WHITENED DATA-BASED CLUSTER ANALYSIS OF INFRARED SPECTRA OF RYUGU. M. Matsuoka[1], H. Iwamori[2], T. Usui[1], K. Kitazato[3], and T. Iwata[1], [1]Institute of Space and Astronautical Sciences, Japan Aerospace Exploration Agency, Kanagawa, 252-5210, Japan (matsuoka.moe@jaxa.jp), [2]Earthquake Research Institute, The University of Tokyo, Tokyo, Japan, [3]University of Aizu, Fukushima, Japan.

Introduction: The Near-infrared Spectrometer (NIRS3) onboard the Hayabusa2 spacecraft obtained NIR reflectance spectra of C-type asteroid 162173 Ryugu first at an altitude of ~20 km from 10th to 12th of July 2018 with spatial resolution of ~40 m (Box-A). Recent NIRS3 observations at a longer solar distance successfully obtained Ryugu's NIR spectra with less thermal effects. NIRS3 data showing a 2.72-µm OH stretching absorption and a low reflectance constantly are globally homogeneous and similar to moderately-heated or shocked carbonaceous chondrite spectra [1, 2].

This study performs cluster analysis of Ryugu NIR spectral data by using a new statistical method [3] based on combinations of k-means cluster analysis (KCA), principal component analysis (PCA), and independent component analysis (ICA) for original Box-A data. The results show the NIR spectral heterogeneity within homogeneous morphological terranes in the northern equatorial region of Ryugu, possibly reflecting mineralogical and/or physical properties of Ryugu surface material.

Instrument: NIRS3 has a 128-channel indium arsenide (InAs) photodiode sensor installed in the spectrometric unit and cooled below 193 K (−80 °C) using a passive radiator. The detectable wavelength range of NIRS3 is 1.8–3.2 µm and spectral sampling resolution is 18 nm [4].

Methods: Our cluster analysis is divided into three steps: (1) standardization and whitening of the original data using PCA, (2) dimension reduction of the data by selecting principal components (PCs) with significant eigenvalues and the corresponding scores of individual data, and (3) performing KCA (and ICA) [3]. Whitening is essential to extract the independent features hidden in the data, which is not possible only by standardization. Here we report preliminary results of KCA and PCA using NIRS3 Box-A data obtained on July 10th 2018. Since a parameter study is required to determine the optimal number of cluster, we reduced the data volume and computational time by selecting eight channels of NIRS3 data with ~200 nm interval from original 128 channels with 18 nm resolution.

Results and Discussion: NIRS3 spectral data obtained around a northern equatorial region, where there are no significant morphological features such as large craters, show that the data variation involves three significant PCs. Then, we performed KCA using the scores of three PCs as the whitened and dimension-reduced data. To find the optimal number of cluster (k), k was varied from three to ten. The case with k = 6 (Figs.1,2) captures well the features of a regional heterogeneity despite the homogeneous morphological features obtained by the Optical Navigation Camera Telescope (ONC-T) images [2].

All the cluster have a common strength OH absorption at 2.72 µm with similar depths, yet they have various albedos (Fig.3) and red slopes (in 1.80-2.50 µm wavelength range) (Fig.4). These spectral features possibly indicate that the observed northern equatorial region experiences similar degrees of thermal alteration and space weathering. Alternatively, more plausible causes producing this NIR feature are as follows; (a) carbon content, (b) opaque material (e.g., Magnetite) abundance, and (c) grain size and porosity at the surface of Ryugu. A previous clustering study [5] suggest that NIR clusters reflect difference in hydrous mineral contents. Our study further propose a possibility the grain size effect for spectral reddening.

In this study we found that NIRS3 looks constant but clustering results indicate NIR spectra possibly have heterogeneity depending on the region. For the next steps, we will perform KCA, PCA, and ICA analyses using global NIR data of Box-A sequence.

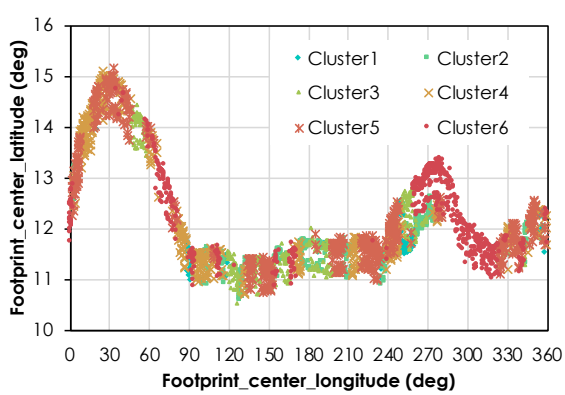

Figure 1. A NIRS3 cluster map obtained on July 10th 2018. The distribution of six clusters are clearly separated by longitude.

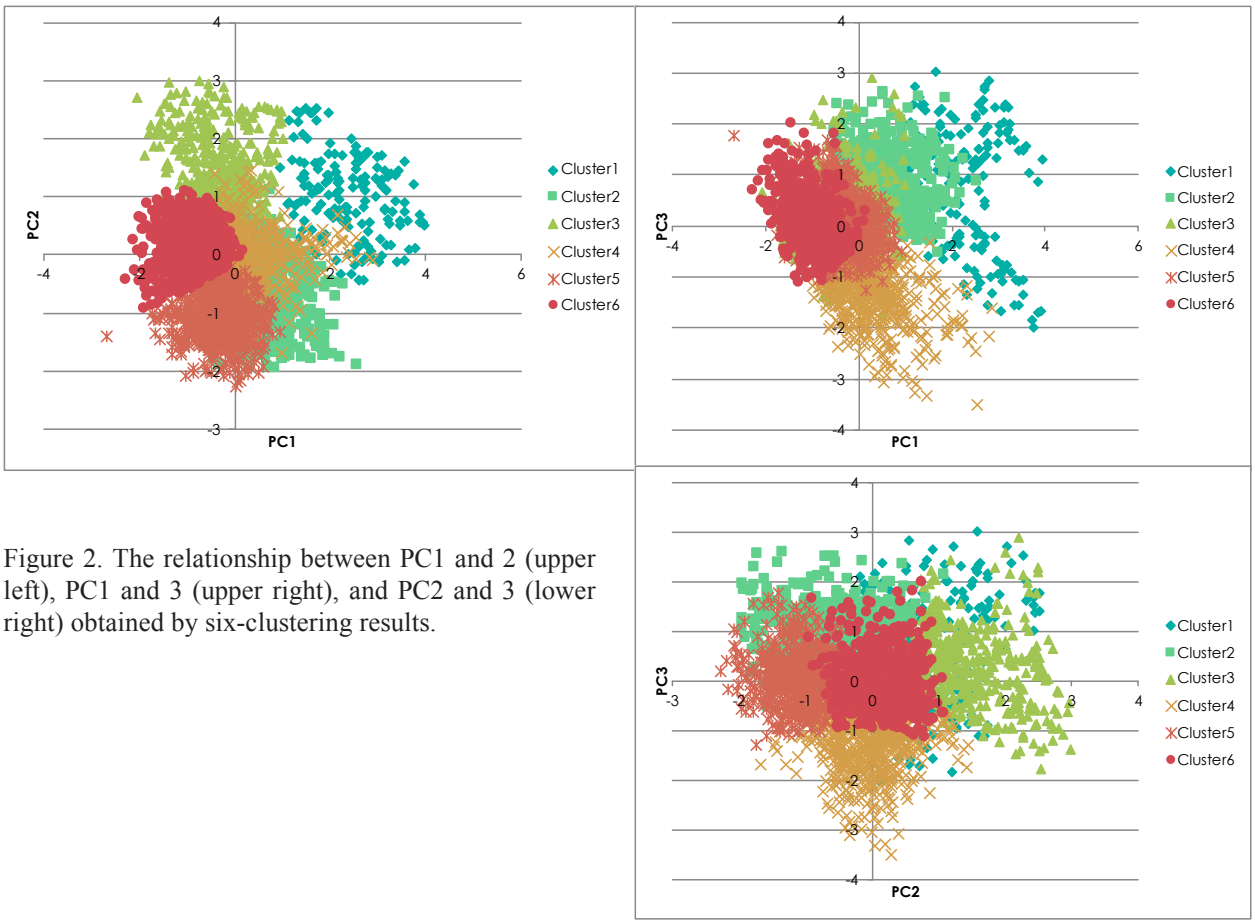

Figure 2. The relationship between PC1 and 2 (upper left), PC1 and 3 (upper right), and PC2 and 3 (lower right) obtained by six-clustering results.

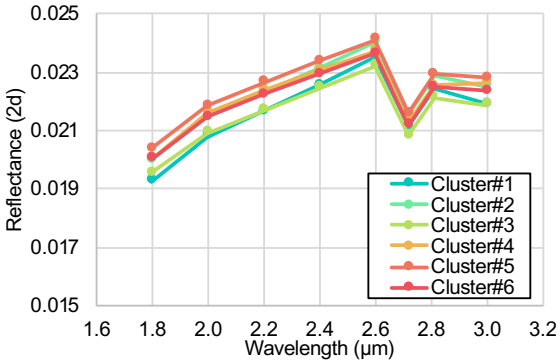

Figure 3. Average spectra of each cluster.

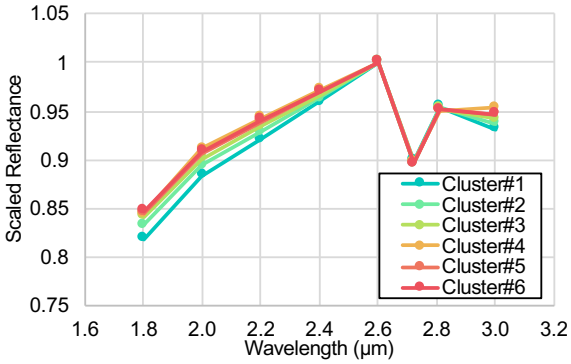

Figure 4. Average spectra of each cluster normalized at 2.60 μm shown in Figure 3.

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References: [1] Kitazato, K. et al. (2019) Science, 364, 272. [2] Sugita, S. et al. (2019) Science, 364, 252. [3] Iwamori, H. et al. (2017) Geocham. Geophys. Geosyst., 18, 994-1012. [4] Iwata, T. et al. (2017) Space Sci. Rev., 208, 317-337. [5] Barucci, A. et al. (2019) Astron. Astrophys., 629, A13.