Table S1: Annual UK net biospheric flux for June 2014 as estimated with an inversion using footprints disaggregated for 24 hours back in time and compared to an inversion using footprints disaggregated for 72 hours back in time. CARDAMOM NEE was used as the prior flux in this test.

Prior	-355
Posterior (24-hour back footprints)	$-356 \pm^{87}_{88}$
Posterior (72-hour back footprints)	$-395 \pm^{90}_{91}$

Table S2: Prior and posterior fit to data statistics for year 2014 (calculated for each month and averaged over the year). Prior modelled mole fractions are added to the posterior baseline before they are compared to the data.

CARDAMOM inversion

Measurement site	Prior R^2	Posterior R^2	Prior RMSE	Posterior RMSE	Prior mean bias	Posterior mean bias
Mace Head	0.13	0.61	2.64	1.58	1.10	0.55
Ridge Hill	0.30	0.69	4.27	2.35	1.17	-0.13
Tacolneston	0.25	0.61	4.34	2.50	0.97	-0.30
Heathfield	0.23	0.74	4.62	2.11	1.83	0.07
Bilsdale	0.17	0.60	3.57	2.38	0.60	-0.52
Angus	0.25	0.71	2.48	1.40	0.73	-0.06

JULES inversion

Measurement site	Prior R^2	Posterior R^2	Prior RMSE	Posterior RMSE	Prior mean bias	Posterior mean bias
Mace Head	0.30	0.64	1.96	1.34	0.61	0.19
Ridge Hill	0.29	0.70	3.37	2.32	0.96	-0.11
Tacolneston	0.25	0.54	3.75	3.12	0.38	-0.76
Heathfield	0.26	0.68	3.69	2.40	0.88	-0.30
Bilsdale	0.28	0.61	2.85	2.56	0.23	-0.96
Angus	0.31	0.71	2.46	1.51	1.16	0.33

15 **Table S3:** Prior and posterior fit to data statistics for year 2014 for the inversion using NEE prior flux as opposed to separating GPP and TER (calculated for each month and averaged over the year). Prior modelled mole fractions are added to the posterior baseline before they are compared to the data.

CARDAMOM inversion

Measurement site	Prior R^2	Posterior R^2	Prior RMSE	Posterior RMSE	Prior mean bias	Posterior mean bias
Mace Head	0.13	0.53	2.28	1.67	0.45	0.33
Ridge Hill	0.3	0.63	3.77	2.64	0.56	-0.08
Tacolneston	0.25	0.55	3.72	2.86	0.38	-0.38
Heathfield	0.23	0.62	3.88	2.59	1.15	0.18
Bilsdale	0.17	0.55	3.21	2.69	-0.02	-0.58
Angus	0.25	0.64	2.16	1.62	0.30	-0.02

JULES inversion

Measurement site	Prior R^2	Posterior R^2	Prior RMSE	Posterior RMSE	Prior mean bias	Posterior mean bias
Mace Head	0.3	0.59	1.76	1.36	-0.05	-0.13
Ridge Hill	0.29	0.64	3.31	2.63	0.19	0.02
Tacolneston	0.25	0.51	3.6	3.14	-0.36	-0.65
Heathfield	0.26	0.59	3.38	2.65	0.03	-0.28
Bilsdale	0.28	0.62	2.9	2.57	-0.58	-0.82
Angus	0.31	0.66	2.19	1.73	0.43	0.30

20

25

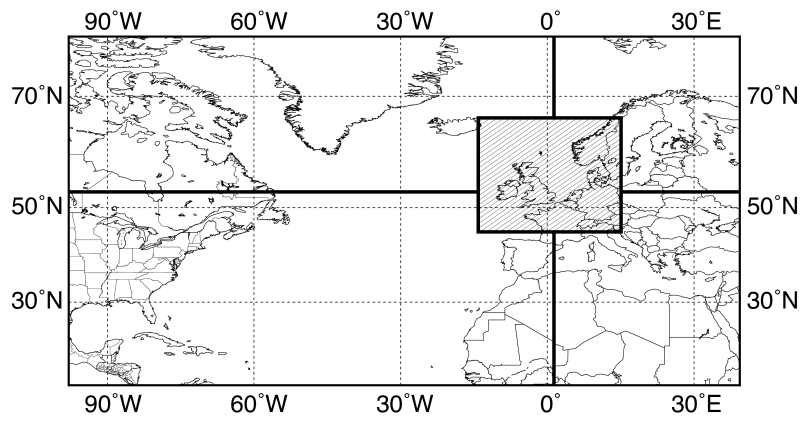



Figure S1: The domain used to calculate NAME footprints. The four edge boxes correspond to four basis functions. The hatched box is the main area of focus for this study and basis functions in this area are based on a fractional map of 6–7 different PFTs.

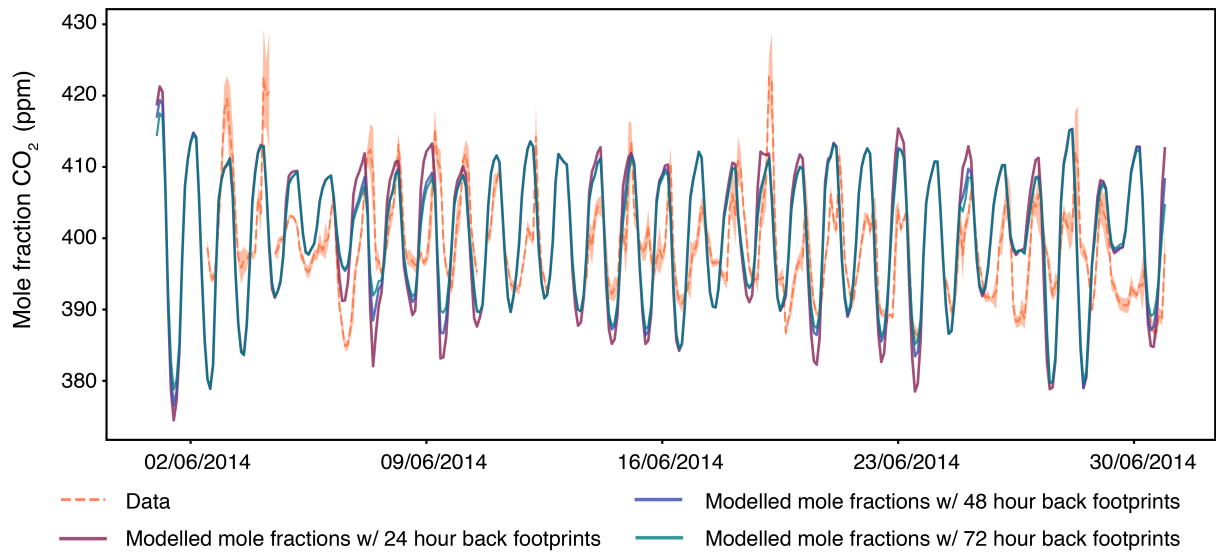



Figure S2: Forward modelled mole fractions at Ridge Hill for June 2014 using CARDAMOM NEE fluxes and NAME footprints that are disaggregated back in time for 24, 48 and 72 hours. Anthropogenic and ocean fluxes have been forward modelled and removed from the data. Shading on the data represents $\pm\,1\sigma$.

35

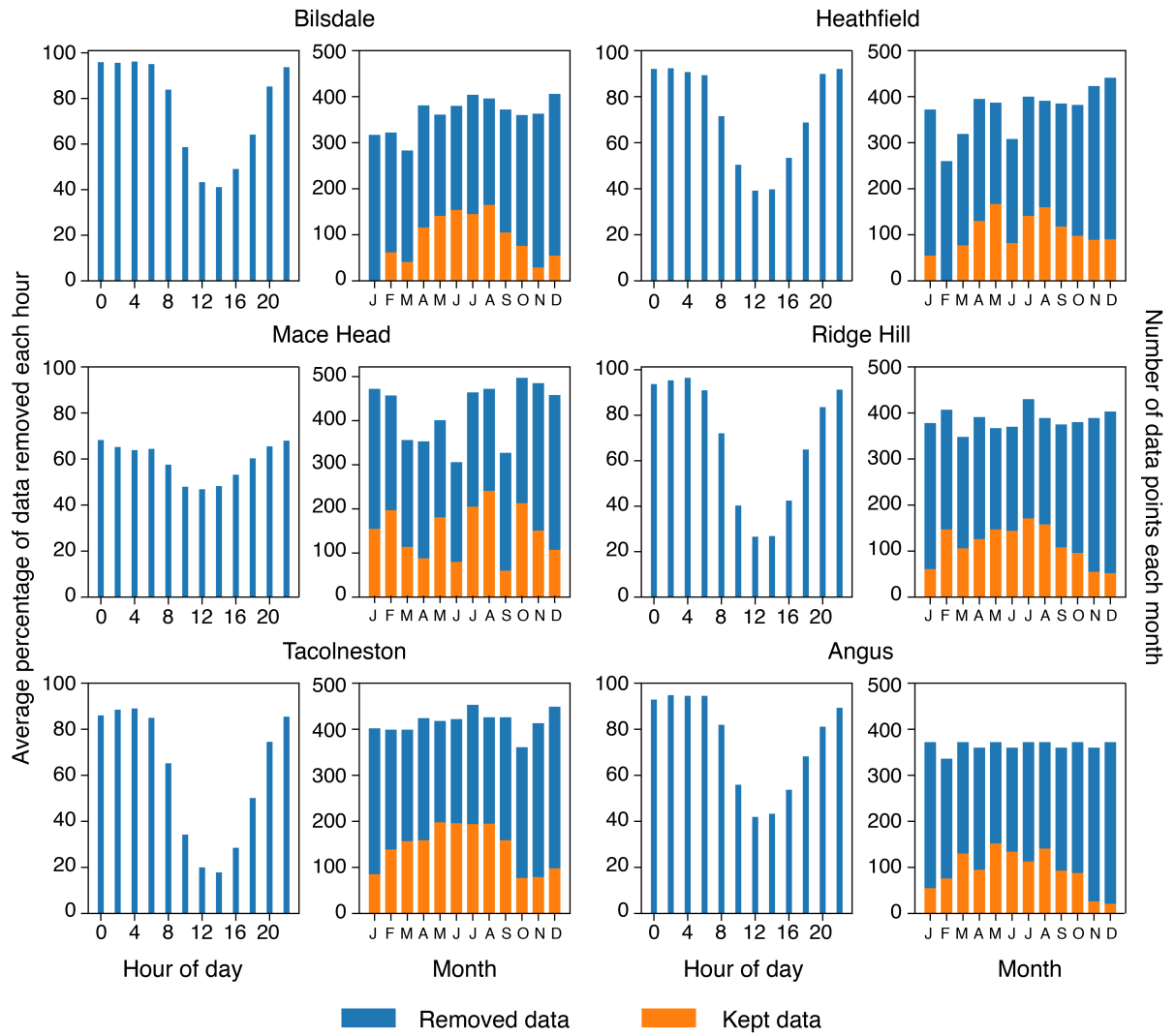
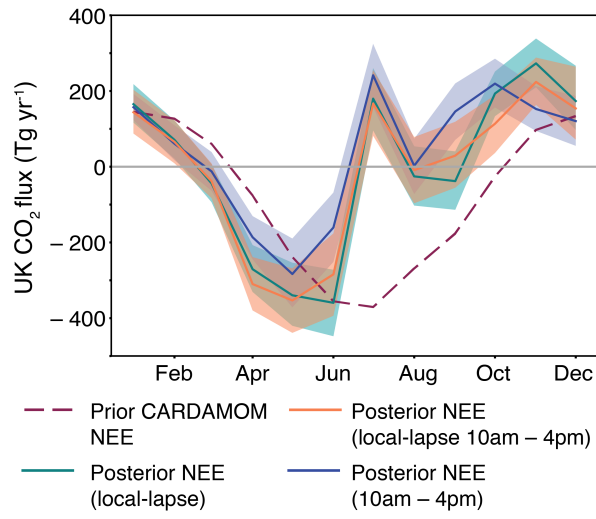



Figure S3: Data filtered out in 2014 using the "local-lapse" filter. Left hand bar charts for each site show the average percentage of data removed for each 2-hour period in the day. Right hand bar charts for each site show the number of data points used in the inversion for each month (orange bars) and the number of data points removed prior to the inversion for each month (blue bars).

45 **Figure S4:** A comparison of the results of three different inversions for 2014 using CARDAMOM prior GPP and TER fluxes and three differently filtered data sets. Local-lapse: the filter used on the final results, a combination of localness and vertical temperature profile metrics. Local-lapse 10am – 4pm: data is filtered with the "local-lapse" filter and then only times between 10am and 4pm are selected. 10am – 4pm: all data between 10am and 4pm is used. Shading represents 5th – 95th percentile.

50

55

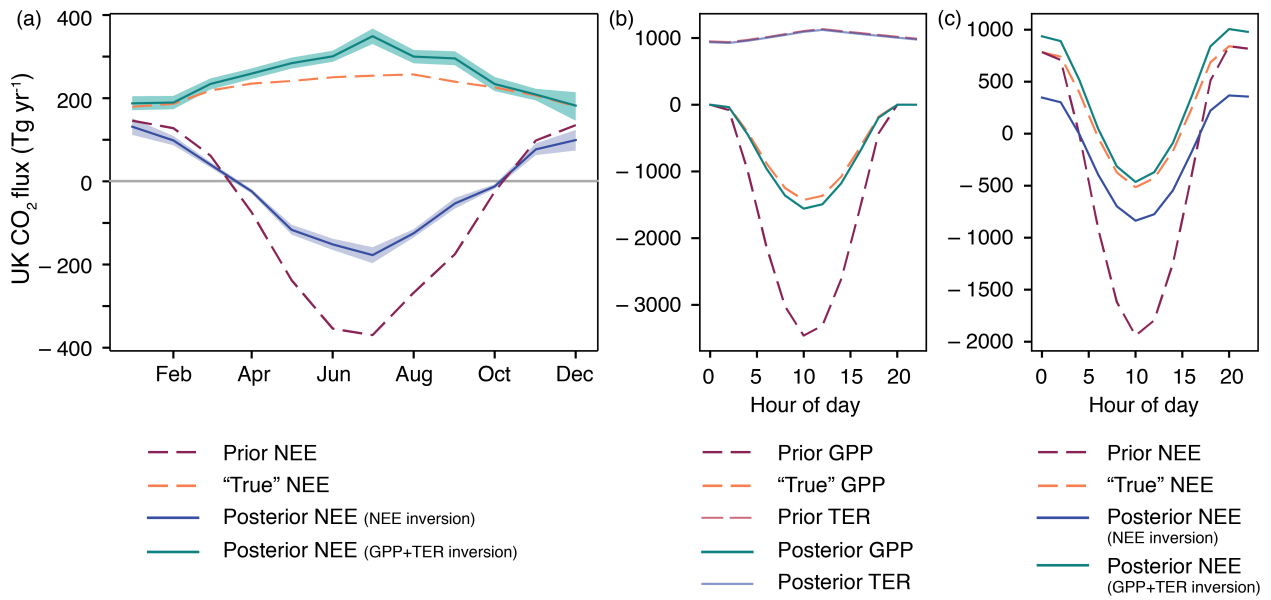



Figure S5: Synthetic test results. Synthetic data was produced using CARDAMOM biospheric fluxes where the GPP was reduced by half – the "true" flux. The "NEE inversion" only scales NEE in the inversion. The "GPP+TER inversion" scales GPP and TER separately in the inversion. NEE prior PDF (x_{NEE}) has Gaussian uncertainty distribution and its standard deviation hyper-parameter ($\sigma_{x_{NEE}}$) has a uniform distribution with a range reflecting an absolute uncertainty of approximately 40–400 Tg (see Table 2 for the comparable set-up for the separate GPP and TER inversion). (a) shows prior and posterior monthly flux estimates for the UK in 2014 compared to the "true" flux. Shading represents the 5th – 95th percentiles. (b) shows average diurnal cycle in June 2014 for prior and posterior GPP and TER in the "GPP+TER" inversion, as well as the "true" GPP ("true" TER is equal to prior TER). (c) shows average diurnal cycle in June 2014 for prior and posterior NEE in both inversions, as well as the "true" NEE.

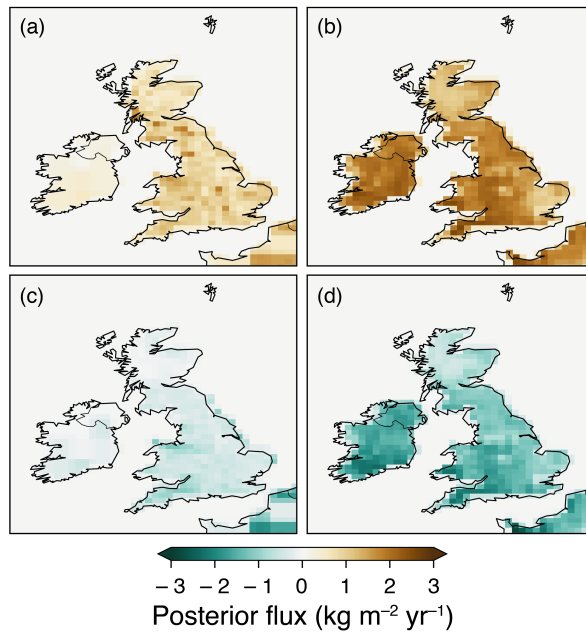



Figure S6: Posterior TER and GPP flux maps averaged over winter 2013 (December 2013, January – February 2014). (a) Winter TER flux from CARDAMOM inversion. (b) Winter TER flux from JULES inversion. (c) Winter GPP flux from CARDAMOM inversion. (d) Winter TER flux from JULES inversion.

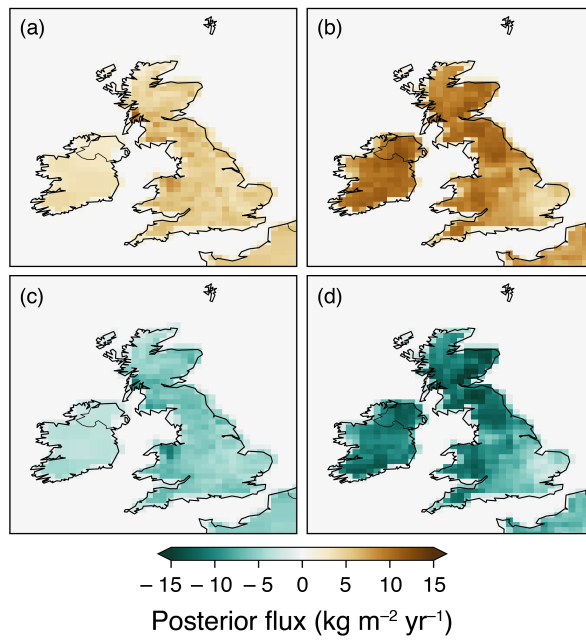



Figure S7: Posterior TER and GPP flux maps averaged over summer 2014 (June – August 2014). (a) Summer TER flux from CARDAMOM inversion. (b) Summer TER flux from JULES inversion. (c) Summer GPP flux from CARDAMOM inversion. (d) Summer GPP flux from JULES inversion.

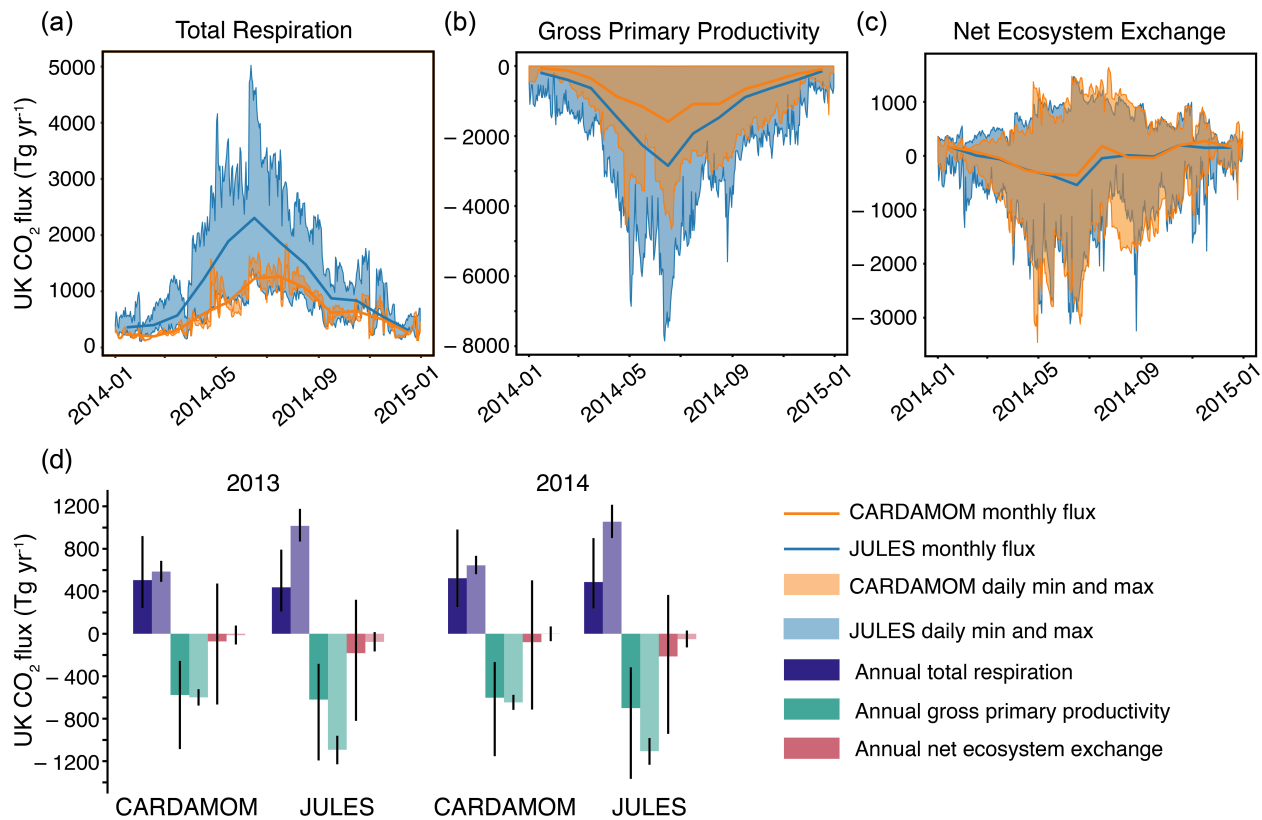



Figure S8: Posterior UK fluxes in 2014. (a-c) Comparison of monthly fluxes and minimum and maximum daily values for TER, GPP and NEE respectively resulting from JULES inversion (blue) and CARDAMOM inversion (orange). (d) Annual CO_2 fluxes for TER, GPP and NEE for 2013 and 2014 from CARDAMOM and JULES inversions. Dark bars denote prior annual fluxes, light bars denote posterior annual fluxes. Uncertainty bars represent $5^{th} - 95^{th}$ percentile.

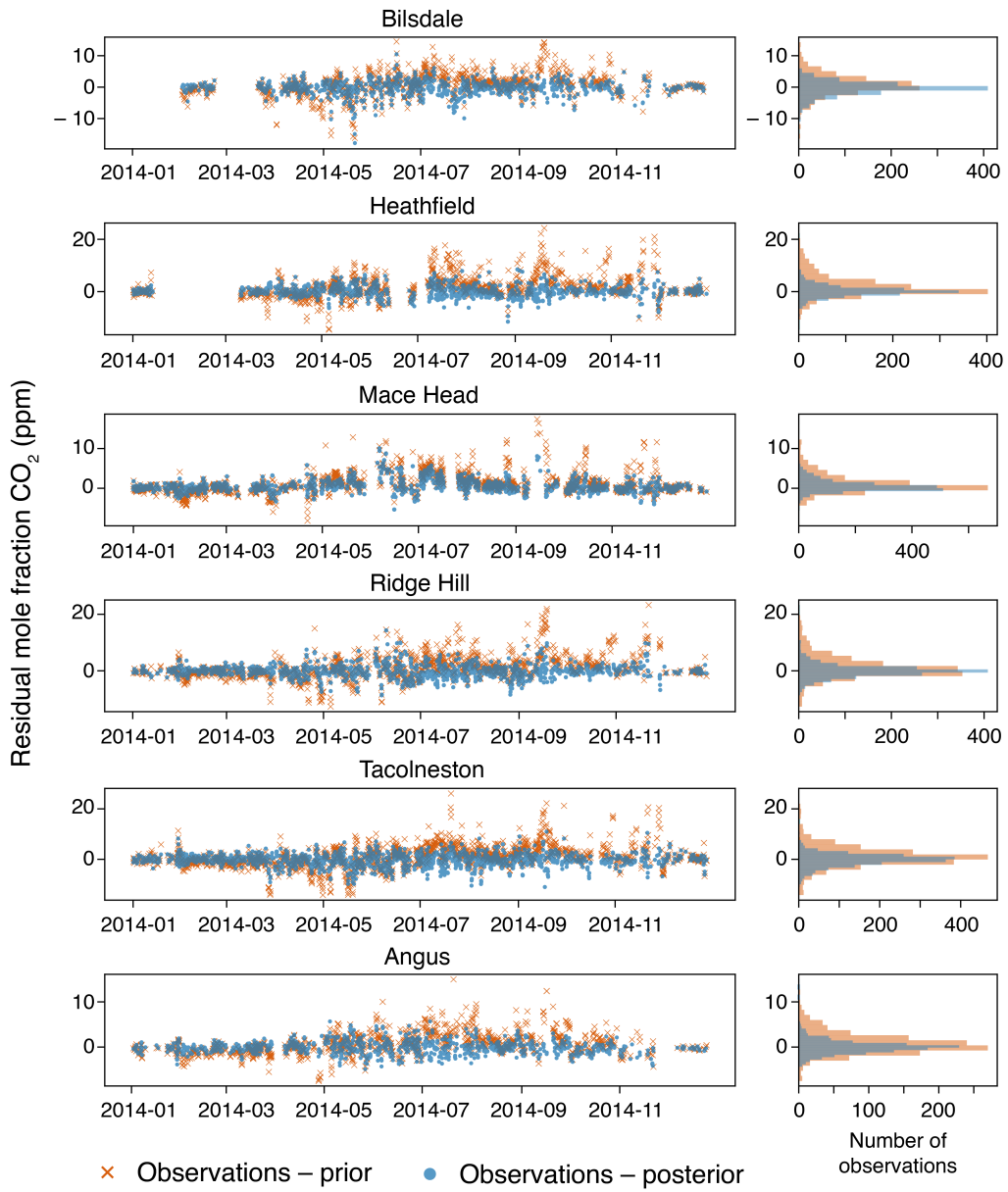



Figure S9: Left: Residual mole fractions for prior and posterior modelled CO_2 concentrations in 2014 using CARDAMOM prior biospheric fluxes. Prior modelled mole fractions are added to the posterior baseline before they are compared to the data. Right: Histogram of prior residuals (orange) and posterior residuals (blue). The mean of the histogram represents the mean bias.

85

90

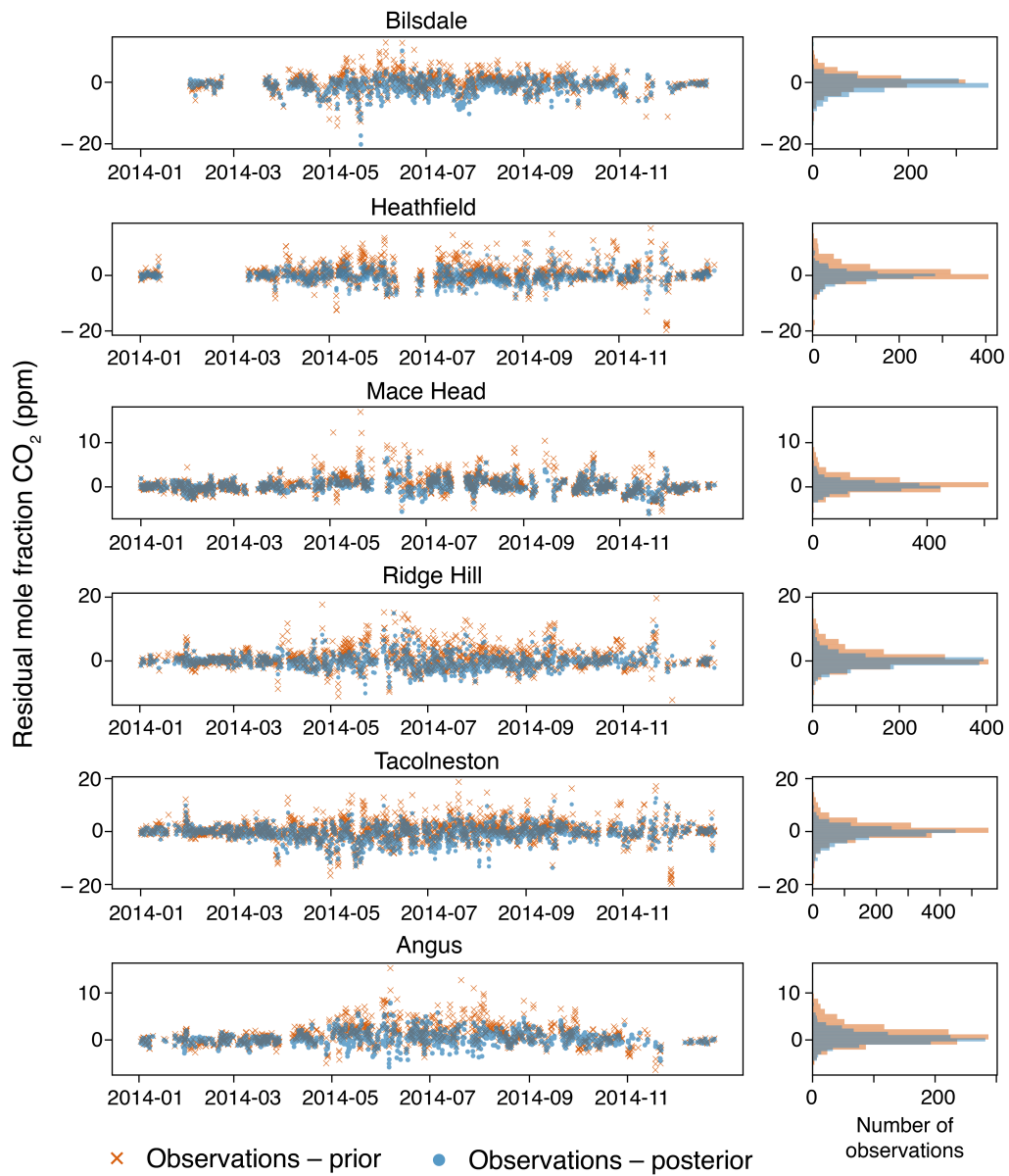



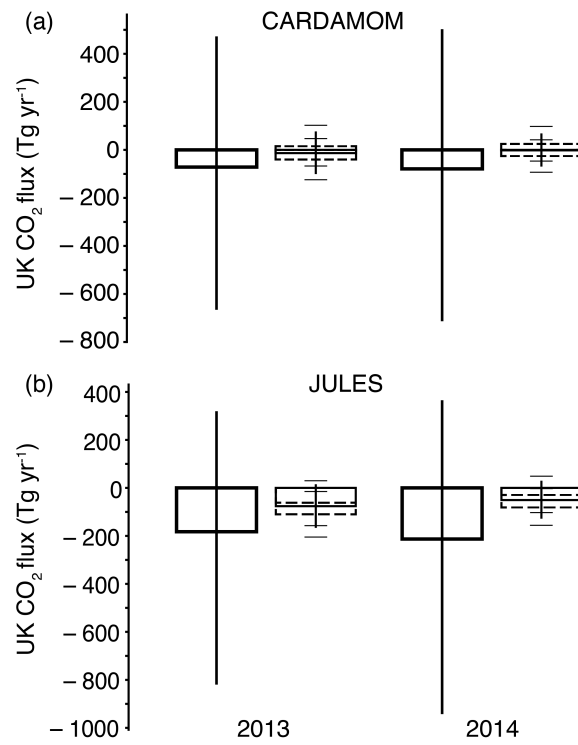
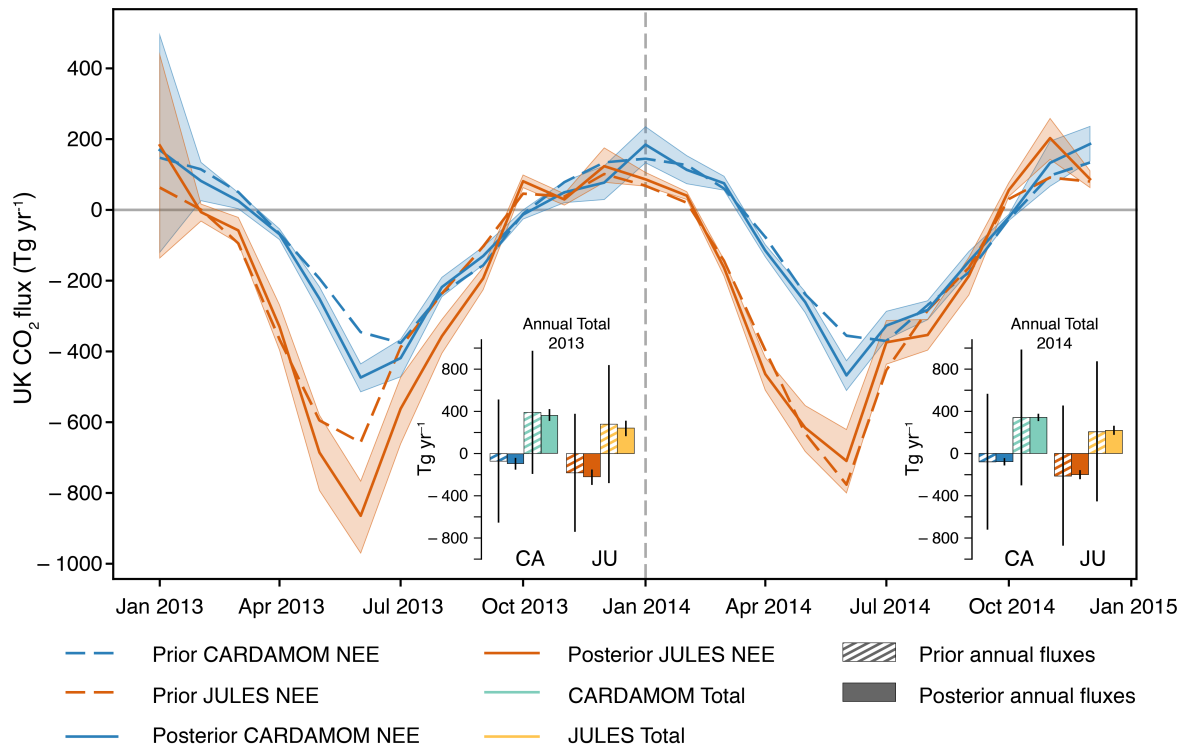
Figure S10: Left: Residual mole fractions for prior and posterior modelled CO_2 concentrations in 2014 using JULES prior biospheric fluxes.
95 Prior modelled mole fractions are added to the posterior baseline before they are compared to the data. Right: Histogram of prior residuals (orange) and posterior residuals (blue). The mean of the histogram represents the mean bias.

100 **Figure S11:** Annual UK NEE flux estimates from CARDAMOM and JULES inversions for 2013 and 2014. Left bars are prior NEE estimates, right bars are posterior NEE estimates. Dashed bars on the posterior estimates represent annual NEE fluxes for inversions that use fixed anthropogenic fluxes multiplied by $\pm 10\%$. Uncertainty bars represent $5^{th} - 95^{th}$ percentile. Solid uncertainty bars on posterior estimates are the uncertainty on the inversions using normal anthropogenic fluxes. Whiskers on the posterior estimates are the uncertainty on the inversions using anthropogenic fluxes multiplied by $\pm 10\%$.

105

Figure S12: Posterior monthly net UK CO$_2$ flux (+ve is emission to atmosphere) for the inversion that scales only NEE rather than GPP and TER separately. Orange and blue monthly fluxes are posterior net biospheric (NEE) fluxes. Prior biosphere fluxes from JULES and CARDOMOM are shown in dashed orange and blue lines respectively. Shading represents 5th – 95th percentile. The bar charts represent annual net UK CO$_2$ flux for 2013 (left) and 2014 (right). Hashed bars denote prior annual fluxes, solid bars denote posterior annual fluxes.
110 The bar colours correspond to the line colours: left hand bars for each model are NEE fluxes, right hand bars for each model are total fluxes (NEE + fixed sources). Uncertainty bars represent 5th – 95th percentile. CA – CARDAMOM. JU – JULES. NEE prior PDF (x_{NEE}) has Gaussian uncertainty distribution and its standard deviation hyper-parameter ($\sigma_{x_{NEE}}$) has a uniform distribution with a range reflecting an absolute uncertainty of approximately 40–400 Tg (see Table 2 for the comparable set-up for the separate GPP and TER inversion).

115