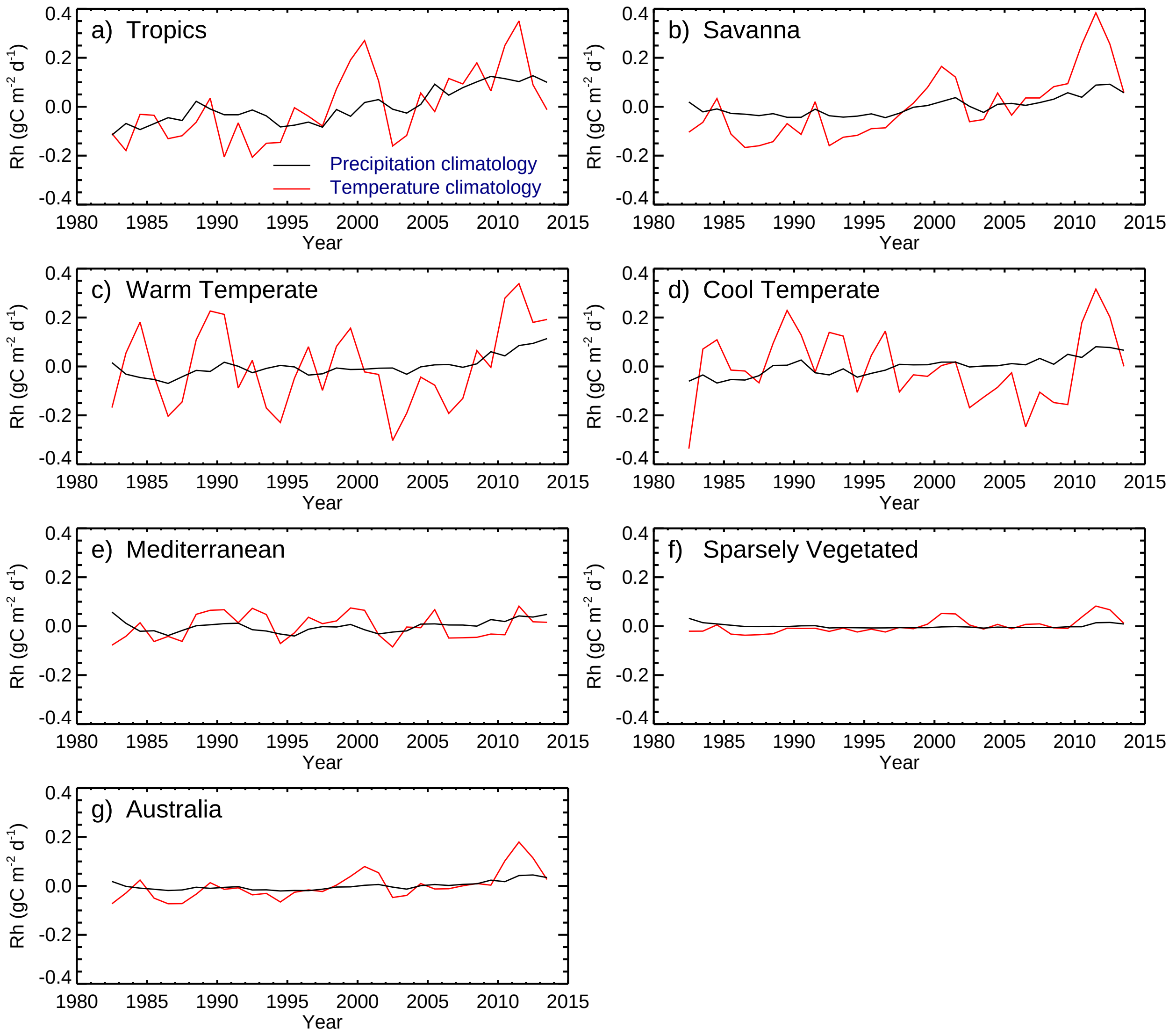

Figure S1: Heterotrophic respiration from the model with either precipitation (black) or temperature (red) set to climatology.

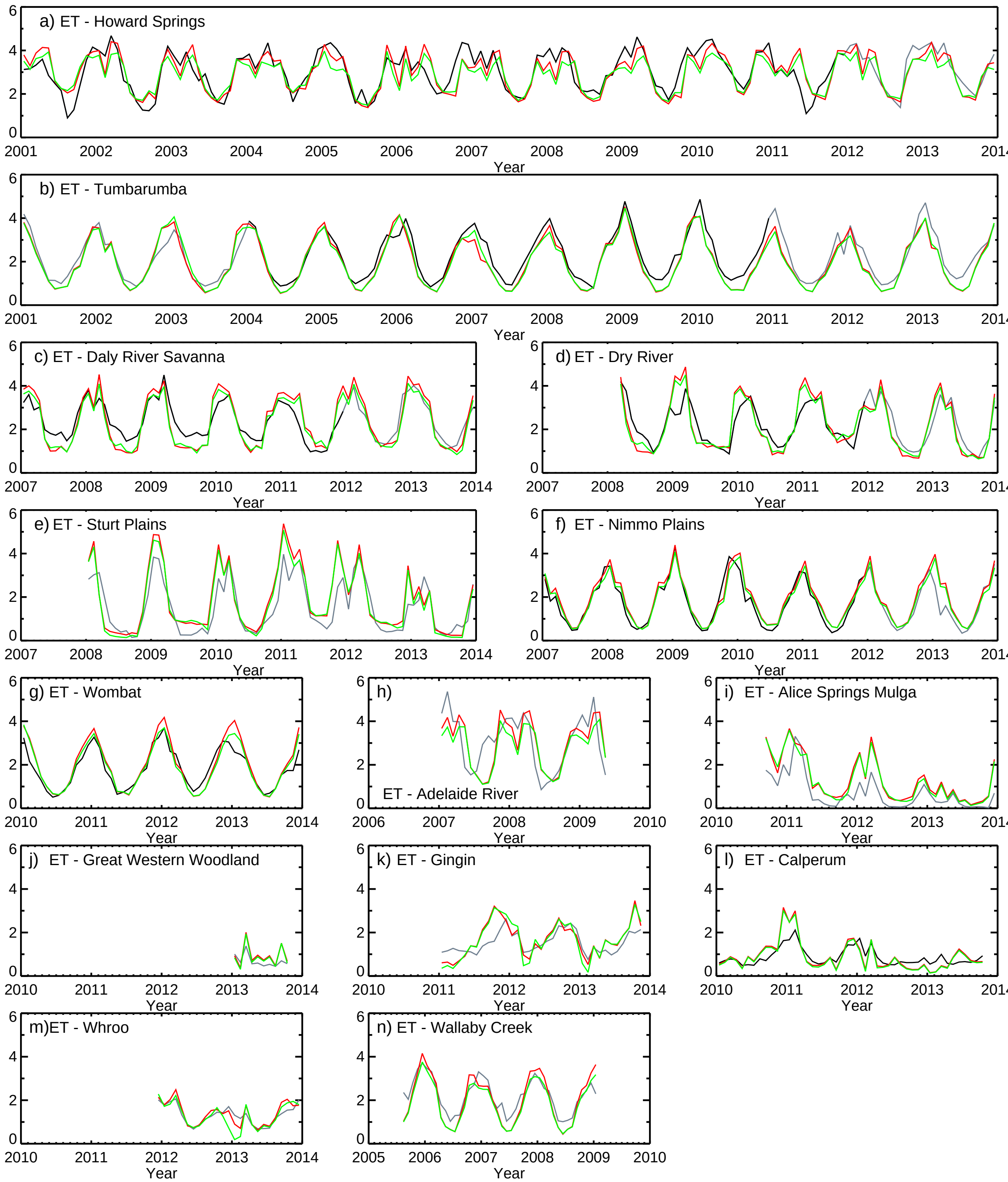

Figure S2: Timeseries of monthly evapotranspiration (mm d^{-1}) at 14 OzFlux sites. Observations used for calibration are shown in black, observations kept for validation are shown in grey. Modelled ET for prior parameters is shown in red and for the best parameter set is shown in green.

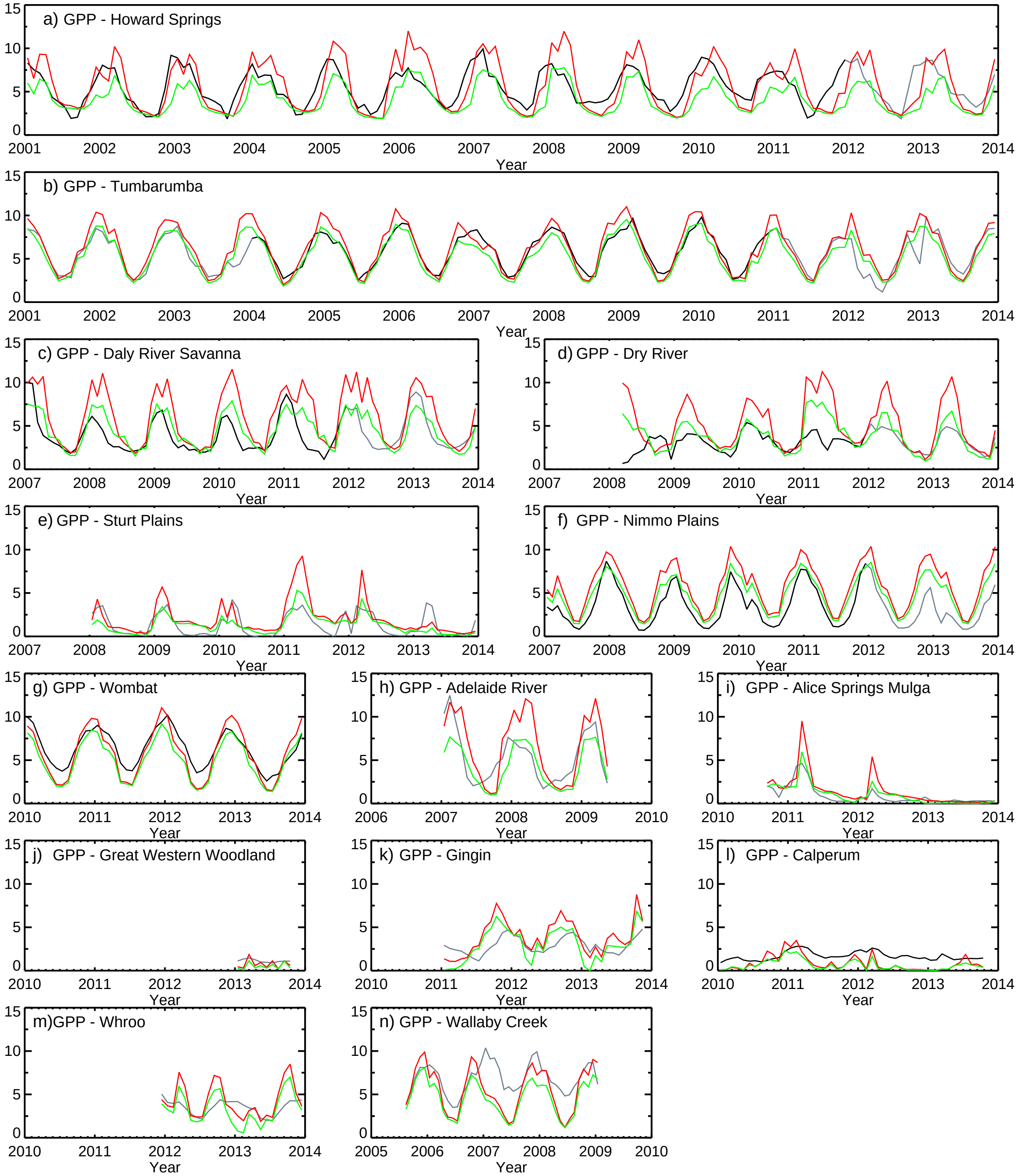

Figure S3: Timeseries of monthly GPP (gC m^{-2} d^{-1}) at 14 OzFlux sites. Observations used for calibration are shown in black, observations kept for validation are shown in grey. Modelled GPP for prior parameters is shown in red and for the best parameter set is shown in green.

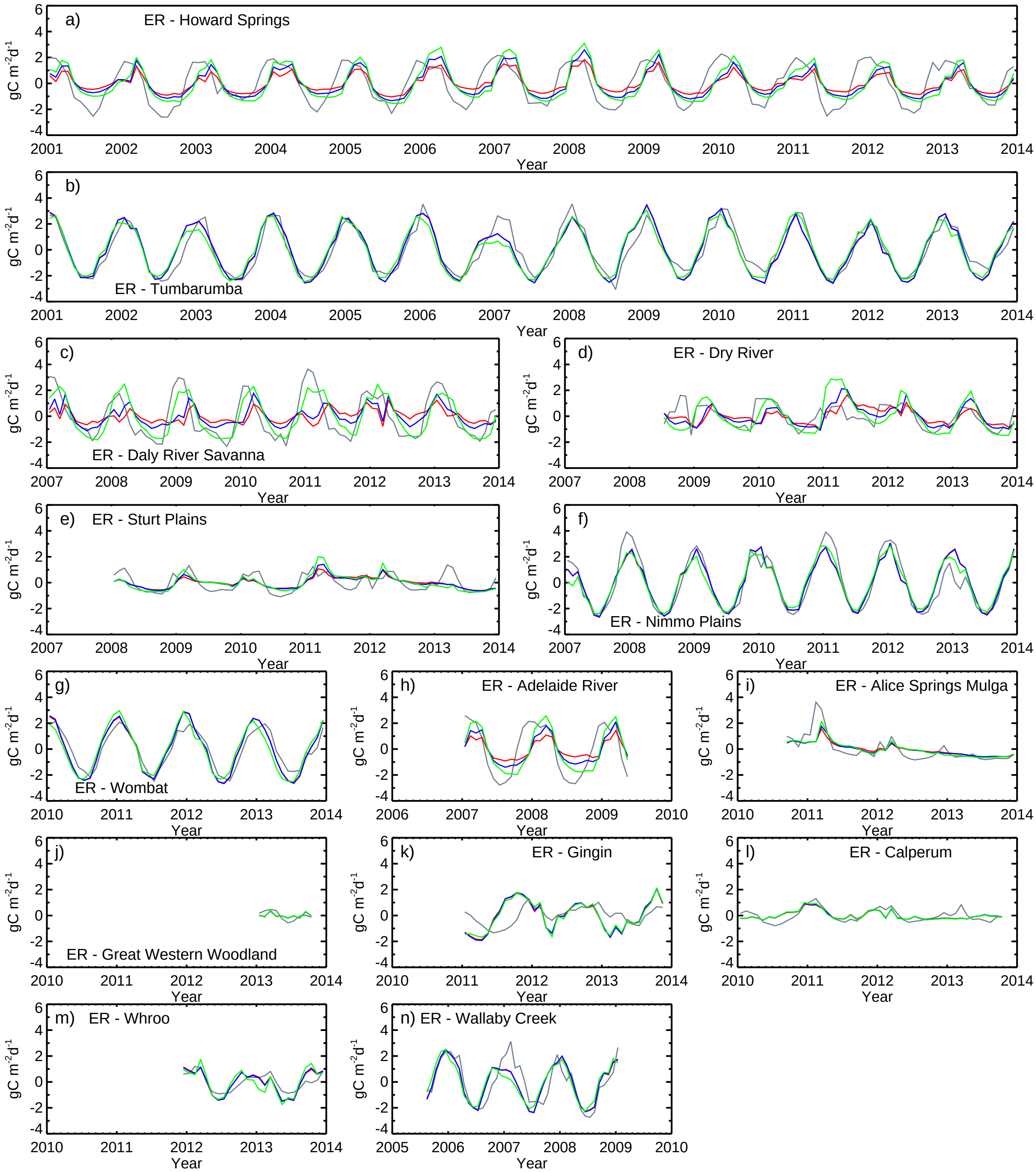

Figure S4: Timeseries of monthly ecosystem respiration (gC m^{-2} d^{-1}) at 14 OzFlux sites. Observations used for calibration are shown in black, observations kept for validation are shown in grey. Modelled ecosystem respiration for prior parameters is shown in red, for the best parameter set is shown in green, and using the Kelly et al. (2000) soil respiration function in blue.

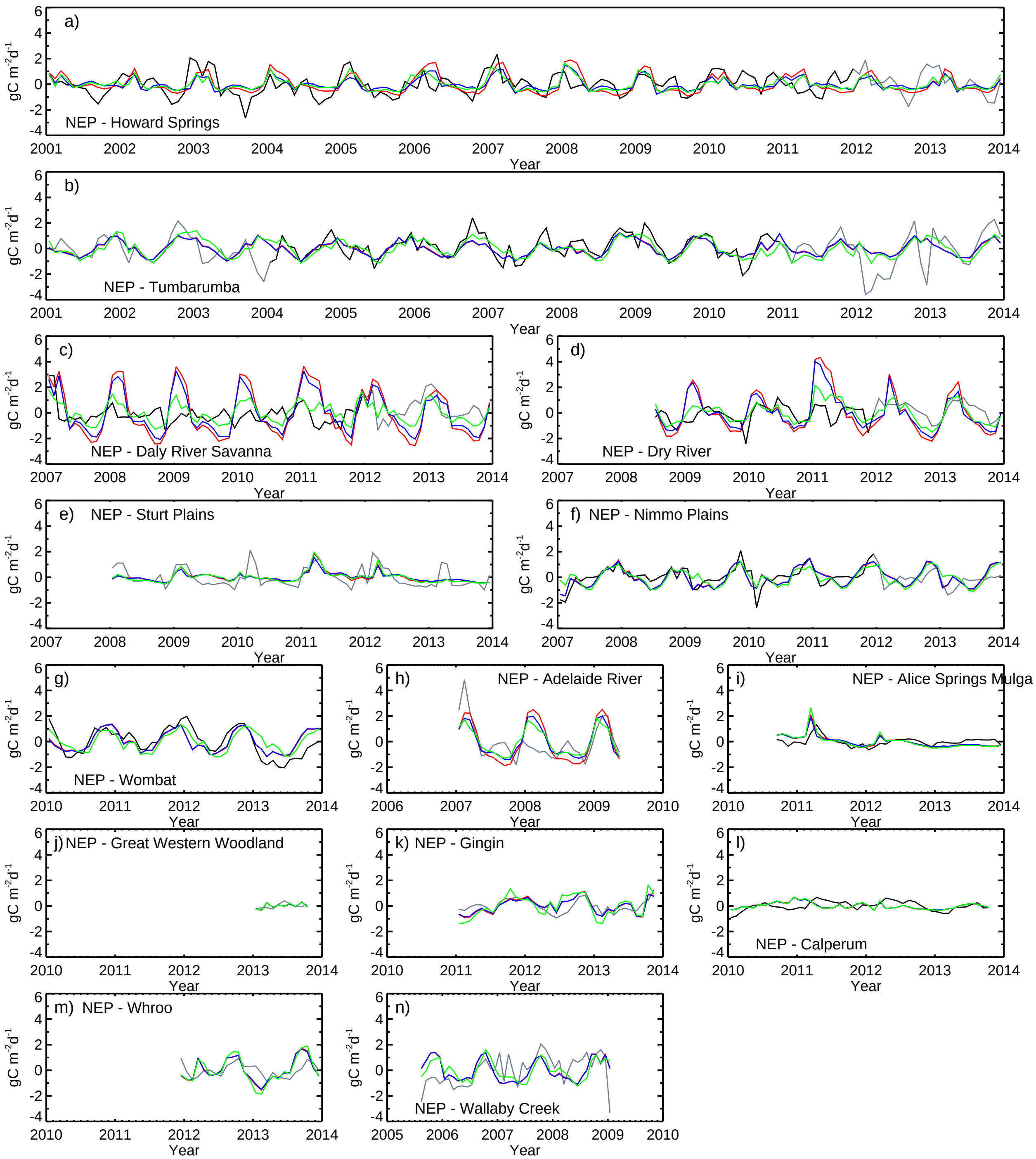

Figure S5: Timeseries of monthly NEP (gC m^{-2} d^{-1}) at 14 OzFlux sites. Observations used for calibration are shown in black, observations kept for validation are shown in grey. Modelled NEP for prior parameters is shown in red, for the best parameter set is shown in green, and using the Kelly et al. (2000) soil respiration function in blue.

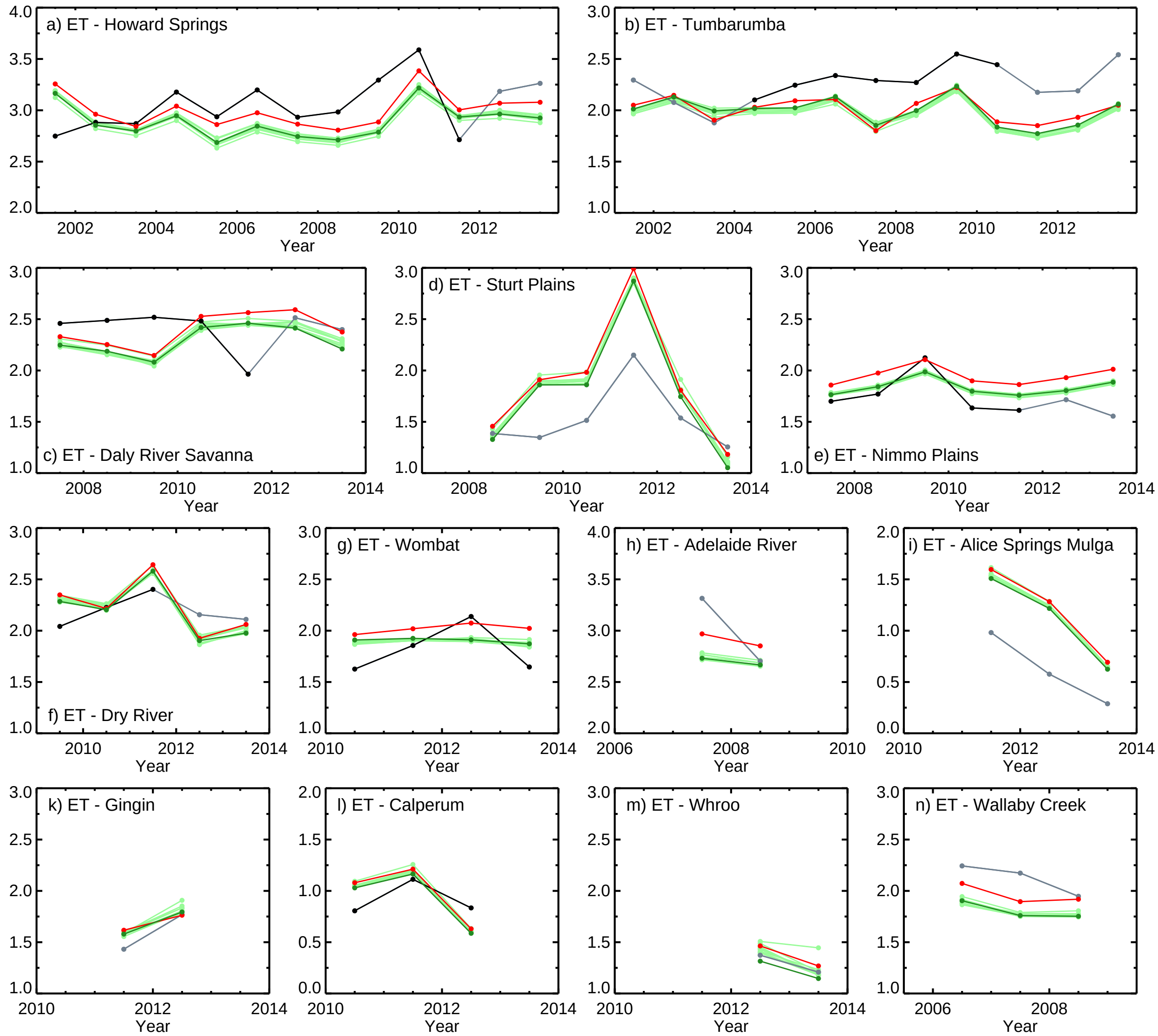

Figure S6: Timeseries of annual evapotranspiration (mm d^{-1}) at 14 OzFlux sites. Annual means of the observations used for calibration are shown in black, annual means of the observations kept for validation are shown in grey. Annual means of modelled ET for prior parameters are shown in red and parameters for the best parameter set are shown in green. Modelled ET for the ensemble of CABLE parameter sets are shown in light green. Annual observations are only calculated when a full year of monthly observations are available. Great Western Woodland is not shown because it has less than a full year of monthly observations.

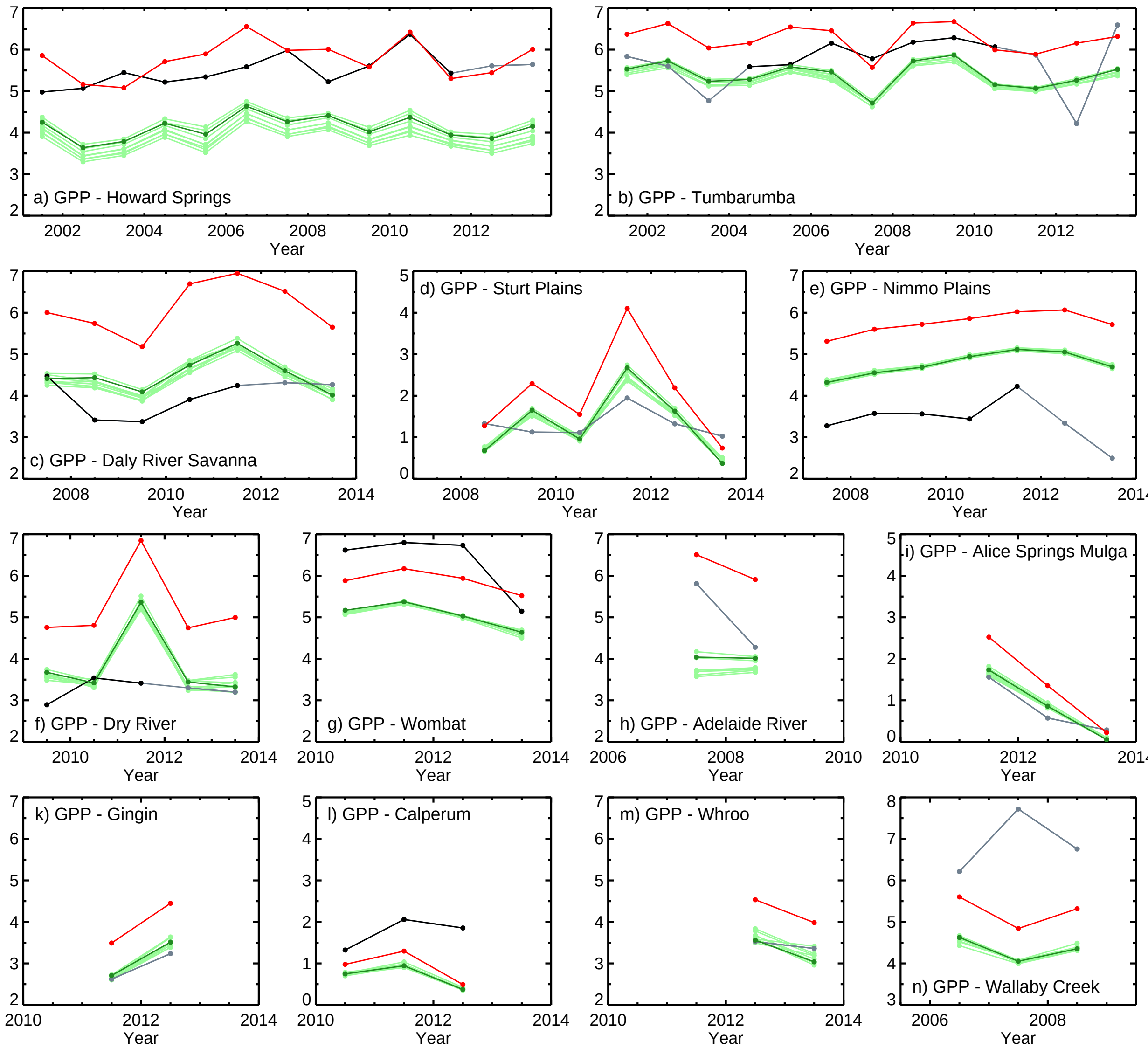

Figure S7: Timeseries of annual GPP (gC m^{-2} d^{-1}) at 14 OzFlux sites. Lines as in Figure S6.

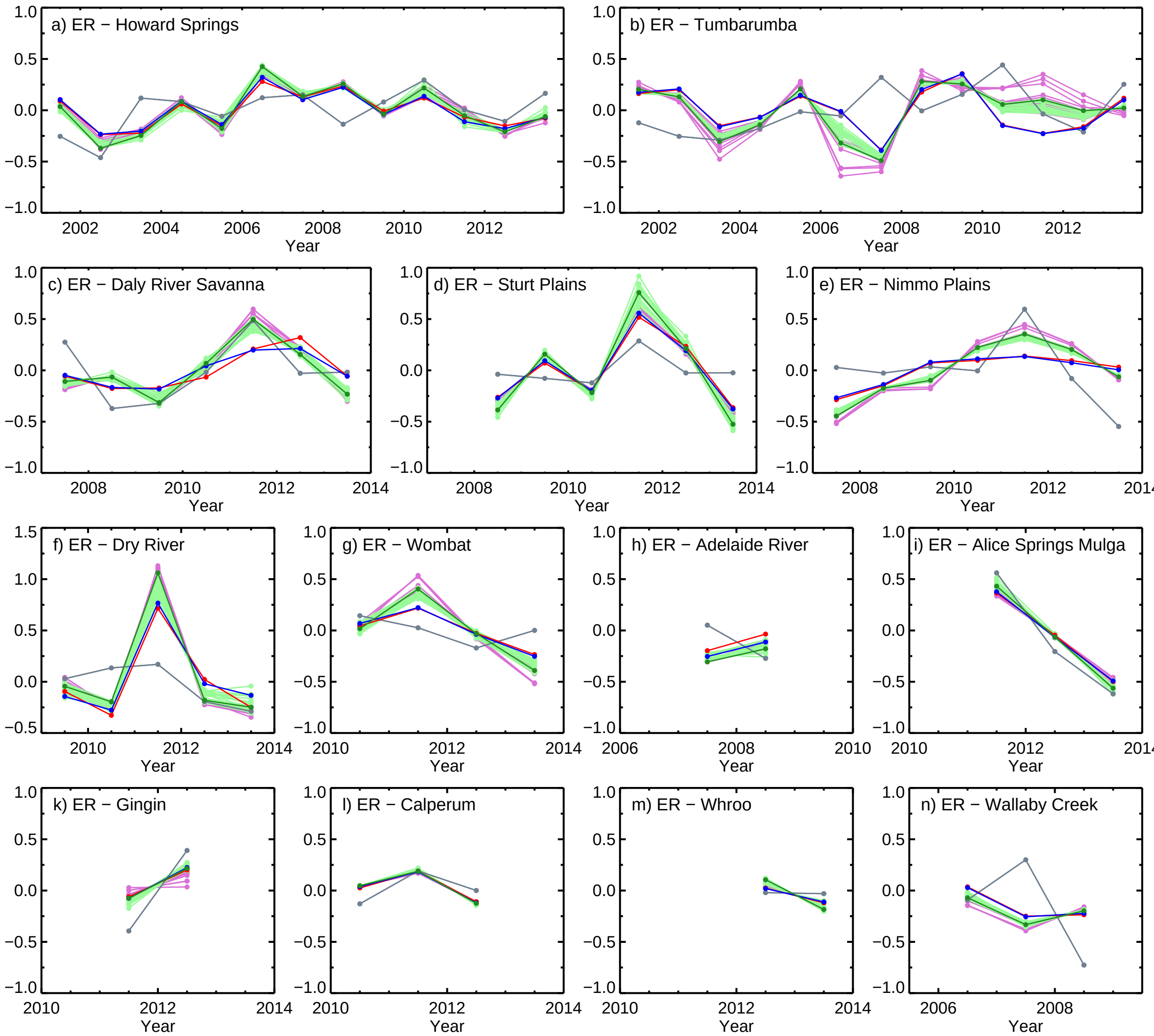

Figure S8: Timeseries of annual ecosystem respiration (gC m^{-2} d^{-1}) at 14 OzFlux sites. Lines as in Figure S6, with the modelled ecosystem respiration for the ensemble of CASA-CNP parameter sets shown in violet.

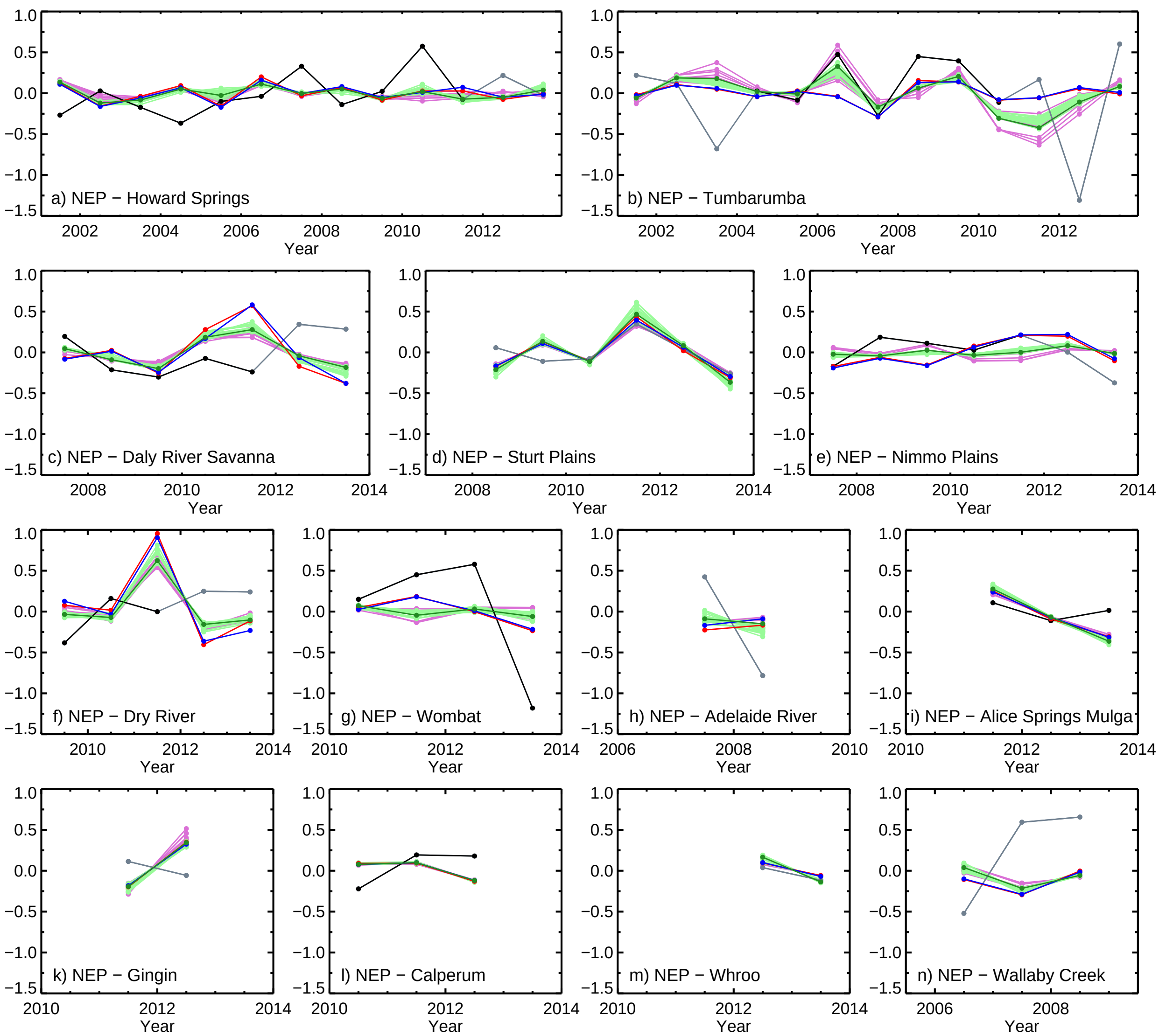

Figure S9: Timeseries of annual NEP (gC m^{-2} d^{-1}) at 14 OzFlux sites. Lines as in Figure S8.

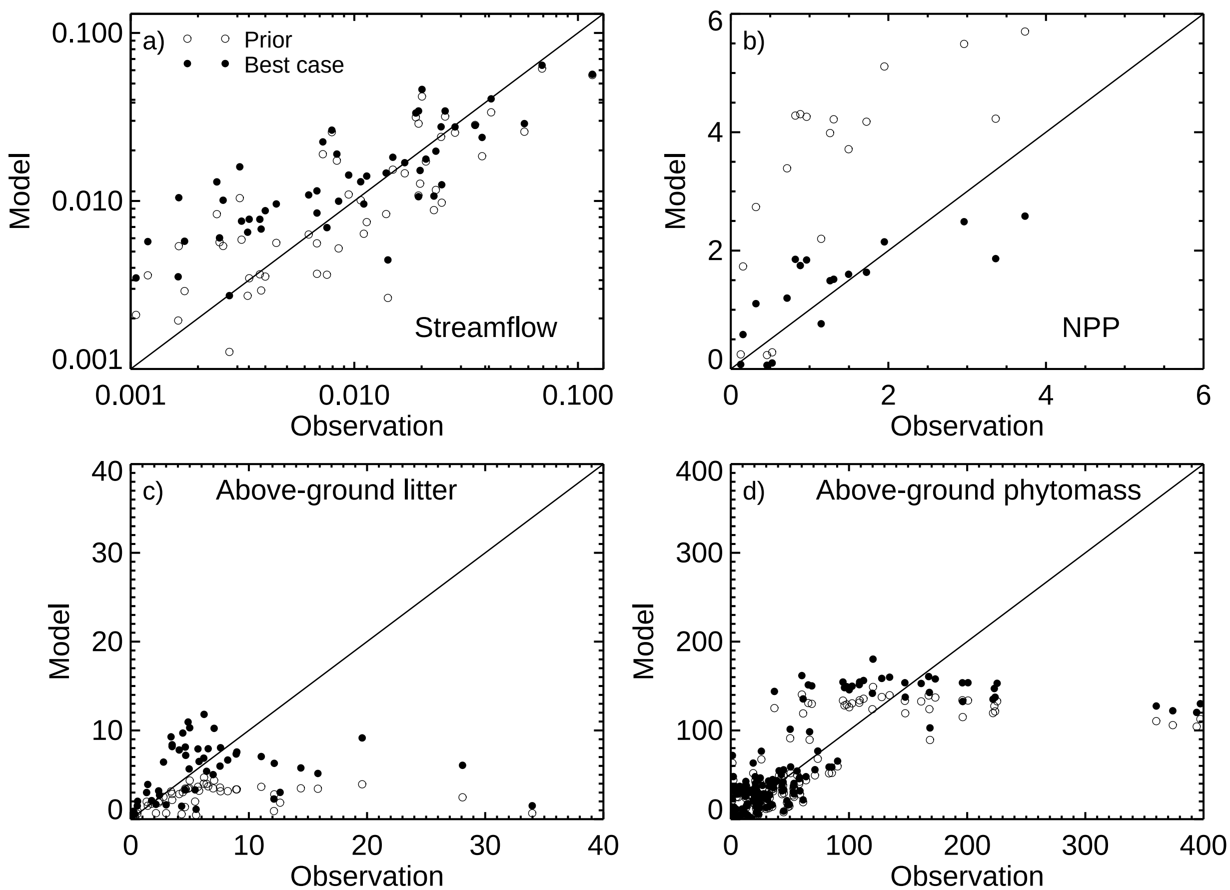

Figure S10: Scatter plots of observed and modelled long-term averaged a) streamflow, b) NPP, c) above-ground litter and d) above-ground phytomass. Model outputs calculated with prior parameters are plotted with open circles, model outputs calculated with the best parameter set are shown with filled circles.

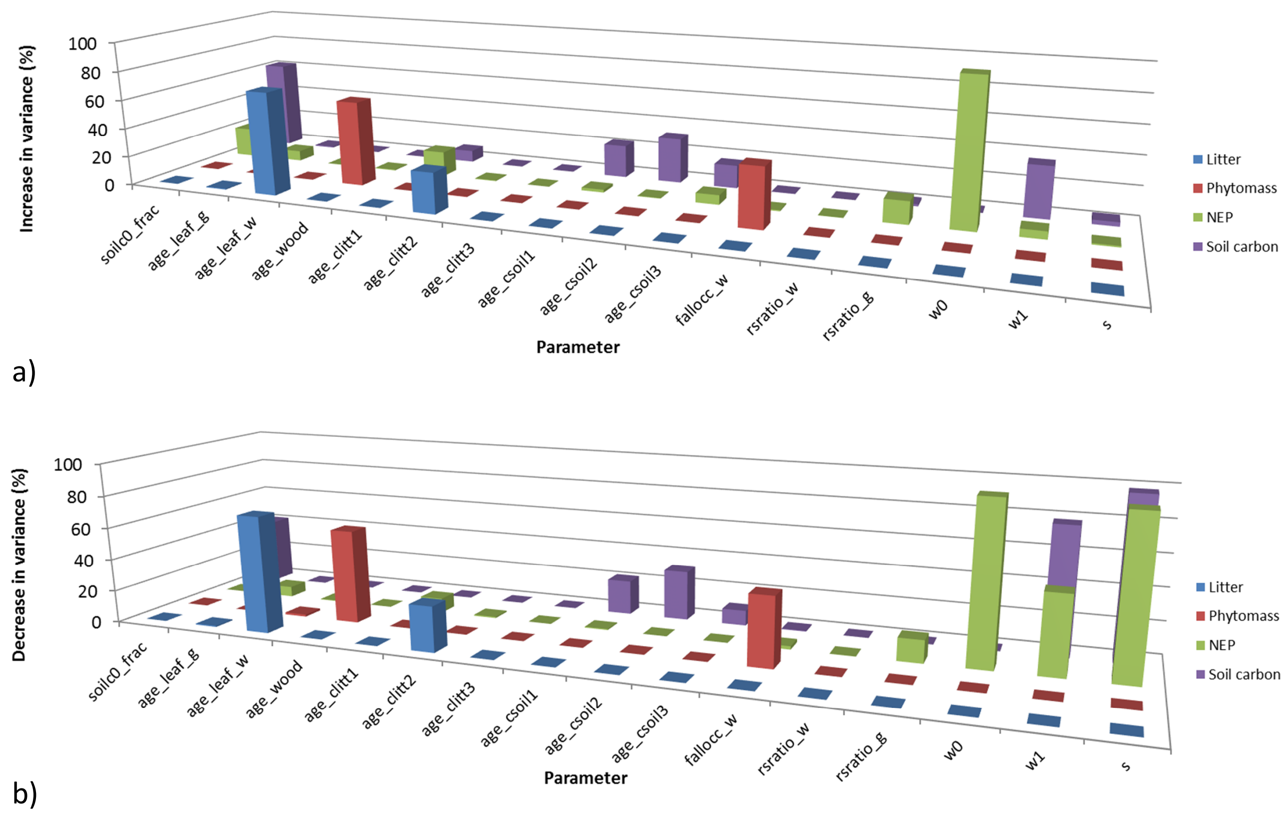

Figure S11: Worth of the different observation groups to the estimate of each CASA-CNP parameter. a) Increase (%) in post-calibration parameter uncertainty variance incurred through loss of observation groups. b) Decrease (%) in pre-calibration parameter uncertainty variance incurred through addition of observation groups.

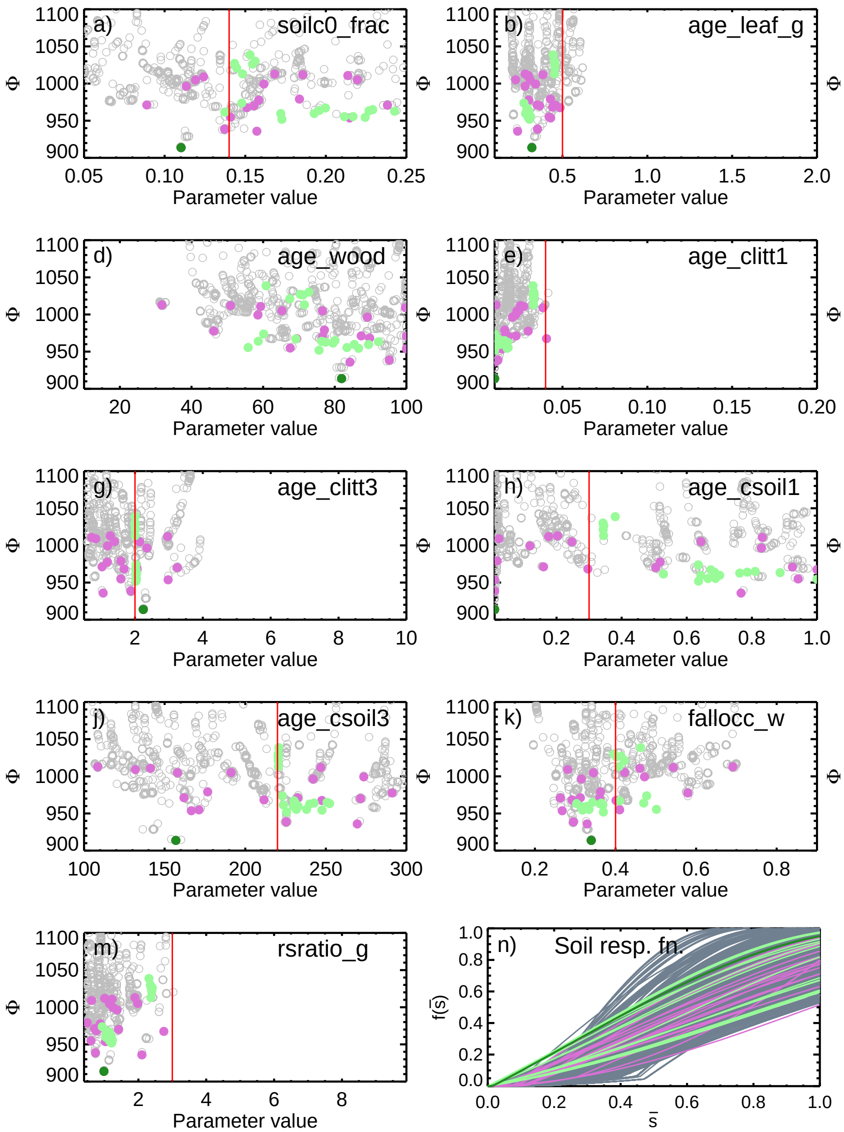

Figure S12: Model-data mismatch, Φ, from CASA-CNP observations plotted against CASA-CNP parameter values. Grey open circles are all parameter sets tested during the null space recalibration. The green circle shows the parameter set with the lowest combined Φ. Light green circles show CASA-CNP parameters for the CABLE ensemble and the pink circles show the parameters for the CASA-CNP ensemble. Red vertical lines show the prior parameter constraints that were used (not all parameters had prior constraints).

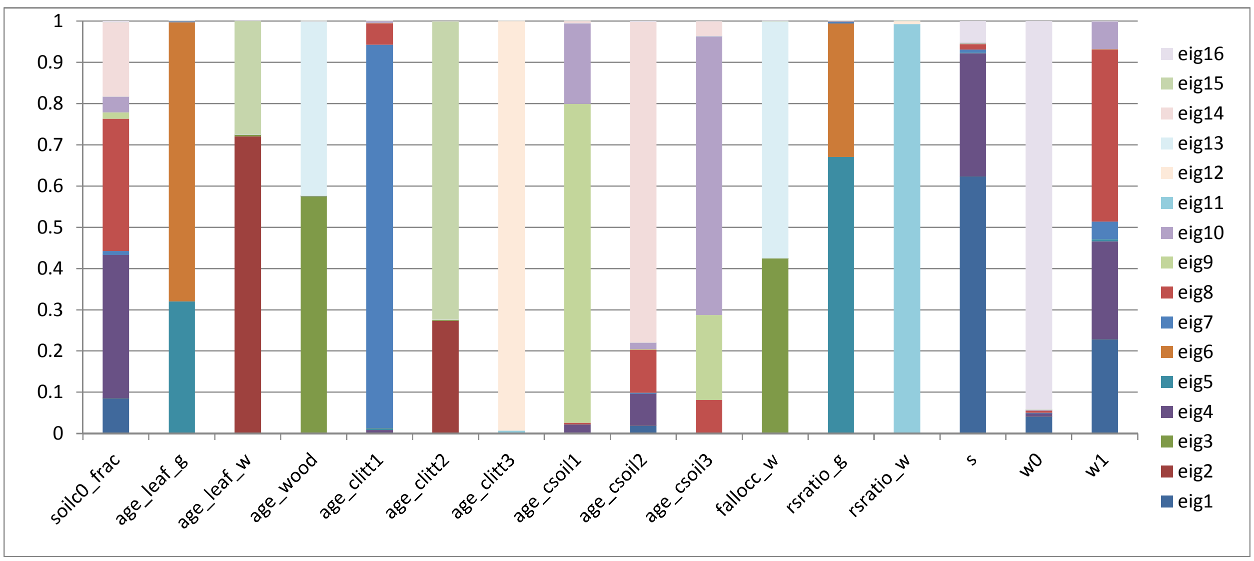

Figure S13: Parameter identifiability for CASA-CNP parameters from PEST's linear analysis tools. Dark colors indicate eigenvectors that are more identifiable than light colors.

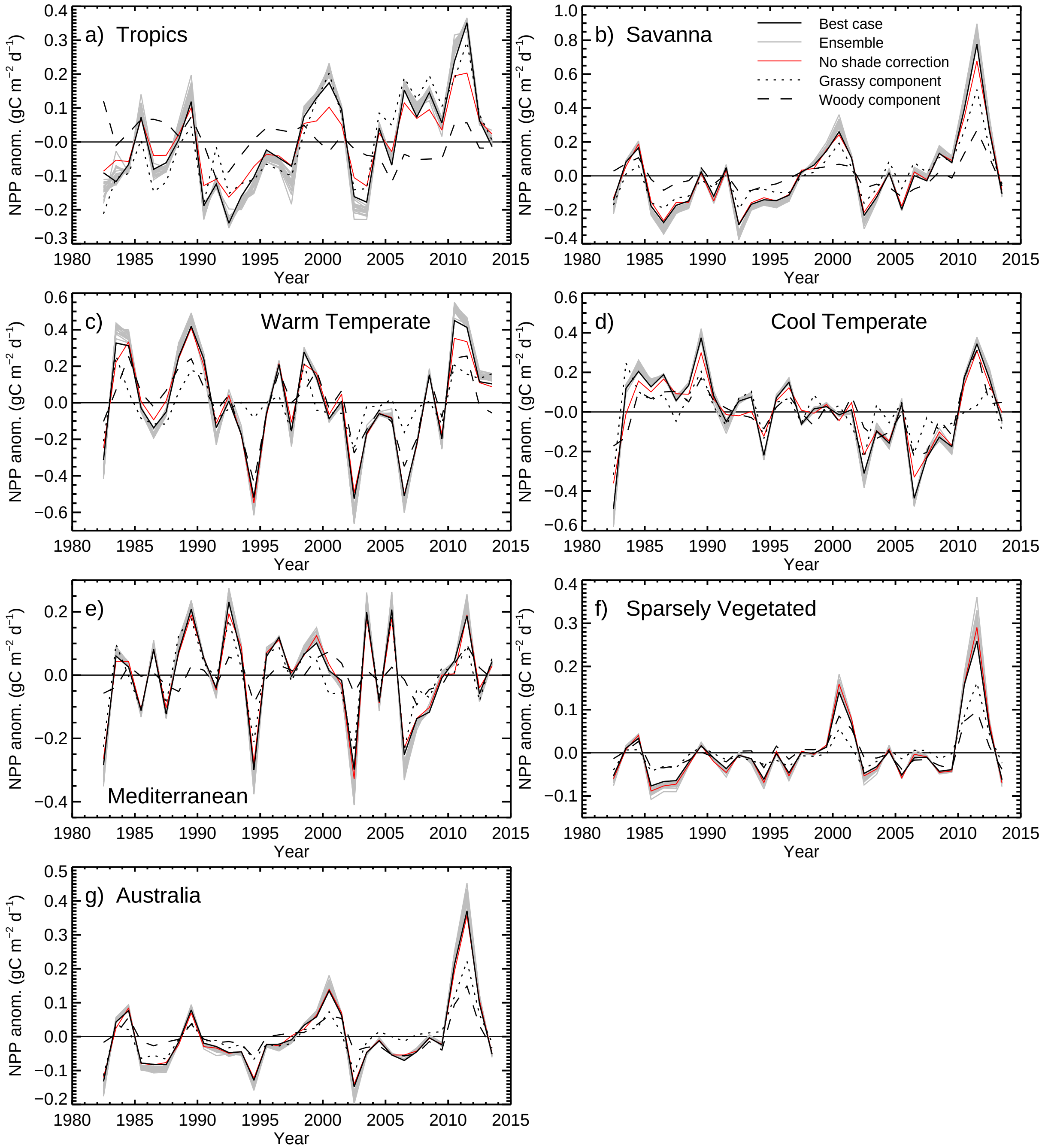

Figure S14: Annual NPP anomaly for six bioclimatic regions and Australia. The solid lines show total NPP (grassy plus woody vegetation), dotted lines show the grassy component and the dashed lines show the woody component. The best case is shown in black and (for total NPP) the other ensemble members are shown in grey, indicating the influence of parameter equifinality. The red line shows the case re-optimised without the shade correction. The location of the bioclimatic regions is shown in Figure 9.

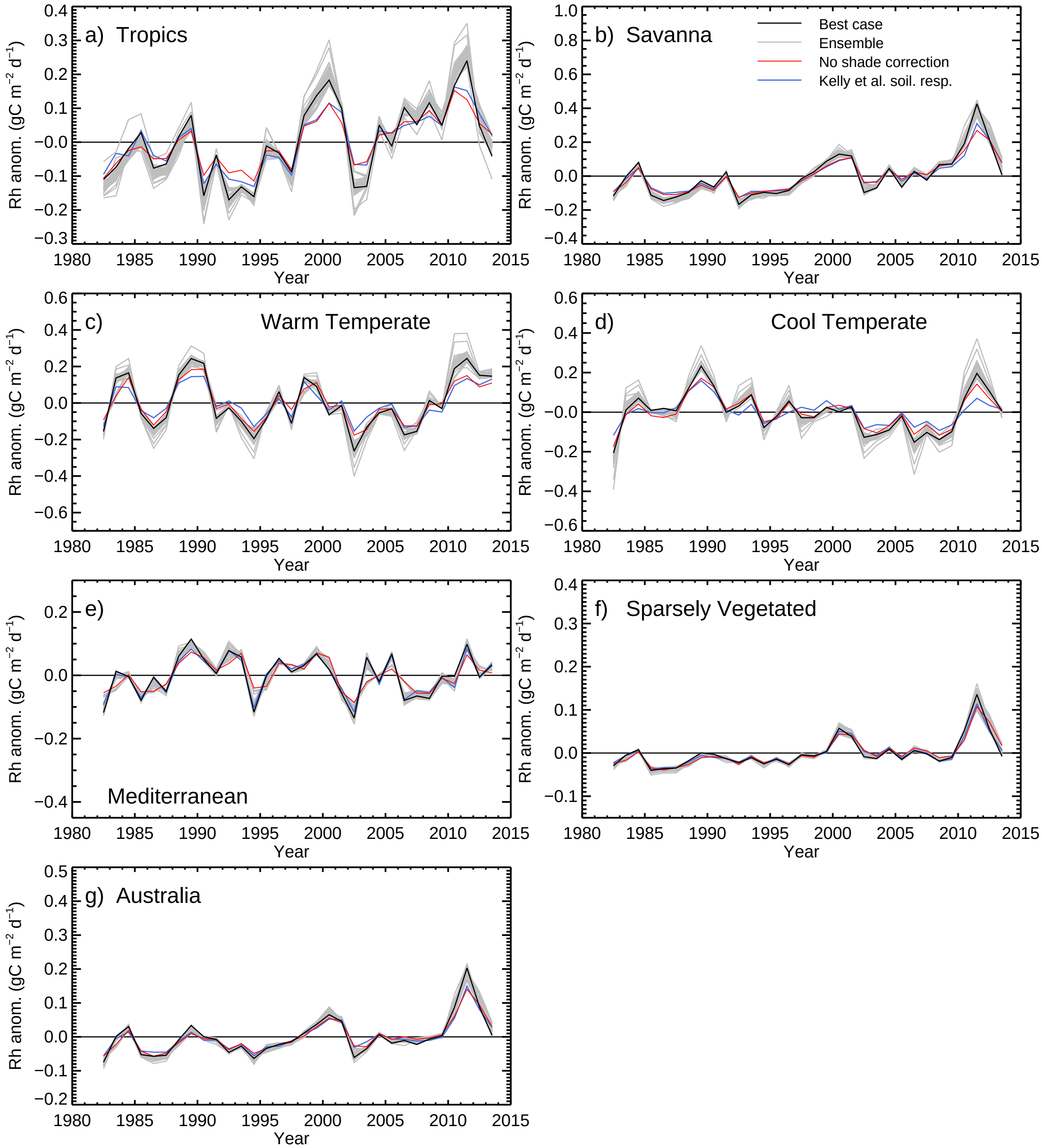

Figure S15: Annual heterotrophic respiration anomaly for six bioclimatic regions and Australia. The best case is shown in black and the other ensemble members in grey, indicating the influence of parameter equifinality. The red line shows the case re-optimised without the shade correction. The blue line shows the case re-optimised with the Kelly et al. (2000) soil respiration function. The location of the bioclimatic regions is shown in Figure 9.

Table S1: Average fluxes and stocks for 1990–2010 for the Tropics, Savanna, Warm Temperate, Cool Temperate, Mediterranean and Sparsely Vegetated regions and Australia. We show values for the best case, ensemble mean and uncertainties due to parameter equifinality for our study (BIOS-2.1). Mean and uncertainty (due to parameters and forcing) for the BIOS-2 study are also given.

	Tropics	Savanna	W. Temp.	C. Temp.	Med.	S. Veg.	Aust.
BIOS-2.1 Best Case							
NPP [$gCm^{-2}d^{-1}$]	1.747	0.964	1.891	2.076	0.991	0.233	0.700
NEP [$gCm^{-2}d^{-1}$]	-0.020	0.029	0.010	-0.023	0.005	0.023	0.017
NEP IAV [1σ $gCm^{-2}d^{-1}$]	0.042	0.102	0.142	0.115	0.089	0.040	0.052
Frac. recurrent NPP [-]	0.43	0.42	0.21	0.27	0.50	0.37	0.37
Biomass [$tCha^{-1}$]	83.90	43.59	121.14	125.01	40.15	9.55	34.42
Litter [$tCha^{-1}$]	9.97	6.32	22.81	31.04	11.32	1.98	6.76
Soil [$tCha^{-1}$]	292.91	154.25	482.44	696.01	321.32	45.31	162.39
BIOS-2.1 Ensemble mean							
NPP [$gCm^{-2}d^{-1}$]	1.837	1.011	1.924	2.100	1.037	0.244	0.727
NEP [$gCm^{-2}d^{-1}$]	-0.030	0.028	-0.001	-0.031	0.001	0.023	0.015
NEP IAV [1σ $gCm^{-2}d^{-1}$]	0.046	0.122	0.160	0.116	0.111	0.049	0.061
Frac. recurrent NPP	0.46	0.46	0.24	0.30	0.53	0.40	0.40
Biomass [$tCha^{-1}$]	82.06	42.58	118.64	122.51	39.09	9.51	33.75
Litter [$tCha^{-1}$]	12.26	7.97	28.00	36.74	14.32	2.70	8.44
Soil [$tCha^{-1}$]	264.92	144.42	426.31	595.58	305.43	50.59	151.93
BIOS-2.1 Parameter uncertainty from ensemble (1σ)							
NPP [$gCm^{-2}d^{-1}$]	0.105	0.059	0.056	0.034	0.057	0.015	0.034
NEP [$gCm^{-2}d^{-1}$]	0.012	0.008	0.007	0.005	0.004	0.003	0.003
NEP IAV [1σ $gCm^{-2}d^{-1}$]	0.008	0.016	0.028	0.016	0.016	0.005	0.008
Frac. recurrent NPP	0.04	0.04	0.03	0.02	0.04	0.04	0.04
Biomass [$tCha^{-1}$]	2.77	1.39	3.94	4.11	1.35	0.33	1.09
Litter [$tCha^{-1}$]	3.37	2.28	7.98	9.41	3.85	0.88	2.33
Soil [$tCha^{-1}$]	80.29	42.54	130.26	186.82	92.34	17.89	45.86
BIOS-2 (Haverd et al. 2013a)							
NPP [$gCm^{-2}d^{-1}$]	1.970	1.179	1.974	1.989	1.129	0.237	0.742
NEP [$gCm^{-2}d^{-1}$]	-0.021	0.034	-0.017	-0.018	-0.010	0.013	0.011
NEP IAV [AVHRR, 1σ $gCm^{-2}d^{-1}$]	0.102	0.129	0.131	0.117	0.132	0.059	0.044
NEP IAV [MODIS, 1σ $gCm^{-2}d^{-1}$]	0.083	0.109	0.083	0.076	0.074	0.066	0.059
Frac. recurrent NPP [-]	0.68	0.74	0.42	0.37	0.68	0.88	0.67
Biomass [$tCha^{-1}$]	57.16	28.45	105.60	119.20	34.19	6.55	25.04
Litter [$tCha^{-1}$]	4.03	2.41	10.36	14.65	4.21	0.67	2.50
Soil [$tCha^{-1}$]	241.14	120.18	323.64	448.18	224.87	29.43	104.90
BIOS-2 (Haverd et al. 2013a) Parameter + forcing uncertainty (1σ)							
NPP [$gCm^{-2}d^{-1}$]	0.407	0.255	0.261	0.262	0.238	0.097	0.143
NEP [$gCm^{-2}d^{-1}$]	0.047	0.014	0.043	0.024	0.010	0.017	0.008
NEP IAV [1σ $gCm^{-2}d^{-1}$]	-	-	-	-	-	-	-
Frac. recurrent NPP [-]	0.07	0.15	0.06	0.04	0.14	0.30	0.14
Biomass [$tCha^{-1}$]	23.78	17.10	30.44	47.60	8.80	7.26	9.20
Litter [$tCha^{-1}$]	2.31	1.60	4.67	7.99	1.81	0.95	1.30
Soil [$tCha^{-1}$]	186.79	107.25	256.89	366.73	220.53	44.26	94.94