Supporting Information for

Attribution of surface temperature anomalies induced by land use and land cover changes

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Introduction

This supporting information contains two text files, one on the data from 75 AmeriFlux sites (see Text S1) and the other on the formulation of the two-resistance mechanism method (see Text S2). It also includes two figures and one table.

Added on Jan 23, 2018: The supplementary materials submitted to GRL included three typos in the formulations of the TRM method, which are corrected and are highlighted in red (see Eq. S2, S7, and S8). In particular, the minus sign in Eqs. (S7) and (S8) was a plus sign in the submitted version. The calculations in the paper were using the correct version of the equations so the typos in the supplementary materials do not affect any conclusions. We apologize for the typos.

Text S1: Data

In this study, we utilize observational data from 75 AmeriFlux sites. The sites span a range of climates, plant functional types, and water/energy limitations (see Table S1). All AmeriFlux data were obtained from the Level-2 Data Repository (http://ameriflux.ornl.gov) and were processed as following Rigden and Salvucci (2015). Days were used if over 50% of daytime hours were available.

Text S2: The Two Resistance Mechanism (TRM) method

Similar to the IBM method, the TRM method starts with the surface energy balance equation (here the ground heat flux and the anthropogenic heat flux are not included but can be easily incorporated):

$$R_n = S_{in}(1-\alpha) + \varepsilon L_{in} - \varepsilon\sigma T_s^4 = H + LE = \frac{\rho c_p}{r_a}(T_s - T_a) + \frac{\rho L_v}{(r_a+r_s)}(q_s^*(T_s) - q_a). \quad \text{(S1)}$$

Linearizing the outgoing longwave radiation and saturated specific humidity terms yields

$$S_{in}(1-\alpha) + \varepsilon L_{in} - \varepsilon\sigma T_a^4 - 4\varepsilon\sigma T_a^3(T_s - T_a) = \frac{\rho c_p}{r_a}(T_s - T_a) + \frac{\rho L_v}{(r_a+r_s)}\left(q_a^*(T_a) + \frac{\partial q^*}{\partial T}\Big|_{T_a}(T_s - T_a) - q_a\right). \quad \text{(S2)}$$

Again denoting $R_n^* = S_{in}(1-\alpha) + \varepsilon L_{in} - \varepsilon\sigma T_a^4$ and $\lambda_o = 1/(4\varepsilon\sigma T_a^3)$, one arrives at

$$R_n^* = \frac{1}{\lambda_o}(T_s - T_a) + \frac{\rho c_p}{r_a}(T_s - T_a) + \frac{\rho L_v}{(r_a+r_s)}(q_a^*(T_a) - q_a) + \frac{\rho L_v}{(r_a+r_s)}\frac{\partial q^*}{\partial T}\Big|_{T_a}(T_s - T_a),$$

namely,

$$T_s - T_a = \frac{R_n^* - \frac{\rho L_v}{(r_a+r_s)}(q_a^*(T_a) - q_a)}{\frac{1}{\lambda_o} + \frac{\rho c_p}{r_a} + \frac{L_v}{(r_a+r_s)}\frac{\partial q^*}{\partial T}\Big|_{T_a}}. \quad \text{(S3)}$$

Further denoting $\Delta = \frac{\partial e^*}{\partial T}\Big|_{T_a}$, $r_o = \rho c_p \lambda_o$, $\gamma = \frac{c_p P}{0.622 L_v}$ and $f_{TRM} = \frac{r_o}{r_a}\left[1 + \frac{\Delta}{\gamma}\left(\frac{r_a}{r_a+r_s}\right)\right]$ leads to

$$T_s - T_a = \frac{\lambda_o\left[R_n^* - \frac{\rho L_v}{(r_a+r_s)}(q_a^*(T_a) - q_a)\right]}{1+f_{TRM}}. \quad \text{(S4)}$$

With the above expression for $T_s - T_a$ and not considering changes in atmospheric properties, one arrives at

$$\Delta T_s = \left(\frac{\partial T_s}{\partial R_n^*}\right)^{TRM}\Delta R_n^* + \left(\frac{\partial T_s}{\partial r_a}\right)^{TRM}\Delta r_a + \left(\frac{\partial T_s}{\partial r_s}\right)^{TRM}\Delta r_s. \quad \text{(S5)}$$

$$\left(\frac{\partial T_s}{\partial R_n^*}\right)^{TRM} = \frac{\lambda_o}{1+f_{TRM}}, \quad \text{(S6)}$$

$$\left(\frac{\partial T_s}{\partial r_a}\right)^{TRM} = \frac{\lambda_o \rho L_v (q_a^*(T_a) - q_a)}{(r_a+r_s)^2}\frac{1}{(1+f_{TRM})} - \frac{\partial f_{TRM}}{\partial r_a}\lambda_o\left[R_n^* - \frac{\rho L_v (q_a^*(T_a) - q_a)}{(r_a+r_s)}\right]\frac{1}{(1+f_{TRM})^2}, \quad \text{(S7)}$$

$$\left(\frac{\partial T_s}{\partial r_s}\right)^{TRM} = \frac{\lambda_o \rho L_v (q_a^*(T_a) - q_a)}{(r_a + r_s)^2} \frac{1}{(1+f_{TRM})} - \frac{\partial f_{TRM}}{\partial r_s} \lambda_o \left[R_n^* - \frac{\rho L_v (q_a^*(T_a) - q_a)}{(r_a + r_s)}\right] \frac{1}{(1+f_{TRM})^2}, \quad \text{(S8)}$$

where

$$\frac{\partial f_{TRM}}{\partial r_a} = -\frac{r_o}{r_a^2}\left[1 + \frac{\Delta}{\gamma}\left(\frac{r_a}{r_a + r_s}\right)^2\right], \quad \text{(S9)}$$

$$\frac{\partial f_{TRM}}{\partial r_s} = -\frac{\Delta}{\gamma} \frac{r_o}{(r_a + r_s)^2}. \quad \text{(S10)}$$

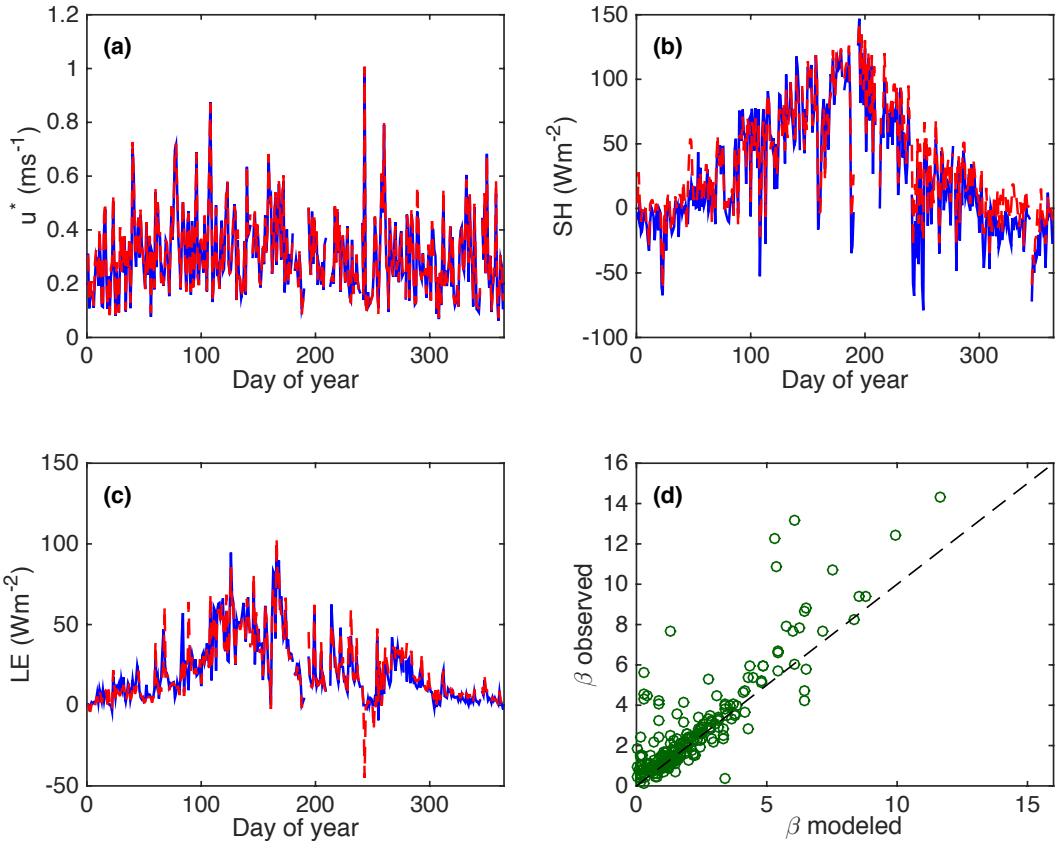

Figure S1. (a-c) Daily average friction velocity (u*), sensible heat flux (H), and latent heat flux (LE) measured (red dashed line) and modeled using optimized parameters (blue solid line) at Fort Peck in 2006. (d) One-to-one plot of the Bowen ratio estimated from measured (y-axis) and modeled fluxes using optimal parameters (x-axis).

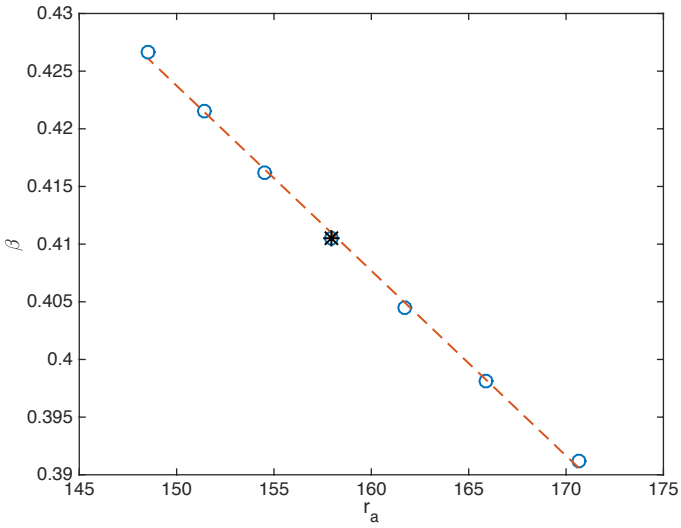

Figure S2. An example of sensitivity analysis at Fort Peck on July 16, 2006 (day of year 197). We varied r_a by varying z_o from the optimal value (black asterisk) by ±10%, ±20%, and ±30% (blue circles).

References

Rigden, A. J., and G. D. Salvucci 2015 Evapotranspiration based on equilibrated relative humidity (ETRHEQ): Evaluation over the continental U.S *Water Resour. Res.* **51** 2951–2973