N89-25792 3P 19

TRANSPORT OF MARS ATMOSPHERIC WATER INTO HIGH NORTHERN LATITUDES DURING A POLAR WARMING; J.R. Barnes and J.L. Hollingsworth, Department of Atmospheric Sciences, Oregon State University, Corvallis, OR 97331

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Several numerical experiments have been conducted with a simplified tracer transport model in order to attempt to examine the poleward transport of Mars atmospheric water during a polar warming like that which occurred during the winter solstice dust storm of 1977. Such transport is of considerable potential significance, both for the formation of the layered terrains as discussed by Pollack et al., (1,2), and for the overall Mars water cycle as suggested by Davies (3). The transport model is identical to that previously employed to examine the transport of dust during a polar warming (4); it is beta-plane and essentially like that developed by Garcia and Hartmann (5). It represents tracer transport by a single planetary-scale wave and the zonal-mean flow, with a severely spectrally truncated latitudinal tracer distribution. This latter aspect of the model constitutes probably its greatest limitation.

The flow for the transport experiments has been taken from numerical simulations with a nonlinear beta-plane dynamical model. Previous studies with this model have demonstrated that a polar warming having essential characteristics like those observed during the 1977 dust storm can be produced by a planetary wave mechanism analogous to that responsible for terrestrial sudden stratospheric warmings (6,7). As discussed by Barnes and Hollingsworth, the residual mean circulation for such a model warming is strongly poleward and downward throughout a deep region at high latitudes (4). To the extent that the residual mean circulation represents a good first approximation to the Lagrangian mean circulation, then poleward and downward tracer transport is implied.

Several numerical experiments intended to simulate water transport in the absence of any condensation have been carried out. Observations and modeling indicate that atmospheric temperatures are sufficiently high during a dust storm that condensation would be restricted to high latitudes and altitudes (8,9). The initial water distribution in these experiments is sinusoidal in latitude, with column abundances ranging from 30 pr μm at 30° latitude to 0.1 pr μm at the north pole (or any constant multiple of these values). Cases with the water uniformly mixed to 40 and 20 km, and falling off rapidly above, have been examined. For some of the experiments an atmospheric source of water has been incorporated, intended to crudely simulate transport of water into the model domain by the cross-equatorial Hadley circulation (which is not explicitly represented in the dynamical model). The source has essentially the same structure as the initial distribution, and a rate such as to largely "replace" the initial water within the period of the simulations (40 sols).

The numerical experiments indicate that the flow during a polar warming can transport very substantial amounts of water to high northern latitudes, given that the water does not condense and fall out before reaching the polar region. For an initial water abundance of 30 pr μm at 30°N, abundances of ~7-15 pr μm are obtained at the pole after ~20 sols (the lower values for no source, the higher with a source). The total water transported north of 60° ranges from ~1-2x10^{14}g (not including the implicit transport by the source). Such amounts would be very significant for the water cycle: net southward transports of this magnitude have been inferred from the annually averaged water distribution (10).

The water and dust transport experiments together appear to lend support to the type of scenario proposed by Pollack et al. (1,2) as playing a key role in the formation of the layered terrains. The mass of water obtained at very high latitudes is roughly comparable to (perhaps slightly smaller than) the mass of dust deposited on the surface in dust transport experiments incorporating sedimentation. Condensation of the water onto dust grains would thus imply slightly larger composite particles; production of very large particles would need to then be by CO_2 condensation or possibly particle aggregation. The dust transport experiments with sedimentation indicate that a composite (water and dust) layer ~10 μm thick can easily be deposited at the north pole during a polar warming event. This is close to the magnitude required for formation of an individual polar layer over the time scale of the Martian orbital variations.

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