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Seasonal cycle of methane on Mars could be produced by variations of the Hadley cell and differential hemispheric releases

Jorge Pla-Garcia^{1,2}, Scot C.R. Rafkin³, Christopher R. Webster⁴, Paul R. Mahaffy⁵, Özgu̇r Karatekin⁶, Elodie Gloesener⁶, and John E. Moores⁷

¹Centro de Astrobiología (CSIC-INTA), Instituto Nacional de Técnica Aeroespacial (INTA). Department of Space Instrumentation, Torrejon de Ardoz, Spain (jpla@cab.inta-csic.es)

²Space Science Institute, Boulder, CO 80301, USA

³Southwest Research Institute, Boulder, CO 80302, USA

⁴NASA Jet Propulsion Laboratory, Pasadena, CA 91109, USA

⁵NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

⁶Royal Observatory of Belgium

⁷Centre for Research in Earth and Space Science (CRESS), York University, Toronto, On M3J 1P3, Canada

The detection of methane at Gale crater by the Curiosity rover has garnered significant attention because it could be a signal from Martian organisms [Webster et al., 2015]. Although it is difficult to reconcile the measured peaks with the modeled transport and mixing unless invoking an unknown rapid destruction mechanism from the lower atmosphere before it spreads globally, the observed low background levels can be reproduced by the model under some circumstances [Pla-Garcia et al. 2019]. It appears to be a seasonal cycle in the background methane concentrations at Gale [Webster et al., 2018]. If ground temperature controls the release of methane on seasonal timescales then the methane flux should be higher during warmer seasons. Methane clathrates are one example where this mechanism could operate, assuming that clathrates could be preserved due to slow dissociation and diffusion rates. The rover weight effect on the soil could also favor the dissociation of these clathrates. Temperature-dependent metabolism of methanogens is another example. MRAMS [Rafkin et al., 2002] is used to study what the role of atmospheric transport and mixing may play in the seasonal cycle. An initial state mimicking the detection by [Mumma et al., 2009; M09] provides one scenario to explore how a large, methane-enriched air mass would be transported, mixed and diffused into the topographically complex Gale region. In order to characterize changes to seasonal transport, simulations were conducted with a continuous surface methane release at three key seasons: Ls155, when the high methane values by M09 were reported; Ls270 when there is a wholesale inundation of the crater by external air [Rafkin et al., 2016]; and Ls90, which is representative of the rest of the year. Ls155 has the highest methane values compared to other MRAMS scenarios. Around the equinoxes, the rising branch quickly crosses from one hemisphere into the other with individual Hadley cells in each hemisphere. Surface winds at the tropical location of Gale converge and help to contain and circulate methane-rich air from M09 release area. In contrast to the equinox, the mean meridional winds are northerly at Ls270 and southerly at Ls90 with no large-scale convergence of air in the

tropics. An additional global tracers experiment, with 18 instantaneous tracers distributed three-dimensionally all over the martian atmosphere was performed to confirm the previous transport results and to highlight the difference emission of methane between hemispheres. The seasonal change in the global circulation combined with seasonal changes in the hemispheric release of methane could produce a seasonal methane signal at Gale. If there is a correlation between methane release and ground temperature, then one would expect a strong correlation between the local atmospheric methane value and the ground temperature in the absence of any transport. This is what was noted by [Webster et al., 2018], except during Ls216-298, when very high latitude northerly air penetrates into Gale. The air in Gale during this season is more representative of a source air mass deep in the northern hemisphere where it is cold and depleted in methane