Supporting information

Evaluating the performance of satellite-derived vegetation indices for estimating gross primary productivity using FLUXNET observations across the globe

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Table. S1 List of 121 eddy covariance flux tower sites used in this study. IGBP refers to the International Geosphere-Biosphere Program land cover classification. ENF: evergreen needleleaf forest; EBF: evergreen broadleaf forest; DBF: deciduous broadleaf forest; MF: mixed forest; OCSH: open and closed shrublands; SAV: savannas; WSA: woody savannas; GRA: grassland; CRO: cropland; WET: wetland

Site Code	Site Name	Lat (°)	Long (°)	IGBP	Date	Reference
AT-Neu	Neustift	47.12	11.32	GRA	2002-2012	(Wohlfahrt et al. 2008)
AU-ASM	Alice Springs	-22.28	133.25	SAV	2010-2013	(Beringer et al. 2016)
AU-Ade	Adelaide River	-13.08	131.12	WSA	2007-2009	(Beringer et al. 2011b)
AU-Cpr	Calperum	-34.00	140.59	SAV	2010-2014	(Beringer et al. 2016)
AU-DaP	Daly River Savanna	-14.06	131.32	GRA	2007-2013	(Beringer et al. 2011b)
AU-DaS	Daly River Cleared	-14.16	131.39	SAV	2008-2014	(Beringer et al. 2011b)
AU-Dry	Dry River	-15.26	132.37	SAV	2008-2014	(Beringer et al. 2011b)
AU-Fog	Fogg Dam	-12.55	131.31	WET	2006-2008	(Guerschman et al. 2009)
AU-Gin	Gingin	-31.38	115.71	WSA	2011-2014	(Beringer et al. 2016)
AU-How	Howard Springs	-12.49	131.15	WSA	2001-2014	(Beringer et al. 2011a)
AU-RDF	Red Dirt Melon Farm, Northern Territory	-14.56	132.48	WSA	2011-2013	(Beringer et al. 2011b)
AU-Rig	Riggs Creek	-36.65	145.58	GRA	2011-2014	(Beringer et al. 2011b)
AU-Rob	Robson Creek, Queensland, Australia	-17.12	145.63	EBF	2014	(Beringer et al. 2016)
AU-Stp	Sturt Plains	-17.15	133.35	GRA	2008-2014	(Beringer et al. 2011a)
AU-Whr	Whroo	-36.67	145.03	EBF	2011-2014	(McHugh et al. 2017)
AU-Wom	Wombat	-37.42	144.09	EBF	2010-2012	(Hinko-Najera et al. 2017)

BE-Bra	Brasschaat	51.31	4.52	MF	2000-2014	(Carrara et al. 2003)
BE-Vie	Vielsalm	50.31	6.00	MF	2000-2014	(Aubinet et al. 2001)
CA-NS1	UCI-1850 burn site	55.88	-98.48	ENF	2001-2005	(Goulden et al. 2006)
CA-NS2	UCI-1930 burn site	55.91	-98.52	ENF	2001-2005	(Goulden et al. 2006)
CA-NS3	UCI-1964 burn site	55.91	-98.38	ENF	2001-2005	(Goulden et al. 2006)
CA-NS4	UCI-1964 burn site wet	55.91	-98.38	ENF	2002-2005	(Goulden et al. 2006)
CA-NS5	UCI-1981 burn site	55.86	-98.49	ENF	2001-2005	(Goulden et al. 2006)
CA-NS6	UCI-1989 burn site	55.92	-98.96	COSH	2001-2005	(Goulden et al. 2006)
CA-NS7	UCI-1998 burn site	56.64	-99.95	COSH	2002-2005	(Goulden et al. 2006)
CA-Qfo	Quebec - Eastern Boreal, Mature Black Spruce	49.69	-74.34	ENF	2003-2010	(Bergeron et al. 2007)
CA-SF1	Saskatchewan - Western Boreal, forest burned in 1977	54.49	-105.82	ENF	2003-2006	(Mkhabela et al. 2009)
CA-SF2	Saskatchewan - Western Boreal, forest burned in 1989	54.25	-105.88	ENF	2001-2005	(Mkhabela et al. 2009)
CA-SF3	Saskatchewan - Western Boreal, forest burned in 1998	54.09	-106.01	COSH	2001-2006	(Mkhabela et al. 2009)
CH-Cha	Chamau	47.21	8.41	GRA	2005-2014	(Merbold et al. 2014)
CH-Dav	Davos	46.82	9.86	ENF	1997-2014	(Alemohammad et al. 2017)
CH-Fru	Früebüel	47.12	8.54	GRA	2005-2014	(Zeeman et al. 2010)
CH-Lae	Laegern	47.48	8.37	MF	2004-2014	(Etzold et al. 2010)
CH-Oe1	Oensingen grassland	47.29	7.73	GRA	2002-2008	(Ammann et al. 2009)
CN-Cng	Changling	44.59	123.51	GRA	2007-2010	-

CN-Du2	Duolun_grassland (D01)	42.05	116.28	GRA	2006-2008	(Sun et al. 2011)
CN-Ha2	Haibei Shrubland	37.61	101.33	WET	2003-2005	(Yu et al. 2006)
CN-HaM	Haibei Alpine Tibet site	37.37	101.18	GRA	2002-2004	(Yu et al. 2006)
CN-Qia	Qianyanzhou	26.74	115.06	ENF	2003-2005	(Yu et al. 2006)
CZ-BK1	Bily Kriz forest	49.50	18.54	ENF	2004-2008	(Marek et al. 2011)
CZ-wet	Trebon (CZECHWET)	49.02	14.77	WET	2006-2014	-
DE-Akm	Anklam	53.87	13.68	WET	2009-2014	-
DE-Gri	Grillenburg	50.95	13.51	GRA	2004-2014	(Hussain et al. 2011)
DE-Hai	Hainich	51.08	10.45	DBF	2000-2012	(Anthoni et al. 2004)
DE-Lkb	Lackenberg	49.10	13.30	ENF	2009-2013	(Lindauer et al. 2014)
DE-Obe	Oberbärenburg	50.79	13.72	ENF	2008-2014	-
DE-RuR	Rollesbroich	50.62	6.30	GRA	2011-2014	(Post et al. 2015)
DE-SfN	Schechenfilz Nord	47.81	11.33	WET	2012-2014	-
DE-Spw	Spreewald	51.89	14.03	WET	2010-2014	-
DE-Tha	Tharandt	50.96	13.57	ENF	1996-2014	(Grunwald and Bernhofer 2007)
DK-NuF	Nuuk Fen	64.13	-51.39	WET	2008-2014	(Westergaard-Nielsen et al. 2013)
DK-Sor	Soroe	55.49	11.64	DBF	1996-2014	(Pilegaard et al. 2001)
FR-Fon	Fontainebleau-Barbeau	48.48	2.78	DBF	2005-2014	(Delpierre et al. 2016)
FR-LBr	Le Bray	44.72	-0.77	ENF	1996-2008	(Carvalhais et al. 2010)
FI-Hyy	Hyytiala	61.85	24.29	ENF	1996-2014	(Suni et al. 2003)
FI-Jok	Jokioinen	60.90	23.51	CRO	2000-2003	(Lohila et al. 2004)
FI-Lom	Lompolojänkkä	68.00	24.21	WET	2007-2009	-
FI-Sod	Sodankylä	67.36	26.64	ENF	2001-2014	-
IT-CA1	Castel d'Asso 1	42.38	12.03	DBF	2011-2014	(Beringer et al. 2016)
IT-CA3	Castel d'Asso 3	42.38	12.02	DBF	2011-2014	(Beringer et al. 2016)
IT-Col	Collelongo	41.85	13.59	DBF	1996-2014	(Stoy et al. 2013)
IT-Cp2	Castelporziano 2	41.70	12.36	EBF	2012-2014	-

IT-Cpz	Castelporziano	41.71	12.38	EBF	1997-2009	(Wei et al. 2014)
IT-La2	Lavarone2	45.95	11.29	ENF	2000-2002	-
IT-Lav	Lavarone	45.96	11.28	ENF	2003-2014	(Fiora and Cescatti 2006)
IT-MBo	Monte Bondone	46.01	11.05	GRA	2003-2013	(Marcolla et al. 2011)
IT-Noe	Arca di Noé - Le Prigionette	40.61	8.15	COSH	2004-2014	(Beier et al. 2009)
IT-PT1	Parco Ticino forest	45.20	9.06	DBF	2002-2004	(Migliavacca et al. 2009)
IT-Ren	Renon	46.59	11.43	ENF	1998-2013	(Marcolla et al. 2005)
IT-Ro2	Roccarespampani 2	42.39	11.92	DBF	2002-2012	(Tedeschi et al. 2006)
IT-SR2	San Rossore 2	43.73	10.29	ENF	2013-2014	-
IT-SRo	San Rossore	43.73	10.28	ENF	1999-2012	(Chiesi et al. 2005)
IT-Tor	Torgnon	45.84	7.58	GRA	2008-2014	(Galvagno et al. 2013)
IT-Isp	Ispra ABC-IS	45.81	8.63	DBF	2013-2014	(Kazantzidis et al. 2006)
JP-MBF	Moshiri Birch Forest Site	44.39	142.32	DBF	2003-2005	(Chen et al. 2015)
JP-SMF	Seto Mixed Forest Site	35.26	137.08	MF	2002-2006	-
NL-Hor	Horstermeer	52.24	5.07	GRA	2004-2011	-
NL-Loo	Loobos	52.17	5.74	ENF	1996-2013	(Dolman et al. 2002)
RU-Fyo	Fyodorovskoye	56.46	32.92	ENF	1998-2014	(Kurbatova et al. 2008)
RU-Ha1	Hakasia steppe	54.73	90.00	GRA	2002-2004	-
SD-Dem	Demokeya	13.28	30.48	SAV	2005-2009	(Sjostrom et al. 2009)
SN-Dhr	Dahra	15.40	-15.43	SAV	2010-2013	(Tagesson et al. 2015)
US-AR1	ARM USDA UNL OSU Woodward Switchgrass 1	36.43	-99.42	GRA	2009-2012	-
US-AR2	ARM USDA UNL OSU Woodward Switchgrass 2	36.64	-99.60	GRA	2009-2012	-
US-ARb	ARM Southern Great Plains burn site- Lamont	35.55	-98.04	GRA	2005-2006	(Stoy et al. 2013)

US-ARc	ARM Southern Great Plains control site-Lamont	35.55	-98.04	GRA	2005-2006	(Stoy et al. 2013)
US-Blo	Blodgett Forest	38.90	-120.63	ENF	1997-2007	(Misson et al. 2005)
US-Cop	Corral Pocket	38.09	-109.39	GRA	2006-2007	(Bowling et al. 2011)
US-GLE	GLEES	41.37	-106.24	ENF	2004-2014	(Massman 2000)
US-Ha1	Harvard Forest EMS Tower (HFR1)	42.54	-72.17	DBF	1991-2012	(Urbanski et al. 2007)
US-KS2	Kennedy Space Center (scrub oak)	28.61	-80.67	COSH	2003-2006	(Wu et al. 2011)
US-Los	Lost Creek	46.08	-89.98	WET	2000-2014	(Sulman et al. 2009)
US-MMS	Morgan Monroe State Forest	39.32	-86.41	DBF	1999-2014	(Schmid et al. 2000)
US-Me1	Metolius - Eyerly burn	44.58	-121.50	ENF	2004-2005	(Irvine et al. 2007)
US-Me2	Metolius mature ponderosa pine	44.45	-121.56	ENF	2002-2014	(Kwon et al. 2018)
US-Me6	Metolius Young Pine Burn	44.32	-121.61	ENF	2010-2014	(Kwon et al. 2018)
US-Myb	Mayberry Wetland	38.05	-121.77	WET	2010-2014	(Knox et al. 2017)
US-NR1	Niwot Ridge Forest (LTER NWT1)	40.03	-105.55	ENF	1998-2014	(Monson et al. 2002)
US-Ne1	Mead - irrigated continuous maize site	41.17	-96.48	CRO	2001-2013	(Suyker et al. 2005)
US-Ne2	Mead - irrigated maize-soybean rotation site	41.16	-96.47	CRO	2001-2013	(Suyker et al. 2005)
US-Ne3	Mead - rainfed maize-soybean rotation site	41.18	-96.44	CRO	2001-2013	(Suyker et al. 2004)
US-ORv	Olentangy River Wetland Research Park	40.02	-83.02	WET	2011	(Mitsch et al. 2005)
US-PFa	Park Falls/WLEF	45.95	-90.27	MF	1995-2014	(Davis et al. 2003)
US-Prr	Poker Flat Research Range	65.12	-147.49	ENF	2010-2013	(Chen et al. 2018)

	Black Spruce Forest					
US-SRG	Santa Rita Grassland	31.79	-110.83	GRA	2008-2014	(Crow et al. 2015)
US-SRM	Santa Rita Mesquite	31.82	-110.87	WSA	2004-2014	(Scott et al. 2009)
US-Syv	Sylvania Wilderness Area	46.24	-89.35	MF	2001-2014	(Desai et al. 2005)
US-Ton	Tonzi Ranch	38.43	-120.97	WSA	2001-2014	(Xu et al. 2004)
US-Tw1	Twitchell Wetland West Pond	38.11	-121.65	WET	2012-2014	(Baldocchi et al. 2015)
US-Tw2	Twitchell Corn	38.10	-121.64	CRO	2012-2013	(Detto et al. 2011)
US-Tw4	Twitchell East End Wetland	38.10	-121.64	WET	2013-2014	(Hilton et al. 2014)
US-UMB	Univ. of Mich. Biological Station	45.56	-84.71	DBF	2000-2014	(Curtis et al. 2002)
US-UMd	UMBS Disturbance	45.56	-84.70	DBF	2007-2014	(Nave et al. 2011)
US-Var	Vaira Ranch- Ione	38.41	-120.95	GRA	2000-2014	(Ma et al. 2007)
US-WCr	Willow Creek	45.81	-90.08	DBF	1999-2014	(Cook et al. 2004)
US-Whs	Walnut Gulch Lucky Hills Shrub	31.74	-110.05	COSH	2007-2014	(Scott et al. 2006)
US-Wi3	Mature hardwood (MHW)	46.63	-91.10	DBF	2002-2004	(Noormets et al. 2007)
US-Wi4	Mature red pine (MRP)	46.74	-91.17	ENF	2002-2005	(Hilton et al. 2014)
US-Wi6	Pine barrens #1 (PB1)	46.62	-91.30	COSH	2002-2003	(Noormets et al. 2007)
US-Wi9	Young Jack pine (YJP)	46.62	-91.08	ENF	2004-2005	-
US-Wkg	Walnut Gulch Kendall Grasslands	31.74	-109.94	GRA	2004-2014	(Scott et al. 2010)

Table. S2 The correlation of R^2 of the relationships between VIs and tower-based GPP with vegetation coverage at the annual scale across all sites. The asterisks - *, ** and *** stand for the significance level $p < 0.05$, $p < 0.01$ and $p < 0.001$, respectively.

	NDVI	**EVI**	**EVI2**	**NDVI$_{_BRDF}$**	**EVI$_{_BRDF}$**	**EVI2$_{_BRDF}$**	**NIR$_V$**	**NIR$_{V,\ BRDF}$**
R	-0.20	-0.05	-0.14	-0.28	-0.20	-0.24	-0.15	-0.16
p	0.06	0.65	0.19	0.01	0.06	0.02	0.17	0.13
significance				**		**		

Table. S3 The correlation of R^2 of the relationships between VIs and tower-based GPP with VPD at the annual scale across all sites. The asterisks - *, ** and *** stand for the significance level $p < 0.05$, $p < 0.01$ and $p < 0.001$, respectively.

	NDVI	**EVI**	**EVI2**	**NDVI$_{_BRDF}$**	**EVI$_{_BRDF}$**	**EVI2$_{_BRDF}$**	**NIR$_V$**	**NIR$_{V,\ BRDF}$**
R	0.48	0.26	0.29	0.52	0.44	0.46	0.32	0.37
p	0.00001	0.0130	0.0061	0.0001	0.00001	0.0001	0.0006	0.0004
significance	***	*	***	***	***	***	***	***

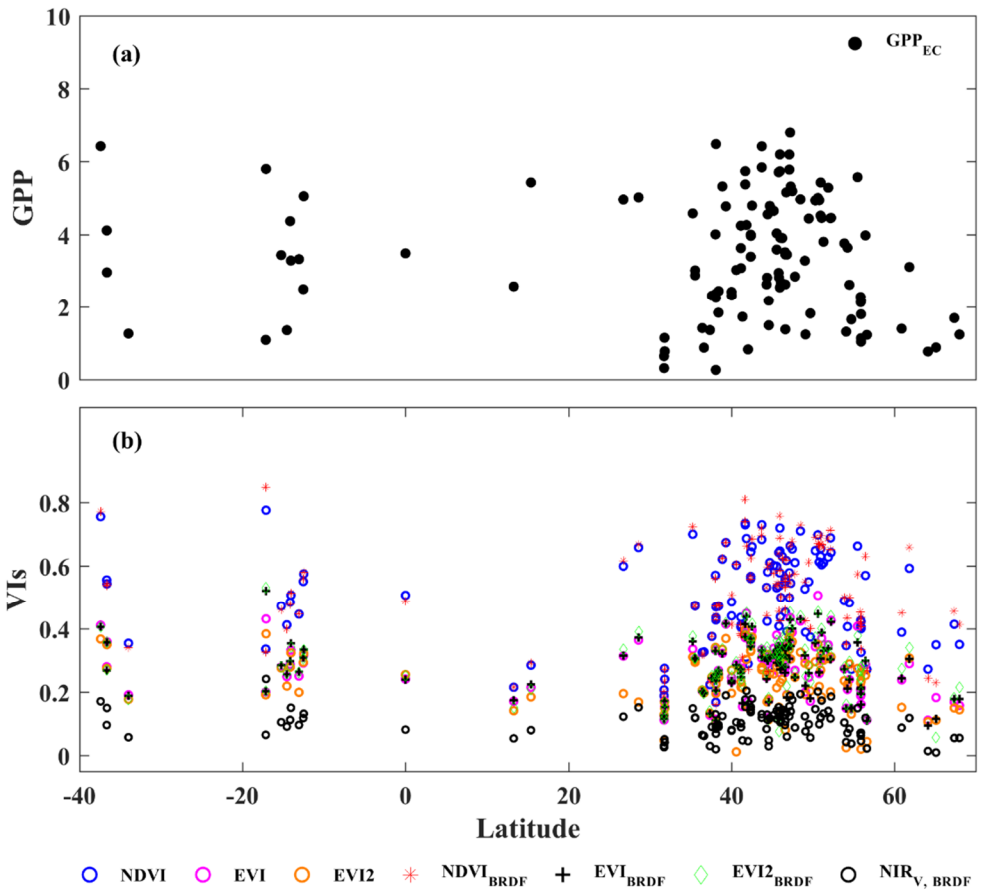

Fig. S1 Flux tower GPP (GPP_{EC}) and MODIS-derived VIs against latitude: (a) GPP; (b) VIs. There are no significant relationships between VIs (GPP) and latitude.

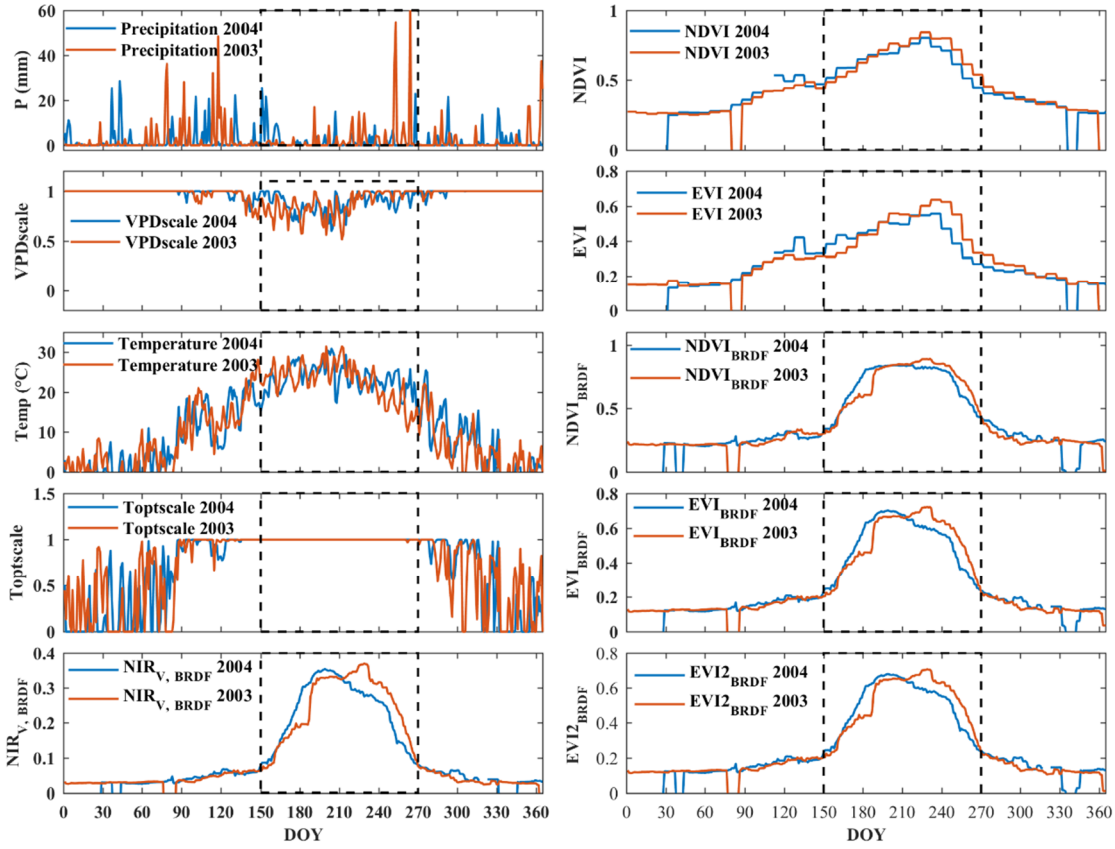

Fig. S2 Daily VIs, temperature, precipitation, temperature stress (f_{Topt}) and water stress (f_{VPD}) in croplands site (US-Ne1) in a normal period from August to September in 2003 and a drought period from June to July in 2004.

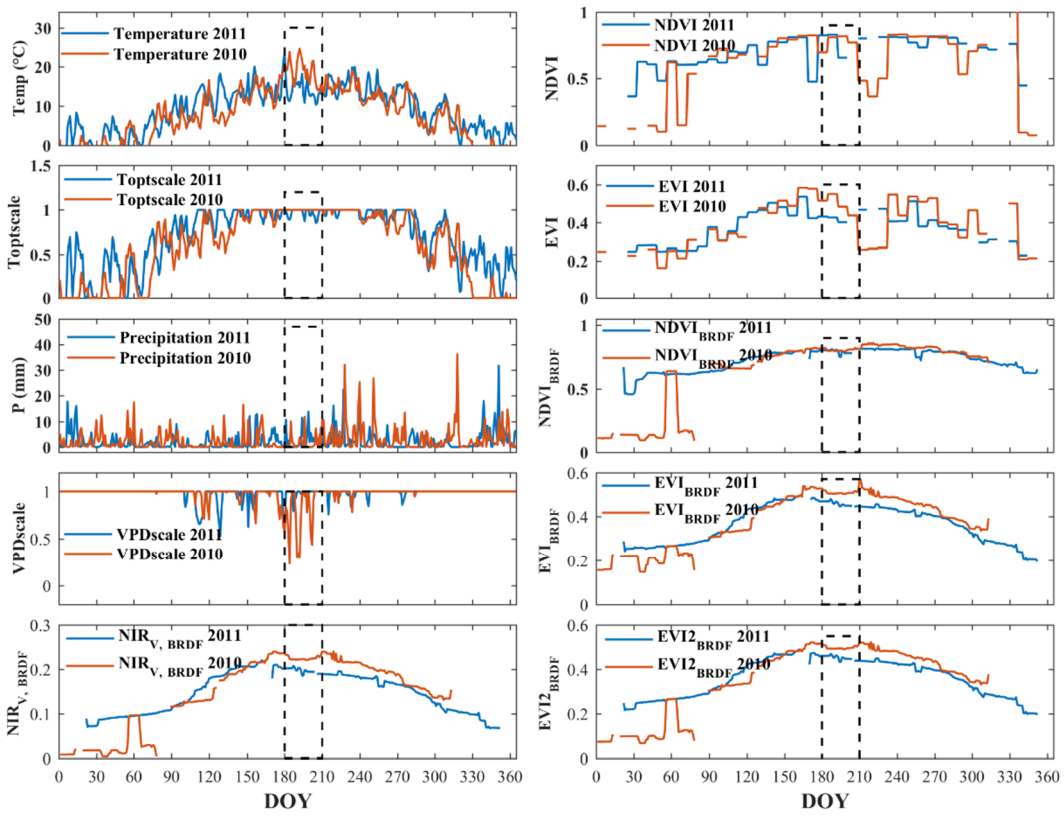

Fig. S3 Daily VIs, temperature, precipitation, temperature stress (f_{Topt}) and water stress (f_{VPD}) at mixed forest site (BE-Vie) in a normal year (2010) and a low temperature year (2011).

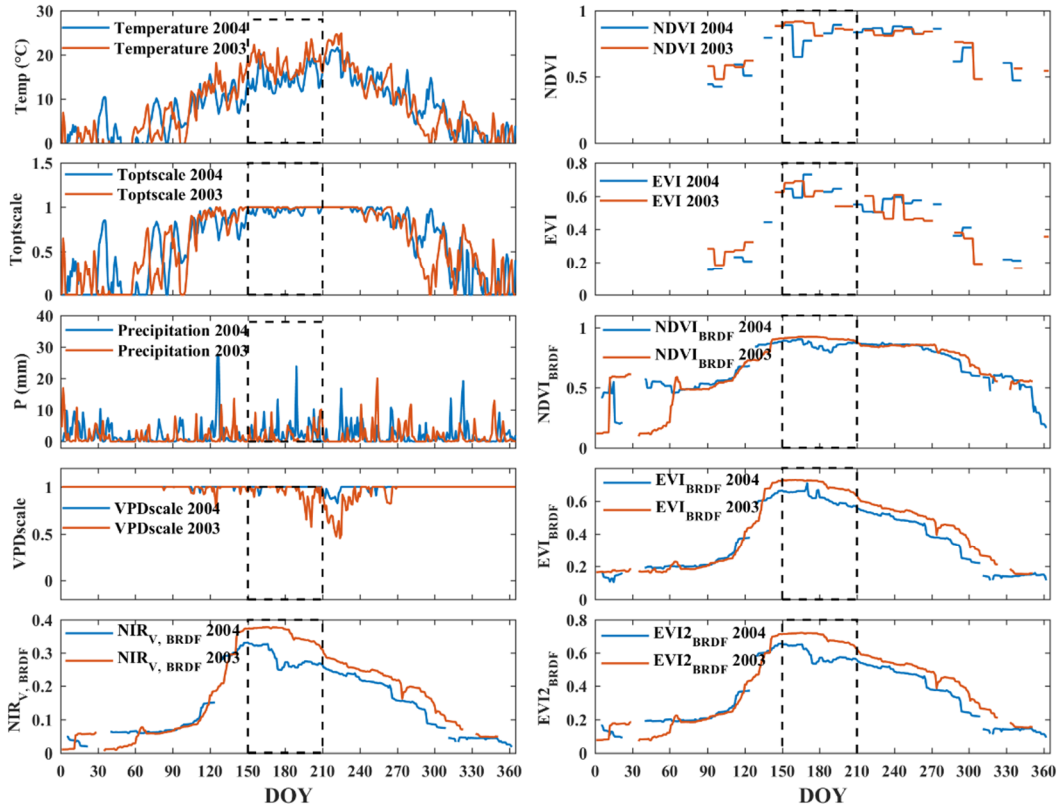

Fig. S4 Daily VIs, temperature, precipitation, temperature stress (f_{Topt}) and water stress (f_{VPD}) in deciduous broadleaf forest site (DE-Hai) in a normal year (2003) and a relative low temperature year (2004).

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