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Evolution of Polar Stratospheric Clouds during the Antarctic Winter

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The occurence of Polar Stratospheric Clouds (PSCs), initially inferred from satellite measurements of solar extinction, have now also been noted by the recent scientific expeditions in the Antarctic. The presence of such clouds in the Antarctic has been postulated to play a significant role in the depletion of ozone during the transition from winter to spring. The mechanisms suggested involve both dynamical and chemical processes which, explicitly or implicitly, are associated with the ice particles constituting the PSCs. It is, thus, both timely and necessary to investigate the evolution of these clouds and ascertain the nature and magnitude of their influences on the state of the Antarctic stratosphere.

To achieve these objectives, a detailed microphysical model of the processes governing the growth and sublimation of ice particles in the polar stratosphere has been developed, based on the investigations of Ramaswamy and Detwiler (Journal of the Atmospheric Sciences, 1986). The present studies focus on the physical processes that occur at temperatures below those required for the onset of ice deposition from the vapor phase. Once these low temperatures are attained, the deposition of water vapor onto nucleation particles becomes extremely significant.

First, the factors governing the magnitude of growth and the growth rate of ice particles at various altitudes are examined. These include the sizes and concentrations of the nucleation agents, and the temperature and water vapor profiles (which determine the saturation conditions). It is possible, for example, to predict whether ice growth or sublimation will occur at a given location and instant during the Antarctic winter, based on the temperature profile.

Second, the ice phase mechanisms are examined in the context of a column model with altitudes ranging from 100 to 5 mb. pressure levels. The model considers explicitly the growth and sublimation processes as well as the fallspeeds of the particles at different altitudes. Particles of different sizes and concentrations are considered, as given by a lognormal distribution. Particles of specific sizes are followed as they grow, decay or fall; no attempt is made to categorise them into bins of definite size range. This, in effect, implies that all particles, initially at specified levels in the column model, are continuously monitored. The forcing for the temporal evolution of the model is the time rate of decrease of temperature. Values considered include those appropriate during July, August and September in the Antarctic stratosphere. Various temporal resolutions have been considered to perform these simulations, ranging from 1/2 minute to a hour. The principal features are the dependence of the cloud evolution on the rate of temperature decrease, water vapor mixing ratios and the particle characteristics. It is also seen that rapid changes in temperature cause rapid changes in the sizes of the ice particles.

In the third stage of the study, the column microphysical model has been used to perform simulations of the cloud evolution, using the observed daily temperatures. The simulations commence from June 1 and last till end of September; different years and geographical locations are considered in this part of the sensitivity study. The results indicate that particles grow large as a result of the ice deposition and, under favorable conditions, can fall down considerable distances. This, in effect, implies a depletion of water vapor and a reduction in the number concentration of nucleating particles at the higher altitudes of occurence of PSCs. These simulations are compared with the temporal evolution of the extinction measurements, as observed by the SAGE satellite.

The effects due to the growth of the particles on the radiation fields are also investigated using a one-dimensional radiative transfer model. Specifically, the perturbations in the longwave cooling and that in the shortwave heating for the late winter/early spring time period are analyzed.