SIMULATION OF THE HDO AND $H_2^{18}O$ CYCLES IN AN ATMOSPHERIC GENERAL CIRCULATION MODEL

(Abstract)

by

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1. INTRODUCTION

In the Antarctic deep ice cores, Petit and others (1981) found 10 to 20 times more dust for the end of the last glacial age (~18 ka BP) than nowadays. The dust, which is in the 1 to 5 µm range, seems to have come mainly from continents, but its geographical origin is not known precisely. According to Petit and others (1981), this great increase could be a global signal linked with enhanced aridity and stronger atmospheric circulation. It seemed, therefore, interesting to test this hypothesis by simulating desert dust rise, transport and removal in an atmospheric general circulation model (GCMA).

A more far-fetched motivation is the future need for simulating climatic feedback mechanisms associated with dust rising over desert areas and its impact on the radiation budget. However, in the present simulations, dust particles are considered as passive scalars without any feedback effect on radiation.

2. MODELLING

2(a). Mobilization

For the purposes we have in mind, we need a fully interactive dust cycle. In the present simulations, we have chosen to raise dust over model-generated dry land. In doing so, we identify dust source areas with arid regions, and with semi-arid regions in the dry season. Since we do not at present model vegetation as an interactive part of the climatic system, we have to neglect its stabilizing effect. Further, we know that all arid regions are not equally efficient as fine dust sources. Therefore, our choice leads to systematic overestimation of source area extent; still we may consider it reasonable to expect that variations in actual dust mobilization rates will be, on average, proportional to variations in the extension of dry regions.

We parameterize dust mobilization in the same way as surface evaporation. The flux of dust particles at the surface depends on a drag coefficient, on the magnitude of wind velocity at the surface, and on the difference between the mixing ratio of dust at the surface and a saturation value proportional to turbulent kinetic energy. This is, in fact, consistent with Gillette's (1977) experimental law. The flux formulation is defined up to a multiplicative constant, which is unimportant since all transport processes are linear.

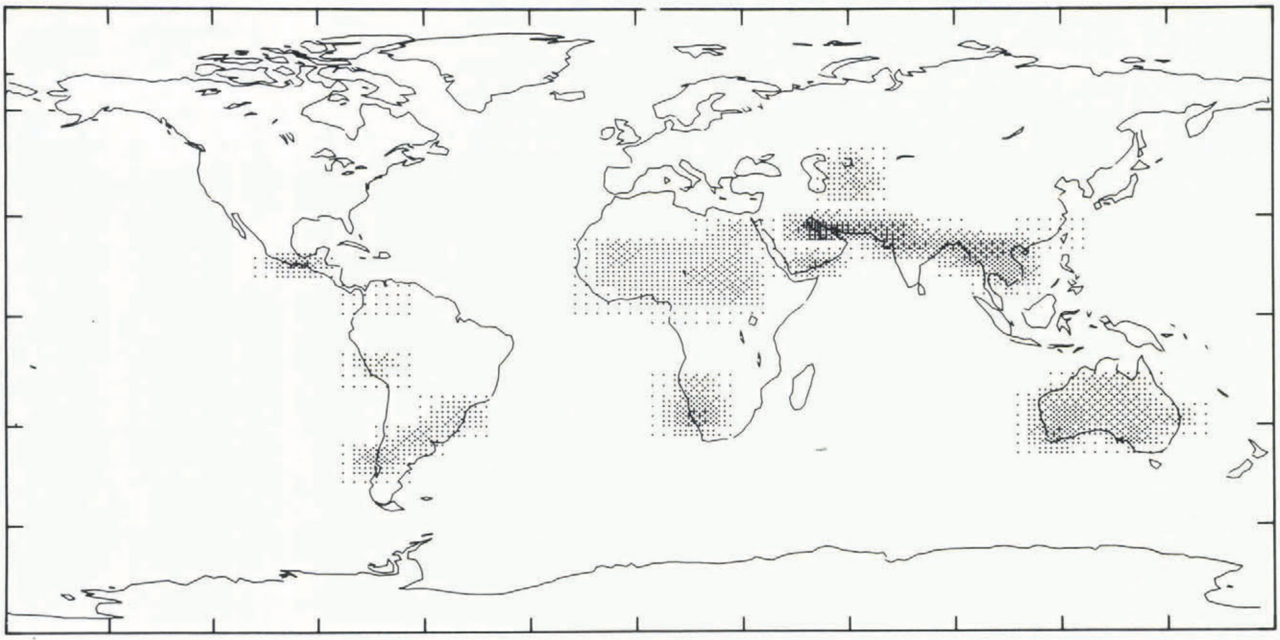

Fig.1. 20-day average simulated mobilization rates. Shading interval: 0.23×10^3; arbitrary units (see text).

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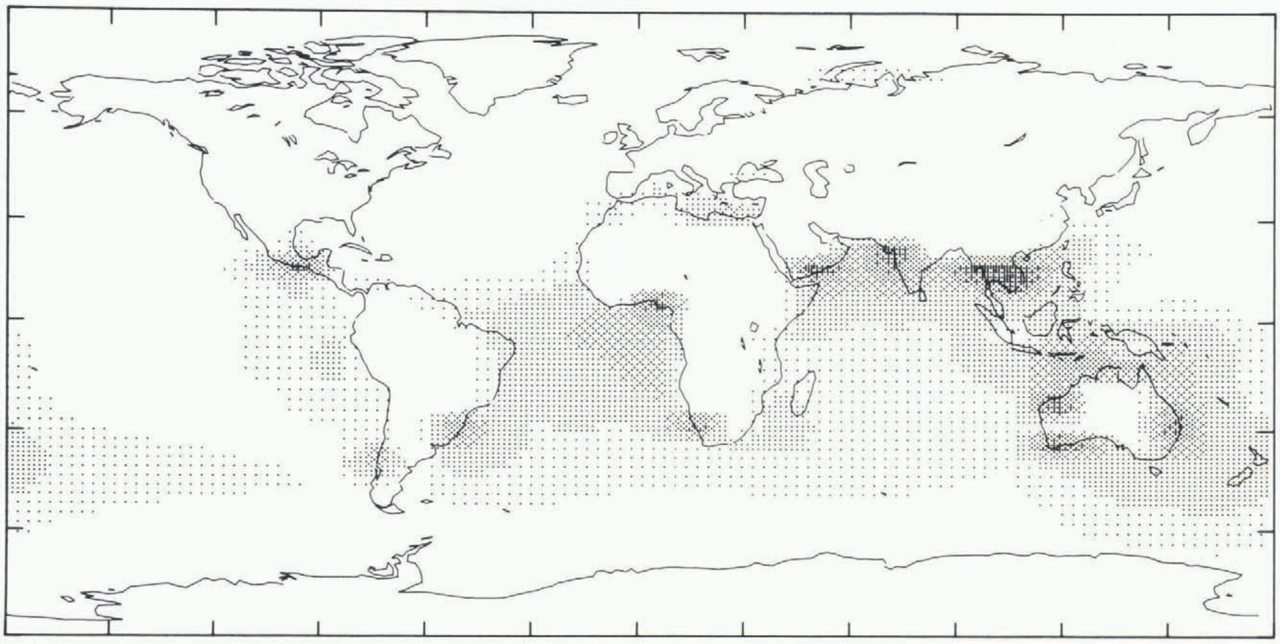

Fig.2(a). 20-day average simulated dust plumes at 1 000 mbar. Shading interval: 0.12; arbitrary units (see text).

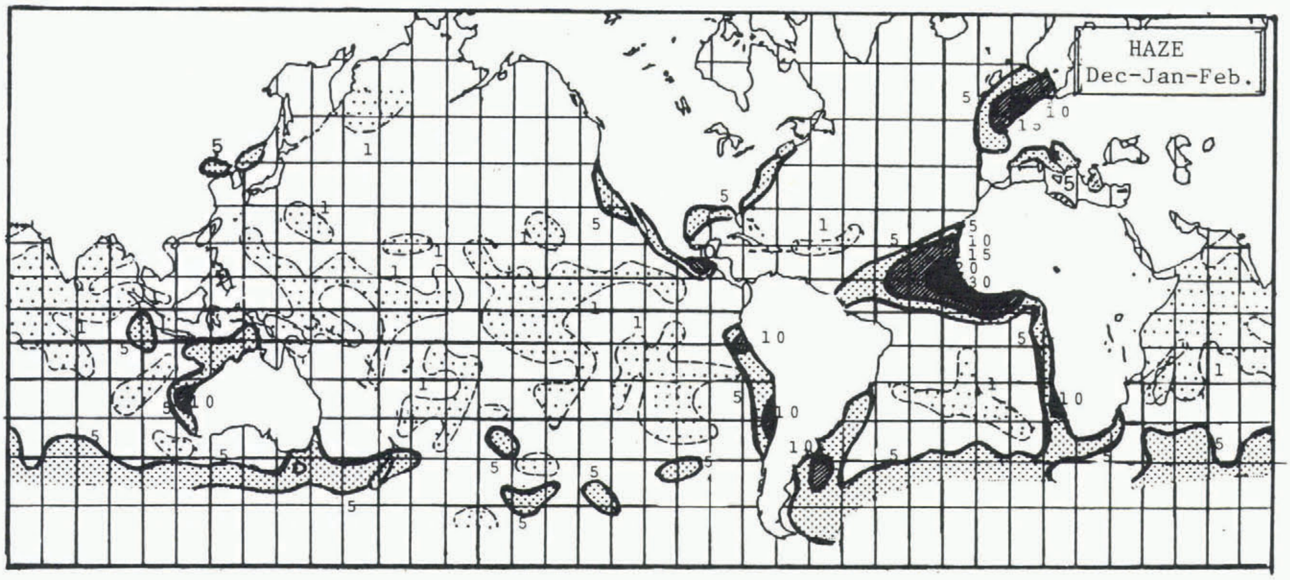

Fig.2(b). Observed haze frequency (Macdonald 1938).

2(b). Removal processes

The main removal process for particles in the 1 μm range is the rainout process (Hidy 1973), in which the dust particles act mainly as condensation nuclei. We have assumed that the proportion of dust particles removed by rainout is equal to the proportion of water vapour which condenses.

Washout processes which are negligible for this range of particle sizes are not taken into account. However the effect of sedimentation velocity, which is weak (of the order of 30 m d^{-1}) but systematic, has been included. We also neglected coagulation and interception by small obstacles. We may note that our parameterization of mobilization acts as a removal process when the air is "oversaturated" in the lowermost layer.

3. RESULTS OF THE NUMERICAL EXPERIMENT

The dust cycle has been included in a 60-day simulation of the January climate using a low resolution version (32 points in longitude, 24 in latitude, 11 layers) of the GCMA developed at the Laboratoire de Météorologie Dynamique (LMD). We differentiate six types of particles according to their geographical origin (North America, South America, Sahara, Southern Africa, Eurasia, Australia). This separation is possible because all mechanisms involved are linear.

All results presented concern quantities averaged over the last 20 days of the experiment. Figure 1 shows the average mobilization rates, indicating that the source regions are roughly realistic, with the possible exception of south-east Asia. Figure 2(a) shows a superposition of all dust plumes at 1 000 mbar compared, in Figure 2(b), to observed haze frequency (MacDonald 1938). The North Atlantic Saharan dust plume is realistic, but the dust transport in the roaring forties is underestimated because the low resolution model fails to simulate strong enough

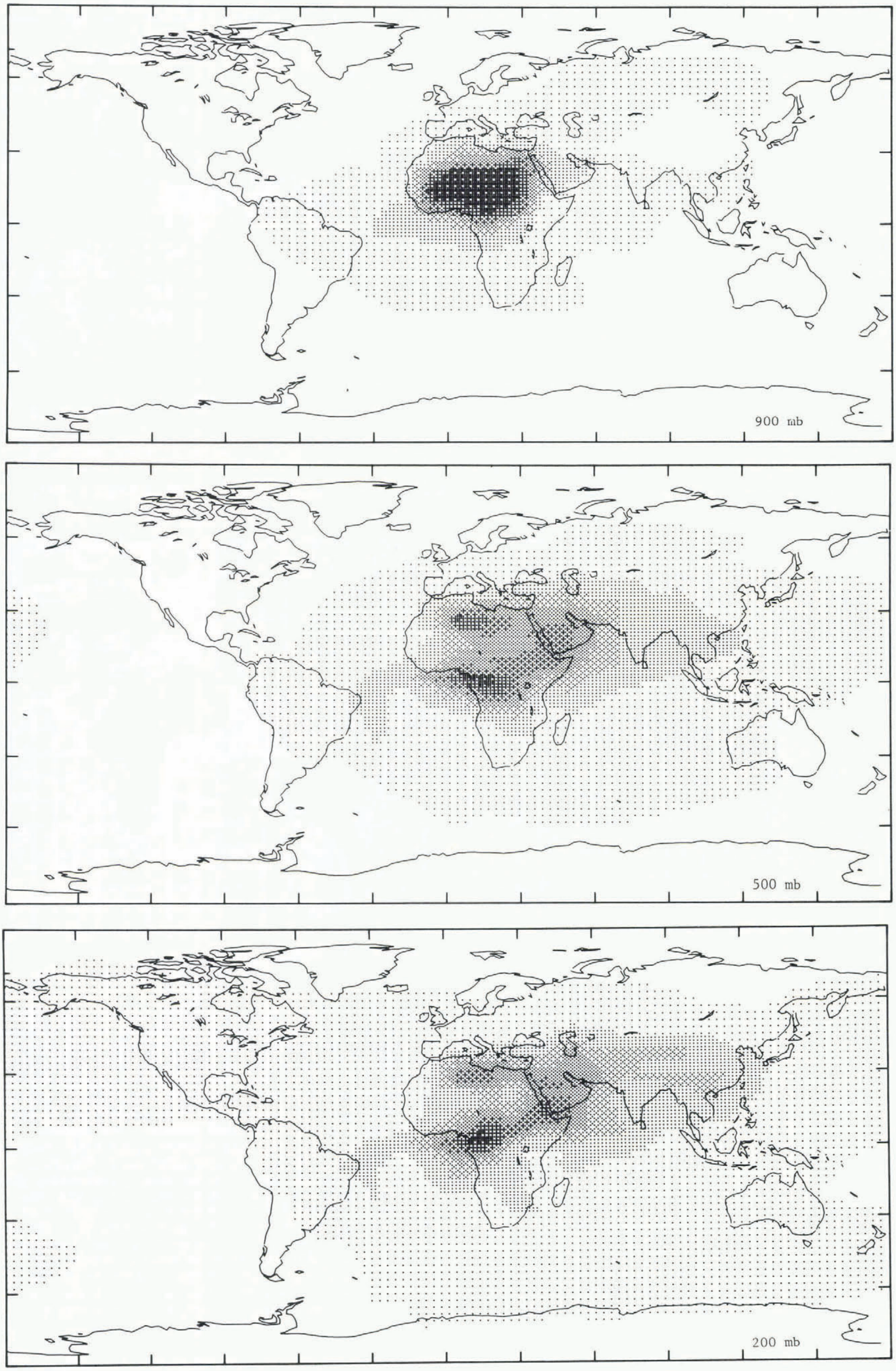

Fig.3. 20-day average simulated Saharan dust plumes at 900, 500 and 200 mbar. Shading interval: 0.13, 0.99 x 10^{-2}, 0.35 x $10^{-[illegible]}$, respectively; arbitrary units (see text).

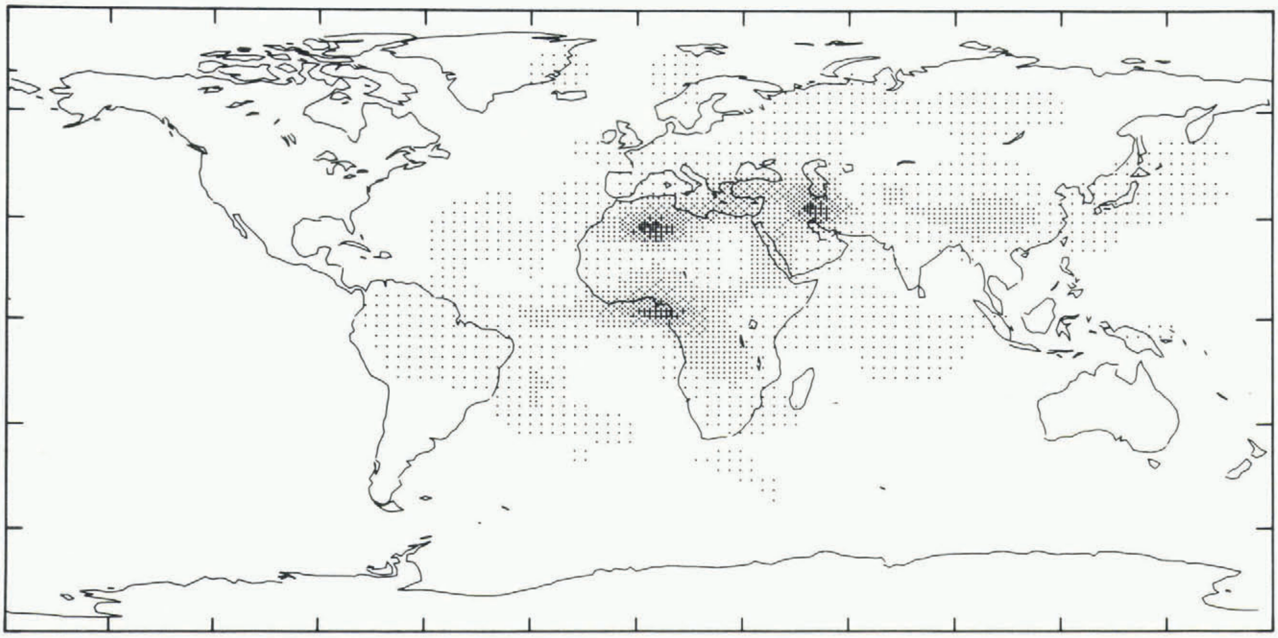

Fig.4. 20-day average simulated Saharan dust precipitations. Shading interval: 0.45 x 10^2; arbitrary units (see text).

westerlies there. Figure 3 shows Saharan dust plumes at 900, 500 and 200 mbar. Finally, precipitations of Saharan dust are displayed in Figure 4. They are quantitatively realistic: precipitations in Cayenne, for instance, are confirmed by the observations of Prospero and others (1981).

For glaciological studies it is interesting to note that dust particles in Greenland originate mainly from North and Central America although the east coast of Greenland also receives some dust from Sahara and eventually South America. Dust in Antarctica originates mainly from Australia and South America.

4. CONCLUSIONS

To conclude, the results seem qualitatively reasonable. The defect of our modelling is obviously the definition of the dust source regions. However, to improve comparison with observations, we plan to perform a present-day climate experiment, with fixed source areas in collaboration with geographers and J M Prospero.

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