Recurring slope lineae on Earth: Implications for hydrological cycles and potential habitability on Mars

*Yasuhito Sekine[1], Maya Nakamura[1], Davaasuren Davaadorj[2], Daigo Shoji[1], Koki Morida[3], Keisuke Fukushi[3], Noriko Hasebe[3], Shawn E McGlynn[1]

1. Tokyo Institute of Technology, 2. National University of Mongolia, 3. Kanazawa University

Knowledge on dynamics and cycles of water on present-day Mars is central to understand the surface environments and habitability of this planet. The present study focuses on recurring slope lineae (RSL). Recurring slope lineae are dark, narrow features that appear on steep slopes in warm seasons and fade in cold seasons. Although the formation mechanism of RSL remains in debate, RSL could provide unique insights into dynamics and cycles of water on Mars. Unlike the previous studies that analyzed remote sensing data of RSL, the present study constrains the formation mechanism of RSL based on search, classification, and field survey of terrestrial RSL analogues. Based on the investigations of the terrestrial RSL analogues, we aim to constrain the dynamics and cycles of water on Mars.
We first search for terrestrial RSL analogues in a global scale using available satellite images. We first discover twelve RSL analogues, which exhibit similar morphological features to Martian RSL, in cold and (semi-)arid areas on Earth. These analogues are classified into three types (types A, B, and C) based on their morphological characteristics. We then conduct the field survey for these terrestrial RSL analogues near the Khangai mountains in Mongolia, where all type of the terrestrial RSL analogues appears. We find that the type-A RSL analogue is formed by exposure of dark soil through removal of surface bright sand grains due to transient surface runoff in warm seasons. The type-B RSL analogue is generated by continuous surface runoff possibly due to melting of subsurface ice in warm seasons. The type-C RSL analogue is formed due to physical weathering of bedrocks on the slopes. We suggest that the type-A RSL analogue can explain all of the characteristics of Martian RSL, including the absence of infrared absorption due to liquid water on RSL and their appearance on steep slopes. To form type-A RSL on Mars, transient surface runoff with high flow velocity needs to occur in warm seasons. Based on modeling of upwelling groundwater from aquifer through rock fractures, we suggest that such surface runoff can occur if aquifer is located at ~500 m below the surface or deeper with a volume less than ~10^4 m^3. This suggests that RSL would be supported by a small, localized water source, rather than a large, global-scale groundwater source. RSL sites could be a potential habitat for chemo-autotrophic microbial life. Our results of microbial community structure analysis for terrestrial RSL analogue suggest that chemoautotrophic methanotroph could exist in the RSL sites. The measured number density of methanotroph in the terrestrial RSL analogue in warm seasons is detectable using existing life-detection techniques for Mars missions. Recurring slope lineae could be a promising target for landing in future missions to find extraterrestrial life.

Keywords: Mars, hydrological cycles, space mission