Time History Observations of Barium Releases from the C-REX Mission and their Relevance to the Thermosphere CUSP Region Density Anomaly

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Objectives

• Use C-REX Barium release optical data to quantify the stopping power, expansion rate, and diffusion coefficient of the Barium cloud
• Create an altitude profile of the impact of the neutral density upwelling on these parameters

Background

Within the geomagnetic cusp region of the Earth’s thermosphere is a neutral density upwelling that has been recorded from a 30% to a 100% perturbation in mass density, as found by the CHAMP satellite at an altitude of 400 km to 450 km [Lühr et al., 2004]. Due to its stability and unidentified mechanism of production, multiple groups including NASA have together formed the Grand Challenge Initiative Cusp to determine the formation of the anomaly.

In November of 2014, the Cusp Region Experiment (C-REX) sounding rocket launched from Svalbard, Norway and released 10 Barium tracer clouds into the thermosphere at different altitudes. The intent was to use the photo-ionization of the cloud to create barium ion clouds to monitor the local electric field, while the neutral strontium clouds show the local neutral winds. While the releases did not show evidence of vertical winds, the pre-ionized neutral Barium clouds can be used to further quantify the anomaly.

Methodology

The Barium releases are injected into the atmosphere by using a thermite reaction to detonate a canister loaded with the constituents. In a perfect vacuum, this would produce an expanding Maxwellian distribution where the expansion characteristics would be dependent on the average temperature of the thermite reaction and the mass of the Barium.

In the case where we are no longer in a perfect vacuum and a background gas is present, the initial distribution would still be a Maxwellian, which Figure 2 shows by using a horizontal profile extending through the center of the Barium release. However, in this scenario, the expansion rate of the cloud, while still being characterized by the previously mentioned parameters of average temperature and mass, is also dependent on the surrounding density of the atmosphere.

To determine the expansion rate of the Barium clouds, the horizontal profiling shown in Figure 2 is applied frame by frame in order to determine the scaling factor of the Gaussian. Then, by using the known exposure time of the camera a time history of the leading edge, chosen to be two times the scaling factor of the Gaussian, of the Barium cloud quantifies the expansion rate of the release, which can be seen in Figure 3 for various altitudes.

References


Current Progress and Results

As can be seen in Figure 3, the expansion rate of the Barium release drops rapidly as the altitude decreases. This is to be expected as the density of the surrounding atmosphere increases, thus increasing the collision rate of the particles in the cloud with the surrounding atmosphere. Since the expansion rate of the clouds is dependent on the diffusion coefficient, it is expected that there will be similar significant decreases in the diffusion coefficient as the altitude decreases.

The study aims to use future C-REX-II optical data for further determination of the diffusion coefficients in the geomagnetic cusp region of the thermosphere. Currently, data from AZURE (Auroral Zone Upwelling Rocket Experiment), which has Barium release data outside the cusp region is being processed with the intent to find significant deviations in these parameters as a product of the neutral up-welling. Alongside the diffusion coefficient, the study aims to characterize the stopping power of the perturbation, which can be described as the time taken for the Barium clouds to thermalize with the background atmosphere.

To compliment the AZURE releases, the study will also make use of the MSIS-E-90 atmospheric model as a means of quantifying the perturbation. Both the AZURE data and MSIS-E-90 model should show significant deviations in the C-REX and C-REX-II data of a magnitude to that of the known perturbation. As a secondary goal, the study aims to use the lower altitude data to look for weak depletion as observed by the streak satellite [Clemmons et al., 2009].