sity from the Mississippian until the expansion of the angiosperms, when species numbers increased significantly. A parallel can be drawn with the expansion of diversity in the marine record associated with the Ordovician radiation of sessile suspension feeders. While the observed Cretaceous-Tertiary rise may be influenced in part by some of the biases previously discussed, we believe that it is nonetheless a real phenomenon associated with the biology of the angiosperms.

The temporal pattern of land-plant diversity in North America resembles that described for marine invertebrates (*2-4*) in nature, if not in timing. Extrapolation of the present data to a historical interpretation of worldwide vascular plant diversity will require consideration of changing levels of geographic and climatic provinciality through time. Estimates of Phanerozoic phytogeographic provinciality show maximums in the Permian and Tertiary-Quaternary (*12*). These correspond to times of maximum climatic or geographic heterogeneity, or both. This suggests the likelihood of a preangiosperm global diversity peak in the late Paleozoic. The coincidence in the present day of both maximum geographic/climatic provinciality and high levels of species packing in many communities supports the hypothesis of Hughes (*13*) that the modern flora contains a greater number of vascular plant species than any previous flora in earth history.

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The "Little Ice Age": Northern Hemisphere Average Observations and Model Calculations

Abstract. *Numerical energy balance climate model calculations of the average surface temperature of the Northern Hemisphere for the past 400 years are compared with a new reconstruction of the past climate. Forcing with volcanic dust produces the best simulation, whereas expressing the solar constant as a function of the envelope of the sunspot number gives very poor results.*

The term "Little Ice Age" refers to the period from about 1430 to 1850 during which the Northern Hemisphere climate was alleged to be cooler than the periods before or after (*1*, p. 151; *2*, pp. 185-186). Earlier attempts to describe the hemispheric average temperature variations during this period have been hampered by a lack of uniformly distributed observations around the hemisphere. As a consequence, most curves describing the climatic change during this period are based on European data compiled by Lamb (*1*, pp. 130 and 152; *2*, pp. 228-229). Using two of these curves, Eddy (*3*) has suggested that the Little Ice Age was caused by variations in the solar constant related to the envelope of the sunspot cycle. In fact, the Maunder sunspot minimum (*4*) does correspond to a cool period in the winter severity index of Lamb (*2*, p. 229), particularly at 50°N, 37.5°E. Both a comprehensive hemispheric average temperature curve and modeling studies, presented below, show this to be a spurious relationship. The hemispheric average temperature is not well represented by an index at one location (*5*), and volcanic dust produces a much better model simulation of the climatic change during and after this period.

Borzenkova *et al.* (*6*) have presented the annual average hemispheric surface temperature from 1881 to 1975; their data are taken from instrumental observations distributed over the hemisphere. Although a dense enough network of stations did not exist before this period from which to obtain a representative hemispheric temperature by spatial averaging, many annual average individual station records do exist. These include instrumental observations from Archangel and Irkutsk, U.S.S.R.; Berlin and Regensburg, Germany; Montreal, Canada; and Philadelphia, Pennsylvania; as well as proxy data such as tree ring

Table 1. Correlation coefficients of model results with observations. Significance levels (in percentage) are given in parentheses (*29*); a dash indicates not significant at the 10 percent level. V = volcanic dust simulation, S = smoothed sunspots, C = carbon dioxide, R = random forcing (natural variability). Autocorrelations of each series are also presented, to be compared with that of the entire data record, .766. The 5-year average correlations are to be compared with the correlation of .93 between this set of observations (*24*) and those of Mitchell (*17*).

Model forcing	Correlation with entire record, 1620 to 1975		Correlation with instrumental observations, 1881 to 1969		Autocorrelation (1-year lag)
	Including linear trend	With linear trend removed	Annual average	5-year average	
V	.408 (.2)	.373 (.5)	.823 (.1)	.965 (.1)	.971
S	.297 (2.0)	.037 -	.269 (2.0)	.384 -	.999
V + S	.441 (.1)	.313 (2.0)	.692 (.1)	.829 (.1)	.986
V + C	.430 (.1)	.384 (.5)	.819 (.1)	.958 (.1)	.972
S + C	.322 (1.0)	.070 -	.297 (.5)	.420 -	.999
V + S + C	.451 (.1)	.323 (1.0)	.681 (.1)	.820 (.1)	.987
R	.035 -	.079 -			.530

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widths from Alaska and Finland and winter temperatures from Tokyo, Japan (7). Groveman and Landsberg (8) have used the technique of multiple linear regression to reconstruct the hemispheric annual average surface temperature from 1579 to 1880, using series such as those above based on their correlations with the data of Borzenkova *et al.* Although this reconstructed temperature record is the best available thus far, it is not a perfect reconstruction of the past climate. The early part of the record, in particular, is reconstructed on the basis of only a few stations, and the record of Borzenkova *et al.* itself is not adequately representative of ocean areas. Decade average values of this time series are presented in the topmost curve of Fig. 1, but annual average values were used in all calculations. The period of the Maunder minimum (1645 to 1715) was not particularly cold; the early 1600's and early 1800's were colder. Landsberg, as reported by Kraemer (9), also concluded that the 1800's were the coldest part of the Little Ice Age.

Earlier modeling studies of the climate of the past 400 years have been inconclusive. Schneider and Mass (*10*), using a very simple global average climate model, looked at solar forcing, volcanic dust, and anthropogenic CO_2 as possible causes of climatic change. Their solar forcing, however, was based on observations of Kondratyev and Nikolsky (*11*), whose conclusions have since been retracted (*12*) because of contamination by volcanic dust from Agung Volcano and atmospheric nuclear tests. Moreover, they did not examine the effects of volcanic dust separately. In addition, a hemisphere average temperature record was not available for comparison with their results, although Mass and Schneider (*13*) reported correlation coefficients with a few individual records. Robock (*14*, *15*), using a detailed seasonal energy balance model (*16*), examined the theories of solar forcing, volcanic dust, anthropogenic influences, and natural internal variability as possible causes of climatic change during the past 100 years. Comparing the results with the observations of Borzenkova *et al.* (6) and Mitchell (*17*), he found that volcanic dust alone produced a very good simulation, that variations in the solar constant as a function of sunspot number produced very poor simulations whether the sunspot number was smoothed over the 11-year sunspot cycle or not, that anthropogenic influences were not yet large enough to be important, and that random natural variability as simulated in the model produced temperature variations as large as those of the past 100 years. The sensitivity of the model was also found to be too large as compared to most other climate models because of its parameterization of ice and snow areas and albedos.

The present study, based on an improved climate model, extends the above study back to the Little Ice Age and compares the model results to the hemispheric temperature reconstruction of Groveman and Landsberg (8). The model has been improved by the incorporation of a new surface albedo parameterization based on the observed seasonal snow and ice fluctuations (*18*). The model now has a very reasonable sensitivity, β, of about 200°C (*19*), that is, a 1 percent change in the solar constant causes a 2°C change in the global mean surface temperature in the same direction. Seven model runs were made with various combinations of the following four theoretical forcings:

1) Volcanic dust, using data from Lamb (*20*) for 1620 to 1850 and Mitchell (*21*) for 1850 to the present. The magnitude of the forcing was calibrated as in (*10*) with a dust veil index of 160 corresponding to a 0.5 percent decrease in the solar constant.

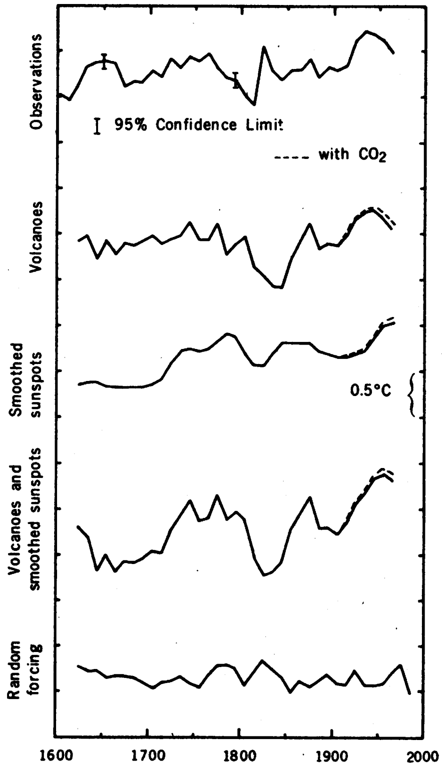

Fig. 1. Northern Hemisphere average surface temperature observations and climate model calculations, shown as 10-year averages. The observations come from the reconstruction of Groveman and Landsberg (8) for 1600 to 1880, shown with the 95 percent confidence interval, and from the data of Borzenkova *et al.* (6) for 1881 to 1975. The model runs are described in the text.

2) Variations in the solar constant as a function of the envelope of the sunspot number, according to the suggestion of Eddy (3, 4):

$$S = 1.94 + 0.0001\,\overline{N} \qquad (1)$$

where S is the solar constant (in calories per square centimeter per minute) and $\overline{N}$ is the Wolf sunspot number with the 11-year cycle smoothed out. The values 1.94 and 0.0001 are not based on observations but are chosen to give a reasonable amplitude to the model response.

3) Variations in CO_2, according to Broecker (*22*).

4) Natural variability simulated by adding random perturbations to the atmospheric eddy heat flux to make the interannual variability of the same amplitude as the observations of Vonder Haar and Oort (*23*).

A more detailed discussion and graphs of the time-dependent forcings may be found in (*15*).

Ten-year average results of the model runs are presented in the four lower curves in Fig. 1. Table 1 presents correlation coefficients between the model results and two sets of data: (i) the entire record from 1620 to 1975, including the reconstruction of Groveman and Landsberg (8) and the observations of Borzenkova *et al.* (6), and (ii) the observations of Budyko and Asakura (*24*) for 1881 to 1969, which represent a preliminary analysis of (6). Correlations between annual average model results and annual average observations are presented for both data sets. Correlations with the linear trend removed from both the model results and observations are given for the entire record. Robock (*15*) found that the correlation for the instrumental period between the 5-year average observations of Mitchell (*17*) and 5-year averages of Budyko and Asakura (*24*) was .93, and so correlations of 5-year averages of the model results and observations are presented to be compared with this number. The significance levels in Table 1 were calculated on the assumption of serially independent data. When significance levels were recalculated including corrections for autocorrelations in the time series (*25*), none of the coefficients was significant. The results which follow must therefore be judged with this qualification. Adding the random results to each of the other runs to lower the autocorrelation and produce a more realistic time series still did not, after correction for autocorrelation, make the results statistically significant. The following comments and conclusions are consequences of the computer calculations of climatic change:

1) Volcanic dust may have been an important cause of climatic fluctuations over the past 400 years. Except for the warm period in the first half of the 1800's (*26*), the computed volcano curve quite closely matches the observations curve (Fig. 1). The correlation coefficients (Table 1, run V) for the entire record are very significant, even with the linear trend removed, and the correlation coefficients for the most recent period, with the best volcano data and actual instrumental observations, are very high. The 5-year average correlation is higher than the correlation between 5-year averages of the two independent sets of observations of Budyko-Asakura (*24*) and Mitchell (*17*).

2) The hypothesis of sunspot-related solar constant changes is not supported. The significant correlation (Table 1, run S) of the entire record with the model result is almost entirely due to the upward linear trend in both series, and is even lower for the most recent period with more reliable data. The computed smoothed sunspot curve (Fig. 1) does not resemble the observations curve in any of its details. Thus the hypothesis of Eddy (*3*) that the Little Ice Age is related to the Maunder sunspot minimum through variations in the solar constant is not supported. This result does not rule out changes in the solar constant as causes of climatic change, but, if there is a relation, these changes must either be related to some yet to be discovered index other than sunspots or to sunspots in some very complex way (*27*).

3) Combining the volcano and sunspot forcings (Table 1, run V + S) (Fig. 1, volcanoes and smoothed sunspots curve) does not improve the volcano results.

4) Carbon dioxide produced by fossil-fuel burning does not seem to have had a significant effect on climatic change as yet. With it the results are slightly better for the entire record and slightly worse for the most recent portion. This conclusion should be qualified because there may be compensating anthropogenic influences such as aerosols (*15*), and the model tends to underemphasize the CO_2 effect as compared to more sophisticated radiation models which treat the stratosphere explicitly (*28*).

5) The random forcing results indicate the amount of natural variability to be expected in the climate without any external forcing. This is certainly an important cause of climatic fluctuations and may explain the difference between the observations and model results from purely external forcing.

6) In judging the above results, one must also bear in mind that both the climate reconstruction and the volcanic dust data are less reliable at the beginning of the record than at the end. Future research should help to clarify the magnitude of this problem and may actually improve the above results.

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$$C \frac{\partial T}{\partial t} = Q(1 - \alpha) - I - \text{div}(F)$$

where T is temperature, t is time, C is the thermal inertia, Q is the incoming solar radiation, α is the planetary albedo, I is the outgoing infrared radiation, and F is the horizontal energy transport by atmospheric and oceanic motions. For a discussion of changes made to the model and a detailed description of its performance, see (*14*) and A. Robock, in *Report of the JOC Study Conference on Climate Models: Performance, Intercomparison, and Sensitivity Studies* (World Meteorological Organization, Geneva, in press).
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19. The sensitivity parameter is defined as

$$\beta = S_0 \frac{d\bar{T}}{dS}$$

where $\bar{T}$ is the global mean surface temperature, S is the solar constant, and S_0 is its present value. It is discussed extensively in (*10*) and by R. D. Cess [*J. Atmos. Sci.* **33**, 1831 (1976)]. The statement that 200°C is a very reasonable value for β is based on the results of Cess who compared several types of climate models. The actual value of β in the real world is not known but probably lies in the range of 100° to 300°C.
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Chlorpromazine and Its Metabolites Alter Polymerization and Gelation of Actin

Abstract. *Hepatic hydroxylated metabolites of chlorpromazine (10^{-5}M to 10^{-4}M), a frequently used phenothiazine tranquilizer, produce solid gel formation with filamentous actin, but the less toxic chlorpromazine sulfoxide metabolite does not. At higher concentrations (5×10^{-4}M) chlorpromazine inhibits actin polymerization. These dose-response relationships parallel the drug's hepatic toxicity in vivo and suggest that interactions between chlorpromazine or chlorpromazine metabolites and actin could be an underlying mechanism of cell injury.*

Chlorpromazine (CPZ), commonly used as a phenothiazine tranquilizer, is an amphiphilic cationic detergent (*1*) that has multiple effects on membrane structure and function (*2*). Whether the therapeutic or untoward effects of CPZ are related to these effects is not known, but the drug produces abnormalities of the liver in many patients and infrequently causes cholestatic jaundice (*3*), probably by altering the properties of hepatocyte membranes. For example, CPZ diminishes bile secretion in the dog (*4*), rhesus monkey (*5*), and isolated perfused rat

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