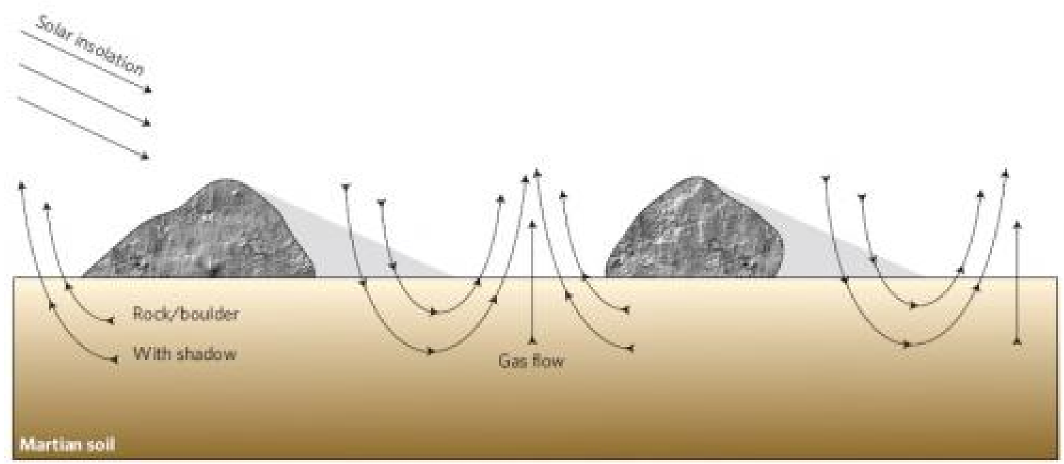
Mars may act as a giant planetary pump

December 23 2013, by Lisa Zyga



The natural soil pump on Mars: Underground gas flows from the cool deeper layers to the warm Sun-heated surface due to thermal creep. At shadowed places on the surface, gas is soaked up into the soil, travels underground, and is pumped up again to the heated surface. Credit: de Beule, et al. ©2013 Macmillan Publishers Limited. All rights reserved.

(Phys.org) —The surface of Mars is full of activity, with dust storms, dust devils, and drifting dunes in constant motion. Scientists suspect that similarly rich activity may exist underneath the surface, even though it has never been seen. Now in a new study, scientists have found that Mars' low-pressure atmosphere and porous soil provide the perfect conditions for the planet's entire surface to act as a giant gas pump, quickly cycling gas and dust particles a few centimeters above and below the soil.

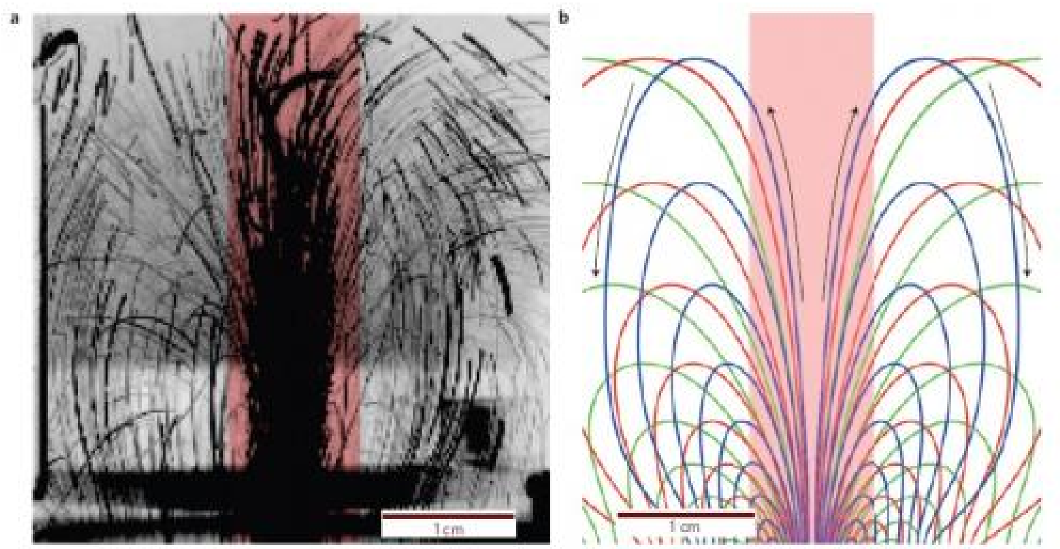
No analogue of this type of planet-wide pump exists on Earth. In fact, the scientists think that Mars is the only body in the Solar System on which such large-scale, continuous pumping can naturally occur. If it does indeed occur as theorized, the pumping might serve as a dominant mechanism for transporting water vapor across Mars' surface.

The scientists, Caroline de Beule, et al., at the University of Duisburg-Essen in Duisburg, Germany, have published their paper on the surface of Mars as a planetary gas pump in a recent issue of *Nature Physics*.

"The idea of the martian soil acting as a planetary gas pump surprised us indeed," de Beule told *Phys.org*. "We found this effect by accident when we studied light-induced dust eruptions under microgravity. As we saw eroded particles moving down to the surface again without thermal convection, we concluded that there must be a gas flow into and—even more important—through the soil.

"So the greatest significance of our work is the detection of a gas flow which is not only above the martian soil, but through it. Until now, only diffusion has been considered as a transport mechanism of, for example, water vapor through the soil and therefore as an interaction between the regolith and the atmosphere. We showed now that there is a directed transport mechanism that is even more efficient, which leads to a gas flow and can for example drag water vapor along with it."

All of this is possible due to Mars' low surface pressure. Although Mars and the Earth have a lot in common, one characteristic of Mars that is different is its very low surface pressure of an average of 6 mbar, which is less than 1% of the surface pressure on Earth. The atmosphere on Mars consists mostly of carbon dioxide, and this surface pressure means that the carbon dioxide molecules have a mean free path (that is, the average distance between successive collisions with each other) of 10 μm.



Particles trajectories (a) in experiments above an illuminated dust bed are consistent with those (b) in gas flow simulations. In both cases, gas quickly flows upward in the center illuminated (red) area, and falls downward more slowly on the sides. Credit: de Beule, et al.

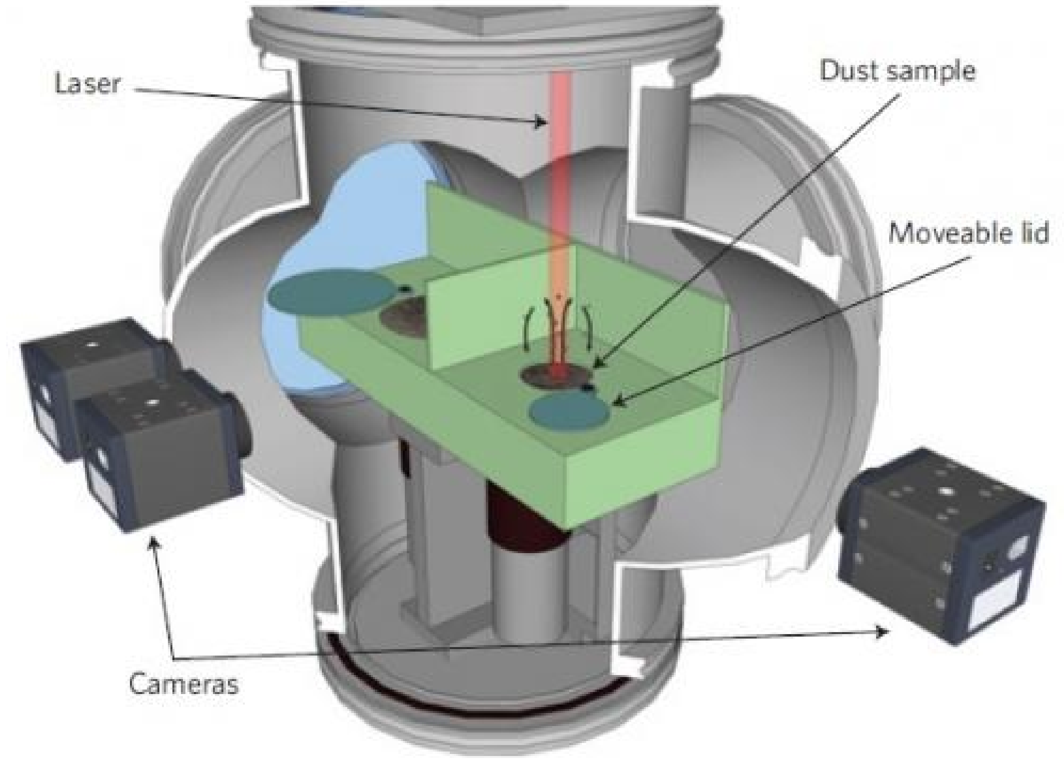
Importantly, the sizes of both the dust particles and the pores in the martian soil are also on the order of 10 μm. Under these conditions—when the mean free path is comparable to particle size and pore size—an effect called thermal creep can occur. When one side of the pore is warmer than the other side, the pore acts as an efficient pump and transports gas from its cold side to its warm side.

The scientists think that thermal creep could play a significant role in transporting gas and dust on Mars. In such a scenario, the Sun would heat the top layers of the soil everywhere except in the shadows, where the soil would be cooler. In these shadowed places, gas molecules would be soaked up into pores in the soil. Then the gas molecules would flow through the pores underground and be pumped up and erupt out of a heated part of the surface.

To test the possibility of thermal creep occurring at conditions similar to those on Mars, the researchers carried out experiments that involved dropping a basaltic dust sample from the drop tower in Bremen, Germany. The dust is enclosed in a vacuum chamber with 4 mbar air pressure, and its being dropped from the tower greatly reduces the force of gravity in order to simulate the conditions on Mars.

While the dust sample is falling, the lid is opened, and the dust is illuminated and heated with a red laser. The laser causes a temperature gradient that pumps the dust particles upward at a velocity of about 10 cm/sec, and then the dust particles move downward at about 1 cm/sec. The trajectories that the scientists observed in these experiments are similar to the scientists' simulated trajectories of gas flow. However, as the scientists calculated, the average particle velocity on Mars would be lower, about 1.6 cm/sec. The lower velocity is due in part to a smaller temperature gradient than in the experiments.

Since buried ice exists under the surface of Mars, one of the most intriguing implications of this study is that the thermal creep effect may explain how underground water vapor can be transported up to Mars' surface. Since gas flow due to thermal creep has a higher velocity than other mechanisms previously considered, such as diffusion, thermal creep could be a dominant transport mechanism for water vapor across large parts of the martian soil.



Schematic diagram of the drop tower experiment. Basaltic dust is illuminated with a red laser as the entire device falls from the drop tower in Bremen, Germany. Credit: de Beule, et al.

"Beside implications for the cycle of dust and the cycle of carbon dioxide, the greatest application of our work is a big step in understanding the global cycle of water on Mars—which is of course linked to the other two cycles," de Beule said. "For example, the rate of water vapor transport through the dust surface on Mars determines the timescale of the existence of ice in the subsurface.

"Due to the fact that Mars might have been habitable a few billion years ago, the current annual cycle of water vapor reflects the present and past behavior of water and is therefore a key interest concerning possible environments for past life on Mars."

The researchers added that there are many other interesting aspects of these results, which they plan to further investigate in the future.

"Our future plans are to study the gas flow through porous material, analyzing compositional effects on the efficiency, like the porosity of the dust or the grain sizes," de Beule said. "Finding the right conditions for Mars, the gas flow perhaps might reach even a meter below the surface. In addition, the flow of gas through porous material in a low-pressure environment might not only be considered for Mars, but for example on other bodies in protoplanetary disks, where a porous body is exposed to the light of the sun, and a gas flow through the illuminated surface parts can influence the rotation and trajectory. As can be seen, the list of potential applications is very long, and we are excited to investigate the details of this effect."

More information: Caroline de Beule, et al. "The martian soil as a planetary gas pump." *Nature Physics*. DOI: 10.1038/NPHYS2821