# SPATIAL AND TEMPORAL PROBABILITY OF DUST STORM ACITIVITY IN CHRYSE, ONE OF THE TENTATIVE LANDING AREAS OF CHINA'S FIRST MARS PROBE.

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**Introduction:** Dust storm, observed in all seasons, is one of the most momentous Mars atmosphere activities. The Entry-Descent-Landing (EDL) activity of a Martian landing mission is influenced by local atmospheric conditions, especially the dust storm activity probability. It is of great significance to know well the dust storm situation that China's first Mars mission may encounter in EDL season in the Chryse area, one of the tentative landing areas.

**Temporal probability of dust storm activity in Chryse:** The daily mean probability of dust storm activity is an extremely significant factor to Mars landing probe, due to its function of improving landing accuracy, which may be affected by severe conditions such as strong winds and dust storms. The daily mean probability $P(A)$ of dust storm activity can be given by [1]:

$$P(A)=\left\{\sum_{i=1}^{4}\frac{N(i,d)\times A(i,d)}{n(d)}\right\} \quad (1)$$

In Eq (1), $i$ is the index of the four Martian years in MGS MOC observations, $N(i, d)$ is the number of dust storms identified on a sol ($d$) of the given Mars year ($i$), $A(i, d)$ is the total dust storm area identified on a sol ($d$) of the $i$ Mars year divided by the whole study area, which is the percentage of dust storm area on the sol ($d$) of the $i$ Mars year. Four Martian years in total, $n(d)$ is the sum of dust storms identified on the same sol of four Martian years. The probability $P(d)$ of dust storms recurring on the same sol ($d$) in four Martian years can be given by:

$$P(d)=\left\{\sum_{i=1}^{4}\frac{Is(i,d)}{4}\right\} \quad (2)$$

where $Is(i, d)$ indicates whether there is a dust storm on sol ($d$) of Martian year ($i$). If dust storms occur on sol ($d$) of Martian year ($i$), the $Is(i, d)$ is 1; while there is no dust storm, the $Is(i, d)$ is 0. According to Eqs (1) and (2), the daily mean probability $P(d, A)$ of dust storm (considering both time probability and area probability) is as follows:

$$Adp\_ds=P(d,A)=P(d)\times P(A) \quad (3)$$

According to Eq (3), the daily mean dust storm activity probability in the Chryse area and within its 1600 km radius ring is shown in Fig. 1 in line with 1172 dust storms observed during MY 24-28.

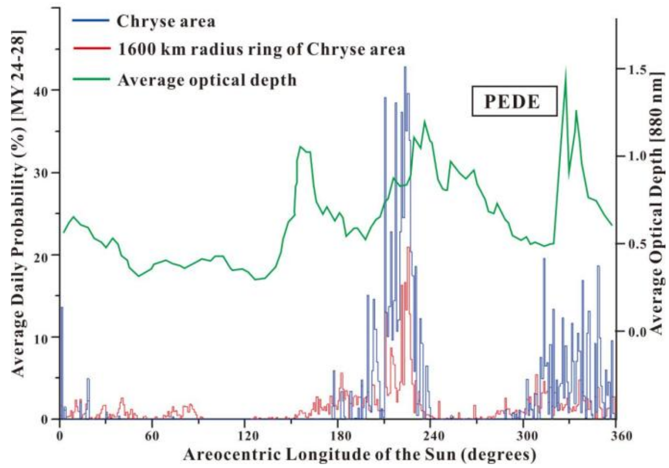


Fig.1 Daily mean dust storm frequency is proportional to Ls of the Chryse area (blue color) and within its 1600 km radius ring (red color) in 1 ° of Ls. The green curve shows the average optical depth gauged by the Spirit Rover [2] in 2.5 ° of Ls.

(1) Adp_ds in the Chryse area showing blue color and within its 1600 km radius ring showing red color peaked at 42.9% with Ls=223 ° and 20.9% with Ls=225 °, respectively. The minimum of Adp_ds in Chryse and within its 1600 km radius ring was 0. For example, during Ls=39 °-72 °, no dust storm was identified in the four Martian years' MOC MDGMs in the Chryse area.

(2) Adp_ds in the Chryse area and within its 1600 km radius ring showed obvious inhomogeneity and seasonality within a Martian year. In the Chryse area, dust storm activity was the most frequent from the northern hemisphere autumnal equinox (Ls=177 °) to the end of autumn (Ls=239 °), with an average Adp_ds of 9.5%. Another period with high Adp_ds in the Chryse area was from the northern hemisphere winter solstice (Ls=288 °) to the next spring (Ls=4 °) on Mars, with an average Adp_ds of 4.1%.

(3) The average optical depth peaked at 1.0 (Ls=160 °), 1.2 (Ls=240 °) and 1.45 (Ls=330 °), respectively. The elevated optical depth obtained by the rover was related to storm activity observations in the Chryse area and its 1600 km radius ring, except for the first peak (Ls=160 °). Chryse and the Spirit Rover were located in different parts of Mars (far away from each other), but the dust storm curves and optical depth obtained from them were similar in laws and shapes.

**Spatial distribution of dust storm activity in Chryse area:** For sake of calculating the Asp_ds in different areas, the research area was divided into regular grid, each grid side length being 0.5° in this paper. The Asp_ds in each 0.5° grid in a whole Martian year can be calculated by:

$$P(g,A,s)\,|\,Y=\left\{\sum_{i=1}^{4}\frac{N(i,g)\times A(i,g)}{n(g)}\right\}\times\left\{\sum_{s=1}^{36}\frac{Is(s,g)}{36}\right\} \tag{4}$$

While the Asp_ds in 0.5° grids during the EDL season can be calculated by:

$$P(g,A,s)\,|\,E=\left\{\sum_{i=1}^{4}\frac{N(i,g)\times A(i,g)}{n(g)}\right\}\times\left\{\sum_{s=1}^{9}\frac{Is(s,g)}{9}\right\} \tag{5}$$

Where $N(i, g)$ is the number of dust storms identified in a given grid ($g$) of the given Mars year ($i$), $A(i, g)$ is the total dust storm area identified in a given grid ($g$) of the given Mars year ($i$) divided by the given grid area, which is the percentage of dust storm area in a given grid ($g$) of the $i$ Mars year. $n(g)$ is the total number of dust storms in the given grid ($g$) of four Martian years. Martian year and the EDL season can be divided into 36 and 9 segments binned by 10° of Ls, separately. $s$ is the index of the segment, and $Is(s, g)$ indicates whether there is a dust storm on segment ($s$) of a given grid ($g$). If there is a dust storm, the $Is(s, g)$ is 1, otherwise, the $Is(s, g)$ is 0.

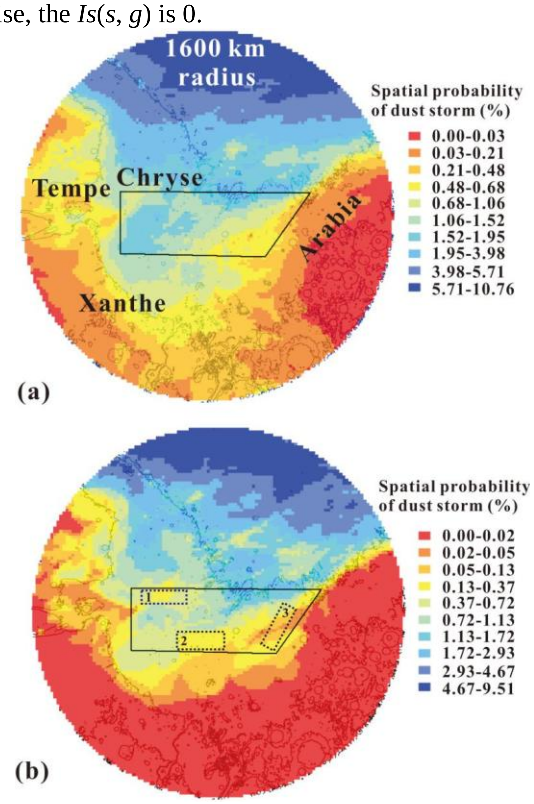


Fig.2 The dust storm activity probability in space within Chryse's 1600 km radius ring in MY (a) and EDL season (b) in each 0.5° grid. The black polygon shows the Chryse area. The dotted rectangles marked with number 1-3 are the PLAs.

(1) The Asp_ds in Chryse's 1600 km radius ring in a whole Martian year ranged from 0% to 10.8% and showed spatial inhomogeneity. Acidalia, the north of Chryse's 1600 km radius ring, was the region where dust storm activity occurred most frequently, followed by Chryse, Tempe and Arabia, the east and west of the monitoring area. The Xanthe, the south of the Chryse, was the region with the lowest Asp_ds. While in the Chryse area (black polygon), the spatial probability of dust storm activity was also nonuniform featured with the fact that the probability was lower in the west and south but higher in the east and north. The Asp_ds in the Chryse area ranged from 0.19% to 2.42%, with an average of 1.22%.

(2) Asp_ds distribution in Chryse area can be explained by three factors: topography, dust storm activity origin and routes of dust storm sequences.

(3) Taking into account the spatial probability of dust storm activity and Chryse's topography, the flat 0.5° grids with lower probability can be selected as the preferred landing areas (PLAs) for China's first Mars probe in 2020. As shown in Fig. 2b, three PLAs (dotted rectangles marked with number 1-3) were labeled. The PLA 1 and 2 were in the west of Chryse area, while the PLA 3 was in its east. The area of three PLAs was 65856 $km^2$, 84744 $km^2$ and 70242 $km^2$ with an average Asp_ds of 0.45%, 0.26% and 0.03% during EDL season in respective.

Finally, based on the dust storm activity probability in time and space in the Chryse area during EDL season, we could draw a conclusion that Ls=18°-65° can be chosen as the preferred landing time of China's Mars probe in 2021 and the three PLAs in Chryse as the preferred landing areas.

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**References:** [1] Cantor et al. (2019), Icarus, 321, 161-170. [2] Lemmon et al. (2015), Icarus, 251, 96-111.