2015 GEM Focus Group Proposal: ULF wave Modeling, Effects, and Applications (UMEA)

1) Topic Description: Ultra Low Frequency (ULF) waves play an important role in magnetosphere-ionosphere coupling [e.g., Keiling, 2009], ring current/radiation belt dynamics [e.g., Murphy et al., 2015; Kress et al., 2007; Turner et al., 2012], modulation of VLF waves/precipitation [e.g., Li et al., 2012; Brito et al., 2015; Jaynes et al., 2015], geomagnetically induced currents (GIC) [e.g., Pulkkinen et al., 2011], substorms [e.g., Kepko and Kivelson, 1999; Liang et al., 2009; Keiling and Takahashi, 2011], and other areas relevant to space weather prediction and GEM. Many current GEM FGs discuss ULF wave observations/models in their respective contexts. This is reflected in topics discussed at the 2014 and 2015 GEM meetings:

**QARBM* discussed radial transport and precipitation associated with ULF waves in the radiation belts.

**IMCEPI* discussed ULF wave-particle interactions in the inner magnetosphere.

**Dayside Transients* discussed solar wind driven ULF waves and roles in MI coupling.

**TIMI* discussed the propagation of Pi2 ULF waves and ionospheric interactions.

**TEDLD* discussed ULF waves in the magnetotail LLBL, plasma sheet, and lunar wake.

**Geospace System Science* discussed using indices of ULF wave activity to characterize the solar wind/magnetosphere/ionosphere systems.

**TPLMAPCDS* discussed wave-like structures in the aurora with ULF periodicities.

**Metrics and Validation* discussed results of a challenge devoted to improving the specification in ULF wave models, with a particular focus on global MHD simulations.

2) Timeliness: As demonstrated above, there is broad interest in ULF waves in the GEM community motivated by (1) unprecedented availability of coordinated, multi-point space and ground-based observations (i.e., Heliophysics Observatory) [e.g., Hartinger et al., 2013; Takahashi et al., 2013], (2) high quality particle and field measurements of ULF wave-particle interactions [e.g., Claudepierre et al., 2013], (3) new and improved simulations better able to capture the excitation and dynamics of ULF waves [e.g., Claudepierre et al., 2010; Lysak et al., 2015]. These factors make this the perfect time to bring together modelers, theorists, and experimentalists to address the following questions: ***What excites ULF waves? How do ULF waves couple to the plasmasphere/ring current/radiation belt populations? What is the role of ULF waves in MI coupling?*** We propose a new ULF wave FG focused on these broad science questions that will (1) improve understanding of the physics of ULF waves and (2) improve the specification of ULF waves in a variety of models with applications in space weather prediction.

3) Fit: We shall work with other FGs to bring researchers together to facilitate communication and address questions about the generation, dynamics, and space weather impacts of ULF waves. Answers to these questions and improved models of ULF waves will benefit all FGs, and there will be many opportunities for joint sessions (see expected activities).

4) Goal & Deliverable: In a recent GEM challenge, the Metrics and Validation FG (ended 2015) compared ULF wave output of several global MHD simulation codes using idealized driving conditions, finding substantial differences. To better understand potential sources of these discrepancies – in particular, to discriminate between numerical effects and missing physics – more model-model and model-data comparisons are needed. This approach also needs to be extended beyond global MHD simulations to other types of models. We propose to continue the work started in the Metrics and Validation FG ULF wave challenge, extending to non-MHD models and comparing with recent observations. Our goal is to facilitate data-model and model-model comparisons that address the basic science questions listed above and lead to improved

specifications of ULF waves in space weather models (see expected activities). This approach will lead to several deliverables. For example:
*New ULF wave indices that can be used as metrics for data-model comparisons.
*Improved radial diffusion coefficients based on modeled wave fields.
*Better characterizations of ULF wave variability, quantitative assessments of differences between event-specific and statistically averaged wave models.
*Assessments of whether radial transport in the radiation belts is diffusive.

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6) Research Area: Global System Modeling

7) Term: 5 years, 2016-2020

8) Expected Activities: We will continue and expand the Metrics and Validation FG's ULF wave challenge. Our expected activities will address broad science questions aimed at improving ULF wave models and facilitating research in other FGs:

What excites ULF waves?

*Discussion sessions on the effect of including the physics of different fluid and kinetic instabilities in ULF wave models. We aim to compare ULF wave models with different capabilities to determine how different instabilities, or combination of instabilities, lead to ULF wave growth/decay.
*Discussion sessions comparing properties of inner magnetosphere ULF waves associated with different external drivers (tail dynamics, ion foreshock, solar wind dynamic pressure).

How do ULF waves couple to the plasmasphere/ring current/radiation belt populations?

*Discussion sessions using models and observations to examine how coupling between ULF waves and particles varies in different energy, density, and composition regimes.
*Discussion sessions on ULF wave variability in the solar wind, magnetosphere, and ionosphere, focusing on improving the characterization of different types of ULF wave activity (e.g., indices, local/global specification of propagation direction, amplitude, wavelength) using both measurements and simulation output.

What is the role of ULF waves in MI coupling?

*Discussion sessions examining how different ionospheric conditions affect magnetospheric ULF waves. We plan to compare models/observations with different ionospheric conditions (e.g., global conductivity pattern) and/or boundary conditions (e.g., the "gap" region in global MHD simulation codes, coupling between magnetosphere/ionosphere) but similar drivers.

These discussions lead naturally to several joint sessions with other FGs:
*QARBM joint sessions to discuss improved radial diffusion coefficients and compare diffusive/non-diffusive radial transport processes induced by ULF waves, examining challenge events already selected by QARBM. Correctly specifying inner magnetosphere ULF wave properties is crucial for these event studies [e.g., Tu et al., 2012; Elkington et al., 2012].
*Geospace System Science joint session to determine which ULF wave indices best capture different types of geomagnetic activity and GIC, or if new indices should be developed.
*TPLMAPCDS/TIMI/QARBM joint session on ULF modulations of precipitation/auroral features, focused on determining the sources of ULF modulations of auroral activity and how they relate to substorm activity and ionospheric impacts (e.g., changing conductivity).
*IMCEPI joint session on the growth and decay of ULF waves via wave-particle interactions.
*TEDLD joint session on solar wind coupling to the magnetosphere/lunar wake via ULF waves.

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