ELONGATED CLOUDS ON MARS. A GLOBALLY AND YEARLY WIDE EXPLORATION. J. Hernández-Bernal[1], A. Spiga[1], A. Sánchez-Lavega[2], T. Río-Gaztelurrutia[2], F. Forget[1], E. Larsen[2], D. Tirsch[3], A. Cardesin-Moinelo[4], M. Crismani[5], K. Connour[6], N. Schneider[6], and M. Wolff[7]. [1] Laboratoire de Météorologie Dynamique, Sorbonne Université, Paris, France (jorge.hernandez-bernal@lmd.ipsl.fr), [2] University of the Basque Country (UPV/EHU), Bilbao, Spain, [3] German Aerospace Center (DLR), Institute of Planetary Research, Berlin, Germany, [4] European Space Astronomy Centre, ESAC, [5] Department of Physics, California State University, San Bernardino, CA, US, [6] Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, US, [7] Space Science Institute, Boulder, CO, USA.

Introduction: Characteristic clouds on Mars exhibiting an elongated (long and narrow) shape have been reported in the literature: the Perihelion Cloud Trails (PCTs) [1,2], and the Arsia Mons Elongated Cloud (AMEC) [3,4]. These clouds have been observed in southern tropical and midlatitudes during the perihelion season. In this work we use a combination of instruments that provide synoptic images to explore the apparition of elongated clouds resembling the AMEC and the PCTs on Mars, beyond the perihelion season and the aforementioned latitudes.

Instruments: For the first time, this work brings together the 3 instruments that currently operate on Mars and are able to obtain synoptic full-disc images: MEX/VMC, MAVEN/IUVS, and EMM/EXI. Full-disc images provided by these instruments are complemented with semi-global higher resolution images obtained by MEX/HRSC and MRO/MARCI. All these instruments together provide a comprehensive coverage of all latitudes, longitudes, seasons (Solar Longitude; Ls), and local times (LT).

Seasonal an latitudinal distribution: Our exploration reveals new cases of elongated clouds resembling the AMEC and the PCTs that are present in other latitudes and seasons (some of which were preliminary reported in [5] and [6]). New cases of elongated clouds (Fig. 1) include: elongated clouds on Ascraeus and Pavonis Mons during the perihelion season (same latitudes and season as the PCTs and the AMEC); elongated clouds at the Tharsis volcanoes during the aphelion season; and elongated clouds in northern and southern midlatitudes during the local autumn and winter (when the polar vortex dominates winds).

The global distribution of these clouds is very connected to the direction and strength of zonal winds (Fig. 1), the predominant direction of elongated clouds tends to follow the seasonal zonal winds, and this enables a simple classification into two big categories: 1. Elongated clouds entrained in the polar vortex, and 2. Tropical elongated clouds.

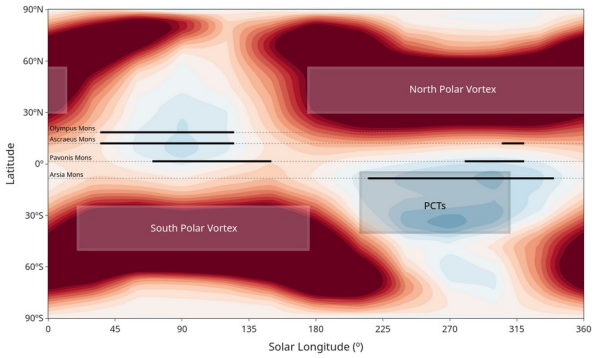

Fig. 1. Latitude-Ls distribution of elongated clouds. Background represents zonal winds Blue: Eastward winds. Red: Westward winds) as extracted from MCD (Mars Climate Database). Squares and thick lines represent the observed occurrence of elongated clouds (Color of lines or square borders. Black: Westward. White: Eastward). Specific cases of elongated clouds not following predominant zonal winds are not represented in this graph.

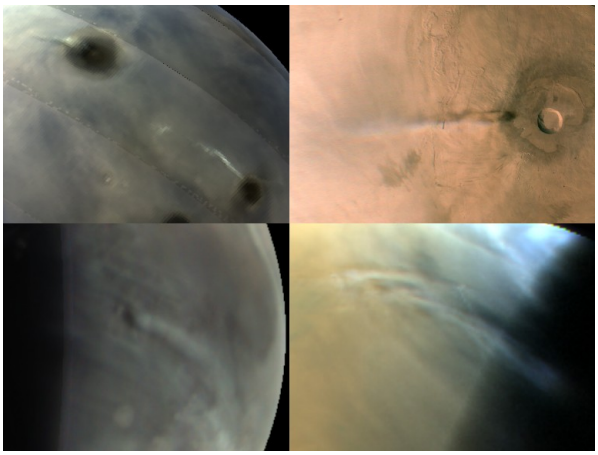

Fig. 2. Some examples of elongated clouds. Upper-left: Ascraeus and Olympus Mons in the morning during the aphelion season. Upper-right: Pavonis Mons in the afternoon in perihelion season. Bottom-left: Area of Thaumasia region as part of the South Polar Vortex. Bottom-right. Phlegra Montes during the aphelion season.

Polar vortex elongated clouds tend to form in orographic obstacles, they expand to the East following zonal winds, and at first sight are present at all LTs.

Some outstanding locations where these clouds form are Alba Mons, Lyot crater, and the peaks of the region of Thaumasia. These clouds are often connected to the Polar Hoods and in some cases their expansion direction differs by a few degrees from the expected wind direction, suggesting dynamics more complex than advection.

Tropical elongated clouds form predominantly in the seasons around solstices, when zonal winds to the West are especially strong in these latitudes. They can be classified in PCTs [2], which happen at various locations in the perihelion season, and Tharsis elongated clouds, which originate on the big volcanoes both in the aphelion and perihelion season. These clouds display clear dependencies with LT. Some clouds with elongated shapes extending in non-zonal directions have been observed, especially on Tharsis volcanoes.

Physical mechanisms and terrestrial analogues: Interestingly, visually similar clouds have also been observed at various locations on Earth, and their source mechanisms are in some cases complex and not fully understood (for example [7,8,9]). The fact that all these clouds on Mars and those on Earth are visually similar does not mean that their source physical mechanisms are the same. We intent to explore the various potentially possible source mechanisms behind these clouds. Explaining how a mesoscale perturbation generated by local topography can propagate downwind for hundreds and thousands of kilometers is not always straightforward and it might provide new insights into the connection between the mesoscale and the global circulations.

References:

[1] Clancy, R. T., Wolff, M. J., Cantor, B. A., Malin, M. C., & Michaels, T. I. (2009). Valles Marineris cloud trails. Journal of Geophysical Research: Planets, 114(E11).

[2] Clancy, R. T., Wolff, M. J., Heavens, N. G., James, P. B., Lee, S. W., Sandor, B. J., ... & Spiga, A. (2021). Mars perihelion cloud trails as revealed by MARCI: Mesoscale topographically focused updrafts and gravity wave forcing of high altitude clouds. Icarus, 362, 114411.

[3] Hernández-Bernal, J., Sánchez-Lavega, A., del Río-Gaztelurrutia, T., Ravanis, E., Cardesín-Moinelo, A., Connour, K., ... & Hauber, E. (2021). An extremely elongated cloud over Arsia Mons volcano on Mars: I. Life cycle. Journal of Geophysical Research: Planets, 126(3), e2020JE006517.

[4] Hernández-Bernal, J., Spiga, A., Sánchez-Lavega, A., del Río-Gaztelurrutia, T., Forget, F., & Millour, E. (2022). An extremely elongated cloud over Arsia Mons volcano on Mars: 2. Mesoscale modeling. Journal of Geophysical Research: Planets, 127(10), e2022JE007352.

[5] Hernández-Bernal, J. (2022). Meteorological Phenomena on Mars studied with Mars Express VMC images. [Doctoral dissertation, Universidad del País Vasco / Euskal Herriko Unibertsitatea, UPV/EHU]. http://hdl.handle.net/10810/59472

[6] Sánchez-Lavega, A., del Río-Gaztelurrutia, T., Spiga, A., Hernández-Bernal, J., Larsen, E., Tirsch, D., ... & Machado, P. (2024). Dynamical phenomena in the Martian atmosphere through Mars Express imaging. Space Science Reviews, 220(1), 16.

[7] Jiang, Q., & Doyle, J. D. (2006). Topographically generated cloud plumes. Monthly weather review, 134(8), 2108-2127.

[8] Dethleff, D. (1994). Polynyas as a possible source for enigmatic Bennett Island atmospheric plumes. AGU (American Geophysical Union).

[9] Kirshbaum, D. J., & Fairman, J. G. (2015). Cloud trails past the Lesser Antilles. Monthly Weather Review, 143(4), 995-1017.