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CEDAR Workshop – MLT Poster Session Abstracts

Day 2 – Wednesday, June 26, 2013

Coupling of the Upper Atmos with Lower Alts

COUP-01 Analytic Model of the Global Electric Circuit - by Greg Lucas

Status of First Author: Student IN poster competition, PhD

Authors: G. Lucas, A. J. G. Baumgartner, J. P. Thayer

Abstract: The Earth's global electric circuit (GEC) embodies the electrical pathways by which currents flow between electrified clouds and the ionosphere and close through return currents between fair weather regions and the Earth's surface. To investigate this pathway, an analytical model based on the original work of Roble and Hays [1979] has been developed to produce estimates of lower and middle atmosphere currents, electric fields, and potential distributions of the global electric circuit. The electrical connections within earth's atmosphere are represented by an electric circuit with charged plates on the ground and in the lower ionosphere. The atmosphere between the ground and the ionosphere is composed of complex current sources and conductivity distributions. In the global electric circuit, current and electric fields are generated and controlled by lightning events that act as generators within the system. Additionally, conductivity influences the distribution of currents and electric fields in time and space. To account for this, detailed conductivity distributions have been derived using the Whole Atmosphere Community Climate Model (WACCM). An analytic solution to Poisson's equation is implemented, which allows for the steady-state calculation of potential, electric fields and currents for specified conductivity distributions and current sources. This model then allows one to determine how different lightning and conductivity distributions impact the electrical characteristics of the GEC. The novel WACCM conductivity maps and existing lightning distributions allow for new insights into the complex processes involved in the formation of the currents and electric fields through the atmosphere.

COUP-02 Time-Dependent Model of the Global Electric Circuit – by Sotirios A. Mallios

Status of First Author: Student IN poster competition, PhD

Authors: Sotirios A. MalliosVictor P. Pasko

Abstract: The Global Electric Circuit (GEC) is a circuit that is formed between the Earth's surface, which is a good conductor of electricity, and the ionosphere, a weakly-ionized plasma at around 80 km altitude [e.g., Rycroft et al., Space Sci. Rev., 137(1-4), pp. 83-105, 2008]. In the absence of any source, the GEC behaves as a leaky spherical capacitor, with the ground being the negative charged plate and the ionosphere the positive one, which discharges through the weakly conducting atmosphere creating fair-weather current, which is about 1 kA integrated over the entire Earth surface [e.g., Bering et al., Physics Today, Oct., 24-30, 1998]. It is accepted that thunderstorms are the main generators in the GEC [e.g., Williams, Atmospheric Research, 91, 140, 2009; Mareev, Physics Uspekhi, 53, 504, 2010].

In this current work, we developed a two-dimensional cylindrical time-dependent model, that calculates the quasi-electrostatic fields created by the slow accumulation of the charge in the cloud, by taking into account the Maxwellian relaxation of the charges in the conducting atmosphere. The simulation domain is chosen to have the same electrical properties with the GEC, and thus from these results we are able to calculate the source currents that are driven to the GEC in the close vicinity of the thunderstorm, and also the fair-weather current that is induced because of the presence of the given thunderstorm. In the steady state limit, the results of the time-dependent model are compared to static GEC solutions similar to those reported previously by Tzur and Roble [JGR, 90, 5989, 1985].

COUP-03 Downward Transport of Nitric Oxide during recent Arctic Winters – by Brentha Thurairajah

Status of First Author: Non-student

Authors: Brentha Thurairajah, Scott M. Bailey, Cora E. Randall, Mark E. Hervig, and James M. Russell III

Abstract: Nitric Oxide (NO) plays an important role in the energy balance and structure of the Arctic Mesosphere and Lower Thermosphere (MLT), and will catalytically destroy ozone if transported to the stratosphere. Recent studies have highlighted the descent of Nitrogen Oxide (NOx) species from the MLT to the stratosphere during dynamically active Arctic winters, also associated with stratospheric sudden warmings (SSWs). We present six years of continuous NO measurements in the Northern Hemisphere by the Solar Occultation for Ice Experiment (SOFIE) aboard the AIM satellite. While downward transport is observed during all years, this transport is pronounced during the early 2009, 2012, and 2013 years. We use a NOx 1-D model to investigate the role of eddy diffusion on this downward transport.

COUP-04 Coupling the Whole Atmosphere Model (WAM) with the Global Ionosphere-Plasmasphere (GIP) Model - by Houjun Wang

Status of First Author: Non-student

Authors: Wang, H., R. Akmaev, T. Fuller-Rowell, N. Maruyama, G. Millward, F. Wu, J. Wang, T.-W. Fang, D. Anderson, and M. Codrescu

Abstract: This poster updates our work on coupling of the Whole Atmosphere Model (WAM) with the Global Ionosphere-Plasmasphere (GIP) model.

WAM is an extension of NCEP's Global Forecast System (GFS) model from 64 model levels (with the model top at about 60 km) to 150 model levels (with the model top at about 600 km). It covers the regions of important ionospheric processes and their variability. WAM includes basic ionospheric effects on neutral atmosphere, i.e., ion drag and Joule heating. Free annual run with WAM produced comparable climatology of tidal wave variability in the mesosphere and low thermosphere (MLT) region. Recently a NEMS version of WAM is implemented and we test the coupling of NEMS-WAM with GIP too.
GIP is derived from the Coupled Thermosphere-Ionosphere-Plasmasphere (CTIP) model. Its geomagnetic field is defined on the modified apex coordinates using the International Geomagnetic Reference Field (IGRF). Its dynamo solver is adapted from NCAR's Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM).

We will present simulations of the January 2009 sudden stratospheric warming (SSW) with the coupled WAM-GIP model.

Instruments or Techniques for Middle Atmosphere Observations

ITMA-01 System design of a mobile ozone DIAL lidar - by Tao Li

Status of First Author: Non-student, PhD

Authors: Tao Li, Xin Fang, Chao Ban, Zhaopeng Wu, Daren Lu

Abstract: In recent years, atmospheric ozone layer recovery process and its response on climate become hot issues in atmospheric sciences. For understanding them, it is significant to measure ozone vertical profile with high temporal and vertical resolutions. We propose a mobile ozone differential absorption lidar(DIAL). It will be used

for measuring about 5-50km ozone vertical profile. Here, we mainly focus on the system design of the lidar. The transmitter emit five laser beams with wavelength 266nm, 289.04nm,299.05nm, 308nm, 355nm respectively. The receiver is consisted of five telescopes: three 200mm diameter telescopes, one 1000mm diameter telescope and one synthetic telescope with 2500mm effective diameter. And in receiver a special chopper with 400mm diameter is designed for cutting strong echo near field of view of telescopes.

ITMA-02 MRI PR-LASER Upgrade to the Arecibo Resonance Doppler LIDAR – by Jonathan S. Friedman

Status of First Author: Non-student

Authors: Juan Arratia, Xinzhao Chu

Abstract: The Puerto Rico Photonics Institute of the Universidad Metropolitana in Puerto Rico has replaced the laser transmitter for the resonance Doppler lidar at the Arecibo Observatory. The new laser, based on technology developed at Light Age and in collaboration with the CEDAR LIDAR Consortium, promises to greatly improve the quality of MLT temperature and K density measurements through its improved spectral performance and higher power. This is an initial step in ultimately converting the lidar to one for measuring Fe, which will further improve measurement quality. In this poster, we present the new laser transmitter and improved lidar at Arecibo.

ITMA-03 New capabilities of Jicamarca incoherent scatter radar system – by Marcos Inonan

Status of First Author: Student IN poster competition, Undergraduate

Authors: Marcos Inonan, Darwin Cordova, Ivan Manay, Ramiro Yanque, Miguel Urco, Marco Milla, Jorge Chau

Abstract: The modularity of the antenna array at Jicamarca gives great flexibility to setup our radar system in multiple configurations. However, the process of changing the configuration used to take long time since it was done manually. In order to have a more efficient, faster, and automatic configuration process and thus extending the capabilities of the radar, the Jicamarca engineering team has developed a modern system that allows us to change the phasing of the antenna array in almost any desired position. This Automatic Beam Switching (ABS) system is a tremendous tool. It is not only able of changing the antenna phases in milliseconds (the manual process took several hours and numerous workers), but also it is able to switch to different beam positions during an experiment (a capability that was not possible in the past). In addition to this improvement, the Jicamarca engineers have updated the Jicamarca Acquisition Radar System (JARS). Now the system is more flexible and has improved its data throughput. JARS is a versatile system that has been used in different applications, from radio astronomy (to detect astrophysical masers) to maritime surveillance (as part of coastal radar system). At Jicamarca, both systems are used in ESF imaging experiments conducted during the JULIA campaigns.

ITMA-04 A New Opportunity for Passive Optical Measurements Inside US National Parks in Utah - by Kasey Johnson

Status of First Author: Student NOT in poster competition, Undergraduate

Authors: Kasey Johnson, Michael Buzbee, and Kim Nielsen

Abstract: Capitol Reef National Park is one of the less known national parks in the United States park system. The location of the park far from major cities and road systems, as well as its location above 6000 feet on the Colorado Plateau bring into existence the darkest night sky known in the US. The Capitol Reef Field Station is a self-sustainable facility operated by Utah Valley University and is located deep inside the park. The facility promotes and support engaged learning and field-based scientific research related to the Colorado Plateau.

Most recent, Utah Valley University acquired a trailer to be hosted at the field station. It is anticipated that the trailer will host a suite of passive optical instruments to support student research in atmospheric and space sciences. The trailer is self-sustainable and has the possibility to be deployed at other locations for campaigns based observations.

This presentation introduces the field site, the trailer system, and new research opportunities to the CEDAR community.

ITMA-05 The role of the transient solar radio emission on the estimation of 30 MHz D-region absorption using riometers - by Alessandra Abe Pacini

Status of First Author: Non-student, PhD

Authors: Pacini, A.A., Brum, C.G.M., Makita, K., Selhorst, C.L., Fernandes, F.C.R, Cunha-Silva, R.

Abstract: Riometry studies evaluate the variability of the Cosmic Noise absorption at the frequencies between 20 and 200 MHz. In theory, the Cosmic Noise emission is constant for the different part of the sky, so any change in its registers must be due to absorption in the Earth's atmosphere, i.e., at the heights of D region where the collision frequency are close to the cosmic noise frequency generally measured. However, in some cases it is possible to identify a negative absorption for daytime periods. Such phenomena could be associated to solar emissions registered during solar flare events (for example). In this work we present some clear evidences of the transient solar radio emission impact on the riometer signal, and discuss the importance of that on the D-region absorption estimation in order to obtain a trustful and real diagnose of the D region for periods of "solar contamination".

ITMA-06 Optimal Beam-Space Sampling Methods for Electronically Steerable ISR – by John P. Swoboda

Status of First Author: Student IN poster competition, PhD

Authors: John Swoboda and Joshua Semeter

Abstract: Recent advancements in incoherent scatter radar(ISR) have greatly expanded the capabilities of these sensors. Researchers are now able to create arbitrary patterns with a large, but limited, number of beams to probe the ionosphere and the atmosphere. With this comes the question, what is the optimal way to sample geophysical structures with these systems? To answer this question we use both theoretical calculation and simulation.

From a theoretical standpoint we attack this problem by framing it as multi-dimensional sampling problem. Doing so will allow us to use various techniques from modern signal processing such as compressed sensing. We will assess the applicability of different techniques to the ISR system.
We will also show preliminary work on an ISR simulation in development to create IQ level data. With this data it we hope to create scenarios where new reconstruction methods can be tested.

ITMA-07 Daytime observation of sodium layer using Faraday filter lidar technique – by Cheng Xuewu

Status of First Author: Non-studen,t Masters

Authors: Cheng Xuewu, Li Faquan, Yang Yong, Song Shalei,Liu Linmei, Lin Xin, Gong Shunsheng

Abstract: Faraday filter as a narrow band optical filter has been developed for many years. Due to its ultra narrow bandwidth (~0.002nm), high transmission and stabilization, Faraday filter has been successfully used in Lidar, solar observation and so on. In this paper, we report the principle and technologies of a sodium Faraday filter used in daytime operation of the sodium Lidar, and some preliminary results of 24-hour continuous observation of Sodium layer.

ITMA-08 **Joint observations of concentric convectively-excited gravity waves using ground-based airglow imagers, AIRS on Aqua, CIPS on AIM and VIIRS on Suomi NPP measurements -** by Jia Yue

Status of First Author: Non-student

Authors: Lars Hoffmann, Brentha Thurairajah, Steve Miller, Takuji Nakamura, Thomas Ashcraft, Walt Lyons, Joan Alexander, James Russell III, Scott Bailey, Cora Randell

Abstract: Because only a portion of gravity wave spectrum (horizontal and vertical wavelengths and wave period) is visible to a certain spaceborne or ground-based imaging technique, we combine various techniques to reveal a more complete picture of concentric convectively-excited gravity waves simultaneously in the stratosphere and mesosphere. The ground-based instrument used is the YRFS OH all-sky imager (40.7N, 105W) in Colorado. Three nadir-viewing instruments on NASA satellites are the Atmospheric Infrared Sounder (AIRS) on Aqua, Cloud Imaging and Particle Size (CIPS) on the Aeronomy of Ice in the Mesosphere (AIM) and the Visible Infrared Imaging Radiometer Suite (VIIRS) on Suomi NPP satellites. Channels near the 4.3 micron CO_2 band on AIRS detect gravity wave perturbations at 40 km. The 8.1 micron channel can be used to identify deep convection. CIPS on AIM observes gravity wave perturbation of the polar mesospheric clouds in summer. The third instrument, the Day/Night Band Imager on VIIRS, measures the broadband airglow emissions directly or reflected back by clouds. Three case studies will be presented on the observations on 3 June 2008, 13 July 2007 and 15 April 2012 to illustrate the potential of joint measurements.

ITMA-09 **Vertical Shear of Mean Doppler Velocity in Sporadic E Layer Structure –** by Ting-Han Lin

Status of First Author: Student NOT in poster competition, Masters

Authors: Yen-Hsyang Chu, Chin-Lung Su, Chien-Ya Wang, Kuo-Feng Yan

Abstract: The 3-meter field-aligned irregularities (FAIs) in ionospheric sporadic E (Es) layer structures have been observed by using the Chung-Li VHF radar since February 2005. The three-dimensional spatial plasma structures of the Es FAIs were able to be reconstructed by using interferometry technique. It is generally accepted that neutral wind may induce the polarization electric fields EP through ion-neutral collision inside Es FAIs structure, which is believed to be responsible for the movement of 3-m FAIs through ExB drift. Radar experiments usually show that there is a tendency for the mean Doppler velocity of the radar returns from 3-m FAIs to vary with height, suggesting a height variation of the electric field (or neutral wind) in the Es layer. Statistics show that the magnitude of the vertical shear of the mean Doppler velocity ranges from -9 ms-1/km to 8 ms-1/km. The slope of the Doppler velocity shear can be positive (increase with height) or negative (decrease with height). The occurrence of the former is generally less frequent than that of the latter by a factor of 3. Plausible mechanisms responsible for the height variations of the mean Doppler velocity with different slopes are discussed in this presentation.

Long Term Variations of the Mesosphere and Lower Thermosphere

LTVM-01 **10-years of potassium lidar measurements at 54°N –** by Jens Lautenbach

Status of First Author: Non-student

Authors: Jens Lautenbach, Josef Hoeffner and Michael Gerding

Abstract: We report about a 10-year data set of potassium density measurements in the MLT region (80-120km) at 54°N in Kühlungsborn, Germany. A total of 5090 hours at 733 days was obtained between 2002 and 2012. The diurnal data set includes around 25% of observations under daylight conditions (>0° solar elevation).

The main parameters of the potassium layer are almost unchanged when daylight measurements are included even though tides have a significant impact on the layer. The first maximum is observed from early December to late February. The second maximum occurs in summer and lasts for about 4 months (May-August). The potassium layer shows very little variation over the years. The topside of the potassium layer changes slightly over the years; however the observed broad extension towards high altitudes in summer is repeated every year.

The impact of tides on the potassium layer is demonstrated by focusing on measurements with duration of more than 12 hours per day. The mean potassium layer height, FWHM and column density changes strongly throughout the day with a modulation of up to 30%. The tides are also visible in the temperature structure measured by the potassium Doppler lidar in combination with the daylight capable Rayleigh lidar, both located at the same site. The combined data set shows tidal effect in altitudes from 110 km down to 40 km. Furthermore we will present the year to year variation of the summer mesopause temperature from this 10-year data set, showing a distinct variation with solar cycle.

<u>Meteor Science other than Wind Observations</u>

METR-01 Simulation of Meteoroid Impact Induced Electrical Anomalies on Spacecraft – by Alexander Fletcher

Status of First Author: Student IN poster competition, PhD

Authors: Alexander Fletcher, Sigrid Close

Abstract: Interplanetary dust particles originating primarily from comets and asteroids, called meteoroids, routinely impact spacecraft with velocities up to 72 km/s. Most meteoroids possess enough energy to ionize and vaporize themselves as well as a significant portion of the satellite material upon impact, forming a plasma in the impact crater that is initially dense (~ 10^28 m−3), but rapidly expands into the surrounding vacuum. The associated electrical effects and potential for damage to satellite electronics through these processes remains largely unknown. Numerous spacecraft have experienced electrical anomalies correlated with meteoroid activity and micro-particle scale momentum transfer events. This area of spacecraft engineering requires a deeper understanding of the underlying physics that occur upon formation and expansion of the plasma that results from an impact.

We present a series of computational multi-physics simulations of micro-particle impacts on spacecraft. These simulations incorporate elasticity and plasticity of the solid target, phase change and plasma formation, strongly coupled plasma physics due to the high density and low temperature of the plasma, a fully kinetic description of the collisionless portion of plasma, and free space electromagnetic radiation. We use a particle-based method that is a variant of smoothed particle hydrodynamics in the high density limit (early stages of impact) and an electromagnetic particle- in-cell in the low density limit (collisionless plasma expansion into vacuum). A discontinuous Galerkin method is used for the coupled solution of Maxwell's equations.

We investigate possible physical mechanisms for radiation from this impact plasma, including coherent oscillation of electrons and a current pulse due to the presence of a charged target. We find plasma temperatures of up to 60eV in the crater, but these cool to < 5eV as the plasma expands. We also find that non-ideal plasma effects noticeably increase the amount of charge generated from a single impact.

METR-02 On the Effect of Turbulence on Specular Meteor Echoes – by Freddy Galindo

Status of First Author: Student IN poster competition, PhD

Authors: F. R. Galindo1, J. V. Urbina1, L. P. Dyrud2 and J. Fentzke2
(1) Communications and Space, Sciences Laboratory, Pennsylvania State University, University Park, PA, USA

(2) Applied Physics Laboratory, John Hopkins University, Columbia, MD, USA

Abstract: The Earth's atmosphere is continuously bombarded by small-size meteoroids. The interaction meteoroid-atmosphere produces a column of ionized plasma behind the meteoroid at altitudes around 100 km, with considerable electron content. This trail of plasma is currently used by radar systems to derive atmospheric parameters such as temperature, pressure and drifts; under the assumption of non-turbulent diffusion rates. In this poster, we present a numerical model to reproduce the effect of turbulence in underdense specular meteor echoes. First, our numerical approach models meteor ablation and ionization to predict the deposition of ionized particles. Next, we test the resulting plasma conditions using Farley-Buneman Gradient Drift instability for meteor trails. Finally, meteor trail evolution is tracked and integrated in altitude and time using a modified version of Fresnel integrals. This new approach is particularly useful in order to infer more accurate mesospheric temperatures from trail diffusion rates and their usage for meteor scatter communication systems. Our simulation results are compared with underdense specular meteor echoes detected with two different radar systems; both instruments operating at a frequency of 50 MHz, and with peak powers of 30 kW and 5kW. By comparing data from different meteor systems, our studies illustrate the significant effect that turbulence plays on the evolution of underdense specular meteor echoes.

METR-03 Phase and Amplitude Calibration of the Jicamarca Radar Using Satellites – by Boyi Gao

Status of First Author: Student IN poster competition, Masters

Authors: Boyi Gao, John D. Mathews

Abstract: The Jicamarca Radio Observatory (JRO) main 50 MHz array radar system with multiple receivers is being used to study meteors using various interferometric configurations. For such an array radar system to perform as desired, it is essential to precisely calibrate the amplitude and phase of each element channel as considerable amplitude and phase differences among the channels can occur. Thus, one of the major challenges in interferometry is to know the phase offsets and amplitude differences between each individual interferometric receiving channel-pairs. Undesired phase offsets and amplitude differences are intrinsic to any such system, and they could be caused by all of the RF hardware such as antenna elements, attenuators, amplifiers, dividers, combiners, switches, connectors, transmission lines, etc.

In response to investigating some ambiguous features in analysis of possible high-altitude meteor head-echoes, we present here a "new" calibration technique that employs satellites to produce accurate phase and amplitude calibrations. Since a satellite can generally be considered a point target, the characteristics of its return resemble those of a meteor head-echo in many ways. Thus satellite returns can be used to test characteristics of the JRO interferometry process as the path of the satellite across the beam is a deterministic graviational orbit. Thus the satellite radar return across the radar beam yields a reliable source for phase and amplitude calibration of the beam. The basis of this technique is the comparison of the position information of an identified satellite with the aid of satellite tracking database, with the measurements of JRO radar, and thus we could calibrate the main array to great accuracy. This approach uncovered subtle phase distortions that are important only to point targets. We present the results of array calibration and radar imaging of satellites from our 15/16 April 2010 meteor observations. Future observations of satellites with a priori known orbits would yield significantly more accurate calibrations.

METR-04 Inference of thermosphere density from metor ablation – by Lorenzo Limonta

Status of First Author: Student IN poster competition, PhD

Authors: Lorenzo Limonta; Sigrid Close

Abstract: A key problem to correctly model the behavior of the atmosphere as well as predicting orbital parameters is knowing its neutral density in the upper layers (80-300 Km). In this poster we present a novel technique for calculating lower thermosphere neutral density using meteor ablation: starting from a scattering model applied to the high-density plasma formed around the meteoroid, coupled with a continuous single particle fragmentation model

and an optimization technique we are able to infer the final values of the surrounding neutral density. Our results show the feasibility of our thought process and the possibility to expand it to other phenomena in the atmosphere

METR-05 Meteoroids and Space Weather: A Probabilistic Approach to Modeling the Large-Scale Distribution in Geospace - by Steven Pifko

Status of First Author: Student IN poster competition, PhD

Authors: Diego Janches, Sigrid Close

Abstract: Meteoroids play a major role in the Geospace environment. In addition to providing the dominant source of metallic atoms in the Mesosphere and Lower Thermosphere (MLT), meteoroids present a serious threat to spacecraft and have been known to cause several on-orbit satellite failures and anomalies due to high energy collisions. Many crucial questions remain unresolved in regards to the properties of meteoroids near Earth, including for example, the global daily input and the distributions of particle mass and speed, and in order to properly assess the impact of meteoroids on the MLT as well as the risk that meteoroids pose to our assets in space, the distribution of meteoroids in the Geospace environment must be accurately modeled and continually monitored. Ground-based radar observation of meteors is a cost-effective and widespread means of achieving this; however, there are several inherent biases that plague these observations and distort the measured distribution of meteoroid properties. Previous work has extensively and adequately accounted for some of the biases associated with radar observations, such as with the derivation of the radar response function, which considers the meteoroid interaction with the atmosphere as well as the specific system parameters of the radar utilized. However, biases associated with the orbital dynamics of the meteoroid have not yet been appropriately addressed, and ground-observed distributions are skewed towards meteoroids that are on trajectories that are more likely to pass within view of the radar.

In this work, a new approach is derived that accounts for meteoroid orbital dynamics in order to determine the likelihood that a meteoroid in Earth orbit will 1) reach the Earth's atmosphere so that it will form a meteor, and 2) will intersect the Earth's atmosphere within view of the radar so that it may be observed. Further, the variation in radial speed is also considered in order to determine the meteoroid distribution as a function of time. This approach allows for ground-based radar observations of meteors to be appropriately used over a larger region than the area immediately surrounding the radar location. Specifically, the developed method allows for the observations from a single radar site to provide probabilistic estimates of the meteoroid distribution 1) over a significant region (approximately one hemisphere) of the atmosphere, and 2) at the altitudes in which the vast majority of spacecraft operate, including LEO and GEO. This methodology is applied to meteor observations conducted with the Southern Argentine Agile Meteor Radar (SAAMER) since January 2012. The results show that biases remain in ground-observed distributions even after correcting for atmospheric and radar effects, and these biases contribute to major differences between ground-based and space-based meteoroid measurements.

METR-06 Characterization of Nonspecular Radar Meteor Trails and Correlation to Corresponding Head Echo Data – by Ana Maria Tarano

Status of First Author: Student IN poster competition, Undergraduate

Authors: Ana Maria Tarano, Jonathan Yee, and Sigrid Close

Abstract: Meteoroids entering the Earth's atmosphere are detected by high-power, large aperture (HPLA) radars as they ablate between 70 and 140 km altitude in the E-region of the ionosphere. The radar returns are classified as head echoes, plasmas surrounding the meteoroids, and trails, the expanding plasma column left in the meteoroid's wake. A particular type of trail is categorized as nonspecular trails, which are thought to be reflections from field aligned irregularities (FAI) after the onset of plasma turbulence when the radar beam is pointed quasi-perpendicular to the background magnetic field. Using data collected at the Advanced Research Project Agency (ARPA) Long-range Tracking and Identification Radar (ALTAIR), which included dual frequency, dual polarized, and high range resolution in-phase (I) and quadrature (Q) returns with additional azimuth and elevation data derived from the monopulse system, a detection algorithm was conceived to efficiently locate head echo and nonspecular trail pairs by combining understanding of range and time dependence of meteor events with image processing techniques.

Detected pairs of head echoes and trails were analyzed in order to characterize the time delay between the head echo and nonspecular trail. Moreover, the detection algorithm also facilitated the correlation of head echo and nonspecular trail features, such as duration, signal to noise ratio (SNR), and altitude of occurrence.

METR-07 Numerical Calculation of Ground Illumination Patterns from Specular Meteor Trail Scatter Under Arbitrary Transmitter, Receiver and Trail Geometries – by Cody Vaudrin

Status of First Author: Student IN in poster competition, PhD

Authors: Cody Vaudrin, Scott Palo

Abstract: Knowledge of the geographical distribution of scattered power from meteor trails on the earth's surface is of prime importance for the design of a multistatic meteor wind radar. Three primary sources by Tinin [2006], Jones [1990] and Dimant [2006] serve as a basis for the study of meteor trail scatter under arbitrary receiver and transmitter geometries with respect to the meteor trail orientation. Using the "classical" forward-scatter theory, one can calculate the power from an oblique trail with some constrains on the geometry, however, the calculation of a ground illumination footprint using the classic forward-scatter radar equation as given by McKinley [1961] is troublesome because his formulation assumes the trail is tangent to an ellipse with foci at the receiver and transmitter locations. Tinin provides a technique for calculating an illumination ground pattern for underdense trails with arbitrary trail geometry, electron density distribution and receiver and transmitter locations. Jones and Dimant formulate two theories of trail diffusion, with Dimant building off of Jones' earlier work. Their modern diffusion theories allow for the calculation of the trail's cross-sectional electron density distribution in the presence of a geomagnetic field and background ionosphere, and when combined with Tinin's work enable the creation of meteor trail forward scatter simulations. Theory and results produced under Tinin's numerical formulation for calculation of the ground illumination patters from VHF meteor trail scatter are presented. These results are used to justify the selection of receiver locations under a proposed multistatic meteor radar configuration.

METR-08 Error bars and statistics for meteor head echoes measured with the Millstone Hill Radar - by Ryan Volz

Status of First Author: Student IN poster competition, PhD

Authors: Sigrid Close, Philip J. Erickson

Abstract: Delay, Doppler shift, and signal strength are the foundational measurements used to study meteor head echoes with radar, yet we typically lack a quantitative measure of their accuracy. How much trust can we place in models derived from data lacking error analysis? We address this blind spot by formulating error bars for the basic measurements made with the Millstone Hill Radar. Our simulation-derived error bars account for system effects like sampling, limited bandwidth, and receiver filtering and therefore provide more realistic bounds than those given by classical matched filter theory. By propagating our error analysis forward, we are able to estimate the error of head echo range, range rate, and radar cross section measurements. This approach lends confidence and gives necessary quantitative insight to our analysis of ten hours of head echo statistics.

METR-09 Detection Dependence of Nonspecular Meteor Trail Turbulent Diffusion Structure on Radar Frequency and Polarization – by Jonathan Yee

Status of First Author: Student IN poster competition, PhD

Authors: Jonathan Yee, Sigrid Close

Abstract: High Power, Large Aperture (HPLA) Radars have been used to characterize the plasmas formed as meteoroids ablate in Earth's atmosphere. These plasmas are referred to as heads, which are the plasmas surrounding the meteoroids, and trails, which are plasmas behind the meteoroids. A particular subset of the trails is nonspecular

trails, which are detected when the radar beam is quasi-perpendicular to the magnetic field. These returns are thought to be the reflection from field aligned irregularities (FAIs) that form due to the onset of turbulence in the meteor trail. We present nonspecular trails detected by the Advanced Research Project Agency (ARPA) Long-range Tracking and Identification Radar (ALTAIR). These data include dual frequency, dual polarized, and high range resolution in-phase (I) and quadrature (Q) returns with additional azimuth and elevation data derived from the monopulse system. In order to further understand the diffusion structure of the plasma turbulence, we first examine the turbulent structure of the nonspecular trails as the detected structure changes from a thin line similar to a wire to a thicker cylindrical column of plasma. Then, using trails that were detected simultaneously in ultra-high frequency (UHF) and very-high frequency (VHF), we examined the dependence of the shape and rate at which the shape changes on the detection frequency used to detect the nonspecular trail. A similar comparison was done for trails simultaneously detected in multiple polarizations, left circular (LC) and right circular (RC), given that ALTAIR transmits in RC waves. Using this analysis, we explored the reasoning for the strong dependence of nonspecular trail detections on radar frequency and the peculiar polarization returns from the transmitted RC wave.

METR-10 Radar Interferometric Imaging using compressed sensing for the Case of Point Targets - by Qian Zhu

Status of First Author: Student IN poster competition, Masters

Authors: Qian Zhu, J. D. Mathews and Ryan Volz

Abstract: The compressed sensing concept is introduced to radar interferometric imaging. For meteor head-echo modeling purposes, a discrete linear radar model in the range-Doppler frequency-cross-range domain has been derived, and the iterative soft-thresholding approach based on compressed sensing concepts is applied to point targets. We demonstrate that this approach can provide better resolution in both temporal and spatial domain by eliminating “ringing” effects. By comparing modeling results with the FFT and maximum entropy approaches, its merits and issues are discussed.

METR-11 A Micro-Scale Radar Study of Hypervelocity Micrometeoroid Impact Plasma for Localizing Instability Driven RF Emission - by Theresa Johnson

Status of First Author: Student IN poster competition, PhD

Authors: Theresa Johnson, Dr. Ivan Linscott, Prof. Sigrid Close

Abstract: The motivations for studying hypervelocity impact-generated plasma emission properties include satellite electrical anomalies at the height of meteor showers. Meteoroids and dust traveling between 11 and 72.8 km/s are constantly bombarding spacecraft while on orbit. These hypervelocity particles may cause electrical anomalies in satellites through electromagnetic pulse (EMP) or electrostatic discharge (ESD) (Close, et al. 2010). This emission is experimentally confirmed in ground based tests, has proven to be electromagnetic via in-plane and orthogonal sensors designed to capture both electric and magnetic field. An electric field of 1V/m is produced in the impact region, and parametric scaling up to masses and velocities found on orbit lead to estimations from 1000 – 10,000 V/m, depending on spacecraft charging and ambient background conditions. The RF emission signal is can be explained by plasma instabilities formed during the expansion phase. Further ground-based tests are proposed to utilize radar to detect plasma parameters of the expanding, oscillating plasma cloud.

Special Note: Poster will be located in IRRI – 15 location due to cancelation

MLT Gravity Waves

MLTG-01 Cancellation Effect in All Sky Imager Observation of Gravity Waves and Its Implications for Wave Analysis - by Jaime Aguilar Guerrero

Status of First Author: Student IN poster competition, Masters

Authors: Alan Z. Liu

Abstract: All sky airglow imagers are widely used as a ground-based remote sensing instrument for observation of atmospheric waves in middle and upper atmosphere. Because of the finite thickness of the airglow layer (~ 10 km for OH and O2), intensity perturbations measured at the ground are not sensitive to wave perturbations with vertical wavelength less than the airglow layer thickness due to cancellation effect. For all sky imagers that have a wide viewing angles, this cancellation effect is different at different viewing angles and for waves with different slopes of phase fronts. This work examines this effect and investigates the relations between wave parameters and wave amplitudes viewed at different angles. This information is important for properly analyzing and explain various wave patterns commonly detected in all sky imagers. It also has the potential to provide an independent estimate of wave parameters.

MLTG-02 **Comparison of gravity wave momentum flux from observations and GCMs –** by Ryan Matthew Agner

Status of First Author: Student IN poster competition, PhD

Authors: Ryan M. Agner

Abstract: While the directionality of gravity wave forcing in global circulation models is overall similar to observation, the magnitude is generally much less than what is calculated from various instruments. Here the gravity wave forcing or momentum fluxes from WACCM, KMCM (Placke et. al., 2011), and the T213L256 High Resolution GCM (Sato et. al., 2009) are compared against observational data from a meteor radar, and an airglow imager (Li. et. al., 2011) at Maui, Hawaii (20.75N, 156.43W), a meteor radar at the Andes LIDAR observatory (30.33S, 70.98W) in Chile, a LIDAR at the Starfire Optical Range (35N, 106.5W) in New Mexico (Gardner & Liu, 2007), and the SABER satellite (Ern et. al., 2007). Analysis of the scales of gravity waves that each instrument observes is presented for a more direct comparison between data sets and model results.

MLTG-03 **Measurements of a gravity wave ducting environment in the Arctic mesosphere using combined lidar and Advanced Mesospheric Temperature Mapper data –** by Katrina Bossert

Status of First Author: Student IN poster competition, PhD

Authors: David Fritts, Mike Taylor, Dominique Pautet, Bifford Williams

Abstract: The combination of both sodium lidar and temperature mapper data allows for detailed studies of mesospheric dynamics. These combined measurements utilize instrumentation at ALOMAR in northern Norway. The Advanced Mesospheric Temperature Mapper provides temperatures and OH intensity in a 2D field at about 87km. The sodium lidar provides temperatures, winds and sodium density vertically and temporally from ~80-105km.

This study focuses on the environment of a gravity wave ducting event in January 2012. The combination of instrumentation allows for a more in depth assessment of gravity wave ducts than possible with a single instrument, and gives the temporal resolution as well as horizontal and vertical spatial scales. The Advanced Mesospheric Temperature Mapper provides unambiguous spatial orientations and phase speeds in conjunction with the lidar measurements. The smaller scale evolution of the gravity wave duct is investigated using this combined data.

MLTG-04 Climatology and Characteristics of Mesospheric Inversion Layers Over Utah – by Michael Laurence Buzbee

Status of First Author: Student IN poster competition, Undergraduate

Authors: Michael Laurence Buzbee, Kim Nielsen, James Russell III

Abstract: Mesospheric inversion layers (MILs) are identified as thermal features exhibiting a relatively strong positive thermal gradient across a narrow altitude region. MIL features can have great influences on the vertical propagation of atmospheric gravity waves (AGWs) as they may introduce reflection points. These turning points can prohibit further vertical propagation of AGWs as well as act as wave guides to sustain thermally ducted wave motion. A recent study by Gan et al., [2012] reported an extensive global climatology of MILs observed by the SABER instrument on board the TIMED satellite. Their findings showed MILs to peak in equatorial and tropical regions, with a second, and less prominent, peak at mid-latitudes during the winter months.

In the study presented here, we focus on characterizing MILs observed by SABER over Utah and discuss their impact on the propagation of AGWs.

MLTG-05 Case study of a gravity wave observation near the stratopause using UV satellite imagery - by Justin N. Carstens

Status of First Author: Non-student, PhD

Authors: Scott M Bailey, M Joan Alexander, Cora E Randall
Abstract: A new data set is being developed for space based observations of gravity waves (GWs) near the stratopause. The data set uses nadir images taken in the UV at 265 nm of Rayleigh scattered sunlight using the Cloud Imaging and Particle Size experiment (CIPS) on the Aeronomy of Ice in the Mesosphere (AIM) satellite. This work will present a case study which will be used to demonstrate the capabilities of CIPS data for GW analysis. Gravity waves are the dominant driver of MLT dynamics and they are insufficiently constrained in global climate models. CIPS observes the waves over much of a hemisphere at a higher altitude than similar observations (for example AIRS), so it promises to help further constrain our understanding of gravity wave forcing on the MLT.
A wave observed on two consecutive orbits on October 10th 2010 to the west of McMurdo station in Antarctica will be presented. The dominant horizontal wavelength of this wave was approximately 150km. Using the apparent phase progression between the two orbits, a ground based phase speed of 20 m/s was estimated, so it is unlikely that this GW was orographically generated. It was propagating in the upwind direction according to winds from MERRA. Using this wind data we estimated the intrinsic frequency of the wave, and from the dispersion relation, we estimated the vertical wavelength to be approximately 22 km. With the horizontal and vertical wavelengths the temperature amplitude was inverted from the observed albedo perturbation, and through that, the pseudo momentum flux was calculated. This is the critical measurement needed to understand GW forcing on the mean flow.

MLTG-06 Characteristics of the Inertia-Gravity Waves in Antarctic MLT Revealed by Lidar, Radar and OH Imager - by Cao Chen

Status of First Author: Student NOT in poster competition, PhD

Authors: Cao Chen, Xinzhao Chu, Xian Lu, Weichun Fong, Zhibin Yu, Brendan Robert, Adrian McDonald, Sharon Vadas, Dominique Pautet and Mike Taylor

Abstract: Three years' of high-resolution temperature observations at McMurdo (77.8° S, 166.7° E) have shown extremely strong and persistent wintertime inertia-gravity waves (IGWs) from the stratosphere to the lower thermosphere. Utilizing the data from three collocated instruments, i.e., Fe Boltzmann lidar, MF radar and OH imager, the parameters of such waves (Intrinsic and observed periods, horizontal and vertical wavelengths etc.) will be analyzed. Our previous case study IGWs in June 2011 suggested that the identified 7.7-h wave likely originates from the stratosphere in a region of unbalanced flow around 45−50 km. A more rigorous gravity wave ray tracing technique will be used to investigate the source regions of such waves.

MLTG-07 Mesospheric Mountain Wave Temperatures at Cerro Pachon, Chile – by Neal Criddle

Status of First Author: Student IN poster competition, Undergraduate

Authors: Neal Criddle, M.J. Taylor, P.-D. Pautet, Y. Zhao, G. Swenson, S. Franke, A. Liu
Abstract: As part of a suite of instruments located at the Andes Lidar Observatory (ALO) in Cerro Pachon, Chile, (30.2° S 70.7° W) Utah State University (USU) operates a mesospheric temperature mapper (MTM) to measure intensity and temperature perturbations in the OH (~87km) and adjacent O2 airglow layers (~94km). Most of the perturbations have characteristics associated with short period freely-propagating or ducted gravity wave events within the mesosphere and lower thermosphere (MLT) region. Of particular interest are a subset of waves above the Andes which are quasi-stationary, consistent with orographic wave generation during the winter season as first reported by Smith et. al. (2009) using all-sky intensity images. Our subsequent study using MTM data revealed further evidence of quasi-stationary mountain waves penetrating into the MLT region in June and July 2010. These events and their wave characteristics are summarized together with new measurements of mountain wave induced temperature perturbations and variability.

MLTG-08 Acoustic Waves Detected by the TIDDBIT (TID Detector Built in Texas) System - by Geoff Crowley

Status of First Author: Non-student

Authors: R. L Walterscheid,M. P. Hickey, J. H. Hecht
Abstract: We have performed a detailed analysis of data from a new Digital HF Doppler sounding system to estimate their propagation parameters of acoustic gravity waves in the F-region. This system called the “TID Detector Built In Texas” (TIDDBIT) is formed by six HF continuous wave (CW) transmitters, four digital receivers, receiving and transmitting antenna sets, and a digital data acquisition system. The system transmits HF radio waves at two frequencies, which are reflected from isionic contours determined by the corresponding plasma frequency, which varies during the day between altitudes ~ 200-400 km. The system records the Doppler shift due to the movement of the isoionic surfaces at 30 s intervals. A spectral analysis of the data from October 30, 2007, when the system was sited near Wallops Island, Virginia, shows strong spectral peaks in the acoustic range in the period interval ~ 3-7 minutes. The power in this region shows a high degree of coherence between three transmission sites located ~ 50 – 100 km from the receiver. A wavelet analysis shows a sequence of discrete events occurring over the day in the 3-7 minute range. An analysis of the phasing between the three transmission sites indicates that horizontal trace speeds in this range are between ~ 500 and 800 m s-1 with horizontal wavelengths between ~ 100 and 300 km. Calculations with a full-wave model indicate that the waves are consistent with internal acoustic waves with upward energy propagation. We conclude that significant acoustic disturbances occurred at F-region altitudes over the TIDDBIT array and that they are upward propagating waves originating below the F region, possibly from tropical storm Noel.

MLTG-09 Propagation of mesospheric gravity waves at 78°N – by Margit Elisabet Dyrland

Status of First Author: Non-student

Authors: Silje Eriksen Holmen, Fred Sigernes, Chris Hall, Mike Taylor, Pierre-Dominique Pautet, Masaki Tsutsumi.

Abstract: Data from an airglow imager operating three winter seasons at the Kjell Henriksen Observatory, Svalbard (78°N, 16°E) have been studied. The number of gravity wave events detected from the images are strongly limited by auroral activity and weather conditions. Wave characteristics and propagation of the observed events are discussed in relation to background conditions measured by meteor radar and spectrometer at the same site.

MLTG-10 Estimation of Atmospheric Gravity Wave Parameters from Airglow Imagery – by Stephen Hall

Status of First Author: Student IN poster competition, PhD

Authors: S. Hall, F. Vargas, A. Mangognia, G. Swenson

Abstract: Passive observation of airglow emissions provides a simple and affordable method for observation of atmospheric gravity waves. This poster presents a method for estimating horizontal characteristics of gravity waves in a single airglow image through matching with a phase-matched Gabor filter. When this analysis is applied to two images representing different times and mean altitudes, estimation of the vertical characteristics of the wave becomes possible. This method is compared to analysis of lidar data and demonstrated through analysis of imagery taken at the Andes Lidar Observatory by members of the UIUC Remote Sensing and Space Sciences group.

MLTG-11 Simulations of reflected and partially ducted waves over Halley, Antarctica – by Christopher James Heale

Status of First Author: Student IN poster competition, PhD

Authors: Christopher J. Heale and Jonathan B. Snively

Abstract: Numerous airglow observation campaigns have noted the ubiquitous nature of short period gravity waves in the mesospheric region. Studies, such as those over Urbana, IL [Hecht et al., JGR, 106, D6, 2001] and Halley, Antarctica [Nielsen et al., JGR, 71, 2009] have reported typical horizontal wavelengths and periods of 15-40km and 7-12 minutes respectively. In addition, gravity waves have been observed to propagate and span horizontal distances of 1000's km due to reflection and partial ducting in the mesopause region. [Suzuki et al., GRL doi:10.1029/2012GL054605]. Through thermal or Doppler trapping, gravity waves can reflect between two vertical boundaries without significant loss, and can thus travel large horizontal distances within the ducting region. For waves with periods ~7-12 minutes, especially for the case of weak meridional winds seen at high latitudes, [e.g. Nielsen et al., JGR, 117, D5, 2012] trapping may occur across the very deep region spanning from the ground or tropopause to the lower thermosphere.

We use a non-linear, fully-compressible 2D model to simulate gravity wave reflection and weak thermal ducting between the ground and the lower thermosphere, under differing solar conditions at high latitudes. Numerical case studies are constructed to quantify short-period gravity wave damping and dispersion over long propagation distances, for typical wave packets. We specify temperature profiles via MSIS, which reproduce realistic lower-thermospheric temperature structure, taken at Halley, Antarctica, while assuming meridional propagation at the high latitudes in order to reduce the influence of Doppler ducting and wind effects. We excite wave packets with central horizontal wavelengths and periods consistent with observed wave characteristics to investigate the long-range propagation of reflected waves trapped between thermosphere and ground. Results suggest that reflection in the thermosphere allows waves with periods ~7-12 minutes to propagate over long distances, on the order of 1000s of km, with packet horizontal scales on the order of 1000km, when conditions are favorable.

MLTG-12 Large winds/wind shears in the MLT region induced by Gravity wave breaking and its interactions with tides - by Xiao Liu

Status of First Author: Non-student, PhD

Authors: Jiyao Xu, Hanli Liu, Jia Yue, Wei Yuan

Abstract: Very large winds and wind shears have been observed by sounding rocket in the mesosphere and lower thermosphere (MLT) region for decades [Larsen, 2002, JGR]. Recently, the strong correlation between their occurrence and local time has been revealed by Colorado State University lidar observations [Yue et al., 2010, JGR]. In this talk, the mechanisms involved in the phenomenon is studied by using a two dimensional numerical model, which solves the nonlinear propagation of gravity waves (GWs) in a dissipative atmosphere with height varying

background wind and temperature. Our simulations on GWs propagation in a windless background show that the large winds and wind shears can be caused by the positive feedback among: momentum deposition associated with GW breaking, mean wind acceleration, and the decreasing vertical wavelength of GWs that further increases the wind shears in the MLT region. Our simulations on GWs propagation in diurnal/semidiurnal tidal backgrounds show that the local time dependency of large wind shears is mainly attributed to the filtering and/or hindering effects of diurnal and semidiurnal tidal wind on GWs. Interestingly, the general agreement of large winds and wind shears between our simulations and the chemical release measurements reveals that interactions between GWs and diurnal/semidiurnal tides play an important role in driving the large winds and wind shears in the MLT region, even though we can not excluded other mechanisms.

MLTG-13 New statistical processing of airglow imaging data using 3D spectral analysis – by Takashi Matsuda

Status of First Author: Student IN poster competition, Masters

Authors: Takashi Matsuda (SOKENDAI), Takuji Nakamura (NIPR), Mitsumu K. Ejiri (NIPR), Masaki Tsutsumi (NIPR), Kazuo Shiokawa (Nagoya Univ.), Yoshihiro Tomikawa (NIPR)

Abstract: Atmospheric gravity waves (AGWs), which are generated in the lower atmosphere, transport significant amount of energy and momentum into the mesosphere and lower thermosphere and because the mean wind accelerations in the mesosphere. This momentum deposit drives the general circulation and affects the temperature structure. Airglow imaging is a useful technique for investigating the horizontal structures of AGWs at around 90 km altitude.

Recently, there are many reports about statistical characteristics of AGWs observed by airglow imaging. However, it is difficult to compare these results obtained at various locations because each research group uses own method for extracting of AGW events.

Spectral analysis with a better reproducibily has significant advantage to manual analyses for processing and comparing airglow image data observed at various locations. We develop new statistical processing of airglow imaging data using 3D spectral analysis technique based on Coble et al., 1998 to determine horizontal propagation characteristics of AGWs such as propagation directions, phase speeds, wavelengths, and observed periods. In this presentation, we will introduce this method and report statistical analysis of sodium airglow imaging data in 2011 at Syowa Station (69S, 39E), Antarctica performed by this method and manual analysis.

MLTG-14 Winter climatology of short period mesospheric gravity waves over Alaska – by Michael Negale

Status of First Author: Student IN poster competition, PhD

Authors: Mike. J. Taylor, Kim Nielsen, Dominique Pautet

Abstract: Observations of short-period (<1 hr) gravity waves over the Arctic region are few and their impact on the Arctic MLT region via momentum deposition is of high interest, but has yet to be determined. The Mesospheric and Airglow Imaging (MAID) project was initiated in January 2011 to investigate the presence and dynamics of these waves over the interior of Alaska. Observations were made from the Davis building at Poker Flat Research Range (65○ N). This site provides an exceptional opportunity to establish a long-term climatology of short-period gravity waves in the Arctic. Here we present summary measurements of prominent gravity waves focusing on their winter-time spatial and temporal characteristics as observed using the all-sky imager. Measurements were made over two consecutive winters 2011 and 2012 yielding 117 quasi-monochromatic events. Their characteristics are compared with recent gravity wave observations at Resolute Bay, Canada (75○ N) and ALOMAR, Norway (69○ N) in the Arctic and Rothera station (67○ S) in the Antarctic.

MLTG-15 Observations of Mesospheric Temperature Variability Over the Andes – by Jonathan R. Pugmire

Status of First Author: Student IN poster competition, PhD

Authors: Jonathan Pugmire, M. J. Taylor, Y. Zhao, P.-D. Pautet, J. M. Russell III, J. Sheer

Abstract: Observations of mesospheric OH(6,2) rotational temperatures by the Utah State University Mesospheric Temperature Mapper (MTM) located at the Andes Lidar Observatory, Cerro Pachon, Chile (30.3°S, 70.7°S) reveal a large range of nightly variations induced by atmospheric gravity waves and tides, as well as strong seasonal oscillations. This study investigates MTM temperature variability over the past 3.5 years comprising over 800 nights of high-quality data and compares the results with ground-based spectrometric measurements from nearby El Leoncito Observatory, Argentina, Maui-MALT, Hawaii MTM measurements (2001-2005) and coincident mesospheric temperature measurement by SABER on the NASA TIMED satellite.

MLTG-16 Adaptation and Validation of an Atmospheric Model to Simulate Acoustic and Gravity Waves in the Martian MLT – by Lynsey B. Schroeder

Status of First Author: Student IN poster competition, Undergraduate

Authors: Lynsey B. Schroeder, Christopher J. Heale, Jonathan B. Snively.

Abstract: In this study, a non-linear compressible atmospheric dynamics model [Snively et al., JGR, 113, A06303, 2008] has been adapted for Martian atmospheric conditions and validated to investigate propagation of internal atmospheric acoustic and gravity waves in the Martian atmosphere. The Martian ambient atmospheric conditions are specified via reference models, such as the Mars Global Reference Atmospheric Model (MarsGRAM), produced by NASA Marshall Space Flight Center [e.g., Justh et al., http://www-mars.lmd.jussieu.fr/paris2011/abstracts/justh_paris2011.pdf, 2011]. The propagation characteristics of acoustic and gravity waves, generated by modeled sources, are investigated above geographically significant sites. Furthermore, the two-dimensional time-dependent results of this investigation are compared with the linearized one-dimensional numerical model results of Parish et al. [Icarus, 203, 28-37, 2009] to assess the upward propagation and dissipation of gravity waves in the Martian lower thermosphere.

MLTG-17 Infrared imaging of short-period mesospheric gravity waves under adverse light conditions from Utah State campus – by Christina Wittwer

Status of First Author: Student IN poster competition, Undergraduate

Authors: Mike Taylor, Dominique Pautet, Yucheng Zhao, Tao Yuan

Abstract: We have made all-sky observations of the broad-band OH emission (87 km) from Utah State University (USU) campus using an infrared (0.9-1.9 micron) InGaAs camera to investigate the potential for high-quality gravity wave measurements under a range of background lighting conditions. Observations of gravity waves were successfully made throughout the lunar cycle filling the full-moon operation gap that normally limits CCD based all-sky imaging systems. Test measurements were made in 2012 for the six-month period of January-June as well as in November. On many occasions coincident Na wind-temperature lidar and mesospheric temperature mapper (MTM) measurements were made enabling detailed studies of individual wave events. Example imagery and results of the coordinated gravity wave data analysis are presented.

MLTG-18 Responses of Global Gravity Waves to Planetary Wave Anomalies Using SABER Observations - by Chihoko Yamashita

Status of First Author: Non-student

Authors: Chihoko Yamashita, Scott England, Thomas Immel, Loren Chang

Abstract: Temperature anomalies in the summer mesopause region associated with planetary wave (PW) anomalies in the winter stratosphere have been observed. Such inter-hemispheric coupling is likely caused by changes in atmospheric waves thus circulation. However, the physical mechanisms are not fully understood, due in part to the lack of global gravity wave (GW) observations in the mesosphere and the lower thermosphere (MLT). This study presents global-scale GW observations and their responses to PW anomalies using TIMED-SABER temperature observation, which provide a better insight into the inter-hemispheric coupling.

We examined responses of GWs to strong PW anomalies during SSWs in the Northern Hemisphere and the Southern Hemisphere. Our results show that SABER GWs in the equator and also in the summer MLT region have positive correlations with PW anomalies in the winter hemisphere. Responses of GWs to PW anomalies are largest with the time lag less than ~5 days. Changes in wind and temperature structures associate with GW changes in the equator and summer hemisphere will be discussed.

In addition, in order to use SABER GWs in this study, we validate them against COSMIC/GPS GWs. Then, we also compare them with SABER tidal amplitudes to examine tidal influence in SABER GW analysis. The climatology of our GW amplitudes is also comparable with previous research and provides us with the confidence to use SABER GWs for this study.

MLTG-19 **Infragravity Waves in the Ocean as a Source of Acoustic-Gravity Waves in the Atmosphere -** by Nikolay Zabotin

Status of First Author: Non-student

Authors: Nikolay A. Zabotin, Oleg A. Godin

Abstract: Infragravity waves (IGWs) are surface gravity waves in the ocean with periods longer than the longest periods (~30s) of wind-generated waves. IGWs propagate transoceanic distances with very little attenuation in deep water and, because of their long wavelengths (from ~1 km to hundreds of km), provide a mechanism for coupling wave processes in the ocean, ice shelves, the atmosphere, and the solid Earth. Here, we build on recent advances in understanding spectral and spatial variability of background infragravity waves in deep ocean to evaluate the IGW manifestations in the atmosphere. Water compressibility has a minor effect on IGWs. On the contrary, much larger compressibility and vertical extent of the atmosphere makes it necessary to treat IGW extension into the atmosphere as acoustic-gravity waves. There exist two distinct regimes of IGW penetration into the atmosphere. At higher frequencies, one has surface waves in the atmosphere propagating horizontally along the ocean surface and prominent up to heights of the order of the wavelength. At lower frequencies, IGWs are leaky waves, which continuously radiate their energy into the upper atmosphere. Using recently obtained semi-empirical model of power spectra the IGWs over varying bathymetry [Godin O. A., Zabotin N. A., Sheehan A. F., Yang Z., and Collins J. A., Power spectra of infragravity waves in a deep ocean, Geophys. Res. Lett., 2013], we derive estimates of the fluxes of the mechanical energy and of the impulse from the deep ocean into the atmosphere due to IGWs. Significance of the IGW contributions into the field of acoustic-gravity waves in the atmosphere is evaluated.

<u>MLT Lidar Studies</u>

MLTL-01 **Expansion of Na Doppler lidar to lower atmospheric and daytime observations –** by Ian Forest Barry

Status of First Author: Student IN poster competition, Undergraduate

Authors: Ian Barry, Wentao Huang, Xian Lu, Xinzhao Chu, John Smith, Zhibin Yu

Abstract: Recent advancements in Na Doppler lidar have greatly improved the quality and resolution of nighttime temperature and wind measurements in the MLT (Mesosphere and Lower Thermosphere) region. In contrast, the ability of these lidars to perform daytime observations or measurements of wind and temperature in the stratosphere, below the MLT region, is limited. Measurements with double-edge filters have demonstrated the ability to measure wind in the lower atmosphere, and Faraday filters have been applied to improve SNR for observation during the day. Lower atmosphere observation may allow for study of the generation of gravity waves by convective processes and topography and their propagation up to the MLT region most extensively under study. Daytime measurements make possible the study of diurnal cycles and the atmospheric effect of solar radiation by ground-based systems. However, the results from both of these magneto-optical filter types have included more noise than is desirable for scientific interpretation. The recent advancements in nighttime data quality, a result of sophisticated optical design, have shown promise for vast improvement in daytime and double-edge performance. As such, improvements to the optical design of both the double-edge and the Faraday filter must be made to expand the range of Na Doppler lidar measurements beyond their current limits. This project focuses on improvements to the temperature conditioning system of the Na vapor cell involved in both types of filter, double-edge and daytime, and to the optical efficiency of the receiver system involved in each filter which has extended the range of nighttime observations to above 110 km with higher SNR than many other lidar systems. Upon construction of these improved optical filters to fit the STAR Na Doppler lidar system developed by the Chu Research Group out of CIRES, attempts will be made to demonstrate improved accuracy of the new double-edge filter design for stratospheric observation and of the new Faraday filter design for daytime measurements. The expansion of the scientific capabilities of the Na Doppler lidar system into the lower atmosphere and the daytime regions will open up new areas of study in phenomena peculiar to these areas, such as gravity wave generation and propagation and variations due to solar radiation or with day-long periods.

MLTL-02 **Concurrent observation of USU Sodium Lidar and Advanced Mesosphere Temperature Mapper (AMTM) on gravity wave breaking over Logan, North Utah -** by Xuguang Cai

Status of First Author: Student IN poster competition, PhD
Authors: Xuguang cai, Tao Yuan, Dominique Pautet, Yucheng Zhao, Mike Tylor

Abstract: On the night of September 9th, 2012 (UT day 253), the USU Sodium Lidar combined with USU Advanced Mesosphere Temperature Mapper (AMTM) observed a gravity wave (GW) breaking evidence. The MTM data directly showed the breaking taking place at around UT11:30 am and the wave before breaking propagated towards North-North-West with the phase speed 74m/s. In addition, the USU Lidar observed large meridional wind acceleration from 11:30am to 12:30am during the GW breaking. The Lidar horizontal wind data reveal that there was no critical level formed within the mesopause region, but the GW breaking likely due to dynamical instability. The Richardson number shows the breaking taking place between 86Km and 88Km. Apart from the breaking GW, another GW with large amplitude (temperature perturbation nearly 30K) was observed passing the breaking region. In this paper, we will investigate whether the warming of breaking zone was only caused by that large amplitude GW or the interaction between that wave and the wave before breaking. The momentum flux and potential energy density are calculated to reflect the gravity wave forcing.

MLTL-03 **Simultaneous Lidar Observations of Fe, Na, Temperature and Wind: Modeling Correlation in Density Perturbations and Computing Vertical Fluxes –** by Wentao Huang

Status of First Author: Non-student, PhD

Authors: Wentao Huang, Xinzhao Chu, Chester S. Gardner, Weichun Fong, and John A. Smith

Abstract: The vertical transport by gravity waves plays important role in establishing the constituent structure in the mesosphere and lower thermosphere (MLT) region, but has not been thoroughly investigated by observations. In August and September 2010, we conducted a lidar campaign at Boulder, Colorado (40N, 105W), using an Fe Boltzmann lidar and a Na Doppler lidar. Mesospheric Fe layer, Na layer, temperature and vertical wind were simultaneously observed. We advanced a theoretical model, which simulates the constituent density variations induced by wave dynamic effects, to simulate for the first time the correlations between two constituents subjected to the same wave influences. The observed Fe/Na density correlations are largely reproduced by this model, thus strongly support that the short-term density variations are dominated by dynamic effects. We also computed from this limited data set the vertical heat flux, Na flux, and for the first time the Fe flux. We will further estimate the dynamical and chemical transports of these two species. The results will help understand the characteristics of vertical transports, particularly for Fe, and improve the atmospheric chemistry model.

MLTL-04 **Thermospheric K layer observed over Arecibo -** by Caitlin Kerr

Status of First Author: Student NOT in poster competition, Undergraduate

Authors: Jonathan Friedman, Christiano Brum, Jonathan Fentzke

Abstract: On March 12, 2005 a layer of neutral K was observed descending from the thermosphere near 150 km above the Arecibo Observatory. We present results from a recent analysis of this event and evidence for similar events. We also present prospects for future studies of the thermosphere using lidar.

MLTL-05 **Direct measurement of MLT Eddy flux made possible by significant gains in resonance-fluorescence signal levels -** by John Anthony Smith

Status of First Author: Student IN poster competition, PhD

Authors: John A. Smith, Xinzhao Chu, Wentao Huang, Chester S. Gardner

Abstract: Resonance LIDAR receiver efficiencies many times higher than previously achieved or even thought possible have paved the way for new frontiers of research in the mesosphere and lower thermosphere (MLT). Large quantities of extremely fine resolution data obtained at the STAR lidar facility in Boulder, Colorado are making direct measurements of Eddy flux possible for the first time, leading to improved estimates of the Eddy diffusion coefficient Kzz. Eddy diffusion parameterization is one of the biggest uncertainties in current models of the upper atmosphere, with both its absolute value and seasonal variation disputed. Direct measurements of Kzz will lead to vastly improved estimates of momentum and energy transport in the upper atmosphere.

MLTL-06 **Rayleigh Lidar Temperature Studies in the Upper Mesosphere and Lower Thermosphere -** by Leda Sox

Status of First Author: Student IN poster competition, PhD

Authors: Vincent B. Wickwar, Joshua P. Herron

Abstract: The Rayleigh lidar system at the Atmospheric Lidar Observatory (ALO) on the campus of Utah State University (41.7° N, 111.8° W) has been making temperature measurements at an altitude range of about 70-115 km since summer 2012. This range pushes the typical altitude limits of Rayleigh lidars of the past and extends the upper altitude limit into the lower thermosphere. The temperature data acquired so far, using this new system, have been retrieved during focused campaigns centered on the annual temperature minimum in the upper mesosphere and the transition periods surrounding the annual minimum. The temperature data from these campaigns will be discussed as well as future plans for the ALO Rayleigh lidar system.

MLTL-07 **Correlative studies between sodium and electron concentrations over Arecibo –** by Eric Garcia Torche

Status of First Author: Student NOT in poster competition, Undergraduate

Authors: Eric G. Torche, Shikha Raizada, Qihou Zhou, S. Sarkhel. and C. A. Tepley

Abstract: Arecibo offers a unique opportunity to study the association between meteoric metals observed using resonance lidars and electron densities using incoherent scatter radar. Most of the earlier work pertaining to sodium atoms has focussed either on individual nights or the influence of dynamics on the average distribution in different seasons. One of the studies from Arecibo showed the dominance of tidal ion layers with downward phase velocities consistent with a diurnal tide having a vertical wavelength of about 20 km. The strength of the layer peaks during summer along with the average maxima in their concentrations. The previous study also pointed out that the diurnal tide frequently results in an ion layer at 95 km around sunset in the spring fall and winter but not in summer. The main objective of the present study would be to extend the earlier work to understand the role of temperature in the variability of the sodium metal layer distribution and their correlation with the electron concentrations.

MLTL-08 A case study on sodium atom layer variation induced by auroral particle precipitation - by Takuo T. Tsuda

Status of First Author: Non-studen,t PhD

Authors: T. T. Tsuda (NIPR); S. Nozawa (Nagoya Univ.); T. D. Kawahara (Shinshu Univ.); T. Kawabata (Nagoya Univ.); N. Saito (RIKEN); S. Wada (RIKEN); Y. Ogawa (NIPR); S. Oyama (Nagoya Univ.); C. M. Hall (Univ. of Tromsoe); M. Tsutsumi (NIPR); M. K. Ejiri (NIPR); S

Abstract: Sodium atom layer is generally distributed at 80-100 km. One of mysterious subjects on high-latitude sodium layers is relationship between auroral particle precipitation and sodium atom layer variation. A previous study suggested a sodium column density decrease during a geomagnetic active period due to that the particle precipitation accompanied by electron density enhancement could induce ionization of sodium atom through their ion-molecule chemistry. Another study pointed a possibility of sodium density increase. For this reason, it is suggested that auroral precipitating particle bombardment on meteoric smoke particles can sputter sodium atoms from the smoke particles. On the other hand, ionospheric electric field, which may become more significant near auroral precipitating regions, could induce ion motions (i.e. can generate sodium ion convergence and/or divergence), and then also could affect generation and/or loss processes of sodium atoms through their ion-molecule chemistry. Thus, for the examination of the causarity, it is vitally important to distinguish the effects of auroral particle precipitation and ionospheric electric field. Using a sodium lidar (which was installed in early 2010) and European incoherent scatter (EISCAT) radar at Tromsoe, Norway (69.6 deg N, 19.2 deg E), we have investigated, for the first time, that the actual effect of the particle precipitation to the sodium density variations without electric filed injection. In the nighttime observation on 24-25 January 2012, we detected a significant decrease of sodium atom density coincied with electron density enhancements (implying strong particle precipitations) and low ion temperatures (implying no electric field injections). These results strongly suggested that auroral particle precipitations induced sodium atom density decrease. Furthermore we discuss time response in the sodium density decrease.

MLTL-09 Development of High Power-Aperture Rayleigh Lidar for Middle and Upper Atmospheric Studies - by John Westerhoff

Status of First Author: Student IN poster competition, PhD

Authors: John Westerhoff, Gary Swenson

Abstract: A high power-aperture Rayleigh lidar has been developed at the University of Illinois with the goal of extending the capability of a Rayleigh lidar to provide useful measurements above 90 km, where typical Rayleigh lidars cannot provide adequate signal. This experimental lidar system has been developed with the goal of opening up new methods for measuring neutral density and temperature in the mesosphere and lower thermosphere. The specific interest for this system is to measure the amplitudes of atmospheric tides, planetary and gravity wave propagation amplitudes and phase. The use of a high-power, new technology laser and large aperture telescopes allow for power-aperture products of 50-750 Wm^2 with this lidar system, where current systems typically employ 5-10 Wm^2. The higher power-aperture increases the signal capability of the system, which increases the maximum altitude from which useful measurements can be taken. The use of the latest in photonic sensor technology also maximizes the signal returns for the imager. Simulations of this experimental lidar system show that useful

measurements can be taken of the neutral atmosphere up to 120 km. A future observatory using this approach could achieve useful measurements up to 200 km, using a high-power laser and large telescope, such as the 8-meter telescope at Cerro Pachon, Chile.

MLTL-10 **Rayleigh Lidar Measurements of Temperature and Gravity Waves in the Arctic Middle Atmosphere -** by Robin Wing

Status of First Author: Student IN poster competition, PhD

Authors: Robin Wing, Richard L. Collins, Brita K. Irving, Matthew J. Titus, & Cameron M. Martus

Abstract: A summary of the Rayleigh lidar technique and a description of the capabilities and improvements made to the Lidar Research Laboratory-Poker Flat Research Range (LRL-PFRR) in Chatanika, Alaska will be given. The measurements made using this technique allow us to infer a nightly temperature profile in the stratosphere and mesosphere. One of the goals of this work is to observe instances of elevated stratopause which is associated with sudden stratospheric warming events. These elevated stratopause events are gravity wave driven and allow insights into the wave-driven circulation of the polar atmosphere. The recent (03/2013) improvements to the LRL-PFRR will yield more robust and higher resolution measurements of temperature and gravity wave activities in the Arctic middle atmosphere to further this understanding.

MLTL-11 **Preliminary Results of Modeling Thermospheric Fe Layers -** by Zhibin Yu

Status of First Author: Student IN poster competition, PhD

Authors: Zhibin Yu and Xinzhao Chu

Abstract: The mesosphere and low thermosphere (MLT) is a chemically and dynamically complex and important region. As the lower boundary of ionosphere and space weather regime, the MLT is still lack of full understanding because of the limited observations. The discoveries of thermospheric neutral Fe layers by Chu lidar group at the McMurdo Antarctic Station (77.8S, 166.7E), to a great extent, explore the lower thermosphere by measuring the chemical composition (atomic neutral Fe), neutral temperatures and waves. Although a qualitative understanding has been offered in Chu et al. paper, the quantitative understanding of the neutral Fe layer formation and wave structures is unresolved. Meanwhile, the chemical process is highly coupled with the electrodynamics and thermodynamics processes in the E-F regions, which leads to more difficulties to understand the new observations. Such challenges stimulate our development of a numerical model, from which a great deal can be learned about atmospheric chemistry, reservoirs of iron and other species, and dynamic processes occurring in the MLT region. We are developing a thermospheric Fe model, which was adapted from the framework of Carter and Forbes but based on the first principles of physics and chemistry. The model solves ions' motions explicitly taking the full Fe chemistry and ambient ions chemistry in the E-F region into account. We will present the preliminary results and compare them to the observations.

Mesosphere or Lower Thermosphere General Studies

MLTS-01 **Charged Mesospheric Ice Particles: In situ measurements during the PHOCUS 2011 rocket campaign and comparison of the results with a microphysical model –** by Heiner Asmus

Status of First Author: Student NOT in poster competition, Masters

Authors: Heiner Asmus, Boris Strelnikov, Markus Rapp

Abstract: During the PHOCUS (Particles, Hydrogen and Oxygen Chemistry in the Upper Summer mesosphere) sounding rocket campaign in the Summer of 2011 at Esrange, Kiruna (68 °N, 21 °E) in Northern Sweden the chemistry and physics of the middle atmosphere were investigated. The focus was on microphysical processes related to formation and evolution of the ice particles. Therefore one sounding rocket was launched through a descending noctilucent cloud (NLC) which was observed by different rocket-borne and ground-based instruments.

Charged ice particles were measured by three different instruments. We present the measurement results of a classical faraday cup. This sensor was mounted on the front deck of the payload. The data show a net negative charged ice particle layer between 81.0 and 81.5 km which is in good agreement with the other instruments.

The results were than compared to a microphysical model to get a better understanding of the microphysical processes involved in the forming of mesospheric ice particles.

MLTS-02 **Observations and solar cycle variation of SOFIE NO in the lower thermosphere –** by Padma L. Carstens

Status of First Author: Student IN poster competition, PhD

Authors: Scott M. Bailey; Brentha Thurairajah; Justin Yonker; Karthik Venkataramani; Jim Russell; Mark Hervig

Abstract: Nitric oxide (NO) is a key minor constituent in the lower thermosphere. Of particular importance is its role in the energy balance in that altitude region. NO is produced through the reaction of excited atomic nitrogen with molecular oxygen. Thus its production is very sensitive to those energy sources able to break the strong molecular nitrogen bond. These include solar soft X-rays and precipitating energetic particles. Nitric oxide emits efficiently in the infrared and is an important cooling mechanism in the lower thermosphere. The abundance of NO is thus both a direct response to recent energy deposition as well as a key mechanism by which the upper atmosphere releases that energy.

In this poster, we analyze the NO observations from the Solar Occultation for Ice Experiment (SOFIE) instrument. The SOFIE instrument was launched on-board the Aeronomy of Ice in the Mesosphere (AIM) satellite on April 25, 2007. It is currently in its sixth year of operation. SOFIE is a 16 channel differential absorption radiometer using the solar occultation technique to measure ice and environmental properties at a range of altitudes, and in particular the mesopause region. One of the constituents measured by SOFIE is NO in the mesosphere and lower thermosphere to about 130 km. The AIM orbit and the solar occultation technique confine observations to latitudes of 65 to 85 degrees in each hemisphere and varying with season.
Here, we present the SOFIE observations and discuss its relationship with current levels of solar X-ray irradiance. We will further investigate the variability in SOFIE NO and solar irradiance for the previous and the current solar minimum and correlate the two. We will also show the variation of SOFIE NO in the lower thermosphere and upper mesosphere from 2007 to 2013 and discuss the factors influencing the changes seen in these observations.

MLTS-03 **Coordinated investigation of mid-latitude Upper Mesospheric Temperature inversion layer and the associated gravity wave forcing by Na lidar and Mesospheric Temperature Mapper at Logan, Utah (42** □N, 112□W) – by Tao Yuan

Status of First Author: Non-student

Authors: Tao Yuan, P. Dominique, Y. Zhao, X. Cai, M. J. Taylor, C. Fish

Abstract: The Mesospheric inversions layer (MIL) is one of the major dynamic features that indicate the gravity wave (GW) breaking induced dramatic anomalies within Mesosphere and Lower Thermosphere (MLT) region, and has been widely utilized to study MLT dynamics. Based on six-day of full diurnal cycle Na lidar observations of temperature and horizontal winds at Logan Utah (42 □N, 112□W) from August
investigated the formations and behaviors of a couple strong MIL events that are captured by the lidar's coordinated campaign with other existing upper atmospheric remote sensing instruments at Utah State University (USU). The co-located Advanced Mesospheric Temperature Mapper provided key observations of small-scale and medium-scale

gravity waves' (GW) characteristics during the nighttime observations to help the lidar measurements locate these waves' critical level and their temporal and spatial variations during the nights, while the Meteor Wind Radar (MWR) at nearby Bear Lake Observatory (BLO) gave the planetary wave activities within the mesopause region during this campaign. The climatological temperature and meridional tidal phase profiles are utilized to help identifying the temporal and spatial locations of tidal wave feature in the mesopause region relatively to MILs and understanding of tidal-GW interactions. We found the two kinds of MILs (both with □T□30 K) that have features, one of which has the well documented feature with downward progression due to tidal-GW interaction but with much slower vertical phase speed than semidiurnal tidal wave, while the other intriguing inversion layer's elevation does not change at all throughout the event. The lidar measurement of nightly averaged GW zonal momentum flux (MF) indicates stronger GW forcing during the two nights with MILs than that of the other nights, thus, directly relates MIL's formation to GW forcing.

MLT Other Tidal or Planetary Waves, or Sudden Stratospheric Warmings

MLTT-01 Identification and Classification of Stratospheric Sudden Warming Events - by Thomas Stephen Ehrmann

Status of First Author: Student IN poster competition, Masters

Authors: John Hughes

Abstract: Analysis of northern hemisphere stratospheric data from 1978-2011 is used to identify and classify Stratospheric Sudden Warming events. A total of 41 events are identified during this 33 year period, resulting in an average occurrence rate of 1.24 events/year. No significant variation in the rate is observed during the period analyzed. The average temperature increase during an SSW event is 12 K and the average duration is 32 days. Each identified event is classified as either a vortex displacement or split event and the ratio of displacement to split events is found to be 0.86.

MLTT-02 Timeline of January 2013 Sudden Stratospheric Warming Event as seen in Real-Time Assimilative IRI and GPS Data - by Larisa P. Goncharenko

Status of First Author: Non-student

Authors: Ivan Galkin, Artem Vesnin, and Bodo Reinisch

Abstract: A major and long-lasting sudden stratospheric warming event occurred in January 2013, peaking between Jan 6-20, 2013. This event triggered significant wave activity at ionospheric heights with various time scales ranging from tidal (~8 and 12 hr) to non-tidal (>24 hr). While such wave activity can be observed by multiple instruments, those allowing a global view of the ionospheric plasma dynamics are of most interest as they provide a deeper insight to the processes of wave generation and propagation. Until recently, global maps of GPS-derived total electron content (TEC) have been most readily available for monitoring the large-scale ionospheric processes. This paper presents first-light analysis of the global 15-minute cadence timelines of foF2 maps (corresponding to the global peak ionospheric density) produced for December 2012 (quiet) and January 2013 (active) periods by the IRI Real-Time Assimilative Model (IRTAM). A comparative analysis with GPS-derived TEC maps for the same period of time is performed as an independent validation. The IRTAM empirical-model formalism avoids uncertainties of the evolving theoretical understanding of the thermosphere-ionosphere coupling processes, and its assimilative capability yields fine temporal resolution to specify the ionospheric processes as they evolve.

Our preliminary results indicate a large variety of ionospheric anomalies observed in different longitudinal sectors between January 9-20, 2013. These anomalies cannot be fully accounted for by neither seasonal change nor solar flux and geomagnetic activity, and indicate contributions to ionospheric variability from wave activity of lower atmospheric origin.

MLTT-03 Planetary Wave Breaking and Extreme Temperature Excursion in the Polar Winter Middle Atmosphere - by Katelynn Greer

Status of First Author: Student IN poster competition, PhD

Authors: Katelynn Greer, Jeffrey P. Thayer, V. Lynn Harvey, Han-li Liu, and Ethan Peck

Abstract: Throughout the winter season the polar middle atmosphere is intermittently disturbed; the most spectacular type of disturbance is a major Sudden Stratospheric Warming (SSW). SSWs are traditionally defined at the 10 hPa (~30 km) altitude level and disturbances at higher altitudes are not captured. However, the region is dynamically active and exhibits other types of disturbances on a more frequent, intraseasonal basis. One such disturbance are synoptic-scale "weather events" observed in lidar and rocket soundings, observations from the TIMED/SABER instrument and UK Meteorological Office (MetO) assimilated data. These disturbances are most easily identified near 42 km where temperatures are elevated over baseline conditions by 50 K and may be vertically coupled with a commensurate cooling observed near 75 km. As these disturbances have a vertical structure extending into the lower mesosphere, they are termed Upper Stratospheric/Lower Mesospheric (USLM) disturbances.

This work compares the climatological characteristics of USLM disturbances in the Whole Atmosphere Community Climate Model (WACCM4) to observations. It then investigates the dynamical mechanisms responsible for USLM disturbances using both observations and the model. Results indicate that WACCM reliably reproduces USLM disturbances in terms of thermal structure, seasonal timing, and the geography of occurrences. The onset of USLM disturbances is related to planetary wave activity and breaking several days in advance. Case studies and composites of the USLM disturbances illustrate the evolution through wave mean-flow interaction, vertical motion, adiabatic heating, and increased vertical shear with the potential to support baroclinic instabilities. Potential vorticity and stability analyses (including the Charney-Stern criteria for instability the role of baroclinic/barotropic instabilities) are used to elucidate the dynamics in the development of USLM events. In addition, USLM disturbances appear to have front-like behavior analogous to the troposphere. Broader impacts of these disturbances and the dynamics associated with them influence gravity wave generation/propagation, vertical air motion and chemical tracer transport.

MLTT-04 Impact of Tropospherically-Generated Tides on the Mean State of the Ionosphere-Thermosphere System - by McArthur Jones Jr.

Status of First Author: Student IN poster competition, PhD

Authors: Jeffrey M. Forbes, Maura E. Hagan, and Astrid Maute

Abstract: It is now widely recognized that vertically-propagating tides exert significant variability on the ionosphere-thermosphere (IT) system. In particular, the impact of tropospherically-generated non-migrating tides on longitudinal variability of the IT system has been a topic of intense research in recent years. However, relatively little is known about how dissipation of these upward propagating waves affect the zonal mean state of the IT system. Herein we report on numerical experiments performed with the National Center for Atmospheric Research (NCAR) Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM) that explore this topic using observationally based tidal lower boundary conditions near 97 km from the Climatological Tidal Model of the Thermosphere (CTMT after Oberheide et al., [2011]) for average solar conditions over a climatological year (i.e., steady-state monthly runs). A robust evaluation of the NCAR TIE-GCM close to the model lower boundary was performed to assess the validity of our results, since the TIE-GCM lower boundary is close to the height regime where many of these upward propagating tides dissipate and exchange energy and momentum with the background IT. Differences between simulations including and excluding CTMT tidal forcing reveal that tides of tropospheric origin are capable of altering the zonal mean zonal winds in the dynamo region by 25 m/s in the boreal winter months. The migrating diurnal (DW1) and semidiurnal (SW2) tides, as well as the eastward propagating diurnal tide with zonal wave number s = 3 (DE3), appear to be the main drivers in the aforementioned zonal mean zonal wind differences. To substantiate the results above, multiple TIE-GCM numerical experiments are performed with several different combinations of tides and stationary planetary waves at the model lower boundary.

MLTT-05 Mesospheric Planetary Waves over Antarctica from 2002 to 2010 – by Andrew J. Kavanagh

Status of First Author: Non-student

Authors: A. J. Kavanagh, T. Moffat-Griffin, and M. Jarvis.

Abstract: Well correlated, large variations in winter-time mesospheric temperature and winds were observed during 2002 over the Antarctic Peninsula. These were subsequently identified as the signatures of long period planetary waves. In subsequent years observations from the British Antarctic Survey station at Rothera have indicated less sustained planetary wave activity during the winter resulting in poorer correlation between the wind and temperature in the mesosphere. We examine the occurrence of planetary waves over the peninsula from 2002-2010 and identify variations in their characteristics.

MLTT-06 Thermal Tides and Eastward Propagating Planetary Waves in the Winter Antarctic - by Xian Lu

Status of First Author: Non-student, PhD

Authors: Xian Lu, Xinzhao Chu, Tim Fuller-Rowell, Weichun Fong, Zhibin Yu, Loren Chang

Abstract: Winter Antarctica is a very dynamic region with exceptionally strong wave activities. In the upper stratosphere, eastward propagating planetary waves with periods of 1–5 days can induce temperature perturbations of 10–40 K and contribute to significant constituent variations, such as O3, H2O and CH4. Such planetary waves are associated with the "warm pool" phenomenon which circles around the South Pole with a period of 4–5 days in winter and persists for months. In conjunction with the poleward and downward movement and strengthening of the stratospheric winter polar night jet, the zonal mean flow is characterized by "double-jet" structure, which induces barotropic/baroclinic instability and generates planetary waves. The temperature variations resulting from these planetary waves, manifested themselves as temperature increase/decrease of 10–20 K in a course of one day, are detected by an Fe lidar at McMurdo (77.83S). Due to the failure of propagating to lower latitudes, such eastward propagating planetary waves are confined to high latitudes and McMurdo corresponds to the peak latitude of the dominant 4- and 2-day planetary waves, thus making it an ideal location to detect the planetary wave influences on local temperature change detected by lidar.

In the mesosphere and lower thermosphere (MLT), extraordinary inertia-gravity waves (IGWs) take over the dominant role in affecting atmospheric thermal and dynamical structure. Temperature perturbations of ±30 K are often observed, resulting from IGWs with periods of 4–9 hrs [Chen et al., 2013]. Thermal tides, on the other hand, are relatively weak in the stratosphere and MLT. However, above 100 km, the amplitudes of the diurnal and semidiurnal tides increase abruptly according to lidar observations. Thermospheric in-situ heating may largely account for the amplitude increase while stronger geomagnetic activity may be capable of elevating the tidal amplitude by several K. The Whole Atmosphere Model (WAM) well simulates the observed tides at McMurdo and are further used to investigate dominant tidal components.

MLTT-07 Is the Day-to-Day Variability of the Migrating Diurnal Tide Stochastic or Deterministic? - by Vu Nguyen

Status of First Author: Student IN poster competition, PhD

Authors: Vu Nguyen, Scott Palo

Abstract: A new technique to produce daily estimates of the migrating diurnal tide (DW1) on a global scale has recently been developed. By utilizing data from two satellites (TIMED/SABER and EOS Aura/MLS), temperature measurements at four solar local times are given on a single day, which allows for a least squares approach to be implemented. As a result, the daily zonal mean temperature, DW1 amplitude and DW1 phase are all estimated on a daily basis. This technique therefore provides a rare opportunity to analyze short-term tidal variability from satellite

observations. The main goal of this study is to characterize the day-to-day changes of the DW1 at the equator where the tide is most dominant. Statistical analyses are performed on DW1 estimates for years 2005 through 2012 to determine the inter-annual, intra-annual and altitude dependence of the daily variability. Wavelet analyses are utilized to determine if any dominant short-term periodicities are present in the observations. Our DW1 estimates are also compared to results from NASA's MERRA reanalysis model. By conducting this study, we show that the day-to-day variability may possess a stochastic rather than deterministic structure.

MLTT-08 **Mesospheric and Thermospheric Observations of the January 2010 Stratospheric Warming Event -** by Qian Wu

Status of First Author: Non-student

Authors: Qian Wu and S. Nozawa

Abstract: We use two ground based Fabry-Perot interferometers (FPI) at Boulder (40N, 105W), Resolute (75N, 95W), and a meteor radar at Bear Island (75N, 19E) to examine the mesospheric and thermospheric winds during a sudden stratospheric warming (SSW) event in January 2010. The two high latitude wind instruments allow us, for the first time, to compute the zonal wavenumber of the semidiurnal tide on a daily basis during an SSW event. The ground based FPIs recorded enhanced lower thermosphere semidiurnal tide before and during the SSW. A substorm on January 20 strongly affected the thermospheric winds from high latitudes to mid-latitudes. A 6-hour wave was observed in the polar lower thermospheric winds during the SSW. The two high latitude stations did not show much westward propagating semidiurnal tide with zonal wavenumber one (SW1) as predicted by model simulations. Several indications of westward propagating zonal wavenumber three semidiurnal tide (SW3) require further verification. Enhancements in the mid-latitude thermospheric semidiumal and teridiumal tides during the SWW were observed.

<u>Sprites</u>

SPRT-01 **Model of streamer-to-leader transition in the Earth's atmosphere –** by Caitano L. da Silva

Status of First Author: Student IN poster competition PhD

Authors: Caitano L. da Silva and Victor P. Pasko

Abstract: Leaders are self-propagating discharges, capable of travel kilometer-long distances at ground and near-ground pressure. They are the mechanism present in lightning discharges, enabling a cloud-to-ground lightning to form a highly conductor path that short-circuits the gap between thundercloud and ground. Leaders escaping upward from a thundercloud are also responsible for a subset of transient luminous events called gigantic jets, which close the gap between thundercloud and ionosphere. The fundamental process that converts a streamer corona into a leader is referred as streamer-to-leader transition. Corona discharges are formed in regions of space where the electric field exceeds the breakdown threshold. A leader is formed if the sustained corona current is capable of significantly heat the air. A leader is a complex structure, nevertheless, its description can be made simpler by recognizing the existence of three different regions: the streamer zone, the leader head or stem, and the channel. The streamer zone is a fan of thousands of streamers and it is where electrical current is produced and injected into the channel. The leader head is where transition between cold non-thermal streamers to a hot leader channel takes place. The leader channel is highly-conducting hot plasma filament, similar to an arc, that behaves approximately as a perfect conductor capable of bringing the high thundercloud potential to the position of the leader head. For this study, we have developed a model for the streamer-to-leader transition process occurring in the leader head, capable of capturing the contraction of the streamer zone current and the development of a thermal-ionizational instability that culminates in the leader formation. The model accounts for energy exchange between plasma and neutral gas (air) through Joule heating and excitation of vibrations in nitrogen molecules, as well as, its delayed relaxation to

translational degrees of freedom. We employ a kinetic scheme involving over a hundred reactions. The reactions involving electrons account for: direct, stepwise and associative ionization, two- and three-body attachment, recombination, and detachment. We account for the effects of superelastic collisions of electrons with excited nitrogen molecules on the rates of electron impact excitations. We present a detailed kinetic mechanism of the fast heating of air due to quenching of excited electronic states. In this study, we focus on realistic parameterization of leader potential, leader head dimensions, and streamer zone characteristics, and their influence on the streamer-to-leader transition process. We discuss the fundamental differences of the plasma instabilities leading to the inception of a leader and a laboratory spark. Finally, we discuss the scaling of streamer-to-leader transition time with air density and its implications for the vertical structuring of gigantic jets.

SPRT-02 **Parallel 3D modeling of quasi-electrostatic fields above thunderstorms –** by Rasoul Kabirzadeh

Status of First Author: Student IN poster competition, PhD

Authors: Rasoul kabirzadeh, Nikolai Lehtinen, Umran Inan

Abstract: Quasi-electrostatic (QE) fields, created by fast (~1 ms) removal of electric charges from a thundercloud, can lead to ionization, heating, and optical emissions at high altitudes (~70 km), which are observed as Red Sprites. Previous studies using numerical modeling of these fields in two dimensions have resulted in a good understanding of the various associated phenomena and their effects on the upper atmosphere. However, a more detailed and realistic study of these phenomena requires a three-dimensional model which is computationally more demanding. This is particularly due to the increased size of the spatial domain because of the added dimension and the limited memory and computational speed of a single processor. To resolve this issue, we have developed a parallel 3D model to solve for the QE fields that can be run on a cluster of processors. We will report the method used to solve the QE equations and some preliminary results of the model and compare them to the previous findings.

SPRT-03 **Characteristics of optical emissions from streamer formation from ionospheric patches at subbreakdown conditions -** by Burcu Kosar

Status of First Author: Student IN poster competition, PhD

Authors: Burcu Kosar, Ningyu Liu, and Hamid K. Rassoul

Abstract: Sprites are fine-structured, high-altitude electrical discharges driven by lightning quasi-electrostatic field [Pasko, JGR, 115, A00E35, 2010]. The filamentary structures within sprites are known as streamers that are highly non-linear and self-organized ionization waves. High-speed video observations of sprites and electromagnetic measurements of lightning electric fields have indicated that sprites are often initiated in a lightning field below the conventional breakdown threshold field Ek [Li and Cummer, JGR, 116, A01301, 2011; Gamerota et al., JGR, 116, A02317, 2011; Li et al., JGR, 117, A09310, 2012]. A physical mechanism to explain sprite initiation at subbreakdown conditions was proposed and investigated by Liu et al., [PRL, 109, 025002, 2012] and Kosar et al., [JGR, 117, A08328, 2012]. These two studies show that sprite streamers can be initiated in subbreakdown fields from ionospheric ionization columns, which are typically 10 m wide, 100 m long; and have a peak plasma density of ~10^10 m^-3. However, sprite halo modeling results obtained by using a 2D plasma discharge model accounting for major ion species and reactions in the lower ionosphere indicate that the existence of high density (~10^10 m^-3) ionization patches is unlikely at halo altitudes [Liu, JGR, 117, A03308, 2012].

This study investigates sprite streamer formation at subbreakdown conditions from ionization patches with a peak plasma density close to the value obtained from halo modeling. It is found that when large (~100 m wide) ionization patches are used, the peak plasma density required can be significantly reduced, with the lowest value obtained so far being 1.25x10^8 m^-3. In addition, the brightening of the lower edge of the patch during streamer initiation is very similar to the observed optical signatures of the structures within the sprite halo or near the halo front that lead to positive streamer formation. We compare the total emission intensity from the luminous lower edge of the patch with the emission intensity from the streamer head. The dependences of the emission intensity ratio between the

luminous edge of the patch and the streamer head on ambient field, initial peak plasma density, and the sharpness of the initial density distribution are investigated.

SPRT-04 Investigation of Long-delayed Sprite Inception Mechanism and the Role of Electron Detachment - by Jeremy Pachter

Status of First Author: Student IN poster competition, Undergraduate

Authors: Jeremy Pachter, Jianqi Qin, Victor Pasko

Abstract: Sprites with extensive vertical streamer structures are spectacular luminous gas discharges in the mesosphere and lower ionosphere, and are usually produced by intense positive cloud-to-ground lightning discharges (+CGs) in the underlying thunderstorms. Sprite streamers spawn from electron density inhomogeneities in the ambient ionosphere, and often appear only several milliseconds after the causative +CGs that produce large charge moment changes in the first few milliseconds. Observations have also shown that in some sprite events, long-delayed sprites can be initiated more than 100 ms after the causative +CGs associated with small initial charge moment changes, followed by additional removal of thundercloud charge by continuing lightning current. Long-delayed sprite ignition was studied by Luque and Gordillo-Vazquez [2011] using a chemical kinetic model, which suggested that the electron detachment processes might play a significant role in the production of long-delayed sprites.

In the current work, we investigated the inception mechanism of long-delayed sprites, particularly the role of the electron detachment and attachment processes, as well as the role of continuing lightning current. Our results indicate that the detachment process shortens the dielectric relaxation time of the lightning-induced quasi-static electric field, suggesting that it is an unfavorable process in terms of sprite initiation. We also found that the attachment process is favorable for sprite initiation, which in conjunction with continuing current, enhances the mesospheric electric field for long-delay sprite initiation from preexisting inhomogeneities in the ambient ionosphere.

SPRT-05 Earthquake Lights: Time-dependent Earth surface-ionosphere coupling model – by Victor P. Pasko

Status of First Author: Non-student

Authors: Victor P. Pasko

Abstract: Co-seismic luminescence, commonly referred to as Earthquake lights (EQLs), is an atmospheric luminous phenomenon occurring during strong earthquakes and lasting from a fraction of a second to a few minutes [e.g., Derr, J. S., Bull. Seismol. Soc. Am., 63, 2177, 1973; St-Laurent, F., et al., Phys. Chem. Earth, 31, 305, 2006; Herauld and Lira, Nat. Hazards Earth Syst. Sci., 11, 1025, 2011]. Laboratory experiments of Freund, F. T., et al. [JGR, 105, 11001, 2000; JASTP, 71, 1824, 2009, and references therein] demonstrate that rocks subjected to stress force can generate electric currents. During earthquakes these currents can deliver significant amounts of net positive charge to the ground-air interface leading to enhancements in the electric field and corona discharges around ground objects [Freund et al., 2009]. The eyewitness reports [Herauld and Lira, 2011] indicate similarities of the blue glow observed during EQLs to St. Elmo's fire observed during thunderstorms around wing tips of airplanes or around the tall masts of sailing ships [e.g., Wescott, E.M., et al., GRL, 23, 3687, 1996]. Recent work indicates that the vertical currents induced in the stressed rock can map to ionospheric altitudes and create 10s of \% variations in the total electron content in the Earth's ionosphere above the earthquake active region [Kuo, C. L., et al., JGR, 116, A10317, 2011]. The magnitudes of the vertical currents estimated by Kuo et al. [2011] based on work by Freund et al. [2009] range from 0.01 to 10 μA/m^2. In this talk we report results from a new time-dependent model allowing to calculate currents induced in the ambient atmosphere and corona currents under application of vertical stressed rock currents with arbitrary time variation. We will report test results documenting the model performance under conditions: (1) relaxation toward the classic global electric circuit conditions in fair weather regions when ionosphere is maintained at 300 kV with respect to the ground; (2) relaxation toward the steady state conditions when the earth-air surface charge is maintained by balance of the current induced by stressed rock and ambient atmospheric current [Kuo et al., 2011]; and (3) a 2 min duration model episode in which the

stressed rock current reaches value of 0.4 μA/m^2 producing electric fields at the ground on the order of 0.5 kV/cm leading to an additional injection of positive corona current. One of the interesting results of this modeling is that the reduced electric field (i.e., field normalized by air density) remains low at the ground-air interface due to the injection of the positive corona charge and at high altitudes due to the naturally high conductivity of the Earth's atmosphere. At the intermediate altitudes in clear air above earthquake region the reduced electric field can dynamically reach values exceeding both relativistic ($\sim$2 kV/cm when scaled to the ground level) and conventional ($\sim$30 kV/cm ground value) breakdown thresholds. The exact geometry would depend on the spatial extent of the earthquake active region, ambient atmospheric conductivity and the time dynamics of the driving stress rock current. We suggest that the enhancements of the reduced electric field in clear air at high altitudes in the Earth atmosphere is a likely scenario leading to transient (sub-second duration) flashes some time observed during earthquakes [Herauld and Lira, 2011].

SPRT-06 Mechanism of Column and Carrot Sprites Derived from Optical and Radio Observations - by Jianqi Qin

Status of First Author: Student IN poster competition, PhD

Authors: Jianqi Qin, Sebastien Celestin, Victor P. Pasko, Steven A. Cummer, Matthew G. McHarg, and Hans C. Stenbaek-Nielsen

Abstract: The lightning current moment waveforms observed simultaneously with high-speed video records of a column sprite event and a carrot sprite event are incorporated in a plasma fluid model to provide quantitative explanation of these two distinct morphological classes of transient luminous events. It is demonstrated that in the carrot sprite event, the upward negative streamers are initiated in a relatively large altitude region where the lightning-induced electric field exceeds 80% of the conventional breakdown field Ek and persists for longer than 2 ms, whereas in the column sprite event such a region does not exist. The minimum requirement for an electric field to initiate upward negative streamers from electron inhomogeneities can also be established using a time integral of the reduced electric field dependent ionization frequency at a given altitude $\int vi(E/N)dt$, with $\exp(\int vi(E/N)dt)$ representing the total number of free electrons produced by a single seed electron through ionization. Modeling results indicate that in the upper atmosphere these integral values never exceed 18, which is the minimum value required for the initiation of sprite streamers from single seed electrons. It is therefore concluded that the presence of electron inhomogeneities in the lower ionosphere is a necessary condition for the initiation of sprite streamers. It is further demonstrated that with the presence of strong inhomogeneities in the lower ionosphere, a minimum value of the integral ~10 is necessary to initiate negative streamers, corresponding to a minimum charge moment change of ~500 C km under typical nighttime conditions. The initiation of upward negative streamers is a necessary morphological attribute of carrot sprites. If the integral values in the entire upper atmosphere are smaller than ~10, only column sprites can be produced, dominated by downward positive streamers.

SPRT-07 The Effects of Ambient Density on Streamer Emission from Hydrometeors in Subbreakdown Electric Fields – by Samaneh Sadighi

Status of First Author: Student IN poster competition, PhD

Authors: Samaneh Sadighi, Ningyu Liu, Joseph R. Dwyer, and Hamid Rassoul

Abstract: Electric field values measured inside thunderclouds have consistently been reported to be up to an order of magnitude lower than the value required for conventional electrical breakdown of air. This result has made it difficult to explain how lightning frequently occurs in thunderclouds. A few different theories have been offered to explain the lightning initiation process, one of them being the theory of lightning initiation from hydrometeors. According to this theory, lightning can be initiated in the vicinity of sharp, long, or curved shaped water or ice particles abundant in thunderclouds. These small objects can cause significant enhancement of the thundercloud electric field, providing the basis for lightning initiation.

In this presentation we report a modeling study of streamer discharges around thundercloud hydrometeors. Streamers are narrow filamentary plasma channels, which serve as precursors for the hot lightning leader channel. Previously, Liu et. al. [PRL, 109, 025002, 2012] reported streamer formation from a model hydrometeor in an

electric field value of half of the conventional breakdown threshold (Ek) for air. According to the modeling results presented here, streamers can be initiated in electric fields as low as one third of the breakdown threshold. The electric field values most recently measured in thunderclouds have been reported by Stolzenburg et. al. [GRL, 34, L04804, 2007] to be between 0.13-0.3 times the breakdown value for air. For field values lower than 0.5Ek our modeling results show that it becomes extremely difficult for streamers to form. In an electric field of 0.3Ek, the streamer will either not form or branch during formation. However, according to experimental results (e.g., Crabb and Latham, Quart. J. Roy. Meteorol. Soc., 100, 191, 1974), streamers have been observed to form in electric field values lower than that. We believe that this could possibly be due to the enhanced ambient electron density due to phenomena like corona discharges, occurring around the hydrometeor. From our results, the enhanced density has a significant effect on streamer initiation. In these cases, not only does the streamer successfully form, it can also form in the vicinity of hydrometeors with smaller dimensions. Further discussion on these results will be provided.

SPRT-08 Monte Carlo Simulation of X-ray Emissions Produced by Stepping Lightning Leaders - by Wei Xu

Status of First Author: Student IN poster competition, PhD

Authors: Wei Xu, Sebastien Celestin, and Victor P. Pasko

Abstract: X-ray bursts have been observed in association with rocket-triggered lightning and natural cloud-to-ground lightning [e.g., Saleh et al., JGR, 114, D17210, 2009; Schaalet al., JGR, 117, D15201, 2012]. It has been suggested that the Relativistic Run-away Electron Avalanche (RREA) mechanism is not likely to be responsible for this phenomenon [Dwyer et al., GRL, 31, L12102, 2004]. These X-rays may instead originate from the acceleration of runaway electrons in the lightning leader field during negative corona ash processes [Celestin and Pasko, JGR, 116, A03315, 2011]. However, the properties of X-ray bursts from lightning are poorly known, mainly due to the low fluence of photons detected from the ground.

In the present study, we use Monte Carlo models to simulate the acceleration of runaway electrons in the electric field produced around the lightning leader tip region and the transport of associated bremsstrahlung photons in the atmosphere. We specifically investigate the properties of this high-energy radiation, including spectra, spatial distribution, and deposited energy.