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SUPPLEMENTARY INFORMATION

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Importance of background climate in determining impact of land-cover change on regional climate

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Supplementary text and figures

The CSIRO-MK3L model's climate sensitivity

For the CSIRO Mk3L coupled model simulations that form the basis of the paper:

(i) The transient climate response (TCR), as defined by the transient increase in global-mean surface air temperature upon a doubling of the atmospheric CO_2 concentration at a rate of 1% per year, is 1.4°C. This value is consistent with the 5-95% uncertainty range for the models reported in the 4th Assessment Report of the Intergovernmental Panel on Climate Change[1] of 1.2-2.4°C, but less than the mean value of 1.76°C (ref 1).

(ii) The equilibrium climate sensitivity (ECR), as defined by the equilibrium increase in global-mean surface air temperature in response to a doubling of the atmospheric CO_2 concentration, is 4.1°C. Direct comparison with other climate models is misleading, as the ECR is generally estimated for other models, rather than being directly determined by integrating the models to equilibrium. Nonetheless, the ECR of 4.1°C for Mk3L is consistent with the 5-95% uncertainty range for the models reported in the 4th Assessment

Report of the Intergovernmental Panel on Climate Change[2] of 2.1-4.4°C, but greater than the mean value of 3.26°C (ref 1). The ECR of CSIRO Mk3L is also consistent with the AR4 report's conclusion that the "likely" value for the climate system lies within the range 2-4.5°C.

The sensitivity of the CSIRO-MK3L model coupled to CABLE to LULCC

An evaluation of how climate models coupled with sophisticated land surface models respond to LULCC has been conducted under the auspices of the international intercomparison project "Land-Use and Climate, IDentification of robust impacts" (LUCID). The role of LUCID was to address the robustness of possible (remote) impacts of LULCC but it has also led to an increasingly thorough examination of exactly how a LULCC perturbation is translated into temperature anomalies at the surface. The first-order results of LUCID have been reported[3] and a detailed analysis of how CABLE responds within LUCID is forthcoming[4].

The version of CABLE used in LUCID was shown to respond to LULCC in ways consistent with most other LUCID models. There was one significant anomaly: CABLE had a very low sensitivity to LULCC in terms of the impact on the net radiation because the parameters used in the calculation of vegetation albedo did not vary as a function of vegetation type. Thus, any change in vegetation type did not cause a change in snow-free albedo. The current version of CABLE used in this paper differs from the version used in LUCID by defining vegetation-specific albedo parameters[5] and calibrating the control simulation to closely match observed net radiation[6]. This approach in CABLE is consistent with how these processes are represented in most other LUCID models[4].

CABLE uses a three-layer snowpack model that computes the temperature, density, thickness and age of snow layers dynamically and adjusts snow albedo as these properties change. While by default snow settles on the soil below the vegetation canopy, effective leaf area index is reduced by the fraction of vegetation height occupied by the snowpack. This allows for realistic roughness and albedo changes if snow falls on short or sparse vegetation types, such as grasslands or open shrub land.

There is value in noting that climate models very likely fail to represent some key phenomenon associated with LULCC. These include biological volatile organic compounds that affect aerosol productions, aerosols linked with fire, possible impacts of the actual patterns of deforestation on turbulence and boundary layer processes and how these and other factors interact with cloud formation, cloud characteristics and rainfall processes. Weaknesses remain in how energy is partitioned between radiative and turbulent energy fluxes[4], and how turbulent fluxes are split between latent and sensible heat.

The resulting impacts of LULCC simulated by CSIRO Mk3L coupled with CABLE are provided in Supplementary Figures. Supplementary Figures S4 shows a seasonally dependent decrease in net radiation resulting from LULCC. This is as expected with LULCC mainly being represented by a change in vegetation from forests to crops and pasture which have a higher albedo and the patterns of reduction in net radiation are consistent with earlier studies[7] in terms of pattern and magnitude. As a consequence of the decrease in net radiation a cooling in air temperature is typically simulated[7,8,9] where the impact of the decrease in net radiation dominates the consequences of a reduction in turbulent energy fluxes associated with the decrease in surface roughness[4]. The changes in the partitioning of net radiation between sensible and latent heat is more important in spring and summer when energy tends to be less limiting, hence temperature can (but do not always) increase due to LULCC[3, 4, 7].

These changes, while not consistently simulated by all models[3] are less controversial than how rainfall will respond to LULCC. LUCID found a very inconsistent result[3] in regions coincident with LULCC and no evidence of remote changes, a result others have previously found[4,7]. Others find evidence of global-scale teleconnections[10,11,12,13]. The results shown in Supplementary Figure S7 are within the range of existing simulations and the apparent decrease in precipitation over Asia is consistent with some earlier regional modelling studies[14]. However, how LULCC affects regional and global precipitation remains very uncertain.

Few previous studies of LULCC have provided seasonal changes in snow in the form of maps, or changes in the geography of snow. While the amplified impact of LULCC on temperatures over northern mid-latitudes shown in our results clearly supports and is consistent with studies associating changes in vegetation with snow masking[15] a systematic comparison of the magnitude of this effect is lacking.

Supplementary figures

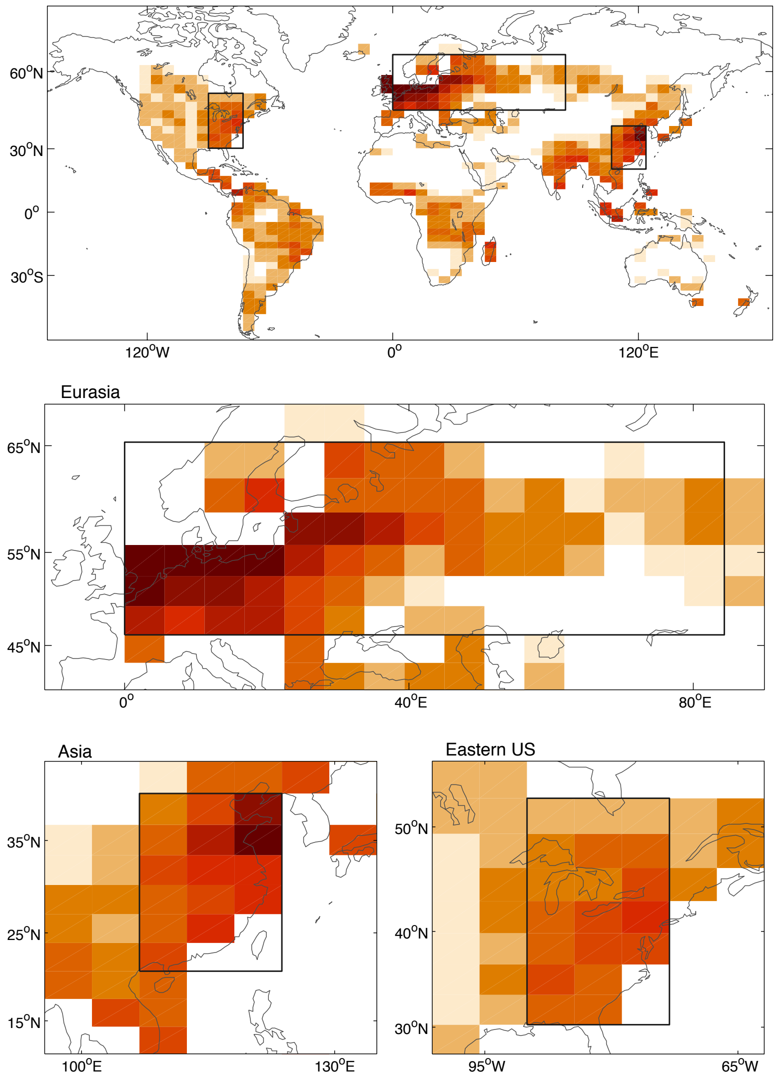

Figure S1. The crop fractions implemented into CABLE, based on Hurtt et al. (2006).

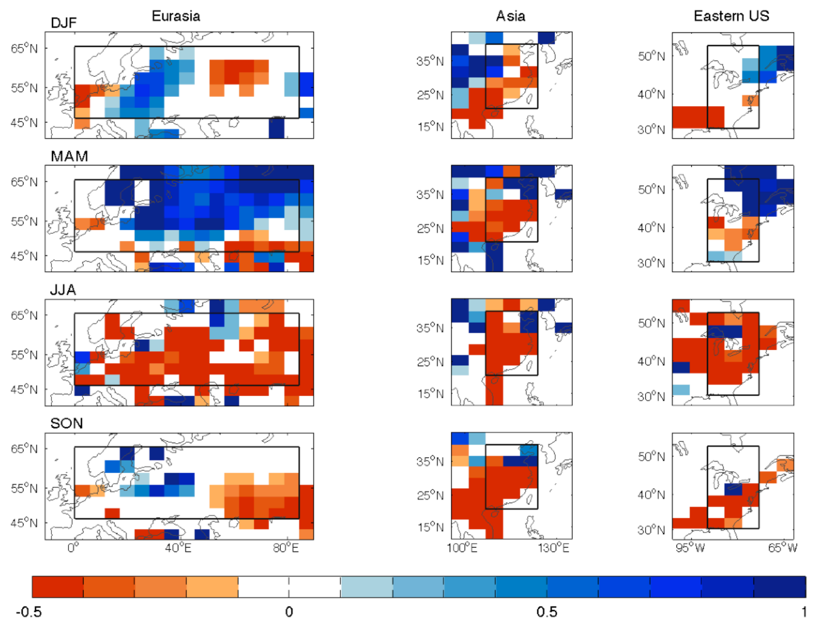

Figure S2. The ratio of the absolute change in surface air temperature (°C) for each season due to LULCC at 1 x CO_2 to the absolute change at 2 x CO_2. Three regions are shown: Eurasia, Asia and eastern United States. A value of 0 is where the changes are identical while -0.5 is where the change at 2 x CO_2 is double the impact at 1 x CO_2. Only points that are statistically significant at a 99% confidence level are shown. Note, negative values occur due to the subtraction of 1.0 from the ratio to centre "no change" on zero.

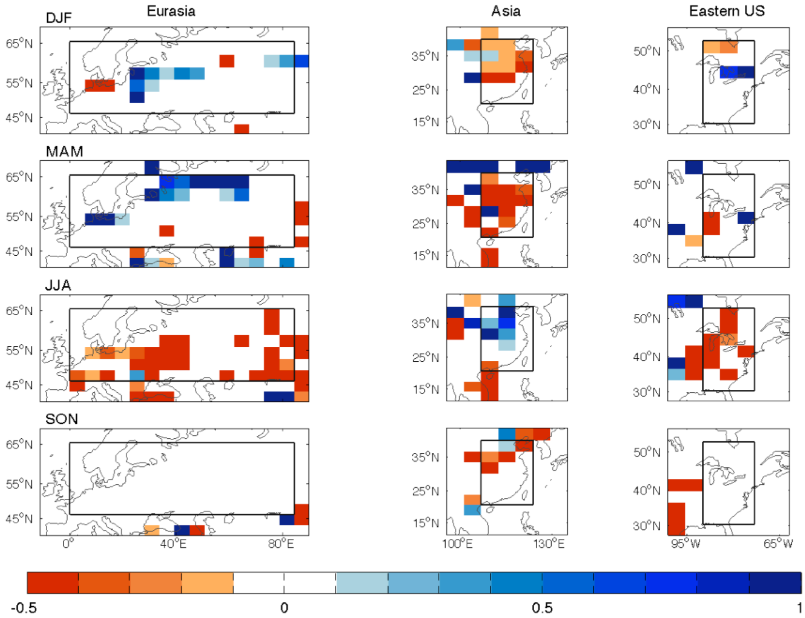

Figure S3. As Figure S2 but for precipitation (mm d^{-1}). Only points that are statistically significant at a 99% confidence level are shown.

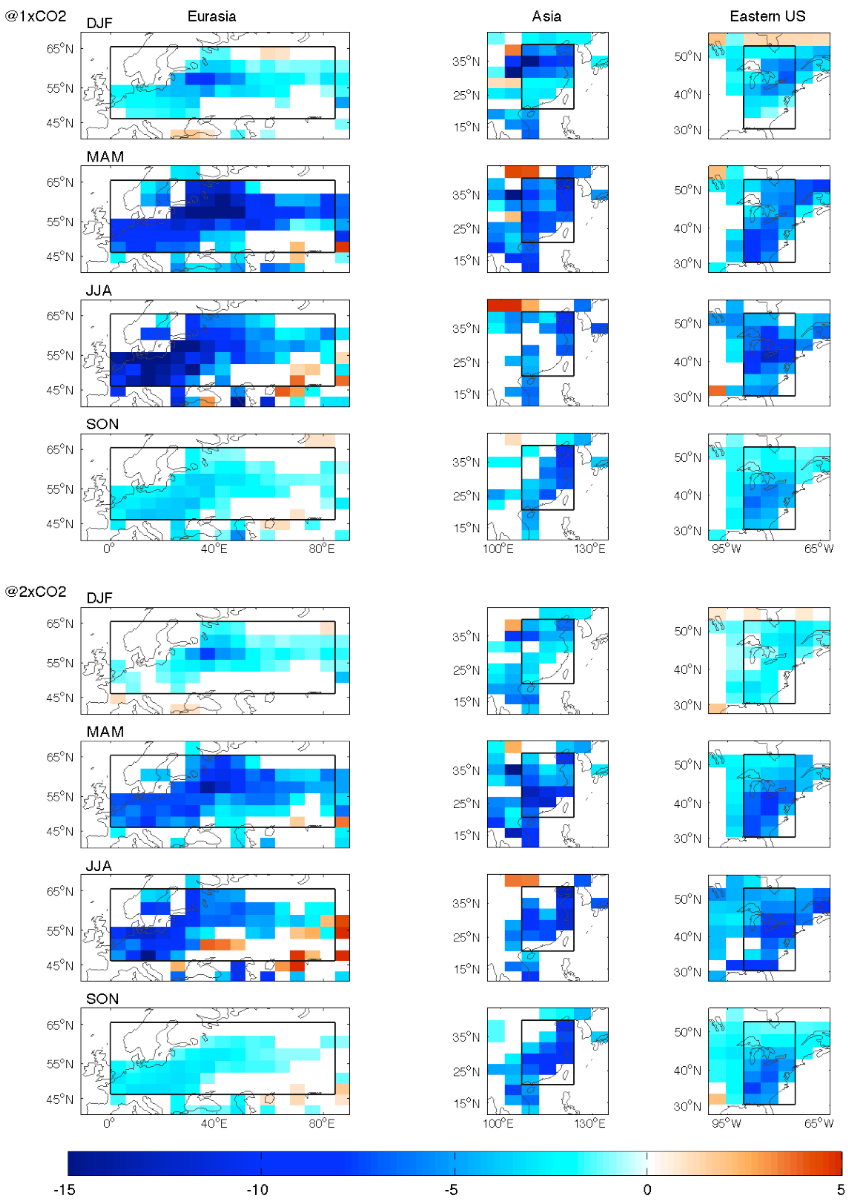

Figure S4. The change in net radiation (W m^{-2}) for each season due to LULCC at 1 x CO_2 (top four rows) and 2 x CO_2 (bottom four rows). Three regions are shown: Eurasia (left), Asia (middle) and eastern United States (right). Only points that are statistically significant at a 99% confidence level are shown.

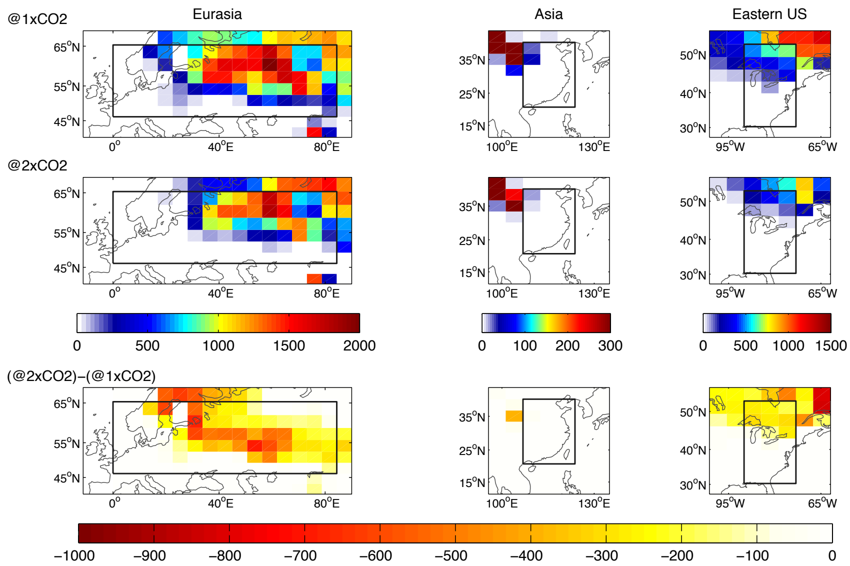

Figure S5. Snow depth (mm) in March-April-May for the three regions for the current land cover. Top - snow depth at 1 x CO_2; middle - snow depth at 2 x CO_2; bottom - difference (2 x CO_2 minus 1 x CO_2). Note different colour scales for the bottom panels. Only points that are statistically significant at a 99% confidence level are shown.

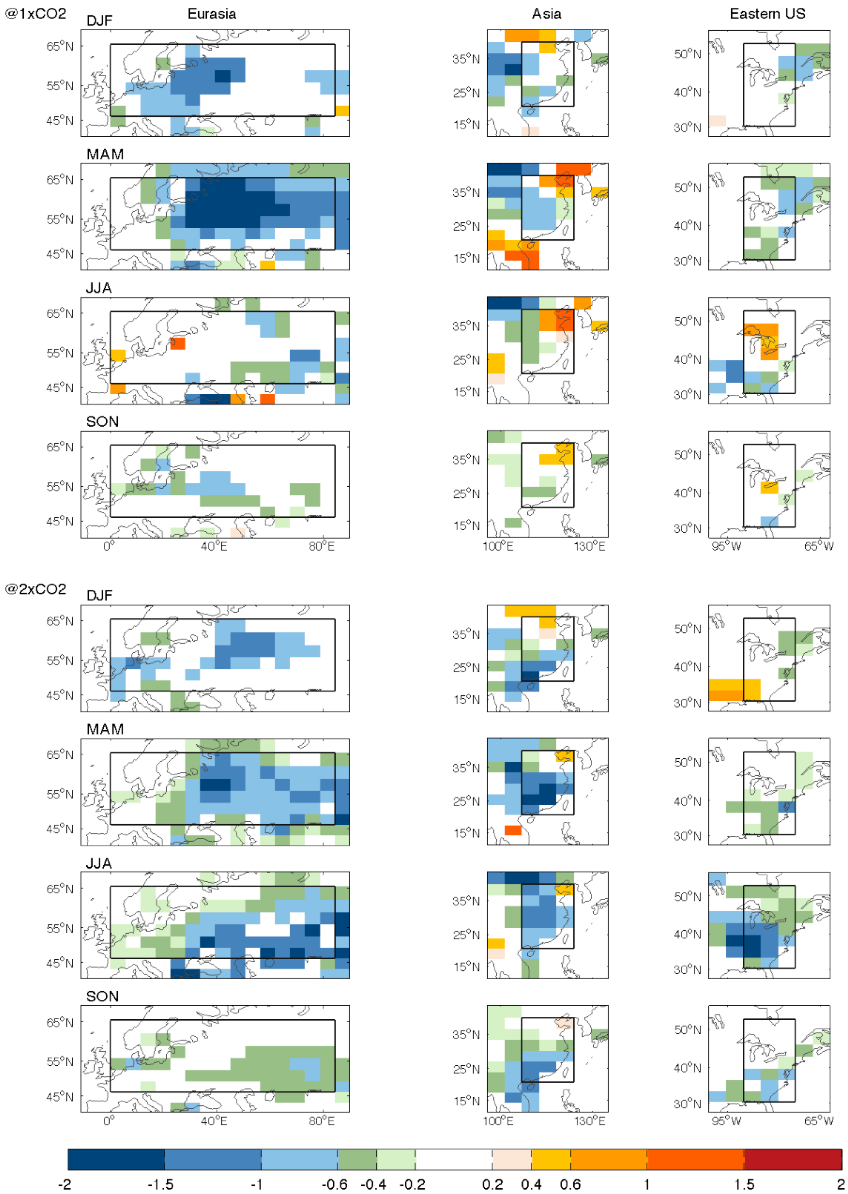

Figure S6. As Figure S4 but for surface air temperature (°C). Only points that are statistically significant at a 99% confidence level are shown.

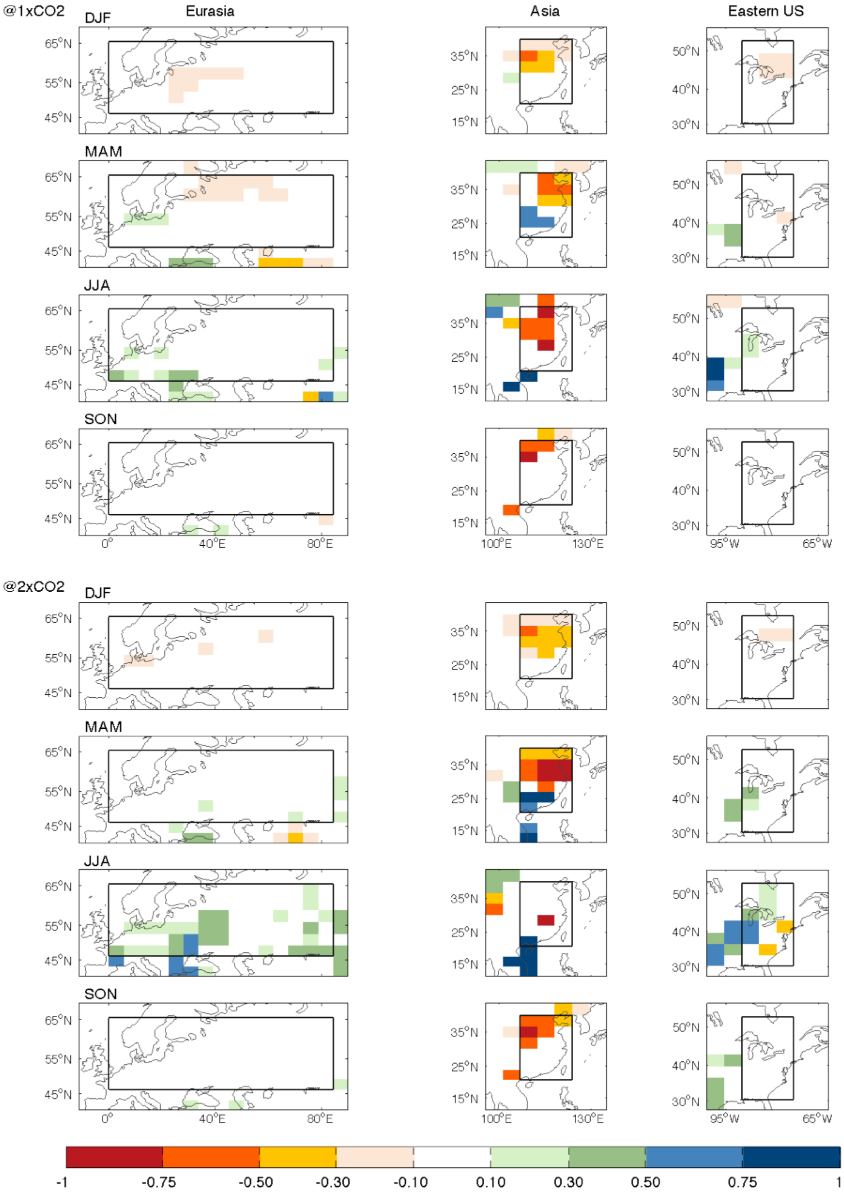

Figure S7. As Figure S4 but for precipitation (mm d^{-1}). Only points that are statistically significant at a 99% confidence level are shown.

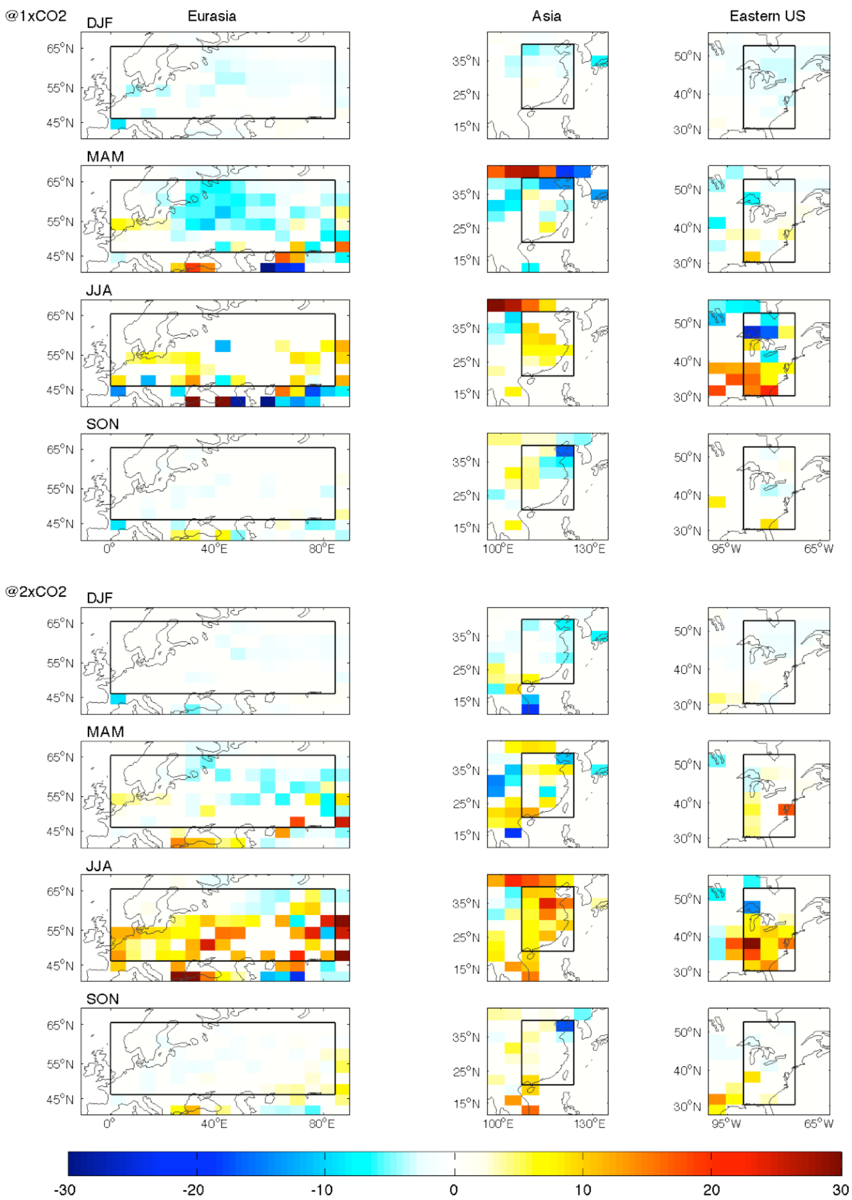

Figure S8. As Figure S4 but for the latent heat flux (W m^{-2}). Only points that are statistically significant at a 99% confidence level are shown.

Supplementary Reference

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