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Numerical Investigations into the Effect of Trench Migration on Three-Dimensional Thermal Structure of the Subduction Zone Mantle Wedge

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The thermal structure of the subduction zone mantle wedge plays an important role in subduction zone volcanism, earthquake generation and upper-plate evolution. Thermo-kinematic models have greatly advanced our understanding of how velocity and age of the downgoing plate and mantle rheology affect temperatures in the mantle wedge, but little work has been done on the effect of trench migration. Plate motion reconstructions indicate that the location of most subduction zone trenches varies through time at velocities that range from 0 to 100% of subduction velocities. Trench migration is most commonly retrograde; that is, opposite to the direction of motion of the plates to which slabs are attached. Such motion generates three-dimensional flow patterns with material moving from below the slab, around the slab's lateral edges (toroidal flow), and into the mantle wedge [Stegman et al., 2006]. However, owing to computational limitations, the influence of this toroidal flow component on the thermal structure of subduction zones has not yet been quantified. In this study, we exploit the computational efficiency of Fluidity [Davies et al., 2011], recently benchmarked against the results of van Keken et al. [2008], to perform a three-dimensional parameter space search into the dominant controls upon mantle wedge thermal structure. We use a thermo-kinematic approach, where slab and trench motion are prescribed and wedge flow is computed dynamically, to examine the role of: (i) slab dip; (ii) slab width; (iii) the depth extent of the slab; (iv) mantle rheology; and (v) trench motion. In all cases examined, poloidal flow dominates in the mantle wedge. However, a significant toroidal component is also observed, amounting to greater than 25% of the poloidal flow. Whilst a toroidal component is also present in models with no trench motion, it increases with trench retreat velocity, particularly at slab dips greater than 50 degrees. We demonstrate that this toroidal component has a significant influence on mantle wedge thermal structure.

References

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