CORRESPONDENCE

Comment on S. H. Schneider's Editorial 'Can Modeling of the Ancient Past Verify Prediction of Future Climates?' (*Climatic Change* 8, 117–119)

Dr Schneider addressed the question of verification of climate model results, and, in particular, climate model sensitivity. Although we agree with his basic premise, that paleoclimate simulations provide a useful test of the ability of climate models to respond to alterations in climate forcing, the model simulations he chose were not comparable. If the different models show different responses to the *same* climate forcings, comparison with paleoclimatic evidence might produce an assessment of which model, or which model parameterization, is most realistic. However, if the models employ different boundary conditions their responses will reflect the boundary conditions as well as any differences in model sensitivity; such is the case in the comparisons cited in the above editorial.

Schneider compared the Younger Dryas simulation of 11 000 yr ago (11k) using the GISS model reported by Rind *et al.* (1986), with the 9k simulation of Kutzbach and Guetter (1984) made with the NCAR CCM. Each run used the orbital parameters appropriate to the particular time, and the difference in insolation between 9k and 11k was small – Northern Hemisphere summer at 9k had 1.3% more solar insolation than at 11k. In both time periods the Northern Hemisphere summer insolation was greater than that of today, and both models showed increased warming over Eurasia in summer compared to the current climate simulation. However, the GISS model, with boundary conditions appropriate for 11k, produced warming of up to 10 °C during this season, while the NCAR model, with a North American ice sheet and the solar insolation change, had warming on the order of 4 °C. This difference is *not* the result of different model sensitivities: instead, it reflects the different boundary conditions used in the simulations.

The GISS 11k simulation included changes of other elements of the climate system appropriate for the late-glacial time, in addition to the orbital parameters. In particular, this simulation included the presence of the 11k land ice, which was still relatively extensive (Denton and Hughes, 1981). The 9k simulation with the NCAR CCM used today's land ice distribution in Eurasia. How would this difference affect the results?

Kutzbach and Wright (1985) discussed the influence of elevated land ice on the local meridional circulation. Regions to the northwest and southeast of the ice sheets tend to experience subsidence (*op. cit.*, Figure 2), as a result of their location vis-a-vis the jet stream. The eastern edge of the ice sheet marks the termination of the zone of increased latitudinal temperature gradient associated with the land ice, and is thus the region in which the jet stream decelerates. The deceleration is accomplished by the effect of the coriolis force on a local indirect circulation, the circulation which produces the subsidence to the southeast. Warming to the southeast associated with this subsidence is the natural response to an ice sheet in a west wind regime, although the degree of warming would be affected by additional processes (advection, radiation, etc.).

The GISS 11k experiment included the remaining Western European land ice at 11k, with an elevation about 2/3 of the full ice age topography. As expected from the above

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discussion, subsidence occurred to the southeast of the ice sheet in the model and was responsible for a portion of the warming over Eurasia. This effect is clearly shown by the following experiments.

In a forthcoming paper (Rind, 1986), the full ice age simulation (for 18k) with the GISS model is compared to a simulation with ice sheet topography reduced to 10 m. The temperature difference between the two experiments for the months of June–August is shown in Fig. 1. Note the large warming over Eurasia in the run with the elevated ice sheets; the subsidence to the southeast of the European ice sheet occurs from great elevations and produces substantial warming in the full ice age run, an effect missing when the ice sheet elevation is reduced. There were no other specified differences in these simulations – in particular, the orbital parameters were the same (those appropriate for 18k).

We can compare this result with the temperature difference between the Younger Dryas experiment for 11k and the current climate simulation (Figure 2). Comparison of Figures 1 and 2 indicates that a substantial portion of the Eurasian warming at 11k has a similar magnitude and pattern to the warming induced by subsidence over the elevated ice sheets at 18k. Note that the 11k experiment had both altered summer insolation *and* elevated ice sheets. It would thus be difficult to deduce what fraction of the 11k warming is due to solar insolation changes alone. In addition, the subsidence reduced the cloud cover over Eurasia, augmenting the impact of the increased solar radiation. Thus

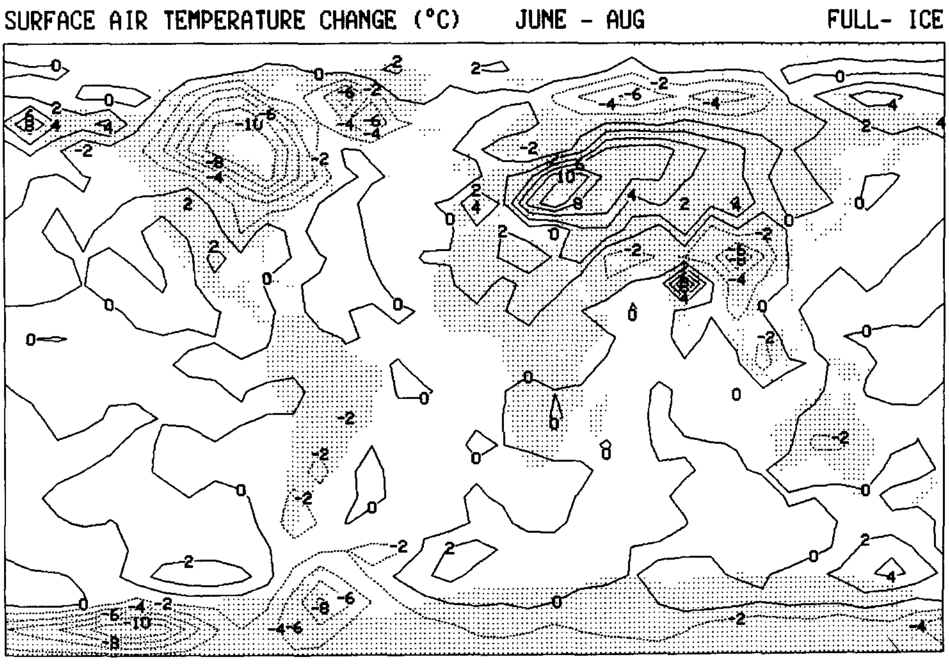

Fig. 1. Difference in surface air temperature between the full ice age simulation for 18k, and a simulation with ice sheets reduced to 10 m in elevation, for the months of June through August. Each run was for four years with results presented from the last three years (from Rind, 1986).

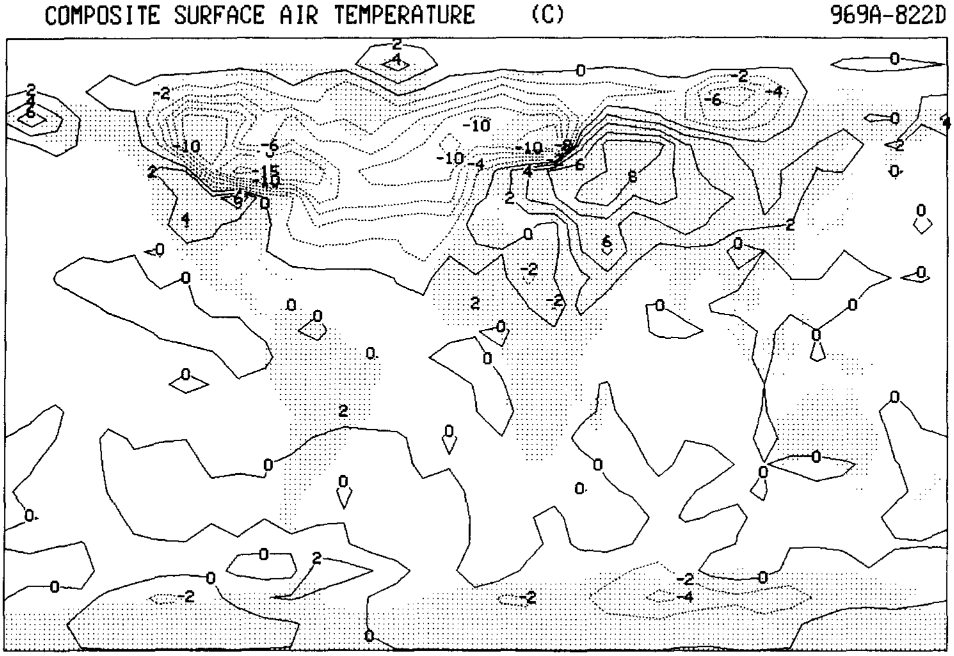

Fig. 2. Difference in surface air temperature between the Younger Dryas and the current climate for the months of June through August, as simulated by the GISS climate model. Each run was for four years, with the results for this season averaged over the last three years (from Rind *et al.*, 1986).

this Younger Dryas experiment *cannot* be used to estimate the sensitivity of the model to orbital parameter changes.

Does the degree of subsidence warming differ among the different models, and can this warming be compared to paleoclimate evidence? As discussed by Rind (1986), different model ice age simulations appear to produce different degrees of warming to the southeast of the ice sheets. This implies that the models may show some variation in their dynamical response to the presence of land ice, although other factors (e.g., cloud cover) may also be important. This is a more specific comparison and of somewhat less consequence than the question of model climate sensitivity, although of considerable interest nonetheless. As the subsidence effect appears most strongly in summer, it results in increased seasonal variation in particular regions in different models, which ideally may be compared to paleoclimatic evidence. However, interpretations of the effect of increased seasonality may be difficult; seasonal limitations on many paleoclimatic indicators, such as pollen, are often poorly known, primarily due to the lack of modern analogs (Rind *et al.*, 1986). Interdisciplinary studies (i.e., the use of isotopes, pollen, macrofossils, and faunal remains) offer the most useful method of establishing seasonal paleoclimatic reconstructions for model comparisons.

In conclusion, while comparison of the results from different models to paleoclimate evidence is likely to be a useful technique for evaluating the realism of model response to climate change scenarios, it is necessary to make sure that the different modeling experiments are really comparable before any such attempt is made. Differences in forcing or boundary conditions may have unexpected consequences. A carefully designed set of paleoclimate experiments run with different models would be useful in establishing model similarities and differences, and might help in interpretation of ambiguous paleoclimatic evidence.

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