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Impact of wave modes of the polar vortices on Mars' water and dust cycles.

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Abstract

Complex simulations of the Martian climate with the GFDL Mars General Circulation Model, taking into account comprehensive treatment of water cycle and aerosol microphysics, shows that in both hemispheres, polar vortex is perturbed by regular wave modes with zonal wavenumbers changing from 1 to 4-5. Mode 3 appears to be an efficient channel of the meridional transport of tracers, that affects both water and dust cycle of the planet. Changes of leading wavenumber is likely triggered by the seasonally determined meridional shear of the zonal flow.

1. Introduction

It is well known that the Martian climate system is affected by regular perturbations known since Viking era as Tillmann transients [3]. Water cycle observation [2] also show that during the Martian year, the periods of relatively stable water vapor distribution are intermitted by strong enhancement of the meridional transport. During the aphelion season, these events are characterized by changes in the zonal structure of water vapor distribution and appearance of water ice clouds in the North polar vortex. We employ comprehensive GCM simulations of the Martian climate to study the dynamical nature of these phenomena, and compare model simulations with data obtained by OMEGA mapping IR spectrometer onboard Mars Express spacecraft.

2. The model

For the Mars climate simulations we employ GFDL Mars General Circulation model [4] that incorporates full microphysics of dust and water ice clouds, comprehensive treatment of water exchange between the atmosphere and surface, and radiative transfer model coupled with the aerosol microphysics. The microphysics of water ice clouds is implemented using a hybrid two-moment scheme with resolved size distribution and constrained by Mars Express vertical profiling of aerosols. The exchange of water between the atmosphere and surface is parameterized by a transport-diffusion model taking into account deposition of frost, as well as adsorption and crystallization of water within the regolith layer. Such a detailed treatment of climate processes allows the model to reproduce temperatures, water and dust cycles with remarkable accuracy and, along with relatively high spatial resolution of 1°×1.5°, makes it a reliable instrument for studying of the Martian climate system.

3. Results

The model systematically reproduces regular, seasonally determined changes in the wave perturbation of the zonal flows, which is revealed in various climate fields, including water vapor, clouds and dust distribution. The role of different wave modes in the meridional transport, that plays an important role in both water and dust cycles, is different.

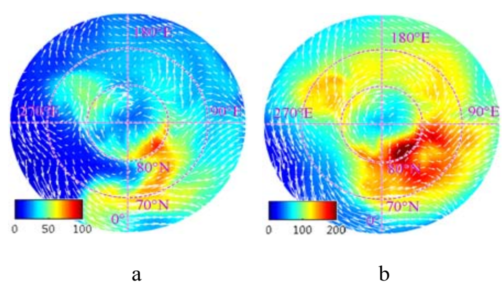

Figure 1: Water vapor column (color maps, pr. µm) and near-surface winds (arrows) according to GCM simulations. (a) Ls=93°-97°; (a) Ls=113°-115°.

Stationary wave 2 feature persists in the tropical atmosphere during the equinoctial seasons, while several times during the solstice season, a short-living wave-3 transients occur. Such transient waves provide significant enhancement of the water transport between polar reservoirs and the tropical and extratropical atmosphere, while wave-1 and wave-2 modes are associated with weak meridional transport.

OMEGA observations strongly support the hypothesis that wave perturbations play an important role in water transport. Symmetric structures associated with the imprints of the atmospheric waves are observed in different fields, including water vapor column, ice microstructure at the North permanent polar cap, and residual water ice deposits in the South hemisphere.

We interpret the model results and OMEGA observations in terms of barotropic instability of the polar vortex. Due to mode competition, the lower the meridional shear of zonal flow, the higher wavenumber dominates. On the other hand, lowering of the zonal wind speed meridional shear provides more suitable conditions for tracer transfer across the flow, i.e. in the meridional direction. Wave-3 mode may also efficiently transfer momentum resulting in transient perturbation of the general circulation. The same mechanism is likely present in the polar vortices of other planets [1]

Acknowledgements

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