Supplementary material:
The remote impacts of climate feedbacks on regional predictability

Feedbacks of equal area

Eq. 1 in the main text relates the pattern of radiative forcing, $R_f(x)$, the pattern of regional radiative feedbacks, $c_i(x)$, and the pattern of anomalous heat-flux divergence, $\nabla \cdot \boldsymbol{F'}(x)$, to the pattern of annual-mean surface temperature response, $T'(x)$:

$$-R_f(x) = -\nabla \cdot \boldsymbol{F'}(x) + c(x)T'(x), \tag{S1}$$

where $c(x) = \sum_{i=1}^{N} c_i(x)$ is the sum of all individual feedbacks.

A given perturbation to this feedback pattern, $c(x) \rightarrow c(x) + \Delta c(x)$, would modify the heat flux convergence, $F'(x) \rightarrow F'(x) + \Delta F'(x)$, and the temperature response, $T'(x) \rightarrow T'(x) + \Delta T'(x)$. The effect of this feedback perturbation on the global-mean temperature response, $\overline{T}' \rightarrow \overline{T}' + \Delta\overline{T}'$, can be found using Eq. 1:

$$\begin{aligned} -R_f(x) = & -\nabla \cdot (\boldsymbol{F'}(x) + \Delta \boldsymbol{F'}(x)) \\ & + (c(x) + \Delta c(x))(T'(x) + \Delta T'(x)). \end{aligned} \tag{S2}$$

Combining Eqs. S1 and S2 gives,

$$\Delta T'(x) = -\frac{\Delta c(x) T'(x)}{c(x)} - \frac{\Delta c(x) \Delta T'(x)}{c(x)} + \frac{\nabla \cdot \Delta \boldsymbol{F'}(x)}{c(x)}. \tag{S3}$$

Taking global means (denoted by overbars) gives the global-mean temperature perturbation that results from a given feedback perturbation:

$$\Delta\overline{T}' = -\underbrace{\overline{\frac{\Delta c(x) T'(x)}{c(x)}}}_{(a)} - \underbrace{\overline{\frac{\Delta c(x) \Delta T'(x)}{c(x)}}}_{(b)} + \underbrace{\overline{\frac{\nabla \cdot \Delta \boldsymbol{F'}(x)}{c(x)}}}_{(c)}. \tag{S4}$$

The terms in Eq. S4 represent contributions to the global-mean warming perturbation from (a) the feedback perturbation actuated by the background warming, $T'(x)$; (b) the feedback perturbation actuated by the the temperature perturbation it induces, $\Delta T'(x)$; and (c) perturbations in anomalous heat-flux divergence. Due to the diffusive nature of the heat transport, term (c) acts to (partially, but not completely) compensate terms (a) and (b).

The impact of a feedback perturbation of a given latitudinal extent and strength on the global-mean temperature response depends on the details of the background feedback and warming patterns

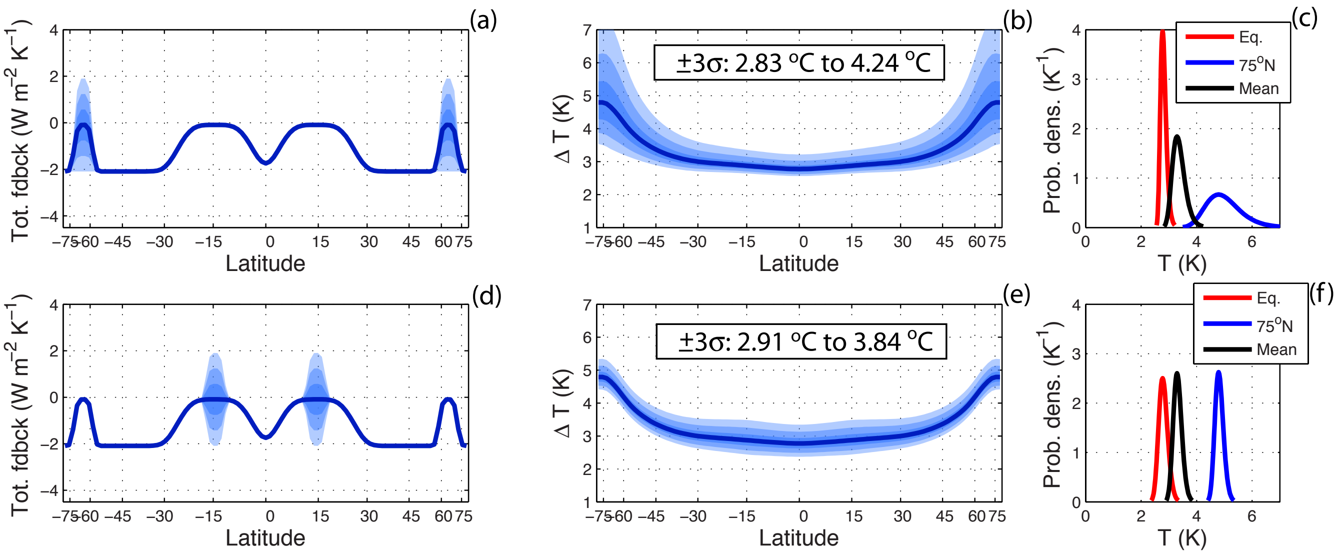

Figure S1: The impact of equivalent area- and magnitude-uncertainty in feedbacks patterns on uncertainty in climate-response patterns in MEBM. Top row: for subtropical feedback uncertainty (a) feedback, (b) response, (c) response PDF at specific latitudes and globally. Bottom row: as for top row, but for ice-line feedback uncertainty. Feedback uncertainty has the form $c(x) = c_o(x) + \sigma_c \exp\left(-[(x - x_0)/\Delta x]^4\right)$; $c_o(x)$ is the mean feedback pattern; $\sigma_c = 0.6\text{Wm}^{-2}\text{K}^{-1}$; $(x_o, \Delta x) = \pm 0.25, 0.05$ for both subtropical and ice-line feedback uncertainty. The numbers in panels (b) and (e) give the $\pm 3\sigma$ range for the global mean temperature.

($c(x)$ and $T'(x)$). $\Delta \overline{T}'$ is maximized when $\Delta c(x)$ coincides with a region of (i) large $T'(x)$, (ii) large $\Delta T'(x)$, and (iii) more positive $c(x)$. All of these conditions are met in the high latitudes, where the background warming $T'(x)$ is amplified, the induced temperature perturbations $\Delta T'(x)$ are large and confined locally, and the feedbacks tend to be more positive (see main text). Thus, global temperature is more strongly influenced by high latitude feedback perturbations than low latitude feedback perturbations (of equivalent area and magnitude)[1].

Likewise, high-latitude feedback uncertainty drives larger uncertainty in global-mean temperature response than does low-latitude feedback uncertainty (of equivalent area and magnitude). Figure S1 illustrates this result within the MEBM for feedback uncertainty within the subtropics and high-latitudes. As in the main text, uncertainty in subtropical feedbacks leads to a globally near-uniform uncertainty in temperature response (blue and red curves in Fig. S1(f)), while uncertainty in high-latitude feedbacks leads to a greater confinement of uncertainty near the poles (blue and red curves in Fig. S1(c)),. However, it is uncertainty in high-latitude feedbacks that leads to the greatest uncertainty in global-mean temperature response (compare black curves in Figs. S1(c) and (f) and the 3σ ranges of global-mean temperature given in panels (b) and (e)).

[1]If the underlying feedback structure $c(x)$ or the warming $T'(x)$ were sufficiently peaked in the low latitudes, then low latitude feedback perturbations could drive comparable or even larger perturbations in global temperature; however, GCM simulations suggest that this scenario is unlikely (e.g., Armour et al 2013; see also main text).

References

Armour, K. C., Bitz, C. M. & Roe, G. H. Time-varying climate sensitivity from regional feedbacks. *J. Climate*, **26**, 4518-4534 (2013).