A Comparison of the Terrain Height Variance Spectra of the Front Range with that of a Hypothetical Mountain

George S. Young, Roger A. Pielke and Robert C. Kessler

Department of Atmospheric Sciences, Colorado State University, Fort Collins, CO 80523

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ABSTRACT

The one-dimensional terrain height variance spectra of the Front Range west of Boulder, Colorado, is compared with that of the hypothetical two-dimensional mountain used by several investigators in their modeling studies of downslope winds. The terrain height variance of the hypothetical mountain exceeds that of the Front Range on scales longer than 25 km. On shorter scales, the terrain height variance of the hypothetical mountain decreases at an unrealistic rate.

The scales at which terrain features of the Front Range can be considered approximately two-dimensional are determined. On scales longer than 25 km, the Front Range is essentially two-dimensional. However, on shorter scales, the Front Range exhibits equal variance in the along-range and cross-range directions.

1. Introduction

Young and Pielke (1983) discuss one-dimensional terrain height variance spectra with respect to grid spacing in mesoscale numerical models. This paper extends that work by comparing the one-dimensional terrain height variance spectra of the Front Range west of Boulder, Colorado, with that of a hypothetical two-dimensional mountain of the form:

$$Z_G = \frac{H_0 B^2}{B^2 + X^2}.$$

Mahrer and Pielke (1974, 1978), Klemp and Lilly (1978), Clark and Peltier (1977), Peltier and Clark (1979), and others have used this form when modeling flows induced by this mountain range. In these models, the terrain height (Z_G) is assumed to vary only in the east to west direction. The parameter values, $H_0 = 2.0$ km and $B = 10$ km used in this Note are as applied by Peltier and Clark (1979).

These measured cross sections were acquired from the NOAA/EDIS/NGSDC 30-second average elevation data tapes described by Dietrich and Childs (1982). Twenty adjacent east to west cross sections were acquired from Sulphur Hot Springs to Boulder. In addition, 20 adjacent north to south cross sections along the continental divide west of Boulder were acquired.

For each cross section, a linear trend was first calculated by the method of least squares and then subtracted from the height series. The terrain height variance spectra of the resulting series were then determined by a computed implementation of the fast Fourier transform algorithm. The spectra of the 20 cross sections in each of the measured data sets were averaged and then compared with the spectrum of the hypothetical mountain, which is

$$S(k) = H_0 B e^{-2\pi k B},$$

where $k = 1/\lambda$.

2. Results

The terrain height variance spectrum of the hypothetical mountain is shown as a solid curve in Fig. 1.

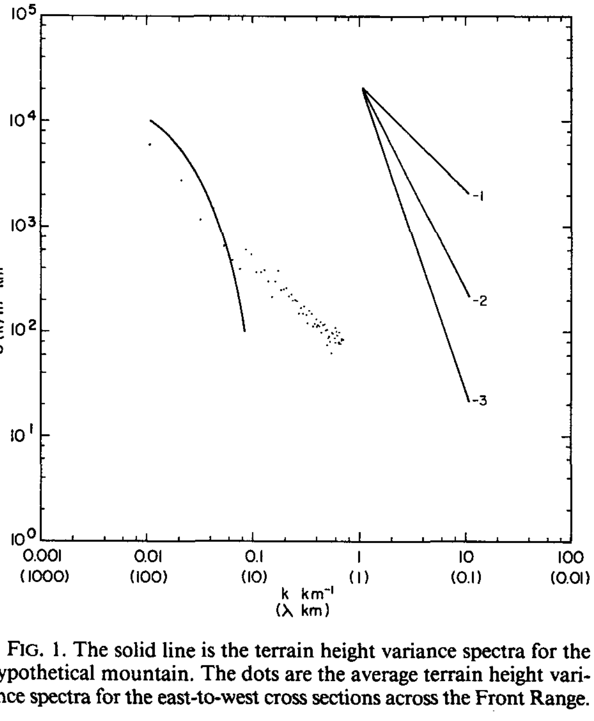

Fig. 1. The solid line is the terrain height variance spectra for the hypothetical mountain. The dots are the average terrain height variance spectra for the east-to-west cross sections across the Front Range.

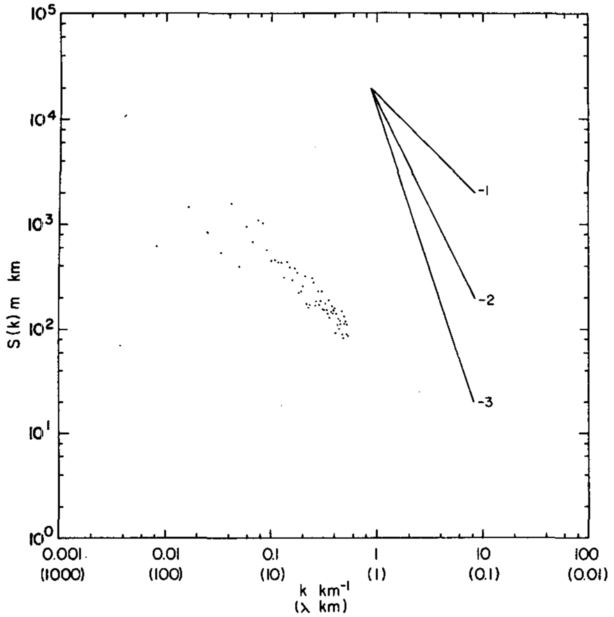

FIG. 2. Average terrain height variance spectra for the north-to-south cross sections near the Continental Divide west of Boulder, Colorado.

The variance is almost entirely accounted for by scales longer than 25 km.

The east-to-west terrain height variance spectrum of the Front Range is shown by the dots in Fig. 1. This spectrum is fitted by the function $S = 1.9\lambda^{0.98}$ with a correlation coefficient, r, of -0.98. The standard deviation of the exponent, s_b, is 0.10, leading to a confidence interval for the exponent of 0.98 ± 0.20 at the $\alpha = 0.05$ level (Edwards, 1979). This spectrum contains less terrain height variance at wave lengths longer than 25 km than does that of the hypothetical mountain. At wave lengths shorter than 25 km, however, this spectrum contains much more terrain height variance than does that of the hypothetical mountain. For example, at the 50 km scale, the terrain height variance of the Front Range is half that of the hypothetical mountain but at the 10 km scale, the terrain height variance of the Front Range is two orders of magnitude greater than that of the hypothetical mountain. This disparity increases further for shorter scales. Thus, the hypothetical mountain is overly smoothed.

The north-to-south terrain height variance spectrum for the Continental Divide west of Boulder is shown in Fig. 2. At scales longer than 25 km it contains less variance than does the east-to-west spectrum. However, at shorter scales, the two spectra contain equal variance. Thus, the Front Range has a predominantly two-dimensional organization, aligned north to south only at scales longer than 25 km. At shorter scales the Front Range is approximately three-dimensional.

3. Conclusions

The hypothetical two-dimensional bell-shaped mountain of the form

$$Z_G = \frac{H_0 B^2}{B^2 + X^2}$$

is commonly used in modeling studies of flow over Colorado's Front Range. This hypothetical mountain overemphasizes the actual topographic features of scales greater than 25 km. At shorter scales, the actual terrain exhibits a three-dimensional structure having much more variance than the hypothetical mountain.

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