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Advective and diffusive transport of methane from shallow subsurface sources on Mars

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Abstract

Methane migration through the martian subsurface is modeled considering diffusive and advective transports as well as adsorption onto rock surfaces. Results will be presented assuming shallow CH_4 sources such as clathrate hydrates.

1 Introduction

During the whole geological history of Mars, methane formation mechanisms could have taken place in the deep subsurface and could still be active nowadays. After its generation, methane would migrate upwards and be either directly released at the surface or trapped in subsurface reservoirs (clathrates, zeolites or sealed traps) where it could eventually accumulate over long time periods before to be episodically liberated during destabilising events.

2 Gas transport mechanisms

When ascending through stratigraphic layers, methane can move via one or several transport mechanisms. The important parameters to determine which gas transport regime is dominant include the mean free path, the pore size and the particle size. Following this, gas transport through porous media can be divided in different mechanisms [1]:

- Free molecule or Knudsen flow occurs when the pore radius is less than one tenth of the gas mean free path, and molecule-wall collisions dominate.
- Viscous or advective flow, in which the gas acts as a continuum fluid under the influence of a pressure gradient. In this mode, molecule-molecule collisions dominate.
- Ordinary or molecular diffusion refers to the relative motion of the different gas species under the influence of concentration gradients, temperature gradients or external forces. In this regime, the pore radius is larger than 10x the gas mean free path and collisions between gas molecules dominate.
- Surface flow or diffusion in which molecules move along a solid surface in an adsorbed layer.

3 The model

Methane transport through the martian subsurface is studied using a one-dimensional numerical model considering adsorption onto, advection and diffusion through the regolith. The total CH_4 flux is given by the sum of the advective flux calculated via Darcy's law and the flux resulting from molecular and Knudsen diffusion. The latter is determined using the mean transport pore model as described by [2]. Surface diffusion is generally not significant [3] and is thus not taken into account in this work. Pressure diffusion and thermal diffusion are also neglected as their contribution is rather small compared to molecular diffusion (concentration gradients) and Knudsen diffusion, which are normally considered to be the most important diffusive processes in soils [4]. Finally, adsorption is modeled similarly to [5].

Experimental methane fluxes from clathrate dissociation [6] are imposed at the base of the model to describe the lower boundary condition. The CH_4 subsurface reservoirs are assumed to be located several meters to several tens of meters below the surface following the clathrate stability zone.

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