Perspectives on the Surface-to-Atmosphere Oxygen cycle of Ganymede and Carbon cycle of Callisto

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As early as twenty years ago Yung and McElroy, [1977] speculated that water vapor sublimated from the satellite surface would be dissociated at wavelengths below 2400 A by solar extreme ultraviolet radiation and, following photochemical reaction chains based upon the chemistry of Earth's mesosphere, that liberated oxygen molecules would escape Ganymede's gravitational field if they acquired energies over 0.63 eV. This argument turns on the premise of a sufficiently collisionally thick atmosphere to maintain suspended water vapor near the Ganymede surface in a time frame longer than timescales for molecular dissociation; on the order of 27 days for water vapor at the distance of Ganymede from the sun. Yung and McElroy, [1977] estimated that in photochemical equilibrium, the Ganymede atmosphere might contain concentrations of O_2 similar to those present on Mars. Frank et al., [1997] have measured flows of H^+ escaping from the region near the surface of Ganymede at as low an altitude as 261 kilometers. This measurement suggests that the Ganymede atmosphere may be far from equilibrium. Frank et al., [1997] and Barth et al., [1997] have argued that the Ganymede atmosphere may be an exosphere populated by hydrogen which is liberated via ion sputtering of the surface. On the other hand, Noll [1996] has argued that mini-atmospheres may form within the surface matrix and liberate molecular oxygen by a slow diffusion process to form a cold, near surface atmosphere. The mechanism proposed for the creation of this emission suggests the presence of background levels of O_2. The presence of O_2 may prove to be significant since molecular oxygen does not condense at the surface temperatures of Ganymede. It is most likely that a complex coupling of mechanisms is at work. **Sublimation** and **sputtering** may liberate a host of neutrals from the surface, but the efficacy of each mechanism differs spatially and temporally. These mechanisms produce a region of thermalized neutrals near the surface which may be quickly ionized and mobilized away from the surface region by charge-exchange with particles of the surrounding plasma environment, or mobilized away from the near-surface in electron and ion dissociative recombination reactions, which impart energy to the neutrals. **Ion bombardment** of the surface which results in the production of atmospheric gases leaves behind reactive radicals HO_2 and H_2O_2 in the surface ice [Bar-Nun et al., 1985]. If the uppermost surface layers of a regolith can be regarded as the "excited skin of the subariel part of the ground", then this material seems ripe for further heterogeneous chemical processing with feedback to the atmosphere and surface. This active region of the regolith was presumed to be 20-200 μm by Noll et al., [1996].

Atmospheric chemistry, including non-thermal reactions can be considered more thoroughly by building an appropriate reaction mechanism and solving the differential equations involved. The chemical equation solver we use, CHEMK [Whitten and Hugo, 1980], has options which allow for time-dependent photolysis rates, for constant dilution of the system (transport), and for time-dependent temperature changes within an arbitrarily sized, single layer box. These features allow for the inclusion of diurnal effects and the lateral flux of molecules. As applied to Ganymede, the model accounts for diurnally varying molecular injection rates from surface sublimation as well as sputtering. The horizontal dimensions of the box are taken to be those of the grid used in the regolith model, with an arbitrary veritical dimension. Each grid section can be studied separately.

The temperature of the box corresponds to the temperature of the surface, and is constant in altitude.

Such a single layer is sufficient to gain understanding of the changing fluxes of the system for now. The model will used to examine the rates of change between constituents of the oxygen and hydrogen families. These constituents are expected to make the major contributions to cycling between water vapor and other members of the water group family. Vertical stratification of atmospheric temperature is reserved for future work. The reaction mechanism of Yung and McElroy [1977] will be modified to account for non-thermal, and surface reactions, new information on O_2 abundance from ground based studies [Hall, et al., 1998], and nominal diurnally varying injection-recondensation rates for water vapor from the sublimation model. The chemical model accounts for reactions of OH, H_2O_2, and HO_2 with the icy surface. Sticking coefficients effectively account for the adsorption of molecules with the surface. Rates for these reactions are approximated using a formulation for heterogenous reactions with atmospheric grains. Calculations will be produced for a single grid section with diurnally-varying water vapor injection rates from the surface from both sputtering and sublimation, and for a length of time which spans 2 Ganymede days. Day and night temperatures inside the box span 90 to 150°K.

A similar study will be presented for the carbon cycle of Callisto. Paricular attention will be payed to the potential for formation of graphite on the surface of Callisto. The presence of a significant layer of graphite might mitigate the need to involk a salty ocean to explain the magnetic signature measured near Callisto by the Galileo Magnetometer. Sputtering, impacts and chemistry may contribute to the fomation of a carbon layer. Electrostatic forces may contribute toward global distribution of carbon in sheet form. The Galileo NIMS instrument cannot distinguish a pure carbon signal, but NIMS does see CO2, CN, and hydrocarbons on the surface, and CO2 in the atmosphere. Processes contributing toward the formation of graphite will be examined by modifying the above model for Callisto and including carbon reactions. Preliminary result will be presented.