# Supplemental Material

**Supplementary Material**

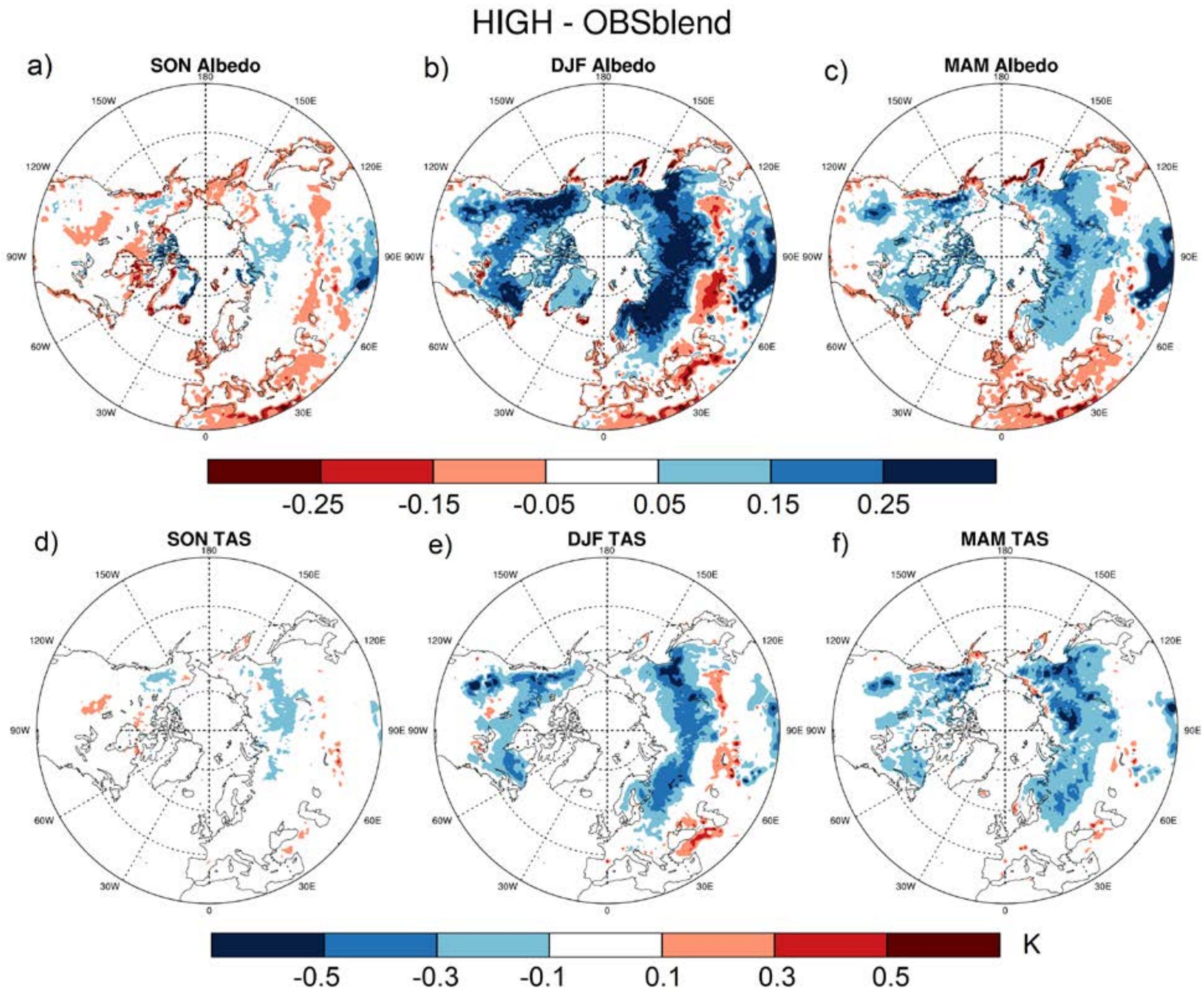


Figure S1: Response to CLM-OFF HIGH albedo forcing in seasonal mean (a, b, c) albedo, (d, e, f) near-surface air temperature relative to the OBSblend experiment.

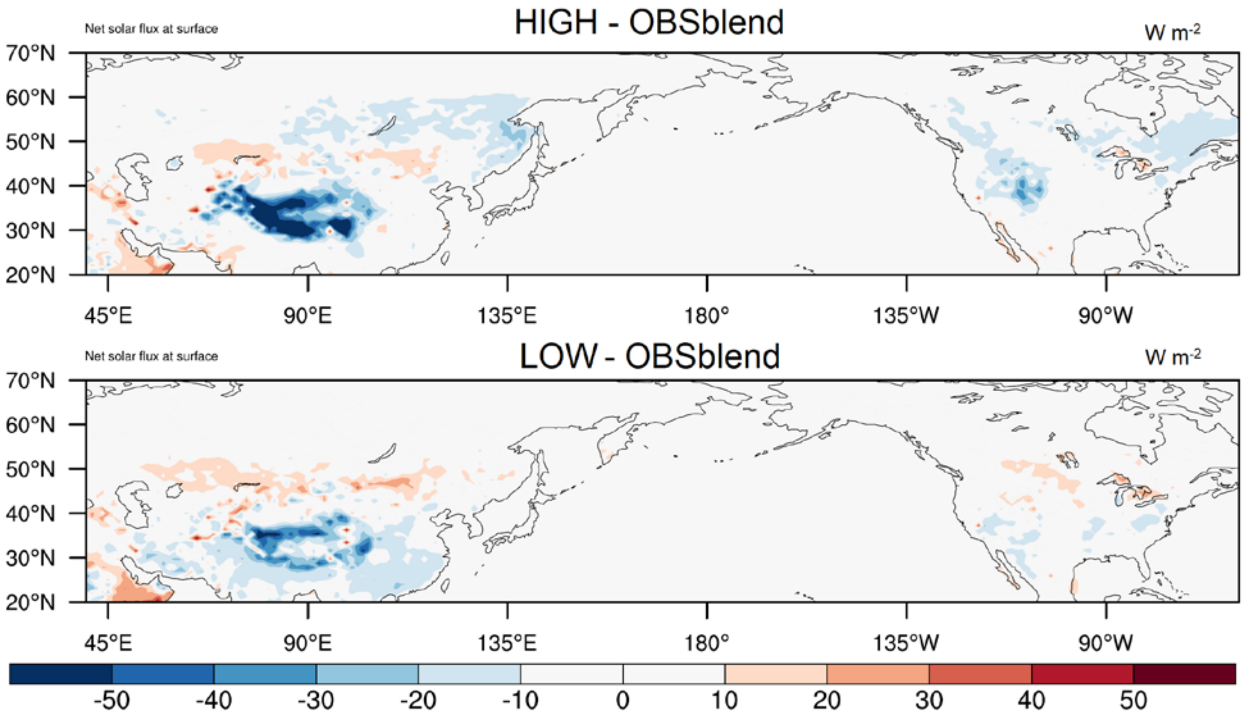


Figure S2: Mean winter net shortwave radiation response for the HIGH (top) and LOW (bottom) experiments relative to OBSblend. Despite their contrasting names, both experiments exhibit a winter albedo forcing that is dominated by large decreases across the Tibetan Plateau. This is consistent with a tendency for climate models to overestimate snow cover across this region (e.g., Fig. 3 from Thackeray et al. 2016).

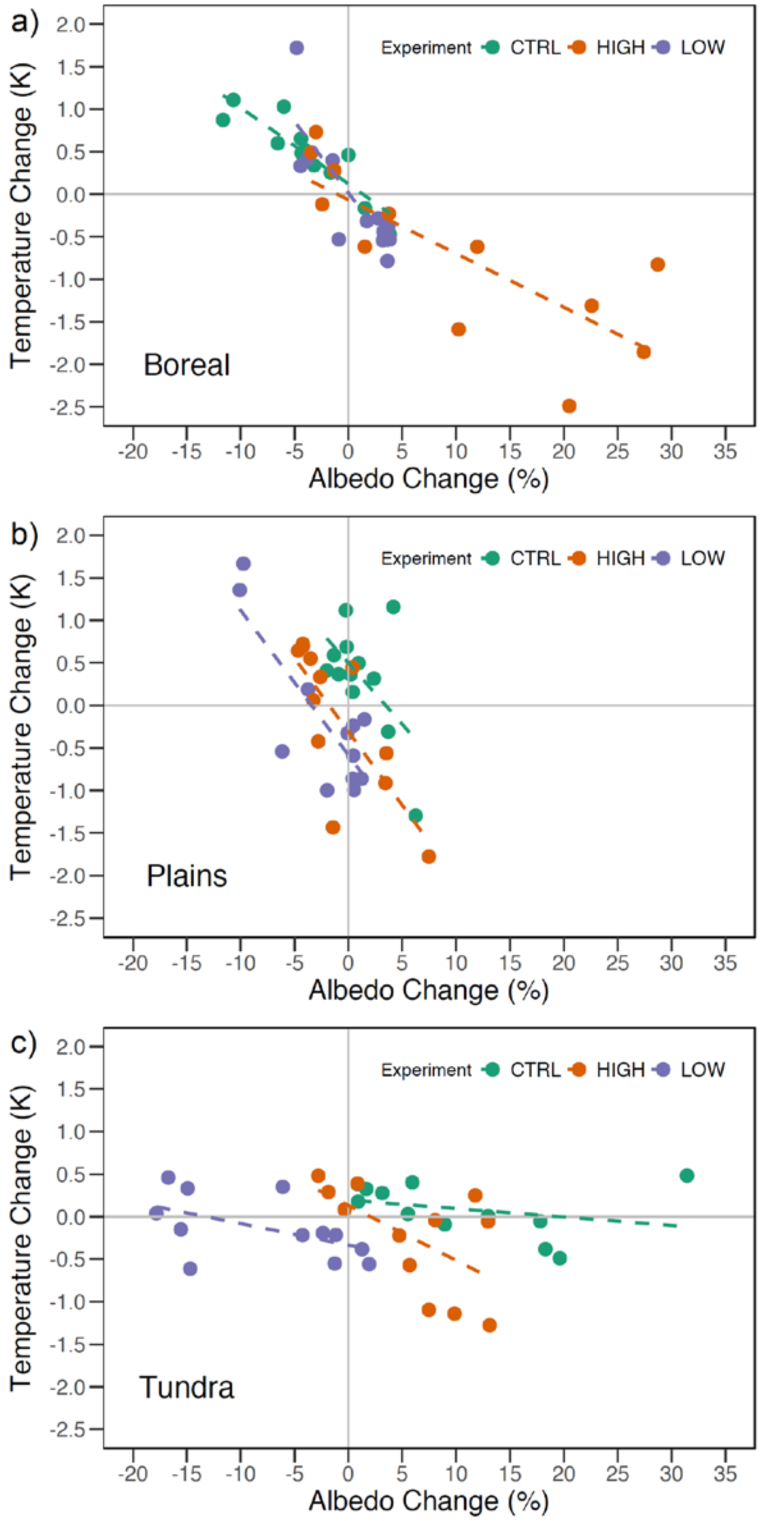


Figure S3: Scatterplots of the albedo difference and temperature difference from three experiments (CTRL, HIGH, LOW) relative to OBSblend. Data are derived from Figure 10, with each point representing the difference between experiments for a single month.

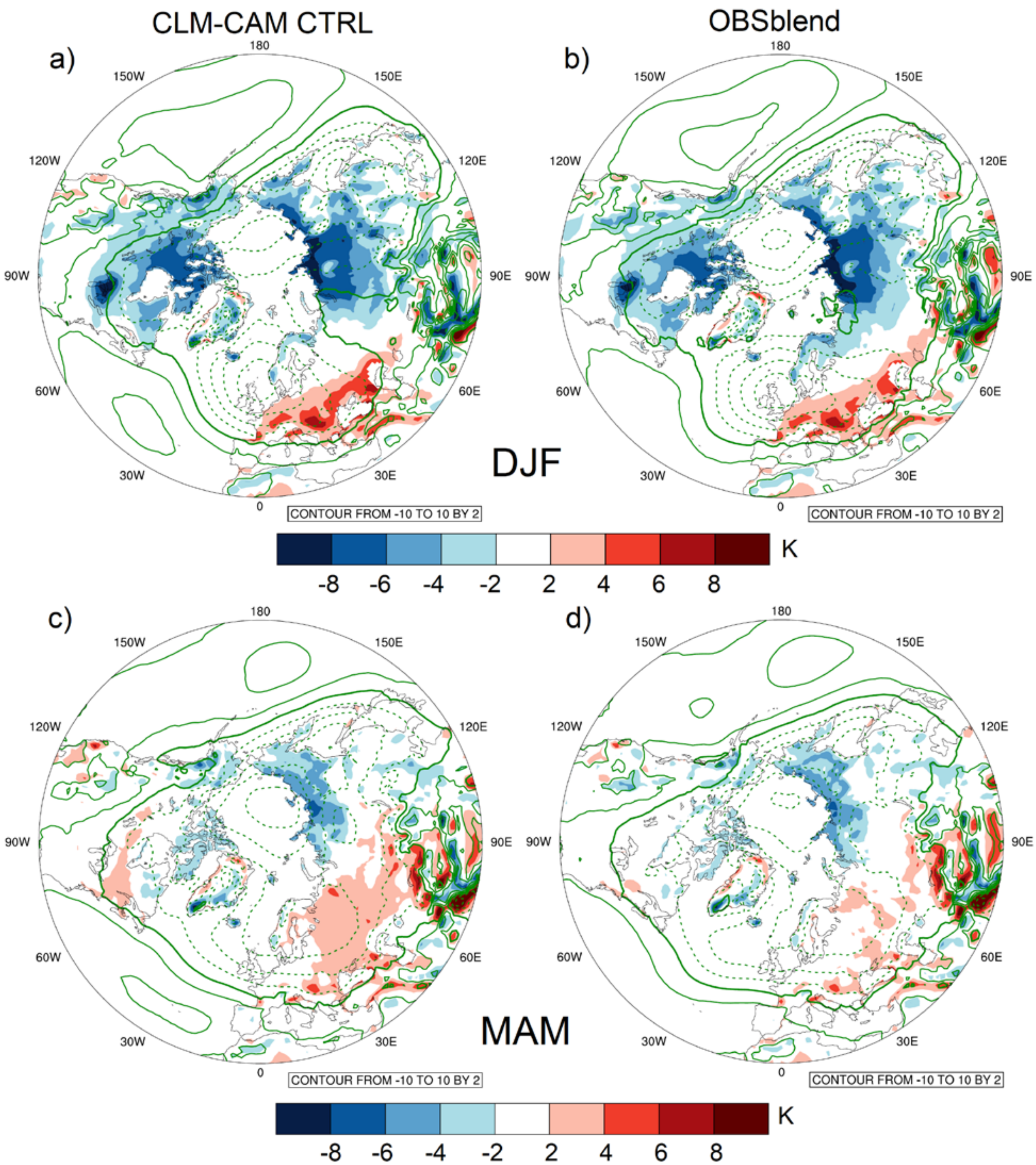


Figure S4: Comparison of the temperature and SLP biases in (a, c) CLM-CAM CTRL and (b, d) OBSblend during (a, b) winter and (c, d) spring. The difference between these two panels is shown in Fig. 4a, b. There is a noticeable reduction in spring near-surface air temperature bias across the boreal regions of North America and Eurasia. On the other hand, corrections to SLP are generally small compared to the original bias.

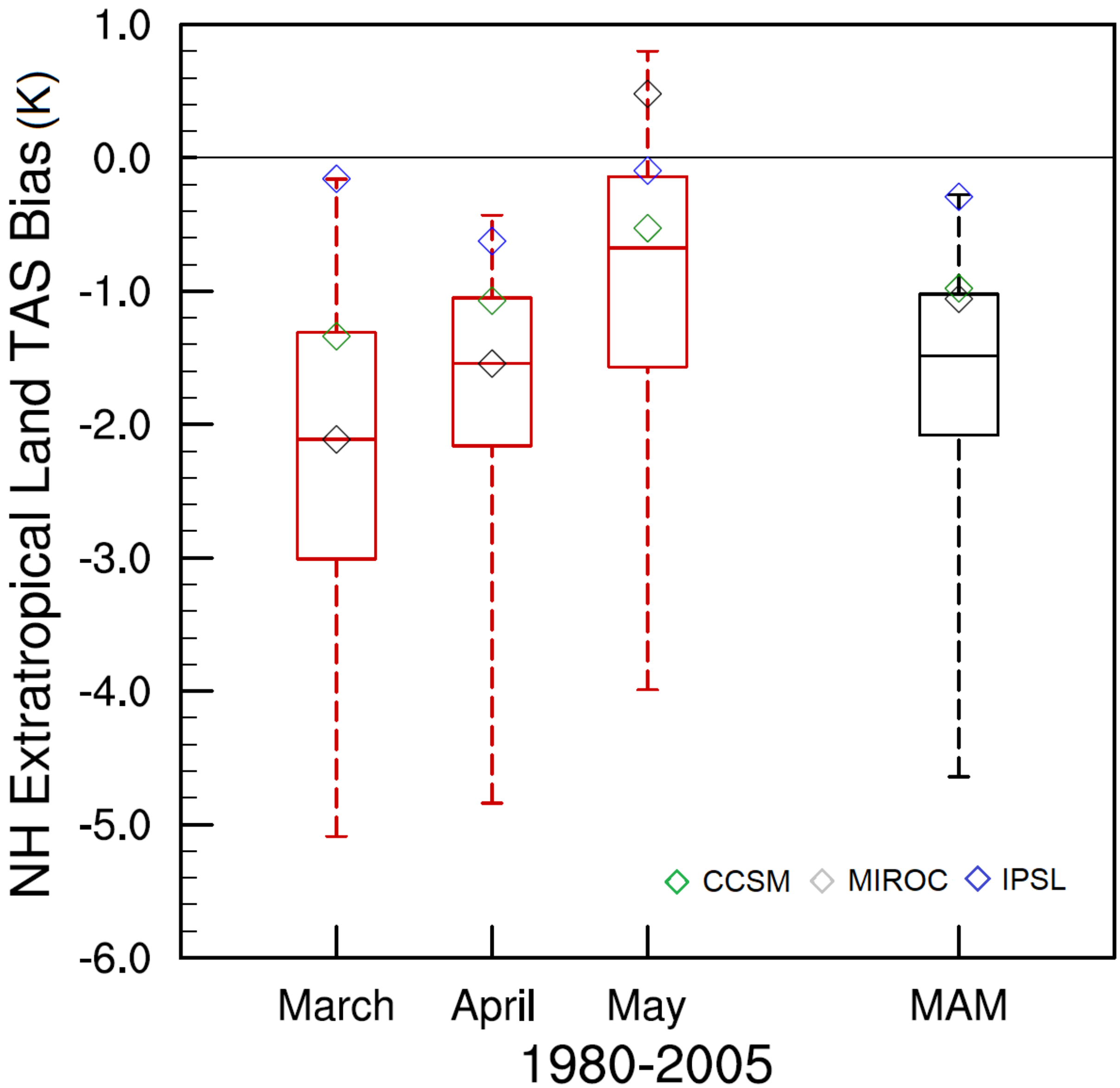


Figure S5: Boxplot of climatological (1980-2005) near-surface air temperature bias from the CMIP5 ensemble over NH extratropical land. The location of the models that we use albedo output from in this study (CCSM4, MIROC5, IPSL-CM5A-MR) are highlighted by different colored diamonds. Model bias is calculated with respect to a blended observational measure derived from the NCEP (Kanamitsu et al. 2002) and University of Delaware datasets (Willmott and Matsuura 2001).

Text S1.

Model Setup:

Here we document the changes to model code that were made for the perturbed albedo experiments. It is necessary to provide more details than given in Section 2.3 because there are several instances of albedo throughout the code, and the ones that are modified should give different results. Our approach for overriding the model calculation of albedo is based on the module interpMonthlyVeg, which is used by CLM to read in monthly LAI data from a file and use timestep information to interpolate daily values from the nearest monthly means. An interpolated daily albedo variable (malb2t) is calculated in this same manner. The variables ALBD (direct albedo) and ALBI (diffuse albedo) are overwritten (by malb2t) in the two-stream approximation routine of SurfaceAlbedoMod to perturb the flux reflected by vegetation. Additionally, the albedo for non-vegetated PFTs is overwritten in the SurfaceAlbedo routine. The new ALBD and ALBI values are then used in the calculation of FSA (solar radiation absorbed by the ground) and FSR (reflected solar radiation) in SurfaceRadiationMod. Both the direct and diffuse streams are assigned the same values because of difficulty separating out radiation components from CMIP5 output. For similar reasons, we assign the same albedo values to the visible and near-infrared components. It should also be noted that over grid cells where no observations are available (a small number of grid cells due to filtering of low quality retrievals; Thackeray et al., 2015), the model's calculated albedo values are used. Additionally, albedo does not vary throughout the day in this setup. Although the prescribed albedo evolves in a smoother nature (linearly from one monthly value to the next) than what would naturally occur, we do not believe this influences the long-term climate because the monthly mean radiation balance at the surface remains the same.

Text S2.

Boreal Experiment:

An additional experiment, where OBSblend albedo was prescribed only over the boreal forest (and CTRL albedo is prescribed elsewhere), reveals a very similar regional temperature response to the full OBSblend experiment (not shown). Interestingly, this experiment does not produce the same SLP responses over the Pacific or Atlantic sectors, giving more credence to the important role of Tibetan Plateau albedo forcing (which is unperturbed in this boreal-only experiment). This experiment allows us to evaluate the direct influence of the albedo bias stemming from issues associated with canopy snow in CLM identified by Thackeray et al. (2014).