Supplementary Materials

Table S1. List of PhenoCam sites used in this study, including the site name, camera name, location, latitude and longitude of each camera. The table is arranged in alphabetical order according to camera name.

Site name (*camera name*)	**Location**	**Latitude (°)**	**Longitude (°)**	**Land cover**
Arbutus Lake (*arbutuslake*)	Huntington Forest, New York	43.9821	-74.2332	DB
Ashburnham State Forest (*ashburnham*)	Ashburnham, Massachusetts	42.6029	-71.9260	DB
Bartlett Experimental Forest (*bartlett*)	Bartlett, New Hampshire	44.0646	-71.2881	DB
Bartlett Experimental Forest (*bartlettir*)	Bartlett, New Hampshire	44.0646	-71.2881	DB
Boston Common (*bostoncommon*)	Boston, Massachusetts	42.3559	-71.0641	DB
Boston University (*bostonu*)	Boston, Massachusetts	42.3504	-71.1044	DB
Boundary Waters Canoe Area Wilderness (*boundarywaters*)	Superior National Forest, Minnesota	47.9467	-91.4955	DB
Cary Institute of Ecosystem Studies (*caryinstitute*)	Millbrook, New York	41.7839	-73.7341	DB
Cedar Creek Ecosystem Science Reserve (*cedarcreek*)	East Bethel, Minnesota	45.4019	-93.2042	DB
Downer Woods Natural Area (*downerwoods*)	Milwaukee, Wisconsin	43.0794	-87.8808	DB
Groundhog (*groundhog*)	Ontario, Canada	48.2174	-82.1555	EN
Harvard Forest EMS Tower (*harvard*)	Petersham, Massachusetts	42.5378	-72.1715	DB
Harvard Forest Barn Tower, Camera 1 (*harvardbarn*)	Petersham, Massachusetts	42.5353	-72.1899	EN
Harvard Forest Barn Tower, Camera 2 (*harvardbarn2*)	Petersham, Massachusetts	42.5353	-72.1899	DB
Harvard Forest Hemlock Tower (*harvardhemlock*)	Petersham, Massachusetts	42.5390	-72.1800	EN
Harvard Forest LPH Tower (*harvardlph*)	Petersham, Massachusetts	42.5420	-72.1850	DB
Hubbard Brook Experimental Forest Headquarters (*hubbardbrook*)	North Woodstock, New Hampshire	43.9438	-71.7010	DB
Hubbard Brook Experimental Forest North Facing Watershed (*hubbardbrooknfws*)	Thornton, New Hampshire	43.9580	-71.7762	DB
Hubbard Brook Experimental Forest South Facing Watershed (*hubbardbrooksfws*)	Thornton, New Hampshire	43.9269	-71.7407	DB

Kellogg Biological Station (*kelloggcorn*)	Michigan	42.4375	-85.3225	AG
Station de biologie des Laurentides (*laurentides*)	Quebec, Canada	45.9881	-74.0055	DB
North Attleboro High School (*northattleboroma*)	North Attleboro, Massachusetts	41.9837	-71.3106	DB
Curtis Walter-Berger Cropland Flux Tower (*nwohiocrop*)	Ohio	41.6285	-83.3471	AG
Proctor Maple Research Center (*proctor*)	Underhill, Vermont	44.5250	-72.8660	DB
Queens Biological Station (*queens*)	Ontario, Canada	44.5650	-76.3240	DB
Austin Prep School Reading (*readingma*)	Reading, Massachusetts	42.5304	-71.1272	DB
Rosemount Agricultural Experiment Station (*rosemount*)	Rosemount, Minnesota	44.7143	-93.0898	AG
Susquehanna Shale Hills Critical Zone Observatory (*shalehillsczo*)	Pennsylvania	40.6500	-77.9000	DB
Hay-Snake State Wildlife Management Area (*snakerivermn*)	Woodland, Minnesota	46.1206	-93.2447	DB
Academy Hill School Springfield (*springfieldma*)	Springfield, Massachusetts	42.1352	-72.5860	DB
Thompson Farm Observatory (*thompsonfarm2N*)	Durham, New Hampshire	43.1086	-70.9505	DB
Turkey Point Carbon Cycle Research Project Mature Deciduous Site (*turkeypointdbf*)	Ontario, Canada	42.6353	-80.5576	DB
Turkey Point Carbon Cycle Research Project 2002 White Pine (*turkeypointenf02*)	Ontario, Canada	42.6609	-80.5595	EN
Turkey Point Carbon Cycle Research Project 1939 White Pine (*turkeypointenf39*)	Ontario, Canada	42.7098	-80.3574	EN
Turkey Point Carbon Cycle Research Project 1974 White Pine (*turkeypointenf74*)	Ontario, Canada	42.7068	-80.3483	EN
University of Illinois Energy Farm maize/soybean agrosystem (*uiefmaize*)	Urbana, Illinois	40.0628	-88.1961	AG
University of Illinois Energy Farm miscanthus agrosystem (*uiefmiscanthus*)	Urbana, Illinois	40.0628	-88.1984	GR
University of Illinois Energy Farm restored prairie (*uiefprairie*)	Urbana, Illinois	40.0637	-88.1973	GR
University of Illinois Energy Farm switchgrass agrosystem (*uiefswitchgrass*)	Urbana, Illinois	40.0637	-88.1973	GR

University of Michigan Biological Station (umichbiological)	near Pellston, Michigan	45.5598	-84.7138	DB
University of Michigan Biological Station (umichbiological2)	near Pellston, Michigan	45.5625	-84.6976	DB
University of Wisconsin Madison Field Station (*uwmfieldsta*)	Saukville, Wisconsin	43.3871	-88.0229	DB
Willow Creek (*willowcreek*)	Chequamegon-Nicolet National Forest, Wisconsin	45.8060	-90.0791	DB
Woods Hole Research Center (*woodshole*)	Falmouth, Massachusetts	41.5495	-70.6432	DB
Worcester State University (*worcester*)	Worcester, Massachusetts	42.2697	-71.8428	DB

Table S2. Statistics comparing phenological transition dates extracted from TIMESAT (double logistic and Savitzky-Golay) with those obtained from the MODIS MLCD C5 product across all years and for the four MODIS tiles used in this analysis. Bias is calculated relative to MLCD, where a negative bias indicates that MLCD dates are later than TIMESAT dates. All correlation coefficient values listed in this table are statistically significant at $p < 0.05$. We used two thresholds corresponding to 10% and 15% of the maximum seasonal amplitude of EVI in spring and fall.

Tile	Method	R	RMSE	Bias	Slope	Intercept
Start of Season (SOS)						
US Southwest	Double Logistic 10%	0.94	10.28	2	0.87	13.21
	Double Logistic 15%	0.97	8.16	8	0.88	18.89
	Savitzky-Golay 10%	0.82	17.26	-9	0.72	16.77
	Savitzky-Golay 15%	0.85	16.06	-1	0.77	20.83
US Midwest	Double Logistic 10%	0.91	7.59	-2	0.95	3.03
	Double Logistic 15%	0.89	8.09	4	0.95	9.18
	Savitzky-Golay 10%	0.74	12.93	-15	0.84	2.71
	Savitzky-Golay 15%	0.80	11.67	-5	0.94	1.86
US Northeast	Double Logistic 10%	0.87	7.36	-2	0.83	16.69
	Double Logistic 15%	0.88	6.57	3	0.82	23.57
	Savitzky-Golay 10%	0.51	12.38	-10	0.49	47.99
	Savitzky-Golay 15%	0.63	11.16	-3	0.59	43.11
Central Canada	Double Logistic 10%	0.25	17.98	-16	0.62	34.50
	Double Logistic 15%	0.28	16.41	-9	0.64	39.70
	Savitzky-Golay 10%	0.62	8.38	-26	0.94	-17.82
	Savitzky-Golay 15%	0.61	8.91	-20	1.01	-21.76
End of Season (EOS)						
US Southwest	Double Logistic 10%	0.76	16.02	9	0.71	100.01
	Double Logistic 15%	0.77	14.33	0	0.65	107.71
	Savitzky-Golay 10%	0.39	21.68	18	0.34	221.69
	Savitzky-Golay 15%	0.48	15.80	9	0.33	216.94
US Midwest	Double Logistic 10%	0.76	13.54	16	0.96	27.11
	Double Logistic 15%	0.80	11.35	7	0.96	18.56
	Savitzky-Golay 10%	0.46	25.39	29	0.82	78.67
	Savitzky-Golay 15%	0.70	15.86	19	0.99	21.63
US Northeast	Double Logistic 10%	0.57	18.95	13	0.98	17.74
	Double Logistic 15%	0.81	8.95	7	0.89	38.72
	Savitzky-Golay 10%	0.12	28.24	21	0.24	245.68
	Savitzky-Golay 15%	0.41	16.47	12	0.54	147.22
Central Canada	Double Logistic 10%	0.14	26.04	18	0.55	139.44
	Double Logistic 15%	0.21	17.97	12	0.57	126.30
	Savitzky-Golay 10%	0.46	11.11	43	0.89	72.59
	Savitzky-Golay 15%	0.41	12.09	35	0.88	66.78

Table S3. Statistics comparing phenological transition dates extracted from TIMESAT (double logistic and Savitzky-Golay) with those obtained from the MODIS MLCD C6 product across all years and for the four MODIS tiles used in this analysis. Bias is calculated relative to MLCD, where a negative bias indicates that MLCD dates are later than TIMESAT dates. All correlation coefficient values listed in this table are statistically significant at $p < 0.05$. We used two thresholds corresponding to 10% and 15% of the maximum seasonal amplitude of EVI in spring and fall.

Tile	Method	R	RMSE	Bias	Slope	Intercept
Start of Season (SOS)						
US Southwest	Double Logistic 10%	0.95	9.68	0	1.00	-1.04
	Double Logistic 15%	0.95	10.36	6	0.99	5.96
	Savitzky-Golay 10%	0.96	8.35	-3	1.00	-3.46
	Savitzky-Golay 15%	0.97	7.86	4	1.00	4.24
US Midwest	Double Logistic 10%	0.88	8.16	1	0.91	12.19
	Double Logistic 15%	0.90	6.73	8	0.86	25.46
	Savitzky-Golay 10%	0.85	9.64	-7	0.96	-2.13
	Savitzky-Golay 15%	0.93	6.33	2	0.99	1.89
US Northeast	Double Logistic 10%	0.81	7.80	3	0.84	21.45
	Double Logistic 15%	0.81	7.53	9	0.83	27.56
	Savitzky-Golay 10%	0.72	10.22	-7	0.84	10.71
	Savitzky-Golay 15%	0.81	8.10	2	0.86	16.71
Central Canada	Double Logistic 10%	0.47	12.21	2	0.68	40.12
	Double Logistic 15%	0.41	11.43	9	0.55	64.08
	Savitzky-Golay 10%	0.55	12.59	-3	0.85	13.91
	Savitzky-Golay 15%	0.70	8.67	2	0.90	13.52
End of Season (EOS)						
US Southwest	Double Logistic 10%	0.63	20.52	15	1.00	13.65
	Double Logistic 15%	0.69	16.10	8	0.96	20.10
	Savitzky-Golay 10%	0.66	17.91	16	0.92	40.58
	Savitzky-Golay 15%	0.72	15.00	8	0.97	16.65
US Midwest	Double Logistic 10%	0.85	9.65	8	0.92	31.11
	Double Logistic 15%	0.86	8.92	0	0.91	25.99
	Savitzky-Golay 10%	0.86	8.87	14	0.91	38.72
	Savitzky-Golay 15%	0.90	7.60	5	0.96	17.12
US Northeast	Double Logistic 10%	0.49	15.99	8	0.73	91.49
	Double Logistic 15%	0.77	9.09	2	0.85	46.93
	Savitzky-Golay 10%	0.68	13.08	12	0.97	20.64
	Savitzky-Golay 15%	0.92	5.80	5	1.07	-17.91
Central Canada	Double Logistic 10%	0.34	9.48	1	0.28	215.91
	Double Logistic 15%	0.31	11.28	-7	0.32	195.94
	Savitzky-Golay 10%	0.62	13.41	6	0.88	42.57
	Savitzky-Golay 15%	0.85	7.74	2	1.02	-3.57

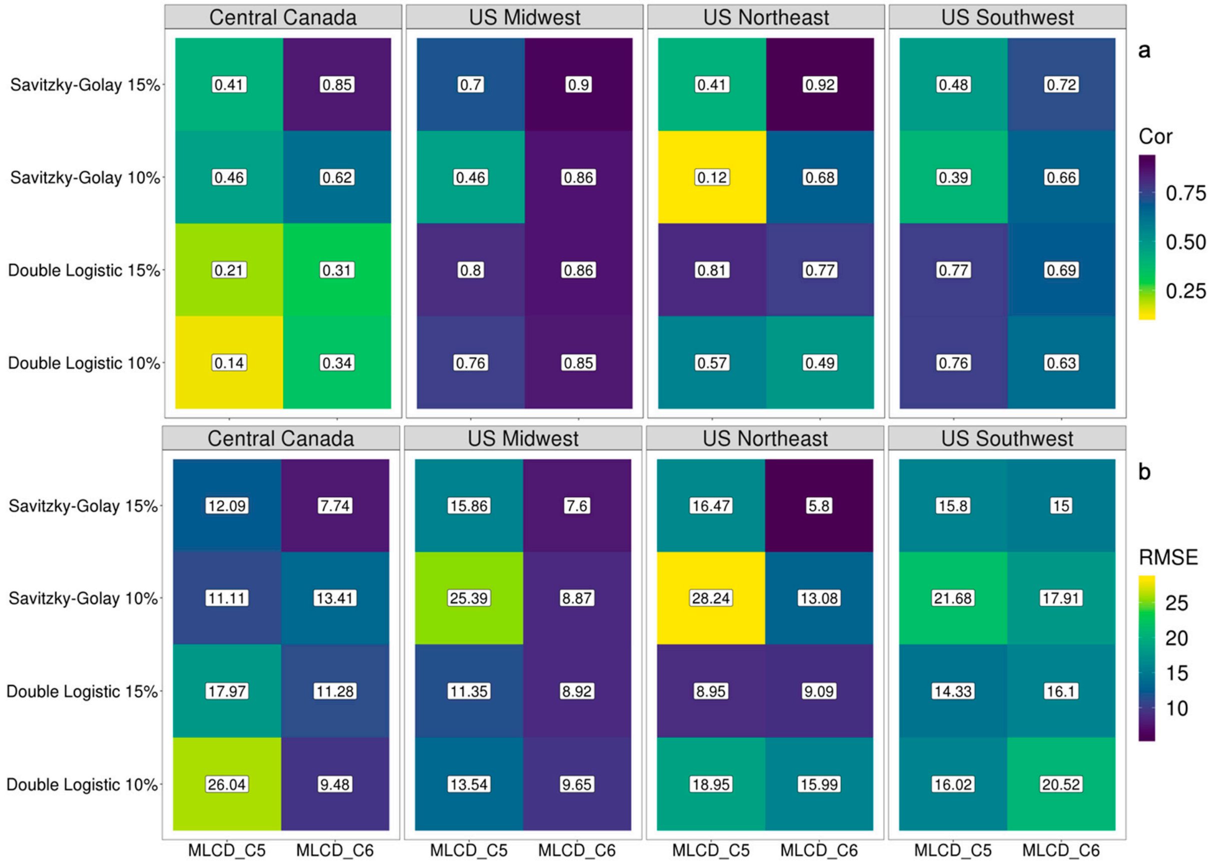

Figure S1. Summary statistics comparing phenological transition dates extracted from TIMESAT with those obtained from the MODIS C5 and C6 MLCD products across 12 years from 2003 to 2014 for four MODIS tiles in Central Canada, US Midwest, US Northeast and US Southwest. Panel (a) shows the correlation and panel (b) shows the root mean square error (RMSE) in days for end of season (EOS). We used two thresholds corresponding to 10% and 15% of the seasonal amplitude of EVI in spring and fall. All correlation values are statistically significant at $p<0.05$.

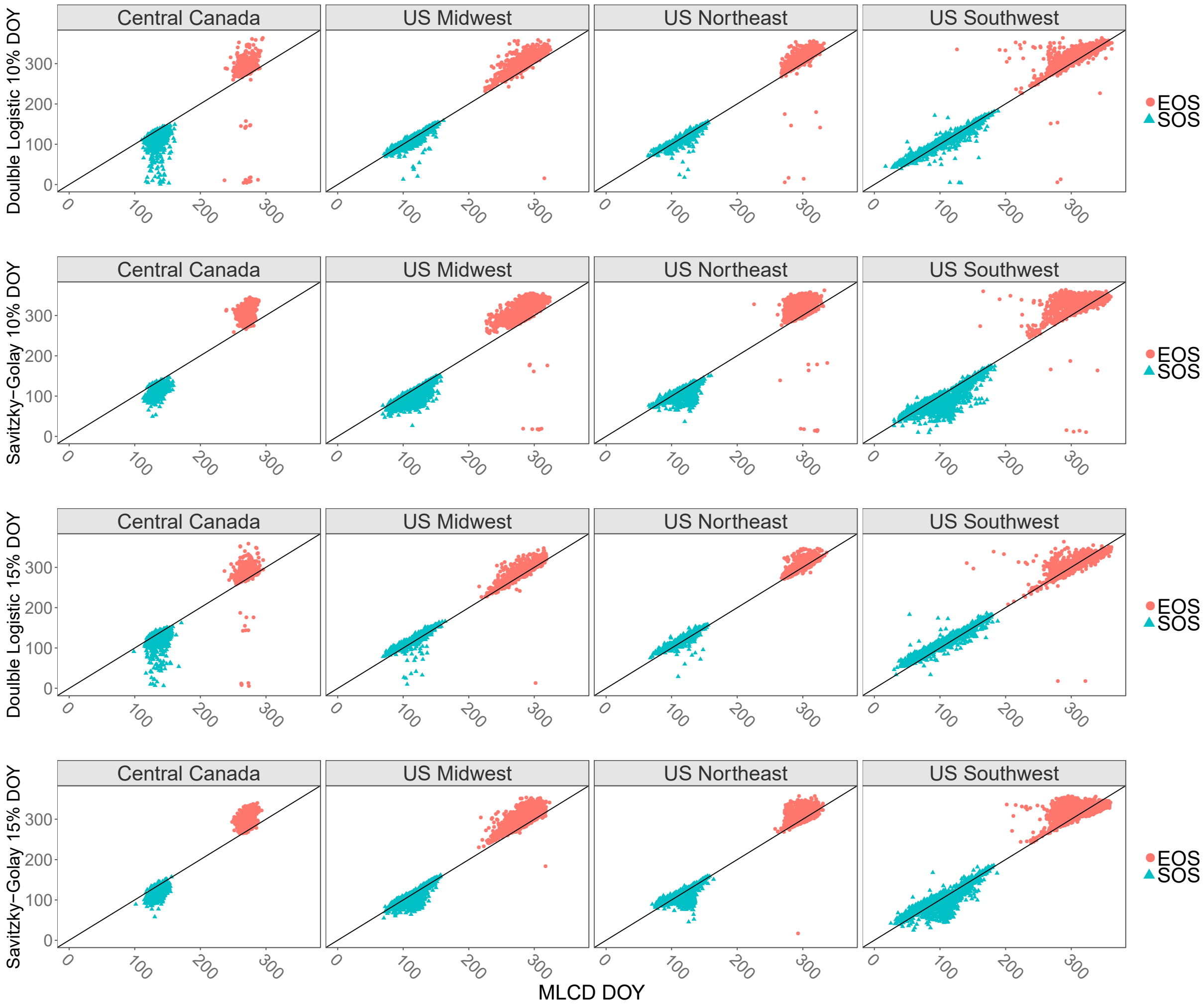

Figure S2. Scatterplots showing agreement among the MODIS MLCD C5 product and the different TIMESAT approaches stratified by season: start of season (SOS) is shown in blue and end of season (EOS) is shown in red. The panels represent the different regions of North America included in this study. Data shown in this plot were screened for snow using normalized difference snow index (NDSI).

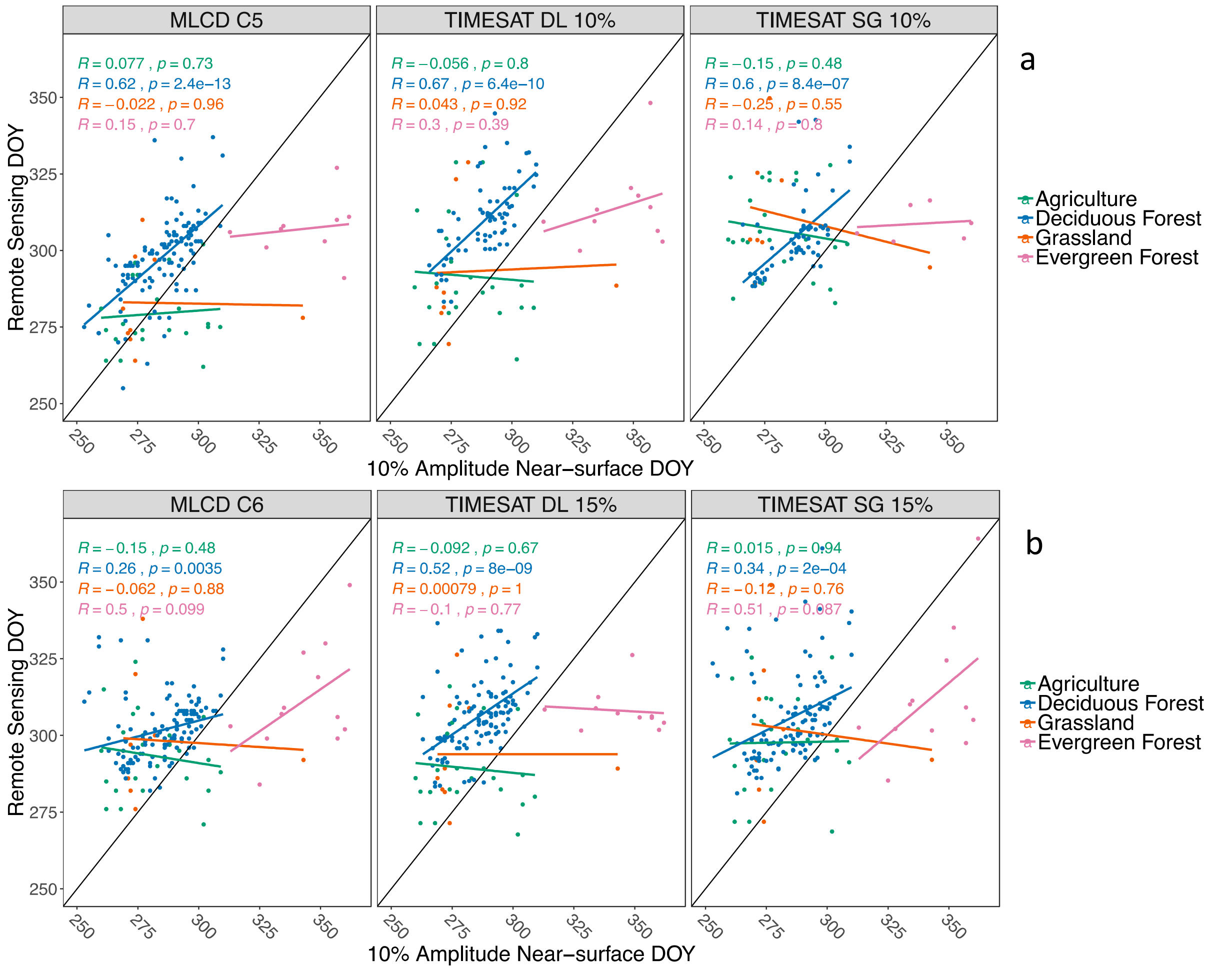

Figure S3. Relationships between PhenoCam and MODIS end of season (EOS) day of year (DOY). Top row (a) shows a comparison of PhenoCam dates against C5 MLCD dates, TIMESAT double logistic (DL), and TIMESAT Savitzky-Golay (SG) results, respectively. Bottom row (b) shows comparison of Phenocam dates with MLCD C6 dates, and TIMESAT results. Solid black lines show 1:1 relationship and solid colored lines show best fit regression models for the four different land cover classes in the field of view of the cameras.

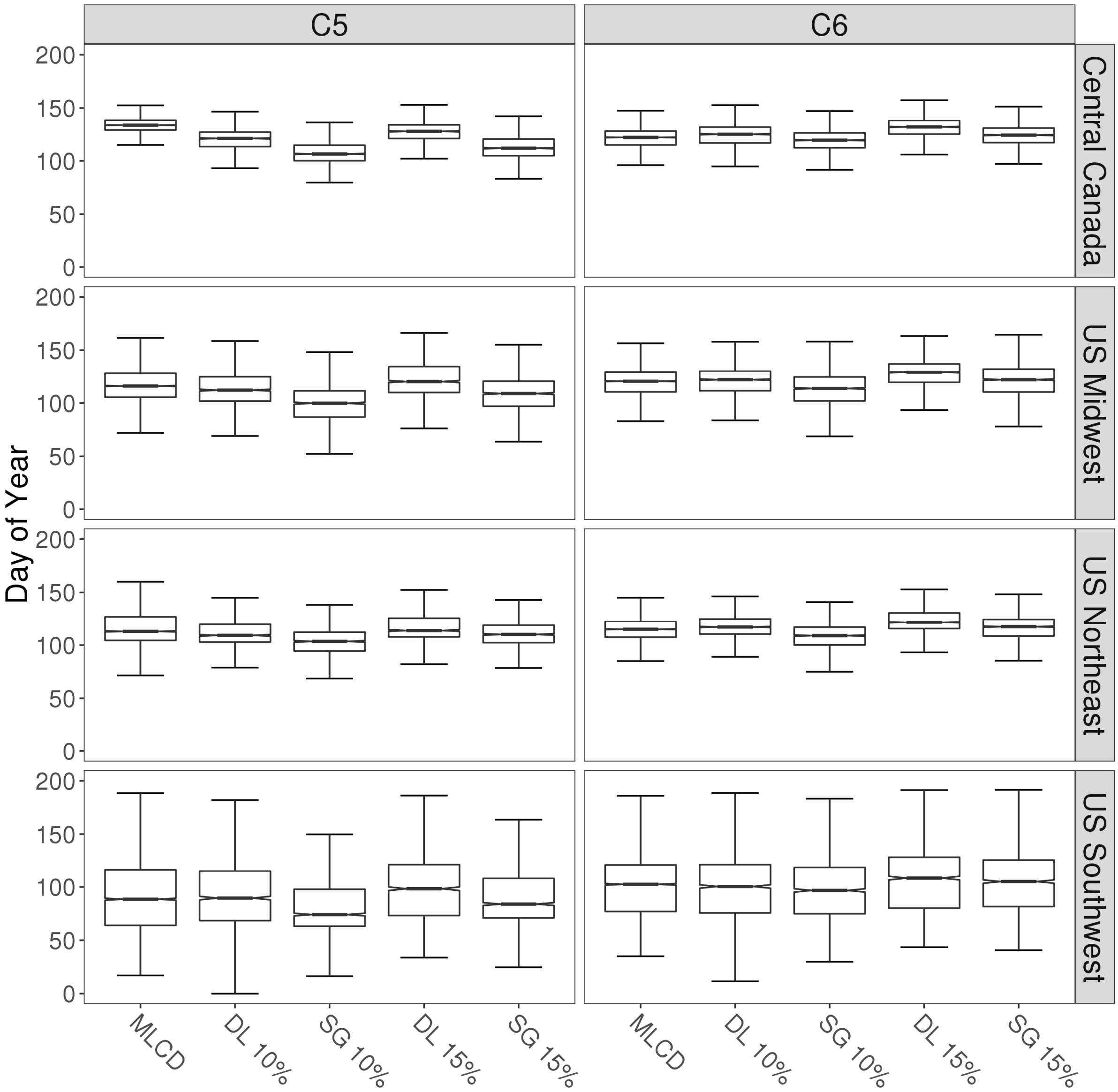

Figure S4. Comparison among median phenological transition dates retrieved from MLCD, TIMESAT double logistic (DL) at 10% and 15% of amplitude, and TIMESAT Savitzky-Golay (SG) at 10% and 15% of amplitude for the time period between 2003 and 2014. The results show the timing of SOS across four different MODIS tiles in North America and for two different MODIS Collections: C5 and C6.

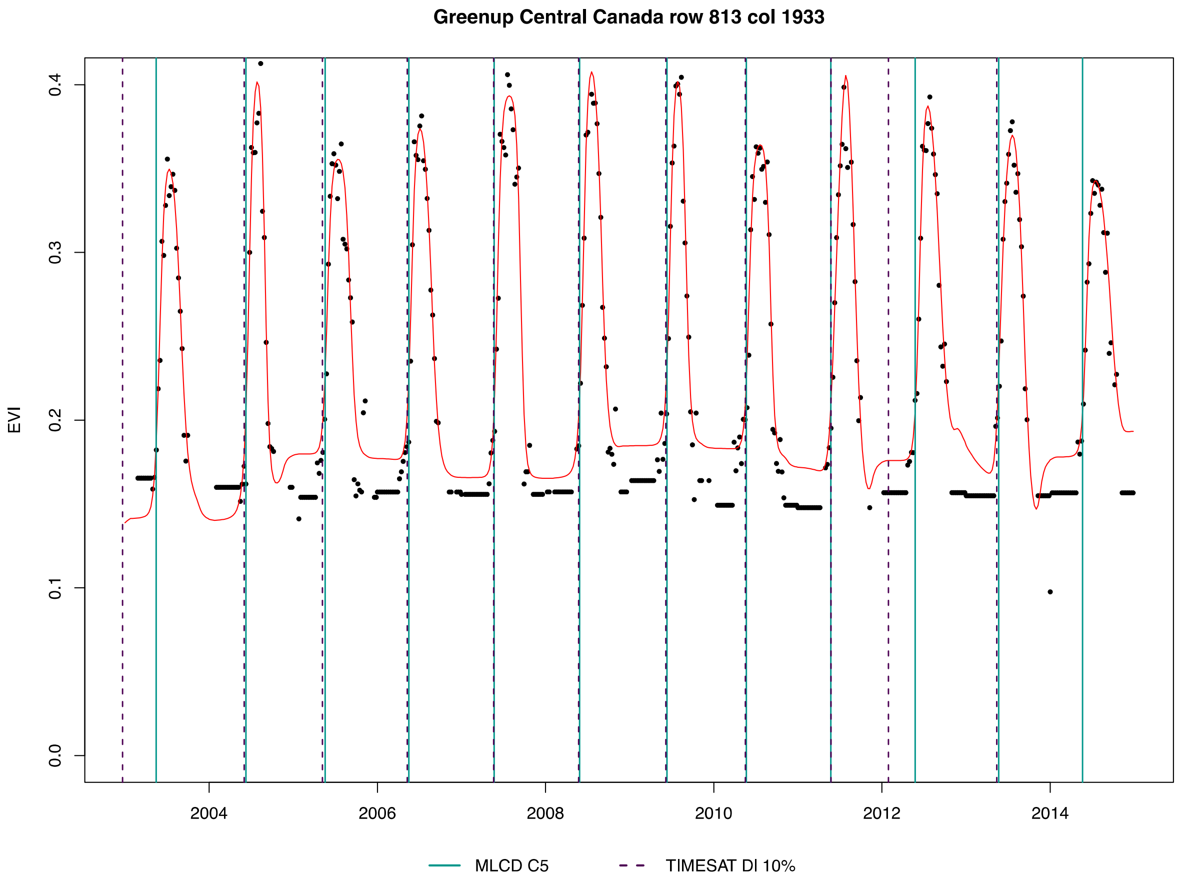

Figure S5. EVI time series for a pixel in Central Canada from 2003 to 2014. The black dots show the EVI observations (screened for snow and gap filled) and the red line shows the TIMESAT double logistic fit. The blue solid line shows the C5 MLCD start of season (SOS) while the purple dashed line shows the TIMESAT SOS based on double logistic at 10% of amplitude.