MESOSPHERIC CLOUD FORMATIONS

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The natural existence of noctilucent clouds at high latitudes during summer suggests that deposition of large amounts of H_2O by HLLV exhausts near the cold mesopause (85 Km) could result in the formation of mesospheric clouds. Studies of mesospheric cloud formation indicate that three conditions must be met in order to form and maintain clouds near the mesopause: (1) As discussed by Witt (1969), homogeneous nucleation is slow, and condensation nuclei are required for sufficiently fast growth of ice particles. (2) The ambient temperature must be less than the frost point temperature at which saturation occurs. (3) Sufficiently large vertical velocities might be required to ensure growth of ice to required dimensions ($\sim .1\mu$) for a given water vapor contents. Also, from the point of view of assessing SPS-related effects, the frequency and magnitude of H_2O injections are factors to be considered.

Witt (1969) points out that an effective source of condensation nuclei might be large water cluster ions, since the coulomb forces act to lower the free-energy barrier against the formation of small droplets, allowing particle growth to proceed relatively easily. In a companion paper (hereafter referred to as Paper I) in this volume entitled "D- and E-Region Effects" it is shown that injections of H_2O into the mesosphere resulting in volume mixing ratios greater than 100 ppmv could convert most of the O_2^+ and NO^+ ions at 85 Km to ions of the type $H^+(H_2O)_n$ (n=1 to 7), and thus provide an abundance of condensation nuclei. In Paper I it is estimated that H_2O mixing ratios greater than 100 ppmv can occur over areas of order 20,000 Km^2 for realistic SPS scenarios.

The terminal fall velocity at 85 Km of particles with density 1 g cm^{-3} and radius $.1\mu$ is about 1 $msec^{-1}$. Updrafts of this magnitude might be required to ensure growth of ice to required dimensions ($\sim .1\mu$) for a given water vapor content. Updrafts of 1 $msec^{-1}$ are not thought to exist at midlatitudes, but only at high latitudes during summer. This is consistent with the observed seasonal and latitudinal occurrence of noctilucent clouds. However, it is shown by Reid (1975) that growth of needle-shaped or disc-shaped particles is much faster than growth of spherical particles, which could relax the requirement of vertical velocities of order 1 $msec^{-1}$.

Ice particles will grow (shrink) depending on whether the ambient temperature (T_a) is less (greater than the frost point temperature (T_f) at which saturation occurs. In Figure 1, the latitude variation of mesopause temperature during summer and winter are plotted with frost point temperatures at 85 Km indicated for 1, 10, 10^2, 10^3, and 10^4 ppmv. During winter, there does not seem to be any possibility of maintaining clouds, even for mixing ratios as high as 10^4 ppmv. During summer, T_f exceeds T_a above 67 deg N for mixing ratios of order 10 ppmv. At midlatitudes (30-45 deg), where SPS launch activities would likely occur, mixing ratios of order 10^3 ppmv would be required for the maintenance of clouds at the mesopause. A crude estimate of possible effects has been obtained by calculating (see Paper I) the post-launch redistribution of H_2O due to diffusion, transport by winds, and photodissociation, and determining over what area T_f exceeds T_a. Assuming HLLV second stage deposits of 7.0×10^{31} molecules of H_2O evenly distributed over 70-120 Km, and injection frequencies ranging from 2 $week^{-1}$ to 8 day^{-1}, T_f is exceeded over areas of order 200 Km^2 around the point of injection. This area estimate is probably correct to within an order of magnitude unless the scenarios examined here are grossly in error with regard to frequency and magnitude of injected H_2O.

It is emphasized that a more definitive answer to the question of mesospheric cloud formation due to repeated depositions of H_2O by space launch vehicles would require much preliminary basic research into the processes and conditions involved in the transition from small nucleation particles to macroscopic cloud particles, and into the transport mechanisms and overall water vapor budget of the mesosphere.

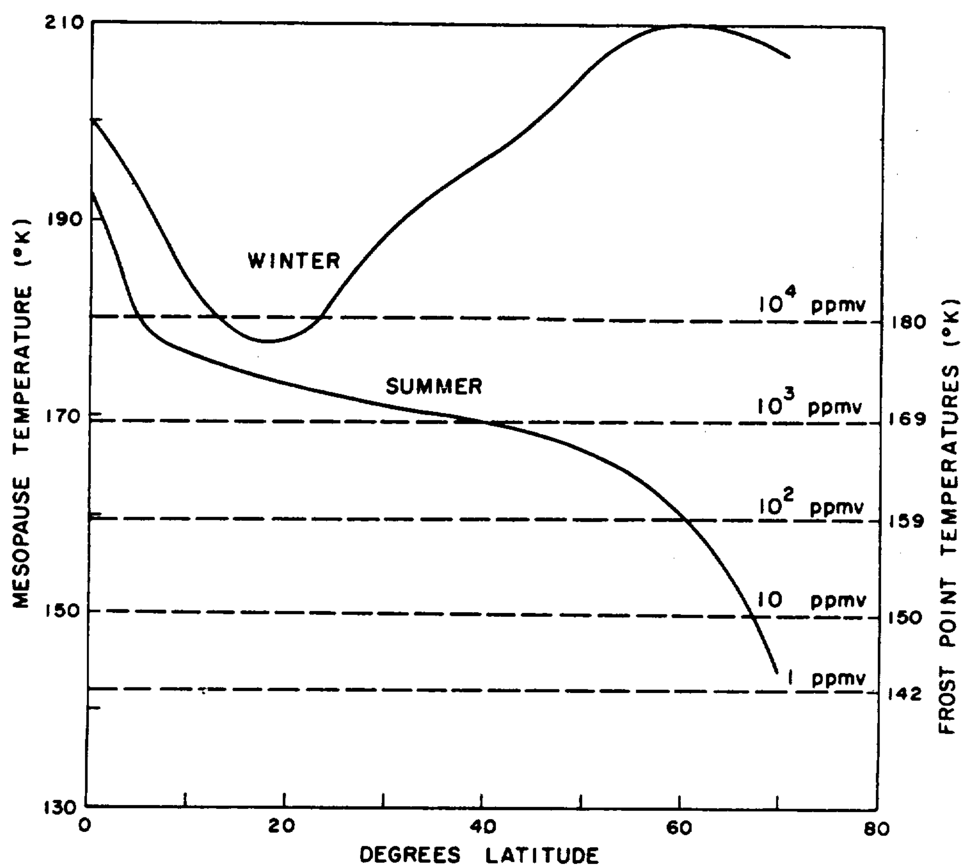

Figure 1. Mesopause temperature vs. latitude and frost-point temperatures for various H_2O volume mixing ratios at 85 Km.

REFERENCES

Reid, G.C., "Ice Clouds at the Summer Polar Mesopause", J. Atmos. Sci., 32, 523-535, 1975.

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