Variability of araneiform spatial patterns at the Martian south pole. J. Hao[1], G. Michael[1], S. Adeli[2], E. Hauber[2], G. Portyankina[3], R. Jaumann[1,2], C. Millot[4], [1]Institute of Geological Sciences, Freie Universität Berlin (Malteserstrasse 74, 12249 Berlin, Germany; J.Hao@fu-berlin.de), [2]Institute of Planetary Research, Deutsche Zentrum für Luft- und Raumfahrt (DLR) (Rutherfordstrasse 2, 12489 Berlin, Germany), [3]Laboratory for Atmospheric and Space Physics, University of Colorado at Boulder, Boulder, Colorado, 80303, USA. [4]Lyon Geology Laboratory: Earth, Planet, Environment, Claude Bernard University, 69622 Villeurbanne Cedex, France.

Introduction: Araneiforms or "spiders" are suggested to form through basal sublimation of a seasonal translucent CO_2 ice slab layer and consequent gas jetting, which occurs only in the Martian southern polar regions [1-6]. Besides their confinement to the southern polar regions, limited information is available on the spatial distribution of spiders. The south polar layered deposits (SPLD) are the major host geological unit for spiders [2]. This was proposed to be the case due to SPLD's cohesive substrate material [2, 4]. However, newly-reported observations of spiders in the vicinity of dunes and crater rims which are out of the SPLD [4, 7] have shown additional locations for spiders. This suggests a variety of local settings where spiders can form, as well as a variability in the conditions of gas jetting. Often, spiders are observed occurring in groups [2, 5, 6], and exhibit non-random spatial configuration in one spider group [6]. These observations motivated us to raise the following questions: is there regional variation in the spiders' local spatial distribution? What are the possible constraints on spatial patterns? We propose that regional variations in the spatial distribution of spiders are related to regional variability of formation conditions for spiders and gas jetting. The objective of this work is to test this hypothesis.

Study regions: We selected 7 study regions in the south polar region (Fig. 1) and labeled from A to G.

Method and results: We performed a spatial randomness analysis for each region following the methodology in [6, 9]. The mean 2nd-closest neighbor distance (M2CND) was determined and then compared with the range (histogram) of M2CND values for a random configuration. M2CND can be understood as corresponding to the average spacing of spiders for each region. If the observed M2CND was found to lie near or beyond the upper extreme of the histogram, this would indicate the population is more ordered than random or non-random (Fig. 2).

The spatial distributions of spiders in the 7 study regions are non-random, as shown by the spatial randomness analysis (Fig. 2). We observe that average spider spacing differs strongly between the study regions (Fig. 1). Region A and B show the smallest distances between individual spiders (55 and 60 m), while region G exhibits the largest (341 m). Intermediate average spacings occur in region C, D, E and F (145~190 m). The average spacing (M2CND) was observed to correlate with spider size (Fig. 3): spiders in regions of larger M2CND are generally larger.

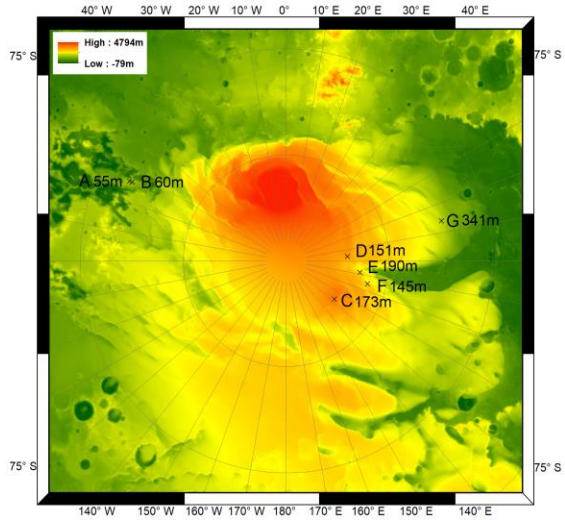

Fig. 1. Geographical locations of 7 study regions at the Martian south pole. The numbers after the region names indicate the average spacing (M2CND) between spiders. Background: MOLA DEM with 115m/pix [8].

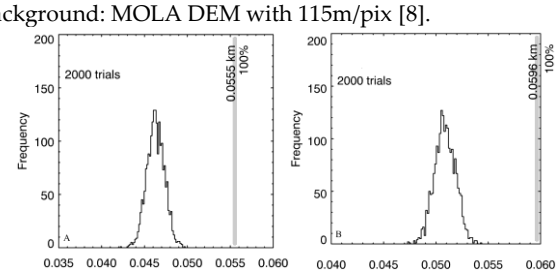

Fig. 2. Two examples (region A and B) of spatial randomness analysis. Histogram and gray bar represent 2000 iterations of a random configuration and observed M2CND (the value is marked on the gray bar), respectively. The X-axis is in unit km. The two percentages indicate two observed M2CND lie outside the histograms in the 100th percentile, i.e., far beyond the histograms.

Several possible parameters may be related to spider formation and spatial configuration. Spider formation process is mainly influenced by (1) properties of the substrate (e.g., permeability, cohesion and porosity) and (2) properties of the seasonal CO_2 ice layer.

(1) When the CO_2 gas moves through the porous substrate [6, 12], its flow is controlled by substrate properties, i.e., **permeability, cohesion and porosity** [13-17]. Regional differences in these properties will thus result in differences in pressure gradients and govern how CO_2 gas moves through and erodes the porous

substrate. In turn, several parameters influence properties of the substrate. **Particle size and shape** of the substrate material are closely related to the substrate permeability and porosity [18-20]. **Water ice content** beneath the seasonal CO_2 ice also has influence on substrate permeability, cohesion and porosity. A dry porous surface layer with depths from few millimeters to meters is generally supposed to overlie a layer rich in water ice [10, 11]. Spider troughs may or may not reach into the water ice-containing layer that has different properties from the dry layer.

(2) **Thickness** and quality of seasonal CO_2 ice layer partly determines the insolation needed to cause basal sublimation and controls the efficiency of the "sealing" layer to retain pressure beneath the CO_2 slab ice layer. The larger the pressure before the jet eruption the stronger abrasive power the under-ice gas flow possesses.

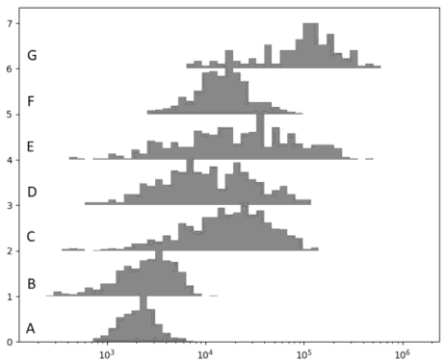

Fig. 3 Histograms for spider sizes in each region with log X-axis. X-axis indicates spider size in m² (spider size is defined as the area of the polygon formed by connecting the ends of each branch of a spider). Y-axis indicates normalized frequency.

Discussion and conclusions:

Thermo-physical modeling shows that a translucent CO_2 ice slab can be formed, CO_2 sublimating gas can be trapped in the substrate, and sufficient pressure can then be accumulated to create gas jetting that mobilizes substrate material [12]. These are necessary formation conditions for spiders. We discuss roles of the above-mentioned factors in these processes to explore possible constraints for spider spatial distribution.

(a) Permeability, cohesion and porosity influence the gas flow rate (permeability and cohesion), and trapped gas amount (porosity). Thus, we suggest they are key controls on the spatial configuration of spiders (permeability and porosity), and also have an influence on spider morphology (permeability, cohesion and porosity). Porosity has a role through its influences on permeability. Either one or any combination of them may contribute to the observed regional variation of average spacing between spiders (Fig. 1).

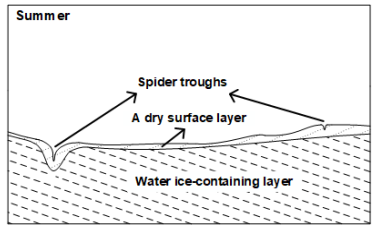

Fig. 4. The schematic of possible locations of spider troughs and layers at the south polar area.

For example, one explanation for our observations in Fig. 3 may be: smaller M2CND (average spacing of a spider population) may suggest lower permeability which possibly causes spiders with radially shorter troughs and smaller sizes. Hence, variation of permeability could be accountable for regional variation of average spacing presented in Fig. 1.

(b) A very thick CO_2 ice layer may suppress basal sublimation and resist fracturing. If it is very thin, the released gas is not sufficiently pressurized for gas jetting. Therefore, only a narrow range of **thicknesses of the seasonal CO_2 ice layer** may be optimal for spider formation. This might explain why spider distributions are confined to restricted locations rather than found everywhere. Within this range, a thinner CO_2 ice slab may favor smaller spiders, with smaller spacings.

(c) Since the depths of spider trough depths range from centimeters to meters [5, 21], spider troughs could be within the dry layer or descend to approach the water ice-containing layer (Fig. 4). In the latter case, water ice that is closer to the trough surface could sublimate away faster under the insolation [5]. We expect the water ice-containing layer to retreat to a certain depth beneath the trough leaving a dry surface layer that is locally deepened (and incised) (Fig. 4). Thus, we believe that the water ice content in the substrate probably does not act to inhibit spider formation. Sublimation of water ice may be very slow, spider erosion is possibly at the same rate scale.

References:

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