For the summer of 2014, I was fortunate enough to participate in the MIT Haystack Observatory's Research Experience for Undergraduates (REU). In this program, I was selected by staff member Larisa Goncharenko to find connections between anomalies in the stratosphere and ionosphere using GPS TEC (total electron content) data from satellites and stratospheric data to try and see how two very anomalous atmospheric events may be coupled.

The most prominent features in the ionospheric TEC data are the Equatorial Ionization Anomalies (EIAs), which are giant bands of high TEC measurements located on the North and South geomagnetic equator that rarely occur. This data was to be processed in order to better understand how features in the TEC data (especially the EIAs), are related to the largest meteorological phenomenon known, the sudden stratospheric warming (SSW).

SSWs are thought to be caused by planetary waves, great meanderings of wind, as they propagate vertically and cause disturbances to the low altitude wind flows of the different layers of the atmosphere. During SSWs, a spike in temperature by tens of degrees occurs over the course of only a few hours. In addition to the dramatic change in temperature, the normally westerly winds of the wintertime polar vortex in the northern hemisphere either slow down in velocity (a minor SSW) or change direction entirely (a major event). Studying SSWs becomes more complicated when considering that current research suggests that they are not necessarily restricted to the stratosphere: the tropical ionosphere in particular is sensitive to influences from SSWs, where the EIAs reach maximum intensity during periods when SSWs are occurring. Due to the complexities of atmospheric layer coupling, the mechanism causing the polar stratosphere to tropical ionosphere coupling is not clear but has many viable possibilities.

In order to better understand how the two events are related, my mentor ambitiously tasked me with creating a 13 year long set (covering the months of November to March, when SSWs occur) of uniformly processed TEC data to contrast the numerous case studies of individual winters, which have the major drawback of not offering any suggestions into long term patterns. So after downloading the TEC and stratospheric data from the Madrigal Geophysical Database, I cleaned, converted, and reorganized the TEC data into a form that would enable me to see how TEC features varied over time of day and day of year. Both the Northern and Southern Anomalies had a map for each of the 13 years, and I plotted the stratospheric data underneath these maps in order to identify SSWs and to record how the shapes and intensities changed with time and any dependence on the type of SSW (major vs. minor).

However, when completing the first run through of the highly iterative process, I realized that I was seeing the TEC contributions from various sources like geomagnetic and solar activity. My mentor and I worked together in order to make a mathematical model of the TEC that accounted for TEC contributions from all known sources. By subtracting this model from the raw data, I finally acquired what I wanted: unaccounted for TEC that should only be caused by the influence of SSWs. With such a high quality dataset, I was asked to edit programs that would create maps and videos showing TEC features for different geographic locations with time variations, which were to be sent to my mentor's colleagues and my teammates to enable a better understanding of this bizarre coupling phenomenon in addition to my own investigations.

In the last few weeks of my project, the direction of my work deviated slightly in response to a question I posed to my mentor: I was curious as to how the atmosphere reacted to lunar gravitational variations. She expressed interest in my question, and so I went about plotting full and new lunar phase dates alongside ionospheric TEC data. I examined each map with the newly added lunar information and measured the intensity of TEC features for every SSW that occurred during the time periods. I concluded that there may indeed be some sort of amplification of EIAs when they coincide with a new or full moon (vs. SSWs that do not occur under such phases). When compared to the background TEC data, the full and new phases were found to increase the intensity by as much as 60%.

My results were unexpected, but my mentor and I were unable to find flawed logic. Her further investigations after verified what I found in another form of data. I began searching for a mechanism for the lunar amplification, but initial analyses were unsuccessful and I ran out of time. Regardless, the dataset is an invaluable tool that has already been shared and used by many scientists, and I feel that I made two respectable contributions to the field.