Geoscientific
Model Development

Supplement of

Representing winter wheat in the Community Land Model (version 4.5)

Yaqiong Lu et al.

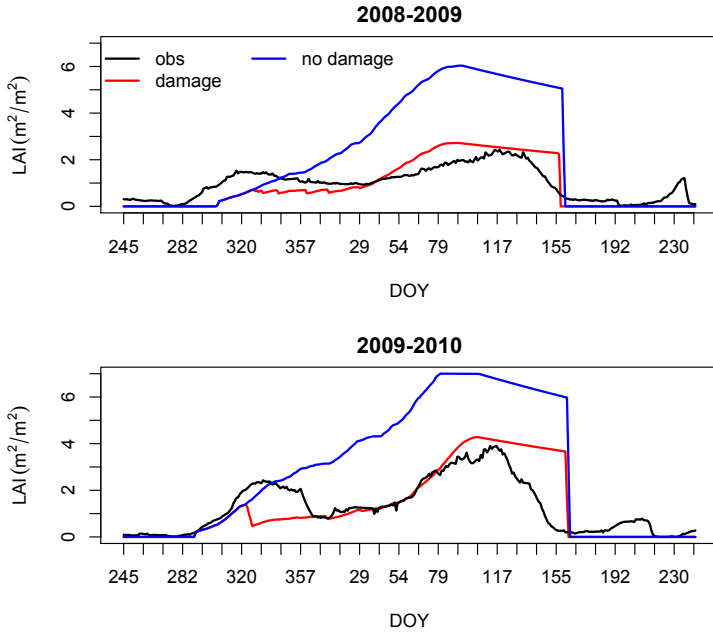*Correspondence to:* Yaqiong Lu (yaqiong@ucar.edu)

Figure S1. Leaf area index simulations with and without frost damage for two winter wheat growing season at US-ARM site.
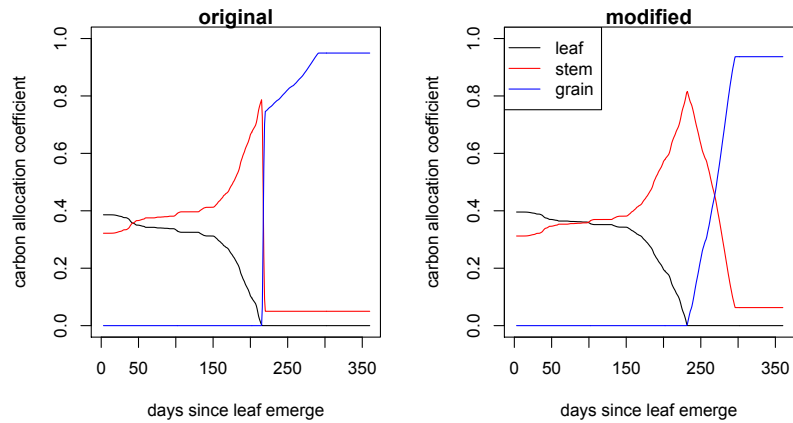

Figure S2. The original and modified winter wheat carbon allocation algorithms in CLM.
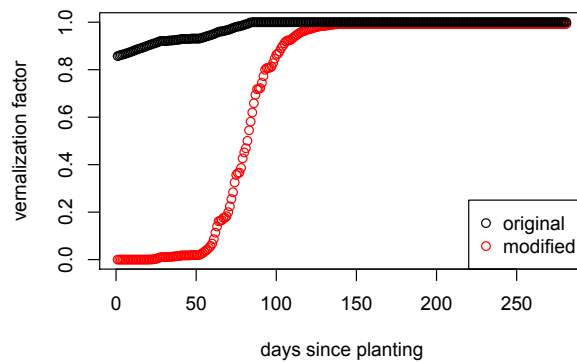

Figure S3. The original and modified vernalization factor

Table S1. The years for land surface variables to reach equilibrium at the nine sites.

Land surface variables	Threshold	Years to reach equilibrium								
		US-ARM	US-PON	US-CRT	CAF-CT	TXLU	KSMA	NESA	NDMA	ABLE
Total ecosystem carbon (TOTECOSYSC)	1 (gC m^{-2})	260	32	760	34	786	660	446	336	840
Total soil organic carbon (TOTSOMC)	1 (gC m^{-2})	110	54	6	45	520	600	496	370	620
Total vegetation carbon (TOTVEGC)	1 (gC m^{-2})	240	156	137	4	6	6	31	31	26
Leaf area index (TLAI)	0.05 (m^2 m^{-2})	20	6	3	4	6	6	6	6	6
Gross primary production (GPP)	1(gC m^{-2})	30	26	12	30	6	6	6	6	6
Total water storage (TWS)	1 (mm)	40	10	15	301	56	6	341	160	440
Latent heat flux (EFLX_LH_TOT)	0.1 (W m^{-2})	30	8	5	6	31	6	16	31	26
Sensible heat flux (FSH)	0.1 (W m^{-2})	30	8	3	10	31	6	11	6	26
Winter wheat yield	0.1 (bu ac^{-1})	30	6	4	4	6	6	11	6	6

Table S2. Comparison of leaf area index (m^2/m^2), leaf dry weight (ton/ha), stem dry weight (ton/ha), and grain dry weight (ton/ha) at the seven site-year. Note: Bias, mean difference between simulation and model; IOA, index of agreement; r, Pearson's correlation coefficient; RMSE, root mean square error. The shaded columns are the modified winter wheat model, while the unshaded columns are the original winter wheat model.

		TXLU-1985		TXLU-1986		KSMA-1985		NESA-1985		NESA-1986		NDMA-1986		ABLE-1986	
LAI (m^2/m^2)	Bias	0.77	-0.54	0.90	-0.87	-0.20	-1.36	1.95	-0.87	2.23	-0.56	1.35	-1.05	1.99	-0.55
	IOA	0.64	0.52	0.64	0.51	0.60	0.46	0.33	0.46	0.33	0.49	0.57	0.48	0.37	0.50
	r	0.72	0.63	0.50	0.50	0.54	0.20	0.06	0.21	0.04	0.43	0.54	0.87	0.11	0.61
	RMSE	0.94	0.71	1.22	1.24	1.05	1.81	2.15	1.06	2.39	0.83	1.70	1.34	2.15	0.92
Leaf weight (ton/ha)	Bias	0.01	-0.46	-0.30	-0.93	-0.41	-0.82	0.01	-1.00	0.61	-0.39	0.26	-0.60	0.48	-0.43
	IOA	0.92	0.48	0.48	0.46	0.52	0.44	0.19	0.42	0.54	0.49	0.72	0.48	0.47	0.49
	r	0.86	0.64	0.45	0.45	0.64	0.07	-0.01	0.56	0.46	0.48	0.56	0.83	0.29	0.73
	RMSE	0.17	0.56	0.87	1.29	0.68	1.05	0.80	1.24	0.74	0.60	0.48	0.73	0.65	0.61
Stem weight	Bias	0.83	-1.03	2.19	-1.90	-1.28	-3.72	2.18	-2.87	2.13	-1.76	1.89	-2.11	3.93	-2.37
	IOA	0.60	0.38	0.33	0.36	0.72	0.47	0.57	0.39	0.57	0.52	0.76	0.50	0.18	0.33
	r	0.50	-0.38	0.14	0.06	0.73	-0.32	0.60	-0.65	0.66	0.51	0.92	0.37	-0.05	0.50

	RMSE	1.33	1.35	2.85	2.14	3.25	5.57	3.15	3.33	2.94	2.25	2.69	2.75	4.65	2.45
Grain weight (ton/ha)	Bias	-0.63	-0.48	-0.31	-0.52	-0.55	-0.35	-1.16	-1.34	-1.11	-1.09	-1.06	-1.31	-1.04	-1.74
	IOA	0.52	0.30	0.63	0.51	0.52	0.31	0.58	0.41	0.65	0.55	0.57	0.43	0.70	0.45
	r	0.55	-0.57	0.37	0.23	0.99	-0.21	0.86	-0.60	0.88	0.53	0.98	-0.02	0.78	-0.07
	RMSE	0.91	1.04	0.86	0.97	1.10	1.31	1.54	1.95	1.69	1.93	1.90	2.43	1.33	2.16

Table S3. Statistical comparison of leaf area index (LAI, m^2/m^2) between observations and simulations at US-ARM and US-PON sites.

	LAI (m^2/m^2)							
	Bias		IOA		r		RMSE	
	WHE	BASE	WHE	BASE	WHE	BASE	WHE	BASE
US-ARM	-0.26	-0.99	0.85	0.5	0.76	0.72	0.71	1.29
US-PON	1.17	-1.43	0.79	0.5	0.78	0.73	1.65	2.05

Note: Bias, mean difference between simulation and model; IOA, index of agreement (Willmott et al., 1985); r, Pearson's correlation coefficient; RMSE, root mean square error. The WHE columns are the modified winter wheat model, while the BASE columns are the original winter wheat model.

Table S4 Seasonal comparison of net radiation (W.m^{-2}), latent heat flux (W.m^{-2}), sensible heat flux (W.m^{-2}), and net ecosystem exchange (umol.m^{-2}.s^{-1}) between observations and simulations across the four sites.

	Net radiation (W.m^{-2})				Latent heat flux (W.m^{-2})				Sensible heat flux (W.m^{-2})				NEE (umol.m^{-2}.s^{-1})			
	Bias		RMSE		Bias		RMSE		Bias		RMSE		Bias		RMSE	
							US-ARM									
ALL	-1.47	-4.6	4.71	7.95	4.83	2.77	9.64	12.67	-7.16	-7.77	11.19	13.72	1.92	2.36	2.21	2.7
DJF	-4.94	-12.81	4.96	13.26	-2.87	-1.32	2.98	5.8	-7.08	-12.91	7.58	13.46	1.44	1.66	1.44	1.66
MAM	2.24	-2.17	3.87	3.71	-0.53	-13.62	7.47	14.54	2.19	7.61	8.17	12.2	0.98	4.19	1.78	4.42
JJA	-1.33	-1	6.14	6.47	11.84	13.92	12.14	14.2	-13.93	-15.12	15.98	16.89	2.72	1.47	2.78	1.5
SON	-1.86	-2.4	3.38	4.64	10.87	12.09	12.63	14	-9.82	-10.65	11.03	11.74	2.54	2.13	2.55	2.14
							US-PON									
ALL	-9.4	-17.44	16.1	23.67	3.27	-5.5	24.08	28.88	-7.84	-7.94	21.69	22.51				
DJF	-25.35	-37.97	26.59	39.88	-15.98	-19.95	16.58	21.36	-4.6	-13.39	9.09	15.78				
MAM	-0.68	-16.22	8.67	18.4	-9.18	-34.98	10.55	35.86	11.34	16.96	12.43	20.89				
JJA	3.52	1.39	3.83	3.44	40.99	37.46	43.79	39.41	-38.66	-35.71	40.45	36.47				
SON	-15.09	-16.97	15.48	17.33	-2.77	-4.55	3.94	6.43	0.56	0.37	2.85	3.44				
							US-CRT									
ALL	-10.54	-17.43	17.66	21.33	-20.75	-24.18	23.82	32.49	23.28	19.86	29.03	28.1	1.97	2.65	2.88	4.4
DJF	4.77	-4.94	4.83	7.82	-11.68	-14.07	11.72	14.11	27.79	21.99	27.81	22.55	0.74	0.75	1.09	1.05
MAM	-5.75	-18.83	7.46	19.4	-21.43	-34.81	24.61	38.34	33.37	31.07	39.22	40.22	3.06	5.9	4.57	7.52
JJA	-27.09	-31.46	29.67	32.05	-28.34	-33.56	32.24	40.83	9.66	11.01	23.11	24.92	1.61	1.7	1.67	3.67
SON	-14.09	-14.48	16.97	18.82	-21.55	-14.27	22.1	29.76	22.3	15.34	22.92	20.32	2.47	2.26	2.88	2.54
							CAF-CT									
ALL	-1.33	-9.53	13.28	13.43	-20.9	-20.33	25.74	24.83	10.83	1.45	29.08	16	-0.24	-0.26	0.32	0.31
DJF	-15.47	-17.24	16.43	18.28	-17.01	-17.48	17.2	17.68	-4.32	-4.68	7.49	7.62	2.06	4.21	2.71	5.13

MAM	7.27	-5.25	13.96	13.83	-29.91	-34.15	31.13	34.6	17.44	4.73	34.63	24.68	2.67	3.17	3.75	4.03
JJA	7.52	-10.84	14.13	12.33	-28.51	-23.2	35.48	28.8	33.59	9.7	45.89	17.98	1.17	1.18	1.3	1.26
SON	-4.64	-4.79	6.4	6.6	-8.17	-6.5	11.26	11.26	-3.4	-3.97	4.67	5.8	1.42	2.08	2.41	3.32