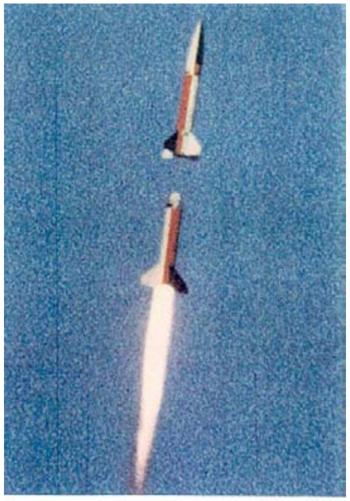
Computational Analysis of TOMEX Flows

Overview



The primary goal of this project is to understand the rarefied, three-dimensional flows experienced during the Turbulent Oxygen Mixing Experiment (TOMEX). The experiment was performed in the mesosphere and low thermosphere region where the payload flew from supersonic to subsonic. These conditions gave that the flight was in the transitional flow regime, which suggests the DSMC method for correct simulations. In order to interpolate the measurement data accurately, the detailed structure of the payload should be modeled in the simulation and enough large computational domain should be employed to adopt the far field flow conditions. The simulation, however, has to meet current computational capability. In our work, the payload is modeled by including all ionization gauges and the components important to overall flow. Then the computational domain is divided into cells and filled with simulated particles where the cell size is less than the local mean free path of air molecules (a near-partner selection technique is otherwise employed). Enough cells are also required to faithfully represent the modeled payload. Simulations are performed on a linux cluster by limiting the total number of simulated particles using a particle weighting technique, otherwise a simlation would be extremely expensive even on a parallel computer using an adaptive domain decomposition technique.

Background

On 26 October 2000, the Turbulent Oxygen Mixing Experiment (TOMEX) was carried out to measure the actual atmospheric response to the existence of unstable layers as determined by wind and temperature measurements from 80 to 105 km. TOMEX combined Na lidar measurements, from Starfire Optical Range in Albuquerque, NM, with a launch of a mother-daughter payload from White Sands Missile Range, located a little over 100 km from Starfire. The payload included a trimethyl aluminum (TMA) release (on the mother payload) to measure winds and diffusion, a three-channel photometer experiment (on the daughter payload) to measure atomic oxygen related airglow, and a five-channel ionization gauge (on the daughter payload) to measure neutral density fluctuations at high vertical resolution. The rocket was launched from the ground when the lidar data indicated the presence of convectively and dynamically unstable regions between 80 and 100 km altitude. After the payload reached an altitude above 65 km, the daughter payload was separated from the mother payload at a separation speed of a few meters per second. The daughter payload traveled with a spin rate of 1 Hz. The flow condition is shown in Fig. 1, where the widely used Mass-Spectrometer-Incoherent-Scatter (MSIS) model is used.

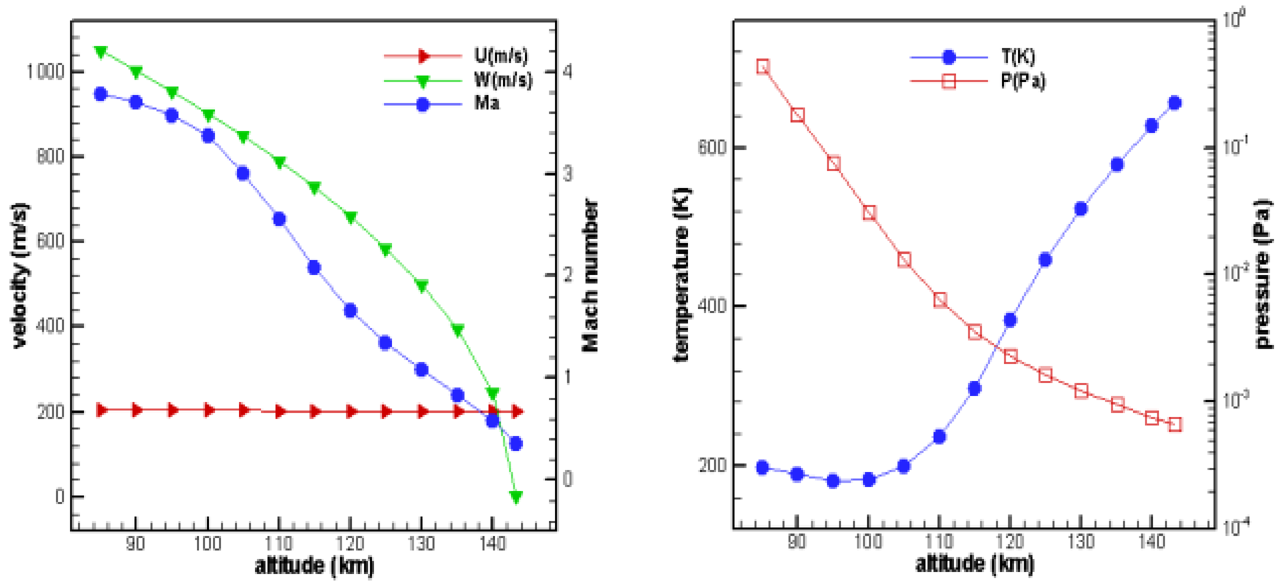


Fig. 1. Flow conditions are altitude dependent

Typical Results

Modeled Payload and Computational Mesh

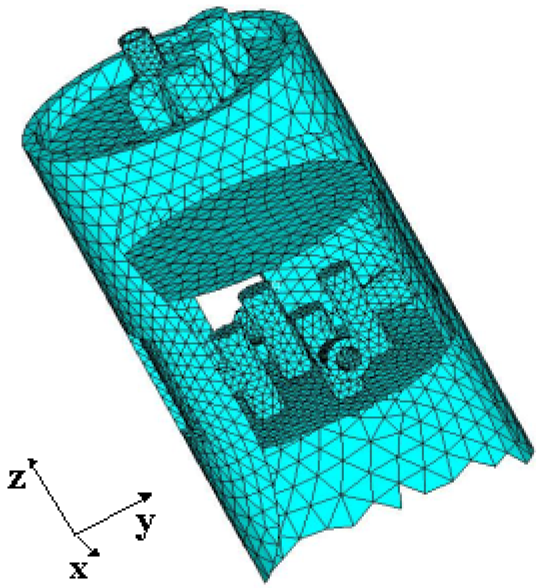


Fig. 2. Cut-open view of payload

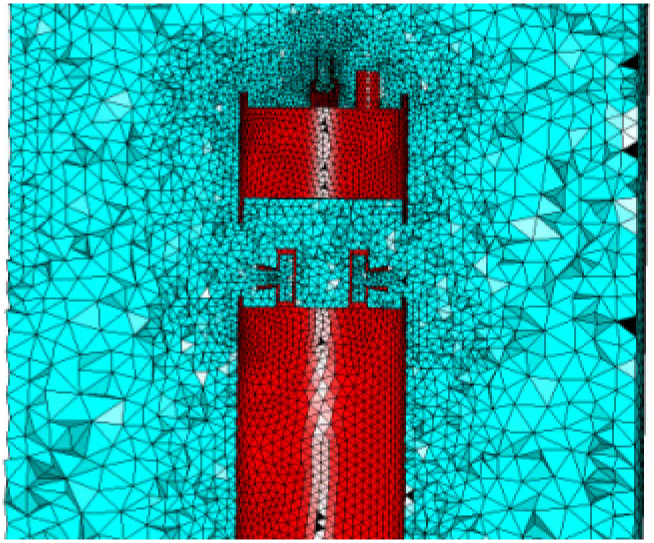


Fig. 3. Cut-open view of a typical mesh

Flow Field

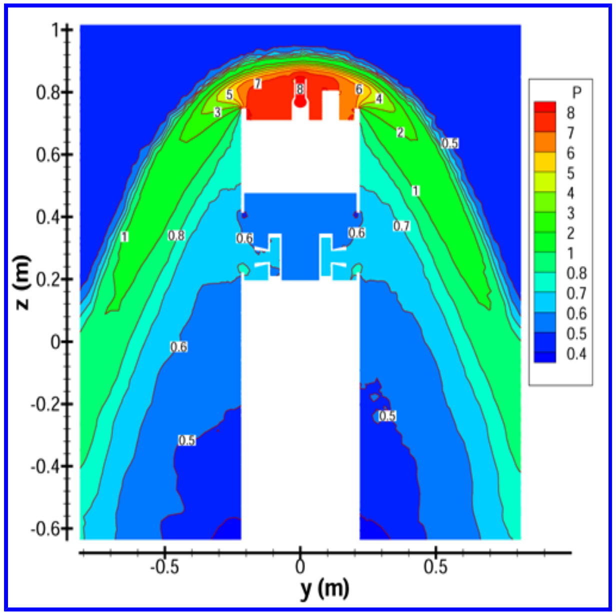


Fig. 4. Pressure contours in x=0 at 85 km

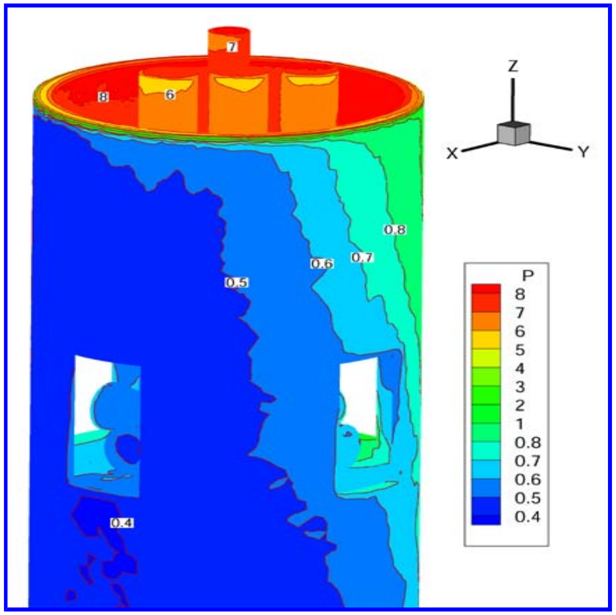


Fig. 5. Surface pressure contours at 85 km

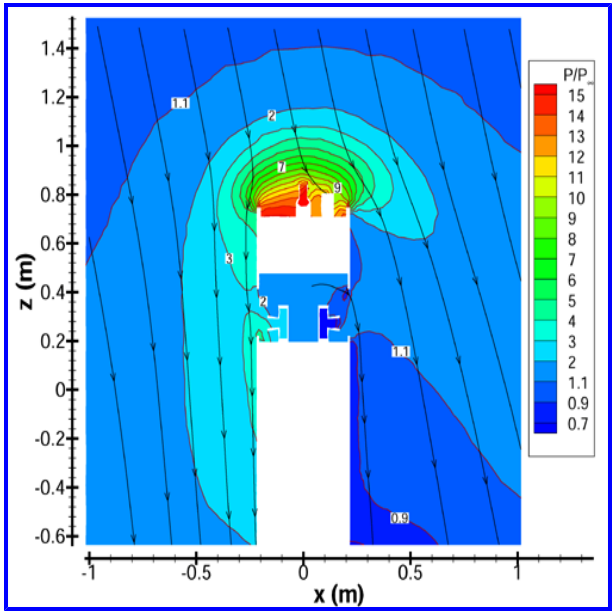


Fig. 6. Pressure contours at 100 km

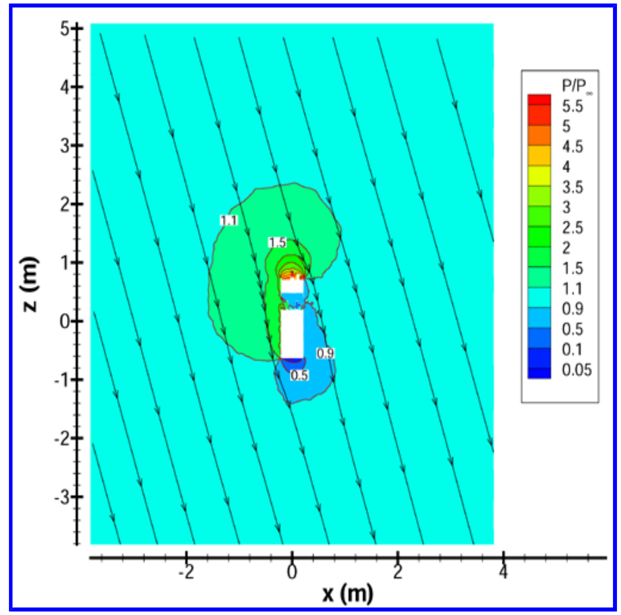


Fig. 7. Pressure contours at 120 km

Results Comparison

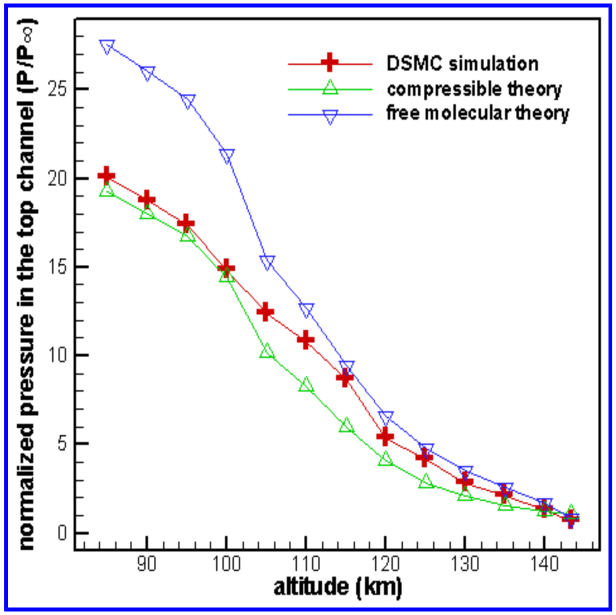


Fig. 8. Normalized pressure in the top gauge

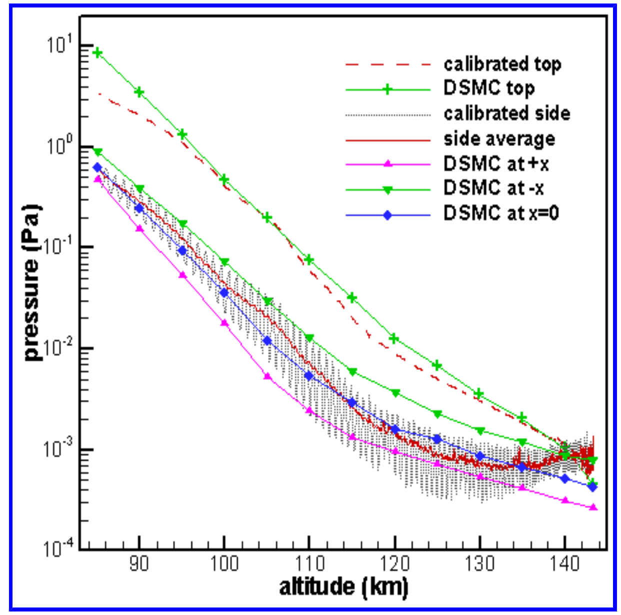


Fig. 9. Comparison between DSMC and measurements

Acknowledgements

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Recently Conference Publications

- Sun, Q., Cai, C., Boyd, I. D., Clemmons, J. H. and Hecht, J. H., **Analysis of high-altitude ionization gauge measurements using the direct simulation Monte Carlo method**, AIAA-2004-2686, *Presented at the 37th AIAA Thermophysics Conference*, June 2004, Portland, OR. [Abstract | PDF (5.98MB)]

Publication Archive

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