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We have previously studied how acoustic waves generated by strong thunderstorms and ocean waves propagate into the thermosphere and heat it. We revisit this investigation to clarify the physical processes contributing to the overall net heating. Our conclusions are based on numerical simulations of wave propagation using a full-wave model that solves the complete linearized equations of continuity, momentum, and energy for a compressible, viscous, and thermally conducting atmosphere with arbitrary altitude variations in thermal structure. It is found that acoustic waves heat the thermosphere through effects of molecular dissipation, sensible heat flux divergence, and Eulerian drift work. Only wave-induced pressure gradient work acts to cool the thermosphere. The net effect of all these processes is acoustic wave heating of the thermosphere at all heights. These physical processes act differently for gravity waves; in particular, gravity wave sensible heat flux divergence can cool the thermosphere. Acoustic waves generated by vigorous convection and storms in outer planet atmospheres could also contribute to the heating of these atmospheres.

SA14A-02 1550h INVITED

Gravity Wave Generation by Equatorial Inertial Instability

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Gravity waves (GWs) and inertio-gravity waves (IGWs) are an important means of transferring momentum from the lower to the middle and upper atmosphere. Gravity wave breaking is responsible for closing off the mesospheric jets and for producing the summer-to-winter-pole mesospheric circulation. They also interact with atmospheric tides and affect other large-scale phenomena in the upper atmosphere. GWs are generally thought to be produced in the troposphere by a number of different processes such as topographic generation, geostrophic adjustment, shear instability and convection. They propagate vertically to higher altitudes where, due to the reduction in density, the momentum they deposit can affect a large change in the background winds. This paper will focus on a different generation mechanism of GWs; specifically IGW generation by equatorial inertial instability. Due to their slow vertical propagation, IGWs may deposit their momentum horizontally far from the region where they were generated. Therefore, IGWs generated in the tropics by inertial instability may affect the background winds at midlatitudes. A 3d primitive equations model will be used to study this generation mechanism. In this presentation we will focus on the spectra and launch altitudes of the IGWs and their effect on the mean flow. Also, because inertial instability occurs typically at the smallest resolvable scales, we will examine the robustness of the results to changes in resolution and small-scale diffusion, both of which can affect the scales and the strength of inertial instability.

SA14A-03 1610h

Seasonal Variation in the Mesospheric Gravity-Wave Potential Energy Over the Antarctic Peninsula

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As part of a joint programme between the University of Illinois and the British Antarctic Survey, Rayleigh and Fe resonance lidar observations have been made from Rothera Station (68S, 68W) on the Antarctic peninsula. Gravity wave perturbations in both the vertical density and temperature structure have been measured, and the seasonal variation of the gravity-wave potential energy has been compiled. In addition, the phase change of the waves with altitude has been used to assess the relative contributions of stationary mountain waves and horizontally propagating gravity waves to the overall potential-energy budget. It has been found that the seasonal changes in the overall wave energy near the mesopause are consistent with the filtering of the gravity wave flux by the stratospheric winds,. The seasonal variations in the ratio of mountain waves to horizontally propagating waves has been correlated to changes in the tropospheric wind field over the Trans-Antarctic Mountains. The impact of this partitioning and its seasonal variation on the forcing of the mesospheric wind field will be discussed.

SA14A-04 1625h

Theoretical Simulations of the Martian Ionosphere and Comparisons to Observations

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Approximately 2000 profiles of ionospheric electron density between 100 and 200 km altitude have been generated by the Radio Science Experiment on Mars Global Surveyor and publicly released on the PDS. We have developed a theoretical ionospheric model to help us analyse these observations. Our model includes photochemistry and diffusion of ions, solar fluxes from the SOLAR2000 model, and a simple fixed neutral atmosphere. We will compare each electron density profile to a predicted profile and investigate how well such basic parameters as the altitude, electron density, and layer width at several ionospheric peaks, total electron content, slab thickness, and topside scale height are predicted. We will compare variations in observed electron density to variations in predicted electron density due to day-to-day changes in the solar flux to test the hypothesis that solar flux variations are responsible for most ionospheric variations on that timescale. Martian ionospheric variabilities attributed to solar flux variations will be compared to terrestrial E-region variabilities. By adjusting the variation of neutral atmospheric density and temperature with altitude in our model, we are able to investigate how the properties of the thermosphere influence and control those of the ionosphere. As noted by Bougher and colleagues, tides in the thermosphere can cause the altitude of ionospheric electron density peaks to vary with longitude. We shall investigate whether other basic parameters extracted from the electron density profiles are also coupled to the thermosphere and show these tidally-induced variations. We shall vary the neutral atmospheric properties in our model to further investigate the effects of thermospheric tides on the martian ionosphere.

SA14A-05 1640h

Investigating tidal effects on mesospheric temperature and airglow emission altitudes

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An important aspect of wave coupling into the mesosphere and lower thermosphere (MLT) region is the propagation of atmospheric tides. Tides are known to have the large effects on wind and temperature variability. Tides also affect the airglow emission intensities and peak altitudes of the emission layers. This paper focuses on two aspects of tidal effects on OH/O2 airglow emission rotational temperature and peak emission altitudes. First we summarize the results of a correlative study of OH rotational temperature measured using Mesospheric Temperature Mapper (MTM) with simultaneous SABER measurements from the NASA TIMED satellite showing best agreement when care is taken to use the appropriate emission altitude as measured by the satellite. Secondly, we utilize coincident temperature measurements by Na temperature lidar and MTM to investigate temporal variability in the altitudes of the emission layers due to long period gravity wave/tidal perturbations. In both studies, the measurements were made over Hawaii (20.8oN, 156oW) as part of the Maui-MALT and NASA TIMED coordinated ground-based study.

SA21A CC: 220 C-E Tuesday 0830h

Interpretation and Observation of Mesospheric Gravity Waves From Earth and Space III Posters *(joint with A, P)*

Presiding: **M J Taylor,** Utah State University**; S M Melo,** University of Toronto

SA21A-01 0830h POSTER

Simultaneous Imaging and Lidar Measurements of a Breaking Internal Gravity Wave in the Mesosphere

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A large wave event was observed in the three upper-mesospheric (80 to 105 km) airglow emissions of O(S), Na and OH by the Boston University all-sky imager at the Arecibo Observatory during the night of 2/3 May 2003. Simultaneous measurements of the 80 to 105 km height region were made by two co-located potassium and sodium resonance lidars. The K lidar measurements indicated the presence of a large temperature inversion (possibly the largest recorded in the mesopause region to date) of 90 K peak-to-peak between 88 and 96 km during the zenith transit time of the disturbance. Strong vertical motions were observed to occur in the K and Na layers during the passage of the disturbance - the top and bottom sides of both layers increased in height by 3 to 5 km. The instability exhibited several characteristics of a bore - a non-linear disturbance commonly observed in rivers, oceans, and the lower atmosphere, and recently identified in the mesosphere. However, the vertical phase variation suggested that it was a large downwardly-propagating internal gravity wave that was in the process of breaking, causing overturning and turbulence, probably as a result of interaction with a large coincident temperature maximum. The behavior of the disturbance was very similar to that of a so-called "wall"-type event (Swenson and Espy, 1995) and the event suggests that "wall"-type events and bores are different manifestations of a single type of disturbance.

SA21A-02 0830h POSTER

A Survey of All-sky Imaging Measurements of Bore- and "Wall"-like Disturbances in Mesospheric Nightglow.

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All-sky imagers regularly record quasi-monochromatic (QM) gravity wave activity in the various night-time mesospheric emissions (Taylor et

al., 1995; Wu and Killeen, 1996; Swenson et al., 1999; Smith et al., 2000, for example). There is, however, a distinct class of uncommon events - sudden and very bright all-sky airglow emission enhancements or depletions followed by a series of propagating waves that are phase-locked to the leading front and lasting several hours. Very few cases have been reported in the literature and they appear to consist of two distinct types of disturbances: "wall" events and bores. This paper will present and discuss observations of these two types of wave events recorded by the Boston University all-sky imagers at four separate locations: Millstone Hill (MA), Arecibo Observatory (PR), McDonald Observatory (TX), and El Leoncito (Argentina). A comparison of these events with those reported in the literature will also be made.

SA21A-03 0830h POSTER

All-sky imaging observations of mesospheric fronts in OI 557.7 nm and broadband OH airglow emissions: Progression towards the dominant tropospheric source

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All-sky imaging observations of distinct, large horizontal spatial scale (order ∼100 km), transient structures in the mesosphere observed in broadband OH and OI 557.7 nm airglow emissions, which we define as mesospheric fronts, were made over Clemson, SC on the night of October 14-15, 2001. We present a brief summary of the night's observations, paying particular attention to the details of the different frontal structures. These data are compared to other observations of mesospheric fronts found in the literature, and we seek to understand them in relation to mesospheric bores, wall-events, large-amplitude gravity waves, and ducted waves. We find that the observed front's characteristics and the atmospheric background structure are most similar with past observations of mesospheric bores. Furthermore, by examining the similarity in atmospheric conditions when compared to past observations, we suggest a potential means for predicting such mesospheric phenomena. However, the events we report are unique in that they progress towards the assumed sourcing region; opposite that reported in many other observations. Can this particularity be explained with a traditional bore mechanism?

SA21A-04 0830h POSTER

Evidence of gravity wave-breaking and ducting in Lidar data

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The Electro-Optics group at the University of Illinois has collected lidar data from systems based in Albuquerque, NM and in Maui, HI. The data set spans many years and many seasons. Evidence of gravity wave overturning occurs almost every night that there is data. From this data set we can get an idea of the statistical nature of these events and we can observe how these events feedback onto the mean wind and temperature as well as subsequent waves entering the region. The heights spanned by the data sets always contain mean and tidal period components and usually only one main wave component whose frequency is often around 3-4 hours suggesting a tidal connection. Sometimes there seems to be (considering the observational window of the lidar) other higher frequency components but they rarely penetrate very far into the height region covered by the lidar. By looking at potential temperature it is clear that when the data is low pass filtered to remove the highest frequency components overturning of the main wave component is often present. Plotting the other measured quantities - sodium density, temperature, and winds - highlights other features such as ducted modes. First a summary of the data will be presented to show a rough climatology of the data - which waves are present and when overturning is evident. Then a few demonstrative examples of wave-breaking will be presented with auxiliary data to show implications of the presence of overturning waves on the dynamical state of the system.

URL: http://aegolius.csl.uiuc.edu/˜patricia/research/lidar_data_processing/index.html

SA21A-05 0830h POSTER

Sharp Front Observations of Mesospheric Bores: Further Evidence and New Classes

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Since the first spectacular gravity wave events observed a decade ago during the Airborne Lidar and Observations of Hawaiian Airglow (ALOHA-93) campaign, additional examples of sharp airglow fronts have been observed by imaging systems at a variety of locales. Many of these events were characterized by small-scale waves tracking behind the sharp onset of a large scale front. Coining the term "mesospheric bore" to describe one of the ALOHA-93 events, Dewan and Picard [1998] proposed the first simple mathematical model for symmetric bore theory, and then extended their model to include a possible mechanism for bore generation [Dewan and Picard 2001]. We describe here subsequent bore events and compare them to the existing model. Building from this new database of events, we present a classification system to categorize mesospheric bores. We investigate the role of mesospheric inversion layers in bore formation, and show that a published example of such a layer would support bore propagation. As in ALOHA-93, our subsequent observations were made over multiple airglow layers and most show the same anti-correlated intensity pattern between upper and lower altitudes. Some of the observations, however, exhibit an inverse intensity relationship between emission layers; these inverse events also show horizontal phase shifts between the emission layers. The possibility of two coexisting bores is proposed here to explain both this inverse phenomenon and the accompanying horizontal phase shift. We also compare the data to the theory by Seyler [submitted 2004], which extends the symmetric bore theory and offers an alternative explanation to the inverse complementarity feature.

SA21A-06 0830h POSTER

Radar Observations of Gravity Waves and Kelvin-Helmholtz Instabilities in the Tropical Mesosphere

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The powerful Jicamarca 50-MHz radar observes daytime mesospheric echo layers, now with 150 meter and 1 minute resolution. The layers often exhibit fine structure like double layers, braids and rolls indicating Kelvin-Helmholtz type shear instability. In addition, radial velocities show fast oscillations near the Brunt-Vaisala frequency evident of gravity wave activity. We present mean vertical wind shears of the zonal and meridional wind and derive the horizontal wavelength for multiple structures. We refine our analysis by studying power and spectral width variations across the instability layers, which provide additional information about the scattering process and the turbulent structures.

SA21A-07 0830h POSTER

GLORIA, a Satellite Experiment for the Mesoscale

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Satellite data have had a huge impact on our understanding of synoptic scale dynamics, chemistry and transport processes in the atmosphere. However, for some questions of particular interest the spatial sampling of satellites currently in orbit or planned to be launched is much to low. We propose an imaging Michelson interferometer obtaining vertical profiles of Temperature and several trace species in the altitude range from 5 km to 60 km. The Instrument will measure at a horizontal sampling of 40km x 40km or finer along a 400km wide path. At tropopause altitudes a vertical spacing of 0.5 km is intended. The aims of the instrument are: 1.) to provide mesoscale distributions on water vapor and freon in the UTLS to study stratosphere troposphere exchange. 2.) to infer gravity wave momentum flux. 3.) to measure subvisible cirrus at unprecidented 3D resolution. 4.) to investigate streamers and filamentation in the stratopshere.

SA21A-08 0830h POSTER

GWIM/EQUARS: A Satellite Instrument to Measure Gravity Wave Signatures in the Airglow

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Upwardly-propagating gravity waves cause intensity fluctuations in the airglow layers of the mesopause region as they pass through. GWIM/EQUARS is a satellite instrument that will exploit these fluctuations to measure gravity wave parameters such as the horizontal wavenumber spectrum and the vertical flux of horizontal momentum A major interest lies in the correlation of the presence of gravity waves with their sources near the surface or in the lower atmosphere. The airglow features to be utilized by GWIM/EQUARS are the Atmospheric band of oxygen at 760 nm and the hydroxyl Meinel bands near 1300 nm. EQUARS is a Brazilian satellite planned for launch into a near equatorial orbit in 2006. The low latitude orbit is particularly suitable for the source studies because of the possibility that the same convective system can be observed more than once.

SA21A-09 0830h POSTER

Fourier and Wavelet Based Characterisation of the Ionospheric Response to the Solar Eclipse of August, the 11th, 1999, Measured Through 1-minute Vertical Ionospheric Sounding

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The aim of the present work is to study the ionospheric response induced by the solar eclipse of August, the 11th, 1999. We provide Fourier and wavelet based characterisations of the propagation of the acoustic-gravity waves induced by the solar eclipse. The analysed data consist of profiles of electron concentration. They are derived from 1-minute vertical incidence ionospheric sounding measurements, performed at the Pruhonice observatory (Czech republic, 49.9N, 14.5E). The chosen 1-minute high sampling rate aims at enabling us to specifically see modes below acoustic cutoff period. The August period was characterized by Solar Flux F10.7 = 128, steady solar wind, quiet magnetospheric conditions, a low geomagnetic activity (Dst

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index varies from -10 nT to -20 nT, Σ Kp index reached value of 12+). The eclipse was notably exceptional in uniform solar disk. These conditions and fact that the culmination of the solar eclipse over central Europe occurred at local noon are such that the observed ionospheric response is mainly that of the solar eclipse. We provide a full characterization of the propagation of the waves in terms of times of occurrence, group and phase velocities, propagation direction, characteristic period and lifetime of the particular wave structure. However, ionospheric vertical sounding technique enables us to deal with vertical components of each characteristic. Parameters are estimated combining Fourier and wavelet analysis. Our conclusions confirm earlier theoretical and experimental findings, reported in [Altadill et al., 2001; Farges et al., 2001; Muller-Wodarg et al.,1998] regarding the generation and propagation of gravity waves and provide complementary characterisation using wavelet approaches. We also report a new evidence for the generation and propagation of acoustic waves induced by the solar eclipse through the ionospheric F region. Up to our knowledge, this is the first time that acoustic waves can be demonstrated based on ionospheric measurements and analysis. We report similarities in generation and occurrence of acoustic and gravity modes in the eclipsed region. Our analysis techniques enable us to "locate" wave bursts in particular height of ionosphere, specify source region and give characteristics of acoustic and gravity wave movement through ionosphere. Altadill D., J.G. Sole, E.M. Apostolov: Vertical structure of a gravity wave like oscillation in the ionosphere generated by the solar eclipse of August 11, 1999, J. Geoph. Res.-Space Phys., 106 (A10), 21419-21428, 2001. Farges T., J.C. Jodogne, R. Bamford, Y. Le Roux, F. Gauthier, P.M. Villa, D.Altadill, J.G. Sole, G.Miro: Disturbances of the western European ionosphere during the the total solar eclipse of 11 August 1999 measured by wide ionosonde and radar network, J. Atmosph. Solar-Terr. Phys., 63 (9), 915-924, 2001. Muller-Wodarg I.C.F, A.D. Aylward, M. Lockwood: Effects of a Mid-Latitude Solar Eclipse on the Thermosphere and Ionosphere - A Modelling Study, Geoph. Res. Letters, 25 (20), 3787-3790, 1998.

SA21B CC: 519 A Tuesday 0830h

Surface-Boundary-Exospheres in the Solar System I *(joint with A, P, SH, SM)*

Presiding: **A Sprague,** University of Arizona**; M Mendillo,** Center for Space Physics, Boston University

SA21B-01 0830h INVITED

Exploring Mercury's Surface-Exosphere-Space Environment System during the MESSENGER Mission.

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When MESSENGER begins its four-Mercury-year orbital mission about the planet, it will carry an Ultraviolet-Visible Spectrometer (UVVS), designed to study the composition and structure of the exosphere. The UVVS is one member of a suite of instruments that will provide us with our first comprehensive picture of Mercury's surface-exosphere-space environment system. Also on board the MESSENGER spacecraft are four instruments that will measure surface elemental and mineralogical composition. These are the Gamma Ray Neutron Spectrometer (GRNS), the X-Ray Spectrometer (XRS), the Mercury Dual Imaging System (MDIS), and the Visual and InfraRed Spectrometer (VIRS). In addition, the Energetic Particle and Plasma Spectrometer (EPPS) and Magnetometer (MAG) will measure magnetospheric and pick up ions and a map Mercury's magnetic field respectively. In this presentation we describe the UVVS investigation and how it will contribute to our understanding of Mercury's exospheric processes. We also describe how measurements from UVVS, EPPS, and MAG can be combined with surface composition measurements to provide an overall picture of Mercury's surface-exosphere-magnetosphere interactions and briefly describe our plans for modeling and visualization of the combined data suites.

SA21B-02 0850h INVITED

Sources of the Escaping Lunar Atmosphere Derived from a Decade of Imaging Science Experiments

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The lunar sodium exosphere owes its existence to the impact of solar photons, solar wind plasma, and meteorites on the lunar surface. Perhaps the most effective methods of testing the effects of each impact process are to make two or more similar observations of the lunar exosphere during periods when the flux of one or more of these agents has changed, or to make a single observation where the effects of different fluxes can be seen simultaneously. We have observed the escaping component of the lunar sodium exosphere under several different sets of conditions. Magnetospheric plasma sputtering was tested during five Full-Moon phase observations in eclipse, where the Moon was in the Earth's magnetospheric plasma sheet three times, and outside of the sheet twice. Multiple observations of the lunar sodium tail at New Moon phase include a unique observation affected by the spectacular 1998 Leonid Meteor shower. Finally, observations near quarter Moon phase show latitudinal variations in solar wind sputtering and/or photon stimulated desorption. In this paper we will summarize the source strengths from each of these mechanisms derived from Monte Carlo simulations studies.

URL: http://sirius.bu.edu/planetary/moon.html

SA21B-03 0910h

Neutral Particle Emission Induced by Solar Wind in Mercury's Environment

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The peculiar configuration of the Hermean magnetosphere, characterised by a weak magnetic field, may allow a solar wind entrance and circulation in Mercury's environment. More particularly, intense ion fluxes are expected in the cusp regions, which are extremely large if compared to the Earth's ones. In the present study we reconstruct the H+ distribution in space, energy and pitch angle by means of a single-particle Monte-Carlo model. The neutral particle emission induced by the solar wind in the Hermean environment is investigated as well. The H+ are likely to rapidly leave the Hermean magnetosphere or precipitate onto the surface of the planet, thus originating neutral particle emission via ion-sputtering as well as energetic neutral atoms, generated via charge-exchange process. Different external configurations of both interplanetary magnetic field and cross-tail potential drop result in variations of the sputtered and charge-exchange neutral particle signal. The Neutral Particle Analyser - Ion Spectrometer experiment (NPA-IS/SERENA), proposed to fly on board of the ESA mission Bepi Colombo, will monitor the circulating ion and neutral particles. The modeled distributions here presented have been processed in the frame of SERENA instrument and may be considered as a reference tool for the future observations.

SA21B-04 0925h INVITED

Laboratory Studies of Alkali Components in Tenuous Planetary Atmospheres

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We report on studies performed at the Laboratory for Surface Modification of Rutgers University and focused on the origin of alkali vapors (Na, K) in the tenuous atmospheres of the planet Mercury, the Moon, and Jupiter's icy satellite Europa [1, 2]; we also address the question why alkaline-earth metals (Mg, Ca) are less abundant in the atmospheres. A variety of ultrahigh-vacuum surface science techniques are used, including X-ray Photoelectron Spectroscopy (XPS), Low-Energy Ion Scattering (LEIS), Thermal Programmed Desorption (TPD), Electron- and Photon-Stimulated Desorption (ESD and PSD), Surface Ionization (SI). Measurements have been made on different samples, including the model mineral binary oxide SiO_2 that simulates lunar silicates, and a lunar sample obtained from NASA. Desorption induced by electronic excitations (mainly PSD) rather than by thermal processes is found to be the dominant source process on the lunar surface. The flux at the lunar surface of ultraviolet photons from the Sun is adequate to insure that PSD of sodium contributes substantially to the Moon's atmosphere. A model based on irradiation-induced charge-transfer is proposed to explain the desorption process. There is a strong temperature-dependence of Na ESD and PSD signals from a lunar sample, under conditions where the Na surface coverage is constant and thermal desorption is negligible [3]. On Mercury solar heating of the surface is high enough that thermal desorption will also be a potential source of atmospheric sodium. Ion bombardment of the lunar sample causes both the sputtering of alkali atoms into vacuum and implantation into the sample bulk. In the future we outline the use a novel method, Nuclear Resonance Profiling (NRP) to study the diffusion of alkalis through model minerals, ices, and lunar samples; these measurements would provide additional information to understand the replenishment of Na at the surface of the Moon, Mercury and Europa. We also describe a new detector that we will use to search for desorption of alkaline-earth atoms.

T.E. Madey, R.E. Johnson, T.M. Orlando, Surf. Sci. 500 (2002) 838. [2] B.V. Yakshinskiy, T.E. Madey, Surf. Sci. 528 (2003) 54. [3] B.V. Yakshinskiy, T.E. Madey, Icarus 168 (2004) 53.

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Sputtering Contribution to Planetary Atmospheres

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We have measured the sputtering of specific species during ion irradiation of water ice, labradorite, albite, anorthoclase, and olivine targets, to understand the importance of sputtering in the generation of atmospheres around icy satellites of the outer solar system by magnetospheric ions, and around the Moon and Mercury by the Solar wind. We use mass spectrometry in ultrahigh vacuum to measure sputtered species and gas evolved during post-irradiation heating to identify chemical species formed by ion implantation. We will discuss the formation of NO and other molecules in the Saturnian system that may be detectable by Cassini, and the relative importance of different mechanism that lead to the formation of Na atmospheres around the Moon and Mercury.

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Surface-Boundary-Exospheres in the Solar System II *(joint with A, P, SH, SM)*

Presiding: **A Sprague,** University of Arizona**; M Cowee,** Institute of Geophysics and Planetary Physics

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State of the Art of our Understanding of Mercury's Exosphere

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Mariner 10 is the only spacecraft to have been close enough to observe Mercury's exosphere by UV spectrometry. After the three flybies of Mariner 10, Earth based observations have provided some complementary information on Mercury's exosphere. Thus, the next planed future missions, Messenger and Bepi Colombo should dramatically improve our knowledge of Mercury's exosphere. Therefore up to now, most of the efforts to describe Mercury's exosphere considered only the sodium exosphere, the best known component easily observable from Earth based ground observatory thanks to its strong resonant emission. In this talk, I will describe the particularities of Mercury's surface bounded exosphere due to the length of Mercury's day