f3/f1 $\sim$ 4.3 for 6 < L < 7. These observations are compared with the theoretical ratios obtained for the density variation of the form $\rho = \mathrm{ReqLRe/R}^{\alpha}$, where Req is the equatorial mass density, R is geocentric distance to the field line, and the power-law density index α is a free parameter. We find that $\alpha \sim 0.5$ fits the average observed frequency ratios at $4 < L < 6$, consistent with a diffusive equilibrium solution. No single value of α fits the average observed frequency ratios at $6 < L < 7$. In that case, theoretical solutions indicate that the mass density is locally peaked at the equator; that is, the mass density decreases as one moves off-equator, then increases again toward the ionosphere. Combined with the results of recent studies of electron density (which have not found such a peak in density at the magnetic equator), this indicates that heavy ions are preferentially concentrated at the magnetic equator.

SM51D-06 0945h

Magnetospheric toroidal Alfven wave harmonics and the field line distribution of mass density

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Measurements of electric and magnetic field taken by instruments on the CRRES spacecraft on July 29, 1991, reveal seven or eight toroidal Alfven wave frequency bands. By using observations of the waves near the magnetic equator and the symmetry of the theoretical modes as a function of magnetic latitude, we can identify which theoretical Alfven wave harmonic corresponds to a particular frequency band. This along with the L shell frequency dependence gives convincing evidence that we are in fact observing the toroidal Alfven mode. Because the harmonics of the toroidal Alfven wave have a different response to mass density at different points along a magnetic field line, the frequencies of these harmonics can be used to infer the distribution of mass density along the field line. While there is a significant uncertainty in the results due to the uncertainty in the observed frequencies, it is nevertheless true that both the solution based the peak (mean) frequencies and the majority of solutions using a Monte Carlo simulation of the effects of uncertainty in frequency show the same result, that there is a local maximum in mass density within about 30° of the magnetic equator. The same result is found for the wave event observed on August 28, 1990. These results imply that heavy ions are preferentially concentrated at the magnetic equator.

SM52A CC: 518 A Friday 1030h

Space Weather: Linking Research and User Needs II *(joint with SA, SH)*

Presiding: **A Posner,** Southwest Research Institute**; H J Singer,** NOAA Space Environment Center

SM52A-01 1030h INVITED

Predicting Extreme Events: the Halloween Storms of 2003

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Space weather from October 19 through November 7, 2003, dubbed the "Halloween Storms," was, by any measure, spectacular. The solar flares, coronal mass ejections, energetic particles, geomagnetic, and ionospheric storms that occurred caused problems - and excitement - for forecasters, customers, and data providers. In addition, the print and electronic media were aggressive in acquiring information on what was occurring. Forecasters were faced with the challenge of discerning what an extreme event must look like: how do you predict the events that almost never occur? What does that data have to look like? How do you convey the significance of the situation to the customers of those predictions, while knowing the odds are against you? Models are increasingly more valuable to forecasters, but are there limitations when the models are asked to predict the "outlier" events? Can forecasters believe the model output when those predictions are so far from what empirical evidence suggests? The customers must integrate these predictions in the context of other considerations that affect their system. Do they blindly react to the prediction or do they hedge? The customer reaction is often influenced by the reports they see and hear from the broadcast media. During the Halloween Storms, more than 300 media contacts, including live on-camera interviews, occurred at the NOAA Space Environment Center. What impact do these distractions have on maintaining a high level of operational integrity? The public interest in this activity was unprecedented. Finally, the system impacts of the Halloween Storms were many. As would be expected, the impacts were seen around the world. For providers of space weather services, each of these areas – the data, the models, the predictions, the users, the media, and the impacts - interleaved to form a service challenge of a very wide expanse. This talk will present representative examples of each of these areas during the Halloween Storms, and offer a glimpse to future space weather services needed for the strongest space weather events.

SM52A-02 1050h

October 29-31, 2003 Storm Effects on Ionospheric Currents and Geomagnetically Induced Currents

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A major solar storm in late October 2003 produced significant currents in the ionosphere. These currents resulted in geomagnetically induced currents (GIC) in several electrical power transmission systems. Using equivalent ionospheric currents determined from an international array of magnetometers, an enhanced understanding is obtained of how the two dimensional spatially extended currents vary over the Northern Hemisphere during this period. Also the temporal variation in the GIC and equivalent currents show several distinct responses to the conditions prevalent in the storm. For IMF Bz positive and strong B, significant amplitude pulsations in the GIC were observed.

SM52A-03 1105h INVITED

Research and User Needs Concerning Geomagnetically Induced Currents in the Ontario Power System

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Hydro One (the Transmission and Distribution successor company of the old Ontario Hydro) has been interested in the effects of Geomagnetically Induced Currents (GIC) in Ontario's High Voltage transmission network for quite a number of years. Since the late 1990s, we have conducted impact studies looking at areas such as protection and control, impact on equipment, and system dynamics. Since 1998 Hydro One has taken operational measures to reduce the possible impact of solar magnetic events (in addition to those suggested by NPCC). Furthermore, Hydro One is in the process of completing a province-wide GIC measuring network to provide real-time data to circuit analysis software designed to estimate dc flows at any point in the HV transmission network. Alternatively, the same software will be able to use magnetic field measurements to complement and improve on the direct current measurements. The ultimate goal of this monitoring network and analysis software is to offer Hydro One's operating authority with the flexibility to make informed decisions during and prior to solar magnetic events. As we gain experience with the GIC detection network, we envision the capability to make planned selective operating decisions, as well as what-if studies to prevent equipment damage and service interruptions during severe solar magnetic events.

SM52A-04 1125h

Possibilities of the GIC modelling using geomagnetic data

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Forecast of GIC in power systems requires knowledge of all the steps from the origin of disturbances on the Sun, their propagation through the solar wind, interaction with the magnetosphere and ionosphere, to the production of local geomagnetic disturbances and associated geoelectric fields and resulting effects on power systems. In this paper we focus on the steps from geomagnetic disturbances to the power system on the ground. We make extensive use of GIC data from 3 recording sites in 3 different power systems to show the empirical relation between the global 3-hour index ap and measured peak GIC. Hourly ranges of the magnetic field variations and hourly peak dB/dt values from the magnetic observatories closest to the GIC recording sites serve as measures of local geomagnetic conditions. These were used to obtain the relation between local magnetic indices and hourly peak GIC. For more detailed modeling we use actual geomagnetic field variations (1-min data) and an earth model to calculate the electric fields in the area of the power system. Assuming a purely resistive model of the power network this should be directly proportional to the GIC in the network. Comparisons of the variations of 1-min electric field values to the measured 1-min GIC values has been done by using a linear regression analysis. Measured GIC data and geomagnetic field data served to determine an empirical frequency-domain transfer function. Application of this with magnetic field variations from a new time period to provide GIC values was used to test the consistency of this relationship. The comparisons using 1-hour and 3-hour indices show that local 1-hour magnetic indices (especially peak dB/dt) are better indices to use for correlations with peak GIC values. An examination of correlation coefficients between 1-min datasets shows a strong directional sensitivity. Each GIC measuring site in each system had a particular "preferred" direction for the electric or magnetic field that was most closely correlated with the GIC at that site. Hourly or 3-hourly indices and hourly or 3-hourly peak GIC values are better correlated than datasets of 1-min values produced by different models from geomagnetic or geoelectric fields and 1-min GIC data. This shows that it is much easier to predict the envelope of the GIC variations rather than the detailed GIC variations themselves.

SM52A-05 1140h

Indicator for the effects of geomagnetically induced currents on power transmission systems

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Geomagnetically induced currents (GIC) flowing in technological conductor systems on the ground are often considered as the end link of the space weather chain originating from the Sun. Despite the other systems affected, partly due to the magnitude of the semi-quantified economic impact, the effects of GIC on high-voltage power transmission systems have been of special interest both from the industrial and scientific viewpoint. In this paper we introduce a novel indicator tailored specifically to describe the effects of GIC on power transmission systems. The goal is to derive an indicator in which both geophysical and technological aspects of the phenomena are properly taken into account. Obviously, the same indicator or a similar approach can also be used for other systems experiencing impacts of GIC. The usage of the novel indicator is illustrated by applying it to the geomagnetcic recordings of the October 2003 superstorm. It is shown that the indicator explains well the time of the GIC-related blackout experienced in southern Sweden in October 30.