2015 GeoPRISMS Theoretical and Experimental Institute on Subduction Cycles and Deformation

Slab Processes

Effects of 3-D Slab Geometry and Oblique Subduction on Mantle Wedge Flow and Thermal Structure:

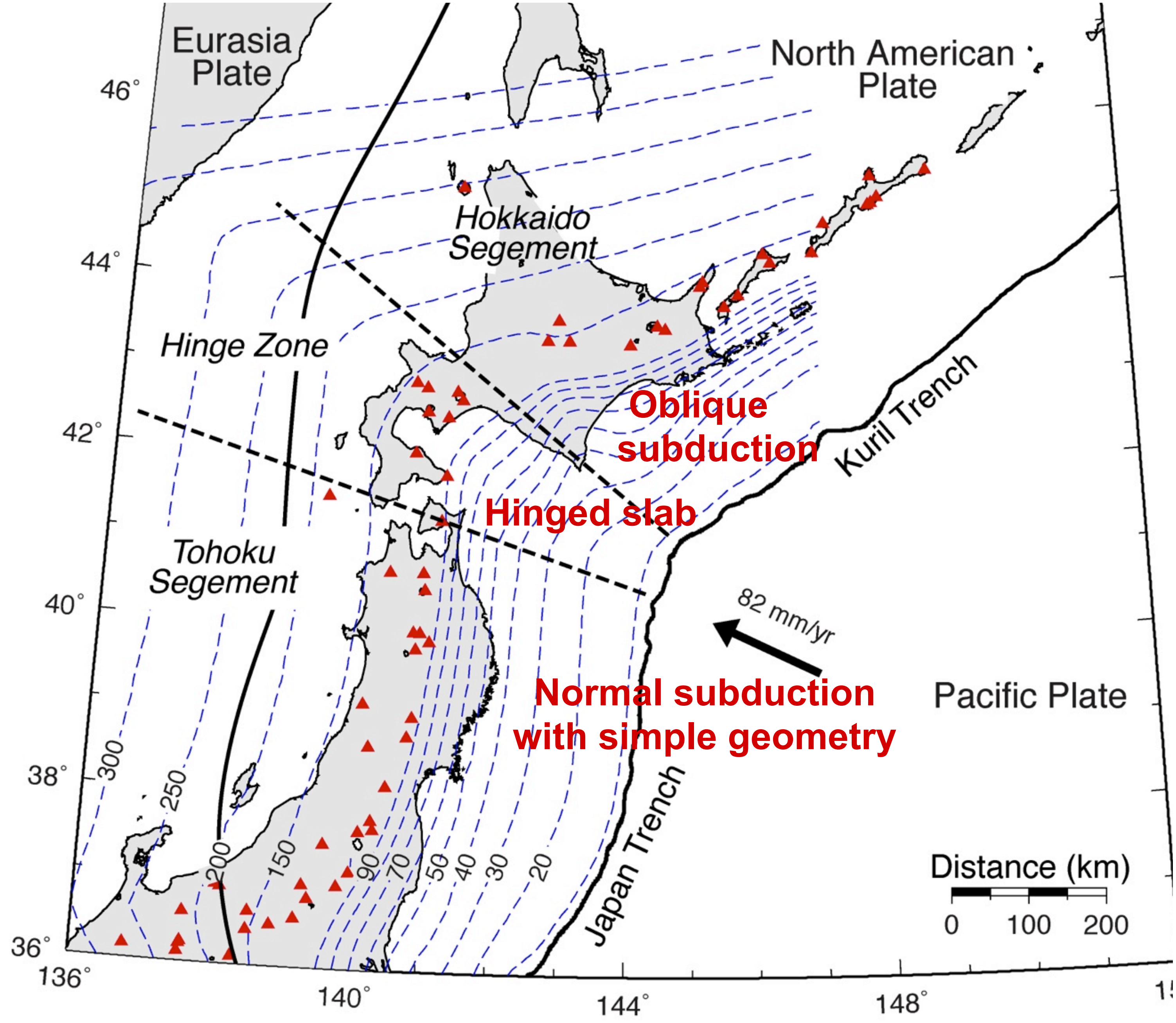
Examples from NE Japan

Ikuko Wada

Department of Earth Sciences, University of Minnesota

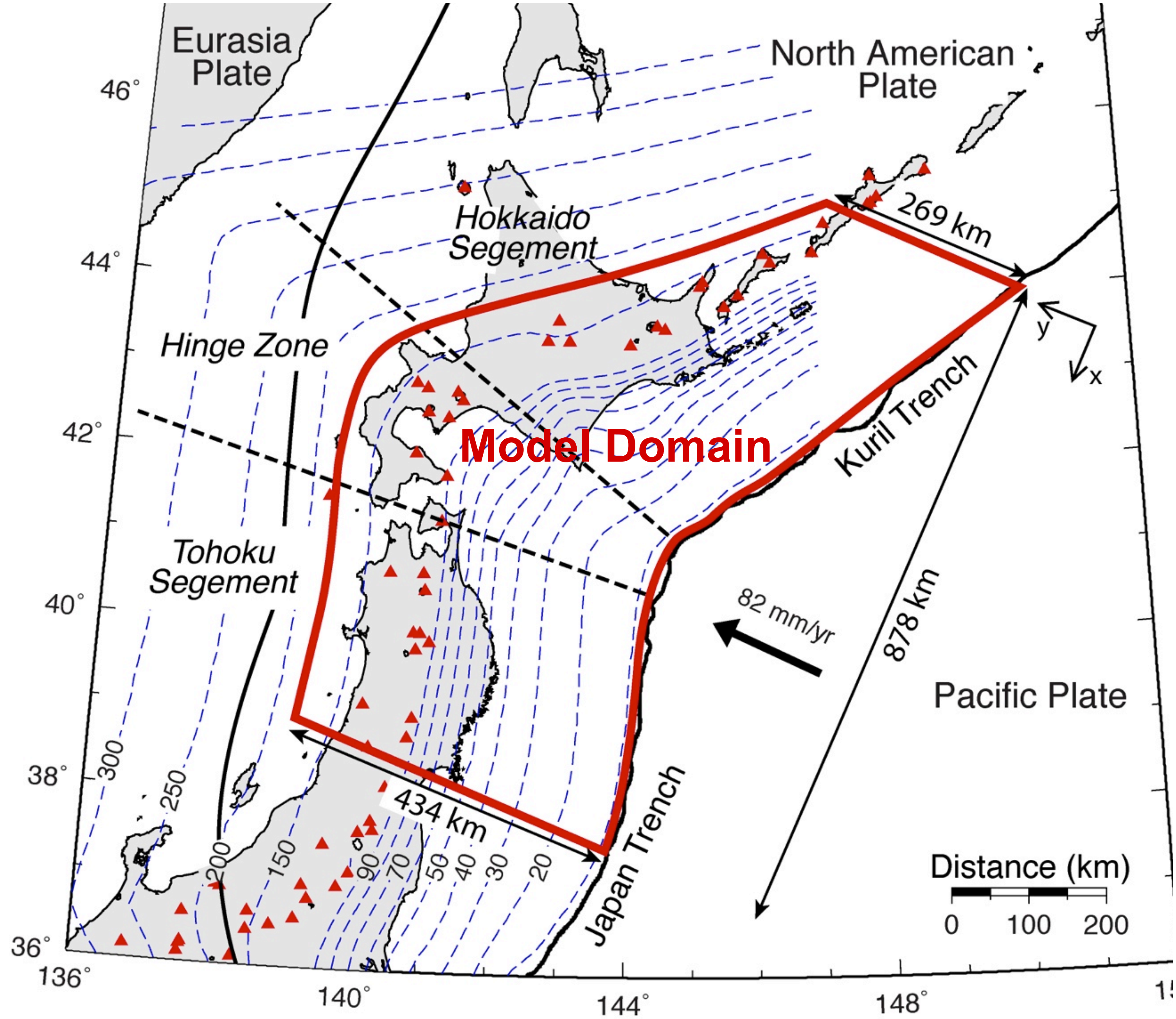
Wada, I., J. He, A. Hasegawa, and J. Nakajima,
***Earth Planet. Sci. Lett.*, *426*, 76–88, 2015**

NE Japan



Slab geometry data from Kita et al. (2010), Nakajima and Hasegawa (2006), and Nakajima et al. (2009); compiled by F. Hirose

NE Japan



Slab geometry data from Kita et al. (2010), Nakajima and Hasegawa (2006), and Nakajima et al. (2009); compiled by F. Hirose

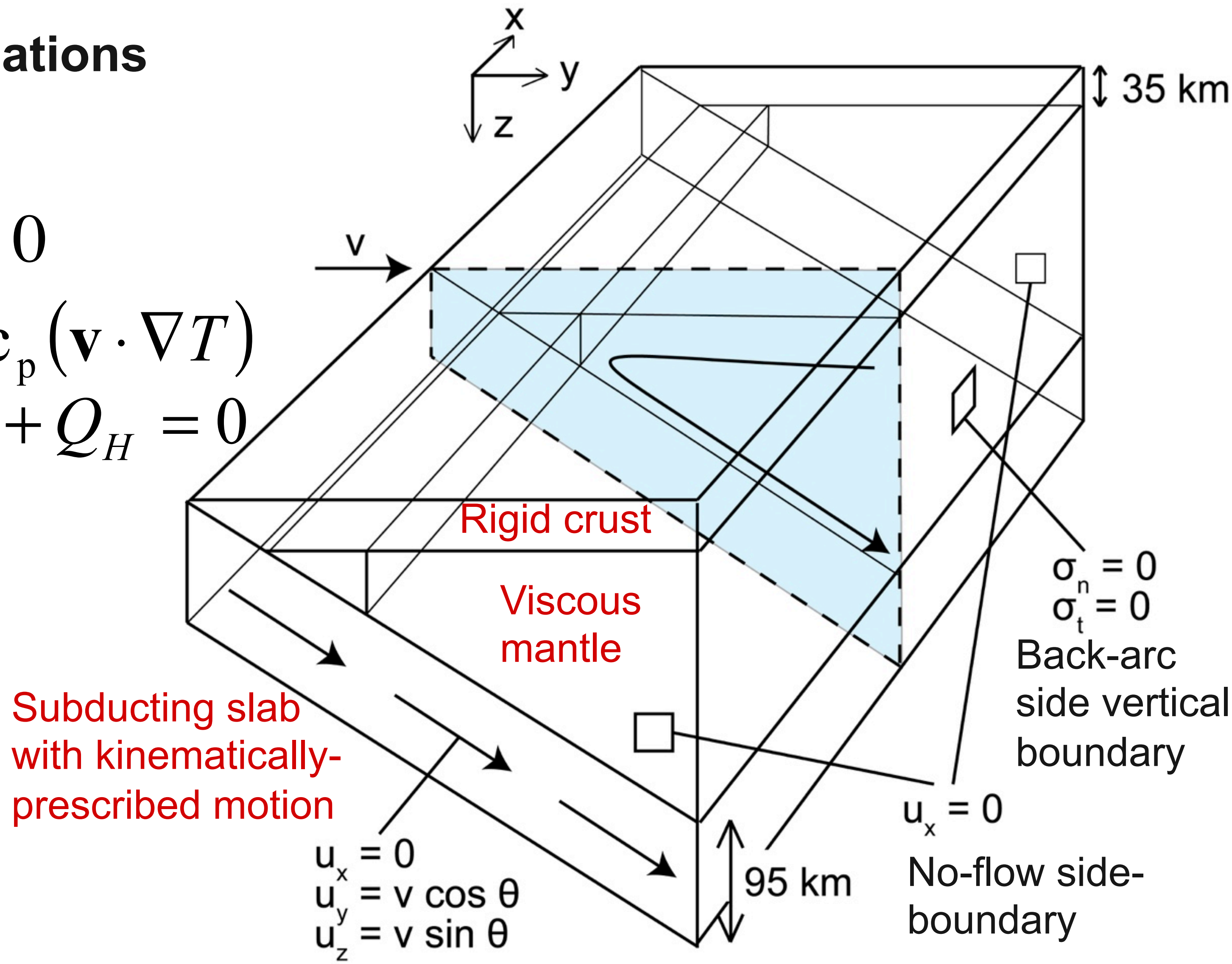
Three-Dimensional Steady-State Finite Element Model

Governing Equations

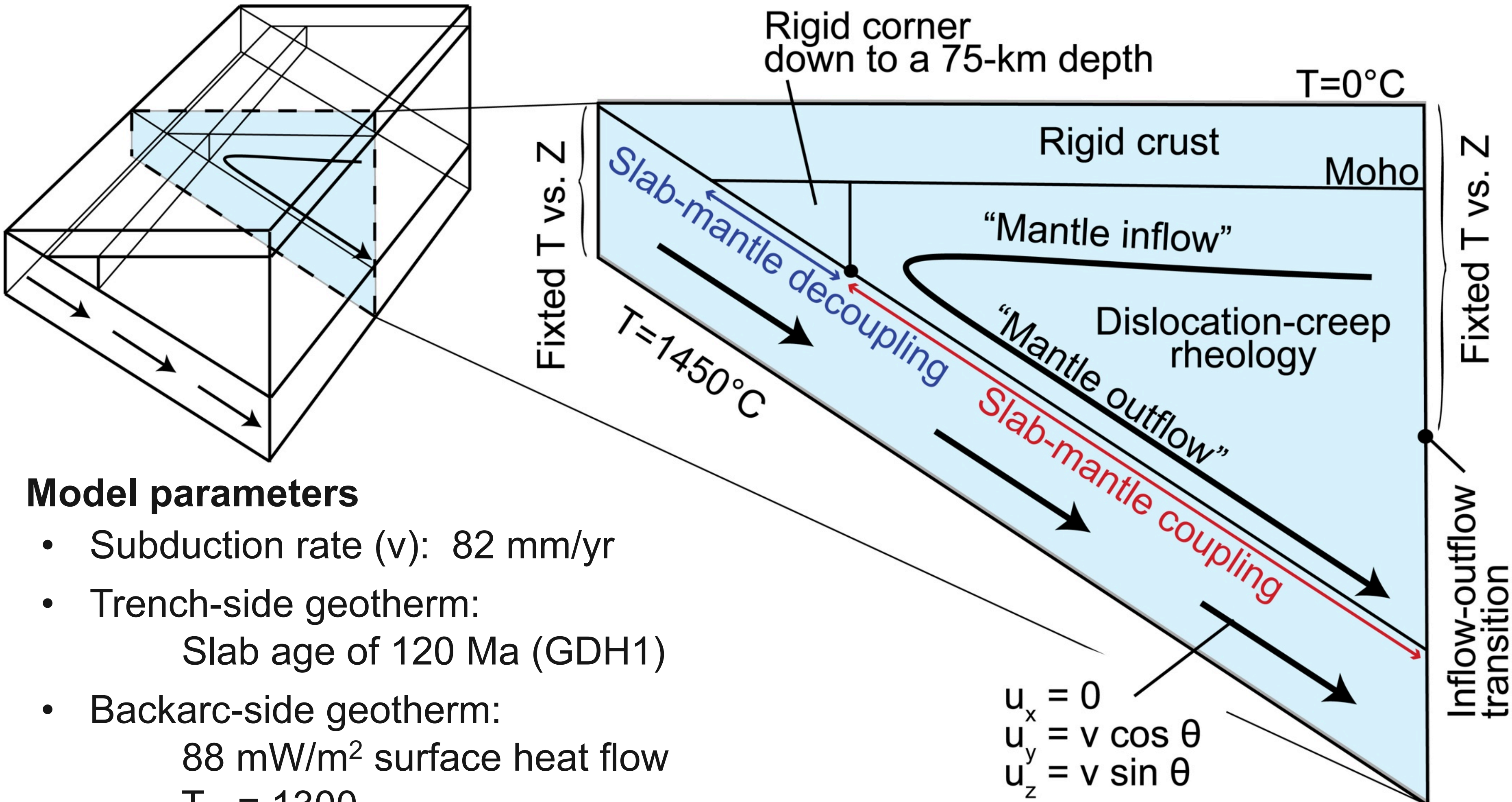
$$\nabla \cdot \mathbf{v} = 0$$

$$\nabla \cdot \sigma' - \nabla P = 0$$

$$\nabla \cdot (k \nabla T) - \rho c_p (\mathbf{v} \cdot \nabla T) + Q_H = 0$$

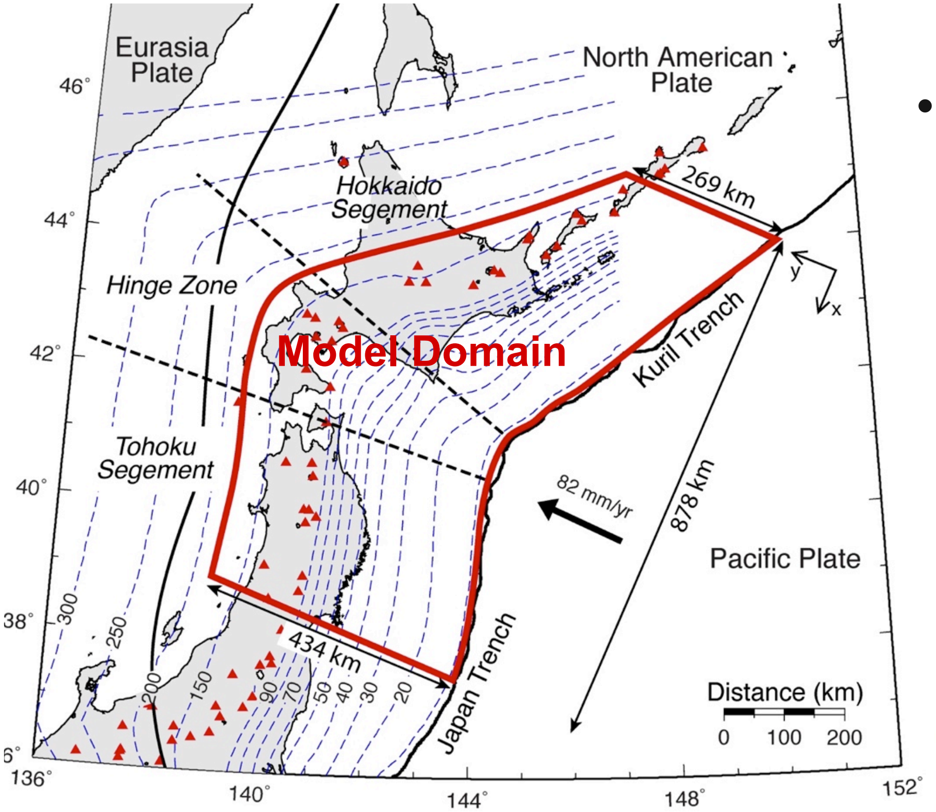


Three-Dimensional Steady-State Finite Element Model

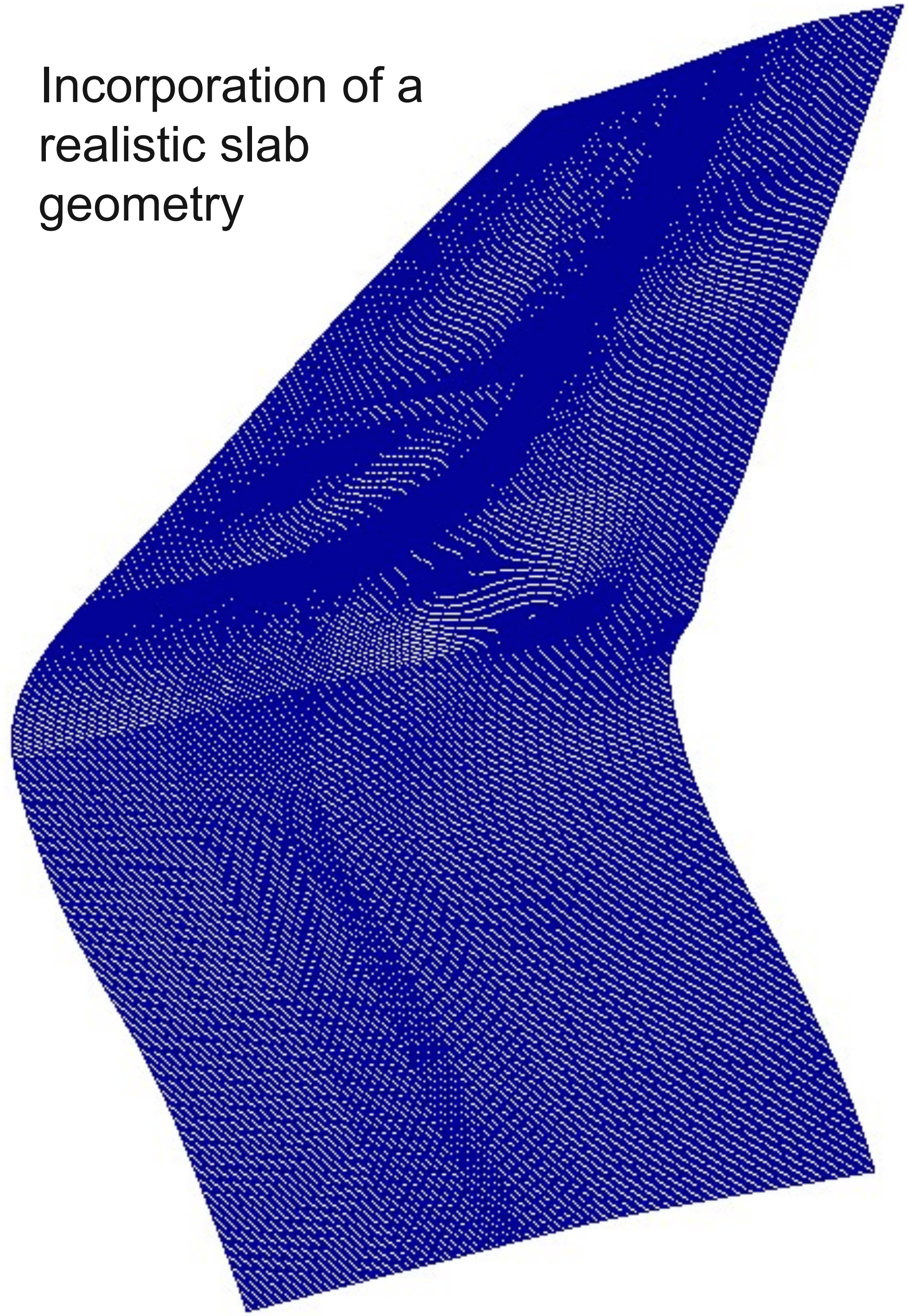


Model parameters

- Subduction rate (v): 82 mm/yr
- Trench-side geotherm:
  Slab age of 120 Ma (GDH1)
- Backarc-side geotherm:
  88 mW/m^2 surface heat flow
  T_m = 1300
  0.3°C/km adiabatic gradient

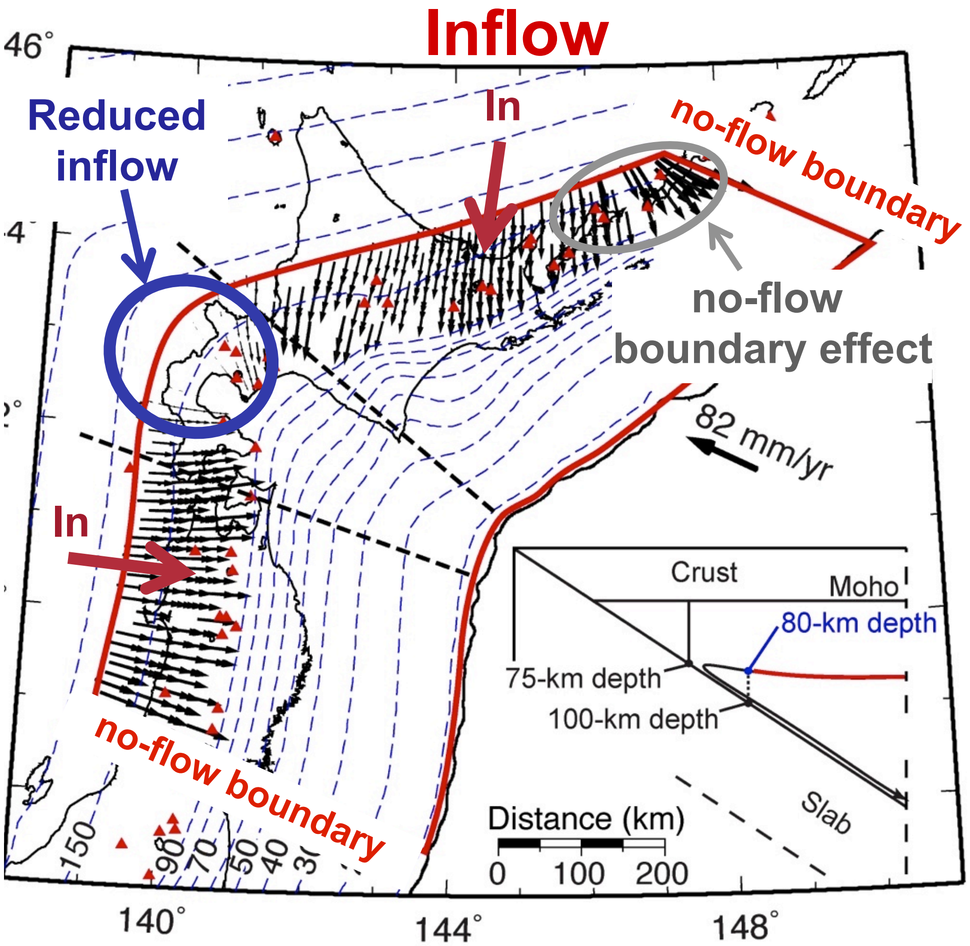


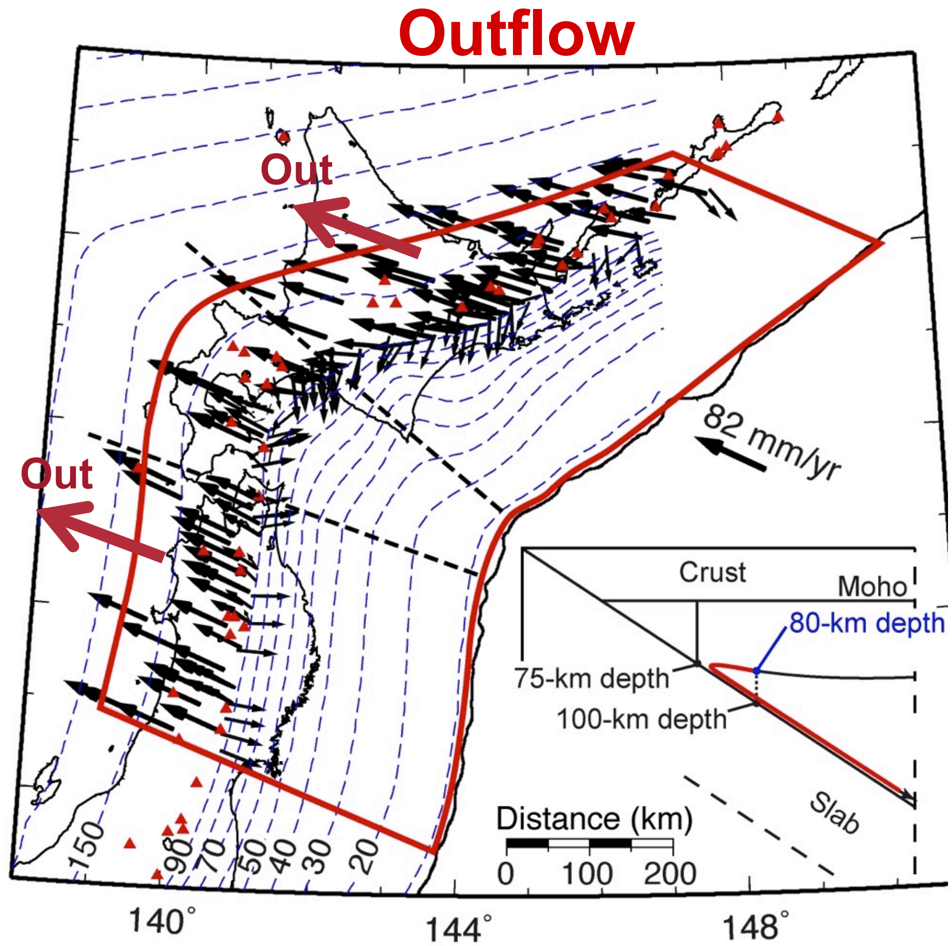
- Incorporation of a realistic slab geometry



A total of ~2 million elements and ~16 million grid nodes in our final calculation

Model-Predicted Flow Directions at 80 km depth

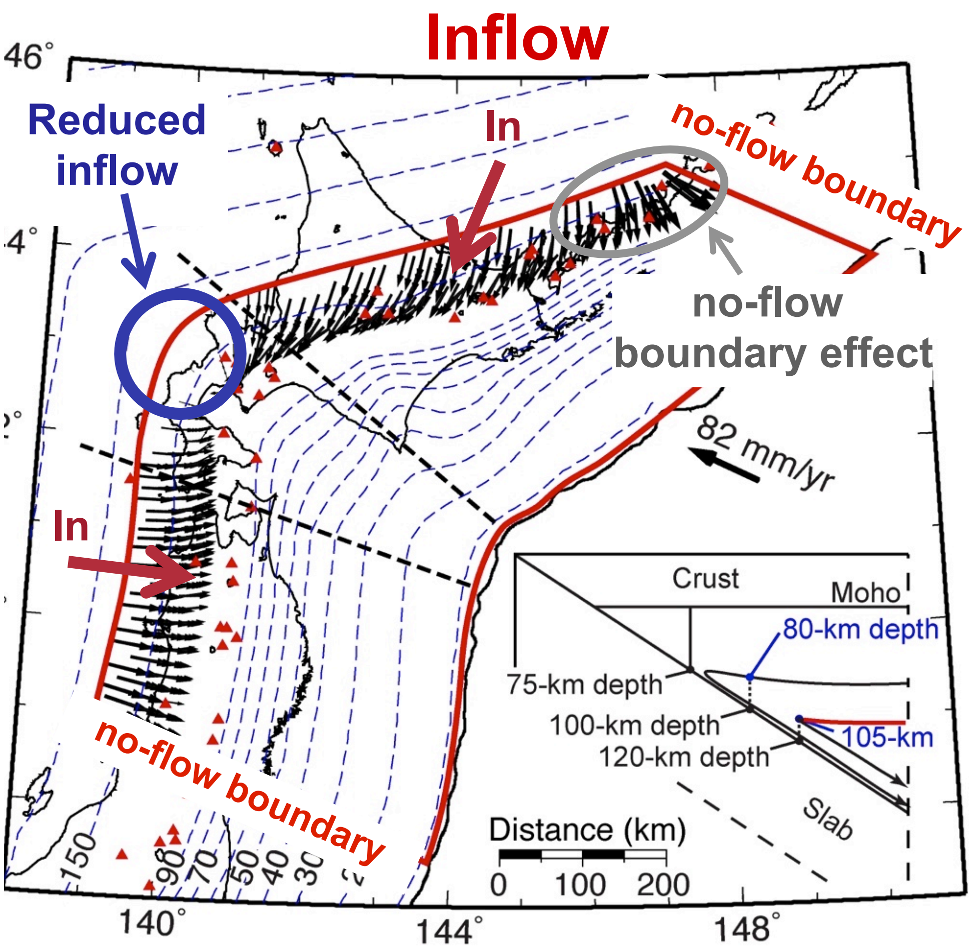




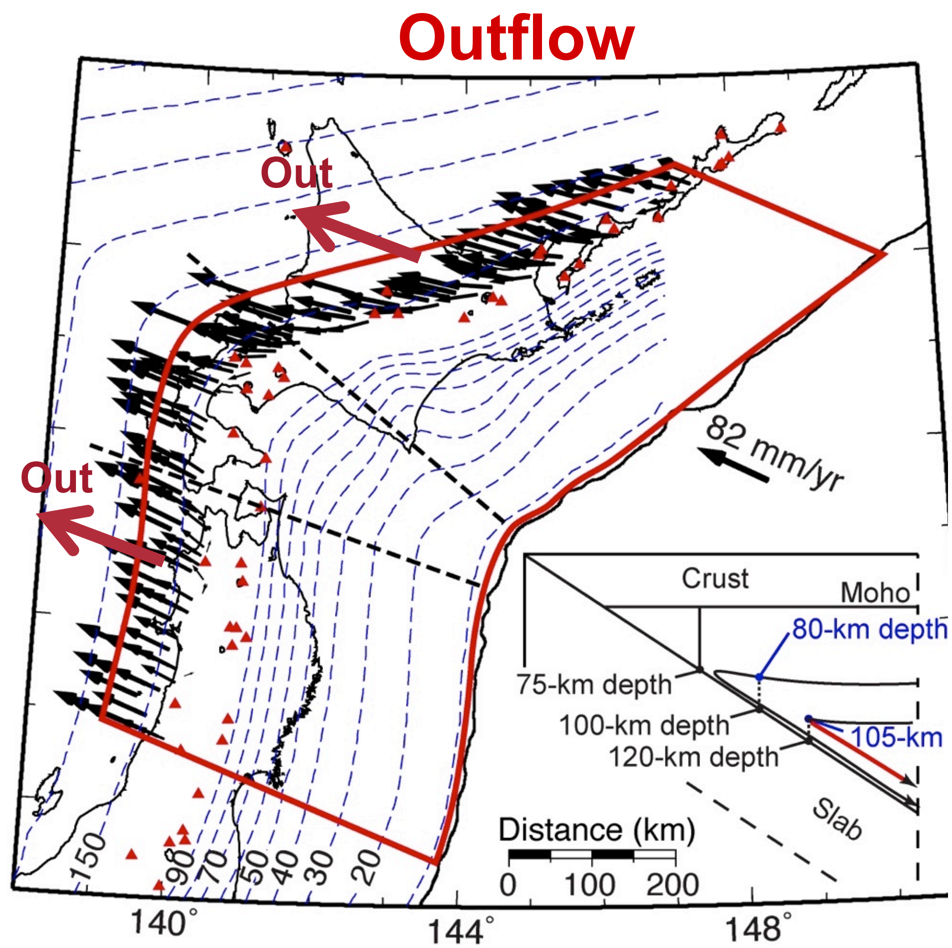
- Inflow from N beneath Hokkaido
- Reduced inflow in the Hinge zone
- Inflow from W beneath Tohoku; little 3-D effect

- Outflow parallel to the subduction direction

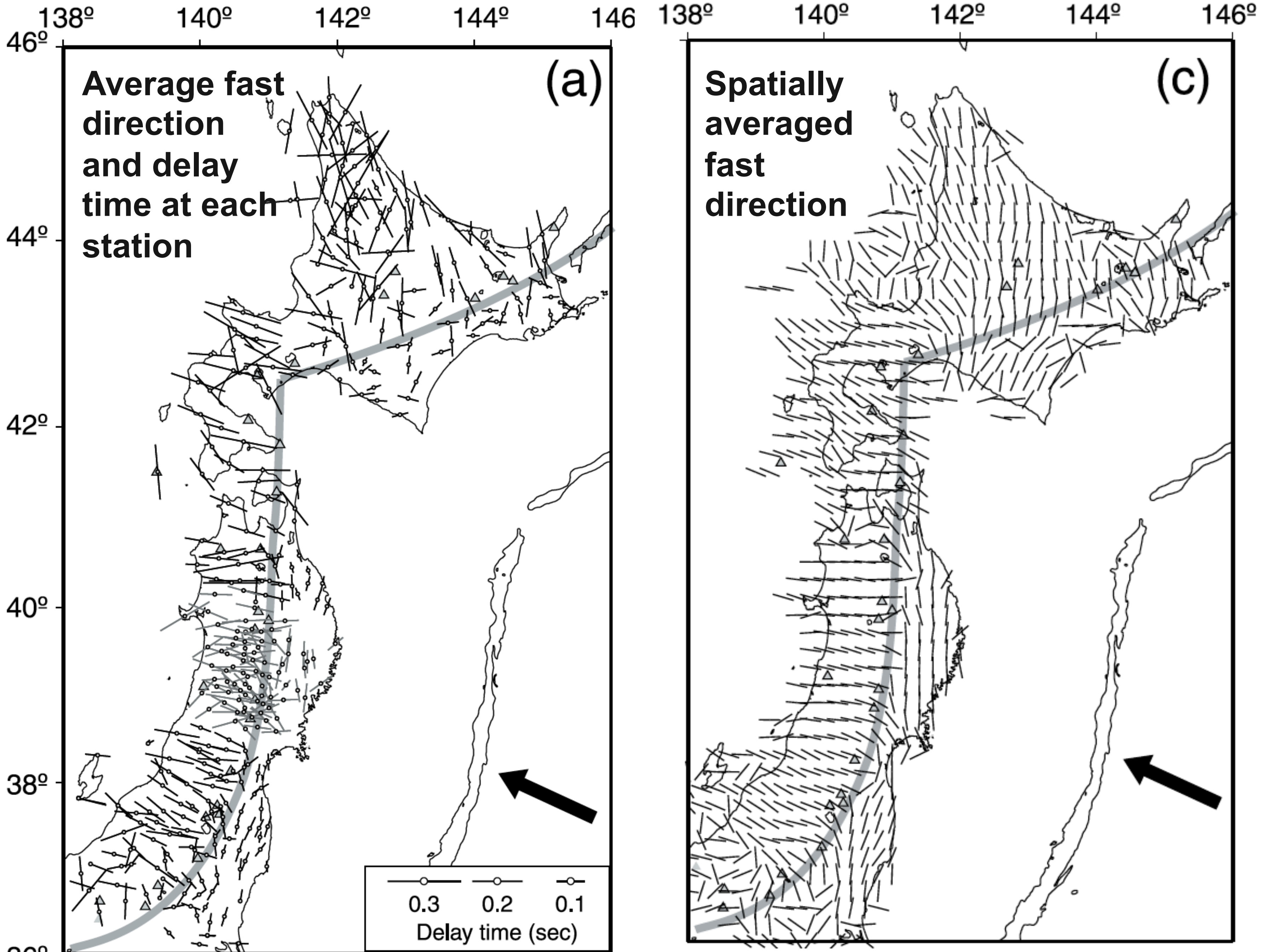
Model-Predicted Flow Directions at 105 km depth



- Inflow from NNE beneath Hokkaido; variation in inflow direction with depth

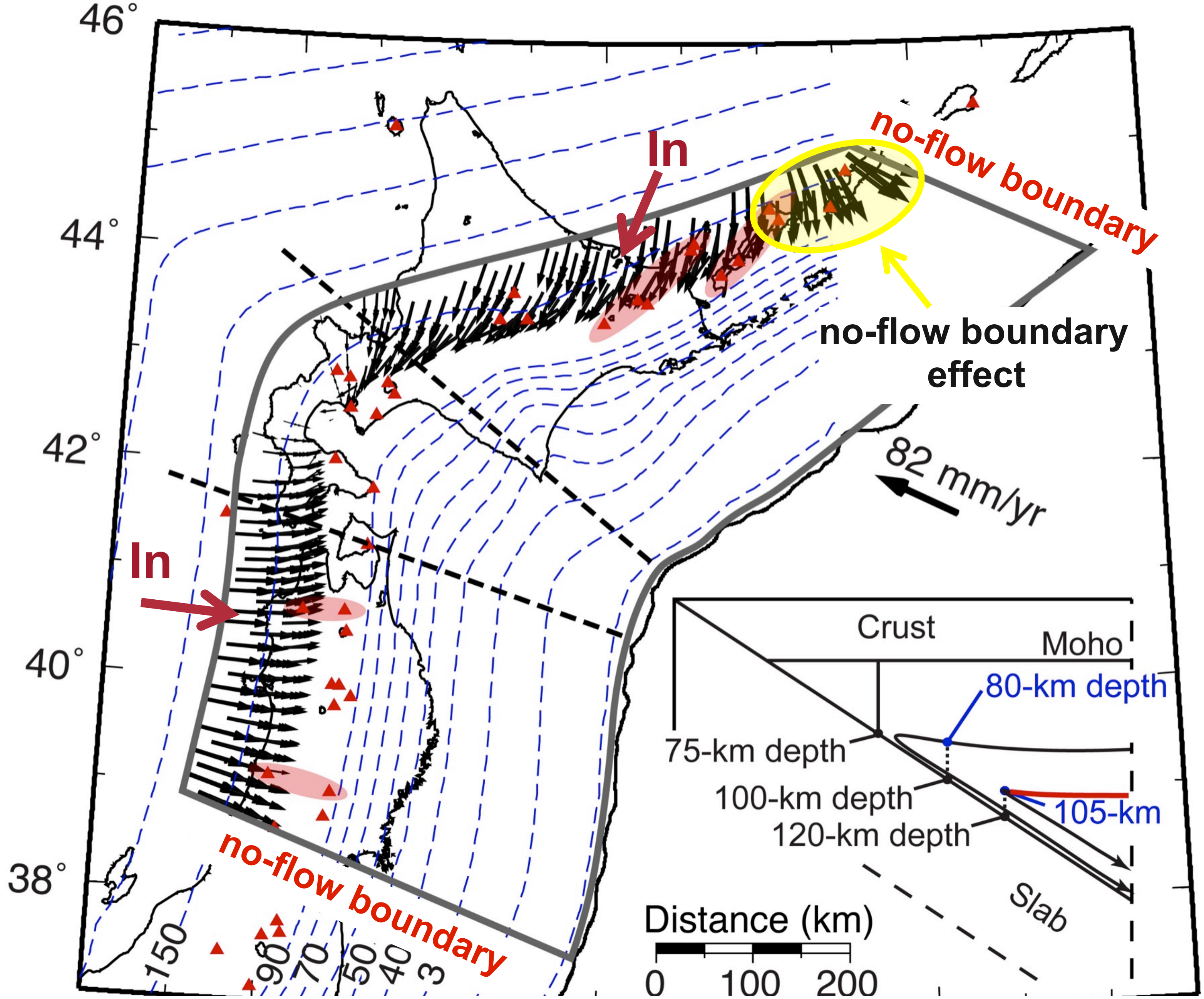


- Little change in the outflow direction with depth

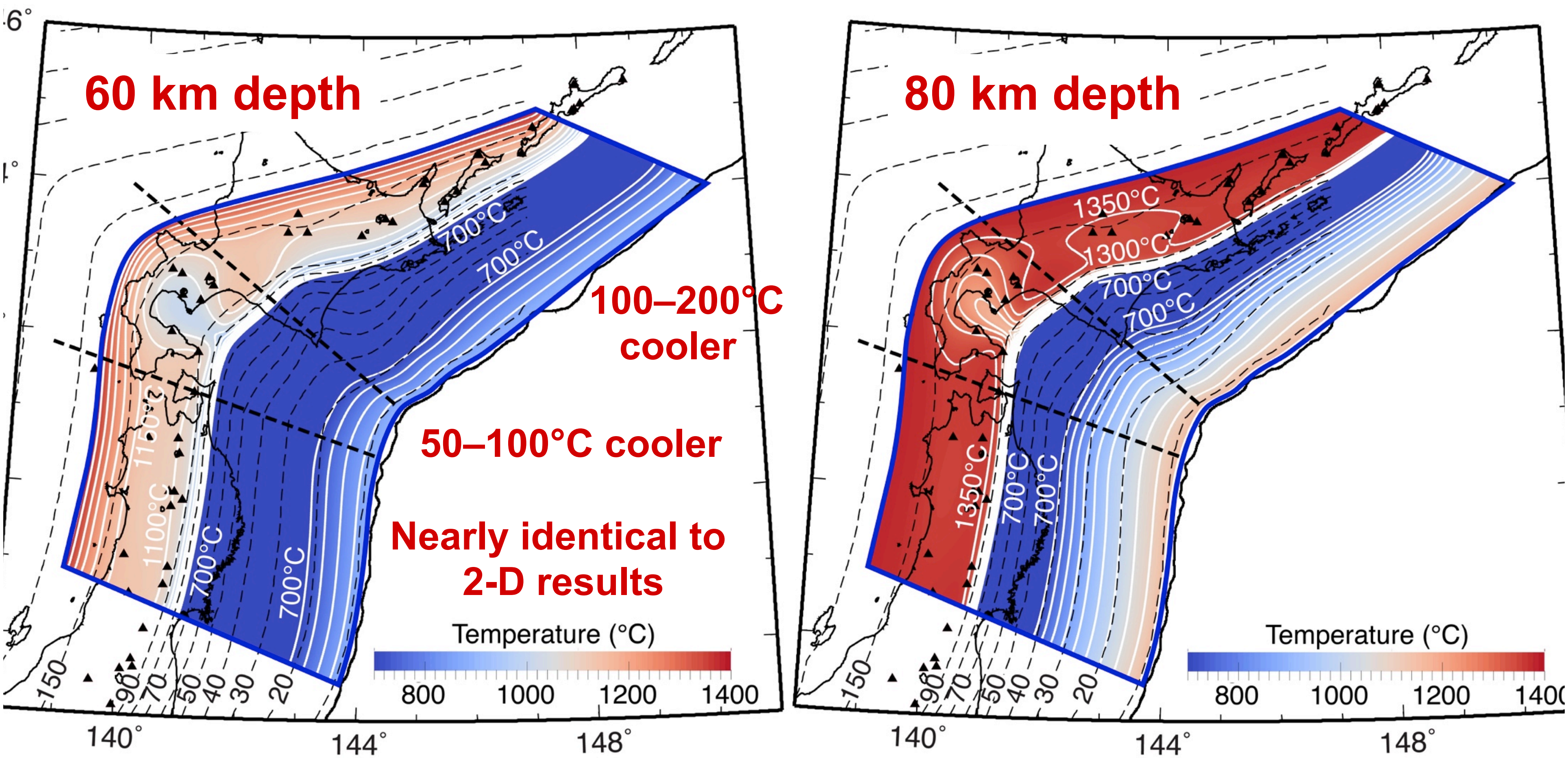


Nakajima et al. [2006]

Inflow Direction and Volcanic Cross-Chain Orientation



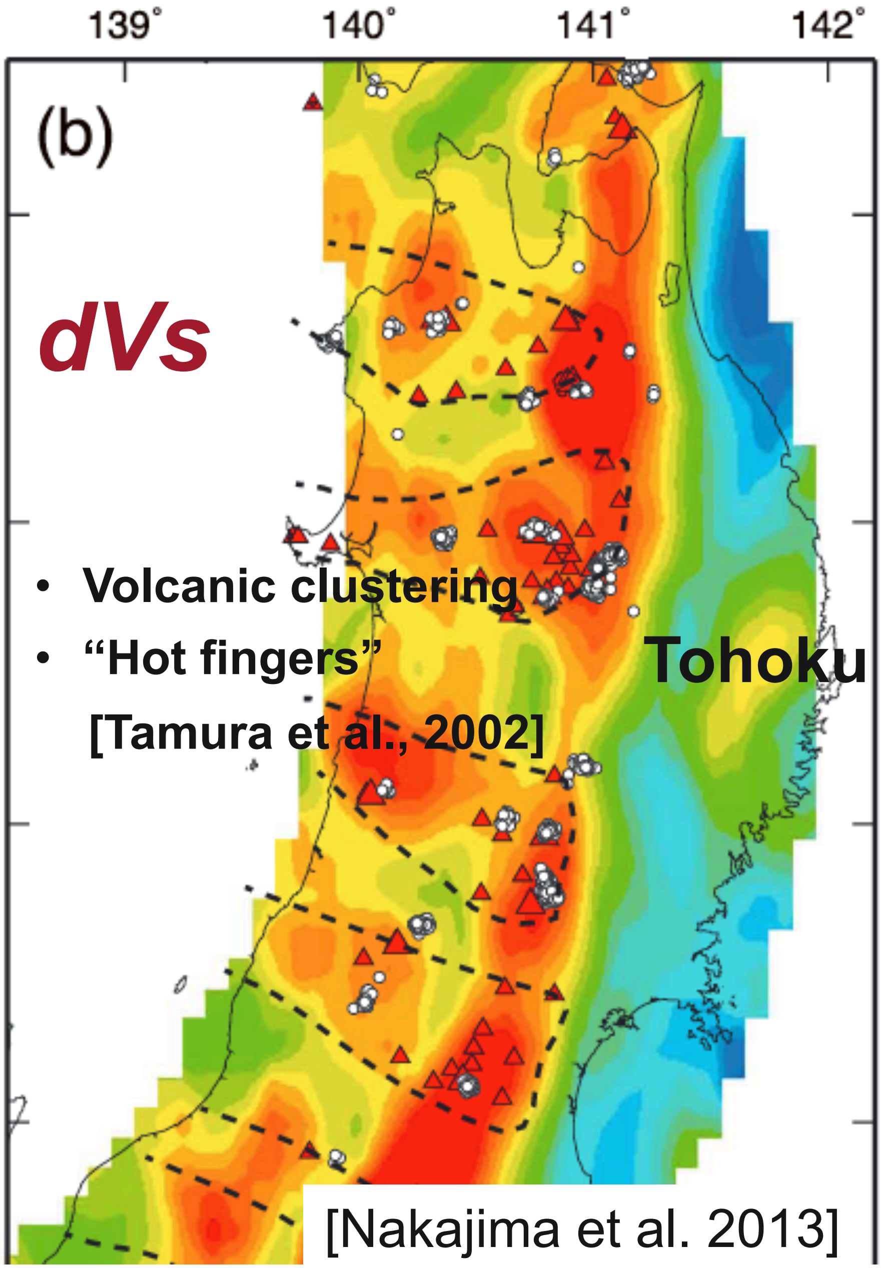
Model-Predicted Mantle Wedge Temperature at 60 and 80 km depths



Compared to Tohoku…

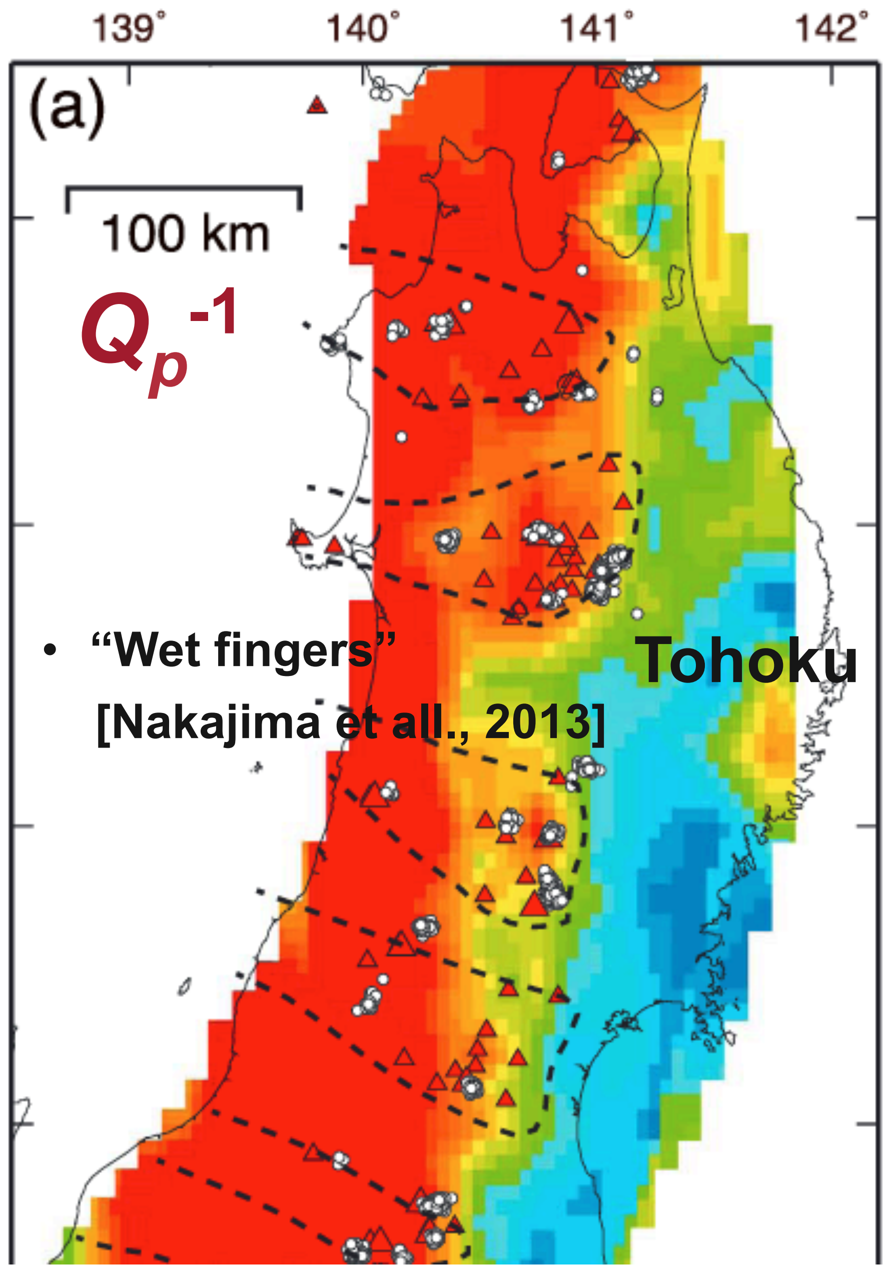
- 50–100°C cooler in Hokkaido due to oblique subduction and steeper dip
- 100–200°C cooler in the hinge zone due to subdued mantle inflow

Seismic Attenuation and S-wave Structures in the Mantle Wedge



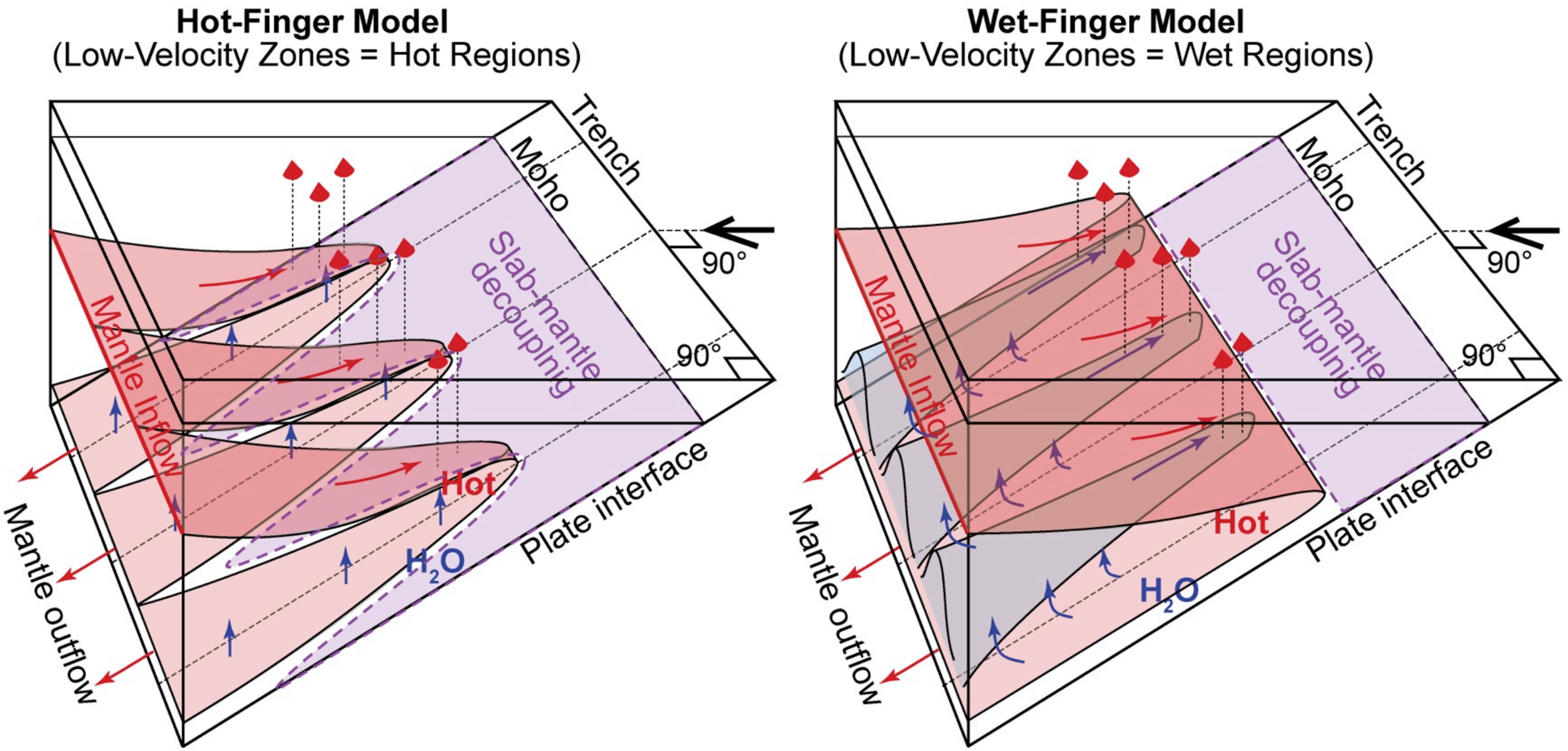
- **Volcanic clustering**
- **"Hot fingers"**
  [Tamura et al., 2002]

[Nakajima et al. 2013]



- **"Wet fingers"**
  [Nakajima et all., 2013]

Low-Velocity High-Attenuation Regions: Hot Fingers vs. Wet Fingers



Summary

- In Tohoku, a 2-D approximation is reasonable.
- In Hokkaido, oblique subduction results northerly inflow and west-northwestward outflow.
- In the hinge zone, the convergence of northerly inflow from Hokkaido and the westerly inflow from Tohoku discourages inflow from northwest.
- Compared to Tohoku, Hokkaido and the hinge zone are colder.
- Mantle inflow direction correlates well with the seismically fast direction and the orientation of volcanic cross-chains.
- A mechanism of volcanic clustering remains to be investigated.