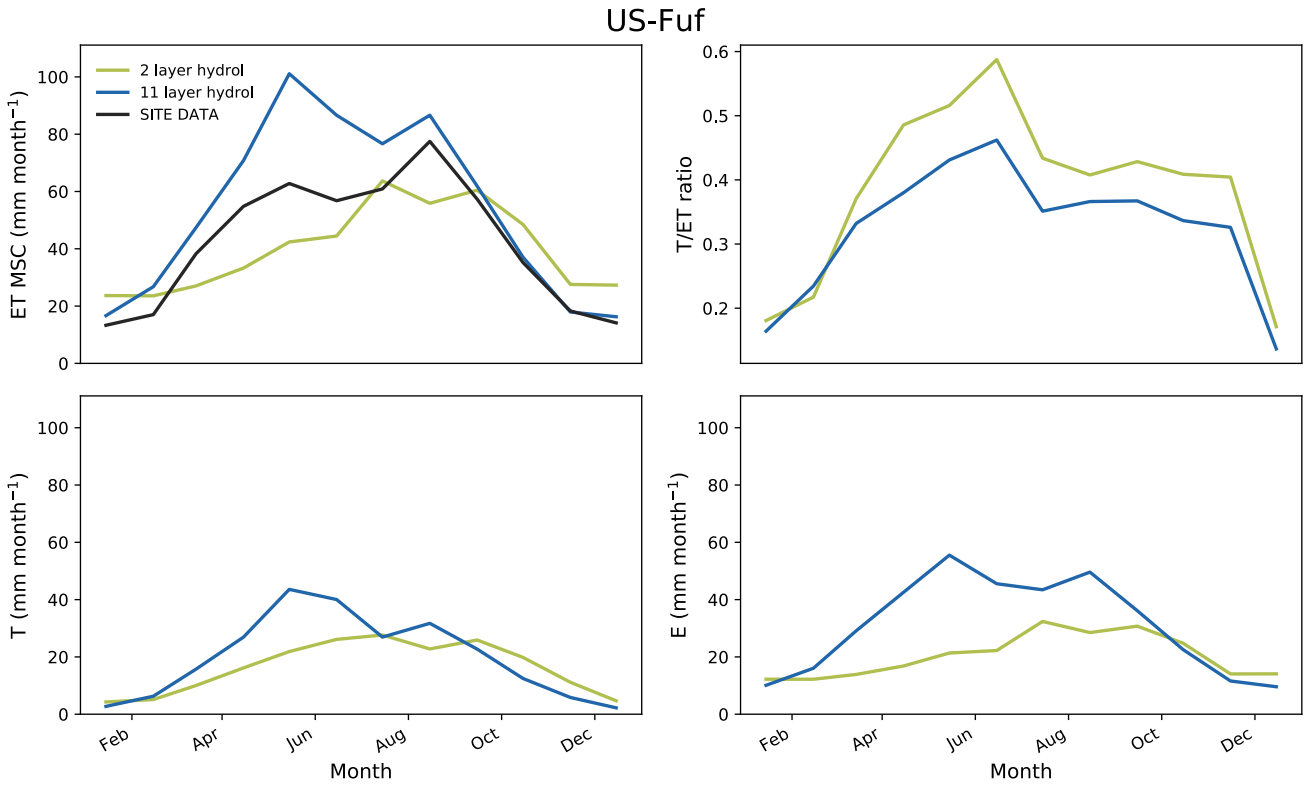
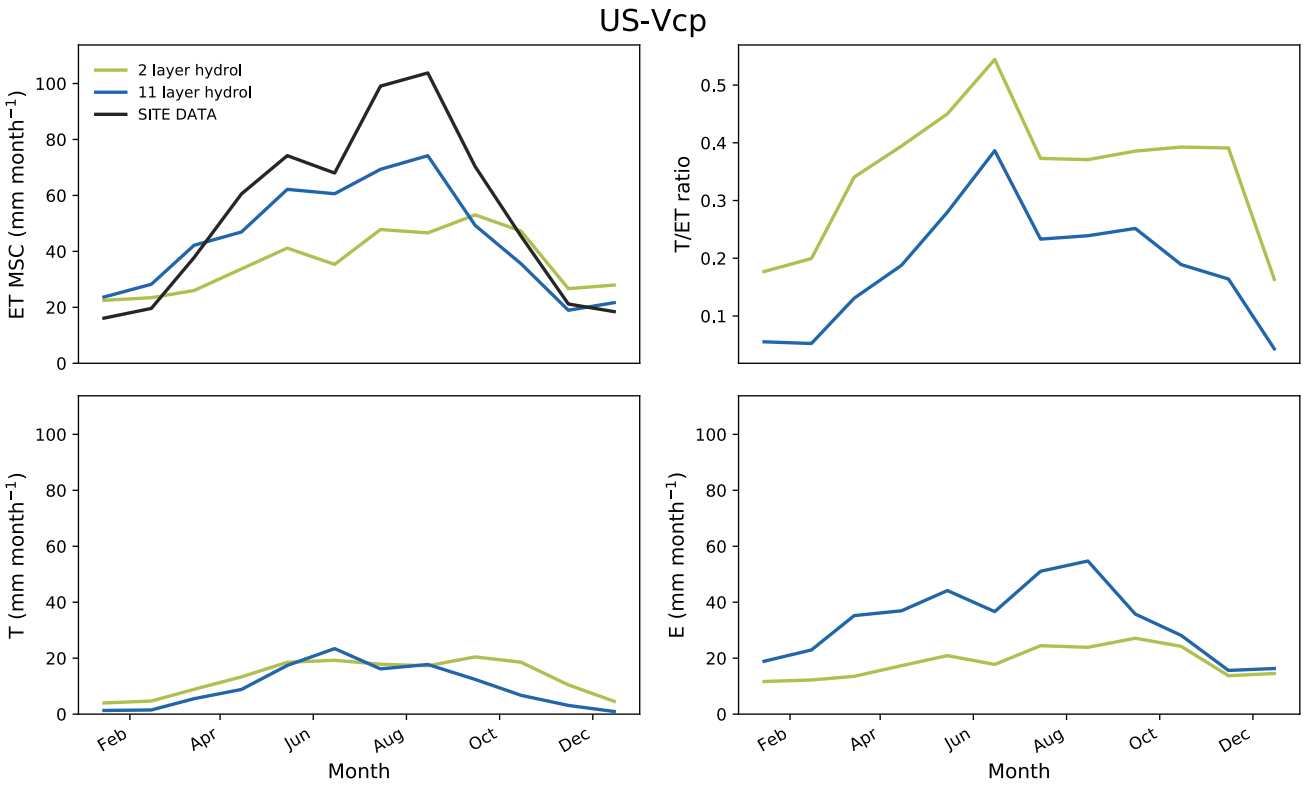
Figure S3: Monthly mean seasonal cycle for each site comparing the 2LAY (green curve) and 11LAY simulations (blue curve) with observations (black curve). Top left: ET; top right: T/ET ratios; bottom left: transpiration, T; bottom right: bare soil evaporation, E. Units in mmd^{-1}. Sites in following order: a) US-Fuf; b) US-Vcp; c) US-SRM; d) US-Whs; e) US-SRG; f) US-Wkg. Units are mm per month (mm month^{-1}).

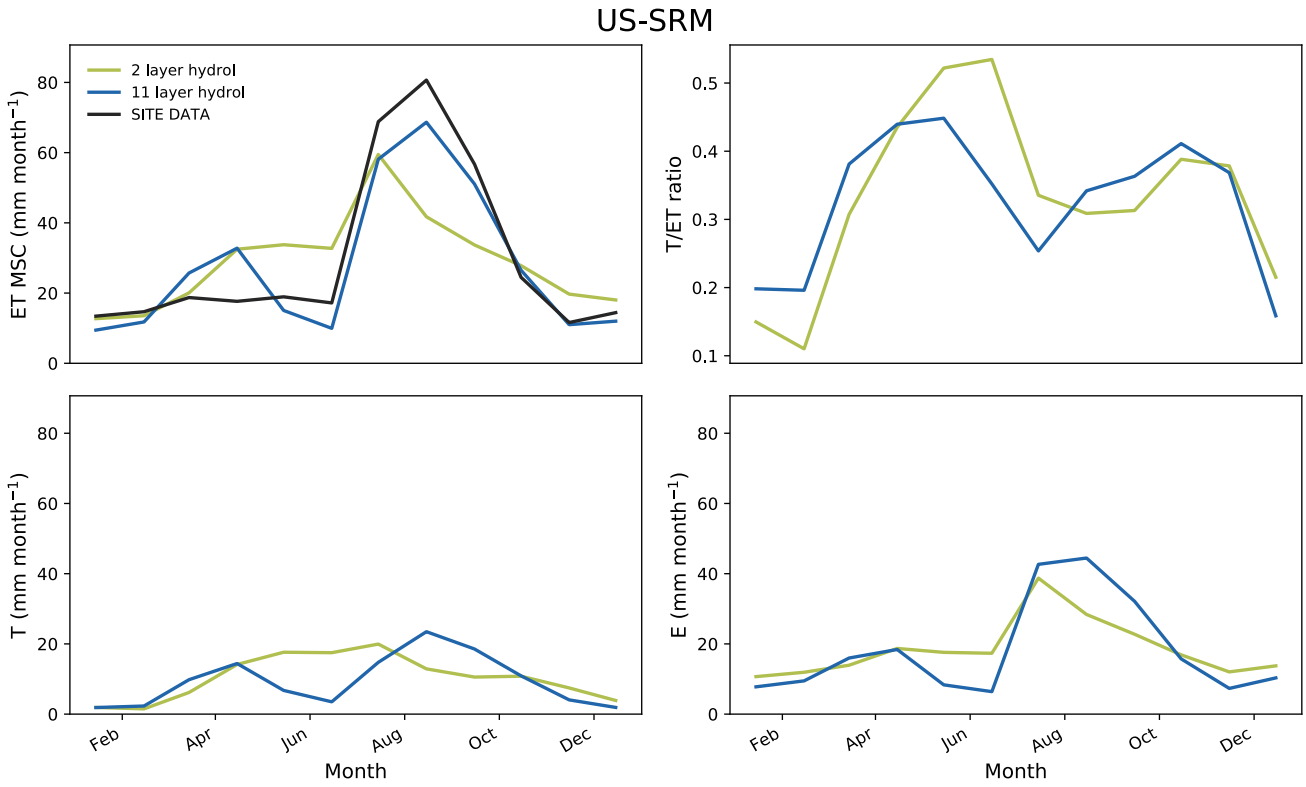
a) US-Fuf



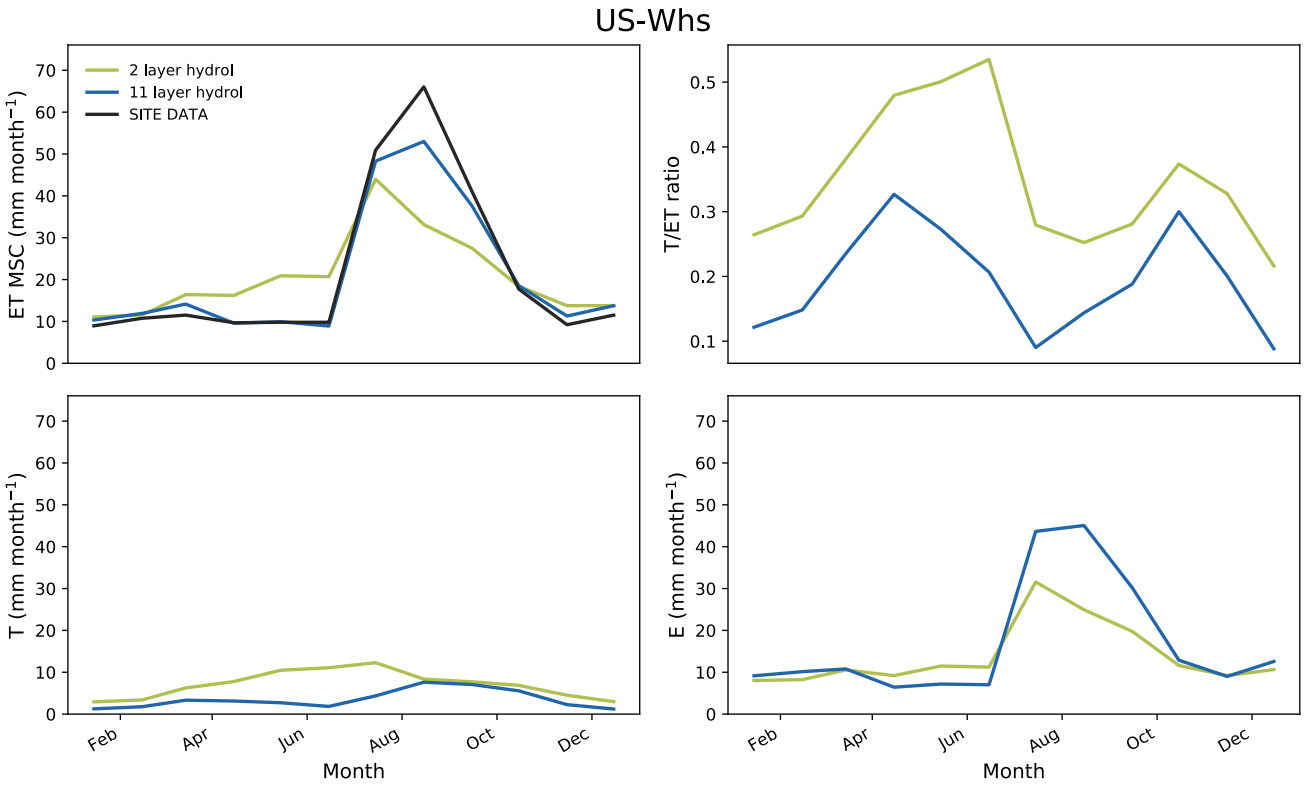
b) US-Vcp


US-Vcp
2 layer hydrol
11 layer hydrol
SITE DATA
ET MSC (mm month⁻¹)
T/ET ratio
T (mm month⁻¹)
E (mm month⁻¹)
Feb
Apr
Jun
Aug
Oct
Dec
Month

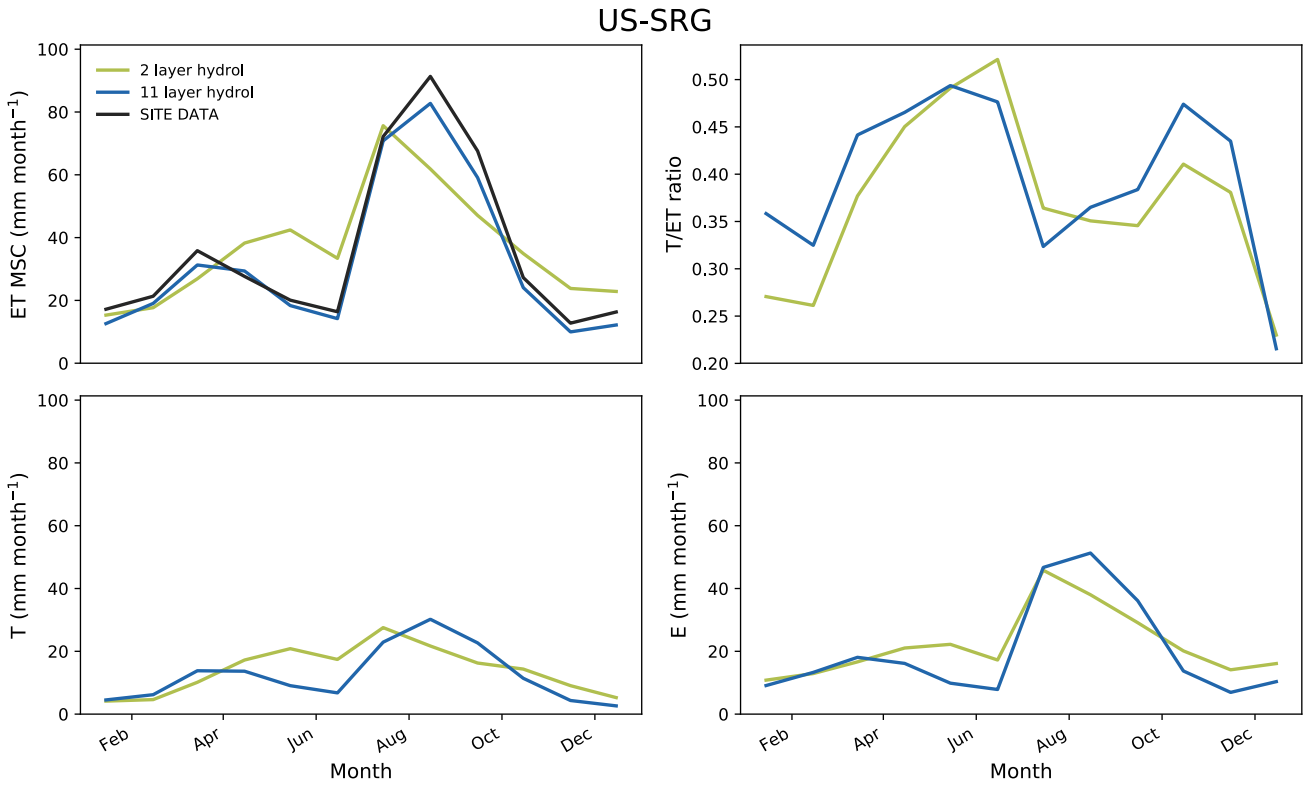
c) US-SRM


US-SRM
2 layer hydrol
11 layer hydrol
SITE DATA
ET MSC (mm month⁻¹)
T/ET ratio
T (mm month⁻¹)
E (mm month⁻¹)
Feb
Apr
Jun
Aug
Oct
Dec
Month

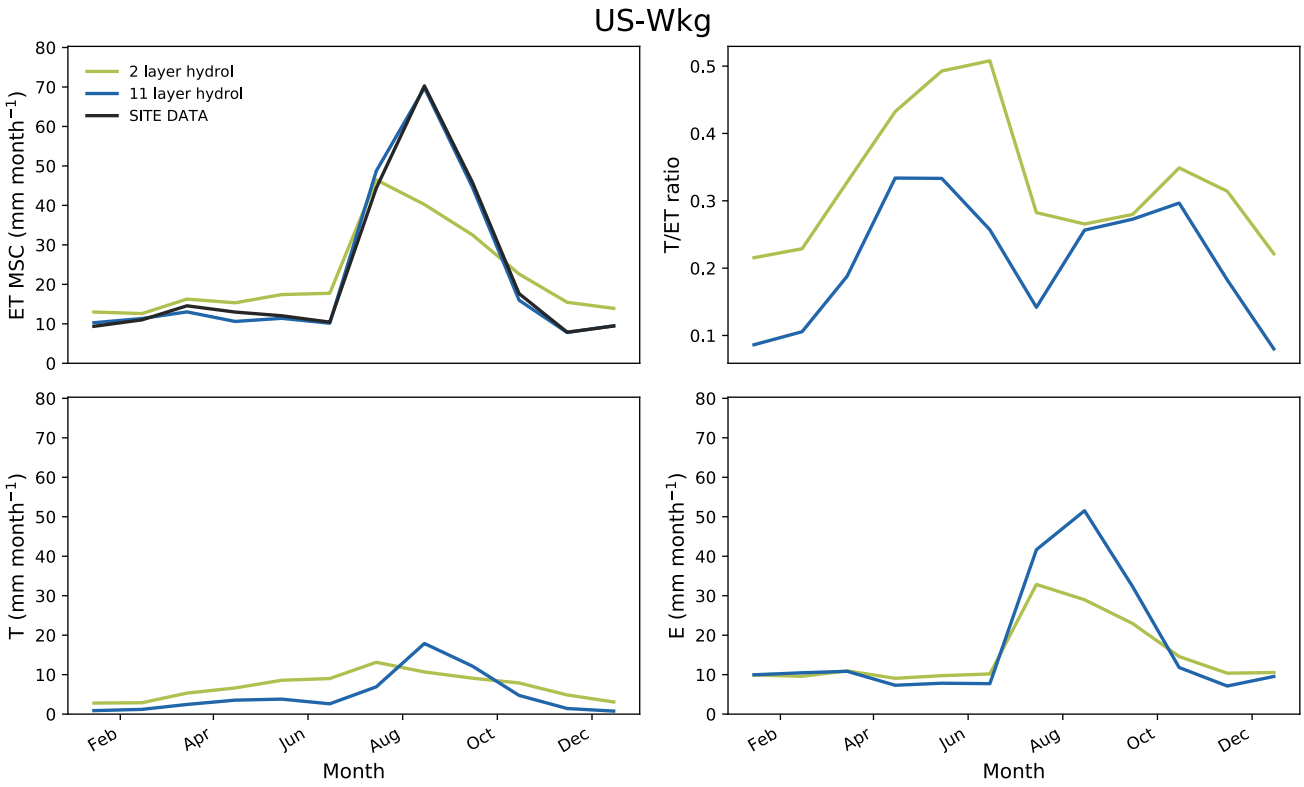
d) US-Whs


US-Whs
2 layer hydrol
11 layer hydrol
SITE DATA
ET MSC (mm month⁻¹)
T/ET ratio
T (mm month⁻¹)
E (mm month⁻¹)
Feb
Apr
Jun
Aug
Oct
Dec
Month

e) US-SRG


US-SRG
2 layer hydrol
11 layer hydrol
SITE DATA
ET MSC (mm month⁻¹)
T/ET ratio
T (mm month⁻¹)
E (mm month⁻¹)
Feb
Apr
Jun
Aug
Oct
Dec
Month

f) US-Wkg



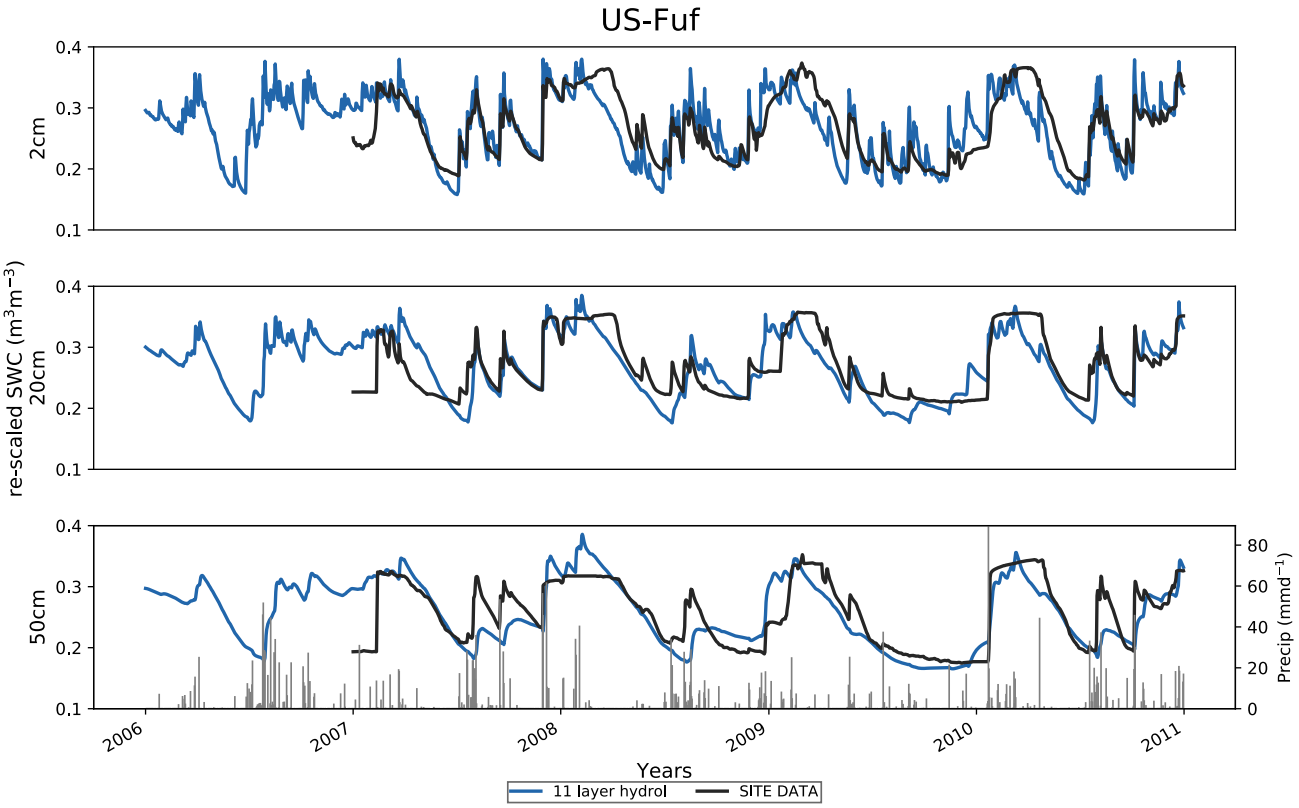
280

285

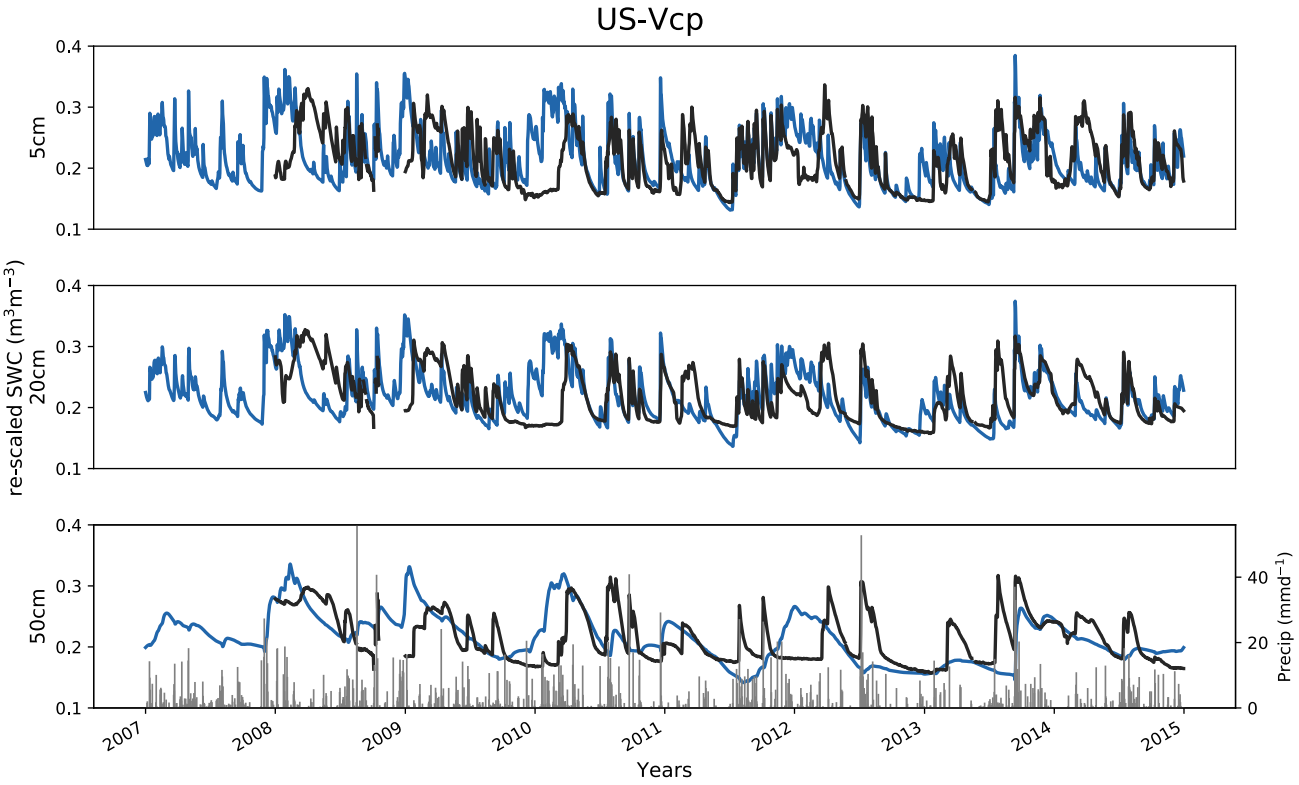
290

Figure S4: Daily simulated volumetric soil water content (SWC – m^3m^{-3}) across all site years (re-scaled via linear CDF matching) compared to observations at each site for three depths (upper, middle, lower) in the soil profile – equivalent to Fig. 4. The soil depths and their corresponding model layers are given in Table 3. Precipitation is shown in the grey lines in the bottom panel for each site.

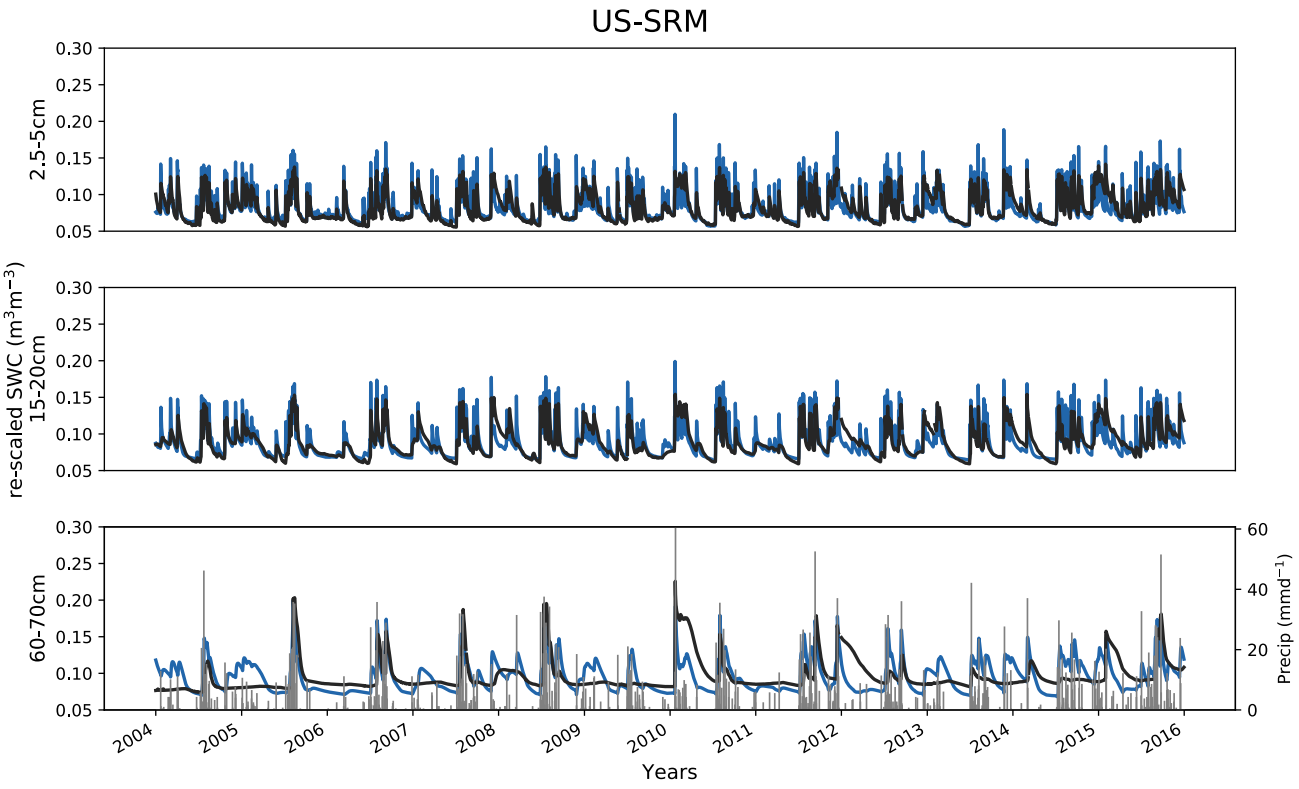
a) US-Fuf



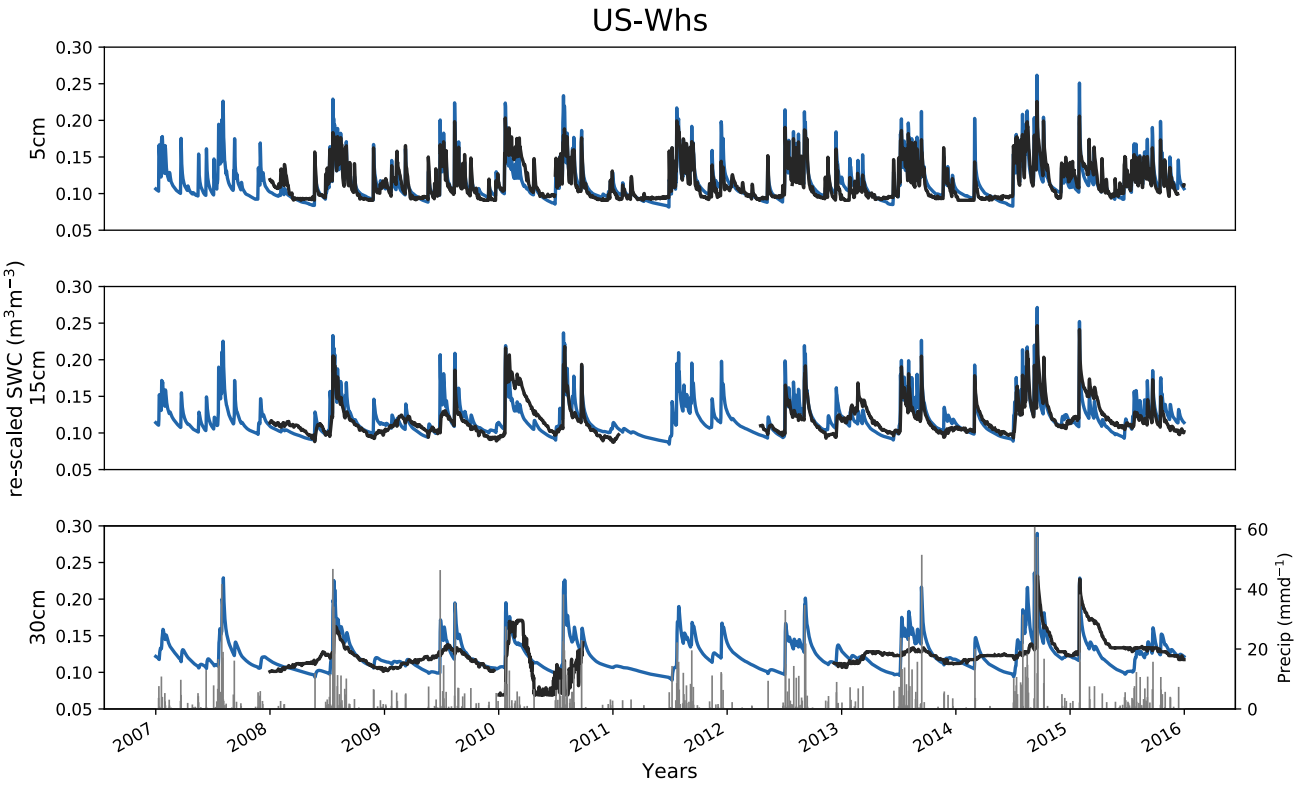
b) US-Vcp


US-Vcp
5cm
20cm
50cm
re-scaled SWC (m^3m^{-3})
Precip (mmd^{-1})
Years
2007
2008
2009
2010
2011
2012
2013
2014
2015

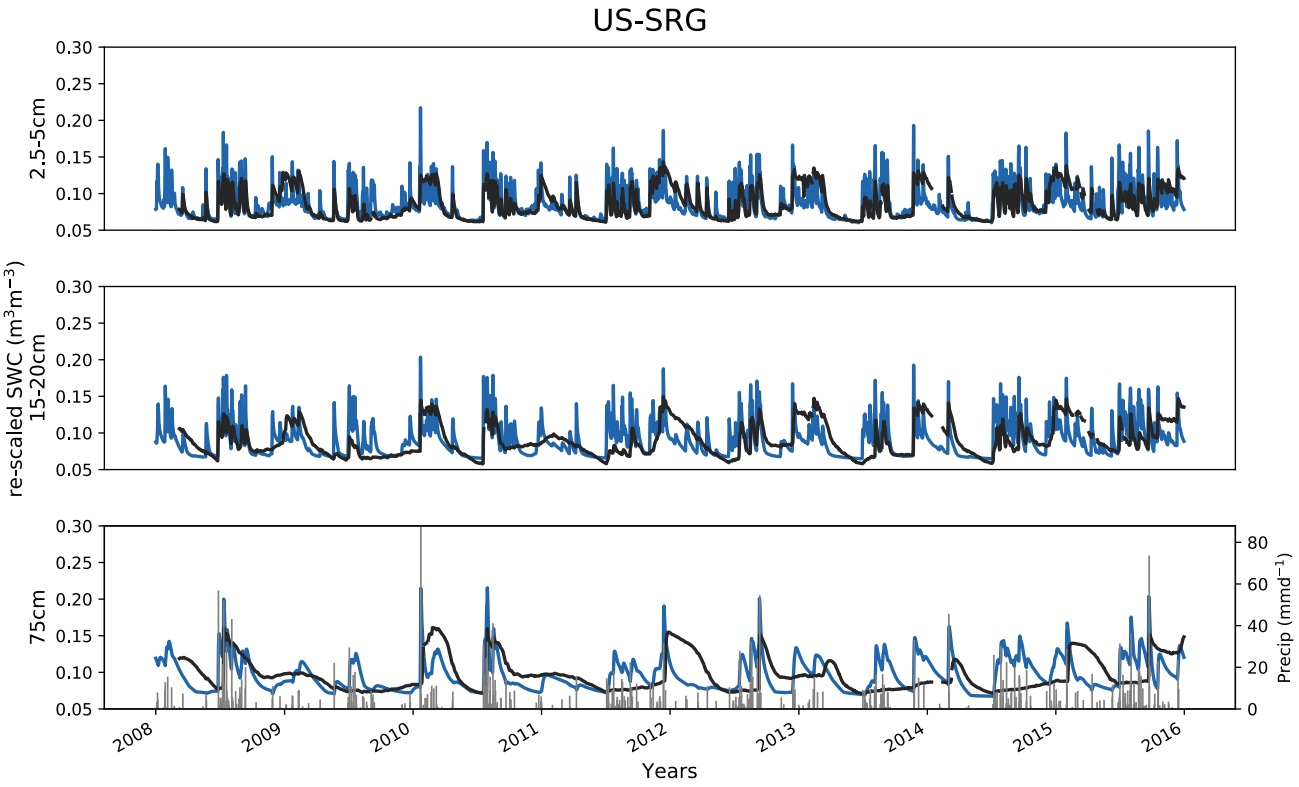
c) US-SRM


US-SRM
2.5-5cm
15-20cm
60-70cm
re-scaled SWC (m^3m^{-3})
Precip (mmd^{-1})
Years
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016

d) US-Whs


US-Whs
5cm
15cm
30cm
re-scaled SWC (m^3m^{-3})
Precip (mmd^{-1})
Years
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016

e) US-SRG


US-SRG
2.5-5cm
15-20cm
75cm
re-scaled SWC (m^3m^{-3})
Precip (mmd^{-1})
Years
2008
2009
2010
2011
2012
2013
2014
2015
2016

f) US-Wkg

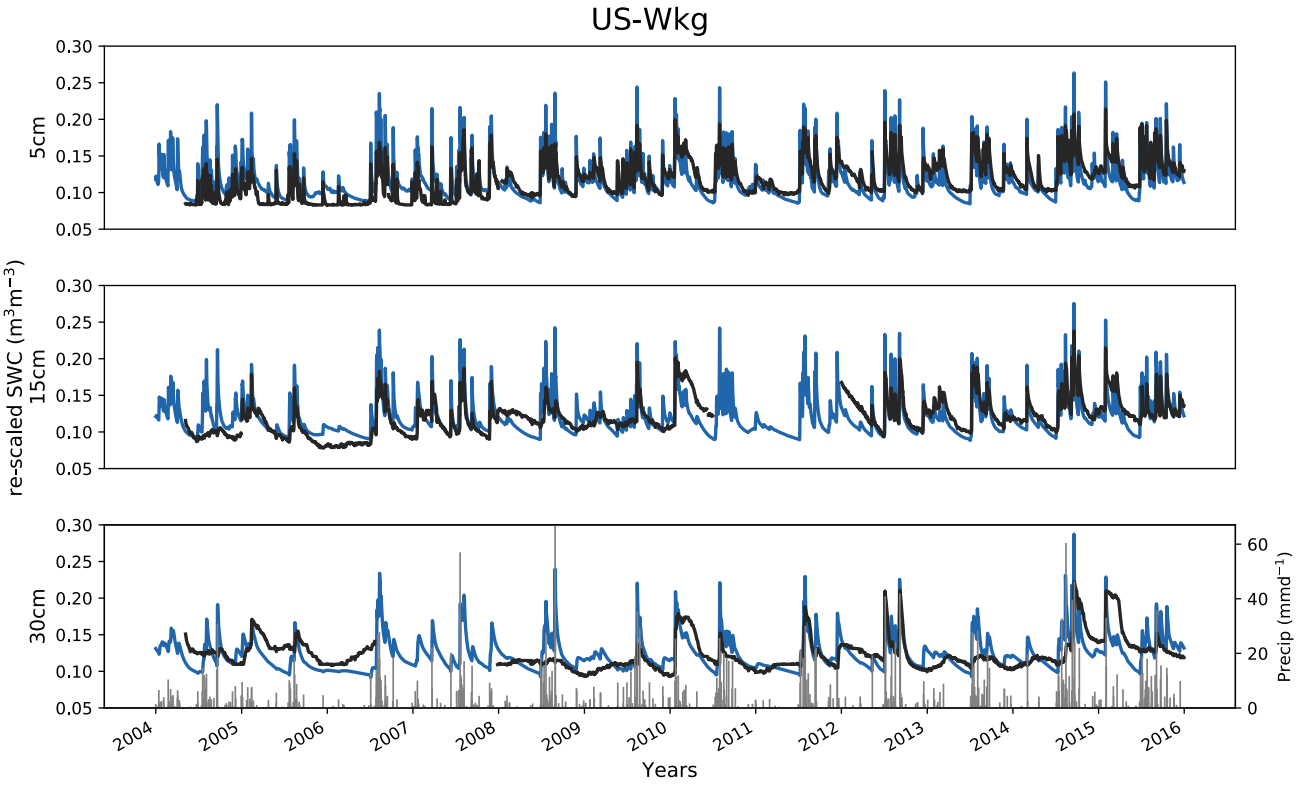

US-Wkg
5cm
15cm
30cm
re-scaled SWC (m^3m^{-3})
Precip (mmd^{-1})
Years
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016

Figure S5: Comparison of US-Fuf daily simulated soil water content (SWC – bottom panel – m^3m^{-3}) across all site years (re-scaled via linear CDF matching) and snow mass (middle panel) for the original 11LAY model version (blue curve) and a repeat simulation with snowfall forcing multiplied by a factor of 10 (red dashed curve) compared to observations (black curve). MODIS snow cover (%) observations (MOD10A1 v6 – downloaded from the National Snow and Ice Data Center: https://nsidc.org/) are shown in the top panel to ilustrate that the model may simulate a too rapid melting of snow (too short snowpack duration).

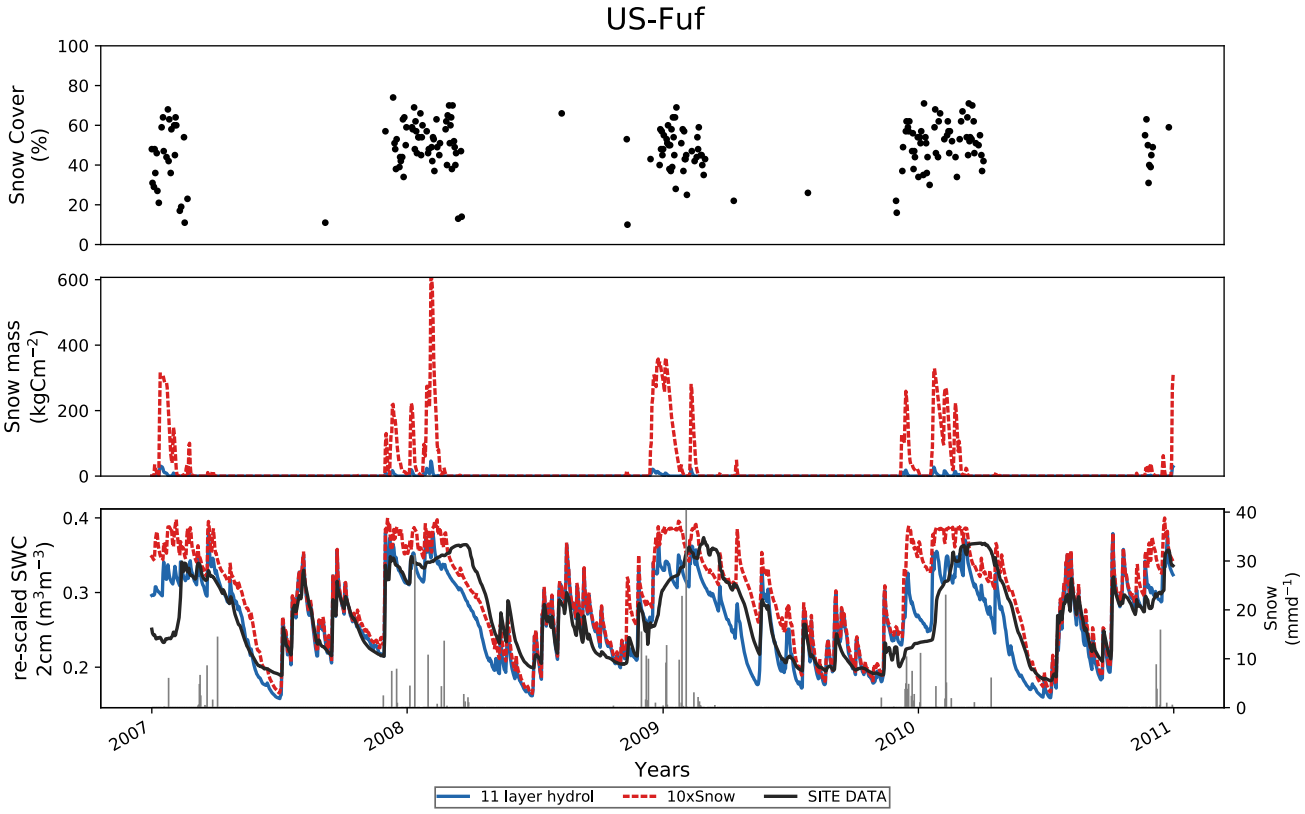


Figure S6: Linear regressions between spring (March-April) mean monthly LAI (m^2m^{-2}) and spring mean monthly ET (mm $month^{-1}$) model-data misfits for each site. The dominant PFT is given in brackets for each site. See Table 1 for PFT acronyms.

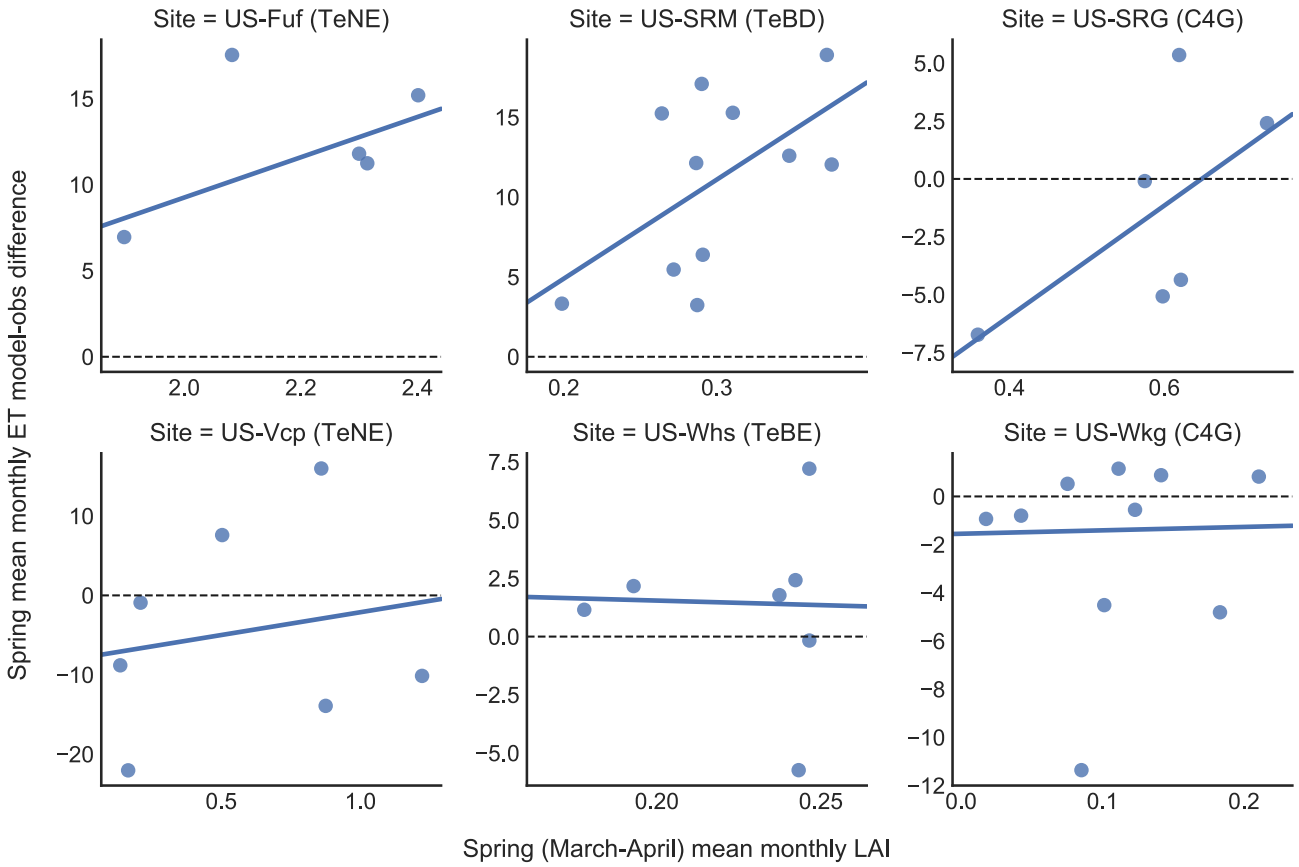


Figure S7: Plots comparing ET and LAI for C4 grasses (C4G) and mesquite shrubs (Temperate Broadleaved Deciduous – TeBD – PFT in ORCHIDEE) monthly mean seasonal cycles at US-SRM for the 2LAY (green curve) and 11LAY (blue curve) model versions in comparison to observations (black curve).

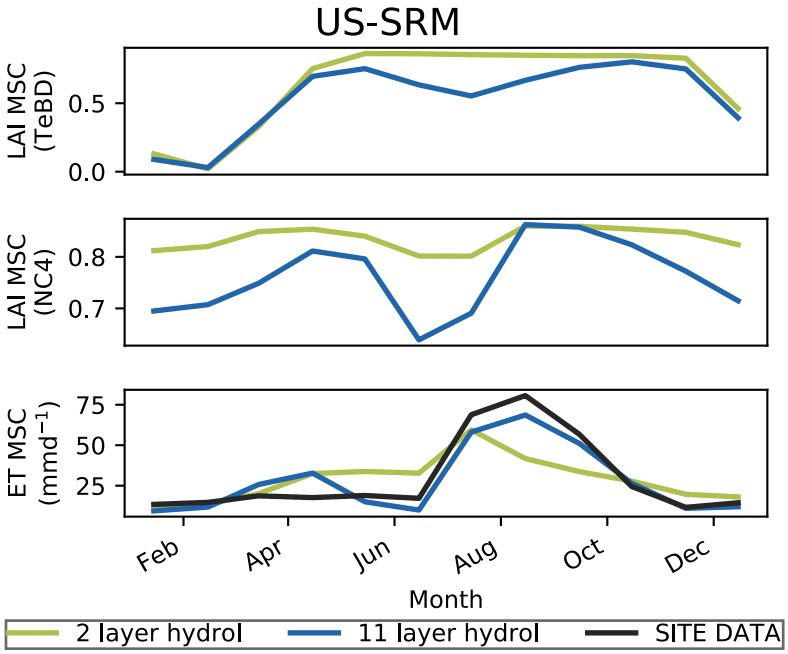
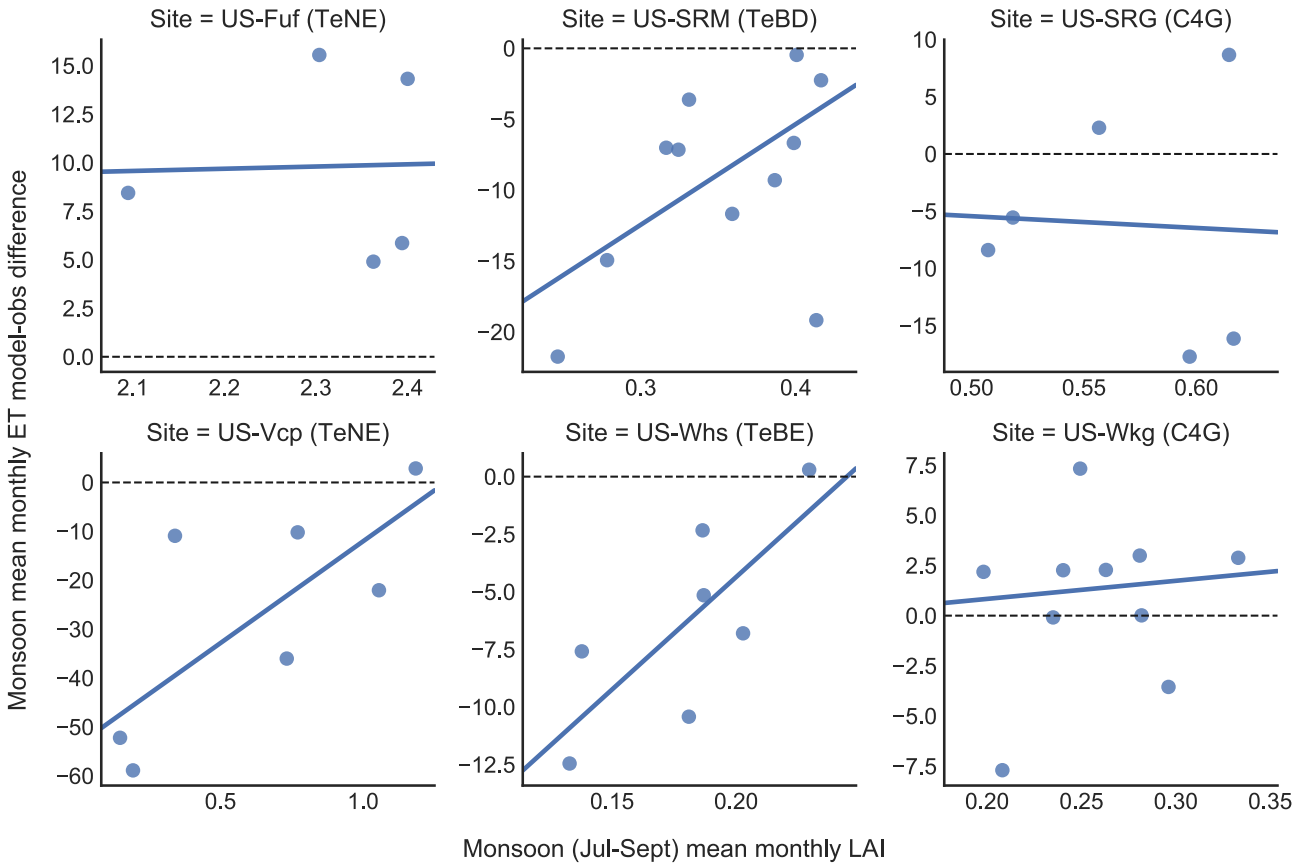


Figure S8: Linear regressions between monsoon (July-September) mean monthly LAI (m^2m^{-2}) and monsoon mean monthly ET (mm $month^{-1}$) model-data misfits for each site. The dominant PFT is given in brackets for each site. See Table 1 for PFT acronyms.

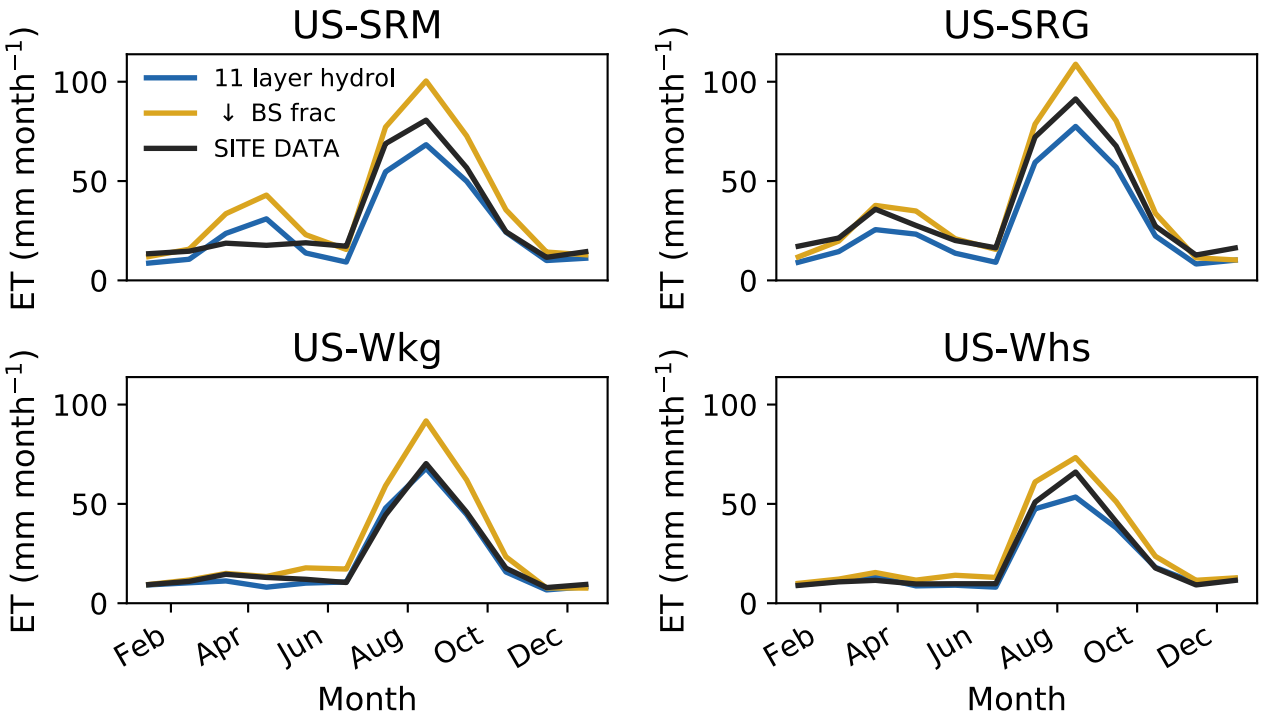


445

450

455

Figure S9: ET monthly mean seasonal cycle for all low elevation sites comparing the default 11LAY simulations (blue curve) with a simulation that increased the C4 grass fraction at the expense of the bare soil fraction (yellow curve). ET is compared to observations (black curve). Units are mm per month (mm month^{-1}).



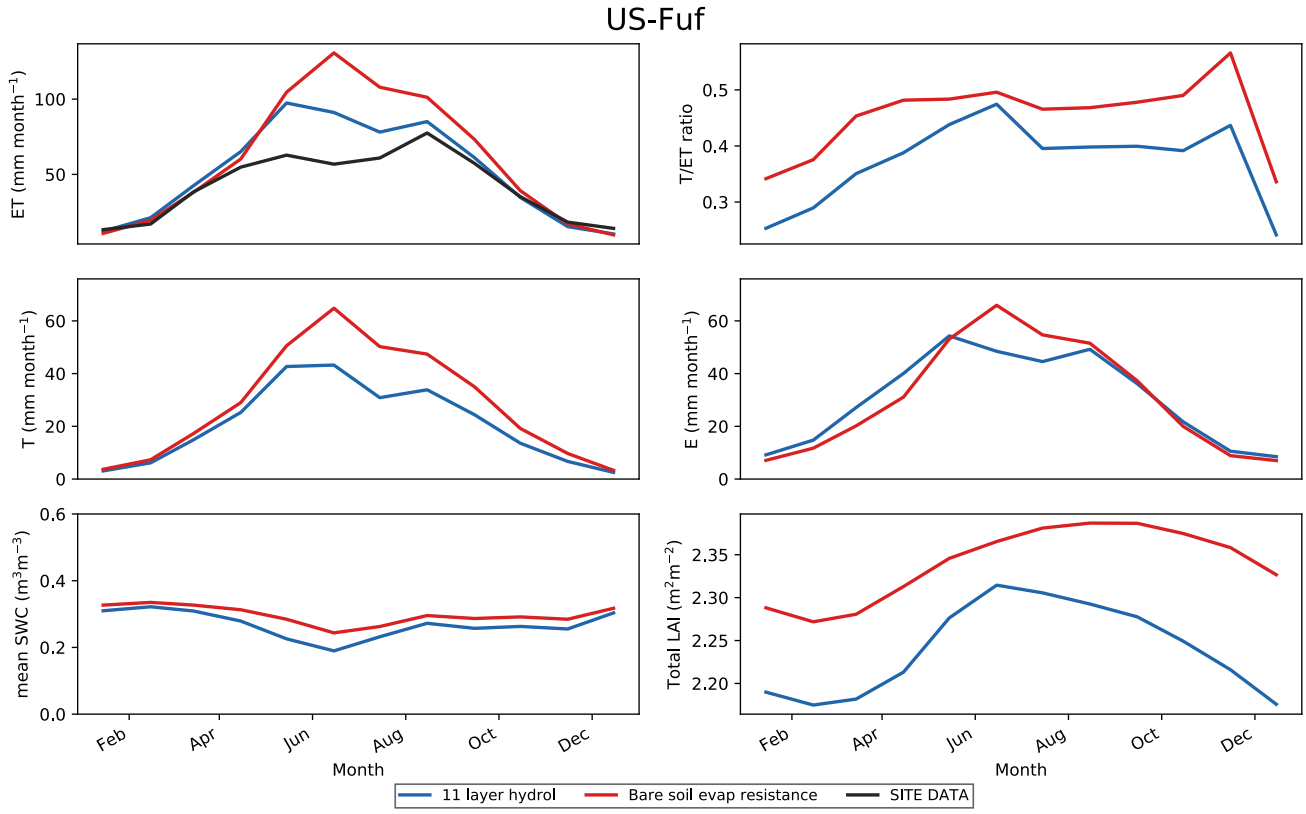
460

465

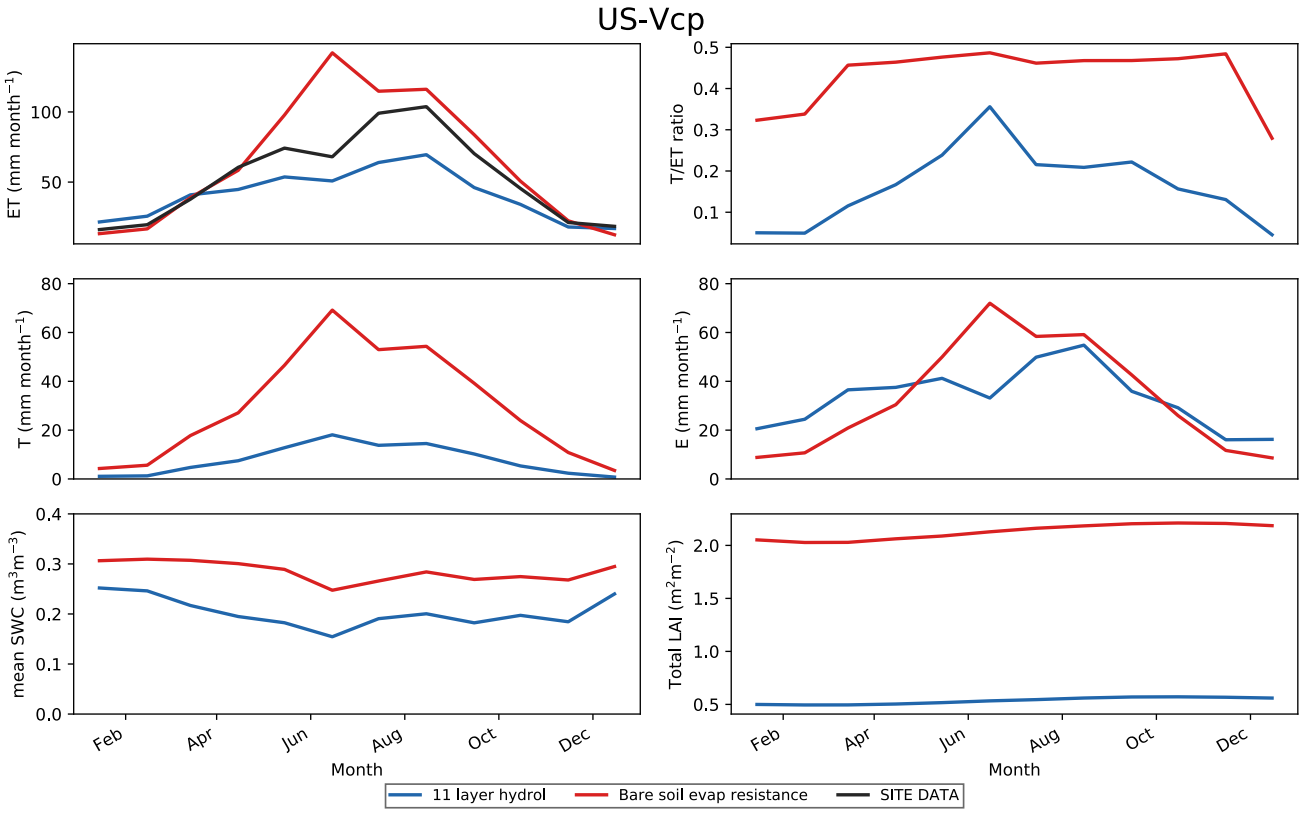
470

Figure S10: Monthly mean seasonal cycle for all sites comparing the default 11LAY simulations (blue curve) with a simulation that included an additional bare soil evaporation resistance term (red curve). ET is compared to observations (black curve). In all subfigures – top left: ET; top right: T/ET ratios; middle left: transpiration, T; middle right: bare soil evaporation, E; bottom left: mean column soil water content, SWC; bottom right: total leaf area index, LAI. Units are mm per month (mm month^{-1}).

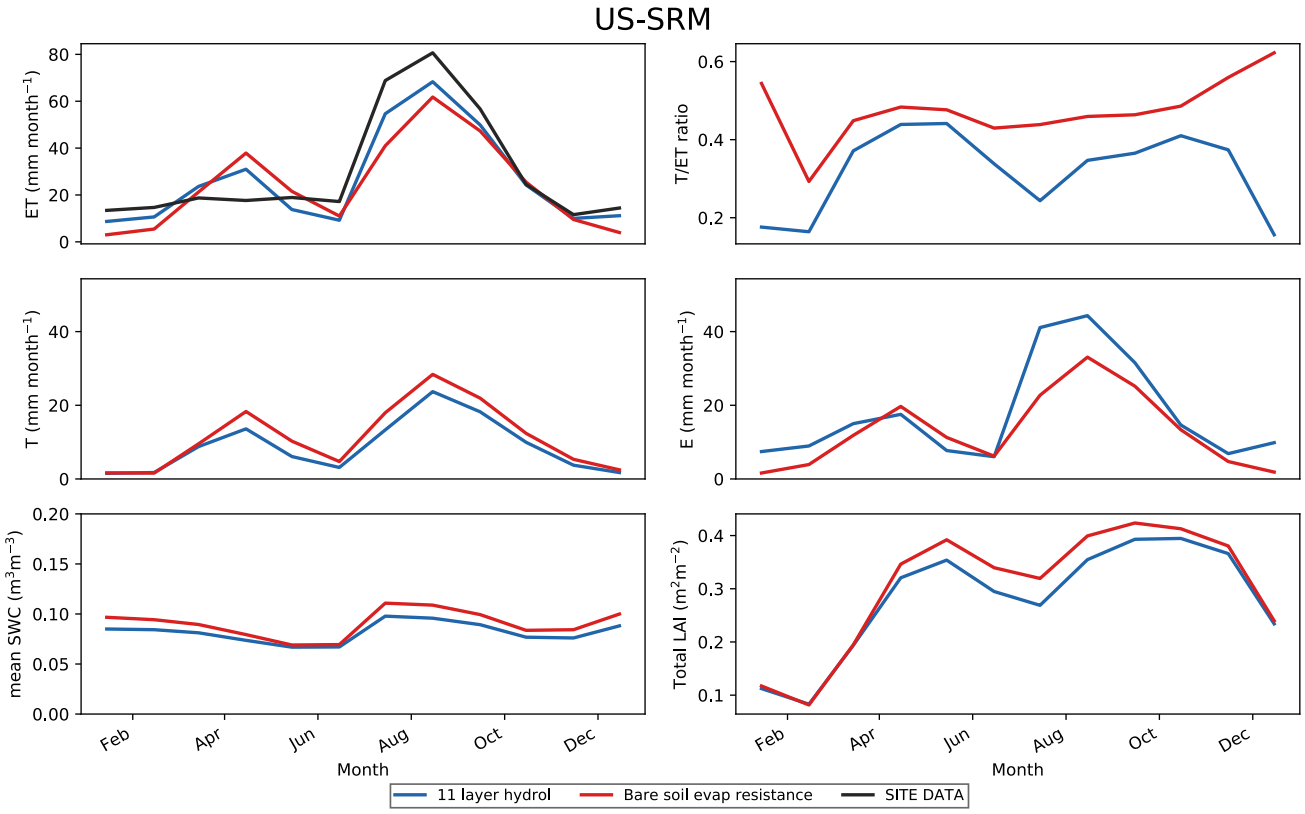
a) US-Fuf



b) US-Vcp


US-Vcp
ET (mm month^{-1})
T/ET ratio
T (mm month^{-1})
E (mm month^{-1})
mean SWC (m^{3}m^{-3})
Total LAI (m^{2}m^{-2})
Feb
Apr
Jun
Aug
Oct
Dec
Month
11 layer hydrol
Bare soil evap resistance
SITE DATA

c) US-SRM

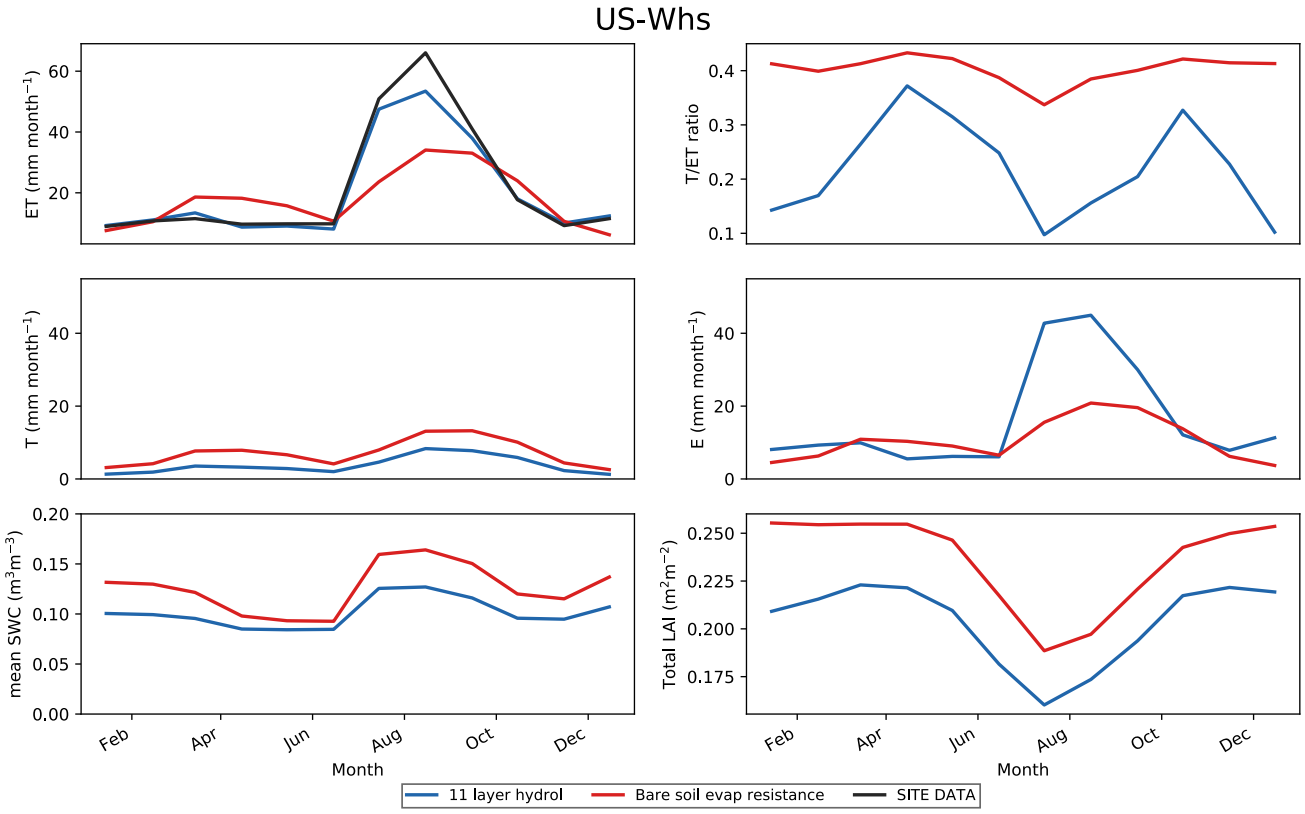


505

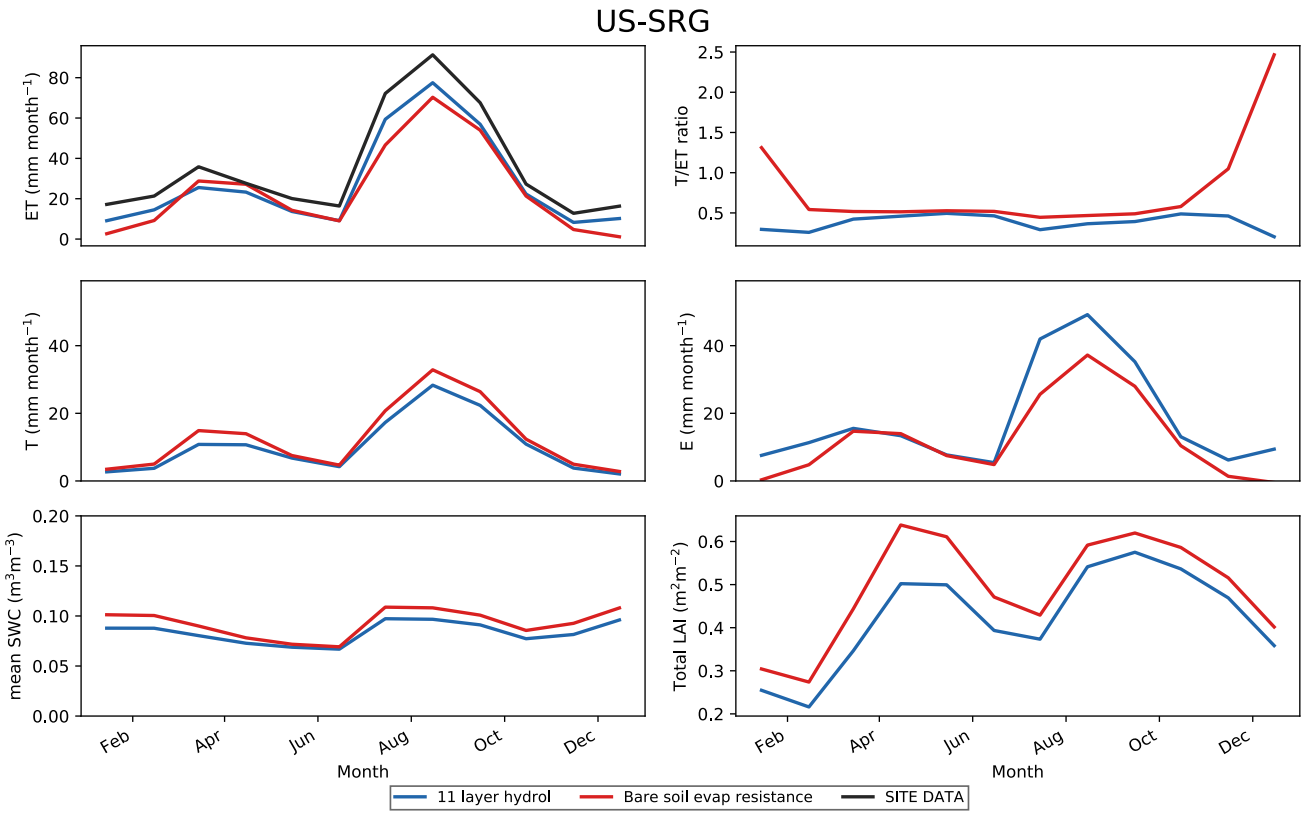
510

515

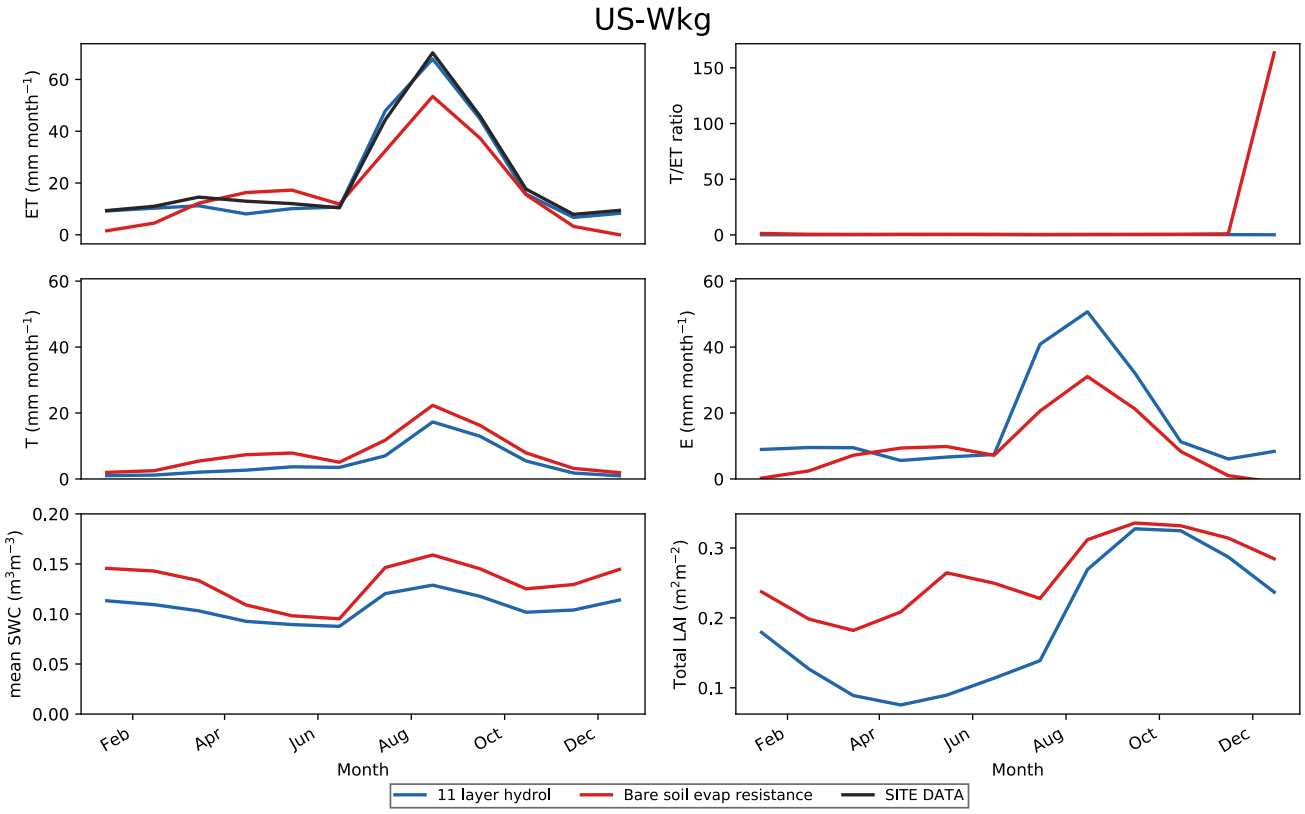
d) US-Whs


US-Whs
ET (mm month^{-1})
T/ET ratio
T (mm month^{-1})
E (mm month^{-1})
mean SWC (m^{3}m^{-3})
Total LAI (m^{2}m^{-2})
Feb
Apr
Jun
Aug
Oct
Dec
Month
11 layer hydrol
Bare soil evap resistance
SITE DATA

e) US-SRG


US-SRG
ET (mm month^{-1})
T/ET ratio
T (mm month^{-1})
E (mm month^{-1})
mean SWC (m^{3}m^{-3})
Total LAI (m^{2}m^{-2})
Feb
Apr
Jun
Aug
Oct
Dec
Month
11 layer hydrol
Bare soil evap resistance
SITE DATA

f) US-Wkg



555

560

565

Figure S11: Monthly mean seasonal cycle for all low elevation grass and shrub sites comparing the default 11LAY simulations (blue curve) with a simulation that decreased the bare soil (BS) fraction and increased the C4 grass fraction (yellow curve) and a simulation that decreased the BS fraction as well as including an additional bare soil evaporation resistance term (red curve). In all subfigures – top left: mean column volumetric soil moisture content (SWC); top right: modelled versus observed (black curve) evapotranspiration, ET; bottom left: transpiration, T; and bottom right: bare soil evaporation, E. Units are mm per month (mm month^{-1}).