Examining Seasonal Trends of the Martian Polar Warming with the NASA Ames Mars Global Climate Model

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Abstract

The presented work focuses on polar warming as a diagnostic of the mean circulation to increase our understanding of processes that control the mean meridional circulation and transport in the Mars' middle atmosphere. The NASA Ames Mars Global Climate Model is utilized to isolate physical processes to determine their impact on polar warming and its seasonal trends.

1. Introduction

The meridional transport of heat, momentum, water, dust, trace species and gases is critical for the control of Mars' climate. Though the nature and structure of the mean meridional circulation has been previously studied, questions remain regarding the seasonal forcing mechanisms, and the implications on the combined thermal and dynamical response for Mars' climate. A useful diagnostic of the mean meridional circulation and transport in the middle atmosphere is polar warming.

Polar warming is a dynamically induced phenomenon that results from the compressional heating of air in the descending branch of the Hadley cell. It is characterized by a reversed (poleward) meridional temperature gradient in the mid-to-high latitudes during winter, spring, and fall. Polar warming was first observed within temperature profiles derived from Mariner 9 IRIS spectra (e.g. [3]). Since Mariner 9, there have been many thermal observations which exhibit polar warming such as; Mars Global Surveyor (MGS) /TES [12]; Mars Odyssey aerobraking (e.g. [13], [2]); Mars Reconnaissance Orbiter (MRO) /MCS (e. g. [8], [10]; [11]); and Mars Express (MEX) /SPICAM [4]. The study by [11] utilized the MRO/MCS-derived atmospheric temperatures to characterize the magnitude, structure, and seasonality of the Martian polar warming. From this study, trends in the polar warming behaviour were identified to suggest the need to further understand the complex mean meridional circulation.

2. Discussion

Observations along with numerical studies can help isolate and quantify the relative contribution and importance of various forcings. Previous numerical work has been done focusing on the contributions of water and dust and their radiative forcings, along with gravity waves, planetary (Rossby) waves, global thermal tides, and other large-scale eddies (e.g. [6], [1], [7], [9]). However, these studies were all focused on a single season. The type of systematic analysis of polar warming that was done by [11] with observations has not been done with a numerical model to understand the seasonal forcing mechanisms.

The NASA Ames Mars Global Climate Model (MGCM), which is supported by the Agency's Mars Climate Modeling Center, is utilized to enable examination of the observed polar warming trends. The MGCM now employs the NOAA/GFDL cubed-sphere finite-volume dynamical core, which has the Legacy MGCM physics implemented as described in [5].

The simulated polar warming, which is derived by the technique provided in [11], from a "nominal" MGCM set up will be compared to the [11] vertical cross-sections of MCS-derived polar warming as shown in Figure 1. Then a series of numerical simulations will be conducted to analyze the contribution from clouds, gravity waves, and radiative effects. The numerical study will provide insight into the dominate mechanisms of polar warming at specific seasons from a self-consistent simulation (i.e. not tuning processes or parameters for specific season).

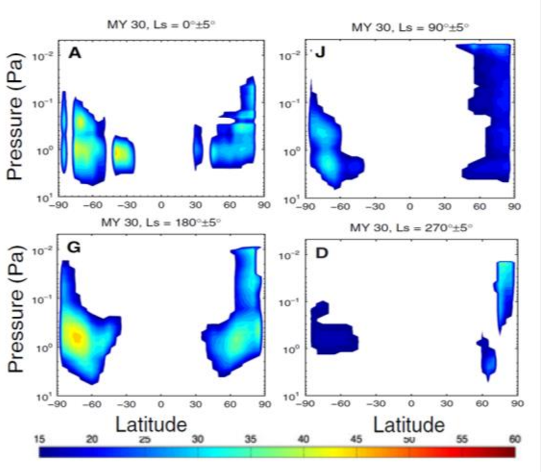

Figure 1: Vertical cross-sections of MCS derived polar warming at 10° -Ls intervals for MY 30 adopted from [11]. The color bar is in K with contours drawn every 2 K.

3. Summary and Conclusions

The mean meridional circulation (and thus polar warming) is generally forced thermally and mechanically, but the relative importance of various forcing mechanisms as a function of season is not yet known. By employing the NASA Ames MGCM, the sensitivity of the Martian middle atmospheric dynamics as a function of various physical processes such as dust, cloud formation, and gravity waves will be examined. Understanding the seasonal forcing mechanism(s) of polar warming will help discern trends of other polar phenomenon (e.g. nightglow emissions) and further, controlling processes of the net mean meridional circulation.

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