SM22A-0840 1330h POSTER

MPACT: Architecture and Design of a COTS Science Co-Processor for Space Science Missions

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As Space Science moves steadily towards missions involving greater numbers of spacecraft and increasingly more capable instrumentation, greater and greater demands are placed on mission communications and operations. However the resource envelopes for these multi spacecraft missions are not likely to be substantially greater than the resource envelopes required to produce and operate single spacecraft missions today. Therefore, the task is to learn how to develop and operate multi spacecraft missions for the cost of single spacecraft missions today. Automation and autonomy will play central roles in achieving the required operational efficiencies. As with most ground-based endeavors, the field of system automation has taken advantage of the rapid advance of computing power in recent years. Some of these techniques are making their way into space missions, but their implementation on board spacecraft is hampered by the retarded progress of space-worthy electronics. Improvements in spacecraft reliability and autonomy have been obtained over the decades, but it is still difficult to make up for the fact that radiation hardened electronics is typically two generations behind Commercial-Off-The-Shelf (COTS) equipment.

NASA/HPCCs Remote Exploration and Experimentation Project (REE) researched ways to bring state-of-the-art COTS computing technology to spacecraft implementation. Focusing on mission applications that require intensive, general purpose computing, REE developed radiation effects models for important COTS components, examined methods of hardware and software implemented fault tolerance, developed a fault-injector testbed, and developed application software to move some science data processing onto spacecraft. We discuss the results of this work and its implications for onboard computation and its resource requirements.

To validate the REE approach and to obtain flight heritage, a Science Co-Processor experiment, named the Magnetospheric Plasma Analysis Computation Testbed (MPACT), is being developed for a test flight as a Hitchhiker payload for the Space Shuttle. A fairly traditional Control Unit based on a radiation hardened processor, e.g. a RAD6000, will control the experiment and monitor the performance of the non-hardened system components. Two COTS-based Compute Nodes using G4 processors will perform automated data processing and reduction functions on data received from the Control Unit. Actual archived Level-0 plasma particle detector data will be used in this experiment. Previous work with such data shows that the construction of high order phase space (fluid) moments for downlink can lead to scientifically lossless effective compression ratios of hundreds or thousands, opening the way for the more intelligent selection of high resolution plasma data. In this way, new opportunities to obtain high resolution data are created. The challenges associated with the production of reliable, high quality plasma moments in real time onboard a spacecraft will be discussed. Future work on applications to plasma wave data will be outlined.

SM22B MC: 300 Tuesday 1330h

Modes of Transport in Geospace: Plasma, Field, and Particle Transport

(joint with NG, SA, SH)

Presiding: **T S Chang,** MIT**; G Consolini,** Inst. Fisica Spazio

SM22B-01 1330h INVITED

Modes of convection in the magnetotail

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The flow of plasma in the Earth's magnetotail cannot reach a steady state, since steady adiabatic convection would lead to too high pressure of the associated magnetic flux tubes closer to the Earth, the so-called pressure catastrophy. The natural way to avoid the pressure catastrophy is to significantly reduce the flux tube volume by reconnection, and observations show a near-Earth reconnection line typically around 20-25 Re downtail. Earthward flows from this reconnection line are rather bursty and typically seen outside of 10 Re. At this point they are strongly braked by the here dominant dipolar magnetic field. The pressure gradients piled up by the flow lead to the substorm current wedge, and possibly other substorm phenonema observed in the Earth's ionosphere. When more and more flux tubes are piled up, the dipolarization front moves tailward and finally shuts off near-Earth reconnection.

SM22B-02 1350h

Estimates of Mass and Momentum Transport by Eddy Turbulence in the Plasma Sheet Using Satellite Observations and a Mixing-Length Theory

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Large-amplitude turbulent fluctuations are observed by satellites in the plasma sheet. ISEE-2 measurements found that the flow-velocity fluctuations have an rms velocity of about 75 km/sec and a correlation time of about 140 sec. From these Eulerian flow measurements, an estimate of the correlation length of the turbulence is obtained with the use of a mixing-length theory [Tennekes and Lumley, A First Course in Turbulence, secs. 2.3 and 7.1, MIT Press, 1974]. This estimate is 10,000 km for the correlation length of the turbulent flow. In a similar fashion, the Eulerian flow measurements can be combined with a mixing-length theory to predict the eddy-diffusion coefficient that governs the turbulent transport of mass and the coefficient of eddy viscosity that governs the turbulent transport of momentum. For the Earth's magnetotail, the calculated eddy-diffusion coefficient is used to predict mass-transport timescales and the calculated coefficient of eddy viscosity is used to construct a flow Reynolds number for the magnetotail. The amounts of turbulent diffusivity and viscosity in the magnetotail are compared with the amounts of numerical diffusivity and viscosity in global MHD codes.

SM22B-03 1405h

Modeling the inner plasma sheet protons and magnetic field under enhanced convection

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In order to understand the evolution of the inner plasma sheet proton distributions and magnetic field under enhanced convection, we incorporate a modified version of the Magnetospheric Specification Model with a modified Tsyganenko 96 magnetic field model to self-consistently simulate protons and magnetic fields with two-dimensional force balance maintained along the midnight meridian. Proton differential fluxes are assigned to the model boundary to mimic a tail source that is a mixture of hot plasma from the distant tail and cooler plasma from the low latitude boundary layer. The source is local-time dependent and is based on Geotail observations and the results of the finite-tail-width-convection model. We previously simulated the inner plasma sheet under weak convection corresponding to a cross polar-cap potential drop (PCP) equal to 26 kV and obtained two-dimensional quiet time equilibrium for the protons and magnetic field. The results from the quiet time simulation reproduce quantitatively the general features of observed distributions of proton parameters, proton flow, and magnetic field configuration. We start our simulation for enhanced convection with the quiet time equilibrium as an initial condition and enhance convection by increasing the PCP steadily from 26 kV to 74 kV in 2 hours. The magnitudes of simulated proton flows at the equatorial plane are found to increase with enhancing convection while the overall flow directions do not change significantly. The radial profiles of proton pressure, number density, and temperature along the midnight meridian show that the magnitudes increase by a factor of $\sim$1.2 to 1.4 while the common feature of increasing magnitude with decreasing distance from the Earth in their profiles remains unchanged. The equatorial profiles of plasma parameters show that the dawn-dusk asymmetries with higher pressure and temperature on the dusk side increase with increasing PCP, while the dawn-dusk asymmetry in density does not change very much. The equatorial magnetic field strengths in the near-Earth plasma sheet decrease more than those further down the tail as the PCP increases, resulting in an increasing flat radial profile with enhancing convection strength.

SM22B-04 1420h

Multiple-Satellite Observations of Plasma Transport Into the Inner Magnetosphere

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In an average sense, the transport of fresh plasma sheet material from the geomagnetic tail region into the inner magnetosphere has been shown to be well ordered by the level of geomagnetic activity, as measured by Kp, and is consistent with the expectations for a simple, large-scale convection electric field, the strength of which is related to Kp. On a finer time scale, however, it appears that this transport occurs on an episodic basis, with fairly sudden convection surges depositing material in the inner magnetosphere. Observations of plasma sheet electron spectra at multiple locations in geosynchronous orbit show that these surges are global (i.e., they extend over distances of several Earth radii) and that they propagate from the near-midnight region toward both the dawn and dusk regions of the inner magnetosphere. These multi-point geosynchronous observations will be compared with simultaneous solar wind observations and other measures of the convection development to help illuminate the processes by which fresh material is transported into the near-Earth magnetosphere.

SM22B-05 1435h INVITED

Similarities and Differences of Transport in the Terrestrial and Jovian Environments

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Jupiters magnetosphere differs from the terrestrial magnetosphere in ways that critically modify the transport of plasma through the system. Of great consequence is the fact that Jupiters moon Io provides a source of heavy ion plasma deep within the magnetosphere. The rapid rotation of the planet subjects the plasma to large rotational accelerations. Interchange instability is of little consequence at Earth but is identified at Jupiter and may be of critical importance in transporting Jovian plasma. Conservation of angular momentum causes the plasma to slow its angular speed with outward motion and this drives currents that couple the equatorial magnetosphere to the auroral zone, producing an aurora with very different sources from those familiar at Earth. The gargantuan scale of the magnetosphere affects the conservation of adiabatic invariants, with time scales of planetary rotation short or of order of the bounce time of thermal plasma. This feature of the magnetosphere results in strong local time-dependent structure. We will discuss these and other aspects of the comparison of the two magnetospheres.

SM22B-06 1520h INVITED

Magnetic Field Transport in the Solar Wind within and at 1 AU

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The many modes of magnetic field transport in the solar wind include several that will be discussed in this paper: 1) injection of magnetic flux by transient events on the sun, including both CMEs and short-lived coronal holes, and subsequent convection through the solar wind; 2) redistribution in space by stream interactions and shock interactions; 3) latitudinal redistribution of existing open magnetic flux; and 4) transfer to smaller scales by fragmentation processes and to larger scales by merging processes. Each of these transport modes involves non-linear dynamical MHD processes. Significant progress is being made in observing these processes, in describing the complex observations using statistical methods, and in the modeling the processes using analytical and numerical deterministic methods. We shall give a brief overview of this work. Evidence for reconnection in the solar wind continues to be found, but the observations are not definitive and the relative importance of reconnection in the solar wind is still an open topic.

SM22B-07 1540h

Magnetic Fluctuations and Wave-Ion Interactions in the Solar Wind

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Large amplitude, long wavelength magnetic fluctuations (sometimes called "turbulence") are ubiquitously observed in the solar wind; by cascading to shorter wavelengths they may heat ions and induce ion/ion flows and ion anisotropies through wave-particle interactions. Thus this cascade drives the plasma away from thermal conditions, just as wave-particle scattering by kinetic instabilities acts to reduce anisotropies and ion/ion flows. If the turbulent fluctuation amplitudes are large enough, theory predicts that the alpha/proton relative flow in the solar wind should be subject to two constraints: an upper bound imposed by electromagnetic alpha/proton instabilities and a lower bound driven by the turbulent cascade. We have searched for these characteristic signatures of wave-particle interactions in the Ulysses/SWOOPS solar wind ion observations. The upper bound is trivially satisfied because the alpha/proton speed is typically well below the instability threshold. The lower bound is satisfied only in the high speed wind, presumably because that is where the magnetic fluctuations have sufficiently large amplitude to drive the alpha/proton flow.

URL: http://nis-www.lanl.gov/∼ *pgary/*

SM22B-08 1555h INVITED

Field Transport in the Near- and Mid-Magnetotail

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Recent observations with the spacecraft Geotail have shown that significant field transport takes place in the near- and mid-magnetotail in the substorm expansion phase and the recovery phase. Magnetic reconnection usually occurs in the mid-magnetotail (20-30 Re) in association with substorm onsets. In the near-Earth tail (inside 20 Re), significant earthward field transport takes place only just after substorm onset, and the Bz field becomes large immediately in the equatorial plane. In the mid-magnetotail (20-30 Re), earthward field transport and tailward field transport take place in the expansion phase. Just after the expansion phase, near the peak substorm activity on the ground, equatorial plasma sheet plasmas can become stationary and the Bz field remains small. In the recovery phase, earthward flows appear with a large Bz spike near the equatorial plane, sometimes sporadically. The large Bz spike often has density compression in front and a counter-streaming ion feature is embedded. This type of field transport, which is also seen in the so-called convection bay activity, is likely caused by magnetic reconnection in the distant magnetotail.

SM22B-09 1615h

Geotail Observations of Magnetic Flux Ropes in Bursty Bulk Flows

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Recent studies have shown that some earthward bursty bulk flows contain embedded magnetic flux ropes. We will present the results of a survey of Geotail measurements taken during the November 1998 to April 1999 "tail season". A total of 35 events were identified and analyzed using a well-tested force-free flux rope model. These flux ropes were observed from GSM X -14 to 30 Re, Y -16 to +18 Re and Z +6 to - 4 Re. All were embedded in earthward BBFs with a mean flow speed of 500 km/s. In most instances, the flux ropes were observed to follow the initiation of the earthward flow event by 1-3 min. The mean flux rope duration was ∼ 30 sec corresponding to a diameter of 2.5 Re. Additional results concerning the ion distributions measured by the LEP instrument in the vicinity of selected flux ropes will also be presented. Finally, the implications of these flux rope events for the nature of the reconnection process in the near tail will be discussed.

SM22B-10 1630h

The ENA, Ring Current, and Auroral Response to "Sawtooth Injections" in the October 4-6, 2000 Storm

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The October 4-6 geomagnetic storm reveals several interesting behaviors that illuminate the injection of plasmasheet material into the inner magnetosphere and the subsequent ring current and auroral responses. The storm began on October 4 in the second half of a North-then-South magnetic cloud. For nearly all of October 4 the IMF was only moderately southward with Bz around -10 nT. During that period of modest solar wind energy input geosynchronous satellites saw a series of "sawtooth injections" which have a very characteristic temporal flux profile indicative of injection followed immediately by renewed plasmasheet thinning. Each sawtooth injection involves a large portion of the nightside and dusk-side magnetosphere. The injections are each accompanied by brightening of the auroral over a broad and expanded auroral oval. The geosynchronous injections are also apparent in simultaneous ENA images from the POLAR and IMAGE spacecraft which show that there is a true injection of fresh plasmasheet material into the inner magnetosphere and not simply an adiabatic reconfiguration of the magnetic field. During the period of sawtooth injections the Dst index decreased slowly to nearly -150 nT over an approximately 20-hour period. During that 20-hour decrease of Dst there is no evidence of trapping of injected ring current particles and nearly the entire build-up appears to be partial or untrapped ring current. The magnetospheric dynamics share many of the features of a "steady magnetospheric convection" event in spite of the fact that there was nothing steady about the response in the inner magnetosphere. The long and slow main phase also provides an unusual opportunity for spacecraft to observe the dynamics during this event.

SM22B-11 1645h

Applying Frequency Distributions on Radiation Belt Data: A New Approach

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The radiation belts, especially the outer belts, are dynamic on all spatial and time scales. It is shown here that frequency distributions of measured radiation belt data are well-represented by power-laws over one to two decades. Furthermore sub-grouping the data as a function of L-shell and local time shows systematic trends in the value of the slope of the power-laws. Applying the concept of self-organised criticality to interpret the shape of the distibutions suggests another approach to complement already existing approaches in the interpretation of how this complicated environment works.

Furthermore this type of study also gives the probability of exceeding a given threshold value over a given time; limiting the size of "an event". The average values can then be compared with models used in spacecraft design.

SM31A MC: Hall D Wednesday 0830h

Storms and Substorms II

Presiding: **F Toffoletto,** Rice University**; N Nishitani,** Nagoya University

SM31A-0737 0830h POSTER

Ion Heating in the Earth's Magnetosphere During Substorm and Storm-time

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In this study, energetic neutral atom (ENA) images from the Medium Energy Neutral Atom (MENA) imager on the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) observatory are analyzed. In the MENA imager, incident ENAs create secondary electrons at a carbon foil and then strike a detector that records their position and time of impact. The electrons are used to determine the trajectory and time-of-flight of the ENA. Trajectory information and the spacecraft spin enable two-dimensional ENA images to be constructed. The time between the electron and ENA pulses provides an energy measurement if the ENAs are assumed to be hydrogen. Using the energy spectrum of the MENA neutral flux data, images of the plasma ion temperature are created based on estimates of the peak line-of-sight ion temperature. The geomagnetic activity of the magnetosphere in the images ranges from mildly active to stormy. The spatial distribution of ion heating in the magnetosphere during storm activity will be discussed.