EPSC Abstracts
Vol. 9, EPSC2014-565-1, 2014
European Planetary Science Congress 2014


# Influence of dust particles on the absorption scale length of snow.

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## Abstract

In contrast to rock and soil surface layers, which absorb and reflect incoming solar radiation immediately at the surface, ices are partially transparent in the visible spectral range, while they are opaque in the infrared. These properties are responsible for the "Solid–State Greenhouse Effect" (SSGE), which may play an important role in the energy balance of icy surfaces in the solar system. To model the SSGE, we need to know not only thermal properties but also optical properties like the albedo and the absorption scale length of the ice. Within the scope of a project conducted at the Open University (UK), a series of tests measuring the e-folding scales of snow/dust mixtures was done.

## 1. Introduction

The planetary atmospheric greenhouse effect and the temperature increase connected with it is a well-known phenomenon. Less known is that a similar effect takes place in solid translucent objects like ice. If such a body is irradiated by sunlight, the visible range of light is either absorbed over a certain distance, or immediately at an absorbing layer, or by embedded dark particles. This may lead to a significantly higher temperature below the surface [1]. The SSGE has implications for many planetary processes. For example, a subsurface temperature increase is a possible scenario for the formation of the so-called Martian spiders [2].

Under terrestrial conditions, the SSGE has mainly been observed in blue ice or snow with a low thermal conductivity. In the 1960s it was discovered that subsurface temperature increases of terrestrial ice can result in the formation of melt pools. Their formation can be completely stopped by keying the surface. This creates a high albedo layer of powdered ice, which means that deeper ice deposits are shadowed and sunlight cannot penetrate deeper into the glacier ice [3].

Investigations concerning the SSGE on comets have also been undertaken. Though the surfaces of comets are thought to be generally dusty, substantial light penetration may occur [4]. The temperature profiles in laboratory ice, natural ice, and ice including dust particles were compared. For ice containing dust particles with similar density as comet P/Halley, no subsurface maximum could be definitively observed [5].

Al though in-situ measurements of the SSGE are currently only available on terrestrial ices, the optical properties of ice covering all kinds of bodies in the solar system are of interest. The amount of dust embedded in the ice has a strong influence on these parameters. Our aim is to create a database for the absorption length (e-folding scale $\zeta$) of snow/dust mixtures to see if there is a realistic basis for the SSGE to occur in "dirty" snow.

## 2. Laboratory experiments

Over a series of tests, the e-folding scale of snow/dust mixtures was determined. The samples for these tests consisted of pure snow, artificially produced by a snow cannon, mixed with different amounts of JSC 1A Mars analogue (grain size $\leq$ 1 mm). The dust was not sieved, which means that the grain size distribution inside a sample is random. During sample preparation, the snow was taken directly from a deep temperature freezer to avoid sintering, so that the optical properties of the snow for each test were similar.

The test vessel consists of several copper rings, with an inner diameter of 86 mm, that allow the height of the sample to be adjusted from 5 mm up to 55 mm, with the bottom ring fixed on a Perspex plate. The vessel was cooled before filling up with the sample which has a temperature of less than -30°C. This ensures that the temperature of the sample stays negative during each irradiation phase (< 1 min duration) and melting can only take place directly at the surface. Therefore the optical properties inside the sample did not change significantly.

The sample was irradiated using a full spectrum Solar Simulator. The transmitted intensity was measured several times for each sample height and mixing ratio, at four different points below the sample, with a standard pyranometer. After each irradiation phase, the sample was removed and the sample container was filled up again. This means that, even for samples with the same snow/dust ratio, the grain size distribution of the dust inside the different samples is not uniform. So the measurement results for each mixing ratio were only reproducible to a certain degree. Figure 1 shows a summary of the measured results.

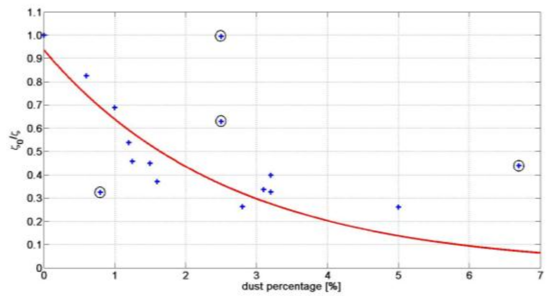


Figure 1: e-folding scale normed to the value for pure snow ($\zeta_0$). The marked points are not included for the calculation of the fit.

## 3. Summary

The measured values show a general trend for an exponential decrease of the e-folding scale as the dust fraction increases. But one can also see that some values are strongly deviating from that trend. This may be caused by the random dust grain size distribution inside the sample. Further measurements with samples consisting of dust only were taken. Four different samples were analysed: i) mud with randomly distributed grain size, ii) dry dust with randomly distributed grain size, iii) dry fine grained dust, and iv) dry coarse grained dust. Again the samples were irradiated and the transmitted intensity was measured at the same four points below the sample. These measurements showed that only in case iii) could tolerably uniform values for the transmitted intensity be measured. Even in this case the deviation from the mean value is up to 10%. For the other three cases the intensity varied by more than 100% at a given point.


## Acknowledgements

This project is funded by the UK Space Agency.


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