studies. Carbon dioxide also absorbs solar radiation in the near-infrared bands resulting in noticeable heating in the mesosphere and providing a correction to the cooling. Long-term observations reveal strong upward trends of the water vapor content in the stratosphere and possibly in the mesosphere over the last four decades. Additional H_2O cooling in the infrared rotational and 6.3-μm bands as well as solar heating in the near-infrared bands have not been previously accounted for in simulations of long-term changes in the mesosphere and thermosphere. These additional radiative processes have recently been incorporated into the Spectral Mesosphere/Lower Thermosphere Model (SMLTM). Their possible effects on long-term trends in the thermal and density structure of the mesosphere and thermosphere over the recent decades will be discussed.

SA53A-03 1400h INVITED

Apparent Detection of Global Anthropogenic Effects Extending Into the Thermosphere

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From a study of long-term orbital decay of Earth satellites, it has been discovered that thermospheric densities have declined substantially since at least 1976. Detection of this decline was first published by Keating et al (2000) in Geophysical Research Letters. They performed an analysis of 5 Earth satellites with periapsis altitudes near 380 km. The study was conducted for conditions near solar minimum to remove the effect of the 11-year solar cycle. Comparisons were made with a standard empirical density model to remove the effects of variations in solar and geomagnetic activity, altitude, season, latitude, time of day, etc. In that article, it was proposed that the cooling trend was caused by anthropogenic effects. Now the data set has been expanded to 14 satellites near 380 km to obtain an improved estimate of the trend and to establish possible variations in the trend. In the new study, the average trend from 1976-1996 is found to be minus 10.3 plus or minus 1.2 percent. This is in accord with the 2000 paper, which gave an average trend of minus 9.8 plus or minus 2.5 percent. The new results show statistically insignificant differences between the trend at low and high latitudes indicating a global response with no significant correlation to geomagnetic activity variations. The results appear to be in accord with theoretical model estimates for the response of the thermosphere to increases in CO2 and CH4 predicted by Roble and Dickinson (1989), Rishbeth and Roble (1992), and Akmaev and Formichev (2000). A paper by Emmert et al (2004) using a similar approach of studying the orbital decay from 27 satellites qualitatively confirms the downward trend originally discovered in the 2000 paper. All 27 of the satellites they studied indicated a downward trend. Twenty of the 27 satellites experienced a decrease in thermospheric density at somewhat higher altitudes, between 500 and 700 km. It is estimated that CO2 will double before the end of this century. Exponential extrapolation of the observed trend indicates densities near 400 km may decrease over this time interval by approximately 50 percent due to the strong anthropogenic cooling of the thermosphere.

SA53A-04 1420h

Long-Term Thermospheric Trends Based on Satellite Drag Analysis

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A new database of thermospheric densities has been derived for the period 1970 - 2000 from satellite orbital decay analysis. The data are generated from actual radar tracking observations, rather than from the less accurate historical element sets, to form precise orbit and drag/density data with improved accuracy and one-day resolution. Satellites with high eccentricities were used to achieve long lifetimes and relatively localized latitude and local time resolution. Data are compared to three empirical models (Jacchia, NRLMSIS and NASA MET). The data were normalized to remove systematic model errors vs solar activity detected in all three models. A linear regression through the normalized data was obtained for each satellite. The weighted average of these fits show, at 400 km altitude, a downward trend of about 5% over 30 years with a 95% confidence interval of about 25%. The data are also analyzed as a function of altitude, solar flux and geomagnetic activity, and compared to theoretical predictions. Assuming a linear fit, these results tend to agree with other recent studies indicating a long-term cooling trend in the thermosphere.

SA53A-05 1435h

A Long-Term Decrease in Thermospheric Density During 1966-2001 Derived From Orbit Data

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The orbital decay rates of long-lived near-Earth space objects indicate a secular decrease in thermospheric density during the period 1966-2001. Over the 200-700 km height range, the trend varies from -6% per decade at solar minimum to -2% per decade at solar maximum. With all solar activity levels combined, the trend increases from -2% per decade at 200 km to -4% per decade at 700 km. The trends do not show a noticeable dependence on geomagnetic activity, local time, season, or latitude. Our results are consistent with the predicted effects of increasing greenhouse gas concentrations. We examine several potential sources of error in our analysis and assess the extent to which they could impact the results.

SA53A-06 1450h

Modeling of Thermospheric Density Variations using Solar EUV Measurements

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In order to interpret inferences of secular change in thermospheric density, an accurate theoretical understanding of solar rotational and solar cycle influences must be obtained. Since the launch of the TIMED satellite in late 2001 and the SORCE satellite in early 2003, improved quantification of solar EUV and X-ray irradiance and variability has become available. In this study, we compare these recent solar observations to measurements of thermospheric density obtained from changes in satellite orbits. Two approaches are adopted: correlation of the satellite drag data to various bands in the solar spectrum, and comparison with simulations using the NCAR Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM) with measured solar inputs. Although the solar measurements are not yet of sufficient duration to fully characterize the solar cycle behavior, the model response to rotational and impulsive forcing can be validated with the satellite drag data.

SA54A CC: 518 C Friday 1530h

Global Change in the Upper Atmosphere and Ionosphere III *(joint with SM)*

Presiding: **S Solomon,** National Center for Atmospheric Research**; E P Shettle,** Naval Research Laboratory

SA54A-01 1530h

Long Term Trends in the Lower Ionosphere Below About 120 km

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The increasing concentration of greenhouse gases in the atmosphere cools the mesosphere and lower themosphere region. The cooling affects various lower ionosphere parameters. A brief overview of long term trends in the ionized component in the lower ionosphere is presented. Below about 87-90 km, the rocket measurements of electron density, the indirect phase reflection height measurements and the A3 radio wave absorption measurements reveal a trend of general increase of electron density at fixed heights corresponding to cooling and shrinking of the mesosphere and related changes in minor components (NO). Above 90 km, rather scarce rocket measurements display a negative trend in electron density, while ground based measurements support a positive trend. Global ionosonde network provides a slight increase of foE and a slight decrease of hE, and the nighttime LF radio wave reflection height measurements indicate increasing electron density near 95 km. The discrepancy between rocket and ground based results is briefly discussed. This work was made for the IAGA/ICMA joint working group Long Term Trends in the Mesosphere, Thermosphere and Ionosphere.

SA54A-02 1545h

Optimally Estimated Msesospheric Ionization and Dynamical Structure From Medium Frequency Radar Measurements

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We describe the application of an optimal estimation inverse method to determine mesospheric electron densities from partially reflected medium frequency polarimeter radar pulses. The method allows us to retrieve both an electron density profile and an electronic structure profile. As well as accounting for the absorption of the two magnetoionic modes formed by ionospheric birefringence of each radar pulse, the forward model of the retrieval parameterises possible Fresnel scatter of each mode by fine electronic structure, phase changes of each mode due to Faraday rotation and the dependence of the amplitudes of the backscattered modes upon pulse width. Monthly mean retrievals from a six year data set (1994-1999) have been processed. Retrieved electron densities are consistent with accepted ideas about seasonal variability of electron densities and their dependence upon nitric oxide production and transport. Retrieved electronic structure values show seasonal variability of ionospheric discontinuity which confirms the predicted seasonal variability of gravity wave breaking height regimes.

SA54A-03 1600h INVITED

Long-term Change in the Ionosphere - Achievements and Challenges

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It is now twelve years since the first results were published showing a trend in the height of the F-region ionosphere. A large number of data sets have since been

analysed by numerous researchers and the picture presented is far from globally consistent. This paper will summarise the past achievements, discuss why some of the current inconsistencies arise and look at the challenges ahead.

SA54A-04 1620h

Trends in Ionospheric Measurements: Techniques and Results

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Detecting trends is identifying a change which is large relative to natural variability. Often, trend detection requires several decades or more of data rendering few datsets useful for long-term trend evaluation. Measurements of several ionospheric parameters, including critical frequencies and layer heights, have been collected routinely for more than 50 years. Historically, the data have been used to assess ionospheric processes relevant to communications, aviation, and satellite navigation. More recently, however, the data have been explored for their suitability for detecting anthropogenic climate change. Results based on analyses of the observations have been reported in the scientific literature and are often conflicting. The apparent disagreements are not entirely surprising and are due, in part, to the myriad of complexities of the data. The ionosphere is a region of large short-term and long-term variability confounding our ability to detect trends.. The E and F2 critical frequencies and layer heights, for example, are strongly affected by solar as well as geomagnetic cycles, and their influences must be well understood before a trend assessment can proceed. Three factors play equally in determining trends in the ionosphere: understanding the existing variability, understanding the quality of the data and applying appropriate statistical techniques which incorporate what we currently understand about the data. Initial results regarding all three of these factors and how they affect trends derived from ionosound data will be presented. The challenges concerning proper quality assurance and analysis will require further resolution before the contributions of natural variability on the ionosphere can be identified and separated from long term trends. Preliminary results will be presented for a select number of stations. The dependency of these results on quality and physical assumptions will be discussed.

SA54A-05 1635h

Observations of Solar Cyclical Variations in Geocoronal Hα Column Emission Intensities

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Understanding the influence of the solar cycle variation on the Earth's upper atmosphere is important for determining the basic state of this region, as well as for distinguishing between natural variability and possible observational signatures of climate change [*Roble*, 1995]. Atomic hydrogen spans the thermosphere and exosphere, becoming increasingly dominant with altitude. Geocoronal hydrogen is the byproduct of middle and upper atmospheric chemical, photolysis, and charge exchange reactions involving its hydrogenous source species below such as methane, water vapor, and molecular hydrogen. Observations of thermospheric+exospheric Hα column emissions by the Wisconsin Hα Mapper (WHAM) Fabry-Perot (Kitt Peak, Arizona) over the 1997-2001 rise in solar cycle 23 show a statistically significant solar cycle variation. The variation observed by WHAM in the thermospheric + exospheric hydrogen column emission intensities over the solar cycle is small compared with variations in hydrogen exobase densities, and the solar excitation flux, with higher Hα emissions seen during solar maximum periods of the solar cycle. The magnitude of the increase in these Hα column emission intensities between solar minimum and solar maximum conditions depends upon viewing geometry; at the mid range shadow altitude of 3000 km, WHAM terrestrial Hα column emission intensities are about 45% higher during solar maximum conditions. The higher signal-to-noise WHAM observations corroborate suggestions of a solar cycle trend seen in Wisconsin Hα emission observations over the previous solar cycle (cycle 22). We present comparisons of WHAM 1997 and 2000-2001 winter solstice Hα observations toward regions of the sky with low galactic emissions. We will also show analysis currently in progress to compare these data with those taken during the previous solar cycle (cycle 22). We will discuss factors necessary to isolate possible geophysical trends from long term comparisons of thermospheric + exospheric Hα emission observations. Requirements include a stable calibration source, cross-calibrated, well-understood instrumentation, reproducible observing conditions, separation of the terrestrial from the galactic emission line, and consistent data analysis, accounting for differences in viewing geometry.

SPA-Solar and Heliospheric Physics

SH13A CC: 518 C Monday 1330h

Fresh Perspectives in Solar-Heliospheric Science I

Presiding: **I G Richardson,** NASA Goddard Space Flight Center**; E J Smith,** Jet Propulsion Laboratory, California Institute of Technology

SH13A-01 1330h INVITED

Ubiquitous Energy Dependence of Ionic Charge States - Challenge and Opportunity

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Early observations of ionic charge states in energetic particles had drawn a relatively simple picture: strong CME-related energetic particle events resembled the charge states of coronal material, while impulsive flare events were characterized by rather high charge states with full ionization for elements up to Mg. In other words, the charge state of energetic particles appeared to reflect nothing but the charge distribution at the source, with no modification in energy. However, the advent of high collection power and resolution instrumentation on ACE, SAMPEX, and SOHO that covers a wide range of energies from the potential sources to several MeV/nuc has revealed an almost ubiquitous presence of energy dependence in the charge states under a wide variety of circumstances. In particle populations that clearly originate from interplanetary acceleration a modest increase in the charge state of Fe with energy is observed that can be explained in terms of rigidity dependent acceleration and loss mechanisms. In several strong solar energetic particle events with unusual composition signatures and in impulsive flare events a very steep increase of the charge state with energy has been observed, which has been shown to be consistent with the effects of stripping for higher energy ions when escaping through a large column density of material. For impulsive events this lends independent support for the idea that the combination of selective acceleration and almost fully stripped ions up to Mg requires a similar scenario. Finally, contributions from sources with different composition and acceleration efficiencies can explain the observation that the He+/He2+ ratio increases with energy for many of the observed episodes. The observed variety of observations poses the challenge to sort out confusing combinations of phenomena, but on the other hand it also provides the opportunity to probe source combinations, acceleration, and escape mechanisms.

SH13A-02 1350h

The Interstellar Boundary Explorer (IBEX)

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The Interstellar Boundary Explorer (IBEX) is one of five Small Explorer (SMEX) missions undergoing Phase A study for NASA's Office of Space Science. Around November 2004, NASA expects to select two of these five missions for development and flight. If selected, IBEX will provide the first global views of the Sun's interstellar boundaries by taking a set of global energetic neutral atom (ENA) images at a variety of energies. Recent advances in ENA imaging have made it possible to remotely image space plasmas and ENA imaging is now poised to image the interstellar interactions and interstellar boundaries at the edge of our heliosphere. On IBEX, these groundbreaking ENA observations are achieved with high sensitivity measurements provided by two very large aperture ENA cameras, using heritage technologies, on a simple spinning spacecraft. IBEX's highly elliptical Earth orbit provides viewing of the outer heliosphere from beyond the relatively bright emissions of the Earth's magnetosphere. IBEX's sole, focused science objective is to discover the global interaction between the solar wind and the interstellar medium. IBEX achieves this objective by answering four fundamental science questions: (1) What is the global strength and structure of the termination shock, (2) How are energetic protons accelerated at the termination shock, (3) What are the global properties of the solar wind flow beyond the termination shock and in the heliotail, and (4) How does the interstellar flow interact with the heliosphere beyond the heliopause? The IBEX objective is central to the Sun-Earth Connection (SEC) theme as demonstrated by both the 2003 SEC Roadmap and 2002 NRC's Decadal Survey and is specifically identified in the 2003 NASA-wide Strategic Plan. In short, the IBEX mission provides the first global views of the Sun's interstellar boundaries, unveiling the physics of the heliosphere's interstellar interaction, providing a deeper understanding of the heliosphere and thereby astrospheres throughout the galaxy, and creating the opportunity to make even greater unanticipated discoveries.

SH13A-03 1405h

Travelling interplanetary shocks: their local orientations and inference of their global characteristics

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The orientation of the evaluated normal direction to the interplanetary shock tells us of its local propagation in the interplanetary medium. It has recently been established for case studies like the Oct 19, 1995 and the July 15, 2000 (1) interplanetary magnetic clouds that the orientation of the respective shock normals appear consistent with their overall evolution, e.g., orientation and propagation of the driver. We test this result for a series of shocks observed simultaneously at widely extended locations. Preliminary single case studies (Jan 1978, Sept 1978, and Apr 1979) are used to infer the global geometry of the shock. We examine the relationship between the existence of a strong shock and the level of energization and intensity of the gradual solar energetic particle events. We will test hypotheses on the possible correlation between the extension of the strong shock and the level of energization and flux intensity observed for gradual solar energetic particle events. For selected cases, we also apply type II radio burst remote sensing using ISEE-3 radio data. Also we compare with some unusual shocks of the current solar cycle. For this purpose we will mainly use Wind magnetic field and plasma data from the MFI and SWE instruments, as well as radio emissions from its radio receiver WAVES. The shock normal will be tested against shock passage at other spacecraft (ACE, IMP-8). [(1) see e.g. Lepping et al, Sol Phys, 204, 287, 2001.]

SH13A-04 1420h

Opening a New Window on the Inner Heliosphere: Remote Characterization of Particles and Fields With Emerging Low-Frequency Radio Telescopes

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We present the results of an ongoing study of the potential for conducting solar and heliospheric science with next generation low-frequency digital aperture synthesis radio interferometers. These new designs for ground-based radio observations build on the rapid advancement in computing power and network bandwidth to enhance observational capabilities. The signals from each antenna may be digitized and sent to a central processing facility for simultaneous aperature synthesis in multiple directions limited solely by the available computing power. Tracking of sources from many locations coupled with sophisticated real-time models of the ionosphere permit the extension of measurements to previously unexplored low-frequencies. It is possible that these telescopes could be used to remotely measure magnetic field and density structures from the corona out to 1 AU. Our study has focused on the baseline design for the Low Frequency Array (LOFAR), a potential future radio array which would operate in the frequency range of about 40 to 240 Mhz. In the current design LOFAR is a centrally-condensed array with 25% of the collectors within a 2 km diameter, 50% within 12 km, 75% within 75 km, and the remainder extending to 400 km. We have identified promising capabilities in the Wide-Field Correlator (WFC) design for LOFAR that would permit new observations of the state of the inner heliosphere. An All-Sky Monitor (ASM) making use of the WFC could produce images of the heliosphere at a cadence of half a second with sub arc-minute resolution. These images could then be used to reconstruct the Faraday Rotation (FR) due to the magnetic field of the inner heliosphere. The output from the WFC could also be used to simultaneously monitor several hundred sources for interplanetary scintillations (IPS). The new observations possible are outlined in a series of case studies. It is shown that there are a sufficient number of linearly polarized extra-galactic sources for the telescope to monitor the FR of about 1,000 sources within 30° of the Sun. Simulations of transient Coronal Mass Ejections suggests that flux ropes could be detected in up to 10,000 sources in the case of Earthward directed events, and that these observations could be used to determine the magnetic topology of the CME ejecta. IPS at lower frequencies could detect the formation of interaction regions and the evolution of interplanetary shocks.

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SH13A-05 1435h

Multispacecraft Views of Global Heliospheric Structure

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