Temporal and Altitude Variation of SO_2 and SO in the Venus Mesosphere: Sub-mm Spectroscopic Observations from the JCMT

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Measurements since 2004 of SO_2 and SO (collectively SOx) in the Venus mesosphere characterize extreme, factor of 30 temporal variability of abundance on a global scale, together with unexpected altitude dependence which is time invariant. Observations with the James Clerk Maxwell Telescope (JCMT) of SO_2 (346.65 GHz) and SO (346.58 GHz) sub-mm absorption lines are conducted simultaneously within a single, 250 MHz spectral region. Line shapes are dominated by pressure broadening, such that depth of absorption vs distance from line center indicates molecular abundance vs altitude.

SO_2 and SO are always restricted to the upper mesosphere, between 84 and 100 km, with temporally variable abundances of <1.7 to 66±5 ppb (SO_2) and 0.7±0.5 to 31±4 ppb (SO). Altitude sensitivity is maximum near 85 km, such that the lower altitude boundary is well defined as 84±2 km. In the 70-84 km lower mesosphere, SO_2 and SO are determined to have upper limits of 15% of their 84−100 km abundances. In the lower thermosphere (100-110) km, SO_2 and SO upper limits of 100 ppb and 30 ppb (respectively) are obtained.

Over the full 2004-2009 observation period, global abundances of each molecular species varies more than 30x. No correlation is found between SO_2 and SO abundances, such that there is strong time-variation of both the ratio [SO_2]/[SO] (0.6±0.4 to >90.) and the total [SO+SO_2] (<3 to 78±9 ppbv). The magnitude of the total SOx variation, together with upper mesospheric aerosol abundance [Wilquet et al., 2009] is consistent with sulfate aerosol as a source/sink for gas-phase SOx, though no physical mechanism has yet been identified to drive such exchange. Short time-scale change is also evident, as extreme as a 5 sigma doubling of SO from 15±3 to 31±4 ppbv over 9 days in August, 2008. This is one of many examples of secular change, independent of Venus local time. However, a diurnal pattern is clear in the full data set. While both SO and SO_2 abundances can be very small both day and night, the largest SO abundances occur on the dayside, and largest SO_2 abundances at night. Clearly, both diurnal and non-diurnal forcing mechanisms are at work.

Global-mean mesospheric (70-100 km) water abundance showed similar extreme temporal variabilty in the period 1998−2004 [Sandor and Clancy, 2005; Gurwell et al. 2007]. Coordinated analysis for SOx and water variability is crucial as an investigation of the role of sulfate aerosol (sulfuric acid in water solution) in mesospheric chemistry. Unfortunately, our ground-based sub-mm observations determine a much drier (than 1998-2004) mesosphere on all 2004−2007 observing dates coincident with SOx measurements. Very low water abundances in those years provide s/n too poor for determination of variability. Our observations in 2008−2009 find more water than at any date since 2002, suggesting a return to conditions when high-sigma water sub-mm measurements are routinely possible. This, together with improved sensitivity of JCMT's heterodyne receivers, indicates simultaneous determination of SOx and water temporal variabilities will be made over the next few years.