

# <sup>1</sup> FEniCS-SZ: Two-dimensional modeling of the thermal structure of subduction zones

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## Software

- [Review](#) 
- [Repository](#) 
- [Archive](#) 

## <sup>7</sup> Summary

## <sup>8</sup> Statement of need

<sup>9</sup> Plate tectonics on Earth is the surface expression of the slow convective release of heat from its interior. Subduction zones form the location of the return flow of mantle convection and <sup>10</sup> are sites of mountain building and significant natural hazards in the form of earthquakes and explosive volcanism. The depth extent of large and sometimes tsunamogenic earthquakes, <sup>11</sup> intermediate-depth earthquakes, and melt formation are linked to thermal transitions and corresponding thermally activated processes such as metamorphic reactions (including those <sup>12</sup> causing dehydration and release of volatile phases such as water and carbon). To understand the short- and long-term evolution of the tectonic and geological processes it is critically <sup>13</sup> important to understand the thermal structure of subduction zones (van Keken & Wilson, <sup>14</sup> 2023a).

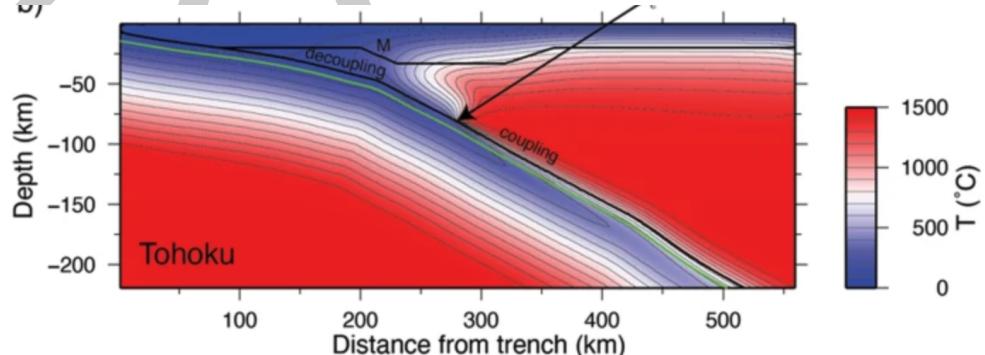


Figure 1: Figure of SZ thermal structure with oceanic and continental Moho.

<sup>19</sup> FEniCS-SZ is cool and is based on Wilson & van Keken (2023).

<sup>20</sup> FEniCS-SZ is intended also for classroom use and interactive work via Jupyter notebooks (Wilson <sup>21</sup> et al., 2025) that explore the FEM examples in Wilson & van Keken (2023). The didactic <sup>22</sup> nature of these tutorials (progressing from the stand-alone Poisson and Stokes equations, <sup>23</sup> reproduction of mantle convection benchmarks, to the fully coupled set of time-dependent <sup>24</sup> equations used in the subduction models) augments the FEniCSX Tutorial (Dokken, 2023), <sup>25</sup> which is itself built on the FEniCS Tutorial (Langtangen & Logg, 2016).

## 26 State of the field

27 Thermal models of subduction zones that are most useful in the prediction of metamorphic  
28 dehydration reactions and their role in seismogenesis and seismic structure, slab dehydration,  
29 arc volcanism, and the long term chemical evolution of the Earth require high numerical  
30 resolution, faithful gridding of material boundaries (such as the slab surface and oceanic Moho),  
31 and ability to handle velocity discontinuities along the seismogenic zone and its extension to  
32 about 80 km depth. Semi-analytical techniques can be used successfully along the shallow  
33 plate interface to limited depth (see discussion and references in van Keken et al. (2019)),  
34 but the effects of the cornerflow with realistic mantle rheology requires numerical solution of  
35 the Stokes and heat equations. A number of dynamical approaches exist that can be used  
36 to trace subduction zone thermal evolution (Holt & Condit (2021), Gerya (2011)) but these  
37 provide slab evolution models that are difficult to use when predicting the thermal structure of  
38 present-day subduction zones since geometry and convergence parameters such as convergence  
39 speed cannot be controlled. Other workers have provided finite element and finite difference  
40 approaches to study the thermal structure (e.g. Wada & Wang (2009); Lee & King (2009);  
41 Lin et al. (2010); Rees Jones et al. (2018); van Zelst et al. (2023)). These approaches  
42 have shown good comparisons with other codes in a code intercomparison (van Keken et al.,  
43 2008), by reproduction of benchmark cases therein, or in direct intercomparisons (van Keken &  
44 Wilson, 2023b). Many of these subduction implementations, however, are not readily available  
45 as open source software even if they are based on general open source finite element software.

## 46 Software design

## 47 Research impact statement

48 Reference papers using predicted thermal structure?

## 49 AI usage disclosure

50 No information or code was harmed by AI.

## 51 Acknowledgements

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