Geophysical Research Abstracts
Vol. 16, EGU2014-14742, 2014
EGU General Assembly 2014

Composition change and its effect on thermosphere mass density response during geomagnetic activity

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Accelerometer data from coplanar orbits of CHAMP and GRACE satellites are used to study the complex altitude and latitude variations of the thermosphere mass density response to geomagnetic activity. Corotating interaction regions / high speed streams for the period of 01-10 December 2008 led to anomalous perturbations in thermosphere mass density from quiet to active conditions with GRACE mass density increasing less (25%) than at the lower CHAMP altitudes (60%) in the winter hemisphere. This behavior is attributed to extreme solar minimum conditions, thermal expansion, vertical winds, and the dynamic behavior in the helium and oxygen transition region. Helium number densities near 500 km are extracted from the CHAMP and GRACE measurements and, with three-degree latitude resolution, clearly show the presence of a winter hemisphere helium bulge. Helium estimates in the upper thermosphere during solar minimum have not been observed since the 1976 minimum. This recent extreme solar minimum indicates winter-time helium concentrations exceed NRL-MSISE00 estimates by 30%-70% during quiet geomagnetic activity after adjusting F10.7 input into MSIS. During active geomagnetic conditions, helium concentrations at GRACE altitudes decrease while oxygen concentrations increase. An investigation of the altitude structure in thermosphere mass density storm-time perturbations reveal the important effects of composition change with maximum perturbation occurring near the He/O transition region and a much weaker maximum occurring near the O/N2 transition region. A helium module has been implemented in the NCAR-TIEGCM model and simulations of mass density response to a geomagnetic storm for thermosphere conditions with and without helium are presented.