Changes in stripe patterns in dark regions on the southwestern Greenland Ice Sheet

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1. Introduction

On the Greenland Ice Sheet, the bare ice surface is exposed at the marginal parts of the ice sheet during summer. In the bare ice area, dark colored ice, called a dark region, appears at the same locations every year. The dark region expands particularly in the southwestern part of the ice sheet over a distance of about 500 km from north to south. In recent years, the area of the dark region has expanded. The expansion of the dark region reduces surface albedo of the ice sheet and promotes absorption of solar radiation, which accelerates melting of the ice and leads to loss of the ice sheet mass. Therefore, it is important to understand the factors that affect the area of the dark region. Field observations and satellite image analyses have shown that the dark region is formed by the deposition of light-absorbing impurities such as dust and snow/ice microorganisms on the ice surface. High-resolution satellite images show that the dark region consists of stripe patterns extending in parallel with the ice sheet margins. However, it is still unclear why dust and snow/ice microorganisms accumulate on the ice surface to form stripe patterns, and what is the relationship between the patterns and expansion of the dark region. The purpose of this study is to analyze the changes in stripe patterns of the dark region in the southwestern part of the Greenland Ice Sheet using satellite images, and to discuss the factors that cause the changes in the dark region.

2. Study site and methods

The bare ice area of the Greenland Ice Sheet can be divided into two areas, which are the white and dark regions. The white region is defined as the area where the surface appears to be bright and tends to distribute the downstream of the bare ice area. The dark region is defined as the area where the surface appears to be dark and tends to distribute the upstream of the bare ice area. Three Landsat-8 OLI satellite images acquired on 10-July, 26-July, and 11-August, in 2019, were used in this study. A transect line across the white and dark regions was selected to be analysed with satellite images. A profile of Band 2 reflectance along the transect line was obtained using a geographic information system application (QGIS).

3. Results and Discussion

The profile of reflectance along the transect line shows that the reflectance was mostly constant in the white region, while it largely varied in the dark region. Baced on the reflectance, the dark region was further divided into three areas: dark stripe, white stripe, and intermediate-stripe. The comparison of the reflectance profiles among the three images in July and August revealed that there was little change in reflectance in the white region while there was a significant change of reflectance in the dark region in July. In the dark region, the reflectance of intermediate-stripe particularly decreased but those of dark and white stripes decreased slightly. Results show that the change in reflectance of the bare ice surface varies from area to area : the reflectance did not changed in the white region, changed slightly in the dark and white stripes, and changed significantly in the intermediate-stripes in the dark region during the melting season. The reason for the significant decrease in reflectance in the intermediate-stripe may be due to the growth of microbes such as glacier algae promoted by more abundant nutrient supply from the ablating ice, and/or to the surface ice structure that aggregate surface impurities on the bare ice surface.