Importance of sublimation flow on the initiation of dust storms over the Hellas basin on Mars.

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Introduction: The carbon dioxide (CO_2) cycle on Mars refers to the annual sublimation and condensation of the polar ice caps and the associated change in the mass of the CO_2 gas in the Martian atmosphere. The southern ice cap of Mars begins to sublimate near the southern spring equinox (L_S = 180°). It has been speculated that some dust lifting activities during the dust season [1] may be due to the sublimation flow in the southern hemisphere. For instance, some jet-like patterns of dust in the southern polar region have been reported in some observational studies (e.g. [2]). On the other hand, dust storms are commonly observed in the Hellas basin [3]. In particular, active generation of dust storms over the Hellas basin around the period of southern equinox has been noted in some modeling studies (e.g. [4], [5], [6]). The dust storms are usually called "Hellas storms" in these studies. By performing some numerical experiments, this study will show that the flow associated with the sublimation of the southern ice caps on Mars could be important to the generation of Hellas storms during this period.

Numerical models and experiments: The numerical experiments discussed in this study were performed by the MarsWRF model [7], which is a general circulation model of Mars developed to simulate the climate of Mars. The configuration of the model is basically the same as that used in [6]. and some important information is in the following. The model domain has 36 latitude × 72 longitude grid points (horizontal spatial resolution ~ 5 degree or 300 km in the equatorial region) and 52 vertical levels. The model top is set at about 0.0057 Pa (about 80 km in altitude) and hydrostatic dynamics has been used. Interactive dust parameterization schemes similar to that described in [4] and [5] have been adopted to simulate the regular dust climate on Mars. More detailed description of the physics parameterizations adopted in the model runs can be found in [6], which showed that the MarsWRF model with this configuration is capable of simulating reasonably well the climate of Mars, such as the thermodynamic field and dust climatology.

The model has been run for two Martian years. The first year is considered as the spin up time and the results will not be used. The second year of the simulation, which is capable of simulating the regular climate of Mars reasonably [6] is considered as the control experiment (CTRL). In CTRL, Hellas storms have been simulated in the southern equinox period around Ls = 200°. The storms usually last for a period between 2 to 5 sols.

A sensitivity experiment EXP_NCO2 has been performed to investigate the role played by the sublimation flow in the initiation of the Hellas storms. This experiment is similar to CTRL except that the process of sublimation in the southern ice cap is shut down on and after L_S = 195.7° (Sol 400), right before the occurrence of the Hellas storms.

Results and discussions: It has been discussed in [6] that the occurrence of the Hellas storms may be related to the abrupt increase in surface temperature difference between the southern edge of the Hellas basin and the ice covered region to its south, resulting in a strong thermally-direct "sea-breeze"-type flow during the southern equinox period. The results in this study show that the thermally driven flow could be not enough to initiate the Hellas storms if the sublimation flow in the southern ice cap is absent. The corresponding dust storm activities in EXP_NCO2 is much weaker compared with that in CTRL over the Hellas basin (Fig.1). This weaker dust activity is basically due to the weaker surface wind stress over the southern edge of the basin (Fig. 2).

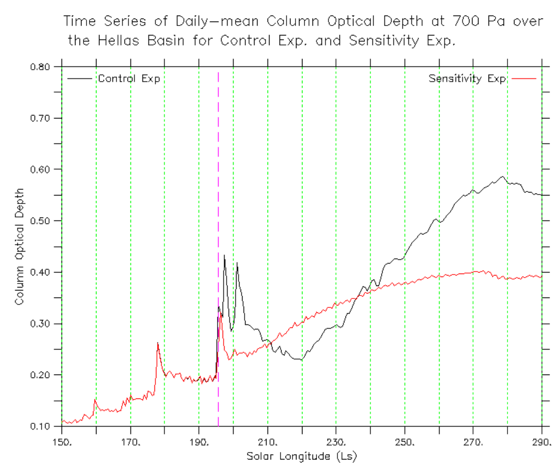

Fig. 1. Time series of column dust optical depth at 700 Pa over the southern edge region of the Hellas Basin from experiments CTRL (black) and EXP_NCO2 (red). The dotted vertical line shows the time when EXP_NCO2 begins.

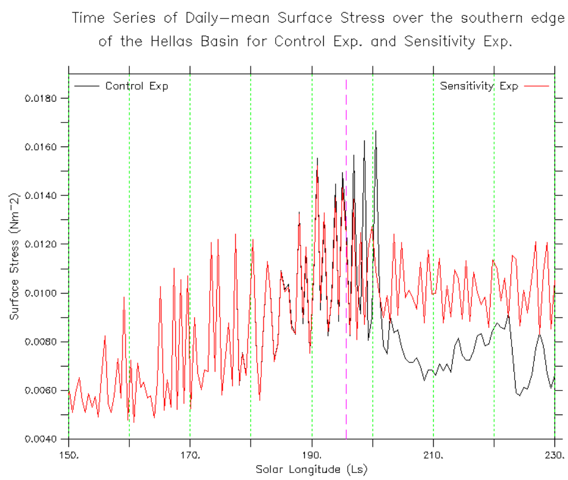

Fig. 2. Similar to Fig. 1 but for the surface wind stress over the southern edge region of the Hellas Basin.

It is also worth noting that the sublimation flow during the occurrence of the Hellas storms could be visualized by considering the difference in surface wind field between the two experiments (Fig. 3). The derived wind field suggests that during this period, the flow associated with the sublimation process is significant mainly in the southern high-latitude region, including the southern edge of the Hellas basin.

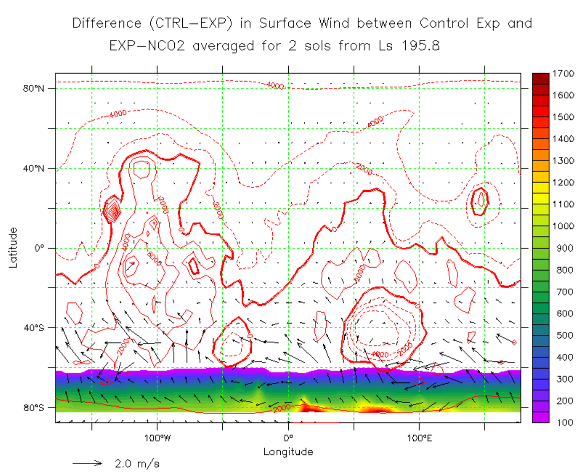

Fig. 3. Difference in near-surface wind field between CTRL and EXP_NCO2 averaged for 2 sols after the shutdown of the sublimation process in EXP_NCO2.

Acknowledgement: This research is funded by the grants from the FDCT of Macau (grant no. 119/2017/A3 and 080/2015/A3).

References:

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