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FEniCS-SZ: two-dimensional modeling of the thermal structure of subduction zones

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Summary

Plate tectonics … subduction zones … volcanoes, earthquakes,…. metamorphism …. temperature control (van Keken & Wilson, 2023)

Figure of SZ thermal structure with oceanic and continental Moho.

Statement of need

`FEniCS-SZ` is cool and is based on Wilson & van Keken (2023).

`FEniCS-SZ` is intended also for classroom use and interactive work via a Jupyter notebooks (Wilson et al., 2025) that explore the FEM examples in Wilson & van Keken (2023). The didactic nature of these tutorials (progressing from the stand-alone Poisson and Stokes equations, reproduction of mantle convection benchmarks, to the fully coupledset of time-dependent equations used in the subduction models) augments the FEniCSX Tutorial (Dokken, 2023), which is itself built on the FEniCS Tutorial (Langtangen & Logg, 2016).

Comparison with other approaches

Thermal models of subduction zones that are most useful in the prediction of metamorphic dehydration reactions and their role in seismogenesis and seismic structure, slab dehydration, arc volcanism, and the long term chemical evolution of the Earth require high numerical resolution, faithful gridding of material boundaries (such as the slab surface and oceanic Moho), and ability to handle velocity discontinuities along the seismogenic zone and its extension to about 80 km depth. Semi-analytical techniques can be used successfully along the shallow plate interface to limited depth (see discussion and references in van Keken et al. (2019)), but the effects of the cornerflow with realistic mantle rheology requires numerical solution of the Stokes and heat equations. A number of dynamical approaches exist that can be used to trace subduction zone thermal evolution (Holt & Condit (2021), Gerya (2011)) but these provide slab evolution models that are difficult to use when predicting the thermal structure of present-day subduction zones since geometry and convergence parameters such as convergence speed cannot be controlled. Other workers have provided finite element and finite difference approaches to study the thermal structure (e.g. Wada and Wang; Katz; Lin; King). While these approaches have shown good comparisons with other codes in a benchmark (vK09) or in direct comparisons (vK23b) they are generally not available as open source software.

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Software design

Research impact statement

AI usage disclosure

No information or code was harmed by AI.

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References

Dokken, J. S. (2023). *The FEniCSx Tutorial*. https://jsdokken.com/dolfinx-tutorial/

Gerya, T. (2011). Future directions in subduction modeling. *Journal of Geodynamics*, *52*, 344–378. https://doi.org/10.1016/j.jog.2011.06.005

Holt, A. F., & Condit, C. B. (2021). Slab temperature evolution over the lifetime of a subduction zone. *Geochemistry, Geophysics, Geosystems*, *22*.

Langtangen, H. P., & Logg, A. (2016). *Solving PDEs in Python* (p. 146). Springer Open. https://doi.org/10.1007/978-3-319-52462-7

van Keken, P. E., Wada, I., Sime, N., & Abers, G. A. (2019). Thermal structure of the forearc in subduction zones: A comparison of methodologies. *Geochemistry, Geophysics, Geosystems*, *20*, 3268–3288. https://doi.org/10.1029/2019GC008334

van Keken, P. E., & Wilson, C. R. (2023). An introductory review of the thermal structure of subduction zones: I—motivation and selected examples. *Progress in Earth and Planetary Science*, *10*(1), 42.

Wilson, C. R., Seebeck, C., Teshome, K., Sime, N., & van Keken, P. E. (2025). *The FEniCS Subduction Zone Jupyter Book*. https://github.com/cianwilson/fenics-sz/blob/main/readme.md

Wilson, C. R., & van Keken, P. E. (2023). An introductory review of the thermal structure of subduction zones: II—numerical approach and validation. *Progress in Earth and Planetary Science*, *10*(1), 1–29.