Atmospheric neutral density variations from GRACE accelerometer data

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The GRACE (Gravity Recovery And Climate Experiment) mission is designed to monitor the mass transport between the Earth's atmosphere, oceans and solid Earth, and has a secondary objective of enable advances in the atmospheric sciences by the recovery of refractivity (and the derived quantities of temperature and water vapor profiles) and small-scale ionosphere structure from the use of GPS radio occultation data. The onboard high accuracy accelerometer (ACC) data, which measure the non-gravitational forces on satellite, are particular well suited for exploring the upper atmospheric density and variations. GRACE was launched into a near circular orbit with the inclination of 89 degree starting at $\sim$485 km altitude on March 17, 2002, with a lifetime predicted to 2009. The current altitude is at $\sim$455 km with a decay rate of $\sim$18 m/day. The ACC data with 5 seconds sampling from two GRACE satellites since July 2002 were analyzed to derive the total atmospheric neutral density. The necessary modeled non-gravitational accelerations were obtained from the precise orbit determination with the best fit to the GRACE GPS tracking data. The current model of the drag force (specified by the atmospheric density and drag coefficient) can only be predicted with an uncertainty no better than 12% for GRACE orbit using the existing empirical atmospheric density and gas-surface interaction model. The total atmospheric densities from GRACE and models (DTM-78 and NRLMSISE-00) were normalized to the altitude of 470 km to study the density variations vs latitude, day of year and local solar time. Comparison shown significant deviations of the GRACE derived density from the existing models over the polar region. The amplitude of the annual variation from the GRACE derived density is estimated to be $\sim$20 % larger than that predicted from the existing empirical density models while the phases are in good agreement. The amplitude of the diurnal variation from GRACE densities is significantly lager than the prediction over the regions with the latitude from $\sim$30 degree south to 40 degree North, and the short period variation is dominant over the region with latitude beyond $\sim \pm$85 degree. With the high resolution with fair spatial and temporal coverage, the GRACE accelerometer data can provide a very significant improvement in understanding of the neutral density variations at the altitude of 300-500 km.