D 44

ENVIRONMENTAL EFFECTS OF SPS: THE MIDDLE ATMOSPHERE

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N82 22760

The heavy lift launch vehicles associated with the SPS would deposit in the upper atmosphere exhaust and reentry products which could modify the composition of the stratosphere, mesosphere, and lower ionosphere. In order to assess such effects, we have performed model simulations to assess the modifications, especially in a geographic zone centered at the launch and reentry latitudes. The models which we used were the following:

(1) a one-dimensional photochemical model which extends from 10 to 120 km altitude and includes 35 chemical species (NASA TP 1002);

(2) a two-dimensional photochemical model which extends from 80°N latitude to 80°S and from the surface to 90 km altitude; it includes about 25 species and parameterizes transport through mean meridional bulk motion and "eddy" diffusion coefficients;

(3) a one-dimensional noctilucent cloud model which simulates ice particle nucleation, growth and evaporation, coagulation sedimentation and vertical eddy diffusion; the model, whose predictions of size and height distribution are in quite good agreement with the observational data available, is an outgrowth of a model of the stratospheric sulfate aerosol layer (NASA TP 1362);

(4) a model for simulating the production of nitric oxide during atmospheric reenetry of the HLLV's; after the entry trajectory is calculated the appropriate mass (including chemical kinetics), momentum and energy conservation equations are solved under the assumption that the flow field is very similar to that around a cone.

(5) an ionospheric model which solves the chemical kinetic equations for 16 species of positive ions and 9 species of negative ions; clustering of water molecules to ions is included.

In order to provide estimates of the width of the long term zonal "corridors" in which the compositional changes might significantly change, we simulated 10 years of launch and reentry operations. The computed water vapor mixing ratio increase (ranging from 0.4% at 30 km to 8% at 80 km altitude) was nearly independent of latitude up to an altitude of 70 km. Above 70 km at the assumed launch latitude (30°N) it was higher than at other latitudes, about 15% excess at 85 km altitude. At latitudes north of 50°N and south of 10°N, the latitude dependence of the water vapor increase was insignificant. From these results we conclude that no "corridor" effect is likely except, perhaps, a very small one at altitudes above ~ 75 km. Similar calculations for the nitric oxide production and redistribution during reentry showed that the computed nitric oxide enhancement at the launch latitude is about a factor of 2 greater than that obtained from the one-dimensional model by assuming hemispherical averaging. The 10 year calculated decrease in the ozone column due to water vapor and NO deposition during launch was about 0.03% (hemispherical average) and the corresponding estimated change in mesospheric $O(^3P)$ was about 0.7%. The estimated ozone change likely to be caused by nitric oxide produced during reentry of the HLLV is about 1×10^{-3}% gain. Also, we compute a substantial increase in thermospheric hydrogen, about a factor of 2 globally averaged.

Noctilucent clouds can apparently form only at the high latitude mesopause because only there is the supersaturation of water vapor sufficient for their formation. Our preliminary estimates of the increase in optical depth at visible wavelengths due to noctilucent cloud formation from deposited water vapor is only $\sim 1 \times 10^{-4}$ in the noctilucent cloud zone (a very small fraction of the earth's surface). If the optical depth over the whole surface of the earth were increased by that amount, the estimated temperature decrease would be only about 10^{-3} K; the threshold for perceptible climate change is about 0.1K. However, immediately following launch the increase in optical depth can be quite large perhaps to $\tau \gtrsim 25$ along the trail axis 1 hour after launch. However, the ice particles in the trail quickly spread and evaporate. Thus, one might expect a substantial contrail to form near the launch point and to dissipate in less than one day.

Our ionospheric calculations showed that on the global scale there would be only a small increase in electron density in the D-layer due to increased NO generated by reentry. Such increases could be very large (order to magnitude or more) in the region near the entry trail for times up to about 1 day.

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