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Investigating the Middle and Lower Thermosphere using a Cubesat Constellation: the QB50 Mission and its Particular Challenges

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CubeSats have emerged as a powerful tool for a new class of flexible, low cost space missions which are respected by academia and the space industry. They have served many objectives but are mainly used to educate young space engineers through hands-on design and manufacturing experience.

The QB50 project aims to use the CubeSat concept to further facilitate access to space for future generations, to carry out scientific measurements and to demonstrate new space technologies. The driving force of the QB50 mission is the unique opportunity to explore the largely inaccessible middle/low thermosphere with a constellation of nano-satellites. These CubeSats will carry on board one of the three sets of scientific instruments: an ion/neutral mass spectrometer (INMS), a flux probe for atomic/molecular oxygen (FIPEX) and a multi-needle Langmuir probe (mNLP); respectively provided by the Mullard Space Science Laboratory of University College London, the University of Dresden and the University of Oslo.

QB50 will offer the opportunity to provide distributed, multi-parameter measurements of the ionosphere-thermosphere (IT) system below about 400km altitude. The connection of the IT system with the lower atmosphere through the upward propagation of waves, mainly tides and gravity waves, is now well established, but the evolution of the wave spectrum with height between 100 and 300km remains to be determined. This is the region where waves are differentially dissipated, and thereby they drive wind, temperature and composition changes in the mean atmosphere. QB50 will enable the latitude and longitude structures associated with these waves to be delineated at unprecedented spatial and temporal scales in this critical height regime.

As the CubeSats are flying through a region of the thermosphere below 400km where the gas is extremely diluted, particle-to-particle interactions can still perturb the flow field around each satellite adding large uncertainties to the atmosphere measurements. Results of Direct Simulations Monte Carlo (DSMC) performed on a CubeSat with a circular orbit at 350km and 120km altitude show an increase of overall density at the stagnation region, where the scientific instruments are located, ranging respectively from 10 to 25 times the density in the freestream.

The latter investigation shows the need for a methodology, based on both satellite altitude and attitude, in order to relate the flight measurements obtained in the satellite stagnation region and the freestream quantities.

Moreover due to the shock wave in front of the CubeSat, an analysis of the DSMC computations is necessary to evaluate the effect of gas temperature on chemistry. In particular, the temperature increase in front of the stagnation region could induce a chemical dissociation process modifying the gas composition and therefore increasing the uncertainty of the in-flight measurements.