P51B MCC: Level 1 Friday 0830h

Outer Planet Satellites Posters *(joint with V, C, MR)*

Presiding: **W B McKinnon,** McDonnell Center for Space Sciences, Washington University; **P A Yanamandra-Fisher,** Jet Propulsion Laboratory, California Institute of Technology

P51B-0442 0830h POSTER

Gas Hydrate Stability at Low Temperatures and High Pressures

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Several papers have recently suggested that decomposition of gas hydrates could have played an important role in the geologic history of Mars and Europa. Gas hydrates form in porous sediments under low temperatures and high pressures. The FREZCHEM model was developed to predict chemical equilibria over the temperature range from -70 to 25°C and the pressure range from 1 to 1000 bars using the Pitzer equations, which are valid to high ionic strengths. The objectives of this paper were to (1) add gas (carbon dioxide and methane) hydrate chemistry to the FREZCHEM model, and (2) use the model to examine hypothetical gas hydrate chemistries on Mars and Europa. For the gas hydrate model, key variables and constants that were quantified as functions of pressure and temperature were solubility products, gas solubilities, and activity coefficients. Based on this work, new state-of-the-art stability diagrams were developed for carbon dioxide and methane hydrates in pure water and seawater. Applications to Mars a

P51B-0443 0830h POSTER

Photometric Evidence for Volatile Transport on Triton

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Past observations of Neptune's moon Triton reveal that its surface is exhibiting both long and short term variability in color relative to baseline data gathered in the 1989 Voyager 2 flyby. These changes are likely due to the seasonal sublimation and deposition of Nitrogen frost and other volatiles (Buratti et al. 1994). Photometric light curves provide an additional verification that volatile transport is occurring on Triton. Steady state models, based on Voyager data and the assumption that Triton's surface is not changing, suggest a visual light curve amplitude of less than 0.05 magnitudes (Hillier et al.1991). Measurements taken in July 2000, however, indicated an amplitude of nearly 0.20 magnitudes (Cobb et al. 2001). Follow-up photometric observations in B,V,R,I broadband filters and an 890nm narrow band filter, covering a broader range in sub-Earth longitudes, were taken in June, July, and August 2003. They indicate a visual amplitude of 0.17 +/- 0.05 magnitudes, in close agreement with the 2001 data. These amplitudes are far larger than expected and may imply substantial volatile transport on Triton's surface. In addition, we observed a larger than expected opposition surge that demands further investigation.

P51B-0444 0830h POSTER

Determining the Incorporation of NaCl into Ice VII by Raman Spectroscopy

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High-pressure H_2O polymorphs have been thought to comprise the interior of some planetary bodies. Ice VII, a polymorph of H_2O with a large range of pressure stability above 2 GPa and room temperature is thought to compose a portion of some Galilean satellites, e.g. Callisto. It has also been hypothesized that these satellites may contain internal salt-water "oceans" (Khurana et al., 1998) that, if present, may affect the distribution of Ice VII at depth. The OH bond in Ice VII has been studied by Raman spectroscopy (Pruzan et al., 1990; Walrafen et al., 1982), however, no data exist on how the bonding structure of Ice VII changes with the incorporation of trace amounts of salt. This study sought to measure the Raman shift in Ice VII formed from NaCl-H_2O solutions to 20 GPa. Samples of pure H_2O, and 5 wt% NaCl were loaded into a Mao-Bell type Diamond Anvil Cell and Raman spectroscopy was used to analyze the samples at pressure increments of 1-2 GPa. The relative OH stretching frequency was measured to observe the bond structure in Ice VII samples formed from the H_2O and NaCl-H_2O solutions as pressure increases. OH shifts from the NaCl-H_2O solutions were compared to pure H_2O measurements observed in this study and also compared to previous studies in the pure H_2O system. All results show a negative linear decrease in OH stretching frequency as pressure increases. OH stretching frequency in Ice VII formed from pure water can be represented by the best-fit line: $v = 3322.8353 - 23.9857P$ where P is pressure in GPa and v is the OH stretching frequency in rel cm^{-1}. OH stretching frequencies in Ice VII formed from the 5 wt% NaCl solution was modeled with a linear equation: $v = 3338.2502 - 22.6019P$. Ice VII formed from 5 wt% data shows a systematic increase of approximately 15 rel cm^{-1} for any given pressure. From Raman spectra, we hypothesize that NaCl is being incorporated into the bond structure of Ice VII formed from low salinity solutions. Future experiments will be conducted to verify the reproducibility of these experiments, analyze a wider range of salinities and salt compositions, and obtain x-ray diffraction data.

P51B-0445 0830h POSTER

The Surface Composition of Europa: Mixed Water, Hydronium, and Hydrogen Peroxide Ice

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Interpretations of the composition of the surface of Europa have been controversial, with different identifications resulting in correspondingly different implications for the origin and evolution of the satellite. The surface of Europa has an unusual water spectrum that has previously been interpreted as resulting from sulfate and carbonate salt minerals. However, the spectra of such minerals at the temperatures of Europa's surface have features which preclude their presence. This has led some investigators to postulate an unspecified hydrated mineral as the cause, and the term "non-icy" is now generally used to describe the Europa material. Europa's "non-icy" spectrum has also been interpreted as a sulfuric acid hydrate. Sulfuric acid hydrate spectral features are not unique to sulfuric acid, because other acids show similar features. These features are interpreted here as being due to hydronium, H3O, in the ice structure. Thus, Europa's "non-icy" material is interpreted as being due to hydronium. Hydronium ice may be caused by ionization defects in regular ice due to bombardment by magnetospheric particles, implantation of protons in the ice surface, or endogenic processes indicating an acidic ocean, or all three. Hydrogen peroxide also has been identified on Europa, and hydrogen peroxide-acid mixtures provide close matches to Europa's "non-icy" material. This too may be caused by ionization defects from the particle bombardment, or may indicate an ocean of acid and hydrogen peroxide. Spectra of Ganymede and Callisto show spectral characteristics of the Europa water-hydronium-peroxide ice, but with less intensity and are consistent with an exogenic modification of the surfaces by particle bombardment, rather than decreasing amounts of salt and oceanic processes as one moves away from Jupiter. Europa's "non-icy" spectra may be composed of >99% ordinary ice that has been disrupted by the particle bombardment, or an acid-hydrogen peroxide mixture composed of about 2/3 water. Liquid acid-hydrogen peroxide mixtures readily attack organic molecules, metals, and other compounds. If a lander melted this surface during its operations, the liquid could attack lander components and destroy experiments. An ocean composed of an acid-hydrogen peroxide mixture is a hostile environment for life as we currently know it.

URL: http://speclab.cr.usgs.gov

P51B-0446 0830h POSTER

Inversion of Airborne Gravity Data over Subglacial Lakes in East Antarctica

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The team of the University of Texas Institute for Geophysics (UTIG) has been performing airborne geophysical surveys in Antarctica since 1991. Over 260,000 line-km have been surveyed during nine field seasons. The UTIG airborne platform is a contracted DeHavilland Twin Otter instrumented with ice-penetrating radar, laser altimeter, magnetometer, and a gravimeter. The gravimeter utilized is a Bell Aerospace BGM-3 marine system, modified for airborne use, which provides measurements of vertical accelerations at 1 Hz, with verticality of the sensor maintained by a gyro-stabilized platform. The aerogeophysical surveys over subglacial Lake Concordia and Lake Vostok in East Antarctica were conducted by a team from UTIG over the course of the Antarctic field seasons. The region surrounding Lake Concordia was sampled by 6 profiles with a 10 km separation whereas the Lake Vostok survey block was 165 x 330 km with a line spacing of 7.5 km with 11.25 km and 22.5 km ties. 2D gravity inversion was performed for both lakes. The forward problem was solved using Talwani's algorithm for a 2D body of irregular shape. It is described by a non-linear equation between the body's shape and it's density contrast with surrounding rocks. The assumption was that the density contrast between ice/water and rock along the profile is constant. The densities of ice and water are close enough, so the ice and water of the lake can be considered as one body. For Lake Vostok the gravity data were inverted for 2-layered model, consisting of ice/water and sediment lying over dense bedrock. Inversion was performed by a conjugate gradient algorithm for several fixed values of density contrasts. The coordinates of layers' corners were chosen as model parameters. The model was constrained by the lake's boundaries and sub-ice topography, determined from radar sounding. Also, several pre-existing seismic soundings were used as a priori' information incorporated into the model. The best agreement with seismic data was obtained for density contrast -1.6 g/cc between water and host rock and -0.6 g/cc between sediment and host rock. The differences in thickness of both water and sediment layers at the cross-points of the inverted profiles are within 50 m. The results of 2D inversion for several profiles over Lake Vostok are also used as constraints for 3D inversion. Lake Concordia is located at the very edge of a geophysical survey block. This creates uncertainty in obtaining a regional trend due to lack of data over one side of the lake. Also, there is no additional a priori' seismic information. Inversion was performed for several values of density contrast between ice/water and surrounding rock. The obtained water thickness for all of density contrasts is not more than 200 m and a sediment layer can not be resolved.

P51B-0447 0830h POSTER

Oceans in ice-rock bodies: conditions for the existence of subsurface liquid water

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In an ice-rock body, it is possible for a subsurface ocean to exist as long as there is a sufficient heat source in the rocky core to maintain melting temperatures in the ice layer. Since the melting point of ice I decreases with pressure, it is only necessary for temperatures to reach ∼ 251 K for liquid water to be present in the ice layer. If ammonia is present, the minimum necessary temperature decreases further, to around 176 K. Heat loss in differentiated ice-rock bodies occurs primarily through thermal convection in the outer layer of ice, as long as the body is not too small (larger than ∼ 200 km radius). To model convection in the ice layer, we used scaling laws for stagnant lid convection with Newtonian rheology (Solomatov, 1995), which relate heat flux to the internal Rayleigh number of the convecting layer. Newtonian rheology is appropriate for the low

stresses under consideration. Since the viscosity of ice I is strongly temperature-dependent, convection in the ice layer occurs in the stagnant lid regime, which allows for higher temperatures at depth than constant viscosity convection. For ice-rock bodies with a given size, composition, and heat source, we calculated the interior temperature and compared it to the ice I solidus to determine whether an ocean could be present. Since both the heat flux at the base of the ice layer and the gravitational acceleration are proportional to the radius of the body, it is effectively much harder for oceans to exist in small bodies. Using plausible choices of parameters for pure ice I, it is possible for oceans to exist in bodies as small as $\sim$ 1000 km radius, meaning that candidates for subsurface oceans include not only the icy Galilean satellites and Titan but also Triton and Pluto. If ammonia is present, oceans can exist in bodies as small as the largest Saturnian and Uranian moons ($\sim$ 750 km radius). In all of these cases, whether oceans can be present depends strongly on the rheological parameters of ice I, which are not well known at planetary conditions. Another important parameter is the radiogenic heating rate of the rock, which may be greater than typical chondritic values if the rock is undepleted in potassium.

P51B-0448 0830h POSTER

Composition and Variability of Io's Pele Plume

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The Pele plume is one of the largest and most dynamic of the plumes on Io. Various observations have been made to characterize the composition and eruptive behavior of this plume. Within the last $\sim$ 15 years the column density of sulfur dioxide (SO_2) gas within the plume has been derived using both spectral and imaging observations. Elemental sulfur (S_2), which has long been suspected to be a major constituent of the Pele plume based on the color of its deposits, has only recently been positively identified within the plume. And, the current SO/SO_2 ratio accepted for the Pele plume is based on high signal-to-noise (S/N) spatially resolved spectra taken three years prior to the S_2 detection. These results have been useful as a probe of magma chemistry and vent conditions. However, because the Pele plume has long been known to be variable in its eruptive behavior, observational constraint of each of the possible plume constituents based on a single observation would greatly decrease the uncertainty in the modeling of Pele's eruption chemistry and magma state. For this reason, in February and March 2003 we obtained spectra of Pele with Hubble's Space Telescope Imaging Spectrograph (STIS) in transit of Jupiter, using the 0.1 arcsec slit, for the wavelength region extending from 2100-3100 A. Because these data were obtained in four visits of 1020s each, an integration time that is four times longer than that used in the initial S_2 detection, the higher S/N may be sufficient to allow reliable estimates of the SO_2, S_2, and SO gas abundances to be made independent of uncertainties with respect to temporal variability of the plume for the first time. We present preliminary analysis of these data reporting the SO_2, S_2, and SO abundances of the Pele plume. We also obtained UV and visible-wavelength images of the plume in reflected sunlight with the Advanced Camera for Surveys (ACS) prior to Jupiter transit, in order to constrain plume dust abundance. We will give a brief overview of the variability of the plume as a function of time during the $\sim$ 1 month period spanned by the observations, in both reflected and transmitted light.

P51B-0449 0830h POSTER

High pressure sulfate-water system in the large icy satellites

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The internal structure and composition of large icy satellites of giant planets are very important topics in planetary sciences. Based on the observed data of CI chondrite materials, it has been expected that three-quarters of the volatiles are sulfates, and 73wt.% of aqueous sulfate is magnesium sulfate $MgSO_4$ [Frederiksson et al. 1998]. Recently, it has been considered that $MgSO_4$ is the most abundant volatiles in the icy objects. In the brine of orgueil meteorites, 97wt.% are composed of $MgSO_4$ and Na_2SO_4. Magnesium sulfate $MgSO_4$, is the most important brine in CI chondrites. We need to investigate the phase relations of the sulfate-water system up to the pressure of 5GPa to discuss the phases expected in the deep icy mantle or, ice-rock mixed core in the large icy satellites such as Callisto. Kargel(1991) suggested that the quantity of $MgSO_4$ in the model of icy objects is about 8-20wt.%, which is close to the eutectic composition at 0.1MPa, 17wt.% $MgSO_4$. Therefore, we adopted his estimation for the present starting compositions, i.e., the compositions of 0-30wt.% $MgSO_4$ in the $MgSO_4$-H_2O system. We used a diamond anvil cell with external heating for the *in situ* optical observation. We used the ruby-fluorescene method [Mao et al. 1986] (the diameter of ruby grains is around 70μm) to determine the pressure. The temperature measurement was made by using the K-type thermocouple which was contacted to the steel gasket of the DAC. We generated temperatures more than 600K at high pressure by this cell. Identification of the phases was made by using the X-ray diffractometer and Raman spectroscope. We have clarified the phase equilibrium in the $MgSO_4$-H_2O binary system at room temperature. An eutectic point locates 14wt.% of $MgSO_4$ where high pressure ice (ice *Y*), magnesium sulfate hepta-hydrate $MgSO_4 \cdot 7H_2O$, and fluid coexist at 1.99GPa at the room temperature. We investigated this $MgSO_4$-H_2O binary system up to 600K and 5GPa with using the diamond anvil cell. At high pressure, we recognized $MgSO_4 \cdot 7H_2O$ phase and some high pressure ices (Ice*Y*, Ice*Z*) above 293K. Thus, we have the conclusions that a deep liquid ocean with the bottom pressure exceeding 1GPa must exist if $MgSO_4$ content exceeds more than 10wt.%. The sediment composed of $MgSO_4 \cdot 7H_2O$ phase might exist in the bottom of the ocean.

URL: http://www.ganko.tohoku.ac.jp/bussei/

P51B-0450 0830h POSTER

Callisto and Titan: What Lies Beneath?

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Assuming that Callisto is hydrostatic, the Galileo-derived value of C_{22} yields a normalized moment-of-inertia of 0.3549 $\pm$ 0.0042. While clearly larger than that of Ganymede, this moment-of-inertia value is significantly lower than that of a completely undifferentiated Callisto (0.38). The rock+metal fraction in Callisto must increase with depth, but gravity data alone are unable to constrain the exact nature of this increase (i.e., whether it is continuous or step-wise). A continuous increase is ruled out, because such would suppress internal convection by solid state creep of the ice fraction, and the resulting conductive temperature gradient would intersect the melting curve and promote further differentiation. Callisto, then, must be layered in terms of its ice/rock ratio (except perhaps for small, restricted regions). The simplest layered model for Callisto consists of a denser (more rock and dense-ice-phase rich) interior surrounded by a less rock-rich and more low-density-ice-polymorph-rich shell. A broad range of shell thicknesses are possible. The rationale for two-layer models is that rock(+metal) can separate from ice if the ice melts or if the rock is in massive enough fragments (or concentrations) that they sink slowly through the ice. The downward Stokes velocity of the rock fragments must exceed interior convective velocities for the latter separation to be effective, but not be so great that the rock escapes remixing with deeper ice-rock, if the two-layered structure is to be maintained. Rock released by melting need not sink with respect to the ice, as long as water can escape to higher levels, but the rock must also remix with deeper ice-rock if the two-layered structure is to be maintained. Whether descending rock fragments (or concentrations) remix with deeper ice-rock depends on the fragment or concentration size and ice viscosity, which are unknown. If, however, the rock descends to the center of Callisto, then a rock core should form, surrounded by a mixed ice-rock layer and an exterior ice mantle. Such 3-layer models, in which the mixed layer has the same ice/rock ratio as the bulk satellite, indicate that a Callisto with the moment-of-inertia above corresponds to a body with $\sim$20 percent of its total rock in a central core $\sim$900 km in radius. New structural models indicate that under such conditions the boundary between the clean ice and mixed ice-rock layers is very close to the depth of ice I-ice III transition pressure (209 MPa). This depth is also the natural level for an ocean to perch, so it is tempting to imagine that thermal conditions that led to melting within Callisto operated at the ice minimum melting temperature, and that the rock+metal separated was able to descend to form a core. Here I examine the issue of whether Callisto can differentiate in this manner (via continuous partial melting in ascending convection currents) or whether a thermal runaway and complete differentiation ensues. The latter possibility has been used as an argument that Callisto must have differentiated in the solid state. These arguments will also be applied to Titan.

P51B-0451 0830h POSTER

Non-thermal production of molecular oxygen on the surface of Europa

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The signature of condensed O2 has been reported in optical reflectance measurements of the Jovian moon Ganymede, and a tenuous oxygen atmosphere has been observed surrounding Europa. The surfaces of these moons contain large amounts of water ice, and it is thought that O2 is formed by sputtering of ice by energetic particles from the Jovian magnetosphere. Knowledge of how O2 is produced in low-temperature ice is crucial for accurate theoretical and experimental simulations of the surfaces and atmospheres of icy solar system bodies. However, the role of electronic excitations and the mechanistic details are poorly understood. This talk will present an overview of the non-thermal processes involved in the production and build up of oxygen and related species in icy surfaces like that of Europa. Discussion will include laboratory measurements of the electron energy threshold, flux and fluence dependence, temperature dependence, and cross-section for O2 production during low-energy (5-100 eV) electron bombardment of thin (40 bilayer) amorphous and crystalline D2O ice films in vacuum that are suitable surrogates of the conditions found on Europa. Comparison of the fluence dependence with kinetic models shows that O2 is formed by direct excitation and dissociation of a stable precursor molecule, and not by diffusion and chemical recombination of radicals. The O2 yield is also strongly dependent on the temperature of the ice, is different for crystalline and amorphous ice films, and shows structure indicative of bulk structural transitions. We also report a previously unobserved hysteresis with temperature cycling. The results point to a novel explanation of thermal effects in ice sputtering, based on a temperature dependence of the dissociative excited state lifetime of water.

P51B-0452 0830h POSTER

Clathrate Hydrates in a Europan Ocean

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The temperature and pressure environments of the europan ice shell and putative ocean may be such that various species of clathrate hydrates are stable. Here we calculate annual fluxes of biologically useful gases to a europan ocean and consider the role of such clathrates in a hypothetical europan ecosystem. It is known that the surface radiation environment of Europa produces O_2, hydrogen peroxide, and H_2S(Carlson et al., 1999) Thus, hydrates of these species could form in the ice shell or in the ocean if conditions were suitable. According to Lipenkov & Istomin, if pressures in the ice shell exceeded 9.7 MPa for temperatures >267 K then oxygen hydrates would form in the ice. Such conditions might be expected at the base of the ice shell or in regions of high tidal stress or strain. If we make the assumption that the solubility of oxygen in Europa is comparable to that calculated for Lake Vostok temperatures and pressures, then we can estimate the extent to which the europan ocean might contain dissolved oxygen and hydrates. Taking an estimate based on radiolytic surface production of hydrogen peroxide (which decays to oxygen) and subsequent delivery to the ocean, we have argued that Europa could have an annual oxygen flux of 10^{12} moles. Over the course of the 50 million year resurfacing timescale, this would produce a 0.020 mole fraction of oxygen in the ocean, in the absence of oxygen sinks (Chyba & Hand, 2001). By comparison with Lipenkov and Istomin, this exceeds the 2.2e-3 maximum solubility for air and thus in this case we would expect to see oxygen hydrate formation in the Europan ocean. Several caveats apply: 1) We have in

this estimate used the solubility for air, not pure oxygen; 2) The gases delivered to the ocean would be at 10MPa and 272 K, this is not a high enough pressure for oxygen hydrate stability, however if the pressure were to reach levels of 11-12MPa then such hydrates would be stable. Once delivered to the ocean, the fate of biologically useful gas hydrates will depend on the density, and hence salinity, of the europan ocean water. If the density of the hydrates exceeds that of the surrounding water and saturation has been reached, then the hydrates will precipitate to the seafloor and form a hydrate sediment. If the hydrates are buoyant in the europan ocean then an accretion layer of hydrates may form at the base of the ice shell. Indeed, such a layer may have implications for ice shell dynamics and evolution.

P51B-0453 0830h POSTER

Formation and Thermal Infrared Spectroscopy of Halite Crusts

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Efflorescent salt crusts form as groundwater evaporates from capillary updraw of brine through sediment. Salts precipitate at the surface, coating and cementing the upper few layers of sediment. If enough brine is present to completely saturate and pond on top of the surface, halite will precipitate at the surface of the brine and settle out as layers of crystalline salt on top of the sediment. In playa environments, salts such as sulfates, carbonates and halides, and forms such crusts. In remote sensing studies of such surfaces, it is important to understand how the presence of salt crusts affects the spectral features of the surrounding sediment. This is especially true when the crusts form from a non-absorbing salt such as halite. Halite has been observed to exhibit unusual spectral properties in the thermal infrared. Specifically, granular mixtures of minerals with halite produced spectra in which the spectral features inverted form reflectivity, shifted to shorter wavelengths and the spectral contrast increased near absorption bands. However, in crusted surfaces, in which the halite cements, coats or overlays the mineral grains, the presence of halite has a different affect on the spectra. This work will examine the precipitation of halite and the formation of salt crusts for several sediment and brine mixtures. Laboratory measurements of thermal emission spectra for the crusts will be compared to previous studies for particulate mixtures of halite with minerals and well as to natural surface crusts. Detailed knowledge of such surfaces will allow for their discrimination and identification in terrestrial playa settings as well as in paleo-environments on Mars.

P51B-0454 0830h POSTER

Ground-based Mid-infrared Observations of Saturn's Rings: Pre-Cassini

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We acquired data at the NASA/InfraRed Telescope Facility (IRTF) from 1995 to 2003 with MIRLIN, a mid-infrared camera at several diagnostic wavelengths in the 8- to 24-μm spectral window. Our observational program has, therefore, covered one fourth of a Saturnian year and followed the progressive march of the rings from their edge-on presentation at the equator in 1995 to their maximum opening, obscuring the northern pole of Saturn. Our specific scientific objectives were to determine the thermal inertia, temperature and opacities of the rings; and thermal asymmetries between the East and West ansae. Our preliminary results indicate that the brightness temperature of the rings peaks near 18 μm. There exists an asymmetry between the East and West ansae of few (2) degrees at low and high ring opening angles. This is similar to the near-infrared albedo asymmetry between the ansae and reflectivities at visible wavelengths. Our current efforts are aimed at modelling the ring opacities in the mid-infrared as function of changes in solar elevation angle, inclination and phase angles of the rings. These models will be validated against previous data sets acquired by Voyager and ISO; high resolution spectroscopic data with GEMINI-N; and SIRTF in preparation for Cassini data to be returned from July 2004.

P51C MCC: Level 1 Friday 0830h

Planetary Atmospheres and Dust Posters *(joint with A)*

Presiding: **H (Wang,** California Institute of Technology**; N O Renno,** University of Michigan

P51C-0455 0830h POSTER

Global Dispersal of Dust Following Impact Cratering Events on Mars

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Hypervelocity impacts on Mars inject dust and vapors into the upper atmosphere. If the particles derived from the projectile or surface are widely distributed, impact events could drive intense weather patterns and perhaps transient climate change on Mars [Segura et al., *Science* (2002)]. Recent work on small impact events (100 m-sized projectiles) find that the mass of dust stirred into the troposphere may be equivalent to global dust storms [Nemtchinov et al., *JGR* (2002)]. For ~10 to ~100 km-sized impactors, dust and greenhouse vapors may be delivered to the upper troposphere and lower stratosphere, where the long residence time has the potential for regional or perhaps even global effects on the weather. In this work, we investigate the transport mechanisms that control the dispersion of dust injected into the upper troposphere from large impact events using a high-resolution global atmospheric dynamics model [Cho & Polvani, *Science* (1996)]. The spreading rates, dispersal extent, and the potential for weather and climatological perturbations from both large (~10 km) and giant (~100 km) impactors are studied. The overarching goals in this study are to identify locations of persistent concentrations of aerosols and to estimate the smallest impact which may generate transient rainfall on Mars. From our simulations we find that modeling of the climatological response from giant, basin-forming events may assume nearly homogeneous aerosol distribution. However, understanding the atmospheric response to the more frequent, smaller cratering events requires explicit treatment of the spatial inhomogeneities caused by the atmospheric motion. Hence, 2-D or 3-D atmospheric models are needed. Intriguing flow concentrations in the southern hemisphere, which could serve as locations for storm fronts, are observed following large impacts over a wide range of conditions.

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Numerical Simulation of Martian Global Dust Storms and the Dust Cycle

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We investigate the triggering, growth, decay and the inter-annual variability of global dust storms (GDS) on Mars. To date, testing of various theories of GDS initiation and variability has been limited by inability to numerically simulate spontaneous, variable storm development from realistic pre-storm model states. Here we describe General Circulation Model simulations that generate spontaneous and variable GDSs from realistic background conditions. Modelled GDSs produce dramatic increases in atmospheric dustiness, global-mean air temperatures, and atmospheric circulation, in accord with observations. The simulations generate global storms in southern spring and summer with significant inter-annual variability in size and timing of occurrence, including years with no storms. We propose a simple explanation for the observed dust cycle on Mars from our simulations. Stresses associated with large-scale (>300 km) wind systems initiate the large storms. Explosive growth results from the intensification of the Hadley circulation and the activation of secondary dust lifting centers. Away from great storms, the annually repeatable cycle of atmospheric temperatures and dust opacities observed in northern spring and summer is a result of convective (dust devil) lifting.

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Vortex Dust Flux: Experimental Results Comparing Terrestrial and Martian Cases

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Evidence for active aeolian processes (dunes, wind-streaks, ripples, dust storms, and dust devils) on Mars have been observed by Viking, Mars Global Surveyor (MGS), Mars Pathfinder (MPF), and Mars Odyssey. Dust devils on Mars, as on Earth, are seasonally dependent and are very common in some areas, leaving both bright and dark streaks in their wakes demonstrating their ability to modify the surface. Previously, experimental work demonstrated that the dust lifting mechanism, predominantly the pressure drop (ΔP) in the dust devil core, is more efficient at lifting dust than boundary layer winds. The amount of dust that is lifted via the ΔP-mechanism (dust flux) is not well understood for Earth or Mars. This study aims to develop that understanding through experiments with the Arizona State University Vortex Generator (ASUVG) at both Earth-ambient (~1000mb) and Mars (~10mb) conditions using physical analogs for martian dust (particles ~2μm in diameter). The ASUVG generates dust-devil-like vortices through a motor-driven blade assembly positioned over a configurable test bed. Currently flux experiments have included a removable test plate that rests on an in situ balance used to measure the dust mass loss as a function of time for a ~5mm-thick bed of dust settled by suspension. Preliminary results have given lower limits on dust devil dust flux for terrestrial (~1-2 g/m^2/s) and martian (~2-4 g/m^2/s) conditions. Martian conditions yield fluxes that are ~1.5-2.0 times that of the analogous terrestrial cases. The terrestrial results are comparable to field observations made by Metzger (1999) in Eldorado Valley, NV, demonstrating the validity of using the ASUVG. Future studies intend the usage of optical systems to relate suspended dust opacity to mass in order to expand the range in sizes and speeds of vortices examined.

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Modeling Electrostatic Discharges Near the Surface of Mars

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Due to the prevalence of Martian dust devils and dust storms, an understanding of the underlying physics of electrical discharges in Martian dust is critical to future Mars exploratory missions. Mars's low atmospheric pressure and arid, windy environment suggest that the dust near the surface of Mars is more susceptible to triboelectric charging than terrestrial dust. When dust particles come into contact, charge can be transferred between the grains. Wind-driven dust studies (Stow, 1969) show that in the case of particles with identical compositions, the particle with the larger radius in a collision preferentially becomes positively charged. Upwinds within a dust cloud can carry the lighter, negatively-charged particles to higher altitudes. The stratification of particle sizes causes an electric dipole to form. When the electric potential within the cloud exceeds the breakdown voltage of the surrounding atmosphere, a discharge occurs. We have