VSRT MEMO #049

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To: VSRT Group
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Subject: Modeling the seasonal variation of nighttime ozone in the mesopause.

The ozone at nighttime is created by three body collisions between atomic oxygen, oxygen and catalytic molecule like nitrogen.

$$O + O_2 + M \rightarrow O_3 + M$$

while it is destroyed by collisions with atomic hydrogen

$$O_3 + H \rightarrow OH + O_2$$

while there are other reactions these are dominant in the mesopause. Following sunset these reactions will reach equilibrium with an ozone mixing ratio of

$$O3_{vmr} = \frac{k1 \times O2_{vmr} \times O_{vmr} \times \rho}{k3 \times H_{vmr}}$$

where ρ is the background number density. The reactions are very temperature dependent.

$$k1 = 6.0 \times 10^{-34} \left(300/T\right)^{2.4}$$

$$k3 = 1.4 \times 10^{-10} \left(-470/T\right)$$

For a typical mesopause temperature of 170K the ozone mixing ratio will increase by a factor of 1.031 for each degree drop in temperature or about 30% in a 10K drop. In addition, the ozone mixing ratio is proportional to the mixing ratio of atomic oxygen and inversely proportional to atomic hydrogen. Semi-annual and annual variations in the mesopause at 40˚ N latitude reported by States and Gardner 2000 are only about 10K so that temperature is probably not a major contributor to the seasonal variations of ozone. Likewise the seasonal variations of atomic oxygen are small. The greatest variation is in the atomic hydrogen, which is created by the action ultra violet on water vapor.

$$H_2O + h\upsilon \rightarrow H + OH$$

The water vapor is thought to be conveyed to the mesopause by meridional circulation driven by a “gravity wave pump” Plumb 2002 . The water is moved from the summer hemisphere to the winter hemisphere via the mesosphere. Inter-hemispheric circulation via the mesosphere was first proposed by Brewer in 1949. This meridional conveyer of water vapor stops and reverses at the equinoxes (or slightly after the equinoxes due to the delay between the air temperatures and solar heating). When the flow is slow or stopped the mesospheric water vapor declines and the mixing ratio of atomic hydrogen drops causing an increase in the ozone in the mesopause.

States, R.J. & Gardner, “Thermal Structure of the Mesopause Region (80-105 km) at 40˚N Latitude.” Part I: Seasonal variations *Journal of the Atmospheric Sciences*, **57**, 66-76, 2000.

Brewer, A.W. “Evidence for a World Circulation Provided by the Measurements of Helium and Water Vapor Distribution in the Stratosphere,” *Quart.J.R. Meteor Soc*, **75**, 251-363, 1949.

Plumb, R.A., “Stratospheric Transport,” *J.R. Meteor Soc. Japan*, **80**, 793-809, 2002.