EFFECTS OF ATMOSPHERIC AND SURFACE DUST ON THE SUBLIMATION RATES OF CO_2 ON MARS. B. P. Bonev[1], P. B. James[1], J.E. Bjorkman[1], G. B. Hansen[2], and M. J. Wolff[3], [1]Ritter Astrophysical Research Center, Dept. of Physics and Astronomy, Univ. of Toledo, Toledo, OH 43606, USA (bbonev@kuiper.gsfc.nasa.gov; pbj@physics.utoledo.edu; jon@physics.utoledo.edu), [2]Planetary Science Institute, Northwest Division, Univ. of Washington, Seattle laboratory, Seattle, WA 98195 (ghansen@rad.geology.washington.edu), [3]Space Science Institute, 3100 Marine Street, Boulder, CO 80303-1058, USA (wolff@colorado.edu).

Introduction: We present an overview of our modeling work dedicated to study the effects of atmospheric dust on the sublimation of CO_2 on Mars. The purpose of this study is to better understand the extent to which dust storm activity can be a root cause for interannual variability in the planetary CO_2 seasonal cycle, through modifying the springtime regression rates of the south polar cap. We obtain calculations of the sublimation fluxes for various types of polar surfaces and different amounts of atmospheric dust. These calculations have been compared qualitatively with the regression patterns observed by Mars Global Surveyor (MGS) in both visible [1, 2] and infrared [3] wavelengths, for two years of very different dust histories (1999, and 2001).

Atmospheric modeling: Our approach is to model the radiative transfer through a dusty atmosphere bounded by a sublimating CO_2 surface. Although we have done some preliminary monochromatic calculations [4], our main focus has been to employ a full spectrum model, which incorporates the main effect of atmospheric dust. This is the redistribution of the radiation incident to the surface from visible frequencies to the IR. We have adapted a monte-carlo radiative equilibrium algorithm, initially developed for modeling circumstellar envelopes [5], to the case of a plane-parallel dusty planetary atmosphere. This model was introduced in a case study [1] applied to the regression of the Mountains of Mitchel, one of the brightest regions in south seasonal polar cap. This work points out that although our model atmosphere is one-dimensional, our radiation transfer code is three-dimensional and includes wavelength-dependent dust opacity, anisotropic scattering and thermal dust emission. We have used the most recently calculated dust single scattering properties for both visible and IR wavelengths [6]. An important modification of the original code, has been the treatment of anisotropic scattering in the visible spectral region, which enabled incorporating the phase function appropriate for Martian dust [7].

Surface modeling: The surface albedo spectrum is a major parameter in this study. Its accurate modeling is of primary importance and without it, the effects of atmospheric dust cannot be assessed correctly. There are a number of parameters influencing the surface albedo spectrum [8], the most important of which is the amount of *surface dust intermixed in the frost*. The amount of surface intermixed dust and water, and the grain size of the CO_2 frost, can be constrained by data from at least three spectral regions: the thermal IR near 25 microns [8], the near-IR [9], and the visible ranges of the Mars Orbiter Camera (MOC) on MGS [10]. We initially conducted a limiting case study [1] of the sublimation of surfaces with zero and very high dust content. In [11] we have examined in depth the albedo changes with surface dust-to-ice mixing ratio and CO_2 frost grain size; the variation of the albedo with photon incident angle and the dependence on the ratio of direct/diffuse incident radiation. In monte carlo calculations the albedo dependence on the direction of the reflected photons is also important. This variable has been held as a free parameter by simulating different laws of surface reflection. A good constraint of the best directional distribution of the photons reflected would enable incorporating this factor accurately into our model.

Sublimation fluxes for different amounts of atmosheric and intermixed surface dust: We have calculated sublimation fluxes (SF) for a number of combinations between the total atmospheric dust optical depth and the type of the CO_2 ice surface. The SF have been normalized to the total flux incident on the atmosphere and calculated as a difference between the spectrally integrated fluxes absorbed and emitted by the surface (set to sublimate at 147 K). An example calculation is presented on Figure 1. It corresponds to a particular grain size, but this parameter has been varied as well [11]. The main model results reproduce qualitatively the observational comparison between 1999 (relatively dust free year) and the 2001 (global dust storm) south polar cap regression patterns, observed by MGS and described in [2, 11]:

1. The absorption of surface frost with a high dust content (1 wt% being the upper limit [8]) is dominated by visual photons. Therefore the attenuation of direct solar radiation by atmospheric dust results in retarded sublimation.

2. Conversely, the absorption of regions with low dust content is dominated by IR photons, owing to the

high visual albedos. In this case the visual-to-IR redistribution of the energy incident to the surface, caused by atmospheric dust, leads to increased sublimation rates.

3. There is a wide range of combinations between surface dust content and frost grain size for which the CO_2 sublimation rates show only subtle variations with the amount of atmospheric dust load. In these cases the surface absorption is distributed equally between visual and IR wavelengths, so the overall atmospheric dust effect is not important. It should be emphasized that the discussed region of the parameter space represents a "typical frost" [8] and consequently explains the apparent insensitivity of the *average decay rate* of the south seasonal cap to dust storm activity [2]. Strong coupling between sublimation and atmospheric dust exists primarily on *local scale* for regions with "deviant" surface albedos such as the Mountains of Mitchel (high visual albedo, faster regression in 2001 [1,3]), and the "Cryptic" region [12] (low visual albedo, slower regression in 2001 [3]).

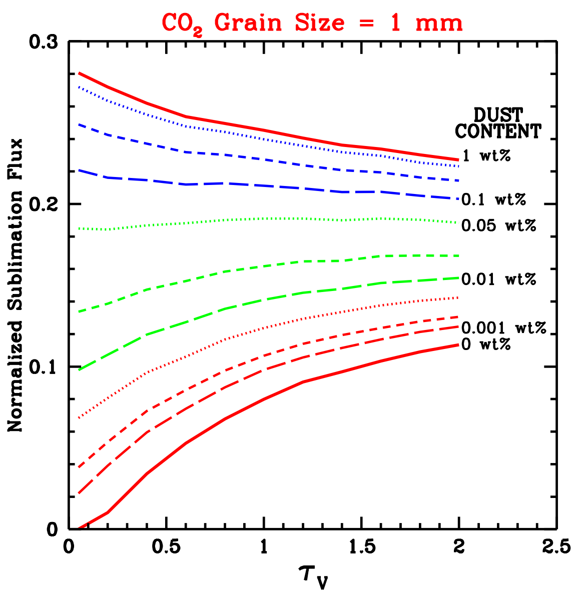

Figure 1. CO_2 Sublimation Flux vs. Total Atmospheric Dust Optical Depth at 550 nm for a frost grain size of 1 mm and various contents of intermixed surface dust.

A note should be made about the possibility that newly deposited surface dust played a role in the faster regression of bright regions (like the Mountains of Mitchel) by lowering the surface albedo and thus increasing the absorbed flux and consequently the sublimation rate. While this scenario cannot be ruled out, it fails to explain the slowing down of the dark regions such as the Cryptic region, which is consistent with the effect of atmospheric dust.

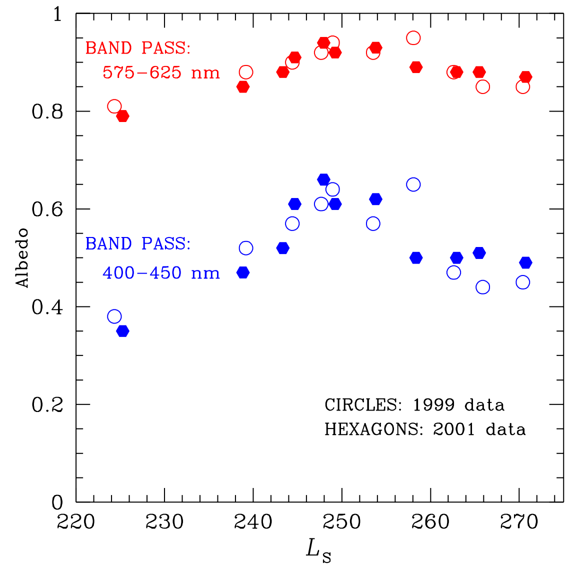

Figure 2. Top-of-the atmosphere Lambert albedos from 1999 and 2001 MOC data, averaged over a region within the perennial residual south polar cap.

In progress: In addition to the presented overview, we will discuss improvements of the atmospheric modeling, and some aspects of the study of the perennial residual south polar cap. The high maximum values of the red visual albedo of the residual cap (Figure 2) suggest small contents of intermixed surface dust and low sublimation rates at dust free conditions. The maximum values of the red and blue albedo measurements (like L_s~148^o, 1999) most likely have minimal atmospheric contribution and can be used to constrain the ice properties through models of surface albedo spectra [8]. The likely higher sublimation the cap has undergone in 1972 (Mariner 9 observations) will also be addressed.

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