REGOLITH-ATMOSPHERE WATER VAPOUR INTERACTION AT GALE CRATER.

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Introduction: The exchange of water between the atmosphere and regolith on Mars has been modelled for many decades, but mainly with simplified 1D models (e.g. [1–3]), and often with few observations to compare with (except more recently for Mars Odyssey subsurface hydrogen observations [4]). Understanding the regolith-atmosphere interaction is important in terms of understanding the locations of subsurface reservoirs of water in both the past and present. Thanks to the Rover Environmental Monitoring Station (REMS) aboard Curiosity, we now have observations of relative humidity at a height of ~1.6 m spanning hundreds of sols [5], allowing us to study the regolith-atmosphere interaction at Gale crater in detail. Some REMS results have recently been interpreted using 1D models [6], but here we use a mesoscale model coupled to a subsurface regolith model. This allows us to study the regolith-atmosphere interaction in and around Gale crater, including atmospheric circulation patterns.

Model Description and Simulations Performed: The mesoscale model was developed at the Laboratoire de Météorologie Dynamique [7]. We have added a regolith water vapour diffusion scheme (an updated version of [8]), which accounts for vapour and ice in the pore spaces of the regolith, and water adsorbed onto the regolith grains. For the boundary conditions we use assimilations of Thermal Emission Spectrometer water vapour columns and Mars Climate Sounder temperature profiles. The model's horizontal resolution is 5 km, and 40 vertical levels extend to an altitude of around 50 km. Simulations have been performed both with and without regolith-atmosphere interaction, and with different adsorption isotherms.

Results: Fig. 1 shows the relative humidity (RH) for two sols at L_S = 320°. While the simulation without regolith-atmosphere interaction (red line) does not match the Curiosity measurements very well (with RH values peaking at around 50%), the simulation including regolith-atmosphere interaction with the palagonite adsorption isotherm of [9] (blue line) does agree well. The reason for the improvement is because water vapour diffuses into the regolith during the night, with the majority becoming adsorbed onto the regolith grains. This reduces the near-surface vapour values, and hence reduces the RH. The peak RH values are still larger than those measured by Curiosity. However, these occur during the coldest part of the night when temperatures get to around –70°C, at which point the humidity

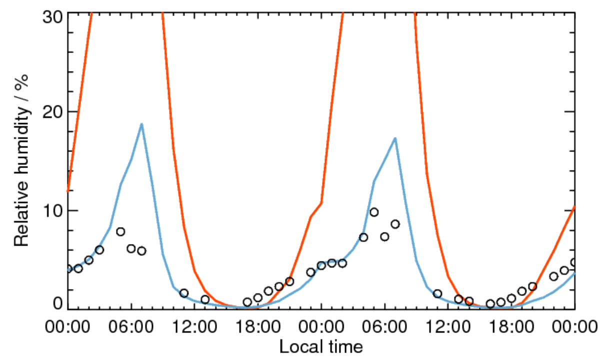

Fig. 1: *Diurnal variation of RH at a height of 1.6 m at the location of the Curiosity rover. Results are shown for two sols at L_S = 320°. The blue and red lines are model RH predictions with and without regolith-atmosphere interaction respectively. Black circles are the corresponding Curiosity measurements from Mars year 31.*

sensor time lag is in the order of hours [5]. As the observations are only made for 5 minutes every hour, they may not capture the true peak RH values.

Fig. 2 shows latitude-height plots of the water vapour distribution at 2 p.m. and 10 p.m. During the day (Fig. 2a) it can be seen that the vapour which diffuses into the atmosphere at the location of Curiosity (shown by the black triangle) remains in a relatively shallow layer, while at the crater rim the upslope winds mix the vapour higher into the atmosphere. During the night, downslope winds advect vapour into the crater (Fig. 2b). However, as the flux of vapour at this time is into the regolith, the crater floor at the Curiosity location remains relatively dry. Coupled with regions of relatively high thermal inertia on the crater floor, this means that no surface ice forms in the simulations at the location of Curiosity.

The spatial distribution of the nighttime water vapour flux at L_S = 320° is shown in Fig. 3. As can be seen, the strong downslope winds at the crater rim and on the southern flank of Mount Sharp increase the flux of water into the regolith. Thus, at all seasons the crater rims contain the largest values of subsurface water during the night. Occasionally enough water vapour diffuses into the regolith for subsurface ice to form. In our models this is most prevalent during northern hemisphere spring (L_S = 60°) where ice can form to depths of ~2 cm (Fig. 4). However, smaller amounts of subsurface ice do still form later in the year at various locations (though not at Gale).

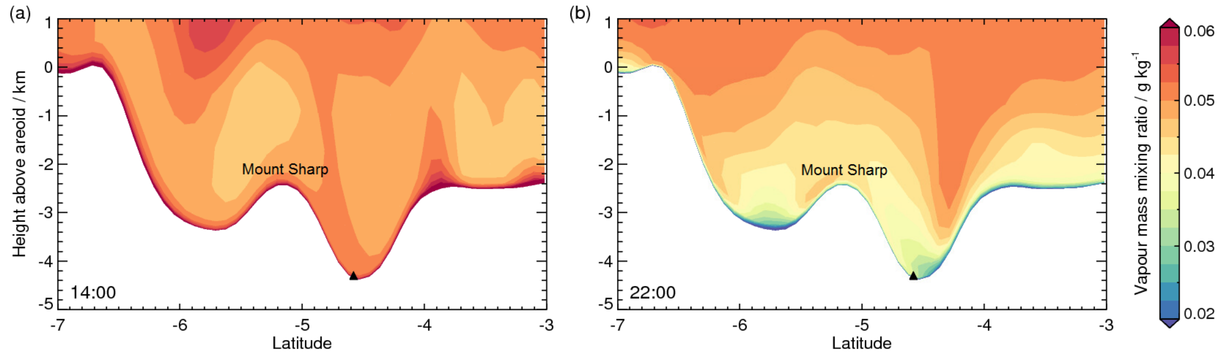

Fig. 2*: Latitude-height plots at 137°E of the water vapour mass mixing ratio at (a) 2 p.m. and (b) 10 p.m. from a simulation with regolith-atmosphere interaction at L_S = 320°. The black triangles show the location of the Curiosity rover, while white shading represents the topography.*

Conclusions: Comparisons between mesoscale model simulations and Curiosity relative humidity measurements confirm the importance of the regolith-atmosphere interaction of water vapour. This interaction is at its greatest at the crater rim, where strong nighttime downslope winds act to increase vapour diffusion into the regolith, and colder temperatures allow this vapour to become adsorbed onto regolith grains. During the day the water then diffuses out of the regolith, with strong upslope winds transporting the vapour to the crater rim. Due to the interaction between the water vapour and the walls of the crater, the crater floor where Curiosity resides is relatively 'cut-off' from the surrounding water vapour distribution, and is drier compared to elsewhere. During northern spring (L_S = 60°) ice forms preferentially around crater rims due to the increased flux of water vapour, and extends to depths of around 2 cm. Subsurface ice is rarer at other times of year. These results help to improve our knowledge of the present day regolith-atmosphere interaction around Gale crater, and will help when looking further back in time at the past climate.

References: [1] Mellon, M. T. and Jakosky, B. M. (1995) *J. Geophys. Res.*, 100, 11,781-11,799. [2] Schorghofer, N. and Aharonson, O. (2005) *J. Geophys. Res.*, 110, E05003. [3] Chamberlain, M. A. and Boynton, W. V. (2007) *J. Geophys. Res.*, 112, E06009. [4] Boynton, W. V. et al. (2002) *Science*, 297, 81–85. [5] Harri, A.-M. et al. (2014) *J. Geophys. Res. Planets*, 119, 2132-2147. [6] Savijärvi, H. I. et al. (2015) *Icarus*, 265, 63-69. [7] Spiga, A. and Forget, F. (2009) *J. Geophys. Res.*, 114, E02009. [8] Böttger, H. M. et al. (2004) *Geophys. Res. Lett.*, 31, L22702. [9] Jakosky, B. M. et al. (1997) *Icarus*, 130, 87-95.

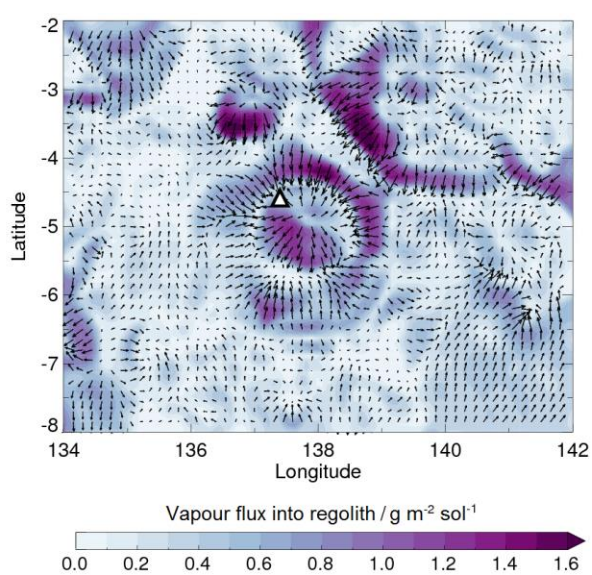

Fig. 3: *10 p.m. flux of water vapour into the regolith (shading) and near-surface wind (arrows) at L_S = 320°. The white triangle shows the location of Curiosity.*

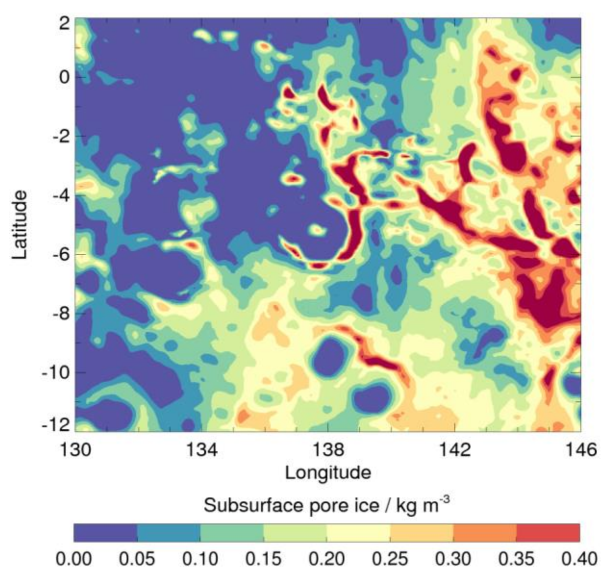

Fig. 4: *10 p.m. subsurface water ice distribution at L_S = 60°. The ice is at a depth of a few millimetres, but can extend down to ~2 cm. Gale crater is in the centre of the plot.*