# Analysis of Land Surface Change over the Tsambagarav Ridge Using the Pixel Quality Assessment Band of the Landsat Data Product

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**Abstract:** The Kobdo active fault passes near the Tsambagarav mountain, which is part of the Mongolian Altai. Information regarding changes in Tsambagarav's surface is useful for assessing natural risks such as landslides, floods, and glacier recession due to earthquakes. Satellite remote sensing techniques provide an opportunity to monitor the surface and to extract hazard information from a long-term perspective. In particular, observational data from the Landsat series have been archived as historical records on the Earth's surface for half a century. There are several data products based on the Landsat raw data. For example, the Landsat Collection 2 Level 2 Science Product (L2SP) contains not only band images for surface reflectance and temperature after atmospheric correction, but also pixel quality assessment (QA) bands. Since the QA band includes a confidence level for snow/ice at the individual pixels, its combinational use with surface band images is expected to be a quantitative and qualitative assessment of natural risks from a long-term viewpoint. In several bands, this study focuses on visible bands of the blue, green, and red wavelength regions for natural color representation that enables visual assessment on the Tsambagarav landscape, with snow/ice information from the QA band. The objective of the present paper was to generate two types of temporal averaged images over multiple years from a time series of the visible and pixel QA bands of L2SP, and to analyze the surface dynamics of Tsambagarav based on the generated images. A simple procedure of generating an image over multiple years was designed to reduce the atmospheric effects, such as rain and snow, which include severe cold and a snow disaster known as a dzud. The procedure consisted of three steps. First, Landsat L2SP data were downloaded under the observation conditions of a clear sky in the summer season. In this study, the conditions were set as there being a cloud coverage lower than 10% in the three months of June, July, and August. Second, a binary classification map was prepared by storing one value, in the event of the snow/ice confidence of the pixel QA band being high. Third, the frequency image and mean color composite images were generated from the binary map and the reflectance images in visible bands, respectively, by performing temporal averaging at the pixel level. Both temporally averaged images were generated within plus/minus a specific year. Numerical experiments were performed using 72 scenes of L2SP collected from 1987 to 2021. Then, 32 scenes were excluded for their extreme conditions of a wide coverage of cloud (6 scenes) and snow (7 scenes), and Landsat 7 after a scan line error was caused (19 scenes). Therefore, 40 scenes were used for the generation of the average images. The span for the temporal average was defined as plus/minus 5 years (10 years in total). After pre-processing to enhance the land surface signals, 40 scenes for the summer season were processed by a temporal

averaging operation for scenes within a decadal span. The operation had a 10-year range; therefore, the middle year of the averaging range started in 1992 and ended in 2016 for the collected data. Adapting the operation to include between 1992 and 2016 yielded two types of multitemporal data cube, which were composed of 25 images. Both data cubes from visible and QA bands were analyzed in time order to evaluate their information regarding Tsambagarav's surface dynamics. Evaluation of the generated multitemporal data cube started with a visual assessment via the natural color composite images. The results of visual inspection of the composite images over 24 years showed a darkening trend in terms of the brightness. In fact, all of the area-averaged values of reflectance images from a natural color composite (blue, green, and red bands) became smaller over time. Another result of the frequency images from binary maps indicated that the cumulative values up to 30% increased, and the frequency value that was higher than 15% to 30% showed a strong correlation (approximately -0.90) with the middle year of the averaging range. Next, the frequency images were converted to a vector format to obtain their spatial profiles as polygons. The data processing was executed in an Esri ArcGIS environment, and the conversion from raster to vector was performed using a 15% threshold. Many of the extracted polygons had smooth curved shapes. The overlay of the extracted polygons on the natural color image showed the mapping area near the edge of the glaciers. Finally, comparisons of polygons from distinct decades, 1987-1997 and 2011-2021, showed various patterns of shape transformations that occurred over 24 years. It was also found that the edge areas became slightly smaller and partially coincided with the actual shrinkage area over Tsambagarav, which implied changing conditions, especially at the edges of glaciers. These findings suggest that the frequency of binary classification for ice/snow confidence by a simple procedure for L2SP is suitable for assessment of the glacier conditions over Tsambagarav under an appropriate percentile setting. For assessing its natural risks under global warming based on the extracted polygons, geospatial analysis with additional bands of L2SP and a terrain model needs to be carried out in future studies.

**Keywords:** Tsambagarav, Landsat, QA Band, natural color composite, Brightness