EPSC Abstracts
Vol. 11, EPSC2017-228, 2017
European Planetary Science Congress 2017

Penetration of Solar Radiation into Solid Carbon Dioxide

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Abstract

The e-folding scale, otherwise known as the absorption scale length, has been determined by laboratory measurements for carbon dioxide slab ice, granular ice and snow. This can give insights into thermal gradients within snow packs or ice covered regolith on Mars, where surface CO_2 ice is naturally occurring. With long-term ice coverage, localised perturbations in subsurface heat flow could occur. This also has implications for the radiative budget of CO_2 ice covered surfaces, as well as physical processes, such as the formation of so-called spider formations in the 'cryptic region' near the Martian south pole.

1. Introduction

Solid carbon dioxide ice exists both on the surface, and in the subsurface of Mars [1]. CO_2 clouds and accumulations of CO_2 ice in snowfall up to 1.5 m deep at the seasonal northern cap have been observed by the Thermal Emission Spectrometer [2] and the Mars Orbiter Laser Altimeter [3], and CO_2 snowfall was modelled to be able to occur in particular locations at high latitudes [4]. The permanent northern polar cap is predominantly water ice, whereas in the south there is a much higher proportion of CO_2 ice, and the seasonal extension of the ice caps in both hemispheres is due to the condensation of CO_2 as slab ice. It is likely that the seasonal ice caps are formed by both direct condensation to the surface, and from snowfall, which anneals to form solid ice [4].

2. Background

It is the current consensus that low albedo slab ice forms during the autumn and winter months outwards from the poles. Of particular interest is the cryptic region, where so-called spider formations are observed during spring time. Work has been done in modelling these observations [5], and has now been successfully recreated experimentally in the laboratory, under particular temperature and pressure conditions [6]. This involved measuring temperature profiles through CO_2 ice with embedded dust particles [7]. However, the optical properties of pure carbon dioxide ice under broad spectrum visible wavelengths are poorly understood.

In this work, we intend on measuring the e-folding scale of each different polymorph of CO_2 ice likely on Mars, which includes slab ice as part of the seasonal polar caps, CO_2 snow, and granular CO_2. The latter is possibly formed in cracks and faults in the slab ice. The thermal expansion coefficient for CO_2 ice is almost twice that of water ice, and so with day to night time temperature variations experienced in these regions on the surface of Mars, it is quite possible that thermal expansion during the day could lead to expansion and buckling of the ice sheet, later contracting overnight and leaving regions of granular ice debris. We measure the e-folding scale of a range of discreet grain size ranges, as small grains of around 500 µm could yield very different results than 5 mm sized grains.

3. Theory

The Solid State Greenhouse Effect is a result of ices being translucent in the visible electromagnetic spectrum but opaque in the infra-red, which means that light can penetrate through a surface ice layer and be absorbed by the underlying regolith [8], [9]; [6]. The extent of this effect is, in part, reliant upon the e-folding scale of the overlying ice. The e-folding scale is defined as the depth through a medium over which intensity is reduced by 1/e of the original intensity, which means it can be compared directly to other materials, such as water ice.

4. Laboratory Experiments

CO_2 snow and ice is made in the lab and used as soon as possible. This minimises water frost contamination or physical alterations, such as sintering of snow particles or excessive thermal cracking in the ice

blocks. Figure 1 shows a simplified diagram of the experimental set up.

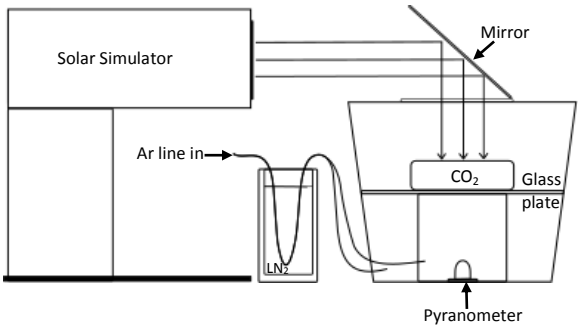

Figure 1 Schematic of experimental set up for the e-folding scale measurements.

CO_2 snow is made using an Air Liquide Snowpack. Translucent slab ice is made using a pressure vessel cooled by liquid nitrogen from the base, as described by Kaufmann & Hagermann [6]. Experimental protocol for measurements for CO_2 snow is based on that used by Kaufmann & Hagermann [7] for water snow experiments.

5. Summary

Results from the measurements of the e-folding scale of CO_2 slab ice, granular ice and snow will be discussed and compared to measurements of other materials available in the literature. The implications of these results will then be discussed in terms of heat-flow and surface processes.

Acknowledgements

This research is funded via an STFC PhD Studentship to HEC.

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