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2D dynamical magma propagation modeling: application to the 2001 Mount Etna eruption

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Numerical and analog studies of dike propagation in a stress field induced by volcanic edifice construction have shown that surface loading tends both to attract the magma and to reduce its velocity. Available numerical models can either calculate the trajectory or the velocity of the ascending dikes, but not both of them simultaneously. We developed a hybrid model of dyke propagation in two dimensions solving both for the magma trajectory and velocity as a function of the source overpressure, the magma physical properties (density and viscosity) as well as the crustal density and stress field. We first calculate a dyke trajectory in 2D and secondly run a 1D dynamical model of dyke propagation along this trajectory taken into account the influence of the stress field seen by the magma along this path. This model is used to characterize the influence of surface load on magma migration towards the surface and compared to previous results obtained by analog modeling.We find that the amplitude of dyke deflection and magma velocity variation depend on the ratio between the dyke driving pressure (source overpressure as well buoyancy) and the stress field perturbation. Our model is then applied to the July 2001 eruption of Etna, where the final dyke deflection had been previously interpreted as due to the topographic load by Bonaccorso et al. [2010]. We show that the velocity decrease observed during the last stage of the propagation can also be attributed to the local stress field. We use the dyke propagation duration to estimate the magma overpressure at the dyke bottom to be less than 4 MPa.