CLUSTERING ANALYSIS OF NIRS3 INFRARED SPECTRAL DATA OF RYUGU. M. Matsuoka[1], H. Iwamori[2], T. Usui[1], D. Domingue[3], K. Kitazato[4], 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]Planetary Science Institute, Arizona, USA, [4]University of Aizu, Fukushima, Japan.

Introduction: The Near-infrared Spectrometer (NIRS3) onboard the Hayabusa2 spacecraft obtained near-infrared (NIR) reflectance spectra of C-type asteroid 162173 Ryugu at an altitude of ~20 km from July 10-12 2018 with a spatial resolution of ~40 m (Box-A). The NIRS3 data show a 2.72-μm OH stretching absorption and a low reflectance which are globally homogeneous and similar to moderately-heated or shocked carbonaceous chondrite spectra [1, 2].

This study performs cluster analysis of Ryugu's NIR spectral data 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 the original Box-A data. The results show spectral heterogeneities within homogeneous morphological terranes in Ryugu's northern equatorial region, suggesting mineralogical and/or physical property differences within Ryugu's surface material.

Instrument: NIRS3 has a 128-channel indium arsenide (InAs) photodiode sensor installed in the spectrometric unit and is cooled below 193 K (−80 °C) using a passive radiator. The detectable wavelength range is 1.8–3.2 μm with a spectral sampling resolution of 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 the 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 11th 2018. Since a parameter study is required to determine the optimal number of clusters, we reduced the data volume and computational time by selecting seven channels ranging from 1.8 to 3.0 μm of NIRS3 data with ~200 nm interval and one channel at 2.72 μm from the original 128 channels.

Results and Discussion: The NIRS3 global spectral data, after photometric correction, show that the data variation can be characterized with three significant PCs. We performed KCA using the values of these three PCs as the whitened and dimension-reduced data. To find the optimal number of clusters (k), k was varied from five to eight. The case with $k = 6$ (Figs.1,2) best captures the spectral properties. Regional heterogeneity is observed, even in the northern equatorial region which displays homogeneous morphological features in the Optical Navigation Camera Telescope (ONC-T) images [2].

All the clusters have a common OH-absorption at 2.72 μm with similar depths, yet they have differences in albedo (Fig.3) and red slope (in 1.80-2.50 μm wavelength range) (Fig.4). The brightest average spectra are distributed around the equatorial ridge and are also widely located in the Southern hemisphere around 150 to 300 degrees in longitude. Interestingly, the spectra of the pole regions are grouped into the same clusters as those distributed in other areas. In addition to global

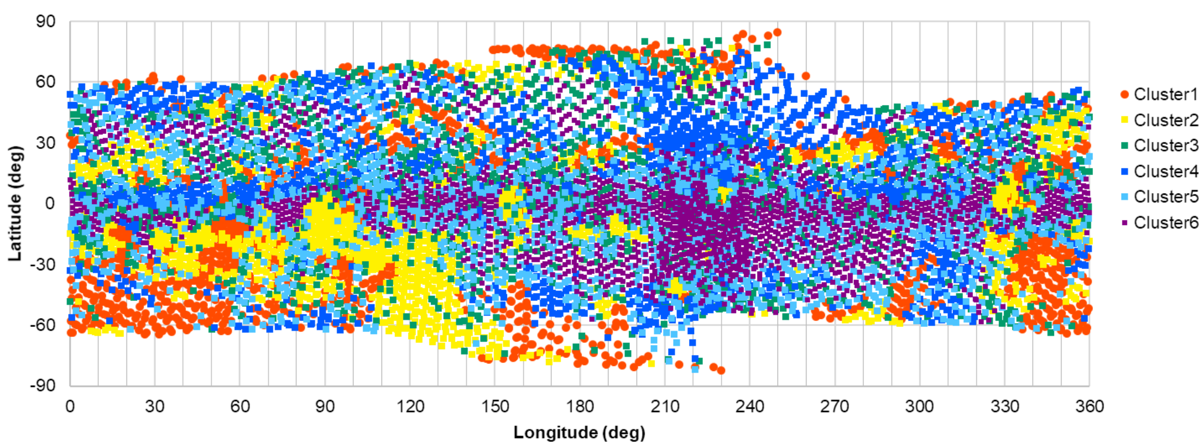
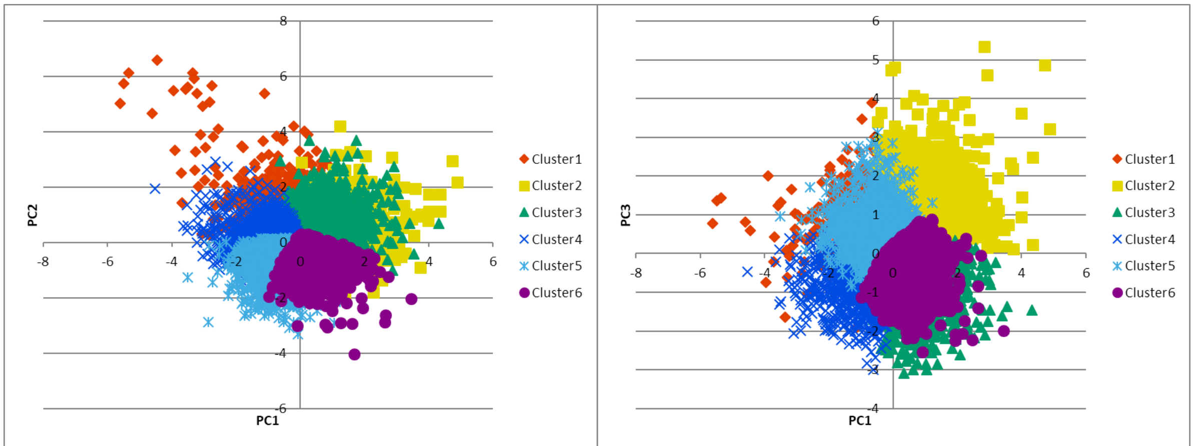


Figure 1. A NIRS3 cluster map obtained on July 11th 2018. The distribution of six clusters are clearly separated by morphological region, such as the equatorial ridge.



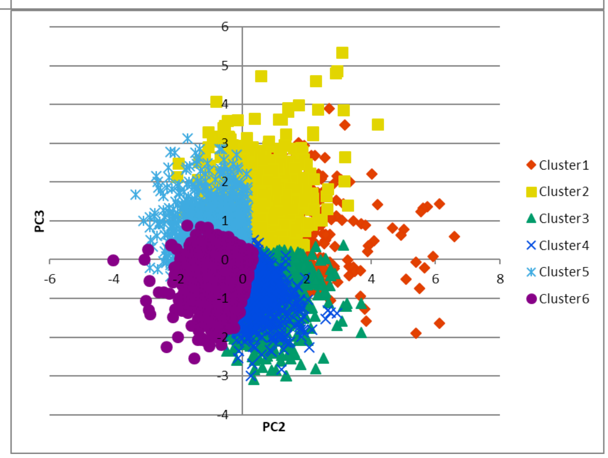


Figure 2. The relationship between PC1 and 2 (upper left), PC1 and 3 (upper right), and PC2 and 3 (lower right) obtained by six-clustering results.

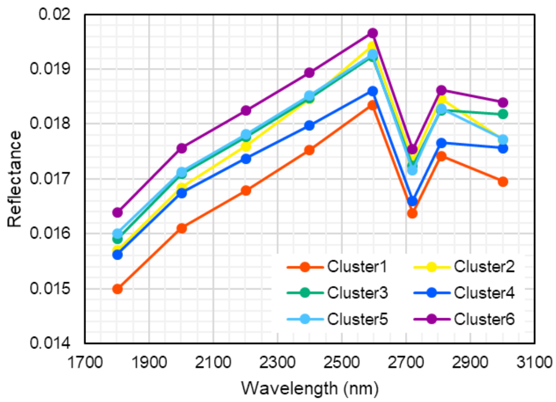


Figure 3. Average spectra of each cluster.

thermal alteration, more plausible causes producing this NIR feature variation include variations in; (a) carbon content, (b) opaque material (e.g., magnetite) abundance, (c) grain size and porosity, and (d) space weathering maturation across the surface of Ryugu. A previous clustering study [5] suggest that NIR clusters reflect differences in hydrous mineral contents. Our study further proposes a possible grain size variation to explain the spectral reddening.

In this study we found that the clustering results indicate NIR spectra can be heterogeneous depending on location. For the next steps, we will perform KCA, PCA, and ICA analyses using photometric-corrected NIR data of lower altitude observations.

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.

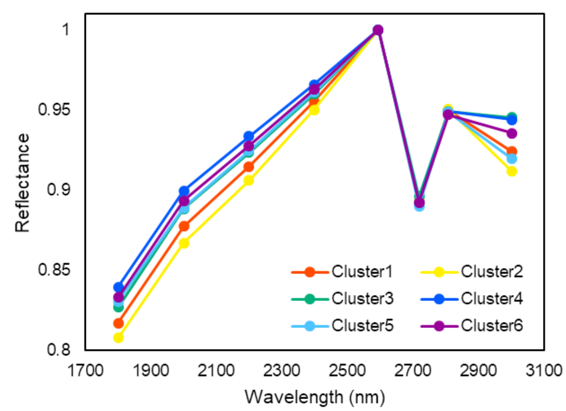


Figure 4. Average cluster spectra normalized at 2.60 μm.

Acknowledgements: We appreciate support from the Japan Society for the Promotion of Science (JSPS) Core-to-Core Program "International Network of Planetary Sciences", and JSPS Grant-in-Aid for Scientific Research on Innovative Areas (Aqua Planetology, No.17H06459). D. Domingue was supported by the NASA Hayabusa2 Participating Scientist Program (NNX16AL34G), and the Solar System Exploration Research Virtual Institute 2016 (SSERVI16) Cooperative Agreement (NNH16ZDA001N) SSERVI-TREX.