Seasonal transition of a hydrological regime in a reactivated landslide underlain by weakly consolidated sedimentary rocks in a heavy snow region

(豪雪地帯の堆積軟岩を基盤とする 再活動型地すべり地における水文過程の季節的遷移)

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Summary

The present study revealed a seasonal transition of a hydrological regime in a reactivated landslide underlain by weakly consolidated sedimentary rocks in Niigata Prefecture, Japan, where the conditions of the ground surface change significantly with seasonal vegetation growth and thick snow cover.

The results of infiltration capacity test at a fixed point through three years revealed that the permeability of the land surface began to increase immediately after snowmelt, reaching a peak in midsummer and decreasing from autumn to winter. The reason for the seasonal change in infiltration capacity was considered to be the effect of biological activity, the growth and decay of vegetation. The permeability of the land surface in winter seemed to be affected by the compaction of the shallow subsurface soil due to the snow mantle. Therefore, I evaluated changes in soil permeability caused by loading using a newly developed apparatus with undisturbed and remolded samples. In the results, the hydraulic conductivity decreased exponentially as the samples were consolidated by loading. This tendency harmonized that the residual materials, consisting of clayey soil, were in an overconsolidated state. These findings suggest that the decrease of topsoil permeability caused by snow load could be related the occurrence of patchy overland flow during the snowmelt period.

I excavated a vertical soil pit to the depth of 2 m and investigated the vertical profiles of hydraulic characteristics using undisturbed samples taken from the pit. The results showed that the shallower gravelly colluvial soil had a larger hydraulic conductivity and lower water retention ability, whereas the deeper tuffaceous residual material was massive and characterized by a smaller hydraulic conductivity and high water retention. The deeper portion, from the residual materials to the sliding surface at the depth of 5.2 m, consisted of fractured

bedrock. Long-term meteo-hydrological monitoring demonstrated seasonal change in hydrological processes. The fluctuation of moisture content in the shallow unsaturated zone changed markedly with the season and was characterized by a prompt response to individual rainfall events during summer and maintenance of stable values under snow cover during winter. The pore-water pressure in the bedrock responded to MR input throughout the year. The pressure head response to rainfall without snow cover had a greater magnitude than that of melting snow. This seasonal difference was likely caused by the suppression of water infiltration into the ground due to the occurrence of overland flow and effective pore-water drainage through the uppermost colluvium. The anomalous foehn event during midwinter resulted in significant snowmelt, and a rapid and prominent increase in pore-water pressure was observed. This phenomenon can be explained by meltwater flowing through preferential paths in the layered structure of the thick snowpack and then draining onto localized points on the ground. The upward hydraulic gradient in the bedrock was enhanced by the increasing moisture content of the surface soils in late fall and snow-melting period, reflecting the convergence of groundwater from the surrounding hillslopes. Landslide reactivation can be triggered by the increasing groundwater influx.

Hydrological modeling revealed seasonal characteristics of the vadose zone, reproducing the short-term response of observed pore-water pressure. An attempt was made to assess whether features of the vadose zone could be used to express hydraulic conductivity and hydraulic diffusivity as variables in a vertical one-dimensional linear-diffusion model. As a result of the modeling, both hydraulic conductivity and hydraulic diffusivity were characterized as being lower during summer and higher during winter. These values can describe an empirical function of pore-water pressure before the event. Short-term fluctuations in pore-water pressure, potentially inducing landslides, can be predicted with high accuracy by characterizing the buffer features of the vadose zone as empirical hydraulic parameters.