THE EXPLOSIVE VOLCANIC ERUPTION SIGNAL IN NORTHERN HEMISPHERE CONTINENTAL TEMPERATURE RECORDS

RAYMOND S. BRADLEY
Department of Geology & Geography, University of Massachusetts, Amherst, MA 01003-0026, U.S.A.

Abstract. Several catalogs of explosive volcanic eruptions are reviewed and their limitations assessed. A new, homogeneous set of high quality gridded temperature data for continental regions of the northern hemisphere is then examined in relation to the timing of major explosive eruptions. Several of the largest eruptions are associated with significant drops in summer and fall temperatures, whereas pronounced negative anomalies in winter and spring temperatures are generally unrelated to volcanic activity. The effect of explosive eruptions on temperature decreases latitudinally away from the location of the eruption. High latitude eruptions have the greatest impact on high and mid latitudes; low latitude eruptions mainly influence low and mid latitudes. Temperature depressions following major eruptions are very abrupt but short-lived (1 to 3 months) decreasing in magnitude over the course of the subsequent 1 to 3 years. Generally any signal is indistinguishable from noise after 12 months but a small recurrent drop in temperature is evident about 12 to 24 months after the initial anomaly. Considering all known eruptions which injected material into the stratosphere over the last 100 years (except the 5 largest eruptions) a significant temperature depression is observed over the continents only in the month immediately following the eruption. There is no evidence that large eruptions over the last 100 years have had a significant effect on low frequency temperature changes.

1. Introduction

The effects of explosive vulcanism on the earth's surface temperature have been investigated on numerous occasions (e.g. Lamb, 1970; Budyko, 1969, 1974; Mitchell, 1961, 1970; Spirina, 1971; Yamamoto et al., 1975; Oliver, 1976; Mass and Schneider, 1977; Taylor et al., 1980; Self et al., 1981; Kelly and Sear, 1984, Angell and Korshover, 1985). However, in spite of this attention, there is still considerable uncertainty about the magnitude and statistical significance of any effects, as well as their geographical distribution and duration (e.g. Ellsaesser, 1983; Parker, 1985). Part of the problem stems from the inadequacies of the basic data on both explosive eruptions and (to a lesser extent) global temperature. In this paper I review the various indices and catalogs of explosive eruptions, and the temperature data sets available for analysis. I then examine: (a) the seasonal response to volcanic forcing; (b) the effects that major eruptions at different latitudes have on temperature over the northern hemisphere continents as a whole and on land areas in different latitude zones and (c) the effects of a

larger sample of smaller volcanic eruptions on temperatures over the northern hemisphere continents.

2. Data

2.1. Temperature Data

The numerous problems associated with obtaining a high quality (i.e. homogeneous) set of long-term temperature data for an extensive area of the globe have been discussed by Bradley and Jones (1985). In all previous studies of the effects of explosive volcanic eruptions on temperature, a limited set of station data was selected (generally from World Weather Records) and were not tested for homogeneity. Only Kelly and Sear (1984) used a very large network of station data representative of the continental land masses as a whole. However, the data they used was also not tested for homogeneity. To be confident that a change in temperature is a true climatic signal and not an artifact of poor data quality it is important that only homogeneous data are examined. Consequently, in this study, the basic temperature data set (described in Bradley et al., 1985) was first screened for homogeneity. Only good quality data were then used in an interpolation scheme to produce a gridded set of monthly temperature anomalies (from a 1951–70 reference period) for northern hemisphere continental regions (Jones et al., 1985, 1986). The anomaly data, on a 10° longitude x 5° latitude grid, were cosine-weighted and averaged to produce time series of hemispheric and zonal mean temperatures (Figure 1). Three approximately equal area zones were selected (0–20° N, 20–45° N, and 45–85° N). It must be emphasized that these are not true hemispheric or zonal averages but are, in fact, land-based or continental chronologies. Furthermore, the geographical coverage of data used to construct these series has varied through time (see Figure 7 in Jones et al., 1986). This explains why the variance is higher in the early part of each record. At the time of optimum data availability (in the 1950s) the gridded set contains 57% of the maximum number of points for the northern hemisphere, decreasing to 30% in 1891 and only 8% in 1851.

2.2. Indices of Explosive Volcanic Eruptions

Data on the occurrence and magnitude of climatically significant explosive eruptions is poor. There are four principal chronologies of explosive eruptions which have been published. These are: a Dust Veil Index (DVI) (Lamb, 1970); a Volcanic Explosivity Index (VEI) (Simkin et al., 1981; Newhall and Self, 1982); an estimate of atmospheric optical depth (Pollack et al., 1976) and a record of electrolytic conductivity or excess sulfate in ice cores (Hammer, 1977; Hammer et al., 1980; Legrand and Delmas, 1987). Here we discuss the derivation of these