NASA Space Grant Fellowship for Summer 2023 Report

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The main focus of my research over the summer of 2023 was to further our understanding of sprite streamers by modeling their interaction with the ionosphere and analyzing high speed image observations. For a short background, sprites occur above thunderstorms near the ionosphere at an altitude spanning 40-90 km and are formed within the electric field established by a strong lightning discharge. They consist of a self-propagating electrical phenomenon known as streamer discharge. Streamers are key components in the formation of the more well known phenomena of lightning and sparks, so learning about their dynamics is crucial in understanding Earth's electrical grid. The natural occurrence of streamers is most often inside a thundercloud. Therefore, only frequencies of the electromagnetic spectrum that can pass through clouds, such as most radio frequencies, can be used in observation and detection. Sprites, with the correct equipment and location relative to the storm, allow for optical observation of streamers in great detail. Since they occur at high altitudes, the neutral air density is much lower than at ground pressure which leads to larger streamers that propagate for a longer time and distance compared to those at lower altitudes. This sums up to meaning that optical observations of sprites are not only an excellent way to understand streamer dynamics, but also by using the knowledge of streamers from computer models and laboratory experiments, we can understand better the environment in which sprites occur.

Recent optical observations, at 100,000 frames per second, captured sprite streamers interacting with the ionosphere in detail never before seen. This led the observers to publish their results and propose a method to estimate the electron number density of the D-region ionosphere above a thunderstorm using the observed optical decay rate of the streamer-ionosphere interaction. I set forth this summer to better understand their observations of the streamer-ionosphere interaction and validate their proposed method. To do so, I used a well-established numerical model that is able to form and follow a realistic streamer through its formation and interaction with a simulated ionosphere. The results not only show similar streamer optical decay, but also give great insight into how the streamer decays. With the help of my advisor, I determined that the electric field of the streamer head, the dominant driver of its dynamics, decreases due to the high conductivity of the ionosphere which leads to a decrease in the electron number density associated with the optical emissions. Furthermore, by using the previously proposed method to determine the electron number density of the ionosphere, I found, using my simulation data, a value within an order of magnitude accuracy. I presented some of these results in a poster presentation at the CEDAR 2023 conference in San Diego, CA in late June. Now, the full results are currently in a manuscript that will be submitted for publication, soon.

At the beginning of the summer, I was invited to Langmuir Laboratory in the Magdalena Mountains near Socorro, New Mexico to help make observations of sprites. The laboratory is a renowned atmospheric research facility due to its prominence of over 10,000 ft which makes for an excellent view of the powerful storms developing over the plains. Spending two weeks there, I learned how to operate many different types of cameras, most of which were high speed. Not only did I manage, with the help of staff and fellow scientists, to capture high speed images of sprites during very late nights and early mornings, but also capture similar photographs of lightning. Towards the end of summer, I used this high speed data to develop an image processing technique to isolate streamer heads in order to analyze their dynamics such as velocity, brightness, and how both of these relate to a streamer phenomenon known as branching. Knowing if and how the velocity and brightness changes during branching events would provide a way to estimate the associated electromagnetic emissions. This is important because it may fit a frequency range associated with unknown processes detected inside thunderstorms. In developing this image processing technique, not only have I found something I enjoy, but I believe that with its results it will help advance the field of atmospheric electricity.