ENSEMBLE SIMULATIONS OF DUST HAZE TRANSPORT ON MARS

K. Ogohara , *School of Engineering, the University of Shiga Prefecture, Hikone, Japan (ogohara.k@e.usp.ac.jp)*

Introduction:
Dust is the major source of the solar heating in the Martian atmosphere and then the transport processes of dust for a long time period should be investigated precisely for climate change researches. [1] and [2] revealed that the surface albedo on Mars had decreased for about 30 Mars years after the Viking mission. However, it is unknown whether the distribution of the surface albedo, which is a result of the dust transport in the atmosphere, is in transition or in equilibrium. Therefore, climatology of the atmospheric processes governing the dust transport in the atmosphere has to be investigated at first. [3] found five favorable regions for dust haze expansion (FRs) and revealed what kind of the atmospheric phenomena controls the dust haze transport around such regions. However, it still remains unclear whether these five FRs are also favorable for dust haze transport climatologically because they performed just a single year calculation. Thus, I specify the climatologically robust FRs in this study by ensemble simulations.

Experiment description:
Each ensemble simulation is performed in the same manner as that by [3]. Although [3] could not separate injected dust from the background dust due to the model architecture, I modify the model in this study so that I can treat the injected and background dust separately. The background dust distribution is set to that used by [4]. As shown in Figure 1, the first spin-up run started from an isothermal (220 K) condition with constant surface pressure (6.4 hPa) and no wind over the entire planet. Fifty kinds of small disturbances are added to the temperature output data of the first spin-up run. The small disturbances of temperature at each σ level are normal random numbers. The standard deviation of the distribution function is 0.01 times of the standard deviation of temperature at the σ level of the first spin-up result. The second spin-up runs are performed for 1 MY from L_s=180 independently using the 50 kinds of the output data of the first spin-up run with small disturbances as the initial data. After these spin-up runs, fifty global maps of dust haze expansion potential are made using the output data from the 50 kinds of the second spin-up runs as the initial data. I also perform a control map produced using the output data from the second spin-up run without the small disturbances. The numbers of hours in a sol and sols in a MY are set to 25 hours and 660 sols..

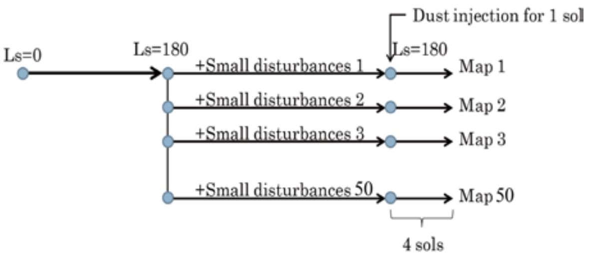

Figure 1. A schematic view of ensemble simulations in this study.

Results:
A control map: Figure 2 shows a global map of dust haze expansion potential for the control case on 3 sols after the start of dust injection. Each box indicates a location of each dust source. Each color indicates area of a dust haze injected from each dust source, which is defined as an area with the dust optical thickness (visible) of > 0.26. Favorable regions for dust haze expansion are the Arabia, the east of Tharsis, the Sirenum-Aonia region, the east of Elysium Mons and the northern Utopia. Dust hazes do not tend to expand easily in high latitudes, the Margaritifer Terra and the Hellas Basin.

Ensemble mean and standard deviation: Figure 3 shows ensemble means and standard deviations of dust expansion potential among the 50 ensemble members. Note that area of a dust haze is redefined as an area with the dust optical thickness of > 0.5. Regions with high averages and low standard deviations of dust expansion potential are ① the Arabia-

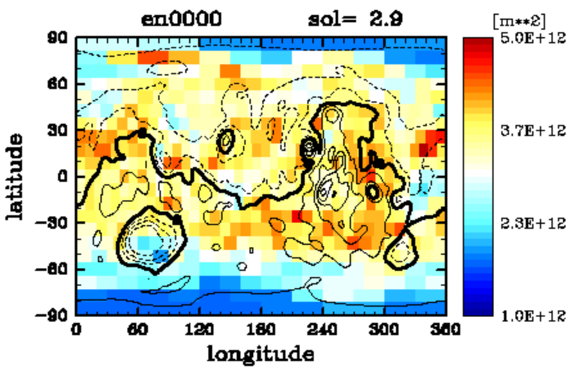

Figure 2. A global map of the dust haze expansion potential on 3 sols after the start of dust haze injection for the control case. The black contours indicate the surface height. The contour interval is 2000 m.

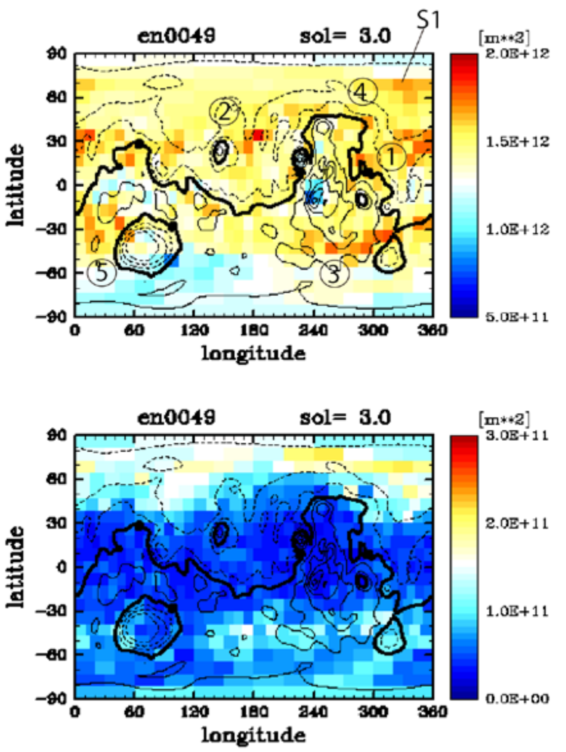

Figure 3. (top) Ensemble means and (bottom) standard deviations in dust haze expansibility among all ensemble members.

Chryse region, ② the east of Elysium Mons and ⑤ the Noachis Terra, which are robust favorable regions for dust haze transport. Dust hazes around these regions were transported widely into other areas in most of the 50 ensemble members. Therefore, actual regional dust storm initiations around these regions depend on whether a local dust haze with the horizontal scale of <1000 km is initiated or not by the mesoscale and microscale wind systems.

Regions with high averages and modest standard deviations of dust expansion potential are ③ the vast regions from the Daedalia Planum to the Aonia and ④ the Acidalia Planitia.

The two storm tracks in the northern hemisphere, the Utopia and the Acidalia, are not remarkable FRs although these were regarded as the outstanding FRs by [3]. However, dust hazes around these regions were transported widely in some ensemble members as suggested by the result that the standard deviations of expansion potential are relatively large.

Composite structures: the Acidalia storm track: Figure 4 shows a histogram of the dust haze areas on 3 sols after the start of dust injection in the case where dust is injected from S1 (Figure 3). The dust haze area does not tend to be close to the mean value and is likely to have an extreme value. As shown in Figure 5, a low pressure lies around S1 in the ensemble members where the dust haze expanded in the case of dust injection from S1. Dust was probably transported extensively since the westerly wind is relatively strong on the south of a low pressure. On the other hand, the wave number 1 component in high latitudes is weak and S1 is located on the north of the low pressure of the wave number 2 or 3 components in the case where the dust haze did not expand extensively from S1. In these cases, dust haze expansion is relatively suppressed since the westerly wind is weakened around the dust source.

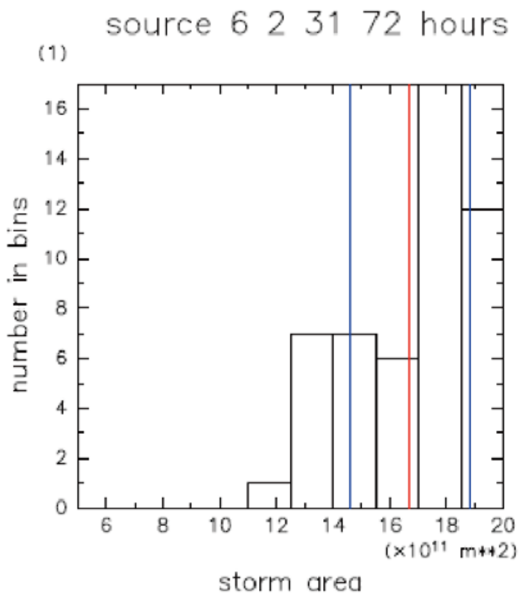

Figure 4. A histogram of the dust haze areas in the case where dust is injected from S1. The red and blue lines indicate the ensemble mean and the ensemble mean ± the ensemble standard deviation, respectively.

Summary: I have detected the climatologically robust FRs by ensemble simulations with 50 members. The robust favorable regions for dust haze expansion are 1) the Arabia-Chryse Terra, 2) the east of the Elysium Mons and 3) the Noachis Terra. The vast regions from the Daedalia to the Aonia and the Acidalia Planitia become FRs in some members. Although the northern mid-latitudes, especially the Utopia and the Acidalia, are not outstanding FRs, these regions become FRs in some ensemble members. Therefore, dust haze expansibility in these regions is probably associated with some large scale waves.

References: [1] Fenton L. K. et al. (2007) Nature, 446, doi: 10.1038/ nature05718, 646-649.

[2] Szwast M. A. et al. (2006) JGR, 111, E11008, doi: 10.1029/2005JE002485.

[3] Ogohara K. and Satomura T. (2011) ASR, 48, 1279-1294.

[4] Forget F. F. et al. (1999) JGR, 104, E10, 24155-24175.

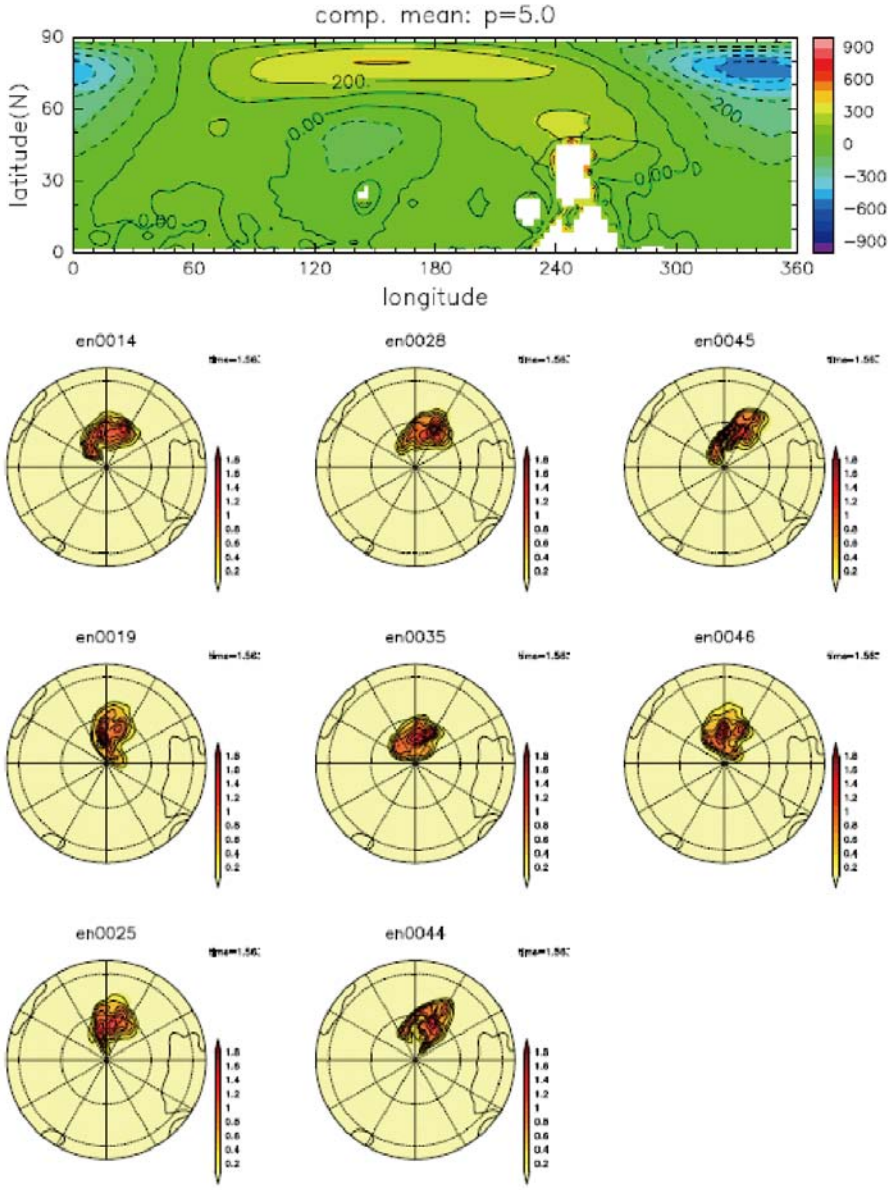

Figure 5. A composite structure of 5 hPa geopotential height in the control cases among ensemble members where area of dust haze injected from S1 becomes larger than (the ensemble mean + the ensemble standard deviation) of dust haze area. This composite structure is the time average for the first sol of the simulations. Horizontal distributions of dust optical depth of these members on 48 hours after the start of dust injection are also shown.

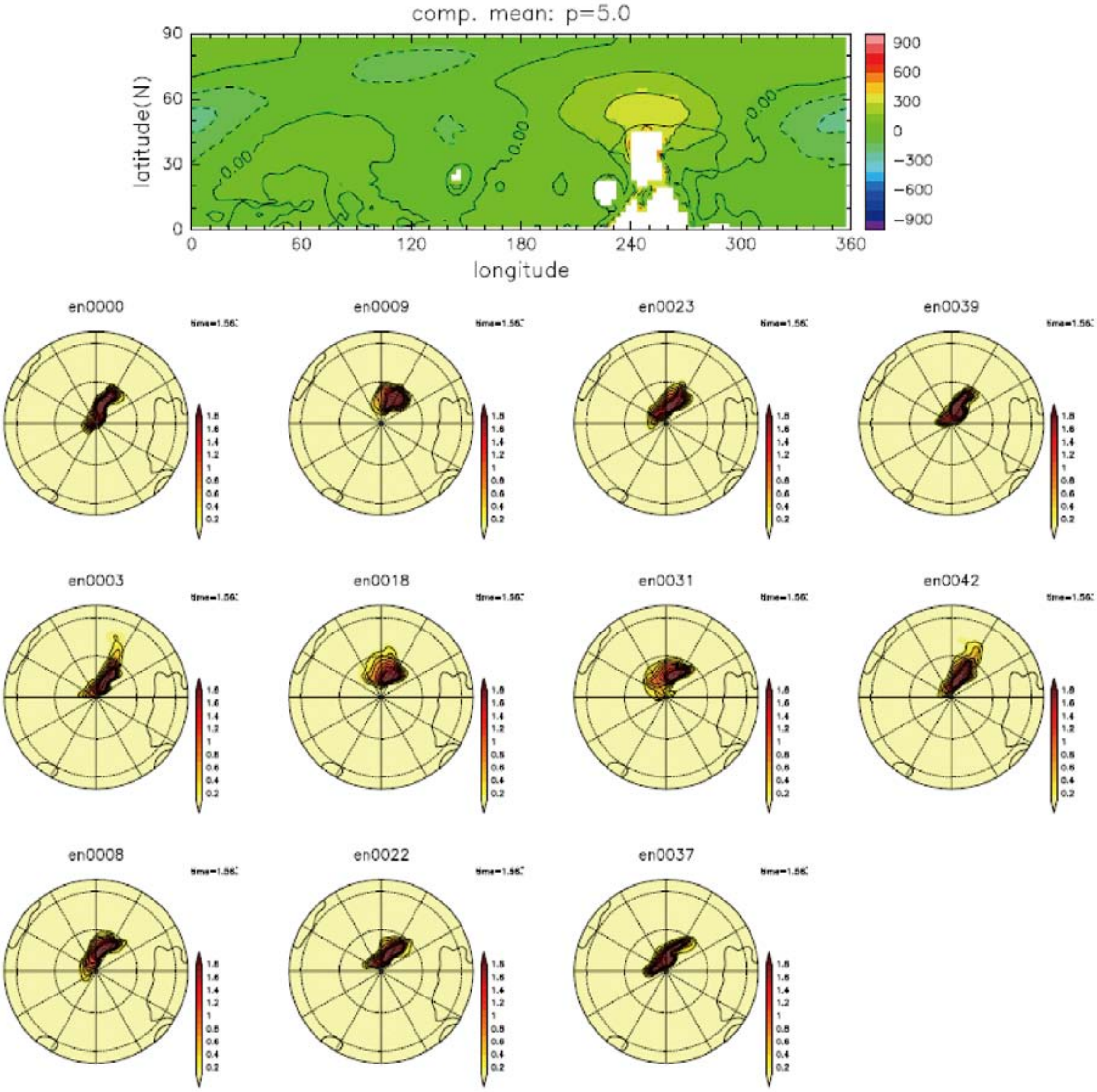

Figure 6. The same figure of as Figure 5 except for the ensemble members. They are ensemble members where area of dust haze injected from S1 becomes smaller than (the ensemble mean - the ensemble standard deviation) of dust haze area.