



Supplement of

Quantifying the UK's carbon dioxide flux: an atmospheric inverse modelling approach using a regional measurement network

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$79\pm^{103}_{106}$
$-207\pm^{85}_{85}$
$-356\pm^{87}_{88}$
$-382\pm_{86}^{92}$
$-412 \pm ^{110}_{101}$

Table S1: Annual UK net biospheric flux for June 2014 as estimated with an inversion using footprints disaggregated for 12, 24, 48 and 72
hours back in time, as well as an inversion using integrated footprints combined with monthly fluxes. DALEC NEE was used as the prior flux in this test.

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20 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 (Fig. S6).



Figure S2: Forward modelled mole fractions at Ridge Hill and Tacolneston for part of June 2014 using DALEC NEE fluxes and NAME footprints that are disaggregated back in time for 6, 12, 24, 48 and 72 hours, as well as using integrated footprints with monthly fluxes. Anthropogenic and ocean fluxes have been forward modelled and removed from the data. Shading on the data represents $\pm 1\sigma$.



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).



35 Figure S4: A comparison of the results of three different inversions for 2014 using DALEC 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.



- **Figure S5:** Synthetic test results. Synthetic data was produced using DALEC biospheric fluxes and NAME simulations– the "true" flux. Prior fluxes are provided by JULES. 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 3 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
- 55 "true" flux. Shading represents the 5th 95th percentiles. (b) shows average diurnal cycle in June 2014 for prior and posterior NEE in both inversions, as well as the "true" NEE. (c) 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.



Figure S6: Maps of plant functional type (PFT) fraction for each of the 6 PFTs used as spatial basis functions within the sub-domain. Note the scale is logarithmic.



Figure S7: Posterior TER and GPP flux maps averaged over winter 2013 (December 2013, January – February 2014). (a) Winter TER flux from DALEC inversion. (b) Winter TER flux from JULES inversion. (c) Winter GPP flux from DALEC inversion. (d) Winter TER flux from JULES inversion.



Figure S8: Posterior TER and GPP flux maps averaged over summer 2014 (June – August 2014). (a) Summer TER flux from DALEC inversion. (b) Summer TER flux from JULES inversion. (c) Summer GPP flux from DALEC inversion. (d) Summer GPP flux from JULES inversion.



Figure S9: 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 DALEC inversion (orange). (d) Annual CO₂ fluxes for TER, GPP and NEE for 2013 and 2014 from DALEC and JULES inversions. Dark bars denote prior annual fluxes, light bars denote posterior annual fluxes. Uncertainty bars represent 5th – 95th percentile.



Figure S10: Annual UK NEE flux estimates from DALEC 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 5th – 95th 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 normal anthropogenic fluxes. Whiskers on the posterior estimates are the uncertainty on the inversions using anthropogenic fluxes multiplied by \pm 10%.



Figure S11: Mean and maximum number of temporal regions each month, taken across the number of algorithm iterations, for each source and spatial region.



Figure S12: Left: Residual mole fractions for prior and posterior modelled CO_2 concentrations in 2014 using DALEC prior biospheric fluxes. Right: Histogram of prior residuals (orange) and posterior residuals (blue). The mean of the histogram represents the mean bias.



Figure S13: Left: Residual mole fractions for prior and posterior modelled CO₂ concentrations in 2014 using JULES prior biospheric fluxes. Right: Histogram of prior residuals (orange) and posterior residuals (blue). The mean of the histogram represents the mean bias.



Figure S14: Left: Residual mole fractions for modelled CO₂ concentrations at Weybourne in 2013 using prior DALEC and JULES fluxes,
 and posterior DALEC and JULES fluxes from both the gross (scaling GPP and TER separately) and net (scaling just NEE) flux inversions.
 Weybourne data was not included in the inversions. Right: Histogram of residuals. The mean of the histogram represents the mean bias.



Figure S15: Posterior monthly net UK CO₂ 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 for DALEC and JULES respectively. Prior biosphere fluxes from DALEC and JULES are shown in dashed orange and blue lines respectively. Shading represents 5th – 95th percentile. The bar charts represent annual net UK CO₂ flux for 2013 (left) and 2014 (right). Hashed bars denote prior annual fluxes, solid bars denote posterior annual fluxes. 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. DA – DALEC. JU – JULES. NEE prior

140 PDF (\mathbf{x}_{NEE}) has Gaussian uncertainty distribution and its standard deviation hyper-parameter $(\sigma_{\mathbf{x}_{NEE}})$ has a uniform distribution with a range reflecting an absolute uncertainty of approximately 40–400 Tg (see Table 3 for the comparable set-up for the separate GPP and TER inversion).

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