LWS Cold Plasma Team Meeting,
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Our Project Title:

The Source of Warm Plasma Cloak Due to Ion Heating by EMIC Waves

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Low-Energy Ions in Earth's Magnetosphere

➔Low-energy ion population plays a controlling role in many magnetospheric processes.

➔For example, heavy ions affect RBs by controlling EMIC wave growth and interactions with the RB electrons and RC ions. The O+ mass-loading may affect the SW-Magnetosphere coupling by quenching dayside reconnection and affecting location and recurrence of reconnection on the night side.

➔Torus of low energy O+ (~ 0.1 eV to a few eV) [e.g., *Horwitz et al.* 1986] is observed in the inner magnetosphere near the plasmapause at all MLTs with higher occurrence rates in the late evening and early morning hours.

➔The so-called warm plasma cloak [e.g., *Chappell et al.,* 2008] is also observed and represents an ion population of intermediate energy from a few eV to greater than several hundreds of eV that is too high in energy to be a direct upward flow of the ionosphere (~ 0.1 to a few eV) and too low to be accepted as part of the plasma sheet and/or RC.

➔Measurements show that the warm plasma cloak is often made up of more O+ than H+, suggesting an ionospheric source [*Kaye et al.,* 1981].

➔The ions of warm plasma cloak display a characteristic bidirectional field-aligned pitch angle distribution but are frequently with a flux depletion near the field line direction in the pitch angle range < 30^o [e.g., *Chappell et al.,* 2008].

➔The warm plasma cloak is draped over the nightside plasmasphere and blown into the morning and early afternoon sectors by a combination of convection and corotation electric fields.

Source of Warm Plasma Cloak Due to Heating by EMIC Waves, 1/2

➔We investigate a specific source of warm plasma cloak due to heating of low-energy ions by EMIC waves using in situ plasma and magnetic field observations by the two Van Allen Probes [*Kessel et al.,* 2013; *Mauk et al.,* 2013].

➔Despite the fact that heating of low-energy ions by EMIC waves is well-known theoretically [e.g., *Thorne and Horne,* 1994], this mechanism of the warm plasma cloak formation was never analyzed before on the global magnetospheric scale and also with using in situ observations for all the relevant plasma and wave parameters.

➔EMIC waves have frequencies below the proton gyrofrequency, and these waves are commonly observed in Earth's magnetosphere [e.g., *Anderson et al.,* 1992a; 1992b].

➔In a multi-ion magnetospheric plasma, where the major species are H+, He+, and O+, the He+ –band of EMIC waves is the dominant band observed in the inner magnetosphere, and this band is followed by the H+ –band [e.g., *Fraser and Nguyen,* 2001].

➔The He+ –band is observed in all MLTs with higher power in the early morning and afternoon to midnight hours, and also in the predawn sector.

➔The H+ –band is also observed in all MLTs with higher power around noon and in the pre-midnight sector [e.g., *Saikin et al.,* 2015].

Source of Warm Plasma Cloak Due to Heating by EMIC Waves, 2/2

➔Instability of the RC proton distributions due to the positive temperature anisotropy is usually responsible for generation of quasi-field-aligned EMIC waves in the near equatorial region [e.g., *Kennel and Petschek,* 1966].

➔As the He+ –band EMIC waves propagate to higher latitudes, their normal angles become oblique, and wave energy dissipation by cyclotron resonant interactions with O+ takes place.

➔A strongest wave dissipation takes place around the second harmonic of the O+ gyrofrequency and typically in the off equatorial latitudinal region |MLAT| > 10^{o} [*Thorne and Horne,* 1994].

➔The He+ –band energy dissipation heats O+ in the energy range from ~eV up to ~10 keV. Because the ion heating mostly takes place in the perpendicular to the magnetic field direction, it increases the O+ pitch angles as well.

➔So the He+ –band EMIC waves can heat both the preexisting geomagnetically trapped thermal O+ and the upgoing ionospheric O+ injected at subauroral latitudes leading to their trapping.

➔A similar wave-particle interaction takes place between the H+ –band and low-energy He+ [e.g., *Thorne and Horne,* 1994], leading to the heating and geomagnetic trapping of He+ as well.

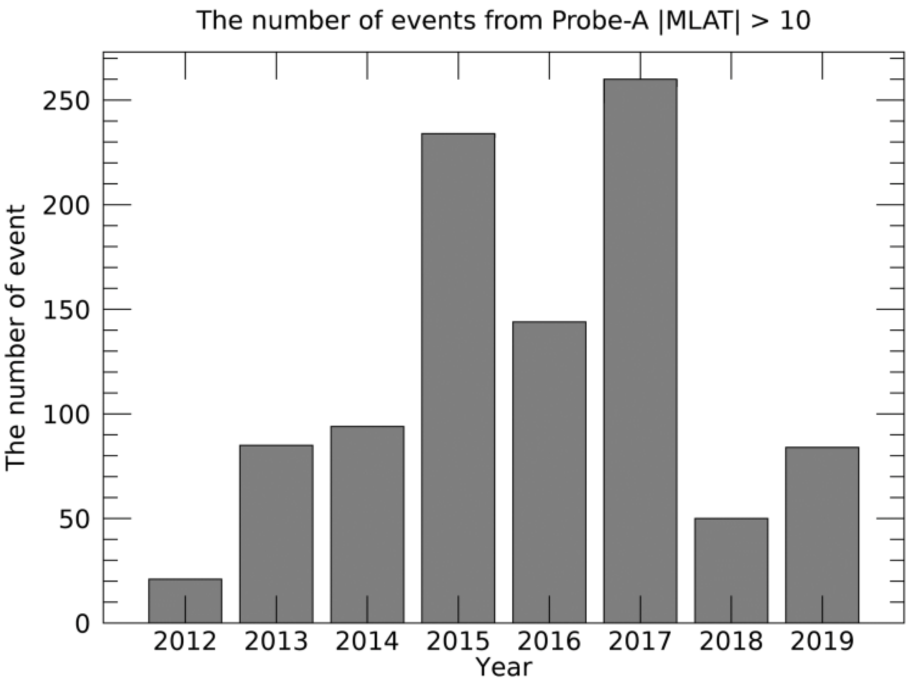
➔The above EMIC wave induced heating increase population of suprathermal O+ and He+ in the inner magnetosphere, contributing to both geomagnetic variability and radiation environment in Earth’s magnetosphere.

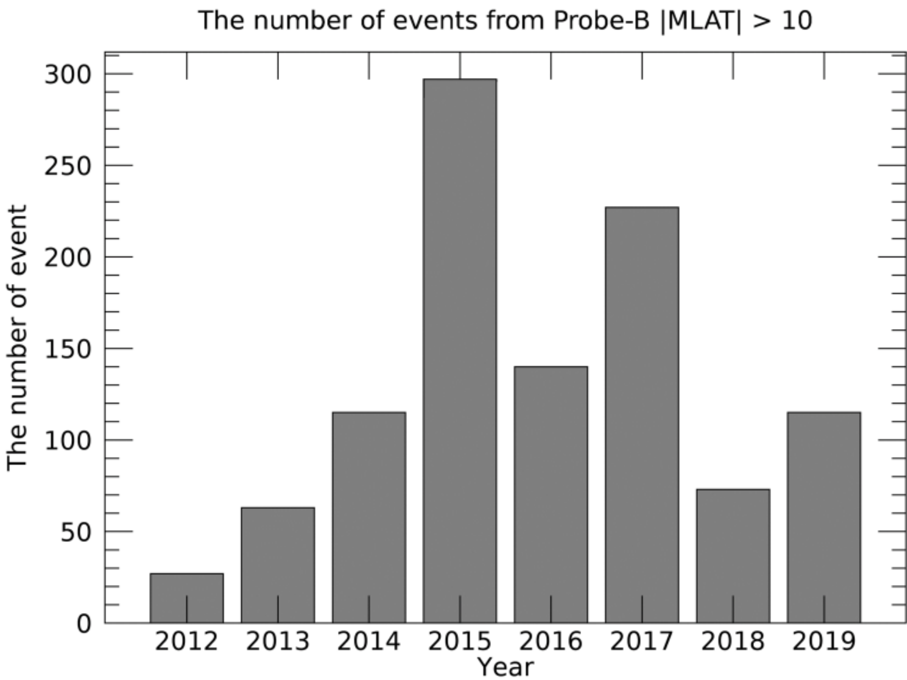
Our Goal and Objectives, 1/3

➔Our goal is to investigate the specific source of warm plasma cloak due to heating of low-energy ions by EMIC waves.

➔The two Van Allen Probes were sampling geomagnetic latitudes in the range |MLAT| < 20^o, giving us an excellent opportunity to study the heating and trapping of O+ and He+ due to dissipation of the He+ – and H+ –band EMIC wave energy, respectively.

➔Figure below shows the EMIC wave events observed by the two Van Allen Probes in the region of |MLAT| > 10^o from the beginning through the end of mission, where for power > 0.1 nT^2/Hz and duration > 1 min there are 972 events from Probe-A and 1057 events from Probe-B.





Our Goal and Objectives, 2/3

➔All the wave and plasma parameters, the DC magnetic field, and ion distribution functions needed for our analysis are taken from observations during each EMIC wave event analyzed. We use the following instruments:
1) EMFISIS to get the DC magnetic field, the high-resolution magnetic field for waves, and electron number density estimated from the upper hybrid (UH) frequency,
2) EFW to monitor spacecraft charging and also to estimate electron number density from the spacecraft potential, and
3) HOPE to get distribution functions of O+, H+, and He+ and to estimate the ion composition as well.

To achieve our goal, we will fulfill the following two objectives.

➔**The 1st objective** is to investigate in detail the individual cases of O+ and He+ heating and geomagnetic trapping due to dissipation of the He+ – and H+ –band EMIC wave energy, respectively. The following steps will be employed for each EMIC wave event analyzed:
(1) FFT will be applied to magnetic field data to obtain frequency spectra along with the estimates for errors,
(2) the observational data will be used to separately calculate the damping rates for He+ – and H+ –band due to interactions with O+ and He+, respectively,

Our Goal and Objectives, 3/3

(3) the O+ and He+ energy and pitch angle ranges that contribute most in the damping rates will be identified, and the ion distributions will be integrated to get number densities of those ions,
(4) the wave energy dissipated during each event will be calculated that gives us an energy per ion absorbed by the heated in the perpendicular to magnetic field direction O+ and He+, and
(5) the resulting increase of the O+ and He+ pitch angles will be estimated that shows us whether a geomagnetic trapping of ions is produced by waves.

➔**The 2nd objective** is to produce the global geomagnetic activity dependent maps of the O+ and He+ heating and trapping parameters due to interaction with EMIC waves. On the global (MLT, L)-scale and during different geomagnetic conditions, we will quantify
(1) the energy and pitch angle ranges of ions interacting with EMIC waves,
(2) the ion densities, energies per ion gained during EMIC wave events, and the resulting increase of pitch angles,
(3) the observed distribution functions of those suprathermal ions, including H+, and
(4) the concurrent EMIC wave and background plasma parameters, including the ion fractions.

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