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Monitoring and Predicting Terrestrial and Space Environments using Electromagnetic Methods

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In this tutorial lecture, I would like to introduce how observations of both natural and man-made electromagnetic (EM) noise contribute to monitor terrestrial and environments and to mitigate natural disasters. I will focus on three different topics such as (1) lightning discharges, (2) electromagnetic phenomena associated with seismic activities, and (3) space weather. Interdisciplinary approach is highly required to tackle problems related to these topics, and so we should closely collaborate with various URSI scientific commissions such as EFGH.

(1) Lightning discharges

Recent global climate change causes more hazardous meteorological events. Most of these events are associated with active thunderstorms with numbers of lightning discharges. Lightning discharges generate strong electromagnetic pulses known as sferics in the wide frequency ranges and the pulses propagate a long distance. I am going to demonstrate practical applications of lightning discharges to the two different fields based upon the electrical properties obtained from different frequency ranges of sferics.

First application of lightning is to monitor and short-term forecast severe weather phenomena such as Tornadoes, wind gust, and heavy rain fall causing flash flood etc. by using so-called Total Lightning (TL), which is a sum of the Cloud to Ground lightning discharges (CGs) and In-Cloud lightning discharges (ICs). Analyzed results of the TL data from Japanese Total Lightning Network (JTLN) will be presented. JTLN detects the DC to HF electric field of sferics and identifies the position, polarity and peak current (*I*p) of both IC and CG from thunderstorm activities around Japan. Results obtained indicate promising for early warning of extreme weather events because the stroke rate of TL tends to increase about 10 ~ 40 minutes before the onset of many of the extreme weather events typically associated with remarkable increase of the stroke rate so-called lightning jump (LJ). Moreover, positive linear relation with rather high cross correlation ($r \sim 0.8$) between TL and Precipitation Volume (PV) [m^3] has been obtained. TL can be promising tool to estimate severe rainfall only from lightning, which will be very useful for areas where high speed meteorological radar system is not available.

Second application is related to mitigate the damage to the power grid systems from very energetic lightning characterized by a large lightning charge *Q*. Extremely Low Frequency (ELF) range so-called ELF transients are utilized to derive the charge moment changes (*Qds*, where *ds* is the height of the charge in the cloud) as a proxy of *Q*. Since ELF waves can propagate a long distance, we can remotely estimate the *Qds* of source lightning discharge (~ 1000 km). Both regional and seasonal dependences in *Qds* and *I*p of CGs can be obtained. These statistical distributions provide the basic information not only about the local lightning characteristics but also to prevent/mitigate potential damages to the power grid systems and renewable power generating systems by a risk assessment because CGs with a large *Q* causes critical incidents to these systems due to the heating by its long-lasting lightning current.

Lightning observations from space such as satellite and International Space Station (ISS) can provide electrical properties of lightning on the ground with uniform and high sensitivity. Such examples from EM observations from French DEMETER satellite and Japanese JEM-GLIMS mission in ISS will be presented.

(2) Electromagnetic phenomena associated with seismic activities

Significant progress has been made on this new science field, exploring a possibility of earthquake (EQ) prediction with EM effects since last few decades. In this talk, basics and recent results of the lower ionospheric perturbation observed by VLF/LF transmitter signals and ULF/ELF geomagnetic anomalies etc. prior to EQs will be presented as promising techniques.

(3) Space weather

Prediction of physical parameters in the space environment are extremely important not only for space weather but also for seismo-electromagnetics. Here machine leaning technique (nonlinear system identification and Neural Network) are applied to build spatio-temporal models to predict energetic electrons flux in the radiation belt (various external space weather parameters including ground-based ULF geomagnetic field data) , VLF/LF transmitter amplitude, and F2 layer critical frequency (foF2). Prediction accuracy of proposed models has been found to be quite high and is proved to be useful.