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There are many observations of sunspots, but few attempts at sunspot simulations. empel ( ) presented realistic magneto-hydrodynamic ( ) sunspot simulations, where the horizontal magnetic field at the top boundary is artificially increased, and which show vershed flows in all filaments. Jur k et al. ( ) showed that the magnetic field of such simulations diers from observations in particular, the B_{ver} at the umbral boundary is too low, and the horizontal field in the penumbra is too strong.

sing the a code and a potential field top boundary condition, we simulated a sunspot using potential field initial conditions. Our simulations give B_{ver} at the umbral boundary consistent with observations and show ongoing flu emergence in the penumbra. When running the simulation with these initial and boundary conditions and a ( ) km horizontal (vertical) resolution, the penumbral filaments show bi-directional flows: in- down-flows in the inner penumbra and outflows in the outer penumbra. owever, when using a ( ) km resolution, some filaments show the same behavior, whereas others show the typical vershed (radially outward) flow.

The bi-directional flows are observed in high-resolution observations of penumbra formation by arca- ivas et al. ( ), whereas the vershed flow is observed in the stable phase of sunspots. We investigate penumbral filaments with these dierent flow regimes within our high-resolution simulation, and with those in a lower resolution simulation and a simulation with a dierent top boundary condition. We compare the dierent flow structures in these penumbral filaments.