Supplementary Material for

Local Atmospheric Decoupling in Complex Topography Alters Climate Change Impacts

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This supplement contains:

Supplementary Online Material

Atmospheric Circulation Analysis

An atmospheric flow strength and curvature analysis was conducted for the H.J. Andrews Experimental Forest. In an initial analysis, flow characteristics at the 700-hPa (~3000-m) level were found to have strong explanatory power for surface temperature, and were used here. Pressure height data from the NCEP/NCAR Reanalysis (Kalnay et al. 1996) were used to quantify the geostrophic flow strength and curvature at 4 AM and 4 PM PST daily for the period 1987-2005. Flow characteristics at 4 AM (12 UTC) represented the daily minimum temperature, and those at 4 PM PST (00 UTC+1 day) represented the daily maximum temperature.

The circulation analysis included deriving three flow strength indices: southerly flow component (*S*), westerly flow component (*W*), and overall strength of the flow (F; Losleben et al. 2000). Days on which *F* fell into the lower one-third of the distribution of all daily flow strengths for this location were designated low flow days, medium for the middle third, and high for the upper third. Also calculated were three flow vorticity (or curvature) indices: southerly vorticity component (*ZS*), westerly vorticity component (*ZW*), and total vorticity of the flow (*Z*). Each day was assigned to a zonal, cyclonic, or anticyclonic flow curvature category based on the sign of *Z* and a comparison of the magnitudes of *Z* and *F*.

The analysis used grid points spaced 5 degrees apart over the western U.S. and northeast Pacific, centered on 45°N and 122.5°W. Fig. S2 shows numbered grid points whose 700-hPa pressure heights were used to calculate circulation indices. Points are labeled p_1 through p_{25} as shown. In the following formulas, the variables *cc*, *sc*, c_1, and c_2 account for differing grid spacing in the latitudinal and longitudinal directions.

Southerly flow component (S) = $cc\left(\frac{p_9 + 2p_{14} + p_{19}}{4} - \frac{p_7 + 2p_{12} + p_{17}}{4}\right)$

where $cc = \frac{1}{\cos(lat)}$

Westerly flow component (W) = $\frac{p_{17} + 2p_{18} + p_{19}}{4} - \frac{p_7 + 2p_8 + p_9}{4}$

Mean flow strength (F) = $\sqrt{S^2 + W^2}$

Southerly vorticity component (ZS) =

$$sc\left(\frac{p_{10} + 2p_{15} + p_{20}}{4} - \frac{p_8 + 2p_{13} + p_{18}}{4} - \frac{p_8 + 2p_{13} + p_{18}}{4} + \frac{p_6 + 2p_{11} + p_{16}}{4}\right)$$

where $sc = \frac{1}{2(\cos(lat))^2}$

Westerly vorticity component (ZW) =

$$c_1\left(\frac{p_{22} + 2p_{23} + p_{24}}{4} - \frac{p_{12} + 2p_{13} + p_{14}}{4}\right) - c_2\left(\frac{p_{12} + 2p_{13} + p_{14}}{4} - \frac{p_2 + 2p_3 + p_4}{4}\right)$$

where $c_1 = \frac{\sin(lat)}{\sin(lat - 5)}$, $c_2 = \frac{\sin(lat)}{\sin(lat + 5)}$, and lat = 45 degrees latitude

Total vorticity $(Z) = ZS + ZW$

Flow curvature = $\left\{ \begin{array}{c} Zonal; |Z| < F \\ Cyclonic; |Z| > F, Z > 0 \\ Anticyclonic; |Z| > F, Z < 0 \end{array} \right\}$

Topographic Index

A "topographic index" grid was created for the HJA, which describes the height of a pixel relative to nearby terrain features. Topographic index provides information on a site's susceptibility to cold air pooling by considering its vertical position relative to the surrounding terrain (Daly et al. 2007, 2008). Stations located in deep valleys and depressions are more susceptible to cold air pooling than those located on slopes or ridge tops.

The process of creating a topographic index grid is a two-dimensional analog to using a high-pass filter to remove low frequency variations from a signal. The topographic index grid is a new map from which the larger (more "slowly" varying in space) features have been removed, leaving only an elevation relative to other nearby points.

For each pixel in a 50-m DEM, the pixel with the lowest elevation within a given search diameter was found, and a grid created from these lowest pixels. Each pixel in this minimum-elevation grid was then subjected to an algorithm that averaged all pixels within a diameter equal to the search diameter, thus creating a third grid. Finally, this averaged minimum-elevation grid was subtracted from the original DEM to produce the topographic index grid.

Topographic index grids with search/averaging diameters of 150, 250, 400, and 500 m were calculated, and each entered with elevation as explanatory variables in the multiple regression function to predict the A-C slope for December T_{max}. The search/averaging diameter of 150 m had the greatest explanatory power, and was used in the final analysis (Fig. S2). This is the smallest possible diameter that could be used with the 50-m DEM (constituting three 50-m pixels), leaving open the possibility that the use of finer-resolution DEMs and smaller diameters could produce topographic index grids with even more explanatory power. The HJA Long-Term Ecological Research Program has sponsored the creation of a very fine resolution DEM of the HJA using LIDAR (Light Detection and Ranging) technology; this DEM will allow us to investigate possible finer-scale topographic interactions. However, it is likely that multiple scales will need to be considered. Cold air drainage appears to be fractal in nature, exhibiting patterns within patterns at scales ranging from large valleys that are tens of km wide to narrow ravines of no more than a few meters in width (Daly et al. 2008).

Literature Cited

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Losleben M, Pepin N, Pedrick S. 2000. Relationships of precipitation chemistry, atmospheric circulation, and elevation, at two sites on the Colorado Front Range. *Atmospheric Environment* 34, 1723-1737.

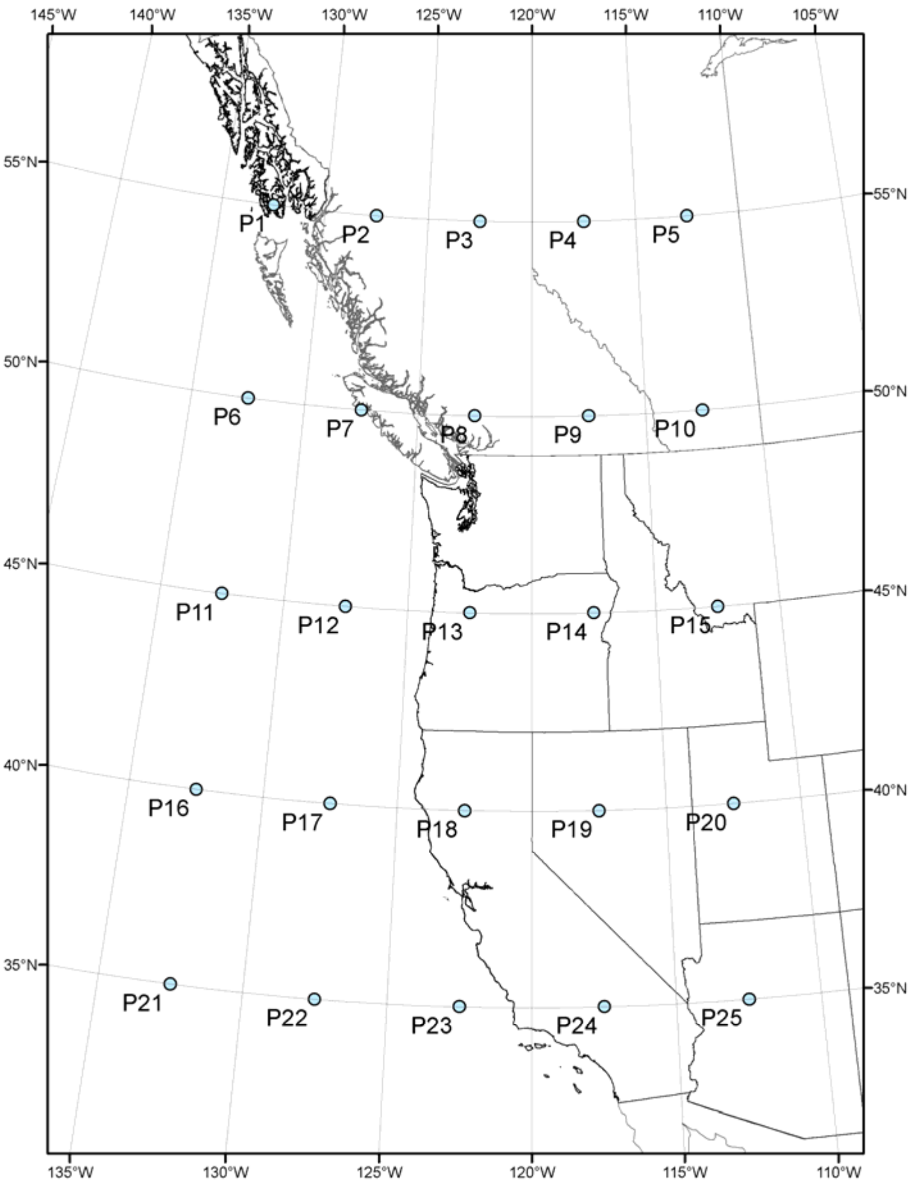

Figure S1. 700-hPa grid points of the NCAR/NCEP reanalysis used in the atmospheric circulation analysis.

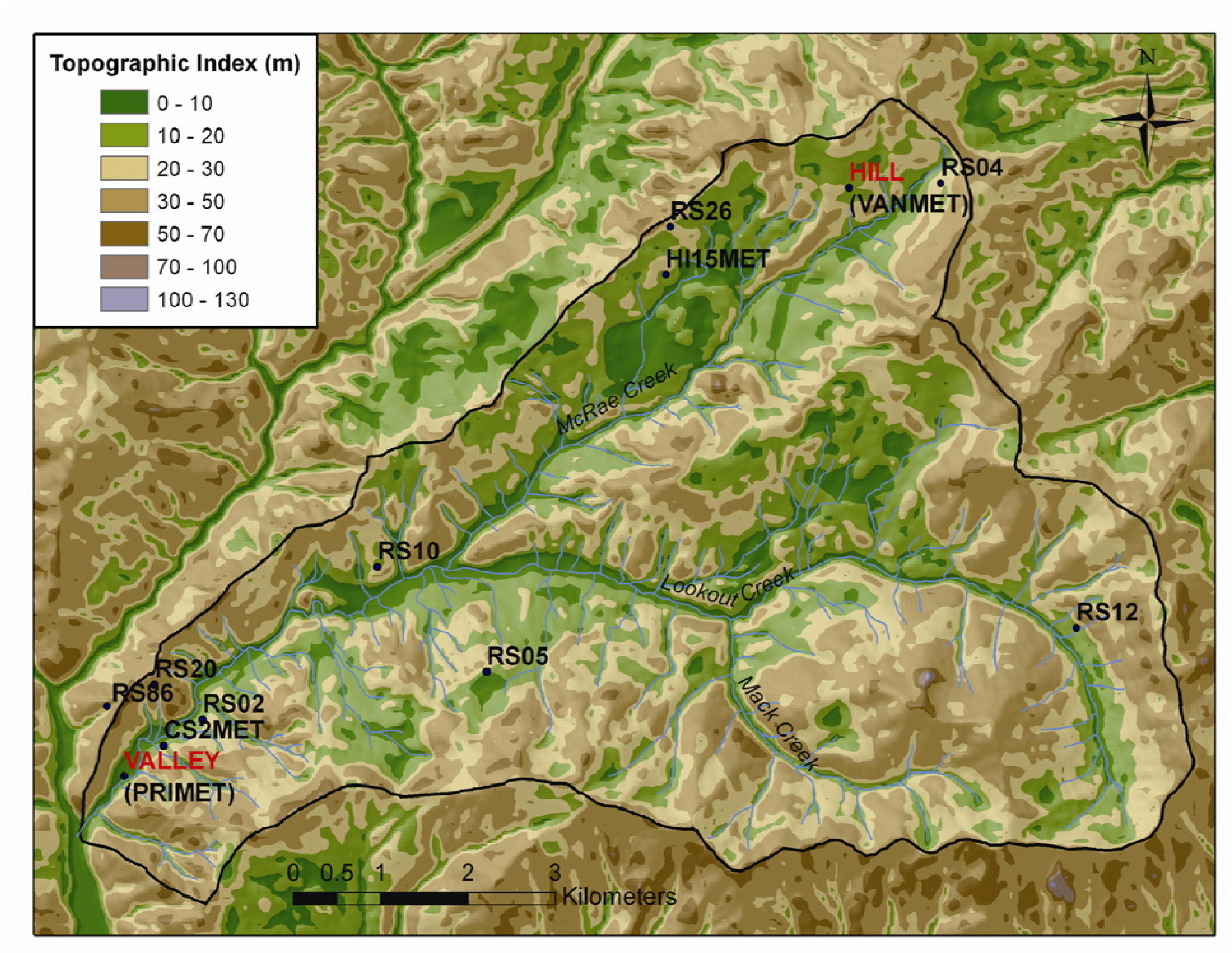

Figure S2. Spatial patterns of topographic index in the HJA. Index value at each pixel is the height of that pixel relative to the generalized lowest terrain within 150 m (see text). Locations of stations used in the analysis, including VALLEY (PRIMET) and HILL (VANMET), are shown.