EGU21-2074
https://doi.org/10.5194/egusphere-egu21-2074
EGU General Assembly 2021

3D mantle flow induced by retreating and advancing slabs: insights from analogue subduction models analysed with a tomographic Particle Image Velocimetry technique

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Slab rollback-induced mantle flow in retreating subduction zones is known to have a significant geodynamic impact on Earth. The resulting quasi-toroidal circulation can deflect mantle plumes, transport geochemical signatures and have an upwelling component that thereby generates atypical intraplate volcanism near lateral slab edges. Nevertheless, the mantle flow generated by advancing slabs remains unstudied and its geodynamic significance unclear. We therefore conducted analogue buoyancy-driven subduction models to investigate the mantle flow generated in both retreating and advancing subduction modes. We analysed our models using a novel tomographic Particle Image Velocimetry technique, allowing us to compute the 3D velocity field in a volume of the mantle. Our model results show that the advancing subduction mode develops a slab rollover geometry that produces a quasi-toroidal mantle flow with mantle material displaced from the mantle wedge domain to below the subducting plate, opposite to mantle flow during the retreating mode. This slab rollover-induced mantle flow generates an upwelling component that is laterally offset from the subducting plate and is located some ~1000 km from the trench on the subducting plate side. Such newly imaged mantle flow may have implications for intraplate volcanism and the distribution of mantellic geochemical signatures associated with advancing subduction zones, such as the Makran, and continental subduction zones, such as the Himalaya.