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Solar diurnal tides in the middle atmosphere: Interactions with the zonal-mean flow, planetary waves and gravity waves

Ulrich Achatz [1], *Fabian Senf* [2], *Norbert Grieger* [3], *Thomas Kessemeier* [1]
[1] *Goethe-Universität Frankfurt, Frankfurt/Main, Germany*
[2] *Leibniz-Institut für Troposphärenforschung, Leipzig, Germany*
[3] *Leibniz-Institut für Atmosphärenphysik, Kühlungsborn, Germany*

The dynamics of solar tides is investigated with regard to variations of the background atmosphere, including planetary waves (PW), and to the interaction with gravity waves (GW). (1) Using a linear model with a clear cause-effect relationship, it is shown that planetary waves play an important role in tidal dynamics, most importantly by inducing non-migrating tidal components from a migrating thermal forcing. (2) Ray-tracing simulations are used to analyze the GW force on the large-scale flow including the solar tides. In comparison to classic GW parameterizations, the inclusion of time-dependence and horizontal refraction leads to a significant decrease of the GW drag. (3) If time is left nonlinear effects of tidal dynamics will be discussed as well.

Presented by: **Achatz, Ulrich**

Performance improvement in momentum flux computation time using EV based post beam steering technique derived winds

VK Anandan , *Kumar Shridhar* , *VN Sureshbabu*
ISTRAC, Indian Space Research Organisation, Bangalore, India -560058

Vertical flux of horizontal momentum of wind fluctuations have been a key parameters for radar measurements in the lower and middle atmosphere. Several studies have presented on error analysis and statistical reliability of the method focusing on various beam configurations. To obtain statistically significant measurements of the momentum flux, long integration times are necessary as the flux is typically a small fraction of the geometric mean energy. The estimate of momentum flux of short-period (T <2 h) wind fluctuations together with the uncertainties in estimation at Jicamarca and concluded that momentum flux estimates exceeding the measurement uncertainties can be obtained after about one day of integration. In another study momentum flux estimated for short period (T <2h), integrated for the different length of times to minimize the error and concluded that optimum time of integration for estimation of momentum flux is about 15-16 hrs.

In this paper a study has been carried out on Vertical flux of horizontal momentum using EV based post beam steering technique in deriving winds from the observations of middle and upper atmospheric (MU) radar at Shigaraki, Japan in multi channel receiver mode. The vertical flux of horizontal momentum has been calculated with four off-zenith beams in 32 different azimuth direction with a beam tilt of 1.5 deg based on symmetric beam method with necessary modification for accommodating different azimuth direction. By this way 8 set of zonal and meridional momentum flux value has been obtained and mean value found. Momentum flux is estimated on 14 hrs observation and statistics are computed. It is observed that the mean value of zonal and meridional momentum flux is ranging between -0.1 to 0.25 m^2s^{-2} and -0.1 to 0.15 m^2s^{-2} respectively for the given day of observation. The statistical study reveals that an irreducible error in is observed by 7-8 hrs integration which is best in the results reported earlier. The value of errors in various ranges are in zonal momentum flux is of the order 0.0280 m^2s^{-2} for 1.05–12 km, 0.0310 m^2s^{-2} for 12–16 km and 0.0250 m^2s^{-2} for 16–20 km and in meridional momentum flux is of the order 0.010 m^2s^{-2} for 1.05–12 km, 0.030 m^2s^{-2} for 12–16 km and 0.0120 m^2s^{-2} for 16–20 km. The study has revealed that a statistically reliable momentum flux observation can be obtained with in a period of 7-8 hrs using the new approach in deriving the winds using EV based post beam steering technique.

Presented by: **Anandan, VK**

Extraction of horizontal wind velocities from a multi receiver phased array radar system using post beam steering technique and efficiency of various beamforming methods

VK Anandan [1], *VN Sureshbabu* [1], *Toshitaka Tsuda* [2], *Jun-ichi Furumoto* [2]
[1] *ISTRAC, Indian Space Research Organisation, Bangalore -58, India*
[2] *Research Institute for Sustainable Humanosphere (RISH), Kyoto University, Uji, JAPAN*

Multi-receiver data analysis broadly divided in space antenna (SA), imaging Doppler interferometry (IDI) and post beam steering (PBS) techniques. DBS has proven to be a reliable means of obtaining the wind vector, other multi receiver methods have also been developed which have proven to have distinct advantages, such as larger signal-to-noise-ratio (SNR) and higher angular resolution.

PBS technique was initially demonstrated in wind profiling by Rottger and Ierkic (1985) as a means of software steering using multi receiver data. Since these measurements typically involve reception on minimum three spatially separated arrays, a systematic phase shift can be applied to the signals to produce a two-way beam pattern in any arbitrary direction within the volume illuminated by the transmitted beam.

In this paper a study has been carried out using spectral based technique on data received from middle and upper atmospheric (MU) radar at Shigaraki, Japan. The array is also capable of steering the beam electronically using phase shifters in transmit and receive path. The experiment was conducted with full array of transmission (beam width 3.6^{o}) in vertical direction. The data collected was subjected to PBS using different digital beam forming algorithms, such as Bartlett, Capon, Multiple Signal Classification (MUSIC) and Eigen Value (EV) based method. In all approach beam is formed at 1.5^{o} off-vertical and radial vectors of winds were determined in azimuth angle separated by 5.6^{o}. The wind profiling that ranges from 1km to 19km is carried out using adaptive moments estimation technique. From the radial velocity obtained, zonal and meridional velocities were computed using least square method.

Results obtained are compared with the wind velocity estimated using the observation conducted in DBS method and GPS sonde observed wind velocity in near time. The results are in good agreement shows capabilities of various beam forming approaches in deriving the wind velocity using PBS. Performances of different algorithms were also studied and the results will be discussed in detail. This is the first time that various beam forming techniques have been applied through the spectral estimation methods and derived the 3-D wind velocities from atmospheric radar signals and also performances of the algorithms have been reported.

Presented by: **Anandan, VK**

Performance analysis of optimum tilt angle with necessary beam configuration to minimize error in measurement of horizontal wind velocities derived by Post Beam Steering technique

VN Sureshbabu [1], VK Anandan [1], Toshitaka Tsuda [2], Jun-ichi Furumoto [2]
[1] ISTRAC, Indian Space Research Organisation, Bangalore-58, India
[2] Research Institute for Sustainable Humanosphere (RISH)

3-D wind profiling of atmosphere becomes very important for meteorological purpose and atmospheric research. Various techniques have been used and most popular is the radar based operating at VHF and UHF frequencies popularly called as ST/MST radar or wind profilers. Using atmospheric radars also wind velocity can be estimated using different approaches such as Doppler beam swinging (DBS), spaced antenna (SA) drift, and post beam steering (PBS). PBS can be mentioned as an extension of DBS where the beam is formed in different direction from data received from vertically transmitted beam having sufficient beam width. Essential requirement of PBS is the formation of steering vectors with the concept of spatial filters using weighting vectors to maximize the gain in a steered direction and reject the undesired signals. The receive beam formed should be within the transmit beam to have better signal-to-noise-ratio (SNR).

A study has been carried out using spectral based technique on data received from middle and upper atmospheric (MU) radar at Shigaraki, Japan. MU radar is a monostatic pulsed phased array radar operates at 46.5 MHz with a peak power of 1 MW. The array is configured as circular array of 475 crossed Yagi elements which are grouped and formed 25 different receiver channels for observational purpose. The array is also capable of steering the beam electronically using phase shifters in transmit and receive path. The experiment was conducted with full array of transmission (beam width 3.6^o) in vertical direction. The data collected were subjected to PBS using different digital beam forming algorithms, such as Bartlett, Capon, Multiple Signal Classification (MUSIC) and weighted subspace fitting (WSF) for different tilt angle starting from 1^o to 1.9^o. The beams are formed in the numbers from 4 to 64 equally separated azimuth directions to obtain the radial wind velocity. From the radial velocity obtained, zonal and meridional velocities were computed using least square method.

Results show that wind velocity estimated at tilt angle of 1.5^o has given very good agreement on wind estimated in comparison with the wind estimated using DBS technique and GPS sonde based observation. It is also observed that the difference is minimal when number of beams used is more than 16 for the estimation of zonal and meridional velocities.

Presented by: **Anandan, VK**

An inter-comparison of wind velocities in different observation approaches and signal processing techniques using multi receiver phased array MU radar system

Kumar Shridhar [1], VN Sureshbabu [1], VK Anandan [1], Toshitaka Tsuda [2], Jun-ichi Furumoto [2]
[1] ISTRAC, Indian Space Research Organisation, Bangalore -58, India
[2] Research Institute for Sustainable Humanosphere (RISH), Kyoto University, Uji, JAPAN

Application of ST/MST radars for observing back ground air motion and deriving 3-D wind velocities has been well established. Today, numerous techniques and methods are available for deriving horizontal wind velocities. Among them Doppler beam swinging is the most popular because of its simplicity by using a single receiver and tilting the beam to minimum three non-coplanar direction one after the other using phase shifters. There are multi receiver phased array radar systems in operation for complimenting and supplementing the observations limited by DBS based system. Multi-receiver data analysis broadly divided in space antenna (SA), imaging Doppler interferometry (IDI) and post beam steering (PBS) techniques. DBS has proven to be a reliable means of obtaining the wind vector, other multi receiver methods have also been developed which have proven to have distinct advantages, such as larger signal-to-noise-ratio (SNR) and higher angular resolution.

In this paper we are presenting a detailed study on wind velocities derived in different observation method and signal processing techniques on the observation conducted with middle and upper atmospheric (MU) radar at Shigaraki, Japan. A modified signal detection approach has been used for deriving the wind velocities using SA technique thereby able to detect the signal upto 18-19km. This has been reported in a companion paper. The same data has used under various Post Beam Steering algorithms and wind velocities were derived. During the observation period radar also operated in DBs mode for shorter duration to obtain DBS based wind velocities. There was an independent observation of winds using GPS sonde observation also recorded. Analysis is carried out on 12hrs of observation, various statistical parameters on winds derived from different approach have been determined. Inter comparison of results shows a very good comparison of all parameters. The result confirms the robustness and reliability of the new algorithms in deriving 3-D winds.

Presented by: **Anandan, VK**

Observation of horizontal wind velocities in presence of convective system using multi receiver phased array MST radar system

VK Anandan [1], *VN Sureshbabu* [1], *Rao S Vijayabhaskara* [2]
[1] *ISTRAC, Indian Space Research Organisation, Bangalore -58, India*
[2] *Dept. of Physics, SV University, Tirupati, India*

One of the most important uses of ST/MST radars is measurement of horizontal winds. Today, numerous techniques and methods are available for deriving 3-D atmospheric winds using radar remote sensing. Among them Doppler beam swinging is the most popular because of its simplicity by using a single receiver and tilting the beam to minimum three non-coplanar direction one after the other using phase shifters. There are multi receiver phased array radar systems in operation for complimenting and supplementing the observations limited by DBS based system. Once the wind fields are changing with in the beam dwell time during convective condition prevails over the observation area, DBS technique fails in deriving the horizontal wind velocities. So there is not much observations were reported on observation of horizontal velocities during convective condition using ST/MST radars.

A study has been conducted on observation of horizontal wind velocities during convective condition with middle and upper atmospheric (MU) radar at Shigaraki, Japan using EV based post beam steering (PBS) techniques. The advantage of this approach is that all the wind fields are derived for the given instant of time, so the derived winds in all direction will be reliable and accurate. In EV based PBS technique, beam is formed at 1.5^{o} off-vertical and radial vectors of winds were determined in azimuth angle separated by 5.6^{o}. This technique has been validated in observation with clear air condition and found to be most reliable and accurate in all post beam steering techniques. Data analysis is carried out on a few number of occasions were convective system was prevailing in the atmosphere. 3-D wind velocities were derived in all cases with very high temporal resolution. The spatial (over the range) and temporal observation helps in identifying the kinematics convective system and the same will be presented in workshop.

Presented by: **Anandan, VK**

Improved performance in Horizontal wind estimation from a multi receiver phased array atmospheric radar system using Spaced Antenna Drift Technique and signal processing approaches

Kumar Shridhar [1], VK Anandan [1], Toshitaka Tsuda [2], Jun-ichi Furumoto [2]
[1] ISTRAC, Indian Space Research Organisation, Bangalore -58, India
[2] Research Institute for Sustainable Humanosphere, Kyoto University, Uji, JAPAN

The Spaced Antenna (SA) drift method is multi receiver alternatives to Doppler beam swinging (DBS) and has been studied thoroughly in the literature. Like the DBS technique, a standard SA experiment uses a single array for transmission but receives the returned signals on three spatially separated antennas with non-collinear baselines. A baseline is defined as the imaginary line drawn between the receiving centers. Assume that the three receivers exist at the vertices of a right angle triangle with the sides along the x and y axes. By calculating the cross-correlation functions between the signals received at the different receivers, one can obtain the delay times along x and y axes. By knowing these delays and receiver separation, horizontal velocities can be estimated.

Middle and upper atmospheric (MU) radar at Shigaraki, Japan is an excellent system to carry out observation using spaced antenna techniques. The array is configured as circular array of 475 crossed Yagi elements which are grouped and formed by 25 different receiver channels for observational purpose. Numerous scientific studies were reported in the past. In most of the studies the array is divided in to three segments and grouped with 3/6 channels to form equilateral triangle base line. In all this studies the wind is estimated up to a maximum height of 10 -14 kms. In general SA based wind estimation could not give good height coverage due to smaller aperture being used for received signals. This will result in poor signal-to-noise-ratio (SNR) and cross correlation between different antenna groups will be low. In this study we have made use of complete array for transmission and received the signal with 25 receiver channels. The receiver channels are divided in to three equal segments and form the baseline suitable to derive the wind velocity using spaced antenna technique. Complete analysis is repeated with 4 different spatial distributions of array group. In each case wind velocity is estimated and quality check is carried out. Velocities from all groups were averaged to obtain the final value. The identification of receive channels for grouping and its phase centers were critical to get the best result in cross correlation and determining the velocity. The results were compared with the wind velocity estimated using DBS technique and wind observed by the GPS sonde. It is observed that the new approach adopted using spatially distributed array grouping has yielded higher height coverage upto 18 to 20 kms and in good agreement with the results obtained using DBS and GPS sonde observations.

Presented by: **Anandan, VK**

ESRAD Radar observations of PMSE during the PHOCUS rocket campaign at ESRANGE on 21 July 2011 07 UTC: preliminary results of coherent radar imaging.

Joel Arnault , *Sheila Kirkwood*
Polar Atmospheric Research, Swedish Institute of Space Physics, Kiruna, Sweden

The summer polar mesosphere has the particularity to provide favorable conditions for ice-crystal cloud formation, particularly at mesopause heights around 80 km. These are known as noctilucent clouds that can eventually be seen from midlatitude regions at dawn / dusk time when the sun illuminates only the upper atmosphere. However noctilucent clouds cannot be seen from polar regions where they can only be detected remotely with lidar measurements. The aim of the PHOCUS campaign that was held in ESRANGE, North Sweden, in June-July 2011, was to launch a rocket up to the mesopause in order to provide in-situ and collocated measurements of such clouds.
Lidar observations of noctilucent clouds are generally associated with enhanced VHF radar echoes, known as polar mesosphere summer echoes (PMSEs). However PMSEs and noctilucent clouds are not exactly collocated since the strength of PMSEs depends on more factors than only the particles' size that eventually make the noctilucent clouds visible (fluctuations in the refractive index at the Bragg scale, the refractive index depending on temperature, water vapor, and also electron density).
When the rocket of PHOCUS campaign was launched on 21 July 2011 07 UTC a strong PMSE was detected by the VHF ESRAD radar at ESRANGE. Since ESRAD radar has six receivers, interferometric imaging techniques can be used to represent the radar signal back-scatterers in 3D. In particular coherent radar imaging allows discriminating different scatterers according to their height, their angular position within the probed volume and their radial velocity, which eventually help improving our understanding of the physics of PMSEs. A preliminary investigation of such coherent radar imaging results will be presented here.

Presented by: **Arnault, Joel**

Dynamical influence of a gravity wave generated by the Vestfjella Mountains in Antarctica: radar observations, fine-scale modeling and kinetic energy budget analysis

Joel Arnault , *Sheila Kirkwood*
Polar Atmospheric Research, Swedish Institute of Space Physics, Kiruna, Sweden

A remarkable case-study of mountain wave generated by the Vestfjella Mountains (in western Droning Maud Land, Antarctica, southwest of the Finnish / Swedish Aboa / Wasa station) has been observed with the Moveable atmospheric radar for Antarctica (MARA) during the SWEDish Antarctic Research Programme (SWEDARP) from 9 to 13 December 2007. The radar observations are compared with a Weather Research Forecast (WRF) model experiment operated at 2 km horizontal resolution. The role played by this particular gravity wave on the atmospheric flow is then quantified with a kinetic energy budget analysis computed in the simulation (tendency of horizontal kinetic energy = horizontal advection + vertical advection + horizontal work of pressure forces + frictional dissipation). The results show that this particular mountain wave reached lower-stratospheric heights, where it broke through convective overturning and generated an inertia gravity wave with a smaller vertical wavelength, in association with a depletion of kinetic energy through frictional dissipation and negative vertical advection. The kinetic energy budget also shows that this gravity wave accelerated locally the horizontal flow through positive vertical advection, suggesting a process more complicated than what is usually proposed. Moreover the apparently strong influence that this gravity wave had on the other terms of the budget, i.e horizontal advection and horizontal work of pressure forces, suggests that evaluating the influence of gravity waves on the mean-flow with the vertical advection term alone is not sufficient.

Presented by: **Arnault, Joel**

Estimation of absolute meteor fluxes from specular meteor observations

Carsten Baumann , *Gunter Stober* , *Ralph Latteck* , *Werner Singer*
Institute of Atmospheric Physics Kühlungsborn

Until today the total meteoric mass input into the mesosphere-lower-thermosphere (MLT) region is still a matter of intense research. Currently available estimates vary over a large range from 10 to 200 tons per day underlining the inherent uncertainties of these values.

A small part of this extraterrestrial meteoric debris is observed by specular meteor radars. Here we present a method which derives absolute meteor fluxes from meteor count rate observations for the sporadic meteor sources and the Geminid meteor shower. The particle size and velocity distribution is determined using a single body meteor ablation model and measurements of the electron line density, which is directly related to the meteoroid mass. Finally, the estimated meteor fluxes for a mean detectable meteoroid size are compared to the meteor fluxes given by Ceplecha, 1998.

Presented by: **Baumann, Carsten**

Main characteristics of polar mesosphere summer echoes observed with the MST radar ESRAD, Kiruna, Sweden during 1997- 2011

Evgenia Belova [1], *Maria Smirnova, Sheila Kirkwood* [1]
[1] *Swedish Institute of Space Physics*

Since 1997 measurements of polar mesosphere summer echoes (PMSE) have been carried out with the 52 MHz ESRAD MST radar located near Kiruna in Northern Sweden. Importantly, these measurements have been made using the same height resolution and pulse-modulation scheme the whole time . ESRAD has been calibrated against radiosondes that allow us to calculate PMSE cross-sections corrected for changes in transmitter output and antenna feed losses from year to year. We analysed the short- and long-term variations as well as trends in the PMSE occurrence and volume reflectivity together with the factors affecting them. We also estimated the in-beam PMSE aspect sensitivities using the FCA technique.

Presented by: **Belova, Evgenia**

Rain kinetic energy measurement with a UHF wind profiler: application to soil erosion survey of a tropical volcanic island

Bernard Campistron [1], *Anne Réchou* [2]
[1] *Observatoire Midi Pyrénées, Toulouse University*
[2] *Laboratoire de l'Atmosphère et des CYclones, La Réunion University*

Land degradation by rainfall events is strongly dependent of the kinetic energy of raindrops that impact the soil. The approach presented here for the assessment of soil erosion is done with UHF wind profiler observations that in spite of a relative long wavelength is very sensitive to the detection of rain even weak such as drizzle. For this frequency band, radar data analysis is facilitated by the fact that attenuation by hydrometeors is negligible and that rain backscattering belongs to the Rayleigh approximation. Drop vertical kinetic energy flux related to the drops terminal fallspeed combined with air vertical velocity, and drop horizontal kinetic energy flux due to drop entrainment by horizontal wind are ones of the most pertinent parameters of rainfall erosivity. We derive in this study the retrieval equations of these two quantities along with those of the precipitation rate function of the mean reflectivity, vertical velocity and horizontal wind provided by the profiler. The analysis is based on the main assumptions of gamma raindrop size distribution and on negligible air vertical velocity. Tests based on the values of reflectivity, vertical velocity, spectral width and skewness of the Doppler spectra are used to discard data that do not fulfill the requirements such as echoes from clear air or snow or from atmospheric regions associated with substantial air vertical motion. The calibration of the profiler using ground raingauge data is also presented. The last part of the work shows an application of the methodology to rain observations collected by a UHF wind profiler located at La Reunion island in the Indian Ocean. This mountainous island, that culminates at an altitude of 3000 m, has a regime of tropical precipitation enhanced by orography. In that case the radar provided continuous measurement of rain rate and rainfall kinetic energy from 600 m above ground level up to the summit of the island.

Presented by: **Campistron, Bernard**

Water vapor analyses in mixed-phase clouds

Edwin Campos

Mixed-phase clouds (clouds that contain interacting liquid and ice particles) play a significant role on the energy budget at the earth surface through modulation of radiative fluxes in cold regions. Mixed-phase clouds are also a frequent atmospheric hazard, particularly when its supercooled droplets are abundant enough to disturb aviation and ground transportation.

For monitoring water-phase dynamics in mixed-phase clouds, this work analyzes vertical profiles of air vapor pressure, and equilibrium vapor pressure over liquid water and ice. Based only on the magnitude ranking of these vapor pressures, we identified conditions where liquid droplets and ice particles grow or deplete simultaneously, as well as the conditions where droplets evaporate and ice particles grow by vapor diffusion. The method is applied to snowstorm observations by microwave profiling radiometer and 915 MHz wind profiler radar.

The results corroborate well with independent radiometer retrievals of vertically-integrated liquid water, reflectivity factor and Doppler velocity observations by vertically-pointing radars, and radiometer estimates of liquid-water layers aloft. This translates in a positive contribution toward monitoring and nowcasting the evolution of supercooled droplets in winter clouds.

Presented by: **Campos, Edwin**

Aspects of Hydrometeor Scattering for Applications in the New Generation of Weather Radars

Madhu Chandra
Technische Universität Chemnitz

In general, hydrometeor scattering properties play a fundamental role in the application and design of weathers radars. Weathers radars, in the recent years, have witnessed several advances in the areas of: polarisation diversity, high frequency applications (above C-Band), and interpretation of diverse polarimetric phases. Central to all these innovations are the polarisation and frequency dependent scattering properties of hydrometers. In this contribution, the relevant scattering behaviour will be examined with the help of both actual radar measurements and model based scattering calculations. The polarisation and frequency based features crucial to the interpretation of radar echoes will be highlighted in the context of application. As a by-product, we shall also address the scattering behaviour expected at rather high frequencies of 24 and 77 GHz. Such high frequencies are now not out-of-question because of the emerging compact weather radar applications.

Presented by: **Chandra, Madhu**

Aperture synthesis radar imaging in coherent scatter radars: Results and lessons from Jicamarca

Jorge Chau [1], *D.L. Hysell* [2], *M. Urco* [1]
[1] *Radio Observatorio Jicamarca, Instituto Geofísico del Perú, Lima*
[2] *Earth and Atmospheric Sciences, Cornell University, Itahca, NY, USA*

Aperture synthesis imaging offers a means of observing atmospheric phenomena in three spatial dimensions with fixed-beam coherent scatter radars. The data supporting the imagery are cross-spectral visibility estimates obtained from spaced receivers on the ground. Extracting imagery from the data is an inverse problem and prompts an investigation of the existence, uniqueness, and stability of the solution. We describe different approaches to the imaging problem including nonparametric and parametric methods, with special emphasis on the MaxEnt algorithm, a Bayesian inversion scheme that uses Shannon's entropy as a prior probability estimate. Finally, we present results and lessons from experiments to observe ionospheric plasma density irregularities using coherent scatter data from the Jicamarca Radio Observatory.

Presented by: **Chau, Jorge**

Aspect sensitivity of clear-air measured by coherent radar imaging

Jenn-Shyong Chen [1], *Jun-ichi Furumoto* [2]
[1] *Department of Computer and Communication Engineering, Chienkuo Technology University, Taiwan*
[2] *Research Institute for Sustainable Humanosphere, Kyoto University, Japan*

Aspect sensitivity of refractivity irregularities in the clear-air was examined with multiple-receiver coherent radar imaging (CRI) of the MU VHF atmospheric radar in Japan. The so-called aspect angle, which is a measurement of aspect sensitivity, was estimated. Two CRI parameters retrieved by the Capon method were utilized to estimate the aspect angle: brightness width from vertical radar beam, and direction of arrival (DOA) of echo center from oblique radar beam. Differing from previous studies with CRI, however, a mitigation of radar beam weighting effect on the CRI brightness distribution was made before estimating the two CRI parameters.

To mitigate the radar beam weighting effect, the intensity distribution of the radar beam was described with a Gaussian function, and moreover, the standard deviation of the Gaussian function, defined as the radar beam width, was recommended to be adaptive to signal-to-noise ratio (SNR) of data as well as off-beam direction angle. Such kind of adaptable beam width has been proposed in our previous study to be able to yield a more reliable CRI brightness.

Observations showed that the aspect angles obtained from the modified brightness width of vertical beam were larger than those of without modification, and they were very close to the values derived from the DOA of 1^{o}-oblique radar beam, suggesting consistent results of the two approaches around the zenith. Moreover, the aspect angle derived from DOA varied with radar beam direction, which is similar to that suggested by some other methods such as comparison of echo powers of two different oblique radar beams. However, the DOA-approach yielded a larger aspect angle in the lower-SNR condition, as compared with the method of comparison of echo powers. Such characteristic of aspect angle gives a benefit: altitudinal variation of aspect sensitivity is more explicit and so the layers with high aspect sensitivity can be identified more clearly. This study has shown an application of adaptable radar beam width, and recommended a feasibility of improving the measurements of atmospheric parameters with CRI after removing the radar beam weighting effect from the CRI brightness.

Presented by: **Chen, Jenn-Shyong**

Introduction to the Kunming atmospheric radar facility (KARF) and the initial results

Jinsong Chen [1], *Lei Zhao* [1], *Na Li* [1], *Jian Wu* [1], *Jiyao Xu* [2]
[1] *China Research Institute of Radiowave Propagation*
[2] *Center for Space Sciences and Applied Research, Chinese Academy of Sciences*

In the late 2000s China Research Institute of Radiowave Propagation (CRIRP) has further expanded its research program to monitor the Earth's middle and upper atmosphere. In attempt to study the dynamics of the MLT region in lower latitude over China, the Kunming atmosphere radar facility (KARF) consisting of a MF radar, an all-sky meteor radar and a ST Doppler radar with meteor radar capability was installed at Kunming Radio Observatory (25.6o N, 103.8o E), 130 km northeast of Kunming which is the capital city of Yunnan Province, in August 2008 by CRIRP. Since then, continuous observation of winds in the MLT has been underway. KARF gives us opportunity to complement the study of atmosphere oscillations in low-latitude MLT region and the nonlinear interaction between atmospheric waves and ionosphere.

The initial results from the KARF during the first observation will be given, which include seasonal variations of tides and gravity waves from MF radar as well as the electron density in D region from Aug. 2008 to Jul. 2009. Also some outcomes from two special experiments launched on the KARF will be presented in this lecture. One involves meteors studied with the ST radar, and the other is related to winds observed simultaneously by the MF radar and two meteor radars with different frequencies in the Kunming site.

Presented by: **Chen, Jinsong**

An Investigation of Clear-air Scatter at Radio and Acoustic Frequencies

Phillip Chilson [1], Charlotte Wainwright [1], Christopher Wilson [1], Timothy Bonin [1], Phillip Stepanian [1], Daniel Russell [1], Abraham Frei-Pearson [1], Robert Palmer [1], Evgeni Fedorovich [1], Danny Scipion [2]
[1] University of Oklahoma, School of Meteorology
[2] École polytechnique fédérale de Lausanne

Active remote sensors such as radar wind profilers (RWP) and monostatic sodars rely on gradients in fields of refractive index and temperature, respectively, to generate backscattered signals from the atmosphere that can be monitored and interpreted. For the case when these gradients are generated by homogeneous and isotropic turbulence in the inertial subrange, the intensity of the backscattered signal can be related to the relevant structure function parameters: C_n^2 for RWPs and C_T^2 for sodars. We have been developing a multi-platform and multi-sensor approach based on empirical and simulated results to investigate the role of clear-air turbulence (CAT) on radar and sodar signal strengths collected in the stable and convective atmospheric boundary layer (ABL). Instrumentation incorporated into the study includes a sodar; a UHF RWP; small, instrumented unmanned aerial vehicles (UAV); instrumented meteorological towers; and rawindsondes. A large-eddy simulation (LES) code is used to generate dynamic and thermodynamic fields representative of the stable and convective ABL under realistic conditions. We have also developed virtual instruments capable of ingesting output fields from the LES and emulating the types of data produced by the RWP, sodar, and UAVs used in the study. Using the LES outputs we are able to determine the structure functions for temperature and the refractive index and, when applicable, the corresponding structure function parameters. Additionally, we have developed a means of estimating the structure function using data from the instrumented UAV and virtual UAV. In this presentation we i) briefly discuss the virtual sodar, RWP, and UAV; ii) describe the method of retrieving structure function parameters from our UAV observations; iii) compare results from the various platforms and methods; and iv) consider the applicability of different scattering theories for the atmospheric conditions being considered.

Presented by: **Chilson, Phillip**

Radar Atmospheric Imaging Techniques: An Overview

Phillip Chilson
University of Oklahoma, School of Meteorology

On the most fundamental level, an atmospheric radar's spatial resolution is prescribed by the aperture of its antenna and duration of the transmitted pulse (and corresponding filters). The recipe to enhance resolution is simple: increase the effective area of the antenna to achieve better angular resolution and transmit / receive narrower pulses to improve range resolution. However, it may not always be feasible to implement these modifications on account of such factors as construction cost or space limitations or frequency limitations. Moreover, radars with narrow beam widths can only detect a limited region of the atmosphere at a given time. Therefore the beam must be mechanically or electronically scanned in order to observe a larger swath of the atmosphere. Ideally, one would like to produce a wide-angle "snapshot" of the atmosphere while still maintaining good angular and range resolution. This can be achieved using imaging techniques. This presentation provides an introduction to radar atmospheric imaging techniques and illuminates some of the benefits and pitfalls associated with them. Several examples of radar systems that utilize imaging techniques along with observations collected with them are presented and discussed.

Presented by: **Chilson, Phillip**

Implementation, Calibration, and Testing of Range Imaging on the Lindenberg 482-MHz Radar Wind Profiler

Phillip Chilson [1], *Volker Lehmann* [2]
[1] *University of Oklahoma, School of Meteorology*
[2] *Deutscher Wetterdienst, Meteorologisches Observatorium Lindenberg*

In November 2009, a new 482-MHz Radar Wind Profiler (RWP) was installed at the Meteorological Observatory Lindenberg (MOL) in Germany. The shortest pulse used by the system is 1.0 µs (corresponding to a nominal range resolution of 150 m) and the occupied bandwidth is about 1.7 MHz. The system is equipped with a digital receiver RVP-910 and it is possible to operate the RWP in a range imaging (RIM) mode using five different carrier frequencies within the bandwidth of the system. Two sets of experiments have been conducted in 2010 and 2011 to i) test the RIM functionality on the 482-MHz RWP, ii) explore possible frequency sets for operational use, iii) develop a means of calibrating the RWP for RIM operation, iv) operate the RWP in RIM mode during several meteorlogical events, v) develop RIM analysis software for the RWP, and vi) compare the RIM results with other data sets. In this presentation we provide an overview of the RIM capabilities of the Lindenberg 482-MHz RWP along with first results from these experiments.

Presented by: **Chilson, Phillip**

The Wave-Driven Circulation and Variability of the Wintertime Arctic Middle Atmosphere

Richard Collins [1], *Amal Chandran* [1], *V. Lynn Harvey* [2], *Kohei Mizutani* [3], *Michael Gerding* [4], *Gerd Baumgarten* [4], *Anja Stromme* [5], *Rolando Garcia* [6], *Daniel Marsh* [6]
[1] *University of Alaska Fairbanks*
[2] *University of Colorado Boulder*
[3] *National Institute of Information and Communications Technology*
[4] *Leibniz Institute of Atmospheric Physics*
[5] *SRI International*
[6] *National Center for Atmospheric Research*

An international network of four Rayleigh lidars located in observatories at Andoya, Norway (69°N, 16°E), Chatanika, Alaska (65°N, 147°W), Kangarlussuaq, Greenland (67°N, 51°W) and Kühlungsborn, Germany (54°N, 12°E) provide a chain of measurements from the eastern Arctic to the western Arctic under distinct synoptic regimes (i.e., the Arctic stratospheric vortex, the Aleutian anticyclone, the stratospheric surf-zone). In this paper we present the use of satellite measurements, lidar measurements, meteorological analyses, and model simulations to understand the wave-driven circulation and variability of the polar atmosphere. Recent Arctic winters have seen major disturbances in the wintertime circulation associated with major Sudden Stratospheric Warming and Elevated Stratopause events. These disturbances are associated with major changes in the planetary wave and gravity wave forcing of the circulation. The lidars yield high-resolution temperature and density measurements that allow characterization of the planetary waves, tides, and gravity waves. The satellite observations yield synoptic-scale temperature measurements of the mesosphere and upper stratosphere while the meteorological soundings and analyses provide synoptic-scale measurements of the troposphere and lower stratosphere. The Whole Atmosphere Community Climate Model provides both free-running and specified dynamic simulations that allow investigation of the observed planetary and gravity wave activity in the Arctic atmosphere. We use this approach to study the circulation at local, regional and global scales. We present results from recent International Polar Year observations, analysis, and simulations associated and discuss current and future studies.

Presented by: **Collins, Richard**

Resonance lidar measurements of atomic energy states in the auroral E-Region

Richard Collins [1], Xinzhao Chu [2], Zhibin Yu [2], Chester Gardner [3], Michael Nicolls [4]
[1] University of Alaska Fairbanks
[2] University of Colorado Boulder
[3] University of Illinois at Urbana-Champaign
[4] SRI International

Resonance lidar observations at Chatanika, Alaska have revealed the presence of large high-altitude sodium layers (~ 110 km) during active aurora [Collins et al., 1996]. More recently lidar observations from McMurdo, Antarctica have revealed the presence of atomic iron present in the E-Region (up to 150 km) coincident with strong auroral displays [Chu et al., 2011]. The lidar measurements, made with an iron Boltzmann lidar, recorded the concentration of iron atoms both in the ground state and first excited state using the 371.993 nm and 373.713 nm transitions respectively [Gardner et al., 2001; Chu et al., 2002]. A Boltzmann thermal analysis of the ratio of the population of iron atoms in the excited state to the ground state suggests temperatures that are several hundred Kelvin higher than the expected from MSIS [Chu et al., 2011]. This initial analysis reveals a temperature profile that has a shape and peak amplitude that is similar to that expected for the Joule heating profiles and provide direct observation of the thermal response of the E-region to auroral forcing. These Antarctic lidar measurements revealed the energetics of the neutral iron atoms, but could not document the structure of iron ions. An Incoherent Scatter Radar (ISR) would provide plasma measurements, independent Joule Heating estimates. In this paper we present an experiment where we use an iron Doppler lidar [Lautenbach and Höffner, 2004; Chu et al., 2008] and an iron density lidar [Hou, 2002] to simultaneously measure the energetics of atomic iron in the ground and first excited state. The iron Doppler lidar provides the population and temperature of the iron atoms using the Doppler broadening of the 371.993 nm transition. The iron density lidar provides the population of the iron atoms in the first excited state using the 373.713 nm transition. Coordinated observations that combine imager, lidar, and radar observations offer the opportunity to more fully understand the energetics of the E-region during auroral substorms and advance our understanding of ion-neutral coupling in the atmosphere.

Presented by: **Collins, Richard**

A VHF profiler network study: Upper level divergence and the SW Ontario tornadoes of Aug 2011.

Matthew Corkum [1], *Peter Taylor* [1], *ZhengQi Wang* [2], *Shama Sharma* [1]
[1] *CRESS, York University*
[2] *ESSE, York University*

Researchers from York University, University of Western Ontario, and McGill University have now completed the acquisition and installation of a Canadian regional scale network of ten Mardoc WindTtracker VHF wind profilers (the O-QNet) in Ontario and southern Quebec. These are providing a valuable data set of hourly and three-hourly winds from about 400m to 15 km above the surface.

We have made a series of comparisons with NWP model analyses and forecasts. We are also using sets of three profilers in triangular arrays to compute upper level divergence and vorticity as indicators of severe summer weather. The approach was originally tested by Zamora et al (1987) but it does not appear to have been used extensively on an operational basis. The goal is to compute divergence and vorticity in real time and supply them to weather forecasters as an additional tool to help identify regions with the potential for severe summer storm development. Radiometers are also being used (by Environment Canada) to obtain temperature and humidity profiles at one location in the region.

We are currently looking at data for Aug 21 24, 2011 when several tornadoes occurred in southern Ontario, including an F3 at Goderich. The profiler data show an upper level divergence pattern crossing the region. We are also computing divergence and vorticity patterns from the forecast models in order to compare with the observed patterns.

Winter cases will also be investigated to see if probable snowsquall regions can be identified.

Zamora, R.J., M.A. Shapiro, and C.A. Doswell, III, 1987: The Diagnosis of Upper Tropospheric Divergence and Ageostrophic Wind Using profiler Wind Observations, Mon. Wea. Rev., 115, 871-874.

Presented by: **Corkum, Matthew**

Further investigation on stratospheric air intrusion in to the troposphere during the episode of tropical cyclone: Numerical simulation and MST radar observations

Siddarth Shankar Das , *S Sijikumar* , *Kizhathur Narasimhan Uma*
Space Physics Laboratory, Vikram sarabhai Space Centre

Stratosphere-troposphere exchange (STE) process has been a topic of research for past several decades due to its impact on global climate change. In this aspect, many ground based, in-situ, satellite measurements, and modelling have been carried out to improve our understanding of physical, chemical and dynamical processes that couples stratosphere and troposphere. Tropical cyclone and convection are the two source mechanisms that give raises to STE processes over tropical region. Owning the important of STE associated with cyclone over the tropical atmosphere, for the first time, spatiotemporal structure of stratospheric air intrusion into the troposphere during the passage of tropical cycloneis simulated using Advanced Research-Weather Research and Forecast (WRF-ARW) model. The WRF-ARW simulation effectively reproduces the spatiotemporal evolution of vertical velocity associated with tropical cyclone and shows good agreement with the mesosphere-stratosphere-troposphere (MST) radar observations at Gadanki (13.5^{o}N, 79.2^{o}E). The observed intrusion in the upper-troposphere has a narrow band with the width of about 50 km and stretch over 200-250 km and vertical structure of 5-6 km. This study shows that the intrusion occurs in the periphery of the cyclone. The detail results will be presented and discussed in the upcoming workshop.

Presented by: **Das, Siddarth Shankar**

Seasonal characteristics of Kelvin-waves in the mesosphere and lower thermosphere (MLT) region over an equatorial station Thumba using SKiYMET meteor wind radar

Siddarth Shankar Das [1], *S Suheela* [2], *Anu Krishna* [2]
[1] *Space Physics Laboratory, Vikram sarabhai Space Centre*
[2] *Dept. of Physics, University of Kerala*

The detailed study of mesosphere lower thermosphere and ionosphere region has historically been difficult because of its relative inaccessibility to direct measurement techniques and the complex and highly coupled processes which occur there. However with the use of various in-situ and ground based probing techniques of the middle atmosphere which includes MST radar, all-sky SKiYMET meteor wind radar, the various atmospheric parameters like wind and temperature can be measured. Tides, planetary wave and gravity wave, forced their in-situ or at lower levels, all participates in and frequently dominates the dynamics of this region. Lower boundaries for the thermosphere models and the upper boundaries for the mesospheric models have been usually specified in lower thermosphere near 80-120 km. this can be a difficult region for the specification of the boundary condition on chemicals and energy balance models because constituents and heat transfer occur readily between thermosphere and mesosphere. Thus for the climate variability and weather prediction, the thorough knowledge of the atmospheric waves especially at mesosphere and lower thermosphere (MLT) region is required. MLT region is dynamically controlled by the wave activities namely; gravity waves, planetary waves and tides which are mainly originate at the lover atmosphere and dissipate their energy and momentum fluxes in the mesospheric region. The major emphasis of the present work was to establish the seasonal characteristics of Kelvin wave in the mesosphere and lower thermosphere (MLT) over and equatorial station Thumba using Meteor wind radar. The detail results will be presented and discussed in the upcoming workshop.

Presented by: **Das, Siddarth Shankar**

The climatology, propagation and excitation of ultra-fast Kelvin waves

Robin Davis [1], *Saburo Miyahara* [2], *Ying-Wen Chen* [2], *Nicholas Mitchell* [1]
[1] *University of Bath*
[2] *Kyushu University*

Wind measurements from a meteor radar on Ascension Island (8°S, 14°W) and simultaneous temperature measurements from the Aura MLS instrument are used to characterise ultra-fast Kelvin waves (UFKW) of zonal wavenumber 1 (E1) in the mesosphere and lower thermosphere (MLT) in the years 2005–2010. These observations are compared with some predictions of the Kyushu-general circulation model. Good agreement is found between observations of the UFKW in the winds and temperatures, and also with the properties of the waves in the Kyushu-GCM. UFKW are found at periods between 2.5–4.5 days with amplitudes of up to 40 m/s in the zonal winds and 6K in the temperatures. The average vertical wavelength is found to be 44km. Amplitudes vary with latitude in a Gaussian manner with the profiles centred over the equator. Dissipation of the waves results in monthly-mean eastward accelera- tions of 0.2–0.9 m/s/day at heights around 95 km, with 5-day mean peak values of 4 m/s/day. Largest wave amplitudes and variances are observed over Indonesia and central Africa and may be a result of very strong moist convective heating over those regions. Rainfall data from TRMM are used as a proxy for latent-heat release in an investigation of the excitation of these waves. No strong correlation is found between the occurrence of large-amplitude mesospheric UFKW events and either the magnitude of the equatorial rainfall or the amplitudes of E1 signatures in the rainfall time series, indicating that either other sources or the propagation environment are more important in determining the amplitude of UFKW in the MLT. A strong semiannual variation in wave amplitudes is observed. Intraseasonal oscillations (ISOs) with periods 25–60 days are evident in the zonal background winds, zonal-mean temperature, UFKW amplitudes, UFKW accelerations and the rainfall rate. This suggests that UFKW play a role in carrying the signature of tropospheric ISOs to the MLT region.

Presented by: **Davis, Robin**

Winds, tides and waves in the mesosphere and lower thermosphere over Bear Lake Observatory (42N 111W)

Kerry Day [1], *Michael Taylor* [2], *Victoria Howells* [1], *Nicholas Mitchell* [1]
[1] *The University of Bath*
[2] *Utah State University*

Atmospheric temperatures and winds in the mesosphere and lower thermosphere have been measured simultaneously using the Aura satellite and a meteor radar at Bear Lake Observatory (42N, 111W). The data presented in this study is from the interval March 2008 to July 2011.

The mean winds observed in the summer-time over Bear Lake Observatory show the meridional winds to be equatorward at all heights during April-August and to reach monthly-mean speeds of – 12 m/s. The mean winds are closely related to temperatures in this region of the atmosphere and in the summer the coldest mesospheric temperatures occur about two weeks after the strongest equatorward meridional winds. In other seasons the meridional winds are poleward, reaching monthly-mean values of up to 12 m/s. The zonal winds are eastward through most of the year and in the summer strong eastward zonal wind shears of up to 4.5 m/s/km are present. However, westward winds are observed at the upper heights in winter and sometimes during the equinoxes. Comparisons of the observed winds with URAP and HWM-07 reveal some significant differences.

Observations of the 12- and 24-hour tides reveal that both tides can reach large amplitudes over Bear Lake, with monthly-mean amplitudes reaching up to 50 and 35 m/s, respectively. Both tides display a clear seasonal cycle. The 12-hr tide maximises in September and December-February. The 24-hour tide maximises in March-April. Comparisons with the Global Scale Wave Model 2009 suggest that the model effectively predicts the September maximum of the 12-hour tide, albeit at smaller amplitudes than observed, but does not predict the winter maximum. In the case of the 24-hour tide, the observed amplitudes are reproduced well, but a predicted autumnal maximum is not observed.

Signatures of the 16- and 5-day planetary waves are clearly evident. Short-lived wave events can reach large amplitudes of up to ~ 15 m/s and 8 K and 20 m/s and 10 K for the 16- and 5-day wave, respectively. A clear seasonal and short-term variability are observed in the 16- and 5-day planetary wave amplitudes. The 16-day wave reaches largest amplitude in winter and is also present in summer, but with smaller amplitudes. The 5-day wave reaches largest amplitude in winter and in late summer. An inter-annual variability of the amplitude of the planetary waves are evident in the four years of observations.

Presented by: **Day, Kerry**

A Mini VHF BLR and the known FCA Wind Magnitude Underestimation

Bronwyn Dolman [1], *Iain Reid* [2], *Andrew MacKinnon* [3]
[1] *ATRAD Pty Ltd*
[2] *University of Adelaide & ATRAD Pty Ltd*
[3] *University of Adelaide*

Radars utilising the Spaced Antenna (SA) Full Correlation Analysis (FCA) technique are known to measure excellent agreement in direction, but typically underestimate the wind magnitude, when compared to other measurement techniques. This magnitude underestimation occurs in all regions of the atmosphere, and results from any effect that suppresses the correct value of the cross-correlation functions of the fading time series calculated between the antenna pairs.

ATRAD developed a miniature Boundary Layer (mini-BL) profiler in 2003, operating at VHF, and consisting of just 3 antennas. The system was deployed at Buckland Park, the University of Adelaide field site, and was used in a 4 day trial, where mini-BL wind estimates were compared to a larger 27 antenna BL profiler. Results of the trial suggest the mini-BL measured wind magnitudes 5-10% greater than the BL, with excellent agreement in direction. Due to equipment requirements, these results were not investigated further.

In 2010 the mini-BL was re-installed at Buckland Park. A study was conducted in 2010, where the mini-BL was set to receive only, and listened to the transmit signal from a nearby 55 MHz 27 antenna BL array. In late 2011 the mini-BL and BL were run as stand-alone systems in an interleaved manner. Results from both studies will be discussed, with particular attention to the bias discussion.

Presented by: **Dolman, Bronwyn**

Small Modular 449 MHz Wind Profiling Radar – First Results

Bronwyn Dolman [1], Iain Reid [2], Robert Vincent [3], Andrew MacKinnon [3], Richard Mayo [1], Gary Jonas [1], Jonathan Woithe [1]
[1] ATRAD Pty Ltd
[2] University of Adelaide & ATRAD Pty Ltd
[3] University of Adelaide

ATRAD Pty Ltd has recently developed a low cost, portable, wind profiling radar. The profiler operates at 449 MHz, using 3 Yagi antennas, and has been designed to be capable of rapid field deployment. The system is also modular in nature, and can be deployed as a single unit, or as an array. The profiler uses the Spaced Antenna Full Correlation Analysis technique to measure the vertical and horizontal wind fields from near ground to around 300 m.

First results from the deployment of the radar will be presented.

Presented by: **Dolman, Bronwyn**

Single- Compared to Dual-Frequency DSD Retrievals During TWP-ICE

Bronwyn Dolman [1], *Christopher Williams* [2]
[1] *ATRAD Pty Ltd*
[2] *CIRES/NOAA*

Well established techniques exist for retrieving the raindrop size distribution (DSD) using either VHF or UHF wind profiling radars. VHF profilers are useful tools in rainfall studies, as they receive echo from both clear-air and precipitation with roughly equal magnitude. A major limitation of VHF retrievals is the inability to retrieve the smallest drops, as the relevant part of the precipitation spectrum is obscured by the clear-air. UHF profilers are capable of retrieving smaller drops, but the clear-air echo is masked by the precipitation peak in all but light rainfall. Correcting the precipitation peak for vertical air motion is a crucial step in the retrieval process, and so the clear-air information must be taken from a VHF profiler. Thus the dual-frequency technique is capable of retrieving smaller drops, but suffers the obvious fiscal drawback of requiring two co-located profilers. Based on a modeling study, we have developed a VHF correction factor for small drops. The first aim of the current study is to compare results obtained using this correction factor, to those obtained using the dual frequency technique.

The TWP-ICE field campaign was conducted in Darwin in January and February 2006. During the campaign, the University of Adelaide operated a VHF Boundary Layer Profiler, located on the ARM site at Darwin airport. At a field site 8 km to the East, the Australian Bureau of Meteorology operated a VHF profiler, co-located with a UHF profiler. All rain events which passed over the University of Adelaide profiler during the campaign have been retrieved and analysed. The same technique will be used to analyse some of the same rain events using the Bureau of Meteorology profiler. These results can then be compared to those obtained using the dual frequency system, and the small drop correction examined. The second aim of this study is to use both VHF retrievals to examine the evolution of the rain field over the 7 km spatial separation. Initial results will be discussed.

Presented by: **Dolman, Bronwyn**

RASS optimisation for mid-latitude summers

Andrew MacKinnon , Bronwyn Dolman , Lenard Pederick , Iain Reid
University of Adelaide

The University of Adelaide operates a Radio Acoustic Sounding System (RASS) at its Buckland Park field site, used in conjunction with a 40 kW, 144 antenna 55 MHz ST profiler. This RASS system consists of three large speakers each individually power by a 1kW amplifier, with each speaker having an acoustic output of over 130 dB. In early 2011, the RASS system was deployed to take advantage of a 2 week field campaign at Buckland Park, which involved a comparison between radar-derived wind profiles and 48 GPS sondes. RASS operated for 5 minutes of every hour between 9 am and 5 pm LT, when a balloon was not in the air. Dependent on the synoptic situation, virtual temperature profiles were recovered from 500 m, to a maximum height between 1 and 5 km. The variation in height coverage prompted a modeling study, which used ray tracing algorithms to optimise the three speaker's placements. The goal of which was to determine optimal placement of the three speakers for a given month or season, depending on horizontal wind patterns. Based on these findings, in early 2012, the speakers were placed in an orientation optimal for the prevailing synoptics of the South Australian Summer. A mini-campaign was then conducted, to examine variations in height coverage, with speakers optimized for the season.

Results from the original field campaign, the modeling study and the mini-campaign will be presented.

Presented by: **Dolman, Bronwyn**

Planetary wave activity during the summer months of 2007 over Gadanki

M.C. Ajay Kumar [1], *Gopa Dutta* [2], *et al.*
[1] *Vanjari Seethaiah Memorial Engineering college*
[2] *Vignana Bharathi Institute of Technology*

Daily wind data measured by MST radar at Gadanki (13.5^o N,79.2^o E) during the summer months of 2007 have been analysed for planetary wave activity in the altitude range of 3-20 km. Fourier Transform Technique (FFT) has been applied to study the amplitude and frequency variations of these oscillations. Strong peaks in zonal and meridional winds are found at 2.5 d, 4 d, 6.5 and 7.5-8.5d periods. A Kelvin wave of 12-15 d period is also seen in zonal wind. The 7.5-8.5 d period wave is found to be most dominant both in zonal (5.6 m/s) and meridional (2.75 m/s) winds at lower stratospheric heights. The Kelvin wave shows maximum amplitude (5 m/s) at ~18 km. The ECMWF Re-Analysis (ERA-Interim) wind data of approximately the same latitude – longitude have been downloaded for the same period and similar analysis have been carried out. The results obtained from radar data and ERA data show striking similarity in period and structure of the waves. The squared-coherence values between the two datasets in terms of cross-spectral amplitudes are found to be highly significant.

Presented by: **Dutta, Gopa**

Response of tropical lower atmosphere to annular solar eclipse of 15 January, 2010

Gopa Dutta [1], *P. Vinay Kumar* [1], *M. Venkat Ratnam* [2], *Salauddin Mohammad* [1], *M. C. Ajay Kumar* [3], *P. V. Rao* [4], *H. Aleem Basha* [5]
[1] *Vignana Bharathi Institute of Technology, Ghatkesar, Hyderabad, India.*
[2] *National Atmospheric Research Laboratory, Gadanki, India.*
[3] *Vanjari Seethaiah Memorial College of Engineering, Patancheru, Hyderabad, India.*
[4] *Vasavi College of Engineering, Ibrahimbagh, Hyderabad, India.*
[5] *Moulana Azad National Urdu University, Gachibowli, Hyderabad, India*

Special experiments were conducted with GPS radiosonde, ozonesonde and MST radar at two tropical Indian stations Hyderabad and Gadanki during the annular solar eclipse of 15 January 2010. Control observations in similar atmospheric conditions have been compared with 15 January measurements to find the eclipse induced effects.

A decrease in tropopause height is observed during and after the end of eclipse. A fall/rise in temperature and ozone concentration is observed below/above the tropical tropopause. Total ozone does not change during eclipse due to its long life time, but its vertical distribution changes. Zonal wind shows significant enhancements (~ 12-16 m/s) in both the stations confirming that the change is due to the obscuration of the sun. Changes in meridional winds are not appreciable.

Study of short period (<2 h) gravity waves show clear enhancement of high frequency (5-15 min) waves close to Brünt Väisälä period in the upper tropospheric and lower stratospheric regions. Higher activity could be observed after the beginning of the eclipse and persisted throughout the observation period. A 40-60 min wave is found to be suppressed in north beam winds during eclipse whereas a 25-35 min wave gets stronger in the east beam measurements. The dynamical changes observed in this region could be responsible for the redistribution of atmospheric species.

Presented by: **Dutta, Gopa**

Piracy, maritime operations and radar-an overview in Nigeria

Aniekan Ediang [1], *Okuku Ediang* [2], *et al.*
[1] *The Nigerian Maritime Administration and Safety Agency, NIMASA, 6 Burmal Road, Apapa, Lagos, Nigeria*
[2] *Marine Division, Nigerian Meteorological Agency*

Despite the importance of the neigbouring oceans to the economics, climates and biodiversity of many Africa Countries, the problems of managing successful maritime safety and security along different coastlines still exist. The research paper is intended to stimulate discussion and recommendations relating to bridging the gap between maritime safety/Security and radar/global satellite data as it relate to marine meteorological forecast in Nigeria and its role in sustainable development in an African context. The paper recognizes that National Meteorological Service (NMSS) must do more than simply pay up services to sustainable development and must focus issues of relevance facing society in area of marine meteorological forecast as it relate to maritime safety and security along its coastal areas.

Presented by: **Ediang, Aniekan**

Taking some advantage from a maritime accident and security along the coastline of Gulf of Guinea via radar feed back management system

Okuku Ediang [1], *Aniekan Ediang, et al.*
[1] *Nigerian Meteorological Agency, PMB1215 OSHODI LAGOS, Nigeria*

This paper gives a general overview of taking some advantage from maritime accident and security along the coastline of Gulf Guinea via Radar feedback Management System.

This work aims at identifying that in West Africa, imagery from radar and satellites observations do provide a mechanism for describing weather features such as Cloud, Precipitation patterns and pressure systems. It's possible to make useful inference about the fields of wind flow.

The rest of the paper is therefore organized first to consider radar is therefore becoming increasingly important for long range planning with developing countries. Secondly, concur that a next several endeavor's to pinpoint certain directions along which future research effort could bedirected for the rest of the 21st century especially in radar as it relates to Maritime Accident and Security along the Coastline of Gulf of Guinea.

Presented by: **Ediang, Okuku**

Investigations on the variability of the tropical mesospheric echoes, winds, waves and associated momentum fluxes

Sunkara Eswaraiah [1], *M. Venkat Ratnam* [2], *B.V. Krishna Murthy* [3], *S. Vijaya Bhskara Rao* [1]
[1] *Sri Venkateswara University, Tirupati-517502, India*
[2] *National Atmospheric Research Laboratory (NARL), Gadanki, Tirupati-517 502, India*
[3] *B1, CEEBROS, Chennai-600020, India.*

For the present thesis work, an extensive long-term database (1998-2009) of high-resolution Indian MST radar observations along with Rayleigh LIDAR (1998-2008), GPS radiosonde (2006-2010) and M-100 rocket (1971-1991) observations has been used. A campaign is also conducted during 13-17 January 2010 to address the eclipse effects on the middle atmosphere.

It is observed that long duration (20-40 minutes and above 40 minutes) echoes occurred mostly in 70-80 km altitude region and are highly sporadic in the regions above and below it. Further, solar zenith angle dependence on the duration of mesospheric echoes was found insignificant. Significant reduction in the echo occurrence is found at the maximum epoch of the solar eclipse as expected. Calculations of D region electron density during eclipse day and on a normal day revealed that background electron density on a normal day prevailing at ~0700 hrs IST existed during solar eclipse maximum obscuration time. High frequency gravity waves close to the eclipse path are detected in the troposphere and mesosphere which is not expected.

The observed mesospheric vertical winds are generally upward in all the seasons. The vertical wind can reach occasionally values as high as 5 ms^{-1} but most of the time (95%) it is, in general, less than ~2.63 ms^{-1}. The present observations are consistent with the general circulation features in recent models for low latitude locations with northward and upward wind prevailing throughout the year representing part of meridional circulation. Though there is a difference in the wind magnitude between MST radar observations and the model, the trends match well particularly between 70 km and 75 km.

The variability in the momentum flux from troposphere to mesosphere associated with the gravity waves of periods 20 min. to 2 h is also investigated. An effort is also made to examine the variations in momentum flux for different cases, viz., during the occurrence of mesospheric temperature inversion and convection events. Interestingly, the vertical flux of zonal momentum estimated from lidar is in the range of those estimated from radar data in the overlap altitude region, though the estimates are from two different techniques. In summer large variations with altitude in mesospheric zonal momentum flux are noticed with a magnitude ~0- 4 m^2/s^2. The meridional fluxes in the mesosphere are higher in equinoxes (~10-12 m^2/s^2). This study will help in better understanding the dynamical aspects of tropical mesosphere using VHF radar observations.

Presented by: **Eswaraiah, Sunkara**

Advances in science and techniques of mesosphere, stratosphere, and troposphere (MST) radar

Shoichiro Fukao
Fukui University of Technology/ Research Institute for Sustainable Humanosphere, Kyoto University

Atmospheric radars generally called MST (mesosphere, stratosphere, and troposphere) radars or ST radars are, with certain limitations, capable of remotely and continuously sensing three-dimensional winds, waves, turbulence, and atmospheric stability over the wide altitude range 1-100 km in the Earth's atmosphere. In particular, direct measurement of vertical wind velocity over such a wide altitude range is possible only with MST radars. Their time resolution of about 1 min and altitude resolution of 75-150 m are unequalled by conventional instruments (e.g., rawinsondes and rocketsondes), making it possible for MST radars to quantitatively investigate the small-scale atmospheric gravity waves that are considered to play important roles in the dynamics of the Earth's atmosphere. Recently, range imaging modes with multiple carrier frequencies have been incorporated in atmospheric radars for an extensive study of micro-scale Kelvin-Helmholtz instabilities and other small-scale processes in the upper troposphere and lower stratosphere.

In the last four decades, this excellent capability has been extensively used to study various dynamical disturbances in the Earth's atmosphere and ionosphere, developing new frontiers of atmospheric research on, primarily, mesoscale and micro-scale phenomena. In the present talk, these advances including application to the practical weather forecast are briefly reviewed.

Presented by: **Fukao, Shoichiro**

Structure and dynamics of air inhomogeneities in the environment of a cirriform cloud from balloon and high-resolution radar measurements

Hubert Luce [1], Shoichiro Fukao [2], Masayuki K. Yamamoto [3], Hiroyuki Hashiguchi [3], Tomoaki Mega [4], Takuya Tajiri [5], Masahisa Nakazato [6]
[1] South Toulon-Var University, La Garde, France
[2] Department of Space Communication Engineering, Fukui University of Technology, Japan
[3] Research Institute for Sustainable Humanosphere, Kyoto University, Japan
[4] Division of Geophysics, Graduate School of Science, Kyoto University, Japan
[5] Meteorological Research Institute, Tsukuba, 305-0052, Japan
[6] Japan Meteorological Agency, Tokyo, Japan

The vertical structure of clouds and air inhomogeneities and their time evolution can be directly measured by vertically pointing radars. This information is generally inferred from aircraft paths, but only at different altitudes and different times, with a time spacing much larger than the span life of the cloudy and clear air structures. Consequently, co-located ground-based cloud and clear air radars are a unique combination of tools for getting some insights into cloud thermodynamics and interaction with their environment.

In October/November 2008, a multi-instrumental experiment was conducted at Shigaraki MU observatory, including the VHF MU radar (mainly sensitive to air refractive index irregularities) in range imaging mode (resolutions: ~several ten meters, ~20 s) and a Ka-band (35.25 GHz) cloud radar sensitive to hydrometeors (resolutions: 50 m, 20 s).

On 11/12 November 2008, cirrus and fallstreaks were monitored by the Ka-band radar above the altitude of 7.3 km. The time-height cross-section of equivalent radar reflectivity revealed convective cloud cells developing at the top of a stratiform cloud layer up to 9.0 km. The convective nature of these structures was supported by the observation from the MU radar of upward air velocities inside the cells and by the identification from balloon data of a conditional instability in their altitude range. Downward air motions were observed between and around the top of the cells. In addition, the cloudy cells were associated with complex features in MU radar echoes: in particular, time-height cross-section of MU radar echo power showed enhancements between the cloud cells (appearing as vertical striations in the images) with maxima at their base. Interpretations of these original observations will be given.

These results support the high potentials of combining high resolution ST radars with cloud radars for investigating cloud dynamics at small scales.

Acknowledgement:
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Presented by: **Fukao, Shoichiro**

Monitoring and data assimilation of Wind Profiler

Catherine Gaffard [1], David Simonin [1], Colin Parrett [1], Richard Marriott [1], Dirk Klugmann [1], David Hooper [2]
[1] UK Met Office
[2] STFC Rutherford Appleton Laboratory

The monthly monitoring against model data show that wind profilers are giving wind with an accuracy comparable to radiosonde wind measurements. The wind profiler winds have been assimilated as radiosonde winds with an error which varies with height but is independent of the site. Variation in quality exists between wind profilers due to contamination associated with specific site (ground clutter, sea clutter, RFI, aging of the antenna). As a first approximation and because when the error exceed a certain threshold wind profilers are blacklisted automatically, the use of non site dependent error is valid. However different wind profilers have different vertical resolutions and a better error characterisation should improve the assimilation of the wind profiler.

In this paper we show some results of the operational monitoring. We will present very preliminary results on adjoin tools sensitivity and show the potential use of such technique to improve the blacklisting process. We look in more detail at the observed quantity and its equivalent model. In particular we show how wind profiler winds are actually used in the UK Met Office UM. One example of wind profiler data assimilation and forecast impact in the very high resolution model (1.5km) is presented.

Presented by: **Gaffard, Catherine**

Radar observations of the Perseid meteor shower activity and meteoroid stream structure from the Gadanki MST radar

Yellaiah Ganji , *K. Chenna Reddy*
Osmania University, Hyderabad

We report the results of our study of Perseid meteoroid stream mass distribution from the shower activity during the year 2004 – 2010 recorded at the Gadanki (13.46^o N, 79.18^o E) MST radar. The distribution of meteor signals reflected from backscatter radar is considered according to their duration.This time duration (t) is used to determine the relative flux of the shower in different particle size ranges producing different classes of echoes with duration intervals t <0.4 s, t = 0.4 – 1.0 s and t ≥1.0 s. From this duration classes, mean activity curves are determined for different sizes of the meteoroid particles of the stream.The averaged value of mass index (s) is 1.67±03 on the peak day of the shower activity. It is sheen that the particle mass distributions are qualitatively same along the entire orbit of the stream. Activity profiles in three echo durations categories are slightly differ in the position of the peak activity which range in the solar longitude of $139^0 \leq \lambda_o \leq 140^0.5$ (J2000.0). The mean activity profiles are showing a systematic change withwax and wane in the strength of the shower outburst.

Presented by: **Ganji, Yellaiah**

'Sky noise' temperature recorded by the UK MST radar at 46.5 MHz

Ivan Astin [1], *Bala Goudar* [1], *David Hooper* [2]
[1] *University of Bath*
[2] *Rutherford Appleton Laboratory*

We present a study of 'sky noise', that has been recorded by the UK MST radar on a quasi-continuous basis since 1997. This data is routinely used to derive SNR. However, it hasn't been the subject of serious study, even though it can be used for long-term system performance monitoring and calibration. There was, however, a short study made in the early 1990s by the University of Sheffield who (in an unpublished report) used signals from the radio source Cassiopeia-A to show that the one of the UK MST radar beams (NE6) was within 0.1º of its nominal pointing direction. We repeat this study here, and show that there has been little change in the beam pointing angle over the 20 years since then. The only change is that the noise power (at a given right ascension and declination) fluctuates by 1-2 dB over time, due to ionsopheric absorption (with the radar acting as a riometer). We also show that both Cassiopeia-A, and Cygnus-A, can be clearly seen by other beams not considered in the Sheffield study, and provide a radio 'map' of the sky at 46.5 MHz covering 24 hours of right ascension and declination from 41º to 60º North. We compare our results to those of Campistron *et al.* (2001)*, who produced a similar map at 45MHz using five ST radars in Continental Europe.

*B. Campistron, G. Despaux, M. Lothon, V. Klaus, Y. Pointin, and M. Mauprivez (2001), 'A partial 45 MHz sky temperature map obtained from the observations of five ST radars', *Annales Geophysicae* 19: 863–871

Presented by: **Goudar, Bala**

Adaptive suppression of aircraft clutter with the PANSY radar training system

Taishi Hashimoto [1], *Koji Nishimura* [2], *Kaoru Sato* [3], *Toru Sato* [1]
[1] *Kyoto University*
[2] *National Institute of Polar Research*
[3] *The University of Tokyo*

PANSY (Program of Antarctic Syowa MST/IS Radar) is a project to construct a large atmospheric radar at Antarctic Syowa Station. PANSY is the first MST radar in the Antarctic region that is the only instrument capable of continuously monitoring three-dimensional structure of the air in high altitude and time resolutions, and thus is expected to substantially progress the polar atmospheric science. PANSY has two antenna arrays, large main array with 1045 Yagi antennas and smaller one towards the direction of the magnetic south pole for the observations of FAI (Field Aligned Irregularity).
Although FAI echoes are of great scientific interests, they can be interferences for the observation of ionospheric incoherent scattering around 100 km, so we must arrange a countermeasure in advance.
Ahead of the construction of PANSY, a training system named "Sumire" had been set up in Shigaraki MU Observatory, Japan. There is a busy air traffic around the observatory, and their clutter has been the pending problem in the atmospheric observations of the MU radar.
Aircraft clutters are similar to FAI echoes in that they are both strong backscattering from rapidly moving objects, but it is less complicated because of its linear movement. For the aircraft clutter suppression with atmospheric radar, a combination of DCMP-CN (Directionally Constrained Minimization of Power with Constraint of Norm) and DOA (Direction Of Arrival) estimation has been suggested. The approach is as follows. First we estimate the DOA of aircraft clutter. Then we add a directional constraint to DCMP-CN to create a null at that direction.
In this presentation, we first show the result of applying this method against the aircraft clutters using two different systems, Sumire and the MU radar, and then discuss the relationship between the effectiveness and the size or shape of the array. While Sumire has only 4 channels with different sizes, MU radar has 25 channels of almost equal sizes. DCMP-CN keeps the shape of main robe using directional and norm constraint, so the remaining degrees of freedom and the location of each channel determine the performance of this method.
Finally, we suggest a selection of channel for the better FAI clutter rejection in PANSY.

Presented by: **Hashimoto, Taishi**

Radar investigations of mesospheric clouds subjected to artificial electron heating– observations and theory.

Ove Havnes [1], *Cesar La Hoz* [1], *Alexander Biebricher* [2], *Meseret Kassa* [1], *Jörg Gumbel* [3]
[1] *Institute of Physics and Technology, University of Tromsø, N-9037 Tromsø, Norway.*
[2] *Andøya Rocket Range, Box 54, N-8483 Andenes, Norway.*
[3] *Department of Meteorology, Stockholm University, S-10691 Stockholm, Sweden.*

It has for some time been known that artificial heating of the mesospheric clouds PMSE/NLC and PMWE can have a profound effect on their radar backscatter properties. In some cases the backscatter can be reduced by a large factor as the heater transmitter is switched on and, if the heater cycling is asymmetric with a comparatively short heater on time but with a much longer heater off time, the backscatter can increase as the heater is switched off, to a value which can be several times its undisturbed value from before the heater was switched on. This effect is called the overshoot effect and the shape of its variation during the heater cycling is, with present modeling, very dependent on the dusty plasma conditions in the radar clouds. We present observations of the overshoot for PMSE and PMWE clouds. We discuss how the observations of the backscatter variation compare with modeling which predict a possibility for significant changes in the overshoot behavior when the radar frequencies becomes lower than ~ 50 MHz. We finally present some recent rocket results of dust structures in PMSE clouds and their possible significance for the shape of the dusty plasma irregularities causing the radar backscatter.

Presented by: **Havnes, Ove**

Measurements of wind variation in surface boundary layer with tilted 1.3GHz wind profiler

Kuniaki Higashi , *Jun-ichi Furumoto* , *Hiroyuki Hashiguchi*
Research Institute for Sustainable Humanosphere (RISH), Kyoto University

This study aims to elucidate the effects of local wind field in the surface boundary layer. In this study, tilted 1.3 GHz wind profiler and fine mesh numerical model are used to investigate behavior of wind field and large eddy in the layer. The wind and large eddy are changed in a short time, and warm or cold air is mixed near surface. These are important parameter to understand lower troposphere phenomena. Many studies depend on tower observations; therefore it is not understand widely distribution of changing wind in surface boundary layer. In this study, to reduce the minimum height of observation, the antenna of the wind profiler is tilted from the ground surface. Three radar beams are used to observe radial wind in the boundary layer. It is appear to non-uniform system.

We also use the fine mesh numerical model called Large Eddy Simulation. The domain of this numerical model is from several meters to several kilometers, and can predict the airflow over complex terrain with high precision. Model domain used 50 m resolution topography data. This topography data was provided from Geospatial Information Authority of Japan. We compared simulation and observation result to appear the phenomena of the surface boundary layer.

Presented by: **Higashi, Kuniaki**

Development of turbulence detection and prediction techniques with wind profiler radar for aviation safety

Hiroyuki Hashiguchi [1], Kuniaki Higashi [1], Seiji Kawamura [2], Ahoro Adachi [3], Yusuke Kajiwara [4], Kotaro Bessho [4], Masanobu Kurosu [5], Mamoru Yamamoto [1]
[1] Research Institute for Suatainable Humanosphere (RISH), Kyoto University
[2] National Institute of Information and Communications Technology (NICT)
[3] Meteorological Research Institute (MRI), Japan Meteorological Agency (JMA)
[4] Observation Division/Meteorological Research Institute (MRI), Japan Meteorological Agency (JMA)
[5] Japan Airlines (JAL)

There are various meteorological phenomena which may cause serious trouble to aircraft operations. Especially, atmospheric turbulence (including wind shear) sometimes brings significant aircraft accidents because it is difficult to detect it by current operational meteorological observations. In 2000-2009, more than half of accidents in large aircrafts were brought by atmospheric turbulence. At present, PIlot weather REPort (PIREP) is a major method for observing atmospheric turbulence, but it is not suitable for monitoring atmospheric turbulence because it cannot continuously observe a specific area or altitude. Therefore, the development of a new observation instrument, which continuously covers wide altitude range, is needed. On the other hand, various forecast techniques for atmospheric turbulence have been developed based on PIREP data, so there is still room for improving its prediction accuracy.

The project supported by 'the Program for Promoting Fundamental Transport Technology Research of the Japan Railway Construction, Transport and Technology Agency (JRTT)' started in July 2011. In the present study, the prototype of the next generation 1.3-GHz wind profiler radar (WPR) that can be observed up to the cruising altitude of the aircraft is developed, and it aims at the establishment of the atmospheric turbulence detection technique by the remote sensing. In addition, the observational data with the WPR is used as verification data to improve the prediction accuracy of atmospheric turbulence. It aims to become the foundation of the aircraft accident prevention.

It is expected that the result achieved by the present study will be built into the WPR network of Japan Meteorological Agency (JMA) for the meteorological observations. In addition, it is expected to contribute to a safe service of the aircraft operation through the improvement of the prediction accuracy for atmospheric turbulence.

Acknowledgments: The present study was supported by the Program for Promoting Fundamental Transport Technology Research from the Japan Railway Construction, Transport and Technology Agency (JRTT).

Presented by: **Higashi, Kuniaki**

Recent advances in radar turbulence studies with emphasis on in-situ comparisons

Wayne Hocking, *Arnim Dehghan*

T.B.D.

Presented by: **Hocking, Wayne**

Good resolution at high power without pulse-coding

Wayne Hocking [1], *Anna Hocking* [2]
[1] *University of Western Ontario*
[2] *Mardoc Inc.*

Pulse coding is currently the most common procedure used to produce fine height resolution with high power. However, new developments with radar processor design have permitted better approaches to data-recording and analysis. Using several multi-core CPUs, we have been able to achieve speeds of up to 40GHz from a standard commerical motherboard, allowing data to be digitized and processed without the need for any type of hardware except for a transmitter (and associated drivers), a receiver and a digitizer. No Digital Signal Processor chips are needed, allowing great flexibiltiy with analysis algorithms.

As a result of these advances, we have been able to re-address the modes of optimal pulse compression. Pulse coding requires that the sampling interval must match the timing between successive sub-elements of the pulse, but our newer procedures allow direct sampling of the RF, permitting alternative stategies such as chirped pulses, and even pulse shape variations from pulse to pulse. Real-time deconvolution with the transmitted pulse permits optimal resolution, and can even remove range-ambiguity effects in high PRF systems.

These new developments are discussed and demonstrated with examples.

Presented by: **Hocking, Wayne**

Incorporation of O-QNet windprofiler data into numerical forecast models

Wayne Hocking [1], *Peter Taylor* [2], *Frederic Fabry* [3], *James Drummond* [4], *et al.*
[1] *University of Western Ontario, Canada*
[2] *York University, Canada*
[3] *McGill University, Canada*
[4] *Dalhousie University, Canada*

Canada now has 10 active windprofiler radars - 8 as part of the O-QNet, 1 additional one in Montreal at McGill University, and one at Eureka in the high Arctic. An extra 3 are slated for incorporation in the next year. The O-QNet is particularly of interest, since it is a relatively dense network (mean spacing between radars less than 200km), and of course the high Arctic is a region of special interest for forecast models.

Data from each of these are now routinely submitted to Environment Canada and E-WINPROF servers, for study and incorporation into forecast models. The process by which this has occurred is an interesting one, and has not been at all trivial. Computer models for data assimilation and prediction are now very sophisticated, and other sources of data like aircraft (AMDAR) are very competitive. Radar data do not always produce a positive improvement in the models, and care is needed both from the perspective of the radar operator(s) and those receiving the data. Misunderstandings can lead to conflict. High accuracy is required, requiring compensation for anisotropy effects, and care with near-0-Hz spectral lines (due to ground echoes)

In this talk, we will discuss the history of the assimilation process, and some of the adjustments needed to optimize it.

Presented by: **Hocking, Wayne**

Annual and interannual variations of mesospheric gravity waves from radar, satellites and models

Peter Hoffmann [1], Manfred Ern [2], Erich Becker [1], Peter Preusse [2], Markus Rapp [1]
[1] Leibniz-Institute of Atmospheric Physics (IAP) at the Rostock University, Kühlungsborn, Germany
[2] Institute for Energy and Climate Research – Stratosphere (IEK-7), Forschungszentrum Juelich, Juelich, Germany

Wind measurements with meteor and MF radars at Juliusruh (55°N, 13°E) and Andenes (69°N, 16°E) are used to estimate annual and interannual variations of the activity of gravity waves (GW) in the mesosphere/lower thermosphere (MLT). The derived results at both locations are compared to high spatial resolution data sets of temperature variations derived from the satellite instrument SABER as well as to the simulated annual cycle using the gravity-wave resolving Kühlungsborn Mechanistic general Circulation Model (KMCM). These data are used for comparison between single ground based observations and zonally averaged results. Observational and computational results show the largest GW energy during winter and a secondary maximum during summer. This semi-annual variation is consistent with the selective filtering of westward and eastward propagating GWs by the mean zonal wind. The latitudinal dependence during summer is characterized by stronger GW energy between 65 and 85 km at mid-latitudes than at polar latitudes, and a corresponding upward shift of the wind reversal towards the pole. Based on long term measurements of mesospheric wind variations at mid and polar latitudes and temperature variations from SABER observations, the interannual variations of the activity of GW with different periods and their dependence on the background winds are investigated. First results indicate that observed zonal wind variations at about 75 km during summer at mid-latitudes go along with an enhanced activity of GW with periods between 3 - 6 hours at altitudes between 80 and 88 km. We will continue our studies of GW variations for other seasons at both latitudes to illuminate the contribution of the selective GW filtering by the background winds.

Presented by: **Hoffmann, Peter**

Renovation of the Aberystwyth MST radar: Evaluation

David Hooper [1], *John Bradford* [1], *Les Dean* [2], *Jon Eastment* [1], *Marco Hess* [3], *Eric Hibbett* [3], *John Jacobs* [4], *Richard Mayo* [3]
[1] *Rutherford Appleton Laboratory*
[2] *Aberystwyth University*
[3] *ATRAD*
[4] *John Jacobs Consulting*

In early 2011, the Aberystwyth MST Radar underwent its first major renovation in its 20 year lifetime. This principally consisted of replacing the components which allow it to operate according to the Doppler Beam Swinging principle. The design and installation work was carried out by ATRAD. The renovation lead to a remarkable 28% increase in useful coverage for wind-profiling purposes. This presentation will look at how the performance of the renovated radar was evaluated using geophysical considerations.

For 2 weeks prior to the renovation work, the radar was operated in a special observation format which made use of all 16 of the available beam pointing directions. Only 6 of these are used during standard operations. The special format continued to be used for 6 weeks after the renovation was completed.

After several days' worth of observations had been accumulated, it was possible to analyse the diurnal variations of spectral noise power. For each beam pointing direction, there should be a specific pattern which follows the variations in 46.5 MHz cosmic emissions along a circle of constant declination. Although the patterns for the pre and post renovation periods were qualitatively well-matched, there was a decrease in the absolute values by approximately 1 dB, suggesting a decrease in system noise.

After several weeks' worth of observations had been accumulated, it was possible to carry out a statistical analysis of the data products. It was immediately obvious that the ratio of signal powers for observations made in the vertical direction and at 6 degrees off-vertical, i.e. nominally a measure of the aspect sensitivity, had decreased. The values are expected to be small throughout much of the troposphere, where isotropic scattering is a common radar return mechanism. This was only the case for the post renovation period. This suggests that the old relay units were causing considerably more attenuation for off-vertical beam pointing directions than for the vertical direction. The difference is estimated to be 5 dB. Moreover, the aspect sensitivity parameter theta_s is used to compensate the horizontal wind speeds for the difference between the nominal and effective beam pointing zenith angles. It is estimated that wind speeds were being over-compensated by 6% prior to the renovation. Independent data quality statistics provided by the Met Office suggest an improvement for the post renovation period.

Presented by: **Hooper, David**

The usefulness of model-comparison statistics for wind-profiling radar operators

David Hooper
Rutherford Appleton Laboratory

Wind-profiler radar data are commonly assimilated by meteorological organisations for the purposes of numerical weather prediction (NWP). Within Europe, the radars are operated by a variety of organisations. Nevertheless, they effectively form a single network through the co-ordination of the EUMETNET Composite Observing System (EUCOS) E-WINPROF programme. This grew out of the CWINDE demonstration network, which was set up under COST-76. As part of E-WINPROF, the quality of the radar-derived wind data is evaluated through comparisons with NWP model data. This presentation will look at the usefulness of such model-comparison statistics from the instrument operators' perspective. They can be used to evaluate improvements in signal processing schemes and to identify changes in instrument performance.

The (UK) Met Office generate statistics from comparisons made against their own NWP model. These are provided on a monthly basis as functions of model level, i.e. of altitude. Owing to the fact that NWP models are not perfect, the differences between radar-derived and model winds cannot be attributed solely to errors in the radar data. Nevertheless, if two sources of data have similar model-comparison statistics, it can be inferred that their measurement accuracies are broadly comparable. Consequently, for each wind-profiling radar, the Met Office also provide model-comparison statistics for radiosonde data from the same geographical region. The combined statistics have been of particular usefulness for the Aberystwyth MST radar in two specific circumstances. Firstly, they were used to demonstrate that an improved signal processing scheme gave data of significantly higher quality than its predecessor. Secondly, they were used to identify a problem with a new data acquisition system. The cause turned out to be a range gating error.

EUCOS generate statistics from comparisons made against the Deutscher Wetterdienst (DWD) COSMOS model. Data quality is summarised by a single value, which covers all model levels and times. As for the case of Met Office statistics, the evaluation period is typically 1 month. However, single day statistics are also available. These have proved to be particularly useful for identifying quality control problems which are confined to limited time and altitude regions. Such problems can otherwise be difficult to identify and to correct.

Presented by: **Hooper, David**

Predicting the occurrence of visual noctilucent clouds

John Rowlands [1], Nicholas Mitchell [1], David Hooper [2]
[1] *University of Bath*
[2] *Rutherford Appleton Laboratory*

This work is motivated by the needs of an amateur noctilucent cloud (NLC) observation network at northern mid-latitudes. The level of public interest in NLCs has been raised considerably after one of us (Rowlands) participated in a BBC Radio popular science programme. Although NLCs are commonly seen above the British Isles during the twilight hours of June and July, it would be useful to know in advance, even if only by a few hours, which nights are likely to offer the best observations. This work is not concerned with the effects of tropospheric clouds, despite the fact they have a dominating influence on whether or not NLCs might be visible. It focuses on the temporal relationships between NLC occurrence and low mesopause temperatures, as measured by a meteor radar, and between NLC occurrence and mesosphere summer echo (MSE) occurrence, as measured by an MST radar.

Visual observations were made on a nightly basis, when the sky was not obscured by tropospheric cloud, during June and July of each year 2009 - 2011. The observation site (53.42 N, -4.45 E) is characterised by low levels of light pollution and flat terrain in all directions. The horizon between west and east through north is over the sea.

Mesopause-level temperatures were derived from the University of Bath's (SKYiMET) meteor radar at Esrange in Northern Sweden (67.89 N, 21.08 E) degrees E). Despite its large (principally meridional) separation from the NLC observation site, there is a reasonable correlation between the occurrence of extensive NLCs (i.e. when the extent rose more than 15 degrees above the horizon) and cool phases of the 5 day planetary wave.

The study is now being extended to include mesopause-level information from a more-local source. The Aberystwyth MST radar (52.42 N, -4.01 E) is located just 115 km to the south of the NLC observation site. It commonly observes daytime MSEs during June and July of each year. The relationship between the occurrence of MSEs and the existence of ice crystals in the uppermost mesosphere is well-established. An initial comparison has revealed that the the most extensive NLC display of the 2011 season occurred during the night following the most extensive MSEs.

Presented by: **Hooper, David**

Detecting low earth orbit (LEO) satellites using UK-based atmospheric radars

Jon Eastment , David Hooper , Darcy Ladd , Chris Walden
Rutherford Appleton Laboratory

Owing to the rapidly-increasing use of the near-Earth space environment, there is a growing need to be able to detect the objects within it. This is primarily motivated by the threats posed to operational satellites, and to manned spacecraft, by collisions with orbital debris or with other satellites. A dedicated space surveillance radar network already exists for this purpose. Nevertheless, due to the ever-increasing number of objects which must be tracked, there is considerable interest in how additional radars, which were designed for other purposes, might also contribute. For example, it has already been demonstrated that the MU radar in Japan is capable of detecting LEO objects. This poster will examine the suitability of two UK-based atmospheric radars for the same purpose: the Chilbolton Advanced Meteorological Radar (CAMRa) and the Aberystwyth MST Radar.

CAMRa is a 3 GHz system which uses a 25 metre diameter parabolic dish, which can be steered at 3 degrees/s in azimuth and 1 degree/s in elevation. Consequently, it is able to continuously track objects, based on their known orbits, as they move across the sky. Under a recent ESA-funded observational campaign, the radar successfully tracked over 40 satellites in LEO at ranges up to 2500 km. The missions of these satellites included communications (IRIDIUM); weather observation (METOP-A, FENGYUN-3A, FENGYUN-3B); remote-sensing research (ADEOS, AQUA, TERRA); earth observation (ENVISAT, RADARSAT-1, SPOT-5); and military/intelligence (COSMOS_1346, COSMOS_1782, GEO-IK-2). Objects with radar cross-sections (RCSs) as low as 2 square-metres (+3 dBsm) were detected at 1000 km range (for example, CRYOSAT-2).

The Aberystwyth MST Radar is a 46.5 MHz system with a phased-array antenna. Owing to its 20 year old radar control and data acquisition system, the maximum inter-pulse period is currently only 640 us. This corresponds to a maximum unambiguous range of 96 km. At this proof-of-concept stage, it will be necessary to rely on range-aliased signals. Tests will initially be made using the International Space Station (ISS), which occasionally passes close to the centre of one of the radar's beam-pointing directions. At the time of writing, the altitude of the ISS orbit varies between 375 and 404 km. If initial observations of the ISS prove successful, the radar will be tested against a set of satellite targets with progressively lower RCSs, so as to establish the limits of its sensitivity and of its range and angular coverage.

Presented by: **Hooper, David**

Higher application of wind profilers to forecasting/nowcasting severe convections and to aviation weather services

<u>Masahito Ishihara</u>
Aerological Observatory

The wind profiler network of the Japan Meteorological Agency (JMA), WINDAS was stablished in 2001 as the third nation/region-wide operational wind plofiler networks following the U.S. NOAA Profler Networok and the EUPROF. WINDAS consists of 31 sets of 1.3GHz wind profilers covering through the whole area of Japan from 24N to 44N. WINDAS has been providing upper-air wind data for mainly the JMA mesoscale numerical model the using 4-dimenisonal variational data assimilation method as well as daily weather serviceis and aviation weather serviceis. It has also been contributed to researches mainly on mesoscale severe convections and typhoons. JMA has started a research project to develope higher application of the wind profilers to forecasting/nowcasting severe convections and to aviation weather services. The project is being conducted in cooperation with the Kyoto University and the National Institute of Information and Communications Technology. The review of the history of the WINDAS and the on-going project will be presented.

Presented by: **Ishihara, Masahito**

Long-term trends of mesosphere/lower thermosphere gravity waves at midlatitudes

Christoph Jacobi [1], *Peter Hoffmann* [2]
[1] *Universität Leipzig*
[2] *Leibniz-Institute of Atmospheric Physics*

Mesosphere/lower thermosphere (MLT) winds over Germany measured with different radar systems (MF radar, LF) have been analysed with respect to variations at the time scales of gravity waves. Background winds are also registered to analyse gravity-mean flow interactions at decadal time scales. A decreasing (towards more westward directed) zonal mean wind long-term trend is observed in the summer mesosphere over Collm since 1984, which decreases with altitude and eventually reverses. The gravity wave proxy trends show opposite tendencies, i.e., decreasing mean zonal winds are connected with increasing gravity wave amplitudes and vice versa. This behaviour can be explained through linear theory: since in summer decreasing/increasing zonal westerly winds are connected with a stronger/weaker mesospheric easterly jet, this leads to larger/smaller intrinsic gravity wave phase speeds and consequently larger/smaller gravity wave amplitudes. This connection between gravity waves and mean wind is also observed on a decadal scale: during solar maximum a stronger mesospheric zonal wind jet leads to larger gravity wave amplitudes. This results in a solar cycle modulation of gravity waves with larger amplitudes during solar maximum. The results are compared with MF radar trend results over Juliusruh.

Presented by: **Jacobi, Christoph**

Climatology of the 8-hour solar tide over Central Europe, Collm (51.3°N; 13.0°E)

Christoph Jacobi , *Tilo Fytterer*
Universität Leipzig, Institut für Meteorologie

The horizontal winds in the mesosphere and lower thermosphere (MLT) at 80-100 km height have been measured using an all-sky 36.2 MHz VHF meteor radar at Collm, Germany (51.3°N, 13°E). The radar has been operating continuously since July 2004, and data from 2005 – 2011 areused for constructing a climatology of the 8-h solar tide. The 8-hour solar tide is a regular feature; its amplitude shows a seasonal behaviour with maximum values at the equinoxes, and generally increasing with altitudes. The largest amplitudes are measured in autumn, reaching up to more than 15 m/s, while the tide is much weaker during summer. The phase, defined as the time of maximum eastward or northward wind, respectively, is earlier in winter and advances to later times in summer. In general, the phase difference between the zonal and meridional components is close to +2h. The vertical wavelengths are short in summer (< 30 km) but significantly longer during the rest of the year. The terdiurnal tide is generally assumed to partly originate from non-linear interaction between the diurnal and semidiurnal tide. Correspondence between semidiurnal and terdiurnal amplitudes is investigated.

Presented by: **Jacobi, Christoph**

Study of radar bright band and freezing level height

Rajasri Sen Jaiswal, R. Fredrick Sonia [2], V. S. Neela [2], M. Rasheed [2], Zaveri Leena [2], V. Sowmya [2] [1]

[2] Sona College of Technology

Radar bright band is a very important factor in identifying the type of precipitation. A stratiform precipitation is generally found to be associated with bright band[1,2], while no bright band is seen in convective precipitation[1,2]. During a precipitation process, when the falling ice particles reach below the transition height, then they start melting and form water coated snowflakes which produce a strong signal in the radar receiver, giving rise to what is called a bright band. Thus, knowledge of radar bright band is essential in understanding the precipitation process. A bright band occurs because of the strong signal reflected from the water coated ice particles below the 0^{o} C isotherm height. At above 10 GHz these snowflakes may lead to attenuation of the signal. Hence, study of bright band is of immense importance in communication also.

It is realized that the atmospheric dynamics over the continent are different from that over the ocean[3]. Hence, it appears that the parameters associated with the bright band will also be different over land and ocean. In this paper the authors have made an attempt to study bright band height (BBH), bright band intensity (BBI) and freezing level height (HFL) within the latitudinal belt 30N-30S during 1999-2002 and 2007. The BBH and BBI data are derived from the level 2 data product 2A23 of the precipitation radar (PR) onboard Tropical Rainfall Measuring Mission (TRMM) satellite. The study presents statistics of BBH, BBI and HFL; the geo location of maximum occurrence of bright band and the geo location of BBH maxima and minima. It is found out that the BBH maxima mostly lie over land, while the minima lie mostly over ocean. HFL shows strong latitudinal dependence. BBH is found to occur mostly below HFL. However, in some cases, the reverse is found true. It is further found that over the continent, there is strong correlation between latitude and the percentage of time BBH goes above HFL.

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Presented by: **Jaiswal, Rajasri Sen**

Active modification of the D-region ionosphere

Antti Kero

Electron temperature dependent properties of the D-region ionosphere can be actively modified by means of radio wave heating. In propagation through weakly-ionised collisional plasma, part of radio wave energy is deformed into thermal motion of the electrons gas in elastic collisions of electrons, oscillating along the radio wave, and neutrals. The D-region ionosphere is an optimal place for this process since high electron-neutral collision frequency and significant abundance of free electrons. A powerful radio transmitter, such as EISCAT Heating facility, is therefore capable of increasing the electron temperature in the D-region ionosphere by a factor of 5-10.

The enhanced mobility of heated electron gas affects directly into the ion chemistry via two competing processes, i.e. (decreased) recombination and (increased) attachment rate. According to the Sodankylä Ion Chemistry model (SIC), the enhanced electron attachment to neutrals, producing negative ions and reducing the electron density, dominates typically below 80 km, whereas above the reduced recombination increases slightly the electron concentration. In this presentation, possible heating induced ion-chemical signatures in incoherent scatter radar observations are discussed.

Presented by: **Kero, Antti**

The MU radar meteor head echo analysis technique and the 2009-2010 observation programme

Johan Kero [1], *Csilla Szasz* [2], *Takuji Nakamura* [3], *David Meisel* [4], *Toshio Terasawa* [5], *Yasunori Fujiwara* [6], *Masayoshi Ueda* [6], *Koji Nishimura* [3], *Jun-Ichi Watanabe* [7]
[1] *Umeå University, Kiruna, Sweden*
[2] *SSC Space, Kiruna, Sweden*
[3] *National Instiiute of Polar Research (NIPR), Tokyo, Japan*
[4] *SUNY Geneseo, NY, USA*
[5] *Institute for Cosmic Ray Research, University of Tokyo, Japan*
[6] *Nippon Meteor Society, Osaka, Japan*
[7] *National Astronomical Observatory of Japan (NAOJ), Tokyo, Japan*

Earth's atmosphere is daily bombarded by billions of dust-sized particles, about 4-200 tonnes of extraterrestrial material per day. Those larger than a few tenths of a millimetre give rise to visible streaks of light on the night sky called meteors, or colloquially shooting stars. Meteor science contains many open questions, and the flux of extraterrestrial material into the Earth's atmosphere is one of them. It needs to be better quantified.

High-power MST radars are powerful tools for providing new insights. This talk contains a review of the analysis algorithms we developed for the 46.5 MHz Shigaraki Middle and Upper atmosphere (MU) radar in Japan (34.85N, 136.10E), and some observational highlights. We conducted a systematic set of monthly 24h meteor head echo observations from 2009 June to 2010 December (>500h) resulting in more than 100,000 high-quality meteor detections. This data set allows investigations of meteor characteristics in form of geocentric velocity and altitude distribution, as well as mapping of the meteor influx seasonal variation.

Meteor showers are caused by the Earth intersecting streams of meteoroids on orbits still similar to those of their parent bodies, which are usually comets. Meteor showers provide opportunities to compare head echo observations with other observation techniques and simulations. An example of such a comparison is given: comet1P/Halley dust observed as the Orionid meteor shower. The comparison indicates that our radar method provides precision and accuracy comparable to the photographic reduction of much brighter meteors with longer detectable trajectories.

Presented by: **Kero, Johan**

Separating sky and ground wave in indirect phase height measurements

Dieter Keuer , *Jörg Trautner*
Leibniz-Institute of Atmospheric Physics (IAP) at the Rostock University, Kühlungsborn, Germany

Since 1959 indirect phase height measurements based on continuous ground-based records of long frequency radio waves reflected in the D-region have been carried out at Kühlungsborn, Northern Germany. Essentially, the phase height is determined from an analysis of the local time appearance of minima and maxima of recorded wave amplitudes. This interference pattern arises because of a superposition of ground and sky wave. However, the interpretation of this interference pattern in terms of an ionospheric reflection height relies on the assumption of a constant ground phase as a phase reference. Obviously, it is of great importance to verify this assumption. The used transmitter near Allouis (France) is seeded by a caesium normal, which gives the opportunity to record both amplitude and phase. Using a GPS-disciplined Rubidium frequency standard and furthermore a second receiving station 120 km apart from Kühlungsborn a method to separate the sky and ground wave is presented and corresponding results are discussed.

Presented by: **Keuer, Dieter**

Boundary layer measurements by the MARA MST radar using a local bistatic technique.

Sheila Kirkwood , *Ingemar Wolf* , *Daria Mikhaylova*
Polar Atmospheric Research, Swedish Institute of Space Physics

The atmospheric boundary layer (the lowest ~1000 m in the atmosphere) is partcularly poorly understood and difficult to model in the polar regions. Strong temperature inversions can build up and the surface conditions become very dependent on the presence or absence of dynamic mixing between the surface and the free troposphere. There are several MST radars in the polar regions which could be used to monitor the boundary layer and provide valuable input for atmospheric (and climate) modelling, if only they could make observations at low heights. Generally, the problems of switching between transmission and reception on the same antenna array limit measurements to heights above 1000 -2000 m. However, boundary layer measurements down to 400 m height have been successfully made using small, separate, transmit and receive arrays (Hocking, 2006). During 2011, MARA (Moveable Atmospheric Radar for Antarctica) has been augmented with additional receivers and outlier antennas (for reception only) to make boundary layer measurements at the same time as the usual monostatic measurements are made throughout the free troposphere, the lower stratosphere and the mesopause region. Successful technical tests were made in Kiruna during summer 2011, showing that measurements at least down to 300 m height should be possible. We will report the results of the first full field tests at the Norwegian Antarctic station Troll, during the 2011/2012 austral summer season.

Presented by: **Kirkwood, Sheila**

Climatological characteristics of tropospheric- and lower stratospheric- turbulence over Kiruna, Sweden

T. Narayana Rao [1], *Sheila Kirkwood* [2]
[1] *National Atmospheric Research Laboratory*
[2] *Swedish Institute of Space Physics*

The measurements made with Esrange Radar (ESRAD) at Kiruna over 15 years have been used to study climatological characteristics of the turbulence in a comprehensive way. The turbulence intensity variations are studied as a function of season, wind direction and wind shear. The turbulence shows significant seasonal variation in magnitude as well as in height. The turbulence intensity is quantified in special events like the tropopause folds and mountain waves. Strongest turbulence at Kiruna is observed in mountain waves and then in folds. Some of the processes (like tropopause folds) occurring near the tropopause are reversible and irreversible transfer of constituents occur mainly due to the turbulence. Also, recently some studies built climatology of chemical constituents (using air-craft measurements) with reference to the tropopause. Keeping the above factors in mind, climatology of the turbulence is studied with the tropopause as a reference altitude. Eddy diffusivity (K) values are estimated and the seasonal and height variation of K are compared and contrasted with earlier climatologies of K. The K values in different seasons are found to be smaller at Kiruna compared to the reported values elsewhere. Nevertheless, extreme 5‰ values of K are quite large and are comparable with those reported often in mountain waves and folds. The height variation of K resembles with that observed in mid-latitudes in some seasons and in tropics in other seasons.

Presented by: **Kirkwood, Sheila**

PMSE – a comparison between ESRAD in Arctic Sweden and MARA at Wasa, Antarctica.

Sheila Kirkwood [1], Evgenia Belova [1], Peter Dalin [1], Maria Mihalikova [1], Daria Mikhaylova [1], Hans Nilsson [1], K. Satheesan [2], Ingemar Wolf [1]
[1] Polar Atmospheric Research, Swedish Institute of Space Physics
[2] Polar Atmospheric Research, Swedish Institute of Space Physics, now at National Center for Antarctic and Ocean Research, Goa, India

The 52 MHz MST radar ESRAD has been monitoring PMSE at 67° N, 20° E every summer since 1996. MARA (Moveable Atmospheric Radar for Antarctica) operated at the Swedish summer station Wasa in Antarctica (73° S, 13° W) during four summer seasons from 2007 to 2011, and will be operated at the Norwegian year-round station Troll (72°S, 2°E) from November 2011. The two radars have been cross-calibrated in 4 different ways to ensure that PMSE reflectivities can be properly compared between the two sites. For low levels of geomagnetic avtivity, PMSE occurrence rates, median reflectivities, and diurnal variations are similar between the two sites. Modulation by 2-day and 5-day planetary waves is seen at both sites. At ESRAD (geomagnetic latitude 65° S) there is a strong dependence of reflectivity on geomagnetic activity, with a relatively high occurence rate of extremely strong PMSE during disturbed conditions. At Wasa (geomagnetic latitute 61° S) the response to geomagnetic disturbances is less extreme, and seems to be delayed by around 1 day. The PMSE height in the early season is much higher at Wasa than at ESRAD. It is particularly noteable that the PMSE season over Antarctica starts while the circulation in the stratosphere is still in its winter (polar vortex) configuration.

Presented by: **Kirkwood, Sheila**

Objectives and tasks of the EUMETNET Composite Observing System (EUCOS)

Stefan Klink , Sabine Hafner , Tanja Kleinert , et al.
EUCOS c/o Deutscher Wetterdienst

EUCOS, which stands for EUMETNET Composite Observing System, is an EIG EUMETNET programme whose main objective is a central management of surface based operational observations on a European-wide scale serving primarily the needs of regional scale numerical weather prediction (NWP). EUMETNET is a consortium of currently 29 national meteorological services (NMS) in Europe that provides a framework for different operational and developmental co-operative programmes between the services.

The work content of the EUCOS Programme includes the management of the operational observing networks, through the E-AMDAR (aircraft observations from commercial airlines), E-ASAP (radiosonde observations from merchant ships), E-SURFMAR (buoy and voluntary observing ship measurements) and E-WINPROF (wind profiler) programmes. Strong links exist to the observation programmes E-GVAP (humidity measurements derived from global navigational satellite systems data) and OPERA (‘weather radar’). The coordination of NMSes owned territorial networks (e.g. radiosonde stations and synoptic stations), data quality monitoring, fault reporting and recovery, a studies programme for the evolution of the observing networks and liaison with other organisations like WMO are among the tasks of the programme.

Changing user requirements on observational data and external drivers like new developments in measurement technology and observing systems demand for a periodic redesign of the existing observing networks. Changes in networks should be based on scientific analyses and therefore EUCOS launched several studies in the past. Such studies usually comprise of a set of observing system experiments (OSE) or similar experiments which are run to assess the impact of different observing systems on NWP forecast skill. NWP groups of NMSes or ECMWF conduct the studies and EUCOS works as an interface between NWP and data providers.

As an example recommendations derived from a ‘Space-Terrestrial Study’ and an ‘Upper-Air Network Redesign Study’ will be presented. Another topic of the presentation will be operational monitoring of EUCOS observation networks with a special emphasis on E-WINPROF. Finally, an outlook will be given on future developments in EUCOS, e.g. inclusion of more 3rd party data, the introduction of a humidity sensor on commercial aircraft within the E-AMDAR programme or plans for new observing system experiments.

Presented by: **Klink, Stefan**

The errors of meteor radar data

Svitlana V. Kolomiyets
Kharkov National University of Radio electronics (KhNURE)

Errors of meteor radar data and the problem of hyperbolic meteors are interconnected. The author used data of the Meteor Automatic Radar System (MARS). MARS was developed at the Kharkov Institute of Radioelectronics. MARS had high effective sensitivity (the limiting magnitude for meteors observed was close to + 12 m) and enabled to carry out an all-round meteor research. Astronomical researches give synoptically model for geophysical meteor data. Geophysical meteor data based on meteor drifts measurements. For interpretation of astronomical data it is necessary to know some results of calculation of errors. The errors of the Kharkov meteor radar data are resulted. Errors of meteor radar data and the problem of hyperbolic meteors are discussed.

Presented by: **Kolomiyets, Svitlana V.**

Observations of atmospheric thermal structures during 2009 and 2010 solar eclipses

S.B.Surendra Prasad [1], M.Venkatarami Reddy [1], A.Hari Krishna [1], K.Krishna Reddy [1], C.J Pan [2], U.V. Murali Krishna [1]
[1] Yogi Vemana University, Kadapa, India
[2] Institute of Space Science, National Central University,Taiwan

Integrated atmospheric measurements were made at Kadapa, India during the solar eclipses on 22nd July 2009 and 15th January 2010. Sensitive, high-resolution meteorological observations revealed dynamical atmospheric effects despite the presence of cloud. Short-term eclipse related changes dominated over temperature, wind speed, and wind directions associated with the synoptic conditions. The solar eclipse is a unique phenomenon gives an opportunity to investigate the atmospheric effects associated with comparatively fast solar radiation changes or when incoming solar radiation is sharply turned off during these events. The temporal variations of the temperature profiles caused by a solar eclipse at about a fixed point aloft are studied by using radiosonde sounding with 3-hour interval resolution, Mini Boundary Layer Mast (MBLM) and COSMIC GPS RO data for 15 January 2010 whereas for 22 July 2009 magnetometer data is additional collected. It is the first time to observe the whole evolution of cooling and heating processes within solar eclipse period. As the approaching the maximum, a very efficient cooling process from surface to about 40 km altitude are noticed. The temperature decreases in stratosphere are much more than those decreases in the troposphere. On the other hand, significant warming takes place at stratosphere in 3 hours after the maximum eclipse is also noticed. Wave-like temperature variations with vertical wavelength about 3-5 km occurred at 11:30 IST as the maximum eclipse taking place. As the inversion layers are not frequently reported in the lower stratosphere and they only last about few hours in this study, these wave-like structures may be due to the Gravity wave induced by the solar eclipse that deserves more study. As the too short life time observes here, it seems reply why there is rare report of those wave activities related to solar eclipse. From COSMIC GPS RO a significant cooling is observed during the 15 January 2010 solar eclipse in lower stratosphere where as 22 July 2009 is dominant warming is observed in lower stratosphere compared to the non eclipse days. Details of the thermal perturbation noticed during annular solar eclipse and total solar eclipse to be discussed.

Presented by: **Krishna, U.V. Murali**

Investigations on Tropospheric ducts by using wind profiler radar and Artificial Neural Network over PALAU in the Pacific Ocean

Punyaseshudu Dupadu [1], Madhusudhana Kallu [2], K.Krishna Reddy [3], U.V. Murali Krishna [3]
[1] Rayalaseema University, Kurnool – 518 002, India
[2] Sri Krishnadevaraya University, Anantapur-515002, India
[3] Yogi Vemana University, Kadapa – 516 003, Inida

A detailed description of ducts (A rapid change in air temperature and humidity with height leads to the generation of tropospheric ducts) and their relevance to radiowave propagation over the Pacific Ocean in the Island of Palau using ground-based wind profiler radar, Radiometer and Radiosonde has been presented. The constantly changing weather conditions over the Ocean mean that marine and coastal environments, in particular, are prone to these unusual tropospheric phenomena that facilitate radio waves to have higher signal strengths and to travel longer distances than expected. Therefore, the influence of evaporation ducts on over-sea radiowave propagation needs to be thoroughly investigated. In this work, an artificial neural network (ANN) model is developed and used to predict the presence of ducting phenomena for a specific time, taking into account ground values of atmospheric pressure, relative humidity and temperature. A feed forward back propagation ANN is implemented, which is trained, validated and tested using atmospheric radiosonde data from the Koror, for the period from 2004 to 2007. The data analyses showed that the wind profiler is able to detect ducting conditions through (i) strong correlation of increase in the turbulence structure function parameter, Cn^2, with negative values of dM/dz and (ii) agreement in increase in potential refractive index (estimated from radar data) with increase in potential refractive index obtained from radiosonde data, within the duct region.

Presented by: **Krishna, U.V. Murali**

Accurate track prediction of cyclones over bay of Bengal using WRF model

M.Venkatarami Reddy , S. Balaji Kumar , S.B. Surendra Prasad , K.Krishna Reddy , U.V. Murali Krishna
Yogi Vemana University, Kadapa, India

Tropical cyclones that form over the Bay of Bengal and Arabian Sea during pre-monsoon (April-May), early monsoon (June), late and post monsoon (September-November) cause vulnerable damage to lives and property over the coastal regions of India with strong winds, heavy rain and tidal wave. The numerical models based on fundamental dynamics and well-defined physical processes provide a useful tool for understanding and predicting Tropical Cyclones (TC). For accurate forecast of TC, it is essential that numerical models must incorporate realistic representation of important physical and dynamical processes as they play crucial role in determining genesis, intensification and movement. In the present study, numerical simulation experiments on severe cyclone Storm "*LAILA*" (17-21 May, 2010) and "*JAL"* (04-08 November, 2010)*is* performed. For "*LAILA*" and "*JAL*" track prediction, a fully compressible, non-hydrostatic Advanced Research Weather Research and Forecasting (ARW-WRF) model with Arakawa C-grid is utilized. The advanced research WRF model was run at grid spacing of 27 km, 9 km and 3 km. The cyclone track study is done with National Center for environmental prediction (NCEP), final analysis fields (NCEP FNL) or the reanalysis data with 1.0 x 1.0 degree grid resolution used as initial and lateral boundary conditions for the WRF model. In *JAL* cyclone track prediction, WRF modeling was performed by changing cumulus schemes such as Kain Fritsch (KF), Betts-Miller-Janjic (BMJ), Grell-Devenyi (GD) and New Grell (NG) without changing microphysical properties, PBL, Radiation Schemes and ***Dynamics***. The track observed with Kain Fritsch (KF) scheme is well compared temporally and spatially with Indian Meteorological Department (IMD) observed track and the remaining Betts-Miller-Janjic (BMJ), Grell-Devenyi (GD) and New Grell (NG) schemes too suitable with IMD observed track only spatially. The cyclone centre pressures, maximum cyclone surface wind speed obtained from the model are well compared with the IMD data. The variation of pressure, temperature and humidity parameters from the Automatic Weather Station at Yogi Vemana University, kadapa (14.47°N; 78.82°E) a semi arid region,SHAR-sulurupet (13.69^{0}N, 80.22^{0}E) and Indhukurpet(14.46^{0}N, 80.08^{0}E) coastal area of India, during the cyclone landfall was analyzed and compared with the modeled parameters. Also we compared the Reflectivity and Doppler Velocity for both cyclonic and non-Cyclonic day using Chennai ***Doppler Weather Radar***. The results are in reasonable in good agreement.

Presented by: **Krishna, U.V. Murali**

Ground-Based Wind Profiler Radar and Lidar Measurements of Marine Boundary Layer evolution over PALAU in Pacific Ocean

U.V.Murali Krishna [1], *K.Krishna Reddy* [1], *R Shirooka* [2]
[1] *Yogi Vemana University, Kadapa,India*
[2] *Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan*

We carried out research at Palau Islands focusing on the Pacific Area Long-term Atmospheric observation for Understanding of climate change (PALAU)projecttounderstand the mechanism of cloud-precipitation processes, land-atmosphere and air-sea interactions over the warm water pool, focusing on seasonal and intra-seasonal variations. We installed several ground based remote sensors at Peleliu and Aimeliik experimental sites in the Palau. For the present study, Wind Profiler Radar (WPR) and Disdrometer are utilized for preliminary understanding of the marine boundary layer (MBL) evolution, diurnal and seasonal variation of precipitating cloud systems associated with easterly and westerly monsoon. To check the WPR performance, a comparison study with Korror radiosonde data is carried out. The results show fairly good agreement between the two measurements considering the spatial separation and data acquisition. The analysis showed that Ventilation Coefficient (VC) is strongly influenced by wind speed during westerly and easterly monsoon; whereas both MBL height and wind speed determine the value of VC during the other seasons over Palau. Ceilometer is a robust instrument that provides continuous and accurate cloud-base determinations as a standard output. Combined information of ceilometer aerosol backscatter data with the WPR, MRR and JWD allows us to investigate how the radiative effects of aerosol correspond to changing meteorological events (easterly and westerly or/during inactive and active phase of MJO) and regional regimes. Also investigated the characteristic features of cloud base height (CBH) over Aimeliik during different seasons (easterly & westerly monsoon). The CBH shows distinct diurnal and seasonal variations during all the seasons and found a minimum during the westerly wind monsoon regime.

Presented by: **Krishna, U.V.Murali**

Observations and modeling studes on severe thunderstorms over north east region of India

S.Balaji Kumar , U.V.Murali Krishna , M.Venkatarami Reddy , K.Krishna Reddy
Yogi Vemana University, Kadapa, India

Thunderstorm is a mesoscale system with space scale of a few kilometers to a couple of 100 kilometers and time scale of less than an hour to several hours characterized by heavy rain showers, lightning, thunder, hail-storms, dust-storms, surface wind squalls, down bursts and tornadoes. Thus, the severe thunderstorms have significant socioeconomic effects in the lives of people of the region. In India, during the pre-monsoon season of April and May, North –Eastern region of India is affected by severe thunderstorms called 'Norwesters' that are locally called Kal Baishaki. It is thus important to understand the growth and decay process and prediction of these severe local storms. A national coordinated intensive observations are conducted over Guwahati (26^{o} 17' N, 91^{o} 77' E), NER of India since 2006 to study the physical and thermo dynamical characteristics of thunderstorms and also forecasting. Since 2009 onwards we carried out field experiments by deploying Micro Rain Radar and PARSIVEL (Particle size and Velocity) Disdrometer. Apart from these we have collected India Meteorological Department (IMD) surface sensors (a network of current weather system, GPS, meteorological sensors, X-band Radar and Radiosonde) data. During 2010 year STORM field campaign, 32- precipitating cloud systems are captured with 22 thunderstorm days (TS) , 4 hail storm days (HS)and 6 non thunderstorm days (NTS) with a total rain accumulation of 6123 mm. Nine Squall lines passed over Guwahati with maximum number of squall in the month of April. The significant difference observed between the drop size distributions at the beginning of the thunderstorm and those found later in the storm for equal rainfall rates has been attributed to the difference in the terminal velocities of the small. Such variations in drop size distribution were not observed for the non-thunderstorm rainfall. Apart from these, we also noticed coexisting rain and hail particles that are distinguishable based on their size, fall velocity. Rainfall intensity is greater in TS days compared to NTS days. Maximum rainfall in TS day is 119.3 mm on 2^{nd} may 2010 and for NTS day is 10.0 mm on 19^{th} May, 2010. Micro rain radar (MRR) vertical profile of Drop size distribution show the existence of maximum occurrence of convective clouds during TS whereas mixed and stratiform clouds observed during TS precipitating event. Radar Reflectivity(Z) – Rain Rate (R) relations obtained from Disdrometer and MRR clearly distinguished the TS and NTS days. An attempt has been made in the present study to simulate a thunderstorm event that occurred on 22^{nd}, 24^{th} April and 13^{th} May 2010 at Guwahati (26.106^{o} N, 91.585^{o} E) using the Fifth-Generation PSU/NCAR Mesoscale Model (MM5) and Weather Research Forecasting (WRF) model .

Presented by: **Krishna, U.V.Murali**

Overview of VHF radar observations of equatorial mesosphere and ionosphere

Erhan Kudeki [1], Gerald Lehmacher [2], Pablo Reyes [1], Marco Milla [3], Jorge Chau [3], Karim Kuyeng [3], Levent Gezer [1]
[1] University of Illinois at Urbana Champaign, USA
[2] Clemson University, South Carolina, USA
[3] Jicamarca Radio Observatory, Lima, Peru

Equatorial ionosphere provides a nearly uninterrupted distribution of VHF radar targets during daytime hours over the altitude range of 50 to several hundred kilometers. These targets can act as tracers of atmospheric wave motions and/or wind driven dynamo fields which develop in the region. Below 90 km we have mesospheric backscatter ("M" of the "MST" radar response) from Bragg scale electron density irregularities produced by mesospheric turbulence and mixing processes exhibiting a height dependent aspect sensitivity and correlation times. Backscatter from the equatorial E-region is dominated by plasma turbulence associated with the gradient-drift and two-stream plasma instabilities. The region extending from ~135 to 180 km exhibits the so-called 150-km echoes of unknown origin. While the physics of 150-km echoes is not understood, the spatial and temporal signatures of scattered radar echoes from the region strongly indicate that interactions and processes involving gravity waves must be playing a major role in this phenomenon. Finally, the quiescent daytime ionosphere above the 150-km region, namely the F-region ionosphere, is observable (at least in principle) in the incoherent scatter mode by VHF radars with sufficient power-aperture product for daytime observation of the mesosphere in the MST mode.

The 50 MHz Jicamarca radar located near Lima, Peru, has the MST and incoherent scatter radar (ISR) capabilities outlined above. During the past decade multi-beam joint MST/ISR observations modes have been developed at Jicamarca given a number of advantages associated with such operations. In MST wind measurements multi-beam radar operations are essential. Since magnetic aspect angles vary across the individual MST beams, the weak incoherent scatter returns detected by these beams from F-region altitudes exhibit a diversity in magneto-ionic polarization response and enable F-region electron density (N_e) estimation. Since ISR backscatter cross-sections are known functions of N_e in probed regions, density estimation calibrates the radar for ISR as well as MST measurements. It is becoming increasingly attractive to use the described joint MST/ISR mode in long-term (several days) Jicamarca campaigns of either mesospheric or ionospheric focus since its additive costs are marginal and its potential benefits are substantial in case of unpredictable events such as solar flares, magnetic storms, and sudden stratospheric warming events. Examples of joint MST/ISR data collected during such events will be presented.

Presented by: **Kudeki, Erhan**

VHF radar observations of non-linear interactions of convectively generated gravity waves using bispectral approach

Kishore Karanam Kumar , *Kizhathur Narasimhan Uma* , *S.R. John*
Space Physics Laboratory, Vikram Sarabhai Space Centre, Thiruvananthapuram-695022, India.

Cumulus convection has received a great deal of attention as a possible source of gravity waves. Now, it is well established that apart from contributing to the drag in the middle atmosphere, convectively generated gravity waves (CGWs) modify the region around the clouds. The exact parameterization of these convectively generated gravity waves needs thorough understanding of such waves including their source mechanisms. In this regard, the present study attempts to discuss the non-linear interactions of convectively generated gravity waves. Continuous VHF radar observations with high temporal resolution of mesoscale convective systems (MCS) are made use for the preset study. The vertical velocity estimates within the MCS form the basis of the analysis. The wavelet spectra of vertical velocity have shown the signature of CGWs in the upper troposphere and lower stratosphere. To study the non-liner interaction among the various harmonics of CGWs, the bispectrum is estimated. The bispectrum analysis using higher order statistics showed the non-liner interaction among the harmonics of CGWs, which is noteworthy result from the present analysis. The results depicted here will have important implications in explaining the observed period of CGW in the middle atmosphere.

Presented by: **Kumar, Kishore Karanam**

New insights into the ambipolar diffusion of meteor trails

Kishore Karanam Kumar [1], *K.V. Subrahmanyam*
[1] *Space Physics Laboratory, Vikram Sarabhai Space Centre, Thiruvananthapuram-695022, India*

Radar echoes from underdense meteor trails have been used to infer the temperature in the 80-100 km region of the atmosphere for decades. Different methods have been used to derive mesospheric temperature values from the meteor decay times and themethod of retrieving temperature has gone through several modifications since its inception.The direct measurements of the ambipolar diffusion coefficient and then conversion to a temperature using assumed values of the pressure is a standard method to retrieve the temperature profile. However, the important assumption in all these methods is the ambipolar diffusion of the meteor trail. So far there are no independent measurements of ambipolar diffusion coefficient to validate this assumption in the height region of 80-100 km. In this regard, we have estimated height profile of ambipolar diffusion coefficient and hence the decay time using temperature and pressure measurements by SABER, which is independent of radar measurements. The comparison of the meteor trail decay time measured by meteor radar at Thumba (8.5^0 N, 77^0 E), and SABER provided very valuable insights into the meteor decay times and also provided much needed validation for assumption of ambipolar diffusion of meteor trail. It is observed that the assumption of ambipolar diffusion is valid only in the height region of 92-100 km where both SABER and radar measurement show excellent agreement in decay times. The present analysis also shows that there are other processes which govern the meteor decay in the 80-90 km region. The difference between the SABER and radar observed decay times are estimated and it is observed that it has very small day-to-day variability. However, there is pronounced diurnal variation in the difference profile. The diurnal variation of difference profile of decay times are quantified for each season and this correction is applied for temperature retrieval, which showed considerable improvement. The important outcome of the present study is the validation of assumption on ambipolar diffusivity of the meteor trails.

Presented by: **Kumar, Kishore Karanam**

Simultaneous observations of small-scale structures in Mesosphere Lower Thermosphere winds and temperature using Meteor radar and OH day-glow photometer over Thumba (8.50 N, 770 E)

Kishore Karanam Kumar , *K.V. Subrahmanyam* , *C. Vineeth* , *T.K. Pant*
Space Physics Laboratory, Vikram Sarabhai Space Centre, Thiruvananthapuram-695022, India

Simultaneous observations of gravity wave induced small-scale structure in the winds and temperature were carried out for the first time over a low-latitude station Thumba. The radial velocities measured within the meteor radar volume are segregated in terms of height, zenith and azimuth angles for further analysis. Two dimensional Fourier analysis is carried out to quantify both the observed time period as well as horizontal wavelength. During the meter radar observations a co-located OH day-glow photometer was operated in the scanning mode at a fixed azimuth angle. . The OH emissions carry signatures of the gravity waves, tidal forcing and planetary wave phenomena which greatly influence the mesosphere lower thermosphere (MLT) processes. As the OH emission layer is located at around 87 km with a thickness of about 9 km, it is believed that the temperature measured by the day-glow photometer represents the atmospheric temperature around 85 to 90 km. This height region is thus overlaps with the meter radar measurements. However, with respect to the temperature measurements it must be remembered that the temperature measured is a weighted average over the emission layer. Thus we obtained simultaneous observations of wind and temperature structures within the MLT region. After quantifying the spatial and temporal variability of wind and temperature, an attempt is made to study the spatial variability of ambipolar diffusion within the radar volume and the same is discussed in the light of day-glow photometer observed temperature structure. It is envisaged that the present study will have important implications in understanding the small-scale spatial variability observed in the MLT region.

Presented by: **Kumar, Kishore Karanam**

Variation of turbulence intensity in cirrus clouds

S. Satheesh Kumar , *T. Narayana Rao*
National Atmospheric Research Laboratory

It is widely accepted that the exchange between the troposphere and stratosphere in tropics occurs primarily through two mechanisms: a fast transport by convection or a slow transport by stratospheric diabatic circulation. Among these processes, the role of convection in dehydrating the air entering into the stratosphere from troposphere is highly debated. Nevertheless, there is a consensus that the turbulence transport in overshooting convective cores is one of the important stratosphere-troposphere exchange mechanisms. Recent studies at Gadanki noted a clear enhancement in turbulence activity in draft cores with the magnitude of turbulence intensity nearly 4.5 times larger in convective cores than in fair weather. Also, recent air craft measurements have reported moderate-marginally severe turbulence not only in active convection regions but also far away from active convection in the anvils. The present study, therefore, attempts to quantify the turbulence intensity in anvil clouds by combining MST radar and Lidar measurements made over Gadanki during 1998-2011. About 650 coincident data sets were collected to study the variability of the turbulence in anvil clouds.

Presented by: **Kumar, S. Satheesh**

MAARSY - The new MST radar on Andøya: system description and first results

Ralph Latteck , *Werner Singer* , *Markus Rapp* , *Toralf Renkwitz* , *Gunter Stober* , *Marius Zecha*
Leibniz-Institute of Atmospheric Physics (IAP) at the Rostock University, Kühlungsborn, Germany

The Middle Atmosphere Alomar Radar System (MAARSY) on the North-Norwegian island Andøya is a 53.5MHz monostatic radar with an active phased array antenna consisting of 433 Yagi antennas. The 3-element Yagi antennas are arranged in an equilateral triangular grid forming a circular aperture of approximately 6300m^2. Each individual antenna is connected to its own transceiver with independent phase control and a scalable power output of up to 2 kW. This arrangement provides very high flexibility of beam forming and beam steering with a symmetric radar beam of a minimum beam width of 3.6°. The system allows classical beam swinging operation as well as experiments with simultaneous multiple beams and the use of interferometric applications for improved studies of the Arctic atmosphere from the troposphere up to the lower thermosphere with high spatio-temporal resolution. The construction of MAARSY started in May 2009 and has been completed in May 2011. Besides standard observations of tropospheric winds and polar mesosphere summer echoes, the first multi-beam experiments using up to 97 quasi-simultaneous beams in the mesosphere have been carried out in 2010 and 2011. These results provide a first insight into the horizontal variability of polar mesosphere summer and winter echoes with time resolutions between 3 and 9 minutes. In addition, first meteor head echo observations were conducted during the Geminid meteor shower in December 2010.

Presented by: **Latteck, Ralph**

Quantifying Atmospheric Turbulence: A validation of the spectral width method with MST radar, boundary layer wind profiler, and aircraft measurements.

Christopher Lee
Centre for Atmospheric Science, University of Manchester

Quantification of turbulence with wind profiling radars has been investigated for decades. The methods used have been continually refined, becoming increasingly complex with fresh mathematical insight, but even the most basic approaches have barely been tested against in-situ measurements. This investigation tests the spectral width method, using a MST radar, a boundary layer wind profiler, and many hours of in-situ aircraft observations. The results highlight the gulf between the theoretical and practical application of radar quantification methods.

There has been a pressing need for a comparison of this nature. Comprehensive climatologies of atmospheric turbulence are needed to support the continuing drive towards weather models with finer resolutions.

Turbulence can be measured using the width of a radar's Doppler velocity spectrum; in stronger turbulence there is a greater spread of turbulent velocities, and so a broader Doppler spectrum width. Alongside turbulence, other factors can broaden the spectrum, and the crux of the spectral width method is to remove those non-turbulent contributions. The most prominent is Beam Broadening, which occurs because the radar observes turbulence over a large volume of the atmosphere. Initial proposals for its correction were straightforward, but more recent studies have combined its correction with other contributions, such Shear Broadening. This study has shown that, whilst the more complex 'combined broadening' form of correction is mathematically rigorous, the technical limitations of a radar can make such improvements insignificant; indeed, under some conditions the simpler approach, which considers broadening terms separately, is more accurate.

Accuracy aside, how representative are radar measurements of turbulence? Aircraft-radar comparisons over the complex terrain surrounding the Capel Dewi MST radar site, in West Wales, show that the variability in spectral widths can be used to quantify fluctuations in turbulence strength over wide areas.

The results presented in this talk provide an extensive validation of the spectral width method, alongside the limitations of the technique. The comparison with in-situ measurements has shown that, with the correct approach, wind profiling radar can be used to quantify atmospheric turbulence in the radars surroundings, paving the way to the first comprehensive climatologies of turbulence in the troposphere and stratosphere.

Presented by: **Lee, Christopher**

Conjuring a Gaussian: A new signal processing approach for turbulent Doppler spectra.

Christopher Lee
Centre for Atmospheric Science, University of Manchester

Doppler radar wind profilers present the best opportunity to construct comprehensive climatologies of atmospheric turbulence. The spectral width method holds the greatest promise, but above the boundary layer, where turbulence is often 'patchy', its key assumption often breaks down: The spectral width method assumes that turbulent Doppler spectra have Gaussian shapes, but in the free troposphere that condition is rarely met. To overcome that problem, this study presents a new approach to Doppler spectrum quantification, constructing Gaussian spectra from non-Gaussian measurements of patchy turbulence.

Many studies have encountered difficulties when quantifying sparse turbulence: The spectral width method assumes that turbulence fills the radar observation volume, so that the ensemble of motions can be measured. Where observation times are too short spectra are non-Gaussian, introducing errors into the quantification of turbulence. Averaging consecutive spectral widths, and the fitting of Gaussians, have both been used to reduce those errors, but neither method is ideal. This study presents a reliable alternative: Combining consecutive Doppler spectra effectively increases the observation time of the radar, and creates a Gaussian spectrum, from which turbulence can be quantified.

Obtaining a Gaussian spectrum is only part of the problem; non-turbulent signals, such as specular reflections, ground clutter, and other contaminants, can make spectral width quantification difficult. This study shows that existing atmospheric signal identification routines used with wind profiling radars (usually tailored for the recovery of winds) can be combined with Gaussian fitting of the Doppler spectrum, and spectral combination, to dramatically improve the accuracy of spectral width retrieval.

Applicable to both boundary layer wind profiler and MST radars, the results presented in this poster demonstrate that the new treatment of Doppler spectra can be used to dramatically increase the accuracy of wind profiler turbulence quantification.

Presented by: **Lee, Christopher**

Development of 53 MHz Multi-Mode Radar for Atmospheric Probing

Parvatala Srinivasulu [1], Polisetti Yasodha [1], P. Kamaraj [1], Meka Durga Rao [1], S. Narayana Reddy [2], A. Jayaraman, PP Leena [4]
[1] National Atmospheric Research Laboratory, Gadanki – 517 112, India
[2] S V U College of Engineering, S V U Campus, Tirupati – 517 502
[4] National Atmospheric Research Laboratory, Department of Space,Government of India

Indian MST radar, evolved under the middle atmosphere program (MAP), is a valuable atmospheric remote sensing tool. It is planned to upgrade this radar, which is operating since 1992, to an active array system using high power solid-state transmit-receive (TR) modules. A separate 133-element pilot array, external to the existing MST radar array, is installed to verify the design concepts like out-door installation of TR modules, Optical Ethernet-working, multi-channel direct digital processing, pulse-to-pulse beam switching, automatic phase calibration etc. All subsystems have been developed and installed except the TR modules, which are being integrated into the system in a phased manner. At present the system is being operated in Doppler beam swinging (DBS) mode with partial array filling. The measured winds are validated by comparing them with those derived from a collocated GPS Sonde.

The quasi-circular shaped antenna array comprises 133 three-element Yagi elements arranged in 7 hexagonal segments, each consisting of 19 elements with triangular grid spacing of 0.7l. Each element of the array is fed directly by a dedicated and collocated *1kW solid-state TR module*, which consists of a *MOSFET high power Amplifier* and *low noise receive section* connected to a common antenna port through a *high-power passive transmit/receive (T/R) switch*. An input section, containing a *digital phase shifter* and *digital attenuator*, is switched between transmit and receive paths by means of a low power T/R switch. A timing and control signal generator (TCSG) card inside the TR module generates the timing and control signals with reference to the input trigger pulse. TCSG is interfaced with optical Ethernet for remote operation. The out-door TR modules are connected to the in-door radar instrumentation through *six-core optical fiber* cable and *Ethernet switches*. Media converters are used on either side of the optical fibers to convert the trigger pulse, reference clock, Tx cal and Rx cal signals from electrical to optical and vice versa.

The DDS-based radar exciter signal is distributed and fed to the 133 TR modules. The receive signals are combined in the respective antenna segments and delivered to the multi-channel direct digital receiver via seven-channel back-end RF unit. A PC-based radar controller (RC) controls the TR modules through optical Ethernet interface network. Multiple GUI is designed for setting the subsystems, calibration and operation of the system. At present, the central antenna segment has been activated with the TR modules and validated with DBS operation while the TR modules are being installed for the rest of the array.

This system is designed for multiple modes of operation such as DBS, Spaced antenna, interferometry, FDI, IDI etc.

Presented by: **Leena, PP**

Development and Validation of L-band Active Array Lower Atmospheric Radar Wind Profilers at NARL

Parvatala Srinivasulu [1], Polisetti Yasodha [1], P. Kamaraj [1], T. Narayana Rao [1], S. Narayana Reddy [2], A. Jayaraman [1], PP Leena [3]
[1] National Atmospheric Research Laboratory, Gadanki – 517 112, India
[2] S V U College of Engineering, S V U Campus, Tirupati – 517 502
[3] National Atmospheric Research Laboratory, Department of Space,Government of India

NARL has developed new 1280 MHz radar wind profiler for lower atmospheric research applications. This system, configured with *active array* and a passive two-dimensional*modified Butler beam forming network,* operates in *Doppler beam swinging* mode. It also has advanced features like *direct IF digital processing* and *pulse compression* schemes. Two profilers have been built and successfully validated.

Low cost dedicated *solid-state 10W transceiver modules*, realized with commercial communication components, are used to feed the individual microstrip patch antenna elements of the square array. Each transceiver consists of a power amplifier (PA) and low noise amplifier (LNA) connected to the common antenna port through a circulator. A transmit/receive switch switches the input port between the PA and LNA. The low power two-dimensional beam-forming network, realized on a printed circuit board, distributes the exciter output signal and feeds the transceivers with appropriate amplitude and phase distribution to generate different beams. This configuration, which is a simplified active array, eliminates the antenna feed loss and achieves best signal-to-noise ratio, thereby increased range coverage. Consequently, this scheme allows smaller antenna size when compared to a conventional passive array system, for the given range performance, and makes the wind profiler compact and transportable. Beam switching is done by controlling a solid state single-pole-multi-through switch. Main advantage of the passive beam forming network is that it avoids the need for periodic phase calibration. Pulse compression feature enhances the height coverage without affecting the range resolution. Direct IF digital processing has advantages like better dynamic range, flexibility, programmability etc,.

Two wind profilers, of 1.4m and 2.8m size each, have been developed. The smaller wind profiler, with an 8x8 array and 64 transceivers, is built as pilot radar to validate the design concepts. It has been deployed at three locations since May 2010 and yielded excellent wind and precipitation data. The larger wind profiler, built with 16x16 array and 256 transceivers, is a stationary system located inside a room for which the planar array acts as roof. This profiler is operating at NARL since March 2011. Typical height coverage (max height) of this system is 4-7 km for the clear air case and 6-14 km during precipitation. Both profilers have been validated by comparing the winds with those obtained by a collocated GPS Sonde.

Presented by: **Leena, PP**

Characteristics of high frequency gravity waves observed using simultaneous high resolution radiosonde and MST radar observations

PP Leena [1]*, M. Venkat Ratnam* [1]*, B.V. Krishna Murthy* [2]
[1] *National Atmospheric Research Laboratory (NARL)*
[2] *B1, CEEBROS, Chennai*

The subject of gravity waves (GWs) has occupied a crucial role in the current atmospheric research due to their myriad effects on atmospheric structure and dynamics. It is well known that GWs play a major role in transporting energy and momentum, in contributing to turbulence and in mixing and influencing the mean circulation and thermal structure of the middle atmosphere. Studies have shown that parameterization of gravity wave drag is required in large-scale numerical models for realistic simulations of the middle atmospheric circulation. For this parameterization, parameters related to wave characteristics are needed which can be determined from observations. Climatology of GWs including complete spectrum is a vital aspect in understanding their role in atmospheric phenomena.

Radiosonde data are widely used for GW research due to their extensive geographical coverage. Until now most of the GWs characteristics reported using radiosonde observations are of low frequency waves. In the present study characteristics of high frequency GWs has been studied by using simultaneous high resolution radiosonde and MST radar using five years of data (2006-2011) collected from Gadanki (13.5^{o}N, 79.2^{o}E). Analysis has been done separately for troposphere (1-16 km) and lower stratosphere (16-28 km) and found that these GWs have the vertical (horizontal) wavelengths of 6-12 km (100-300 km) and 3-7 km (100-500 km) in the troposphere and lower stratospheres, respectively. These characteristics are completely different with that reported for inertial periods for Gadanki station. Most striking result obtained using simultaneous radar observations is that these GWs have periods of 2-6 hours. Horizontal direction of propagation shows that they propagate towards south-east/north-west irrespective of seasons. But in the stratosphere they propagate towards south east direction in the monsoon season.

These studies have been further extended for the radiosonde stations of Truk, Rochambeau, Singapore, Seychelles and Darwin distributed across the globe within ±15^{o}latitude and extracted high frequency GW components. This study, if implemented across the globe, will help to parameterize the high frequency GWs also in the global models.

Presented by: **Leena, PP**

The challenge of providing continuous high-quality measurements with an operational radar wind profiler network

Ronny Leinweber , Volker Lehmann
German Meteorological Service (DWD) , Lindenberg Meteorological Observatory / Richard-Aßmann-Observatory, 15848 Tauche OT Lindenberg, Germany

Ground based remote sensing of the vertical profile of the horizontal wind by radar wind profiler (RWP) has been significantly developed since the first demonstration of clear air radar measurements in the early 1970s and there exist several operational networks of RWP worldwide. One example is the CWINDE network in Europe, which is currently comprised of 30 profilers. Many of the CWINDE RWP provide high quality wind measurements in real-time and it is only such data that can be successfully assimilated in numerical weather prediction models. The main challenge of running such networks is therefore to continuously provide high quality data in a sustainable fashion on a 24/7 basis. It is well known that RWP are able to provide high-quality measurements if they are well-operated and well-maintained. However, these seemingly trivial requirements require a constant endeavor in the operational practice.

The Deutscher Wetterdienst is operating an operational wind profiler network since 2003. It consists of four 482 MHz RWP which are also part of the CWINDE network. Based on our experience in CWINDE, the presentation will focus on practical aspects and problems which are most relevant for the operational use: Frequency management, proper system configuration (in particular signal processing and quality control), maintenance and data monitoring.

The high sensitivity of the RWP makes them vulnerable to any external radio-frequency interference (RFI) of sufficient strength that is in band. As more and more technical applications are using electromagnetic waves, frequency spectrum has become a scare resource. Effective frequency management is therefore an essential issue for operational networks. Nevertheless, RFI is an increasing problem and needs to be considered to avoid spurious data.

Clutter and its detection and filtering is a longstanding problem of RWP. Signal processing and quality control needs to be constantly refined to guarantee a high level of data quality, even with new clutter types like wind turbine echoes. Modern RWP software packages make it possible to address particular clutter problems through a customized processing. This can be very helpful for the suppression of site specific clutter or RFI.

RWP are complex instruments and regular maintenance is necessary to guarantee high level of data quality. This includes both hardware and software. As an example, the advantages of a system upgrade for the DWD RWP network in 2011 will be presented.

Most important for any operational system is a continuous data quality evaluation which is nowadays mainly based on statistical comparison with state-of-the-art NWP models. An example of the capabilities of NWP monitoring to identify a hardware issue with a 482 MHz profiler will be presented.

Presented by: **Lehmann, Volker**

Comparison of wind profiler radar measurements with Doppler Wind Lidar profiles measurements at the Lindenberg GRUAN site

Ronny Leinweber [1], *Stefan Emeis* [2], *Bernd Stiller* [1], *Simone Lolli* [3], *Matthias Mauder* [2], *Ludovic Thobois* [3], *Volker Lehmann* [1]
[1] *German Meteorological Service (DWD) , Lindenberg Meteorological Observatory / Richard-Aßmann-Observatory, 15848 Tauche OT Lindenberg, Germany*
[2] *IKT- Institute of Meteorology and Climate Research (IMK-IFU) Kreuzeckbahnstraße 19 82467 Garmisch-Partenkirchen, Germany*
[3] *LEOSPHERE, 76 Rue Monceau, 75008 Paris, France*

The wind field is one of the most important atmospheric parameters. Its accurate measurement with a high spatial and temporal resolution is crucial for the improvement of Numerical Weather Prediction (NWP) models as well as necessary to obtain reliable calculations of transport of air pollution and trace gases. Radar wind profilers (RWP) are the most thoroughly developed and widely used sensors for ground based remote sensing of the wind field. They provide vertical profiles (up to 15 km) of the horizontal wind at high temporal resolution under all weather conditions, that is in both the cloudy and clear atmosphere. Moreover, new portable wind Doppler lidar systems have been developed due to requirements of the rapid growing wind engineering to measure the wind field. Since these systems work in the near infrared spectrum (1.4 µm – 2.2 µm) the vertical range of the measurements depend on both clouds and aerosol content. These very compact systems complement the group of remote wind field sensors.

We present a comparison of two different Doppler Wind Lidar systems, developed by Leosphere and Halo Photonics, respectively, with a 482 Mhz Wind Profiler. The comparison was done at the Lindenberg GCOS Reference Upper-Air Network (GRUAN) site for a period of two months (October/November 2011). Radiosonde and NWP model output data was additionally used for the comparison.

The 482 MHz radar wind profiler was operated in a 4-beam Doppler Beam Swinging (DBS) configuration similar to Leosphere lidar. The Halo lidar was configured to use a classical Velocity Azimuth Display (VAD) configuration using 24 discrete beams. The paper will present the first results of this intercomparison.

Presented by: **Leinweber, Ronny**

PMSE observations with the EISCAT VHF and UHF-radars: Ice particles and their effect on ambient electron densities

Qiang Li , *Markus Rapp*
Leibniz-Institute of Atmospheric Physics (IAP) at the Rostock University, Kühlungsborn, Germany

Polar mesosphere in summer is host to the coldest temperature on Earth leading to the presence of nanometer-size ice particles which can become charged due to electron attachment. This process modifies the charge balance in the ambient environment. It is now common belief that polar mesosphere summer echoes (PMSE) originate from turbulence induced scatter in combination with a large Schmidt number due to the presence of charged ice particles. According to this theory, volume reflectivity-ratios of PMSE simultaneously observed at two frequencies can be used to calculate the Schmidt number and hence radii of the charged aerosol particles. In this study, we do this exercise on the simultaneous PMSE observations with the EISCAT VHF and UHF radars, collocated near Tromso (69^{o}N, 19^{o}E) and operated at frequencies of 224 and 930 MHz, respectively. The resulting particle radii both display excellent agreement with expectations from microphysical models and independent optical observations of microphysical ice parameters. Furthermore, electron densities deduced from the UHF-observations (i.e., in the absence of UHF-PMSE) have been used to statistically study electron density depletion in the presence of PMSE simultaneously observed with the EISCAT VHF-radar. Calculated Havnes-parameters Λ reveal values which are much smaller than unity for the large majority of observations.

Key words: Polar Mesosphere Summer Echoes; Schmidt number; Volume reflectivity; Electron density

Presented by: **Li, Qiang**

A new field campaign for tropospheric turbulence studies with the MU radar and intensive insitu observations with RS92G Vaisala radiosondes.

Hubert Luce [1], *Richard Wilson* [2], *Francis Dalaudier* [2], *Noriyuki Nishi* [3], *Shoichiro Fukao* [4], *Masanori Yabuki* [5], *Hiroyuki Hashiguchi* [5], *Jun-ichi Furumoto* [5], *Yoshiaki Shibagaki* [6], *Tomoyuki Nakajo* [4]
[1] *South Toulon-Var University, La Garde, France*
[2] *LATMOS-IPSL, UPMC Univ Paris 06, Univ. Versailles St-Quentin, CNRS/INSU, Paris, France.*
[3] *Division of Geophysics, Graduate School of Science, Kyoto University, Kyoto, Japan*
[4] *Department of Space Communication Engineering, Fukui University of Technology, Fukui, Japan*
[5] *Research Institute for Sustainable Humanosphere, Kyoto University, Uji, Japan*
[6] *Osaka Electro-Communication University, Negagawa, Japan*

Soon after their conceptions, ST VHF radars have been used simultaneously with instrumented balloons for measuring atmospheric parameters. Intercomparisons improved our knowledge on the radar backscattering mechanisms at VHF which, in turn, provided some information on atmospheric dynamics and structures at various scales. Various methods were then developed for retrieving small-scale turbulence parameters from ST radars. However, the dominant sources and characteristics of the turbulent events detected by the ST radars in the troposphere are still poorly documented partly due to the lack of resolution of these instruments.

The MU radar can be operated in range imaging (FII) mode so that a range resolution of several ten meters can be achieved at a time resolution of a few tens of seconds. For the first time, a field campaign was carried out in September 20011 for about three weeks with intensive balloon observations (59 RS92G Vaisala radiosondes launched every three hours mainly during night periods). The balloon data were devoted to the detection of turbulent events using an original processing method based on Thorpe analysis of potential temperature profiles (see the companion abstract by R. Wilson et al.). In addition, static stability and Richardson number profiles could be estimated in the vicinity or even within some turbulent layers. These data helped us to identify the nature of the instabilities detected by the MU radar and the background atmospheric conditions in which they occurred. Dynamical shear instabilities and convective instabilities at cloud edges will be particularly addressed in this work.

Presented by: **Luce, Hubert**

Radar and lidar observations in the summer mesosphere at Davis, Antarctica

Franz-Josef Lübken [1], *Josef Höffner* [1], *Bernd Kaifler* [1], *Timo Viehl* [1], *Ray Morris* [2]
[1] *Leibniz-Institute of Atmospheric Physics, Kühlungsborn*
[2] *Australian Antarctic Division, Hobart, Australia*

We report the first simultaneous measurements of temperatures by a mobile Fe resonance lidar and polar mesosphere summer echoes (PMSE) by a VHF radar both located at Davis, Antarctica (69°S, 78°E). The lidar was installed at Davis in December 2010 and measures temperatures in the iron layer, i. e. approximately from 80 to 100~km. It is based on probing the Doppler broadened resonance line of iron atoms and can operate under daylight conditions. Typical values for temperature uncertainty, altitude and time resolutions are 3-5 K, 1 km, and 1 hour, respectively. The 55 MHz VHF radar performs measurements since February 2003. Several hours of simultaneous lidar/radar observations are now available from the Antarctic summer season 2010/2011. Ice particles in the summer mesosphere can be detected by lidar (`noctilucent clouds', NLC) and also create strong radar echoes known as PMSE. The existence of ice particles relies on temperatures being lower than the frost point temperature. Temperatures measured by our Fe lidar are generally very low in the mesopause region but occasionally show some unexpected features. For example, we sometimes find the mesopause at significantly higher altitudes compared to similar latitudes in the northern hemisphere. The VHF radar frequently detects PMSE. Temperatures are below the frost point at PMSE altitudes assuming reasonable water vapor concentrations. To our surprise PMSE were persistently absent at altitudes where temperatures are much lower than the frost point. We note that (apart from low temperatures) more ingredients are required for PMSE, for example, charged ice particles of sufficient size, background electrons, neutral air turbulence etc. We present a first overview of our measurements at Davis and discuss potential explanations for the presence and absence of PMSE. We also compare with the general circulation at lower altitudes and present first measurements of thermal tides in Davis and comparison with corresponding NH observations.

Presented by: **Lübken, Franz-Josef**

An FPGA-Based Wind Profiler Controller and Signal Processor

Charles Martin , *Eric Loew* , *Chris Burghart* , *William Brown* , *Brad Lindseth*
National Center for Atmospheric Research, Boulder, CO USA

Reconfigurable computing and board level integration have experienced phenomenal advancement in the last decade. These have enabled the functionality for radar system control, signal processing and data acquisition to be migrated from rack-sized systems and extensive custom circuitry onto off-the-shelf cards hosted in generic computer workstations.

The Software-Defined Digital Down Converter (SD3C) is a complete radar processor built on a single commercial digital transceiver card. The off-the-shelf card is based on a Field Programmable Gate Array (FPGA). Multi-channel IF digitization, down-conversion, transmit pulse generation, and digital timing signals are all provided by the PMC format card. The hardware vendor supplies core firmware for controlling the hardware assets on the card and integrating with the host operating system, and the developer simply inserts application specific processing blocks within this framework. Flexible firmware and host software implement a variety of signal processing tasks, such as configurable filtering, data tagging, pulse coding/decoding, and coherent integration. Other capabilities are possible. Reconfiguring the signal processing behavior is achieved simply by loading different firmware. A single card supports up to four channels of down conversion and one transmit pulse output. Multiple cards can be combined to increase the number of channels in the system.

The SD3C system requirements and design are presented, with application to a newly developed spaced antenna wind profiler. The functional components and their interconnections are explored, with discussion of the development challenges and lessons learned. Robust and well-designed software is the key to easily deploying the processor in different profilers, and the SD3C host software architecture is detailed. Performance measures and observational results are given for the NCAR 449 MHz wind profiler.

Presented by: **Martin, Charles**

The NCAR 449 MHz Modular Wind Profiler – Prototype and future plans

Stephen Cohn , William Brown , Brad Lindseth , Charles Martin
National Center for Atmospheric Research

NCAR is developing a prototype modular wind profiler radar network to support measurements for a broad range of meteorological studies. The new wind profiler operates at 449 MHz, and will feature a low side-lobe antenna design, scalable electronics and advanced signal processing methods. The modular design uses a set of panels that can be operated together in various groupings to provide flexible profiling capability that covers a range of altitudes and network sizes. For example, the modules could be deployed as multiple small radars to study the boundary layer over an extended area. Alternatively, the modules could be combined together to create a more powerful and sensitive radar capable of probing higher into the atmosphere.

A prototype 3-module boundary layer system has been constructed and successfully deployed during the recent PCAPS (Persistent Cold Air Pool Study) experiment in the Salt Lake valley, and preliminary results will be presented. The system is currently being expanded to 7 modules. Ultimately at least 19 modules are envisioned, which would allow six (3-module) boundary layer profilers, or two (7-module) mid-troposphere profilers, or one (19-module) full troposphere profiler to be deployed. The new system would be deployed as an integrated suite of instruments, with lidars and other in-situ and remote sensors, and is intended to meet the diverse needs for studies of the atmospheric surface layer, boundary layer, free troposphere, and tropopause region.

Presented by: **Martin, Charles**

Quality aspects of the measurements of a wind profiler in a complex topography.

Mercedes Maruri [1], *Juan Antonio Romo* [2], *Leixuri Gomez* [2]
[1] *(1) Euskalmet/Tecnalia Unidad de Meteo. (2) UPV-EHU University of the Basque Country.*
[2] *UPV-EHU University of the Basque Country*

It is well known for the scientific community that some remote sensing instrumentation have considered the assumption of homogeneity conditions in the sample volumes to achieve a quality meteorological profile but generally, in a complex topography and extreme meteorological conditions, this assumption is faulty in the lower layers. This paper shows the results of a work that test the homogeneity wind field over a boundary layer wind profiler radar sited in a complex terrain at a coast, over different meteorological conditions. The result of this work reveals how important is for quality purpose to know the deviations of the assumption and evaluate its effect in the final product. This information is useful as the starting point to look for the best alternative that the system offers to build the wind profile. The methodology used is crucial, taking into account that the amount of data is high and not all of them are comparable, many decisions are assumed to avoid misinterpretation. Finally the results are being considered to integrate in a quality algorithm implemented at a product level.

Presented by: **Maruri, Mercedes**

A Model Study on the Measurement Error of Wind Profiling Radar Observations in the Atmospheric Boundary Layer

Makoto Matsuda [1], *Toshitaka Tsuda* [1], *Kuniaki Higashi* [2], *Jun-ichi Furumoto* [1]
[1] *RISH, Kyoto University*
[2] *RISH, Kyoto University / Japan Meteorological Corporation*

A Wind Profiling Radar (WPR) with the Doppler Beam Swinging (DBS) is widely used to measure the wind velocity in the lower troposphere regardless of weather conditions, such as WINDAS of the Japan Meteorological Agency (JMA). For a monostatic WPR with three or five antenna beams (hereafter called WPR3B and WPR5B), we assume homogeneity of wind fields within the horizontal region of antenna beam steering, which could, however, induce estimation error of the wind velocity under disturbed conditions. In the planetary boundary layer below about 2km, range difference inside the radar illuminating volume may not be negligible, which produces a weighting for integration of scattered echoes.

Using a numerical model, we investigated the measurement errors; (1) horizontal inhomogeneity of winds, and (2) finite range volume effects. In particular, we discuss advantages of a bistatic WPR (WPRB) with a pair of antennas for transmission and reception.

We first calculated the shape of the range volume assuming a realistic specification of WPR operated on 1.3GHz, i.e., pulse width of 0.66microsecond and 2m x 2m array antenna. We assumed a simple model of the horizontal wind velocity with a linear shear along height (5m/s/km), and the wind shear is changed at a certain height to 10m/s/km. The error of the horizontal wind velocity is about 1 % for both WPR3B and WPR5B. The error increased to about 5% at the altitude where the wind shear changed. For WPRB the measurement error becomes smaller, because it determines the wind velocity in an overlapping volume between two antenna beams, and therefore, the vertical resolution becomes better.

In order to investigate the effects of horizontal variations of the wind fields, we used a realistic wind data provided from the Large Eddy Simulation(LES). Under a quiet atmospheric state, no much differences are seen in both methods. However, when atmospheric disturbance occurs, the measurement error with WPR5B is less than that with WPR3B, because the former is not affected by the linear horizontal gradient of horizontal wind field. However, the linear horizontal gradient of vertical wind produces error even for WPR5B. These measurement errors due to the horizontal gradient of winds do not appear for WPRB.

We estimated the measurement error for WPR, and found that WPRB provides a better accuracy. As the system configuration, however, becomes more complicated for WPRB, further investigation is needed to propose a better observation system.

Presented by: **Matsuda, Makoto**

Characteristics of the "Hiccup" during the fall transition

<u>Vivien Matthias</u> [1]*, Theodore Shepherd* [2]*, Charles McLandress* [2]*, Peter Hoffmann* [1]*, Markus Rapp* [1]
[1] *IAP*
[2] *University of Toronto*

By combining global satellite and high-resolution radar observation at Andenes (69°N,16°E) and Juliusruh (54°N,13°E) with assimilated model data, the characteristics of the disruption of the fall transition in the northern hemisphere is investigated at stratospheric and mesospheric altitudes. With the help of the global temperature observations from the Microwave Limb Sounder (MLS) aboard the Aura satellite, the latitudinal and longitudinal dependence of the "Hiccup" is investigated and the assimilated CMAM-DAS data are validated. The composite pictures of wind, temperature and wave activity are also considered and imply a correlation between the Hiccup and the onset up of the polar vortex. The role of planetary-wave drag, gravity-wave drag and downward control will also be analyzed in the dynamics of the fall transition Hiccup.

Presented by: **Matthias, Vivien**

Renovation of the Aberystwyth MST radar: Technical issues

Richard Mayo [1], *John Bradford* [2], *Les Dean* [3], *Jon Eastment* [2], *Marco Hess* [1], *Eric Hibbett* [1], *David Hooper* [2], *John Jacobs* [4]
[1] *ATRAD*
[2] *Rutherford Appleton Laboratory*
[3] *Aberystwyth University*
[4] *John Jacobs Consulting*

In early 2011, the Aberystwyth MST Radar underwent its first major renovation in its 20 year lifetime. This principally consisted of replacing the components which allow it to operate according to the Doppler Beam Swinging principle. The design and installation work was carried out by ATRAD. The renovation lead to a remarkable 28% increase in useful coverage for wind-profiling purposes. This presentation will look at the technical aspects.

The original DBS system employed 100 phasing units which were distributed throughout the antenna array. Each unit used electro-mechanical coaxial relays to switch in lengths of cable to give a 3 bit binary phase shift. These relays had a nominal lifetime of 1 million operations, which each relay typically performed in a single year. Owing to their high cost and to their large numbers, faulty relays were reconditioned rather than being replaced. The 6 monthly testing and reconditioning of these units became the major recurrent maintenance task for the radar. Additionally, the 100 cables used to control the relays were prone to weather and vermin damage. This contributed to radar performance degradation and to maintenance cost.

The design of the replacement phasing units took the above experiences into account. It aimed to minimise long-term maintenance time and material costs, while actually improving the radar system capability. The new phasing units use a microprocessor based design. They employ a standard 2.4 GHz industrial protocol to communicate DBS and diagnostic information to a central controller in the radar hut. The new phase shift relays cost just a few dollars each and have a nominal lifetime of 20 million operations. This has allowed an improved 6-bit phase shift design to be implemented. The power and control signals to the new phasing units are delivered through the existing radar RF cable network. The original control cables have been removed entirely. In the case of a failure, a phasing unit can be easily replaced with a spare before being brought back to the workshop for test and repair. The new diagnostic information has already proved itself to be useful for identifying problems in other parts of the system. For example, it can indicate when one of the transmitters has unexpectedly stopped operating.

Presented by: **Mayo, Richard**

New Developments and Innovations in VHF Radar

Richard Mayo , Bronwyn Dolman , Gary Jonas , Iain Reid , Jonathan Woithe
ATRAD P/L

A number of new developments and innovations have recently been put into service for both scientific and commercial radars produced by ATRAD. The most significant of these is a combined Digital Transceiver system incorporating Digital Exciter, Digital Receiver and Data Acquisition subsystems. The Digital Transceiver supports radars operating in the MF, VHF and UHF bands. It has a highly flexible architecture with the raw acquired data being delivered via a gigabit data channel. The number of receiver channels can be expanded in multiples of three and limited only by the data bandwidth of the computer system processing or storing the data. The Digital Transceiver is now used in MST, Boundary Layer, Meteor and Ionospheric Radars and has been in use operationally for over 2 years. While no systematic intercomparisons have yet been completed, evidence suggests a typical increase of up to 20% in meteor counts. This results in counts well over 30,000 per day on a 20kW All-sky meteor radar. The Digital Transceiver has also produced marked improvements in the spectral results obtained from Doppler radars, allowing for a very significantly improved ability to discern precipitation returns from clear-air returns. Moreover, the results of an extended balloon sonde inter-comparison against a 55 MHz ST-class Doppler radar and a 55 MHz Boundary Layer radar demonstrate the ability to obtain reliable coverage down to 500m for the Doppler radar and 300m for the Boundary Layer radar. The 10% underestimation bias often observed on spaced-antenna radars operating the Full Correlation Analysis has also been corrected.
Substantial effort has also been devoted to the development of improved beam-steering systems. As a result it has been possible to all but eliminate self-generated clutter in high power beam-steering applications and switching systems. A further development of these beam-steering systems was used to good effect in the upgrade of the Aberystwyth MST. This utilises a system of intelligent phase controllers distributed through the array, powered and controlled using ZigBee network communications down the RF feeder network. This provides almost the same practical radar capability as a radar using electronic beam-forming, but has the advantage of being able to be retrofitted to older radars at a fraction of the cost of a complete upgrade. The system also provides rich selfdiagnostic functions, automatically sending warning messages and allowing a user to remotely assess identify the nature of the fault and at which node the fault is occurring.

Presented by: **Mayo, Richard**

Australian Government Bureau of Meteorology Next Generation Wind Profiler Network

Daniel McIntosh
Australian Government Bureau of Meteorology

To date, the primary source for obtaining wind data within the stratosphere and troposphere has been with balloon flight observations; I.e. Radar tracked balloon or GPS sonde. In its continued efforts to modernise and optimise its composite observations network, the Australian Government Bureau of Meteorology (BoM) has elected to procure and deploy radar wind profiler systems at various remote locations around Australia. The goal is to implement a cost effective observing system that provides high temporal resolution tropospheric wind data for use in forecasting and nowcasting as well as input into Numerical Weather Prediction (NWP). The supplier of the profilers is an Australian company Atmospheric Radar Systems (ATRAD). The BoM will make use of two profiler types: A low level Boundary Layer Profiler (BLP) and an upper level Stratospheric Tropospheric Profiler (STP). All systems will be located within approximately 15 km of airports to provide support for aviation forecasting. The BLP systems will utilise the Spaced Antenna (SA) technique and the STP systems will utilise the Doppler Beam Steering (DBS) technique. ATRAD have implemented a bias correction algorithm to correct for the speed bias associated with SA systems.

This presentation will discuss the impetus for the network along with showing some initial results. We will also outline plans for establishing a systematic process for establishing some form of traceability of wind measurements

Presented by: **McIntosh, Daniel**

Atmospheric radar reception using LOFAR technology

Derek McKay-Bukowski
Rutherford Appleton Laboratory

Traditional radar and radio-astronomy methods have often been on diverging paths owing to differences in frequency, sampling, control and the practicalities of equipment implementation. However, with recent advances in digital signal transport and processing, the techniques are showing convergence again. The LOFAR (Low-Frequency Array) project is a massive phased-array radio-astronomy programme, with many useful advances applicable to radar communities. This presentation gives an overview of the LOFAR facility, and discusses recent developments within the KAIRA (Kilpisjärvi Atmospheric Imaging Receiver Array) project which will use LOFAR technology for VHF radar reception.

Presented by: **McKay-Bukowski, Derek**

Eureka meteor radar temperatures compared with Aura and SABER

Chris Meek [1], *Alan Manson* [1], *Wayne Hocking* [2]
[1] *Institute of Space and Atmospheric Studies, University of Saskatchewan,Canada*
[2] *Department of Physics and Astronomy, University of Western Ontario, Canada*

The meteor trail echo decay rates are analysed on site to provide daily temperature at near 90Km. In order to get absolute temperature, either knowledge of the pressure, or of the background temperature height gradient near 90Km is required (Hocking,1999). The gradient is assumed to just depend on latitude and time of year. Hocking et al.(2004) have developed an empirical gradient model, which is used in the SKiYMET meteor analysis. Here we look at the sensitivity of the resulting temperature to the assumed gradient and compare the temperatures with daily Aura averages near Eureka. The gradient model is also compared with Aura and SABER gradients. And finally, long term oscillations in temperature and wind are compared.

Presented by: **Meek, Chris**

Mesosphere vertical velocity and tilts.

Chris Meek , *Alan Manson*
Institute of Space and Atmospheric Studies, University of Saskatchewan, Canada

Saskatoon MF radar (MFR) analysis includes angle of arrival (AOA) phase and Doppler velocity. The criteria for these are based on S/N only. We have been interested in vertical velocity for years (J Atmos Sci., 46, 849-858, 1989) but dissuaded by the difficulty in assuring that it is a vertical value, not due to a Tx beam or ionospheric scatterer tilts. With the wide beams necessary at M,F an ionospheric tilt is the more likely cause of horizontal motion contamination. The "best" tilt is defined as that which minimizes the mean squared difference between measured and predicted (by tilt and horizontal wind) Doppler velocities, and can be found by a least squares fit. Multi-year statistics show that the tilts are seasonal and is quite consistent year to year: about 4 degrees westward in summer (corroborated to some extent by AOA phase) and 2 degrees southward in winter. In spring, especially, and fall the tilts are small. Platteville MFR data are similar, which rules out individual antenna array characteristics as a cause. Gravity waves travelling against the wind (tilt up in the direction of propagation) may be an explanation, at least for the summer feature,

Presented by: **Meek, Chris**

Advanced Capabilities and applications of the new Digisonde DPS-4D at Juliusruh

Jens Mielich
Leibniz-Institute of Atmospheric Physics (IAP) at the Rostock University, Kühlungsborn, Germany

The IAP field station in Juliusruh (54.6°N 13.4°E, URSI code JR055) is well known for over 50 years of continuous and high quality ionosonde data. Since the end of 2011 we have installed the latest version of Digisondes, a DPS-4D, which provides a wide range of technical and software innovations to speed up and improve the quality of standard ionograms and save time for additional ionospheric measurements of interest. We present results of first experimental experiences with E- and/or F-region drift measurements by producing echo location skymaps and calculating horizontal and vertical drift velocities of the ionospheric plasma above.

Beside this scientific aspect of the Digisonde, it is routinely used for monitoring and predicting ionospheric conditions especially for HF communication users. For this purpose we plan to use the oblique sounding capabilities in the silent reception mode to monitor neighbouring transmitting digisondes.

The Juliusruh ionosonde station is part of the international Global Ionospheric Radio Observatory (GIRO) and the European Digital Upper Atmosphere Server (DIAS).

Presented by: **Mielich, Jens**

Case-study of tropopause fold observation by MARA MST radar at Wasa, Antarctica – comparison with ECMWF and WRF model data.

Maria Mihalikova , Sheila Kirkwood , Joel Arnault , Daria Mikhaylova
Swedish Institute of Space Physics

Tropopause folds are one of the mechanisms of Stratosphere-Troposphere exchange, which can bring ozone-rich stratospheric air to low altitudes. They can be observed in mid–latitudes but also known to reach polar regions of the Northern Hemisphere. With the help of MARA (Moveable Atmospheric Radar for Antarctica) 54.5MHz MST radar, which was operated at the Swedish summer station Wasa in Antarctica (73°S, 13°W) from season 2007 to 2011, and will be operated at the Norwegian year-round station Troll (72°S, 2°E) from November 2011, tropopause folds events were observed passing the radar site in polar regions of the Southern Hemisphere. A case study of a tropopause fold observed by MARA during the summer season 2010-2011, together with collocated ozone-sonde measurements, will be presented. Comparison of observed changes in tropopause height during this tropopause fold events with ECMWF and WRF model data simulations will be made.

Presented by: **Mihalikova, Maria**

VHF/UHF Radio-Wave Backscatter from Corrugated Sheets in the Stably Stratified Atmosphere

Andreas Muschinski
NWRA, CoRA Division

One of the long-standing research topics in radio science is the relative importance of turbulent vs. non-turbulent refractive-index fluctuations for VHF/UHF backscatter from the optically clear atmosphere. The well-known near-zenith echo intensity aspect sensitivity observed at VHF frequencies (50 MHz) has been explained as Fresnel scatter from non-turbulent, quasi-horizontal "sheets," which often dominates Bragg scatter from turbulent refractive-index fluctuations. It appears to be less well understood, however, why there is typically no aspect sensitivity at frequencies of 400 MHz and higher.

Here, I present and discuss a theoretical analysis of the effects of small-scale "sheet roughness" on the echo intensity as a function of radar wavelength and zenith angle. The sheet roughness is characterized in terms of the two-dimensional, horizontal wavenumber spectrum of the elevation fluctuations of a sheet. The theoretical development builds on the Born approximation of the backscattered wave and the Fresnel approximation of the transmitted wave (see Doviak and Zrnic, Radio Sci., 1984; Muschinski, Radio Sci., 2004).

Presented by: **Muschinski, Andreas**

Vertical flow in atmospheric boundary layer observed by a lower troposphere radar under clear air condition

Tomoyuki Nakajo [1], *Kenji Sasaki* [2], *Yuki Ogura* [3], *Yoichiro Saito* [3], *Hiroyuki Hashiguchi* [4], *Manabu D. Yamanaka* [5], *Shoichiro Fukao* [1]
[1] *Department of Electrical, Electronics and Computer Engineering, Fukui University of Technology, Fukui, Japan*
[2] *Department of Space Communication Engineering, Fukui University of Technology, Fukui, Japan*
[3] *Department of Electrical Engineering, Fukui University of Technology, Fukui, Japan*
[4] *Research Institute for Sustainable Humanosphere, Kyoto University, Uji, Japan*
[5] *Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology, Japan*

The atmospheric boundary layer (ABL) is one of most important atmospheric layers in terms of having a direct influence on our life, the detailed motion of atmosphere, however, have not been fully investigated because of its immense complexity.

One of powerful tools for exploring ABL is Lower Troposphere Radar (LTR) which can observe wind velocity in 3D from a few hundred meters to about ten km in altitude with the range resolution of a few hundred meters and the temporal resolution of a few minutes. There is no other observing tool which can realize so highly resolved observation of ABL.

We re-analyzed LTR data obtained at Shigaraki MU observatory in Japan from 2000 to 2006. In order to investigate the mean picture of ABL under clear air condition, the daily average of wind velocity, echo power and spectral width were calculated by using the data obtained in the case of clear sky. As the results, it is clarified that the altitude of top of ABL reaches 1 km in winter and more than 2 km in the condition of summer. In addition, we found that the downward flow with the velocity of a few 10 cm/s grew up in all altitudes from the minimum of observable altitude to top of ABL and was maintained in daytime ABL. This downward flow was observed in all seasons, however, seemed to be strongest in summer. Moreover, we also found that upward flow was almost always observed after ABL dissipated at sunset.

Around Shigaraki MU observatory, there are no high mountains which cause mountain-valley wind that can reach 2 km in altitude, therefore, we consider there may be another cause which determines the vertical flows in ABL except for the effect of solar insolation or local topography.

Presented by: **Nakajo, Tomoyuki**

Adaptive beamforming technique for accurate vertical wind measurements with multi-channel MST radar

Koji Nishimura [1], Takuji Nakamura [1], Toru Sato [2], Kaoru Sato [3]
[1] National Institute of Polar Research
[2] Graduate School of Informatics, Kyoto University.
[3] Department of Earth and Planetary Science, The University of Tokyo

Aspect-sensitive backscattering of the atmosphere causes a small error in an effective line-of-sight direction in vertical beam observations leading to a serious degradation in vertical wind estimates due to contamination from horizontal wind components. An adaptive beamforming technique for a multi-channel MST radar is presented which enables us to measure the vertical wind velocity with higher accuracy by adaptively counter-steering the reception beam against the imbalance of aspect-sensitive reflectivity pattern. The technique employs the norm-constrained direction-constrained minimization of power (NC-DCMP) algorithm which provides not only robustness but also a higher accuracy than basic DCMP algorithm under realistic conditions.
Although the technique decreases the signal-to-noise ratio (SNR), the amount is controlled and bound at a specified level by the NC. In case the decrease of -3dB can be accepted in a vertical beam observation, in which usually much higher SNR is obtained than in oblique beams, the maximum contamination is suppressed to 1/10 at its maximum even if the possible severest imbalanced aspect sensitivity exists.

Presented by: **Nakamura, Takuji**

Long-term variability and trends of mean winds in the mesosphere and lower thermosphere within ±22°

Venkateswara Rao Narukull [1], *Toshitaka Tsuda* [1], *D. M. Riggin* [1], *S Gurubaran* [2]
[1] *RISH, Kyoto University, Uji, Japan*
[2] *EGRL, Indian Institute of Geomagnetism, Tirunelveli, India*

We studied the long-term variability of mean zonal and meridional winds in the Mesosphere and Lower Thermosphere at seven locations; Kauai (22°N, 154°W), Tirunelveli (8.7°N, 77.8°E), Christmas Island (2°N, 157°W), Koto Tabang (0.2°S, 100.3°E), Jakarta (6°S, 107°E), Pameungpeuk (7.4°S, 107.4°E), and Rarotonga (21.2°S, 159.7°W). Locations with nearly similar latitudes such as Christmas Island and Koto Tabang, and Jakarta and Pameungpeuk are treated as single location and the data are appended at each latitude to get the long-term data. The mean meridional wind shows a distinct annual oscillation at all locations. They also show opposite long-term trends at ~ ±8° with the winds changing from northward to southward at Tirunelveli (8.7°N) and from southward to northward at Jakarta and Pameungpeuk (~ 7°S). The zonal wind shows a distinct semiannual oscillation at all locations. The annual mean zonal winds within ±8° are westward biased and are eastward biased outside. The zonal winds does not show any significant long-term trends. Furthermore, we use regression analysis to obtain linear trends and trends associated with forcing due to Quasi Biennial Oscillation (QBO), Southern Oscillation Index (SOI), and Solar Cycle (SC).

Presented by: **Narukull, Venkateswara Rao**

Momentum Flux Determination using the Multi-Beam Poker Flat Incoherent Scatter Radar

Michael Nicolls [1], *David Fritts* [2], *Diego Janches* [3], *Craig Heinselman* [1]
[1] *Center for Geospace Studies, SRI International, Menlo Park, California, USA*
[2] *Colorado Research Associates, NorthWest Research Associates, Boulder, Colorado, USA*
[3] *NASA / Goddard Space Flight Center, Greenbelt, Maryland, USA*

We present an estimator for the vertical flux of horizontal momentum with arbitrary beam pointing, applicable to the case of arbitrary but fixed beam pointing with systems such as the Poker Flat Incoherent Scatter Radar (PFISR). This method uses information from all available beams to resolve the variances of the wind field in addition to the vertical flux of both meridional and zonal momentum, targeted for high-frequency wave motions. The estimator utilizes the full covariance of the distributed measurements, which provides a significant improvement over the direct extension of previously developed techniques. We find that for the PFISR experiment, we can construct an unbiased and robust estimator of the momentum flux if sufficient and proper beam orientations are chosen, which can in the future be optimized for the expected frequency distribution of momentum-containing scales. We address the effects of beam pointing errors on the estimator, which comes as a result of the finite beamwidth (1 deg x 1.5 deg referring to the +/-3-dB pattern) of PFISR, and find that expected biases for the specific geometry considered are no more than a few m^2/s^2. We apply the estimator to PFISR mesospheric measurements (60-85 km altitude), and show expected results as compared to mean winds and in relation to the measured vertical velocity variances.

Presented by: **Nicolls, Michael**

High-latitude Observations of Atmospheric Gravity Waves in the Mesopause Region

Dominique Pautet [1], *M.J. Taylor* [1], *Y. Zhao* [1], *W.R. Pendleton Jr* [1], *Peter Hoffmann* [2], *Werner Singer* [2]
[1] *Center for Atmospheric and Space Science (CASS)*
[2] *Institute of Atmospheric Physics (IAP)*

Atmospheric gravity waves propagating from the troposphere up to the lower thermosphere play a key role in the thermal structure and large-scale circulation of the mid-atmosphere. These waves have been extensively studied using wide-angle CCD imagers, but mostly from sites located at low and mid-latitudes. High-latitude observations are more difficult due to the permanent twilight during the summer months and the frequent presence of auroras contaminating the airglow signatures during the winter period.

To better quantify the effects of gravity waves at MLT (mesosphere lower thermosphere) heights (~80-100 km) over high-latitude sites and improve the knowledge on their propagation characteristics, and geographic variability, several Utah State University optical instruments were recently deployed at the ALOMAR Arctic facility (69.3°N), and at the Amundsen-Scott South Pole Station (90°S).

During the 2009-10, a wide-angle (~120°) broadband infrared (0.9-1.7mm) InGaAs camera was operated at ALOMAR. It provided key measurements to study the main characteristics of the short-period gravity waves propagating over the observatory, including horizontal wavelength, propagation direction, observed period and phase speed. In November 2010, this instrument was upgraded to measure the mesospheric temperature using the ratio between the OH (3,1) and (4,2) bands.

The characteristics of the short-period gravity waves and their effects and response to the MLT region dynamics will be discussed and compared with observations from other high-latitude sites.

Presented by: **Pautet, Dominique**

Apparent electron density modulation under RF heating at EISCAT UHF and its application for estimating the electron-ion temperatures ratio

Henry Pinedo [1], *Cesar La Hoz* [1], *Ove Havnes* [1], *Mike Rietveld* [2]
[1] *University of Tromsø, department of Physics and Technology*
[2] *EISCAT, Heating Division Ramfjordmoen*

In a co-located campaign with UHF radar and Heating EISCAT facilities on June 7 2010 in Tromsø¸-Norway, standard EISCAT analysis show an apparent electron density modulation during heating-on times. The modulation is fairly evident at heights above 90 km of altitude and is manifested as a depletion of density of approximately 40% respect to the background level during heating-off times. The increase of electron temperature in a controlled way is an expected result of artificial heating perturbation. However, the amount of energy required to produce density modulations sensible to radar systems on the ground is much more than what the HF can produce and transfer to the plasma. The associated plasma transport process due to pressure gradients induced by electron temperature variations is slowed down by the ion mass according to ambipolar diffusion. Therefore, the plasma transport time scale to produce measureable plasma depletion is larger than the current 20sec Heating-on time. The apparent electron density modulation is attributable to how the corresponding parameters have been estimated. The assumed criterion of equal temperature for electrons and ions inside the involved region is not valid under heating conditions. This situation provides an opportunity for simple and reliable estimation of Te/Ti ratio during heating-on times, based on a density modulation-less process using the radar equation.

Presented by: **Pinedo, Henry**

Comparison of mesospheric gravity wave momentum fluxes derived by MF Doppler radar and meteor radar measurements at 69°N

Manja Placke , *Peter Hoffmann* , *Markus Rapp* , *Werner Singer* , *Ralph Latteck*
Leibniz-Institute of Atmospheric Physics (IAP) at the Rostock University, Kühlungsborn, Germany

The gravity wave momentum flux is an essential parameter to study the dynamics of the middle atmosphere. With the Saura MF radar (69°N, 16°E) narrow beam wind measurements can be performed in the upper mesosphere from about 60 to 100 km. Running in the Doppler Beam Steering (DBS) mode, gravity wave momentum fluxes can be determined from radial velocity variations of coplanar beams by using the method from Vincent and Reid (1983). The co-located Andenes meteor radar offers wind measurements from reflections at ionization trails of ablating meteoroids between about 80 and 100 km. Gravity wave momentum fluxes can simultaneously be determined together with wind variances by applying a regression method proposed by Hocking (2005).

In order to validate these observations, we investigate the momentum fluxes with both methods. Using several selection criteria for the calculations we compare both mean profiles as well as the day-to-day variation of the momentum fluxes obtained from these two independent instruments and methods for a case study in April 2011.

Presented by: **Placke, Manja**

Chemistry of meteor trail formation

John Plane [1], *Wuhu Feng* [2], *Diego Janches* [3]
[1] *School of Chemistry, University of Leeds*
[2] *Schools of Chemistry and Earth & Environment, University of Leeds*
[3] *Godddard Space Flight Center, NASA*

This paper will discuss three aspects of meteor trail chemistry. First, the ablation process itself will be considered: what are the important thermodynamic and kinetic processes which control the ablation rates of different meteoric constituents, how well do we understand these processes; and how can important uncertainties be resolved, perhaps through laboratory simulations? The current version of the Leeds Chemical Ablation Model (CABMOD) appears to predict the process of differential ablation quite well, as evidenced by satisfactorily modelling the time evolution of meteor head echoes. However, combining this model with an astronomical model of dust sources in the solar system to derive the Meteoric Input Function (MIF) for the earth reveals a significant problem regarding the relative injection rates of Na, Fe and Ca atoms into the atmosphere.

This leads onto the second topic of the paper, the nature of the ablation products and how they evolve with time. Hyperthermal collisions with air molecules should lead to complete atomization of any molecular products, as well as significant ionization (the resulting electrons are observed by meteor radars). Laboratory studies of metal ion-molecule reactions have provided a much better understanding of how the metal ions and electrons will react as they diffuse into the ambient atmosphere and encounter atomic O and O_3. This can influence the apparent diffusional time-constant of a meteor trail, which is sometimes used to infer the air density and hence temperature in the vicinity of the trail.

The third topic is the formation of meteoric smoke. There is a long-standing assumption that meteoric ablation products diffuse so rapidly into the background atmosphere that they do not condense to form metal silicates within the trail itself. While this appears to be a valid assumption, metal silicate molecules (e.g. $MgSiO_3$, $MgFeSiO_4$) are so stable that they could evaporate at temperatures around 2000 K. If most of this evaporation occurred into the trail behind the meteoroid, then a fraction of these molecules might survive intact, leading to permanent sinks for these metals and providing "seeds" for smoke formation. While this is only a conjecture, it would help to explain the relative inputs of Na to Fe in the upper mesosphere.

The final aspect of meteor trail chemistry to be discussed is the role that these metal silicates play in the charged state of the *D* region, where there is now growing evidence that they are often largely responsible for the observed depletion of electrons relative to positive ions below 90 km.

Presented by: **Plane, John**

Satellite observations of gravity wave momentum flux and interpretation by global ray-tracing modeling

Peter Preusse , Manfred Ern , Silvio Kalisch
Forschungszentrum Jülich, IEK-7

Temperature measurements of the infrared limb sounder SABER are analyzed for GWs in the altitude range 25 to 100 km. In a first step global scale structures up to wavenumber 6 are removed by a space-time spectral analysis. Residual vertical profiles are analyzed by a combination of MEM and sinusoidal fits. Using profile pairs with an along-track distance of less than 300~km, absolute values of GW momentum flux are determined. Global distributions are interpreted in terms of various sources. Gravity wave maxima from the subtropics shift poleward as the GWs propagate upward and also the polar vortex maximum widens widen with altitude. Time series are discussed for the annual cycle, QBO and long-term variations. The measurements are compared to ray tracing simulations. Finally, an outlook to proposed satellite missions is given.

Presented by: **Preusse, Peter**

Differences in the Atmospheric Boundary Layer (ABL) characteristics between active and break spells of the monsoon

A. Sandeep , T. Narayana Rao
National Atmospheric Research Laboratory

The Atmospheric Boundary Layer (ABL) is the layer that is directly influenced by the presence of the earth's surface and its forcing. The surface forcing depends on several factors starting from geography to surface characteristics and to dynamics of the atmosphere at lower levels. Therefore, one would expect significant changes in the ABL characteristics during rainy days and non-rainy days. In this regard, it is important to remember that the rainfall during the monsoon season doesn't occur as a continuous deluge; rather occurs in spells (known as active spells). Also, recent studies have shown that the background thermal and dynamical characteristics of the atmosphere near the surface and aloft are different in different spells of the monsoon. Any change near the earth's surface modifies the boundary layer structure and its evolution. Unfortunately, there was no documentation on these changes in different spells of the monsoon, partly due to the paucity of continuous high-resolution data to study the intraseasonal differences in the evolution of ABL. Therefore, the main aim of this study is to understand the differences in the winds and turbulence characteristics in different spells of the monsoon using high-resolution measurements made by a UHF radar at Gadanki. The present study also includes statistical characteristics of wind speed and direction, vertical velocity, SNR and spectral width (a measure of turbulence) in different spells of the monsoon. Special emphasis has been given to understand differences in low level jet characteristics between spells.

Presented by: **Rao, T. Narayana**

First three - dimensional observations of polar mesosphere winter echoes: Resolving space - time ambiguity

Markus Rapp , Ralph Latteck , Gunter Stober , Peter Hoffmann , Werner Singer , Marius Zecha
Leibniz-Institute of Atmospheric Physics (IAP) at the Rostock University, Kühlungsborn, Germany

We present the first three-dimensionally resolved observations of polar mesosphere winter echoes obtained with a 25 beam-experiment covering a volume of about 50 km in diameter (horizontal distance) at altitudes between 65 and 85 km. This allows us to resolve the classical space time ambiguity of single beam observations and reveals that the echoing structure was tilted in the East–West direction but showed no considerable tilt in the North–South direction. The Doppler shifts derived from the 24 off-zenith beam directions are consistent with the mean background wind measured independently by a co-located MF-radar. The time development of the 3-D echo-pattern is consistent with scattering structures that follow the constant phase lines of a medium frequency gravity wave that is propagating against the mean flow. Wave parameters derived from these observations are independently confirmed by the analysis of co-located wind measurements with the aforementioned MF-radar. Overall, the observed echo morphology in time and space is reminiscent of gravity wave breaking which is known to lead to a maximum of turbulence activity that moves with the phase of the wave.

Presented by: **Rapp, Markus**

The Tropospheric cooling and the Stratospheric warming at Tirunelveli during the Annular Solar Eclipse 15 January, 2010

Kusuma G. Rao [1], Nelli Narendra Reddy [1], Raj Kumar Choudhary [2]
[1] Atmospheric Science Programme, Indian Space Research Organization, New BEL Road, Bangalore 560094, India, kusuma@isro.gov.in
[2] Space Physics Laboratory, Vikram Sarabhai Space Center,Thumba PO, Trivandrum - 695002, India

The transition region between the troposphere and the stratosphere is of concern to climate scientists as it is crucial in determining the water vapour and other trace gases transport between the two regions, which inturn determine the radiative warming and cooling of the troposphere and the stratosphere. To examine, the troposphere and stratosphere coupling interms of tropospheric cooling and stratospheric warming, a major experiment facility was set up for upper air and surface measurements during the Annular Solar Eclipse (ASE) of January 15, 2010 at Tirunelveli (8.72 N, 77.81 E) located in 100% eclipse path in the southern peninsular India by installing GPS radiosonde system, an instrumented 15 m high Mini Boundary Layer Mast, an instrumented 1 m high Near Surface Mast (NSM), radiation and other sensors at the surface. The ASE of January 15, 2010 was unique being the longest in duration (9 min, 15.3 sec) among the similar ones that occurred in the past.

Upper air measurements were made by launching six balloons everyday to study the contrast in eclipse impact and as well to study the evolution of atmospheric thermal and wind structure. Striking result here is the net cooling in the troposphere with peak cooling of ~ 5 ^{o}C at ~ 15 km and intense warming in the stratosphere of ~ 7 ^{o}C at ~ 19 km in the vertical. On the eclipse day, an unusual marching in temperature structure is observed with a warm layer seen from near surface to 1 km height in the vertical and a cool layer subsequently up to ~19 km height with coldest temperature crossing ~ -75 ^{o}C at ~ 17.5 km during the ASE in comparison with the temperature variations outside the eclipse time window. Cooling of the Troposphere as the eclipse advanced and the revival to its normal temperature is clearly captured in upper air measurements. Lower stratospheric waves are observed in upper air wind measurements during the ASE window. Further analysis is being carried out to quantify the wind variations.

Stratospheric warming may be attributed to the indirect thermodynamic influence associated with variations in stratospheric circulation induced by net cooling in the troposphere. For instance, the maximum warming of the lower stratosphere could be due to occurrence of maximum downward motion at that level. Also our aim here is to understand the possible links between the lower stratospheric warming and the surface layer parameters.

Presented by: **Reddy, Nelli Narendra**

Meso highs and Meso lows observed over the Indian region during Deep convective conditions

Nelli Narendra Reddy , *Kusuma G. Rao*
Atmospheric Science Programme, Indian Space Research Organization, Bangalore, India

An attempt has been made here to understand the impact of deep convection embedded in Mesoscale Convective Systems (MCS) of Indian summer monsoon in inducing surface pressure variations, such as meso highs and lows, leading to localized thunderstorms. Data utilised for the analysis is from PRWONAM meso-network of instrumentation, namely, Instrumented micrometeorological towers (50 m high, 15 m high), AWS, Micro Rain Radar, GPS Radiosondes along with MST Radar, LAWP, Disdrometer at NARL, Gadanki. Also merged IR brightness temperatures, TRMM 3B42 rainfall and COSMIC RO profiles data for the May to September period in the years, 2000 and 2011 are used in the analysis. The results are presented for six Case studies for convective events at Dibrugarh (27.44 N, 94.89 E) on 22 July, 2009, at Gadanki (13.27 N, 79.10 E) on 18 November, 20095 and 5, 12 July, 2010, at Bangalore at two locations (12.54 N, 77.22 E; 12.55 N, 77.30 E) on 19 April, 2011 and at Ranchi (23.25 N, 85.25 E) on 5 May, 2011. The major findings from the analysis carried out here are the following. 1. Frequency of occurrence of Very Deep (BRT < 210 K) to Deep (240 K < BRT < 210 K) cloud systems at Bangalore location during April-September months of 2009 and 2010 is observed to be maximum between 18hrs to 06 hrs (local time IST). 2. Precipitating Deep clouds caused a significant dip in the surface temperature by ~10 oC and a sharp rise in wind speed by 5 – 8 m s-1 and pressure anomaly of ~ 2 mb along with a drop in surface specific humidity by ~ 2 gm kg-1 and surface equivalent potential temperature by ~ 7 K. A sudden change in the wind direction is observed during the passage of convective lines of MCSs. 3. A reduction in CAPE by ~ 1200 J kg-1, shrinking of Tropical Tropopause Layer (TTL) and cooling of Cold Point Tropopause (CPT) are noteworthy observations inferred during the deep convection at Gadanki. 4. The observed pressure perturbations during the Case studies are associated with strong downdraft and updrafts in the MST radar measurements. Possible explanations for the observed pressure perturbations are being explored in terms of hydrostatic effects like latent heating in updraft and non hydrostatic effects like low level convergence and strong downdrafts.

Presented by: **Reddy, Nelli Narendra**

Characterisation of Deep Convective System of Indian Summer Monsoon using spaceborne Cloud Profiling Radar on CloudSat

M. Muhsin [1], Rao Kusuma [1], Nelli Narendra Reddy [2]
[1] Atmospheric Science Programme, Indian Space Research Organization, Bangalore, India
[2] Indian Space Research Organisation HQ.

It is well known from satellite imageries that Indian Summer monsoon variability is a manifestation of the propagating deep cloud systems embedded in the continental and oceanic Tropical Convergence Zones (TCZ) .

CloudSat is the first satellite carrying spaceborne millimeter radar called the Cloud Profiling Radar (CPR), and was launched on April 28, 2006 as a part of A-train constellation. Cloud Profiling Radar (CPR) measures the vertical structure of clouds and precipitation primarily through 94 GHz radar reflectivity. CloudSat standard data products are produced at each CloudSat profile location. Each Profile consists of 125 vertical bins of width ~ 240 meters. Each CloudSat profile is generated over a 160 millisecond interval which corresponds to a 1.1 km along track distance. With orbital motion, this produces a footprint which is approximately 1.4 km (across-track) by 2.5 km (along track). A granule of CloudSat data (one orbit) consist of ~ 40000 profiles. CloudSat data products are radar reflectivity, cloud type, cloud liquid water content, cloud ice water content, cloud optical depth, atmospheric radiative flux and heating rate, etc.

Here an attempt is made to characterize Deep Convective System of Indian summer monsoon region using the above mentioned CloudSat data products. The region taken for study made here is [10S:40N-50E:110E]. As a first step, we gridded this region in to 30 grids of 10 X 10 degree resolution. Using 2B-CLDCLASS data product, relative percentages of occurrence of deep convective systems has been calculated by counting only the deep convective cloud profiles for the monsoon months of the year 2009 for all the 30 grids. It has been seen that major CloudSat observed zones of deep clouds (~70-100%) during the August-September months are in the oceanic convergence zones of Indian Ocean. At the same time, the percentage of occurrence of deep clouds over the central parts of India and Head, Bay of Bengal is observed to be relatively less. This result indiactes that reverse Hadley circulation was stronger during 2009. The CloudSat observed zones of deep cloud system indicate that oceanic TCZ was intense leading the monsoon to be weaker and hence the year 2009, a worst drought year.

Liquid and ice water content will be extracted to characterize the monsoon deep cloud systems along with the collocated data sets from TRMM. Simultaneous data from PRWONAM meso-network are being used to characterize the Deep Convective systems of the monsoon region.

Presented by: **Reddy, Nelli Narendra**

Impact of Total Solar Eclipse on troposphere and stratosphere thermal and wind structure at Dibrugarh on 22 July, 2009

Kusuma G. Rao , Nelli Narendra Reddy
Atmospheric Science Programme, Indian Space Research Organization, Bangalore, India

For the first time, an experiment facility was set up at Dibrugarh (27.45N, 94.92E) in the north-eastern Indian region to make Micro-meteorological and Upper measurements for studying the near surface and tropospheric response to the Total Solar Eclipse (TSE) of 22 July, 2009 by installing an instrumented Mini Boundary Layer Mast (MBLM, 15 m high), GPS radiosonde system and several ground sensors. The duration of the eclipse was for 02 h 09 m 37.5 s, with a totality of 03 m 32.1 s at Dibrugarh. The Surface layer is characterized on cloudy, rainy and clear sky days in all the observed surface layer parameters. The Incoming SW radiative flux reduced drastically by ~63-85% at its peak during the cloudy conditions associated with blanketing effects of clouds, against the clear sky conditions. The Solar eclipse is characterised by a dip of 25.8 W m^{-2} in the Incoming SW radiative flux from its peak value during the PSE-1 to near zero values with total cut off during the TSE.

A near constancy in temperature at ~ 27.3 ^{0}C at 4 m height is noted over a short time window around TSE. A decrease in the wind speed with a reversal in the average wind direction from north-westerlies during the PSE-1 through south-westerlies during the TSE to south-easterlies during the PSE-2 at 4 m height is noticed.

Upper air measurements revealed near surface inversion in temperature of ~1.3 ^{0} C in the height region of 240-370 m above the surface at the TSE timings comparable with the nocturnal inversion observed during the experiment period. A warm layer has been observed in the lower troposphere between 400 m – 2.6 km in the vertical during the eclipse with maximum warming by 0.75 ^{o}C at 1.8 km. Mid troposphere cooling in the region from 2.6 km to 12 km is observed during eclipse with maximum cooling of ~ 4.8 ^{o}C at ~ 8.8 km height.

Wind measurements indicatedthat easterlies prevailed from close to surface up to ~ 1.5 km height in the vertical with reversal to westerlies beyond up to ~5 km height. A low wind transition region is found between 5~10 km with relatively stronger easterlies prevailing at higher heights. On the eclipse day of 22 July, 2009, a wave like pattern with wavelength ~2.3 km is observed in wind speed in the height region, 18.3 – 20.6 km above the Earth's surface.

Presented by: **Reddy, Nelli Narendra**

Shrinking of Tropical Tropopause Layer during the Disturbed Convective conditions over the Bay of Bengal with JASMINE Measurements

Kusuma G. Rao , Nelli Narendra Reddy
Atmospheric Science Programme, Indian Space Research Organization, New BEL Road, Bangalore 560094, India, kusuma@isro.gov.in

The Indian summer monsoon variability on the intra-seasonal time scales of 30-40 days and on the "Active" and "Break" cycles, is largely accounted by the varying convective activity over the Bay of Bengal. Very little is known about the impact of intense convection of the monsoon region on the upper tropospheric and lower stratospheric circulation systems and on the dynamics/thermodynamics of the Tropical Tropopause Layer, a transition region from troposphere to stratosphere. Moistening and drying of TTL, being a region of Low Background Humidity (humidity drops by four orders of magnitude from the surface to TTL), locally or globally, is a key factor for the Global Climate Change observed. This is because the Long Wave Radiative fluxes show strong sensitivity to humidity variations in the region. While there are extensive studies to show significant impact of convection on TTL for Pacific, Indonesian and other regions, there are very few studies for the monsoon region on the impact of organized monsoon convection on the Tropopause layer dynamics and thermodynamics

Thus the question we tried answer here is, what is the impact of organized convection of Bay of Bengal, sustained over a few days, on the Tropopause Layer? An effort is made here to answer this question by carrying out analysis of the measurements available from the International field programme, JASMINE (Webster et al., 2002) conducted in the year 1999 (April to June and September) over the Bay of Bengal with the research vessel, the NOAA Ship Ronald H Brown using GPS radisondes, cloud radar, instrumented mast, etc . Thus, our chief objective here is to discuss the nature of the TTL variations during the periods of organized convection over the Bay of Bengal. Also our aim here is to understand the possible links between the TTL variations and the surface layer parameters.

Based on JASMINE data analysis, we inferred here that, during convective conditions, both the lowering of Cold point tropopause temperature and the corresponding CPT Altitude (CPTA) are significant, unlike in the normal case determined by normal temperature lapse rates. TTL thickness shrinks during the convective conditions due to lowering of the upper boundary of TTL (CPTA) and deepening of the lower boundary (LRMA, Lapse Rate Minimum Altitude) of the TTL. The result that Unlike Normal cases are associated with higher CAPE and higher surface equivalent potential temperatures lead to explain the possible mechanisms underlying the observation made here of CPT cooling at relatively lower altitudes.

Presented by: **Reddy, Nelli Narendra**

Impact of Meso-Network Observations on prediction of Extreme Rain Events of the Indian Summer Monsoon during PRWONAM

Kusuma G. Rao [1], *Rani Jacob* [1], *Nelli Narendra Reddy* [2]
[1] *Atmospheric Science Programme, Indian Space Research Organization, New BEL Road, Bangalore 560094, India, kusuma@isro.gov.in*
[2] *Indian Space Research Organisation HQ.*

The changing rainfall pattern of the Indian summer monsoon with increasing trend in Extreme Rain Events attributed to the unequivocal warming of the environment is a subject of concern in recent times.

Based on TRMM 3B42 data for the twelve years period, 1999-2010, preferred regions of occurrence of Extreme /Intense Rain Events are examined over both the Indian Land and the adjoining Sea with the observed rain events constructed every day. The classification in to Moderate, Intense and Extreme Rain Events (MRE, IRE, and ERE) are based on the thresholds devised on the accumulated rainfall of the events normalised with their respective duration for the homogeneous Central Indian region. Three broad prominent regions have been identified for occurrence of EREs, namely, the 1. West-Central Parts of India and the adjoining Arabian Sea [WCI region], 2. Central and North-Central parts of India [CI region] and 3. North-Eastern parts of India and the adjoining Bay of Bengal [NEI region]. The striking inference is the shift in preferred regions of EREs observed from NEI region to WCI region with the trends reversed in the study period. Most of these ERE/IRSs are associated with short lived mesoscale weather systems.

Accurate weather prediction in the tropics using dynamical models is a challenging task today. PRWONAM (Prediction of Regional Weather with Observational Meso-Network and Atmospheric Modelling), a unique national science mission of Indian Space Research Organization, initiated in the year 2006, aimed at resolving and modelling the mesoscale weather systems of the Indian region.The PRWONAM meso-network of Instrumentation all over the Indian land region, consists of AWS, GPS radiosondes, Micro-meteorological towers (50 m high), Mini Boundary Layer Masts (15 m high), ST Radars/Micro Rain Radars, etc. Several field campaigns have been carried out to observe and predict Extreme Rain Events.

Model experiments to predict Extreme rain Events of the Indian region have been carried out with NCAR Weather Research Forecast (WRF) model to examine the impact of meso-net data assimilation in to NCEP GFS initial conditions. It is established beyond doubt that predictions significantly improve with meso-net data assimilation. Also, model experiments are conducted to understand the processes underlying the genesis of Extreme Rain Events by comparing the model physics based scaling laws of surface fluxes with the observed behaviour arrived at in measurements from 50 m towers.

Presented by: **Reddy, Nelli Narendra**

60 years of meteor radar at Adelaide

Iain Reid
University of Adelaide

With the exception of the use of very high power incoherent scatter radars to study meteors, meteor radar development at Adelaide typifies that of the technique around the world, and it is now almost 60 years since the first measurements of atmospheric winds in the 75-105 km height region were made using meteor radar at Adelaide. This was in June 1952. Construction of this system commenced in 1950, and the first photographic recordings showing Doppler beats were recorded in December 1951. Winds were measured by observing the drift of meteor trails using photographic recording and subsequent manual analysis. This system operated until March 1955. In 1958 a field site was established at St Kilda north of Adelaide, and meteor work continued there from this time until the mid-1970s. Meteor work using the BP MF radar was first undertaken during 1969-72, and continued through the 1990s. In the early 1990s, narrow beam meteor work resumed on the ST VHF radar at the Buckland Park field site, also north of Adelaide. In the late 1990s meteor work using small pulsed operation VHF radar systems started in Adelaide.

These systems have now become commonplace, and considerable progress has been made in exploiting the meteor technique to measure winds and temperatures in the 80 to 110 km height region, and to measure meteor velocities. In this paper, a brief history of the development of the technique at Adelaide, and some of these recent developments are presented and discussed.

Presented by: **Reid, Iain**

New Equipment and Data Processing Techniques at the University of Adelaide Field Site

Iain Reid [1], *Bronwyn Dolman* [2], *Joel Younger* [3], *Jens Lautenbach* [4], *Andrew MacKinnon* [3]
[1] *University of Adelaide & ATRAD Pty Ltd*
[2] *ATRAD Pty Ltd*
[3] *University of Adelaide*
[4] *Leibniz Institute of Atmospheric Physics*

Buckland Park (BP) is the University of Adelaide field site, located 36 km north of the city of Adelaide, and the University campus. BP is currently home to a 55 MHz BL Profiler, 55 MHz ST Profiler, MF Profiler, 55 MHZ Meteor Radar, 55 MHz mini-BL Profiler, RASS, OH and 0_2 spectrometer, three-field photometer and an all-sky airglow imager. A Rayleigh Lidar and SuperDARN radar are currently under development.

Recent upgrades at BP include new ATRAD digital transceivers on the BL, ST and meteor radars, and a new ATRAD beam steering unit on the ST profiler. The BL and ST profilers are also running with new quality control algorithms. Improvements to the BP systems have resulted in new capabilities, such as ST wind estimation down to 500 m, and clean raindrop size distribution retrievals from 500 m to the freezing level on both the BL and ST systems. Ice retrievals above the freezing level are also now possible with the ST system. BP developments and new results will be discussed.

Presented by: **Reid, Iain**

Validation of the receiving pattern of the MAARSY phased antenna array

Toralf Renkwitz , Ralph Latteck , Werner Singer , Gunter Stober
Leibniz-Institute of Atmospheric Physics (IAP) at the Rostock University, Kühlungsborn, Germany

In 2009/2010 the Leibniz-Institute of Atmospheric Physics (IAP) installed a new powerful VHF radar on the island Andoya in Northern Norway (69.30°N, 16.04°E). The **M**iddle **A**tmosphere **A**lomar **R**adar **Sy**stem (MAARSY) is designed for improved studies of the Arctic atmosphere with high spatial and temporal resolution in the troposphere/lower stratosphere and in the mesosphere/lower thermosphere. The monostatic radar is operated at 53.5 MHz with an active phased array antenna consisting of 433 Yagi antennas. Each individual antenna is connected to its own transceiver with independent phase control and a scalable power output of up to 2 kW. These properties give the radar a very high flexibility of beam forming and beam steering. During the design phase of MAARSY several model studies have been carried out in order to estimate the radiation pattern for various combinations of beam forming and steering. However, parameters like mutual coupling, active impedance and ground parameters may have an impact to the radiation pattern, but hardly can be measured. Hence, experimental methods need to be implied to verify the model results.

For this purpose, the radar has occasionally been exclusively used in passive mode, monitoring the noise power received from both distinct galactic noise sources like e.g., Cassiopeia A and Cygnus A, and the complete diffuse galactic background noise. The analysis of the collected dataset enables us to verify beam forming and steering attempts. These results document the current status of the radar during its development and provide valuable information for further improvement. However, a limitation of these experiments is that they provide information about the receiving system. The transmitting part of the radar needs to be investigated separately by other means. For this purpose we are planning an airborne electric field probe which shall be used to directly sample the radiation pattern in the far field region.

Presented by: **Renkwitz, Toralf**

VHF Radar Scatter Microstructure Measured by Combined Spatial and Frequency Domain Interferometry: A developing approach

Jürgen Röttger

Besides the application of the Spatial Domain Interferometer method (SDI), measuring particularly variations in the horizontal structure, also the Frequency Domain Interferometry (FDI), measuring the line-of-site structure and velocity (mostly vertical), had been introduced successfully. The combination of these two methods, which is the main topic of this paper, allows determination of the development of the three-dimensional fine structure of the atmospheric radar refractivity. It will also be applied at high temporal resolution in the order of several seconds, and it allows range resolutions down to better than 100 meters. These are observational requirements to view and interpret the fine structure of atmospheric turbulence and stable laminae or sheets, which are the generators of the refractive index irregularities giving rise to VHF radar echoes.

This novel way combining the Spatial and Frequency Domain Interferometry is called in short "SFDI", and measures the main three parameters of position, bulk and fluctuating velocity of the refractivity distribution in three dimensions. The variation of these distribution functions show for instance that the velocityfluctuations (usually assumed to be a measure of turbulence) are not directly related to changes in radial position. The velocity fluctuations can be interpreted as a measure of the roughness of moving, specular reflecting, corrugated refractive index surfaces and not necessarily as active turbulence. The consequences of these and some more new observations using this technique will be discussed, namely many MST VHF radar echoes are believed to bedue to specular-type reflections from steep vertical gradients of the refractive index, which are corrugated or rough.

This roughness can be caused by a spectrum of waves and turbulence, which, however, is not the particular scatterer itself. The view of locally rough surfaces of refractivity with specular reflection regions moving with given velocities can explain the shift and in particular the widening of the radar signal spectrum. The latter is usually assumed to be a proper estimate of turbulence, which may be questioned due to the shown specular-type reflection from quasi-horizontally stratified rough layers. These implications will finally be discussed.

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This paper was originally presented at the International Symposium on the 25th Anniversary of the MU Radar at RISH, Kyoto University, Uji, Japan, 2-3 September 2010.

Presented by: **Röttger, Jürgen**

Diurnal wind variations in the lower-tropospheric wind over Japan as revealed with wind profilers and analysis/reanalysis data sets

Takatoshi Sakazaki , *Masatomo Fujiwara*
Graduate School of Environmental Science, Hokkaido University

This study investigates diurnal variations in lower-tropospheric wind (from surface to 5 km in height) over Japan during 2002—2008 using data from 31 stations of the Wind profiler Network and Data Acquisition System (WINDAS) as well as Japan Meteorological Agency mesoscale analysis data (MANAL) and four global reanalysis data sets (JRA25, ERA-Interim, NCEP1 and NCEP2). The diurnal and semidiurnal components are extracted and analyzed to identify the dominant dynamical processes.

An analysis of wind profiler data shows that the characteristics of the diurnal wind component heavily depend on height range and season. The maximum amplitude of diurnal wind over Japan occurs in summer near the surface, in spring and autumn at 1—3 km, and in winter at 3—5 km. Using analysis/reanalysis data, it is found that these characteristics are found to be controlled by the four different dynamical processes: (1) Local wind systems (e.g., land—sea breezes) near the surface throughout the year, (2) Diurnal eastward-moving eddies at 1—3 km in winter-spring, (3) Medium-scale eastward travelling waves above 3 km, and (4) Atmospheric tides above 3 km in summer.

On the other hand, the semidiurnal wind component is primarily controlled by the semidiurnal migrating tide above 1 km, and is influenced by local wind systems below 1 km. The semidiurnal amplitude shows a marked seasonal variation with its maximum in winter.

Presented by: **Sakazaki, Takatoshi**

Diurnal wind variations in the upper-tropospheric and lower stratospheric wind over Japan as revealed with MU radar and five reanalysis data sets

Takatoshi Sakazaki [1], *Masatomo Fujiwara* [1], *Hiroyuki Hashiguchi* [2]
[1] *Graduate School of Environmental Science, Hokkaido University*
[2] *Research Institute for Sustainable Humanosphere, Kyoto University*

Diurnal variations in the troposphere are a source of the diurnal tides which are the prevalent dynamical phenomenon in the mesosphere and lower thermosphere. They are also discussed as contributing to the excitation of Rossby waves. Here we study diurnal variations of upper tropospheric and lower stratospheric winds (up to 22 km) over Japan from 1986 to 2008 mainly using data from the middle and upper atmosphere (MU) radar (34.85°N, 136.10°E) and JRA25/JCDAS data, as well as other four global reanalysis data sets (ERA40, ERA-Interim, NCEP1, and NCEP2) and output data from Global Scale Wave Model (GSWM).

The diurnal and semidiurnal components are extracted and analyzed. For the diurnal wind component, the amplitude monotonically increases with height above 15–20 km. The phase shows an upward progression up to 15 to 20 km, while above 15 to 20 km, it shows a downward progression in most months. It is found that the diurnal tide, defined as the diurnal component with absolute zonal wave numbers of ≤6, is dominant in the upper troposphere (explaining 60 to 80% of the variance) and in the stratosphere (explaining 80 to 90% of the variance). Also, medium-scale waves contributed to the diurnal wind component in the upper troposphere from winter to spring (~20% of the variance).

For the semidiurnal wind component, the semidiurnal migrating tide is dominant through the troposphere and the lower stratosphere. The amplitude shows a marked seasonal variation in the troposphere being largest in winter and smallest in summer.

Presented by: **Sakazaki, Takatoshi**

Preliminary observation of temperature profiles by radio acoustic sounding system (RASS) with a 1,280 MHz Lower Atmospheric Wind Profiler at Gadanki, India

T.V. Chandrasekhar Sarma [1], *Parvatala Srinivasulu* [1], *Toshitaka Tsuda* [2]
[1] *National Atmospheric Research Laboratory, Dept of Space, Govt of India, Gadanki 517 112 AP, India*
[2] *Research Institute for Sustainable Humanosphere, Kyoto University, Uji, Kyoto 611 0011, Japan.*

A UHF wind profiler operating at 1280 MHz has been developed at NARL for atmospheric studies in the planetary boundary layer. In order to explore application of radio acoustic sounding system (RASS) technique to this profiler, a suitable acoustic attachment was designed and implemented using commercial-off-the-shelf (COTS) components. Preliminary experiments were conducted on 27-30 August 2010 with this system along with the Indian MST-Radar RASS system. Height profiles of virtual temperature, $T_{v,}$ in the planetary boundary layer were derived with 1μs and 0.25μs pulses, corresponding to a height resolution of 150 m and about 40 m, respectively. From the plot of T_v, Diurnal variation was clearly recognized, and perturbations of T_v were also seen in association with a precipitation event that occurred during this experiment. The periodogram analysis of T_v profiles shows that the maxima in the temperature occur around 1500 LT at lower heights whereas they are progressively delayed as altitude increases. The amplitudes of the diurnal temperature variation due to surface heating also decrease with altitude. This phenomenon delineates the boundary layer from the free troposphere. Using the T_v data the height of the boundary layer could be clearly delineated. Usually the boundary layer height extends up to about 3.5 km at Gadanki. However, as this preliminary experiment was conducted on an overcast day, signatures of boundary layer height could be discerned only up to the lower range bins of MST radar - RASS observations viz., up to about 2.5 km. Simultaneous operations of the LAWP-RASS along with the MST Radar-RASS and an onsite 50 m tower demonstrate the capability to continuously profile the atmospheric temperature from near the ground to lower stratosphere.

Presented by: **Sarma, T.V. Chandrasekhar**

Semi-diurnal tidal coupling at low-latitudes during sudden stratospheric warming events

S Sridharan [1], S Sathishkumar [2], S Gurubaran [2]
[1] *National Atmospheric Research Laboratory, Gadanki 517 112, India*
[2] *Indian Institute of Geomagnetism, EGRL, Krishnapuram, Tirunelveli 627 011, India*

We examined low-latitude mesospheric tidal variabilities in relation with the occurrence of high-latitude sudden stratospheric warming (SSW) events. It is found that there is an enhancement of semi-diurnal tide and suppression of diurnal tide in the low-latitude mesosphere and consecutive occurrence of counter-electrojet events lasting for several days. We proposed that the enhancement of semi-diurnal tide may be due to the non-linear interaction between migrating tides and planetary waves, the ozone variability due to change in the circulation pattern in the middle atmosphere associated with the SSW events and non-migrating tides generated by the latent heat released in the deep equatorial convection induced by the potential vorticity advection at higher levels as a result of breaking of Rossby waves during the SSW events. While investigating which mechanism is more effective, it is found that the ozone mixing ratio increases at low latitudes during the SSW and it could probably be due to the SSW induced reversal of meridional circulation towards southward, which may aid the transport of ozone from high to low latitudes, but prevent the same from low to high latitudes. As semi-diurnal tide is produced due to solar insolation absorption of ozone, the increase in the ozone mixing ratio could be a reason for the increase in the semi-diurnal tidal amplitude. The effectiveness of other suggested mechanisms has been investigated and the results obtained will be presented during the meeting.

Presented by: **Sathishkumar, S**

The program of the Antarctic Syowa MST/IS radar (PANSY)

Kaoru Sato [1], *Masaki Tsutsumi* [2], *Toru Sato* [3], *Takuji Nakamura* [2], *Akinori Saito* [4], *Yoshihiro Tomikawa* [2], *Koji Nishimura* [2], *Hisao Yamagishi* [2], *Takashi Yamanouchi* [2]
[1] *Department of Earth and Planetary Science, The University of Tokyo*
[2] *Naional Institute of Polar Research*
[3] *Department of Communications and Computer Engineering, Kyoto University*
[4] *Department of Geophysics, Kyoto University*

Since 2000, we have developed an MST/IS radar to be operational in the Antarctic and have made feasibility studies. After solving various significant problems such as treatment against strong winds, energy saving, weight reduction, and efficient construction method, we reached the final system design which is a VHF Doppler pulse radar with an active phased array consisting of 1045 Yagis. This project was authorized as a main observation plan for JARE (Japanese Antarctic Research Expedition) 52-57 in 2008, and finally funded by Japanese government in 2009. The radar construction started in late December, 2010. Here we will present hot results from this radar and discuss the uniqueness of the MST radar observation on the middle atmosphere research. The observation will continue for 13 years covering one solar cycle.

Presented by: **Sato, Kaoru**

Re-examination of observed gravity wave characteristics by using a high-resolution GCM

Kaoru Sato
Department of Earth and Planetary Science, The University of Tokyo

Gravity waves are an essential component of the Earth's climate because of their ability to transport momentum mainly upward from the lower atmosphere to the middle atmosphere. The momentum deposition is important for maintaining weak wind layers in the lower stratosphere and in the upper mesosphere, and for simultaneously driving meridional circulations. The thermal structure of the middle atmosphere is largely affected by adiabatic heating/cooling associated with the wave-driven global circulations.

By recent development of computer and satellite technologies, our knowledge on global distribution and seasonal variation of small-scale fluctuations such as gravity waves in the atmosphere has been significantly improved. For example, it has been considered that gravity waves transport energy mainly vertically. Thus, most gravity wave parameterizations used in the global circulation models (GCM) ignore lateral propagation of gravity waves. However, recent results from gravity-wave resolving GCM simulations and high-resolution satellite observations indicate that lateral propagation of gravity waves even forced by topography is not negligible and causes significant gravity wave drag over the ocean. It was shown that an extra orographic gravity wave drag over 60S significantly improved model simulation of seasonal variation of the stratospheric polar vortex and hence the Antarctic ozone hole.

In this talk, gravity wave characteristics such as seasonal variation of momentum fluxes and wave energy and vertical wavenumber spectra shown by previous studies using MST radars, radiosondes, and rockets are re-interpreted by comparing with corresponding results from a high-resolution GCM.

Presented by: **Sato, Kaoru**

Atmospheric processes and variability up to the lower thermosphere – Numerical studies with HAMMONIA

Hauke Schmidt
Max Planck Institute for Meteorology

Most general circulation models of the middle atmosphere have their upper boundary in the 70-90 km region while “classical” models of the thermosphere/ionosphere mostly had their lower boundary near 80-95 km. HAMMONIA is one of the few models built to overcome this separation. It is an upward extension of the ECHAM5 general circulation model of MPI-M coupled to NCAR’s MOZAR3 chemistry scheme. The model covers the atmospheric altitude range from the Earth's surface up to $1.7*10^{-7}$ hPa (about 250 km), which means not only tropo-, strato-, and mesosphere but also a considerable part of the thermosphere. In the recent years HAMMONIA has been used for studies in a wide range of fields, covering the effects of solar variability and GHG increase, vertical coupling in the entire atmosphere, tidal activity, middle atmospheric wave activity in general, long-periodic oscillations in the mesosphere, and the distribution of trace gases. This presentation is intended as an overview on results obtained with HAMMONIA. A focus will be on the region of the mesosphere and lower thermosphere (MLT) which links the more dynamically controlled lower and middle atmosphere with the upper atmosphere that is influenced strongly by external forcing of in particular solar origin. Consequently, in the MLT, it is often difficult to assess if signals are caused by local processes (e.g. of varying absorption of solar radiation or changing concentrations of radiatively active gases) or rather related to dynamical changes in the lower atmosphere that are influencing the region due to changes in propagation conditions of waves. It will be shown that numerical simulations can provide a useful tool to better understand the possible role of these different phenomena. Furthermore, the importance of observational studies for numerical models like HAMMONIA and possible future improvements in entire atmosphere modeling will be discussed.

Presented by: **Schmidt, Hauke**

Interferometric measurements of meteor-head echoes with MAARSY

Carsten Schult , *Gunter Stober* , *Ralph Latteck* , *Werner Singer* , *Markus Rapp*
Institute of Atmospheric Physics (IAP)

Meteors entering the Earth`s atmosphere typically ablate in an altitude range between 70-130 km. The kinetic energy of the meteoroid is sufficient to ionize the meteoric constituents due to collisions with the neutral atmosphere which also leads to the formation of a plasma surrounding the meteoroid. This phenomenon is known as a meteor head echo and has recently been studied with various high power large aperture (HPLA) radars.

Here we present first meteor head echo observations with MAARSY (Middle Atmosphere Alomar Radar System). The meteor head trajectories are determined by an interferometric analysis using the multi-channel receiving capability of the radar. Using this method we have studied the Geminid meteor shower during the ECOMA sounding rocket campaign in 2010. These data are used to derive distributions of entry velocities, source radiants and observation heights.

Presented by: **Schult, Carsten**

Diurnal and Seasonal Variability of D-Region Electron Densities at 69°N

Werner Singer [1], *Martin Friedrich* [2]
[1] *Leibniz-Institute of Atmospheric Physics (IAP) at the Rostock University, Kühlungsborn, Germany*
[2] *Technical University of Graz, 8010 Graz, Austria*

Electron densities of the lower ionosphere are estimated with the Saura MF Doppler radar (3.17 MHz) near Andenes, Norway since summer 2004. The narrow beam transmitting/receiving antenna consists of 29 crossed half-wave dipoles arranged as a Mills Cross resulting in a beam width of about 7°. Antenna and transceiver system provide high flexibility in beam forming as well as the capability forming beams with left and right circular polarization at alternate pulses.

The experiment utilizes partial reflections of ordinary and extraordinary component waves from scatterers in the altitude range 50-90 km to estimate electron number densities from differential absorption (DAE) and differential phase (DPE) measurements. Height profiles are obtained between about 55 km and 90 km with a time resolution of 9 minutes and a best height resolution of 1 km. The electron density profiles independently derived from DAE and DPE measurements are in remarkable good agreement. We discuss the diurnal and seasonal variability of electron densities obtained at Andenes as well as the response of D-region electron densities to solar activity storms, solar proton events, and geomagnetic disturbances.

The radar results are compared with previous rocket-borne radio wave propagation measurements at Andenes as well as with recent co-located simultaneous insitu observations using radio wave propagation experiments (differential absorption and Faraday rotation) which showed good agreement between the two techniques. In summer, the insitu measured electron densities show in presence of polar mesosphere summer echoes (PMSE) an electron biteout at PMSE-altitudes. This phenomenon is an often observed characteristic of the mesospheric electron densities derive from the radar observations and confirmed by simultaneous plasma probe measurements.

Presented by: **Singer, Werner**

Studying mesospheric dynamics from PMSE backscatter using velocity azimuth displays (VAD)

Gunter Stober , Markus Rapp , Ralph Latteck , Werner Singer , Marius Zecha
Leibniz-Institute of Atmospheric Physics (IAP) at the Rostock University, Kühlungsborn, Germany

Since several decades MST radars have been used to observe atmospheric dynamics. These radars have been proven to provide reliable and continuous measurements of prevailing winds and to gain information about the scattering processes from the troposphere up to the mesosphere. The recently installed new MST radar MAARSY at the island of Andoya in Northern Norway allows to resolve the space time ambiguities due to its more advanced beam steering capabilities, which permit to conduct systematic scanning experiments at mesospheric altitudes with high spatial and temporal resolution. On the basis of these experiments we applied a more advanced wind analysis technique, such as a velocity azimuth display (VAD). The VAD method is suitable to retrieve additional kinematic properties of the wind field, e.g. horizontal divergence, stretching and shearing deformation. Here we present first results applying the VAD technique to PMSE backscatter providing new insights into the dynamical structure of the summer polar mesopause region.

Presented by: **Stober, Gunter**

In-situ measurements of small-scale structures in neutrals and plasma species during ECOMA-2010

Boris Strelnikov , Artur Szewczyk , Markus Rapp
Leibniz-Institute of Atmospheric Physics (IAP) at the Rostock University, Kühlungsborn, Germany

In December 2010 the fourth and final ECOMA rocket campaign was conducted at Andøya Rocket Range (69 °N, 16 °E) in Northern Norway. Three sounding rockets were launched to study the effect of the Geminid meteor shower on the properties of meteor smoke particles. The main instrument, the ECOMA particle detector has measured, among other things, number densities of charged dust particles with very high spatial resolution. In addition, all payloads carried instruments to measure densities of positive ions and neutral air also with very high spatial resolution. These high resolution in-situ measurements allow us to investigate small-scale features in all the constituents. In particular, from the measured small-scale density fluctuations of neutral air we derive turbulence energy dissipation rate. From the small-scale density fluctuations of the charged species, i.e. meteoric smoke particles (MSP) and positive ions, we derive the Schmidt number for the MSP and ions, respectively. We focus on the last rocket flight, ECOMA09, where all the instruments produced the best data.

Presented by: **Strelnikov, Boris**

Spectral characteristics of incoherent scatter radar observations from the D-region

Irina Strelnikova , *Markus Rapp*
Leibniz-Institute of Atmospheric Physics (IAP) at the Rostock University, Kühlungsborn, Germany

Radar backscatter is a widely used powerful tool for studying the mesosphere. The two main processes causing the backscattering of the radar waves from the D-region plasma are the scattering from irregularities in electron density caused, for example, by turbulence (coherent scatter) and "Thomson" scattering from free electrons (incoherent scatter, IS).

We present an IS data analysis technique that utilizes the shape of the spectra (or, equivalently, the autocorrelation function) to infer information about

1) the presence (or absence) of coherent structures in the scattering volume, and 2) the presence of charged mesospheric aerosols (only in the case of incoherent scatter).

This technique has been applied to a total of 380 min of simultaneous and common volume observations of PMSE with the EISCAT VHF and UHF radars in Tromsø (Norway) made with a time resolution of 30 s.

We considered both shape and width of the considered spectra and found that the VHF spectra are on average well described by a Gauss shape, whereas the UHF-spectra show a small deviation from this shape (due to relatively small signal-to-noise ratios). Spectral widths do largely agree but show a small systematic difference, i.e., the UHF spectra are on average 0.1 m/s narrower than the VHF spectra at an average spectral width of 3.5 m/s. This small systematic difference is largely explained by considering the overall effect of beam-, shear-, and wave-broadening.

Finally, results from the application of the same technique to coherent mesospheric echoes from the winter mesosphere are also presented.

Presented by: **Strelnikova, Irina**

Long-term variability of 16 day planetary wave in the equatorial mesosphere and lower thermosphere in relation with QBO and SSW events

Sathishkumar Sundararaman [1], *Sridharan Sundarajan* [2], *Gurubaran Subaramanian* [1], *et al.*
[1] *Indian Institute of Geomagnetism*
[2] *National Atmospheric Research Laboratory*

Planetary waves with periods in the range of 2 to 16 days play an important role in the dynamical coupling between the lower and middle atmosphere by transporting energy and momentum both vertically and horizontally. As observations have shown the inter-hemispheric propagation of 16 day planetary wave, in particular, which becomes dominant during northern hemispheric winter, their role in the lateral and vertical coupling needs to be addressed. It is commonly observed as a wave of gravest symmetrical wavenumber 1 propagating westward. In the present work the mesosphere and lower thermosphere (MLT) wind observations from the medium frequency (MF) radar situated at Tirunelveli (8.7^{o}N, 77.8^{o}E) along with satellite and reanalysis data sets are used to investigate the long term variability of ~16 day wave during 1993-2009 over Tirunelveli. It is observed that the 16 day wave amplitude, as expected, shows primary maximum in winter and secondary maximum in summer. Besides, the wave activity appears to be enhanced in association with transition phase of quasi biennial oscillation (QBO) and prior to the occurrence of sudden stratospheric warming (SSW) events. The major SSW events of 2006 and 2009 appear to influence the variabilities of the wave during winter, as the wave amplitudes decrease drastically in the low-latitude mesosphere during and several days after the occurrence of SSW events. More cases are being studied to establish the relation between the variabilities of 16-day wave with QBO and SSW events and their role in the variabilities of equatorial mesosphere, lower thermosphere region. Results obtained will be presented during the meeting.

Presented by: **Sundararaman, Sathishkumar**

De-noising of atmospheric radar signals using Spectral based sub-space method

VN Sureshbabu [1], *VK Anandan* [1], *Toshitaka Tsuda* [2], *Jun-ichi Furumoto* [2]
[1] *ISTRAC, Indian Space Research Organisation, Bangalore -58, India*
[2] *Research Institute for Sustainable Humanosphere (RISH), Kyoto University, Uji, JAPAN*

Post beam steering (PBS) and digital beam forming (DBF) is getting greater interest in radar signal processing community with its advantage in detecting the target with better temporal and spatial resolution. This is supported by advanced signal processing approaches and complex algorithms being developed in the recent past with the availability of high power computers at a cheaper cost.

Generally atmospheric signals are very weak and contaminated with noise. Retrieving the signal information in the noise background is always an issue. Various techniques and quality checks have been used to extract these signals. In this paper a study has been carried out for de-noising the atmospheric signal using sub-space based method on the data received from middle and upper atmospheric (MU) radar at Shigaraki, Japan. MU radar is a monostatic pulsed phased array radar operates at 46.5 MHz with a peak power of 1 MW. The array is configured as circular array of 475 crossed Yagi elements which are grouped and formed by 25 different receiver channels for observational purpose The array is also capable of steering the beam electronically using phase shifters in transmit and receive path. The experiment was conducted with full array of transmission (beam width 3.6^{o}) in vertical direction. The data collected is subjected to PBS using sub-space method mainly MUltiple SIgnal Classification (MUSIC) and Eigen Value (EV) based method. The sub-space method has unique advantage of looking distinctly on to signal sub-space and noise sub-space for a given steered direction. Result shows that in the power spectral distribution, the signals only visible by completely removing noise fluctuations. This approach has shown distinct advantage in identifying the atmospheric signals from a noisy environment. The wind velocity estimated through this approach is compared with other estimation algorithms and shown excellent agreement.

Presented by: **Sureshbabu, VN**

Coordinated observations of mesospheric gravity waves with airglow imager, lidar, and radar

Shin Suzuki [1], *Takuji Nakamura* [2], *Matsumu K. Ejiri* [2], *Masaki Tsutsumi* [1], *Kazuo Shoikawa* [1], *Takuya D. Kawahara* [3]
[1] *Solar-Terrestrial Environment Laboratory, Nagoya University, Nagoya, Japan*
[2] *National Institute of Polar Research, Tachikawa, Japan*
[3] *Faculty of Engineering, Shinshu University, Nagano, Japan*

To investigate gravity wave dynamics in the mesosphere and lower thermosphere (MLT) region, we conducted coordinated observations of mesospheric gravity waves over Japan during the Aeronomy and Dynamics Observation campaign. Two all-sky airglow imagers were used in this campaign to derive a two-dimensional structure of the gravity waves; these imagers were installed at the middle and upper atmosphere (MU) observatory in Shigaraki (34.9°N, 136.1°E) and at the Dynic Astropark Observatory in Taga (35.2°N, 136.3°E). Simultaneous measurements of the horizontal winds and the temperature in the MLT region were provided by the meteor-mode observations of the MU radar at Shigaraki and by a sodium temperature lidar at Uji (34.9°N, 135.8°E), respectively. On 2 October 2008, gravity waves having a horizontal wavelength of ∼170 km, wave period of ∼1 h, and propagating northeastward at ∼50 m/s were observed in the airglow keograms. Similar wave structures were observed in the time series of the meteor wind and lidar temperature data; the polarity of these waves varied consistently with the airglow intensity variations according to the linear theory of gravity waves. The phase speeds and momentum fluxes of the gravity waves, estimated from the wind and temperature observations, were also in good agreement with those obtained from the airglow measurements. These results demonstrate, both qualitatively and quantitatively, that an identical gravity wave structure was detected in all the airglow intensities, radar winds, and lidar temperature.

Presented by: **Suzuki, Shin**

Comparison of Calibrated Cn^2 Measurements and Determination of Kinetic Energy Dissipation Rates from a Relatively High-Density VHF Windprofiler Network in Canada

N. Swarnalingam[1] and W. K. Hocking[2]

(1) MYU Consulting, London, Ontario, Canada.

(2) Department of Physics and Astronomy, University of Western Ontario, London, Ontario, Canada.

The O-Q NET is a network of relatively closely spaced VHF windprofiler radars in Ontario and Quebec, Canada. Using frequencies in the range 40 to 55 MHz, the network provides hourly horizontal winds, vertical winds, turbulence estimates, tropopause height determination, and scatterer anisotropy characteristics, from 400 m to typically 14 km altitude. The radars are absolutely calibrated and their efficiencies are determined using the method described in Swarnalingam et. al., 2009. This allows direct measurements of refractive index structure function constant Cn^2 In this paper, we compare Cn^2 measurements and determine the kinetic energy dissipation rates using on site in-situ measurements.

Presented by: **Swarnalingam, Nimalan**

EISCAT-3D: Volumetric imaging radar in Northern Scandinavia for studies of the atmospheric and geospace environment

Esa Turunen , et al.
EISCAT Scientific Association, Kiruna, Sweden

EISCAT_3D will be the next-generation incoherent scatter radar (ISR) for the study of the atmosphere and geospace environment. It will be a distributed phased-array facility built in modular fashion from a few tens of thousands up to 100 000 individual antenna elements, located in northern Scandinavia in the auroral zone and at the edge of the polar vortex. The first Design Study of the technical concept was conducted in 2005-2009. As the EISCAT_3D proposal was accepted on the European Roadmap of strategically important large-scale research infrastructures, the EU granted funding of 4.5 MEUR for a 4-year long Preparatory Phase study in 2010-2014. Recently the Swedish Research Council granted a 0.8 MEUR planning support for the next 2 years in order to facilitate the technical development so, that construction could start as soon as funding is available.
EISCAT_3D will go beyond anything currently available in ISR technology, with multiple large phased-array antenna transmitters/receivers and multiple receiver sites, direct-sampling receivers and digital beam-forming and beam-steering. Five key attributes are combined in one radar: (1) volumetric imaging and tracking in a large geographic area, (2) aperture synthesis imaging for small scale structures down to metres, (3) multistatic configuration for calculation of vector velocities in the atmosphere as well as for using adaptive Faraday rotation techniques, (4) by an order-of-magnitude improvement in sensitivity and (5) transmitter flexibility allowing arbitrary modulations.
In addition to standard remote sensing of the ionospheric plasma, EISCAT_3D addresses the interactions between geospace and the atmosphere, as well as between the atmospheric layers themselves and offers a unique opportunity to study the atmospheric energy budget and solar system influences, such as the effects of solar wind, meteors, dust, energetic particles and cosmic rays in the atmosphere. New measurements will support studies of upward energy flow from the stratosphere, to the mesosphere, and thermosphere, lower atmospheric tidal variability and interactions with the mean atmospheric circulation, gravity waves, planetary waves, and ionospheric variations, gravity wave excitation mechanisms, the implications of significant observed gravity wave geographical and temporal variability, and the impacts of stratospheric warming events on the ionosphere.
In this talk, after first reviewing the science case and concept proposed in the Design Study, we summarize the current development of the technical work, as well as the major results after the first year of the Preparatory Phase, including the proposed site configuration, technical performance target and signal processing.

Presented by: **Turunen, Esa**

Sodankylä-Leicester Ionospheric Coupling Experiment - Selected First Results

Thomas Ulich [1], *Juha Vierinen* [1], *Neil Arnold* [2], *Chris Thomas* [2], *Mark Lester* [2]
[1] *Sodankylä Geophysical Observatory, Finland*
[2] *Leicester University, U.K.*

The Dept of Physics and Astronomy, Leicester University, has installed a new SKiYMET Meteor Radar at the Sodankylä Geophysical Observatory (SGO), Sodankylä, Northern Finland (67° 22' N, 26° 38' E). SGO operates the radar as part of the joint research endeavour SLICE (Sodankylä-Leicester Ionospheric Coupling Experiment).
The radar has seven crossed dipole aerials in a cross configuration (14 receiver channels) and one crossed dipole transmitter antenna. It operates currently at 15kW power and the centre frequency is 36.9 MHz. Operations began in early
December 2008.
Here we will present selected first results, most notably we will show mesurements during Sudden Statospheric Warming (SSW) events. We invite colleagues interested in the data to get in touch with us (thomas.ulich@sgo.fi).

Presented by: **Ulich, Thomas**

The transceiver-based approach to phased array radars – applications and advantages

Brenton Vandepeer , *Pramod Aryal* , *Adrian Murphy* , *Daniel O'Connor* , *Brian Fuller*
Genesis Software Pty Ltd, Adelaide, Australia

Newly-developed transceiver modules for high power pulsed coherent radars find application in MST, meteor, ionospheric and boundary layer troposphere radar topologies. The transceiver approach breaks the shackles usually encountered in traditional designs, allowing increased freedom in the design of antenna arrays, steered beam experiments, and other novel radiation pattern shapes. We discuss a number of examples where the use of transceiver modules as the core building block of the radar system can yield these advantages, and where increased precision in beam forming results when contrasted to traditional approaches.

Presented by: **Vandepeer, Brenton**

Quasi-coherent bistatic radar - implementation and observations

Brenton Vandepeer , *Adrian Murphy* , *Daniel O'Connor* , *Brian Fuller*
Genesis Software Pty Ltd, Adelaide, Australia

A technique for operating two or more non-colocated coherent radars is presented in which both pulse timing and carrier frequency are synchronised. This allows accurate and reliable Doppler measurements to be made of targets in the common observable volume using forward scattered radiation. The technique has been utilised to build variations of SKiYMET meteor radars which are able to detect and map forward scattered echoes from meteor trails in the mesosphere and lower thermosphere. Further applications include bistatic receive stations for MST, boundary layer troposphere and ionospheric radars. Components of these radar systems are discussed to exemplify the technique and some observations presented.

Presented by: **Vandepeer, Brenton**

Colorado Software Defined Radar: Hardware, Results, Reconfigurabity and Deployment

Cody Vaudrin , *Scott Palo*
University of Colorado

An overview and hardware update of the Colorado Software Defined Radar (CoSRad) system. A brief hardware examination is followed by a description and demonstration of the time coherent echo detection software and visualization tools using data recently acquired at Platteville, Colorado and at the Jicamarca Radio Observatory. An educational slide on the roll of noise and interference in direct-convert sampling systems is followed by the presentation of a number of interesting and unusual echoes extracted from a variety of data sets.

CoSRad's reconfigurability is showcased through a description of current and past experiments with a variety of existing radar systems including those located at Jicamarca, Platteville, Argentina and the South Pole. A NOAA funded Linear Frequency Modulation Continuous Wave (LFMCW) Tropospheric Boundary Layer Radar based on CoSRad currently in development is discussed. Geographically distributed synchronization of multiple receivers is mentioned. Our talk concludes with various logistical elements and anecdotes including cost and the challenges involved with deploying hardware in hostile international environments.An overview and hardware update of the Colorado Software Defined Radar (CoSRad) system. A brief hardware examination is followed by a description and demonstration of the time coherent echo detection software and visualization tools using data recently acquired at Platteville, Colorado and at the Jicamarca Radio Observatory. An educational slide on the roll of noise and interference in direct-convert sampling systems is followed by the presentation of a number of interesting and unusual echoes extracted from a variety of data sets.

Presented by: **Vaudrin, Cody**

Frequency dependence of gravity wave momentum flux estimates in the lower atmosphere: First observations using MST radar wind data at Gadanki

P Vinay Kumar [1]*, M.C. Ajay Kumar* [2]*, P. V. Rao* [3]*, Salauddin Mohammad* [1]*, Gopa Dutta* [1]
[1] *Vignana Bharathi Institute of Technology, Aushapur, Hyderabad, India.*
[2] *Vanjari Seethaiah Memorial College of Engg., Patancheru, Hyderabad, India.*
[3] *Vasavi College of Engineering, Ibrahimbagh, Hyderabad, India.*

It is now well established that internal gravity waves play a significant role in the momentum budget and thermal structure of the lower and middle atmosphere. The gravity wave parameterization problem is one of the most significant issue confronting climate modelers. MST radar is a powerful tool to measure momentum flux of gravity waves. This paper addresses the important issue of comparison of momentum fluxes carried by gravity waves in two period bands - (2-8) hours and Inertia Gravity Wave (IGW) using Gadanki MST radar data, a tropical Indian station in the northern hemisphere. It is found that gravity waves of 2-8 hour periodicity transport higher momentum flux than IGW in the troposphere and lower stratosphere. Momentum flux frequency spectra show prominent oscillations between 2.5 - 6 hours. Wavelet transforms show significant variability and localization of the estimates with time. The dominant gravity wave momentum fluxes are found to arise from discrete and localized wave packets in frequency and time.

Presented by: **Vinay Kumar, P**

Small scale turbulence and instabilities observed simultaneously by radiosondes and the MU radar

Richard Wilson [1], *Hubert Luce* [2], *Hiroyuki Hashiguchi* [3], *Francis Dalaudier* [1], *Shoichiro Fukao* [4], *Tomoyuki Nakajo* [4], *Yoshiaki Shibagaki* [5], *Masanori Yabuki* [3], *Jun-ichi Furumoto* [3]
[1] *LATMOS-IPSL, UPMC Univ Paris 06, Univ. Versailles St-Quentin, CNRS/INSU, Paris, France*
[2] *Université du Sud- Toulon Var, La Garde, France*
[3] *Research Institute for Sustainable Humanosphere, Kyoto University, Uji, Japan*
[4] *Department of Electrical, Electronics and Computer Engineering, Fukui University of Technology, Fukui, Japan*
[5] *Osaka Electro-Communication University, Neyagawa, Japan*

A Japanese-French field campaign devoted to the study of turbulence and instabilities in the troposphere and lower stratosphere was conducted in September 2011 for three weeks at the Shigaraki MU observatory (Japan). During the experiment, 59 radiosondes (Vaisala RS92G) were successfully launched and MU radar/lidar measurements were performed.

The detection of turbulence from the in situ profiles is based on a Thorpe analysis. We have developed an original method for selecting the "true" turbulent events within the profile, i.e for rejecting the events induced by instrumental noise. The method is based on both an optimal noise reduction and a statistical hypothesis test.

From the raw data of radiosoundings (3-6 m vertical resolution), we detected those turbulent regions whose vertical extent is larger than ~ 40 m in the troposphere, ~15 m in the lower stratosphere. By taking into account the water vapor saturation effects, we also detected (conditional) static instabilities within the clouds.

In addition, the MU radar measurements were acquired in range imaging (FII) mode, allowing to observe turbulence and KH instabilities with an exceptional time-space resolution (~ several 10 m, 20 s).

We shall present the very first results of this campaign including direct comparisons of turbulent events observed simultaneously by radiosondes and MU radar.

Presented by: **Wilson, Richard**

Air quality measurements with Lidar, SODAR and tethered balloon profiling in the surface boundary layer over Shigaraki, Japan

Masanori Yabuki [1], *Kenshi Takahashi* [1], *Taichi Hayashi* [2], *Chikara Miyawaki* [1], *Makoto Matsuda* [1], *Toshitaka Tsuda* [1]
[1] *Research Institute for Sustainable Humanosphere, Kyoto University, Kyoto, Japan*
[2] *Disaster Prevention Research Institute, Kyoto, Japan*

Knowledge of the properties of atmospheric minor constituents that determines air quality is essential for studies on climate change and its effects on human health. The concentrations of ambient trace gases and aerosols, which are emitted by natural and anthropogenic sources, are influenced by the diffusion due to the thermodynamic processes during the air-mass transportation along the prevailing wind flow. On the other hand, their chemical and physical properties vary both temporally and spatially in the course of different atmospheric processes such as scavenging, nucleation, evaporation and condensation. Therefore, to gain an understanding of the air quality, a comprehensive approach that takes into consideration atmospheric chemistry as well as dynamics and thermodynamics has to be adopted.
Here, we focus on the vertical distributions of trace gases and aerosols in the surface boundary layer and their variation with wind velocity and water vapor content. For this purpose, simultaneous measurements with lidar, SODAR and tethered balloon profiling were carried out at a middle and upper atmosphere (MU) radar site (34.9 ° N, 136.1 ° E), Shigaraki, Japan, on September 5–16, 2011. Water vapor mixing ratio and aerosol properties were determined using a multi-wavelength Mie-Raman lidar designed for performing measurements from near the surface. Aerosol characteristics such as particle size, shape, and hygroscopicity can be estimated from this lidar data. The SODAR was used for observing the wind velocity at altitudes from 50 to 400 m. Measurements with a high temporal resolution were made for profiling trace gases by using a tethered balloon as a research platform and instruments for real-time gas analysis. We also observed the altitude dependence of the secondary species such as nanoparticles that are formed from NOx, SO2, volatile organic components (VOCs), etc. via atmospheric photochemical reactions. In this study, we introduce an outline of our research on measurement of trace gases and aerosols. We also show the preliminary results related to the altitude variance of the atmospheric minor constituents with the vertical flow.

Presented by: **Yabuki, Masanori**

Measurement of vertical air velocity and hydrometeor in stratiform precipitation by the Equatorial Atmosphere Radar and polarization lidar

Masayuki K. Yamamoto [1], *Tomoaki Mega* [1], *Yasukuni Shibata* [2], *Makoto Abo* [2], *Hiroyuki Hashiguchi* [1], *Toyoshi Shimomai* [3], *Yoshiaki Shibagaki* [4], *Noriyuki Nishi* [5], *Mamoru Yamamoto* [1], *Manabu D. Yamanaka* [6], *Shoichiro Fukao* [7], *Timbul Manik* [8]
[1] *Research Institute for Sustainable Humanosphere, Kyoto University*
[2] *Faculty of System Design, Tokyo Metropolitan University*
[3] *Interdisciplinary Faculty of Science and Engineering, Shimane University*
[4] *Faculty of Information and Communication Engineering, Osaka Electro-Communication University*
[5] *Graduate School of Science, Kyoto University*
[6] *Japan Agency for Marine-Earth Science and Technology, SATREPS-MCCOE Promotion Office, Kobe University*
[7] *Fukui University of Technology*
[8] *National Institute of Aeronautics and Space (LAPAN), Indonesia*

Simultaneous measurement of vertical air velocity (W), particle fall velocity, and hydrometeor phase was carried out using a 47-MHz wind profiling radar and a polarization lidar installed at Sumatra, Indonesia (0.2S, 100.32E, 865 m MSL) in December 2008. The 47-MHz wind profiling radar, referred to as the Equatorial Atmosphere Radar (EAR), measured W and reflectivity-weighted particle fall velocity relative to the air (V_z) simultaneously. The lidar measured linear depolization ratio (LDR), which is an indicator of hydrometeor sphericity. A stratiform precipitation case on 8 December 2008 and that on 16 December 2008 were compared to describe differences of W, V_z, and LDR.

Surface rainfall intensity was greater than 2 mm/h in the 16 December case, while raindrops evaporated until they reached to the ground in the 8 December case. Upward W above the melting level was greater than 0.2 m/s in the 16 December case, while it was weak (less than 0.1 m/s) or absent in the 8 December case. V_z of 1.6 m/s at 300 m above the 0 degC altitude (5.2 km MSL) in the 16 December case was greater than the 8 December case (1.3 m/s). The thickness of melting layer in the 16 December case (900 m) was greater than the 8 December case (300 m). Because V_z is an indicator of particle size, the results suggests that the size growth of hydrometeors under the presence of upward W contributed to the formation of thicker melting layer in the 16 December case. Owing to complex interfaces of water-coated ice crystal branches, LDR at the melting level increased 0.17- 0.20 in the two cases. Lidar dark band was also observed in the two cases.

V_z of raindrops in the 16 December case (7.0-7.5 m/s) was greater than that in the 8 December case (3.7-3.9 m/s) due to larger sized raindrops in the 16 December case. LDR of raindrops in the 8 December case was less than 0.01, while it was 0.05-0.10 in the 16 December case. A possible reason for the LDR difference is discussed.

Presented by: **Yamamoto, Masayuki K.**

Development of digital radar receiver using software-defined radio technique

Masayuki K. Yamamoto , *Hiroyuki Hashiguchi* , *Noor Hafizah Binti Abdul Aziz* , *Youhei Wakisaka* , *Mamoru Yamamoto*
Research Institute for Sustainable Humanosphere (RISH), Kyoto University

Coherent radar imaging (CRI) is important to clarify fine-scale structure of turbulence, quantitative measurement of turbulence parameters, and clutter rejection. In order to implement CRI function to conventional atmospheric radars with reduced development cost, RISH has been developing new digital receiver system. As the computer-hosted hardware, Universal Software Radio Peripheral 2 (USRP2) offered by Ettus Research LLC is used. USRP2 is connected to the host computer through Gigabit Ethernet interface. The host computer uses GNU Radio and Universal Hardware Driver (UHD) software libraries for controlling USRP2. Because only sequential data transfer is available, the host computer executes ranging by detecting transmitted signals leaked to the receiving line. On-line data signal processing (i.e., pulse decoding and coherent integration) is also executed by the host computer. Current receiver system configuration and measurement results using a 1.3-GHz wind profiling radar are presented.

Presented by: **Yamamoto, Masayuki K.**

Observation of turbulence and clouds in the tropics by the Equatorial Atmosphere Radar

Masayuki K. Yamamoto [1], *Hiroyuki Hashiguchi* [1], *Mamoru Yamamoto* [1], *Shoichiro Fukao* [2]
[1] *Research Institute for Sustainable Humanosphere, Kyoto University*
[2] *Fukui University of Technology*

Since its installation at the Equatorial Atmosphere Observatory at Sumatra, Indonesia (0.2S, 100.32E) in 2001, the Equatorial Atmosphere Radar (EAR), a 47-MHz atmospheric radar, has been utilized for studies of turbulence and clouds in the tropics.

Owing to its output power of 100 kW and active phased array antenna with a diameter of approximately 110 m, the EAR is able to measure wind and turbulence up to an altitude of approximately 20 km. EAR observations have revealed turbulence generation associated with breaking of Kelvin wave and easterly wind jet in the upper troposphere-lower stratosphere (UTLS) region. Range imaging (RIM) is a technique which improves radar range resolution by applying adaptive signal processing to signals collected using multiple carrier frequencies. RIM measurement using the EAR has revealed fine-scale structure of turbulence associated with breaking of Kelvin wave in the UTLS region. In the presentation, results of wave and turbulence measurements by the EAR are reviewed.

Vertical wind is a crucial factor that determines generation and dissipation of clouds. The EAR is able to measure vertical wind velocity both in clear and cloud regions, because atmospheric radars using approximately 50-MHz frequency are able to detect echoes from refractive index irregularities at Bragg scale and those from hydrometeors separately. On the other hand, millimeter-wave cloud radars and lidars are useful to measure cloud particles. Therefore multi-instrument measurements using the EAR and cloud radar/lidar have been carried out in order to observe interactions between vertical wind and cloud processes. In the presentation, results from multi-instrument measurement of cloud and precipitation using the EAR are reviewed.

Presented by: **Yamamoto, Masayuki K.**

HCOPAR: Hainan VHF Coherent Scatter Phased Array Radar System Description and First Results

Jingye Yan [1], *Jürgen Röttger, Sheping Shang* [1], *Jiankui Shi* [1], *Heguang Liu* [1], *Chi Wang* [1], *Ji Wu* [1]
[1] *National Space Science Center, Chinese Academy of Sciences.*

Hainan VHF Coherent Scatter Phased Array Radar (HCOPAR) is a key equipment of the Chinese Meridian Space Weather Monitoring Project (Meridian Project for short). The project set up a large-scale ground-based monitoring system composed of 15 stations along the longitude of 120°E and the latitude of 30°N. After 3 years of constructing, 95 equipments have been built. Among them the HCOPAR and a few other equipments are located at Hainan Sounding Rocket Base (HSRB, 19.31N, 109.08E), Chinese Academy of Sciences.

HCOPAR is implemented with active phase array and is composed of 72 Yagi antennas. Its array is a rectangle of 4 by 18 elements. With 0.7 lambda distance between adjacent elements, the radar provides a scanning field of -30º~+30º,the antenna beam width is of 5ºand 21º along latitude and longitude, respectively. Differing from similar equipments in the world, HCOPAR is benefited from the advances of modern electricity. Dedicated pre-processor is designed and imbedded into each T/R unit. The pre-processor is composed of high speed DSP and FPGA. It receives synchronous clock from the central high performance crystal oscillator to keep all the array work with accurate timing. The pre-processor communicates with the hiberarchy central processors via TCP/IP protocol. Bidirectional signals flow through the star-shape network cables between central processor and all the pre-processors. The transmitted waveform, coding method, signal processing and many other parameters are reconfigurable even for single element. The transmitting signal is generated at local T/R unit with direct digital synthesizer (DDS). Received echo is digitized at local T/R unit and transferred to central computer over TCP/IP. Amplitude and phase weighting over the array is applicable. Basically, HCOPAR is a combination of 72 small radars. Each is reconfigurable and works independently/synchronously, according to user's requirements.

The quality of the raw data has shown to be of good standard. It is already allows some initial interpretation in terms of the scattering structure of irregularities. This can be deduced from the variation of signal power as function of beaming angle, which primarily is dominated by the aspect sensitivity of the scatterers. The variability of power spectra indicates mostly type 2 irregularities as typically seen in the Equatorial Electrojet (EEJ).

It will be briefly discussed how spatial interferometer measurements should be done as a next obvious step in the application of this radar.

Presented by: **Yan, Jingye**

Occurrence of mid-latitude field-aligned irregularities observed with VHF coherent scatter ionospheric radar in South Korea

Tae-Yong Yang [1], *Young-Sil Kwak* [2], *Jae-Jin Lee* [2], *Young-Deuk Park* [2]
[1] *Korea Astronomy and Space Science Institute / University of Science and Technology*
[2] *Korea Astronomy and Space Science Institute*

The 40.8-MHz VHF coherent scatter ionospheric radar, located in South Korea(Gyeryong, 36.18°N, 127.14°E), has been operating since December 2009 to investigate ionosphere E- and F-region field-aligned irregularities(FAIs) of mid-latitude. During the observation, we found E- and F-region FAIs appeared frequently: interesting daytime irregularities, continuous echoes during the post-sunrise period and Quasi-Periodic(QP) echoes at nighttime for E region; strong post-sunset and pre-sunrise FAIs for F region. We present characteristics of mid-latitude E- and F-region plasma irregularities observed using Korea VHF radar. Additionally, we also present seasonal and local time variations of occurrence of mid-latitude E- and F-region FAIs during low solar activity period, December 2009 - May 2011. It is worth to note our occurrence result since long term observation over a year in the mid-latitude has not yet been carried out.

Presented by: **Yang, Tae-Yong**

A Low Power Software Defined Incoherent Scatter Radar System Design Concept for Continuous Sounding the Earth's Ionosphere

Ming Yao
Nanchang University, Nanchang, China

The incoherent scatter radar (ISR) is the only ground based instrument, which can detect the space plasma parameters from tens to thousands of kilometers height above the earth, especially the ionosphere. Although ISR is the most effective ionospheric sounding instrument, its' exorbitant constructing and running fee limit its wide application. Compared with the traditional ISR, the novel ISR design concept introduced in this paper has the advantages of low power and continuous working. It can probe real time plasma parameters in the whole ionosphere range (80-1000 Km). Successful development of such ISR will resolve the problem of continuous detection of ionospheric electric field and other parameters. This paper will introduce the design concept of this low power software defined ISR.

Presented by: **Yao, Ming**

Atmospheric Density and the Height Distribution of Meteor Radar Detections

Joel Younger [1], *Iain Reid* [1], *Robert Vincent* [1], *Damian Murphy* [2]
[1] *University of Adelaide*
[2] *Australian Antarctic Division*

Radar-detectable meteor trails are formed at heights around 70-110 km by the ionization of material evaporated from the surface of meteoroids entering the atmosphere. The height at which meteor trails occur is a function of the properties of the incident meteoroids and the density profile of the atmosphere. Variations in the density profile of the atmosphere will cause variations in the distribution of heights over which meteors are detected.

The formation of meteor trails for a population of meteoroids with different initial sizes, velocities, and angles-of-entry have been numerically simulated using model atmospheric data. The meteor radar response function was then applied to the simulated trails to determine whether each trail was detected. The detected trails were then weighted according to the properties of the simulated meteor population to produce a height distribution of detected meteors. It is predicted that the width of the approximately Gaussian height distribution of meteor detections is a nearly linear function of the density scale height of the atmosphere. This result can be derived independently from an analytic consideration of the energy budget of individual meteors during ablation. Further predictions include a correlation between the peak detection height and extinction height (minimum detected height) and the height of constant density surfaces in the meteor ablation region. A comparison of model atmospheric density profiles with actual meteor detections is consistent with these predictions. As such, the height distribution of meteor radar detections may provide a method for observing density variations in the meteor ablation region.

Presented by: **Younger, Joel**

The Effect of Aerosol Absorption on Meteor Decay Times at Different Wavelengths

Joel Younger [1], *Iain Reid* [1], *Robert Vincent* [1], *Damian Murphy* [2]
[1] *University of Adelaide*
[2] *Australian Antarctic Division*

The free electrons in meteoric plasma are susceptible to absorption by aerosols in the meteor ablation region. The loss of electrons from meteor trails due to absorption by aerosols may be responsible for the discrepancy in echo decay time estimates of the ambipolar diffusion coefficient made by meteor radars with different wavelengths.

It is possible to numerically simulate the simultaneous diffusion and absorption of meteor trail electrons to determine the effect of aerosol absorption on the decay time of meteors with different initial electron line densities measured with different radar wavelengths. The simulations performed indicate that the observed decay time of a meteor radar echo in an absorptive environment may be reduced or extended, depending on the initial line density of the trail and the properties of the absorbing aerosols. The dependence of the decay time modification on the properties of the absorbing aerosols provides an opportunity to determine under what aerosol regimes absorption becomes a significant factor in the estimation of the ambipolar diffusion coefficient from meteor radar echo decay times.

The results of the numerical simulations have been compared with observations of co-located 33 and 55 MHz meteor radars located at Davis Station, Antarctica. A comparison of the disagreement in diffusion coefficients as a function of electron line density is consistent with the predictions of the numerical simulations. Expected seasonal trends due to the modulation of aerosol charge by solar irradiance and the formation of PMSE are, however, not seen, which may indicate that aerosol absorption is not the sole cause of the wavelength dependence of meteor radar diffusion coefficient estimates.

Presented by: **Younger, Joel**

The Diffusion of Multiple Ionic Species in Meteor Trails

Joel Younger , *Iain Reid* , *Robert Vincent*
University of Adelaide

Meteor trails are composed of material evaporated from the surface of ablating meteoroids and can be comprised of a number of different elements. The diffusion of ions in meteor trails is usually considered using an average value for all of the elements in the trail. Numerical simulations have been performed to determine the diffusive behavior of meteor trails made out of multi-constituent plasma. This is further separated into two problems: that of the initial radius of the distributions of different ions and the subsequent diffusion of different ions in a meteor trail. Particular attention is paid to the effect of multi-species diffusion on the observed meteor echo decay times at different radar wavelengths.

Presented by: **Younger, Joel**

Accuracy of Meteor Shower Velocity Estimates Obtained from the Fresnel Transform Method

Joel Younger [1], *Iain Reid* [1], *Robert Vincent* [1], *Damian Murphy* [2]
[1] *University of Adelaide*
[2] *Australian Antarctic Division*

Dedicated meteor radar systems can be used to detect meteor showers caused by discrete filaments of debris in Earth-intersecting orbits. The velocities of individual candidate meteors for each shower can be used to produce an estimate of the apparent geocentric velocity of meteoroids in the shower. A meteor shower is formed by bodies with the same orbital parameters, which means that all meteoroids in a shower share the same initial velocity. Therefore, an analysis of the distribution of velocities of shower meteors can also be used to assess the precision of the velocity estimation technique. Furthermore, the observations of the same meteor showers made by other radar techniques and optical methods provide an opportunity to compare the accuracy of shower velocity estimates.

The velocity estimates of 522 shower detections obtained during a survey of VHF meteor radar data from 2006-2007 have been used to assess the performance of the Fresnel transform method of velocity estimation. It is shown that the estimates for high velocity showers above at least 50 km/s are strongly influenced by the angle-of-entry of the meteors, due to the removal of early-stage ablation meteors in shallow trajectories by the underdense echo high altitude cutoff phenomena. Furthermore, it is shown that the precision of single-station estimates of meteor shower velocity is strongly dependent on the number of shower meteors detected, converging to a relative value of about 8% for intense showers.

Presented by: **Younger, Joel**

The Role of Sputtering in the Formation of Meteor Trails

Joel Younger , *Iain Reid* , *Robert Vincent*
University of Adelaide

Sputtering of material from the surface of meteoroids can occur when collisions with molecules of atmospheric gasses impart energy in excess of the lattice energy of the meteoric material. While most of the detectable plasma in meteor trails is produced by evaporation at high temperatures, sputtering produces mass loss at high altitudes well in advance of the onset of evaporation. Numerical simulations have been performed for meteoroids with different compositions, initial sizes, and initial velocities. It was found that sputtering only constitutes 1-2% of the detectable ionization in underdense meteor trails. This result allows the ablation of meteoroids to be modeled using the simpler all thermal energy budget equation. It was however found that sputtering can produce ionization at much higher altitudes than is seen for the case of evaporation only. This indicates that sputtering may be an important mass loss mechanism for high altitude meteors as detected by radars with longer wavelengths.

Presented by: **Younger, Joel**

3D-measurement results by MAARSY using radar interferometry methods

Marius Zecha , Ralph Latteck , Markus Rapp , Werner Singer , Gunter Stober , Toralf Renkwitz
Leibniz-Institute of Atmospheric Physics (IAP) at the Rostock University, Kühlungsborn, Germany

Usually the spatial resolution of measurements by pulsed VHF radars is limited by the radar beam width, transmitting pulse length, and sampling time. Due to these technical restrictions the typical small-scale structures in the mesosphere often cannot be resolved. Furthermore the quality of the estimation of dynamic atmosphere parameters is reduced if the position and direction of scatter returns cannot determined exactly.

Radar interferometry methods have been developed to reduce these limitations

In the recent years the MST radar MAARSY was installed in Andenes/Norway (69°N). This new radar was designed to allow improved three-dimensional observations in the atmosphere. It consists of 433 Yagis and allows a minimum beam width of about 4 degree. The beam direction can be changed pulse-by-pulse freely in azimuth angle and practicable up to 40 degree in zenith angle. The typical used pulse length is set to 300 m and could be reduced down to 50 m. Up to 16 receiving channels of spaced antennas can be used.

In this presentation we demonstrate the detection of the angle-of-arrival and the verification of the beam steering with MAARSY. We show the improvement of measurement results by using radar interferometry methods. The differences to the results of conventional methods depend on beam width, range resolution, distance between radar and measurement volume, zenith angle of the beam, and so on. We show that the application of interferometry is necessary to improve considerably the quality of 3D-measurement results.

Presented by: **Zecha, Marius**