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Application of ASTER SWIR bands in mapping anomaly pixels for Antarctic geological mapping

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Abstract. Independent component analysis (ICA) was applied to shortwave infrared (SWIR) bands of ASTER satellite data for detailed mapping of alteration mineral zones in the context of polar environments, where little prior information is available. The Oscar II coast area north-eastern Graham Land, Antarctic Peninsula (AP) was selected to conduct a remote sensing satellite-based mapping approach to detect alteration mineral assemblages. Anomaly pixels in the ICA image maps related to spectral features of Al-O-H, Fe, Mg-O-H and CO3 groups were detected using SWIR datasets of ASTER. ICA method provided image maps of alteration mineral assemblages and discriminate lithological units with little available geological data for poorly mapped regions and/or without prior geological information for unmapped regions in northern and southern sectors of Oscar II coast area, Graham Land. The results of this investigation demonstrated the applicability of ASTER spectral data for lithological and alteration mineral mapping in poorly exposed lithologies and inaccessible regions, particularly using the image processing algorithm that are capable to detect anomaly pixels targets in the remotely sensed images, where no prior information is available.

1. Introduction

Remote sensing satellite data are commonly used for reconnaissance mapping of inaccessible regions, lithological mapping, structural analysis and mineral exploration in arid and semi-arid and tropical regions around the world [1, 2, 3].

In particular, remote sensing satellite imagery has high potential to provide a solution to overcome the difficulties and limitations associated with geological field mapping and mineral exploration in inaccessible region such Antarctic environments. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) is a high performance sensor for geological application and has VNIR subsystem with three bands between 0.52 and 0.86 µm (spatial resolution 15 m), SWIR subsystem with six bands from 1.6 to 2.43 µm, (spatial resolution of 30 m), and TIR subsystem with five band from 8.125 to 11.65 µm (spatial resolution of 90 m) [4]. Numerous research investigations used the ASTER data for geological application due to specific characteristics of ASTER bands for mineral exploration and lithological mapping [1, 2, 3].

Independent component analysis (ICA) is used on multispectral or hyperspectral datasets to transform a set of mixed, random signals into components that are mutually independent [4]. It is a statistical method for transforming an observed multidimensional random vector into components that are statistically as independent from each other as possible [5]. This transformation serves as a tool for blind source separation (BSS), where no prior information on the mixing is available [4, 5].

In this investigation, to map alteration mineral zone in inaccessible region such Antarctic environments, Independent Components Analysis (ICA) methods was applied to SWIR bands of ASTER data covering Oscar II coast area in eastern Graham, Antarctic Peninsula (AP).

2. Material and methods

2.1 Geology of the study area

The Antarctic Peninsula (AP) contains a variety of poorly exposed lithologies and areas that have not been mapped directly providing an appropriate test of the use of image processing methods to multispectral remote sensing satellite data such as ASTER for alteration mapping in the polar context. In this research, the Oscar II coast area north-eastern Graham Land, Antarctic Peninsula (AP) was selected to conduct a remote sensing satellite-based mapping approach to detect poorly exposed lithological units and alteration mineral assemblages in the Antarctic environments.

Figure 1 shows geological map of the Oscar II coast area. The lithological units in this area consisting of (i) volcanic and volcaniclastic rocks (Mapple Formation); (ii) intrusive rocks; (iii) sedimentary rocks (Botany Bay and Trinity Peninsula Groups)) [6].

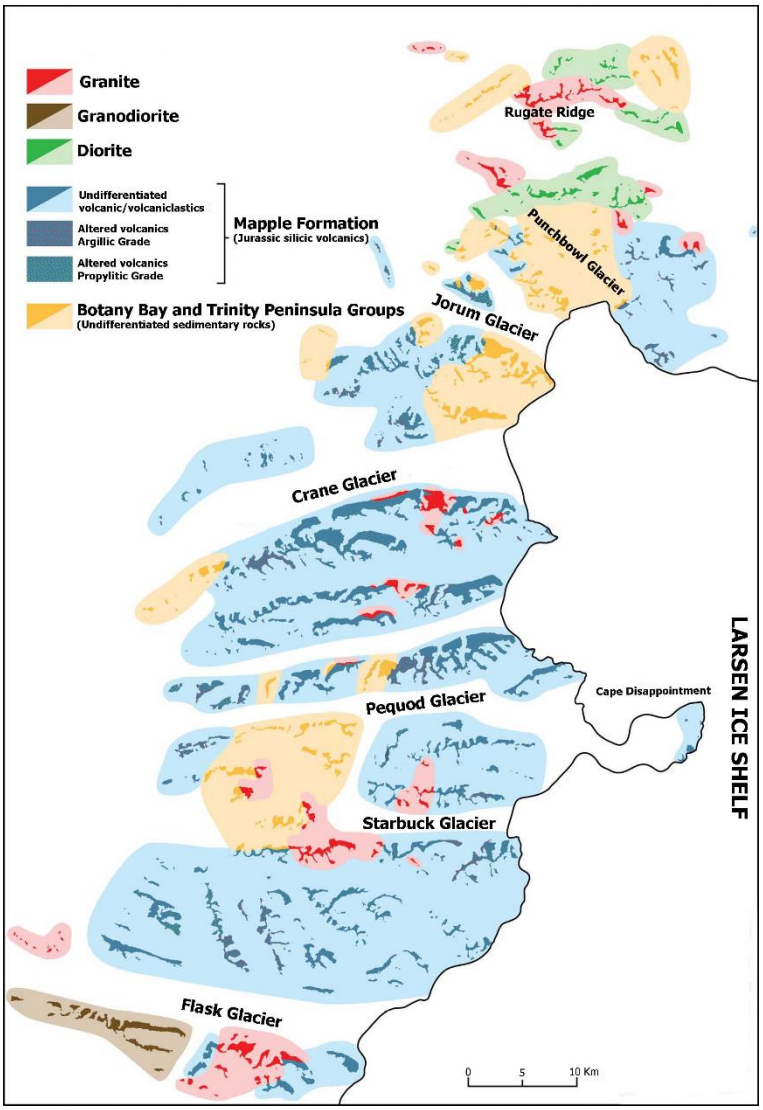

Figure 1. Geological map of the Oscar II Coast area. Extrapolated geological units are depicted as light coloured areas

2.2 Remote sensing data

The ASTER data used in this investigation were obtained from U.S. Geological EROS (http://glovis.usgs.gov/). An ASTER level 1 T (Precision Terrain Corrected Registered At-Sensor Radiance) scenes covering the Oscar II coast region north eastern part of Graham Land, Antarctic Peninsula (AP) were acquired on November 22, 2001. The average of cloud cover for the ASTER data used in this study is less than 10 %. The images were pre-georeferenced to UTM zone 20 South projection using the WGS-84 datum.

2.3 Data processing

Preprocessing of ASTER data was also required before analysis. Crosstalk correction was performed on the ASTER data sets used in this study. FLAASH atmospheric correction algorithm was applied on SWIR subsystems of the ASTER data sets. To minimize the reflectance effects of snow, ice and cloud areas from ASTER scene a masking procedure was used to restrict image processing algorithms to just regions of exposed rock.

ICA transformation can distinguish features of interest (defined target in this study for instance alteration mineral zones) even when they occupy only a small portion of the pixels in the image. ICA was applied to ASTER SWIR bands a datasets of the study region Forward IC rotation with sample X resize factor: 0.700000 and sample Y resize factor: 0.700000 was implemented to the datasets used in this study. IC parameter was adjusted as follows; change threshold: 0.00010000, maximum iterations: 100, maximum stabilization iterations: 100, contrast function: LogCosh and coefficient: 1.000000.

3. Results and discussion

In order to detail discrimination of alteration mineral assemblages and lithological units at regional scale, ICA was applied to ASTER SWIR bands, separately. IC bands contain anomaly pixels attributed to distinctive spectral features were assigned to RGB color combination for generating image map of alteration mineral assemblages in the study area. IC bands selected from ASTER SWIR dataset were used to generate FCC image maps for identification of alteration mineral assemblages in the study area.

Figure 2 shows FCC image map of ASTER full scene covering Oscar II coast area, IC5 (band 8 of ASTER: 2.295-2.365 μm), IC4 (band 7 of ASTER: 2.235-2.285 μm) and IC3 (band 6 of ASTER: 2.185-225 μm) were assigned to produce RGB image map. Anomaly pixels in this image map comprise spectral features related to Al-O-H, Fe, Mg-O-H and CO3 groups. Sericitically-altered rocks have a Al-OH absorption feature at 2.2 μm (the equivalent of band 6 of ASTER). Kaolinite shows Al-OH 2.165 μm and 2.2 μm absorption features (the equivalent of band 6 of ASTER). Propylitically-altered rocks contain Fe, Mg-O-H and CO3 2.31–2.33 μm absorption features (the equivalent of band 8 of ASTER) [3, 7, 8].

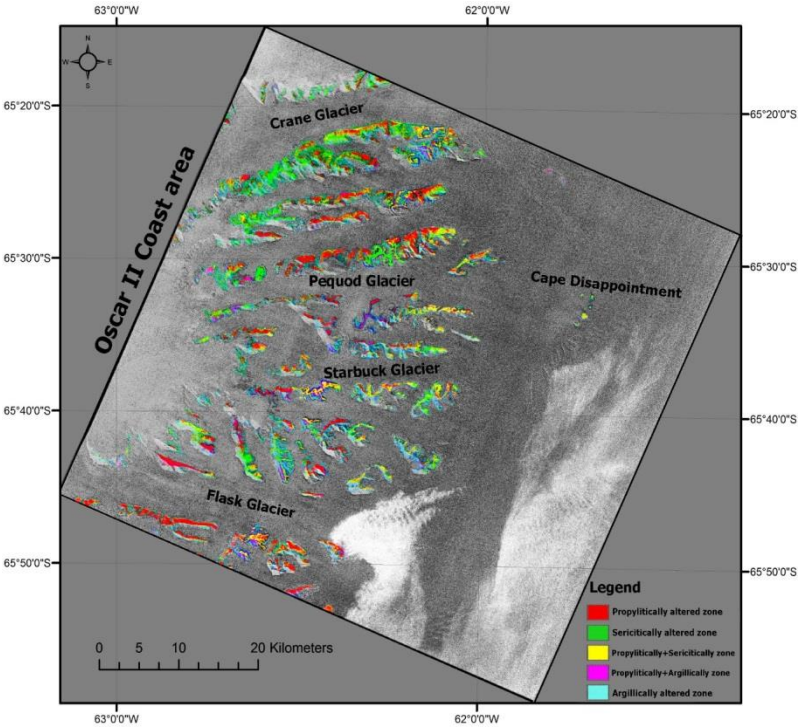

Figure 2. FCC image map (IC5, IC4 and IC3; SWIR bands) of ASTER full scene, Oscar II coast region

As shown in Fig. 2, FFC image map contains anomaly pixels exhibiting five colors. Each color class is indicative of surface abundance of different alteration mineral assemblages. Red color represents chlorite, epidote and calcite mineral group (propylitically-altered rocks). Green color is indicative of muscovite spectral features (sericitically-altered rocks). Aqua color is considered to show Kaolinite and alunite mineral assemblages (argillically-altered rocks), which is mixed with green color in many parts. Yellow color appearance indicates mixture of chlorite mineral group and muscovite (propylitically- and sericitically- altered rocks). Magenta color illustrates combination of chlorite, epidote and calcite mineral group (propylitically-altered rocks) and argillic alteration zone.

Comparison with geology map (see Fig. 1) of the Oscar II coast area and previous remote sensing study [9], indicate that the red pixels match chlorite and muscovite mineral assemblages. The green pixels match well with the muscovite high abundance zones. Aqua color pixels correspond with the Kaolinite and alunite high abundance regions. Yellow color pixels consist of muscovite-chlorite and Kaolinite-alunite mineral assemblages. Magenta color pixels coincide with chlorite-muscovite class. Furthermore, several anomaly pixels exhibiting distinctive alteration mineral assemblages were mapped in many parts of the Oscar II coast area (Fig. 2), which have been previously classified as low albedo or unassigned to any alteration mineral groups. Figure 3 displays FFC image map covering northern sector of the Oscar II coast.

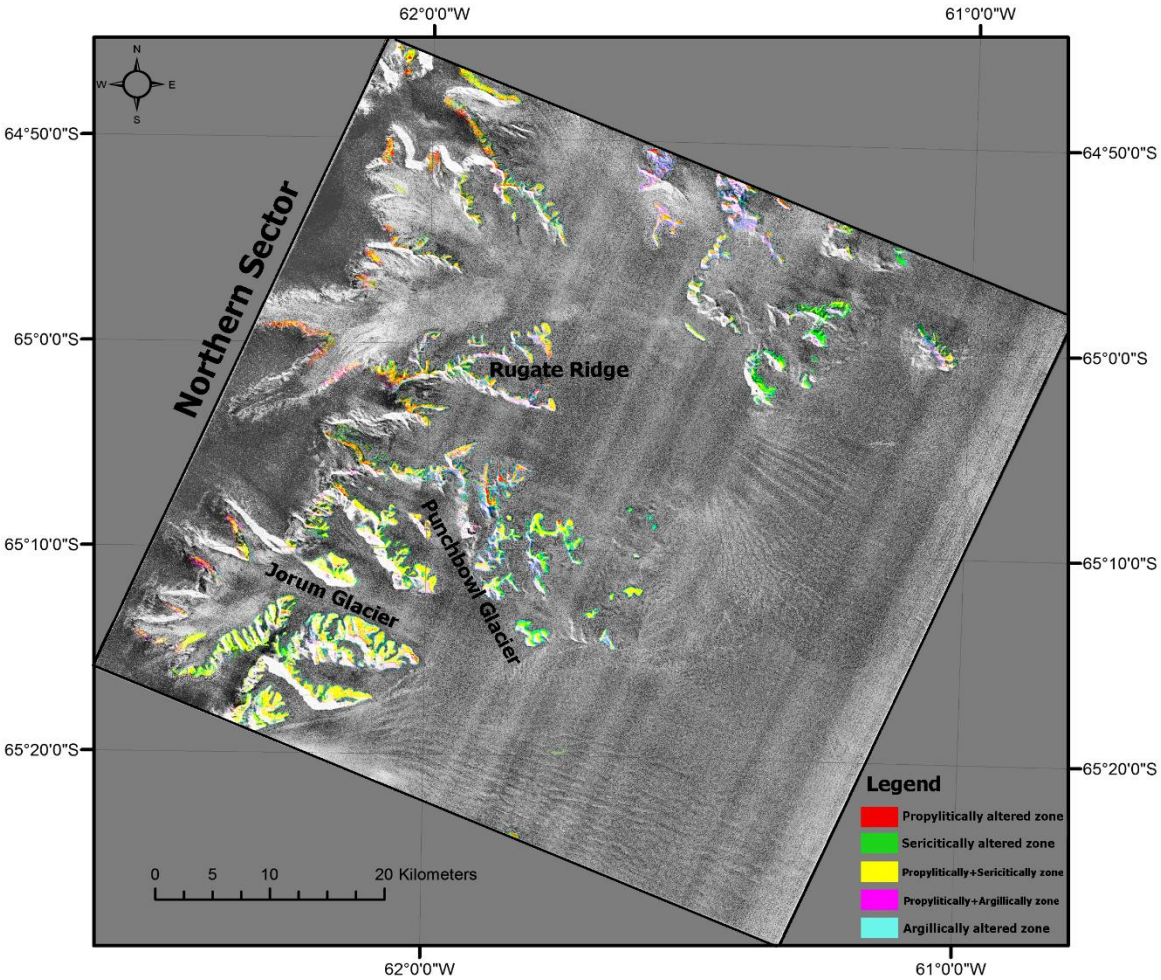

Figure 3. FCC image map (IC5, IC4 and IC3; SWIR bands) of ASTER full scene, northern sector of the Oscar II coast region

As shown in Fig. 3, anomaly pixels appear four dominant alteration mineral assemblages, including muscovite-chlorite and Kaolinite-alunite (yellow pixels), chlorite, epidote and calcite

mineral group (red pixels), muscovite (green pixels) and chlorite- Kaolinite-alunite (magenta pixels). With reference to geology map of the northern part of the Oscar II Coast, undifferentiated sedimentary rocks (Botany Bay and Trinity Peninsula groups) and volcanic/volcaniclastic (Mapple Formation) located near Jorum and Punchbowl Glaciers are coincided with high abundance of yellow pixels and very low dissemination of red pixels.

However, intrusive rocks such as granite and diorite near Rugate Ridge are matched with high distribution of red, magenta and green pixels associated with low abundance of yellow pixels. Thus, poorly exposed lithologies detected in the northern part of Figure 3 might be dominated by intrusive rocks such as granite, granodiorite and diorite units and volcanic/volcaniclastic rocks. Propylitically- and sericitically- altered rocks and propylitically altered rocks are more distributed in the north western part of the image (Figure 3). However, north eastern part of the image dominates by propylitically- and sericitically- altered rocks and sericitically-altered rocks.

4. Conclusion

This investigation has indicated the application of SWIR bands of ASTER datasets for extrapolating satellite-based imagery from relatively mapped area such Oscar II coast area, in north-eastern Graham Land, Antarctic Peninsula (AP) into poorly mapped or unmapped domains. ICA mapped pixel related to Al-O-H, Fe, Mg-O-H and CO3 groups. ICA method provided image maps of alteration mineral assemblages and discriminate felsic to mafic lithological units with little available geological data for poorly mapped regions and/or without prior geological information for unmapped regions in northern sector of Oscar II coast area, Graham Land. The approach used in this study performed very well for alteration mineral mapping with little available geological data or without prior information of the study region.

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