HEPPA SOLARIS 2014

High Energy Particle Precipitation in the Atmosphere
Solar Influences for SPARC (Stratospheric Processes and their Role in Climate)

ABSTRACT BOOK

5th International HEPPA Workshop in conjunction with
SPARC/SOLARIS-HEPPA

5-9 May 2014, Kongresshaus Baden-Baden, Germany

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Agenda HEPPA/SOLARIS 2014

Monday, 5 May 2014

8:00-	8:45	Registration (registration is open all days 8:30 - 17:00 h)

Chair: Gabi Stiller

8:45-	9:00	Welcome and logistics (**Gabi Stiller**)
9:00-	9:45	Radiation belt particle precipitation and its effects on atmospheric interaction: Van Allen probes observations (**Harlan Spence**)
9:45-	10:15	The challenges and problems in measuring energetic electron precipitation into the atmosphere (**Mark A. Clilverd**)
10:15-	10:45	One-slide presentations for poster session I (**Posters A and E**)
10:45-	11:15	Coffee break leading into
11:15-	12:30	Poster session I (**Posters A and E**)
12:30-	14:00	Lunch break

Chair: Harlan Spence

14:00-	14:45	Measurements of solar irradiance - is the controversy solved? (**Thierry Dudok de Wit**)
14:45-	15:15	The solar cycle 24 and predictions of future solar variability (**Natalie Krivova**)
15:15-	15:45	Coffee break leading into
15:45-	17:30	Poster session I (**Posters A and E**)
18:00-	20:00	Ice breaker at the ”Kongresshaus”

Tuesday, 6 May 2014

8:30-	17:00	Registration

Chair: Cora Randall

9:00-	9:45	Variability of the thermal structure, composition, and energy balance of the mesosphere and thermosphere and influence of energetic particles as revealed by SABER (**Martyn Mlynczak**)
9:45-	10:15	The effects of precipitating radiation belt electrons on the mesospheric hydroxyl and ozone (**Monika E. Andersson**)
10:15-	10:45	One-slide presentations for poster session II (**Posters B**)
10:45-	11:15	Coffee break leading into
11:15-	12:30	Poster session II (**Posters B**)
12:30-	14:00	Lunch break

Chair: Martyn Mlynczak

14:00-	14:45	Progress in the detection of solar cycle signals in the lower atmosphere (**Dan Marsh**)
14:45-	15:15	Mathematical methods in atmosphere and climate modelling (**Marko Laine**)
15:15-	15:45	Coffee break leading into
15:45-	17:30	Poster session II (**Posters B**)

18:30-	20:00	Guided walking tour through Baden-Baden (optional, extra cost 5 Euro); meeting point: in front of the "Kongresshaus"

Wednesday, 7 May 2014

8:30-	17:00	Registration

Chair: Katja Matthes

9:00-	9:45	The influence of solar variability on North Atlantic Climate (**Jeff Knight**)
9:45-	10:30	Solar and Particle Effects on the Tropospheric Climate (**Eugene Rozanov**)
10:30-	11:00	One-slide presentations for poster session III (**Posters C and D**)
11:00-	11:30	Coffee break leading into
11:30-	12:30	Poster session III (**Posters C and D**)
12:30-	14:00	Lunch break

Chair: Manuel López-Puertas

14:00-	14:45	Possible implications of a future grand solar minimum for surface climate (**Amanda Maycock**)
14:45-	15:15	HEPPA/SOLARIS outstanding questions (**Bernd Funke, Katja Matthes**)
15:15-	15:45	Coffee break leading into
15:45-	17:30	Poster session III (**Posters C and D**)

18:30-	20:00	Conference dinner at the "Kurhaus Baden-Baden"

Thursday, 8 May 2014

8:30-	17:00	Registration
9:00-	**12:30**	**Overview of ongoing international activities and plans**
Chair: Pekka Verronen		
9:00-	9:20	SPARC SOLARIS-HEPPA overview (**Bernd Funke, Katja Matthes**)
9:20-	9:40	SOLID - an FP7 Project towards the First European Comprehensive Solar Irradiance Data Exploitation (**Margit Haberreiter**)
9:40-	10:00	ROSMIC - Role of the Sun and the Middle Atmosphere/thermosphere/ionosphere in Climate (**Annika Seppälä**)
10:00-	10:20	Update on the International ISSI team: Quantifying Hemispheric differences in particle Forcing Effects on Stratospheric Ozone (**Dan Marsh**)
10:20-	10:40	ISSI Project "Specification of Ionization Sources Affecting Atmospheric Processes" (**Irina Mironova**)
10:40-	11:10	Coffee break
Chair: Scott Bailey		
11:10-	11:30	TOSCA: a COST action on the impact of solar variability on the Earth's climate (**Thierry Dudok de Wit**)
11:30-	11:50	Response of the Atmosphere to Impulsive Solar Events (RAISE) (**Cora Randall**)
11:50-	12:30	Discussion (synergy and collaborations) (**All**)
12:30-	14:00	Lunch break
14:00-	**17:30**	**Presentations of ongoing SPARC SOLARIS-HEPPA activities (HEPPA-II, SolarMIP)**
Chair: Dan Marsh		
14:00-	14:20	Latest HEPPA II model-measurement intercomparison results (**Bernd Funke**)
14:20-	14:40	Intercomparison of trace gas observations during the 2008/2009 northern hemisphere winter (**Kristell Pérot**)
14:40-	15:00	Comparison of nitric oxide measurements in the mesosphere and lower thermosphere from ACE, MIPAS, Odin/SMR, and SCIAMACHY (**Stefan Bender**)
15:00-	15:20	3dCTM studies on MLT NOx from energetic particles and photoionization (**Holger Nieder**)
15:20-	15:40	Tracer experiments during and after the SSW in winter 2008/2009: set-up and first results (**Miriam Sinnhuber**)
15:40-	16:10	Coffee break
16:10-	**17:30**	**Presentations of ongoing SPARC SOLARIS-HEPPA activities (HEPPA-II, SolarMIP) ctd.**
Chair: Thomas v. Clarmann		
16:10-	16:30	Solar Signals in CMIP-5 Simulations, Part 1: The Stratospheric Pathway (**Presenter tbd**)
16:30-	16:50	Solar Signals in CMIP-5 Simulations, Part 2: Climate Response (**Stergios Misios**)
18:00-	22:30	Wine tasting at the wine cooperative Affental (optional, extra costs 30 Euro); bus leaves at Ludwig-Wilhelm-Platz (behind Evangelische Stadtkirche, church)

Friday, 9 May 2014

8:30-	12:00	Registration
9:00-	**12:30**	**Break-out sessions for SPARC SOLARIS-HEPPA activities (HEPPA-II, SolarMIP, etc.)**
10:30-	11:00	Coffee break
11:00-	12:30	HEPPA and SOLARIS break-out sessions cntd.
12:30-	14:00	Lunch break
14:00-	14:30	HEPPA-II and SolarMIP Reporting session (**Bernd Funke, Katja Matthes**)
14:30-	**15:30**	**Discussion on new/future projects within SOLARIS-HEPPA**
Chair: Bernd Funke and Katja Matthes		
14:30-	15:00	CCMI evaluations: Solar trend (Discussion lead: **Bernd Funke, Katja Matthes**)
15:00-	15:30	CCMI evaluations: Solar forcing uncertainties (Discussion lead: **Bernd Funke, Katja Matthes**)
15:30-	16:00	Coffee break
Chair: Gabi Stiller		
16:00-	17:00	Final discussion, next meeting, etc.
17:00		Close of workshop, adjourn

Poster Session I: Monday, 5 May 2014, 11:15-12:30 and 15:45-17:30

Topic A (Solar and Particle Variability) and
Topic E (Tools for Assessing Solar and Particle Influences (new or improved measurements, models, etc))

Author	Titel	Topic	Board Nr.
Beharrell, Mathew	Substorm induced energetic electron precipitation: morphology and prediction	E	13
v. Clarmann, Thomas	MIPAS: A dataset for testing hypotheses on the impact of particle precipitation on the atmosphere	E	16
Duthie, Rodger	A model of energetic electron precipitation fluxes inside and outside of the plasmasphere during space weather events	E	18
Hardman, Rachael	Investigating electron precipitation events using near-conjugate observations from St. John's, New Foundland, and Halley, Antarctica	A	42
Jahn, Jörg-Micha	Low altitude energetic neutral atom emissions: Remote sensing energetic particle precipitation with neutrals	E	22
Kalakoski, Niilo	Impacts of using different meteorological datasets for nudging WACCM	E	24
Kaufmann, Martin	Atomic oxygen measurements in the mesopause region from 2002 to 2012	E	26
Kero, Antti	Ionospheric electron density profile estimation by spectral riometry	A	40
Misios, Stergios	Lagged climate responses to the 11-year solar cycle in the CMIP5historical simulations	E	37
Nesse Tyssøy, Hilde	Parameterization of the day-night asymmetry in the atmospheric energy deposition during solar proton events	A	8
Newell, Patrick	OVATION Prime-2013: Solar wind Driven Precipitation Model Extended to Higher Geomagnetic Activity Levels	E	28
Peck, Ethan	Correction to the POES MEPED instrument data	E	30
Sandanger, Marit Irene	A new method of recalibrating NOAA MEPED proton measurements	E	47
Shetti, Dadaso	GPS-TEC and Equatorial Plasma Bubbles observations during the period 2002-2013	A	10
Urban, Jo	Effects of solar activity and high energetic particle precipitation on middle atmospheric composition as observed by the Odin Sub-millimetre Radiometer	E	7
Vlasov, Alexey	The vertical extension of EMAC to the MLT region	E	32
Wissing, Jan Maik	The Atmospheric Ionization Module Osnabrück (AIMOS)	E	34

Poster Session II: Tuesday, 6 May 2014, 11:15-12:30 and 15:45-17:30

Topic B (Solar and Particle Effects on the Stratosphere and Above)

Author	Titel	Topic	Board Nr.
Bednarz, Ewa	The response of chemistry and climate to the 11-year solar cycle in UMUKCA	B	1
Funke, Bernd	Hemispheric distributions and inter-annual variability of Noy produced by Energetic Particle Precipitation in 2002-2012 as measured by MIPAS	B	43
Funke, Bernd	A semi-empirical model for mesospheric and stratospheric Noy produ-ced by energetic particle precipitation	B	45
Fytterer, Tilo	Solar and particle induced ozone variations and temperature/dynamical feedbacks in the middle atmosphere	B	3
Hendrickx, Koen	Effects of high energetic particles on nitric oxide measured by Odin-SMR	B	5
Kren, Andrew	Examining the stratospheric response to the solar cycle in a coupled WACCM simulation with internally generated QBO	B	48
Kren, Andrew	Examing the decadal variability in the stratosphere in two 200-yr WAC-CM simulations	B	50
Megner, Linda	Solar impact on total water content in the summer polar mesopause	B	9
Meraner, Katharina	Downward transport of nitrogen oxides in HAMMONIA	B	11
Nieder, Holger	Nox production due to solar forcing in the MLT region - advances in ion chemistry treatment	B	39
Orsolini, Yvan	Impact of energetic particle precipitation on the middle atmosphere through stratospheric nitrid acid	B	15
Päivärinta, Sanna-Mari	Observed effects of solar proton events and sudden stratospheric war-mings on odd nitrogen and ozone in the polar middle atmosphere	B	20
Pérot, Kristell	Unusually strong nitric oxide descent in the Arctic middle atmosphere in early 2013 as observed by Odin/SMR	B	17
Reddmann, Thomas	Long-term impact of Noy transport from the lower thermosphere in the KASIMA model	B	19
Seppälä, Annika	Energetic particle forcing of the Northern hemisphere winter stratosphe-re: Comparison to solar irradiance forcing	B	23
Sinnhuber, Miriam	Local Nox response to geomagnetic activity from the upper stratosphere to the lower thermosphere	B	33
Verronen, Pekka	Comparison of modelled and observed effects of radiation belt electron precipitation on mesospheric hydroxyl and ozone	B	21
Whiter, Daniel	A descent of the aurora over Lapland	B	35

Poster Session III: Wednesday, 7 May 2014, 11:30-12:30 and 15:45-17:30

Topic C (Solar and Particle Effects on the Troposphere and Climate)
Topic D (Atmosphere and Ocean/Atmosphere Coupling)

Author	Titel	Topic	Board Nr.
Bailey, Scott	SOFIE observations of gravity wave activity and thermosphere to stratosphere descent triggered by the 2013 Stratospheric Sudden Warming	D	12
Benze, Susanne	The Polar Mesospheric Cloud season onset and end as indicators of atmospheric coupling and solar cycle effects	D	14
Calisto, Marco	Influence of a Carrington-like event on the atmospheric chemistry, temperature, and dynamics: revised	C	2
Didebulidze, Goderdzi	The seasonal variations of cloudless days and nights in Abastumani and their possible coupling with cosmic factors and climate change	C	4
Hackett, Adrianna	Evidence for elevated stratopause events in modern and historical meteorological data	D	25
Holt, Laura	Indirect effect of EPP and sudden stratospheric warming events in observations	D	27
Lam, Mai Mai	Response of the lower atmosphere to changes in the global atmospheric electrical circuit associated with solar wind variability	C	6
Maliniemi, Ville	Spatial distribution of Northern Hemisphere winter temperatures during different phases of the solar cycle	C	29
Misios, Stergios	The role of the oceans in shaping the tropospheric response to the 11 year solar cycle	C	44
Misios, Stergios	A SOLID survey on the needs of climate and chemistry-climate modelling communities for new irradiance data sets	C	46
Sunkara, Eswaraiah	Vertical and latitudinal coupling of lower and middle atmosphere observed with network of Radars over Indian region	D	36
Thiéblemont, Rémi	North Atlantic Surface Response to the 11-year Solar Cycle	D	38
Yoshida, Kohei	Solar influence on Last Millennium climate simulated by MRI-CGCM3	C	31

Abstracts

The effects of precipitating radiation belt electrons on the mesospheric hydroxyl and ozone

Monika E. Andersson, Pekka T. Verronen, Craig J. Rodger, Mark A. Clilverd, Shuhui Wang, Annika Seppälä and Bonar R. Carson

FMI, Finland

Energetic electron precipitation (EEP) from the Earth's outer radiation belt continuously affects the chemical composition of the mesosphere in the polar regions. With the magnitude of the forcing depending on solar activity and magnetic storms, EEP contributes to catalytic ozone loss in the mesosphere through ionisation and enhanced production of hydroxyl (OH). By analysing OH time series from the Microwave Limb Sounder (MLS/AURA) together with electron count rate observations from Medium-Energy Proton and Electron Detector (MEPED/POES) we provide clear evidence of the connection between precipitating radiation belt electrons and mesospheric OH at geomagnetic latitudes 55-65 N/S. Our analysis indicates that for the time period 2004-2009 EEP has measurable effect in about 30% of cases. We investigate the longitudinal distribution of the OH changes, compare the results with MEPED precipitation maps, and discuss the similarities and differences. Finally, by utilising 11 years of observations from the Global Ozone Monitoring by Occultation of Stars (GOMOS/ENVISAT), Sounding of the Atmosphere using Broadband Emission Radiometry (SABER/TIMED) and MLS instruments, we show that the precipitation-induced increase in OH is typically accompanied by decrease in ozone at altitudes between 60-80 km.

Specification of ionization sources affecting atmospheric processes

Karen Aplin, Frank Arnold, Galina Bazilevskaya, Bernd Funke, Giles Harrison, Alexei Krivolutsky, Vladimir Makhmutov, Irina Mironova, Keri Nicoll, Eugene Rozanov, Miriam Sinnhuber, Ilya Usoskin, Jan Maik Wissing

Saint Petersburg State University (SPbGU), Russia

Investigation of the role of ionization in the Earth's atmosphere and its applications is a multidisciplinary problem that requires a collaboration of specialists looking at the problem from different points of view. Here we present an overview of the ISSI Team project where we aim to increase and synthesize the understanding of ionization sources in the Earth's atmosphere, in particular the parameterization of ionization rates by middle range energies and relativistic electrons, whose atmospheric impact is still to a large extent unknown. We see two clear strands of work, one concerned with atmospheric measurements of ionization, and the other with the parameterization the ionization rates and their influence on atmospheric processes. These two streams are, of course, complimentary and inter-related.

SOFIE observations of gravity wave activity and thermosphere to stratosphere descent triggered by the 2013 Stratospheric Sudden Warming

S. M. Bailey, B. Thurairajah, C. E. Randall, L. Holt, D. E. Siskind, C. Y. Cullens, V. L. Harvey, K. Venkataramani, M. E. Hervig, P. Rong, and J. M. Russell, III

Virginia Tech, USA

Arctic winter observations in 2013 by the Solar Occultation for Ice Experiment (SOFIE) show significant transport from the lower-thermosphere to the stratosphere of air enriched in nitric oxide, but depleted in water and methane. The transport is triggered by the Stratospheric Sudden Warming (SSW) on January 11 and is continuously tracked for over three months. Ultimately, SOFIE shows lower thermospheric air at 40 km in mid-April. Area integrated NO fluxes are compared with previous events in 2004, 2006, and 2009, to show that this event is the 2nd largest in the past 10 years. The SOFIE data are combined with a meteorological analysis to infer descent rates from 40-90 km. The descent profile initially peaks near 75 km, shifting downward by approximately 5 km per 10 days. Gravity wave (GW) activity determined from SOFIE-observed temperature fluctuations shows the growth of GW potential energy with altitude during the different phases of the SSW event. At both 40 and 60 km, compared to the non SSW year of 2011, the GW activity in the SSW of 2013 (and 2009, 2010, and 2012) was reduced after the warming, during the occurrence of an isothermal atmosphere and an elevated stratopause. In contrast, at 80 km the GW activity was highly variable between the individual stratospheric warming events. Comparing SOFIE GW activity and 40-90 km-H2O during the 2013 warming event indicates a correlation between increase in wave activity at each altitude and the time of downward descent of air.

The response of chemistry and climate to the 11-year solar cycle in UMUKCA

Ewa Bednarz, Paul Telford, Amanda Maycock, Luke Abraham, Peter Braesicke, John Pyle

NCAS, UCAM, UK

UV variability associated with the 11-year solar cycle leads to changes in ozone and temperature in the upper stratosphere. Observational and modelling studies suggest that such changes are the starting point for a chain of processes resulting in circulation changes in many areas of the atmosphere. However, details of the interactions between chemical and meteorological changes induced by solar variability remain uncertain.

Here, we use a version of the UMUKCA chemistry-climate model with consistent spectrally-resolved solar variability. While the solar cycle in heating rates has been applied with the method used in HadGEM2-ES, a spectrally-resolved solar variability has been incorporated into the Fast-JX photolysis scheme. We perform two 50-year-long perpetual year (PY) solar maximum and solar minimum integrations and complement them with a three member ensemble of a transient 1960-2010 integration in which boundary conditions correspond by and large to the CCMI Ref-C1 scenario. We discuss how the inferred solar signals vary between the PY and transient experiments. Interannual variability and contributions from other processes (e.g. QBO) make finding the solar signal in the transient integrations ambiguous, but the PY experiments can be used to support detection. This highlights that long data series are needed to ensure correct attribution of the modelled and observed anomalies.

In addition, we present results from two PY experiments in which the solar cycle was applied in either short-wave heating or photolysis. We find some significant non-linear behaviour. The sum of the changes caused by either short-wave heating or photolysis differs in some areas of the atmosphere significantly from the changes caused by the combination of both between solar minimum and maximum. This highlights the subtle nature of the dynamical response to the solar cycle forcing and indicates the need for interactive chemistry with a detailed photolysis scheme for modelling the solar-climate interactions fully.

Substorm induced energetic electron precipitation: morphology and prediction

M. Beharrell, C.J. Rodger, F. Honary, M.A. Clilverd

Department of Physics, Lancaster University, UK

Until recently, the accurate prediction of auroral energetic electron precipitation (EEP) was thought never to be likely. The difficulty comes primarily from its high variability, often with small spatial and temporal scales. Here we present examples of substorm induced EEP in multiple instruments, and show how the events can be modeled and predicted when the onset timing of substorms is known, for example by utilising the SuperMAG substorm onset list. Several known features of substorm EEP emerge from the model results, including each of the 4 categories of riometer spike events.

Comparison of nitric oxide measurements in the mesosphere and lower thermosphere from ACE, MIPAS, Odin/SMR, and SCIAMACHY

S. Bender, M. Sinnhuber, T. von Clarmann, G. Stiller, J. P. Burrows, B. Funke, M. López-Puertas, J. Urban, K. Pérot, K. Walker

KIT, Germany

We compare the nitric oxide measurements in the mesosphere and lower thermosphere (70 km to 150 km) from four instruments used in the HEPPA II initiative: ACE-FTS, MIPAS, Odin/SMR, and SCIAMACHY. We use the available daily zonal mean data in that altitude range for the years 2004–2012 (ACE-FTS), 2005–2012 (MIPAS), 2003–2012 (Odin/SMR), and 2008–2012 (SCIAMACHY).

We first compare the data qualitatively with respect to their morphology, focussing on the major features, and then compare the time series directly and quantitatively. At selected locations, we also compare the vertical density profiles on coincident measurement days. We carried out an additional multi-linear regression analysis since none of the instruments delivers continuous daily measurements in this altitude region. This regression analysis considers annual variability in form of harmonic terms and inter-annual variability by responding linearly to the solar Ly-alpha radiation index and the geomagnetic Kp index. This analysis helps to find similarities and differences in the individual data sets with respect to the inter-annual variability caused by geomagnetic and solar variability.

We find that the data sets are consistent and that they only disagree on minor aspects. Odin/SMR and ACE-FTS deliver the longest time series in the mesosphere and they both agree remarkably well. The shorter time series from MIPAS and SCIAMACHY also agree with them where they overlap. The data agree to within 10% when the number densities are large and they can differ by 5 to 10 x 10^7 cm^{-3} when the signal is low.

The Polar Mesospheric Cloud season onset and end as indicators of atmospheric coupling and solar cycle effects

Susanne Benze, Bodil Karlsson, Cora E. Randall

Stockholm University, Sweden

Polar Mesospheric Clouds (PMCs) are indicators of processes and interactions in the upper atmosphere. Cloud variability is connected to 1) the 11-year solar cycle, 2) the stratosphere through wave-mean flow interactions, and 3) climate change of the upper atmosphere. The 11-year solar cycle is negatively correlated with cloud occurrence frequency and brightness, and inter- and intra-seasonal PMC variability is coupled to the same and opposite hemisphere stratosphere through wave-mean flow interactions. Climate change is expected to lead to cooling of the upper atmosphere and therefore to more and brighter clouds. This work presents correlations of the timing of the PMC season onset and end to stratospheric temperatures and winds as well as to the 11-year solar cycle. We use the long-term PMC dataset of the Solar Backscatter UltraViolet (SBUV) satellite instruments for defining the dates of PMC onset and end, ERA-Interim temperatures and zonal mean winds, as well as solar Lyman-α as an indicator of the state of the solar cycle. We find that the Southern Hemisphere (SH) PMC onset date is dominantly correlated to the timing of the SH stratospheric wind reversal from winter to summer conditions. This is due to gravity wave (GW) - mean flow interactions: an early reversal from winter eastward to summer westward winds causes a changed GW drag in the summer mesopause region that leads to an early onset of cold temperatures and thus an early formation of PMCs. After removing this strong dynamical component from the PMC onset dates through multiple linear regression, a clear correlation of the SH PMC onset dates and the solar cycle emerges. Similar investigations are presented regarding the timing of the NH PMC season onset as well as the timing of the NH and SH PMC season end.

Influence of a Carrington-like event on the atmospheric chemistry, temperature and dynamics: revised

M. Calisto, I. Usoskin and E. Rozanov

ISSI, Switzerland

We present a 3D Chemistry Climate Model study on the influence of a Carrington-like solar proton event (SPE) on atmospheric chemistry, temperature and dynamics. The ionization rates were parameterized according to CRAC:CRII (Cosmic Ray-induced Atmospheric Cascade: Application for Cosmic Ray Induced Ionization) describing the effects of SPEs in the entire altitude range from 0-80 km. This is the first study of the atmospheric effect of such an extreme event that considers all the effects of energetic particles, including the variability of galactic cosmic rays, in the entire atmosphere (Usoskin et al., 2010). We have assumed two scenarios for the event, a hard (February 1956) and a soft (August 1972) spectrum of solar particles. We have placed such an event to take place in the year 2020 in order to investigate the impact on the modern, near future atmosphere. We find significant responses of NOx, HOx, ozone, temperature and zonal wind. The results show an increase of NOx of up to 80 ppb in the northern polar region and an increase of up to 70 ppb in the southern polar region. HOx shows an increase of up to 4000%. Due to the NOx and HOx enhancements, ozone reduces by up to 60% in the mesosphere and by up to 20% in the stratosphere for several weeks after the event started. The model also identifies SPE induced statistically significant changes in the surface air temperature, with warming in the eastern part of Europe and Russia of up to 7 K for January. We conclude that a SPE, if it took place in the near future with an intensity similar to that of the Carrington event, must be expected to have a major impact on the atmospheric composition throughout the middle atmosphere.

MIPAS: A dataset for testing hypotheses on the impact of particle precipitation in the atmosphere

Thomas von Clarmann and the IMK/IAA MIPAS team

IMK-ASF, KIT, Germany

MIPAS is a high spectral resolution infrared limb sounder which measured the composition of the atmosphere from 2002 to 2012. The measurements are global, cover daytime and nighttime, and range from the upper troposphere to the middle mesosphere (in the nominal measurement mode) and to the thermosphere (in special observation modes). The data product covers temperature as well as mixing ratios of numerous constituents relevant to the investigation of the impact of particle precipitation in the atmosphere. Among these are the HO_x reservoirs HOCl and H_2O_2 (2002-2004 only), the NO_x species NO and NO_2, the NO_y species HNO_3, HNO_4, $ClONO_2$, N_2O_5, the chlorine radical ClO, the chlorine reservoirs $ClONO_2$ and HOCl, the dynamical tracers N_2O, H4, CFC-12, CFC-11, CO and SF_6. These data cover nearly a full solar cycle with a couple of solar proton events and are available to the scientific community. For certain applications, the content of a priori information of the data causes problems. Thus, for the upcoming data version, along with the regular data product a maximum likelihood data product will be offered in addition. The latter does not contain any a priori information. The altitude resolution is directly defined by the altitude grid on which the data are represented. The pros and cons of this data representation for hypothesis testing will be critically discussed.

The challenges and problems in measuring energetic electron precipitation into the atmosphere

Mark A. Clilverd (1), and Craig J. Rodger (2)

(1)British Antarctic Survey, Cambridge, UK
(2)University of Otago, Dunedin, New Zealand

Significant progress has been made in the understanding of energetic particle precipitation and its effects on the middle and upper atmosphere. Model simulations now include the chemical and energetic forcing from a broad range of energetic particles, including electrons and protons. Studies have shown that significant forcing of the atmosphere can occur during periods of high geomagnetic storm activity, initially driven by processes occurring on the Sun. Energetic electron precipitation occurs at medium and high geomagnetic latitudes from the Van Allen radiation belts, geomagnetic substorms and the aurora. Proton precipitation occurs at high geomagnetic latitudes due to solar proton events and the aurora. No significant precipitation events are expected close to the equator.

Although there is now more than a solar cycle of electron precipitation measurements from satellite, the observations of electron flux and energy is incomplete, and requires considerable thought in its analysis. In this talk we will identify the challenges and problems that need to be addressed when providing electron precipitation information for use in atmospheric models. These issues include proton contamination of the electron detectors on satellite, inaccurate measurement of electron flux due to limited detector viewing capabilities, and non-uniform precipitation into the atmosphere due to the configuration of the Earth's magnetic field. These issues change in significance during the course of a geomagnetic storm, and change in significance depending on electron energy.

In this talk we discuss ways in which electron precipitation measurements can be interpreted, validated, and provided for input into atmospheric models. We describe work being undertaken to complement the satellite observations through ground-based instrumentation which uses the atmosphere itself as a detector.

The seasonal variations of cloudless days and nights in Abastumani and their possible coupling with cosmic factors and climate change

Goderdzi G. Didebulidze, Maya Todua

Abastumani Astrophysical Observatory, Ilia State University, Georgia

The seasonal variations of cloudless days (CD) and cloudless nights (CN) in Abastumani Astrophysical Observatory (AAO, 41.75N; 42.82E) were considered. Number of CD days is greatest in August when daily mean temperature at the Earth's surface in this region is maximal. For geomagnetically disturbed condition, when planetary geomagnetic index Ap$\geq$12, the greatest number of CD shifts to September, where there is the highest frequency of magnetically disturbed day-nights (as well as at spring equinox periods). Such a coupling observed between inter-annual distribution of CD and occurence of geomagnetic disturbances indicates possible link of cloud covering processes with cosmic factors. This also shows that in AAO the biggest number of CN occurs in September and it moves to August for geomagnetically quiet conditions (Ap$\leq$11). This assumption of influence of cosmic factors on cloud covering is supported by the fact that geomagnetically disturbed cloudless nights appear more frequently in June, while for quiet ones their number is minimal. Galactic cosmic rays (GCRs) flux variations are thought as a possible cosmic factor that could affect the cloud covering process, since it is considerably low for cloudless nights of the considered dataset in June. This decrease grows at strong geomagnetic disturbances (Ap$\geq$50). We consider that different influence of cosmic factors on day- and night-time cloud covering processes is significant for climate change. This is also indicated by the observed decrease (negative trend) of the number of geomagnetically disturbed cloudless nights and increase (positive trend) of cloudless days during the same season.

Measurements of the solar irradiance - is the controversy solved?

T. Dudok de Wit

LPC2E, CNRS/University of Orléans, France

For three decades, satellite measurements of solar UV variability have shown changes that were consistent with solar cycle variations, and with irradiance models. Measurements made since 2003 by the SORCE satellite have started departing from this convenient picture, stirring controversy and fuelling a debate. Although these measurements from SORCE are hard to reconcile with past observations, there is also clear evidence for the Sun to be today in an unusual state of activity. This is a fascinating and multi-faceted problem that may not have the kind simple answer we are looking for. In this review, we shall start with an overview of the patchwork of existing irradiance measurements and see how they will eventually be merged into a single composite. Next, we shall determine how recent observations can be constrained by past data, and how this may lead to scenarios for future solar activity. This review will largely be based on the findings made by the TOSCA COST action and the FP7 SOLID project, both of which are investigating the solar radiative output and its connection with the Earth's climate.

TOSCA: a COST action on the impact of solar variability on the Earth's climate

T. Dudok de Wit, on behalf of the TOSCA team

LPC2E, CNRS/University of Orléans, France

TOSCA is a multidisciplinary European network of scientists from 19 countries whose objective is to provide a better understanding of the hotly debated role of the Sun in climate change. This action aims at assessing the various contributions of solar variability to the Earth's climate by bringing together solar physicists, space scientists, atmospheric scientists, climate modellers, paleoclimatologists, and more. As a COST action, TOSCA aims at fostering interactions between these different communities. The action will run until mid-2015 but we still welcome participation (http://www.tosca-cost.eu)

A model of energetic electron precipitation fluxes inside and outside of the plasmasphere during space weather events

Roger J. A. Duthie; Mark A. Clilverd; Craig J. Rodger; Janos Lichtenberger; Anders Jorgensen; Ian Whittaker

British Antarctic Survey, UK

The outer edge of the plasmasphere has a strong influence on the geographic location of high energy particle precipitation into the atmosphere. In this study, we will present a description of the PLASMON-developed model of energetic electron precipitation (EEP) fluxes inside and outside of the plasmasphere during space weather events. The aim of the PLASMON EEP model is to identify energetic electron precipitation into the ionosphere generated by ULF/VLF waves in the magnetosphere. Wave generation is influenced by MLT-dependent plasmaspheric density structures such as the plasmapause. During geomagnetic disturbances the intensities of the ULF/VLF waves are enhanced, plasmaspheric structures are modified, and differing levels of precipitation flux are generated. The model will characterise the variations in electron precipitation relative to the plasmapause, building on the outputs of the PLASMON data assimilative model of the plasmasphere, and observations of EEP characteristics made by the PLASMON ground-based VLF receiver network (AARDDVARK).

Vertical and latitudinal coupling of lower and middle atmosphere observed with network of Radars over Indian region

S. Eswaraiah, M. Venkat Ratnam, S. Vijayabhaskar Rao, E. Kosalendra, K. Kishore Kumar, S. Sathish Kumar, and S. Gurubaran

Sri Venkateswara University, India

It is well known that gravity waves and tides play an important role in delineating the middle atmospheric structure and dynamics. Significant advancement has been in recent days in understanding the role of gravity waves and tides using different techniques in the lower, middle and upper atmosphere. However, only few results are available with simultaneous observations of all the three regions mentioned above. Further, no effort has been made so far in dealing with the latitudinal forcing of these waves and tides. With the establishment of advanced meteor radar at Sri Venkateswara University, Tirupati (13.63°N, 79.4°E) and up gradation of MF radar at Kolhapur (16.8°N, 74.2°E) together with existing MST radar at Gadanki (13.5°N, 79.2°E), Meteor radar at Thumba (8.5°N, 77°E) and MF radar located at Tirunalveli (8.7°N, 77.8°E) forms a unique network to address lower atmospheric forcing and its impact on middle and upper atmospheric structure and dynamics. All the above mentioned radars have been operated for few days simultaneously for investigating the short period gravity waves and tides (diurnal, semi-diurnal and ter-diurnal). Using simultaneous MST radar, Rayleigh lidar located at Gadanki and SVU meteor radar, lower atmospheric forcing and its impact of upper atmospheric is investigated. First results on short period gravity waves and tides are presented. Large day-to-day day variability in gravity waves and tides is observed within a station and among the stations providing insight on vertical and lateral coupling. Thus, long-term measurements with all the above mentioned instruments is planned to address effectively the vertical and latitudinal wave forcing.

Hemispheric distributions and inter-annual variability of NOy produced by Energetic Particle Precipitation in 2002-2012 as measured by MIPAS

B. Funke, M. López-Puertas, T. von Clarmann, G. Stiller, L. Holt and C. Randal

IAA, CSIC, Spain

The MIPAS Fourier transform spectrometer on board Envisat has measured limb emission spectra in the mid-IR for a 10-year period (2002-2012) which have been used to retrieve vertical profiles of the six principal reactive nitrogen (NOy) compounds (HNO3, NO2, NO, N2O5, ClONO2, and HNO4) with global coverage and independent of illumination conditions. From these data, the contribution of NOy produced by energetic particle precipitation (EPP) has been discriminated from the background NOy by using a tracer correlation method based on co-located MIPAS CH4 and CO measurements. The obtained EPP-NOy distributions demonstrate a regular indirect EPP impact on the entire stratosphere (down to 22-25 km) by polar winter descent and show a clear solar cycle signal in consonance with the change in the geomagnetic activity. Furthermore, a pronounced hemispheric asymmetry is observed, with higher concentrations of EPP-NOy in the Southern Hemisphere (SH) and a larger variability in the Northern Hemisphere (NH). In this paper, possible drivers of the observed hemispheric asymmetry are discussed. We also show by multi-linear regression of the temporal evolution of EPP-NOy with the Ap index that 80-90% of the SH inter-annual variability (excluding direct contributions by Solar Proton Events) can be attributed to changes in the geomagnetic activity. This tight relationship holds throughout the winter season and at all vertical levels. In the NH, a similar well-correlated relationship is found until mid-winter. Afterwards, the Ap correlation breaks down above the 2 hPa level in years with elevated stratopause occurrence.

A semi-empirical model for mesospheric and stratospheric NOy produced by energetic particle precipitation

B. Funke, M. López-Puertas, T. von Clarmann and G. Stiller

IAA, CSIC, Spain

Estimates of hemispherically integrated amounts of NOy produced by energetic particle precipitation (EPP) and transported into the stratosphere and lower mesosphere during polar winters in 2002-2012 have recently been derived from MIPAS observations by means of a tracer correlation method. The obtained EPP-NOy data set allows for quantification of the EPP indirect effect (EPP-IE) in the entire stratosphere. It has been shown that the EPP-IE is highly correlated with geomagnetic activity as indicated by the Ap index in the lower and middle stratosphere. Above, this compact correlation is also given in the Southern hemisphere (SH), and in the Northern hemisphere (NH) except for episodes of sudden stratospheric warming (SSW) and elevated stratopause (ES) events, primarily occurring in the second part of the winter. Here we exploit the dependence of the EPP-NOy on the Ap (or aa) index, available since 1870, in order to construct a semi-empirical model for retrodiction/prediction of the EPP-IE. This parametrization is intended to be used in chemistry climate models (CCM) which do not explicitly model mesospheric EPP effects, and to allow for "historic" CCM simulations of time spans not covered by satellite-based particle flux records.

SPARC SOLARIS-HEPPA overview

B. Funke (1), K. Matthes (2)

(1) IAA, CSIC, Spain
(2) GEOMAR-Helmholtz Centre for Ocean Research Kiel, Germany

SPARC's international working group SOLARIS-HEPPA aims at clarifying the effects of solar influence on climate with special focus on the importance of middle atmosphere chemical and dynamical processes and their coupling to the Earth's surface with state-of-the art chemistry-climate models (CCMs) as well as mechanistic models and observations.This talk will provide an overview of the working group's activities during the last year. Plans for future projects will also be discussed.

Solar and particle induced ozone variations and temperature/dynamical feed-backs in the middle atmosphere

T. Fytterer, K. Karami, H. Nieder, M. Sinnhuber, G. Stiller, J. Urban, S. Versick

KIT, Germany

O3 is directly influenced by ultraviolet solar radiation, indirectly also by energetic particles through the production of several trace gases, including odd nitrogen NOx (N + NO + NO2), which catalytically destroys O3. Since O3 is also the major radiative heating source in the stratosphere, imposing a perturbation on the concentration of this gas will result in a change on the radiative energy budget, consequently leading to modified temperatures and dynamics. In this study we use satellite measurements of three independent instruments (ENVISAT/MIPAS, Odin/SMR and TIMED/SABER) and a global Chemistry-Transport model (3dCTM) to investigate the indirect impact of precipitating particles on O3 as well as a Chemistry-Climate Model (EMAC) to simulate the middle atmospheric ($\sim$10 - 120km) temperature and wind field response to changes in the O3 concentration. During low solar activity (2005 - 2010), we analysed O3 measurements inside the Antarctic polar vortex in an altitude range from 20 - 70 km and found a clear negative response to the Ap index and the $\geq$2 MeV electrons flux propagating downwards throughout the polar winter. The results are in qualitatively good agreement with the O3 pattern simulated with the 3dCTM. The EMAC simulations indicate that O3 changes over the tropical stratopause by $\pm$4% lead to an apparent temperature and zonal wind response extending from the equator region well into midlatitudes during winter.

SOLID - an FP7 Project towards the First European Comprehensive Solar Irradiance Data Exploitation

Margit Haberreiter and the SOLID consortium

PMOD/WRC, Switzerland

Variations of solar irradiance are the most important natural factor in the terrestrial climate and as such, the time dependent spectral solar irradiance is a crucial input to any climate modelling. Important advances have been made in the previous years, but the precision of by how much the spectral and total solar irradiance changed on yearly, decadal and longer time scales still needs to be improved. Observations of irradiance data exist in numerous disperse data sets. Therefore, it is important to analyse and merge the complete set of irradiance data. We report on the results of the European collaborative effort SOLID to bring together all European groups involved in irradiance modelling and reconstruction along with collaborators in the US. The project includes the detailed analysis and compilation of all existing SSI and proxy data sets. Furthermore, two different state of the art approaches to produce reconstructed spectral and total solar irradiance data as a function of time are employed, the empirical and semi-empirical modeling of the SSI. These reconstruction results will be used to bridge gaps in time and wavelength coverage of the observational data. This will allow the SOLID team to reduce the uncertainties in the irradiance time series - an important requirement for any user community. In this talk an overview of the SOLID project and first results will be given.

Evidence for elevated stratopause events in modern and historical meteorological data

Adrianna Hackett, Cora Randall, Lynn Harvey

LASP, USA

The stratospheric ozone budget is important to understand since ozone protects the Earth's surface from harmful ultraviolet radiation, and plays a primary role in controlling stratospheric temperatures and thus global circulation. One factor contributing to the budget is descent of NO_x ($NO + NO_2$), routinely formed in the mesosphere and lower thermosphere through energetic particle precipitation (EPP), into the stratosphere where it catalytically destroys ozone. In the northern hemisphere (NH), dynamical activity can lead to sudden stratospheric warmings (SSWs) which are sometimes followed by enhanced descent in the mesosphere. In the region of enhanced descent the air compresses and warms, resulting in the formation of an elevated stratopause (ES). Historical data records (ERA-40 reanalyses) and modern satellite data and reanalyses (SABER, MLS, GEOS-5, and MERRA) are used to identify winters in which ES events occurred. Historical data sets extend only to around 60 km in altitude which is below ES formation; thus ES events cannot be identified directly. This limitation is addressed by identifying a proxy indicator at lower altitudes that is tested on modern data sets and compared with recent work on ES. As an ES forms, there is cooling above and below the ES that results in a cold pool formation around 40-50 km in altitude. This cold pool formation is used to infer the presence of ES throughout the ERA-40 data record (1957-2002).

Investigating electron precipitation events using near-conjugate observations from St John's, New Foundland and Halley, Antarctica

Rachael L. Hardman, Mark A. Clilverd; Craig J. Rodger; Janos Lichtenberger, Donald Danskin

BAS, UK

A form of high energy particle precipitation into the atmosphere is EMIC-induced electron precipitation. In this study, we use a narrow-band radio receiver recently installed at St John's, New Foundland, Canada, as part of the AARDDVARK network, to investigate this particular type of electron precipitation. The aerial is located close to the site of the first successful trans-Atlantic subionospheric wireless radio signal reception made by Marconi in 1901. The AARDDVARK receiver can detect near-by perturbations in subionospheric radio wave propagation conditions caused by enhanced ionization in the altitude range 50-90 km. We present the results of an investigation of electron precipitation events during 2012 and 2013 using near-conjugate observations with Halley, Antarctica. Using the signal received from the LF transmitter located in Iceland (id: NRK, 37.5kHz) we detect changes in amplitude caused by electron precipitation events that can be linked to observations made at Halley via widebeam riometer absorption, or VLF wave occurrence, or the presence of electron magnetic ion-cyclotron (EMIC) waves.

Effects of high energetic particles on Nitric Oxide measured by Odin-SMR

K. Hendrickx, L. Megner, A. Kero, J. Urban, K. Pérot, D.P. Murtagh

Stockholm University, Sweden

High energetic particles originating from our Sun affect the Earth's atmosphere by for example increasing the amount of reactive nitrogen NOx. Through catalytic reactions this reactive nitrogen can lead to an increased ozone break down and temperature gradients, which implies altered atmospheric dynamics. With data from the Sub-Millimeter Radiometer (SMR) onboard of the Odin satellite we investigate the effect of particle precipitation on NO. This will help us entangle the role of transport such as for instance how efficiently NO is transported into the winter polar vortex. In order to study the local effect of high energetic particle precipitation on the evolution of mesospheric NO, we compare SMR data with ground based instruments. A chain of riometers maintained by Sodankylä Geophysical Observatory in Finland measures in a 90^{sfo} beam the cosmic radio noise passing through the atmosphere and determines the amount of atmospheric absorption and the ionisation rate. High energetic particles increase the atmospheric ionisation and will show up as absorption events in riometer data. Co-locational observations between SMR and the riometers are however very limited: during the period 2007-2013 Odin passes roughly 5 times over each riometer station. However, if the particle precipitation is close to uniform over a large area, more Odin observations could be used. We therefore investigate how large scale the structures of precipitation events are, to see how much we can extend the geographical area and still consider co-located measurements. We find a correlation between riometers stationed at the same geomagnetic latitude band on the one hand and between geographically different located riometers on the other hand for large precipitation events. By selecting correlated events in this way we can use more Odin passages and obtain enough data to study the relationship between local high energy particle precipitation and mesospheric NO. Here we show the first results of this study.

Indirect effect of EPP and sudden stratospheric warming events in observations

Laura Holt, Cora Randall, Lynn Harvey, Scott Bailey

LASP, USA

Modeling studies have shown a strong relationship between the indirect effect of energetic particle precipitation and sudden stratospheric warming events. Specifically, earlier warming events lead to a larger stratospheric deposition of NOx. In this poster we show support for the model results with satellite observations.

Low Altitude Energetic Neutral Atom Emissions: Remote Sensing Energetic Particle Precipitation with Neutrals

J.-M. Jahn, D. Mackler, C. J. Pollock

SwRI, USA

An often overlooked aspect of energetic ion precipitation into Earth's atmosphere is the presence of energetic neutral atoms created by charge exchange of ions with the extended hydrogen and oxygen atmosphere of earth (geocorona). At moderate energies below a few 100 keV, this charge exchange has multiple consequences. Precipitating ions can become neutral while trailing along the magnetic field line on their way to Earth. This leads to a neutral precipitation in addition to a charged particle precipitation. Second, since individual particles can undergo this process multiple times, this tends to broaden the region over which precipitation (neutral and charged) occurs. Third, if charge exchange occurs at an altitude where magnetic mirroring allows at least some of the incoming ions to reemerge from the atmosphere before being lost, energetic neutrals can function as a remote sensing device to locate and observe ion precipitation. In this presentation we give an overview over lower energy (1.0 to 10.0 keV ion precipitation as seen from space using the energetic neutral atom remote sensing technique. We will discuss how the spatial and temporal evolution of neutral atom emissions emanating from the ion precipitation region can be used to study ion precipitation in places and at times where no local, in situ resource is available to observe precipitation.

Impacts of using different meteorological datasets for nudging WACCM

Niilo Kalakoski, Annika Seppälä, Monika Andersson, Sanna-Mari Päivärinta, Pekka Verronen

FMI, Finland

We have studied the influence of using three different meteorological datasets: GEOS5, MERRA and ERA-Interim, in the Specified Dynamics version of the Whole Atmosphere Community Climate Model (SD-WACCM). WACCM is the atmospheric component of the Community Earth System Model (CESM). In preparation for climatological model simulation runs we set up three sets of similar model runs using the different external meteorological databases over the period of 2004-2012. Our goal was to see first hand how these different datasets would influence dynamical coupling in the middle atmosphere, what the impact would be for downward transport of mesospheric and thermospheric air, and what the main differences in the stratosphere would be, with the purpose of determining the optimal meteorological database to use with SD-WACCM for studying EPP effects.

Reception of Over Horizon GPS propagation and Earthquake Precursors

Sheetal Karia, Kunvar Yadav, Kamlesh Pathak

Department of Applied Physics, Sardar Vallabhbhai National Institute of Technology (SVNIT), India

The present paper reports the modification in refractivity prior to the Iran earthquake that had occurred on 16 April 2013 in Iran (28.10°N, 62.05°E). The reception of over horizon GPS signal from two GPS receivers Surat (21.16°N, 72.78°E) and Lucknow (26.91°N, 80.95°E) and the results of atmospheric refractivity profile derived from Radio Occultation observations from COSMIC satellite obtained for epicenter region are presented in this paper. It is seen that atmospheric refractivity gets modified from 8 to 6 days prior to the earthquake the epicenter. In an effort to find a pre-EQ energy exchange, the relevant observation of surface latent heat flux around the epicenter are also obtained. Explanations on possible causes leading to such anomalous reception is reviewed with the presented results in assosiation with the pre-seismic effects in the Atmosphere.

Atomic oxygen measurements in the mesopause region from 2002 to 2012

Martin Kaufmann, Yajun Zhu, Martin Stöckle und Martin Riese

Forschungszentrum Jülich, Germany

Abstract not available

Ionospheric electron density profile estimation by spectral riometry

Antti Kero, Derek McKay-Bukowski, Antti Solonen and Juha Vierinen

SGO, Finland

In the so-called spectral riometry, cosmic radio noise absorption is measured simultaneously at multiple radio wave frequencies, instead of a single band used in the traditional riometry. The main advantage of this approach is a possibility to invert the electron density height profile of the D-region ionosphere based on the frequency dependence of the absorption. However, this inversion turns out to be both nonlinear and highly ill-posed, hence needing some strong prior information on the unknown. To tackle this problem, we have applied a model dimensionality reduction method based on the principal components of the Gaussian prior covariance matrix. In practise, the method provides arbitrary smooth electron density profiles, parameterised by a limited number of coefficients to be determined by the MCMC. Simulations reveal that the electron density profiles can, indeed, be determined with some reasonable accuracy in the altitudes of relatively strong absorption.

The influence of solar variability on North Atlantic climate

Jeff Knight (1), Nick Dunstone(1), Adam Scaife (1), Sarah Ineson (1), Lesley Gray (2), Mike Lockwood (3), and Amanda Maycock (4)

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(3) NCAS-Climate, Department of Meteorology, University of Reading, UK
(4) Centre for Atmospheric Science, Department of Chemistry, University of Cambridge, UK

There has long existed observational evidence for a link between solar activity (both the semi-regular 11-yr cycle and longer term variability) and regional climate variability. In the last few years progress is starting to be made in understanding such observational correlations from physical mechanistic viewpoint. Firstly, new observations of solar spectral irradiance from the SORCE satellite have raised the possibility of much larger variability in the UV than previously appreciated. Secondly, state of the art computer climate models now explicitly resolve the Earth's stratosphere allowing the influence of solar variability to be simulated here. By driving such climate models with the larger solar UV variability implied by the latest satellite observations, surface climate impacts have been shown in the Northern Hemisphere winter that are consistent with late 20th century climate data. Low solar activity is associated with the negative phase of the North Atlantic Oscillation (NAO) and hence colder winters over northern Europe and the USA. We discuss the implications for seasonal/decadal climate prediction. Further work has examined the role of ocean feedbacks in amplifying this tropospheric response. There is robust statistical evidence that such a feedback operates in the observations and gives a lag of 3-4 years for the maximum tropospheric response after the maximum solar forcing. This lag does not generally appear to be reproduced by current climate models. We discuss how this observational evidence may be a valuable way of assessing the relative strength of ocean-atmosphere coupling in the present generation of climate models. The prolonged solar minimum during the transition between solar cycles 23 & 24, combined with the relatively low maximum activity of cycle 24, have increased suggestions that we may be coming to the end of the grand solar maximum which dominated the 20th century. A return to Maunder Minimum like solar activity is therefore a possible scenario during the 21st century. We illustrate the possible regional climate impacts that an associated projected decline in the UV flux would have and how this would interact with regional anthropogenic climate change.

Examining the stratospheric response to the solar cycle in a coupled WACCM simulation with an internally generated QBO

A. C. Kren, D. R. Marsh, A. K. Smith, and P. Pilewskie

LASP, USA

The response of the stratosphere to the combined interaction of the Quasi-Biennial Oscillation (QBO) and the solar cycle in ultraviolet (UV) radiation, and the influence of the solar cycle on the QBO, are investigated using the Whole Atmosphere Community Climate Model. Transient simulations were performed beginning in 1850 that included fully-interactive ocean and chemistry model components, observed greenhouse gas concentrations, volcanic eruptions, and an internally generated QBO. Over the full length of the simulations we do not find a solar cycle modulation of either the QBO period or amplitude. We also do not find a persistent wintertime UV response in polar stratospheric geopotential heights when stratifying by QBO phase. Over individual ∼40-year periods of the simulation, a statistically significant correlation is sometimes found between the northern polar geopotential heights in February and UV irradiance during the QBO westerly phase. However, the sign of the correlation varies over the simulation, and is never significant during the QBO easterly phase. Complementing this is analysis of 4 simulations using a QBO prescribed to match observations over the period 1953-2005. Again, no consistent correlation is evident. In contrast, over the same period, meteorological reanalysis shows a strong positive correlation during the QBO westerly phase, although it weakens as the period is extended. The results raise the possibility that the observed polar solar-QBO correlation may have occurred because of the relatively short data record and the presence of additional external forcings rather than a direct solar-QBO interaction.

Examining the decadal variability in the stratosphere in two 200-yr WACCM simulations

A. C. Kren, D. R. Marsh, A. K. Smith, and P. Pilewskie

LASP

Several studies have shown decadal variability in the stratosphere, specifically in ozone, temperature, and zonal winds. Often these decadal changes are attributed to the solar cycle, however this can be difficult since other external forcings are at play. In this study, we examine the decadal variability in the stratosphere by analyzing two WACCM simulations. Both simulations are 200 years in length. The first is a pre-industrial time-slice simulation with fully interactive ocean but with no solar cycle. The second uses specified sea surface temperatures from the first simulation along with spectral solar irradiance variability. We compare stratospheric decadal variability in the two simulations with the aim of separating variations directly forced by changes in solar irradiance and unforced decadal variability that is internal to the ocean that propagates upward to the stratosphere.

The solar cycle 24 and predictions of future solar variability

Natalie Krivova

MPS, Germany

Various extensive observations of the Sun over the last several decades have provided significant amount of valuable information about solar activity and variability. As chance would have it, the Sun was fairly active over this period. The last activity minimum in 2008, however, turned to be weaker and longer than the earlier minima that we had witnessed before, leading to speculations on future solar activity. A summary of our present understanding and the forecast efficiency of solar variability on solar cycle and longer time scales will be given.

Mathematical methods in atmosphere and climate modelling

Marko Laine

FMI, Finland

I will review mathematical and statistical uncertainty quantification (UQ) methods for large scale models used in atmospheric and climate research. UQ refers to the analysis of the effect of the input uncertainties to the uncertainty in the quantities of interest in model output. Typically the methods are based on Monte Carlo simulations, either by using parallel ensemble of model runs or sequential algorithms such as Markov chain Monte Carlo (MCMC). Examples are related to tuning of closure parameters in climate models and parameter sensitivity analysis for an atmospheric chemical transport model FinROSE, and for the Sodankylä Ion Chemistry model SIC.

Response of the lower atmosphere to changes in the global atmospheric electric circuit associated with solar wind variability

M. M. Lam, G. Chisham, and M.P. Freeman

BAS, UK

The existence of a meteorological response in the polar regions to fluctuations in the interplanetary magnetic field (IMF) component By is well established. More controversially, there is evidence to suggest that this Sun-weather coupling occurs via the global atmospheric electric circuit (GEC). In this talk I present further evidence of the solar wind's influence on the polar troposphere, communicated via the GEC. In particular, our recent results show a response to IMF By throughout the Antarctic troposphere within about 1-5 days, and indications of a resulting delayed influence on the lower stratosphere. We observe an increase in the response time with increasing altitude which is suggestive of an upward propagation of the influence of the solar-wind-induced variability on the lower troposphere. These results are in contrast to the observed slower downward propagation of meteorological effects, from the stratosphere to the lower troposphere, due to mechanisms associated with solar variability involving ultra-violet radiation or energetic particle precipitation.

It has been assumed that the meteorological response to fluctuations in IMF By maximizes at high latitudes and is negligible at low and mid-latitudes, because the perturbation by the IMF is concentrated in the polar regions. We demonstrate, however, a previously unrecognized influence of IMF By on mid-latitude surface pressure. The difference between the mean surface pressures during times of high positive and high negative IMF By possesses a statistically significant mid-latitude wave structure similar to atmospheric Rossby waves. Our results show that a mechanism that is known to produce atmospheric responses to the IMF in the polar regions is also able to modulate pre-existing weather patterns at mid-latitudes. The amplitude of the effect is comparable to typical initial analysis uncertainties in ensemble numerical weather prediction so could have an important effect, via the nonlinear evolution of atmospheric dynamics, on critical atmospheric processes.

Spatial distribution of Northern Hemisphere winter temperatures during different phases of the solar cycle

V. Maliniemi, T. Asikainen and K. Mursula

University of Oulu, Finland

Several recent studies have found variability in the Northern Hemisphere winter climate related to different parameters of solar activity. While these results consistently indicate some kind of solar modulation of tropospheric and stratospheric circulation and surface temperature, opinions on the exact mechanism and the solar driver differ. Proposed drivers include, e.g., total solar irradiance (TSI), solar UV radiation, galactic cosmic rays and magnetospheric energetic particles. While some of these drivers are difficult to distinguish because of their closely similar variation over the solar cycle, other suggested drivers have clear differences in their solar cycle evolution. For example, geomagnetic activity and magnetospheric particle fluxes peak in the declining phase of the sunspot cycle, in difference to TSI and UV radiation which more closely follow sunspots. Using 13 solar cycles (1868-2013) we study winter surface temperatures and North Atlantic oscillation (NAO) during four different phases of the sunspot cycle: minimum, ascending, maximum and declining phase. We find significant differences in the temperature patterns between the four cycle phases, which indicates a solar cycle modulation of winter surface temperatures. However, the clearest pattern of the temperature anomalies is not found during sunspot maximum or minimum, but during the declining phase, when the temperature pattern closely resembles the pattern found during positive NAO. We find this to be independent of the overall level of solar activity. The results support solar wind related or recently proposed lagged solar cycle response to the Northern Hemisphere winter circulation and surface temperatures.

Progress in the detection of solar cycle signals in the lower atmosphere

Daniel Marsh

NCAR, USA

Detecting the atmospheric response to changes in solar irradiance and energetic particle fluxes on timescales up several decades remains a significant challenge. The satellite observational record is still comparatively short. Attribution is hampered by the presence of other natural variability (e.g., that induced by volcanoes, ENSO or stratospheric sudden warmings) and also the possible non-linear response to a combination of forcings. Still, models and observations are rapidly improving. Several climate models now fully resolve the stratosphere and include interactive chemistry. The observational database is growing to better characterize irradiance and particle fluxes and now includes many chemical constituents. This allows us to better represent both the solar-induced forcing of the atmosphere and how the physical system responds to that forcing. In this overview, I will attempt to summarize recent progress towards identifying and correctly attributing solar-induced variability in the stratosphere and troposphere, aided by recent advances in model and observational capabilities.

Update on the International ISSI Team: Quantifying Hemispheric Differences in Particle Forcing Effects on Stratospheric Ozone

D.R. Marsh (1), M.A. Clilverd (2), B. Funke (3), C.H. Jackman (4), H. Nieder (5), E. Peck (6), C.E. Randall (6), C. Rodger (7), A. Seppälä (8), M.Sinnhuber (5), J. Urban (9), P. Verronen (8), S. Versick (5), J.M. Wissing (10)

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(6) University of Colorado, USA
(7) University of Otago, New Zealand
(8) Finnish Meteorological Institute, Finland
(9) Chalmers University of Technology, Sweden
(10) University of Osnabrück, Germany

This presentation will provide an upate on the progress made by the International Space Science Institute (ISSI) Team focussed on quantifying hemispheric differences in wintertime energetic particle precipitation (EPP) NOx and its effects on stratospheric ozone. The study is motivated by the fact that the dynamical variability of the winter polar stratosphere in the Northern Hemisphere modulates the downward transport of NOx and subsequent ozone loss, whereas the lack of variability of the winds in the Southern Hemisphere winter results in a consistent conduit of upper atmospheric NOx into the stratosphere. A combination of satellite data and model simulations are used to estimate wintertime EPP, NOx production and its effects on stratospheric ozone with the aim of assessing which hemisphere responds more directly to EPP forcing on timescales up to the 11-year solar cycle. This is a necessary first step in understanding the role of stratospheric EPP-induced ozone loss in driving tropospheric climate variability.

Possible implications of a future grand solar minimum for surface climate

Amanda C. Maycock

University of Cambridge, UK

Electromagnetic radiation from the Sun is the fundamental source of energy for the terrestrial climate system, and hence changes in solar activity have the potential to influence global climate. The period of relatively high solar activity over the last $\sim$50 years has coincided with a so-called 'grand solar maximum'. Analysis of past variations in solar activity suggests that the current grand maximum may come to an end within the next few decades, after which the Sun may be expected to evolve towards a state of lower output. Further evidence for these claims comes from the unusually deep and persistent 11-year solar cycle 23 minimum and the current weak solar cycle 24 maximum. As a result, interest in the possible implications of a longer-term decline in solar output has increased over the past few years. In this talk, I will review a number of modeling studies that have investigated the possible implications of an onset of a grand solar minimum over the 21st century for surface climate. In particular, I will focus on the possible interactions between the effects of a decline in solar output with the signals of anthropogenic climate change. It will be shown that the impacts of a grand solar minimum on regional European winter climate may be comparable to the differences between individual greenhouse gas forcing scenarios discussed in the recent IPCC AR5 report.

Solar impact on total water content in the summer polar Mesopause

Linda Megner, Bodil Karlsson

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It has long been known that solar Lyman-alpha light photodissociates water and therefore a negative correlation between water vapour and the solar cycle is to be expected. However, in the summer polar mesosphere, where Noctilucent clouds form, the relationship is not this straight forward. Most likely the reason is that a large part of the water content is stored in the cloud ice particles, and thus invisible to instruments that observe water vapour. Moreover, apart from breaking down the water vapour via dissociation, the solar radiation also increases the temperature, which leads to evaporation of water vapour from the ice particles. Thus increased solar radiation can lead to both increase and decrease of water vapour. Due to this ambiguity we here combine observations of water vapour, from Odin SMR with observations of ice from Odin Osiris, to study how the total water content, reacts to Lyman alpha radiation.

Downward transport of nitrogen oxides in HAMMONIA

K. Meraner and H. Schmidt

MPI, Germany

Energetic charged particles enter the Earth's atmosphere in the polar region. We distinguish between two types of energetic particles according to their location of acceleration: Solar energetic particles (SEP) are accelerated by solar wind and penetrate into the stratosphere, where they increase by ionization the amount of odd hydrogen and odd nitrogen, which in turn cause ozone destruction. Magnetospheric energetic particles (MEP) are accelerated in the magnetosphere of the Earth during strong geomagnetic events. They, however, reach only the mesosphere and lower thermosphere, where they enhance the ion concentration leading to an increase in nitrogen oxides (NOx). It is supposed that during polar night these components can be subsequently transported downwards to the stratosphere, where they also contribute to ozone destruction. This would affect the strength of the polar vortex, which in turn may influence the climate in the troposphere.

However, it is still not clear which kind of transport causes the descent of NOx into the stratosphere. Here, we analyze the transport of nitrogen oxides through the mesopause with the Hamburg Model of the Neutral and Ionized Atmosphere (HAMMONIA) with two different horizontal resolutions. We perform simulations with a passive tracer where single transport processes are switched off in order to assess their importance. Previous studies (Kieser, 2011; Funke et al., 2011) showed that the vertical transport in HAMMONIA increases strongly with increasing horizontal resolution of the model. Hence, we use, additional to simulations with a low resolution (T31, 3.8°x3.8° gridbox), simulations with a higher spatial resolution (T63, 1.9°x1.9° gridbox) to analyze the dependency of the transport on the horizontal resolution.

Lagged climate responses to the 11-yr solar cycle in the CMIP5 historical simulations

Misios S., Mitchell D., Tourpali K., Gray L. and SolarMIP members

AUTH, Greece

The Solar Model Inter-comparison Project (SolarMIP) is a SPARC initiative comparing the Coupled Model Inter-comparison Project Phase 5 (CMIP5) model responses to the change in solar irradiance and ozone. We here analyze historical simulations (1850-2005) to quantify effects of the 11-yr solar cycle as brought about by 'top-down' and 'bottom-up' mechanisms. Solar signals in 24 different models are extracted with a lead/lag multiple linear regression model, used to highlight delayed responses in the oceans and troposphere. Our analysis identifies a delayed global mean warming that peaks one to two years after the forcing. The west tropical Pacific and Indian oceans are found warm after solar maximum whereas the warming in the east Pacific is weaker. Following the oceans, the troposphere warms two years after solar maximum in contrast to the stratosphere which responds immediately to the increased solar irradiance. Results are compared to 11-yr solar cycle signals in reanalysis and the relative role of the 'top-down' and 'bottom-up' mechanisms is discussed.

The role of the oceans in shaping the tropospheric response to the 11 year solar cycle

Stergios Misios, Hauke Schmidt

AUTH, Greece

Observational data indicate a weakening and poleward shift of the subtropical tropospheric jets in the maximum phase of the 11 year solar cycle, commonly explained in terms of a direct 'top-down' propagation of solar signals from the stratosphere to the troposphere. We here demonstrate possible linkages to oceanic variability, instead. The observed response of the jets is qualitatively and quantitatively reproduced in an ensemble of simulations with a global model forced only at the lower boundary by the observed sea surface temperatures and sea ice concentrations, while keeping solar cycle forcing constant. The twentieth century reanalysis, in which only surface observations are assimilated, is characterized by a similar shift of the jets. These findings suggest that changes at the ocean surface could contribute considerably to the poleward shift of the subtropical tropospheric jets, although a top-down influence on the oceans and hence indirectly on the jets cannot be excluded.

Solar Signals in CMIP-5 Simulations, Part 2: Climate Response

Stergios Misios et al.

AUTH, Greece

Abstract not available

Solar Signals in CMIP-5 Simulations, Part 1: The Stratospheric Pathway

Daniel Mitchell et al.

University of Oxford, UK

Abstract not available

Variability of the thermal structure, composition, and energy balance of the mesosphere and thermosphere and influence of energetic particles as revealed by SABER

Martin Mlynczak (1), Linda Hunt (2), Manuel López-Puertas (3) and the SABER Science Team

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(2) SSAI, USA
(3) IAA, CSIC, Spain

The Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument has achieved over 12 years of nearly flawless operations in orbit on the TIMED satellite. SABER observes the thermal structure, the chemical composition, and the major infrared radiative cooling terms in the thermosphere and mesosphere and the major solar and chemical heating terms in the mesosphere. From these observations, particularly in the mesosphere, a nearly complete picture of the radiative energy balance is derived. We examine the 12-plus years of SABER data to understand the variability in the energy balance and also the role that ultraviolet and geomagnetic variability influence the energy balance and atmospheric structure. SABER data clearly show substantial short-term variability driven by geomagnetic events involving particle precipitation as well as long-term variability associated with the nominal 11-year solar cycle. The SABER observations will be summarized and new results from solar cycle 24 will be presented.

Determination of solar regression coefficients in the Limpopo Province of South Africa

T.S. Mulaudzi, E.N. Maluta and V. Sankaran

Department of Physics, University of Venda, South Africa

South Africa (SA) has very good resources of solar energy with the average daily solar radiation reaches 7.0 kWh/m2 even in the winter in some areas like Limpopo Province. The deployment of the renewable technologies is taking off slowly in South Africa. Due to high rate of the usage of fossil fuels, emission of carbon is too high throughout the world, so SA has strategized to use alternative energy resources and has a target of 10 000 GWh for renewable energy production in the near future. In order to reach the target, an extensive study and analysis of solar energy is required to enable the renewable energy technologists to develop renewable systems suitable for a particular location. A variety of models for estimating the global solar radiation on the horizontal surfaces using the daily actual sunshine have been evaluated internationally. Hence there is a dire need for such study for South Africa. An attempt has been made in the present study to study the solar radiation pattern in the Limpopo Province of South Africa. The observed global solar irradiance from the two selected stations in Limpopo Province together with the actual sunshine was used to determine the average solar regression coefficients where a = 0.222 and b = 0.481 so as to enable us to predict the irradiance using Angstrom model. The possible sunshine hours (N) and the extraterrestrial solar radiation were computed. The daily plots of the clearness index (K) versus the relative sunshine (RSS) exhibits a good correlation. The computed average regression coefficients were employed to estimate the global solar irradiance and compared with the observed data. The estimated and the observed global solar irradiance were in agreement. The temperature model by Sarmani was also used to evaluate the estimated irradiance. The MBE, RMSE and MPE were determined for validation of the global solar radiation. The results obtained in our present investigation will be discussed in detail.

Parameterization of the day-night asymmetry in the atmospheric energy deposition during Solar Proton Events

Hilde Nesse Tyssøy and Johan Stadsnes

Birkeland Centre for Space Science, Department of Physics and Technology, University of Bergen, Norway

To accurately quantify the effect of SPEs on the atmosphere requires a good estimate of the particle energy deposition in the middle atmosphere (60-100 km) and how the energy is distributed globally. Protons in the energy range 1-20 MeV are of particular interest here. These energies are subject to a more complex dynamics with strong day night asymmetry compared to higher energy particles. Our study targets 6 solar proton events from 2003-2012. By using measurements from MEPED (Medium Energy Proton and Electron Detector) on all available POES satellites, we show that in the main phase of the storm the dayside cutoff latitudes are pushed poleward, while the nightside cutoff latitudes have the opposite response, resulting in a strong day night asymmetry in the energy deposition. Assuming that the protons impact the polar atmosphere homogeneously above a fixed nominal boundary will therefore give a significant overestimate of the energy being deposited in the middle atmosphere during SPEs. We provide a simple applicable parameterization of the cutoff latitude which includes both day and nightside cutoff latitude variability using only the Dst and solar wind pressure.

OVATION Prime -2013: Solar Wind Driven Precipitation Model Extended to Higher Geomagnetic Activity Levels

P. T. Newell, K. Liou, Y. Zhang, T. Sotirelis, L. J. Paxton and E. J. Mitchell

JHUAPL

OVATION Prime is an auroral precipitation model parameterized by solar wind driving. Distinguishing features of the model include an optimized solar wind-magnetosphere coupling function (dΦMP/dt) which predicts auroral power far better than Kp or other traditional parameters, the separation of aurora into categories (diffuse aurora, monoenergetic, broadband, and ion), the inclusion of seasonal variations, and separate parameter fits for each MLATxMLT bin, thus permitting each type of aurora and each location to have differing responses to season and solar wind input (as indeed they do). We here introduce OVATION Prime-2013, an upgrade to the 2008 version currently widely available. The most notable advantage of OP-2013 is that it uses UV images from the GUVI instrument on the satellite TIMED for high disturbance levels (dΦMP/dt $>$ 12,000 (nT2/3 (km/s)4/3 which roughly corresponds to Kp = 5+ or 6-). The range of validity is thought to be about 0 $<$ dΦMP/dt = 30000 (say Kp = 8 or 8+). Other upgrades include a reduced susceptibility to salt and pepper noise, and smoother interpolation across the postmidnight data gap. We will also provide a comparison of the advantages and disadvantages of other current precipitation models, especially OVATION-SuperMAG, which produces particularly good estimates for total auroral power, at the expense of working best on an historical basis.

NOx production due to solar forcing in the MLT region - advances in ion chemistry treatment

Holger Nieder, Daniel Marsh, Miriam Sinnhuber, Nadine Wieters, Holger Winkler

KIT, Germany

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 leads to production of neutral reactive species such as NOx (N, NO, NO2) both directly from dissociation of neutrals and from subsequent ion-neutral reactions.

Studies with a state-of-the-art ion chemistry model were carried out, revealing the influence of the atmospheric background state on the effective NOx production rate per ion pair created. The results of these studies were assembled to a production rate database suitable for readout in 3d CTMs.

Results from 3d CTM runs including the precomputed ion chemistry for energetic particle precipitation are discussed; the results are compared to those obtained using a constant parameterization (1.25 NOx per ion pair).

An extension of the database solution to cover photoionization processes by considering different possible distributions of primary ions is discussed, as well as preliminary results from its implementation in a 1d chemistry model and a 3d CTM.

3dCTM studies on MLT NOx from energetic particles and photoionization

Holger Nieder, Miriam Sinnhuber

KIT, Germany

New results from the 3dCTM are presented in this talk. Improvements have been made in the neutral mesospheric chemistry as well as for the parameterization of NOx production.

NOx production is caused by ionization and dissociation of the constituents, both originate from energetic particle precipitation or EUV radiation. The distribution of primary ions and atoms formed depends on the energy spectrum of the particles and radiation, which is variable and extends down to a few eV for radiation and a few keV for energetic particles at thermospheric altitudes. Both particle ionization and photoionization contribute to the high amounts of NOx in the upper atmosphere, and the new runs will enable to investigate the relative contribution of each of these to the EPP indirect effect.

A new treatment of ion chemistry, considering variable distributions of primary ions, was implemented in the 3dCTM, and preliminary results will be discussed.

Impact of Energetic Particle Precipitation on the middle atmosphere through stratospheric nitric acid

Orsolini, Y.J, Kvissel, O.-K., Stordal, F. and Santee M.

NILU, Norway

Enhancements in nitric acid (HNO_3) are often observed in satellite or ground-based data in the winter polar upper stratosphere, and are thought to be linked to energetic particle precipitation. These enhancements are poorly represented in chemistry-climate models. In order to improve this effect of energetic particle precipitation, we have modelled the chemical and dynamical middle atmosphere response to the introduction of a chemical pathway that produces HNO_3 by conversion of N_2O_5 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. 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 polar distributions of constituents such as NO_x or O_3. We see an improved seasonal evolution of modelled HNO_3 compared to satellite observations from Microwave Limb Sounder (MLS), albeit not enough HNO3 is produced at high altitudes.

Through O_3 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 the spring-to-summer period. This 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.

Through this mechanism, energetic particle precipitation affects the entire middle atmosphere, and possibly the tropospheric circulation.

Observed effects of solar proton events and sudden stratospheric warmings on odd nitrogen and ozone in the polar middle atmosphere

S.-M. Päivärinta, A. Seppälä, M. E. Andersson, P. T. Verronen, L. Thölix, and E. Kyrölä

FMI, Finland

We use satellite observations from the ACE-FTS, MLS/Aura and SABER/TIMED to study the effects of solar proton events (SPEs) and strong sudden stratospheric warmings (SSWs) on the middle atmospheric odd nitrogen (NOx) and ozone levels in the Northern Hemispheric polar region. Three winters (January-March) are considered: (1) 2005 (SPE), (2) 2009 (SSW), and (3) 2012 (SPEs and SSW). These different cases provide a good opportunity to study the roles that transport from the mesosphere-lower thermosphere region and in situ production due to particle precipitation have on stratospheric NOx levels and the consequent effects on the middle atmospheric ozone. The observations show increases in NOx after both the SPEs (days to weeks) and SSWs (weeks to months) by up to a factor of 25 between 40 and 90 km. The largest mesospheric NOx increases are observed following the SSW in late January 2009, but the most substantial effects in the upper stratosphere are seen when both an SSW and in situ production by SPEs take place (2012), even though the in situ NOx production in 2012 was relatively weak in magnitude compared to periods of much higher solar activity. In 2012, both short-term (days, due to SPEs and odd hydrogen) depletion and longer-term (months, due to several drivers) depletion of ozone of up to 90% are observed in the mesosphere and upper stratosphere, coinciding with the enhanced amounts of NOx.

Variations in vertical profiles of atmospheric refractivity prior to and on an earthquake day

K. Pathak, S. Karia

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The present paper reports the modication in atmospheric refractivity prior to two earthquakes, the Sumatra earthquake that occurred on 11 April 2012 (2.311N, 93.063E) and the Iran earth- quake that occurred on 16 April 2013 in Iran (28.10N, 62.05E). The results of atmospheric refractivity profile for Radio Occultation observation around the epicenters are presented in this paper. It is seen that atmospheric refractivity gets modified from 8 to 6 days prior to the earthquake for the Iran Earthquake and also 7 days prior to and on the earthquake day for the Sumatra Earthquake. We conclude that in search of precursory signatures for an earth- quake,atmospheric refractivity can be a potential parameter.

Correction to the POES MEPED instrument data

E. D. Peck, C. E. Randall, J. Green, J. Rodriguez, X. Fang, D. R. Marsh

LASP, USA

In this work we present a correction method to the Polar Operational Environmental Satellite (POES) Medium Energy Proton/Electron Detector (MEPED) instrument data. POES MEPED has been plagued by cross-contamination between electron and proton detectors, limiting the usefulness of the data set. The correction applied in this work seeks to remove most of that cross-contamination such that the data can be used for scientific work in studying both trapped and precipitating protons and electrons.

Inter-comparison of trace gases observations during the 2008 / 2009 northern hemisphere winter

Kristell Pérot (1), Joachim Urban (1), Bernd Funke (2), Miriam Sinnhuber (3), Gabriele Stiller (3), Stefan Bender (3), Donal Murtagh (3) and the rest of the HEPPA II team

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(3) Karlsruhe Institute of Technology, Karlsruhe, Germany

Energetic Particle Precipitation (EPP) refers to the process by which energetic protons and electrons affect the Earth's middle atmosphere. It leads, amongst other things, to the production of odd nitrogen by the magnetospheric electrons reaching the mesosphere / lower thermosphere (MLT). In winter polar night conditions, at high latitude, EPP generated-NOx can be transported down to the stratosphere, where it can affect the atmospheric chemistry. This mechanism is generally called the EPP indirect effect (EPP IE). The 2008/2009 northern hemisphere winter was characterized by a strong and persistent stratospheric sudden warming, which was followed by the reformation of a strong upper stratospheric vortex associated with very efficient descent of air. These exceptional dynamical conditions led to a relatively strong EPP IE, despite the low geomagnetic activity level. Moreover, this winter was very well covered by the observations. These are the reasons why it has been chosen as a reference period to study this mechanism within the framework of the HEPPA II - Model Measurement Inter-comparison working group.

We will show the preliminary results of an inter-comparison study focused on that particular winter. Many different instruments are involved in the HEPPA II initiative, including Odin/SMR, Odin/OSIRIS, MIPAS, SCIAMACHY, ACE-FTS, Envisat/GOMOS, MLS/Aura. Numerous short-lived trace gases (e.g. NO, NO_2, HNO_3), longer lived trace gases (e.g. H_2O, CO), as well as temperature and of course ozone have been measured by these instruments in the middle atmosphere. The inter-comparison of a selected set of these observations will be presented. The goal is to carry out a comprehensive study to validate all the important measurements performed in polar winter conditions. This work will then be used as a basis for the HEPPA II model vs. observation inter-comparison core study.

Unusually strong nitric oxide descent in the Arctic middle atmosphere in early 2013 as observed by Odin/SMR

Kristell Pérot, Joachim Urban, Donal Murtagh

Chalmers University of Technology, Sweden

The Sub-Millimeter Radiometer (SMR) on board the Odin platform, launched in 2001, is a limb emission sounder measuring trace gases in the stratosphere, mesosphere, and lower thermosphere. 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). SMR is involved in the SPARC project HEPPA II-MMI (High Energy Particle Precipitation in the Atmosphere - Model-Measurement Inter-comparison).

Energetic Particle Precipitation (EPP) refers to the process by which energetic protons and electrons affect the Earth's middle atmosphere. The precipitation of magnetospheric electrons into the polar atmosphere during geomagnetic perturbations leads to nitric oxide (NO) formation in the polar upper mesosphere and lower thermosphere (UMLT). During polar winter, EPP-generated NO can be transported downward into the stratosphere by the meridional circulation, where it can affect the ozone concentration. This important solar-terrestrial coupling mechanism is called the EPP indirect effect (EPP IE).

Odin/SMR observed a particularly strong event of that kind during last winter. The middle atmosphere has indeed been affected by an exceptionally strong major stratospheric warming (SSW) in early January 2013. These unusual meteorological conditions led to a breakdown of the polar vortex, followed by the reformation of a strong upper stratospheric vortex associated with a particularly efficient descent of air. Measurements by SMR show that very large amounts of EPP-generated NO could thus enter the polar stratosphere during the months following the stratospheric warming. Up to 20 times more NO than average were observed, much more than in 2009, when a similar event happened. This situation is the result of the combination between a relatively high geomagnetic activity and an unusually high dynamical activity, which makes this case a prime example to study the EPP impacts on the atmospheric composition. Our poster will present a case study of this outstanding event.

Response of the Atmosphere to Impulsive Solar Events (RAISE)

Cora Randall and the RAISE team

LASP, University of Colorado, USA

This talk will give an overview of a recently funded NASA project that investigates the response of the atmosphere to impulsive solar events (RAISE). The goal of this project, which involves many HEPPA-SOLARIS participants from several countries, is to explore the broad question of how the Earth's atmosphere responds to impulsive solar events (ISEs). Solar energy input is a critical driver of the Earth's climate system, yet the climatic effects of ISEs are poorly understood. The key to improving our knowledge is unraveling the complex response of the atmosphere to ISEs, to clarify the mechanisms by which impulsive radiation and particle variations impact the atmosphere. Initial impacts on the ionosphere and upper neutral atmosphere can trigger a cascade of reactions including production of chemically reactive constituents and changes in temperatures and possibly circulation. This raises the following broad questions that will be addressed by RAISE:

(1) How well do coupled chemistry climate models (CCMs) simulate effects of recent ISEs?

(2) What are the primary factors that control the atmospheric response to ISEs?

(3) What is the range and sensitivity of the atmospheric response to ISEs?

(4) Are there long-term, cumulative effects of ISEs on the atmosphere and climate, and with what certainty can these effects be modeled?

This talk will summarize the RAISE project and plans for achieving the goals.

Long-term impact of NOy transport from the lower thermosphere in the KASIMA model

T. Reddmann, S. Versick, G. Stiller, T. v. Clarmann (1), B. Funke (2)

(1) Karlsruhe Institute of Technology, Institute for Meteorology und Climate Research, Karlsruhe, Germany
(2) Instituto de Astrofisica de Andalucia - CSIC, Granada, Spain

Transport of NOx from the lower thermosphere to the mesosphere and subsequently to the stratosphere during polar winters can be an important supply of additional NOy in the middle atmosphere, besides N2O oxidation. This mechanism couples solar and geomagnetic activity to the chemical budget of the middle atmosphere, and can in principle affect climate via chemical-dynamical interaction and stratosphere-troposphere coupling. As part of the upper branch of the meridional circulation of the middle atmosphere, the downward transport of NOx in the mesosphere shows a strong seasonal cycle and interhemispheric differences. For example, in the Arctic especially after strong sudden stratospheric warmings the downward transport can be very effective. The exact mechanism which brings lower thermospheric NOx to the mesosphere, that is molecular compared to eddy diffusion or bulk transport, is still under discussion. We performed model simulations with the 3D model KASIMA where an additional thermospheric NOx layer has been introduced into the model. We compare the results with observations of the MIPAS instrument on ENVISAT and estimate the subsequent additional ozone loss caused by the NOx transported from the lower thermosphere in the model for the period 2000 - 2012.

Solar and particle effects on tropospheric climate

E. Rozanov

PMOD/WRC and IAC ETHZ, Switzerland

The Earth's atmosphere is affected by the solar irradiance and energetic particles. The enhancement of the solar UV-B and -C irradiance directly leads to warming and ozone increase in the stratosphere, while the radiation with the longer wavelengths may directly heat up the surface. The ionization of the neutral atmosphere by different energetic particles such as Galactic Cosmic Rays, Solar Protons and energetic electrons leads to the production of chemically active species which can destroy ozone in the polar stratosphere leading to a cooling inside the polar vortex. All these direct processes have further implications for the atmospheric dynamics and tropospheric climate. In this review talk I will discuss all involved mechanisms and their representation in the state-of-art climate models. Different features of the simulated atmospheric response to solar variability will be presented and compared with the observation data. The solar and energetic particle effects on the atmospheric chemistry and climate will be considered in a long term perspective for the periods when the solar activity substantially differs from the recent decades.

A new method of recalibrating NOAA MEPED proton measurements

Marit Irene Sandanger, Linn-Kristine Glesnes Ødegaard, Hilde Nesse Tyssøy, Johan Stadsnes, Finn Søraas, Kjellmar Oksavik

Birkeland Centre for Space Science, UiB, Norway

Since 1978 the NOAA/POES satellites have continuously monitored energetic particles with the MEPED instrument. After some years of operation, the particle detectors become degraded due to radiation damage. Fortunately, both new and older satellites are operational at the same time. By comparing the monthly averaged proton energy spectra from a newly launched satellite with all the older satellites in the same altitude range, we derive the correction factor due to radiation damage. For the years in between new satellites, we calculate the correction factor using different methods based on cumulative flux and the Ap index. The cumulated flux for each satellite gives an estimate of the amount of radiation damage and therefor the degradation. The Ap index describes the level of geomagnetic activity in the detector environment.

Energetic Particle Forcing of the Northern Hemisphere winter stratosphere: Comparison to solar irradiance forcing

Annika Seppälä and Mark Clilverd

FMI, Finland

Variation in solar irradiance is considered an important factor in natural climate forcing. Variations in the solar UV in particular are now regarded as a major source of decadal variability in the stratosphere, influencing surface climate through stratosphere-troposphere coupling. In this study, by analyzing meteorological re-analysis data we found that the magnitude of the solar controlled energetic particle forcing signal in stratospheric zonal mean zonal winds and polar temperatures is equivalent to those arising from solar irradiance variations during the Northern hemisphere polar winter months. We find that energetic particle forcing drives warmer polar upper stratospheric temperatures from early winter leading to an anomalously strong polar night jet via modulation of the vertical temperature gradient. By midwinter the stratosphere-troposphere coupling pathway becomes analogous to the solar UV impact at high latitudes. This not only highlights the importance of the energetic particle forcing contribution to stratospheric circulation, but enables us to understand the pathways responsible for the previously reported energetic particle forcing impacts on the troposphere in terms of the coupling of solar UV forcing to dynamics in the latter part of the winter.

ROSMIC - Role Of the Sun and the Middle atmosphere/thermosphere/ionosphere In Climate

A. Seppälä, F-J Lübken, W. Ward

FMI, Finland

ROSMIC is one of the four scientific elements launched under SCOSTEP's (Scientific Committee On Solar-Terrestrial Physics) new science program VarSITI. The science program will run from 2014 until 2018 and is aimed at providing an platform for international collaboration and discussion. ROSMIC is formed of four working groups: Solar Influence on Climate, Coupling by Dynamics, Trends in the MLT, and Trends and Solar Influence in the Thermosphere, all of which are highly relevant for the HEPPA-SOLARIS scientific community. This presentation will give an overview of ROSMIC and and discuss the synergies with HEPPA-SOLARIS.

GPS-TEC and Equatorial Plasma Bubbles observations during the period 2002-2013

D.J. Shetti

Smt. Kasturbai Walchand College, India

The Total Electron Content (TEC) is computed from Global Positing System (GPS) from Bangalore (13.02°N, 77.57°E) IGS station for the period 2002 to 2013. We have found out the simultaneous occurrence of EPBs in both TEC and OI 630.0 nm emissions using both radio and optical techniques. In the present work we have also discussed the possible mechanism of day-to-day variability in the occurrence of EPBs. We present the mean diurnal, monthly, seasonal, and annual variation in the ionospheric TEC and % occurrence rate of Equatorial plasma bubble during the highest to highest solar activity phase for the periods of 2002-2013. We found that the both average GPS-TEC and % occurrence rate of plasma bubbles are positively correlation with solar flux for the entire 12 year period.

Local NOx response to geomagnetic activity from the upper stratosphere to the lower thermosphere

M. Sinnhuber, S. Bender, F. Friederich, H. Nieder, B. Funke, G. Stiller, T. von Clarmann

KIT, Germany

We investigate the response of NOx (NO, NO2) to geomagnetic activity using MIPAS and SCIAMACHY observations from the upper stratosphere to the lower thermosphere. Only observations taken during polar summer are used to investigate the direct local production of NOx during geomagnetic storms. Night-time NO2 from MIPAS in the time-period 2007-2009 is used in the upper stratosphere (40-60 km), daytime NO from SCIAMACHY in the period 2002-2012 is used in the mesosphere (62-82 km), and both SCIAMACHY and MIPAS NO observations in the period 2008-2012 are used in the upper mesosphere and lower thermosphere.

We use different statistical methods - a superposed epoch analysis in the stratosphere and mesosphere, and a multi-linear regression analysis in the mesosphere and lower thermosphere - to separate short-term variations due to enhanced geomagnetic activity from the background variations. A small but significant response of night-time NO2 is observed in the upper stratosphere around 48 km at geomagnetic latitudes corresponding to the radiation belts. In the mesosphere and lower thermosphere, a clear linear relationship between daytime NO and the geomagnetic Kp index is observed with a strong maximum in the lower thermosphere around 106 km, and another maximum with a weaker amplitude around 72 km. The mesospheric and thermospheric response is largest at latitudes between 60-75° in the Northern hemisphere, between 45-75° in the Southern hemispheres. However, enhanced NOx values related to geomagnetic activity are not as closely confined to the auroral / radiation belt region as in the upper stratosphere, probably due to the faster horizontal mixing.

We determine the ionization rate necessary to achieve the observed NOx enhancements with a one-dimensional photochemical model. This model includes a state-of-the art parameterization of the NOx production due to atmospheric ionization. These results provide a simple parameterization of the atmospheric ionization due to geomagnetic activity ranging from the upper stratosphere to the lower thermosphere ($\sim$45 - 120 km) for use in global models.

Tracer experiments during and after the SSW in winter 2008/2009: set-up and first results

M. Sinnhuber, S.-M. Päivärinta, T. Reddmann, P. T. Verronen, S. Versick

KIT, Germany

Large differences were observed between the model results of the downwelling NOy signal after the major warming in late January 2009; peak altitudes differed by more than 10 km in late March and early April. To investigate possible reasons for these large discrepancies, a number of idealized tracer experiments were set up and carried out by EMAC, FinROSE, KASIMA, and 3dCTM. Tracer experiments involve injection of different idealized tracers into the mesosphere and lower thermosphere during the warming event. Here we will present first results of the comparison between the results of the tracer experiments of the different models.

Radiation belt particle precipitation and its effects on atmospheric interaction: Van Allen Probes observations

Harlan E. Spence, the NASA RBSP-ECT Van Allen Probes Science Team, and the NSF Sun-to-Ice Science Team

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Now nearly two years into the NASA Van Allen Probes mission, the Radiation Belt Storm Probes (RBSP) Energetic Particle, Composition, and Thermal Plasma (ECT) suite continues to explore the dynamics and structure of the radiation belts. The RBSP-ECT observations are the best ever from the heart of the inner and outer zone belts, providing high fidelity measures of the phase space density of electrons and ions as a function of the first, second, and third adiabatic invariants. The RBSP-ECT instrumentation has been calibrated and cross-calibrated so that complete energy and pitch angle spectra can be combined with magnetic field information to quantify the phase space density and its time variation. A portion of these particles enter the loss cone where they collide with the atmosphere and are lost from the radiation belts. At high enough energies, these particles penetrate to very low altitudes where they affect the middle atmosphere. In this talk, we present the latest understanding of this population of precipitating particles, including electrons from the outer belt and protons from the inner belt. In addition, we report on spectra of intermittent solar proton populations that gain entry at high magnetic latitudes. Finally, we report on the impacts of these particles, summarizing highlights from the ”Sun-to-Ice” project.

North Atlantic Surface Response to the 11-year Solar Cycle

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Variability in solar irradiance is connected to changes in surface climate at regional scales. Observational and idealized modeling studies have shown a robust lagged solar response in the North Atlantic sector that resembles the North Atlantic Oscillation (NAO) arising from ocean-atmosphere coupling processes. In our study, we propose to investigate this mechanism in realistic simulations performed with NCAR's Community Earth System Model (CESM, version 1.0.2), a coupled model system including the Whole Atmosphere Community Climate Model (WACCM). Two multidecadal experiments (145 years) are performed by either (i) including, or (ii) suppressing the input solar irradiance variability. For each experiment, the anthropogenic forcing contribution is excluded by keeping constant greenhouse gases and ozone depleting substances at the 1960's level. The results show a statistically significant NAO signature in response to solar variability. The cross-spectral analysis of the NAO and the F10.7 indices reveal a maximum coherency for the 11-years period lagged by two years which is significant at the 95% level. The mechanisms are discussed with respect to stratosphere/troposphere and ocean/atmosphere coupling processes.

A SOLID survey on the needs of climate and chemistry-climate modelling communities for new irradiance datasets

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AUTH, Greece

The incident radiation of the Sun is a crucial input for climate modelling. Products of the First European Comprehensive Solar Irradiance Data exploitation (SOLID) FP7 project, such as spectral solar irradiances paired with the associated uncertainties, will be primary exploited by the climate modelling community. As such, the products released should meet the end-user needs as close as possible. So far, interaction between solar physics and climate modelling communities was poorly established and solar data were produced according to the needs of solar physics and then handed out to climate scientists. This report presents results from a survey of the chemistry-climate model community aiming at specifying needs for solar irradiance products. The survey collected answers for different questions from a representative sample of modelling groups and end-users that exploit general circulation models for climate research. The resulting databases will be used to tailor the SOLID outputs to meet end-user needs, facilitate data exploitation in modelling studies and ultimately reduce potential friction in adopting a new irradiance dataset.

Effects of solar activity and high energetic particle precipitation on middle atmospheric composition as observed by the Odin Sub-Millimetre Radiometer

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The Sub-Millimetre Radiometer (SMR) on board the Odin satellite is a limb emission sounder measuring a variety of HEPPA relevant trace gases (H2O, O3, CO, N2O, HNO3, NO) and temperature in the stratosphere, mesosphere, and lower thermosphere. Many Odin data sets span now a period of more than one solar cycle.

Shorter lived species such as NO, HNO3 or O3 are directly or indirectly affected by solar activity and 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). The SMR data set, starting in 2003, provides a clear signature of the 11-year cycle of solar activity. Superimposed on this background distribution is the variability of NO caused by atmospheric transport. During polar night downward transported NOx adds for example to the NOy budget in the mesosphere and stratosphere. Enhanced NOx can be slowly converted to the longer-lived nitric acid (HNO3) involving heterogeneous chemistry on stratospheric aerosol or water ion cluster surfaces in the mid-stratosphere during polar night. Besides indirect effects requiring transport, also direct effects of high energetic particle precipitation on HNO3 have been observed.

In the stratosphere and lower mesosphere short-lived species like nitric oxide exhibit a strong diurnal variation which makes interpretation of the measurements outside of the polar night regions challenging. In contrast, HNO3 has only a very small diurnal cycle in the stratosphere. Local time corrected (scaled) monthly zonal mean climatologies have therefore been created and these data sets have been evaluated against measurements of other limb sounding satellite sensors.

The global distributions of longer-lived target species water vapour (H2O) and carbon monoxide (CO) are mainly governed by the global meridional circulation. These Odin measurements provide information on the variability of large-scale transport which is essential for the analysis of the short-lived species observations. Examples are the enhanced downward transport from the mesosphere into the stratosphere in the aftermath of major stratospheric warming events or the upward transport occurring during winter in the polar lower thermosphere.

The presentation will focus on an overview of the available Odin/SMR data sets, provide information on recent updates, and will include some science highlights.

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).

Comparison of Modeled and Observed Effects of Radiation Belt Electron Precipitation on Mesospheric Hydroxyl and Ozone

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Energetic electron precipitation (EEP) produces odd hydrogen (HOx = H + OH + HO2) in the middle atmosphere through ionization and ion chemistry. HOx is a useful monitor for short-term EEP variations, because its concentration responds rapidly to both increases and decreases in EEP forcing. Observational studies have already shown that mesospheric HOx is significantly affected by EEP at magnetic latitudes connected to the outer radiation belt. Here we use the Sodankylä Ion and Neutral Chemistry (SIC) model to reproduce the changes in OH and ozone observed by the Microwave Limb Sounder (MLS/Aura) during four strong EEP events. The daily mean electron energy-flux spectrum, needed for ionization rate calculations, is determined by combining the Medium Energy Proton and Electron Detector (MEPED/POES) fluxes and spectral form from the IDP high-energy electron detector on board the DEMETER satellite. We show that in general SIC is able to reproduce the observed day-to-day variability of OH and ozone. In the lower mesosphere, the model tends to underestimate the OH concentration, possibly because of uncertainties in the electron spectra for energies $>$300 keV. The model predicts OH increases at 60-80 km, reaching several hundred percent at 70-80 km during peak EEP forcing. Increases in OH are followed by ozone depletion, up to several tens of percent. The magnitude of modeled changes is similar to those observed by MLS, and comparable to effects of individual solar proton events. Our results suggest that the combined satellite observations of electrons can be used to model the EEP effects above 70 km during geomagnetic storms, without a need for significant adjustments. However, for EEP energies $>$300 keV impacting altitudes $<$70 km, correction factors may be required.

The vertical extension of EMAC to the MLT region

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We report the first results of an vertically extended version of the EMAC model. The aim of this work is to realistically simulate Mesosphere-Lower-Thermosphere coupling processes, which have been shown to be improtant in the context of energetic particle precipitation and following NOx intrusions. Such intrusions could impact the ozone budget in the stratosphere and more generally for a more realistic representaton of Gravity Wave drag and the resulting upper branch of the Brewer-Dobson circulation. Within the EMAC (ECHAM-MESSy) concept the extesion is possible once the relevant physical processes and the proper bounadry conditions are provided. Following the approach of the HAMMONIA model parametrizations for molecular diffusion module, long-wave and non-local thermodynamic equilibrium radiation schemes have been implemented in EMAC, together with te required modifications of the standart parametrizations (e.g. gravity wave and radiation modules). First results of the extended version with the upper boundary around 125km showing the climatology of temperatures and winds are presented together with the passive tracer transport experiments.

A descent of the aurora over Lapland

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A very large statistical study (∼350000 measurements) into the peak emission height of the aurora has shown that the aurora over Lapland descended significantly between 1996 and 2007. The study was performed using images from a network of ground-based all-sky cameras which form part of the MIRACLE (Magnetometers-Ionospheric Radar-All-sky Cameras Large Experiment) network, and are located at various observation stations across northern Finland and Sweden. The height of the aurora was first measured about a century ago. Since then, it has generally been assumed that the peak emission height of any particular auroral emission is constant for similar geomagnetic and precipitation conditions. The present work was motivated by the need to improve estimates of the height of the aurora used to calculate other ionospheric and auroral properties, such as optical flow velocities and auroral arc widths. In recent years MIRACLE has produced approximately 100000 images of the aurora per station per year. In order to analyse such a large number of images, a novel fast and automatic method was developed for finding the peak emission height of an auroral structure from a pair of all-sky camera images with overlapping fields of view. This method has been applied to all auroral images recorded by the MIRACLE intensified CCD cameras in operation between 1996 and 2007. Such a large data set allows the study of variations in the height of the aurora with time (yearly, monthly, hourly) and with solar and geomagnetic indices such as F10.7 and Kp. Results from the statistical study show that the peak emission height of green (557.7 nm, O1S-O1D transition) aurora over Lapland descended by about 10 km between 1996 and 2007. This descent occurred independently of the solar cycle. One possible cause for this descent is cooling and subsidence of the mesosphere and lower thermosphere.

Atmospheric Ionization Module OSnabrueck

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The Atmospheric Ionization Module OSnabrueck (AIMOS) calculates the 3D atmospheric ionization rate due to particle precipitation. Including particles of solar and magnetospheric origin AIMOS covers an altitude range from the troposphere (for protons) and mesosphere (for electrons) up to the thermosphere. The model itself is based on a Geant4 Monte-Carlo Simulation for the particle interactions and in-situ particle measurements from the POES and GOES satellites. A user-friendly website allows easy adoption of the AIMOS results on a user-specific model grid.

Since AIMOS is subject to a constant development process, we will now present the main aspects of the recent modifications, as there is: (a) local time sector restructuring, now using MLT instead of LT, resulting in a more structured diurnal variation in the magnetospheric ionization. (b) improved filter of spikes and outliers in the mean precipitation maps and in the scaling of the recent fluxes. This supersedes the former smoothing of the and therefore preserves the extreme steepness (e.g. 4 orders of magnitude when entering the auroral oval) of the spatial distribution. (c) a modified spatial resolution: low latitude regions that are not affected by significant particle precipitation are left out in order to get a higher spatial resolution in high latitudes. (d) adjustment of the polar cap size: high energetic particles' cap size has been adjusted to the more accurate spatial resolution in high latitudes. In fact this resulted in a slight increase of the polar cap size. (e) attempt to reduce proton crosstalk in the MEPED electron channels: electron fluxes will be neglected in case that the omnidirectional proton channel P7 shows energetic proton flux. This for example effectively cuts out the SAA. Further on there are two options, first, using all MEPED electron channels with a correction algorithm or second ignoring the heavily contaminated highest electron channel. The differences will be discussed.

Solar influence on Last Millennium climate simulated by MRI-CGCM3

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An overview of 'Last Millennium' (LM) simulation in the MRI-CGCM3 is presented. The LM simulation has two dominant external forcing changes: solar radiation and aerosol generated by volcanic eruption. The MRI-CGCM3 consists of the atmospheric model (TL159L48), the ocean and sea ice model (1deg*0.5deg*L51), and the aerosol model (TL95L48). The model simulation well reproduces large-scale temperature variations according to proxy-based climate reconstructions. Model comparison between CMIP5 LM simulations shows reasonable response of huge volcanic eruption events to climate. Relationships between solar forcing and long-term variability of the Northern Annular mode (NAM), Southern Annular Mode (SAM), El Niño Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), and tropical cyclone activity are examined. As one of the interesting results, NAM shows the significant negative phase in the late Maunder minimum.

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