VSRT MEMO #043

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To: VSRT Group
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Subject: Ozone kinetic temperature in the lower thermosphere

The narrow width of the nighttime ozone spectra at 11.072 GHz suggests that the kinetic temperature of ozone may be lower than the kinetic temperature of nitrogen and other molecules. The calculated half-power half width due to Doppler broadening are as follows:

Temp K	Width kHz
100	5.7
150	6.9
200	8.1

Energy balance in the upper mesosphere lower thermosphere (MLT) collisions are infrequent enough that different molecules may take on different temperatures. At 100 km the rate for kinetic energy exchange via collisions approximately $10^2 s^{-1}$. On the other hand the infrared from the Einstein A coefficient for ozone at 9.6 microns is approximately $4\times10^3 s^{-1}$. A 9.6 micron photon has ten times the kinetic energy at 200 K. At 200 K the relative population of the upper states of the 9.6 micron transitions is about 6×10^{-3} so the energy loss via the 9.6 micron emission expressed as a ratio to the energy transfer rate via collisions is

$$6\times10^{-3}\times4\times10^{3}\times10\times10^{-2}\approx 2$$

This very approximate estimate shows that at 100 km the 9.6 micron absorption and emission could have significant influence on the kinetic temperature of ozone. If we ignore collisions and consider only the radiative equilibrium due to the 9.6 micron transitions the high altitude ozone sees the cooler ozone down at (around 200K) over about 2π steradians and the cooler sky (around 3K from CMB) at night. In this case an energy balance would be reached with a drop of about 30K to 170K. In the day time the Sun will make only a small increase additional energy at 9.6 microns.

The VSRT measurements have insufficient spectral resolution to provide an accurate measurement of the ozone temperature but do suggest that the temperature is below 180K. Changes in the observing software are being made to improve the spectral resolution by a factor of 2 or more. In addition the frequency calibration is being improved. A new version of the ozone spectrometer is currently being tested at Haystack Observatory.

Appendix:

Energy balance at a single wavelength for surface on one side using Planck's law

$$4e^{\frac{h\nu}{KT_1}} = e^{\frac{h\nu}{KT_2}} \qquad h\nu >> KT$$

solving $1/T_1 = 1/T_2 + (\ln 4)\, K/h\nu$