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We present an analysis of GUVI observations of the thermospheric and ionospheric response to the solar flares and ensuing magnetic storms and solar particle events known collectively as the "April Storm" of 2002. GUVI's scanning spectrometer provides continuous imaging of emissions from atomic oxygen, molecular nitrogen, and atomic hydrogen in the earth's upper atmosphere and geocorona. The absolute and relative intensities of these emissions are diagnostic of flare-driven changes in the composition and thermal structure of the atmosphere, in addition to transient variations in the excitation rates of the transitions that give rise to the observed radiation.

## SA21B-0433 0830h POSTER

### On Modeling the April 21, 2002 SEP event

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Gradual solar energetic particle (SEP) events, where particles are often accelerated to 10's MeV (sometimes even GeV) energies, are often associated with CME-driven shocks. Thus, interpreting the observational data requires understanding the structure of the shock, the acceleration process, and the subsequent transport of energetic particles. Theoretically, the underlying acceleration mechanism is thought to be first-order Fermi acceleration, also known as diffusive shock acceleration. Such a mechanism leads naturally to power-law particle spectra, which are often observed. To connect observations with the underlying theory, a comprehensive model that tracks particle acceleration and transport is necessary.

In this work, we describe our model of particle acceleration and transport at CME-driven shocks and compare the model simulation with a particular event - the April 21st, 2002 event. We chose this event for its relatively clean intensity-time profile which is relatively free of contributions from other events. The parent shock is thought to be driven by a CME associated with active region 9906 (S03 W56) and was magnetically well connected to Earth. Velocity dispersion observed during the onset of the event is a signature of particles being accelerated near the Sun and their subsequent transport through the interplanetary medium to 1 AU. In this work, we have modeled the intensity-time profiles and particle energy spectra obtained over a broad range of energies between $\sim$ 0.08 MeV/nucleon through $\sim$ 100 MeV/nucleon from instruments on ACE, Wind, and SAMPEX. We find excellent agreement between our model simulations and the observations, suggesting that this approach may provide an important step toward understanding and tracking the influence of large SEP events in the interplanetary and geospace environments.

## SA21B-0434 0830h POSTER

### SAMPEX Measurements of Geomagnetic-Cutoff Variations During the 4/21/02 Solar Energetic Particle Event

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During large solar energetic particle (SEP) events the entry of solar and interplanetary energetic particles into the upper atmosphere is controlled by the geomagnetic cutoff. We define the cutoff latitude ($\Lambda_C$) for a given rigidity particle to be effectively the minimum invariant latitude down to which particles can reach the upper atmosphere. The instruments on the polar-orbiting SAMPEX spacecraft have been used to measure geomagnetic cutoffs during a large sample of SEP events from solar cycle 23. During those events in which there is an associated geomagnetic storm, there are often large cutoff variations of as much as $5^\circ$ to $10^\circ$ in invariant latitude over the course of the event. This paper will combine measurements from the HILT, MAST, and PET instruments on SAMPEX to provide a comprehensive view of geomagnetic cutoff variations during the large SEP event of 4/21/02. We find that during the first two days of the event the cutoff latitude for $\sim$ 30 MeV protons was at typical quiet-time levels. On April 23, following the arrival of a strong interplanetary shock, there was a sudden drop in the cutoff that lasted $\sim$ 12 hours, with sizable local-time differences. During the next two days the cutoff steadily increased, giving a total variation of $\sim 5^\circ$ over the five days of the event. We combine these measurements of cutoff variations with measurements of the composition and energy spectra in the 4/21/02 event in order to estimate changes in the area of the polar caps over which particles of a given rigidity had access to the upper atmosphere.

## SA21B-0435 0830h POSTER

### Magnetospheric energetic particle response during the April 2002 event

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We examine the magnetospheric energetic particle response to the April 2002 storm events. During this period the magnetosphere was impacted by large CMEs and a major flare occurred on the sun. The Dst index shows a complicated structure with 3 separate storm signatures. Protons were observed injected deep within the magnetosphere and relativistic electron flux increases also peaked at low L values. We use energetic particle sensors onboard SAMPEX and Polar to survey this event. We present detailed time histories of electron and proton fluxes over a wide energy range including relativistic electron energy spectra. SAMPEX and Polar cover most L shells being in polar orbits with the former in low earth orbit and the latter at a much higher altitude. Characterization of energetic particles is important as they form a vital link in the Sun-Earth connection with their affects reaching down to the terrestrial atmosphere.

## SA21B-0436 0830h POSTER

### RHESSI Observation of Atmospheric Gamma Rays from Impact of Solar Energetic Particles on 21 April 2002

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The *RHESSI* high-resolution spectrometer detected $\gamma$-ray lines and continuum emitted by the earth's atmosphere during impact of solar energetic particles from 1600-1700 hours UT on 21 April 2002. The particle intensity at the time of the observation was a factor of 10 – 100 weaker than previous events when gamma-rays were detected. De-excitation lines were resolved that, in part, come from $^{14}$N at 728, 1635, 2313, and 5105 keV, and from $^{11}$B and $^{12}$C spallation products at $\sim$4440 keV. Several other unresolved lines were also detected. We provide best-fit line energies and widths and compare these measurement with atmospheric line measurements made by *HEAO 3* and *SMM*. We use line ratios to estimate the spectrum of solar energetic particles that impact the atmosphere. The 21 April spectrum was significantly harder than that measured by *SMM* during the 20 October 1989 shock event; it is comparable to that measured by *Yohkoh* on 15 July 2000. This is consistent with measurements of particles made in space at the time of the $\gamma$-ray observations.

## SA21B-0437 0830h POSTER

### An Inventory of the Energetic Particle Input to the Atmosphere during the April, 2002 Storm

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The period April 14 through 24, 2002 was distinguished by a several episodes of high geomagnetic activity and a significant solar energetic particle event. Energetic charged particles entered the atmosphere over a wide range of latitudes and particle energies. TIMED satellite observations exposed significant chemical changes, especially much increased NO densities, in response to those particle inputs. Energetic particle observations, electrons >30 to >300 keV and protons from 30 keV to >100 MeV, from the NOAA-15 and NOAA-16 satellites were analyzed during this period to provide a global inventory of the particle input on a 3-hour cadence for use in modeling the atmospheric response. This paper describes the analysis that was done to achieve this objective and presents examples of the results.

## SA21B-0438 0830h POSTER

### Observations of Energetic Particles From the Polar Cap to the Equator During the April 2002 Storms

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Geomagnetic storms can be studied from the polar cap to the equator at several local times using low-altitude spacecraft data. The unique data coverage offered by NOAA-15 and 16 is indeed very useful, since huge geomagnetic storms are affecting the ionosphere both at high and low latitudes. In the polar cap intense precipitation of MeV protons takes place, and at low L-values a Storm Time Equatorial Belt (STEB) of trapped protons and energetic neutral atoms appears. In this paper we employ multi-spacecraft data to study the April 2002 storms.

## SA21B-0439 0830h POSTER

### Modeling Saw-Tooth Injections During April 17-18, 2002

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During April 2002, a number of magnetic storm occurred in the magnetosphere, which included a number of interesting features. One of these is sawtooth-type injections, observed by geosynchronous satellites on April 18. During the same period, oscillations were also observed in the cross polar cap potential. At the present time, the relation between these two phenomena as well as the source of the quasi-periodic injections is not understood. Using a combination of the BATSRUS global MHD simulation developed by the University of Michigan and Mei-Ching Foks ring current model, we will examine the relationship between injections in the inner magnetosphere and the underlying magnetospheric dynamics. In particular, we will examine the timing of the oscillations in the cross polar cap potential and injections in the ring current, as well as their causal connection. Our results will be compared to the observations during the period of interest.

## SA21B-0440 0830h POSTER

### Substorm Local Time and Compositional Characteristics During the April, 2002 Geomagnetic Storms

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The geomagnetic storm associated with the solar events of April 14-21, 2002 is characterized by substorm activity of a nature probably restricted to particular storm conditions. The substorm dipolarization during the main phase of this storm acts more or less globally. The geosynchronous geomagnetic field appears to dipolarize almost simultaneously on the nightside and the dayside. The geosynchronous particle detectors also show simultaneous injections over almost the entire local time range. As long as the IMF $B_z$ is negative the injections reccur with a 2-3 hour period and display a sawtooth like injection pattern in the LANL particle data *[G. Reeves]*. Global energetic neutral atom (ENA) images from the HENA imager onboard IMAGE display almost global enhancements of ENA fluxes at each of these events, implying that this is a more global depolarization than the classical picture provides. Furthermore, the ENA enhancements are much more prominent in energetic (50 to 180 keV) oxygen, than in hydrogen. Ground magnetometer data is under investigation for this type of event *[Kitamura et al., this conference]*. In this presentation we will use the global energetic neutral atom (ENA) images from the HENA imager on board IMAGE together with ground magnetometer data and other datasets (Geosynchronous magnetic field and particles, aurora, plasmasphere) to discuss the global signatures of this phenomenon.

## SA21B-0441 0830h POSTER

### Growth phase signature in the magnetotail associated with sawtooth injections

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We have examined magnetic field and plasma signatures observed by the Geotail spacecraft during the magnetic storm event of April 2002. On April 18 and19 during this storm, Los Alamos National Laboratory (LANL) satellites observed sawtooth injections at geosynchronous orbit. Geotail was staying in the midtail region at R $\sim$ 27 Re and observed an increase and then decrease of total (kinetic plus magnetic) pressure associated with each sawtooth injection. A detailed examination shows that the total pressure started to increase tens of minutes before each injection and then decreased to even below the previous levels after the injection. These features are similar to what we observe for regular substorms, and the observed increase and decrease in the total pressure are probably related to the substorm growth and expansion phases, respectively. The IMF and solar wind data acquired from the ACE satellite show no clear change of plasma or magnetic field parameters that can be associated with the trigger of injections, but the IMF BZ gradually changed from southward to northward. Therefore the present results suggest that for the sawtooth injection, energy is continuously provided by the solar wind to the magnetosphere but is released only periodically by a certain internal process rather than a change of external conditions.

## SA21B-0442 0830h POSTER

### Magnetotail Behavior Associated With 'Sawtooth Injections' During the Magnetic Storm in April 2002

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A magnetic storm commenced on April 17, 2002 with multiple local minima in the Dst index from April 17 to April 20. During this storm period, Geotail traversed the magnetotail from the midtail region near the dusk flank and mostly in the tail lobe to the near-Earth region near the dawn flank and mostly in the plasma sheet. Simultaneous observations of energetic particles at the geostationary altitude showed the feature known as 'sawtooth injections' remarkably well from April 18 to April 19. This conjunction allows us to examine the magnetotail behavior in the tail lobe and the plasma sheet associated with sawtooth injections. In the tail lobe, nearly one-to-one correspondence is found between injection onset and start of southward dipping of magnetic field vector in the tail lobe, a feature which was noted previously as a substorm expansion signature in the mid-tail. In the plasma sheet, intermittent occurrences of plasma flow reversal from sunward to tailward and of magnetic field from northward to southward were found. These are substorm signatures in the plasma sheet. There was no indication of the magnetotail being driven in a relatively 'steady state' in association with sawtooth injections during the storm main phase. The present findings are consistent with the idea that sawtooth injections are substorm features and that these substorms involve a large local time sector of both the inner magnetosphere and the magnetotail.

## SA21B-0443 0830h POSTER

### Dynamics of the Auroral and State of the Magnetosphere During Storms of April, 2002: DMSP and TIMED/GUVI Observations

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Major magnetic storm activity was detected between April 17 and 20, 2002. Precipitating electron spectral data from DMSP satellites (F12 through F15) were used to identify boundary of the auroral oval during the storm period. The boundaries for MLT between 18:00 and 06:00 (night side) were scaled to define the auroral oval boundaries at 24:00 MLT. There was a good agreement between the calculated change in the 24:00 MLT boundary and Dst, IMF Bz, AE index, and auroral hemispheric power. We have investigated the relation between the boundary and state of the magnetosphere. The boundaries calculated from the DMSP satellites electron spectra also agree well with those obtained from TIMED/GUVI observations. The mechanism behind this phenomenon and its application will be discussed.

## SA21B-0444 0830h POSTER

### Transient Polar-Cap Potential Enhancements During the April 2002 Storm Interval

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The interval from 16-24 April 2002 exhibited a series of solar events that produced significant disturbances in the Earths magnetosphere and ionosphere. One phenomenon that has been reported in association with these disturbances is the observation of rapid (sawtooth-like) enhancements in the energetic particle population at geostationary orbit that appear nearly concurrently at all local times. These enhancements are similar to the particle enhancements observed near midnight in association with magnetospheric substorms, but they do not exhibit the delayed response at other local times. The objective of this paper is to report the association of these events with transient enhancements in the cross polar cap potential drop. The observations that we present were obtained with the northern hemisphere component of the SuperDARN radar network. Specifically, we observed rapid increases (2-6 minute) in the cross-polar-cap potential that endured for 6-30 minutes immediately preceding the sawtooth onset. As the particle fluxes increase, the cross-polar-cap potential observed by SuperDARN drops rapidly to preexisting levels. The magnitudes of the increase in electrical potential-drop have been observed to range form 10-30 kV and they are observed to occur for a wide range of IMF conditions. Since similar enhancements in the cross-polar-cap potential drop are also observed at non-storm times, we suggest that the transient enhancements we observe may be associated with the substorm growth phase and that the sawtooth events during the April interval may be particularly strong substorm onsets.

## SA21B-0445 0830h POSTER

### Polar Cap Observations From DMSP During the April 2002 Magnetic Storms

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During the April 2002 series of magnetic storms three DMSP satellites are orbiting, F13 in the 06 - 18 LT plane, and F14 and F15 in the 09 - 21 LT orbital plane. Starting on the 17th April and continuing through 20th April, high density patches of cold plasma are detected intermittently in the southern polar cap by all three satellites. At times these high density patches are observed simultaneously with energetic electrons (1 keV < E < 10 keV) in the southern cap. Energetic electrons with energies up to 1 keV are detected on crossings of the northern cap. These electron signatures persist throughout the entire day. We will discuss the polar cap signatures in the context of coupling to the interplanetary medium which allows cold ionospheric plasma to be convected across the cap giving rise to the patches, as well as direct entry of energetic electrons.

## SA21B-0446 0830h POSTER

### Penetration of the Solar Wind Electric Field Throughout the Magnetosphere/Ionosphere System

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On April 17, 2002 an intense, long duration electric field penetration event was captured by the Jicamarca incoherent scatter radar. Other radars in the U. S. chain detected the event as well, although not with as much clarity. The interplanetary electric field (IEF) is available from the ACE satellite as well. The ratio of the dawn dusk component of the IEF to the dawn dusk component in the equatorial ionosphere for periods less that about two hours is 15:1. We argue that this corresponds to the ratio of the size of the magnetosphere to the length of the connection line between the interplanetary magnetic field (IMF) and the Earth's magnetic field. Simultaneous magnetic field measurements at Huancayo reveal the same high frequency components and suggest that a chain of stations or an equatorial fleet of satellites in low earth orbit could be used to monitor the connection length continuously.

## SA21B-0447 0830h POSTER

### Substorm Expansion Phases During Magnetic Storms in April 17-23, 2002: IMAGE FUV Observations

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Three magnetic storms occurred during April 17-23, 2002 as an important SEC effect driven by several solar flares and CMEs. FUV auroral data from the IMAGE spacecraft have ∼ 85% coverage for the double main phases of the second magnetic storm that occurred during April 19-20, and have 57% coverage for the main phase of the third magnetic storm that occurred on April 23. During the second storm, when the IMF Bz was strongly southward, north - south auroras, auroral torches and double auroral ovals occurred within substorm expansion phases. Simultaneously, observations of energetic particles at the geosynchronous altitude showed the feature of "sawtooth injections" at every substorm expansion onset. During the third storm, when the IMF Bz was mainly in a strong northward direction, the first auroral expansion onset occurred ∼12 min after an intense interplanetary shock arrived at the nose of the magnetopause. There were no energetic particle injections or electrojets observed at the geosynchronous orbit or by CANOPUS magnetometers for this auroral expansion onset. FUV data showed auroral poleward expansion, but mainly within the midnight sector. There might be two substorm expansion phases that occurred at the middle and near the end of the storm main phase. Comparison studies between the two magnetic storms and between the observations from space and the ground will be performed to better understand the storm-substorm relationship. The effects of the two storms on the magnetosphere - ionosphere coupling will be studied as well.

## SA21B-0448 0830h POSTER

### Dayside auroras during storms of April 2002: TIMED/GUVI observations

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During the major magnetic storms on April 17-20, 2002, TIMED/GUVI observed a new feature of dayside auroras: a separated diffused auroral oval at magnetic latitudes below 70 degrees. Such auroral feature was very dynamic and did not exist all the time. Energetic electrons/protons drifting from the night side magnetosphere may be the source of the auroras. We will discuss the IMF and magnetospheric conditions for the auroras to occur.

## SA21B-0449 0830h POSTER

### A Comparison of FUV Auroral Emissions During the April 2002 Events as seen by the IMAGE/FUV and TIMED/GUVI Instruments

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The auroral emissions that resulted from the series of solar particle events and magnetic storms during 14-24 April 2002 provide an excellent data set for the cross-comparison of the IMAGE/FUV and TIMED/GUVI auroral imagers. The IMAGE/FUV instrument comprises the SI spectral imager (121.8 nm and 135.6 nm) and the WIC imaging photometer (LBH) and observes the entire Earth from high Earth orbit. The TIMED/GUVI spectral imager (121.6 nm, 130.4 nm, 135.6 nm, LBH short, and LBH long) scans a nadir-to-limb swath from low Earth orbit. Although there is a large difference in spatial resolution, preliminary comparison of simultaneously-observed diffuse auroral emissions indicates fairly good agreement between the calibrated brightnesses determined for common spectral features. We will present a detailed simulation of one or more of the April 2002 events as seen by each imager to determine if a single description of the auroral precipitation can self-consistently account for the proton- and electron-generated FUV emissions observed from the two spacecraft.

## SA21B-0450 0830h POSTER

### Validation of the GUVI Auroral Radiance Measurements Using the UARS/PEM Instrument

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One of the key goals of the TIMED mission is to determine the energy input to the atmosphere. Auroral particle precipitation is responsible for a significant component of atmospheric heating, both via direct heating and via conductance enhancements contributing to Joule heating. The GUVI instrument on TIMED

provides images of the auroral brightness, from which can be obtained estimates of the characteristic energy and flux of the precipitating electrons. However, the GUVI estimates must be validated.

In this paper, we use direct measurements of precipitating electrons (5 eV to 5 MeV) from the Particle Environment Monitor (PEM) on the Upper Atmosphere Research Satellite (UARS) to validate the GUVI observations. We use the PEM data to produce a forward model of the GUVI brightnesses in different FUV wavelength bands. Several high latitude conjunctions of the two spacecraft occurred during April 2002, with corresponding auroral precipitation. We present the observations and discuss the significance of the comparisons.

## SA21B-0451 0830h POSTER

### Sawtooth substorm injections, their triggering, and their ionospheric signatures during the April 2002 storm

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During the April 2002 storm, geosynchronous satellites measured periodic particle injections from the magnetotail to the inner magnetosphere. The particle fluxes exhibited a well-defined "sawtooth" profile with gradual decreases (flux dropouts) followed by rapid increases (injections). The sawtooth injections represent the signatures of periodic substorms. Each flux dropout corresponds to the growth phase of a substorm, and each flux increase corresponds to a substorm onset. Magnetospheric electric fields associated with substorms penetrate to the middle- and low-latitude ionosphere and cause disturbances in the F region plasma density and E region currents. We will present observations of the solar wind, magnetospheric magnetic fields, geosynchronous plasma fluxes, and ionospheric plasma density and currents, and discuss the relationship among perturbations in the solar wind, magnetosphere, and ionosphere in this event. We will also discuss several outstanding problems in magnetospheric substorms, such as what causes onsets of periodic substorms during magnetic storms, whether substorms have some specific periodicity, and what determines the periodicity.

## SA21B-0452 0830h POSTER

### The Global Ground Geomagnetic Disturbance Field on April 17 - 19, 2002

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The geomagnetic storm disturbances observed during the period of April 17 - 19 are extremely large and complex. The geomagnetic field experiences a sequence of large changed in solar wind dynamic pressure and periods of extreme southward interplanetary magnetic field. The spatial and temporal consequences of these drivers can be seen in global maps of the low latitude magnetic disturbance field displayed as a function of LT and UT. These maps show the global results of sudden compressions of the geomagnetic field, substorm disturbances, as well as the field depression resulting from the growth of the partial and symmetric ring currents. In particular, features of recurrent activity will be examined with respect to solar wind drivers. The complex activity during the April 2002 interval will be contrasted to the disturbance field observed during other large magnetic storms that have been the recent focus of community studies.

## SA21B-0453 0830h POSTER

### Local-time Distribution of Low-latitute Ground Magnetic Disturbances at Sawtooth Injections of April 18-19, 2002

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A magnetic storm which occurred on April 17-19, 2002 has been studied to investigate a development of the ring current and the current structure which was set up during the magnetic storm. A Coronal Mass Ejection (CME) passed through the Earth on April 17, 2002, which caused an intense magnetic storm on the ground. The main phase of the magnetic storm started at 11 UT on April 17 and developed until 19 UT on April 18 with minimum Dst of -123 nT. On April 18, low energy electron flux observed by four LANL satellites showed quasi-periodic perturbations (2-3 h) in the energy range of 50-315keV: Events of this type has been called "saw-tooth" events. In the solar wind data from the ACE satellite, the IMF-Bz component was stable and southward (-10 nT) from 1 UT till 17 UT on April 18.

On the other hand, magnetic variations on the ground showed Bay-like magnetic variations with amplitudes of 10-40 nT that were synchronized with particle injections observed by the LANL satellites. We have used magnetic data from 8 ground stations of the Circum-pan Magnetometer Network (CPMN) which are LMT (Mlat=-33.53 deg.), MUT (6.39), EWA (21.57), GAM (5.64), YAP (0.50), SMA (-19.82), LAQ (36.25) and HER (-42.12): They are widely separated in longitudinal direction in the middle and low latitudes. The Bay-like magnetic variations, which were synchronized with the particle injections, were predominant in the H-component, and showed similar waveforms at all stations. D-component variations were smaller than the H-component.

Clear Pi 2 pulsations also appeared globally, corresponding to the above magnetic variations. We have so far studied the Pi 2 which occurred at 19:07 UT on April 18: In this case, each ground stations located at 04:30 MLT (LMT), 05:00 (MUT), 06:30 (GAM), 06:15 (YAP), 12:00 (EWA), 17:00 (SMA), 22:00 (LAQ) and 21:00 (HER). Amplitudes of the Pi 2s were large in the morning sector ($> 1$ nT) and weak at other local times ($< 0.5$ nT). We have calculated the directions of the perturbation magnetic vectors during the Bay-like magnetic variations ($\Delta$D, $\Delta$H) and polarizations of the Pi 2s. As a result, we have found the following features.

The direction of the polarization shows a consistency with the existence of the current wedge, as suggested by Lester et al. [1984]. On the other hand, the directions of ($\Delta$D, $\Delta$H) were opposite to those of the Pi 2 polarizations in the southern hemisphere, although they were the same in the northern hemisphere. Thus, the Bay-like magnetic variations in this event cannot be interpreted in terms of the field aligned currents (FACs) of the nominal current wedge which produced the Pi 2 pulsations. They are also difficult to explain in terms of the nominal partial ring current, because the low-latitude H-component increased, not decreased, for the events, and because the low-latitude D-component did not change its sign across the equator. We will discuss possible causes of the Bay-like variations.

## SA21B-0454 0830h POSTER

### Ionospheric Response to the Recurrent Geomagnetic Activity of April 02: Total Electron Content and GPS/UHF Scintillation Variations From the Magnetic Pole to the Equator

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We report the study of a rather unusual response of the ionosphere to the recurrent magnetic activity of April 17-21, 2002. The study has been based on UHF scintillation observations at AFRL scintillation sites dispersed from the pole to the equator and GPS measurements of the total electron content (TEC) of the ionosphere and their fluctuations at widely dispersed stations of the International Geodynamic Service (IGS). The scintillation, TEC and TEC fluctuation dataset are being examined in the context of the observations of the GUVI sensor on the TIMED satellite and satellite in situ measurements by the DMSP satellites and the low inclination ROCSAT-1 satellite.

During this period of recurrent magnetic activity, strong UHF scintillation associated with polar cap patches was recorded at Thule, Greenland. The patch activity occurred during IMF Bz southward orientation that favored magnetic reconnection and the formation of patches. The DMSP satellites showed that an expanded auroral oval was sustained throughout this storm period. The nighttime trough was consistently located at magnetic latitudes near 55 degrees. This explained the occurrence of recurrent nighttime scintillation events and GPS TEC fluctuations at the subauroral location of Hanscom AFB. During this magnetically active period, equatorial scintillation at UHF was detected over limited longitudes that commenced near midnight and continued till the pre-noon period in the presence of E-region conductivity. It is interesting to note that not only was the generation of irregularities longitudinally confined, but the irregularities were also quenched due to their fast decay across a sharp longitude boundary. The storm-time penetration of high latitude electric field to the equatorial region over a limited longitude region is currently being intensively investigated. The DMSP satellites also detected electron density irregularities over a limited longitude interval. The ROCSAT-1 satellite observations are being examined to determine the characteristics of the zonal electric field over the equatorial region.

## SA21B-0455 0830h POSTER

### Observations of the High-Latitude Ionospheric Response to the Onset of the April 2002 Storm

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The high-latitude incoherent scatter radars at Sondrestrom, Greenland, and Longyearbyen, Svalbard, observed detailed ionospheric behavior during the initial shock, occurring near 11:00 UT on April 17, and the onset of the geomagnetic storm. During this period, the Sondrestrom radar observed extreme electric field enhancements in excess of 120 mV/m. The direction of the electric field at Sondrestrom indicates the measurements are located in the sunward convection region of the dawn and pre-noon sector. These large electric fields subsequently produced very high levels of Joule heating rates (greater than 80 mW/m2), extreme ion heating events (in excess of 3500 K), aurorally enhanced electron temperatures and current-driven instabilities leading to extreme electron temperatures in the lower E region (in excess of 2000 K). Additionally the F-region meridional neutral wind response and E region neutral winds are inferred. Concurrent observations on Svalbard, in the post-noon and dusk sector, also indicate enhanced F- and E-region ion and electron temperatures. Though the ionospheric response observed by the radars are determined locally, electric field enhancements estimated by AMIE runs during this period of the storm suggest that these effects may, in fact, occur over a much larger region.

## SA21B-0456 0830h POSTER

### Ionospheric Effects of April 2002 Magnetic storms: Observations from the Network of Incoherent Scatter Radars

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We present the first study of a major geomagnetic storm interval incorporating data from 8 incoherent scatter radars. The radars operated on Apr 15-17, 2002, with some radars continuing operations to Apr 18-20, 2002. The data was taken as a part of the CEDAR/TIMED collaborative storm study with the primary goal of investigating the extent of storm-related disturbances in latitude and altitude. We describe the variety of phenomena observed by different radars depending on their location relative to the auroral oval and on the local time zone.

During the initial positive phase of the storm, an increase in electron density by 10-20% is observed at Irkutsk (52.8N) and Kharkov (50.0N). Large depletions of electron density due to changes in the neutral composition are seen at high and mid-latitudes, reaching a factor of 5-6 at Sondrestrom (67.0N) and a factor of 2-3 at Irkutsk (52.8N) and Millstone Hill (42.6N).

We also identify several periods of penetration of magnetospheric electric fields from high to low latitudes and discuss their effects at different locations. Several intervals of rapidly changing electric fields, with the largest at ∼12 UT and ∼14 UT, are observed at EISCAT Svalbard (78.1N, L=20) and Sondrestrom (67.0N, L=12). Short spikes in electron density and temperature are observed at these locations during the time when the electric field direction and magnitude are changing, and represent regions of hot dense plasma moving in and out of the radar's field of view. At sub-auroral location (Millstone Hill, 42.6N, L=2.8), only a small increase in electron density is observed in response to the rapidly varying electric field, while electron temperature variations are hardly discernible. Similar electron density variations are observed at mid-latitude locations (Irkutsk, 52.8N, L=2.1, Kharkiv, 50.0N, L=2.1). In contrast to this, lower latitude observations (Arecibo, 18.3N, L=1.4), reveal variations in electron density of the order of ∼50% and anti-correlated variations in electron temperature up to 500 K. The same penetrating eastward electric field is clearly seen at equatorial latitude (Jicamarca, 11.95S, L=1.1).

## SA21B-0457 0830h POSTER

### Large-Scale Ionospheric Disturbances during the April 2002 Storms

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Global and regional snapshots of ionospheric disturbances during April 17-21, 2002, will be presented with total electron content (TEC) data measured from hundreds of ground-based global positioning system (GPS) receivers. During this period continuous interactions between the solar wind and Earths magnetosphere, and between the magnetosphere, ionosphere, and thermosphere occurred and created several geomagnetic storms successively. The TEC snapshots reveal overwhelming negative ionospheric effects at middle latitudes, while increased TEC and enhanced equatorial anomaly features are also seen at low latitudes. Distinguished large-scale TEC depletion and enhancement in both hemispheres are also observed in different longitude sectors simultaneously, indicating the local time effects of electrodynamical perturbations and global thermospheric circulation changes. This presentation will compare the GPS data with magnetometer data, FUV images obtained from the IMAGE mission, and coupled-modeling results to assess the ionospheric responses to the peculiar conditions of the successive storms in a high solar activity year.

## SA21B-0458 0830h POSTER

### Observations of Topside Ionospheric Responses at 600 km Altitude During the April 17, 2002 Storm Period

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The ROCSAT-1 orbiting at 600 km altitude observes a textbook-like response of the plasma flow variations in the topside ionosphere during the April 17, 2002 magnetic storm. At the impingement of the interplanetary shock, low frequency Pi-1 plasma flow oscillations at the noon sector have been observed for more than two minutes. The storm induced disturbance dynamo effect begins an hour later with the post-midnight enhancement of the upward flow pattern described in the model of Scherliess and Fejer [1997], and the enhanced zonal flow pattern described in the model of Heelis and Coley [1992]. However, the dynamo induced vertical electric field is noticed to decay at a faster rate than the induced eastward electric field in the post-midnight sector. A unusually large density depletion is then observed at the end of this disturbance dynamo effect. It occurs at the mid-latitude of 34° (27° dip latitude) at the sunrise terminator. The density decreases more than two orders of magnitude from the background level and the depletion width is about 500 km wide. An upward flow of 750 m/s is found inside the depletion. The NO ions found inside the depletion region implies that the depletion has been raised from the bottom-side ionosphere in accordance with the large upward flow observed. Large and rapid east-west reversing flows up to 300 m/s are also observed together with large parallel flow variations of similar magnitudes. The temperature inside the depletion is found to increase to 2400 K from the background temperature of 1400 K outside the depletion. The temperature variation inside the depletion indicates a good correlation with the parallel flow variation but fails to anti-correlate with the density variation. This implies that the model of energy deposit by the photoelectrons that are produced at the sunshine apex height at the equatorial region [Oyama et al., 1988] can not explain the observation because the highest temperature does not occur at the deepest density depletion region. Instead, the temperature increase could be resulted from the adiabatic heating of compressing ions along the field lines from the equatorial region to high latitude region in the model of Bailey and Heelis [1980].

## SA21B-0459 0830h POSTER

### Extremely Low Ionospheric Densities Observed During April 2002 Storm

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Ion densities, observed during the April 2002 geomagnetic storm by polar-orbiting DMSP satellites in the evening sector of the southern polar cap decreased by factors of 10 to 100 relative to their values equatorward of the mid-latitude trough. Comparisons of electric fields with magnetic perturbations due to field-aligned currents suggest that the conductivity of the lower ionosphere also dropped significantly. This implies that the unusually low density characterized the ionosphere at all altitudes beneath the spacecraft.

We present DMSP plasma and field measurements to illustrate how the quiet-time polar ionosphere evolved toward the extraordinarily low-density state apparent during the April 2002 storm. Remotely sensed FUV emissions detected by optical sensors on the Polar and TIMED satellites indicate that wide-spread regions of low O/N2 ratios developed at southern high latitudes during this period of prolonged geomagnetic disturbance. Our analysis will assess the contributions of Joule heating, altered F-layer chemistry, plasma transport and solar-photon replenishment to the very low topside densities observed during the April 2002 magnetic storm, but not in other storms.

## SA21B-0460 0830h POSTER

### The Morphology of Equatorial Plasma Density Depletions Observed by GUVI

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The Global Ultraviolet Imager (GUVI) on NASA's Thermosphere Ionosphere and Mesosphere Energetics and Dynamics (TIMED) detected dark features mostly extended in the north-south directions in the low-latitude region. Comparisons of the GUVI images with the radar observations at Sao Luis in Brazil indicated that the occurrence of the dark features were closely related to the development of plumes to higher altitudes. The coincidence observations of the plasma density from the ROCSAT and DMSP satellites further verified that they were produced by the plasma bubbles. The bubble signatures were most pronounced near the equatorial ionization anomalies owing to the bright background. The dark features were mostly tilted westward and, occasionally, a whole arch shaped depletion layer was observed on one orbit. GUVI images showed first time the global view of the westward tilt of the plasma bubbles, which supports the presence of the vertical shear, i.e., an increase of the zonal plasma drift velocity with altitude in the topside ionosphere.

SA21B-0461 0830h POSTER

## TIE-CGM Simulation of the Low-latitude Topside Ionospheric Responses to the April 17-24, 2002 Storms and Comparison with the ROCSAT-1 and ionosonde Data

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We have run the TIE-CGM model to study of the low-latitude topside ionospheric responses to the April 17-24, 2002 storms. The results of the storm disturbance dynamo effects on the vertical and zonal flow variations as well as the density variations are compared with the ROCSAT-1 observations at the 600 km altitude and the ground ionosonde data. In particular, we have investigated the mechanism in the TIE-CGM model to produce the observed different time-scale effects in the disturbance dynamo on the rises and decays of the zonal flow component in comparison with the vertical flow component.

SA21B-0462 0830h POSTER

## Search for solar connections in neutral winds at 80-100 km by MF/Meteor radars in April 2002

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During the CEDAR-TIMED storm campaign in April 2002, Medium Frequency and Meteor Wind radars at more than 20 worldwide locations provided continuous wind measurements in the altitude range of 80-100 km. Preliminary results show that the zonal mean winds and amplitudes of the diurnal tide at low latitudes, such as at Kauai (22N) and Rarotonga (22S), are much larger during the first half of the month compared to the second half of the month. This phenomenon may be related to variations in the solar flux. Winds at high latitudes such as at Andenes (67N) show a significant change in the pattern presented in geomagnetic coordinates during the storm on April 17th, which may be related to the change in geomagnetic activity. Wind structures in the mesopause region are extremely complex. Large variations were observed at various radar locations, which may be caused by planetary waves and tides, that may mask the effects of geomagnetic storms.

URL: http://www.haystack.mit.edu/~szhang/mfr-apr.html

SA21B-0463 0830h POSTER

## Did the April 14-24 storms impact the mesopause region sodium density, temperature and wind over Fort Collins, CO (41N, 105W)

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The April 14-24 storms is under intense study to determine, among other things, its MLTI response. The change in sodium density, neutral temperature and winds in the mesopause region (80-110km) is a useful signature to look for. The Colorado State Sodium Lidar happened to have made nocturnal observations of sodium density, neutral temperature and zonal wind in April, 8th, 12th, 13th, 18th, and 22nd through 25th. We hope to determine and report if statistically meaningful changes in these important quantities had indeed occurred.

SA21B-0464 0830h POSTER

## Lower Thermospheric Dynamics During April 2002

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During geomagnetically undisturbed conditions the large-scale dynamics of the lower thermosphere are governed by solar atmospheric tidal perturbations which may be modulated by other more transient large-scale waves. Signatures of these waves are inherent in TIMED measurements, but they are difficult to resolve because the satellite measures convolved spatial and temporal perturbations. The dynamical signatures of the lower thermosphere are further complicated by the downward penetration of storm effects during geomagnetic disturbances. We quantify the global-scale wave signatures and their modulation during the April 2002 solar storms as modeled by the National Center for Atmospheric Research (NCAR) thermosphere-ionosphere-mesosphere- electrodynamics general circulation model (TIME-GCM). We also analyze the subset of these results that would be obtained if the TIMED satellite flew through the NCAR TIME-GCM domain.

SA21B-0465 0830h POSTER

## The Investigation of Structures in the Meinel OH Bands and the Oxygen Infrared Atmospheric Bands Observed During the April 2002 Solar Storms Observed With the OSIRIS Imager on the Odin Satellite

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The OSIRIS Imager made observations of the neutral atmosphere before, during and after the solar storms of April 2002. It is shown that the airglow structures in the oxygen infrared atmospheric bands are essentially the same during the entire period and there is no apparent response in the mesospheric neutral atmosphere chemistry to the solar flare. The tomographic analysis of the OH band emissions shows that extensive dynamic structures are the typical situation in the airglow and that the presence of any enhanced gravity wave effects is not easily identified. In this paper the dynamic structures observed in both the oxygen and OH airglows are described and it is suggested for the wavelength scales that can be observed with the imager that the mesosphere was essentially unperturbed by the solar flares.

SA21B-0466 0830h POSTER

## Observations of the April 2002 Storm Period with TIMED-TIDI

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TIDI is meeting its basic requirement, which is to measure the global wind field in the mesosphere and lower thermosphere, the core study region. Since February 2002, TIDI has been in a routine science data-taking mode. During April 2002, TIMED was positioned at a high beta angle (angle between the plane of the satellite orbit and the Earth-Sun line) resulting in a series of TIDI measurements near the dusk/dawn terminator. The field of view of TIDI allows it to obtain measurements from pole to pole, while the repetition rate of the sky-scanner allows it to obtain several scans within the auroral oval region on each orbit. This paper will discuss TIDI measurements obtained during the April 2002 storm period, including OI (5577) intensity data and neutral wind data sets.

SA21B-0467 0830h POSTER

## Global Observations of $O/N_2$ in Earth's Thermosphere During the April 2002 Sun-Earth Storms

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During the period of April 14-24, 2002, a series of solar disturbances began several chains of events that influenced geospace. Earth's thermosphere is one endpoint for these chains. The Polar spacecraft was in a unique position to observe the end effects on the thermosphere. During April 2002, the 8 $R_E$ apogee altitude of the Polar orbit was near the equator at approximately 1000 local time. The ultraviolet sensitive Earth Camera of the Visible Imaging System on the Polar spacecraft acquired global images of Earth's dayglow through a broadband filter at FUV wavelengths. For this filter, percentage variations in dayglow intensity relative to quiet times across the dayside hemisphere are related to variations in the $O/N_2$ ratio of the thermosphere. An initial small decrease in the O/N2 ratio was observed on April 17, 2002. The $O/N_2$ ratio reached a maximum depletion of 45% during the magnetospheric storm on April 19, 2002 at 1907 UT. Full recovery of the $O/N_2$ ratio followed in less than 36 hours. The $O/N_2$ depletions were located in the polar regions and extended to mid-latitudes in both the northern and southern hemispheres. These depletion regions were highly structured and differed significantly between the hemispheres. The variability of the solar EUV photon flux can be observed in the hemisphere-integrated dayglow intensities and must be taken into account in order to obtain accurate retrieval of the $O/N_2$ ratios.

### SA21B-0468 0830h POSTER

## The Response of Thermospheric Nitric Oxide to the Geomagnetic Storm of April 2002

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The presence of nitric oxide in the lower thermosphere is important for several reasons. NO plays a strong role in the thermospheric energy balance as it emits efficiently in the infrared, it is the terminal ion in the lower ionosphere and, if transported to lower altitudes, will catalytically destroy ozone. NO is primarily produced through the reaction of excited atomic nitrogen with molecular oxygen. One of the primary loss mechanisms of NO is photodissociation by solar ultraviolet irradiance. In order to produce the excited atomic nitrogen atom, the strong N2 molecular bond must be broken. It has been shown that at high latitudes, auroral electrons and the energetic secondary electrons provide the source of energy that leads to the large amounts of NO that are observed. The Student Nitric Oxide Explorer (SNOE) satellite has been observing NO in the thermosphere daily since February of 1998. Global observations of the abundance of NO were made throughout the period of the large geomagnetic storm that occurred April 16-20 of 2002. Large increases in NO abundance were observed during the storm. Auroral production of the NO is demonstrated by the distribution with magnetic latitude. Equatorward enhancement of NO was observed and suggests transport by meridional winds. Because the NO molecule has a lifetime of about one day, a high latitude observation of NO provides an indication of the integrated auroral energy deposition over the previous day. In this talk we will present the NO observations during the time period of the storm. We will also compare the observations to results from the ASPEN version of the TIME-GCM model now in use at SWRI.

### SA21B-0469 0830h POSTER

## Comparison of the TIMEGCM model to Jicamarca and Arecibo measurements during the April 2002 World Day observations

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The April 2002 ISR World Day observations spanned both a very calm time period and a time of intense storm activity lasting several days. This dataset provides an ideal setting to evaluate the response of the Thermosphere Ionosphere Mesosphere Electrodynamic General Circulation Model (TIMEGCM) for unusually stressed space weather conditions. We make comparisons between TIMEGCM and both an equatorial station (the Jicamarca Radio Observatory) and a midlatitude station (the Arecibo Observatory), both of which were collecting data during this time period. Parameters used in this comparison include the electron density, ion and electron temperatures, ion velocities, and the neutral wind. There are many regions of good agreement between the model and the data, and we identify areas where the model could be improved.

### SA21B-0470 0830h POSTER

## Thermospheric Density Response to Solar Disturbances During April 15-24,2002: CHAMP/STAR Accelerometer Measurements

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During April 15-24, 2002, disturbances originating on the Sun were manifested in the upper atmosphere of Earth through the deposition of particle, field, and photon energy. In the present work, the response of total mass density near 410 km is investigated through STAR accelerometer measurements on the CHAMP satellite. Data are available near 1500 LT and 0300 LT from 87°S to 87°N latitude. The latitude vs. time response of the upper atmosphere is thus revealed on both the day and night sides of the Earth. Perturbations over quiet levels of order 50-100% occur. A variety of density enhancement and depletion structures are also apparent at high latitudes.

### SA21B-0471 0830h POSTER

## A study of shear in the neutral wind during geomagnetic storms

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A good assumption in most cases, and one that is used often as a boundary condition, is that there is very little shear in the neutral wind in the thermosphere. However, we have noticed that in cases of strong density perturbations, such as a sudden rise in the height of the F peak, there are often strong shears in the neutral wind as ion drag drives the wind, overpowering viscocity. On April 17, 2002, during an intense geomagnetic storm, there was strong electron density depletion over the Arecibo Observatory accompanied by a significant shear in the neutral wind. Neutral winds over Arecibo are calculated using the standard Burnside method, and we compare the results to FPI measured winds to ensure that we reproduce the correct trend. We compare the predicted neutral wind from TIMEGCM to the calculated wind over Arecibo, and note that TIMEGCM does not predict this shear. We present a local model based on first principles to attempt to recreate this shear. We also compare the forcing terms from TIMEGCM, our local model, and the actual data.

### SA21B-0472 0830h POSTER

## Analysis of the April 2002 Geomagnetic Storm Effect on Global $CO_2$ Infrared Limb Emission as Observed by TIMED/SABER.

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The SABER instrument on TIMED is continuously measuring limb radiance profiles of $CO_2$ $\nu_3$(4.3-$\mu$m) and $\nu_2$(15-$\mu$m) with unprecedented sensitivity. SABER provides limb radiances up to 130km for the 15- $\mu$m channel and 140-150km (approaching 200km during strong aurora) for the 4.3-$\mu$m channel. During the April 2002 geomagnetic storm the 4.3-$\mu$m band nighttime emission which also includes aurorally excited $NO^+(v)$ emission above about 100km responded dramatically. In the auroral region limb radiance was enhanced by more than a factor of 20 above the quiescent nighttime levels, at times being as bright as the daytime emission. The enhancement expanded equatorward as the storm effects intensified. However, the $CO_2$ 15-$\mu$m band was not significantly enhanced. We will examine the global behavior of the limb radiance, including other bands such as the $O_2$ $^1\Delta_g 1.28-\mu$m band and the 2.0-$\mu$m band, and TIMED GUVI EUV atomic oxygen and molecular nitrogen emissions, in an effort to distinguish direct auroral excitation from storm related temperature and composition changes.

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# SA22A MCC: 124 Tuesday 1330h

## Extracting Power from Multiple Rivers of Data II *(joint with SH, SM)*

***Presiding:*** **J W Hughes,** Boston University**; R A Behnke,** National Science Foundation

### SA22A-01 1330h INVITED

## Data Assimilation In Models: The Time Has Come

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Models of the space environment are maturing; at the same time, increasing amounts and kinds of observational data are becoming available. If meteorological modeling experience is any guide, the development of physics-based space environment models that assimilate multiple data streams, during the model calculation, will improve our understanding of the physical processes at work. This type of data assimilation is quite different from using observations to set initial or boundary conditions on models. The need for data assimilation was recognized by the National Research Councils recent Decadal Survey of solar and space physics.

This talk sets the stage for this session by presenting the case for building data assimilation into models of the space environment. I will show the remarkable abundance of data quantity and types that will become available in the next few years. Some of the data will be available in real time; other data will become available later to provide a more comprehensive description of an event. The benefit of using contemporaneous in situ and remote sensing (perhaps from multiple perspectives) observations in models will be illustrated by cartoon examples.

### SA22A-02 1350h INVITED

## Atmospheric data assimilation for scientific and operational purposes.

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Data assimilation can be thought of as a mathematical technique for updating the fields of a forecast model in a controlled manner with information obtained directly by observations. The technique was originally developed for numerical weather prediction purposes, and much of the progress obtained in this field over the past few decades has been made possible by advances in data assimilation algorithms. These algorithms are now being applied also in other areas of the atmospheric sciences (e.g. atmospheric chemistry and climate research), as well as in other geo-sciences (most prominently in oceanography). In this presentation, we will give an introduction to the conceptual framework upon