ULF Wave Modeling, Effects, and Applications Focus Group

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The "Ultra Low Frequency wave Modeling, Effects, and Applications" focus group (UMEA, 2016-2020) seeks to bring researchers together to address broad questions of interest to many GEM FG: What excites ULF waves? How do they couple to the plasmasphere/ring current/radiation belt? What is their role in magnetosphere-ionosphere coupling?

UMEA held four breakout sessions this year: two standalone and two joint with other focus groups. Sessions were well attended (e.g., ~80 participants in the first breakout session) with lively discussions on a range of ULF wave topics. Several presentations are posted on the GEM wiki.

1. UMEA update and plans, general discussion of ULF wave modeling and observations

This session began with updates on UMEA activities, including Heliophysics/Geospace System Observatory (HGSO) coordination for ULF wave studies. An overview of the 2 May 2017 Poker Flat Incoherent Scatter Radar (PFISR) conjunction event included in situ EMIC wave and precipitation measurements, ULF modulation of ionosphere electron density and conductivity, and ULF waves in ionospheric flows. Propagating structures seen in PFISR and SuperDARN could map to ULF waves seen at numerous THEMIS, Cluster, GOES, and RBSP satellites. The 2 May event is promising for understanding many aspects of global ULF wave energy transfer and will be discussed further at mini-GEM, with updated information posted to the GEM wiki.

Expanded ULF wave observation datasets were also discussed. High-time resolution (6s) SuperDARN radar measurements are providing new information about statistical distributions of ULF waves observed in the ionosphere. New releases of NOAA GOES magnetometer data will provide 20+ years of 0.512 ms measurements while an automated wave detection scheme will create an extended database of ULF wave events. High-latitude South Pole all-sky camera measurements enable investigations into ULF modulation of dayside aurora, including the relationship with Pc3 compressional waves from the ion foreshock. Finally, the theory of magnetospheric buoyancy waves was discussed, with new MHD simulations showing evidence of these waves between the plasmapause and middle plasmasheet.

2. ULF wave interactions with the radiation belts and ring current

This session focused on observations and modeling of ULF wave interactions with the radiation belt and ring current populations, with emphasis on advances that are most needed to characterize ULF wave interactions in these regions.

Picking up from the last presentation in the first session, the theory and observations of inner magnetosphere ULF waves were discussed in the context of drift mirror waves and compressional poloidal waves. Observations, theory, and simulations with realistic geometries are providing more constraints on the properties of these waves in the inner magnetosphere, with significant differences between waves in low and high Beta regimes and with/without pressure anisotropy. More observations are needed for statistical data-model comparisons.

Other presentations focused on higher frequencies, with observations indicating (1) that the relationship between plasmapause location and helium band EMIC wave activity is not as strong as previously thought and (2) that EMIC waves are commonly associated with H+ injections with no clear change in anisotropy before/after injection. 3-D simulations of radiation belt dynamics indicate that without EMIC waves, electron phase space densities are overestimated and localized loss processes cannot be reproduced. Presentations and discussion indicate the importance of constraining EMIC wave properties and generation mechanisms from observations so they can be accurately specified in models.

Finally, a presentation of global simulations of ULF waves driven by Alfven fluctuations indicate the magnetosphere can act as a bandpass filter for solar wind drivers with broadband frequency spectrum, leading to the generation of a variety of magnetospheric ULF waves that could interact with radiation belt electrons. Observations of ULF Pc5 waves and radiation belt electron fluxes near geostationary orbit indicate post-noon ULF waves are more strongly correlated with flux changes. More modeling and observation work is needed to better understand how ULF waves interact with radiation belt electrons.

3. ULF wave modeling, including CCMC modeling challenge: Joint with MMV

New results were presented from the CCMC ULF wave modeling challenge, comparing ULF wave output in different global MHD simulation codes with the same driving conditions. Several challenge events were discussed as candidates for the next stage of the ULF wave modeling challenge, including QARBM FG events with RBSP observations that could be used to validate simulated diffusion coefficients and magnetopause surface wave observations that could be used to validate simulated surface wave properties and coupling to other wave modes. Additional events were also proposed, including more recent events with global coverage from ARASE, RBSP, MMS, THEMIS, GOES, and other satellites, along with metrics to validate simulations such as azimuthal wave number measurements from GOES. UMEA plans a telecom and follow up discussion at mini-GEM.

The rest of the session included further presentations and discussion of ULF wave modeling: MHD simulations of ground magnetic perturbations and currents during pressure pulses with different IMF By conditions, comparisons between observations and models during a cavity mode event excited by an interplanetary shock, and theory of 3D Alfven resonances. These presentations and discussion highlighted the need for 3D models that can capture the system response to a range of driving conditions, along with the need for globally distributed observations to validate the models.

4. Magnetosphere-Ionosphere coupling processes associated with localized disturbances caused by dayside kinetic phenomena: Joint with "Dayside Kinetic Processes…" and "Testing proposed links…"

Dayside kinetic phenomena such as magnetosheath high speed jets and hot flow anomalies (HFA) generate localized disturbances on the magnetopause that in turn drive a range of processes in the magnetosphere and ionosphere. The session began with an overview of global current systems and ground perturbation patterns generated by localized disturbances, including

discussion of how travel time magnetoseismology can be used to infer properties of disturbances; currently, there is an ISSI team developing new magnetoseismology techniques. The next presentation provided an overview of magnetospheric ULF wave observations during different types of HFAs, with estimated scales of 5 RE on the magnetopause. Attempts to model this type of localized disturbance using ad hoc specification in global MHD simulations have been challenging.

The rest of the session included presentations showing observations of magnetosheath high speed jet induced auroral features and magnetospheric ULF waves, modeling discussion of how velocity fluctuations affect surface wave growth and scale sizes in the magnetosheath, and statistical comparisons between geostationary ULF wave period and IMF magnitude that suggest ion foreshock sources. Discussions in this session highlight the need for globally distributed observations to compare with models; these are needed to characterize the global ULF response to disturbances with different scales on the magnetopause.