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Early warning, warning or alarm systems for natural hazards? A generic classification.

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Early warning, warning and alarm systems have gained popularity in recent years as cost-efficient measures for dangerous natural hazard processes such as floods, storms, rock and snow avalanches, debris flows, rock and ice falls, landslides, flash floods, glacier lake outburst floods, forest fires and even earthquakes. These systems can generate information before an event causes loss of property and life. In this way, they mainly mitigate the overall risk by reducing the presence probability of endangered objects. These systems are typically prototypes tailored to specific project needs. Despite their importance there is no recognised system classification. This contribution classifies warning and alarm systems into three classes: i) threshold systems, ii) expert systems and iii) model-based expert systems. The result is a generic classification, which takes the characteristics of the natural hazard process itself and the related monitoring possibilities into account. The choice of the monitoring parameters directly determines the system's lead time. The classification of 52 active systems moreover revealed typical system characteristics for each system class. i) Threshold systems monitor dynamic process parameters of ongoing events (e.g. water level of a debris flow) and incorporate minor lead times. They have a local geographical coverage and a predefined threshold determines if an alarm is automatically activated to warn endangered objects, authorities and system operators. ii) Expert systems monitor direct changes in the variable disposition (e.g crack opening before a rock avalanche) or trigger events (e.g. heavy rain) at a local scale before the main event starts and thus offer extended lead times. The final alarm decision incorporates human, model and organisational related factors. iii) Model-based expert systems monitor indirect changes in the variable disposition (e.g. snow temperature, height or solar radiation that influence the occurrence probability of snow avalanches) or trigger events (e.g. heavy snow fall) to predict spontaneous hazard events in advance. They encompass regional or national measuring networks and satisfy additional demands such as the standardisation of the measuring stations. The developed classification and the characteristics, which were revealed for each class, yield a valuable input to quantifying the reliability of warning and alarm systems. Importantly, this will facilitate to compare them with well-established standard mitigation measures such as dams, nets and galleries within an integrated risk management approach.