

# Sub-millimeter JCMT Observations of the Venus Upper Atmosphere : Winds, Temperatures, and Composition

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A decade-long record of wind, temperature and compositional profiling for the Venus mesosphere and lower thermosphere (75-110 km) has been supported by sub-millimeter line observations with the James Clerk Maxwell Telescope (JCMT). These heterodyne spectral line observations include 330-360 GHz line absorptions for <sup>13</sup>CO, <sup>12</sup>CO, HDO, SO, and SO<sub>2</sub>; as well as new 660-690 GHz line absorptions for <sup>13</sup>CO and <sup>12</sup>CO. A variety of observation-specific results have been reported from these data, for which a general picture emerges of an extremely dynamic, time-variable compositional-thermal-circulation state for the Venus mesosphere and lower thermosphere. In particular, Venus mesospheric water vapor has varied by large factors (100's%) over several-year timescales; mesospheric CO and temperatures vary over shorter timescales; zonal and subsolar-to-antisolar (SSAS) wind fields, which increase rapidly from the mesosphere into the lower thermosphere, exhibit large variations on all observed timescales (as short as one day); CO and temperature variations across the nightside lower thermosphere exhibit two distinct spatial distributions that alternate over timescales greater than several weeks; and unsuspected upper mesospheric increases in SO and SO<sub>2</sub> abundances exhibit both solar-zenith-angle and temporal variations.

Although certain aspects of these variations may be reasonably correlated, a broad description of the full interrelations among these various behaviors remains elusive due to the incomplete spatial and temporal overlaps among the spectral line observations. Furthermore, we have only recently obtained resolved measurements of dayside behaviors due to the decreasing Venus disk size with solar illumination as viewed from the earth. Observations near Venus elongation, when the dayside portions of the disk are resolved (particularly with the 660-690 GHz transitions), indicate very strong cross-terminator winds as well as potential solar tides in mesospheric-lower thermospheric temperature profiles. We present a synthesis of the JCMT sub-millimeter line observations, with an intent to address relationships among the retrieved atmospheric variabilities as well as their comparison to relevant Venus Express and ground-based observations.