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Developments of hydrogeophysical characterization and long-term monitoring for landslide early warning

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Landslides are major and frequent natural hazards. They shape the Earth's surface, and endanger communities and infrastructure worldwide. Within the last decade, landslides caused more than 28,000 fatalities and direct damage exceeding $1.8 billion. Climate change, causing more frequent weather extremes, is likely to increase occurrences of shallow slope failures worldwide. Thus, there is a need to improve our understanding of these shallow, rainfall-induced landslides and develop techniques that can be used as reliable early warning systems. In this context, integrated geophysical characterization and monitoring can play a crucial role by providing volumetric data that can be linked to the hydrological and geotechnical conditions of a slope. This enables understanding of the complex hydrological processes most-often being associated with landslides. Here we present data gathered at the Hollin Hill Landslide Observatory over the last decade. During this time, the landslide has experienced different activity characteristics, including creep, flow, and rotational failures. The research at this observatory has been focused on the development of 4D geoelectrical monitoring techniques to estimate electrode positions from the resistivity data, incorporating these into a time-lapse inversion, and imaging hydrological processes that control the landslide behaviour. This work is underpinned by a detailed characterization of the landslide, using geomorphological and geological mapping, geotechnical investigations, and a thorough geoelectrical and seismic characterization of the landslide mass. Hence, the data gained from the Hollin Hill landslide observatory has improved our understanding of the shallow landslide dynamics in response to climate change, their mechanics and evolution, and allowed defining a moisture content threshold that can be used for landslide early warning. The methodological and technical developments achieved at this site are suitable and applicable for implementation on other landslides worldwide.