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Statistical analysis of geogenic carbon dioxide dispersion in atmospheric layers: Application to the seismically sensitive Syabru-Bensi hydrothermal system, central Nepal

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Significant geogenic carbon dioxide (CO2) emissions have been reported worldwide at plate boundaries in both volcanic and non-volcanic contexts. Specific hydrothermal manifestations observed at the surface show large CO2 emissions that remain difficult to quantify precisely. These include "CO2 rivers", which are turbulent, negatively buoyant flows that propagate near the surface following the topography and entrain large amounts of air due to wind shear. Understanding their temporal variations, possibly related to tectonic deformation and earthquakes, is crucial to mitigate the associated hazards and risks to the population. Here, we develop a statistical analysis to constrain CO2 dispersion in the first atmospheric layers using the numerical model TWODEE, a 2D shallow-layer code for dense flow dispersion. We apply the analysis to the Syabru-Bensi hydrothermal system located in the upper Trisuli Valley, central Nepal, where metamorphic CO2 is produced at depth and released at the surface on slopes and alluvial terraces. This system was severely affected by the 2015 Gorkha earthquake crisis. Constrained by CO2 concentration data at different heights above the ground and by surface CO2 fluxes, our simulations help to identify different turbulent zones from the CO2 source, to predict the spatiotemporal variations of CO2 concentration at different heights above the ground under various conditions, and to estimate the total CO2 emission. We obtain significant differences between interseismic and postseismic regimes, following the Gorkha earthquake. Our study provides a better characterisation of the atmospheric CO2 dispersion and opens promising perspectives for the airborne detection of geogenic CO2 in Himalayan valleys.

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