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Structure and Appearance of South Polar Jets on Mars

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Abstract

The High Resolution Imaging Science Experiment (HiRISE) onboard Mars Reconnaissance Orbiter (MRO) has been used to monitor the seasonal evolution of several regions at high southern latitudes on Mars and, in particular, the jet-like activity which may result from the process described by Kieffer [2] involving translucent CO2 ice. In this work, we concentrate on attempting to model the dusty CO2 gas jets using a computational fluid dynamics code. Models incorporating a 20° slope were investigated as an analogy to the jet activity seen in "Inca City" (81°S, 296°E). Models were also constructed which included wind across a flat surface thereby representing regions such as the "Manhatten" (86°S, 99°E) area. The structure of the gas jet, the particle distribution within the jet, the deposition pattern (including its dependence on particle size), the appearance of a jet when viewed from different orientations (including from a nadir-pointing camera), and the effects of mass loading have been investigated for a range of input parameters. The influences of the cross-section and the length of the orifice linking source to vent have also been studied. The results provide predictions for the size-dependency of altitudes of particles within a plume and the distribution of particle sizes in the deposition fans.

1. Introduction

This is a follow-up paper to three articles [1,5,6] published in an Icarus special issue in January 2010. These articles were based upon analysis of data from the HiRISE experiment on MRO [3,4]. In the second article [6], Thomas et al. described the deposition patterns resulting from presumed jet-activity and used crude methods to estimate jet emission parameters. The so-called Inca City region (81°S, 296°E) was studied in depth. In this work, we investigate the jet activity using a fluid dynamics model taking advantage of the constraints provided by observations of fans.

2. Calculation approach

The calculations have been made using a commercial fluid dynamics code called Phoenics (see http://www.cham.co.uk). For the simulations presented herein, we normally use a calculation domain which is 101 m x 101 m x 151 m (x, y, z) in a Cartesian coordinate system. The calculation is fully 3-D. Note that we use the term "inlet" to describe the point (or more correctly the area) where gas enters the domain. The gas then expands up a "tube" to the surface where it emerges from a "vent". The domain is filled with CO_2 at 6.11 mbar pressure at a fixed temperature of 147.75 K. The gravitational acceleration on Mars can be fully taken into account vectorially.

Although observations of the Inca City region acquired in 2007 [6] appear to indicate little or no influence of wind, observations at other sites (e.g. Manhatten and Ithaca) suggested that wind was important. This has been simulated by using a constant wind velocity within the system. The wind was implemented as being constant with height. The surface has been assumed to be non-absorbing for gas. The simulation is iterated to steady-state.

Dust and fines can be incorporated into the calculation. The code tracks particles moving through a flow field, taking into account the effects of fluid velocity, temperature, turbulence etc. The effect of the particles on the continuous (gas) phase can also be considered.

3. Results

The work has produced a vast number of interesting results. Only a small fraction can be presented here. We choose to discuss some aspects of pure gas jets. Figure 1 shows an example of a relatively weak jet which exudes 50 g/s of CO_2 with no dust. The observation shows how ambient gas is sucked into the flow by the jet motion (Fig 1; right). It also shows how the gas cools during its expansion. In this particular case, the cooling is NOT sufficient to produce super-saturation.

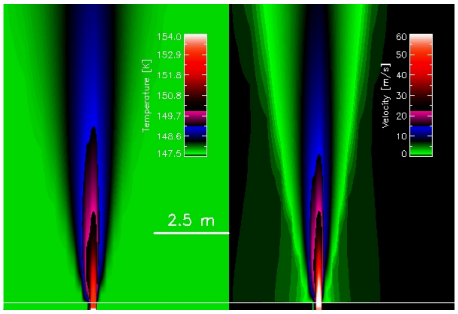

Figure 1 Model 208: Left: Temperature. Close-up of the vent and the initial interaction with the ambient atmosphere. This model used a gravity vector tilted by 20 deg to the y axis to simulate a slope. The ambient atmosphere is at 147.75 K while the source is at 155.7 K. The tube to the surface can be seen and is 25 cm long. Right: Magnitude of the velocity. Note that the gas rapidly accelerates from its initial velocity (20 m/s) to a maximum velocity of about 60 m/s. Note also the contours on either side of the vent indicating flows at the surface but not directly above the vent.

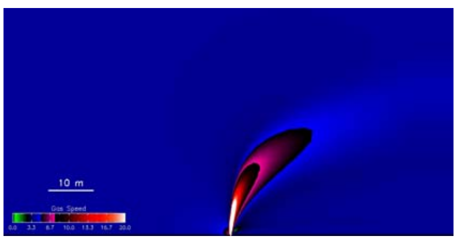

Figure 2 Influence of wind on the velocity distribution within a jet. Wind speeds used in the calculation were typically 3-6 m/s.

In Figure 2, we show the influence of wind on the velocity structure of the jet. The winds used here were relatively light and yet there is a strong influence because of the limited mass inflow rates.

4. Conclusions for gas jets

The ambient atmosphere limits the altitudes the gas plumes can attain. The gas plumes cool initially (directly above the vent) but the gas temperature then rises as the inflow velocity is converted to locally increased kinetic temperature. The gas plumes do not develop a fountain-like appearance but the higher local temperatures lead to a rising flow because of buoyancy effects. The mass flux through the tube to the vent controls physical parameters (e.g. velocity) at the vent itself but afterwards the gas mass inflow controls the height and structure of the plume. Hence, the cross-sectional area of the orifice combined with the pressures and gas speeds under the ice control the appearance of the gas plume. From the calculations made here, the orifices (vents) must be 10 cm or so in diameter at least in order to allow sufficient mass flow to explain the heights of the plumes. They are comparable in size to the HiRISE spatial scale. In other words, the vents are not millimeter-sized cracks but substantial openings in the ice.

A far more detailed description of the work is being submitted to Icarus.

Acknowledgements

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