Supplementary material for: Modelling sun-induced chlorophyll fluorescence (SIF) in evergreen conifer forests with terrestrial biosphere model QUINCY

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S1 Supplementary tables

Table S1. The r^2 and RMSE values of simulated versus observed red and far-red region SIF values, according to different radiative transfer approaches at US-NR1. The metrics are also shown for GPP, which is from default QUINCY configuration. The morning values are from 6 a.m. to 9:30 a.m., midday values from 10 a.m. to 1:30 p.m. and the afternoon values from 2 p.m. to 5:30 p.m.

Variable (unit) / r^2 (RMSE)	Daily	Morning	Midday	Afternoon
GPP ($\mu\mathrm{mol\,m^{-2}\,s^{-1}}$)	0.80 (1.99)	0.75 (2.65)	0.78 (2.62)	0.69 (2.23)
Red region SIF ($\mathrm{Wm^{-2}s^{-1}nm^{-1}sr^{-1}}$)				
mSCOPE	0.67 (0.29)	0.59 (0.37)	0.68 (0.36)	0.63 (0.24)
L2SM	0.62 (0.30)	0.59 (0.38)	0.62 (0.34)	0.60 (0.26)
LZ	0.63 (0.67)	0.59 (0.80)	0.65 (0.78)	0.58 (0.59)
Upscaled	0.69 (1.95)	0.61 (2.35)	0.70 (2.45)	0.67 (1.59)
Far-red region SIF ($\mathrm{Wm^{-2}s^{-1}nm^{-1}sr^{-1}}$)				
mSCOPE	0.74 (0.28)	0.74 (0.35)	0.76 (0.36)	0.70 (0.25)
L2SM	0.70 (0.37)	0.73 (0.45)	0.69 (0.42)	0.66 (0.33)
LZ	0.73 (1.37)	0.73 (1.61)	0.73 (1.67)	0.66 (1.23)

Table S2. The r^2 and RMSE values of simulated versus observed red and far-red region SIF values, according to different radiative transfer approaches at FI-Sod. The metrics are also shown for GPP, which is from default QUINCY configuration. The morning values are from 6 a.m. to 9:30 a.m., midday values from 10 a.m. to 1:30 p.m. and the afternoon values from 2 p.m. to 5:30 p.m.

Variable (unit) / r^2 (RMSE)	Daily	Morning	Midday	Afternoon
GPP ($\mu\mathrm{mol\,m^{-2}\,s^{-1}}$)	0.90 (0.87)	0.91 (0.99)	0.91 (1.08)	0.91 (1.07)
Red region SIF ($\mathrm{Wm^{-2}s^{-1}nm^{-1}sr^{-1}}$)				
mSCOPE	0.88 (0.13)	0.86 (0.14)	0.81 (0.26)	0.65 (0.16)
L2SM	0.85 (0.33)	0.86 (0.36)	0.81 (0.36)	0.58 (0.35)
LZ	0.82 (0.87)	0.84 (0.95)	0.80 (0.93)	0.57 (0.86)
Upscaled	0.86 (1.78)	0.88 (1.98)	0.82 (1.95)	0.59 (1.79)
Far-red region SIF ($\mathrm{Wm^{-2}s^{-1}nm^{-1}sr^{-1}}$)				
mSCOPE	0.87 (0.20)	0.86 (0.22)	0.79 (0.25)	0.65 (0.21)
L2SM	0.88 (0.36)	0.88 (0.40)	0.82 (0.40)	0.59 (0.36)
LZ	0.87 (1.33)	0.87 (1.40)	0.84 (1.47)	0.59 (1.32)

S2 Supplementary figures

Table S3. Absolute values for different radiative transfer approaches and observations, and overestimation of simulations compared to observations is in parenthesis calculated for July-August midday values (10 a.m. to 1:30 p.m) at the three sites. Overestimation is a relative value, i.e., how many times the simulation is overestimating the measured value.

Values (Overestimation) ($\mathrm{Wm^{-2}s^{-1}nm^{-1}sr^{-1}}$)	CA-Obs	US-NR1	FI-Sod
Red region SIF			
Observation	0.15 (-)	0.13 (-)	0.23 (-)
mSCOPE	0.63 (4.15)	0.60 (4.53)	0.43 (1.94)
L2SM	0.66 (4.37)	0.56 (4.28)	0.55 (2.46)
LZ	1.21 (7.98)	1.15 (8.62)	1.10 (4.94)
Upscaled	3.24 (21.45)	3.47 (26.11)	2.11 (9.45)
Far-red region SIF			
Observation	0.36 (-)	0.36 (-)	0.18 (-)
mSCOPE	0.79 (2.22)	0.82 (2.27)	0.36 (2.84)
L2SM	0.96 (2.70)	0.87 (2.46)	0.51 (4.04)
LZ	2.75 (7.67)	2.59 (7.20)	1.54 (12.32)

Table S4. Parameter values with their uncertainties in parenthesis from fit to hyperbolic function ($y = ax/(b+x)$), shown in Figure 6.

Set of points	a	b
Observations		
CA-Obs	22.26 (0.70)	0.25 (0.02)
US-NR1	15.80 (0.70)	0.19 (0.02)
FI-Sod	11.47 (0.37)	0.05 (0.01)
Simulations		
CA-Obs	21.62 (0.32)	0.61 (0.02)
US-NR1	17.97 (0.57)	0.45 (0.04)
FI-Sod	13.87 (0.42)	0.39 (0.03)

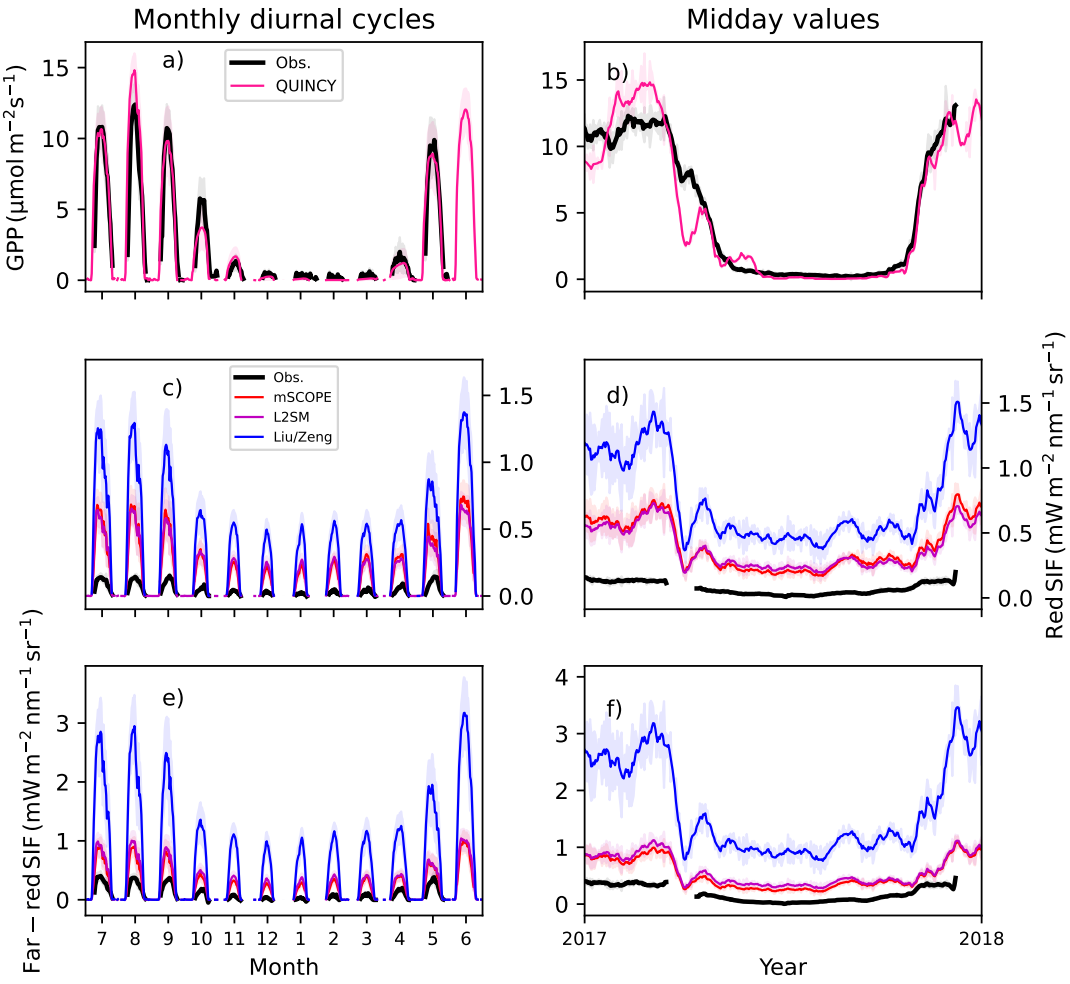

Figure S1. The monthly diurnal cycles for GPP (a), red region SIF (c) and far-red SIF (e) and midday values, calculated from winter time between 10 a.m. and 1:30 p.m., for GPP (b), red region SIF (d) and far-red SIF (f) at US-NR1. The black line is in all plots observation, the pink line in the GPP plots is the QUINCY simulation results. For the SIF plots, red line is the mSCOPE results, magenta the L2SM and blue the LZ approach.

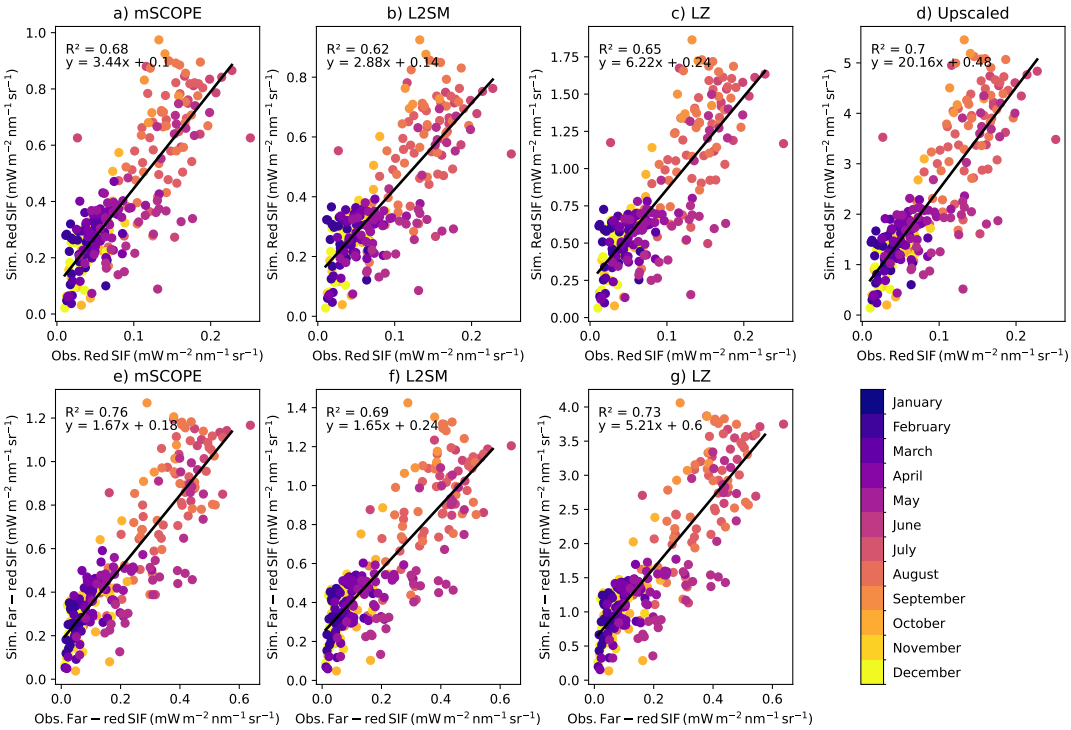

Figure S2. Observed vs. modelled SIF midday values in red region (QUINCY-mSCOPE: a, Q-L2SM: b, Q-LZ: c, Upscaled: d) and far-red region (QUINCY-mSCOPE: e, Q-L2SM: f, Q-LZ: g) at US-NR1. Values from different months are color-coded. The black line show a fit with corresponding parameters shown in each panel. Months from June to December are from year 2017 and months January to May from 2018.

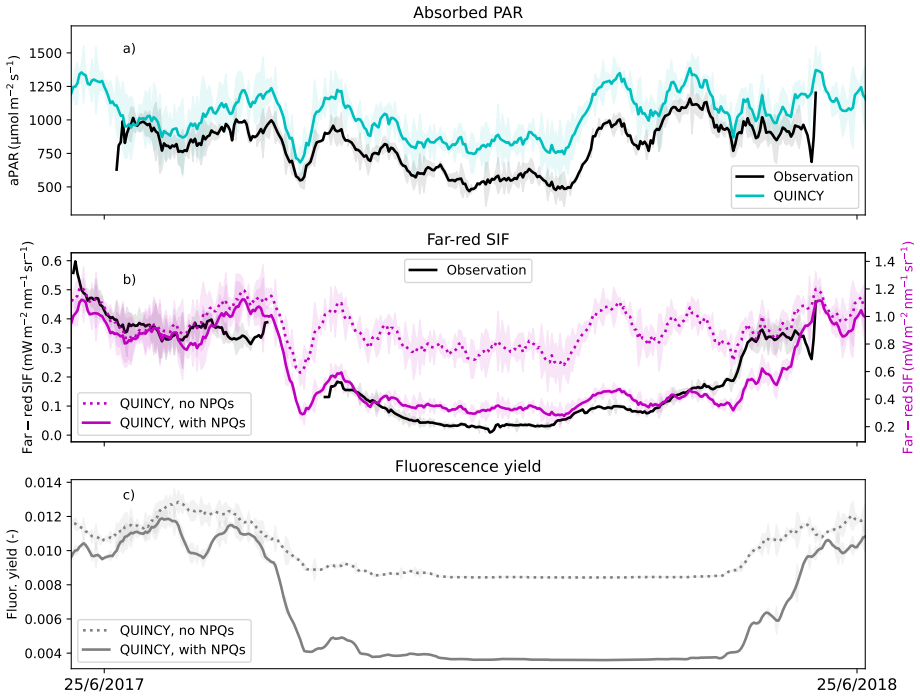

Figure S3. The observed and simulated absorbed radiation at US-NR1 (a), near-infrared SIF values with and without sustained NPQ (b) and simulated chlorophyll fluorescence yields with and without sustained NPQ (c). The simulations have been done using L2SM. The values are averages of midday (10 a.m. to 2 p.m.) values, the standard deviation is shown as shaded regions.

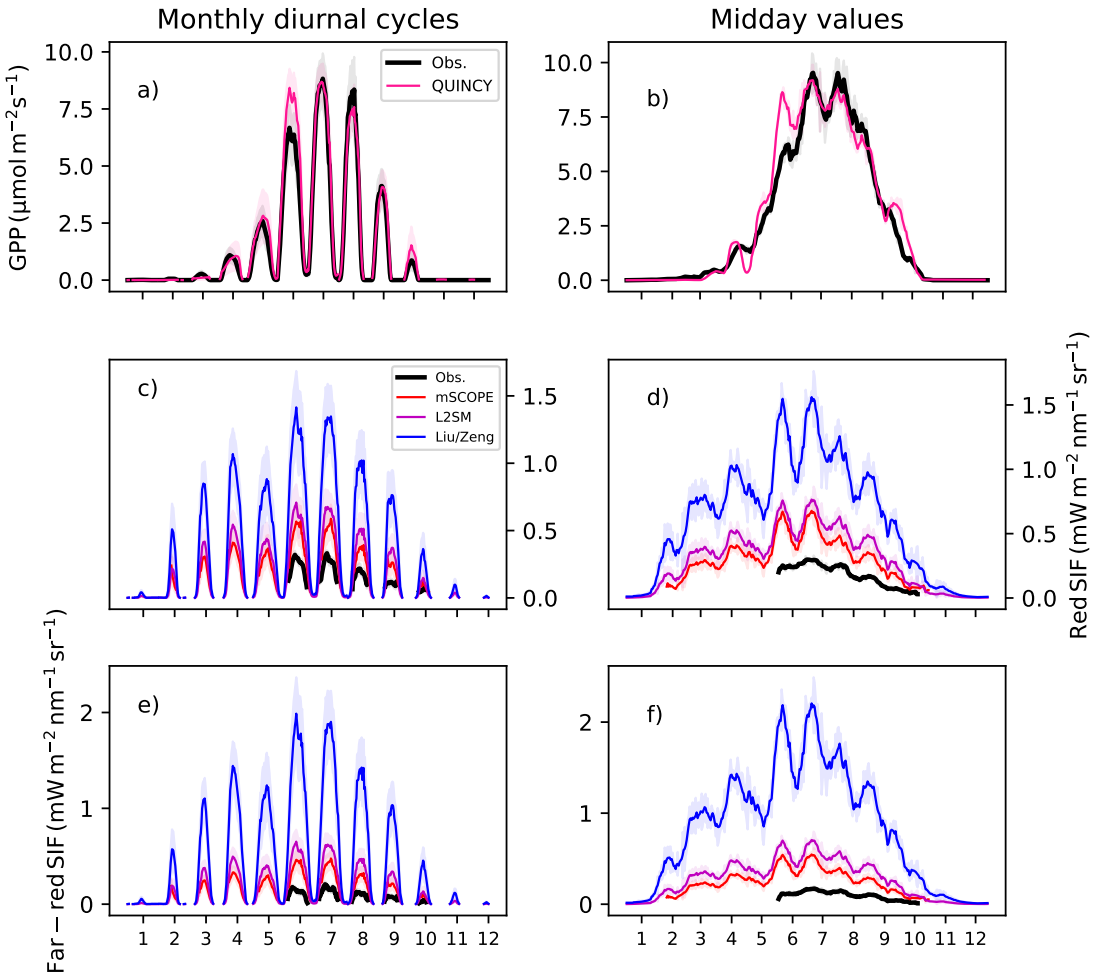

Figure S4. The monthly diurnal cycles for GPP (a), red region SIF (c) and far-red SIF (e) and midday values, calculated from winter time between 10 a.m. and 1:30 p.m., for GPP (b), red region SIF (d) and far-red SIF (f) at FI-Sod. The black line is in all plots observation, the pink line in the GPP plots is the QUINCY simulation results. For the SIF plots, red line is the mSCOPE results, magenta the L2SM, blue the LZ approach and for the red region SIF only the upscaled SIF in cyan.

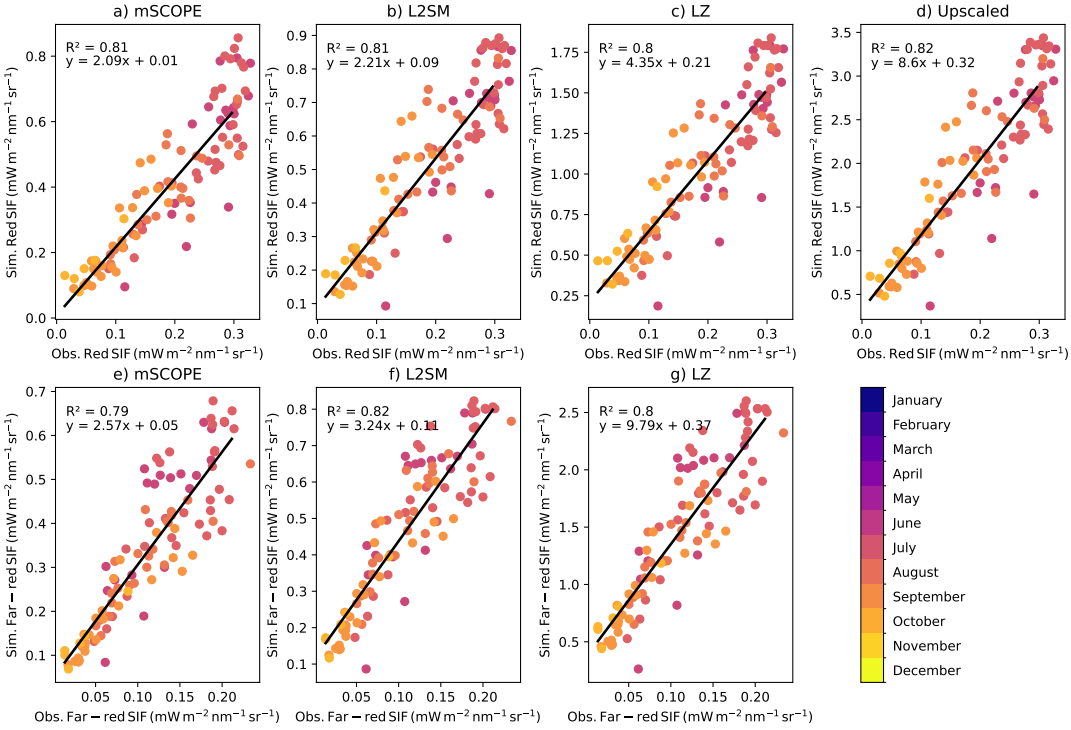

Figure S5. Observed vs. modelled SIF midday values in red region (QUINCY-mSCOPE: a, Q-L2SM: b, Q-LZ: c, Upscaled: d) and far-red region (QUINCY-mSCOPE: e, Q-L2SM: f, Q-LZ: g) at FI-Sod. Values from different months are color-coded. The black line show a fit with corresponding parameters shown in each panel.

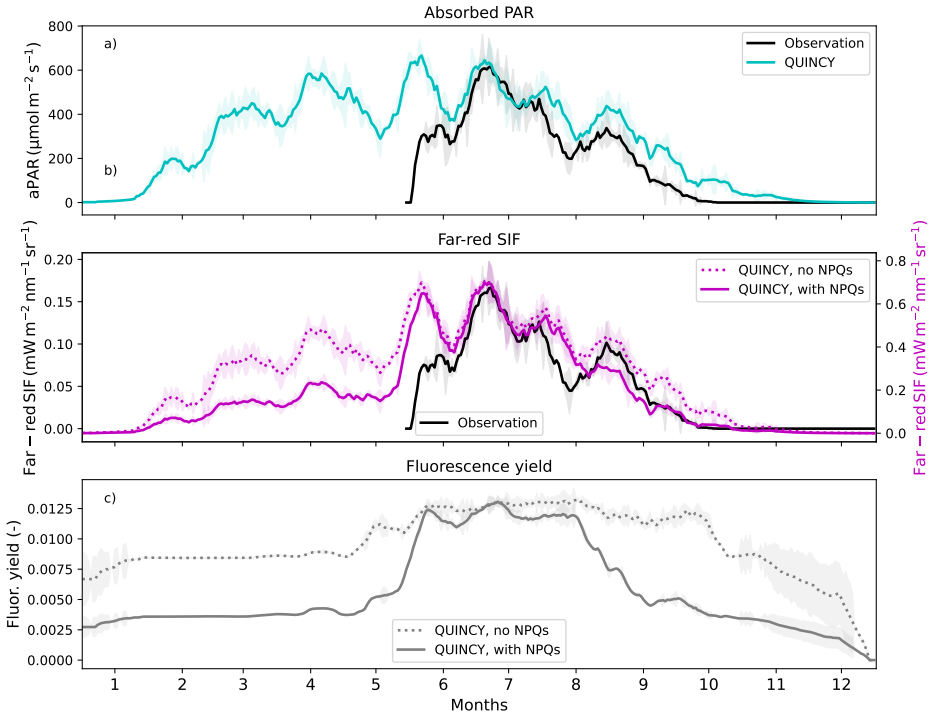

Figure S6. The observed and simulated absorbed radiation at FI-Sod (a), near-infrared SIF values with and without sustained NPQ (b) and simulated chlorophyll fluorescence yields with and without sustained NPQ (c). The simulations have been done using L2SM. The values are averages of midday (10 a.m. to 2 p.m.) values, the standard deviation is shown as shaded regions.

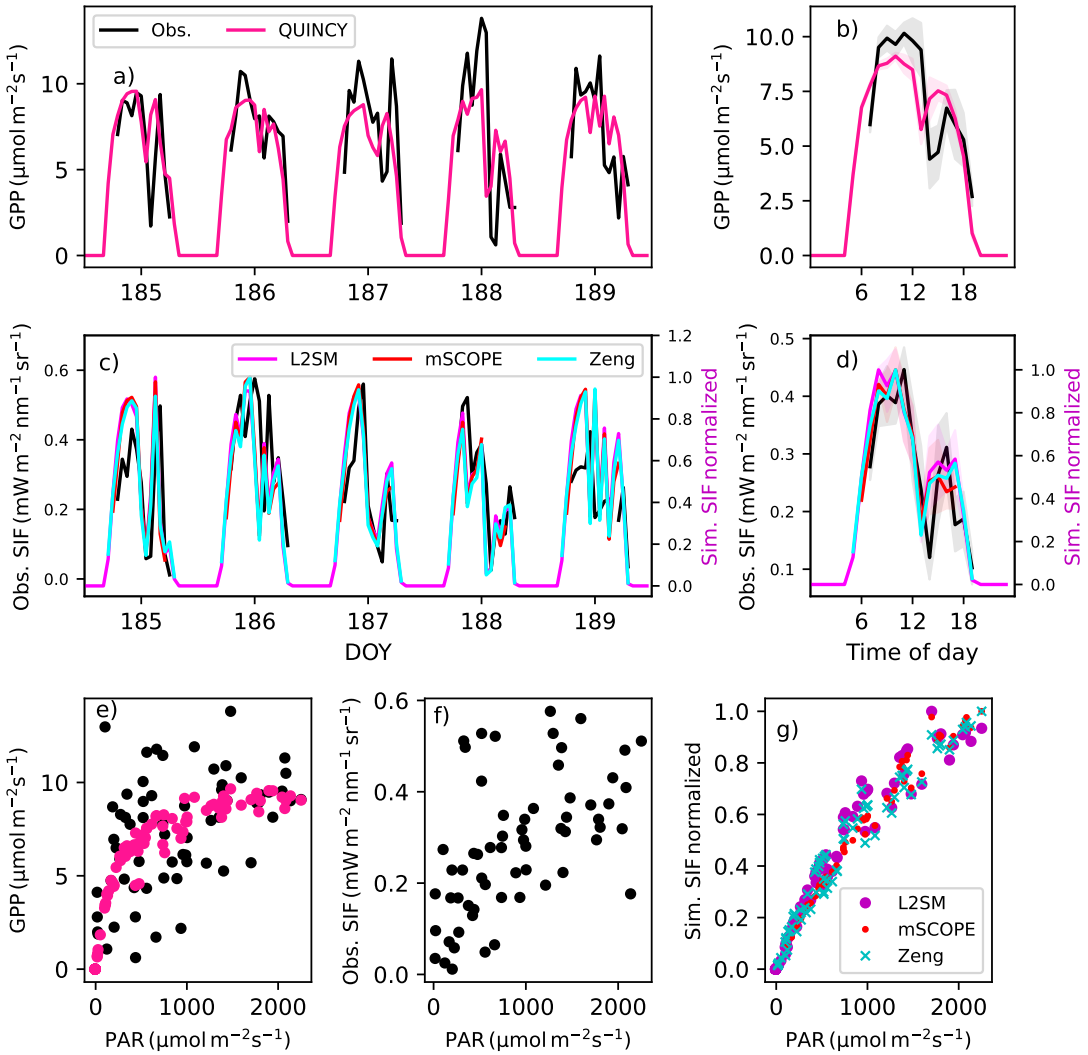

Figure S7. The observed and simulated GPP (a) and far-red region SIF (c) for days 185-189 (July 4-July 8, 2017) and averaged over these five days (b for GPP and d for far-red region SIF) at US-NR1. The shaded regions in b and d show the standard deviations of the averaged values. The light response of observed and simulated GPP for these five days (e), of observed far-red region SIF (f) and of simulated far-red region SIF (g). The observations are in black, simulated GPP in pink and simulated far-red region SIF in magenta or L2SM, red for mSCOPE and cyan for the Zeng approach.

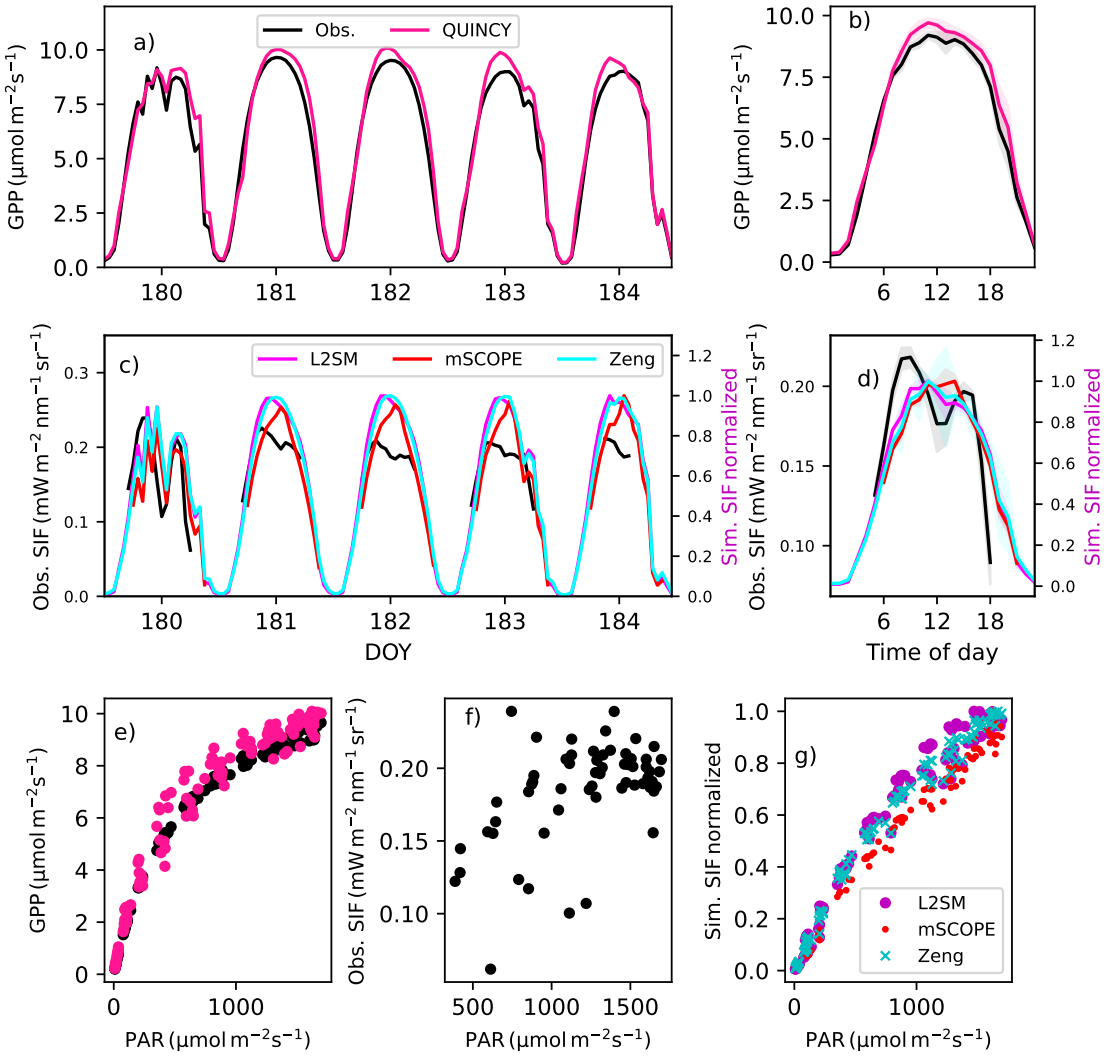

Figure S8. The observed and simulated GPP (a) and far-red region SIF (c) for days 180-184 (June 29-July 3, 2021) and averaged over these five days (b for GPP and d for far-red region SIF) at FI-Sod. The shaded regions in b and d show the standard deviations of the averaged values. The light response of observed and simulated GPP for these five days (e), of observed far-red region SIF (f) and of simulated far-red region SIF (g). The observations are in black, simulated GPP in pink and simulated far-red region SIF in magenta for L2SM, red for mSCOPE and cyan for the Zeng approach.