Numerical simulations of the possible atmospheric origin of Martian perchlorate

Conference or Workshop Item

NUMERICAL SIMULATIONS OF THE POSSIBLE ATMOSPHERIC ORIGIN OF MARTIAN PERCHLORATE.

M. K. D. Duffy, S. R. Lewis, N. J. Mason, *Department of Physical Sciences, The Open University, Milton Keynes, UK (m.k.d.duffy@open.ac.uk)*, **F. Lefèvre,** *Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS), Paris, France*, **F. Forget,** *Institut Pierre Simon Laplace Laboratoire de Météorologie Dynamique (LMD), Paris, France*.

The first detection of perchlorate salts in the Martian regolith was made by NASA's Phoenix Mars lander in the northern polar plains [1, 2]. Perchlorate salts are important as they can lead to the formation of brines [3], are a possible energy source for microbes [4] and can be used as a marker for climate change from wet to dry conditions [5, 6]. There is currently no known mechanism of perchlorate production on Mars though an atmospheric chemical pathway resulting in perchlorate has been proposed [6,4].

The pathway requires a source of gaseous chlorine. On Mars the most likely source of such a gas is gaseous hydrogen chloride (HCl) evolved from volcanic vents [7]. HCl has not yet been detected in the Martian atmosphere though several campaigns have attempted a detection [8, 9]. The observations have given an upper limit of HCl volume mixing ratio of 200 parts per trillion, however this is a disk averaged mixing ratio and so a larger mixing ratio can still be present in a transient event more characteristic of volcanism.

This study uses the UK version of the LMD MGCM, the model shares the same physical packages as the LMD MGCM [10, 11] but uses a spectral dynamical core and semi-lagrangian advection scheme [12, 13]. The LMD photolysis sub-model, developed by Lefèvre et al, 2004 [14, 15], has also been added to the UK model allowing the UK model to simulate important chemical pathways such as the formation and destruction of ozone. In addition to the existing photochemistry scheme five photolysis reactions and 46 gas-phase reactions representing the atmospheric chlorine chemical pathway for perchlorate production have been added.

Initial results using the new chemistry scheme can be seen in Figure 1 which shows the seasonal evolution of the zonally averaged ozone column density (μm-atm) for Mars Year 27 (MY27), firstly using the UK model with standard photochemistry and then for an identical simulation using a sub-set of the new chlorine scheme. The third plot shows the difference in μm-atm between the two plots and shows a clear decrease in the ozone column at the north pole during northern hemisphere winter when using chlorine chemistry. This is an interesting result as the addition of chlorine chemistry must be consistent with known observations of ozone and so an upper limit for the globally averaged mixing ratio of HCl can be estimated from our simulations and compared with those derived from the attempted observations of HCl.

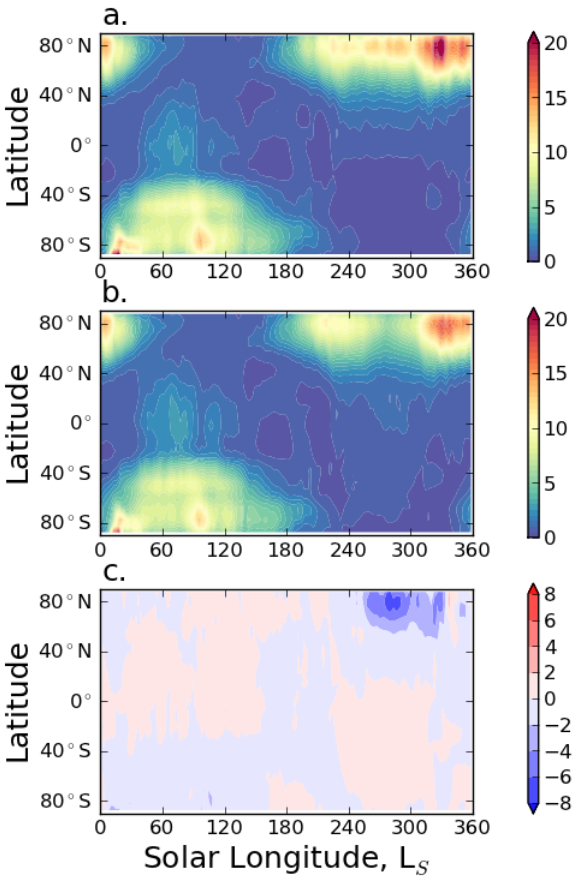

Figure 1: a. shows the seasonal evolution of the zonally averaged ozone column density (μm-atm) predicted by the UK model for Mars Year 27 (MY27), b. shows preliminary results from an identical model simulation using a sub-set of the new chlorine reactions which was initalised with a uniform mixing ratio of HCl gas of 1 part per billion volume and c. shows the difference in μm-atm between the two runs, blue representing a net decrease in ozone column density when chlorine reactions are added and red a net increase.

Results from simulations using a range of values of initial mixing ratio of uniformly distributed HCl will be presented to ascertain the atmospheric lifetimes of the chlorine-bearing species, an upper limit of HCl mixing ratio consistent with ozone observations and the mass of HCl required for perchlorate production in the regolith. In addition, simulations of HCl outgassing to test the likelihood of observing transient outgassing events will be discussed.

Acknowledgements

MKDD and SRL would like to thank the Science & Technology Facilities Coucil and The Open University for funding this work.

References

[1] M. H. Hecht, S. P. Kounaves, R. C. Quinn, S. J. West, S. M. M. Young, D. W. Ming, D. C. Catling, B. C. Clark, W. V. Boynton, J. Hoffman, L. P. DeFlores, K. Gospodinova, J. Kapit, and P. H. Smith, "Detection of Perchlorate and the Soluble Chemistry of Martian Soil at the Phoenix Lander Site," *Science*, vol. 325, pp. 64–, July 2009.

[2] S. P. Kounaves, D. Catling, B. C. Clark, L. Deflores, K. Gospodinova, M. H. Hecht, J. Kapit, D. W. Ming, R. C. Quinn, and Phoenix Science Team, "Aqueous Carbonate Chemistry of the Martian Soil at the Phoenix Landing Site," in *Lunar and Planetary Institute Science Conference Abstracts*, vol. 40 of *Lunar and Planetary Institute Science Conference Abstracts*, p. 2489, Mar. 2009.

[3] T. S. Altheide, *Experimental study of the stability and activity of brines on the surface of Mars*. PhD thesis, University of Arkansas, 2009.

[4] S. P. Kounaves, M. H. Hecht, J. Kapit, K. Gospodinova, L. DeFlores, R. C. Quinn, W. V. Boynton, B. C. Clark, D. C. Catling, P. Hredzak, D. W. Ming, Q. Moore, J. Shusterman, S. Stroble, S. J. West, and S. M. M. Young, "Wet Chemistry experiments on the 2007 Phoenix Mars Scout Lander mission: Data analysis and results," *Journal of Geophysical Research (Planets)*, vol. 115, p. 0, Jan. 2010.

[5] J. E. Quinn, D. C. Golden, T. G. Graff, D. W. Ming, R. V. Morris, S. Douglas, S. P. Kounaves, C. P. McKay, L. K. Tamppari, P. H. Smith, A. P. Zent, and P. D. Archer, "Chemistry and Mineralogy of Antarctica Dry Valley Soils: Implications for Mars," in *Lunar and Planetary Institute Science Conference Abstracts*, vol. 42 of *Lunar and Planetary Inst. Technical Report*, p. 2670, Mar. 2011.

[6] P. D. Archer, H. B. Franz, B. Sutter, A. McAdam, D. W. Ming, R. V. Morris, P. R. Mahaffy, and MSL Science Team, "Abundances of Volatile-Bearing Species from Evolved Gas Analysis of Samples from the Rocknest Aeolian Bedform in Gale Crater," in *Lunar and Planetary Institute Science Conference Abstracts*, vol. 44 of *Lunar and Planetary Institute Science Conference Abstracts*, p. 1720, Mar. 2013.

[7] D. C. Catling, M. W. Claire, K. J. Zahnle, R. C. Quinn, B. C. Clark, M. H. Hecht, and S. Kounaves, "Atmospheric origins of perchlorate on Mars and in the Atacama," *Journal of Geophysical Research (Planets)*, vol. 115, p. 0, Jan. 2010.

[8] V. A. Krasnopolsky, G. L. Bjoraker, M. J. Mumma, and D. E. Jennings J. Geophys. Res., vol. 102, pp. 6525–6534, Mar. 1997.

[9] P. Hartogh, C. Jarchow, E. Lellouch, M. de Val-Borro, M. Rengel, R. Moreno, A. S. Medvedev, H. Sagawa, B. M. Swinyard, T. Cavalié, D. C. Lis, M. I. Błęcka, M. Banaszkiewicz, D. Bockelée-Morvan, J. Crovisier, T. Encrenaz, M. Küppers, L.-M. Lara, S. Szutowicz, B. Vandenbussche, F. Bensch, E. A. Bergin, F. Billebaud, N. Biver, G. A. Blake, J. A. D. L. Blommaert, J. Cernicharo, L. Decin, P. Encrenaz, H. Feuchtgruber, T. Fulton, T. de Graauw, E. Jehin, M. Kidger, R. Lorente, D. A. Naylor, G. Portyankina, M. Sánchez-Portal, R. Schieder, S. Sidher, N. Thomas, E. Verdugo, C. Waelkens, N. Whyborn, D. Teyssier, F. Helmich, P. Roelfsema, J. Stutzki, H. G. Leduc, and J. A. Stern, "Herschel/HIFI observations of Mars: First detection of O_2 at submillimetre wavelengths and upper limits on HCl and H_2O_2," A&A, vol. 521, p. L49, Oct. 2010.

[10] F. Forget, F. Hourdin, R. Fournier, C. Hourdin, O. Talagrand, M. Collins, S. R. Lewis, P. L. Read, and J.-P. Huot, "Improved general circulation models of the Martian atmosphere from the surface to above 80 km," J. Geophys. Res., vol. 104, pp. 24155–24176, Oct. 1999.

[11] S. R. Lewis, M. Collins, P. L. Read, F. Forget, F. Hourdin, R. Fournier, C. Hourdin, O. Talagrand, and J.-P. Huot, "A climate database for Mars," J. Geophys. Res., vol. 104, pp. 24177–24194, Oct. 1999.

[12] C. E. Newman, S. R. Lewis, P. L. Read, and F. Forget, "Modeling the Martian dust cycle, 1. Representations of dust transport processes," *Journal of Geophysical Research (Planets)*, vol. 107, p. 5123, Dec. 2002.

[13] C. E. Newman, S. R. Lewis, P. L. Read, and F. Forget, "Modeling the Martian dust cycle 2. Multiannual radiatively active dust transport simulations," *Journal of Geophysical Research (Planets)*, vol. 107, p. 5124, Dec. 2002.

[14] F. Lefèvre, S. Lebonnois, F. Montmessin, and F. Forget, "Three-dimensional modeling of ozone on Mars," *Journal of Geophysical Research (Planets)*, vol. 109, p. 7004, July 2004.

[15] F. Lefèvre, J.-L. Bertaux, R. T. Clancy, T. Encrenaz, K. Fast, F. Forget, S. Lebonnois, F. Montmessin, and S. Perrier, "Heterogeneous chemistry in the atmosphere of Mars," Nature, vol. 454, pp. 971–975, Aug. 2008.