Numerical Modeling of Slab-released Fluids in the New Madrid Seismic Zone

Stress concentration and Intraplate Seismicity

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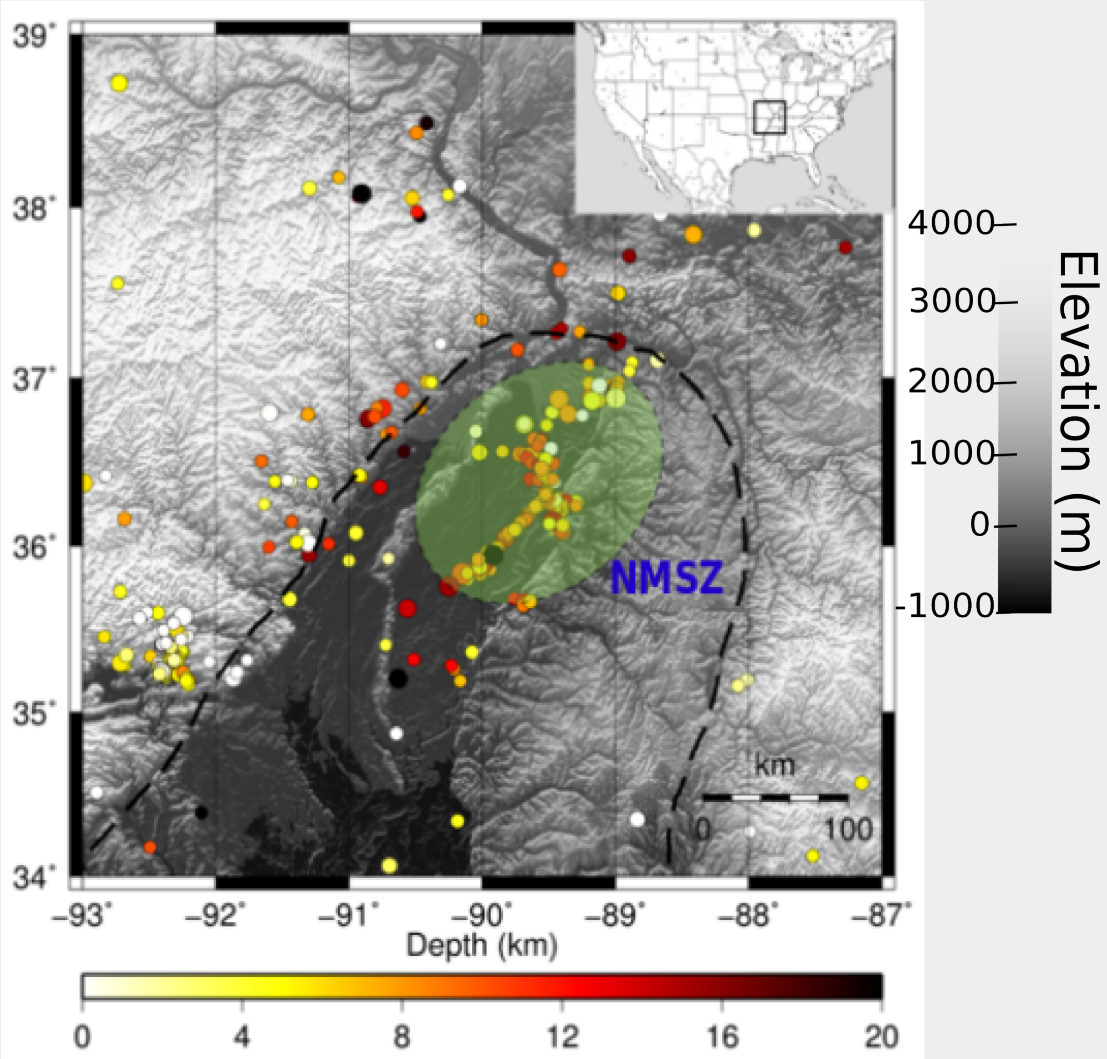
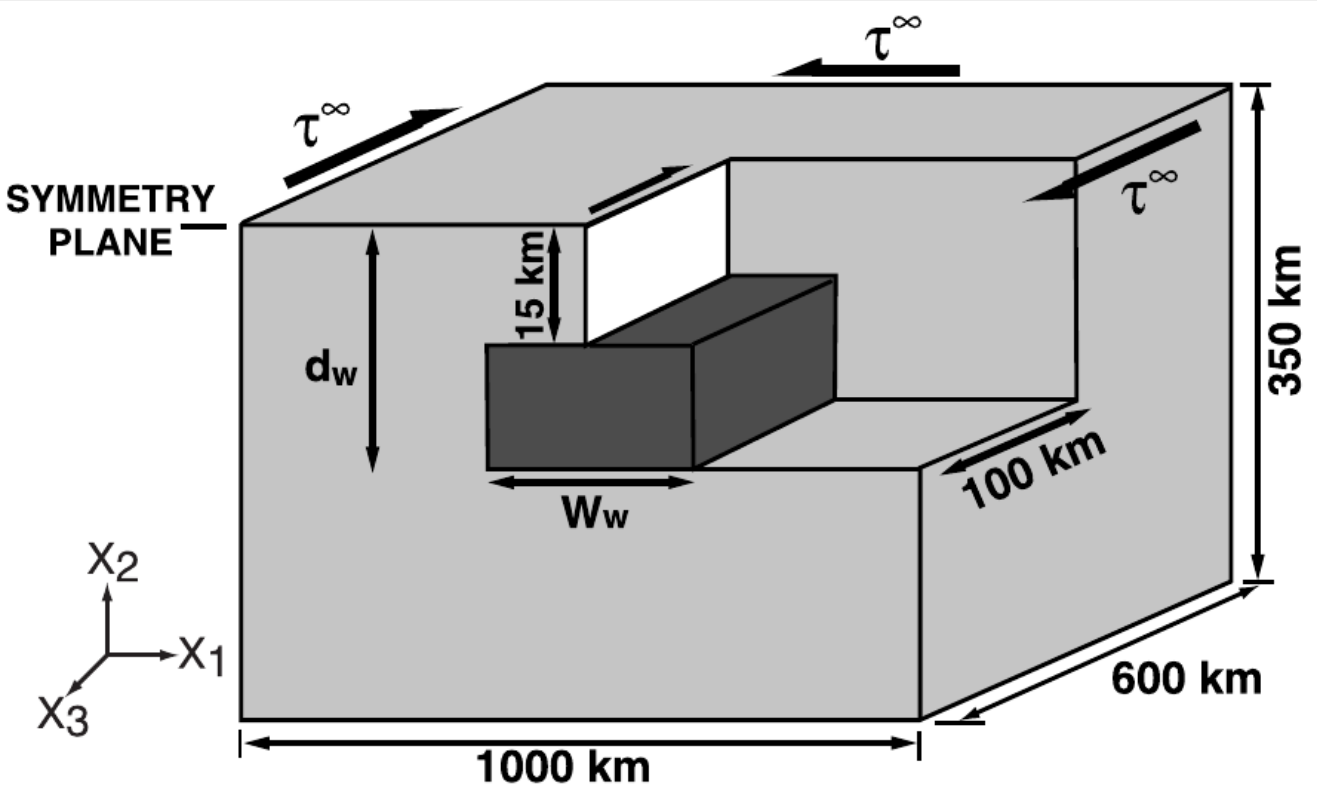
Why this study?

New Madrid Seismic Zone:



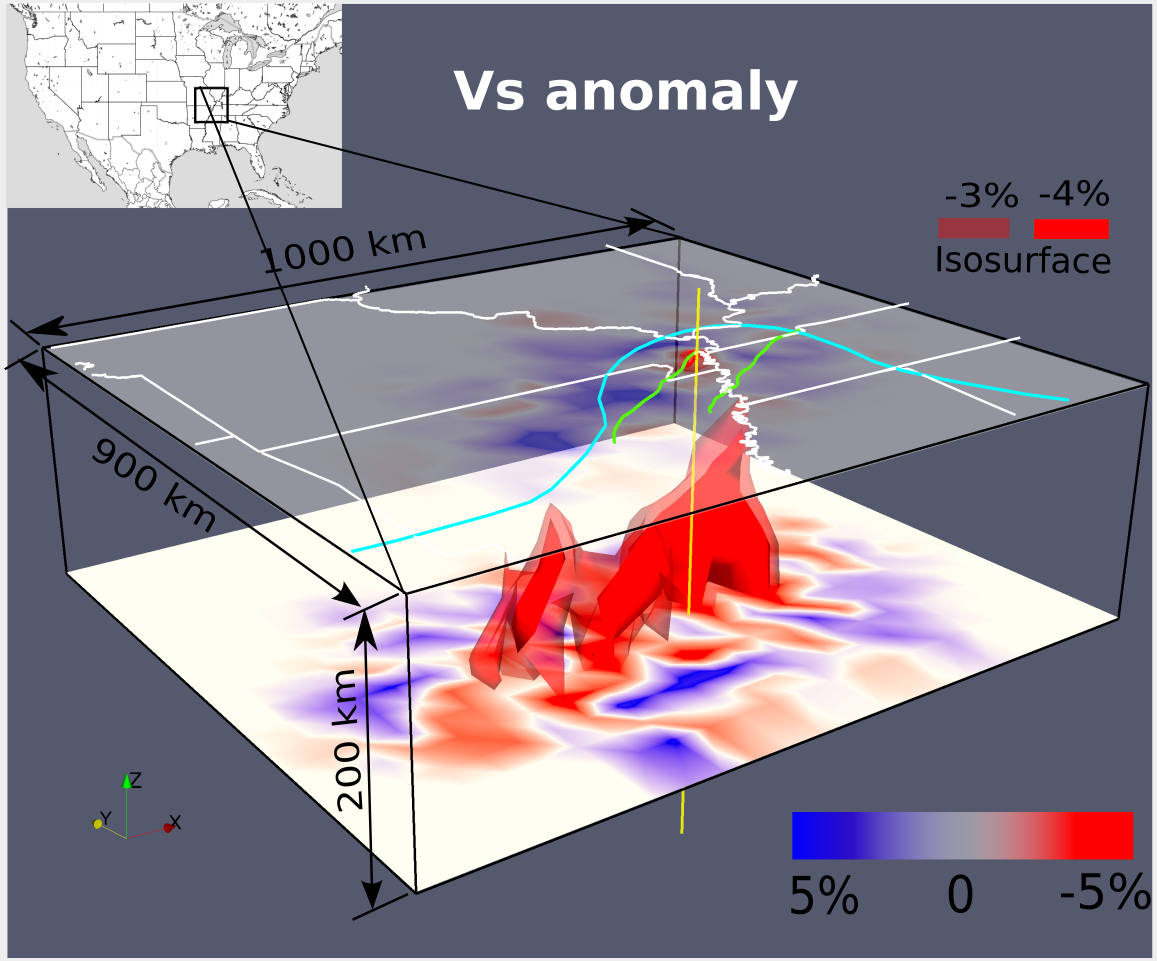
Models for Intraplate Seismicity

Kenner and Segall, 2000: "Intraplate earthquakes are caused by stress transferred to the seismogenic fault from a local source in the lower crust and upper mantle".



Recent findings

From the tomography study by Nyamwandha et al., 2016:



Recent findings

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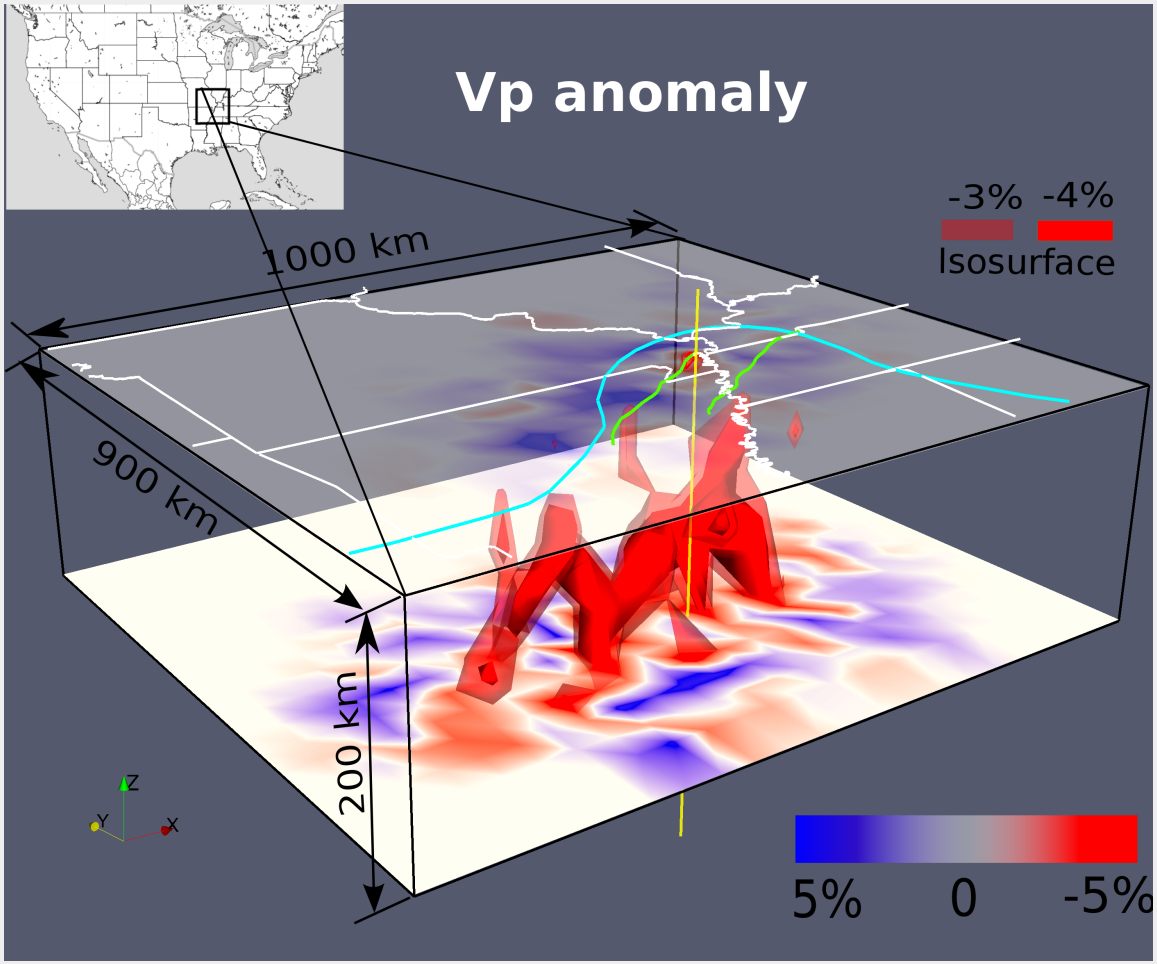
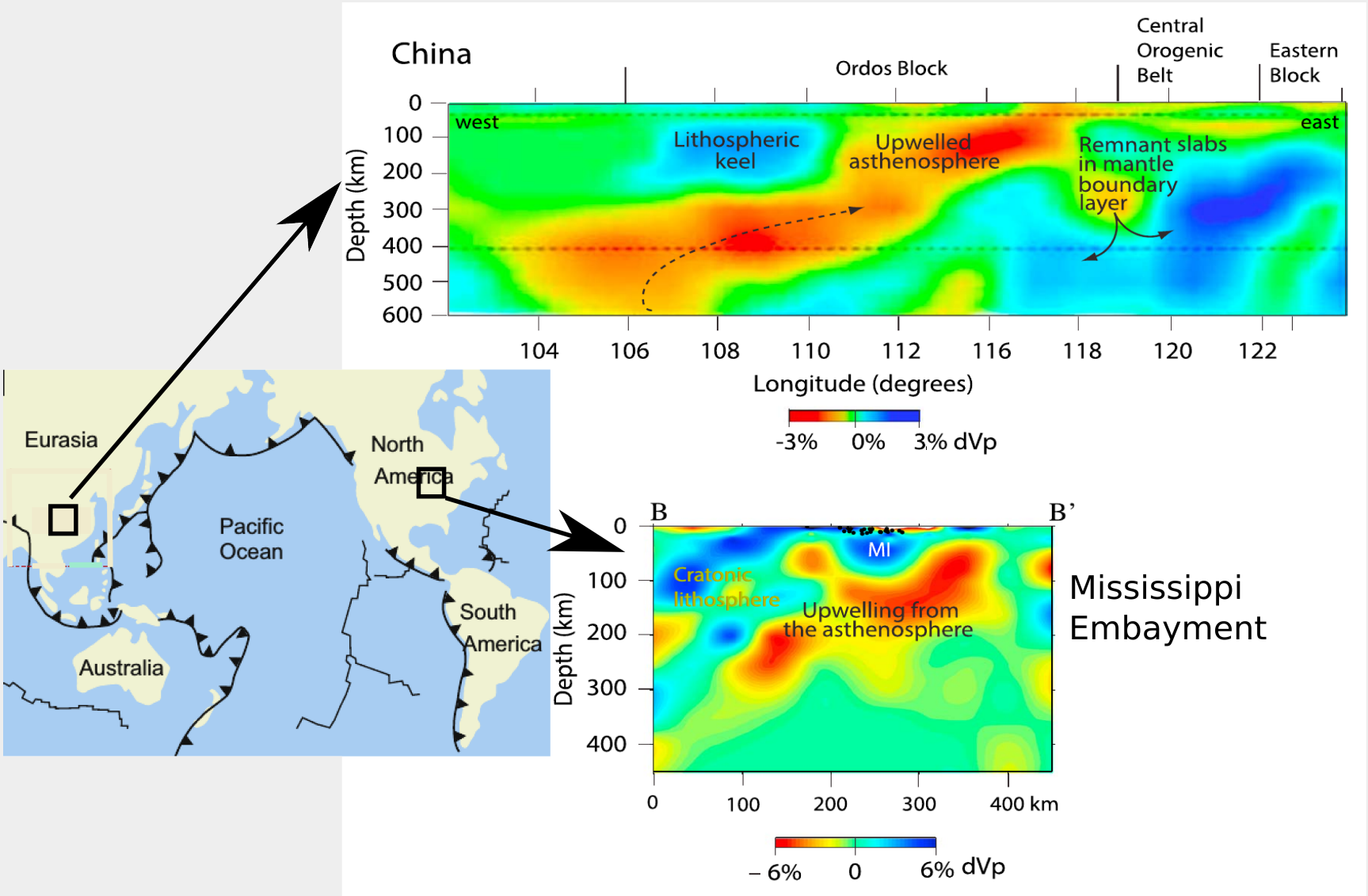


Startling Similarity

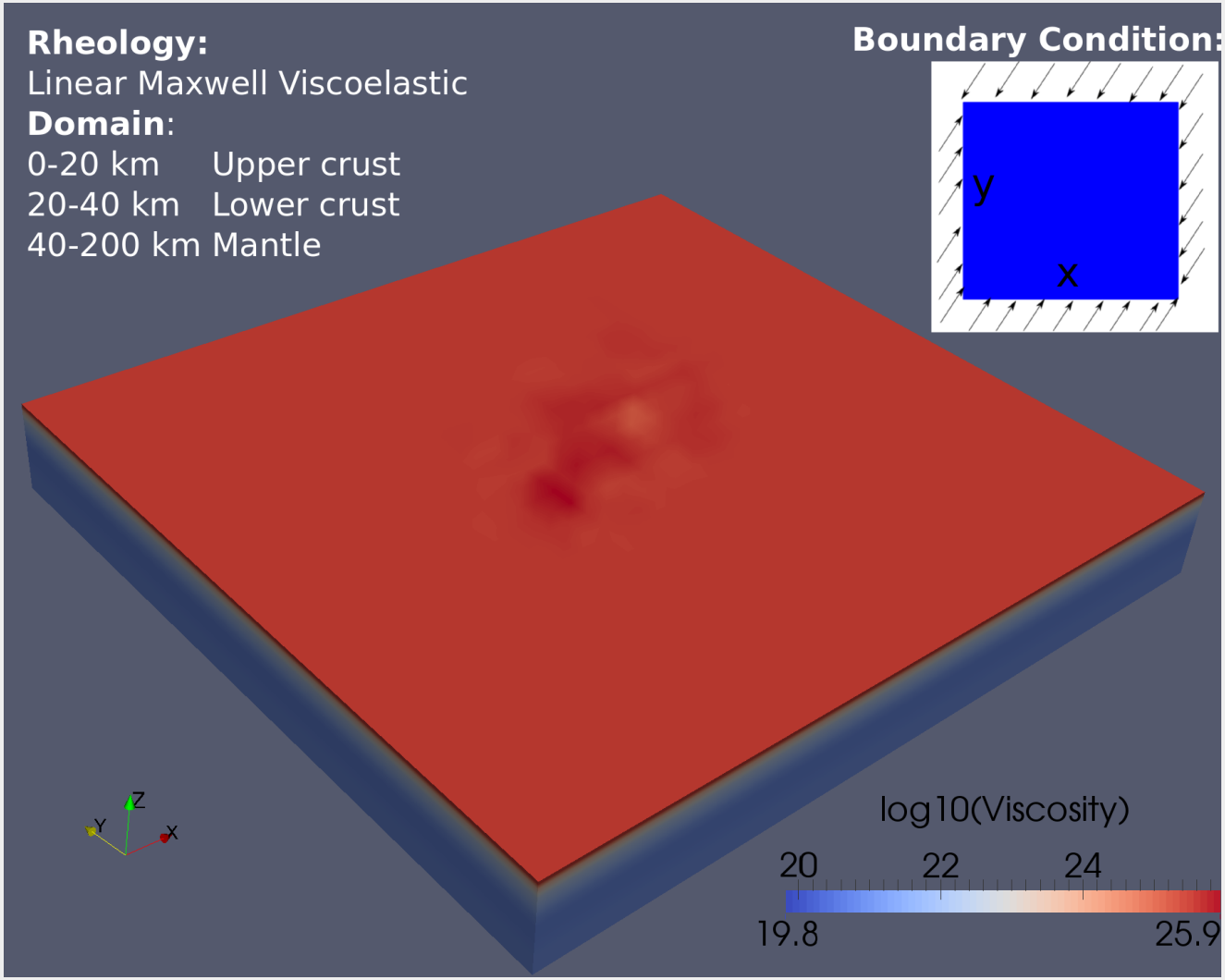


(Modified from Nyamwandha et al., 2016)

Main Hypothesis

Fluids released from the stagnant Laramide slab (Sigloch et al., 2008) alters the mantle, concentrating stress into the overlying crust promoting, seismicity in the NMSZ

Model Setup


Rheology:
Linear Maxwell Viscoelastic
Domain:
0-20 km Upper crust
20-40 km Lower crust
40-200 km Mantle
Boundary Condition:
y
x
Z
Y
X
log10(Viscosity)
20
22
24
19.8
25.9

Model Setup

Tomography $\rightarrow$ Rheology Conversion for :

1. δVs converted to temperature only

$$\eta_{eff} = \dot{\varepsilon}^{\frac{1-n}{n}} \left(A \exp(-H/RT)\right)^{-1/n}$$

2. δVs and δVp converted to temperature and fluid added in the whole domain

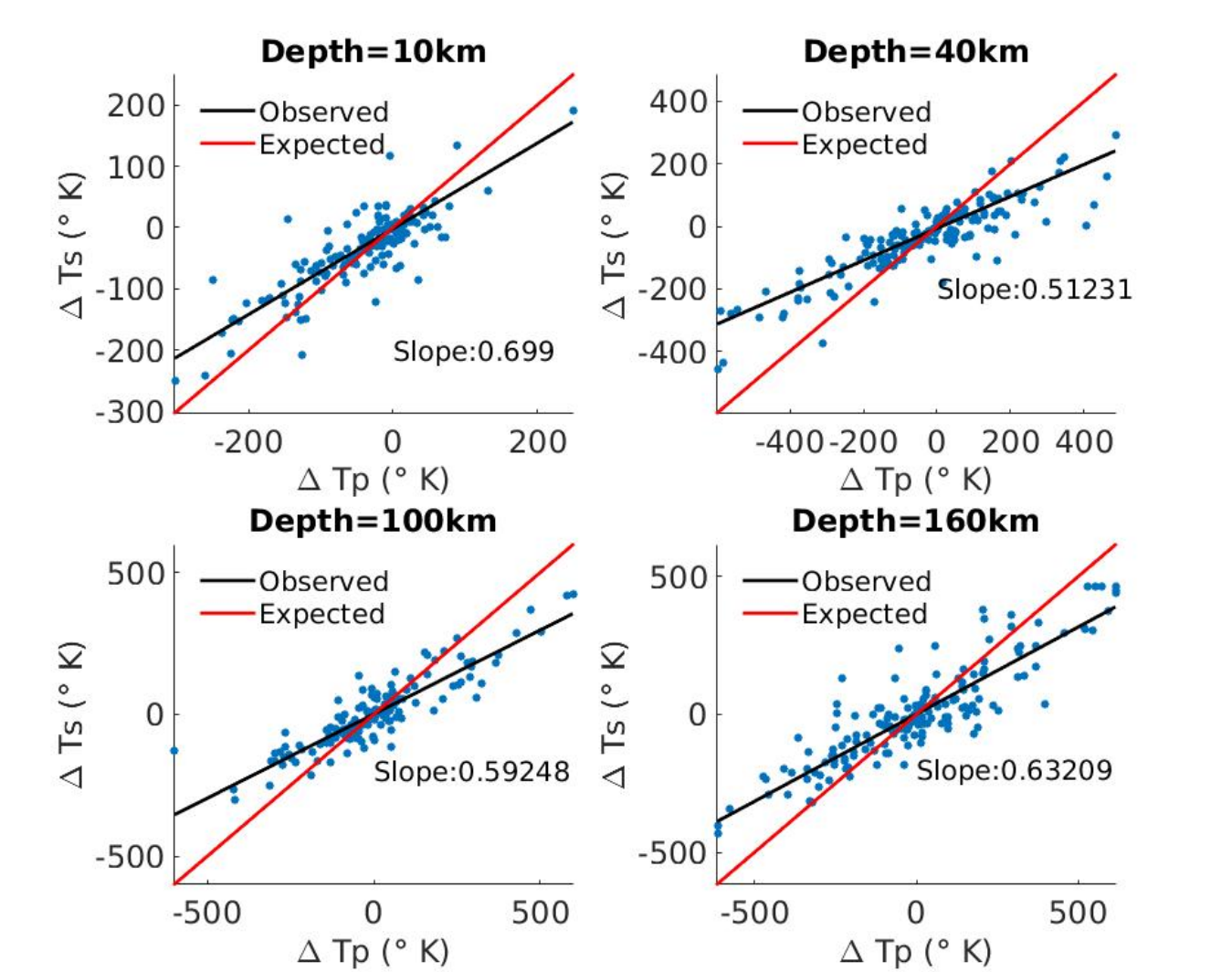
$$\eta_{eff} = \dot{\varepsilon}^{\frac{1-n}{n}} f_{H_2O}^{\frac{-r}{n}} \left(A \exp(-H/RT)\right)^{-1/n}$$

3. δVs converted to temperature and fluid added selectively
4. δVp and δVs simultaneously converted to temperature and orthopyroxene

$$\eta_{eff} = (1 - X)\eta_{ol} + X\eta_{opx} \text{ : Voigt Scheme}$$

Case I: Only temperature

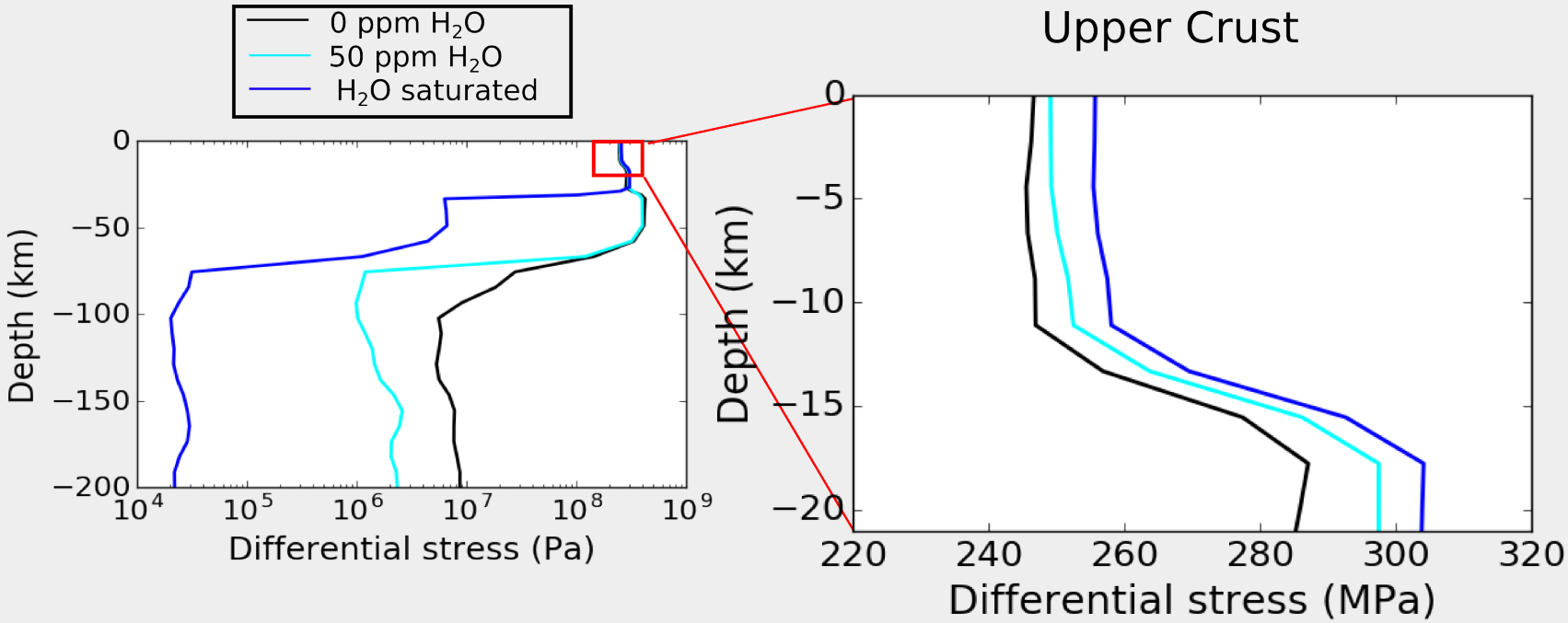
Temperature anomalies calculated from the tomography do not coincide.



(Using conversion factors from Goes et al., 2000)

Case II: Fluid throughout the domain

Higher concentration of differential stress in upper crust with wetter (weaker) mantle.



Converting **P wave** anomalies into temperature (Goes et al., 2000) and varying water content (Dixon et al., 2004)

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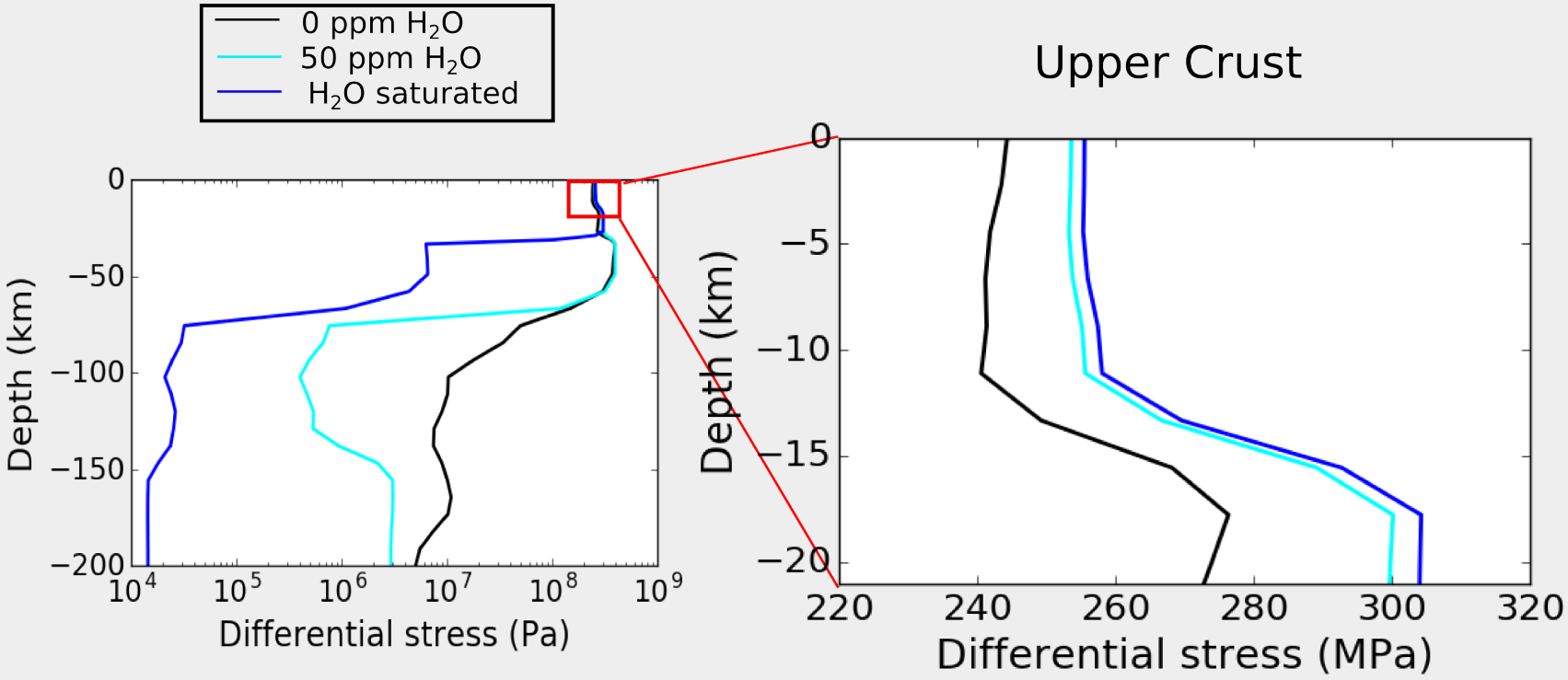
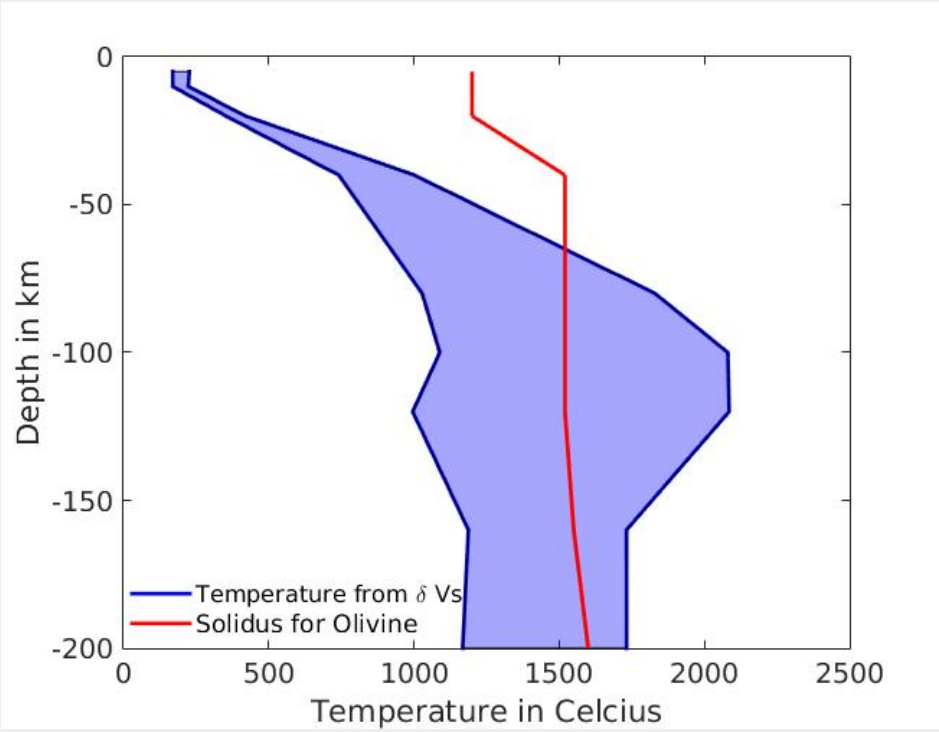


Converting **S wave** anomalies into temperature (Goes et al., 2000) and varying water content (Dixon et al., 2004)

Case III: Selective Fluid in Mantle

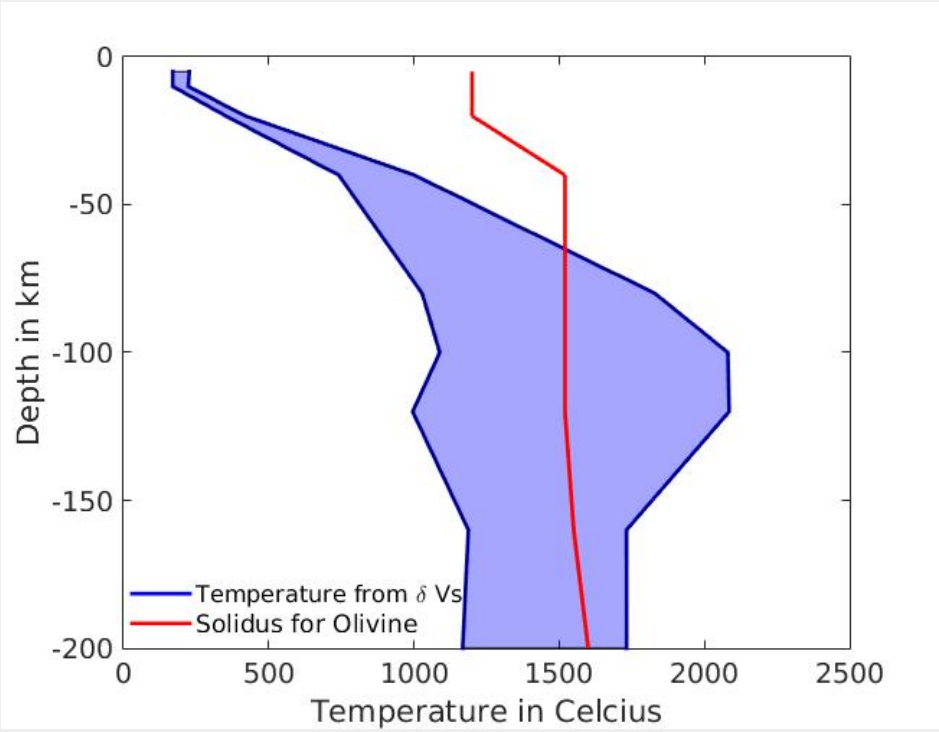
Temperature Distribution



(solidus from Hirschmann, 2000)

Case III: Selective Fluid in Mantle

Temperature Distribution



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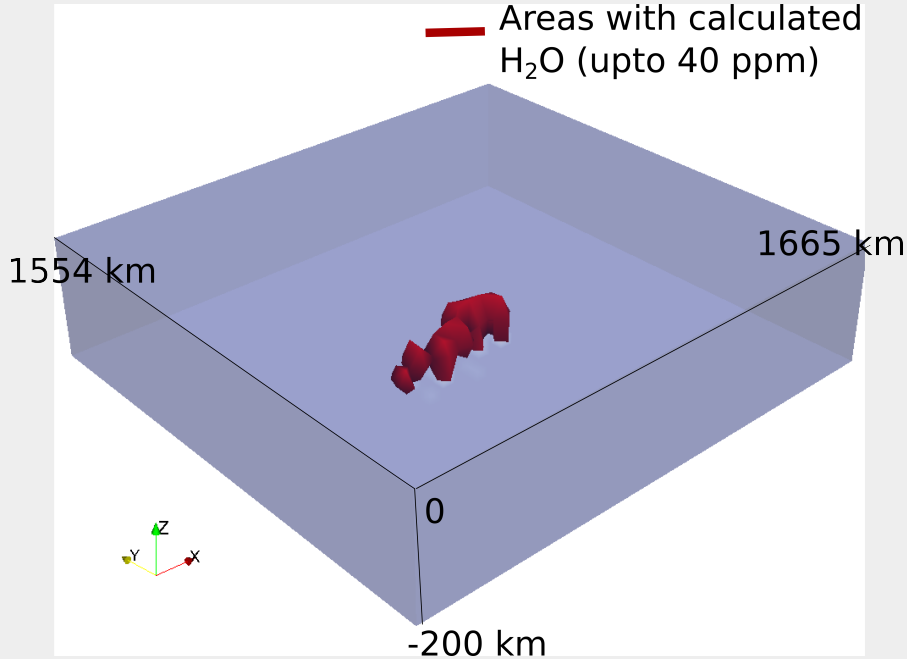
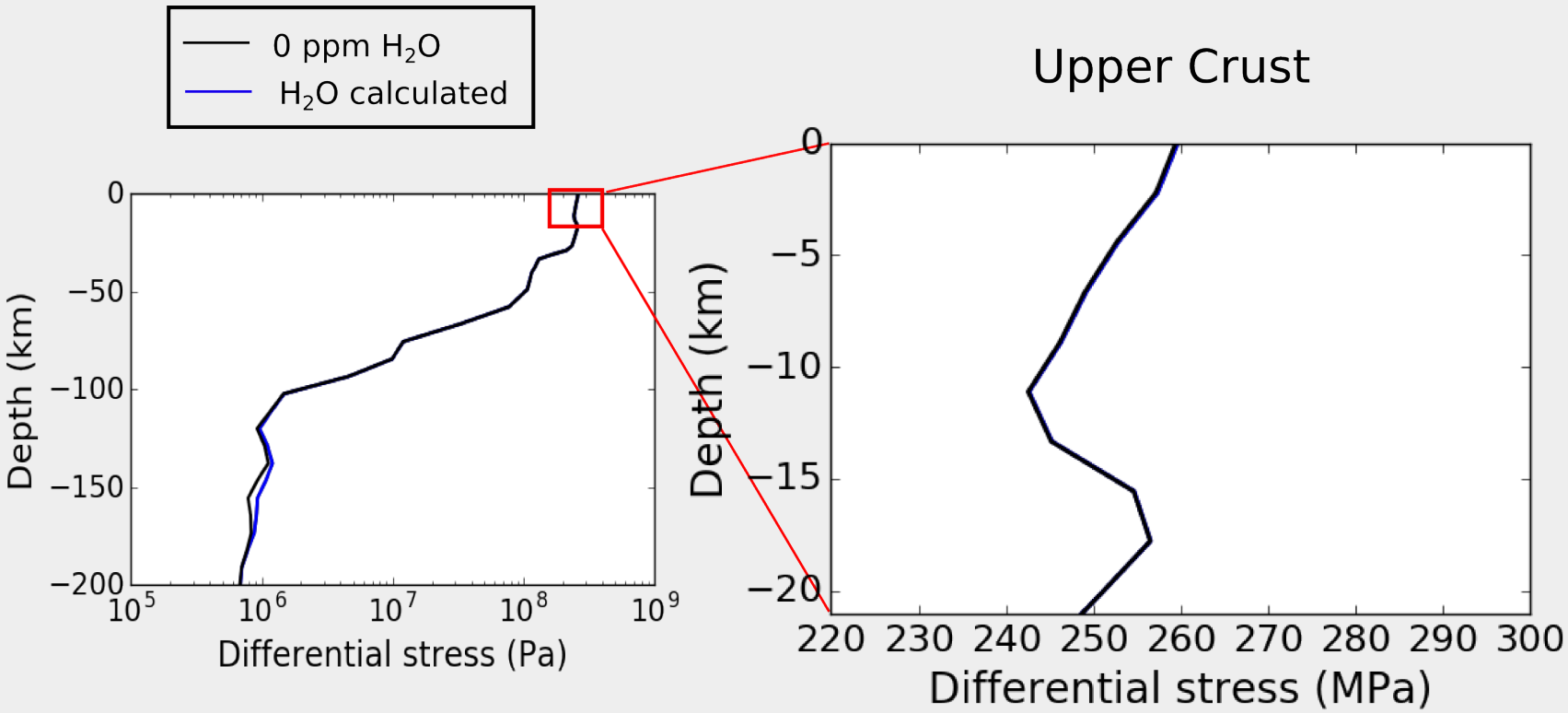
Water Content Calculated



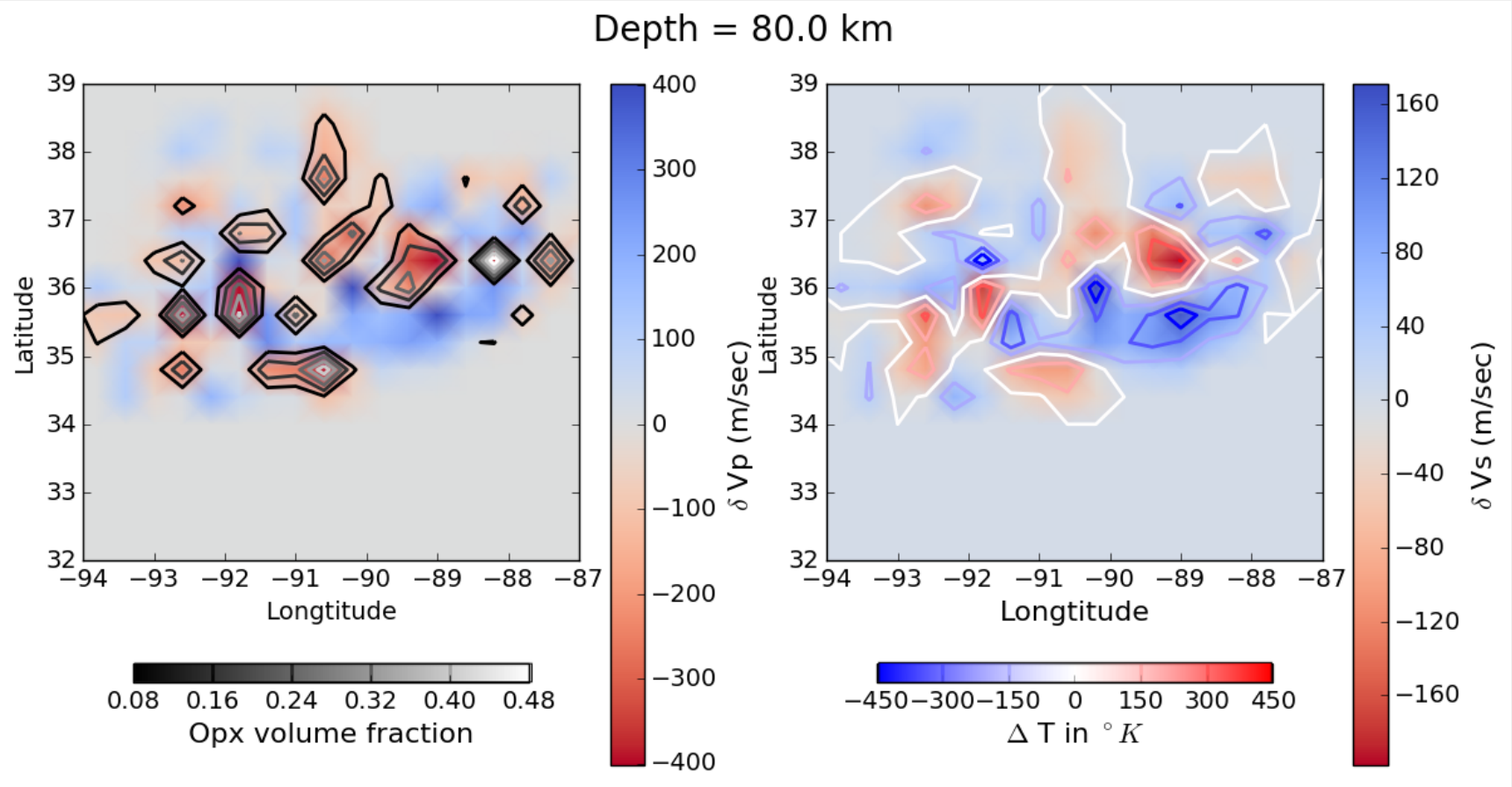
Case III: Selective Fluid in Mantle

Fluid weakens the mantle but doesn't affect the differential stress in the upper crust.



Case IV: Inversion of X_{opx} and Temperature

X_{opx} sensitive to ∂Vp and ΔT sensitive to ∂Vs:



(Temperature and compositional gradients from Goes et al., 2000 and Schutt and Lesher, 2010 respectively)

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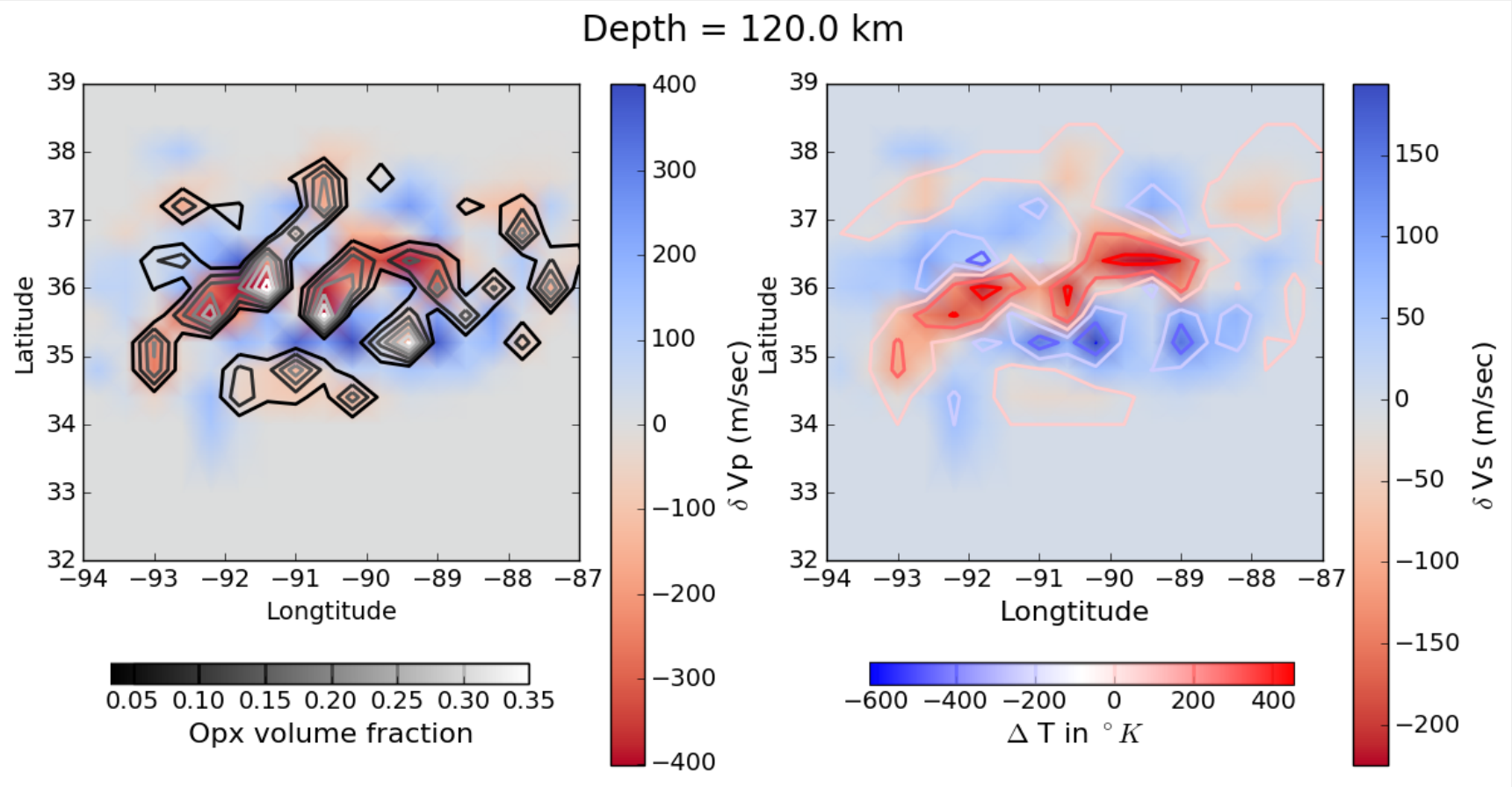
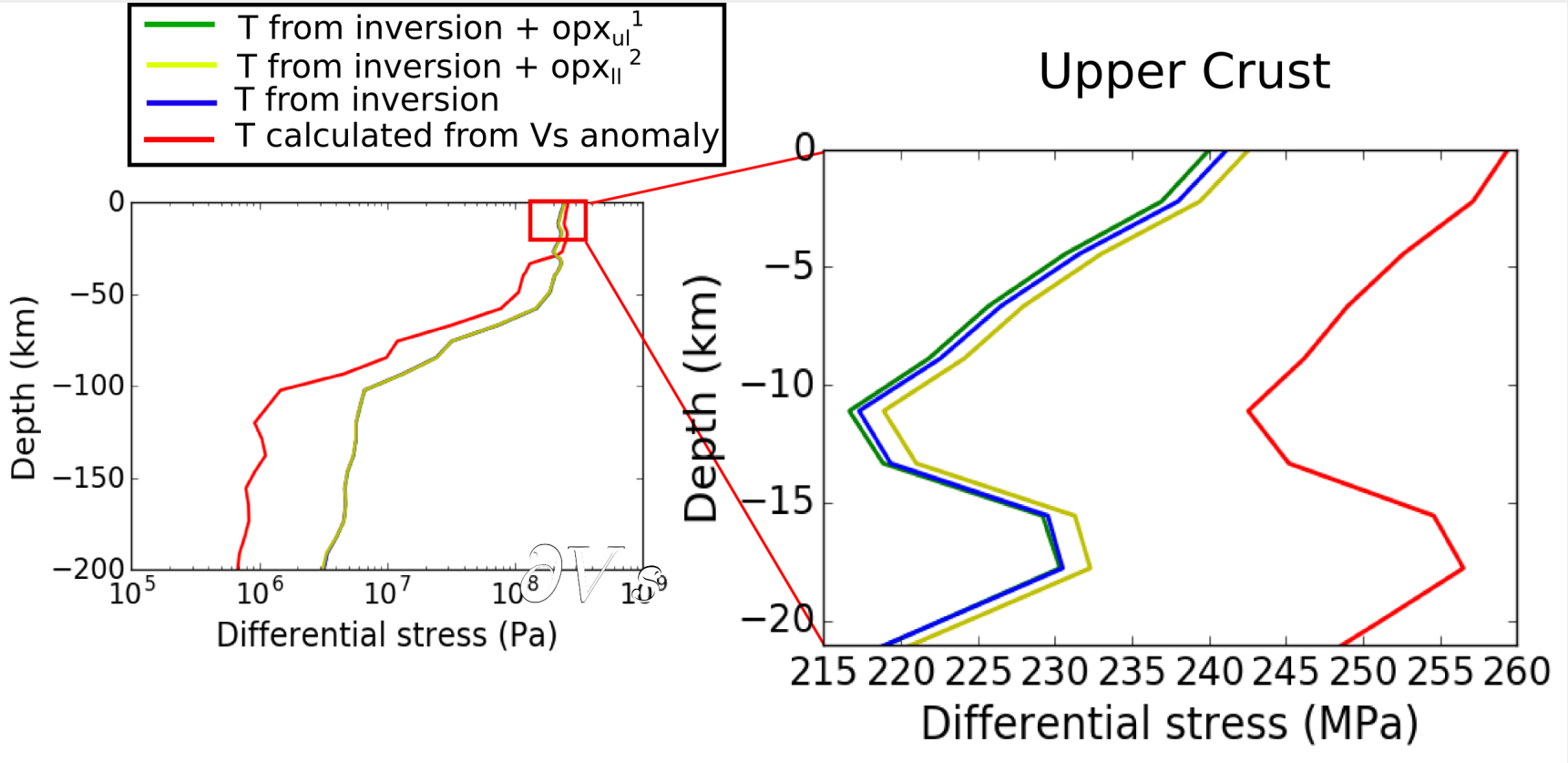


(Temperature and compositional gradients from Goes et al., 2000 and Schutt and Lesher, 2010 respectively)

Case IV: Inversion of Opx and Temperature

Temperatures from inversion are lower than calculated from velocity gradients, concentrating lesser stress.



[1] Hansen et al., 2015

[2] Ji et al., 2001

Summary

- High temperature and/or fluid increases differential stress in the upper crust but affects ∂Vs more than ∂Vp
- Fluid weakens the mantle more than temperature but does not differ in loading of the upper crust significantly
- If there is a flat Laramide slab, opx enrichment occurs above the flat slab (Wagner 2008) and could explain both Vp and Vs anomalies along with temperature

Thank you!

Questions