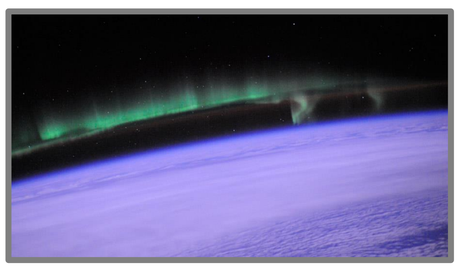
Abstract ID - Th1-P006

Effects of Coronal Mass Ejections on Earth's Thermosphere

Bhavesh Rajpoot[1], Dr. Pratibha B. Mane[1], Dr. Raka V. Dabhade[1]
[1]Fergusson College (Autonomous), Pune
rajputbhavesh04@gmail.com

Motivation

The Upper Atmosphere of Earth is driven by many factors such as TEC, Aerosol Concentration, Cloud Formation Rate, etc. Solar Flares and Coronal Mass Ejections (CMEs) affect these factors by ionizing the upper layers and injection of highly energized plasma. The motivation was to observe the effects of incoming High-Energy Particles in the Thermosphere, as a minimal study has been done in this field.



Credit: Image Science & Analysis Laboratory, NASA

Objectives

I. To study the effects of High-Energy Particles from CMEs on Thermosphere.

II. To determine a correlation between a CME hit and Thermospheric Aerosol No. Density (AND) variation.

Methodology & Study Area

This project uses exploratory research methodology to

i. understand the association of CMEs with Earth's Magnetosphere and Thermosphere,

ii. mining and analysis of archived High-Energy Proton Flux (HEPF) data and AND data, and

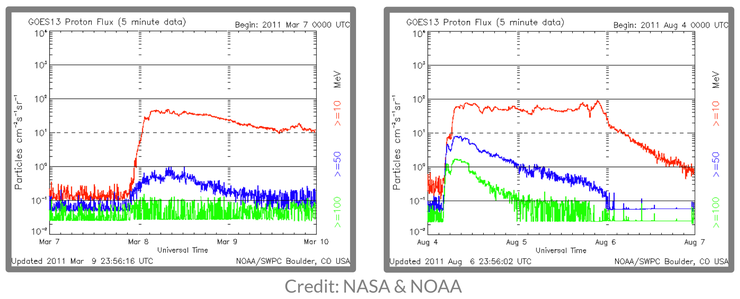
iii. exploring a correlation between a CME hit and Thermospheric AND variation.

For the project, Thermosphere was chosen as the effects by solar weather are prominent in that regime.

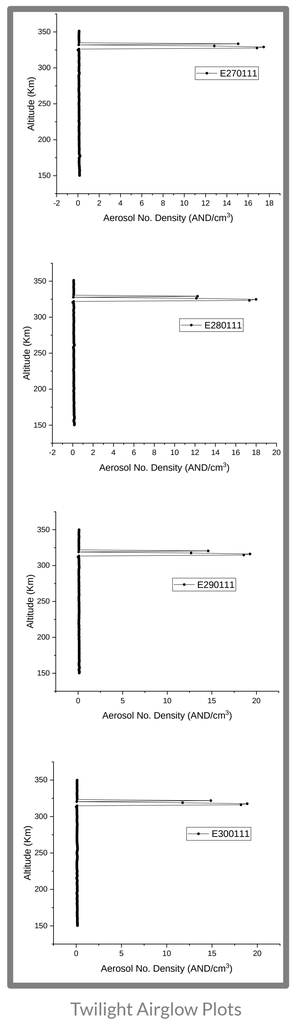
The AND data was received in terms of scattering intensity by Aerosols at corresponding heights, ranging from few meters to 600 km. The data was recorded by Semi-Automatic Twilight Photometer with high spatial resolution enabling us to inspect the Aerosol loading and unloading at relatively smaller altitude differences. The following equation was used to convert the data in terms of AND/cm^3 for further analysis,

$$AND/cm^3 = Antilog_{10}\left\{\left[-\frac{1}{I}\left(\frac{dI}{dH}\right)\right] - 1\right\}^{[1]}$$

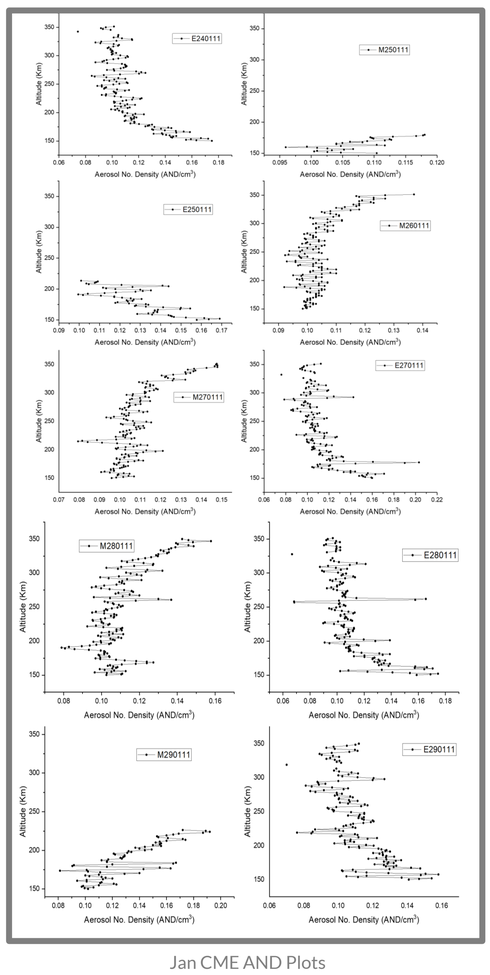
CME hits all over the year were confirmed by the inspection of corresponding HPEF plots recorded by the GOES-13 satellite.



Credit: NASA & NOAA



Twilight Airglow Plots



Jan CME AND Plots

Results

The 28/01/2011 CME,

- Particle Density – approx. 40 particles cm-2 s-1 sr-1 (>=10 MeV)
- Change in AND/cm3 observed – 30% increment
- Occurrence of Twilight Airglow at altitude of 330 kms caused due to the excitation of Atomic Oxygen giving of the radiation of 620 nm .

The 08/03/2011 CME,

- Particle Density – approx. 600 particles cm-2 s-1 sr-1 (>=10 MeV)
- Radial Velocity – approx. 2200 km/s (fastest CME in the last 6 years from 2011)
- Origin – Sunspot 1164
- Accompanying Flare – X1.5, R3 Radio Blackout
- Geomagnetic Storm – G2, happened 2 days after event
- Change in AND/cm3 observed – 5% increment
- The percent increase observed speculated of low magnitude because the majority of the aerosol particles coagulated to form clouds.
- It was also speculated that due to very high particle density of this CME, the upper layers of Thermosphere were greatly ionised which led the Ion-Aerosol Nuclei Condensation hence, resulted in the occurrence of Contrails, high-level Cirrus clouds and Cumulous clouds.

Conclusion & Future Scope

- This study can help us to understand how the Solar Phenomena drives the atmosphere of our planet.
- Can be further done during the Solar Minima.
- Can also be extended to create an atmospheric model of the planet with the varying factors.
- Such a model can be applied to different planets or moons to understand their atmosphere and geological evolution.
- This study on the aerosol in the Thermosphere region is one of its kind as work on this region is very few as compared to the work done in the Troposphere and Mesosphere.

Acknowledgements & References

Acknowledgements

- To Dr. Raka V. Dabhade for idea pitching and her guidance throughout the project.
- To Dr. Pratibha B. Mane for providing the data and suggestions on results.
- To IMS for the conduction of the conference and giving the opportunity to represent my work.

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