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Nonlinear response of small-scale rockfall activity to rainfall intensity: the importance of gross secondary rockfall events

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Rockfall is a major hazard which causes significant economic damage and loss of life in every mountain environment. People have little influence on the hazard itself, but we can decrease vulnerability enormously if we succeed in understanding the spatial and temporal patterns of rockfall.

From 1999-2003, 140,000 kg of rockfall deposits were collected and analysed in 940 m^2 of rockfall collectors in the Reintal, Wetterstein Mountains, Bavarian Alps. As this study aimed to link rockfall intensity to the presence of certain triggering forces we measured rockfall with a high temporal resolution of up to one day. The rockfall data was compared with hourly rainfall intensities that were obtained from a nearby rain gauge and precipitation radar images with a temporal resolution of 15 minutes and a spatial resolution of 2 km. Seismic activity and freeze-thaw events were assessed, too.

More than 90 % (130.000 kg) of the total rockfall deposition from 1999-2003 occurred within two hours branded by the activity of intense rainstorms. The two rainstorms at August 1, 2003 and June 14, 2003 yielded previously unreported rockfall intensities that ranged from 0.56 to 300 kg m^{-2} h^{-1} and exceeded rockfall intensities of dry, warm periods by up to 10 million on average. We termed this previously unreported type of rockfall “gross secondary rockfall events”. The g.s.r. events were defined as

a short-term mass deposition of fine-grained rockfall material that originates from intermediate storages in the rock wall and is released by fluvial processes and debris-saturated flows active in the rock face; the short-term intensity of rockfall deposition exceeds the deposition during dry periods without frost by a factor of at least 10^4.

The rockfall response to short-term rainfall intensity was very similar for all rockfall collectors. Rainfall intensity values up to 9-13 mm/h yield no or only a very small increase in rockfall intensity. Rainfall intensities exceeeding threshold values of 13 mm/h yielded g.s.r. events and thus a sudden nonlinear increase in rockfall activity. We established three nonlinear logistic growth functions for different topographic settings that model rockfall response to short-term rainfall intensity with correlations from R^2 = 0.89 to 0.99.