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Systematic Variations Detected in the Thermospheres of Venus and Mars from Accelerometry and Orbital Decay Measurements

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Measurements of over 2000 vertical structures of the Mars thermosphere have been obtained from accelerometers aboard Mars Global Surveyor (MGS) and Mars Odyssey (MO). The accelerometers are calibrated each orbit by first making measurements above the measurable atmosphere and correcting for any changes of bias. One vertical structure is determined flying inbound toward periapsis and a second one flying outbound after periapsis. Knowing the variation of density with altitude allows excellent estimates of scale height, temperature, and other parameters. Entry probes have provided only 5 such measurements of vertical structure in the thermosphere.

To properly interpret results various ancillary data are also required: quaternions to determine orientation of the velocity vector relative to the accelerometer axes and spacecraft cross-section; angular rates not associated with drag effects; thruster firing times to remove spurious accelerations; and a number of others including spacecraft orbital elements, and orbital decay results.

A number of discoveries have been made from the MGS and MO accelerometer measurements of the Martian atmosphere. During MGS at the beginning of aerobraking, a dust storm in the Southern Hemisphere suddenly increased densities by a factor for 3 in the Northern Hemisphere (Keating et al., 1998) at 130km. This showed a very strong coupling between the upper and lower atmosphere. Enormous planetary scale waves were detected (Keating et al., 1998) at 130km. This included Kelvin Wave 1, which created ±30 percent variations in the thermosphere, but a weak variation (±1 percent) in the lower atmosphere. Again we see evidence of coupling between the lower and upper atmosphere. On Earth, such strong coupling is difficult to detect. More recently, with MO we have discovered winter polar warming in the thermosphere. This may be caused by unexpectedly strong meridional circulation from the summer to winter hemisphere.

Later this year, the Mars Reconnaissance Orbiter (MRO) will be launched with QA 2000 accelerometers as facility instruments. This will allow us to further explore the Southern Hemisphere. The QA 2000 accelerometers were also used in atmospheric studies aboard MO, and QA 2000 accelerometers will also be used on the soon to be launched Venus Express (VEX).

Hundreds of orbital decay measurements have been obtained from the Pioneer Venus Orbiter and the Magellan spacecraft of conditions in the Venus upper atmosphere (Keating et al., 1979). The periapsis of both spacecraft drifted upwards, allowing measurement of scale height and temperature in addition to density

This has resulted in detection on the nightside of Venus of temperatures as low as 100K; hence, this region is sometimes called the cryosphere. Temperatures on the dayside were determined to be about 300K (Keating et al., 1977a). The strong temperature gradient near the terminator was difficult to generate using General Circulation Models (GCMs) unless wave breaking was invoked near the terminator (Keating and Bougher, 1992). A number of other discoveries have been made from atmospheric drag effects. A 27-day oscillation was discovered apparently 27-day rotation period of the sun. From the 27-day thermospheric oscillation, the energy balance of the thermosphere was estimated (Keating and Hsu, 1995). It was found that with increased solar activity, increased O-CO_2 cooling also occurred, so that O-CO_2 cooling acted as a natural thermostat and the result was a weakening of both the 11-year and 27-day thermospheric oscillation. A number of other systematic variations were detected including a 4 to 5 day oscillation probably related to the super-rotation at the cloud tops (Keating et al. 1979b).