An Analysis of Polar Mesospheric Cloud Observations from the POAM II and POAM III Instruments in the Southern Hemisphere

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Polar mesospheric clouds (PMCs) have been observed with both the Polar Ozone and Aerosol Measurement (POAM) II and III instruments. POAM II conducted measurements during the 93/94, 94/95 and 95/96 Southern Hemisphere PMC seasons, and results from the first two seasons have been previously reported in Debrestian et al., 1997. POAM III has been in operation since 1998 yielding PMC measurements for the 98/99, 99/00 and 00/01 Southern Hemisphere PMC seasons. The two POAM instruments are in identical orbits and are very similar in design and measurement-capability, although POAM III has increased sensitivity due to a better signal-to-noise ratio. These similarities allow for the creation of a consistent long-term PMC data record by combining the two POAM datasets. A common PMC detection algorithm, which takes into account the different instrument sensitivities, has been used to analyze this dataset to determine trends in the inter-annual variability of PMC frequency. POAM PMC probabilities decreased significantly from a maximum in the first two POAM II seasons to a minimum in the 99/00 season, and increased to near 93/94 values in the 00/01 season. The POAM PMC measurements have also been analyzed using a geometrical cloud model to determine inter-annual variability in cloud thickness, height and extinction. The multi-wavelength capability of the POAM III instrument has been used to study wavelength dependence of the measured slant optical depth. The results of this analysis are compared with Mie scattering theory to derive upper and lower limits of the modal PMC particle radii.

Polar Mesospheric Clouds as Observed by the Student Nitric Oxide Explorer and the Solar Mesosphere Explorer

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The first climatology of Polar Mesospheric Clouds (PMCs) was derived from observations by the Solar Mesospheric Explorer (SME) made during 1981 through 1986. SME detected clouds as it observed the Earth's ultraviolet limb radiance. SME observations showed seasonal variations with a typical PMC season lasting from approximately 90 days beginning 21 days before summer solstice. The Student Nitric Oxide Explorer (SNOE), like SME, observes the Earth's UV limb radiance and thus also observes PMCs. The instrumentation on SNOE and SME are nearly identical making the observations comparable. SNOE was launched on February 27, 1998; thus, the combination of SNOE and SME measurements cover a span of nearly two decades. SNOE continues to operate and to date, has observed four northern and three southern PMC seasons.

The two nearly identical observational scenarios separated in time by a period of 15 to 20 years allows us to look at the long term variability of PMCs. Long term variability may be the result of either solar cycle effects or longer term global change. In this talk we show the first results of the initial comparisons between PMC climatologies derived from both SNOE and SME observations.

Joint PMSE/Heating experiments using the EISCAT VHF radar and Heating facility

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Polar mesosphere summer echoes (PMSE) are abnormally strong radar returns that occur during summer months near the mesopause at high latitudes. The first joint PMSE - ionosphere heating experiments using the EISCAT VHF radar and the Heating facility were conducted at the EISCAT site near Tromsø during the period July 9-14, 1999. They were performed during a short break due to the bad weather conditions in the MIDAS-DROPPS rocket campaign at Andoya, Norway. An analysis of radar back-scattered power showed that PMSE were indeed affected by artificial ionospheric heating. The echo power fell during heating in less than 2 seconds. The decrease of PMSE power during heating is height dependent and varies from one case to another. This variability of the heating effect on PMSE power may be related to height-dependence and case-to-case variation of the electron temperature enhancements due to ionosphere heating as well as to changing background levels of PMSE power. The results of experiments for different heating modulation frequencies and radiated powers will be also presented. The former can provide us information about a characteristic time scale of the mesopause plasma phenomena, which could be responsible for the PMSE formation. The latter allows us to estimate a "heating threshold" to affect PMSE. The possible relation of electron recombination, diffusion, and aerosol charging to the observed reduction of PMSE power during heating will be discussed. Results of the second joint PMSE/Heating experiment on June 2001 will be also presented. New opportunities to study PMSE by means of " artificial ionospheric heating" and possible coordination with rocket experiments will be discussed.

Size distributions of NLC ice particles as described from an multiple particle system

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A numerical study of the formation processes of ice particles in the high latitude summer mesopause region has been performed. In our model approach we describe a multiple particle system containing 2.000.000 smoke particles which act as potential condensation nuclei in a supersaturated cold atmosphere. These smoke particles are transported simultaneously by a Lagrangian scheme in a background atmosphere which is specified by a self--consistent data set of 3-d time dependent horizontal and vertical winds, temperature and water vapor distributions. While being transported, a simplified microphysical parameterization allows the condensation nuclei to condensate to ice, then to grow, to sedimentate, or perhaps to sublimate as a function of actual background conditions.

The entire ensemble shows statistic characteristics which can be interpreted as large scale ice cloud events in which the history and lifecycle of each individual particle can be investigated. The model results imply a strong interaction of ice particles with the background water vapor due to processes like freeze drying. Polward of 70 N the altitude of maximum brightness of NLCs is located at an almost constant height of 82.5 km. The size distributions of ice particles is closer to a Gaussian normal distribution than to the commonly assumed log-normal distribution.

Furthermore, the actual ice cloud features are highly sensitive to eddy diffusion processes. Finally, we will compare the structures of simulated ice distributions with observed properties of NLCs measured over Alomar (69 N).

Rocket probing of PMSE – results from the recent MIDAS/SOLSTICE campaign

Blix, T.

In the period 12-26 June 2001, the MIDAS/SOLSTICE campaign took place at Andoya Rocket Range (69N, 16E) in Norway. Two MIDAS payloads were launched in two different salvoes to study the dynamics of PMSE layers. The payloads were equipped with instruments that measured positive ions, electrons, charged aerosols and neutrals. Preliminary results from the campaign will be presented and compared with previous measurements. We will especially consider the small scale structure measured during the passage of PMSE layers. The results will be discussed in light of different mechanisms put forward to explain the existence of PMSE.

Mean Seasonal And Diurnal Variations Of Polar Mesosphere Summer Echoes From VHF Radar Observations At Northern And Central Europe

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Polar mesosphere summer echoes are strong radar echoes from an altitude range of about 80–90 km mainly observed in the VHF range during summer months at polar latitudes. But also at mid-latitudes such echoes have sometimes been found, they are called here MSE (mesosphere summer echoes). Although known since more than 20 years the phenomenon of PMSE and MSE is not fully understood. Therefore, during the last years PMSE observations have been carried out at Andenes in Northern Norway (69.3°N, 16.0°E) with two different VHF radars, from 1994 – 1997 with the ALOMAR SOUSY radar and from 1999-2001 with the ALWIN radar both at a frequency of 53.5 MHz. MSE have been observed at Kühlungsborn (54.1°N, 11.8°E) also at 53.5 MHz during 1998 and 2000 - 2001.

PMSE are normally detected near May 20 at first, reaching their maximum occurrence probability during June and July and gradually fade away during August. Near the end of August/beginning of September last PMSE are observed. The occurrence probability of MSE is markedly smaller. Only during the months June and July MSE occur during limited periods ranging from some minutes until some hours.

The diurnal variation of PMSE is mainly characterized by a maximum near noon and a marked minimum in the late afternoon, whereas the maximum near midnight and the minimum in the morning hours are not so pronounced. MSE are normally observed only during daytime with a maximum occurrence probability near noon.

The influence of temperature as well as of ionization in the mesopause region on PMSE and MSE is investigated to explain at least some parts of their seasonal and diurnal variations.

SAGE II Observations of Polar Mesospheric Clouds

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The Stratospheric Aerosol and Gas Experiment (SAGE II) satellite instrument measures Polar Mesospheric Clouds (PMC) utilizing the solar occultation method. Transmission through the PMCs as a function of tangent height is measured along the Earth's atmospheric limb during each sunrise and sunset as observed by the satellite. These measurements are made at seven wavelengths from 385 to 1020 nm, although only the thickest clouds are detectable with the longer wavelengths. The SAGE II instrument was developed to measure ozone, aerosols, nitrogen dioxide, and water vapor in the stratosphere and upper troposphere, and has been operational since shortly after its launch in 1984. It was only with the Version 6.0 data, (released in June 2000) that the transmission profiles were processed to altitudes above 90 km with sufficient quality to detect PMCs.

Because of its inclined orbit, the latitude of the SAGE II measurements changes gradually taking about 40 days to cover a full range from one poleward extreme to the other. This means that the SAGE II measurements only reach sufficiently high latitudes for a few periods of one to two weeks each during the three-month PMC season, centered shortly after summer solstice. The timing and exact latitude coverage vary slightly from one year to the next. Because of the strong dependence of the expected PMC frequency of occurrence on latitude and date, for trend studies it is necessary to correct the SAGE II PMC observation for these year-to-year changes in coverage. This is done by normalizing the SAGE data to the expected frequency of occurrence as a function of date and latitude based on the SME climatology, (1981-1986). We will present comparisons with other satellite observations such as POAM, and discuss the variations in the PMC frequency and optical thickness over the 16-year period.

Ultraviolet and Visible Imaging and Spectrographic Imaging of Polar Mesospheric Clouds

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The Ultraviolet and Visible Imaging and Spectrographic Imaging (UVISI) instrument on the Midcourse Space Experiment (MSX) satellite affords an interesting and unique view of polar mesospheric clouds. From an altitude of 900 km, the polar-orbiting satellite pointed UVISI's suite of imagers and spectrographs at the limb and recorded over 20,000 frames of PMC observations (per sensor) over both the northern and southern poles during the 1997-1999 summer seasons. Exploiting the stability of the platform (jitter < 10 µrad), small pixel size of its imagers (~400m), and wide spectral range of its spectrographic imagers (110-600 nm at sub-nmresolution), UVISI measured PMC altitudes as functions of latitude, constructed transpolar PMC maps, and determined the first complete PMC spectrum from the far ultraviolet to the visible. Use of the middle ultraviolet wavelengths, which do not penetrate the obsfucating atmosphere, permit separation of "near-field" and "far-field" effects, so that the narrow FOV imager (235-263 nm) could make unprecedented maps of PMC structures on a transpolar scale. Imager observations confirmed that PMC's have essentially the same altitudes in the south and north (82.7±1.3 km) and that the cloud altitudes remain essentially constant with latitude. A Lomb periodogram analysis of the sub-horizon imagery reveals the transpolar structure of PMCs at ~3 km spatial resolution, indicating the existence of PMC features with wavelengths ranging from ~100 km to ~3000 km, with most of the wave "power" concentrated between 500 and 1000 km. In spite of observational scattering angles differing by ~60°, the northern and southern PMC intensities are essentially the same (~12 MR in the mid-UV band). In both hemispheres, the PMC intensities increased systematically with latitude, although the southern clouds seemed to increase at a faster rate. Spectrographic investigations indicate that the clouds have a solar-like spectrum, complete with Fraunhofer absorption features, from wavelengths of 200 nm to 600 nm. For wavelengths shorter than 200 nm, the PMC intensities decrease to essentially the atmospheric background level. For wavelengths longer than ~315 nm, the PMC spectra become confused with ground albedo effects. Between 200 and 315 nm, the PMC spectra resemble power laws in wavelength with exponents of -1.0 to -1.5, which differ from the -4.0 expected from pure Rayleigh scattering. Best fits of the spectra to a log-normal distribution of Mie scatterers indicate a mode of ~85 nm and a dispersion of ~1.25 nm, suggesting a somewhat larger particle size but narrower distribution than results of scattering angle studies. The distribution of the particles is investigated as functions of time from solstice and latitude.

Maps of Polar Mesospheric Clouds

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Middle-ultraviolet images, obtained on the limb below the ozone horizon, have been mapped in latitude and longitude to reveal the transpolar PMC field in two spatial dimensions. PMC maps have been constructed for the southern PMC seasons of 1997-1998 and the northern season of 1999. The clouds closely resemble in many ways tropospheric clouds and evidence structures reminiscent of weather fronts, cyclonic whirls, occasional waves, and isolated "blobs." These features appear on scales ranging from several hundred kilometers down to the tens of kilometers. In particular, PMC patterns often appear approximately aligned along constant latitudes. This zonal pattern may indicate large-scale mesospheric winds or D-region convection.

A Study of Aspect Sensitivity Within Polar Mesosphere Summer Echoes Using Coherent Radar Imaging

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The Esrange VHF radar (ESRAD), located in northern Sweden (67.88N, 21.10E), is regularly used for investigations of polar mesosphere summer echoes (PMSE). During July/August of 1998, a specially designed experiment was initiated, with the central motivation being to study the dynamic evolution of PMSE with high temporal and spatial resolutions. To this end, coherent radar imaging (CRI) was employed for the data analysis, and for this particular application, the Capon method was used. One of the products of such a CRI analysis is an estimate of the angular brightness distribution within the radar's probing volume. It can be shown that the brightness distribution is directly related to the radar reflectivity. Consequently, these data can be used in turn to investigate the aspect sensitivity of PMSE. In addition to the CRI analysis, the full correlation analysis (FCA) has been used to derive estimates of prevailing three-dimensional wind associated with the PMSE observations. It has been shown that regions within the PMSE having enhanced aspect sensitivity have corresponding high signal-to-noise ratio (SNR). Regions of enhanced aspect sensitivity were additionally shown to correlate with the downward going phase of wave oscillations embedded in the PMSE. The correlation was most evident when the vertical shear in the horizontal wind was not too strong.

Lidar Studies of The Diurnal, Seasonal and Interannual Variations of Polar Mesospheric Clouds at the South Pole and North Pole

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Polar mesospheric clouds were observed above the North Pole and Coast of Alaska in the summer of 1999 and at the South Pole in two austral summer seasons from 1999 to 2001 by an airborne/ground-based Fe Boltzmann Temperature Lidar. Several hundreds hours data of PMCs collected at the South Pole provide new insights into the diurnal, seasonal and interannual variations of PMCs, and possible hemispherical differences.

A striking point of our results is the obvious differences of PMC altitudes in two hemispheres: the PMCs at South Pole are about 2-4 km higher than typically observed elsewhere. Strong semidiurnal and diurnal oscillations of PMC altitude and backscatter parameters are also observed at the South Pole. We also discuss the seasonal trends of PMC altitude and occurrence probability in both seasons: PMC height peaks around 15 days after summer solstice, then gradually decreases by about 64 m/day as the upwelling weakens over the pole; PMC occurrence probability reaches maximum around 35 days after summer solstice. Data show that during the 2000-2001 summer season the PMC altitudes are lower by about 1 km while the PMC backscatter coefficients are about 60% larger than during the 1999-2000 season.

Radar and lidar studies of the Arctic summer mesopause region in Alaska

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Radar and lidar observations of the Arctic mesopause region were conducted in Fairbanks, Alaska during the summer of 2001. The radar observations were made at the High Power Auroral Stimulation (HIPAS) Observatory. HIPAS, operating at 4.53 MHz, probed the mesosphere above Fairbanks from 80 to 90 km with 2 km height resolution and was sensitive to polar mesospheric summer echoes (PMSE) that occur near noctilucent cloud (NLC) formations. Two lidars systems were used to make observations at Poker Flat Research Range (PFRR). A Rayleigh lidar, operating at 532 nm, provided measurements of the atmospheric density and aerosols in the stratosphere and mesosphere. A resonance lidar, operating at 589 nm, provided measurements of the mesospheric sodium layer. PMSE were seen for at least 50% of the observation period. The purpose of the experiment was to create a seasonal database of these phenomena. We describe the scientific program, discuss the geophysical conditions during the observations, and present some of the preliminary results.

Evidence for a Two-Component Distribution of Positively Charged Subvisible Particles in PMSE/NLC Regions

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As part of the DROPPS (Distribution and Role of Particles in the Polar Summer Mesosphere) coordinated rocket/ground-based program conducted at the Andoya Rocket Range, Norway, two essentially identical payloads launched during observed PMSE/NLC events carried probes to measure associated electron/ion/charged particle behavior. We report on Gerdien condenser measurements of positively charged subvisible particles obtained by the first DROPPS payload (flight 21.123), launched at 2336:30 UT on July 5, 1999, during strong PMSE and weak NLC conditions. The Gerdien condenser was mounted on the front payload deck so that it operated under ram flow conditions. An attitude control system was used to align the instrument's central axis to the velocity vector during passage through the NLC/PMSE layered regions. The collection voltage, swept between -40 V and +5 V, was sufficient to ensure collection of low-mobility (subvisible), positively charged particles in addition to more mobile, gas-phase ion species. For these flights, design enhancements for the Gerdien condenser and refinements to our data analysis were realized by computer modeling of the probe's electric field and flow geometries.

Based on our mobility measurements and their associated concentrations, we are able to identify two very different groups of positively charged species. Calculated reduced mobilities using the model proposed by H. Tammet [J. Geophys. Res.,103, 13,933-13,937, 1998] indicate that both mobility groups are suggestive of positively charged particles. Specifically, we observe positively charged particles of approximate radii 1-2 nm and 6-10 nm in the PMSE layered region. In the mesosphere, the concentration of relatively larger particles increases with altitude (and colder temperatures), becoming comparable to the number density of smaller particles in the PMSE region. Interestingly, there is no noticeable presence of gas-phase positive ion species. Also,our other probe data indicate that the PMSE region is depleted of electrons and associated with this, we observe negatively charged aerosols. We consider the role of charged aerosols in mesospheric layering and related PMSE/NLC observations.

22 Years of PMC Observations from SBUV and SBUV/2 Instruments

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Satellite observations of polar mesospheric clouds (PMCs) are extremely useful, because they provide wide geographic coverage and frequent sampling often unavailable to a single ground-based observer. Nadir-viewing SBUV-type measurements pose a challenge for PMC detection because of ther elatively bright terrestrial background in the mid-ultraviolet and the competing effects of geophysical ozone variability. We have analyzed 22+ years of continuous measurements from SBUV-type instruments, beginning with Nimbus-7 SBUV in November 1978 and continuing through the SBUV/2 instruments on the NOAA-9, NOAA-11, NOAA-14, and operational NOAA-16 spacecraft. We use a revised version of the algorithm developed by Thomas et al. [1991] to extract PMC events from SBUV and SBUV/2 data. The nearly identical design of these instruments allows direct comparison of overlapping data sets for seasonal and latitudinal variations. In addition, we can evaluate the possible influence of solar UV activity variations during the last 2 complete solar cycles. Additional SBUV/2 instruments are scheduled to fly through 2010, providing the opportunity to develop a PMC climatology covering more than 3 decades.

Nocilucent Clouds Over Canada on 18-19 July, 1990: A Mountain Wave-Driven Event?

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On 18–19 July 1990, an extensive display of noctilucent clouds (NLCs), covering an estimated area of 2.7 million square kilometers, was reported by a coordinated network of ground-based observers in western Canada (Zalcik and Lohvinenko, Bull. Am. Meteor. Soc., 72, 1001, 1991). Despite its brightness and large areal extent, this extended deck of NLCs was observed at most sites only during the evening twilight: next morning the NLCs were gone at all but a few sites on the west coast. Zalcick and Lohvinenko (1990) speculated that upper mesospheric heating from concomitant auroral activity may have led to the rapid dissipation of the NLCs.

Here, we use reanalysis winds and temperatures from the National Centers for Environmental Prediction (NCEP), together with the Naval Research Laboratory Mountain Wave Forecast Model (MWFM), to ``hindcast'' mountain wave activity during this period. We show that unusual tropospheric weather systems over Canada and Alaska created a well-defined westward wind channel from the ground up to the mesopause, which allowed mountain waves to propagate into mesospheric regions over Canada. The channel was transient and peaked over Canada and Alaska around $\sim$17-18~July, 1990, which correlates well with the timing of the NLC event given a typical propagation time of $\sim$1~day for typical mountain waves from the ground to $\sim$82~km. Hindcast upper-level mountain wave activity correlates reasonably well with the estimated extent and duration of the NLC event. Thus, we speculate that transient mountain wave-induced cooling of this region of the mesopause, either directly via mesoscale temperature fluctuations or indirectly via mean upwelling induced by wave breaking, may have played a role in triggering this NLC display. Since this wind channel moves rapidly westward and eliminates mountain waves from the Canadian mesosphere a day or so later, it also explains the short duration of the event.

If valid, this finding is noteworthy on several levels. First, mountain waves are generally assumed to be removed from the middle atmosphere by critical levels during summer, and thus to have no influence on the summer mesosphere. Conversely, the analysis here suggests a direct role for mountain waves in this widely-observed NLC event. Secondly, the hindcast reveals that rapidly-evolving low-level tropospheric weather systems were the key ingredient that allowed this intermittent burst of mountain wave activity into the mesosphere. This implies an interesting "teleconnection" here between low-level tropospheric weather systems and the formation/sublimation of these particular NLCs in the mesosphere.

Investigation of the Polar Mesosphere with a UV Limb Sounder: The SHIMMER Instrument on AIM

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Currently, the Aeronomy of Ice in the Mesosphere (AIM) Mission is part of a NASA Small Explorer concept study. The suite of instruments on the AIM mission includes the high resolution UV spectrometer SHIMMER Spatial Heterodyne Imager for Mesospheric Radicals). The objective of SHIMMER is to provide data about polar mesospheric (PMC) cloud occurrence, PMC brightness, hydroxyl and water vapor concentrations in the PMC region and synoptic temperature. SHIMMER will use a monolithic spatial heterodyne interferometer, a new optical technique allowing us to address the science objective and fit within the constraints imposed by a small satellite mission. We present results of the characterization and first laboratory measurements of the world's first monolithic spatial heterodyne interferometer and an overview of the AIM-SHIMMER instrument.

Equilibrium Temperature of Mesospheric Aerosols

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The growth rates of PMC and PMSE particles, their charging rates and the ultimate sizes they reach all depend upon the temperature of the particles themselves. The radiative heating of aerosols in the rarified atmosphere near the mesopause can overcome the collisional cooling of the ambient gas, and drive their temperatures above the point where they will begin to sublimate. Here we extend previous work by using a collisional heat transfer model for spherical particles in a free molecular flow regime that allows us to incorporate a wind field and particle fall velocity appropriate for the high-latitude summer mesosphere. Updated optical properties of ice and their temperature dependence have been used, as have more realistic radiance data and atmospheric conditions. The results of these model calculations will be presented, and the resulting infrared signature of the aerosols will be compared to recent rocket measurements.

Investigations of PMCs with WINDII and OSIRIS Observations

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Findings from our investigations of polar mesospheric clouds (PMCs) from WINDII on UARS are reviewed. Extensive observations were conducted in January,1994,1995,1996 and 1997 over the southern hemisphere and in July,1992,1993,1994 and 1995 over the northern hemisphere. The WINDII instrument on the UARS satellite has an imaging camera with several filter channels after the interferometer. The limb images cover an area 150 km wide and 30 km high. In the background filter channel at 553 nm, images of scattered sunlight from the earth's atmosphere can be measured in the daytime from 75 km to 95 km. The presence of noctilucent clouds is indicated in most January profiles at southern latitudes above 55S; the occurrence of PMCs was mapped for each day from early January until early February. PMCs were always observed in the SH in January and were apparently brighter than in the northern hemisphere in July. Backscatter ratio versus altitude plots of the clouds indicate that they are very narrow, often with a vertical structure less than 2 km thick; the peak backscatter ratios were often over 10 at 83 km. It was found that lower clouds are brighter. A statistical analysis was conducted for each day in January. The histogram of the number of occurrences versus backscatter ratio often indicates two peaks, perhaps indicating the presence of two different sizes of ice particles. The diurnal variation of brightness has been investigated using data to cover the local time from 07:00 until 21:00; this analysis indicated only a modest diurnal variation of brightness. Estimates of the particle size were obtained from the 2 fields of view of WINDII; a mean radius of about 25 microns was usual. The intercomparison of WINDII with other satellites by cumulative distributions will be summarized. The measurement of PMCs with OSIRIS observations will be discussed.

Turbulence Dynamics and Implications for Transport and Layering in the MLT

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This talk will review recent studies of turbulence generation due to shear instability and gravity wave breaking and its impacts at MLT altitudes. Shear instability accompanies low-frequency gravity waves and leads to strong turbulence in confined layers. These layers have sharp edges and result in strong thermal and velocity gradients that may persist for long times and have significant radar and in situ signatures. Wave breaking accompanying higher-frequency waves leads to turbulence of a very different character. Though the transition dynamics are much the same, the effects are very different because this turbulence source follows the phase of the wave, thus leading to significant transport but a lack of sharp edge regions. Time permitting, the implications of such turbulence for the formation of strong thermal and velocity gradients in the MLT will be explored.

Arctic Mesopause Dynamics: Wind Measurement with the ALOMAR Sodium Lidar

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A sodium wind and temperature lidar was installed at the Arctic Lidar Observatory for Middle Atmosphere Research (ALOMAR), Norway, during 2000. The lidar system is collocated with other mesospheric measurements -- a Rayleigh-Mie-Raman lidar, VHF and MF radars, and airglow instrumentation. In March 2001 a CSU/CoRA campaign succeeded in obtaining over 50 hours of sodium lidar measurements, including four nights of zonal wind measurements of more than 6 hours duration. We will present results of the analysis of this campaign data and prospects of future ALOMAR measurements.

Dropps: A Study Of The Polar Summer Mesosphere With Rocket, Radar And Lidar

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DROPPS (The Distribution and Role of Particles in the Polar Summer Mesosphere) was a highly coordinated international study conducted in July, 1999. It involved two sequences of rockets launched from the Norwegian rocket range in Andøya, Norway. These studie s were designed to investigate the properties of the polar summer mesosphere, particularly relating to polar mesospheric summer echoes (PMSE) and their possible relationship to particles (aerosol and dust layers) and to noctilucent clouds (NLC). Each of the two sequences included a DROPPS NASA-Black Brant payload, consisting of an array of instruments to measure the electrodynamic and optical structure of the mesosphere and lower thermosphere. These were provided by participants from several US and European scientific laboratories. The DROPPS payloads were each accompanied by a sequence of several European payloads (MIDAS, Mini-MIDAS, and Mini-DUSTY) designed to study electrodynamic structure of the same region, and by several meteorological rockets to provide wind and temperature data in the critical region of study. ALOMAR Lidars, and MF and MST Radars (all located adjacent to the Andøya launch site) were used to continuously monitor the mesosphere for NLCs and PMSEs, respectively. EISCAT VHF radar (Tromsø, Norway) provided similar information about PMSEs, approximately 130 km downstream from Andøya. Sequence 1 was launched during the night of 5-6 July into a strong PMSE display with a weak NLC at the base of the PMSE. Sequence 2 was launched on the early morning of 14 July into a strong NLC, but surprisingly with no PMSE evident. Differences in the observed measurements during each event appear to help explain how this might occur. This overview reviews the program and discusses the current findings with their possible implications.

Observations of the Summer High Latitude Mesosphere by CRISTA

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During its second mission in August 1997 the Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere (CRISTA) experiment observed the northern high latitude mesosphere and lower thermosphere regime up to about 710N in limb scan mode. The measurements were taken around local noon and included the infrared emissions of CO2 (4.35m and 155m bands), CO (4.75m band), O3 (9.65m band), and a single water vapor line near 16.95m. In addition to these molecular emissions broadband signatures from PMCs were detected mainly near 115m but are also found at far infrared wavelengths. Due to the low temperatures in the vicinity of the PMCs the signals are weak and some spectral co-adding is required. Temperatures are retrieved from the 155m CO2 band up into the lower thermosphere using a non-LTE model in combination with a line-by-line radiative transfer code. These temperatures yield the first global distribution derived from the 155m band in this altitude regime and reveal the very cold mesopause at high northern latitudes in summer. The same code was used to derive CO2 and O3 densities up to 130km and 95 km, respectively. The paper gives an overview about the CRISTA temperature and trace gase results in conjunction with the PMC recordings.

The Coupling of Ion Chemistry and Particle Charging in the Summer Mesosphere

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In the summer mesosphere, ion chemistry and the presence of neutral and charged particles are closely inter-related. While the capture of electrons and ions by particles strongly influences the ion-chemical reaction scheme, the detailed ion composition in turn determines the rates of particle charging. We present a model that for the first time couples detailed ion chemistry and charged particles. Case studies illustrate this coupling for various mesospheric / ionospheric conditions. We focus on the cold summer mesosphere where interactions between neutral and charged processes are intimately involved in phenomena like NLC and PMSE. It is shown that the presence of ice particles generally enhances the growth of cluster ions (proton hydrates). As these cluster ions are potential nuclei for the formation of new ice particles, positive feedback can cause local enhancements of both particle and charge density. Implications for the formation of PMSE are discussed.

Electric Field measurements in Noctilucent Clouds

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Two rockets were flown through NLC during the DROPPS experiment from Andoya, Norway in July 1999. Each was equipped with three axis, double-double Langmuir, high impedance probes (12 probes each flight), and produced unprecedented resolution of the electric potential distribution around the rockets in and near a weak NLC (DROPPS1) and a very strong NLC (DROPPS2). Detailed analysis of the vehicle interaction during the weak NLC encounter allows an interpretative model for understanding the strong NLC encounter where apparent fields reached a few volts per meter. This paper will present the measurements and a discussion of our work on verifying the field measurements.

Observations During the EISCAT PMSE Campaign, June 2001

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During June 2001, a joint UK-Norwegian campaign was run using the EISCAT radar to characterise Polar Mesosphere Summer Echoes (PMSE) in the mid-summer mesosphere. A series of radar observations were made between 12 June and 25 June, coordinated with the MIDAS/SOLSTICE rocket campaign at the nearby Andoya rocket range. The EISCAT VHF radar (224MHz) was operated each evening for several hours around local midnight to investigate variations in PMSE strength and structure. A recently-developed radar program was used to provide information about the spectral characteristics of both the PMSE and the background D-region. In addition, the EISCAT dynasonde (digital ionosonde) was operated in a mode which provides mesospheric winds and scattered power at 3 MHz. As well as persistent PMSE, the campaign period included a 10 MeV Solar Proton Event on 15-16 June 2001 during which the D-region ionisation was enhanced and IS spectra were detectable down to altitudes as low as 65km. Preliminary results from the EISCAT radars will be presented.

Seasonal Climatology of PMSE from Kiruna

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The ESRAD 52 MHz MST radar has been making continuous observations of the mesosphere, stratosphere and troposphere since August 1996. During summer PMSE have been detected each year between late May and mid-August. During August each year since 1998, noctilucent clouds over the radar site have also been monitored by automatic cameras placed about 400 km south of the radar site. The PMSE time sereis (5 summer seasons) is still too short to detect any long term trend. However, it provides an excellent database for statistical study of seasonal and other shorter-term variations, such as the strong 5-day modulation which is often observed.. In this presentation statistical and case studies of PMSE and NLC are combined with information on middle-atmosphere winds and planetary waves from global meteorological analysis (UKMO). This allows us to examine whether seasonal and multi-day variations in PMSE and NLC can be confidently related directly to dynamical influences propagating up from below.

Polar Mesosphere Winter Echoes—PMWE

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Polar mesosphere Summer Echoes are well known, strong radar echoes from narrow reflecting layers located between 75 and 95 km height seen even by relatively low-power VHF radars during summer at high latitudes. During winter such radars normally see no echoes from the mesosphere. However, during solar proton events narrow layers of enhanced reflectivity can be seen – these we name Polar Mesosphere Winter Echoes – PMWE. PMWE have been observed on several occasions during 2000 and 2001 by the ESRAD 52 MHz radar located in Kiruna, Sweden. All appeared during solar proton events or during periods of strong high-energy electron precipitation. The echoes were confined to thin layers (from less than 300 m to about 2 km in thickness, most often filling only 1 range-gate of 300 m or 600 m) with between 1 and 3 layers seen on each occasion (a few km apart). They appeared at heights from 50 – 80 km and were seen during every major solar proton event between November 2000 and April 2001.

A strong solar proton event in September 2000 did not lead to any visible layers and the very strong solar proton event in July 2001 did not lead to any enhanced echoes below 75 km (only slightly enhanced PMSE between 75 and 80 km). PMWE above 70 km altitude occur at all times of the day, PMWE below 70 km appear only during daylight. Comparison with modelled ion and electron densities in the relevant height intervals indicates a strong dependence on the availability of free electrons. Although the echo power in PMWE is 30 dB less than in PMSE, the narrowness of the layers and their often descending motion is similar to PMSE. Wintertime radar echoes were recodred by the high-power Poker Flat MST radar more than 20 years ago. The limited height resolution of the Poker Flat radar (2.2 km) did not allow identification of these very narrow layers. Only much broader layers were identified and an explanation in terms of breaking gravity waves was proposed. The new observatio! ns of the extreme narrowness of the layers and their sensitivity to free electrons suggests rather a possible explanation close to that of PMSE – i.e., charging of pre-existing aerosol layers. The restriction of PMWE to the winter months suggests that the proposed aerosol layers are present below 80 km only in winter.

Mesospheric Turbulence Parameters from Observations of Persistent Leonid Meteor Trains

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Persistent meteor trains have fascinated observers for many years. The heightened Leonid activity of the last few years has fueled considerable research efforts, much of it dealing with this interesting phenomenon. Results of the comprehensive study of persistent trains conducted at the Starfire Optical Range (SOR) on Kirtland Air Force Base, New Mexico, during the 1998-1999 Leonid showers are reported here. For the first time, the time-evolution of persistent trains is used in conjunction with lidar observations of winds, temperatures, and Na density to determine the eddy diffusion coefficient and other turbulence parameters at mesopheric heights.

The Effect of a Solar Proton Event on Polar Mesosphere Summer Echoes Observed on Svalbard

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Besides neutral atmosphere processes the mesosphere is also influenced by magnetospheric processes, such as particle precipitation and electric fields. Phenomen a in the mesopause region are related to the interaction of neutral dynamics, electrodynamics and particle physics. Coherent scatter from the middle atmosphere resulting from these processes is measured with the VHF radar technique. Particular examples of these processes are Polar Mesosphere Summer Echoes (PMSE).

VHF radar observations of PMSE have been made with the SOUSY Svalbard Radar at 53.5 MHz (78 degrees N, 16 degrees E) during the major coronal mass ejection (CME) event on 14 July 2000, called the Bastille-II event. Partially, the EISCAT Svalbard Radar (500 MHz) was operated as well. This event occurred in a period of generally enhanced ionospheric disturbance.

Resulting from this very strong CME on 14 July 2000 a short enhancement of the electromagnetic noise level occurred. This was followed by a strong solar proton event (SPE) showing up as a continuous decrease in the cosmic noise level, which lasted for more than 50 hours. The enhancement of electron density in the D-region, which causes this absorption, is primarily due to the ionizing effects of high-energy solar protons down to even the low altitudes of the upper stratosphere.

In this paper we will discuss the variation of PMSE during the strong geomagnetic/ ionospheric disturbance around the CME Bastille-II. We note two phenomena: (1) A general increase of PMSE reflectivity over many days below 85 km, which exceeds levels of earlier years and of times outside this period. (2) A significant reduction of the upper height of the PMSE layer for a shorter period of about two days following the CME. We will concentrate on the discussion of (2). PMSE occur when the electron diffusion is reduced in the presence of ice particles and aerosols embedded in the ionospheric plasma. Thus, the temperature and ionization density as well are strongly controlling the PMSE. We estimate the Joule heating rate due to increase in ionization and the electric field, which we obtain from plasma density and velocity measurements done with the EISCAT Svalbard Radar. This heating may increase the mesopause temperature by some Kelvin through local heating or heat conduction, which can lead to a reduction of ice particles. This in turn reduces the scatter cross section of PMSE. We also estimate the increase of the electron diffusion when the electron density exceeds certain limits. This results in a reduction of the scatter cross section, too. Both these effects reduce the upper height of PMSE occurrence, which we observed.

We conclude that it is essential for the investigations of the aeronomy of the polar mesosphere, and in particular the Polar Mesosphere Summer Echoes, to perform simultaneous common volume observations with the SOUSY Svalbard Radar and the EISCAT Svalbard Radar, where the latter observes incoherent scatter and coherent PMSE scatter as well.

Rocket Observations of Low Latitude Mesospheric Layers

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Electron densities and fluctuations at the four 1994 MALTED flights launched at Alcantara, Brazil show a variety of features in the D region that could be related to mesospheric layers. The data were obtained by Langmuir electron probes. The observed structures include steep electron density gradients, layers with fluctuations, and large spikes of unknown origin, mostly between 80-85 km. The observations will be discussed in the context of mesospheric radar echoes and previous rocket observations.

The First Detection of Atmospheric Structures with the IR Imager on the Odin Satellite

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The Odin spacecraft was launched on February 20, 2001, from the Svobodny Cosmodrome in eastern Siberia. The satellite, which carries both a sub-millimeter radiometer and an optical spectrograph-infrared imager system (OSIRIS), is in a sun- synchronous orbit (ascending node 1800 hours) at an altitude of 620 km. On May 14 the attitude control system put the OSIRIS instrument into a limb scanning mode for the first time. OSIRIS recorded signals from both the day and night time atmosphere that can be used to infer and derive structures in the atmosphere. The IR Imager measurements have been used with a tomographic inversion procedure to follow the motion, and structure, of the airglow layers between 40 and 100 km. This paper presents some of the early results from these observations and clearly demonstrates that limb observations can clearly identify both horizontal and vertical structure in the layers.

First Results From the ROMA Project at Longyearbyen, Svalard, in Summer 2001

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The thermal structure in the vicinity of the summer mesopause at very high latitudes (>70degrees) is basically unexplored. Model studies and observations of polar mesosphere clouds (PMC) and polar mesosphere summer echoes (PMSE) indicate that the temperatures around the mesopause could be even smaller compared to those at high latitudes (<70degrees), but no reliable measurements of the temperatures exist up to now. In summer 2001 the field campaign ROMA (Rocket studies of the middle atmosphere) will be conducted at Longyearbyen (Svalbard, 78N) with a combination of in-situ and round based measurements. A total of 25 meteorological rockets (falling spheres) will be launched to measure temperature and horizontal wind profiles from approximately 95 to 35 km. Furthermore, a newly developed potassium lidar with daylight capability will continuously measure (i.e., whenever weather conditions permit) temperatures in the potassium layer (approximately from 85 to 110 km) and will also be used to detect noctilucent clouds (NLC). The SOUSY Svalbard Radar will observe PMSE and measure winds within the PMSE layer. In addition the EISCAT Svalbard Radar will be used at some times for PMSE studies and temperature measurements between 90 and 110 km. First results of these measurements will be presented in this paper. From this unique set of measurements we hope to get a better understanding of the thermal structure of the upper atmosphere at very high latitudes and its relation to layered phenomena, such as NLC and PMSE.

Global Images of Polar Mesospheric Clouds from the SNOE Spacecraft

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Polar Mesospheric Clouds (PMC) have been observed from several spacecraft over the last three decades. These experiments have shown the seasonal behavior of PMCs and have provided some morphological information. The Student Nitric Oxide Explorer (SNOE) has been observing PMCs since 1998 and has successfully measured six PMC seasons. SNOE is a spinning satellite in a sun-synchronous near-polar orbit at 10:30 am/pm local time. SNOE has a significant advantage over its predecessors in that it is able to observe PMCs globally each day. In the summer seasons, the Ultraviolet Spectrometer (UVS) limb measurements include detections of PMCs around 83 km. Because SNOE orbits the earth 15 times a day, it obtains global coverage of the mesosphere. By combining the 15 orbits, we can produce daily global images of PMC observation frequency and scattering ratio.

The SNOE measurements show that PMCs start to form at high latitudes (75 degrees and higher) in the beginning of the PMC season, three weeks before summer solstice. By the middle of the season, PMCs form globally down to 50 degrees in latitude and then recede back to higher latitudes in the latter part of the season. The daily images, shown in a movie format, show the day-to-day variability in latitude and longitude of the PMC occurrences. The images suggest the influence of dynamics on the creation and destruction of PMCs.

Observations of Charged Particles in NLC/PMSE Regions during the DROPPS Coordinated Rocket/Ground-based Program

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The NASA-sponsored DROPPS (Distribution and Role of Particles in the Polar Summer Mesosphere) Program, conducted at the Andoya Rocket Range, Norway, was our most recent opportunity to measure the electrical environment and related aerosol properties during observed PMSE/NLC events. The first DROPPS payload (flight 21.123), launched at 2336:30 UT on July 5, 1999, was flown during strong PMSE and weak NLC conditions. The subsequent DROPPS flight (21.124), involving an essentially identical payload, was launched at 0328:45 UT on July 14, 1999, during strong overhead NLC conditions and no evidence of PMSEs. Local magnetometers indicated weakly disturbed conditions for the first launch, while the second one occurred during a quiet geomagnetic period.

Our participation involved instrumenting the two DROPPS payloads with probes to measure the ion, electron, and charged aerosol properties associated with PMSE/NLC-layered regions. Specifically, a Gerdien condenser, a DC Langmuir hemispheric tip probe, and two fixed-bias blunt probes were included with each payload. The Gerdien condenser, mounted on the front deck to operate under ram flow conditions, measured the region's polar electrical conductivities and positive ion mobilities and concentrations, including smaller charged aerosols. The two blunt probes, positioned beside the Gerdien condenser, operated with different collection voltages (+2.5 V and -2.5 V) to facilitate the discrimination of the current component associated with impacting charged aerosols/dust from the more mobile ion species. A sun shield and gridded screen at the aperture of each blunt probe established a confined local electric field geometry to reduce undesirable fringing that could interfere with other instruments. Finally, the hemispheric tip probe flown at the aft (rear) end of the ayload was biased at +5 V to measure relative electron density and associated large- and small-scale vertical structures.

For both flights, electron density bite-outs of about two orders of magnitude were measured in PMSE/NLC regions. Coincidentally, the blunt probes indicated the presence of impacting negatively charged aerosols in the region of strong PMSEs (83-86 km) during the first DROPPS flight (21.123). Very small mobility values measured by the Gerdien condenser are suggestive of positively charged subvisible particles that appear to be more prevalent at PMSE/NLC altitudes. An overview of these measurement results will be presented with the focus on understanding their relation to aerosol properties and behavior.

Laboratory Studies of Atomic Oxygen Uptake on Ice

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This paper will describe experimental and theoretical work on an important aspect of noctilucent cloud chemistry: the role of ice particles in removing atomic oxygen by surface-catalysed recombination. Rocket-borne measurements, principally by Witt's group, have shown that atomic O is severely depleted by 1 - 2 orders of magnitude in the vicinity of an NLC.

We have recently constructed a fast flow reactor, with detection of atomic O by resonance fluorescence at 130 nm, to study the recombination of atomic O on an ice surface between 100 and 250 K. The results show that the uptake coefficient, g, increases from about 0.001 at 180 K, to 0.2 at 100 K i.e. a two order of magnitude increase! We will demonstrate using a 1D atmospheric model that this result, combined with the typical volumetric surface area of an NLC (derived from the 3-colour lidar measurements at ALOMAR), easily explains the observed atomic O “bite-outs”.

The laboratory experiments were then modified to utilise a novel reverse chromatographic technique: pulses of O atoms were injected into the flow tube, and the pulse shape monitored by time-resolved photon counting. Analysis of the pulse shape provides information on the residence time of O atoms on the ice surface and the binding energy (ca. 30 kJ/mol). We then employ advanced quantum theory calculations of several ice monolayers to show that the O atoms bind to single dangling hydrogen atoms at the surface.

Two ramifications of O atom depletion are then considered. First is the effect on the plasma around the NLC particles. Reaction with atomic O is the major route for electron detachment from the negative ions in the upper mesosphere. Hence, when ice-catalysed depletion of O occurs, the free electron density will be significantly reduced by the formation of negative ions, as well as electron attachment to ice particles. The second effect is the modification to the ice surface itself by the considerable energy released by O recombination. The laboratory evidence is that this causes significant annealing of the reactive sites of the surface (at temperatures above 150 K, g is reduced irreversibly by at least a factor of 10 after prolonged exposure to O). In small particles there may also be significant evaporation of water molecules, effectively slowing down the rate of growth of the particles.

Polar Mesospheric Cloud Observations from Three Satellite Experiments: Establishing Decadal Trends

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POAM II (Polar Ozone & Aerosol Monitor) provided the first detection of Polar Mesospheric Clouds (PMC) using the transmission of solar radiation in the mid 1990s. This was surprising because POAM II is somewhat less sensitive to these weak scattering signatures than other satellite experiments and it only made observations at the boundaries of the accepted PMC distribution, in space and time. The POAM II PMC observations have been confirmed using the WIND Imaging Interferometer (WINDII) experiment on the Upper Atmospheric Research Satellite (UARS). We have also compared both of these recent data sets with the extensive PMC observations made by the Solar Mesospheric Explorer (SME) satellite in the early 1980s - a solar cycle earlier. These comparisons have been limited to the southern hemisphere. A careful analysis leads us to conclude that bright PMC are more plentiful at these at these lower latitudes, in the recent decade, than they were in the prior decade. This is in rough agreement with ground-based observations of Noctilucent Clouds (NLC) over the Northern hemisphere.

AC Electric Field Measurements Gathered on the DROPPS Sounding Rocket During Strong PMSE Conditions.

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Electric field wave measurements gathered on a sounding rocket flown in the presence of polar mesospheric summer echoes reveal a distinct layer of irregularities between 83 - 86 km with broadband amplitudes of > 10 mV/m rms. The waves are characterized by bursty, spiky waveforms with lower frequencies (~ 10 Hz) dominant in the upper portion of the layer near 85 km and broader band emissions, extending to higher frequencies (~ 1000 Hz) dominant in the lower portion of the layer near 83.5 km. The lower altitudes correspond to a region of weak optical emissions associated with a noctilucent cloud. The waves appear in and around regions where charged/neutral aerosols (1-10 nm) and large electron density depletions were observed. The irregularities likely result from a variety of processes including space charge inhomogeneities, mixed neutral and plasma motions, and complex effects associated with charged aerosols of varying sizes. We discuss the results in the context of current theories regarding PMSE and NLC wave phenomena.

NLC and PMSE: Rocketborne Observations and Microphysical Modelling

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We present rocketborne observations of the thermal structure in the vicinity of NLC and PMSE. The temperature profiles show significant disturbances with wavelengths ranging from 2-7 km which are most probably due to the transience of gravity waves. All simultaneously observed PMSE layers are found to be centered around one of the local temperature minima, and in three out of all 9 cases an NLC was observed at the lower edge of the PMSE. During the recent MIDAS/Solstice campaign in June 2001 we have launched two sounding rockets into two triple layer PMSE, the three layers being separated by 2-4 km. Interesting enough the temperature profiles measured with the CONE sensor onboard the sounding rocket show wavelike disturbances with comparable wavelengths.

We have used a microphysical model of the formation and growth of ice particles in the mesopause region to identify the physical processes relevant for the observed correlation of gravity wave induced local temperature minima and ice clouds. We find that gravity waves with periods of more than seven hours amplify NLC with the ice cloud being located in a local temperature minimum. Shorter period waves, on the other hand, tend to destroy NLC. Estimating the amount of charged ice particles as a proxy for PMSE from the ice model simulations in combination with an aerosol charging model we also find a satisfying agreement between calculated PMSE profiles and observations. Finally, we consider if wave disturbances in the temperature profile can give rise to multi layer PMSE.

MF Radar Observations of Semidiurnal Motions in the Mesosphere at High Northern Latitudes

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We present MF radar measurements of winds from Poker Flat, Alaska (65N, 147W) and from Andenes, Norway (69N, 16E), obtained since October 1998. Based on the data analyzed thus far, semidiurnal motions observed from these high latitude sites are enhanced in summer and the amplitudes are highly variable on shorter timescales year round. Around the summer solstice, the semidiurnal amplitudes can exceed 20 m/s peak. The summer enhancement in semidiurnal amplitudes is confined to heights above the westward jet (above 88 km). Possible relationships to summertime conditions (i.e., cold mesospause) are discussed.

On Modeling The Cold Summertime Mesopause Region

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The cold summertime mesopause region is of considerable scientific interest not only because it is the coldest place in the Earth's atmosphere but also because of the unique physical and chemical processes that occur in the region. The Thermosphere - Ionosphere - Mesosphere - Electrodynamics General Circulation Model (TIME-GCM) is used to model the temperature, compositional and dynamic structure of the upper atmosphere from 30-500 km during December and June solstice conditions. The magnitude and height of the temperature minimum in the summer mesosphere is controlled by the strength of the subgrid-scale gravity wave forcing that is parameterized within the model. The model calculates two oppositely directed circulation cells operating in the vicinity of the summer mesopause. An upward directed cell below the temperature minimum that brings water vapor and other lower atmosphere species upward and a downward directed cell bringing atomic species down from the thermosphere. The overall dynamics, energetics, circulation and compositional structure in the vicinity of the summer mesopause region will be described.

Comparison of PMSE scatter cross sections: SOUSY Svalbard Radar (53.5 MHz) and EISCAT Svalbard Radar (500 MHz)

Röttger, J.

Polar Mesosphere Summer Echoes (PMSE) occur in single or multiple thin stratifications and thicker patches. The signal power of PMSE varies substantially as function of time, altitude and frequency. Of special interest is the latitudinal and hemispheric dependence as well. For the purpose of comparisons of PMSE the signal-to-noise ratio (SNR) has erroneously been used by many researchers. We show that instead the comparison of effective scatter cross sections or reflectivities needs to be done, since the SNR depends on frequency, diurnal variation of the skynoise level, the interference and last not least on the radar system parameters and the analysis methods applied. We have designed a special method to obtaining well calibrated reflectivity estimates for the two radar systems, the SOUSY Svalbard Radar and the EISCAT Svalbard Radar, allocated at 78 degrees N. The PMSE reflectivities of these two radars differ by several orders of magnitude. We can show that the absolute reflectivities observed on these spatial scales of 3 m and 0.3 m can be explained by reduced electron diffusivity comprising Schmidt numbers larger than 100. It is suggested that a standard method for system calibration and estimation of reflectivities should be adopted.

40 years of NLC observations near Moscow : Database and some results

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NLC near Moscow (55 N, 37 E), Russia are observing in specially organized campaigns every summer season from 1962 up to present time. During this period all the observers have been following the same procedure of NLC registration and accompanying comments , elaborated by 1962.

Now the group of Moscow NLC observers possesses one of the best NLC local database in the World. The total number of observations exceeds twenty thousand 15-minute intervals. That corresponds to 1250 duty nights, including 405 nights with registered NLC. Summarized duration of NLC visibility is 830 hours. For every 15 minutes of observation the database contains not only a fact of presence or absence of NLC, but also NLC brightness estimations (on the base of special brightness scale), types of NLC by the morphological classification and weather conditions (percent of twilight sky segment covering by troposphere clouds).

Some statistical results were obtained from the database. Particular attention was paid to comparison of different seasonal parameters of NLCs to solar indices within several solar cycles. One of important advantages of the database is an accurate accompanying meteorological information. It allowed to separate the cases of NLC no-registration due to a break in observations or due to bad weather from the cases of NLC real absence during a clear night. Such separation proved to be substantial for obtaining of geophysically significant time series of NLC parameters. Long-term behaviour for seasonal probability of NLC appearence during a clear night and for seasonally averaged NLC brightness is discussed.

VHF Radar Observations in the Summer Polar Mesosphere using the SOUSY-SVALBARD-Radar

Rüster, R.

Measurements have been carried out at high polar latitudes in the summer mesosphere using the mobile SOUSY VHF Radar located at Svalbard (78 N, 16 E). An overview of the height and time variation of the polar mesospheric summer echoes (PMSE) is presented. The PMSE, showing a characteristic double layer structure, are used as tracers for studying dynamical processes at the mesopause region. Mean zonal and meridional background winds at these heights are characterized by a westward and southward flow, respectively. Waves with periods greater than 8 h clearly reveal the presence of a diurnal as well as a semidiurnal tide. The latter one exhibits a pronounced temporal and spatial variability. A temporary anticorrelation between the strength of the diurnal and semidiurnal tide as well as the existence of 14- to 16-h waves indicate that nonlinear interaction processes may have occurred.

HALOE Observations of Long-term Changes in the Mesopause Region

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The Halogen Occultation Experiment (HALOE) has been operating on the Upper Atmosphere Research Satellite without flaw since it was first turned on October 11, 1991. The experiment uses the broadband and gas filter radiometry instrument techniques and the solar occultation experiment approach to measure vertical profiles of temperature, HCl, HF, O3, NO, NO2, CH4, H2O and aerosols from the upper troposphere in some cases (i.e. H2O, CH4, and O3) to the lower thermosphere for other parameters (e.g. NO). HALOE has operated for almost ten years and has provided extensive data during spring and summer in the 50 to 75 degree latitude range in both hemispheres where PMCs form. We report in this paper on studies of long-term changes in mesospheric water vapor, nitric oxide and temperature. Methods of PMC identification and changes in PMCs observed over the life of the experiment will also be discussed. Sampling, signal-to-noise and solar effects are especially important considerations in this high altitude and latitude region. We will describe the analysis approach and discuss long-term changes implied in the data set. The Aeronomy of Ice in the Mesosphere (AIM) satellite experiment now in Phase A development to study PMCs, will be briefly described.

Satellite Temperature Measurement Validation Using Rocket-borne Falling Spheres

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Temperature measurements from small meteorological rockets have been used for the validation of a variety of satellite-borne instruments. Following the launch of the Upper Atmosphere Research Satellite, UARS, a significant number of rocket-borne falling spheres were launched in conjunction with the UARS overpass for the validation of the various remote instruments. Upper stratosphere and mesosphere temperatures measured with the HRDI and HALOE instruments on UARS, and the CRISTA instrument were validated with inflatable spheres launched from Wallops Island, Brazil, Hawaii, Norway, and Sweden. Validation measurements of the HRDI instrument occurred at Wallops Island when it passed within 20 minutes and 330 kilometers of the launch site; validation time and space differences of other satellites varied, for example HALOE overpasses ranged to within "5 days and in some cases spatial differences of up to 30 degrees longitude occurred. Falling sphere measurements mostly obtained between 1991 and 1995. CRISTA validation measurements were made within minutes and a few kilometers of the satellite overpass resulting in temperature differences between the remote and in situ instruments of better than 0.5°C. The CRISTA validation occurred in November 1994 and again in August 1997. Falling sphere temperatures near 70 kilometers altitude have a bias toward lower temperatures, but availability of improved software and a new atmospheric model helped reduce this bias. The validated remote instrument measurements permitted a new perspective of atmospheric structure to be formed, not possible with the limited number of falling sphere measurements. Features of the remote measurement temperature profiles will be discussed.

The agreement found between the clusters of falling sphere temperatures and remote temperatures is quite good and begs the argument, what is validation? What does it mean? And, what is the proper method to be employed to achieve the highest scientific return from remote instrument validation or comparison? An effort is made to identify the usefulness of close-in-time and close-in-space validation measurements as well as the value of a simple comparison of the data regardless of relatively large time and space separation.

Comparative Behaviour of Oxygen and Hydroxyl Airglow Emissions as Observed by WINDII

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The WINDII instrument on the UARS spacecraft observes the atomic oxygen O(1S), molecular oxygen O2 Atm (0,0) and hydroxyl Meinel (8,3) airglow emissions which appear at altitudes of about 97, 94 and 87 km respectively. Despite the small differences in altitude, these emissions at times show drastically different behaviour patterns, providing information on the dynamics occurring at these altitudes. Observations are presented and discussed in terms of different dynamical influences.

Longitudinal Variations of Mesospheric Temperature - the WINDII Perspective

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Longitudinal variations of mesospheric temperatures observed by the Wind Imaging Interferometer (WINDII)will be presented and discussed. The study will examine global day-to-day and year-to-year variabilities in the height range of 65 to 95 km. Planetary scale perturbations analysed employing LMS spectral techniques will also be presented and discussed.

Long-term Observations of PMCs from Satellite Platforms

Shettle, E.P.

NRL

The first reported observations of Polar Mesospheric Clouds [PMC] from a satellite platform were from the Orbiting Geophysical Observatory [OGO 6] in 1969, [Donahue et al. 1972]. In the three-decades since then, there have been a number of different satellite instruments, for which PMC measurements have been reported. These include SME, WINDII, MSX, POAM II & III, HALOE, SNOE, METEOSAT, SBUV & SBUV/2, and SAGE II. Most of these instruments have only made measurements over a period of a few years. However, in the past year or so, analyses of two satellite data sets covering more than an eleven-year solar cycle have become available. These are the SAGE II data covering from 1984 to the present, and the SBUV and SBUV/2 series of data that covers from 1978 to the present. Both of these will be discussed in separate papers at this workshop, as will most of the other satellite measurements. I will discuss some of the time trends that can be derived from these and the various other satellite instruments. Examining an extended time period utilizing a single satellite instrument or a series of essentially the identical instruments minimizes differences that might impact any trends. However, PMC measurements from different instruments [each only covering a few years] can be placed in a common framework, which allows them to be combined, effectively producing a longer time-series. I will discuss an example of this approach, which has been applied by Shettle et al. [2001] to compare PMC observations from POAM II and WINDII with those from SME a decade earlier.

Analysis of an NO Climatology for the Summer Mesopause Region: Inference of Ionization Rates

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Eight years of HALOE data are combined to produce a climatology of nitric oxide in the summer mesopause region. The NO data are placed on a magnetic coordinate system as a function of latitude and longitude and are binned according to geomagnetic activity level. A clear auroral-like oval is seen in the polar plots for altitudes as low as 80 km. In addition, mesopause NO densities are enhanced by factors of 2-3 during geomagnetically active periods relative to quiet periods. Photochemical model calculations are presented to compare with the observed NO. The model is driven by climatological ionization rates from the NOAA/Medium Energy Proton and Electron Detector (MEPED) dataset. By comparing the model with averaged NO profiles from various locations, we can infer spatial and temporal variations of the ionization rate. Of interest are the ionization rates at the locations where PMSEs are commonly observed (e.g. Poker Flat Alaska, St. Georges Island). These comparisons may be relevant to explaining observed geographic variations in PMSE intensity.

Charged Aerosol Collection Inside a PSME by a Magnetically Shielded Probe During MIDAS/SOLSTICE 2001

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A charged aerosol detector was flown during the MIDAS/SOLSTICE rocket campaign in June 2001 over Andoya, Norway. The probe is a graphite collection surface with a permanent magnet underneath to deflect electrons and light ions. This probe was first used on a sounding rocket over White Sands, NM in 1998, where it measured a sharp positively charged layer at 86.5km, followed by a broad negatively charged layer which extended a few kilometers lower. The flights aboard the two MIDAS payloads were the second use of the probes. The first MIDAS launch was into a triple layered PMSE which extended from 82 to 90km. On upleg, the probe measured a broad region of negatively charged particles inside a local ion and electron biteout at approximately 85km. Cloud cover prevented lidar support. The second launch was fired into a very strong single-layered PMSE. On upleg, the probe measured another broad region of negative particles within the PMSE. On downleg, more negatively charged particles were seen in the PMSE, this time in a broad region with a very sharp upper boundary. During both flights the probe also measured a positively charged background which was well-correlated with an onboard positive ion probe. Also seen was a photoelectron signal due to solar UV. These other signals show that the probe functioned as expected during flight. Further analysis is underway. This work was funded by NASA.

Collision Cross Section Measurements of Small Water Clusters

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An apparatus has been constructed that generates water clusters. The first experiment was to measure the collision cross section of small water cluster molecules $[H_2O]_N$. In the experiment a controlled mixture of water vapor and argon gas expands into vacuum producing neutral water clusters in a supersonic molecular beam. The clusters undergo collisions in a scattering cell with target gases Ar, N_2, and He. After the attenuation, the clusters are ionized by 70 eV electron impact and detected by a quadrupole mass spectrometer. The cluster ions are proton hydrates $H^+[H_2O]_K$. The apparent collision cross sections determined from the attenuation measurements are approximately 3×10^{-18} m^2 for Ar and N_2 target gases, and 10^{-18} m^2 for He. Additional data, with a beam having smaller proportion of heavy clusters gives the same cross section of the $K = 3$ cluster that suggests that there is one dominant channel for the generation of ions from clusters. The apparatus may be used to calibrate rocket-born detectors.

OH and Ice Above 92 km in November: New Results From MAHRSI 1

Stevens, M.H. and Englert, C.R.

The Middle Atmosphere High Resolution Spectrograph Investigation (MAHRSI) simultaneously measures OH(0,0) solar resonance fluorescence near 309 nm and Rayleigh or Mie scattered sunlight from the atmosphere at a spectral resolution of 0.02 nm. In November 1994, MAHRSI flew on the CRISTA-SPAS (Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere-Shuttle Pallet Satellite), which was deployed and retrieved by the space shuttle for eight days of observations at an altitude of about 317 km and an orbital inclination of 57º. Nominally, MAHRSI scans the limb to infer OH density profiles where the pointing accuracy of CRISTA-SPAS is ± 0.3 km at the tangent point. On one orbit, however, MAHRSI was commanded to stare at a tangent altitude of 87.0 km, where OH can be produced by photodissociation if water vapor is present.

Throughout most of the orbital day, no measurable signal from OH was observed and the background brightness was very low. However, near 60º N latitude and at the end of the orbital day, more than 200 unambiguous OH spectra were measured during nine minutes of observations with peak intensities near 50 kR indicating that a large cloud of water vapor was present. Because the tangent height was fixed, the cloud was between 87 km and the MAHRSI orbital altitude and we will constrain its height by calculating the temperature from the relative intensity of the OH rotational lines that are described by Boltzmann statistics. During the observation of high OH radiances, the background intensity also became significantly enhanced and peaked later in the orbit. We infer that this background signal is due to Mie scattering from water ice in the atmosphere above 87 km. Possible sources of water vapor at these altitudes will be explored as well as the conditions required for ice to form.

A Search for Mesospheric Clouds at Unusually Low Latitudes

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Noctilucent clouds (NLC) are a beautiful, high-latitude, summertime phenomenon that was first reported over 100 years ago. They are seen during the hours of twilight by the scattering of sunlight from sub-micron sized ice crystals that form in the vicinity of the cold mesopause region. NLC are quite distinctive, often appearing silvery-blue in color. In recent years there has been a marked increase in the frequency of occurrence of these mesospheric clouds possibly due to an increase in mesospheric water vapor and/or to a cooling of the mesopause region prompting speculation that they are "harbingers" of potentially serious atmospheric changes. In concert with this trend there are also a growing number of cloud sightings at significantly lower latitudes than expected. Since June 1999 when NLC were observed as far south as ~40°N we have conducted a survey of the twilight summertime skies from Logan, Utah in search of their signatures. In this paper we present the results of our survey, including observations of NLC at unusually low latitudes (<50°) recorded over the past few years and discuss anomalous mesospheric cloud sightings reported in the literature.

Arctic Mesospheric Cloud Observations and Characterization by the Sondrestrom, Greenland, Rayleigh Lidar from 1994 through 2000

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Since 1994, Rayleigh lidar measurements of the arctic middle atmosphere have been conducted at the Sondrestrom atmospheric research facility near Kangerlussuaq, Greenland (67.0N,50.9W). The summer lidar observations typically cover the mid-June through late August period. From these observations, 220 hours of noctilucent clouds (NLC) have been detected by the lidar spanning 16 hours of local time. Gravity wave signatures are often observed in the cloud detections. The basic characteristics of cloud centroid height, full-width-half-maximum (FWHM), and peak volume backscatter coefficient (VBC) show no clear local solar time (LST) dependence between 18 and 10 LST, once the variable performance of the lidar system is considered and removed. Organizing the cloud characteristics over these local times reveals the most common cloud height to be 82.5 km, the most common FWHM to be 0.7 km, and the most common peak VBC to be 20 ´ 10-11 m-1sr-1. We found the backscatter strength to increase with decreasing cloud height while the cloud thickness decreased with decreasing cloud height. A determination of the mean time rate of change of cloud height illustrates downward motion at all heights with a mean rate of 15 cm/sec at 85 km decreasing to less than 5 cm/sec at 81 km. Together this mean NLC behavior supports the classic growth-sedimentation model representative of a particle population with a mean radius of 50 nm falling through a supersaturated region within the mesosphere. To help support this result, simulations from the Community Aerosol and Radiation Model for Atmospheres (CARMA) model were performed under summer mesospheric conditions with and without gravity wave activity. Upon including gravity wave activity the model simulation produced results similar to the observations.

Science Objectives Of The Aim Satellite Mission To Study Pmc's And Their Atmospheric Environment

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The Aeronomy of Ice in the Mesosphere (AIM) has been selected for a Phase A Study by NASA in its Small Explorer Program. The overall goal of AIM is to resolve why Polar Meospheric Clouds (PMC) form and why they vary. By measuring PMC's and the thermal, chemical and dynamical environment in which they form, we will quantify the connection between these clouds and the meteorology of the polar mesosphere. AIM includes four instruments: SOFIE (Solar Occultation for Ice), an infrared solar occultation radiometer; CIPS (Cloud Imaging and Particle Size Experiment), a panoramic UV imager; SHIMMER (Spatial Heterodyne IMager for MEsospheric Radicals), a near-UV inteferometer; and CDE (Cosmic Dust Experiment), an in-situ dust detector.

The coordination of the various experiments is vital in making common volume measurements needed to constrain the environmental parameters controlling PMC (such as temperature and water vapor).This paper will describe the observational strategy needed to satisfy the science goals of AIM.

New Lidar Observations of NLCs from ALOMAR and Svalbard

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We report on new observations of NLC parameters and characteristics as observed by the ALOMAR Rayleigh/Mie/Raman lidar at ALOMAR (69°N) and our potassium lidar at Longyearbyen, Svalbard (78°N). At ALOMAR, we have continued our studies of the NLC particle size distributions through 3-color lidar observations. Furthermore, we have obtained a first lidar measurement of the depolarisation caused by NLC particles which points towards a non-spherical shape of the scattering particles. The occurrence frequency of NLCs during the summer 2000 (= solar activity maximum) was unexpectedly high. We also report on observations of a number of "very high altitude" scattering layers in which the ALOMAR RMR lidar seems to detect particle ensembles with median radii as small as 10 nm. Our first lidar observations of NLCs above Svalbard in summer 2001 indicate (so far) an altitude of NLCs similar to that measured at ALOMAR.

Dynamics of the Cold Summer Mesopause

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Gravity wave transports of momentum, heat, energy and minor constituents have a profound effect on the seasonal-latitudinal variations of the general circulation. The most notable manifestation of the wave control of the general circulation in the MLT is the deceleration of the zonal winds and the reversal of the latitudinal temperature gradients above the mesospheric jets, with the coldest temperatures in the atmosphere being at the mesopause over the summer pole, contrary to radiative equilibrium. Wave control of the general circulation in the upper mesosphere and lower thermosphere is accomplished by wave transport of momentum and by the wave-induced residual circulation (which provides a mechanism for wave stresses to cause temperature changes). Observations show momentum fluxes that agree with the forcing required to maintain the observed meridional temperature gradient. In addition, simulations indicate that forcing by planetary waves may play a significant role in maintaining the cold summer mesopause. The mechanisms of wave forcing of the seasonal ariation in the mesopause region will be reviewed (including nonacceleration conditions and the residual circulation). The application of present theory, the state of observations and the requirements for future measurements will also be discussed.

Physical Details of Ice Particle Formation in the Summer Mesosphere

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Mesospheric sub-micron particles are formed under extreme conditions regarding temperature, density, chemical environment and the available supply of condensable matter. Whereas the physical properties of optically detectable particles in the 30-80 nm size range are known, the presence of smaller particles or water clusters in not well established. Nor have the initial steps been fully identified. As to the composition of these particles it is generally agreed upon that the material is solid H2O. Until recently, this had to rely on plausibility arguments. However, water ice features conspicuous spectral features in the IR spectrum, notably the O-H stretching vibration at 3267 cm-1 or 3.08 microns and it has been suggested (Witt, 1969) that an IR radiometric measurement of noctilucent clouds would deliver the desired proof. In a recent experiment, P Espy (2000) has performed this kind of measurement that provided this proof. Moreover, in recent studies from two spacecrafts, CRISTA and MSX (Gumbel & al, 2001) thermal radiation from NLC layers could be identified as a further proof. The thermal emission itself is of interest as it determines the equilibrium temperature of the particles and hence the conditions of particle growth and sublimation. The thermal properties of NLC particles illuminated by the Sun and the ground depend crucially on the refractive index and to some extent on the shape of the particles. This problem has been analyzed earlier (Witt,1868 ; Fiocco & Grams, 1973) and shows that the temperature of ice particles is higher than the ambient, the temperature excess being determined by the size, the ambient pressure and the accommodation coefficient. A simple model study indicates that the temperature excess presents a limitation to the growth rate and maximum particle size that can be attained. The particle temperature needs therefore to be accounted for in modeling mesospheric clouds. This contribution discusses the physical details of ice particle formation on the basis of current knowledge from theory and laboratory experiment, in particular the shape, and optical properties of than particular type of ice in question. As to mesospheric water vapor, some of the first results from the Summer Mesosphere mission of the Odin satellite now in orbit will be presented.

An Investigation of Scattering Mechanisms and Dynamics in PMSE Using Coherent Radar Imaging

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NCAR/ATD

In this work, coherent radar imaging (CRI) was implemented using the ESRAD (ESrange RADar) system in Kiruna, Sweden (67.88N, 21.10E) in the summer of 1998. For the first time, horizontal structures of polar mesosphere summer echoes (PMSE) are studied with high temporal and angular resolution using CRI. Frequency jumps, which represent sudden changes in radial velocity, were observed in several regions during this experiment. Spectrograms and the horizontal structures of PMSE provided by CRI during two cases of frequency jumps, suggest that the frequency jumps were caused by reflecting points originating from a horizontally stratified layer which was modulated by a wave. It was further verified using simulated data and shown that the vertical amplitude of the wave must have exceeded a particular threshold for a given transmit beamwidth. The horizontal wavelength and phase velocity of the proposed wave were estimated to be on the order of 25-34 km and 50-70 m/s, respectively. Additionally, the vertical amplitude of this wave was up to 400 m, covering several range gates. A hypothesis of phase synchronized multiple layers perturbed by waves is proposed to explain the presence of the frequency jumps at several altitudes simultaneously.

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Properties of Mid-Latitude Mesosphere Summer Echoes

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Mesosphere summer echoes (MSE) at mid-latitudes are a rare phenomenon in contrast to the polar mesosphere summer echoes (PMSE) at arctic latitudes. Studies of MSE characteristics are therefore more seldom than studies of PMSE. During the summers 1998, 2000 and 2001 MSE observations were performed with a 53.5 MHz VHF radar system at K¨1hlungsborn (54.1N, 11.8E). Mesosphere Summer echoes occur in summer in the height range of about 80 km to 90 km, but MSE are restricted to daytime in contrast to PMSE. We discuss aspect sensitivity, spectral width and related parameters (scales of the scatterers) as main characteristics of MSE radar echoes. The measured spectral width is often dominated by beam broadening. The MSE layers are characterized by a high aspect sensitivity described by the width of the polar diagram of backscatters with ¦¨s values between 3 and 5 degree. Finally, the results are compared with similare observations at polar latitudes.