Investigation into albedo-controlled energy loss during the last glaciation

Bielefeld, Britta, University of Göttingen, Department of Geography, Goldschmidtstr. 5, 37077 Göttingen, Germany

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Abstract: In recent years, attention has increasingly been paid to the question of the stability of the earth’s climate. It has been observed that changes in climate are usually related to changes in the earth’s surface. On this question, Liedtke writes ‘A change in climate can lead to considerable landscape changes’ (Liedtke 1990, p. 38). There seems to be some form of interaction between climate and the condition of the earth’s surface. If solar radiation is taken to be the primary energy source for the earth’s climate, the question arises as to how insolation affects the character of the earth’s surface, and vice versa, how does the character of the earth’s surface affect the insolation which occurs? Reconstructions of the last great Pleistocene glaciation 18,000 years ago show that the form of the earth’s surface at that time was considerably different to its present form. In view of the interaction mentioned above between climate and earth surface, does this suggest a difference between the earth’s radiation budget 18,000 years ago and that of today? If, as is widely believed, the area of the earth’s surface covered by ice 18,000 years ago was approximately three times the current area (Liedtke 1990, p. 42), this presumably would have had at least some influence on the earth’s radiation budget. The ice-covered areas may have modified the radiation budget by means of their high reflexivity. In other words, an albedo-related loss of radiation may have occurred. The results of this investigations show, that the global radiation budget at 18,000 B.P. was about 7–10% less than that of today.

1. The earth’s radiation balance

The sum of the radiation currents affecting the earth’s heat budget is known as the radiation balance, ‘R’ (Albrecht 1940; Budyko 1963; and others). This is calculated as follows:

\[ R = G (1 - a) - IR \]

where

\[ R \] = radiation balance
\[ G \] = global insolation
\( (1 - a) \) = albedo
\( IR \) = effective long-wave radiation

In this essay, the influence of albedo on the radiation balance will be investigated. If an interaction between the form of the earth’s surface and the radiation budget exists, this should be quantifiable by estimating the albedo value. The precondition for such a calculation is a global record of the average annual values for all the parameters used in calculating the radiation balance, namely ‘R’, ‘G’, ‘a’ and ‘IR’.

2. Current radiation budget

The latest values for the current global insolation budget can be found in Dieter Henning’s ‘Atlas of the Surface Heat Balance of the Continents’ (1989). These values were mainly calculated according to Albrecht’s method.\(^2\) This differs only slightly from e.g. Budyko’s method.\(^3\) Albrecht’s mathematical method is collaborated by meteorological data gathered from 4000 climate stations. The parameters are illustrated by Henning in the form of isoline maps. In order to achieve a uniform network of co-
ordinates, the intersection points of every fifth degree of latitude with every fifth degree of longitude were taken as ‘measuring points’. All intersection points on the continents were numbered, giving 620 ‘measuring points’. The radiation balance parameters ‘R’, ‘a’ and ‘IR’ were calculated for these 620 ‘stations’. With these parameters, the global insolation ‘G’ can be calculated, as

\[ G = R + IR \]

Therefore

\[ G = \frac{R + IR}{1 - a} \]

This calculation gives the following results:

<table>
<thead>
<tr>
<th>IR Ly/d</th>
<th>R Ly/d</th>
<th>G Ly/d</th>
<th>a %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>486</td>
<td>489</td>
<td>1194</td>
</tr>
<tr>
<td>Africa</td>
<td>1816</td>
<td>2136</td>
<td>5075</td>
</tr>
<tr>
<td>Asia</td>
<td>2635</td>
<td>2788</td>
<td>7096</td>
</tr>
<tr>
<td>Australia</td>
<td>517</td>
<td>571</td>
<td>1424</td>
</tr>
<tr>
<td>N. America</td>
<td>1410</td>
<td>1403</td>
<td>3785</td>
</tr>
<tr>
<td>S. America</td>
<td>945</td>
<td>1481</td>
<td>2933</td>
</tr>
</tbody>
</table>

IR = Continental long-wave emission.
R = Continental radiation balance.
G = Continental global insolation.
a = Average continental albedo.

3. The earth surface radiation budget at 18,000 B. P.

In order to comment on the radiation budget during the last glaciation, the parameters ‘G’, ‘a’, ‘IR’ and their possible differences from today’s values must be taken into account. As no data for these parameters is available from the last Ice Age, they must be reconstructed using climatic indicators. Because the radiation balance during the ice age was probably closely related to the form of the earth’s surface, it is important to examine a model of the form of the earth’s surface at 18,000 B.P, as this was considerably different from that of today.

3.1. The albedo of the earth’s surface at 18,000 B.P.

The ice cover of the continents 18,000 years ago is calculated to have been approximately 44.4 million km², three times as much as today. The related drop in sea level led to an extension of the coastline and thus to an expansion of the continental area. A global drop in temperature led to landscape zones shifting and to considerable changes in the vegetation distribution on the continents (Liedtke 1990, p. 40). Using