THE POLAR REGIONS AND MARTIAN CLIMATE: STUDIES WITH A GLOBAL CLIMATE MODEL. R. J. Wilson[1], M. I. Richardson[2], and M. D. Smith[3], [1]Geophysical Fluid Dynamics Laboratory, Princeton, NJ 08542 (rjw@gfdl.gov), [2]Division of Geological and Planetary Sciences, MC 150-21, California Institute of Technology, Pasadena, CA 91125 (mir@gps.caltech.edu), [3]NASA Goddard Space Flight Center (Michael.D.Smith@gsfc.nasa.gov).

Introduction: Much of the interest in the polar regions centers on the fact that they likely contain the best record of Martian climate change on time scales from years to eons. This expectation is based upon the observed occurrence of weathering product deposits and volatile reservoirs that are coupled to the climate. Interpretation and understanding of these records requires understanding of the mechanisms that involve the exchange of dust, water, and carbon dioxide between the surface and atmosphere, and the atmospheric redistribution of these species. We will summarize our use of the GFDL Mars general circulation model (MGCM), to exploration aspects of the interaction between the global climate and the polar regions. For example, our studies [1] have shown that while the northern polar cap is the dominant seasonal source for water, it can act as a net annual source or sink for water, depending upon the cap temperatures and the bulk humidity of the atmosphere. This behavior regulates the annual and global average humidity of the atmosphere, as the cap acts as a sink if the atmosphere is too wet and a source if it is too dry. We will then focus our presentation on the ability of the MGCM to simulate the observed diurnal variations of surface temperature. We are particularly interested in assessing the influence of dust aerosol and water ice clouds on simulated surface temperature and the comparison with observations. Surface thermal inertia and albedo are critical boundary inputs for MGCM simulations. Thermal inertia is also of intrinsic interest as it may be related to properties of the surface such as particle size and surface character.

Model: The GFDL Mars general circulation model simulates the circulation of the Martian atmosphere from the surface to roughly 90 km [2]. The MGCM includes parameterizations for radiative transfer associated with CO_2 gas and for aerosols. An arbitrary number of aerosol populations can be transported by the simulated circulation. Dust may be injected at the surface using a prescribed rate and spatial distribution. We have recently added a dust source scheme that associates injection with resolved wind stresses and parameterized dust devil activity. This scheme allows the seasonal cycle of air temperatures and dust to match observations well at times when large-scale dust storms are not occurring. The model has also proven capable of simulating global dust storms with interannual variability in size and timing of occurrence. A potential source of memory for interannual variability is the spatial distribution of dust on the surface, as suggested by spacecraft and telescopic observations of interannual albedo variations. An ongoing line of research is considering the coupling of injection and sedimentation to the surface budgets of dust to investigate their role in interannual variability and assess net transport of dust onto the polar caps.

The water cycle is represented by surface ice and regolith water reservoirs, atmospheric transport and ice cloud formation [1,3]. The optical properties of predicted ice clouds can be passed to the radiative heating codes, allowing cloud radiative feedbacks and dust-water ice interactions to be examined.

Surface Temperature:

The daily and seasonal variation in surface temperature is a central element in the description of the martian climate. In the case of an optically thin atmosphere, surface temperature provides the bottom boundary condition that fundamentally influences the profile of overlying atmospheric temperature. The low thermal inertia of the Mars surface allows for the large seasonal variation in diurnal-mean surface temperature that reflects the seasonal migration of the subsolar latitude and the annual variation in insolation due to the eccentric orbit. We have used MGS TES surface temperatures and thermal inertia estimates [4,5] to derive thermal inertia and albedo maps suitable for use in the MGCM. It is important to note that estimates of thermal inertia must account for atmospheric opacity due to dust and water and CO_2 ice clouds. These effects are significant in the polar regions and will influence the characterization of the polar surfaces. By using relatively coarse spatial resolution compared to [4], we can more readily trade off spatial resolution for temporal resolution and relate the evolution of observed morning and afternoon temperatures (and thermal inertia estimates) to variations in atmospheric opacity.

Figure 1 shows the seasonal evolution of zonally-averaged daytime (2pm) surface temperature (contoured) from a reference simulation representing relatively clear sky conditions. There is a large seasonal variation in temperature that reflects the seasonal migration of the subsolar latitude and the annual variation in insolation due to the eccentric orbit. The advance and retreat of the polar CO_2 ice caps approximately follows the 150 K isotherm. It is apparent that very strong temperature gradients develop along the retreating edge of the polar caps as spring advances into summer in each hemisphere. These gradients likely give rise to strong local thermal wind systems that evidently are associated with observed local dust storm activity along the cap boundaries [*6*].

Figure 1 also shows the difference between zonally-averaged TES surface temperatures and those from a reference MGCM simulation. This figure clearly highlights the seasonal changes of observed temperatures that may largely be attributed to variations in atmospheric opacity. Temperature differences are minimal during the relatively clear NH spring/summer season when the atmospheric opacity assumed in the simulation most closely approximates that of the actual Mars atmosphere. The effects of a regional scale dust storm at L_s=225^o in the first mapping year and a major, planet-encircling dust storm at L_s=185^o in the second year are evident. A dusty atmosphere leads to an increase in morning temperature and a decrease in afternoon temperature.

There are systematic temperature differences in the vicinity of the polar caps. These are due, in part, to errors in simulating the polar cap latitude. Significant temperature differences are also due to the presence of dust and polar hood clouds in the vicinity of the polar caps. The aphelion season tropical water ice cloud has a clear influence on apparent tropical nighttime temperatures. We will show how simulated temperatures depend on atmospheric opacity. In a related manner, we consider how atmospheric opacity affects the determination of surface thermal inertia.

References: [1] Richardson, M. I. and Wilson, R. J. (2002) *JGR 107(E5)*. [2] Wilson, R. J. and Hamilton, K. (1996) *J. Atmos. Sci., 53*, 1290-1326. [3] Richardson, M. I., Wilson, R. J. and Rodin, A.V. (2002) *JGR 107(E9)*, 5064. [4] Mellon et al., (2000), *Icarus, 148*, 437-455. [5] Christensen et al. (2001) *JGR 106*(E10), 23823-23872. [6] *Cantor et al*. (2001), JGR 106, 23653-23687.

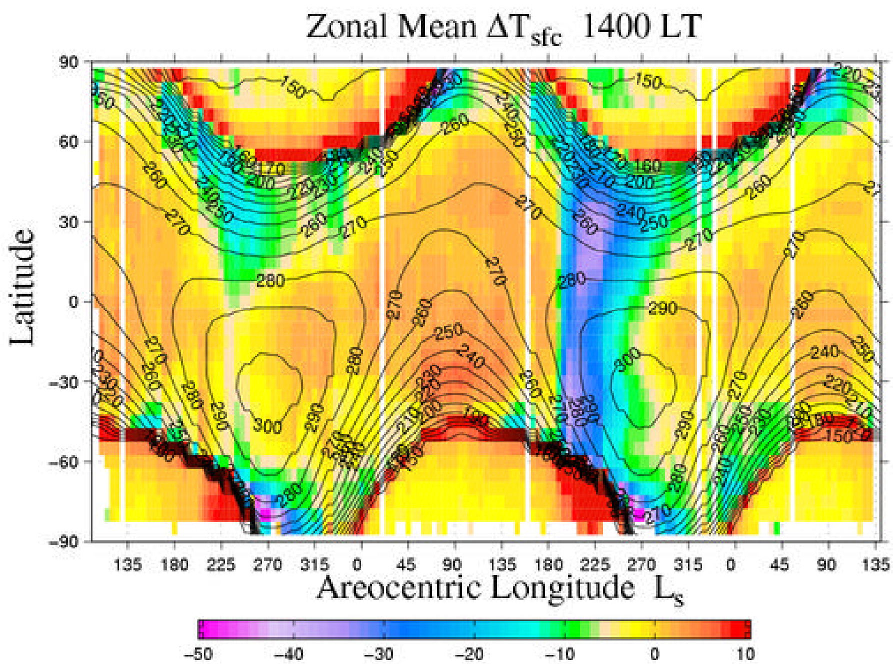

Figure 1. The seasonal evolution of zonally-averaged afternoon surface temperature anomaly derived from TES spectra. Afternoon temperatures nominally correspond to 1400 LT. Predicted surface temperatures from a MGCM simulation employing a low (τ=0.1) atmospheric dust column have been subtracted from the observed surface temperatures to highlight changes in surface temperature due to atmospheric opacity. The simulated surface temperature is contoured. A dusty and/or cloudy atmosphere leads to a decrease in observed afternoon temperature (and an increase in observed morning temperature) relative to the reference simulation. The effects of a regional scale dust storm in the first year (L_s=225^o) and a major, planet-encircling dust storm in the second year (L_s=185^o) are evident.