Seasonal variations of the Hadley cell and differential hemispheric methane release could drive the seasonal methane cycle on Mars. J. Pla-García[1,2], S.C.R. Rafkin[3], C. R. Webster[4], P. R. Mahaffy[5],O. Karatekin[6], E. Gloesener[6] and J. E. Moores[7]; [1]Centro de Astrobiología (CSIC-INTA)jpla@cab.inta-csic.es; [2]Space Science Institute; [3]Southwest Research Institute; [4]NASA Jet Propulsion Laboratory; [5]NASA Goddard Space Flight Center, [6]Royal Observatory of Belgium; [7]Centre for Research in Earth and Space Science (CRESS)

Introduction: The detection of methane at Gale crater by the TLS-SAM instrument aboard the Curiosity rover has garnered significant attention because it could be a signal from Martian organisms [1]. Neglecting the spikes of concentration, there appears to be a seasonal cycle in the background methane concentrations at Gale crater [2]. The mean value is ~0.4 ppbv (compared with 1.8 ppmv on Earth, the background methane content at Gale crater is 4,500 times less) and ranges from a minimum about 0.3 ppbv near the northern summer solstice to a maximum of 0.7 ppbv sometime between the northern autumn equinox and the winter solstice. 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. Temperature dependent metabolism of methanogens is another example. Also, our colleagues on the MSL team (Christina Smith, John E. Moores and co-authors) show in their LPSC2019 abstract that seasonal variation in TLS-SAM data can be satisfactorily replicated with a diffusive-adsorptive model if sub-surface seepage is permitted through the regolith.

Method: The Mars Regional Atmospheric Modeling System (MRAMS) 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 [3] (hereafter 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 (1.8 kg $m^{-2}s^{-2}$) 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 crater air season [4, 5]; and Ls90, which is representative of the rest of the year. The imposed methane flux rate is based on theoretical estimates from clathrate [reference]. Different emission rates from any process may be easily considered by post facto scaling of the atmospheric methane abundance predicted in the simulations.

Results: Ls155 has the highest methane values compared to other MRAMS scenarios (Figure 1). Around the equinoxes (Ls0 and Ls180), 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 (Figure 2, left) that 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. Furthermore, the source of the air at Gale at Ls270 is found to be from deep within the cold northern high latitudes. The source air at Ls90 emanates from more modest latitudes of the southern hemisphere (SH) with properties similar to those in Gale. An additional global tracers experiment, with 18 instantaneous tracers distributed three-dimensionally all over the martian atmosphere is being performed to confirm the previous transport results and to highlight the difference emission of methane between hemispheres.

Discussion: 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 [2], 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 (NH) where it is cold and depleted in methane. In contrast, the source air in Gale at other seasons is more tropical in nature, because the general circulation does not transport air from deep in the southern high latitudes.

. Short term spikes in methane abundance could result from nearby and perhaps even ubiquitous releases, but the fast destruction mechanism could keep the global methane abundance within the surface observed range. The incoming TGOhigh resolution observations will help to validate the MRAMS results.

References: [1] Webster, C. R. et al. (2015). Science, 347(6220). [2] Webster, C. R. et al. (2018). Science, 360(6393). [3] Mumma, M. J. et al. (2009), Science, 323(5917). [4] Pla-Garcia, J. et al. (2016), Icarus, 280. [5] Rafkin et al. (2016), Icarus, 280.

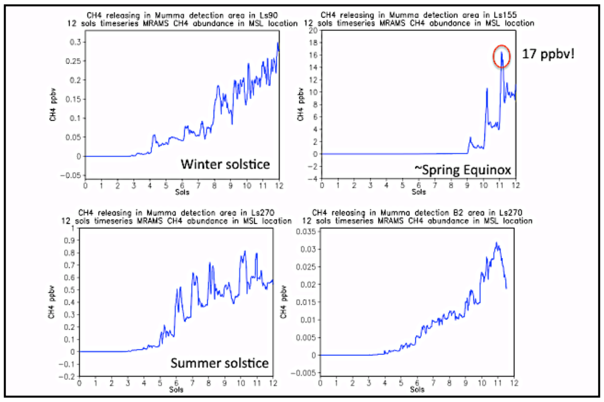

Figure 1. Twelve-sol timeseries of MRAMS methane abundances sampled at the MSL Curiosity rover location for a steady-state methane emission at the M09 detection location (> 3,000 km away from Gale) forLs 90 (top left), Ls 270 (bottom left), Ls270 over a M09 limited area (B2) (bottom right) and Ls 155 (top right). Ls155 has the highest CH4 values compared to other MRAMS scenarios because is approaching to the spring equinoctial global wind period.

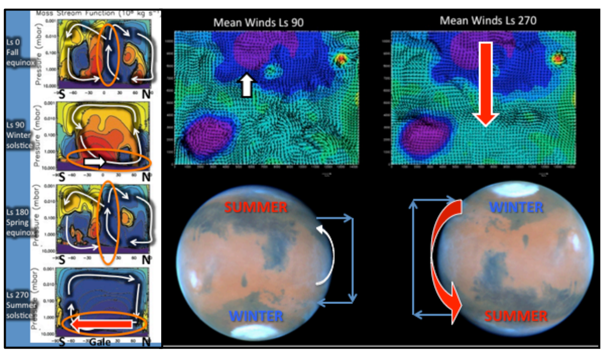

Figure 2.Methane enrichment measurements (black squares with sol numbers) compared with REMS maximum ground temperature (colored circles) as a function of areocentric longitude (Ls). Symbol color denotes Mars year. The seasonal change in the global circulation combined with seasonal changes in the hemispheric release of CH4 could produce a seasonal CH4 signal at Gale. Adapted from Webster et al. (2018)

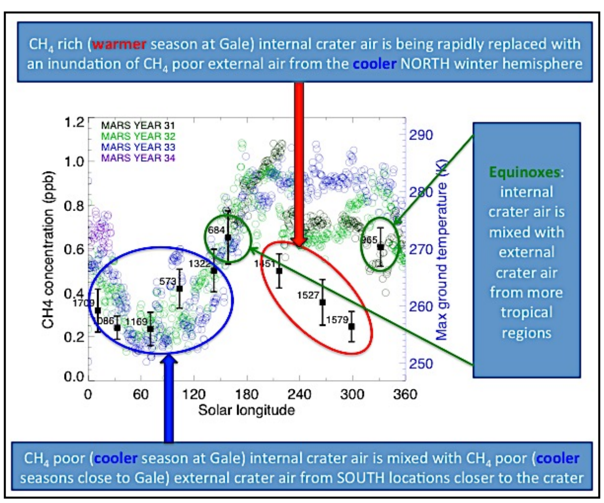

Figure 3. Methane enrichment measurements (black squares with sol numbers) compared with REMS maximum ground temperature (colored circles) as a function of areocentric longitude (Ls). Symbol color denotes Mars year. The seasonal change in the global circulation combined with seasonal changes in the hemispheric release of CH4 could produce a seasonal CH4 signal at Gale. Adapted from Webster et al. (2018)