LPMR workshop 2017 (LPMR-2017)

Kühlungsborn, Germany, 18-22 September 2017

Monday, 18 September - - 08:00 - 08:30

Shuttle from hotels

Monday, 18 September - Foyer - 08:00 - 09:00

Registration

Monday, 18 September - - 09:00 - 09:20

Welcome

Monday, 18 September - Conference room - 09:20 - 10:20

Observations of the MLT

Observations 1-O-01

Simultaneous observations of Noctilucent Clouds and Mesospheric Summer Echoes at a mid-latitude site (Kühlungsborn/Germany, 54°N): Hints for advection of ice particles.

Michael Gerding, Marius Zecha, Kathrin Baumgarten, Franz-Josef Lübken

Leibniz-Institute of Atmospheric Physics at the Rostock University, Kühlungsborn, Germany

Occurrence of ice particles in the summer mesopause region is an intriguing phenomenon that can be observed either optically as Noctilucent Clouds (NLC) / Polar Mesospheric Clouds (PMC) or by radar as (Polar) Mesosphere Summer Echoes ((P)MSE). These observations are directly related with distinct atmospheric properties like temperature, humidity, winds, turbulence, and electron density. A question especially at mid-latitudes is whether the ice clouds are formed locally or whether they are advected from polar latitudes. Such an investigation provides additional insight into an atmospheric region, where long-term records are sparse. The simultaneous observation of small and large ice particles requires the combination of radar and daylight-capable lidar techniques, which is typically not available at mid-latitudes. Since 2010 we operate a daylight capable RMR lidar at our site at Kühlungsborn/Germany (54°N, 12°E) for optical observations of NLC during night and day, i.e. independent from solar elevation. In combination with the co-located OSWIN radar we are able to compare the occurrence and altitude structure of NLC and MSE at mid-latitudes for the first time. We will present examples and statistical averages of the altitude coverage of both phenomena. The lower edges of simultaneously observed NLC and MSE typically agree, as expected from observations by the ALOMAR RMR lidar at polar latitudes. The top edge of MSE is on average observed nearly 500 m above the NLC edge, indicating the presence of ice particles being too small to be observed by lidar. Surprisingly, this height difference is much smaller than observed at polar

latitudes. This hints at different size distributions of mid and high latitude ice clouds and, by this, different growing conditions. The data suggest that advection from polar latitudes plays a larger role for ice cloud occurrence at our site, compared to local formation in the cold mesopause region. This is supported by, e.g., wind measurements showing a higher probability for ice occurrence during northerly winds. Therefore, our data indicate that mid-latitude NLC do not only depict local mesospheric conditions, but mirror also high-latitude conditions, which is important for, e.g., evaluation of NLC in climate research.

Observations 1-O-02

Constraints on meteoric smoke composition and meteoric influx using SOFIE observations with models

Mark Hervig[1], John Plane[2], James Brooke[2], Charles Bardeen[3], Wuhu Feng[2]

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This study presents observational constraints concerning the chemical composition of meteoric smoke particles in the mesosphere, using measurements from the Solar Occultation For Ice Experiment (SOFIE) in conjunction with meteoric smoke models. Comparing the multi-wavelength observations with models suggests compositions magnetite, magnesiowüstite, or olivine. Some smoke compositions are excluded in the SOFIE-model comparisons, however, this may because the materials are weakly absorbing at the SOFIE wavelengths. Knowledge of smoke composition allows the SOFIE extinction measurements to be converted to smoke volume density (V). Comparing observed V with model results for varying meteoric influx (MIF) provides constraints on the ablated portion of the MIF. The results indicate an ablated MIF that likely represents meteoric iron and magnesium only, when considering the identified compositions and simulations of smoke extinction at the SOFIE wavelengths.

Observations 1-O-03

The MATS satellite mission - looking into the future in three dimensions

Ole Martin Christensen

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MATS (Mesospheric Airglow/Aerosol Tomography and Spectroscopy) is a Swedish satellite mission scheduled for launch in 2019. MATS science focuses on mesospheric wave activity and noctilucent clouds. Primary measurement targets are O2 Atmospheric band dayglow and nightglow in the near infrared (759-767 nm) and sunlight scattered from noctilucent clouds in the ultraviolet (270-300 nm). While tomography provides horizontally and vertically resolved data, spectroscopy allows analysis in terms of mesospheric composition, temperature and cloud properties.

During 2017 the MATS instrument completed its critical design review and is now into its final phase of testing before the flight model of the instrument is built. In its final design the instrument will have one telescope with 6 channels, 2 in UV for measuring NLCs and 4 NIR channels for measuring the A-band. Each channel produces an image covering 250 km across-track and 40 km vertically at the with a resolution down to 5 x 0.2 km (horizontal/vertical) in

tangent plane. Additionally the instrument will have one image channel and two photometers pointing in the nadir direction performing complementary measuremets of the airglow.

At this point performance tests have now been completed on a component level, and tomographic methods have been developed to effectivly convert MATS images into 3D fields of airglow and NLC brightness. Furthermore, modelling studies have been carried out to assess MATS ability to retrieve gravity wave structures from the O2 Atmospheric band.

The presentation will give an overview of the MATS mission, its goals, schedule and current status. It will discuss the design, and present the analysis and trade-offs leading to it, including results from straylight and imaging tests on a prototype telescope. It will also discuss the details on how to produce such 3 dimensional tomographic data within reasonable computaional constraints. Finally, it will give examples of the scientific data that MATS will produce including the quality we expect it to have based on the tests an analysis perfomed with the MATS prototype.

Monday, 18 September - Conference room - 11:00 - 12:20

Ice microphysics

PMC/NLC I-O-01

Lab experiments on the complex microphysics controlling PMC formation

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Until recently it was believed that surface properties which determine the contact parameter of ice on the ice nuclei surface are *the* major uncertainty in the description of mesospheric ice particle formation processes. However, the combination of laboratory experiments and numerical simulation studies on Polar Mesospheric Cloud (PMC) formation showed that other parameters such as the absorption coefficient for solar and infrared radiation, atmospheric dynamics and the kinetics of ice particle growth may play a comparably important role in the PMC formation process.

Key properties influencing cloud formation such as desorption energy, contact parameter and light absorption coefficient of the materials that are presumed as Meteoric Smoke Particle (MSP) constituents as well as type and saturation vapor pressure of the possible ice phases of PMC particles are insufficiently known at mesospheric conditions.

To tackle these issues we performed laboratory experiments using the mesospheric ice cloud chamber MICE-TRAPS on artificially produced MSP analogues of variable iron silicate composition. We present measurements of the desorption energy and contact parameter of the investigated materials. We use these parameters in Classical Nucleation Theory (CNT) and show that despite unmet assumptions the formalism of CNT can be used to predict nucleation rates of water ice on small nanoparticles and therefore forecast critical saturations needed for cloud formation under mesospheric conditions.

We also show that the absorption of light can play a significant role in the ice activation of MSPs. In particular, the absorption of light can lead to the startling effect that (depending on seed particle composition) ice nucleation on smaller seed particles may be favored with respect to larger particles. We present measurements on the absorption coefficient of iron silicates and show that great care has to be exercised employing refractive index literature values for the interpretation of absorption data.
Furthermore, our experiments show that the actual saturation vapor pressure over mesospheric ice may differ by more than 100% from what is usually assumed for ice at mesospheric conditions. The experiments also provide indications on the shape and morphology of ice particles in PMCs.

PMC/NLC I-O-02

Implications of recent laboratory results for the formation of mesospheric ice particles

Henrike Wilms[1], Denis Duft[2], Mario Nachbar[3], Markus Rapp[1], Thomas Leisner[2, 3]

[1]*Deutsches Zentrum für Luft- und Raumfahrt, Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany*

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[3]*Institute of Environmental Physics, University of Heidelberg, Heidelberg, Germany*

In the past few years, laboratory experiments have advanced our understanding of the microphysics of mesospheric ice particles. Important parameters for the nucleation have been determined, such as the contact parameter, the desorption energy and the saturation vapor pressure over ice at mesospheric temperatures. Further, the absorption of visible light by meteoric smoke particles (MSPs) and the following increase of the MSP equilibrium temperature have been confirmed.

We incorporated the laboratory results into the Community Aerosol and Radiation Model for Atmospheres (CARMA) and studied the development of polar mesospheric clouds (PMCs). The experimentally determined desorption energy and contact parameter lead to nucleation rates which are many orders of magnitude larger than those currently assumed. The resulting PMCs are characterized by high ice particle number densities and rather small radii. MSPs acquire an equilibrium temperature which depends on their size and composition and which can be several Kelvin higher than the temperature of the surrounding atmosphere. As a result, the nucleation of those warmer MSPs is inhibited, which is a significant effect in particular for larger MSPs. We find that only the smaller MSPs close to the critical radius are relevant for the formation of PMCs.
Furthermore, we discuss the effect of different ice phases (amorphous ice and stacking disordered ice) which form in different temperature regimes and demonstrate the challenge to model PMCs in a gravity wave perturbed background when considering all microphysical details.

PMC/NLC I-O-03

On the impact of condensation nuclei characteristics on observable mesospheric ice properties

Linda Megner

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Noctilucent clouds and polar mesospheric summer echoes are both manifestations of ice particles near the summer polar mesopause. These ice particles are believed to form mainly on pre-existing ice condensation nuclei. The characteristics and especially the concentrations of such nuclei have been considered important factors in determining ice properties. But to what extent is this true?

Results from Megner (2011) suggest that the observable mesospheric ice properties are fairly independent of the condensation nuclei characteristics. These results have been questioned by Wilms et al (2015) who do observe a sensitivity. I here compare the two studies with the aim to determine under which conditions the two seemingly opposing conclusions apply.

PMC/NLC I-O-04

Interpretation of longitudinal and local time variations in polar mesospheric clouds

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It is known that polar mesospheric clouds (PMCs) are modulated by traveling planetary waves and migrating tides. However, the role of nonmigrating tides is unknown. In this paper, we study the local time and longitudinal variability in PMC parameters from AIM/CIPS observations and 0-D modeled ice driven by NOGAPS-ALPHA temperature and water vapor. We used the differences between the CIPS ascending and descending nodes at 75°N, and mapped the 0-D model results to the CIPS times and locations. Agreement between CIPS and the 0-D model results on individual days in the 2009 northern PMC season (June, July and August) is reasonable for most days, but can be notably poor for others. We speculate that the differences are caused by multi-day variability such as 2-day or 5-day waves. Monthly averages indicate fairly robust longitudinal variability, confirming the existence of non-migrating tides. Different variables, such as ice water content (IWC) and vertically maximum ice mass density (m_{ice}) for the 0-D model results, and IWC and albedo for CIPS, are used. The results are highly consistent between different PMC variables, suggesting that the analysis is not sensitive to the variables chosen. A tidal analysis of the NOGAPS-ALPHA temperature and 0-D model IWC shows that both diurnal and semidiurnal nonmigrating tides could have contributed to the longitudinal variability in the observed CIPS ascending and descending IWC differences.

Monday, 18 September - Conference room - 13:30 - 14:50

Long period waves in NLC

Dynamics 1-O-01

Signatures of the semidiurnal lunar tide in noctilucent clouds in AIM/SOFIE data

Christoph Hoffmann[1], Christian von Savigny[1], Mark Hervig[2], Esther Oberbremer[1]

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Noctilucent clouds (NLCs) exhibit a pronounced temporal variability on various time scales. Not all the sources of this variability have been identified so far, which complicates particularly the discussed use of NLCs as an indicator for trends in the mesopause region. One possible natural source of variability are gravitational tides, which are caused by the moon.

The influence of lunar tides has been demonstrated for several mesospheric parameters like temperature, winds and airglow emissions. Also for some NLC parameters the lunar influence has already been shown, e.g., for the maximum NLC brightness. However, these studies were based on visual observations. Recently, lunar tides have been also identified in systematic satellite measurements of NLCs, particularly in the NLC occurrence rate, the NLC albedo and the ice water content measured with the SBUV instruments.

We extend this analysis here to the diverse dataset of the Solar Occultation for Ice Experiment (SOFIE) on the AIM satellite. As SOFIE is particularly designed for NLC research, it contains a variety of parameters including the background atmosphere (e.g., temperature and trace gases), NLC properties (e.g., ice water content, top and bottom altitude), microphysical properties (e.g., the particle size distribution), and mesopause properties. We find a signature of the semidiurnal lunar tide in all of these parameters and estimate amplitudes and phases of the response to the lunar forcing. The amplitudes and particularly the phases show for many parameters a complex altitude dependent structure. Although individual relationships between the signatures of different parameters can be attributed qualitatively to known NLC physics, the mechanisms behind other relationships cannot be easily explained.

Dynamics 1-O-02

Solar and lunar tides in NLC data of the ALOMAR RMR-lidar

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Noctilucent clouds (NLC) are an excellent tracer for processes in the upper mesosphere. The clouds consist of ice particles whose existence sensitively depends on ambient temperature and water vapor content. Both parameters are hard to measure directly with high accuracy. Therefore NLC are used to characterize changes of the mean state as well as the dynamics in the mesopause region. The daily cyclic absorption of solar energy by the atmosphere causes thermal tides which are detected in various atmospheric parameters like temperature, density, winds, and NLC.
The inflcence of the lunar gravitation on the atmosphere has been identified in surface air pressure already more than 170 years ago. Since then lunar tidal signatures were found in several parameters even in the upper mesosphere. However, studies on lunar tidal influences on NLC are
very limited and the results are partly contradictory. The lunar signal is presumably small

compared to the solar signal and hence it needs a large database for identification. Only recently the lunar semidiurnal tide was found in satellite observations of NLC by SBUV instruments.

The ALOMAR RMR-lidar, located at 69°N, started operation in 1994 and covers by now 2990 hours NLC detections during 6230 measurement hours within 23 seasons. This dataset contains variabilities of basic cloud parameters like occurrence, altitude and brightness on time scales ranging from minutes to years. NLC above ALOMAR are strongly influenced by solar tides, e.g. the clouds occur twice as often per hour during the morning than during the rest of the day, and the cloud altitude shows mean variations of about 1 km in the course of the day. Now the dataset was investigated for the first time regarding lunar tidal signatures. We will present results obtained by the superposed epoch analysis method, showing a lunar impact on NLC occurrence frequency and altitude.

Dynamics 1-O-03

Planetary wave effects on Polar Mesospheric Clouds during the Northern Hemisphere 2014 season

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Observations by the Cloud Imaging and Particle Size (CIPS) instrument on the Aeronomy of Ice in the Mesosphere (AIM) satellite show an anomalous decline in northern hemisphere polar mesospheric clouds (PMCs) from 22 July to 6 August 2014. The decline is attributed to the summer mesospheric 2-day wave and interhemispheric coupling (IHC) triggered by planetary wave activity in the Antarctic stratosphere. The results indicate that the IHC in 2014 occurred via a pathway that previous studies have not emphasized. Based on Aura Microwave Limb Sounder (MLS) and Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) data, we suggest that strengthening of the summer easterly jet gave rise to baroclinic instability that supported the growth of the 2-day wave. The large 2-day wave led to enhanced meridional mixing in mid-latitudes and weakened ascent and warming at the polar summer mesopause. We also show that the 5-day planetary wave modulates the response to IHC, in that PMCs persist in the trough when zonal mean temperatures are too high to support PMCs and are absent in the ridge when mean temperatures are low enough to support PMCs.

Dynamics 1-O-04

The role of the winter residual circulation in the Northern Hemisphere summer mesopause in WACCM

Maartje Kuilman, Bodil Karlsson

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This study investigates the role of the winter residual circulation in shaping Northern Hemisphere summer mesopause conditions. In a recent study carried out with the Kühlungsborn Mechanistic general Circulation Model (KMCM), it was shown that the interhemispheric

coupling mechanism has a net cooling effect on the summer polar mesospheres. In this study, the comprehensive Whole Atmosphere Community Climate Model (WACCM) is used to reconfirm the hypothesis that the summer polar mesosphere will be much warmer without a gravity wave driven residual circulation in the winter. We reaffirm that it is the equatorial temperature response in the mesosphere that is the crucial step in interhemispheric coupling.

The role of the summer stratosphere in shaping the conditions of the NH summer polar mesosphere is also investigated. Without GWs in the winter, it is the summer stratosphere that controls the temperature in the summer mesopause region. It is found that if there are no GWs in the winter hemisphere, a weaker Brewer-Dobson circulation would lead to a cooling of the summer mesosphere region instead of the warming of this region associated with interhemispheric coupling.

Monday, 18 September - Poster area - 15:30 - 16:50

Posters 1

Posters 1-P-01

Methods of retrieval of daytime $O(^3P)$ and O_3 concentrations in the mesosphere and lower thermosphere

Valentine Yankovsky, Rada Manuilova

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The small components of the Earth daytime mesosphere and lower thermosphere (MLT) $O(^3P)$, O_3 and CO_2 are responsible for the thermal regime of the MLT region. Based on YM2011 model of kinetics of excited products of O_3 and O_2 photolysis in the MLT of the Earth we proposed and justified the methods of retrieving the atomic oxygen and ozone vertical distributions from the observation of emissions of the excited oxygen molecules and $O(^1D)$ atom. In the YM2011 model the processes of energy transfer among electronically-vibrationally excited singlet levels $O_2(b^1\Sigma$, v=0–2), $O_2(a^1\Delta$, v=0–5), vibrationally excited levels $O_2(X^3\Sigma$, v=1–35) of the O_2 molecules in the ground electronic state, and also excited atomic oxygen $O(^1D)$ were considered. For these excited levels the corresponding system of 45 kinetic balance equations was solved. Besides the O_3 photolysis in Hartley spectral band, we also considered the photolysis in the Chappuis, Huggins, and Wulf spectral bands in the interval of 200−900 nm and the photolysis of O_2 in Schumann–Runge continuum and Lyman-alpha line H atom, as well as resonant absorption of solar radiation in 629, 688 and 762 nm bands by O_2. Using a sensitivity study and uncertainty analysis of the contemporary model of O_3 and O_2 photolysis in the MLT, YM2011, we determined that populations of four excited electronic-vibrational levels $O_2(b^1\Sigma$, v = 0 - 2), $O_2(a^1\Delta$, v=0) and of metastable $O(^1D)$ atom depend on $[O(^3P)]$ and $[O_3]$ concentrations. We have tested all five excited components as the proxies of $[O_3]$ and $[O(^3P)]$ in the MLT region. For $[O(^3P)]$ altitude profile retrieval any from these 5 proxies can be used for different altitude range. Four proxies - $O_2(b^1\Sigma$, v = 0, 1), $O_2(a^1\Delta$, v=0) and $O(^1D)$ are suitable for retrieving the altitude $[O_3]$ profile in the range of 50-100 km. In the interval 85 – 100 km the problem of independent and simultaneous retrieval of $[O_3]$ and $[O(^3P)]$ can be solved by using individual proxy for each of the target component. Commonly used $[O_3]$ retrieval proxy $O_2(a^1\Delta$, v=0), transition from which forms the 1.27 μm O_2 IR Atmospheric band, has more than one hour photochemical lifetime in the MLT region. On the other hand, the $O(^1D)$ and $O_2(b^1\Sigma$,

v = 0 - 2) lifetime in the altitude region of 50−140 km is less than 14 sec. So, the proposed $O_2(b^1\Sigma$, v = 0 - 2) and $O(^1D)$ proxies can be used for tracking fast variations of the O_3 and $O(^3P)$ atmospheric concentrations generated by wave processes and electron precipitations, and so on, when the $O_2(a^1\Delta$, v=0) proxy becomes useless.

Posters 1-P-02

Development of a mobile Doppler lidar sytstem for wind and temperature measuements at 30-70km in China

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A mobile Doppler lidar system has been developed to simultaneously measure zonal and meridional winds and temperature from 30 to 70 km. Each of the two zonal and meridional wind subsystems employs a 15 W power, 532 nm laser and a 1 m diameter telescope. Iodine vapor filters are used to stabilize laser frequency and to detect the Doppler shift of backscattered signal. The integration method is used for temperature measurement. Experiments were carried out using the mobile Doppler lidar in August 2014 at Qinghai, China (91°E, 38°N). The zonal wind was measured from 20 to 70 km at a 3 km spatial resolution and 2 h temporal resolution. The measurement error is about 0.5 m/s at 30 km, and 10 m/s at 70 km. In addition, the temperature was measured from 30 to 70 km at 1 km spatial resolution and 1 h temporal resolution. The temperature measurement error is about 0.4 K at 30 km, and 8.0 K at 70 km. Comparison of the lidar results with the temperature of the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER), the zonal wind of the Modern-Era Retrospective Analysis for Re-search and Applications (MERRA), and radiosonde zonal wind shows good agreement, indicating that the Doppler lidar results are reliable.

Posters 1-P-03

Study of the global nickel and aluminium layers in the upper atmosphere

Shane Daly[1], Michael Gerding[3], Juan C. M. Gómez Martín[1], Josef Höffner[3], Wuhu Feng[1, 2], John M. C. Plane[1]

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The major source of metals in the upper atmosphere is the ablation of the ~34 tonnes of interplanetary dust that enters each day from space (Carrillo-Sanchez et al., 2016). This gives rise to the layers of metal atoms and ions that occur globally in the upper mesosphere/lower thermosphere (MLT) region between 75 and 120 km. Metal species in the upper atmosphere offer a unique way of observing processes in this region and of testing the accuracy of climate models in the domain. The main objective of this project will be to explore the MLT chemistry of two elements – Al and Ni. These elements have not been previously studied in this region of the atmosphere with the exception of the first Ni layer measurements by (Collins and Martus., 2015). This research presents the kinetic studies of Al + O_2 to form AlO as well as the first attempted lidar measurements of the AlO layer, with a total of ~18 hours of observations. If successful, this would be the first time that a molecular metallic species was observed in the atmosphere. Further lidar measurements of Ni layer will also be made, which appears to be

significantly broader than the well-known Na and Fe layers. The lidar observations were performed at the Leibniz Institute of Atmospheric Physics, Germany. A novel flow tube calibration setup was designed for the lidar to ensure that each species was measured at the specified wavelength.

Posters 1-P-04

A 3D-model for O2 airglow perturbations induced by gravity waves in the upper mesosphere

Anqi Li

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To investigate the influence of atmospheric waves in the mesosphere, a new Swedish satellite MATS (Mesospheric Airglow/Aerosol Tomography and Spectroscopy) will be launched in 2019. It will observe infrared emissions at 762 nm from the $O_2(b^1\Sigma^+_g)$ airglow in the region of 70 - 110 km altitude. As a part of the design work for the MATS project, an accurate forward model is needed to estimate what MATS is expected to measure. The results from this model will be used to evaluate the retrieval methods for processing the measurements from MATS.

In this thesis project, a gravity wave model and a photochemistry model were coupled to simulate both the day- and nightglow emission fields in three spatial dimensions and time. Simulated satellite images were generated taking into consideration the sphericity of the Earth and the limb-viewing geometry of MATS. Simulation parameters were set according to the preliminary design of the instrument, such as the satellite orbit, image resolution and spectral selections. These satellite images were the first simulated airglow limb images made for the MATS project.

By analysing the output data, the relations between wave parameters and airglow perturbations were investigated. It was shown that wave patterns can be easily observed between 85 - 105 km due to the relatively large perturbation in airglow emissions. The O2 airglow emission field was found to be highly sensitive to atomic oxygen concentration field as an input. Furthermore, as expected, wave patterns projected on simulated satellite images largely depend on the horizontal orientation of the wave propagation. This implies that a tomographic reconstruction is needed when the angle between the wave front and the limb-viewing direction is large. Finally, limitations of the model were discussed.

Posters 1-P-05

Exploring the behavior of a mesospheric front using Odin tomographic data combined with CIPS PMC images

Lina Broman[1], Susanne Benze[1], Brentah Thurairajah[2], Jörg Gumbel[1]

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A distinct front-like structure was observed in CIPS Ice Water Content and Albedo images on 16 June 2010 at high latitudes. Simultaneous observations of this mesospheric front were made with the OSIRIS and SMR instruments on the limb viewing Odin satellite.

Mesospheric fronts appear as structures similar to gravity waves in CIPS images and manifest them self as a disturbance in cloud brightness when propagating through an NLC layer. They can also be observed with different observation methods such as all-sky airglow images, lidar measurements, and pictures from ground-based cameras. The physical processes that could be responsible for generating mesospheric fronts have been discussed in recent papers and it has been proposed that mesospheric fronts appear in ducting conditions and are generated from intense wind shear, a temperature inversion layer or a combination of these two.

At the time of the observation of the mesospheric front in our study, the Odin satellite was run in a special mesospheric mode with short limb scans that allowed for multiple lines of sight through the cloud volume, thus enabling a tomographic retrieval of cloud structures in 2D. Since the resolution of the tomographic retrievals is as fine as 1 km in the vertical and 200 km along track it is possible to perform a detailed analysis of NLC properties, mesospheric temperature and water vapor across the front. The Odin satellite observed the frontal structure perpendicular to the wave propagation during four consecutive orbits with roughly 90 min difference, thus enabling the investigation of the evolution of the front in time.

In this project, we focus on how a mesospheric front propagating through an NLC layer affects cloud properties such as cloud brightness, ice mass density, mean radius and number density. We also investigate the dynamics and the background atmosphere in the vicinity of the front.

Posters 1-P-06

The Structure of Ice in Polar Mesospheric Clouds

Thomas Mangan, John Plane, Ben Murray

University of Leeds, Leeds, United Kingdom

Polar Mesospheric Clouds (PMCs) form in the summer high latitude mesosphere at temperatures below 150 K and are comprised of water ice. Water ice within PMCs is often assumed to exist as the cubic form of ice I. However, under the extreme temperatures at which PMCs form, historic laboratory work indicates that ice I could be forming in the hexagonal, metastable stacking disordered or even the amorphous forms. However, many historic studies were performed under conditions not necessarily relevant for PMCs, hence it is not clear which phases form. Knowledge of the specific structure of ice occurring in PMCs is crucial for understanding the microphysics of PMCs as a whole. Differences in crystal structure would affect a range of PMC particle properties including crystal shape and vapour pressure.

In order to investigate the structure of water ice forming under mesospheric temperature conditions an environmental chamber was used. Ice was deposited in a series of experiments at deposition temperatures ranging from 115 to 145 K using a humidified nitrogen gas flowed over a temperature controlled stage within the environmental chamber. The specific structure of the ice formed was probed using X-ray Diffraction (XRD). XRD patterns show that the ice exists in several different crystal structures across the temperature range studied and the specific structure that forms is extremely sensitive to the deposition temperature. We observe amorphous, stacking disordered and hexagonal ice depositing at mesospheric temperatures. Notably, we also observe hexagonal ice depositing at temperatures at and above 140 K, where samples of ice deposited at much lower temperatures and warmed to this temperature persist in a metastable stacking disordered phase. Since hexagonal ice and stacking disordered ice are expected to produce crystals with large aspect ratios, while cubic and amorphous ice are not, the results help explain the observed high aspect ratios of ice crystals in PMCs and also inform modelling studies.

Monday, 18 September - - 17:00 - 17:30

Shuttle to hotels

Monday, 18 September - - 19:00 - 22:00

Opening ceremony

Tuesday, 19 September - - 08:15 - 08:45

Shuttle from hotels

Tuesday, 19 September - Conference room - 09:00 - 10:20

NLC / PMSE observations

Observations 2-O-01

PoSSUM Citizen Science Airborne Noctilucent Cloud Tomography

Jason Reimuller[1, 2], Dave Fritts[1, 2], Bjorn Kjellstrand[3], Glenn Jones[3], Michele Limon[3]

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Noctilucent Clouds (NLCs) are the central focus to NASAs '*PMC-Turbo*' high-altitude balloon mission, which will fly a suite of seven high-resolution camera systems and an airborne lidar system through a two-week mission around the circumpolar vortex above the Antarctic continent. A unique opportunity arose to validate the imagers developed for this experiment while studying NLC structure and temporal development through airborne NLC observations coordinated with ground and satellite observations. The PoSSUM airborne noctilucent cloud tomography campaign was a 14-day aircraft flight experiment conducted between 24 June and 7 July, 2017 from High Level Airport, Alberta. The experiment was mostly citizen-science and privately-funded. The objectives of the campaign were to 1) validate the *PMC-Turbo* camera systems on actual noctilucent cloud structures, 2) produce tomographic reconstructions of small-scale noctilucent cloud structures, 3) observe the temporal evolution of small-scale features not observed from the ground, 4) interpolate the low-latitude threshold of satellite imagery through synchronized observations with the AIM satellite, and 5) enable broad science communication by involving a diversity of citizen scientists.

The cameras were 16.7MP monochromatic cameras paired with 135mm lenses. One of the '*PMC Turbo'* camera systems was configured on a research aircraft that flew on a constant line of latitude at an altitude of 7000m between two ground stations where identical camera systems were positioned. Several sorties were timed with overpasses of the Aeronomy of Ice in the Mesosphere (AIM) satellite.

Observations 2-O-02

Lidar temperature measurements during a rare mid-latitude noctilucent cloud event

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We present lidar soundings of the only noctilucent cloud event recorded above GERES station in the Bavarian Forest (48.8 N, 13.7 E) during the 2016 season. A single thin NLC layer was observed for several hours at a low mean altitude of 81.1 km. Due to darkness and the high power of the CORAL lidar, Rayleigh temperatures could be obtained between 30 and 86 km altitude, reaching well above the NLC layer. By density interpolation, we estimate temperatures also within the NLC layer. Interestingly, we find high temperatures directly above the NLC layer which is embedded in a cold region extending well below the layer. Using meteor radar data, we argue that the NLC did not nucleate at the site of observation but was meridionally transported from higher latitudes during a 2-day planetary wave event. The NLC was unusally bright given the latitude and during observation, the layer was subject to variations with periods ranging from 11 min to 60 min. We bring small scale variations in NLC centroid altitude and brightness in relation with gravity wave structures inferred from temperature measurements. The lidar measurements reveals that the NLC layer resides in the cold phases of gravity waves passing through the mesosphere, lower thermosphere region.

Observations 2-O-03

Validation of Low Latitude PMCs with OMPS NP and OMPS LP

Nick Gorkavyi

Science Systems and Applications, Inc. (SSAI), Lanham, United States

The combined data set of polar mesospheric clouds (PMCs) from multiple SBUV instruments, which now extends for 38 years, has been shown to be very effective for evaluating long-term trends of ice water content, temperature, and water vapor in the mesosphere. These studies have focused on the latitude range where PMCs are most commonly observed (>50° in both hemispheres). Increased mesospheric water vapor (resulting from increasing methane) and decreased mesospheric temperature (caused by CO2 cooling) are also predicted to expand the PMC existence region to lower latitudes. However, this region (e.g. 40°-50° latitude) is very challenging for nadir-viewing PMC detection due to the combination of higher background albedo, weaker PMC signal, and greater stratospheric ozone variability. Current SBUV results in this region are quite uncertain, and difficult to validate. The Ozone Mapping and Profiler

Suite (OMPS), flying on the Suomi NPP satellite, includes a Nadir Profiler (NP) instrument that is very similar to SBUV. OMPS also includes a Limb Profiler (LP) instrument that measures limb scattered radiation looking backwards along the S-NPP orbit track. LP thus collects “common volume” profile measurements with 1 km sampling approximately 7 minutes after NP observations along the entire S-NPP orbit. The LP data provide a robust indicator of PMC existence and brightness that can be used to evaluate NP performance. We will present results from 5 years of S-NPP observations.

Observations 2-O-04

Enhancing PMSE spatio-temporal features with MIMO techniques using MAARSY

Juan M. Urco, Jorge L. Chau

Leibniz-Institute of Atmospheric Physics at the Rostock University, Kuehlungsborn, Germany

Multi-input multiple-output (MIMO) techniques have been used in digital communications and hard-target radar applications to enhance the performance over single antenna (channel) in the last decade. In MIMO radar, the techniques improve the performance of multi-receiver array by using more than one spatially separated transmitter. We have successfully applied this concept at the Jicamarca Radio Observatory to improve the aperture synthesis radar imaging observations of equatorial electrojet irregularities. Given the transmitting modularity of Jicamarca, the implementation was straightforward, increasing the effective number of receiving modules, i.e., enhancing the visbility plane by adding one additional transmitter. In this work we plan to present preliminary results from experiments conducted at the Middle Atmosphere Alomar Radar System (MAARSY) in northern Norway. Previous aperture synthesis radar imaging experiments at MAARSY were conducted with 15 receiving antennas within MAARSY's ~100 m diameter array. Our MIMO experiments use three different anemones on transmission which implements time diversity. This configuration allow us to: (1) increase the number of effective receiver from 15 to 45 and (2) increase the effective diameter from ~100 m to ~150 m. The improved radar images are shown and discussed for the observations of Polar mesospheric summer echoes.

Tuesday, 19 September - Conference room - 11:00 - 12:20

Airglow and radiation

AG-O-01

Laboratory Studies Offer New Insights for Mesospheric Nightglow

Konstantinos S. Kalogerakis, Daniel Matsiev

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The hydroxyl radical has a key role in the chemistry and energetics of the Earth’s middle atmosphere. A detailed knowledge of the rate constants and relevant pathways for OH(high v) vibrational relaxation by atomic and molecular oxygen and their temperature dependence is absolutely critical for understanding mesospheric OH and extracting reliable chemical heating rates from atmospheric observations.

We have developed laser-based experimental approaches to study the complex collisional energy transfer processes involving the OH radical and other relevant atmospheric species. Work in our laboratory indicated that the total removal rate constant for OH(v = 9) + O at room temperature is more than one order of magnitude larger than that for removal by O_2. Thus, O atoms are expected to significantly influence the intensity and vibrational distribution extracted from the Meinel OH(v) emissions. Our recent laboratory measurements corroborated the aforementioned result for OH(v = 9) + O and provided important new insights on the multi-quantum energy transfer pathways involved. We will discuss relevant atmospheric implications, including warranted revisions of mesospheric nightglow models.

Research supported by SRI International Internal R&D and NSF Aeronomy Grant AGS-1441896. Previously funded by NASA Geospace Science Grant NNX12AD09G.

AG-O-02

Influence of temporal and spatial variability in observations used to develop Multiple Ariglow Chemistry model on derived chemical heating rates

Olexandr Lednyts'kyy, Christian von Savigny

Ernst-Moritz-Arndt-University of Greifswald, Greifswald, Germany

The Multiple Airglow Chemistry (MAC) model was developed to reflect coupling of the identified electronic states of molecular oxygen in the MLT (upper mesosphere and lower thermosphere). The MAC model was tuned and verified using in-situ observations obtained during the WAVE2004 campaign and collocated observations of SABER (Sounding of the Atmosphere using Broadband Emission Radiometry) instrument aboard TIMED (Thermosphere Ionosphere Mesosphere Energetics Dynamics) satellite. Temporal and spatial variability in the used observations was analyzed using all relevant observations obtained during the WAVE2004 campaign. Particularly, the foil chaff and ground-based all-sky imaging indicated the presence of shear instability, and not the presence of convective instability. The evidence of the dynamically (and not statically) unstable regions in the MLT was reflected in the rate profiles of chemical heating derived with the developed MAC model and compared with the reference heating rate profiles obtained using the SABER instrument. The shape of the heating rate profiles is discussed using parameters of atmospheric stability in the MLT. The performed verification and discussion enabled us to conclude that the results of our retrievals and evaluations are consistent with each other and coherent with obtained datasets.

AG-O-03

New non-LTE model of the nighttime OH and CO_2 IR emissions in the mesopshere/lower thermosphere

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We present a new detailed non-LTE model of OH and CO_2 emissions in the nighttime mesosphere/lower thermosphere (MLT). The model accounts for chemical production of vibrationally excited OH and for various vibrational-vibrational (VV) and vibrational-translational (VT) energy exchanges with main atmospheric constituents. It also accounts for the new "indirect" vibrational-electronic (VE) mechanism $OH(v) \rightarrow O(^1D) \rightarrow N_2(v) \rightarrow CO_2(v_3)$ of the OH vibrational energy transfer to N_2 and further to CO_2 vibrations, which was recently suggested by Sharma et al. [2015] and proved in laboratory studies by Kalogerakis et al. [2016]. We study the impact of this mechanism on the OH(v) and CO2(v) populations and emissions in the SABER/TIMED channels at 1.6, 2.0, and 4.3 µm, as well as compare our modeled results with ground and space observations of OH(v) densities. We show that our model reproduces these ground and space observations for various atmospheric conditions significantly better when compared to previous studies. First results of this model application to the self-consistent three-channel OH, $O(^3P)$ and CO_2 retrievals from SABER nighttime observations of the MLT will be discussed.

Tuesday, 19 September - - 13:30 - 14:10

Introduction to IAP and tour or walk

Tuesday, 19 September - Conference room - 14:10 - 14:50

Metal layers

Metal Layers 1-O-01

Recent results of the mobile IAP Fe lidar campaigns to Antarctica and the Arctic

Timo Viehl, Josef Höffner, Franz-Josef Lübken

Leibniz-Institute of Atmospheric Physics at the Rostock University, Kuehlungsborn, Germany

The mobile IAP Fe lidar is a transportable resonance lidar probing the meteoric Fe layer, temperatures, and aerosols in the mesopause region. It was in operation at Davis, Antarctica (69°S, 78°E) from December 2010 to December 2012 and has been obtaining measurements at ALOMAR, Norway (69°N, 16°E) since July 2014. Here we present recent and important results of the campaigns about the metal layer dynamics and chemistry, temperatures, and the comparison to other instruments and models. The inter-hemispheric comparison shows expected similarities but also clear differences in metal layer densities as well as the mesopause temperature structure and the diurnal behaviour. A comparison to co-located OH(6-2) observations allows to draw some conclusions about the temperature derivation.

Metal Layers 1-O-02

A three dimensional global atmospheric model of meteoric metal layers: An update

WUHU FENG[1, 2], John Plane[1], Shane Daly[1], Juan Diego Carrillo-Sánchez[1], Daniel Marsh[3], Chester Gardner[4]

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The upper atmosphere (50-150 km) is a region which is affected both by anthropogenic activities from the surface and space weather above. One of the interesting phenomena is the presence of the meteoric metal layers in a very narrow altitude range in the mesosphere / lower thermosphere (MLT), which has been known for several decades through lidar, rocket and satellite measurements. The meteoric metals are very useful tracers for investigating coupling processes and testing atmospheric models of the upper atmosphere. Investigating different MLT metal layers within the same model allows a better understanding of the astronomy, chemistry and transport processes that control the different metal layers in the MLT. Since 2013 we have successfully developed the first global atmospheric model of meteoric metals (Na, Fe, K, Si and Mg) (e.g. Marsh et al., 2013, Feng et al., 2013, Plane et al., 2014; 2016, Langowski et al., 2015) based on the NCAR Community Earth System Model (CESM), and have built a self-consistent model to form meteoric smoke particles from ablated metal atoms. One interesting problem is reconciling the injection flux of the different metals required by the model, with the meteoric input function derived from lidar observations of vertical Na and Fe fluxes, and the cosmic spherule deposition at the surface (Carrillo-Sanchez et al., 2016). Here we revisit the global atmospheric model of meteoric metal layers based on the new NCAR WACCM5 (and WACCM-X which extends up to 600 km). Recently we have run WACCM spectral element (ne30) with a higher horizontal resolution of 1 x 1 degree, in order to test whether the lack of horizontal resolution in the standard version of the model (1.9 x 2.5 degree) means that gravity-wave driven chemical transport is underestimated. We will also present the WACCM-Ca model result and introduce our recently funded project "First study of the global Nickel and Aluminium Layers in the upper atmosphere (NIALL)" which is to explore the MLT chemistry of two elements - Ni and Al - that have not been studied before.

Tuesday, 19 September - Conference room - 15:30 - 16:50

Metal Layers / MSP

Metal Layers 2-O-01

Impact of Solar Proton Event (SPE) on mesospheric Na layer over Utah, Logan (42ºN, 112ºW)

TIKEMANI BAG

Postdoctoral Fellow,National Atmospheric Research Laboratory, Gadanki, India, Gadanki, Chittoor District, India

The solar proton event (SPE) induces the changes in the neutral and ion species in Earth's atmosphere. The highly energetic protons produce, after a series of chemical reactions, odd hydrogen (OH_x) and odd nitrogen (NO_y) during SPE. The production of odd hydrogen and odd nitrogen severely affects the mesospheric structure, chemistry and dynamics due to the presence of secondary ozone layer. This ozone density along with atomic oxygen dictates the behavior of Na density layer. The impact of SPE on mesospheric Na layer is studied over Utah (42ºN, 112ºW) during the SPE of 19 July 2012 using Na density as measured by Utah State University (USU) Na LIDAR. The changes in the mesospheric Na density layer is discussed in

contrast with the atomic oxygen density and neutral temperature obtained from NRLMSISE-00 neutral model atmosphere along with the proton and x-ray fluxes measured by GOES satellites.

Metal Layers 2-O-02

Retrieval of MLT Na profiles from satellite Na D-line nightglow observations – testing the Chapman excitation mechanism

Christian von Savigny, Martin Langowski, Bianca Zilker

Ernst-Moritz-Arndt-University of Greifswald, Greifswald, Germany

We report on the retrieval of Na density profiles in the mesopause region from satellite observations of the Na D-line nightglow emission near 589 nm made by the Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) on the Envisat spacecraft. The retrieval is based the Na D-line excitation mechanism originally proposed by Sydney Chapman in 1939. The retrieved Na profiles are compared to independent satellite measurements. The largest source of error is the remaining uncertainty of the branching ratio f for the production of Na(2P) via the reaction of NaO and O. Good agreement with independent observations is found in terms of peak altitude, peak concentration, and vertical column density, after an empirical adjustment of the branching ratio to a value of f = 0.09. This value is in good agreement with several earlier studies. The retrievals constitute the first Na profile retrievals from satellite observations of the Na D-line nightglow emission profile. They enable our understanding of the Na nightglow excitation mechanism to be tested.

Metal Layers 2-O-03

Characteristics of neutral and ionized layers in the E-region over Arecibo

Jens Lautenbach, Eframir Franco, Jonathan Friedman, Michael Sulzer, Shikha Raizada

Arecibo Observatory / SRI International Space & Atmospheric Sciences, Arecibo, Puerto Rico

The Arecibo Observatory has a unique instrument cluster to measure simultaneously ion layers (Sporadic-E and descending layers) along with neutral metal layers, using incoherent scatter radar (ISR) and resonance lidars respectively. The Arecibo data set presents excellent opportunities to investigate the role of ion-neutral coupling, and the connection between tidal ion layers and thermospheric metal layers. The origin of the latter is still a subject of considerable interest, and it can be further understood through simultaneous observations of ionized and neutral species. In this paper, we will present case studies, through which we expect to reveal clearer insights about metal layers at thermospheric altitudes and how these will guide our future endeavors. This study will focus on

(a) an example of thermospheric neutral layers in Na and K along with electron density data showing no correlation between them. Some additional examples revealing descending layers in ISR data over Arecibo but lacking of neutral layers also suggest that neutralization of metal ions could not be the source of metals at altitudes higher than the meteor ablation zone, and

(b) neutral Sporadic layers observed in Na (Na_S) and Fe (Fe_S) along with their relationship to Sporadic E (E_S) as seen in ISR data will also be discussed.

Such studies highlight the significance of making multi-metal observations and also suggest the importance of implementing the capability that will allow Fe measurements using narrowband Alexandrite laser in the future.

Metal Layers 2-O-04

On small scale mesospheric dust structures and secondary charging effects observed by the MAXIDUSTY payload

Tarjei Antonsen, Ove Havnes

University of Tromsø, Tromsø, Norway

The MAXIDUSTY rocket campaign consisted of two payloads, launched from Andøya Space Center (69.17'N 16.1'E) on the 30th of June and 8th of July 2016 respectively. The instrumentation was aimed towards analyzing the multi-scale structure of mesospheric dust clouds, as well as characteristics such as size distribution and composition of nanoscale ice and meteoric smoke particles. In the present work, we compare measurements from the Faraday cup probe DUSTY and the impact Faraday cup MUDD. The MUDD probe utilizes an impact grid which fragments ice particles, and can be used to estimate the meteoric content of mesospheric ice. In particular, differences between the two probes in detected dust current signatures from small scale dust structures is analysed. We also discuss a method from which the dust size distribution, and thereof estimates for secondary charge production in MUDD, can be obtained from DUSTY measurements. It is found that the latter probe can be used reproduce secondary charge measurements from MUDD, and therefore act as a reference for it.

Tuesday, 19 September - - 17:00 - 17:30

Shuttle to hotels

Wednesday, 20 September - - 08:15 - 08:45

Shuttle from hotels

Wednesday, 20 September - Conference room - 09:00 - 10:20

PMSE

Observations 3-O-01

PMSE spectral parameter estimation from aperture synthesis radar imaging experiments with MAARSY

Ralph Latteck, Jorge Chau, Miquel Urco, Toralf Renkwitz

Leibniz-Institute of Atmospheric Physics at the Rostock University, Kühlungsborn, Germany

The Middle Atmosphere Alomar Radar System (MAARSY) provides a high flexibility of beam forming and beam steering in combination with multi receiver capability allowing beam swinging operation as well as the use of interferometric applications for improved studies of mesospheric echoes with high spatiotemporal resolution. The implementation of imaging algorithms such as Capon or Maximum Entropy on the multi-channel receiving system of MAARSY is suitable to discriminate space and time scattering ambiguities. We present PMSE spectral parameter estimations from MAARSY experiments using a wide radar beam experiment in combination with a multi-receiver setup allocated to 15 subgroups of the MAARSY antenna array. The temporal variations of PMSE characteristics are discussed on the basis of spatial resolved structures of the derived parameters as e.g. signal strength, spectral width and radial velocity within the radar beam. Our preliminary results show that PMSE scattering is not homogeneous by improved estimations of turbulence and horizontal wind fields.

Observations 3-O-02

Mean vertical wind in the summer polar mesosphere: Are radar measurements reliable?

Nikoloz Gudadze, Gunter Stober, Fazlul Laskar, Jorge L. Chau

Leibniz-Institute of Atmospheric Physics at the Rostock University, Kühlungsborn, Germany

Vertical component of the neutrals wind is an important parameter in the dynamical processes of the mesopause region. The mean vertical motion plays a significant role in the global circulation of the mesosphere. Nevertheless observations and models indicate large discrepancies in magnitudes and direction of mean vertical flow. Here we present the observational results of the mean vertical wind during summer season in the polar region. Vertical components are derived from the continuous multi-beam radar observations of the radial velocities obtained using Polar Mesosphere Summer Echoes (PMSE) as tracer. We analyzed data from June and July 2016 observed by MAARSY, which is located in northern Norway. Besides the results from PMSE, we present and discuss climatology of recent horizontal divergence estimates obtained from combining closely located specular meteor radars. Our preliminary results show downward flow below the summer polar mesopause region. Height profiles of the mean vertical winds with high altitude resolution indicate a significant minimum value close to 81 km, while upward flow is observed at higher altitudes. Obtained results are contrary to recent model estimations. The Differences between model and observational results leave the open questions, which needs subsequent discussions.

Observations 3-O-03

On aspect sensitivity of Polar Mesospheric Summer Echoes – and its dependence on the measuring method

Cesar La Hoz[1], Jorge Chau[2], Henry Pinedo[1]

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The determination of aspect sensitivity – that is, the distribution of scattering strength on direction, or anisotropy – of polar mesospheric summer echoes (PMSE) has attracted the attention of many investigators ever since the first measurements of PMSE were made in the 1970's. The aspect sensitivity of the scattered signals

serves as an indicator of the scattering mechanism. Various techniques have been employed: Doppler beam swing (DBS), spatial correlation analysis (SCA), mean angle of arrival (MAOA), coherent radar imaging (CRI) and their synonymous. The common attribute of these techniques is that they all give different results, ranging from high aspect sensitivity (2-3 degrees) to moderate aspect sensitivity (8-15 degrees). In one case the accidental contribution of an antenna side lobe made it possible to make a measurement at 36-38 degrees. One reason for the discrepancies is that in many cases the assumptions on which the methods rely on are not fullled. An example is the assumption of gaussian angular distribution of the scattering that has only three degrees of freedom in two dimensions (the major and minor axis and the orientation of the elliptically shaped iso-contours).The methods have been also constrained by what is feasible on account of availability and/or affordability of the instruments. MAARSY – the most capable aperture synthesis imaging MST radar as of today – has recently highlighted the outstanding capabilities of the radar imaging technique and the serious limitations of the other techniques. It is argued that the multi-static radar technique, as employed in incoherent scattering radar, is the method that gives correct measurements of aspect angle with a minimum of assumptions, one of them being that the beamwidth of the remote probing antenna be narrow compared to the desired aspect angle resolution, an assumption that is met reasonably well by the EISCAT tri-static VHF radar system. The multi-static method is equivalent to the standard method to measure the directional radiation pattern of an antenna or aerial employing a bright stellar radio source, unsurprisingly, since scattering aspect sensitivity is physically the same as the directional pattern of the scattering. The SCA is also a multi-static method in which the assumption of a gaussian distribution attempts (mostly unsuccessfully) to mitigate the limitation of very short baselines. The EISCAT tri-static VHF measurements show that PMSE, as a rule, is not aspect sensitive, as scattering is detected nearly routinely at unprecedented very large scattering angles. This is a pleasing result since it strengthens the theory that PMSE is induced by neutral turbulence and as such it should agree with Kolmogorov's hypothesis that turbulence in the inertial sub-range and in its extension due to high Schmidt number – should in general be isotropic.

Observations 3-O-04

Multi- VHF frequency, multi-angle and multi-location studies of polar mesospheric summer echoes using KAIRA and MAARSY

Jorge Chau[1], Nikoloz Gudadze[1], Derek McKay[2], Juha Vierinen[2], Thomas Ulich[3], Ralph Latteck[1]

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Polar mesospheric summer echoes (PMSE) have been studied with radar and in-situ probes since more than 20 years and their existence is well understood. On-going efforts are devoted to use them as tracers of the background dynamics and to understand their spatial and temporal evolution. Recently, Sommer and Chau [2016] has shown, using aperture synthesis radar imaging, that scattering from irregularities associated to PMSE is mainly isotropic and they are mainly organized in patches smaller than 5 km in horizontal extension (i.e., smaller than typical illuminated areas). To further validate this finding, common volume observations with different observing angles are needed. In this work we present preliminary results of such measurements, using MAARSY (Middle Atmosphere Alomar Radar System) and KAIRA (Kilpisjärvi Atmospheric Imaging Receiver Array). KAIRA is a radio receiver array (Low-frequency Array - LOFAR) with one of its arrays operating in the 10 to 80 MHz VHF band. Our results are based on a campaign conducted in August 2016. Besides using MAARSY for transmission and

reception (at 53.5 MHz), we have also used the Andenes specular meteor radar for transmission and reception (at 32.55 MHz). Both frequencies were received simultaneously at KAIRA, located approximately 190 km east from MAARSY. We also present results from different frequencies and different locations using these multi-static configurations. Our multi-angle results indicate that indeed PMSE is not as aspect sensitive as previously thought.

Wednesday, 20 September - Conference room - 11:00 - 12:20

Gravity waves

GW-O-01

Gravity wave coupling from the troposphere to the mesosphere: insights from a series of combined airborne and ground based field campaigns in both hemispheres

Markus Rapp, Andreas Dörnbrack, Bernd Kaifler, Natalie Kaifler

German Aerospace Center (DLR), Institute of Atmospheric Physics, Oberpfaffenhofen, Germany

Gravity waves are the major coupling mechanism between the troposphere and the mesosphere. In order to investigate the full process chain from wave excitation in the troposphere, over the horizontal and vertical propagation through the troposphere and the middle atmosphere up to their dissipation in the mesopause region, we have conducted a series of combined airborne and ground based research campaigns in Northern Scandinavia (2013 and 2015/16) and in New Zealand (2014). Corresponding results show a wealth of complex wave processes like wave trapping and evanescence at the tropopause, refraction into the polar night jet, wave breaking in the mid stratosphere and mesopause region, and the excitation of secondary waves. In this talk, we present research highlights from these field programs, identify important open questions, and we will describe our near and mid-term plans to address some of the remaining open issues.

GW-O-02

Small scale dynamics in the summer mesopause region as revealed by the vertical and horizontal structure of noctilucent clouds.

Baumgarten Gerd, Fiedler Jens, Lübken Franz-Josef, Stober Gunter

Leibniz-Institute of Atmospheric Physics at the Rostock University, Kühlungsborn, Germany

The remarkable structure of noctilucent clouds (NLC) has attracted researchers since more than 130 years. The structures have even been used to deduce the altitude of the clouds, that is about 83 km where the atmosphere pressure is about 5 orders of magnitude lower than at the earth surface. The clouds and their structures have been used as tracers for dynamical processes in a height region that is difficult to study with other methods. The structured appearance of NLC has been found to be closely linked to atmospheric waves and their transition to turbulence.

We make use of measurements of NLC with the ALOMAR RMR-lidar, located in Northern Norway at 69°N, that is detecting NLC with sub-second resolution. Although the particles in NLC are smaller than the wavelength of visible light, they can be measured by lidar when

observing the clouds at different colors. In combination with ground and space based cameras the horizontal structure is investigated on scales from meters to hundreds of kilometers. We present recent results from lidar and camera that show the rich structure of NLC - as seen by the naked eye – which is caused by the peculiar nature of the clouds: At times the brightest part of NLC is limited to 100 m or less vertical extend, making the clouds a proxy for small scale atmosphere dynamics with a resolution superior to other layers in the mesosphere lower hermosphere region.

GW-O-03

Small-scale gravity waves in the Alpine region observed in OH-airglow - comparison of measurements at Oberpfaffenhofen, Germany, and Sonnblick, Austria

Patrick Hannawald[1], René Sedlak[1], Carsten Schmidt[2], Sabine Wüst[2], Michael Bittner[1, 2]

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The OH-airglow layer in about 87 km altitude is well-suited for the investigation of atmospheric dynamics, allowing continuous observations of the night-sky throughout the year. Especially, atmospheric gravity waves are prominent features in the data of airglow imaging systems.

Our imaging system FAIM 1 (Fast Airglow IMager 1) focusses on small-scale wave-like structures in the horizontal wavelength range of 1 km to 50 km at mesopause heights. This range covers small-scale gravity waves as well as larger scale instability structures and is rarely investigated in literature beyond case studies.

For FAIM 1 three years of measurements are available at present in a high temporal and spatial resolution. For the first year the instrument was located at Oberpfaffenhofen, Germany (48.087N, 10.280E) and for another 1.5 years it was set-up at Sonnblick Observatory, Austria (47.054N, 12.958E). To analyse the vast amount of image data, the two-dimensional FFT is used for extracting the wave parameters. For both stations, the dominant horizontal wavelengths and main propagation directions are retrieved; the similarities and differences are presented and discussed as well as a seasonal relationship.

This work received funding from the Bavarian State Ministry of the Environment and Consumer Protection.

GW-O-04

PMC-Turbo: a Balloon-Borne Mission to Image Gravity Waves and Turbulence in Polar Mesospheric Clouds

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PMC-Turbo is a balloon-borne experiment that will fly at an altitude between 35 and 40 km. It is designed to record gravity wave events in polar mesospheric clouds with high spatial and temporal resolution as they unfold across a large field of the sky.

The project is motivated by the serendipitous observation of PMCs during the balloon flight of EBEX, an observational cosmology experiment which flew in 2013 at an altitude of about 35 km. EBEX included two star cameras, each of which had a field of view of 4 by 3 degrees, a resolution of 2.5 m at 80 km altitude, and an image cadence of 30 seconds. Even though EBEX was not designed to observe PMCs, instability and turbulent structures were visible with features at scales down to 20 m in the star camera images. However, it is difficult to put the images in context due to the inconsistent pointing, slow image cadence, and the narrow field of view.

PMC-Turbo was designed leverage the strengths of the EBEX star cameras to observe gravity wave events at various length scales. This requires capturing a wide view while remaining sensitive to small features, as well as recording images at a high cadence. It carries seven cameras, four of which are wide field cameras that together cover a field of view of about 150 by 40 degrees with an 8 m per pixel resolution. Cameras with narrow field lenses provide smaller fields of view of 10 by 15 degrees with about 3 m per pixel resolution and are situated within in the larger field of view. The cameras can sustain 3.5 frames per second and can capture bursts of images up to 8 frames per second. The payload also carries a Rayleigh lidar from the DLR Institute of Planetary Research and an airglow camera from Utah State University. These instruments will provide additional context to observed events in the form of thermal profiles and infrared mapping.

PMC-Turbo is scheduled to fly next year from either Sweden or Antarctica. We anticipate a fourteen day flight over Antarctica, and we expect to capture about 14 million images. An arctic flight would last around 5 days, but we anticipate several gravity wave events during this time. In addition to lab testing of our equipment, we have had opportunities to collect data with the PMC-Turbo instruments in the field. This December we will fly one camera as a piggyback on the Super Tiger payload from Antarctica. In July, we used several cameras on the ground to capture PMC images in High Level, Alberta. We hope to resolve tomography from the images captured during that campaign. If we fly from Sweden, we plan to coordinate ground-based tomographic imaging with the balloon flight.

Wednesday, 20 September - - 13:20 - 22:00

Excursion

Thursday, 21 September - - 08:15 - 08:45

Shuttle from hotels

Thursday, 21 September - Conference room - 09:00 - 10:20

Trend

LongTerm-O-01

58 years of phase-height measurements – Long-term variability of the mesospheric temperature over Europe

Dieter H.W. Peters, Günter Entzian, Dieter Keuer, Jorge L. Chau

Leibniz-Institute of Atmospheric Physics at the Rostock University, Ostseebad Kühlungsborn, Germany

The formation of polar mesospheric clouds (PMCs) depends on water vapor and cold temperatures in summer. Since the end of 1950s, that means over more than 5 solar cycles, field strength measurements of the broadcasting station, Allouis (Central France), have been performed at Kühlungsborn (54° N, 12° E, Mecklenburg, Northern Germany. These so-called indirect phase-height measurements of low frequency radio waves (here with a frequency of 162 kHz) are used to study the long-term variability and trends of the mesosphere over Europe. The advantages of the method are the low costs and the simplicity of operation. The reanalyzed forth release of standard-phase height measurements (SPH-R4) with a loss rate below 10% is presented and discussed for summer months.

The plasma-scale height is used as a proxy for mean temperature variability of the upper mesosphere and the calculated thickness-temperature is used as proxy for the column-integrated mesospheric temperature. The derived thickness-temperature of the mesosphere decreased statistically significant over the period 1959-2017 after pre-whitening with summer means of solar sun spot numbers. The trend value is in the order of about -1 K/ decade if the stratopause trend is excluded. The linear regression with time is stronger for the period of 1963-1985 (2 SCs), but 2.6 times weaker during 1986-08 (next 2 SCs). The upper mesospheric temperature derived from plasma-scale height shows no significant change in summer. Furthermore the influence of solar variability on mesospheric temperatures is discussed.

LongTerm-O-02

On consistency of variability and long term trends in temperature, CO2 VMR, and Cooling-Heating rates derived from SABER/TIMED

Rezac Ladislav[1], Paul Hartogh[1], Jia Yue[2], Yongxiao Jian[2]

[1]*Max Planck Institute for Solar System Research, Göttingen, Germany*
[2]*Center for Atmospheric Science, Hampton University, Hampton, United States*

The Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument on board the Thermosphere Ionosphere Mesosphere Energetics and Dynamics satellite has been measuring radiances for more than 15 years with nearly a global coverage. These measurements allowed simultaneous retrieval of CO2 VMR and temperature vertical profiles, along with consistently calculated cooling/heating rates. We investigate the coupling between the long-term trends in the Thermosphere-Ionosphere (T-I) (as captured by several ionospheric indicators) and spatial distributions of long-term trends of green-house gases in the MLT region. The CO2 long-term changes in the MLT are believed to be stable, reflecting the tropospheric trends, as there are no sources of carbon within the upper atmosphere, and it can act as a forcing on the local thermal field. First, we analyze whether the derived products are consistent with each other, and how they compare with other similar datasets. Then, the spatial and temporal variability for each of the parameters covering period (2002-2016) is quantified in order to better understand the CO2 coupling with the T-I region, known to undergo a long term contraction. Although the T-I is known to be strongly coupled system with the lower atmosphere, resolving the long term behavior of CO2, its spatial distribution and solar energy input response is important step disentangling the individual components driving the changes of this atmospheric region.

LongTerm-O-03

Long Term Airglow Variations by the Influences of CO2 Increase, Solar Cycle Variation, and Geomagnetic Activity

Tai-Yin Huang

Physics Department, Penn State University - Lehigh Valley, Center Valley, United States

Two airglow models, OHCD-90 and MACD-90, are used to simulate the induced variations of O(1S) greenline, O2(0,1) atmospheric band, and OH(8,3) airglow by the CO2 increase, the F10.7 solar cycle variation and geomagnetic activity for a time period from 1960 to 2015. Our results demonstrate that airglow intensity and the peak Volume Emission Rate (VER) variations of the three airglow emissions are strongly correlated, and in phase, with the F10.7 solar cycle variation. In addition, there is a linear trend, be it increasing or decreasing, existing in the airglow intensities and VERs due to the CO2 increase. On other hand, airglow VER peak heights are strongly correlated, and out of phase, with the Ap index variation of geomagnetic activity. The CO2 increase acts to lower the VER peak heights of OH(8,3) airglow and O(1S) greenline by 0.2 km in 55 years and it has no effect on the VER peak height of O2(0,1) atmospheric band.

LongTerm-O-04

Probability density distributions of PMCs

Uwe Berger, Gerd Baumgarten, Jens Fiedler, Franz-Josef Luebken

Leibniz-Institute of Atmospheric Physics at the Rostock University, Kuelungsborn, Germany

In this paper we present a new description about statistical probability density distributions (pdfs) of Polar Mesopheric Clouds (PMC) and noctilucent clouds (NLC) occurrence frequencies. The analysis bases on observations of maximum backscatter ratios measured by the ALOMAR RMR-lidar for aNLC seasons from 1997 to 2013. From these lidar data record we estimate an additional observational quantity of ice water density. For these two data sets we derive new classes of pdfs that describe the statistics of PMC/NLC events different from previously statistical methods using the approach of an exponential distribution commonly named g-distribution. The new theory is very successful in describing the probability statistic of ALOMAR lidar data. It turns out that the former g-function statistic is embedded in our new theory as a special case. In general the new theory allows to derive basic parameters of

climatological ice particle distributions, namely mean ice radii and variances, and, secondly, the theory can be generally applied to many kinds of different observational data sets, e.g. measurements of albedo, ice water content, and ice water densities by satellite instruments, or backscatter signals by lidars, respectively.

Thursday, 21 September - Conference room - 11:00 - 12:20

Solar cycle and trend in PMC

SCyc-O-01

Solar Cycle Response in SBUV PMC Ice Water Content

Matthew DeLand[1], Gary Thomas[2]

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The combined data set of polar mesospheric clouds (PMCs) from multiple SBUV instruments, which now extends for 38 years, demonstrates long-term variations with both periodic and trend characteristics. The periodic component of these variations appears as an anti-correlation between the level of solar activity, as characterized by solar Lyman alpha flux, and various indicators of PMC behavior (occurrence frequency, albedo, ice water content). This relationship was fairly distinct during the 1980s and 1990s, but has been considerably weaker during the 2000s. This has led to suggestions that forcing from additional sources, such as stratospheric warming caused by volcanic eruptions, may have enhanced the apparent periodic response at certain times.

Extending the SBUV PMC record through the most recent season (NH 2017) provides us with approximately 3½ solar cycles of data, which makes it possible to apply statistical techniques such as superposed epoch analysis (SEA) to these data. We will present the updated SBUV PMC data set, which now includes OMPS Nadir Profiler (NP) data, and describe the results of applying SEA to both Northern Hemisphere and Southern Hemisphere data.

SCyc-O-02

Long-term H_2O and CH_4 variability in the Middle Atmosphere Observed by SOFIE on the AIM Satellite

Jia Yue[1], James Russell[1], Pingping Rong[1], Mark Hervig[2], Tom Marshall[3]

[1]*Center for Atmospheric Research Hampton University, Hampton, United States*

[2]*GATS, Inc, Driggs, United States*

[3]*GATS, Inc, Newport News, United States*

Polar Mesospheric Clouds (PMCs) have been suggested to be a sensitive indicator of long-term atmospheric change in the polar summer mesopause region due to increasing greenhouse gases and solar effects. [Thomas, 1996]. IAP scientists [Lubken, Berger et al.] have suggested that cooling in the stratosphere and mesosphere causes a shrinking of the atmosphere that extends to PMC heights. Recently, Hervig et al. [2016] concluded that both the cooling in the stratosphere and mesosphere and increasing H_2O contribute to increasing PMCs over the last

36 years observed by the SBUV series of satellites. 2017 marked the 10th year anniversary of SOFIE (2007-) measurements. With this long dataset, we study the long-term variability of H_2O and CH_4 from SOFIE, including linear trends, solar cycle response and other naturally occurring periodicity. The change of SOFIE H_2O and CH_4 at high latitudes will be compared with the theoretical estimation in Hervig et al. [2016]. Depending on the data processing status, we may present the updated long term variability of SABER H_2O which covers the low and mid latitudes.

SCyc-O-03

Long term evolution of mesospheric ice particles

Franz-Josef Lübken, Gerd Baumgarten, Uwe Berger

Leibniz-Institute of Atmospheric Physics at the Rostock University, Kühlungsborn, Germany

The MIMAS (Mesospheric Ice Microphysics and Transport) ice model is used to study the trend behavior of polar mesospheric clouds (PMCs) responding to long-term changes in mesospheric temperatures and water vapor at northern high latitudes from 1871 until now.

The calculated trends in PMC formation are partly forced by a long-term change in the thermal and dynamical state of atmospheric background. We estimate the climate change in the PMC environment using trend studies with our Leibniz-Institute Middle Atmosphere (LIMA) model. We take into account long-term changes in solar activity and trace gas distributions of CO2 and O3. Furthermore, LIMA adapts NCEP reanalysis data (20th century) that describes the temporal evolution of troposphere/lower stratosphere since 1871.

In the past we have concentrated on trends in ice layers mainly for period after the late 1970s since satellite observations of background parameters relevant for our topic are available since then. More recently we have extended our trend analysis of background temperatures and noctilucent clouds (NLC) to a longer period, namely from 1871 to present. We concentrate on the most important drivers for NLC trends, namely carbon dioxide (CO2) and water vapor (H2O). Since the main increase of these species occurs in the last 40-50 years, NLC parameters such as occurrence frequency, mean integrated backscatter (IBS), mean altitude, and mean ice water content (IWC) increase accordingly. First, we will present and discuss long term trends in temperatures and water vapor. To separate their impact on the long term evolution of NLC, we have performed runs with temperature trends (caused mainly by increase of CO2) and water vapor trends (caused mainly by increase of CH4) separately. Trends of NLC parameters are rather small in the first couple of decades (namely from 1870 until approximately 1930) and accelerate significantly thereafter. We find that the reason for the observed enhancement of NLC brightness etc. in the last decades is primarily the increase of water vapor, whereas the decrease of temperatures plays a secondary role. In our presentation we will discuss the implications of our results for the role of NLC as indicators for climate change.

Thursday, 21 September - - 13:30 - 14:10

IAP tour or walk

Thursday, 21 September - Conference room - 14:10 - 14:50

PMWE / PMC in the Arctic and Antarctic

Observations 4-O-01

Characteristics of winter time mesosphere echoes over Syowa and Davis in the Antarctic obtained using PANSY and MF radars

Masaki Tsutsumi[1], kaoru Sato[2], Toru Sato[3], Damian Murphy[4]

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[3]*Department of Communications and Computer Engineering, Kyoto University, Kyoto, Japan*
[4]*Australian Antarctic Division, Tasmania, Australia*

Characteristics of winter time mesosphere echoes have been investigated over Antarctic stations of Syowa (69.0S, 39.6E) and Davis (68.6S, 78.0E) using PANSY radar at Syowa (47 MHz) and MF radars at Syowa (2.4 MHz) and Davis (1.94 MHz). At Syowa low altitude MF radar echoes below about 70 km showed a similar seasonal, day-to-day and local time variations with those of the PANSY radar. Polar mesosphere winter echoes (PMWEs) by the PANSY radar and the low altitude MF echoes mostly coexisted appearing during day time and also for a few hours after sunset, while summer echoes in the lower height region were absent in both radar observations suggesting a close relationship in the generation mechanisms of 47 MHz and 2.4 MHz echoes. In other words winter time low altitude MF echoes can be used as a proxy of PMWEs in VHF. A preliminary comparison between Syowa and Davis MF radar winter echoes showed clearly different day-to-day variations suggesting that PMWEs have a longitudinal structure.

Angles of arrival of Syowa MF echoes were estimated using the interferometry capability of Syowa radar and showed a more isotropic nature in winter. Because gravity wave activity is much higher in winter than in summer over Syowa [Yasui et al., 2015] and also over Davis [Dowdy et al., 2007], higher turbulence energy in winter caused by gravity wave breaking may be responsible for the generation of the winter echoes and their isotropic behaviour. Comparison of gravity wave activity and MF echo power will further be conducted.

Observations 4-O-02

Sounding rocket project PMWE

Boris Strelnikov[1], Franz-Josef Lübken[1], Ralph Latteck[1], Jorge L. Chau[1], Martin Friedrich[2], Markus Rapp[3, 4]

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Authors: B. Strelnikov, F.-J. Lübken, R. Latteck, I. Strelnikova, H. Asmus, T. Staszak, T. Renkwitz, J. L. Chau, M. Friedrich, and M. Rapp

The PMWE (Polar Mesosphere Winter Echoes) research project initiated by the Leibniz Institute of Atmospheric Physics (IAP) in partnership with the Institute of Space Systems (IRS)

and the Ludwig-Maximilians-University in Munich (LMU) involving collaboration between several international and national partners will launch a total of four instrumented sounding rockets from the Andøya Space Center distributed over two campaigns in 2017 and 2018.

PMWE are relatively strong coherent radar returns from ~55–85 km altitudes, which primarily occur in the winter season at high latitudes. PMWE are also observed at mid-latitudes, although very much more rarely. Because of their extremely low occurrence rate, they are still poorly investigated. As a consequence, the origin of these echoes is still under debate.

Currently most acceptable explanations of PMWE formation mechanism suggest that the key role plays neutral air turbulence. However, there are some features, which need additional players to explain this phenomenon. The most important among them is the background electron density which is needed to make PMWE detectable for the radars. This explains why PMWE more often occur during day time when the solar radiation ionizes the Earth's atmosphere. Another important player in the formation of PMWE is suggested to be the dust particles or the so-called Meteor Smoke Particles (MSP). Their importance was suggested by interpretation of the PMWE observations with the European Incoherent Scatter radar (EISCAT).

In the paper we give a short review on the existing data related to PMWE and their scientific interpretations. We also introduce the experimental approach of the ongoing PMWE sounding rocket project.

Thursday, 21 September - Poster area - 15:30 - 16:50

Posters 2

Posters 2-P-01

Case studies of downward-propagating gravity waves observed with mesospheric lidars

Bernd Kaifler, Natalie Kaifler, Markus Rapp

Institute of Atmospheric Physics, German Aerospace Center, Oberpfaffenhofen, Germany

Secondary gravity waves excited in the middle atmosphere contribute to vertical coupling and are not well understood. Using a novel analysis method based on two-dimensional wavelet analysis, we select gravity waves depending on their apparent vertical phase velocity using lidar temperature soundings in the 30 to 85 km altitude range. Wave packets of upward and downward-propagating gravity waves can thus be separated and quantified. From two Rayleigh lidar datasets obtained in Finland and New Zealand, we present cases with enhanced occurrence of downward-propagating waves and study possible wave generation mechanisms.

Posters 2-P-02

Project PoSSUM: Aeronomy Citizen Science, Education and Public Outreach

Jason Reimuller[1, 2], Gary Thomas[3], Dave Fritts[1, 2], Zoltan Sternovsky[3], Mike Taylor[4], Gerd Baumgarten[5]

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[5]*Leibniz-Institute of Atmospheric Physics at the Rostock University, Kühlungsborn, Germany*

Project PoSSUM, an acronym for Polar Suborbital Science in the Upper Mesosphere, is a 501(c)3 aeronomy research and education program that grew from the opportunity created by the 'Noctilucent Cloud Imagery and Tomography Experiment', selected by NASA's Flight Opportunities Program in March 2012. A custom instrument was developed for this experiment to produce high-resolution noctilucent cloud and OH-layer imagery coincident with in-situ temperature measurements and neutral and charged particle density measurements in a manner from which tomography may be constructed. This tomography aims to characterize the roles of gravity wave and instability dynamicsin the mixing and transport processes of the upper atmosphere. The experiment was the only manned flight opportunity ever selected by NASA.

The human component of the PoSSUM experiment provides opportunities beyond traditional funding sources for increased funding through private sources including participant tuition, commercialization f media products, and sponsorships. In June 2017, PoSSUM conducted a privately-funded airborne reserach campaign from High Level, AB using three camera systemsdesigned and constructed for the NASA 'PMC-Turbo' high-altitude balloon mission. Other privately-funded PoSSUM citizen-science reserch yielded publications in bioastronautics, human factors, and educational methods.

The human component also provides a means to inspire general audiences while communicating sciience. PoSSUM manages two educational programs at the Embry-Riddle Aeronautical University in Daytona Beach, FL and a third program at the Space Foundation in Colorado Springs, CO. These programs have drawn students from 24 different countries to learn about aeronomy, remote sensing of the mesosphere, and noctilucent cloud science while they conduct simulated suborbital missions using actual instrumentation in fully-pressurized spacesuits.

Posters 2-P-03

MICE-TRAPS: Nanoparticles as a sensitive probe for studying the properties of atmospheric vapors

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Time-of-Flight mass spectrometry (TOF-MS) is an established experimental technique used in a wide range of scientific fields and industrial processes. One of many reasons contributing to the success of this technique lies in the fact that very high (atomic) resolution can be achieved while maintaining a high signal-to-noise ratio.

We employ this technique in our experimental setup, which consists of the Molecular flow Ice Cell (MICE) within the Trapped Reactive Atmospheric Particle Spectrometer (TRAPS), for studying the nucleation and condensation of condensable vapors on atmospheric aerosol nanoparticles. The TOF-MS enables us to investigate nucleation and condensation processes at extreme atmospheric conditions where typical experimental methods fail. The nanoparticles are trapped in MICE and are used as a probe for the properties of the condensable vapors under investigation. The low initial mass of the nanoparticles of roughly 20kDa enables us to identify very low adsorption rates of few molecules per minute.

In this contribution we present the experimental setup in detail together with results on desorption energy, critical saturation for nucleation, contact parameter, saturation vapor pressure and aerosol light absorption coefficient during the deposition of Water and CO_2 under conditions found in the middle and higher atmospheres of Earth and Mars.

Posters 2-P-04

MF radar technique for investigating the long-term dynamics and structure of the mesopause over Langfang, China

Cunying Xiao[1], Xiong Hu[1], Junfeng Yang[1], Xuan Cheng[1, 2], Qingchen Xu[1]

[1]*National Space Science Center, Chinese Academy of Sciences, Beijing, China*
[2]*University of Chinese Academy of Sciences, Beijing, China*

Medium-frequency (MF) radar is one of the few regular technique to investigate the neutral upper atmosphere. It has the advantages of low cost and no effect by the weather which can be used to routinely and continuously measure wind velocities and electron densities, and then study the long term dynamics and structure of the mesosphere and lower thermosphere (MLT) region. Langfang (39.4ºN, 116.7ºE) MF radar was established in May 2009 in China. Since June 4, 2009, the radar has been used to routinely measure winds and electron densities in the MLT region. This MF radar operates at a frequency of 1.99MHz and employs four sets of crossed dipoles for transmitting and receiving. The spaced-antenna technique are applied. Wind measurements are made at 2km height intervals and at time intervals of 4min with full correlation analysis algorithm. With these so far 8-years continuously wind data, the long-term variations of winds, tides and turbulence intensities in mesopause are reported. The motivation is to grasp the features of mesopause over mid-latitude and to help to understand the coupling between high-latitude and low-latitude.

Posters 2-P-05

Multi-Year Survey of Persistent Gravity Wave Parameters in the Mesosphere and Lower Thermosphere at McMurdo (77.8°S, 166.7°E), Antarctica

Ian Geraghty, Xinzhao Chu, Jian Zhao, Cao Chen

University of Colorado Boulder, Boulder, United States

The existence of an iron layer in the Mesosphere and Lower Thermosphere (MLT) produced by meteoric deposition provides a unique opportunity to study the dynamics of this region of the atmosphere. The McMurdo lidar observational campaign, conducted by the University of Colorado lidar group, has been underway since December 2010. The deployment and operation of an Fe Boltzmann lidar at Arrival Heights observatory (77.8 ºS, 166.7 ºE) has produced multiple years of iron temperature and density measurements.

Recent observations made using the Fe Boltzmann lidar reveal that temperature variations in the Antarctic MLT are driven by seemingly ever present, persistent gravity waves. Waves with periods of ~3 – 10 hours and vertical wavelengths of ~20 – 30 km have been present and dominant in the upper atmosphere temperature perturbations for every lidar run over multiple

years of observations. Thus far the extensive calculations of gravity wave characteristics in this region have only been conducted in June along with a few cases in May and July [Chen et al., 2016; Chen and Chu, 2017]. Internal gravity waves play a key role in distributing energy and momentum throughout the atmosphere and so an understanding of any seasonal changes in their properties is necessary to fully understand the dynamics of the MLT region.

In order to characterize seasonal variations of these gravity waves, a two-dimensional fast Fourier transform is used to analyze the period and vertical wavelength spectra as well as potential energy densities of multiple years of iron temperature and density measurements. Iron density measurements will be used to assist the calculations of gravity wave parameters in the summer, fall, and spring seasons whenever Fe temperature measurements do not provide high resolutions due to the high solar background hindering signal to noise ratios. Proposed wave sources and generation mechanisms include secondary wave generation, spontaneous radiation caused by jet stream interactions, and even a resonance oscillation of the Ross Ice Shelf. We hope that this analysis and comparison with seasonal gravity wave trends in the stratosphere provides clues as to dominant wave sources.

Posters 2-P-06

Seven years (2010-2017) of lidar observations of polar mesospheric clouds at Arrival Heights (77.8ºS, 166.7ºE) in Antarctica

Mattia Astarita, Xinzhao Chu, Jian Zhao

University of Colorado Boulder, Boulder, United States

Polar mesospheric clouds (PMC) are thin layers of water ice particles that form at high latitudes in the mesopause region (~85km). These clouds occur in both hemispheres during the respective summer seasons when the temperatures fall below 150 K. PMC are of particular interest as they directly reflect the presence of water vapor and temperature change in the middle-upper atmosphere, thus representing an important tool for the monitoring of climate change. The Fe Boltzmann temperature lidar, located at McMurdo and run by the University of Colorado Boulder, has continuously been operating since December 2010 at Arrival Heights near McMurdo, Antarctica. The lidar provided multiple years of PMC measurements, which allow one to effectively monitor the occurrence and the main characteristics of PMC.

The purpose of this study is to analyze seven seasons (2010-2017) of polar mesospheric clouds during the months of November, December, January and February. The research focuses on the hourly mean profiles of backscatter ratio R(z), volume backscatter coefficient beta(z), total backscatter coefficient $beta_{Total}(z)$, centroid altitude Z_C and the RMS width. In order to improve the accuracy of the study, a method of data screening has been implemented. By comparing the signal to noise ratios integrated at Rayleigh altitude (30-45 km), it was possible to notice that generally anything with SNR < 8 had to be excluded from the data sets. This screening resulted in much clearer 374 nm and 372 nm Fe layer and PMC contours, which therefore facilitated the recognition of PMC. After plotting histograms of the aforementioned hourly parameters for each season, the study compares seasonal means, seasonal variations, and diurnal variations in order to characterize the PMC properties at this important high southern latitude. The preliminary results confirm the findings by *Chu et al.* [GRL, 2011] that the mean PMC centroid altitude is ~84.6 km, in between the altitudes at the South Pole and Rothera stations. Furthermore, the seven seasons of data clearly exhibit an anti-correlation between the total backscatter coefficient and centroid altitude. Our further analysis will reveal the diurnal variations in addition to the seasonal and inter-annual variations.

Thursday, 21 September - - 17:00 - 17:30

Shuttle to hotels

Friday, 22 September - - 08:15 - 08:45

Shuttle from hotels

Friday, 22 September - Conference room - 09:00 - 10:20

Mesospheric temperatures and inversion layers

Dynamics 3-O-01

A comparison of mesospheric temperatures derived during the WADIS 2 campaign

Raimund Wörl[1], Josef Höffner[1], Boris Strelnikov[1], Franz-Josef Lübken[1], Michael J. Taylor[2], Bifford P. Williams[3]

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[3]*GATS Inc., Boulder, Colorado, United States*

The IAP Fe-lidar is in operation since summer 2014 at the ALOMAR observatory (Arctic Lidar Observatory for Middle Atmosphere Research). The period around the WADIS 2 rocket launch on 5th of February 2015 at the Andoya Space Center in Northern Norway is exemplarily used to analyse and compare results determined in the mesopause region.

Up to 24 hours continuous measurements around the rocket launch time with different instruments located at the ALOMAR observatory near the launch site are available. Vertical profiles of temperature of the ALOMAR RMR-, the IAP Fe-lidar and the ALOMAR Na lidar are compared with high resolved large-area images of the Utah State University Advanced Mesospheric Temperature Mapper (AMTM). The in-situ measurements of the WADIS 2 rocket are also compared to the remote sensing instruments.

Strong tides in lidar temperature measurements during the whole night are found. The rocket born vertical temperature profiles of both the up- and downleg are in good agreement to the lidar data and show large vertical temperature gradients which are caused by tides. The OH temperatures (AMTM) are in good agreement to the lidar measurements, too.

Dynamics 3-O-02

Modeling Mesospheric Inversion Layers: Role of entropically consistent turbulence parameterization

Almut Gassmann

Institute of Atmospheric Physics Kühlungsborn, Kühlungsborn, Germany

Sharp mesospheric inversion layers (as they are observed) could not be modeled adequately in the past. This study uncovers the reason for this failure as due to contemporary turbulence parameterization schemes for heat fluxes and proposes an alternative and more adequate method.

Numerical formulations of turbulent heat fluxes must lead to positive energy dissipation and positive internal entropy production. Current parameterization approaches only deliver positive dissipation rates for free convection, not for forced convection. This contribution explains how positive dissipation rates are achieved by a new formulation of subgrid-scale terms in the case of stable stratification. This is of importance for the numerical realization of the breakdown of gravity waves.

A turbulent atmosphere tends to an isentropic stratification, because in addition to turbulent heat diffusion, pressure work leads to expansion when air is rising and contraction when air is sinking. This pressure work remains completely subgrid-scale when the atmosphere is unstably stratified. When the atmosphere is stably stratified, this pressure work has to be done by the outer environment. Therefore, a turbulent pressure gradient term is introduced in the vertical momentum equation and the equations account for the irreversible energy conversion from resolved kinetic energy into the model's internal energy.

Numerical experiments for breaking gravity waves in the mesosphere highlight the different behavior of new and conventional approaches. The conventional approach leads to a deepening of the wave amplitudes, whereas the new approach supports wave overturning. The observed foliate structure of very sharp inversion layers is indeed simulated with the new approach for stable stratification. In contrast to the traditional setting the new scheme does not evolve into persistent non-physical wave structures on long timescales.

Dynamics 3-O-03

Dynamics of Gravity Waves Encountering a Mesosphere Inversion Layer

Ling Wang[1], David Fritts[1], Brian Laughman[1], Thomas Lund[2]

[1] *GATS, Inc., Boulder, United States*

[2] *NorthWest Research Associates, CoRA Division, Boulder, United States*

In this presentation, direct numerical simulation results of gravity waves encountering a mesosphere inversion layer (MIL) from an anelastic model will be reported. The MIL has a moderate static stability enhancement centered around 75 km and a layer of weaker static stability above. Two scenarios of representative gravity wave packets are examined here; specifically, the gravity wave packets have an initial horizontal wavelengths of 20 km and vertical wavelengths of 20km and 40 km, respectively. Both three dimensional and two dimensional (i.e., streamwise and vertical) simulations are performed. The instability dynamics for these MIL cases will be described. Implications for mixing will also be discussed. For instance, we find that instabilities occur within the MIL when the gravity wave amplitude

approaches that required for gravity wave breaking due to compression of the vertical wavelength accompanying the increasing static stability. Also, we have found that mixing is much weaker than what had been generally assumed in the past for those cases considered.

Dynamics 3-O-04

Causative Mechanisms of Tropical (10°N-15°N) Mesospheric Inversion Layers: Dynamics Vs Chemistry

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Mesospheric inversion layer (MIL) is a layer of enhanced temperature with several kilometers vertical thickness that is superimposed upon the characteristically decreasing mesospheric thermal structure. Although MILs have been known for decades through all sorts of available techniques, their study is still of significant relevance for understanding of the energy and momentum budget of mesosphere and lower thermosphere (MLT) region. The suggested causative mechanisms for the occurrence of MILs are: gravity wave (GW) breaking, planetary wave (PW) critical level interaction, GW-tidal interaction and chemical heating. A large MIL has been observed at ~79-84 km (amplitude ~50 K and thickness ~4.5 km) using Rayleigh lidar temperatures on the night of 24th January 2007 over a tropical site, Gadanki (13.5°N, 79.2°E). It is observed that a dominant GW (T~33 min, λ_z~6.4 km) propagates vertically and attains convective instability in the MIL region. The horizontal wave parameters are derived from the GW dispersion relation using rocketsonde and MF (medium frequency) radar winds over SHAR (13.7°N,80.2°E) and Tirunelveli (8.7°N,77.8°E) respectively. Further it is evident that the wave amplitude gets saturated at ~80 km and the eddy diffusion coefficient (D_{eddy}) increases drastically in the inversion region (~80-85 km). The heating/cooling rates (~10 K/hr) observed at the bottom/top levels of the MIL further elucidates the inversion layer occurred mainly due to the turbulence generated by the gravity wave breaking. However the TIMED-SABER total chemical heating by seven major exothermic reactions among H, O, O_3, OH, HO_2 plays minor role during this MIL event. On contrary, it is also evident that chemistry dominates dynamics during a few large MIL events observed in January-February 2011 over Gadanki region.

Friday, 22 September - Conference room - 10:20 - 10:30

Farewell

Friday, 22 September - - 11:15 - 12:15

Bus transfer to Rostock railway station