MODELING MICROSCALE MARS POLAR PHENOMENA RELATED TO CO_2 ICE. Tim I. Michaels

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Introduction: It is now generally understood (from decades of global-scale computer modeling work) that the details of the net energy balance of Mars’ near-polar regions (particularly near/during winter) significantly modulate the planet’s contemporary climate. Four broad categories of processes and phenomena comprise this regional energy balance near/during winter: Dynamics (atmospheric), radiative transfer, thermal conduction, and phase changes of volatile substances (carbon dioxide and water). All of these do not truly occur independently of one another, at times resulting in substantial feedback. Furthermore, these processes and phenomena occur at widely varying spatial and temporal scales, often with two-way feedbacks between the different scales. Global and regional climate models must parameterize the effects of processes and phenomena they cannot resolve. Such models for Mars are increasingly requiring more realistic parameterizations to further validate/refine their solutions in the presence of substantial quantities of relevant spacecraft observations. Perhaps the most practical method of obtaining the copious information necessary to construct a more realistic Mars parameterization is to conduct microscale simulations. Such microscale model runs are performed with quite small grid-spacings (10s to 100s of meters) and are often three-dimensional, since many phenomena that occur at such small spatial scales are significantly 3-D in nature.

Targeted Phenomena: The work discussed here involves the microscale modeling of two Mars polar phenomena that are currently unable to be tackled with a global or regional climate model: (1) carbon dioxide ice clouds (and precipitation) in the polar nights and (2) the genesis of the south polar early springtime transient small-scale albedo features (e.g., dark fans, bright streaks) present in spacecraft imagery. Observations supporting the suspected presence of clouds composed of carbon dioxide ice crystals in the lower atmosphere of Mars date to at least the early part of the Mars Global Surveyor (MGS) mission. Intriguing MOLA laser ranging results in the polar night indicate the nearly undeniable presence of populations of unidentified aerosol particles capable of reflecting or absorbing/scattering a significant portion of the near-infrared laser pulse. Furthermore, MGS radio science temperature retrievals in the polar night often exhibit regions aloft where the air temperature is significantly less than the carbon dioxide ice saturation temperature.

In the south polar region of Mars in early spring, numerous small-scale albedo features (e.g., dark fans, spots, and bright streaks) are present in spacecraft imagery. These features can change relatively rapidly (e.g., [2]), an observation that constrains potential genesis processes. The formation hypothesis proposed by [2], which entails a pressurized venting (or “jet”) of carbon dioxide gas and entrained dust through weaknesses in the overlying CO_2 ice sheet, is explored here via microscale modeling. In such a scenario, much of the dust should preferentially deposit onto the ice surface downwind of the vent site, and a bright streak originating at the vent may be due to CO_2 snowfall resulting from a jet event.

Methodology: The quasi-idealized microscale model of the Mars Regional Atmospheric Modeling System (MRAMS; [1]) is used here. Capabilities relevant to this work include non-hydrostatic dynamics, a size-resolved aerosol microphysics submodel (CO_2 ice and dust species; also subject to turbulent diffusion, advection, and gravitational sedimentation processes), and a detailed surface/subsurface model. The quasi-idealized carbon dioxide cloud simulations were initialized with a plausible thermodynamic sounding and surface/subsurface characteristics from a relevant mesoscale model (MRAMS) run. Cyclic lateral boundary conditions were employed, the vertical and horizontal grid spacings were 50 meters, and no topography was imposed. Random potential temperature perturbations of 0.1 K were imposed on the initial state at the vertical level nearest the surface. A initial mean wind (isotropic with height) of 5 m/s was also specified. The carbon dioxide jet simulations were also quasi-idealized, with cyclic lateral boundaries, and no topography. A grid spacing of 0.5 meters was employed, and the jet was initialized in varying ways as a warm, dusty mass of gas with a specified vertical velocity at the model level nearest the surface.

Preliminary Results: Carbon dioxide clouds of a convective nature are evident (dominant) in the cloud simulations, and often exhibit precipitation streamers. The carbon dioxide jet simulations exhibit many characteristics similar to the observed surface albedo features.