

Supplementary Material

Table S1. List of abbreviations and variables used.

Abbreviation	Description
AVC	aggregated vegetation classes; all vegetation classes aggregated
CRO	crop
CV	Coefficient of variation
DBF	deciduous broadleaf forests
DCF	daily mean correction factor
EBF	evergreen broadleaf forests
ENF	evergreen needleleaf forest
FWHM	full-width half-maximum
GLM	Generalized linear model
GPP	gross primary productivity
GRA	grasslands
IDL	Interactive Data Language
IGBP	International Geosphere Biosphere Programme
LAI	leaf area index
LOS	Length of season
LST	local standard time
LUE	light use efficiency
MF	mixed forest
MMA	Ministério do Meio Ambiente
NPQ	non-photochemical quenching
OCO-2	Orbiting Carbon Observatory-2
OSH	open shrubland
R	R programming language
SAV	Savannas
SIF	solar-induced fluorescence
SIF _d	SIF with DCF applied; daily average SIF
SIF _{inst}	instantaneous solar-induced fluorescence
SIF _{xxxnm}	SIF measured at wavelength xxxnm
SZA	solar zenith angle
T	temperature
T _{air}	air temperature

T_{can}	canopy temperature
TIMESAT	TIMESAT software for seasonality
VI	reflectance-based vegetation index
VPD	vapor pressure deficit
WSAV	woody savannas

Table S2. IGBP classification and descriptions [1].

Class	Class name	Description
1	Evergreen needleleaf forests	Lands dominated by needleleaf woody vegetation with a percent cover >60% and height exceeding 2 m. Almost all trees remain green all year. Canopy is never without green foliage.
2	Evergreen broadleaf forests	Lands dominated by broadleaf woody vegetation with a percent cover >60% and height exceeding 2 m. Almost all trees and shrubs remain green year round. Canopy is never without green foliage.
3	Deciduous needleleaf forests	Lands dominated by woody vegetation with a percent cover >60% and height exceeding 2 m. Consists of seasonal needleleaf tree communities with an annual cycle of leaf-on and leaf-off periods.
4	Deciduous broadleaf forests	Lands dominated by woody vegetation with a percent cover >60% and height exceeding 2 m. Consists of broadleaf tree communities with an annual cycle of leaf-on and leaf-off periods.
5	Mixed forests	Lands dominated by trees with a percent cover >60% and height exceeding 2 m. Consists of tree communities with interspersed mixtures or mosaics of the other four forest types. None of the forest types exceeds 60% of landscape.
6	Closed shrublands	Lands with woody vegetation less than 2 m tall and with shrub canopy cover >60%. The shrub foliage can be either evergreen or deciduous.
7	Open shrublands	Lands with woody vegetation less than 2 m tall and with shrub canopy cover between 10% and 60%. The shrub foliage can be either evergreen or deciduous.
8	Woody savannas	Lands with herbaceous and other understory systems, and with forest canopy cover between 30% and 60%. The forest cover height exceeds 2 m.
9	Savannas	Lands with herbaceous and other understory systems, and with forest canopy cover between 10% and 30%. The forest cover height exceeds 2 m.
10	Grasslands	Lands with herbaceous types of cover. Tree and shrub cover is less than 10%.
11	Permanent wetlands	Lands with a permanent mixture of water and herbaceous or woody vegetation. The vegetation can be present either in salt, brackish, or fresh water.
12	Croplands	Lands covered with temporary crops followed by harvest and a bare soil period (e.g., single and multiple cropping systems). Note that perennial woody crops will be classified as the appropriate forest or shrub land cover type.
13	Urban and built-up lands	Land covered by buildings and other man-made structures.
14	Cropland/natural vegetation mosaics	Lands with a mosaic of croplands, forests, shrubland, and grasslands in which no one component comprises more than 60% of the landscape.
15	Snow and ice	Lands under snow/ice cover throughout the year.
16	Barren	Lands with exposed soil, sand, rocks, or snow and never have more than 10% vegetated cover during any time of the year.
17	Water bodies	Oceans, seas, lakes, reservoirs, and rivers. Can be either fresh or salt- water bodies.

Table S3. Table of values for the distribution of SIF observations by biome and vegetation class: number of OCO-2 footprints, Area covered by Footprints, and percent of biome and percent of Brazil.

Biome	Vegetation Class	Number of OCO-2 footprints	Area Covered by Footprints	% Biome footprints	% Brazil footprints
Amazon	NA/LOWQ	13724	37466.52	1.91	1.31
Amazon	ENF	2875	7848.75	0.40	0.27
Amazon	EBF	613499	1674852.27	85.52	58.41
Amazon	DBF	843	2301.39	0.12	0.08
Amazon	MF	2150	5869.5	0.30	0.20
Amazon	CSH	640	1747.2	0.09	0.06
Amazon	OSH	3489	9524.97	0.49	0.33
Amazon	WSAV	11368	31034.64	1.58	1.08
Amazon	SAV	51092	139481.16	7.12	4.86
Amazon	GRA	9851	26893.23	1.37	0.94
Amazon	PW	2003	5468.19	0.28	0.19
Amazon	CROP	405	1105.65	0.06	0.04
Amazon	UBU	174	475.02	0.02	0.02
Amazon	CNVM	4625	12626.25	0.64	0.44
Amazon	SNOW	0	0	0.00	0.00
Amazon	BAR	597	1629.81	0.08	0.06
Atlantic_Forest	NA/LOWQ	306	835.38	1.69	0.03
Atlantic_Forest	ENF	37	101.01	0.20	0.00
Atlantic_Forest	EBF	2624	7163.52	14.47	0.25
Atlantic_Forest	DBF	263	717.99	1.45	0.03
Atlantic_Forest	MF	32	87.36	0.18	0.00
Atlantic_Forest	CSH	67	182.91	0.37	0.01
Atlantic_Forest	OSH	218	595.14	1.20	0.02
Atlantic_Forest	WSAV	2335	6374.55	12.88	0.22
Atlantic_Forest	SAV	5567	15197.91	30.70	0.53
Atlantic_Forest	GRA	1867	5096.91	10.30	0.18
Atlantic_Forest	PW	43	117.39	0.24	0.00
Atlantic_Forest	CROP	1267	3458.91	6.99	0.12
Atlantic_Forest	UBU	93	253.89	0.51	0.01
Atlantic_Forest	CNVM	3356	9161.88	18.51	0.32
Atlantic_Forest	SNOW	0	0	0.00	0.00
Atlantic_Forest	BAR	59	161.07	0.33	0.01
Caatinga	NA/LOWQ	1268	3461.64	0.85	0.12

Caatinga	ENF	47	128.31	0.03	0.00
Caatinga	EBF	2126	5803.98	1.42	0.20
Caatinga	DBF	2721	7428.33	1.82	0.26
Caatinga	MF	40	109.2	0.03	0.00
Caatinga	CSH	5786	15795.78	3.88	0.55
Caatinga	OSH	25673	70087.29	17.20	2.44
Caatinga	WSAV	23272	63532.56	15.59	2.22
Caatinga	SAV	63687	173865.51	42.68	6.06
Caatinga	GRA	19077	52080.21	12.78	1.82
Caatinga	PW	15	40.95	0.01	0.00
Caatinga	CROP	1338	3652.74	0.90	0.13
Caatinga	UBU	167	455.91	0.11	0.02
Caatinga	CNVM	3621	9885.33	2.43	0.34
Caatinga	SNOW	0	0	0.00	0.00
Caatinga	BAR	397	1083.81	0.27	0.04
Cerrado	NA/LOWQ	487	1329.51	0.31	0.05
Cerrado	ENF	38	103.74	0.02	0.00
Cerrado	EBF	17487	47739.51	11.11	1.66
Cerrado	DBF	1291	3524.43	0.82	0.12
Cerrado	MF	137	374.01	0.09	0.01
Cerrado	CSH	742	2025.66	0.47	0.07
Cerrado	OSH	4514	12323.22	2.87	0.43
Cerrado	WSAV	25645	70010.85	16.30	2.44
Cerrado	SAV	82187	224370.51	52.23	7.82
Cerrado	GRA	8169	22301.37	5.19	0.78
Cerrado	PW	82	223.86	0.05	0.01
Cerrado	CROP	3645	9950.85	2.32	0.35
Cerrado	UBU	26	70.98	0.02	0.00
Cerrado	CNVM	12483	34078.59	7.93	1.19
Cerrado	SNOW	0	0	0.00	0.00
Cerrado	BAR	424	1157.52	0.27	0.04
Pampa	NA/LOWQ	50	136.5	1.77	0.00
Pampa	ENF	10	27.3	0.35	0.00
Pampa	EBF	187	510.51	6.61	0.02
Pampa	DBF	52	141.96	1.84	0.00
Pampa	MF	12	32.76	0.42	0.00
Pampa	CSH	36	98.28	1.27	0.00
Pampa	OSH	58	158.34	2.05	0.01
Pampa	WSAV	611	1668.03	21.58	0.06

Pampa	SAV	761	2077.53	26.88	0.07
Pampa	GRA	582	1588.86	20.56	0.06
Pampa	PW	14	38.22	0.49	0.00
Pampa	CROP	151	412.23	5.33	0.01
Pampa	UBU	6	16.38	0.21	0.00
Pampa	CNVM	292	797.16	10.31	0.03
Pampa	SNOW	0	0	0.00	0.00
Pampa	BAR	9	24.57	0.32	0.00
Pantanal	NA/LOWQ	38	103.74	0.69	0.00
Pantanal	ENF	53	144.69	0.97	0.01
Pantanal	EBF	616	1681.68	11.22	0.06
Pantanal	DBF	142	387.66	2.59	0.01
Pantanal	MF	23	62.79	0.42	0.00
Pantanal	CSH	40	109.2	0.73	0.00
Pantanal	OSH	43	117.39	0.78	0.00
Pantanal	WSAV	765	2088.45	13.94	0.07
Pantanal	SAV	2612	7130.76	47.59	0.25
Pantanal	GRA	804	2194.92	14.65	0.08
Pantanal	PW	162	442.26	2.95	0.02
Pantanal	CROP	13	35.49	0.24	0.00
Pantanal	UBU	1	2.73	0.02	0.00
Pantanal	CNVM	172	469.56	3.13	0.02
Pantanal	SNOW	0	0	0.00	0.00
Pantanal	BAR	4	10.92	0.07	0.00

Table S4. Vegetation class-specific mean SIF_d for each biome.

Biome	Vegetation Class	Mean SIF _d
Amazon	DBF	0.30
Atlantic_Forest	DBF	0.23
Caatinga	DBF	0.14
Cerrado	DBF	0.24
Pampa	DBF	0.18
Pantanal	DBF	0.28
Amazon	EBF	0.38
Atlantic_Forest	EBF	0.30
Caatinga	EBF	0.28
Cerrado	EBF	0.32
Pampa	EBF	0.26
Pantanal	EBF	0.32
Amazon	GRA	0.26

Atlantic_Forest	GRA	0.25
Caatinga	GRA	0.14
Cerrado	GRA	0.20
Pampa	GRA	0.23
Pantanal	GRA	0.22
Amazon	SAV	0.32
Atlantic_Forest	SAV	0.25
Caatinga	SAV	0.16
Cerrado	SAV	0.23
Pampa	SAV	0.27
Pantanal	SAV	0.25
Amazon	WSAV	0.31
Atlantic_Forest	WSAV	0.25
Caatinga	WSAV	0.15
Cerrado	WSAV	0.22
Pampa	WSAV	0.25
Pantanal	WSAV	0.26

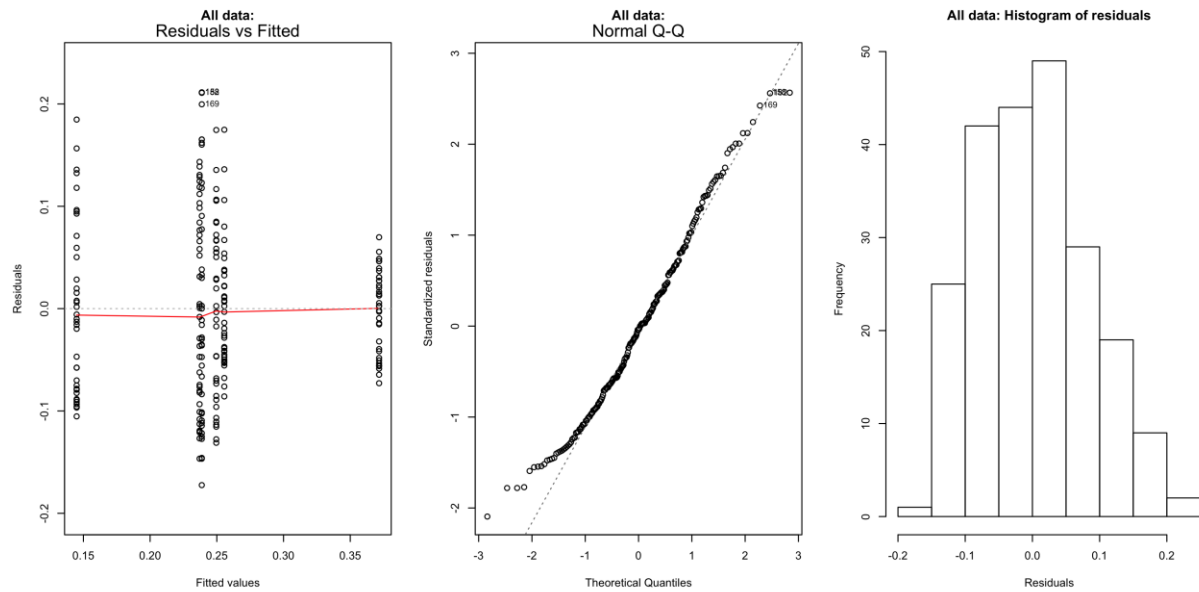


Figure S1. Plots of residuals for all OCO-2 SIF data examination for normality. L to R: Residuals vs. Fitted, q-q plot, histogram of residuals.

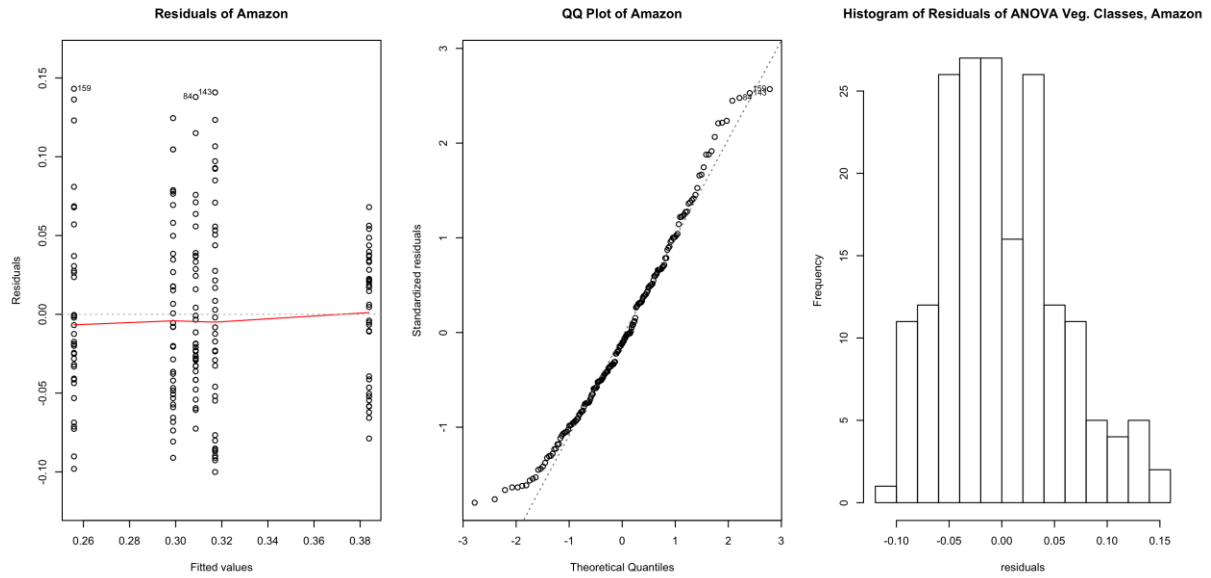


Figure S2. Plots of residuals for Amazon biome OCO-2 SIF data examination for normality. L to R: Residuals vs. Fitted, q-q plot, histogram of residuals.

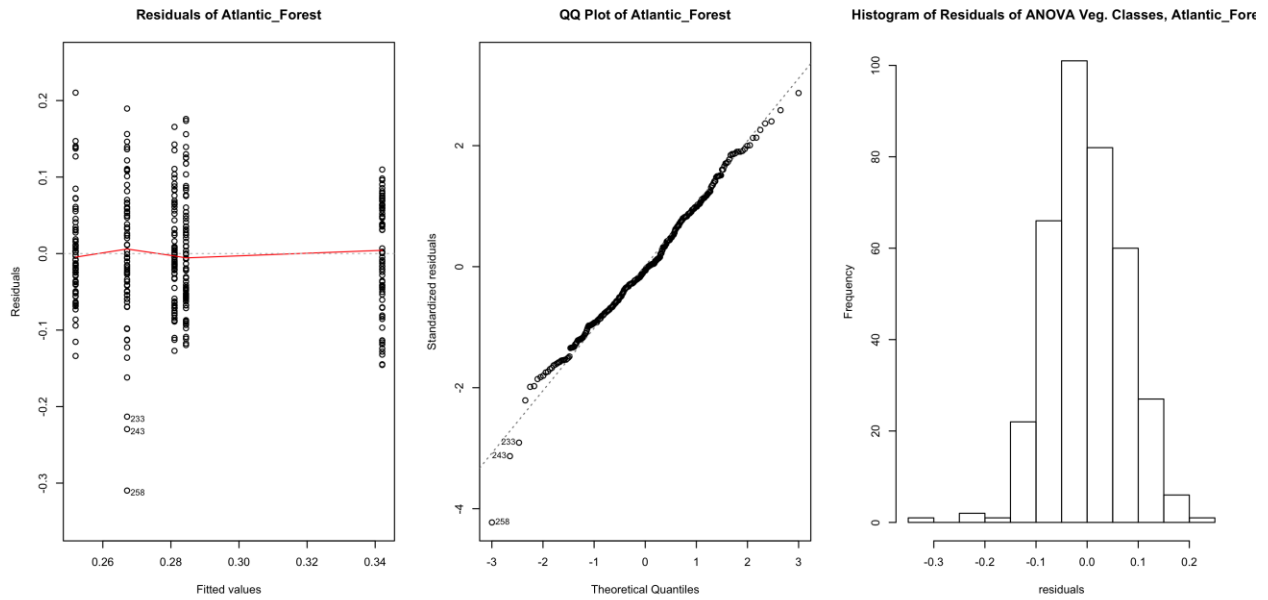


Figure S3. Plots of residuals for Atlantic Forest biome OCO-2 SIF data examination for normality. L to R: Residuals vs. Fitted, q-q plot, histogram of residuals.

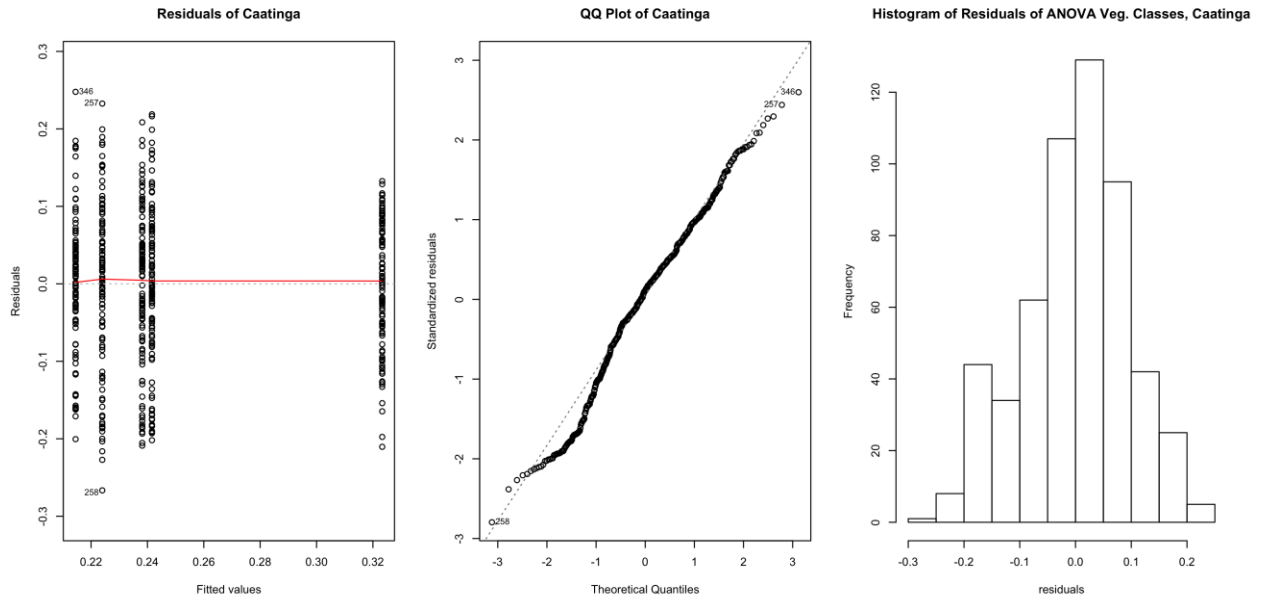


Figure S4. Plots of residuals for Caatinga biome OCO-2 SIF data examination for normality. L to R: Residuals vs. Fitted, q-q plot, histogram of residuals.

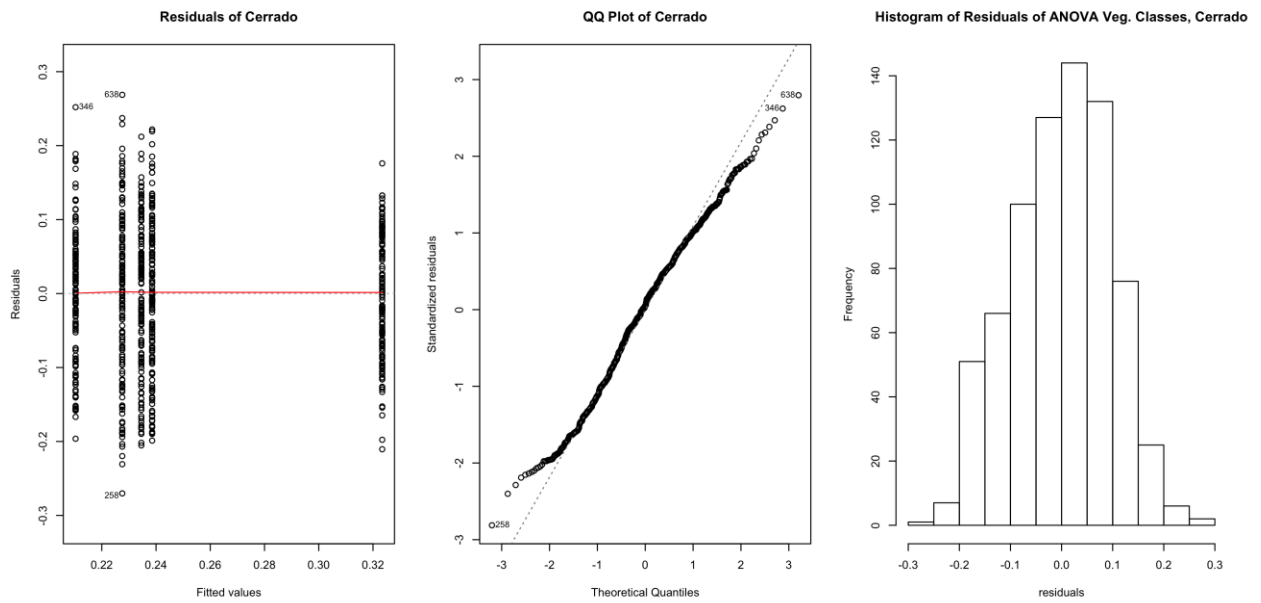


Figure S5. Plots of residuals for Cerrado biome OCO-2 SIF data examination for normality. L to R: Residuals vs. Fitted, q-q plot, histogram of residuals.

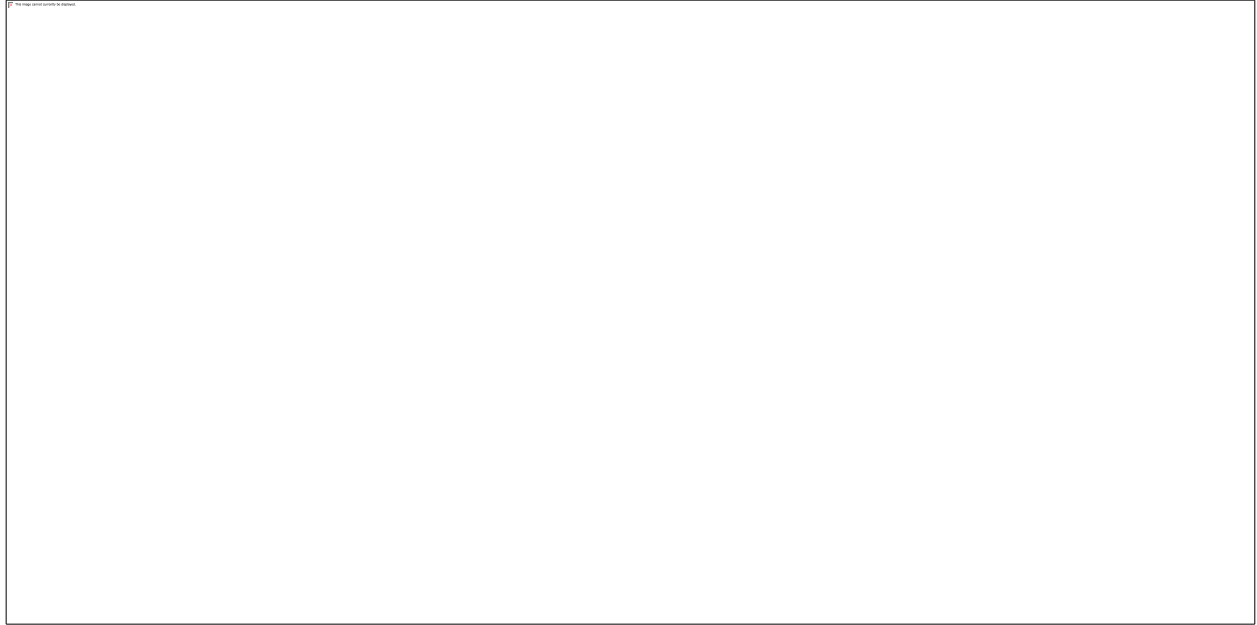


Figure S6. Plots of residuals for Pampa biome OCO-2 SIF data examination for normality. L to R: Residuals vs. Fitted, q-q plot, histogram of residuals.

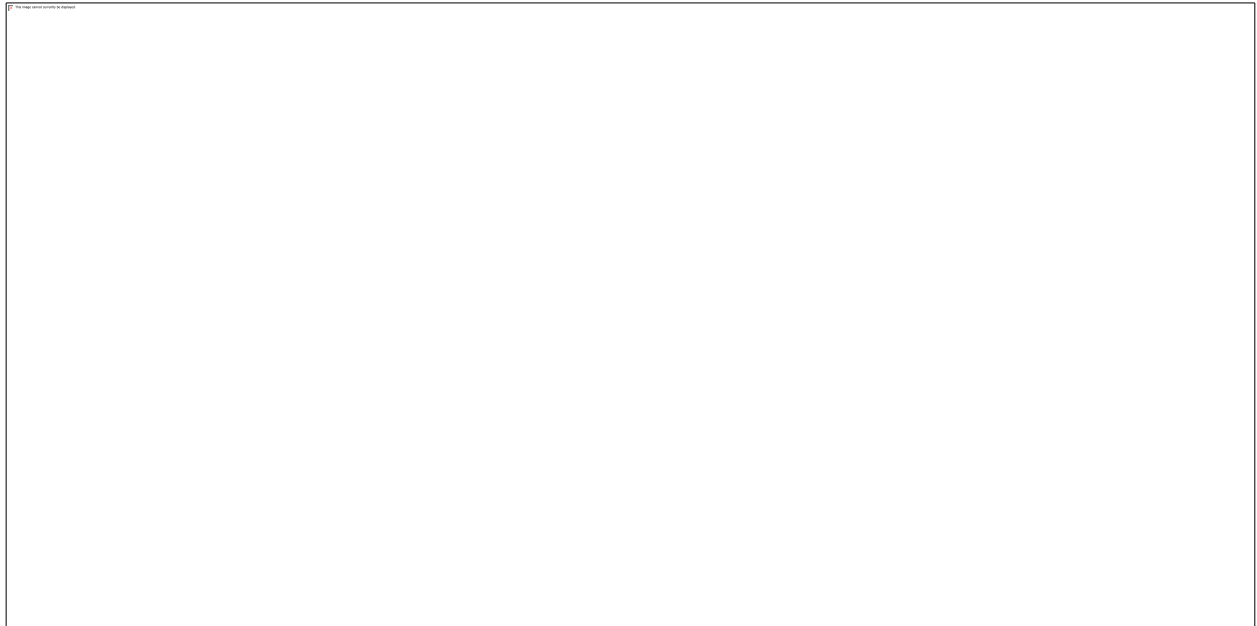


Figure S7. Plots of residuals for Pantanal biome OCO-2 SIF data examination for normality. L to R: Residuals vs. Fitted, q-q plot, histogram of residuals.

Table S5. p-values of post hoc Tukey’s HSD Test for differences in Biome level SIF_d (AVC) across Brazilian Biomes. P-values below significance level of 0.05 are highlighted.

Tukey's HSD Test	Difference in Means	Lower 95% CI	Upper 95% CI	Adjusted p-value
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Atlantic_Forest-Amazon	-0.12	-0.17	-0.06	0.00
Caatinga-Amazon	-0.23	-0.28	-0.17	0.00
Cerrado-Amazon	-0.13	-0.19	-0.08	0.00
Pampa-Amazon	-0.13	-0.19	-0.08	0.00
Pantanal-Amazon	-0.12	-0.18	-0.07	0.00
Caatinga-Atlantic_Forest	-0.11	-0.17	-0.05	0.00
Cerrado-Atlantic_Forest	-0.02	-0.07	0.04	0.93
Pampa-Atlantic_Forest	-0.02	-0.07	0.04	0.95
Pantanal-Atlantic_Forest	-0.01	-0.06	0.05	1.00
Cerrado-Caatinga	0.09	0.04	0.15	0.00
Pampa-Caatinga	0.09	0.04	0.15	0.00
Pantanal-Caatinga	0.10	0.05	0.16	0.00
Pampa-Cerrado	0.00	-0.05	0.06	1.00
Pantanal-Cerrado	0.01	-0.04	0.07	0.99
Pantanal-Pampa	0.01	-0.05	0.07	0.99

Table S6. p-values of Tukey's HSD Test for differences in vegetation class-specific SIF_a across Brazilian Biomes. P-values below significance level of 0.05 are highlighted.

Tukey's HSD Test				
Amazon	DBF	EBF	GRA	SAV
EBF	0.00	NA	NA	NA
GRA	0.01	0.00	NA	NA
SAV	0.64	0.00	0.00	NA
WSAV	0.95	0.00	0.00	0.97
Atlantic Forest	DBF	EBF	GRA	SAV
EBF	0.00	NA	NA	NA
GRA	0.73	0.00	NA	NA
SAV	0.61	0.00	0.06	NA
WSAV	0.78	0.00	0.12	1.00
Caatinga	DBF	EBF	GRA	SAV
EBF	0.00	NA	NA	NA
GRA	0.95	0.00	NA	NA
SAV	0.65	0.00	0.22	NA

WSAV	0.81	0.00	0.35	1.00
Cerrado	DBF	EBF	GRA	SAV
EBF	0.00	NA	NA	NA
GRA	0.54	0.00	NA	NA
SAV	0.86	0.00	0.09	NA
WSAV	0.97	0.00	0.20	1.00
Pampa	DBF	EBF	GRA	SAV
EBF	0.00	NA	NA	NA
GRA	0.98	0.00	NA	NA
SAV	0.21	0.00	0.05	NA
WSAV	0.59	0.00	0.22	0.96
Pantanal	DBF	EBF	GRA	SAV
EBF	0.00	NA	NA	NA
GRA	0.61	0.00	NA	NA
SAV	0.57	0.00	0.03	NA
WSAV	0.85	0.00	0.10	0.99

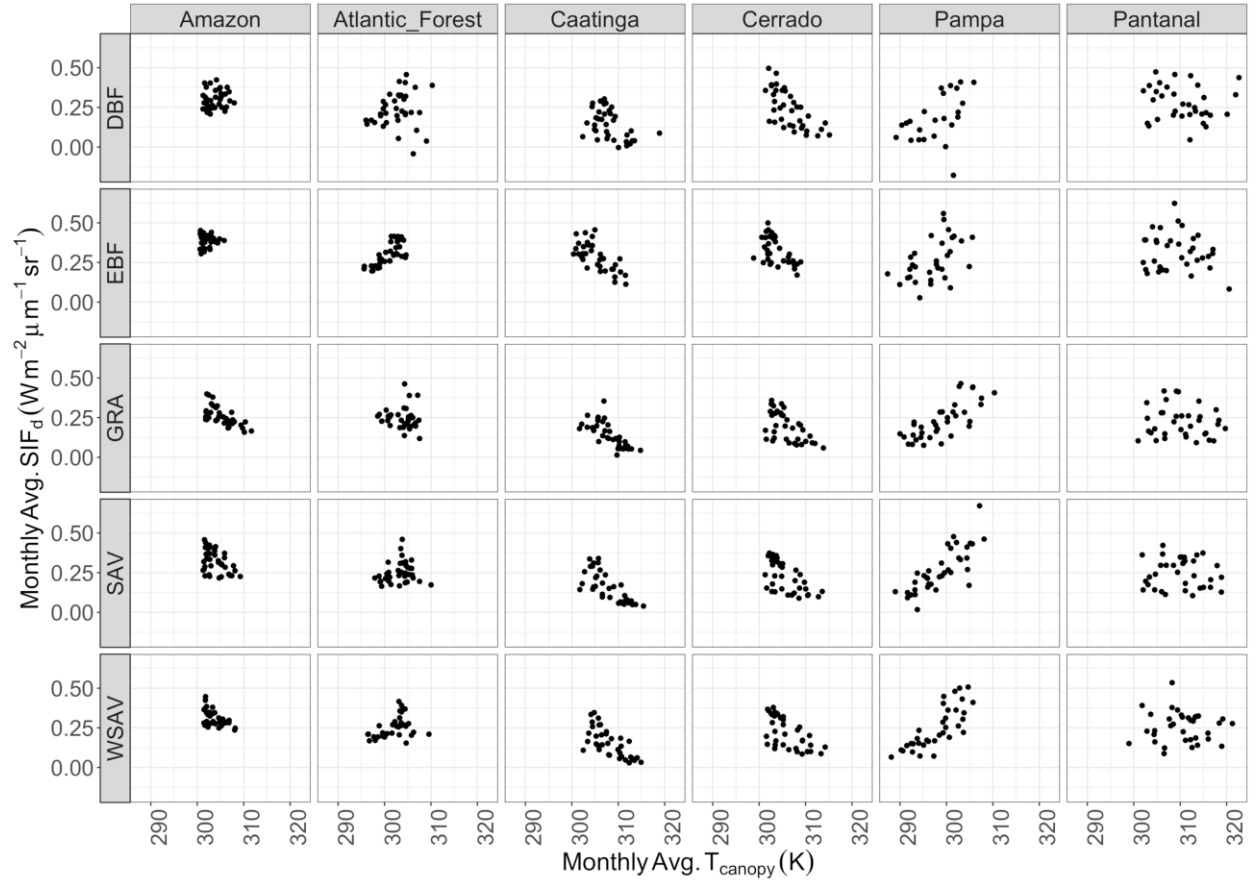


Figure S8. Scatterplots of SIF_d vs. T_{can} for each vegetation class (indicated in each row) in each biome (indicated in each column).

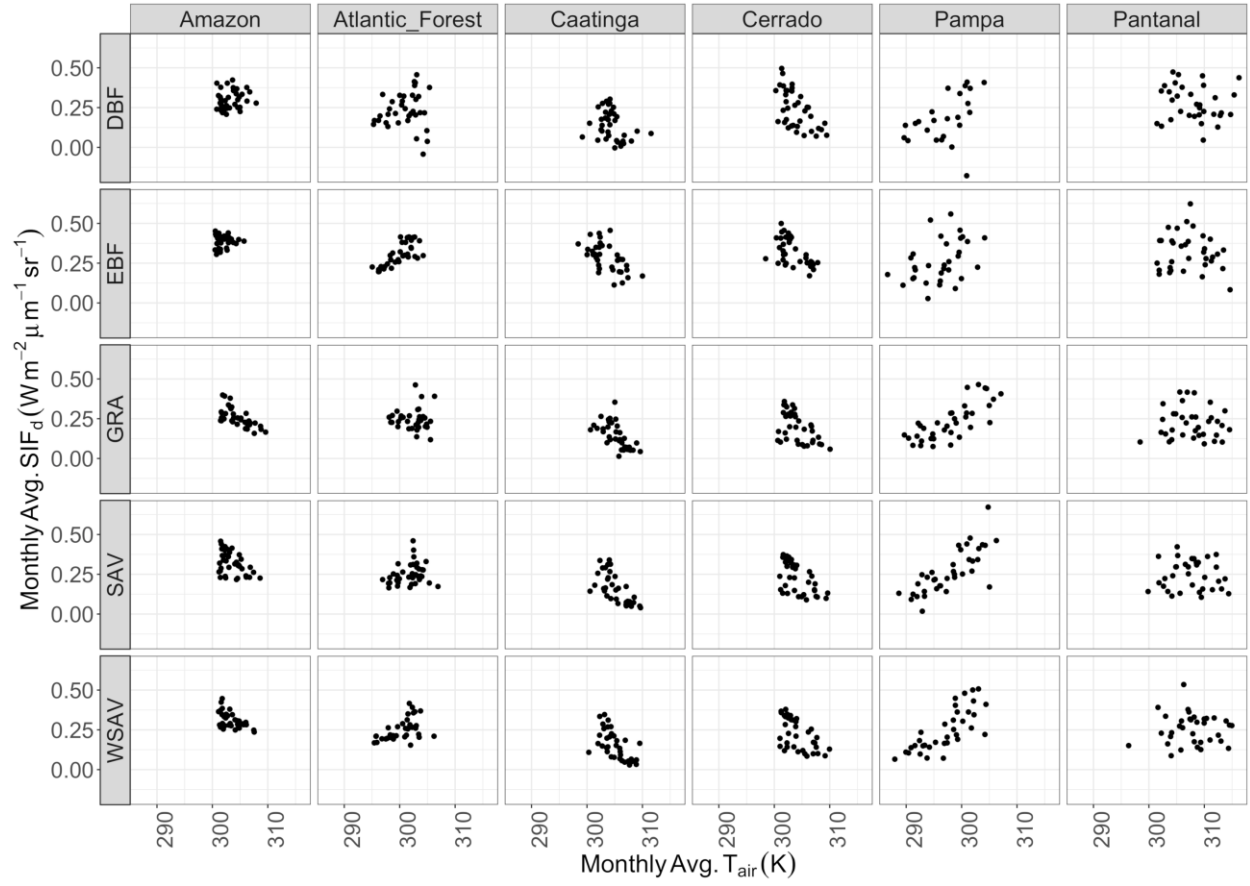


Figure S9. Scatterplots of SIF_d vs. T_{air} for each vegetation class (indicated in each row) in each biome (indicated in each column).

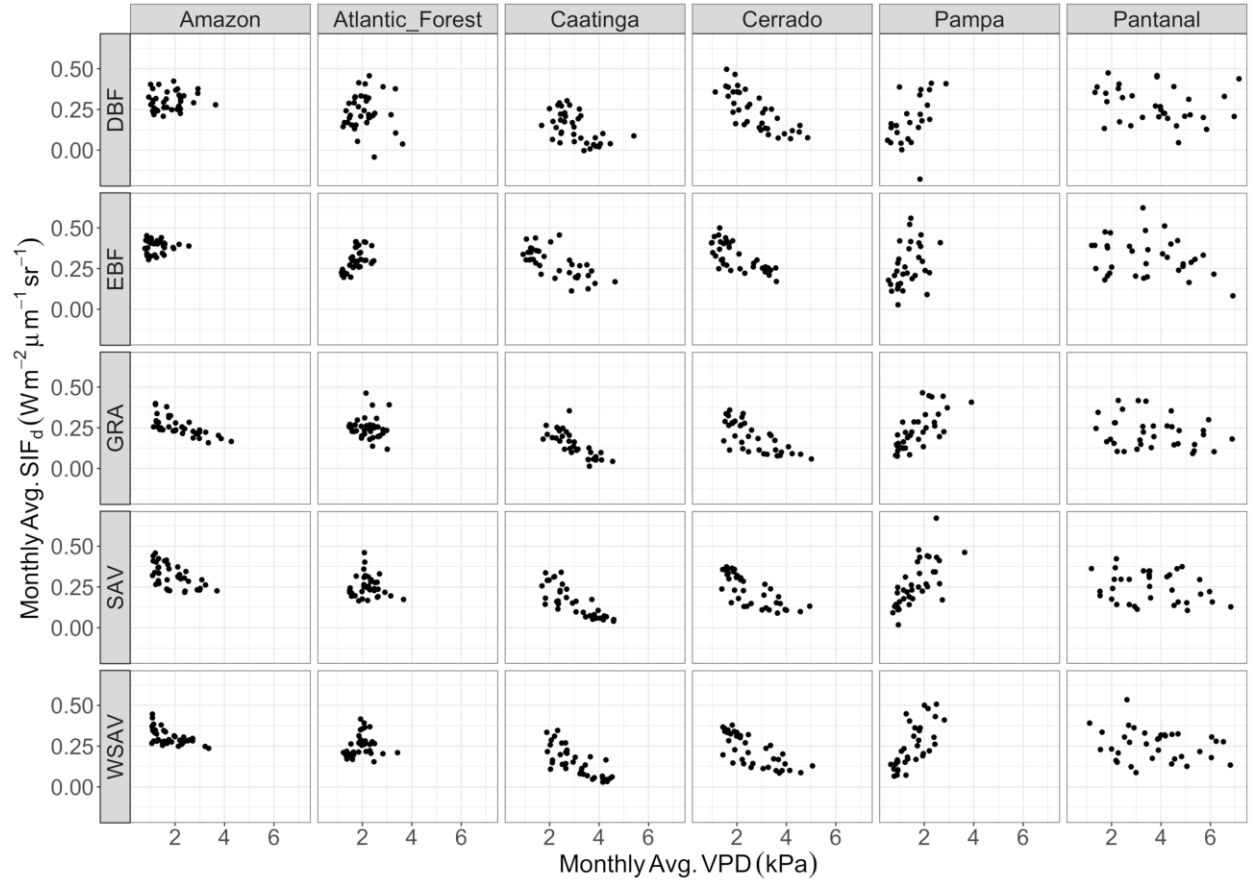


Figure S10. Scatterplots of SIF_d vs. VPD for each vegetation class (indicated in each row) in each biome (indicated in each column).

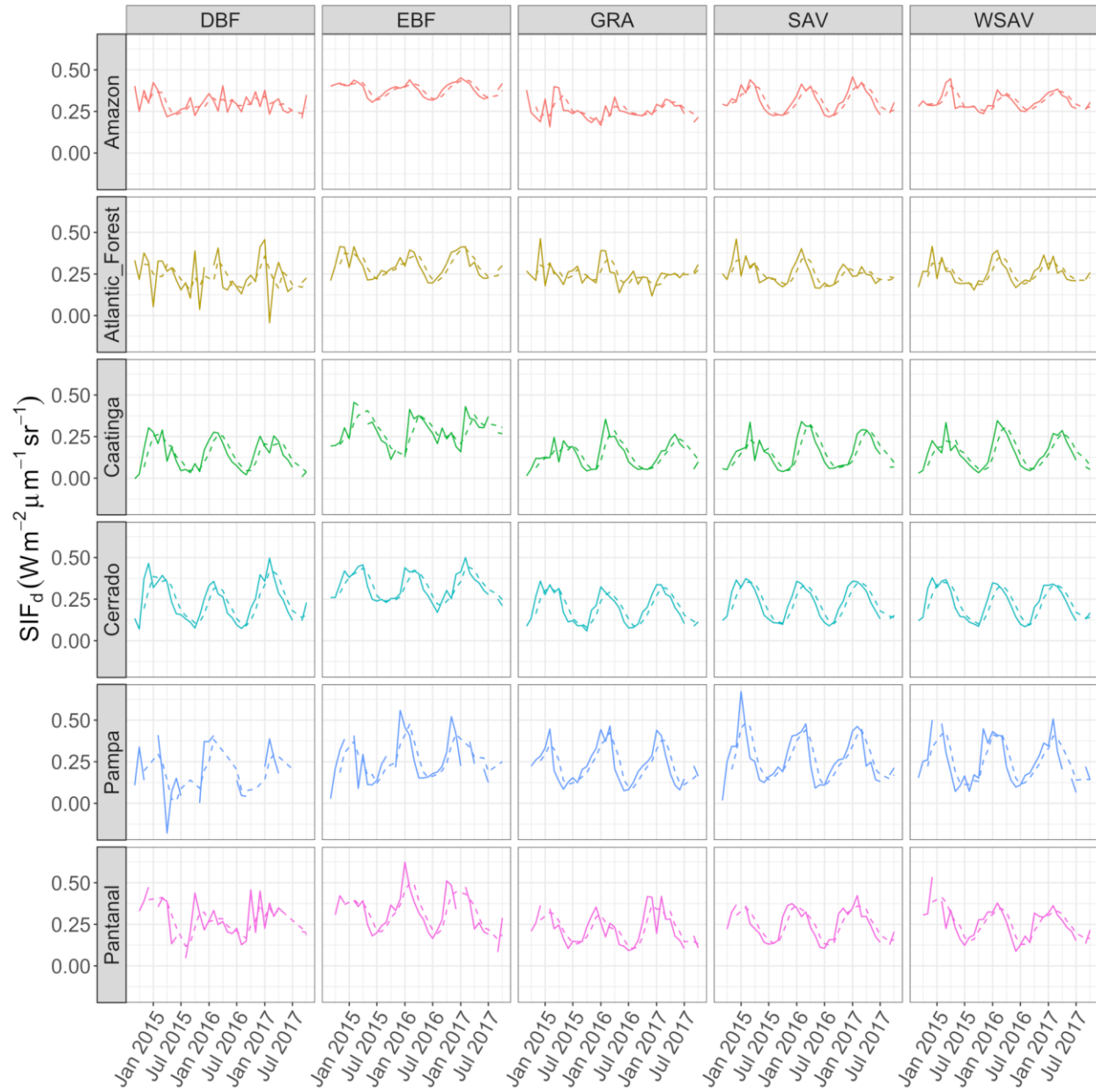


Figure S11. Time series of SIFd for vegetation classes in each biome. Rows correspond to biome: top to bottom-Amazon, Atlantic Forest, Caatinga, Cerrado, Pampa, Pantanal. Columns correspond to vegetation class: Left to Right-DBF, EBF, GRA, SAV, WSAV. Solid lines indicate raw data and dashed lines indicate smoothed data (Moving Average, window=3).

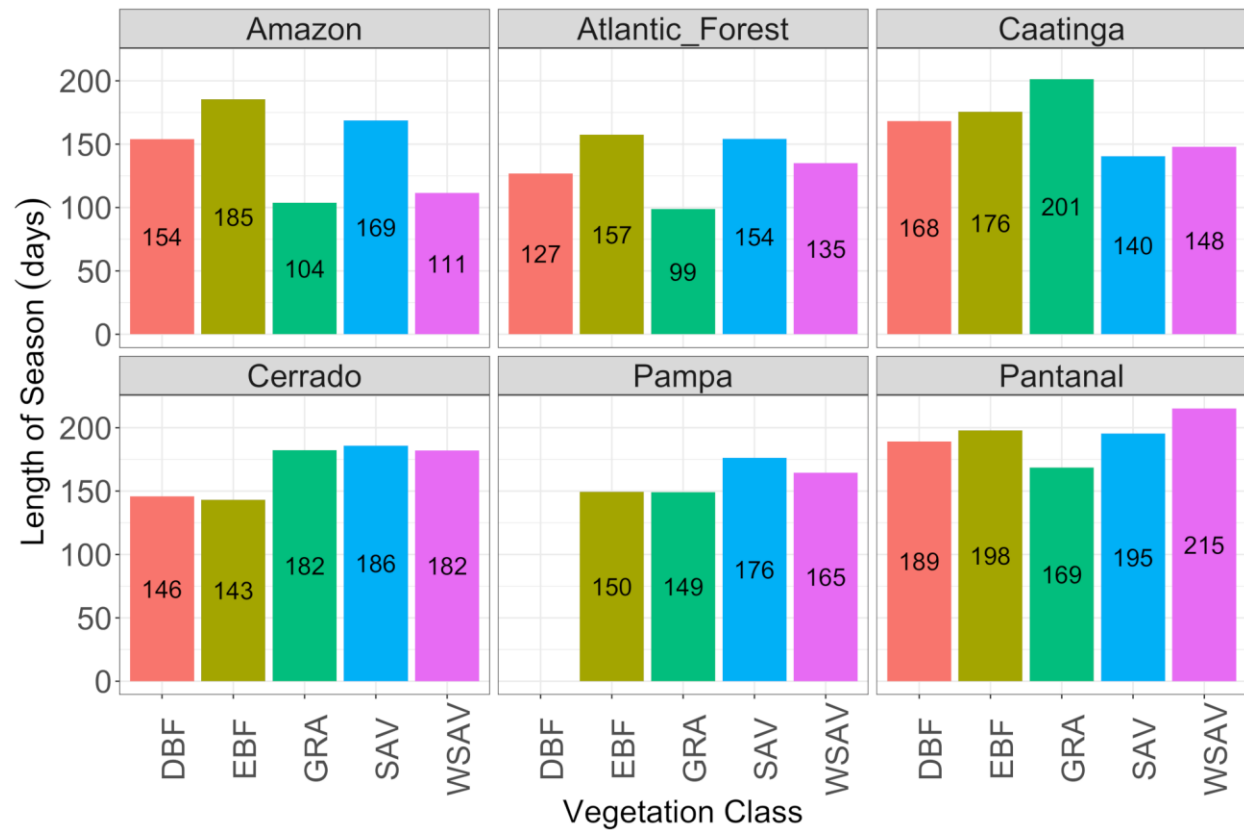


Figure S12. Bar plots of SIF_a length of season of vegetation classes within biomes for the a) Amazon b) Atlantic Forest c) Caatinga d) Cerrado e) Pampa and f) Pantanal. Values for integrated SIF_a are printed on the corresponding bars.

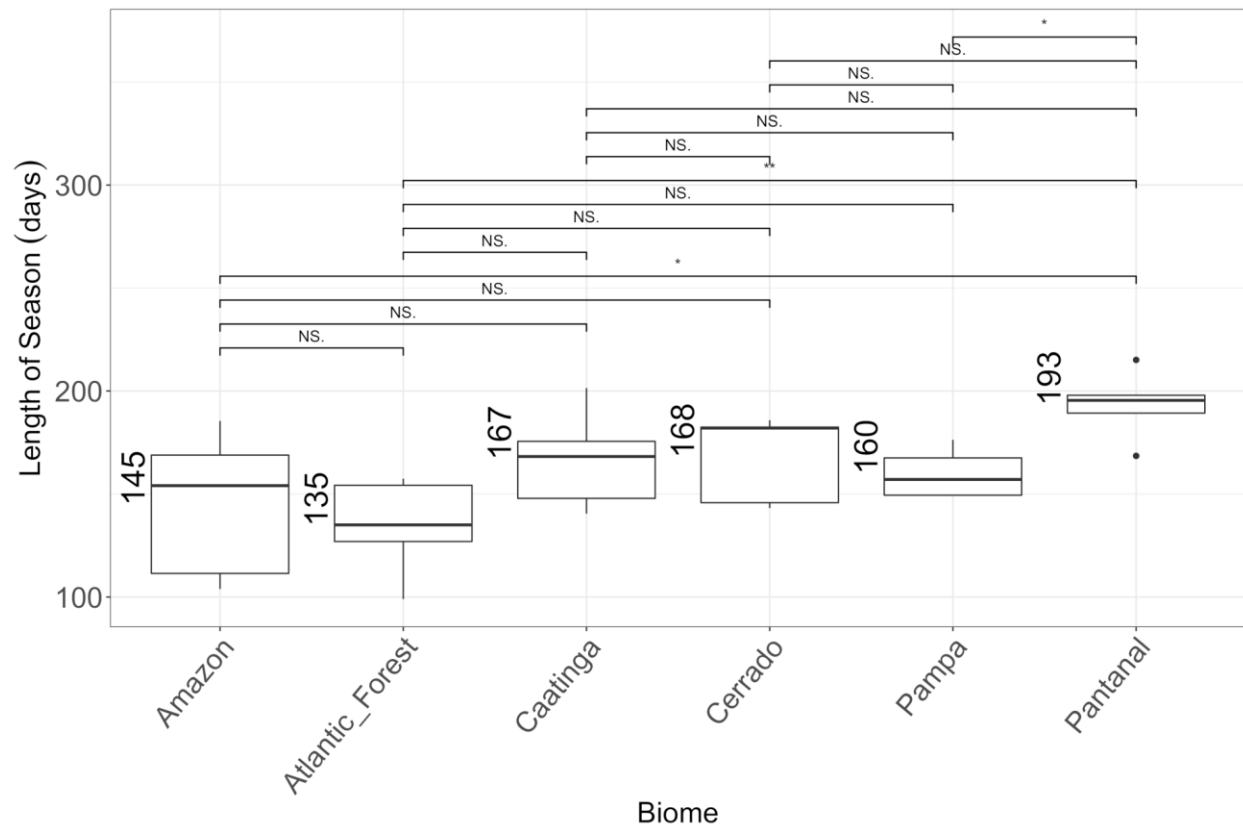


Figure S13. Boxplots of length of season of vegetation classes' SIF_d for biomes a) Amazon b) Atlantic Forest c) Caatinga d) Cerrado e) Pampa and f) Pantanal. Horizontal bars with corresponding p-values indicate significance: ***= $p < 0.001$, **= $p < 0.01$, *= $p < 0.05$, NS>=no significant difference in mean. Boxes represent minimum, 1st quartile, median, 3rd quartile, and maximum values, and the mean value of length of season of vegetation classes' SIF_d is printed vertically to the left of each biomes' box.

References

1. Zhang, X., et al., *Monitoring vegetation phenology using MODIS*. Remote Sensing of Environment, 2003. **84**: p. 5.