

Supplemental Materials

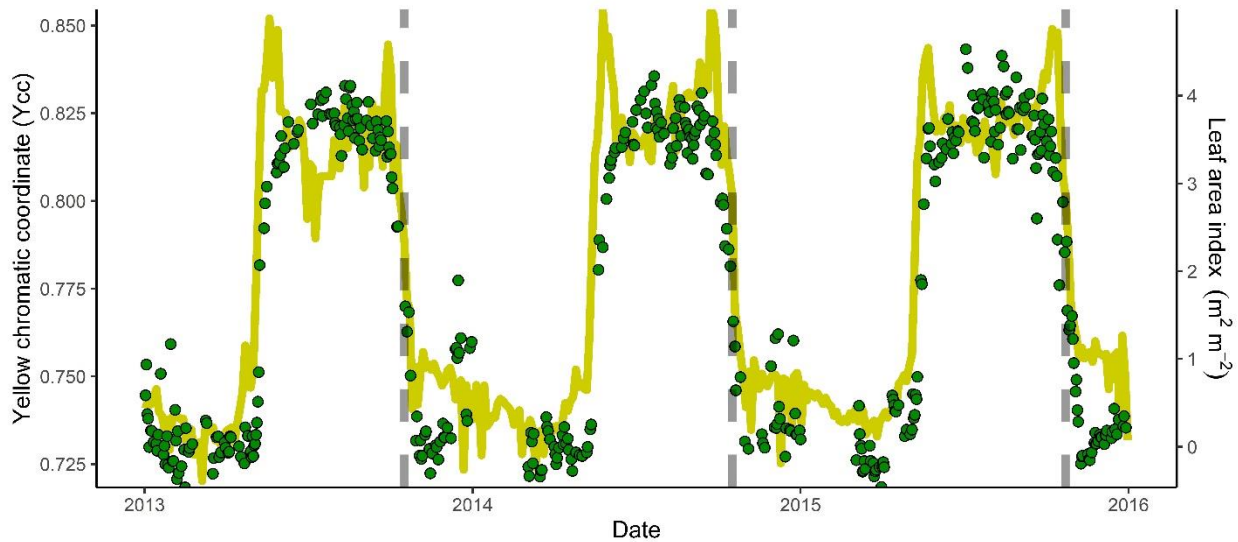


Fig S1. Yellow chromatic coordinate (Ycc) values extracted from PhenoCam data (yellow line) compared to leaf area index (LAI) values extracted from fPAR data (green circle), both collected at Bartlett Experimental Forest from 2013-2016. The extracted end of fall transition date (when Ycc reaches 50% of the fall amplitude) is shown as a dashed gray line. See Toda and Richardson 2018 for more information on estimating LAI from fPAR measurements.

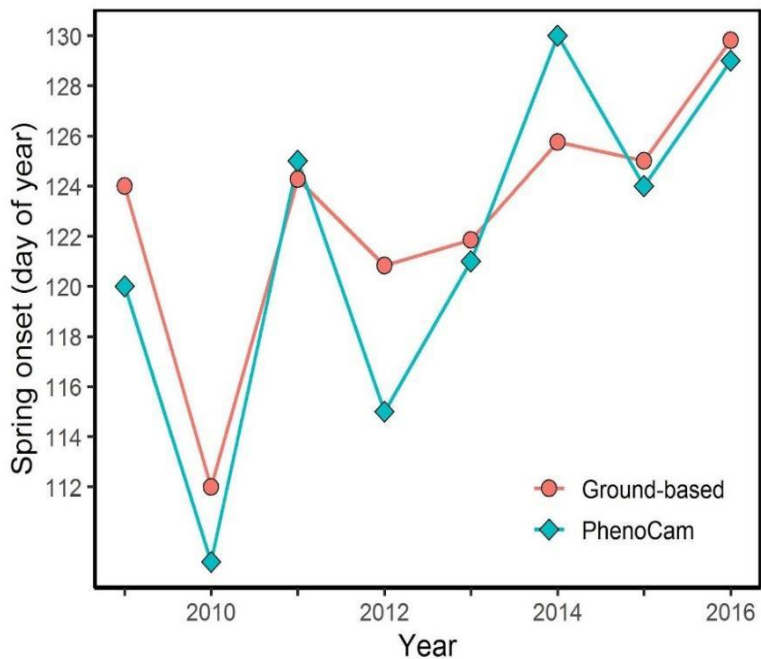


Fig. S2. Transition dates derived from PhenoCam (25% greenness of seasonal amplitude) correspond to ground observations at Hubbard Brook from 2009-2016.

Table S1. The relationships (R^2) between daily modeled vs. measured ecosystem carbon exchange (NEP = net ecosystem productivity, GPP = gross primary productivity, and Reco = ecosystem respiration) from 2004-2020 using different combinations of spring and fall phenology models. The fixed model was based on the average transition dates derived from PhenoCam.

Spring Model	Fall Model	R^2			RMSE		
		NEP	GPP	Reco	NEP	GPP	Reco
SM1	CDD	0.60	0.90	0.64	1.9	1.6	2.1
PA	CDD	0.60	0.90	0.64	1.9	1.7	2.2
PTT	CDD	0.60	0.90	0.64	1.9	1.7	2.1
SM1	CDDP	0.61	0.89	0.64	1.9	1.7	2.1
PA	CDDP	0.61	0.89	0.64	1.9	1.7	2.1
PTT	CDDP	0.61	0.89	0.64	1.9	1.7	2.1
PnET	PnET	0.48	0.88	0.67	2.1	1.6	2.0
Fixed	Fixed	0.61	0.87	0.63	1.9	1.8	2.0

Table S2. Parameters generated from the calibration of phenology models in phenoR (Hufkens et al. 2018). Data for calibration included spring and fall transition dates from 96 site years from 8 sites in northern deciduous forests. There are two critical accumulating temperatures, F_{crit} and F_{crit2} , corresponding to the beginning and end of the seasonal transition.

model	season	t0	t0_chill	T_base	T_opt	T_min	T_max	C_ini	F_crit	F_crit2	C_req
SM1	Spring	92	74	5.74	9.96	-1.34	14.86		81.70	189.83	4.36
PA	Spring	91	72	7.38	4.24	-0.87	10.72	0.09	9.83	28.33	142.49
PTT	Spring	92		7.29					66.72	142.28	
CDD	Fall	226		25.08					-384.80	-784.22	
CDDP	Fall	250		10.68					27.12	96.46	

Table S3. Acknowledgements and site information for the PhenoCam sites used in this study. The sites are listed in alphabetical order.

Site name	Description	MAT (°C)	Years	Acknowledgement
bartlett	Bartlett Experimental Forest, Bartlett, New Hampshire	6.7	2007-2016	Research at the Bartlett Experimental Forest tower is supported by the National Science Foundation (grant DEB-1114804) and the USDA Forest Service's Northern Research Station.
bartlettir	Bartlett Experimental Forest, Bartlett, New Hampshire	6.7	2017-2020	Research at the Bartlett Experimental Forest tower is supported by the National Science Foundation (grant DEB-1114804) and the USDA Forest Service's Northern Research Station.
caryinstitute	Cary Institute of Ecosystem Studies, Millbrook, NY	8.6	2010-2020	
harvard	EMS Tower, Harvard Forest, Petersham, Massachusetts	8	2008-2020	Research at Harvard Forest is partially supported through the National Science Foundation's LTER program (DEB-1237491), and Dept. of Energy Office of Science (BER)
howland2	North Tower (Regrowing clearcut, ca. 1990), Howland Forest, Howland, Maine	6	2010-2019	Research at Howland Forest is supported by the Office of Science (BER), US Department of Energy, and the USDA Forest Service's Northern Research Station.
laurentides	Station de biologie des Laurentides, University of Montreal, St-Hippolyte, Quebec, Canada	4.3	2014-2020	
proctor	University of Vermont, Proctor Maple Research Center, Underhill, Vermont	12.6	2009-2020	Supported by the Agricultural Experiment Station of the University of Vermont
queens	Queen's University Biological Station, Lake Opinicon, Ontario, Canada	6.8	2009-2020	
turkeypointdbf	Mature Deciduous Site, Turkey Point Carbon Cycle Research Project, Ontario, Canada	7.8	2012-2020	