SM31A CC: 220 C-E Wednesday 0830h

Ground-based Arrays for the Twenty-First Century IV Posters
(joint with SA)

Presiding: **M J Engebretson,** Augsburg College; **J W Meriwether,** Clemson University

SM31A-01 0830h POSTER

THEMIS Ground-based Magnetometers

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This paper describes the design and development of a fluxgate suitable for full earth's field ground measurements and to be used for the ground-based segment of the THEMIS project.. The operation of the electronics is based on a 2nd order sigma-delta technique that yields a 24 bit/axis vector value with 4ppm measurement resolution at 2Hz without the use of analog to digital converters. This digital design produces superior noise performance over more conventional techniques while dramatically increasing the resolution of the magnetic field measurement. The magnetometer system is equipped with a DAC offsetting system which by program control can offset the Earth's field in any sensor orientation. Time and position data are maintained to an accuracy of 100usec and 40 meters with a dedicated Trimble Acutime2000 GPS receiver. The magnetometer may be powered from any un-regulated DC source capable of delivering 300ma. @ +10-24VDC. All data are output via USB or RS-232 interface to LabView host software which has been developed to support either Windows or Linux operating systems.Interrogation and control of the magnetometer is available via TCP protocol through a host internet connection.

SM31A-02 0830h POSTER

The Expanded and Upgraded CANOPUS Magnetometer Array: An Extensive Ground-based Magnetometer Array in the THEMIS and ILWS Era.

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The ground-based CANOPUS magnetometer array presently consists of 13 fluxgate magnetometers sampling at 5s. Following the award of $1.3M from the Canada Foundation for Innovation, the array will be expanded through the deployment of an additional 15 3-component fluxgate magnetometers together with 8 two-component induction coil magnetometers. Data from the expanded 28 site CANOPUS Magnetometer Array (CMA) will be upgraded to provide a standard 1s resolution data product, with raw fluxgate sampled data at 8Hz also being stored. The induction coil magnetometers will sample at 20 Hz. Collectively, the expanded array will provide a unique capability for monitoring the magnetic signatures of geomagnetic activity on a continental scale. Here we outline the funded planning for the expansion of the CMA, and review the highest priority science targets which can be addressed with the plasmasphere-polar cap coverage provided by the expanded array. These include the monitoring and characterization of ULF wave disturbances in response to solar wind forcing, detecting the Pi2 and PiB response at substorm onset, the magnetic location of the substorm current wedge, cross-phase remote-sensing plasmaspheric dynamics, including plasmaspheric refilling and loss, characterizing the ground-based signatures of the ionospheric Alfven resonator, meso-scale characterization of the excitation and ducting of EMIC waves and their relation to the plasmapause and to local precipitation, and the excitation of poloidal ULF waves by ring current ions. The 1s data from the expanded array will be collected in real-time using very small aperture terminal satellite High Speed internet (HSi) technology. The expanded CMA will also provide an important element of the ground-based magnetometer coverage to be provided in support of the THEMIS satellite project, CANOPUS magnetometer data forming a formal part of the THEMIS ground-based magnetometer data product. Together with partner ground-based measurements within the Canadian Geospace Monitoring (CGSM) program, the expanded CMA will continue to ensure that real-time global magnetic monitoring with unprecedented coverage continues through the ILWS era.

SM31A-03 0830h POSTER

Present and Future Magnetometer Arrays in Canada

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Because of its location relative to the auroral oval and polar cap Canada is an attractive location for magnetometer arrays. This presentation is a compilation of information about currently operating networks and arrays and those arrays which will be installed within the next few years. Although the map only shows the locations of semi-permanent vector magnetometer installations, we have also compiled information about installations that do not fall into these categories. If all planned installations are implemented the number of magnetometers operating in Canada will soon exceed 80.

SM31A-04 0830h POSTER

Baselining of CANOPUS Magnetometer Data for Automated Inversion

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Automated Forward Modelling (AFM) can be simply applied to meridian chains of magnetometers. This procedure calculates the magnetic field due to an east-west-directed ionospheric current crossing the meridian, and adjusts the position where the current is found, along with the magnitude of the current, until an optimal match to the data is found. Under many circumstances, this may be regarded as the position of the auroral electrojets. In individual event studies, a baseline may often be taken from a nearby quiet period at each station. This level is chosen by the investigator based on experience. When one wishes to invert a large amount of data from an archive, or if one seeks a real-time space weather application, an automated method of choosing quiet periods must be used. Both long-term and daily variations not mainly due to electrojets must be removed. We found that 'quiet days' do not occur frequently enough to be useful for baselining over periods of a year: instead we must select quiet hours and fit trends at each hour of the day, throughout the year, based on the quiet hours. We have found Chebyshev interpolation to be the most stable way to represent the quiet day baselines. We have found the CANOPUS data set to require considerable baseline treatment if we hope our baselines to be useful at about the 10 nT level which could reveal weak electrojets. Our procedure produces an error estimate which is used in the AFM technique to reduce weight of data in proportion to how poorly determined its baseline is.

SM31A-05 0830h POSTER

Field Testing and Calibration of Low-Cost Pulse-counting Magnetometers

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Development of pulse-counting magnetometers based on proprietary sensors from Speake & Co. and PIC microcontrollers, with a GPS time base, has progressed to the point of field testing. The basic design of the microcontroller board is now nearly static. Heads using two opposed sensors per axis for three axes have attained resolutions of about 1/3 nT while sampling once per second. While this configuration reduces thermal effects, we have found that the sensors can interact, particularly in the Y component where they operate at nearly the same frequency. We still must characterize thermal effects and are experimenting to determine whether thermal calibration can be done well enough to attain 1 nT resolution with only one head per axis. This would simplify head design. It is anticipated that the final head design will involve burial to minimize thermal effects. By characterization and numerical removal of thermal effects we hope to avoid active thermal control. With slowly time-varying temperatures, which are measured accurately near the sensor, we are able to calibrate within the 1 nT design goal. We describe the calibration procedure, which characterizes the nonlinear response of the sensors (a minor disadvantage for geomagnetic variation studies) and the thermal response. With this calibration, we have attained our goal of making a digital triaxial magnetometer capable of better than 1 nT resolution and costing less than $500. The development of these "PIComags" will allow a dense local array to be developed in Alberta to study auroral onset and propagating magnetic disturbances, with an educational component also envisaged.

SM31A-06 0830h POSTER

A Near-real-time Data Transport System for Selected Stations in the Magnetometer Array for Cusp and Cleft Studies (MACCS)

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The Magnetometer Array for Cusp and Cleft Studies (MACCS) is a two-dimensional array of eight fluxgate magnetometers that was established in 1992-1993 in the Eastern Canadian Arctic from 75° to over 80° MLAT to study electrodynamic interactions between the solar wind and Earth's magnetosphere and high-latitude ionosphere. A ninth site in Nain, Labrador, extends coverage down to 66° between existing Canadian and Greenland stations. Originally designed as part of NSF's GEM (Geospace Environment Modeling) Program, MACCS has contributed to the study of transients and waves at the magnetospheric boundary and in the near-cusp region as well as to large, cooperative, studies of ionospheric convection and substorm processes. Because of the limitations of existing telephone lines to each site, it has not been possible to economically access MACCS data promptly; instead, each month's collected data is recorded and mailed to the U.S. for processing and eventual posting on a publicly-accessible web site, http://space.augsburg.edu/space. As part of its recently renewed funding, NSF has supported the development of a near-real-time data transport system using the Iridium satellite network, which will be implemented at two MACCS sites in summer 2004. At the core of the new MACCS communications system is the Data Transport Network, software developed with NSF-ITR funding to automate the transfer of scientific data from remote field stations over unreliable, bandwidth-constrained network connections. The system utilizes a store-and-forward architecture based on sending data files as attachments to Usenet messages. This scheme not only isolates the instruments from network outages, but also provides a consistent framework for organizing and accessing multiple data feeds. Client programs are able to subscribe to data feeds to perform tasks such as system health monitoring, data processing, web page updates and e-mail alerts. The MACCS sites will employ the Data Transport Network on a small local Linux-based computer connected to an Iridium transceiver. Between 3-5Mb of data a day will be collected from the magnetometers and delivered in near-real-time for automatic distribution to modelers and index developers. More information about the Data Transport Network can be found at http://transport.sri.com/TransportDevel .

SM31A-07 0830h POSTER

Evaluation of solar wind coupling to surface magnetic fields

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Long records of geomagnetic measurements allow for many studies to be carried out that are not possible using data from a few events or by using geomagnetic indices. We present examples of using longer-than 5 year records of magnetometer data along with L1 solar wind measurements to determine (1) the spatial distribution of the predictability of ground magnetic fields and their time derivatives, (2) the influence of solar wind variability on rapid, short time scale changes in the ground magnetic field, and (3) the spatial distribution of the influence of the amplitude of turbulence in the solar wind on the average value of the ground magnetic field. It is shown that a long record of data from a meridional chain of magnetometers can be used to reproduce features observed in single event studies and give new and spatially resolved insights into how the solar wind drives magnetospheric dynamics.

URL: http://lasp.colorado.edu/~weigel

SM31A-08 0830h POSTER

Typical and Atypical Storm Sudden Commencements

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We define two types of Storm Sudden Commencement (SSC) based upon the sudden jump measured in the low- and mid-latitude ground magnetic field response. For the typical SSC, the jump in the field occurs globally with a nearly uniform magnitude. For the atypical SSC, the jump in the field is concentrated on the night side with little or no jump in the field near local noon. The positive jump in the low latitude ground magnetic field is thought to be the response to the sudden compression of the magnetosphere by the high dynamic pressure behind a solar wind propagating shock. Two suggestions have been put forward to explain the atypical events. One asserts that the disturbance field is the result of a triggered substorm in response to the sudden change in solar wind dynamic pressure. The second suggestion explains the disturbance field in terms of a transition current system that develops when the IMF changes from pointing south to north simultaneously with the sudden pressure change. We investigate a variety of global data sets for a collection of both typical and atypical responses to sudden changes in the solar wind dynamic pressure to test these hypotheses.

SM31A-09 0830h POSTER

ULF Resonance Monitoring of Diurnal Plasmaspheric Refilling: Results from the MEASURE Magnetometer Array

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We present the first statistical study of the diurnal mass density of the inner magnetosphere using the ULF resonance technique. The results were obtained using the MEASURE (Magnetometers Along the Eastern Atlantic Seaboard for Undergraduate Research and Education) longitudinal magnetometer array, which is the first permanent magnetometer chain developed to routinely measure the field line resonance (FLR) frequency at low to mid-latitudes. We find at low and mid-latitudes a mass density minimum near dawn and a maximum before dusk with a maximum-to-minimum ratio typically between 1.3 and 1.8. This diurnal variation is superimposed on the daily average change in mass density due to changing geomagnetic conditions.

SM31A-10 0830h POSTER

Transionospheric HF Propagation from SuperDARN and CADI Transmitters

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Coordinated radio propagation experiments using the Super Dual Auroral Radar Network (SuperDARN) and the Canadian Advanced Digital Ionosonde (CADI) ground-based facilities are planned in conjunction with the e-POP (Enhanced Polar Outflow Probe) satellite mission. These experiments will provide us with a new perspective on the details of propagation and scattering of HF radio waves. The e-POP Radio Receiver Instrument (RRI) will record radio signals from SuperDARN and/or CADI while their receivers measure the ground and ionospheric echoes of the same transmission. Radio wave parameters to be studied will include signal amplitude, delay, Doppler shift and direction of arrival. One type of ionospheric structure that ground radio signals are expected to encounter on the way to e-POP receiver will be undulations of the F-region that are caused by passing atmospheric gravity waves (AGWs). It is anticipated that some of the transionospheric radio signals that will be focussed/defocussed by quasi-periodic density structure. In preparation for these experiments, and in order to gain better understanding of what might be expected in the propagation characteristics of a ground-originated signal when it reaches the e-POP receiver, HF ray tracing in a model ionosphere structured by traveling ionospheric disturbances (TIDs) was performed. Poynting flux (signal amplitude) at the satellite location is determined by using a three-ray pencil beam.

SM31A-11 0830h POSTER

Solar Wind Alfvén Waves: A Source of Pulsed Ionospheric Convection and Atmospheric Gravity Waves

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SuperDARN radar ground scatter signatures of medium scale travelling ionospheric disturbances (TIDs) caused by atmospheric gravity waves with periods of 20-50 min can be traced to a high latitude source, namely Pulsed Ionospheric Flows (PIFs) due to bursts in the convection electric field. The significance of PIFs and TIDs in the context of solar-terrestrial interaction is that Alfvénic fluctuations of the interplanetary magnetic field observed in the solar wind plasma streaming from coronal holes correlate with PIFs and TIDs. PIFs are interpreted as ionospheric signatures of magnetic reconnection pulsed by solar wind Alfvén waves at the dayside magnetopause or attributed to pressure pulses resulting from the interaction between solar wind Alfvén waves and the bow shock. The interpretation of the observed TID signatures in the radar ground scatter is supported by ray tracing of gravity waves transmitted to the F region from a source in the E region after being reflected/refracted upward in the upper mesosphere. The observed one-to-one correspondence between the convection electric field bursts and TIDs is consistent with the modeling results by Millward (1994). The correlation with solar wind Alfvén waves points to very direct coupling of solar wind energy into the subauroral atmosphere. Millward G. H., Ann. Geophysicae, 12, 94-96, 1994.

SM31A-12 0830h POSTER

Statistics of MF-Burst Emissions: Analysis of Data from South Pole Station and from Multiple Northern Hemisphere Stations

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Medium-frequency burst (MF-burst) is a broadband impulsive emission at 1-5 MHz observed at ground level during auroral substorm onsets [Weatherwax et al., 1994; LaBelle et al., 1997; review by LaBelle and Treumann, 2002]. Its amplitude is comparable to that of auroral hiss, with which it often coincides. Polarization measurements indicate that MF-burst propagates in the LO mode in the ionosphere [Shepherd et al., 1997], but aside from that its generation mechanism is unknown. In order to measure MF-burst and related auroral emissions, Dartmouth College operates LF/MF/HF radio receivers at South Pole Station and at various northern hemisphere observatories. South Pole is one of the best sites worldwide for observing MF-burst, because of the low level of man-made and natural noise in the 1-5 MHz band. This low noise level allows easy identification of events and semi-automatic data analysis; exploiting these, we present statistics of MF-burst amplitudes, frequencies, dates and local times of occurrence, etc., for one full year of data collected in 2003. To complement this single-station statistical study, we examine MF-burst data from 1997-8 when simultaneous data from up to five northern hemisphere stations, separated by 200-400 km north-south, exist. 80–90% of the MF-burst events occur at a single station; however, some events occur on up to four of the five stations simultaneously. In MF-burst emissions which occur at multiple stations, the onset of the emission often shifts poleward as the substorm onset progresses. We examine the statistics of this poleward shift in comparison to other substorm diagnostics. References: Weatherwax, A.T., J. LaBelle, and M.L. Trimpi, A new type of auroral radio emission at 1.4-3.7 MHz observed from the ground, *Geophys. Res. Lett., 21*, 2753, 1994. LaBelle, J., S.G. Shepherd, and M.L. Trimpi, Observations of auroral medium frequency burst emissions, *J. Geophys. Res., 102*, 22221, 1997. Shepherd, S.G., J. LaBelle, and M.L. Trimpi, The polarization of auroral roar emissions, *Geophys. Res. Lett., 24*, 3161, 1997. LaBelle, J., and R.A. Treumann, Auroral Radio Emissions, 1. Hisses, Roars, and Bursts, *Space Sci. Rev., 101*, 295–440, 2002.

SM31A-13 0830h POSTER

A Study of Pc5 Geomagnetic Pulsations in the South Atlantic Anomaly

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ULF geomagnetic pulsations in the period range 180 to 1000 seconds following sudden commencement impulses are examined for the stations situated at low latitudes and also in the South Atlantic magnetic anomaly - SAMA region in Brazil. We selected for this study few large pulsation events following SC impulses during the period of September 2000 to December 2001. When a sudden increase of the solar wind dynamic pressure following an interplanetary shock compresses the Earths magnetosphere, the magnetopause moves inward towards the Earth and intensifies the currents at the magnetopause. It is sensed by the ground magnetometers as a sudden increase of the geomagnetic field intensity. It is also known that electric fields are generated in the ionosphere as a result of the interaction

of hydromagnetic waves of SC impulses with the ionosphere and these electric field drive the ionospheric currents to which ground magnetometers respond during sudden impulses and sudden commencements. Power spectra and polarization characteristics of these pulsation events are presented and discussed in the light of the physical processes due to the Equatorial Ionization Anomaly - EIA and possible enhancement of electric fields in the SAMA region. In order to investigate the relationship of the pulsation events on the interplanetary shock parameters, plasma and IMF data from the satellite ACE are used.

SM31A-14 0830h POSTER

A Survey of Dayside Pc 3-4 Magnetic Pulsations Observed by the Polar Satellite and Antarctic Ground Stations

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Pc 3-4 pulsations (with frequencies from ∼15 to 50 mHz) are commonly observed in magnetic field data from satellites throughout much of the dayside magnetosphere, and in ground-based data at latitudes from the equator to the cusp. The precession of Polar's apogee from its initial location over the northern polar cap in 1996-1997 to equatorial latitudes in 2002-2003 allows it to survey the outer magnetosphere over a wide range of latitudes and L shells. In this study we compare simultaneous magnetic field data from the Polar satellite with data from a set of ground-based search coil magnetometers in Antarctica (at latitudes from 66° to 74° MLAT) in order to characterize the regions of Pc 3-4 pulsation activity in the noon sector in terms of L shell and magnetic latitude, and to characterize those waves which do or do not appear simultaneously in space and on the ground at high latitudes. We find that Pc 3-4 activity with observed compressional components consistently appeared over a range of L shells and latitudes between +20 and -30 degrees, typically crossing the equator; a small number of purely compressional wave events appeared to be localized very near the magnetic equator. Purely transverse pulsations occurred over a much broader latitudinal range than those with compressional components. The overall power of the compressional component of Pc 3-4 activity seems to increase with distance from the Earth.

SM31B CC: 518 C Wednesday 0830h

Relativistic Electrons in the Earth's Inner Magnetosphere: Observations, Models, and Space Weather Implications I

Presiding: **S R Elkington,** University of Colorado**; R H Friedel,** Los Alamos National Laboratory

SM31B-01 0830h INVITED

The Rate of Electron Acceleration and Loss due to Wave-Particle Interactions

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Intense plasma wave emissions are generated in the radiation belts during the convective injection of plasmasheet particles into the outer radiation zone. Natural gradients in the velocity space distribution of the injected low-energy population provide the source of free energy for the excitation of these waves. Excited waves can also resonant with the high-energy relativistic electrons, causing either precipitation loss or local acceleration by energy diffusion. In the basically collisionless magnetospheric environment, plasma waves provide an efficient mechanism for the transfer of energy from thermal plasmasheet particles to the high-energy radiation belt population. Model calculations of the effective rate of local electron acceleration and loss will be presented and applied to explain observations of the global distribution of energetic radiation belt electrons during geomagnetically disturbed conditions.

SM31B-02 0845h INVITED

Relativistic Electron Phase Space Density Gradients: Past, Present, and Future

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A critical parameter for understanding radiation belt electron dynamics is the gradient in phase space density as a function of radius. Typically one wants to calculate phase space densities as a function of the adiabatic invariants of particle motion. Phase space densities gradients at fixed values of the invariants help reveal diffusive transport processes, stochastic acceleration processes, adiabatic motion of particles in response to the storm time ring current, loss due to atmospheric precipitation, and other critical processes for radiation belt dynamics. The primary challenge in these studies is that instruments do not measure phase space density or the adiabatic invariants. They measure fluxes in fixed energy channels as a function of spatial location and time. This drives us to use magnetic field models to calculate the adiabatic invariants (particularly the bounce and drift invariants) leading to a strong relationship between the accuracy of the field models and the accuracy of the gradients. Furthermore satellite orbit periods are typically similar to the relevant time scales for physical processes. Typically multi-satellite measurements are needed to compare phase space densities at different locations. This talk will review recent work on determining phase space density gradients as a function of fixed invariants. We will discuss the conclusions of those studies and the limits on their generality. We will consider current work using the present configuration of satellites measuring the inner magnetosphere and explore what types of studies can be most fruitful for closure of current scientific questions. We will also look at the limitations of current models and measurements and look ahead to what will be possible given future missions such as LWS.

SM31B-03 0900h

Pre and Post Storm Energetic Electron Observations in the Inner Magnetosphere

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We examine the energetic electron observations from SCATHA and other satellites to study the inner magnetosphere electron distributions both pre and post storm. In particular, we examine the SCATHA electron radial profiles to set the pre storm conditions and monitor the changes following the storm. The SCATHA satellite provides electron observations covering the energy range from keV to > 1 MeV over a radial distance of 5.2 to 7.2 Re geocentric near the magnetic equator in the 1980's. These data will be compared with simultaneous LANL geosynchronous (GEO) and GPS near equatorial data at 6.6 and 4.2 Re respectively where available. Similarly, we will compare HEO and GPS data for recent storms. The HEO satellites sample L values ranging from 2 to more than 10, spanning the GPS and GEO coverage in L but not at the equator. As an example, the SCATHA data for the 12 April 1981 storm shows that during the initial post main-phase electron flux rise the phase space density (PSD) radial profile at M=100 MeV/G is flat in the L=5.5–6.5 range and falling for L=6.5–8.3, indicating a possible peak in PSD below GEO altitudes. At the time of the peak flux at GEO and SCATHA on 17–18 April the PSD radial profile is essentially flat over the L=5.5–8.4 range indicating that any earthward fall-off in PSD is well below L=5.5. The observations provide a view of the energetic particles from the source region, beyond geosynchronous, down to SCATHA perigee at 5.5 and, at times, down to L=4.2, near the peak of the outer electron radiation belt. The results will provide constraints on the PSD profiles that can be assumed in transport models and will be discussed in that context.

SM31B-04 0915h

Statistical Results of POLAR Relativistic Electron Phase Space Density Gradients

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A major outstanding question in inner magnetospheric research is the origin and acceleration mechanisms responsible for the variability of the relativistic electrons in the Earth's radiation belts. A critical parameter for such dynamics is the gradient in phase space density (PSD) as a function of radius, with PSD calculated as a function of the adiabatic invariants of particle motion. In a recent study, POLAR data has been examined over a range of L and a peak in PSD at 4-6 Earth radii has indicated the possibility of a localized source region of radiation belt relativistic electron enhancements. This result has been repeated in a study by the current authors, which also suggested a sufficient population at CLUSTER radial distances to supply the inner magnetosphere by radial transport, agreeing well with particle tracing models. In this study we extend previous work by examining a measurements by the POLAR satellite over its mission lifetime, 1997 to the present day. Due to the precession of the orbit, POLAR equatorial crossings range from L=4 to L=9 depending on the year of measurement, such that in a statistical sense POLAR fills in the region of primary interest with an unprecedented density of equatorial PSD measurements. Our statistical analysis of equatorial crossings provides the first opportunity to investigate the phase space density profiles over a full range of all three invariants (mu, J, and L*) and over a variety of geomagnetic conditions.

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Vision for a Virtual Radiation Belt Observatory

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Satellite engineers, operators, and scientists now share a common desire to understand the structure and variability of the earth's radiation belts. Continuing upsets to space operations demonstrate a need for improved scientific understanding of the radiation belts, more accurate models, and better transfer of scientific understanding to space technology and operations. Currently, the resources necessary for such advancements are beyond the scope of an individual researcher. Thus, we discuss plans to advance our understanding of the radiation belts and mitigate the hazards they pose