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**Precipitating radiation belt electrons and enhancements of hydroxyl in the mesosphere during 2004-2009**

Monika Andersson

Energetic particle precipitation leads to enhancement of odd hydrogen (HOx) below 80 km altitude through water cluster ion chemistry. Using measurements from the Microwave Limb Sounder (MLS/Aura) and Medium Energy Proton and Electron Detector (MEPED/POES) between 2004-2009, we study the effect of energetic electron precipitating from radiation belts onto nighttime OH at geomagnetic latitudes 55-65 ˚N/S. Our analysis indicates that electron precipitation has a clear effect on OH mixing ratios at altitudes above 50 km during time periods when high electron count rates are observed. At 75km, in about 34% of the 65 months analyzed we find a correlation r>=0.35 (corresponding to random chance probability lower than 5%) and 10 of these have r>= 0.6. Although similar results are obtained for both hemispheres in general, in some cases the differences in atmospheric conditions make the OH response more difficult to detect in the South. Considering the latitude extent of electron forcing, we find clear effects on OH at magnetic latitudes 55-72˚, while the lower latitudes are influenced much less. Because the time period 2004-2009 analyzed here coincided with an extended solar minimum, and the year 2009 was anomalously quiet, it is reasonable to assume that our results provide a lower-limit estimation of the importance of energetic electron precipitation at the latitudes considered.

**Variability of the Polar Night Upper Stratosphere/Lower Mesosphere Region from MERRA, SOCOL and HAMMONIA**

Natalia Andronova

The variability in the polar stratospheric ozone content is a potential driving force in the solar forcing amplification mechanism for two important reasons: (1) the variability of the ozone content is sensitive to atmospheric reactive species, such as nitric oxide (NO) produced by solar particle precipitation (SPP); and (2) it is closely connected to distributions of the lower- and middle-atmosphere‚ temperature and winds, which indirectly define the variability of terrestrial climate. Our overarching goal is to uncover the role of auroral (low-energy SPP) particles that precipitate into the Antarctic region during polar nights in linking the lower thermosphere, in which NO is produced, and the stratosphere, in which ozone is depleted. In particular, we are trying to separate the in situ effects of high- and medium-energy SPP (directly -- if rarely -- deposited into the lower atmosphere) from the indirect effects of weaker (but constantly deposited) particles. We consider SPP with energies below 150keV, which occur within the auroral oval zones and do not penetrate below an altitude of 100 km. To this end, we used a version of MERRA reanalysis data, which spans vertically up to 78 km. To constrain the information on downwelling favorability within the polar vortex, we applied indices of the polar vortex and geomagnetic activity strength. Initially, we used temperature to diagnose components of the Volume Variability index calculated over the Northern and Southern Hemisphere Polar Regions for the 55-90 N and S latitude band between 30km and 78km vertically, for the month of July and January from 1997 onward. Between 1997 and 2010 there were approximately four SH winters with high Ap index values, and minimal values of Ap and temperature-based VarTz were observed during 2001-2003, where the strongest indirect effect of SPP has been initially attributed. We used corresponding data from SOCOL and HAMMONIA models to compare with MERRA results.

**Calibrated NOAA/POES energetic electron database**

Timo Asikainen

The NOAA/POES satellites have provided a valuable long-term database of low altitude energetic particle observations by the MEPED instrument spanning from 1978 to present. Recently we have corrected the proton fluxes of the entire NOAA database for the degrading effects of radiation damage and detector noise. While the electron detectors do not suffer from these problems, they have their own problematic issues for long-term homogeneity. It is well known that the MEPED electron detectors are contaminated by protons of certain energy range. Using the corrected proton fluxes we are now able to remove this contamination. We have also discovered that the SEM-2 version of the electron detector flown onboard the satellites since 1998 (starting with NOAA-15) displays systematically lower level of electron fluxes than the SEM-1 version. Here we show that this difference arises due to differences in SEM-1 and SEM-2 instrument construction, which affects the detector efficiency. We have estimated the detector efficiencies and used them to normalize the SEM-1 and SEM-2 electron fluxes to a comparable level. We present the entire time series of the electron fluxes and discuss the differences of the calibrated and uncalibrated fluxes as well as their long-term variation.

**Relationship between energetic particle precipitation and geomagnetic indices according to the corrected NOAA/POES database**

Timo Asikainen

Many studies concerning the effects of energetic particles precipitating from the magnetosphere into the atmosphere have used geomagnetic activity indices such as Kp (and Ap) as proxies for the intensity of this particle precipitation. Despite their good long term coverage these indices are only a proxy for the particle fluxes and the exact relationship between indices and fluxes is still somewhat unclear. To study this issue, we have used here over 30 years of energetic proton measurements from the NOAA/POES satellites, which have been corrected for the effect of radiation damage and detector noise. Here we review the problems of the NOAA/POES energetic proton data and the methods we use to correct them. We have compared the precipitating fluxes to several geomagnetic indices (Ap, AE and Dxt, a version of Dst). We find good overall correlation between the fluxes and the Ap/AE indices. The correlation with Dxt is somewhat smaller. We also note that the correction of the proton data increases the correlation with the indices significantly. However, while the overall correlation with indices is good, we find that the relationship between fluxes and indices is not constant in time, but displays systematic and quite large long-term variations. This should be taken into account when using geomagnetic indices as proxies for energetic particle precipitation in long-term studies.

**The Fate of Nitric Oxide Produced in the Polar Night**

Scott M. Bailey, Brentha Thurairajah, Justin D. Yonker, and Karthik Venkataramani

There is strong evidence that Nitric Oxide (NO) is a key coupling agent by which the magnetosphere channels solar energy through energetic particle precipitation in the polar night. While NO has long been understood as an important species in the upper atmosphere, its highly variable abundance remains poorly understood in the polar regions and especially during nighttime conditions. There is a large and rapidly growing body of evidence that NO created by energetic precipitating particles in the thermosphere is transported to the lower atmosphere during polar night, enabled by the lack of dissociating solar irradiance, where it has a significant and potentially long term effect on stratospheric ozone distributions. In this study we use the Whole Atmosphere Community Climate Model extended to the exosphere (WACCM-X) to examine the fraction of NO which is transported from the thermosphere to the stratosphere. Our approach is to use the WACCM-X winds and offline calculations of diffusion rates and chemical loss processes (using WACCM-X fields) to follow the trajectories of individual NO molecules. We calculate the lifetime of molecules in the thermosphere during polar night conditions, the fraction of molecules which are transported equatorward into the sunlight where they are rapidly destroyed, and the fraction which are able to cross the mesopause and eventually enter the stratosphere.

**Nitric oxide descent in 2008/2009 detected with SCIAMACHY**

Stefan Bender, M. Sinnhuber, M. Langowski, J. Burrows, M. Scharringhausen, B. Funke, M. López-Puertas

SCIAMACHY performed observations in the mesosphere and lower thermosphere (50-150 km) regularly twice per month; this new limb mesosphere-thermosphere (MLT) state was coordinated with the MIPAS upper atmosphere (UA) mode once every 30 days. We use the UV spectra measured by SCIAMACHY in the range 230--300 nm to retrieve the NO number densities from emissions in the gamma bands in the atmospheric region of interest. First results show that the vertical NO columns from 70 km to 140 km compare very well to MIPAS measurements. In the winter 2008/2009, in particular in late January 2009, a sudden stratospheric warming (SSW) occurred with the consequence that in the following weeks, the peak nitric oxide density descended from the lower thermosphere around 100 km down to 70 km. This event was observed by a number of instruments, such as MIPAS, ACE-FTS, and OSIRIS and SMR on ODIN. We present the results from our SCIAMACHY NO retrieval for this time. Achieving a vertical resolution of about 5--8 km in the altitude range from 70 km to 140 km and a horizontal resolution of about 9 degree, we are also observing a descent of the NO number density. Hence, our retrieval provides an independent verification of previously published observations of the NO in Jan/Feb 2009, both in absolute strength and in the altitude difference of the downward transport.

**The solar proton events in 2012 as seen by MIPAS**

Thomas von Clarmann

MIPAS is a limb emission Fourier transform spectrometer for measurements of atmospheric trace gases and temperature in the stratosphere and mesosphere. Its data products cover species relevant to the assessment of the atmospheric response to proton forcing, e.g., ozone, reactive species like NO, NO2 and ClO, reservoirs like HNO2, ClONO2, N2O5, as well as tracers like CH4, N2O, CO, and H2O. The temporal development of these species after the solar storms in January and March 2012 will be presented and discussed. Similarities and differences with respect to the Halloween solar storm in October 2003 will be highlighted.

**Determining energetic electron precipitation fluxes into the atmosphere**

Mark Clilverd

Satellite measurements of energetic electron populations are important in providing context for the impact and significance of different space weather events on the Earth's upper atmosphere. However, when it comes to determining the flux of energetic electrons that are precipitating into the atmosphere the picture is complex and incomplete. Satellite-based particle detectors trying to resolve the atmospheric loss-cone suffer from several issues including, being unable to observe the whole of the loss cone, the inclusions of a combination of loss-cone and trapped pitch angles, and contamination from energetic proton fluxes. These factors vary from measurement to measurement, event to event, and are difficult to correct with satellite datasets alone. In this work we describe several energetic electron precipitation events observed from satellite, and from the ground. We use sub-ionospheric radio propagation (AARDDVARK instruments), and trans-ionospheric radio propagation (Riometer instruments) to determine the levels of excess ionization at altitudes of ~50-85km during the events. The results are compared with equivalent satellite electron precipitation measurements, and some idea of the disparity between the measurement techniques is identified. As expected, the level of disparity is highly variable with satellite observations showing both increases and decreases in energetic electron flux during electron precipitation events, and the disparity between the measurement techniques varying by orders of magnitude from event to event.

**Wave Driven Circulation of the Wintertime Arctic Middle Atmosphere**

Richard Collins

Recent observations have highlighted how the middle and upper atmosphere circulation modulates the impact of solar processes on the atmosphere through transport of significant amounts of thermospheric NOx produced by energetic particle precipitation into the mesosphere and stratosphere. The wintertime Arctic middle atmosphere has been dominated by sudden stratospheric warming events (SSWs) where the wintertime circulation of the Arctic stratosphere and the polar vortex has been disrupted by breaking planetary waves. Strong vertical transport in these dynamically active winters has been associated with the reformation of the vortex in the mesosphere. We analyze the wave driven circulation in these winters using lidar, reanalysis, and satellite data. We use the lidar data to characterize the gravity wave activity in the stratosphere and mesosphere. We use the satellite and reanalysis data to analyze the synoptic structure of the polar vortex and the Aleutian anticyclone, the planetary wave activity, and the mean winds. We find considerable interannual variations in the level of gravity wave activity correlated with the level of disturbance of the circulation (e.g., no SSW, minor, SSW, major SSW, and elevated stratopause) and the synoptic structure. We examine the coherence of the synoptic structure in the stratosphere, mesosphere and lower thermosphere under different levels of disturbance. We interpret these findings in terms of recent results from the Whole Atmosphere Community Climate Model

**Unexpected behavior of subrelativistic electron fluxes under Earth radiation belts**

Oleksiy Dudnik

The analysis of electron flux variations under Earth radiation belts at heights ~550 km in May and August, 2009, is performed on the base of experimental data obtained from the satellite telescope of electrons and protons STEP-F as a part of scientific apparatus complex PHOTON on board the Russian spacecraft CORONAS-Photon. The temporal connection of particle intensity changes that were detected by the view cone of the device under radiation belts and in the South Magnetic Anomaly (SAA) zone with various phases of weak magnetic storm of May, 7-8, as well as with parameters of high speed solar wind streams are investigated. Changing electron fluxes in a wide range of energies are detected at any geographic latitude and longitude due to the large geometric factor of detectors (~21 cm2 sr), and associated with the dynamics of the solar wind parameters as well as with the growth of magnetospheric activity. Throughout the whole month, in the range of low and medium energies of electrons there were recorded 2 inner radiation belts: the main and famous one on L-shell ‚ 2.28, and sporadically appearing an additional inner belt on L-shell ‚ 1.61, where L is McIlwain parameter. The appearance of the latter belt at height 550 km as well as the particle fluxes in both belts has been depended on the level of geomagnetic activity. Both inner belts had registered on the geographic longitudes which are not coincided with those ones of SAA zone location.The next feature is the appearance of enlarged electron fluxes in inner belts followed by significant growth in the same energy ranges in the outer radiation belt at the initial phase of magnetic storm. It was repeated for both: weak magnetic storm of May, 7-8 (Dst <30 nT) and sub-storm of May, 14-15.The empirical values of various energy electron lifetimes in the basic inner and outer radiation belts are defined. The electron lifetime at low Earth orbits (LEO) is ~1.5 days for inner belt, and ~4.5 days for the same energy ranges. At the same time there is the tendency of lifetime declining in the outer radiation belt with the increase of electron energy as well as dependence of lifetime values as a function of pitch-angle at fixed energy. The most unexpected in the behavior of electrons with energies E<0.51 MeV in August, 8-10 were the registration of micro bursts of particles at low geographic latitudes and near equatorial zones, i.e. in those areas where they should not be detected at all according to the various models of radiation belts (AE8, SALAMMBO, SPENVIS, etc.). Duration of these bursts varies from few seconds to several ten seconds; the spectral flux density is close to that one in the basic inner radiation belt. August of 2009 was characterized by almost full absence of solar activity. The search of possible source of such unusual and sporadic electron fluxes in the southern near equatorial hemisphere had led to the hypothesis that mentioned electrons are connected with the strong Earthquake of magnitude 7.1 at Izu Islands, Japan region (August,9) and of magnitude 7.5 at Andaman Islands, India region (August, 10). Such possibility and features of micro bursts are discussed.

**Atmospheric Effects of Solar Spectral Irradiance changes**

Juan Fontenla

The possible solar influence on climate has been debated for a long time mainly in the context of Total Solar Irradiance (i.e. the integral across the spectra) variations. However, the strong influence of the XUV/EUV/FUV Solar Spectral Irradiance variations on the upper atmosphere has been long known by its photo-chemical, photo-ionizing, and heating effects. The complete Solar Spectral Irradiance (SSI) effects, however, are not so well known. Recent advances have occurred in atmospheric measurements. Also, advances occurred in solar observations and modeling, namely SORCE observations, non-LTE solar modeling by the Solar Radiation Physical Modeling project, and ground-based solar observations. These data are showing spectral variability different from the previously assumed. In this presentation we briefly show the new data and how we are investigating the different effects produced by these different SSI spectral variations. Our study add to other research ongoing on the subject of stratospheric effects from simplified models and consists of ongoing 50 year simulations using the CESM 1.0.3 (WACCM) with fully interactive deep ocean. Preliminary results will be shown that display interesting differences between conflicting models of spectral variability over the solar cycle. These differences affect not only the stratosphere but also apparently the troposphere, at least in the Pacific tropical and subtropical ocean. However, the results are yet preliminary since more instances are still in progress to quantify the natural variability and try to disentangle the various processes.

**Searching for lower mesospheric NOx production due to electron precipitation during 2008**

F. Friederich, M. Sinnhuber, T. von Clarmann, G. Stiller, and B. Funke

Electron precipitation can produce NOx (NO + NO2) from N2 by excitation, dissociation, and following ion chemistry reactions. Most of the NOx-production caused by electron precipitation takes place in the lower thermosphere (~110 km). We examine whether NOx can also be produced in situ in the upper stratosphere/lower mesosphere during geomagnetic storms by analyzing observations of NO and NO2 taken by the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) on ENVISAT. In order to avoid contaminations by descending thermospheric air masses, we restrict the analysis to polar summer conditions. In our study, we use a statistical approach (Superposed Epoch Analysis) to compare the NOx volume mixing ratio (vmr) observed in the Northern Hemisphere to the geomagnetic index Ap from 21 March 2008 until 7 October 2008. Although a positive correlation between 54 km and 62 km altitude has been found in the zonal band where the radiation belts intrude into the middle atmosphere (52˚N – 62˚N geomagnetic latitude), we show that this correlation is artificially caused by mapping of the thermospheric 5.3 µm signal into the NO retrieval in the lower mesosphere. The application of the statistical analysis to nighttime NO2 suggests that there is a no detectable NOx production by EEP as response to geomagnetic perturbations at lower mesospheric altitudes.

**Atmospheric measurements relevant to SOLARIS and HEPPA: What we have and what we need**

Bernd Funke

Atmospheric measurements from ground and space have significantly improved our knowledge on how the Sun is influencing the Earth's climate. This talk will give an overview on past and present observations of the middle atmosphere used in the analysis of the impact of solar irradiance variations and particle precipitation effects and will highlight the scientific advances achieved. Strengths and weaknesses of the employed observation techniques will be discussed and an attempt to identify the needs for future measurements in the context of open scientific questions will be made. Although this evaluation cannot be more than an individual point of view it is thought to stimulate the discussion on observational data needs for the HEPPA and SOLARIS communities in order to consolidate recommendations for future observations such as currently conducted within the SPARC measurement requirement initiative.

**Quantification of the stratospheric EPP-NOy deposition during 2002-2012 from MIPAS observations**

B. Funke, M. López-Puertas, G. P. Stiller, T. von Clarmann, S. Kellmann, and A. Linden

The MIPAS Fourier transform spectrometer on board Envisat has measured limb emission spectra in the mid-IR during 2002-2012. We have employed the scientific MIPAS level 2 processor developed and operated by the Institute of Meteorology and Climate Research (IMK) together with the Instituto de Astrofisica de Andalucia (IAA) to derive vertically resolved distributions of 6 principal reactive nitrogen (NOy) compounds (HNO3, NO2, NO, N2O5, ClONO2, and HNO4) with global coverage and independent on illumination (i.e., including the polar night). The obtained data set provides an unique climatological record of NOy in the middle atmosphere for a 10 years period. From this data set we extract the stratospheric contribution of NOy produced by energetic particle precipitation (EPP-NOy) be means of a tracer correlation method. Co-located CH4 observations from MIPAS have been used to constrain the stratospheric NOY-CH4 correlation and hence to distinguish between the stratospheric background produced by N2O oxidation and the contribution from EPP. In this presentation we discuss the latitudinal structure and the inter-annual variability of the derived excess NOy and its contribution to the global middle atmosphere NOy budget.

**Atmospheric coupling by planetary waves, gravity waves, and tides**

Larisa Goncharenko

The dynamics and phenomenology of the quiet time atmosphere are affected by vertical coupling through atmospheric waves (gravity waves, tides, and planetary waves) that propagate upward from the troposphere and stratosphere. Although wave amplitudes are small in the stratosphere, they reach significant magnitudes in the mesosphere and the lower thermosphere, where they deposit their momentum during break-up and dissipation. This talk discusses the fundamentals of wave-induced coupling and provides a perspective on the major manifestations and consequences of different waves in the atmosphere. Topics include generation of waves, wave/mean wind interactions, and upward wave propagation. Experimental and modeling evidence will illustrate how variations in the stratosphere are communicated upward, and how variations in the mesosphere/lower thermosphere are communicated downward, with specific examples for the periods of sudden stratospheric warmings.

**Observed solar cycle signal in the North Atlantic / European Region**

Lesley Gray

An analysis of long-term observations of mean sea level pressure and sea surface temperatures is presented. A statistically significant signal is found in the Atlantic / European sector that resembles the structure of the North Atlantic Oscillation (NAO). Knowledge of this solar cycle signal will provide very useful input to seasonal and decadal forecasting in this region.

**Small-scale structure in trapped and precipitating medium-energy electrons in the noon sector**

John Hargreaves

The spacial structure of, and relations between, trapped and precipitating fluxes of medium energy (>30 keV)electrons in the auroral region have been explored in the noon sector using observations from the Polar Orbiting Environmental Satellites. From a selection of overpasses from three years of differing solar activity, three types of relationship have been identified. It appears that two kinds of mechanism are involved, one (probably) pitch angle diffusion, and the other (possibly) involving structures within the magnetosphere. Some quantitative relationships are given.

**HEPPA-II Model Measurement Inter-comparisons with MLS and ACE**

V. L. Harvey, C. E. Randall, and the HEPPA-II MMI Team

We compare temperature and trace gas distributions in the Arctic middle atmosphere observed by the Microwave Limb Sounder (MLS) and by the Atmospheric Chemistry Experiment (ACE) to geolocated model output during the 2008-2009 winter. For this work, simulations performed by the following atmospheric models: the Bremen 3-D Chemical Transport Model (B3dCTM), Fin-ROSE, the Karlsruhe Simulation Model of the Middle Atmosphere (KASIMA), the ECHAM5/MESSy Atmospheric Chemistry (EMAC) model, and the Whole Atmosphere Community Climate Model (WACCM4) will be compared to MLS and ACE satellite observations. Model-measurement comparisons will quantify differences in temperature, O3, ClO, ClONO2, CH4, CO, H2O, HNO3, NO, NO2, N2O, and N2O5. Differences in CO, CH4, H2O, and N2O will reflect discrepancies between observed and modeled descent rates.

**Modeling transport of NOx created by energetic particle precipitation in WACCM**

Laura Holt

Energetic particle precipitation (EPP) creates NO in the mesosphere-lower thermosphere (MLT). Observations have shown that this EPP-created NOx (EPP-NOx) is transported from the MLT to the stratosphere during the polar night. Simulations from the Whole Atmosphere Community Climate Model (WACCM) also capture this phenomenon, but the amount of EPP-NOx transported to the stratosphere is underestimated in the model compared to observations. We do not yet know whether this is because of a problem with the model dynamics or with the EPP source (or both). In this poster, we explore the sensitivity of EPP-NOx transport to tuning the model dynamics. We compare results from several WACCM simulations for the 2003-2004 and 2005-2006 Arctic winters that are nudged with Modern-Era Retrospective Analysis for Research and Applications (MERRA) data to satellite observations.

**The Sea Level Pressure Response to 11-Yr Solar Forcing: Observational Analyses and Comparisons With Model Simulations**

Lon Hood

Evidence for a statistically significant response to 11-yr solar forcing of sea level pressure (SLP) during northern winter (DJF) in the Pacific sector has been obtained by a number of authors using long-term data records (e.g., Christoforou and Hameed, GRL, 1997; van Loon et al., JGR, 2007; Roy and Haigh, ACP, 2010). A multiple linear regression (MLR) analysis of Hadley Centre data over the 1850-2009 period confirms previous evidence for a positive response, on average, in the North Pacific during DJF under solar maximum conditions. This response represents a weakening of the climatological Aleutian low and the mean response in the Northern Hemisphere (NH) can be characterized to first order as ``La Nina-like'' and consistent with a positive phase of the Arctic Oscillation (AO).Here, we report a comparison study in which the same MLR statistical model is applied also to monthly mean model SLP data obtained from a series of simulations using an atmosphere-ocean GCM (EGMAM; Bal et al., GRL, 2011). The EGMAM model has no QBO and no interactive chemistry but it simulates a realistic ENSO and extends to a top level of 0.01 hPa. Previous results using a composite difference comparison method have shown that the model can simulate approximately the observed SLP response during northern winter for certain conditions during some centennial periods (Bal et al., 2011). Three 231-yr simulations were performed using sinusoidal 11-yr solar forcing. The assumed spectral irradiance change from solar minimum to maximum was consistent with the NRL SSI model. Several alternate 11-yr variations of ozone in the stratosphere are specified to account approximately for the solar-induced ozone response. For Simulation 1, the ozone variation was specified using 2D model calculations (Haigh, 1994). For Simulation 2, the ozone variation was specified at low and middle latitudes using observations (Soukharev and Hood, JGR, 2006). For Simulation 3, the ozone variation was as in Simulation 2 but was extended to high latitudes using offline 2D model calculations. Direct comparisons using the MLR method show that the DJF SLP response obtained from the simulation that assumed a solar cycle variation consistent with observations at latitudes less than 60 degrees, declining to zero at the poles (Simulation 2), yields the best agreement with the observed SLP response, at least during selected centennial periods. The other two simulations do not yield good agreement with the observed response during any centennial period. The sensitivity of the results to the assumed stratospheric ozone variation supports the importance of stratospheric (top-down) forcing in producing the observed SLP response. This sensitivity also indicates a necessity for a given model to simulate a realistic ozone response in order to produce a realistic surface climate response.

**The Tropical Lower Stratospheric Response to 11-Yr Solar Forcing: Relation to the BDC and Dependence on the Phase of the QBO**

Lon Hood

A decadal variation of tropically averaged column ozone that correlates approximately with 11-yr solar UV variability is present in satellite data records since 1979 and in ground-based records since the mid-1960's. A corresponding decadal variation of tropical lower stratospheric temperature is also present in reanalysis data sets since 1979 with maximum amplitude near the 50 hPa level. It has been previously concluded that the observed 11-yr responses are produced mainly by a solar-induced modulation of the Brewer-Dobson circulation (BDC), with a secondary contribution from the Hadley circulation in the lowermost stratosphere (e.g., Hood and Soukharev, JAS, 2012). Here, the hypothesis that the tropical lower stratospheric solar cycle signal is mainly a consequence of 11-yr changes in the strength of the tropical upwelling branch of the BDC is tested further and the dependence of the response on the phase of the equatorial quasi-biennial wind oscillation (QBO) is evaluated.The analytic approach is to investigate empirically the sensitivity of the tropical upwelling response of the BDC to observed changes in extratropical wave forcing on time scales (days to weeks) that are short compared to the effective radiative lifetime in the lower stratosphere. Results are given for the northern winter season (Nov.-March) as a function of the phases of the QBO and the 11-yr solar cycle. On these short time scales, neglecting heat transport by meridional winds, ozone and temperature tendencies in the tropical lower stratosphere are approximately proportional to the vertical velocity. Temperature tendencies are calculated at a series of lower stratospheric pressure levels using 31 years of daily NCEP/NCAR reanalysis data, zonally averaged over 20˚S to 20˚N. As a measure of extratropical wave forcing, meridional eddy heat flux, approximately proportional to the vertical component of the planetary wave flux, is used. The zonal mean eddy heat flux (v'T') is also calculated from daily NCEP data at latitudes from 50˚N to 80˚N and pressure levels ranging from 100 to 50 hPa. Linear regression analysis is then applied to estimate the sensitivity of the tropical mean upwelling rate (~ temperature tendency) to changes in extratropical wave forcing (~ eddy heat flux). When all data are considered, no significant dependence of the calculated sensitivity on the phase of the QBO (evaluated using equatorial zonal wind data at 45 hPa) is obtained. However, the sensitivity is significantly larger (at the one standard deviation level) under solar minimum conditions than under solar maximum conditions. This supports the above hypothesis since advective lower stratospheric temperature and ozone increases should occur on decadal time scales near solar maxima relative to solar minima, as is observed. Separation of the data by QBO phase shows that most of the solar cycle difference in sensitivity occurs during the west phase; no significant difference over a solar cycle is obtained during the east phase but a large difference (nearly 2 standard deviations) is obtained during the west phase. Consistently, multiple regression analysis of monthly mean temperature data near 50 hPa and column ozone data for the northern winter season yields a more statistically significant and stronger solar cycle response in the tropics during the west QBO phase than during the east QBO phase. The region of significant ozone and temperature response during northern winter is shifted toward the southern (summer) hemisphere, as expected if the response is due to a solar modulation of the BDC.

**SOLAR AND SUSPENDED PARTICLES EFFECTS ON URBAN TROPOSPHERE: A CASE STUDY OF SOUTH INDIA**

Sirajuddin M. Horaginamani

Suspended particles in the troposphere may affect the radioactive balance and therefore climate- either directly or in directly. The direct effect involves the absorption and scattering of both incoming solar radiation and long wavelength terrestrial radiation. The indirect effects influence in the formation and structure of clouds. Suspended particles may alter climate by influencing the type, structure and formation, location, or optical properties of clouds. This could affects earth- atmosphere energy balance, since clouds are a contributory factor both to the amount of solar radiation that is reflected back to space, and to the green house effects. Many anthropogenic suspended particles can act as condensation nuclei for water vapour, increasing cloud droplet number and reflectivity to incoming solar radiation. A study has been done to know the effects of solar and suspended particles on urban troposphere of south India.**Geomagnetic Activity: Structure and Variability of Particle Precipitation**

Richard Horne

The Earth’s magnetic field contains several different populations of charged particles. These particles are usually trapped inside the geomagnetic field but large geomagnetic disturbances can result in substantial particle precipitation into the Earth‚Äôs atmosphere. Precipitation increases ionisation which affects atmospheric chemistry and may couple further down into the atmosphere via dynamical processes. Since changes in the geomagnetic field are driven by variations in the solar wind, particle precipitation is one method of transmitting solar variability into the upper atmosphere. In this talk we discuss the sources of precipitating particles, including their energies, fluxes and geographic (geomagnetic) distributions and how they respond to the solar driver. We discuss how the Earth‚Äôs electron radiation belts at energies of a few MeV respond to different types of solar wind drivers such as fast solar wind streams and geomagnetic storms driven by coronal mass ejections, and the various types of wave-particle interactions that are responsible for particle precipitation at different energies and different magnetic local times. We discuss the difference between the bounce and the drift loss cone and the differences in precipitation between the northern and southern hemispheres. We discuss discrete auroral electron precipitation at lower energies of a few keV, and diffuse auroral precipitation and their relationship to storms and substorms. We show that there is a 1-2 year delay between the 11 year sunspot cycle and the number of geomagnetic storms at the Earth, and a seasonal dependence in geomagnetic activity that can affect particle precipitation. Finally we briefly discuss solar energetic particle events and their occurrence, and the relative contribution of proton verses electron precipitation.

**An Overview of Energetic Particle Precipitation Effects on the Earth’s Atmosphere and (Potentially) Climate**

Charles Jackman

Energetic precipitating particles (EPPs) can cause significant constituent changes in the polar mesosphere and stratosphere (middle atmosphere) during certain periods. Both protons and electrons can influence the polar middle atmosphere through ionization and dissociation processes. EPPs can enhance HOx (H, OH, HO2) through the formation of positive ions followed by complex ion chemistry and NOx (N, NO, NO2) through the dissociation of molecular nitrogen.The solar EPP-created HOx increases can lead to ozone destruction in the mesosphere and upper stratosphere via several catalytic loss cycles. Such middle atmospheric HOx-caused ozone loss is rather short-lived due to the relatively short lifetime (hours) of the HOx constituents. The HOx-caused ozone depletion of greater than 30% has been observed during several large solar proton events (SPEs) in the past 50 years. HOx enhancements due to SPEs were confirmed by observations in solar cycle 23. A number of modeling studies have been undertaken over this time period that show predictions of enhanced HOx accompanied by decreased ozone due to energetic particles. The solar EPP-created NOx family has a longer lifetime than the HOx family and can also lead to catalytic ozone destruction. EPP-caused enhancements of the NOx family can affect ozone promptly, if produced in the stratosphere, or subsequently, if produced in the lower thermosphere or mesosphere and transported to the stratosphere. NOx enhancements due to auroral electrons, medium and high energy electrons, relativistic electron precipitation (REP) events, and SPEs have been measured and/or modeled for decades. Model predictions and measurements show that certain years have significant winter-time meteorological events, which result in the transport of EPP-caused NOx enhancements in the upper mesosphere and lower thermosphere to lower altitudes. The NOx-caused ozone depletion has also been observed during several solar proton events (SPEs) in the past 50 years. Model predictions indicate that the longer-lived SPE-caused polar stratospheric and mesospheric ozone decrease can be >10% for up to five months past the largest events and is statistically significant; however, total ozone measurements do not indicate any long-term SPE impact. This talk will provide an overview of several of the EPP-related important processes and their impacts on the atmosphere.

**Antarctic Mesospheric winds during energetic particle precipitation**

Andrew Kavanagh

During March 2012 a solar proton event (SPE) occurred that coincided with a large, short-lived, change in the neutral wind field in the upper mesosphere above Rothera station on the Antarctic peninsula. We speculate on potential causative links and examine whether past SPE have been accompanied by similar effects. We examine longer-term changes in tidal amplitudes and background winds above Halley and Rothera during the SPE and an ensuing geomagnetic storm and look at past storm-time periods to determine whether there is a significant link.

**Solar influences on the troposphere through dynamical processes**

Kunihiko Kodera

Recent measurements from the space indicate that the variation of the total solar irradiance is too small to produce directly a meaningful climatic impact on Earth’s surface. In the present study, indirect solar influences through a stratospheric dynamics are presented. Although a solar cycle variation of the visible part of the solar spectrum is small, that of the ultraviolet is much larger. This produces about 1- 2K of temperature change around the stratopause in the middle atmosphere during a solar cycle. Larger meridional temperature gradient in the winter hemisphere results in a stronger lower mesospheric subtropical jet. Anomalous stratospheric zonal winds interact with vertically propagating planetary waves from the troposphere. In consequence, the anomalous zonal wind moves poleward and downward and finally affects tropospheric circulation in mid- and high-latitudes. The change in wave activity due to solar cycle also modulates the stratospheric mean meridional circulation. This leads to a change in the tropical temperature near the tropopause, which modify the convective activity in the tropical troposphere.

**Examining the stratospheric response to the solar cycle in coupled WACCM simulations with an internally generated QBO**

Andrew Kren

We examine the stratospheric response as a function of the solar cycle and respective of the Quasi-Biennial Oscillation (QBO). Since the 1980s, studies have shown a possible link between the Sun and QBO, whereby the correlation between geopotential heights at the poles and solar flux depends on the phase of the QBO (easterly or westerly). Yet there is no well accepted mechanism to explain this relationship. We show results from two Whole Atmosphere Community Climate Model (WACCM) ensemble runs with fully interactive ocean, chemistry, greenhouse gas and volcanic forcing, and for the first time, an internally generated QBO. Both ensembles are transient simulations and free running; ensemble 1 was run for 155 years (1850-2005), and ensemble 2 for 93 years (1850-1943). These runs are longer than the current observational record and allow a detailed examination of the Solar-QBO relationship. Results are compared to observations and past simulations with a specified QBO.

**Potential effects of cosmic rays on the atmosphere and climate**

Jon Egill Kristjansson

Despite recent advances in climate research, there is still a large uncertainty concerning the role of solar activity for climate variations. In addition to variations in total solar irradiance (TSI), consideration needs to be given to possible mechanisms that might enhance the TSI signal. Among these is the suggestion of a modulation of clouds by galactic cosmic rays, either via cosmic ray induced ionization (CRII) and aerosol formation or via electrical charges associated with clouds. Since clouds strongly influence the Earth‚Äôs radiation budget through reflection of solar radiation and trapping of thermal infrared radiation, variations in cloud properties might exert a strong signal on the climate system. Such cosmic ray effects have been proposed on various time scales, ranging from days in the case of Forbush Decrease events via decades in the case of solar cycle variations to time scales of millions of years in the case of galaxy spiral band variations. Despite the controversy, global aerosol models and even global climate models have started accounting for CRII as a possible catalyst for aerosol formation in the presence of supersaturated precursor gases. We will present an overview of the various aspects of this topic. This includes statistical studies of possible cosmic ray-cloud-climate links using satellite retrievals, as well as model studies in which the physical processes linking cosmic rays to aerosol formation are parameterized and their impact a global context assessed. We will seek to reconcile the results from different observational studies, as well as between the observational studies and the model studies. Thereby we seek to alleviate some of the confusion and controversy that has accompanied the cosmic ray-climate topic for more than a decade. Furthermore, we will make suggestions for future research directions in this intriguing area of research.

**The Monsoons in Sunspot Peaks**

Harry van Loon

The absorption of UV by O3 (they both are at maximum at sunspot peaks) creates temperature gradients in the stratosphere which cause vertical and horizontal wave motions. Apparently, that raises the tropopause level in the tropics and thus enhances tropical convection, especially in areas where the convection is already strong such as the monsoons. The climatological mean is thereby strengthened.

**On the effects of solar protons events on thermospheric temperature and nitric oxide concentration**

M. López-Puertas, B. Funke, M. Garcia-Comas, F. Friederich, G. P. Stiller, T. von Clarmann, M. Sinnhuber, U. Grabowski, N. Glatthor, and Gang Lu

The Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) on board Envisat (ESA) has been observing regularly (1/10 days) the thermosphere (up to 170 km) since 2007, providing rotationally resolved 5.3 µm emission from NO bands. These emissions have been used to retrieve global distributions of thermospheric NO abundances and kinetic temperature (Bermejo-Pantale et al., JGR, 2011). Vibrational, as well as rotational and spin non-LTE have been taken into account in the inversion of the spectra. In this work we focus on the effects of solar protons events (SPE) on the thermospheric temperature and NO. MIPAS captured the SPE on January 2005 by taking measurements just before, during, and shortly after the SPE in its upper atmosphere (UA) mode (40-170 km).Here, we analyze the changes in these quantities caused by the SPE and compare with TIME-GCM model simulations specifically performed for those conditions. While the broad changes are well simulated by the model, the absolute magnitudes and the hourly-time evolution of temperature and NO present significant differences. Possible reasons for explaining the differences are discussed. MIPAS also measured with a cadency of each other day from 24 January to 7 February 2012 in its upper atmospheric mode. Hence it also captured the effects of the Jan 2012 SPE (taking place mainly from Jan 23 until Jan 30) in the thermosphere. A preliminary analysis of these measurements is also expected to be presented.

**Update on the NOAA Polar Satellite Program, Data, and Products**

Janet Machol

The constellation of operational NOAA/EUMETSAT polar satellites is one of the few sources of near real time and historical measurements of energetic particles impacting the atmosphere. These measurements are critical for understanding how particle precipitation affects atmospheric chemistry, circulation and ultimately climate. Here we provide an update on the current and future plans regarding the polar satellite fleet, data, and derived products. The current satellite fleet consists of five Polar Orbiting Environmental Satellites (POES) operated by NOAA and the MetOp-A satellite operated jointly by NOAA and EUMETSAT. Upcoming changes to the fleet include the expected launch of the MetOp-B satellite in September 2012 and the decommissioning of the NOAA 17 satellite in early 2013. All POES/MetOp satellites carry the SEM-2 instrument package that measures fluxes at multiple angles of 50 eV to >1 MeV electrons and 50 eV to 250 MeV protons. These fluxes are of interest for a variety of users including climate modelers, airlines, power companies, satellite operators, and GPS users. The NOAA National Geophysical Data Center (NGDC) is currently updating the software for processing the space weather data from the POES/MetOp satellites to provide higher quality data in a more timely fashion. The new system, will make processed data available in near real time as it is received from the satellite (nominally once per 90-minute orbit) rather than on a daily cadence. Accuracy will be improved by calculating current magnetic parameters instead of relying on look-up- tables updated yearly. Additionally, the new code will provide data in physical units rather than engineering units. Future plans include improved global maps of particle precipitation based on the near real time measurements and new processing techniques for removing contaminating signals.

**Effect of electron precipitation on winter time surface temperature and tropospheric circulation**

Ville Maliniemi

Recent research has shown that energetic particle precipitation into the upper atmosphere can change its ion and neutral chemistry, e.g., by enhancing NOx concentration in the mesosphere, which in turn can affect stratospheric ozone balance under appropriate conditions. It has also been suggested that this may even affect surface temperatures at high latitudes by modulating tropospheric circulation. Motivated by such results we compare here the Winter time energetic electron precipitation (EEP) with North Atlantic oscillation (NAO) and surface air temperature (SAT) in the Northern hemisphere. We use the recently recalibrated energetic electron data from the MEPED instrument of NOAA/POES satellites in two energy ranges (30-100 keV and 100-300 keV), the NAO index from NOAA and the NASA GISS surface temperature analysis for years 1980-2010. We find a statistically signicant correlation between EEP and NAO index and also between EEP and SAT in certain geographic regions. The strongest negative correlation is found in Northeast Canada/Greenland, while the strongest positive correlation is found in North Siberia/Barents sea, in agreement with similar studies using global geomagnetic activity. We find higher correlation when the two winters (1984/1985 and 2004/2005) of unprecentedly strong sudden stratospheric warmings are excluded from the analysis. We also find that the different QBO phases lead to dramatically different correlation patterns, with negative QBO producing considerably stronger and spatially wider correlation and larger temperature responses than positive QBO. Our results suggest that the effect of electron precipitation is relatively stronger when the circulation pattern is weaker.

**Chemistry-Climate Models: What we have and what we need**

Daniel Marsh

This overview will describe the numerous ways in which solar and energetic particle forcing is implemented in current chemistry-climate models (CCMs). Depending on the intended model application, model domain, length and number of simulations, the complexity of the implementation varies drastically. For example, heating rate changes over the solar cycle may be scaled with the annual mean total irradiance changes, whereas some models specify daily spectral irradiance from the x-rays to the infrared. The majority of CCMs used in climate studies simply neglect particle forcing. However, recent event studies have included both energetic electron and proton particles covering a broad range of energies. Large differences also exist in how the energy is deposited in the atmosphere and its immediate and secondary chemical effects. In addition, the climate response to the induced perturbation in chemistry will depend on the accuracy of the model dynamical transport and radiative transfer. The diversity of approaches can lead to very different estimates of the atmospheric response to solar and geomagnetic variability. This is compounded by uncertainty in the variability and magnitude of these external drivers. Looking forward, as more models used in future climate prediction incorporate chemistry, it is clear that the solar and atmospheric communities should continue to critically evaluate solar and geomagnetic forcing within CCMs, and provide clear recommendations for their specification in light of new observations and model-data intercomparisons.

**Overview of solar irradiance effects on the Earth's atmosphere and climate**

Katja Matthes

Understanding the influence of solar variability on the Earth’s climate requires knowledge of solar variability, solar-terrestrial interactions, and the mechanisms determining the response of the Earth’s climate system. A summary of our current understanding in each of these three areas will be presented. Observations and mechanisms for the Sun’s variability are described, including solar irradiance variations on both decadal and centennial time scales. Corresponding observations of variations of the Earth’s climate on associated time scales are described, including variations in ozone, temperatures, winds, clouds, precipitation, and regional modes of variability such as the monsoons and the North Atlantic Oscillation. Finally, mechanisms proposed to explain these climate observations are presented.

**Recent variability of the solar spectral irradiance and its impact on climate modelling**

Katja Matthes

During periods of high solar activity, the Earth receives 0.1% higher total solar irradiance (TSI) than during low activity periods. Variations of the solar spectral irradiance (SSI) however, can be larger, with relative changes of 1 to 20% observed in the ultraviolet (UV) band, and in excess of 100% in the soft X-ray range. SSI changes influence the Earth's atmosphere, both directly, through changes in shortwave (SW) heating and therefore, temperature and ozone distributions in the stratosphere, and indirectly, through dynamical feedbacks. Lack of long and reliable time series of SSI measurements makes the accurate quantification of solar contributions to recent climate change difficult. In particular, the most recent SSI measurements show a larger variability in theUV spectral range and anomalous changes in the visible and near-infrared (NIR) bands with respect to those from earlier observations and from models. A number of recent studies based on chemistry-climate model (CCM) simulations discuss the effects and implications of these new SSI measurements on the Earth's atmosphere, which may depart from current expectations.This poster summarises the content of a recently submitted article about our current knowledge of SSI variability and its impact on Earth's climate. An interdisciplinary analysis of the topic is given. New comparisons and discussions are presented on the SSI measurements and models available to date, and on the response of the Earth's atmosphere and climate to SSI changes in CCM simulations. In particular, the solar induced differences in atmosphericradiative heating, temperature, ozone, mean zonal winds, and surface signals are investigated in recent simulationsusing atmospheric models forced with the current lower and upper boundaries of SSI solar cycle estimated variations from the NRLSSI model data and from SORCE/SIM measurements, respectively. Additionally, the reliability of available data is discussed and additional coordinated CCM experiments are proposed.

**Using trace gas measurements to quantify the modulating influence of transport on the EPP-IE**

Adrian McDonald

Atmospheric transport and the resultant mixing potentially has a strong impact on the strength of the Energetic Particle Precipitation Indirect Effect (EPP IE) observed in the polar regions. A large number of studies have examined atmospheric tracers to examine horizontal and vertical transport in the middle atmosphere. The aim of this study is to utilize observations of Carbon monoxide (CO), Nitrous Oxide (N2O) and Methyl chloride (CH3Cl) from the EOS-MLS instrument onboard the Aura Satellite to examine horizontal and vertical transport in the middle atmosphere and determine the potential for examining the magnitude of this modulating effect. We initially focus on using the probability distribution function (PDF) of the tracer data to identify the locations of transition regions (or transport barriers) in the stratosphere and mesosphere. We then utilise reanalyses data to perform a domain filling scheme on the tracer observations‚ this procedure allows us to form high resolution maps which can be used to quantify the number and positions of filamentary leak structures. A tracer PDF derived quantification of coherent regions is then used in the calculation of descent and ascent rates in those regions. The resultant data is then considered in the context of the EPP IE.

**The coupled climate system response to variations in total solar irradiance**

Gerald Meehl

There is a building body of observational evidence that the 11 year cycle of total solar irradiance (TSI) has measurable influences on the earth’s climate system, particularly in the Indo-Pacific region. Coupled climate system model experiments have demonstrated how the relatively small fluctuations of the 11 year solar cycle can produce the magnitude of the observed climate signals in the tropical Pacific and elsewhere associated with such TSI variability. Two mechanisms, a top-down stratospheric response of ozone to fluctuations of shortwave solar forcing, and a bottom-up coupled ocean-atmosphere surface response, have been shown to act together to enhance the climatological off-equatorial tropical precipitation maxima in the Pacific, lower the eastern equatorial Pacific sea surface temperatures during peaks in the 11 year solar cycle, and reduce low latitude clouds to amplify the solar forcing at the surface. Dynamical air-sea coupling is an essential element of this response to fluctuations in TSI. A recent climate model experiment that includes both mechanisms has been used to simulate a possible near-term grand solar minimum (on the order of the Maunder Minimum). Results show that globally averaged warming from now to mid-century using a mid-range emissions scenario could be reduced around 30%, from about 1.0 ˚C to roughly 0.7 ˚C.

**Impact of solar spectral variability on middle atmospheric ozone**

Aimee Merkel

The Spectral Irradiance Monitor (SIM) and the Solar Stellar Intercomparison Experiment (SOLSTICE) onboard the Solar Radiation and Climate Experiment (SORCE) measure solar spectral variability in the 110-2400 nm range, accounting for about 97% of the total solar irradiance (TSI). These instruments monitored the descending phase of solar cycle 23 and are now continuing observations in the rising phase of cycle 24. The SORCE observations show rotational modulation of spectral irradiance due to the passage of active regions, but also indicate slower evolutionary trends in solar spectral irradiance over longer time periods that are both in and out of phase with the TSI. To estimate the atmospheric response to the solar variability implied by these observations, quiet sun and active solar reference spectra were created as input into the Whole Atmosphere Community Climate Model (WACCM). The model output using these observations produces a very different ozone response relative to standard semi-empirical models of SSI. WACCM with SORCE irradiance observations predicts an ozone reduction in the lower mesosphere at solar active conditions. The atmospheric structure predicted by the model is commensurate with contemporaneous observations of ozone from AURA-MLS and SABER. In addition, recent analysis of ozone from the Solar Mesospheric Explorer (SME) indicates that the mesospheric response is out-of-phase in solar cycle 21 (1982-1986).

**Projection of the 11-yr solar cycle signal on internal modes of the tropical Pacific decadal variability**

Stergios Misios

The possible influence of the 11-yr solar cycle on the coupled atmosphere-ocean system of the tropical Pacific has drawn considerable attention in the recent years. Analyses of observations and historical reconstructions detected either an El Nino-like warming or a La Nina-like cooling in solar maxima. We first show that both signals can be explained without evoking the solar cycle forcing per se. The detected cooling results from the oversampling of La Nina episodes, whereas the El Nino-like response is related to the tropical Pacific Quasi-Decadal oscillation (TPQDO), which is a mode of variability likely excited by internal dynamics of the tropical Pacific system. This does not preclude the possibility that the increased solar forcing favors a La Nina excitation. Likewise, the TPQDO could be synchronized to, not excited by, the solar cycle. To examine the aforementioned possibilities, we conduct simulations with the middle atmosphere version of ECHAM5 coupled to two types of ocean models: a mixed layer and a full-coupled dynamical model. Our simulations do not support the notion of a La Nina excitation in solar maxima. Instead, we find that the solar cycle signal projects on the simulated TPQDO, which is internally excited in a control run with constant solar forcing. The tropical Pacific warms in solar maxima both in the mixed layer and the full-coupled ensembles, with stronger warming in the former ensemble. The tropical Pacific hydrology changes accordingly. Although the tropical upper atmosphere responds immediately to the solar forcing, the tropospheric response lags by 1 to 2 years, in rhyme with the surface response. We further discuss mechanisms whereby the simulated warming over the tropical Pacific may affect remote regions as the North Atlantic Ocean and Europe. There, the full-coupled ensemble successfully captures the solar cycle signals detected on proxy-based surface temperature reconstructions.

**A model of auroral precipitation based on SuperMAG generalized auroral electrojet and substorm onset times**

Elizabeth Mitchell

We introduce a precipitation model (OVATION-SM), which includes substorm cycle information and the SuperMAG SME (generalized AE) index. 22 years of particle precipitation data from the Defense Meteorological Satellite Program (DMSP) are separated by type (diffuse, monoenergetic, broadband, and ion aurora), magnetic latitude, and magnetic local time. Each bin of data is subjected to multiple linear regression analysis using the SuperMAG SME index (1-minute cadence), the time from the last substorm onset in seconds, and the time to the next substorm onset in seconds. The nightside auroral power from OVATION-SM explains 75% of the variance in the nightside auroral power from Polar UVI, which is greater than the 58% explained by OVATION Prime as seen by Newell et al. [2010]. This preliminary empirical model with the SuperMAG SME index allows the space weather community access to 30+ years of continuous high-cadence nightside auroral power.

**Observations of nitric oxide in the Antarctic middle atmosphere during recurrent geomagnetic storms**

David Newnham

We report ground-based measurements of the polar middle atmosphere made using a 230-250 GHz passive microwave radiometer [Espy et al., 2006; Newnham et al., 2011] deployed at Troll station (72.01˚S 02.32˚E, L = 4.8), Antarctica. This location is directly under the region of radiation belt electron precipitation, pole-ward of the South-Atlantic Magnetic Anomaly, equator-ward of the auroral zone, and deep within the polar vortex during the Austral winter. Our observations show enhanced mesospheric NO volume mixing ratio (VMR) reaching 1.2 ppmv during a series of small recurrent geomagnetic storms in the 2008 polar winter. The Lomb normalized periodogram of the NO VMR time series averaged over 65-80 km for days 130 to 220 of 2008 (9 May to 7 August) shows a peak exceeding the 95% confidence limit at 26 days, close to the solar rotation period. NO VMR is moderately correlated with POES 90˚ telescope trapped and quasi-trapped electron count rates over L = 3.5 to L = 5.5 for the >100 keV (90e2) channel (r = 0.50, lag time of 4.1 days) and the >300 keV (90e3) channel (r = 0.48, lag time of 4.8 days) of the SEM-2 MEPED instrument. Superposed epoch analyses have been carried out for the six most significant geomagnetic storm periods and three Carrington Rotations (2070-2072) within the selected observation period. The altitude profile of mesospheric NO, and estimates of >50 keV electron flux from the AARDDVARK (Antarctic-Arctic Radiation-belt (Dynamic) Deposition - VLF Atmospheric Research Konsortium) network, suggests that mesospheric NO is produced by ~100-300 keV electron precipitation with significant downwards transport in the southern-hemisphere winter-time polar vortex.

Espy, P. J., P. Hartogh, and K. Holmen (2006), A microwave radiometer for the remote sensing of nitric oxide and ozone in the middle atmosphere, Proc. SPIE, 6362, 63620P, doi:10.1117/12.688953.

Newnham, D. A., et al. (2011), Direct observations of nitric oxide produced by energetic electron precipitation into the Antarctic middle atmosphere, Geophys. Res. Lett., 38, L20104, doi:10.1029/2011GL048666.

**NOx production due to energetic particle precipitation in the MLT region - results from an ion-chemistry model**

Holger Nieder

The chemistry in the mesosphere/lower thermosphere (MLT) region is driven by forcing from solar radiation and energetic particles. The resulting ionization, dissociation and excitation of the constituents lead to production of neutral reactive species such as NOx (N, NO, NO2) and HOx (H, OH, HO2), both directly from dissociation of neutrals and from subsequent ion-neutral reactions. As NOx is long-lived during polar winter, it can be transported down to the stratosphere and contribute to catalytic ozone depletion. To study the effective NOx production rates during an ionization event, runs with a one-dimensional state-of-the-art ion chemistry model (UBIC) are carried out and analyzed. The model starts with a neutral atmosphere and uses direct ion and neutral production rates from Porter et al. (1976) and Rusch et al. (1981), adapted for the MLT region. Including raw ionisation rates from external sources such as AIMOS is possible. The ion-neutral reactions in the charged atmosphere are computed until equilibrium is reached, resulting in an effective production rate including impact of ion-neutral reactions. The indirect NOx production rate is found to depend on atmospheric parameters such as pressure, temperature and the abundance of NOx, atomic oxygen and H2O. For the MLT region, this leads to an increasing amount of NOx per ionpair created with increasing altitude due to an increasing atomic oxygen VMR. Values of >1.6 NOx per ionpair can be obtained. An approach to make the results available to 3D Chemistry Transport Models, without excessive use of computing power, is the setup of a database containing production rates for frequently occurring parameter combinations. The setup process of such a database is presented and discussed.

**MACE - the Mesosphere and Climate Experiment**

Johannes Orphal

MACE, the Mesosphere and Climate Experiment, has been proposed to ESA for operation on the International Space Station (ISS). MACE will provide highly-resolved (1-2 km) vertical profiles of trace species (CO2, O3, CO, NO, CH4, H2O, and H and O through OH) and of temperature, in the 40-100 (option: up to 150) km altitude range, including their diurnal variations.

**Chemical and dynamical effects of EPP through nitric acid formation by ion cluster chemistry**

Yvan Orsolini

Recurrent polar enhancements in nitric acid (HNO3) are observed by satellite instruments in the mid and upper stratosphere, and thought to be a consequence of energetic particle precipitation (EPP). Such enhancements are poorly reproduced in standard chemistry transport models or in chemistry-climate models. In order to improve the effects of EPP upon the nitrogen family and ozone in chemistry-climate model, we have modelled the chemical and dynamical middle atmosphere response to the introduction of a chemical pathway that produces HNO3 by conversion of N2O5 upon hydrated water clusters H+(H2O)n. We have used an ensemble of simulations with the National Center for Atmospheric Research (NCAR) Whole-Atmosphere Community Climate Model (WACCM) chemistry-climate model, using a fixed but latitude and height dependent distribution of hydrated water clusters. The chemical pathway alters the internal partitioning of the NOy family during winter months in both hemispheres, and ultimately triggers statistically significant changes in the climatological distributions of constituents including: i) a cold season production and loss of HNO3 and N2O5, respectively, and ii) a cold season decrease and increase in NOx/NOy-ratio and O3, respectively, in the polar regions of both hemispheres. We see an improved seasonal evolution of modelled HNO3 compared to satellite observations from Microwave Limb Sounder (MLS), albeit not enough HNO3 is produced at high altitudes. Through O3 changes, both temperature and dynamics are affected, allowing for complex chemical-dynamical feedbacks beyond the cold season when the pathway is active. Hence, we also find a NOx polar increase in spring-to-summer in the SH, and in spring in the NH. The springtime NOx increase arises from anomalously strong poleward transport associated with a weaker polar vortex. We argue that the weakening of zonal-mean polar winds down to the lower stratosphere, which is statistically significant at the 0,90 level in spring months, is caused by strengthened planetary waves induced by the mid-latitude zonal asymmetries in O3 and short-wave heating.it is quite remarkable that the inclusion of this chemical pathway has changed the magnitude and the seasonal march of the stratospheric jet. Such change highlights the importance of NOx in modulating ozone abundances, and of EPP processes for the entire middle atmosphere.

**Ozone at the secondary maximum during elevated stratopause events**

Yvan Orsolini

We investigate the dynamical and chemical variability of the mesosphere during Stratospheric Sudden Warming events accompanied by a stratopause jump. The formation of such an elevated polar stratopause has been extensively observed in satellite observations. Such events are followed by strong mesospheric descent that is of paramount importance for the transport of species like NOx or CO into the stratosphere. In this paper, we further investigate the variability in mesospheric ozone during such events and, in particular, modulations in the amplitude of the ozone secondary maximum found near 100 km. To this end, we use three-hourly WACCM simulations of SSWs. We examine mesospheric ozone in some case studies, and we further characterize a composite life cycle of such SSWs from the surface up to 130 km. The ozone variability is intimately connected to zonal-mean wind reversals, and to mean meridional circulation cells, driving stratospheric and thermospheric downwelling as well as mesospheric upwelling. We further analyze in detail the factors governing night-time ozone near 100km, and the associated changes in nitrogen oxides, atomic hydrogen, atomic oxygen and temperature.

**Geomagnetic and dynamical effects on NOx and O3 in early 2005, 2009 and 2012 in the Northern Hemisphere**

Sanna-Mari Päivärinta

Energetic particle precipitation (EPP) affect the upper and middle atmosphere through ionization of neutral molecules in the atmosphere. Via ionization ozone destroying substances, such as odd nitrogen (NOx), are produced. Especially, during polar winter in the presence of a polar vortex, EPP can have substantial effects on the amount NOx and ozone. However, also the dynamical conditions in the atmosphere can lead to EPP reminiscent situations with a strong descent of NOx from the mesosphere to stratosphere.In this study we have used ACE-FTS, MLS/AURA and SABER/TIMED observations to study January-March of 2005, 2009 and 2012 because of their exceptional characteristics: 1) solar proton events (SPEs) that occurred in 2005 and 2012 and 2) major sudden stratospheric warmings that took place in 2009 and 2012. This gives us a good opportunity to study the effects of SPEs and SSWs separately (2005, 2009) and together (2012). The observations indicate that the amount of NOx can increase both due to dynamical factors and SPEs by about 300-3000% between the altitude range of 40-90 km. The results, however, show that the dynamical effects alone i.e. the downward transport of NOx does not lead to the decrease of O3 in a similar manner as the SPEs do. In the years of SPEs (2005, 2012) O3 decrease of 20-100% between about 45-75 km is observed. The most profound effects can be found during geomagnetically active periods with a strong polar vortex after a major SSW as observed in 2012.

**Solar Cycle Influences on Southern Hemisphere Polar Lower Stratospheric Ozone**

Ethan Peck

Solar cycle changes in both auroral energetic particle precipitation (EPP) and solar irradiance have been modeled using the Whole Atmosphere Community Climate Model version 4 (WACCM4) in the Community Earth System Model version 1.0.3 (CESM1.0.3) framework. Simulations were run with different combinations of high EPP, low EPP, high solar irradiance, and low solar irradiance. The simulations show a small but statistically significant difference in ozone concentrations during the southern hemisphere summer. Data from the Modern Era-Retrospective Analysis for Research and Applications (MERRA) dataset and the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) instrument were also analyzed for solar cycle differences. Relative to the WACCM4 simulations, data from MERRA show larger differences in ozone concentrations between solar maximum and solar minimum conditions. Results suggest that annual summer ozone recovery in the southern hemisphere may be affected by the solar cycle through EPP and solar irradiance changes.

**An Overview of Historical, Current, and Planned Solar Irradiance Measurements**

Peter Pilewskie

The current uninterrupted 34-year total solar irradiance (TSI) climate data record is the result of several overlapping instruments flown on different missions. This record clearly exhibits variability over the 11-year solar cycle and over shorter time scales. Measurement continuity has allowed successive instruments to be linked to the existing data record despite offsets between instruments, but does make the record susceptible to loss in the event of a gap in measurements. New measurements have resolved the source of a 5 Wm-2 offset among instruments, leading to a new accepted value for the TSI. Future instruments with uncertainties approaching 0.01% will improve the capability of detecting climate-significant trends in solar forcing while reducing the risk associated with gaps in the record. Like TSI, continuous observations of solar ultraviolet radiation also began in 1978 but with varying spectral coverage and resolution among the measurements comprising the record. The measurement of the full solar irradiance spectrum from space is a much shorter record than TSI, commencing only 11 years ago. Recent results have suggested that ultraviolet trends during the last solar cycle were larger than those observed in previous cycles, and were compensated by trends in other bands that increased with decreasing solar activity. These measurements are currently undergoing rigorous validation; improvements in future instrumentation based on lessons learned will enhance our ability to monitor the small changes in spectral irradiance required for determining the mechanisms behind climate response to solar variability.

**Auroral Energy Particle Precipitation: An Atmospheric Coupling Agent?**

Cora Randall

Whole Atmosphere Community Climate Model (WACCM) simulations were run with high and low levels of auroral electron precipitation to investigate the effects of energetic electron precipitation (EEP) on the atmosphere. Relative to the low EEP simulation, NOy mixing ratios in the high EEP case increased by up to ~75% in the southern hemisphere (SH) upper stratosphere, and by 10-50% in the middle and lower stratosphere; increases in the north were greater than 10% but statistically significant only down to about 40 km. Wintertime warming and O3 depletion was evident in the lower thermosphere. At lower altitudes, chemical effects from the excess NOy were statistically significant only in the SH polar region. The excess reactive odd nitrogen, NOx, caused decreases in O3 mixing ratios of up to 12% in the SH polar middle and upper stratosphere during the months of July-December. O3-depleted air descended into the lower stratosphere in December and persisted until the following August. In the SH lower polar stratosphere below about 25 km during the months of November-January, NO2 from the excess NOy reacted with ClO to form ClONO2, thereby mitigating halogen-induced O3 loss and leading to O3 mixing ratio increases of more than 20%. The high EEP simulations also showed warming in the lower stratosphere near 80˚S of ~2-4 K in December, and a shift in the zonal mean zonal wind in the middle and upper stratosphere toward a more easterly or summer-like state. A simulated increase in the upward component of the residual circulation was coincident with a cooling in the polar mesopause region of nearly 10 K in late November and early December. We will discuss the implications of these results, as well as limitations of the simulations.

**Transport of NOx from the lower Thermosphere into the middle Atmosphere in the KASIMA Model**

T. Reddmann, S. Versick and A. Vlasov

Transport of NOx from the lower thermosphere to the mesosphere and subsequently to the stratosphere during Arctic winters is possibly an important supply of additional NOy in the middle atmosphere besides N2O oxidation. Previous studies showed that the KASIMA model failed to reproduce the observed large amounts of NOx transported from the mesosphere/lower thermosphere region in winters with pronounced stratospheric warmings. Here we examine the dependence of the vertical coupling in the MLT region on the chosen gravity wave drag configuration. Adjusting the source spectrum of gravity waves in our Lindzen type gravity wave drag parameterization stronger downward transport after strong stratospheric warmings and a prevailing elevated stratopause is simulated. We examine the transport properties of the KASIMA mechanistic model in the adjusted configuration during and after sudden stratospheric warmings for the period 2001 to 2011, estimate the additional NOy transported into the middle atmosphere and the subsequent ozone loss assuming an additional NOx source in the lower thermosphere, and evaluate consequences of the adjusted parameterization on the general transport properties of the model using the full ERA-Interim period 1979 - 2011 in terms of mean-age of air and other long-lived tracers.

**Energetic (>10keV) and relativistic electron (>500keV) precipitation into the mesosphere - evidence and limitations**

Craig J. Rodger and Mark A. Clilverd

It is widely accepted in the HEPPA community that NOx produced by auroral electrons (energies less than about 10keV) can play a significant role in polar atmospheric chemistry, through the so-called "indirect effect" where NOx produced in the lower thermosphere is transported downwards into the upper stratosphere. In this talk we will present recent evidence which suggests that energetic electron (greater than about 10keV) and relativistic electron (greater than about 500keV) precipitation can lead to significant production of HOx and NOx in the mesosphere, and hence may couple to the downward travelling NOx produced by auroral electrons. We discuss the nature of electrons trapped in the radiation belts and their precipitation into the atmosphere, to demonstrate the relative difficulty of making electron precipitation measurements - and in particular the paucity of existing measurements which can be used to directly drive atmospheric chemical and climate models. For example, while the widely utilised POES MEPED observations can provide excellent context for changes in precipitation levels from the radiation belts there are still significant uncertainties as to the absolute flux of energetic electrons into the atmosphere, and almost no absolute measurements of relativistic electrons.

**Solar cycle signals in the Pacific and the issue of timings**

Indrani Roy and Joanna D. Haigh

We analyse the solar cycle signal in sea level pressure, 1856-2007. Using composites of data from January/February in solar cycle peak years we confirm the strong positive signal in the region of the Aleutian Low found by previous authors. We find, however, that signals in other regions of the globe, particularly in the South Pacific, are very sensitive to the choice of reference climatology. We also investigate the relationship between solar activity and sea surface temperatures in the tropical East Pacific. We find a marked overall association of higher solar activity with colder temperatures in the tropical Pacific that is not restricted to years of peak sunspot number and we do not find a consistent ENSO-like variation following peak years. Both the SLP and SST signals vary coherently with the solar cycle and neither evolves on an ENSO-like timescale. The solar signals are weaker during the period spanning approximately 1956-1997 which we suggest is due to masking by a stronger innate ENSO variability at that time.

**Unprecedented Solar Energetic Particles and Galactic Cosmic Rays during Observations of Cycle 24**

Nathan Schwadron

The Sun is now emerging from a deep protracted solar minimum when Galactic Cosmic Rays (GCRs) achieved the highest levels observed in the space age [Mewaldt et al., 2010], and the power, pressure, flux and magnetic flux of solar wind were at the lowest levels [McComas et al., 2008; Schwadron et al., 2008; Connick et al., 2011]. Even observations of the global heliosphere show remarkably rapid changes [McComas et al., 2010] caused by dropping solar wind pressure. Does the recent anomalous deep solar minimum hint at larger changes in store? As GCR fluxes change, we are forced to ask fundamental questions about the effects on our atmosphere, and the implications for the planet. Over the last year between 2011 and 2012, we have begun to observe the changes in the space environment associated with the first large SEP events of Cycle 24. The events we have observed in 2012 extend to very high energies, and despite relatively low fluxes, have in some cases caused Ground Level Enhancements. Recent observations give insights into a very different regime of solar behavior than we have observed during the space age. These observations provide critical hints about the regimes that may have prevailed in historic periods such as the Maunder Minimum and during the Carrington Event. Simultaneous with the observations of large changes in solar behavior, the space physics community has developed the broadest and deepest array of solar and heliospheric observations ever assembled. Observations from missions such as SDO probe low coronal conditions during the initiation of CMEs and provide unprecedented insights into the acceleration of SEPs associated with CME propagation. As we look to the historic record of SEP events from Ice Cores, considerable controversy exists and significant questions have been raised concerning the timing, accuracy or even the ability of Ice Cores to store information concerning SEP events. Thus, we are developing a new picture of solar behavior and the formation of SEP events in an unprecedented solar cycle, but fundamental questions remain concerning the accuracy of our historic record of SEP events.

**EPP contribution to tropospheric variations**

Annika Seppala

It is well known that ionization from Energetic Particle Precipitation provides a direct chemical coupling mechanism from the Sun to the atmosphere via the production of NOx and HOx, constituents which are important to middle atmosphere ozone balance. Geomagnetic activity/EPP driven signatures have also been found in various climate records, but it has remained unclear which mechanisms would be responsible for communicating geomagnetic activity variations to climate variables such as tropospheric temperatures. In the recent years model simulations and statistical studies using re-analysis data have started to address this question of EPP indirect contributions to variations in the lower atmosphere. Model studies such as those of Rozanov et al. (2005) and Baumgaertner et al (2011) have suggested that including a mesospheric NOx or NOy source at the model top could have an impact on the dynamics of the middle atmosphere, propagating all the way to the surface where variability could be detected in climate variables such as temperatures. Similar results to those of the model prediction for the surface level have been gained from re-analysis data (Seppala et al., 2009). The mechanism able to communicate EPP induced changes from the source altitudes in the thermosphere, mesosphere or stratosphere, all the way to the troposphere and surface has, however, remained unclear. This talk will focus on the tropospheric and stratospheric dynamical variations which have been linked to EPP/geomagnetic forcing. I will address the potential linkages between high altitude EPP effects and lower altitude dynamical variables and discuss how these may be affected by or linked with other natural variations in the atmosphere, such as the solar irradiance cycle.**Polar night NO densities in the MLT: Odin, ACE, and WACCM**

Patrick Sheese

The Optical Spectrograph and Infrared Imaging System (OSIRIS) on the Odin satellite currently has an eight-year database of nighttime Antarctic nitric oxide densities, [NO], in the mesosphere - lower thermosphere (MLT) region. The OSIRIS database is compared with similar datasets from the Sub-Millimetre Radiometer (SMR), also on the Odin satellite, and from the Atmospheric Chemistry Experiment - Fourier Transform Spectrometer (ACE-FTS) on the SciSat-I satellite. There are large systematic differences between the three datasets, but the [NO] variations on timescales of months to years are in good agreement and correspond to the 27-day and 11-year solar cycles. The satellite data are also compared to model results from the Whole Atmosphere Community Climate Model (WACCM), and NO production through auroral precipitation within WACCM is discussed.

**Night Airglow OI 630nm emissions and GPS-TEC observations from low latitude station Kolhapur and Hyderabad, India**

Dadaso Shetti

The GPS data of IGS Hyderabad station (17.410N, 78.550E) , Bangalore (13.020N, 77.570E) and Kolhapur station (16.8N,74.2E) have been used to compute Total Electron Content (TEC) using UNB Ionospheric Modelling Techniques and RD\_RINEX slant TEC software and ground based photometric observations of OI 630.0 nm emission line have been carried out from Kolhapur station during the quiet and disturbed period. The signature of Midnight Temperature Maximum (MTM) and the plasma bubble has been found in both night airglow (OI630.0 nm) and d(TEC)/dt observations. The nocturnal variations observed in the atomic oxygen airglow emission at low latitude are well correlated with the dynamical variations seen in the F-region ionospheric parameters such as d(TEC)/dT, for both quiet and disturbed days. Storm positive and negative effects on temporal changes in TEC were investigated. In the next few years solar activity reach maximum so there will be ample opportunities to study in detail solar- terrestrial events with the observations of Night Airglow emission and GPS-TEC parameters for better understanding of the effect of solar activity on ionosphere at low latitudes.

Key Words: Ionosphere, Night Airglow, Total Electron Content (TEC), Low Latitude

**Influence of ion chemistry on middle atmosphere composition during energetic particle precipitation events: comparison of parameterizations and a full ion-chemistry model**

Miriam Sinnhuber, Holger Nieder, Nadine Wieters

Production of NOx and HOx during energetic particle precipitation events in the middle atmosphere are governed by fundamtental interactions leading to dissociation, dissociative ionization, and ionization of N2, O2, and O, followed by a number of ion chemistry reactions. Global models considering energetic particle precipitation impacts on the middle atmosphere use parameterizations of the formation rates of neutral species like NOx and HOx; however, these parameterizations have been derived using very simplified assumptions about the ion chemistry, which in the middle atmosphere is quite complex, and e.g., involves the formation of large cluster ions. We use an ion chemistry model of the middle atmosphere and lower thermosphere, the UBIC model, to derive the formation rates of N, NO, H, and OH in the middle atmosphere as a function of the atmospheric ionization rate. With these formation rates, we force NOx and HOx production in a neutral chemistry model of the middle atmosphere, and compare results derived with commonly used parameterizations. Focus of the investigation is the impact on NOx and HOx production and subsequent ozone loss.

**Using the "function M" to quantify the modulating influence of transport upon the EPP-IE**

Madeleine Smith

The dynamics of the stratospheric polar vortices can have a significant modulating influence on the strength of the energetic particle precipitation indirect effect (EPP IE) . Using new methods to measure these dynamics may lead to a better understanding of the impact of transport and mixing upon the quantity of EPP-produced chemicals that reaches the stratosphere in the polar regions. The “function M” is a measure that has recently been proposed as a means of quantifying transport in dynamical systems and as a potential measure of the strength of the vortex as a barrier to horizontal mixing. The value of M for an air parcel can be derived from forward and backward trajectories by integrating over the entire arc length of these trajectories. A Lagrangian parcel trajectory model has been used to calculate M at isentropic levels between 600-1300K in the Northern and Southern hemispheres during winter using wind velocity data from the MERRA reanalysis (for 2004-2011). A range of measures, including the average value of M at the vortex edge, identified using the equivalent latitude coordinate system, are then used as quantitative measures of polar vortex strength and used to track how the polar vortices evolve with time. Variations in polar vortex strength are studied in particular detail over the period between August-October 2009 in the Southern Hemisphere. These results are then compared with measurements of EPP-produced trace gases from EOS-MLS in order to examine how accurately the function M represents the effect of the polar vortices' dynamics upon the strength of the EPP IE.

**On the Controversy of Extreme Solar Particle Event Signatures in Arctic Ice Cores: Sun to Ice?**

Harlan E. Spence

On the morning of September 1, 1859, a particularly large and complex active region destabilized, launching an extremely fast Coronal Mass Ejection (CME) toward Earth. A large solar flare blazed; its optical brightness lasted 5 minutes and equaled that of the background Sun. A plausible yet partly controversial description of ensuing events is as follows. The ejecta propagated rapidly away from the Sun, generating a fast-mode wave ahead of it, which in turn steepened into a fast-mode forward shock. The shock, traveling in excess of 2000 km/s accelerated supra-thermal ions in the ambient solar wind to high energies. The rest of these so-called Solar Energetic Particles (SEPs) arrived at the Earth within an hour. Energetic particles entered the Earth's magnetospheric environment directly through the polar cap region. Highly energetic particles penetrated to the stratosphere and produced nitrogen oxides (NOx) via impacts with molecular nitrogen and oxygen. The lower energy particles generated NOx and hydrogen oxides (HOx) in the mesosphere and thermosphere. Acting as a catalyst, NOx (HOx) rapidly destroyed stratospheric (mesospheric) ozone, substantially decreasing ozone concentrations immediately following the arrival of the energetic particles. The most controversial part of the story follows. Over a period of 4 months, vertical winds enhanced by the polar vortex transported the remaining NOx from the middle and upper atmosphere into the stratosphere, leading to a second depletion in the main ozone layer. Some ice core analyses further suggest rapid nitrate deposition (within weeks of production), requiring prompt downward transport to the surface through gravitational precipitation (i.e., snow), though more direct pathways of the nitrates to the ice may be possible. A few recent studies reveal a provocative, striking, and surprising correlation between ice core nitrate spikes and Ground Level Enhancements (GLEs), a signature of large SEPs in Earth-based neutron monitors. However, glaciochemists and the scientific community studying snow photochemistry cannot with traditional models describe a mechanism for maintaining such prompt nitrate enhancements in ice. Furthermore, recent studies have challenged the SEP-nitrate association by demonstrating other sources of nitrate spikes including biomass burning, pollution, and sea salt deposition. In this poster, we articulate these controversies associated with the final link in the "Sun to Ice" chain: whether or not nitrate spikes in the ice core record are associated with solar particle events, and even if so, can they be used to assess historical solar events quantitatively.

**Middle stratospheric to lower mesospheric polar HNO3 during and after SPE compared to EEP production**

Gabriele Stiller

During and after SPEs a sudden increase of HNO3 in the middle stratosphere to lower mesosphere occurs, without correlated production of N2O5. Verronen et al. (2008) have related the HNO3 production to ion recombination reactions involving NO3- and protonated water clusters. On the other hand, subsiding NOx due to EEP production in the mesosphere/lower thermosphere (MLT) region produces N2O5 and subsequent HNO3, due to reactions of N2O5 with protonated water clusters (de Zafra and Smyshlyaev, 2001; Stiller et al., 2005; Reddmann et al., 2010). This process, however, seems to have only limited importance during and directly after SPEs, but occurs only some days to weeks later when MLT-produced NOx has been subsided into the stratosphere. Data from MIPAS observations covering the SPEs during the MIPAS mission life time 2002 to 2012 and the EPP-related NOx increases in Northern and Southern polar winters are used to build a composite of the related events. We will analyze the different processes leading to enhanced HNO3 in the middle to upper stratosphere and try to understand which preconditions lead to the dominance of which of the two reactions.

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**Are Sunspots Disappearing?**

Giuliana de Toma

Penn & Livingston have suggested that sunspots are disappearing from the Sun and we will reach a new Maunder Minimum by 2022.Recent work on USAF/SOON sunspot morphology seems to indicate that small spots have decreased since solar cycle 23 and this has been interpreted as observational evidence in support of Penn & Livingston prediction. We analyzed photometric data from San Fernando Observatory to study variations in sunspot area and contrast over the last two solar cycles and found no evidence that spots are changing and small spots are disappearing. A re-analysis of the sunspot data from the USAF/SOON Observatories support the San Fernando results.

**Stratospheric and tropospheric effects of solar activity in CCMVal-2 model simulations**

Kleareti Tourpali

The 11-year solar cycle influence on stratospheric and tropospheric climate is examined using simulations of couple chemistry-climate models from the CCMVal-2 activity. A summary is provided of the variations of stratospheric ozone, temperature and winds, as well as on tropospheric climate on associated time scales, including the effects on regional modes of variability, such as the North Atlantic Oscillation. The results are compared to those derived from analyses of observations

**Electron Precipitation in the Ionospheric D region during the IPY Period 2007-2008, as seen by the EISCAT Svalbard Radar**

Esa Turunen

EISCAT Svalbard Radar (ESR) was operated in a continuous mode during the International Polar Year (IPY), with experiment start on 1 March 2007 and end on 29 February 2008. This period occured during the prolonged solar minimum time and was on the average geophysically very quiet. The incoherent scatter radar experiment was designed to cover the entire altitude range of the ionosphere, from D and lower E regions to the ionospheric F peak, reaching into the topside ionosphere.The low altitude IPY electron density data from backscattered power measurements, with 3 km range resolution and 2.25 km steps, start from the altitude of 45 km. The lowest altitude data is subject to variable sea and/or tropospheric clutter, but normally data is usable for altitudes higher than 70 km. This unique set of electron density data from a high-latitude station reveals repeated occurence of short lasting low-altitude ionisation enhancements and thus high-energy electron precipitation events, in spite of the generally geomagnetically quiet conditions. We compare the occurence of the high energy precipitation to sudden variations in the solar wind parameters, and specially with occurence of high-speed solar wind. By selecting a threshold for the occurence of the high-speed streams we make a superimposed epoch analysis of simultaneus electron density measured by the radar. This analysis suggests that the low altitude ionization enhancements are directly driven by the high-speed streams. Comparison between riometer data from Svalbard and mainland stations shows that precipitation is generally very localized and restricted to higher latitudes. The repeated high energy electron precipitation events seen in the IPY ESR data set offer a unique opportunity to see chemical effect of ionization enhancements in the atmosphere at high latitudes during solar minimum time. We perform analysis of the atmospheric effects of these ionisation events by using the detailed Sodankyla Ion Chemistry model of D region.

**Proton Precipitation into the Mesosphere as deduced from GOES and NOAA/POES Satellites during the SEP Event in January 2012**

Hilde Nesse Tyssoy

The access of solar protons into the Earth’s magnetosphere is limited by the particle cutoff energy. The GOES energetic particle measurements give the proton fluxes and energy spectra at geosynchronous orbit. At a specific time this measurement is made at the geomagnetic local time where GOES is located. The geomagnetic cutoff energy is strongly dependent both on radial position in the magnetosphere and on magnetic local time. This means that one has to be very cautious when using GOES particle measurements to estimate the particle energy deposition into the upper atmosphere over a specific ground (GB) based station. The GB station should be located close to the magnetic latitude of the geomagnetic footpoint of GOES and also not be too far away in longitude.The NOAA/POES satellites cover different MLT sectors and measure the energetic proton precipitation at all latitudes from equator to about 81 degrees. This enables us to study how the geomagnetic cutoff energy varies with latitude in different local time sectors.We have studied geomagnetic cutoff effects during the SEP event in January 2012. We have also calculated height profiles of the EEP energy deposition in the mesosphere over Tromso based on GOES data and on NOAA/POES data. In some periods we find striking differences in the estimated energy deposition based on GOES versus those based on NOAA data for altitudes greater than 65 km.

**Direct and indirect effects of high energetic particle precipitation on middle atmospheric composition as observed by Odin**

Jo Urban

The Sub-Millimetre Radiometer (SMR) on board the Odin satellite, launched in 2001, is a limb emission sounder measuring trace gases in the stratosphere, mesosphere, and lower thermosphere. The Odin target species water vapour (H2O) and carbon monoxide (CO) are relatively long-lived and their spatio-temporal distribution is strongly influenced by the global meridional circulation. The measurements provide e.g. information on the variability of large-scale transport during polar winter, allowing fro example to study enhanced downward transport from the mesosphere into the stratosphere in the aftermath of major stratospheric warming events as well as upward transport occurring during winter in the polar lower thermosphere. Shorter lived species measured by Odin are directly affected by the precipitation of high energetic particles. Nitric oxide (NO) is formed in the thermosphere when N2 is dissociated by solar radiation and through energy from particle precipitation (e.g. auroral activity). During polar night downward transported NOx contributes to the NOy budget in the mesosphere and stratosphere. Enhanced NOx can slowly be converted to the longer-lived nitric acid (HNO3) involving heterogeneous chemistry on stratospheric aerosol or water ion cluster surfaces during polar winter in the mid-stratosphere. Besides indirect effects requiring transport, also direct effects of high energetic particle precipitation have been observed.Odin is a Swedish-led satellite project funded jointly by Sweden (SNSB), Canada (CSA), Finland (TEKES), and France (CNES), with support by the 3rd party mission programme of the European Space Agency (ESA).

**Changes in HOx and NOy Species During Solar Proton Events - Analysis and Parameterization**

Pekka Verronen

In the middle atmosphere, enhanced ionization by precipitating particles leads to changes in minor neutral composition through ion chemistry. For example, nitrogen and water vapor molecules are dissociated, and odd hydrogen (HOx = H + OH + HO2) and odd nitrogen (NOx = N + NO + NO2) species are produced. Increase in HOx and NOx concentrations can then boost the catalytic reaction cycles that destroy ozone. In this paper, we utilize the Sodankyla Ion and Neutral chemistry model (SIC), which combines ion and neutral chemistry for particle precipitation studies. Based on an analysis of the SIC chemistry, we demonstrate how positive ion chemistry produces NOx and HOx, while negative ion chemistry redistributes NOy species by converting NOx and N2O5 to HNO3 and NO3). Recent SIC results on OH and HNO3 changes during solar proton events are presented, including comparisons with satellite instruments. We put forward an improved parameterization, which takes into account both positive and negative ion chemistry and can be used to model the atmospheric effects of particle precipitation.

**Effects of MEPED electrons and ions on global upper atmosphere and ionosphere during Jan. 15-23, 2005 storm events**

Wenbin Wang

The effect of MEPED electrons and ions on the upper atmosphere and ionosphere during the Jan. 15-23 major storm events has been simulated using the Thermosphere Ionosphere Mesosphere Electrodynamics Global Circulation Model (TIMEGCM). The TIMEGCM is driven by high latitude inputs of ion convection and auroral precipitation patterns from AMIE and MEPED electrons and ions obtained from NOAA particle measurements. It is found that MEPED electrons affect the upper atmosphere by localized ion production and associated chemical processes at altitudes between 50 and 90 km. These effects include increases of electron density and OH concentration in this altitude range. However, MEPED electrons do not have noticeable effects on the ionosphere or the upper atmosphere above about 100 km. On the other hand, the TIMEGCM shows that MEPED ions have a global effect on the upper atmosphere and the ionosphere. There are large changes in the ionospheric F2 peak densities at middle and low latitudes. These changes are associated with changes in neutral winds and, consequently, neutral wind dynamo that alter the transport of ionospheric plasma. The current numerical study thus suggests that MEPED ions can have some interesting and significant effects on the global neutral atmosphere and ionosphere system, which has not been explored in previous studies that focused primarily on their effects in the high latitude region.

**Model simulations of the impact of energetic particle precipitation on the chemical composition and heating rates**

Nadine Wieters

Solar eruptions and geomagnetic storms can cause high energy particle precipitation (EPP) into the upper and middle polar atmosphere. These energetic particles can penetrate into the Earth atmosphere down to the stratosphere and cause an increase in odd-hydrogen (HOx) and nitrogen species (NOx) through ion chemistry. This increase in both HOx and NOx results in the reduction of ozone, since they are both catalysts for reactions of ozone depletion. Measurements as well as model studies show that EPP events also have an influence on atmospheric temperatures and dynamics. This is mainly due to a change in atmospheric heating rates. During an EPP event, atmospheric heating rates are affected by joule heating in the upper mesosphere and lower thermosphere, radiative heating in the upper stratosphere and lower mesosphere due to the destruction of ozone, chemical heating because of odd-hydrogen production and ozone loss in the mesosphere, and dynamically induced adiabatic heating. To study the impact of EPP events on the chemical composition, as well as on radiative and chemical heating rates in the middle and upper atmosphere, we performed model simulations for the period 2002-2004 with the Bremen 3-dimensional Chemistry and Transport Model (B3dCTM). The model is driven by the high-resolution meteorological data of an annual cycle as simulated with the Kuehlungsborn Mechanistic general Circulation Model (KMCM). We perform calculations of the radiative and chemical heating rates and estimate the changes in these parameters that result from EPP events. In this context the effects of precipitating particles on HOx and ozone are of particular importance. Corresponding results will be presented.

**Assumptions and limitations in modeling atmospheric ionization by precipitating particles**

Jan Maik Wissing and May-Britt Kallenrode

Atmospheric ionization is partially caused by precipitating particles. In order to model the effects these particles have to be detected, differentiated by species and energy, and interpolated to a global coverage. Pitch angle distributions need to be estimated, full energy spectra to be fitted, fit functions to be presumed, energy depositions to be calculated, and depositions to be transformed into ion pair productions. Within the modeling process different assumptions have to be made, some with just small, some with tremendous impact on the results. Here, an overview on the main assumptions within the complete modeling process and their impact on the ionization rates -in terms of error ranges- will be given. As far as possible error limits for different assumptions will be given and competing solutions will be compared.The main idea is to sensibilize the users of ionization rates for the immanent uncertainties and to focus the ionization community on the aspects/assumptions that create them.Some aspects will be sketched using the Atmospheric Ionization Module OSnabruck (AIMOS). However, most of the implications are generally applicable for all kind of ionization models that are based on particle measurements.

**Atmospheric Ionization Module OSnabruck (AIMOS) - Overview and recent Improvements**

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We present a 3D numerical model deriving atmospheric ionization due to precipitating particles (electrons, protons and alphas) with high spatial resolution. The Atmospheric Ionization Model OSnabruck (AIMOS) consists of two parts: a GEANT4-based Monte Carlo simulation and a sorting algorithm to assign observations from different polar orbiting and geomagnetic satellites to horizontal precipitation cells, depending on geomagnetic activity. AIMOS has been checked against (a) EISCAT radar in the thermosphere with sound results and (b) MIPAS measurements in the stratosphere and mesosphere in the context of the last HEPPA/MIPAS model-intercomparison - with good results in general, but also revealing issues with the electron input data set. This poster is meant to give a short overview on the model itself as well as presenting the recent development and in particular the correction of the electron issue. As AIMOS is available as web-applet results may also be shown interactively.