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Flow associated with the Condensation and Sublimation of Carbon Dioxide Ice on Mars

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Abstract

By performing numerical experiments with a Mars general circulation model, the patterns of flow associated with the condensation and sublimation of carbon dioxide ice in the atmosphere of Mars have been interpreted.

1. Introduction

Carbon dioxide (CO_2) is the major constituent in the atmosphere of Mars. During a Martian year, the sublimation and condensation of CO_2 may result in a substantial change (up to 25%) in the total mass of the atmosphere, and so is important to the general circulation of the planet. In addition, it has been suggested that the sublimation flow near the ice cap edges may facilitate the process of dust lifting in the regions near the cap edge such as the Hellas Basin [1]. However, the patterns of the condensation and sublimation flow are not easy to be interpreted, as observational data is generally not available. A direct numerical simulation of these flows in a realistic general circulation model (GCM) is also not feasible in general. In this study, the patterns of these flows will be interpreted in an indirect way based on some numerical experiments by a Mars GCM.

2. Numerical Experiments

The GCM used is the MarsWRF [2]. The model domain has 36 x 72 grid points (horizontal resolution ~ 5 degree or 300 km), with 52 vertical layers. The model top layer is at the attitude about 80 km. The model has a radiation scheme specific to Mars [2], which has considered the heating/cooling effects of dusts and CO2. The model also includes some physical process parameterizations which are specific to Mars such as the CO2 cycle [3] and dust lifting. The parameterization of the dust process in the model includes an active dust scheme and a dust devil scheme similar to those used in [4]. The emission of dust is proportional to the surface wind stress when the stress is over a certain threshold value, while the suspended dusts may change the atmospheric radiation and so the circulation. The process of dust devils is parameterized to provide the background dust field, with amount mainly depending on the surface temperature.

The model was run for two years. The first year is considered as the spin-up period. The simulation in the second year is considered as the control simulation CTRL. Based on CTRL, some sensitivity experiments LHX5 have been performed in which the latent heat of CO_2 ice sublimation in either the northern or southern icecap is increased by 5 times starting from several chosen time instants. These are the periods when sublimation or condensation of CO_2 icecap occurs in the southern or northern hemisphere (Fig. 1). It can be shown that the effect of increasing the latent heat substantially in LHX5 is very similar to the effect of shutting down the process of sublimation or condensation.

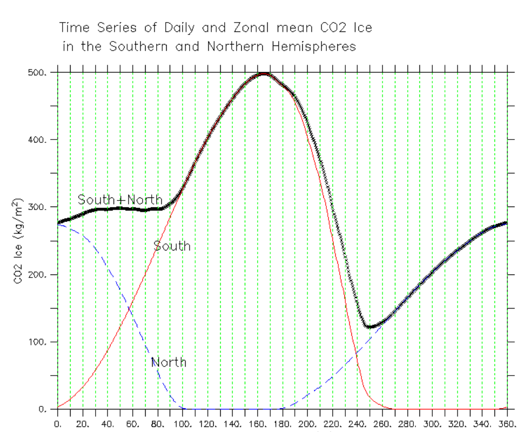
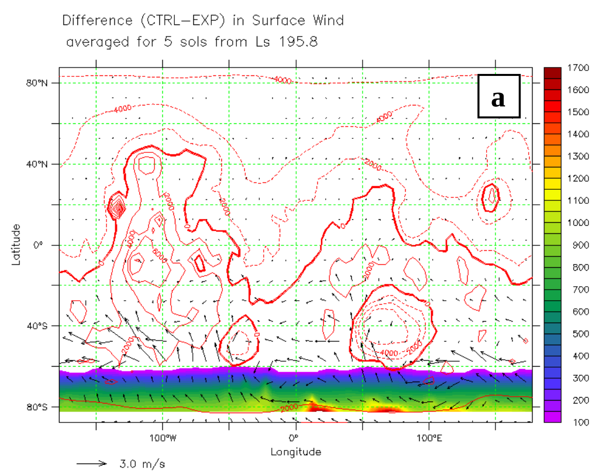


Figure 1: Seasonal variation of zonal-mean mass of CO_2 ice in the southern hemisphere (red), northern hemisphere (blue dotted) and both hemispheres (crosses) simulated in CTRL.

3. Results

The flow associated with the sublimation of CO_2 ice in the southern ice cap can be interpreted by considering the difference in the flow filed between CTRL and LHX5 after the increase in latent heat. To eliminate the signals of diurnal variation, the results averaged for 5 sols will be considered.



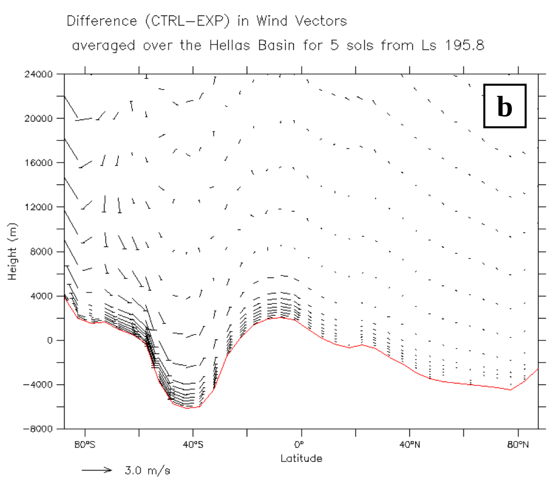


Figure 2: Five-sol mean differences in wind field between CTRL and LHX5 started at L_S = 195.8 °. (a) Surface wind field with topography in contours, and surface CO_2 ice (shading, kg m^{-2}). (b) Height-latitude profile of velocity vectors (m s^{-1}, vertical component multiplied by 100) averaged over the longitudes of the Hellas basin region.

The results of the experiments suggest that the surface wind of the sublimation flow is rather significant in the middle to high latitudes of the southern hemisphere (Fig. 2a). In fact, the sublimation flow may be rather shallow in general (Fig. 2b) except near the southern high latitude region.

It is interested to perform a similar analysis to interpret the sublimation flow at the northern icecap. The results suggest that the sublimation flow in the northern hemisphere is much weaker than that in the southern hemisphere (Fig. 3a). Compared with the sublimation flow, the magnitude of the condensation flow is generally much weaker in both hemispheres. However, the magnitude is still generally stronger in the southern hemisphere (Fig. 3b).

Acknowledgements

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4. Summary and Conclusions

The results of the numerical experiments suggest that the sublimation flow in the southern hemisphere is much stronger than that in the northern hemisphere, and the maximum magnitude of the flow is generally around L_S ~ 240 °. The sublimation flow is rather shallow and is significant mainly near the surface.

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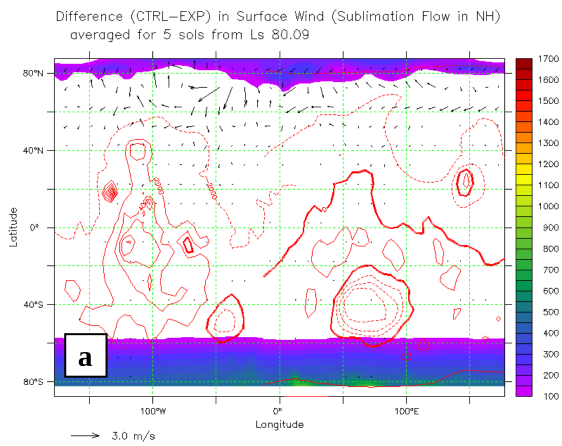

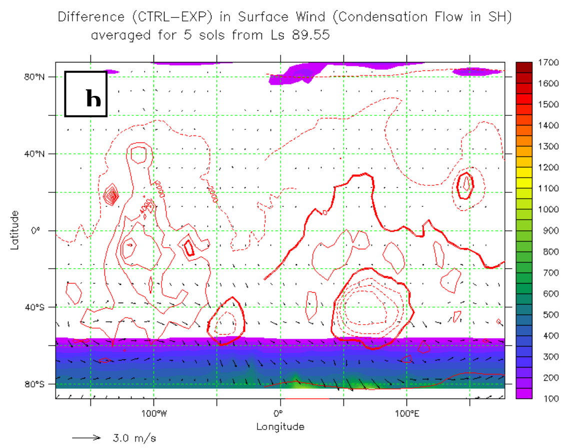

Figure 3: Similar to Fig. 2a, but for interpreting the sublimation flow in the northern icecap around L_S = 80 ° in (a), and the condensation flow in the southern icecap around L_S = 90 ° in (b).