PROJECT SUMMARY

THE INTELLECTUAL MERIT OF THE PROPOSED RESEARCH ACTIVITY

The overarching objective of the proposed 1 year effort is an extension of the driven wave formalism to the near ion-cyclotron frequency driven waves capable of generating large-scale electric fields. The driven wave formalism was developed by the PI and his collaborators in recent years. Ion-cyclotron wave dissipation channel for Alfven waves in the magnetized flowing medium, the work that we would like to extend using the driven wave formalism, was also first proposed by the PI [Kaghashvili, 1999b]. In the driven wave formalism, the short-term changes in the initial waveform are studied. These changes appear due to the linear interaction of the initial natural mode and the inhomogeneity in the system. Such a treatment allows us to obtain analytical solutions for the driven waves. In the proposed work, we will apply driven wave formalism to the magnetospheric plasma waves. The main tasks undertaken in this project are: (a) develop of the driven wave formalism for the ULF Alfvén wave drivers, (b) conduct comparison studies of the driven wave generated electric fields for differently polarized initial drivers, and (c) quantify the local effects of the driven wave generated electric fields in different regions of the Earth's magnetosphere. The above listed tasks will produce tangible results; and the developed physics is expected to be an important step in expanding our understanding of the magnetospheric waves and wave-particle interaction processes.

BROADER IMPACT OF THE PROPOSED ACTIVITY

One of the major objectives of the National Space Weather program is to understand the nature of the disturbances generated due to the solar wind-magnetosphere interactions and to study their characteristics. The proposed research has an exceptionally broad impact in two directions of the NSF magnetospheric physics program, namely 1) it advances our understanding of the important wave processes occurring in the magnetosphere and 2) it deals with the origin of the observed electric fields.

PROJECT DESCRIPTION

1. RESULTS FROM PRIOR NSF SUPPORT

The PI, Edisher Kaghashvili never had a prior NSF or NASA support.

2. INTRODUCTION

The overarching objective of this project is the extension of our driven wave generated electric field work for near ion-cyclotron frequency driven waves. The driven wave formalism was developed by the PI and his collaborators in recent years; and several very important processes, which have not been addressed before, were discovered. Two specific results related to the proposed work are: (a) properties of the properly embedded linearly polarized Alfvén wave in the flowing magnetized plasma [Hollweg and Kaghashvili, 2012], and (b) the large scale electric fields generated by the driven waves that, as was shown by Kaghashvili [2012] can far exceed the Dreicer electric fields for electrons in both hot and relatively cool solar coronal plasma. The later work introduced a new physics that is expected to play an important role in a wide range of laboratory, observed or theoretically studied plasmas. Here, we propose to apply driven wave formalism to the magnetospheric plasma waves. The main tasks undertaken in this project are: (a) develop of the driven wave formalism for the ULF Alfvén wave drivers, (b) conduct comparison studies of the driven wave generated electric fields for differently polarized initial drivers, and (c) quantify the local effects of the driven wave generated electric fields in different regions of the Earth's magnetosphere.

The expending solar plasma material guided by the fanned out solar magnetic field cannot directly penetrate the Earth immediate surroundings due to the Earth's strong magnetic field. The pressure of the shocked solar wind plasma compresses the dayside of the Earth's dipole magnetic field and creates the elongated tail-like magnetic field structures on the nightside. Due to this natural obstacle created by the Earth, most of the solar wind material is pushed away around the Earth's magnetic field. The solar rotation and the tilt of its rotation axis with respect to a Sun-Earth line produces changes in the solar wind plasma; hence the Earth's immediate surroundings consist of dynamic regions with their own non-stationary boundaries and characteristic plasma processes. Energy embedded in the solar wind fluctuations (observation have shown that the main power resides in Magneto-hydro-dynamic (MHD) disturbances originated on the Sun and propagating outwards; see e.g., Kepko et al., 2002), particles, and magnetic field that is able to penetrate into the near-Earth geospace environment are the ultimate source of the important processes taking place in the magnetosphere-ionosphere system.

Wave energy, mainly carried by Alfvén waves in the ultra-low-frequency (ULF) range, is channeled into the magnetosphere, and from the high magnetospheric radial distances down to the ionosphere, where it has a profound effect on the geomagnetically induced currents [e.g., Sibek et al., 2000; Pukkinen et al., 2007] and can impact the technological infrastructure on and around the Earth [e.g., Boteler et al. 1998; Hapgood, 2012; Schrijver and Mitchell, 2013]. It is believed that geomagnetic pulsations ultimately derive their energy and are supported by sources in the solar wind. The variability in the magnetosphere can have both internal (e.g., cavity modes, etc.) and external sources, but the externally driven variability is more prevalent. The major external factors that play a dominant role are: fore-shock physics, the solar wind, and fluctuations embedded in the solar wind. Today, it is firmly established that the Alfvén waves play an important role in geophysical plasma processes [e.g., Kepko et al. 2002; Chaston et al., 2006; Claudepierre et al., 2008].

Understanding these waves, their characteristics, their evolution and generated fields, and how the ULF waves are related to near ion-cyclotron waves that can effectively interact with particles are of major interest in the magnetospheric physics [e.g., Lysak, 2004; Chaston et al., 2007; Lysak, 2008]. Geomagnetic fluctuations are also a likely candidate driver for the energization of so-called "killer electrons" [Baker et al., 1997; Li et al., 2002; Horne, 2007]. In the proposed work, we will use the general treatment that can be applicable to the magnetospheric waves despite their origin.

In this proposal, we will extend the driven wave generated large-scale electric field mechanism [Kaghashvili, 2012], to near ion-cyclotron frequency Alfvén waves. The term "Kinetic Alfvén waves", as such waves are commonly referred in the magnetospheric community, are waves with the transvers wave vector component along the background magnetic field comparable to the ion-inertial length of the plasma. In this regime of the plasma, the ideal MHD equations are no longer valid and the plasma description as a fluid breaks down. When studying the realistic/observed plasma configurations, authors often invoke the lower-order non-ideal terms in the Ohm's law in order to study the wave particle interaction. Kaghashvili [2012] showed that the driven waves can generate the large scale electric fields even in the ideal MHD regime. In the proposed work, our specific goals are: (a) extend the driven wave formalism for the high-frequency waves, (b) consider the magnetospheric ULF waves as the drivers and investigate the possibility of the generation of near ion-cyclotron frequency waves, and (c) quantify the generated large-scale electric fields for waves with different characteristics that are observed or predicted for different regions of the magnetosphere.

2.1. DRIVEN WAVES GENERATED ELECTRIC FIELD

This brief description of the driven wave generated, large scale electric fields is taken from Kaghashvili [2012], where the generation of the non-zero phase averaged electric fields in the ideal MHD using the linear Alfvén waves was first discussed. As was shown, the driven waves can generate the large scale electric fields that can effectively interact with particles.

Recently, we have used the driven wave formalism to obtain analytical solutions for the generated large scale electric field in the ideal MHD. In the driven wave formalism, one looks for the short-term changes in the initial waveform due to the linear interaction of the initial natural mode of the system and the flow inhomogeneity. In this formalism, instead of looking for how the initial natural frequency mode of the system partitions its energy into other MHD modes, we were focused on the early time evolution and propagation of the initial wave in the plasma with inhomogeneous flow; thus the objective is to understand and qualitatively describe fluctuations that are excited in the system by the velocity shear that modify the initial waveform. [e.g., Kaghashvili et al., 2006, 2009; Kaghashvili 2007; Hollweg et al., 2009; Hollweg & Kaghashvili, 2012; Kaghashvili 2012a-c]. This formalism allows us to obtain the analytical solutions for the driven waves that are excited in the system.

To demonstrate the new physics of the large scale electric field generation, we follow Kaghashvili [2012]. Consider the simple case of the homogeneous magnetic-field aligned flow with a linear cross-field shear: $\mathbf{V}_0 = (S_y \mathrm{y}, 0, 0)$ where S_y =const. The homogeneous background plasma is given as $\rho_0 = const.$, $\mathbf{B} = (\mathrm{B}_0,\ 0,\ 0)$ and P_0 = const., where ρ, B, and P denote density, magnetic field, and plasma pressure. The assumption of the uniform magnetic field is employed for the linear waves when the scale length of the waves is much smaller than the scale of the background magnetic field variation. (We caution that in the solar atmosphere only waves with wavelengths much smaller than the characteristic scales of the background variables will pass this assumption. However, the characteristic scale-height in the solar corona is much greater than in the lower layers of the solar atmosphere.).

Following Kaghashvili [2012], we consider a cold plasma case, i.e. effects of the plasma thermal pressure are ignored. This is a restriction of our current analysis, but this is the approximation that is commonly used when studying the wave phenomenon in the magnetically dominated solar plasma regions [e.g. Kaghashvili, 1999b]. The wave phenomenon in such system may be described by the following ideal MHD equations [e.g., Kaghashvili, 2007; Hollweg and Kaghashvili, 2012]:

$$\frac{\partial^2 \mathrm{b}_x}{\partial t^2} + k^2 v_a^2 \mathrm{b}_x = 2ik_x v_a S_y \mathrm{v}_y , \tag{1}$$

$$\frac{\partial^2 \mathrm{v}_y}{\partial t^2} + k_x^2 v_a^2 \mathrm{v}_y = iv_a \left(k_x S_y \mathrm{b}_x - K_y \frac{\partial \mathrm{b}_x}{\partial t} \right), \tag{2}$$

$$\frac{\partial^2 \mathrm{v}_z}{\partial t^2} + k_x^2 v_a^2 \mathrm{v}_z = -ik_z v_a \frac{\partial \mathrm{b}_x}{\partial t} , \tag{3}$$

$$\frac{\partial^2 \mathrm{b}_{\{y,z\}}}{\partial t^2} + k_x^2 v_a^2 \mathrm{b}_{\{y,z\}} = k_x \{K_y, k_z\} v_a^2 \mathrm{b}_x \tag{4}$$

where k_i and v_i denote the wave vectors and Alfvén speed normalized velocity fluctuations, respectively. $K_y = k_y - k_x S_y t$ and v_a is the Alfvén speed. Magnetic fluctuations, b_i are normalized to B_0. The above second order ordinary differential equations are obtained from the typical linear MHD wave equations describing the wave processes in the shear flows [e.g. Chagelishvili et al. 1996; Poedts et al. 1998; Kaghashvili 1999a, b; Shergelashvili et al. 2006; Li et al. 2006; Gogoberidze et al. 2007; Camporeale et al. 2010]. The initial conditions correspond to the linearly polarized Alfvén wave propagating along the background magnetic field [e.g. Hollweg and Kaghashvili, 2012].

Our goal now is to obtain analytical solutions for flow-shear driven non-WKB fluctuations at early times, before compressions and refraction significantly modify the propagation of the initial Alfvén wave, and before nonlinear processes take over to cascade the wave energy. Since the coupling between the fast and Alfvén waves becomes very strong when the initial wave-vector is nearly parallel to $\mathbf{B}_0$, the first requirement generally means that the Alfvén wave has to start out propagating highly obliquely to $\mathbf{B}_0$. Moreover, S_y has to be small enough so that K_y does not change appreciably from its initial value during the time considered: $K_\mathrm{y} \cong k_{\mathrm{y}0} = const.$ This assumption translates as an assumption that during the time-scale of interest no significant changes occur in the natural frequencies of the system, i.e. $\omega_i^2(t) \cong \omega_i^2(t=0) = const.$ where i index denotes the specific characteristic natural frequency of the plasma. (Note that these requirements can be relaxed, but the time interval where the solutions given below are valid, typically of the order of approximately a several Alfvén time-scales, will change) Then we can solve the above system analytically for flow-shear driven non-WKB waves. The general solution can be written in the Laplace space. Since the shear parameter is small, we look for the solutions of such a system as a sum of the terms proportional to the velocity shear parameter, S_y. Here, we keep only the terms linearly proportional to the velocity shear parameter, S_y.

The solutions for the perpendicular velocity and magnetic field fluctuations are given by:

$$\mathrm{v}_{\{y,z\}} = \mathrm{v}_{A\{y,z\}} + \mathrm{v}_{D\{y,z\}} = \mathrm{v}_{\{y,z\}0} e^{i\boldsymbol{k}\cdot\boldsymbol{r} - ik_x v_a t}$$
$$+ \frac{k_{\{y,z\}} S_y \mathrm{v}_{y0}}{2k_\perp^4 v_a^2} \left\{ - i(k - k_x)^2 e^{i\boldsymbol{k}\cdot\boldsymbol{r} + ikv_a t} - i(k + k_x)^2 e^{i\boldsymbol{k}\cdot\boldsymbol{r} - ikv_a t} + 2 e^{i\boldsymbol{k}\cdot\boldsymbol{r} - ik_x v_a t} \left[i(k^2 + k_x^2) + k_x v_a t (k^2 - k_x^2) \right] \right\} \tag{5}$$

$$\mathrm{b}_{\{y,z\}} = \mathrm{b}_{A\{y,z\}} + \mathrm{b}_{D\{y,z\}} = \mathrm{b}_{\{y,z\}0} e^{i\boldsymbol{k}\cdot\boldsymbol{r} - ik_x v_a t}$$
$$+ \frac{k_x k_{\{y,z\}} S_y \mathrm{v}_{y0}}{2kk_\perp^4 v_a^2} \left\{ - i(k - k_x)^2 e^{i\boldsymbol{k}\cdot\boldsymbol{r} + ikv_a t} + i(k + k_x)^2 e^{i\boldsymbol{k}\cdot\boldsymbol{r} - ikv_a t} - 2k e^{i\boldsymbol{k}\cdot\boldsymbol{r} - ik_x v_a t} \left[2ik_x + v_a t (k^2 - k_x^2) \right] \right\} \tag{6}$$

where $k_\perp^2 = k_y^2 + k_z^2$, $k^2 = k_x^2 + k_\perp^2$ and solutions are written as a sum of the initial Alfvén wave (first terms on the right hand sides) and driven wave components correspondingly. Fluctuations with "0" subscript denote the amplitudes of the initial Alfvén wave. Solutions for all other fluctuating components can be derived this way and the generated electric field can be calculated using the ideal MHD equations. Note that for the longitudinal velocity and magnetic field fluctuations, shear-parameter independent components are zero. Keeping only the terms linearly proportional to the shear parameter, their solutions are given by:

$$\mathrm{v}_x = -i \frac{S_y \mathrm{v}_{y0}}{k_x v_a^2} \exp(i\boldsymbol{k}\cdot\boldsymbol{r} - ik_x v_a t), \tag{7}$$

$$\mathrm{b}_x = \frac{S_y \mathrm{v}_{y0}}{2kk_\perp^2 v_a^2} \left\{ i(k - k_x)^2 \exp(i\boldsymbol{k}\cdot\boldsymbol{r} + ikv_a t) - i(k + k_x)^2 \exp(i\boldsymbol{k}\cdot\boldsymbol{r} - ikv_a t) + 4ik_x k \exp(i\boldsymbol{k}\cdot\boldsymbol{r} - ik_x v_a t) \right\}. \tag{8}$$

The above given longitudinal velocity solution is derived when the initial condition $\mathrm{v}_x(t=0) = -iS_y \mathrm{v}_{y0}/(k_x v_a)$ is used for the embedded driver Alfvén wave; something that was first discussed in Hollweg and Kaghashvili [2012], who have explicitly noted that the initial streamline deformation leads to $\mathrm{v_x} \neq 0$ at $\mathrm{t} = 0$. Hollweg and Kaghashvili investigated the driven density fluctuations analytically.

Electric field components are calculated using the ideal MHD equations and are given by:

$$\mathrm{E}_x = -\frac{1}{c} \left\{ \delta\mathrm{v}_y \delta\mathrm{b}_z - \delta\mathrm{v}_z \delta\mathrm{b}_y \right\} \equiv \langle \mathrm{E}_x \rangle, \tag{9}$$

$$\mathrm{E}_y = \frac{1}{c} V_0 \delta\mathrm{b}_z - \frac{1}{c} B_0 \delta\mathrm{v}_z - \frac{1}{c} \left\{ \delta\mathrm{v}_z \delta\mathrm{b}_x - \delta\mathrm{v}_x \delta\mathrm{b}_z \right\} \equiv \frac{1}{c} V_0 \delta\mathrm{b}_z - \frac{1}{c} B_0 \delta\mathrm{v}_z + \langle \mathrm{E}_y \rangle, \tag{10}$$

$$E_z = -\frac{1}{c}V_0\delta b_y + \frac{1}{c}B_0\delta v_y - \frac{1}{c}\{\delta b_x\delta b_y - \delta v_y\delta b_x\} \equiv -\frac{1}{c}V_0\delta b_y + \frac{1}{c}B_0\delta v_y + \langle E_z \rangle, \tag{11}$$

where the last terms on the right hand side in these dimensional equations are the phase averaged electric fields in the corresponding directions. δ-symbol in front of the variable denotes the corresponding linear fluctuation without normalization. It is straightforward to verify that locally $\mathbf{E}_{\|}(=\mathbf{B}\cdot\mathbf{E})\equiv 0$. All phase averaged electric field components can be calculated analytically using above solutions. As an example, the electric field parallel to the constant background magnetic field given by:

$$\frac{c\,E_x}{B_0 v_a} = \frac{S_y v_{y0}(k_z v_{y0} - k_y v_{z0})}{2kk_\perp^2 v_a^3} \times \cos(k_x v_a t - \boldsymbol{k}\cdot\boldsymbol{r})$$

$$\times \left\{(k+k_x)\sin(kv_a t - \boldsymbol{k}\cdot\boldsymbol{r}) - (k-k_x)\sin(kv_a t + \boldsymbol{k}\cdot\boldsymbol{r}) + 2k\sin(\boldsymbol{k}\cdot\boldsymbol{r} - k_x v_a t)\right\}, \tag{12}$$

where the spatial Fourier harmonic part of the fluctuations was also considered to obtain the actual spatial and time dependence of the waveform. As seen, E_x owes its existence to the driven waves.

Eq. (12) shows that the generated electric field depends on the local plasma characteristics, local flow geometry and the initial Alfvén wave characteristics. To demonstrate that the driven wave generated large scale electric fields are important, following Kaghashvili [2012], we take the plasma parameters for the driver Alfvén wave and the background velocity shear are taken as follows: $k_x = 2\pi/(1.6\times10^5)$ km^{-1}, $k_y = k_z = 2\pi/(2\times10^4)$ km^{-1}, and $|\delta\mathbf{v}_{\perp 0}| = \sqrt{\delta v_{y0}^2 + \delta v_{z0}^2} = \sqrt{2}|\delta v_{y0}| = 100$ km s^{-1}. The shear parameter is taken to be 5×10^{-3} s^{-1}; the local Alfven speed, $v_a = 10^3$ km s^{-1} and $B_0 = 10$ Gauss. These plasma parameters are similar to those used for the driven density fluctuations study in the solar corona in Kaghashvili et al. [2009; see also Hollweg and Kaghashvili, 2012]. Two oscillating periods of the system will be $T_a \approx 160$ sec and $T_f \approx 14$ sec for the Alfvén and fast magnetosonic waves, correspondingly. Using these parameters, the actual value for E_x in mV/m units is given by:

$$E_x \approx 39.8\times\cos\left(\frac{2\pi t}{T_a} - \boldsymbol{k}\cdot\boldsymbol{r}\right)\times\left\{1.09\times\sin\left(\frac{2\pi t}{T_f} - \boldsymbol{k}\cdot\boldsymbol{r}\right) - 0.91\times\sin\left(\frac{2\pi t}{T_f} + \boldsymbol{k}\cdot\boldsymbol{r}\right) + 2\times\sin\left(\boldsymbol{k}\cdot\boldsymbol{r} - \frac{2\pi t}{T_a}\right)\right\},$$

Spatial dependence of the E_x electric field shows that its wavelength is roughly a half of the initial driver Alfvén wave. For comparison, the Dreicer electric field for electrons [Dreicer, 1959; 1960], which characterizes the run-away acceleration, is approximately $\approx 7\times10^{-2}$ mV/m for the relatively cool corona, and $\approx 2\times10^{-1}$ mV/m for the hot coronal plasma [Holman, 1985]. This simplest cold-plasma cases calculations indicate that the driven wave generated electric fields are strong and can play an important role in the escaping solar plasma dynamics.

In the magnetsopheric community, the special attention is given to the kinetic Alfvén waves which play an important role in the wave processes in the magnetosphere. In this regime, the particles motions become important. The equations for the waves propagating in the electron-proton plasma when there is the inhomogeneous flow present were first presented in Kaghashvili [1999b], who investigated the wave coupling in the solar corona using the commonly accepted procedure [e.g., Melrose, 1977a,b, Wentzel, 1989; Chagelishvili et al., 1996, 1997; Poedts et al., 1998; Kaghashvili, 1999a; Mahajan and Rogava, 1999; Rogava et al., 2000; Gogoberidze et al., 2004; Rogava and Gogoberidze, 2005; Webb et al., 2005a,b; Shergelashvili et al., 2006; Gogoberidze et al., 2007; Webb et al. 2007] in the cold-plasma case. The governing equations have been later extended to the warm electron-proton plasma case as well [e.g. Kaghashvili, 2002; Chen et al. 2006]. In the proposed work, we will extend the treatment of the electron-proton plasma using the driven wave formalism. Specifically, we will consider the ULF waves to be a driver and remove the cold plasma assumption and expand our analysis to warm plasma case. Different initial driver Alfvén waves, like circularly polarized Alfvén wave, elliptically polarized Alfvén wave, standing Alfvénic wave that is produced by the superposition of two oppositely propagating equal amplitude waves, etc. will be examined. The specific list of the undertaken tasks is given in the next section.

3. PROJECT PLAN

The PI, Kaghashvili E. Kh., has been working on the wave process in the coronal, solar wind and near Earth' environment plasma more than 10 years. He also has previous experience in the global solar wind magnetosphere interaction simulations and the simulated data comparison with observation [e.g. Kaghashvili and Raeder, 2007]. Currently, the PI is leading Atmospheric and Environmental Research (AER) system engineering team that develops some of the operational ground-processing scientific algorithms for the upcoming GOES-R mission.

The PI will extend his own previous work about the ion-cyclotron wave generation in the magnetized flowing electron-proton plasma [Kaghashvili, 1999b]. This work that dealt with wave coupling in a commonly accepted sense will be extended using recently introduced driven wave formalism developed by the PI and his collaborators [e.g., Kaghashvili, 2007; Hollweg and Kaghashvili, 2012; Kaghashvili, 2012; 2013]. In the proposed work, the driven wave generated electric fields will be studied for a wide range of parameters representing different regions of the Earth magnetosphere.

During the proposed 1 year period project, the following important task will be undertaken:

- Develop the driven wave formalism for the ULF Alfvén wave drivers,
- Conduct comparison studies of the driven wave generated electric fields for differently polarized initial drivers,
- Quantify the local effects of the driven wave generated electric fields in different regions of the Earth's magnetosphere.

4. MANAGMENT PLAN

The PI (E. Kh. Kaghashvili) will be responsible for accomplishing the objectives proposed in this proposal. The project will be accomplished during the NSF funding period.

A TBD research associate/technical writer will be assigned to provide support in the publication of the final scientific results.

5. EVALUATION/ASSESMENT PLAN

The proposal is a 1 year specific result-focused effort to extend the original work of the PI about the ion-cyclotron dissipation channel for Alfvén waves [Kaghashvili, 1999b] using the new driven waves formalism developed by the PI and his collaborators [Kaghashvili, 2007; Hollweg at al. 2009; 2013; Kaghashvili, 2012; 2013]. In the proposed work, the PI will commit 4 months to carry out the research tasks. The budget also supports a TBD research associate or technical writer for 1 month.

We have to emphasis that the proposed work is theoretical in nature, and it is about the new physics that has never been considered in the magnetospheric physics. The above listed tasks will produce tangible results that will be published in the peer-reviewed journal such as the Journal Geophysical Research, or other high-level scientific journal as appropriate, and are expected to be very important in furthering our understanding of the magnetospheric wave- and wave-particle interaction processes.

6. DISSEMINATION

Dissemination of all the results from the proposed research will be pursued through conference and seminar presentations and publication in peer-reviewed journals.

Since the physics of generation of the high-frequency waves is one of the high priorities of the magnetospheric physics research, the PI requests travel budget to attend 3 domestic conferences on the subject to introduce a new physics of the near ion-cyclotron frequency driven wave generation to the magnetospheric physics community.

Funds of $3000 are requested to support the page charge cost of $150/page in publishing the research findings of the work. This fund should support the publication of at least 2 scientific papers plus additional publishing cost incurred.

7. SIGNIFICANCE OF PROPOSED WORK AND BROADER IMPACTS

Two topics that will be addressed in the proposed work, namely (a) the physics of the generation of high-frequency driven waves that can effectively interact with particles, and (b) the generation of the large-scale electric field by such driven waves are both outstanding problems of the magnetospheric physics. Due to the importance of these processes and their social impact (loss of satellite components, damage of the power-lines on the ground due to the severe space weather, radiation hazard for the over the pole flights, etc.), almost all currently operational satellites (THEMIS, CLUSTER, POLAR, Van Allen Probes, etc.; for complete list of the currently operated missions see http://www.nasa.gov/missions/current/) and the ones that will be lunched (MMC, for example) carry instruments to measure electromagnetic fields and particle fluxes in order to understand their origin. Magnetospheric wave phenomena are ubiquitous and a large body of work has been done in the magnetospheric community about the above mentioned processes. What we are proposing here is to introduce an important and never before considered physics of the generation of the high-frequency waves and large scale electric fields which can play an important role in above the mentioned processes. Our intention is to lay the theoretical foundation of the driven wave formalism as it is applicable to the magnetospheric plasma environment.

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