Solid Earth Discuss., 3, C503–C507, 2011
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Solid Earth Discussions

Interactive comment on "Constraining fault interpretation through tomographic velocity gradients: application to Northern Cascadia" *by* K. Ramachandran

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General comments: This well-written paper presents a promising approach in using additional information inherent in seismic tomographic velocity model data to better identify subsurface structures including faults and basement structures. Traditional tomographic velocity model cross-sections are smoothed such that structures represented by abrupt velocity contrasts, such as crustal faults, may not be obvious. The author illustrates the use of a velocity gradient method whereby the change in velocity (in both vertical and horizontal directions) is mapped, in order that structures represented by velocity contrasts will appear sharper when viewed as a contrast in velocity

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gradient than when viewed as a smoothed change in velocity.

The author succeeds in illustrating the efficacy of this method as applied to crustal faults in northern Cascadia. The Darrington-Devil's Mountain, Tacoma, Seattle, and Southern Whidbey Island faults are all clearly more identifiable using the velocity gradient method compared to the velocity model profiles. The Coast Range Boundary Fault, which is not at all apparent from the velocity model sections, is clearly identified by velocity gradient discontinuities. Therefore the case is clearly made that tomographic velocity model analyses should incorporate velocity gradient interpretation for better identification of subsurface structures.

Specific comments: In the abstract and introduction: "spatial gradients..are seldom used in interpreting the velocity model/subsurface fault structures." Please provide some examples and references of where this approach has been used previously. It is obviously important to know whether or not it has shown similar results in other applications.

Also, more explanation of the approach is needed in the introduction. A contrast in velocity gradient is a much more difficult concept to grasp than a contrast in velocity, which has a clear physical meaning. Perhaps provide some examples, e.g., in section 3.6 it is implied that sediments exhibit higher spatial velocity gradients than basement rocks.

The figures require some improvement before final publication. The main issue is that some of the colours in the gradient plots (making up most of the X and Y gradient cross-sections) do not match the colour scale provided.

Minor technical corrections: P840 L12-13: Change ".. velocity model, absolute velocity model has .." to ".. velocity models, absolute velocity models have ..". L18-19: Suggested change: "..locations of Tacoma Fault, Seattle Fault, Southern Whidbey Island Fault, and Darrington Devils Mountain fault much clearly" to "locations of the Tacoma, Seattle, Southern Whidbey Island, and Darrington-Devil's Mountain faults much more

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clearly.” Throughout the text, there is an inconsistent use of “Fault” versus “fault” for named faults.

P841 L8: Change “with in” to “within”. L10: Add “s” to “velocity variation”. L12: Hyphenate “ill conditioned”. L16: Add “the” before “northern Cascadia subduction zone”. L18-19 and L22: Change “much clearly” to “much clearer” or “much more clearly”. L21: Add “the” before “Z”.

P842 L3: “Traveltime” should be “traveltime”. L15: Change “there in” to “therein”. L16-17: Add “the” before “horizontal”, “vertical”, and “Z”. Change “an 1-D” to “a 1-D”.

P843 L3: Change Vx to Vz? L6: Add “the” before “Z direction”. L8: Add “the” before “earth’s upper crust”. L9-10: Add “s” to “variation” and “model”. L12: Add “A” before “practical case study”. Suggest adding “(profile locations in Fig. 1)” after “five vertical cross sections”. Otherwise Fig. 1 is only referred to in later sections. L13: Suggest change “describe” to “illustrate”. L15: Suggest changing “profile IJ..is in the SW-NE direction” to “profile IJ..is oriented SSW-NNE”. Profiles AB and CD are as close to SW-NE as profile IJ. L21: Add “(Fig. 1)” after “Leech River Fault”.

P844 L1: “imaged. . .as a thrust fault dipping..to the northwest..”. Please specify where it has been imaged – the fault cannot dip to the NW along those sections where it strikes NW - much of its length according to Fig. 1. Or is it dipping to the northeast? L3: Add “the” before “Metchosin”. L4: “..are identified on profiles AB and CD.” Please refer to Figs. 2 and 3. The Metchosin Igneous Group is not identified to the reader on these profiles – please label. Is there any other evidence for the position of the southern extension of the Leech River fault? No references are given for fault traces shown in Fig. 1. L5: Change “meta sedimentary” to “metasedimentary”. L6-7” Change “sharp gradient changes on the X and Y gradients” to “sharp changes in the X and Y gradients”. L8: Add “contrast” after “gradient”. L9: Add “the” before “Metchosin” and change “Rocks” to “rocks”. L13-14: “Outer Island” versus “Outer Islands” Fault - which is it? L17-19: Please clarify: the younger sediments extend much deeper.. to the NE

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than to the SW? L22: It would be useful if all 3 main splays of the SWIF were shown on Fig. 1. L24-26: Suggest adding “and tsunamigenic” after “seismogenic”. Might also be worth adding here that Holocene displacements have been documented on the SWIF; Kelsey et al. (2004) noted a possible tsunami deposit for the most recent paleoearthquake.

P845 L2-3: Confusing repetition here. Suggest changing 2nd sentence to: “At 105 km, the X and Y gradient discontinuities coincide with a line of earthquake hypocenters..”. L13: The DDMF marker and arrow on the top of Fig. 3 are confusingly placed at around 135 rather than 140 km. L15: Change “110 km” to “approximately 160 km”. 110 km marks the SWIF, not the DDMF. L22: Add “(Fig. 1)” after “Hood Canal fault zone”. L23-24: Suggest removal of “the feature is”.

P846 L1-3: To my eyes, the velocity plot appears to show a sharper discontinuity near 30 km than the gradient plots, which show a strong discontinuity further east, closer to 40 km. L4-5: However, the statement from L1-3 applies much better to profile GH. L7: Change “Settle” to “Seattle”. Add “(Fig. 1)” after “fault zone”. L13: May be worth mentioning that Holocene seismicity and tsunamigenesis have been documented on the Seattle fault (e.g., Atwater and Moore, 1992). L14: Add “the” before “Seattle fault zone”. L18-19: This statement implies that sediments are characterized by greater internal differences in velocity than are basement rocks – this could be spelled out in the introduction to help the reader get their head around the concepts of velocity gradients and velocity gradient contrasts. L22: Add “also” after “Gower et al. (1985)”. L24: Add “(Fig. 1)” after “Tacoma fault”. Add “a” before “smooth”. L25: Holocene uplift? L26: Looks like the Tacoma fault can also be identified on the Y and Z gradient sections at ∼40 km location.

P847 L4-5: Add reference to Fig. 1. Remove “Beneath Puget Sound” – according to Fig. 1, at least the surface expression of the fault runs completely to the east of the sound. L9: Replace “along the proposed CRBF, a right-lateral strike-slip fault” with “along this right-lateral strike-slip fault”. The word “proposed” could be added at first mention of the CRBF in L4. L17: Change “velocities” to “velocity variations (see top panel of Figs. 4 and 5)”. Add “the” before “CRBF”. L18-19: This suggests that the fault trace as plotted on Fig. 1 should be moved at least 10 km further east where it crosses profile GH. L20-26: Discrepancy between faults identified “west” of the CRBF and earthquake hypocenters to the “east”. “West” seems to be a typo?

P848 L6: Add “s” to “contact”. L8: Change to “..of the velocity gradient interpretation..”. L10-11: Change to “The gradient plots also depict the correlation of some of these faults with seismicity in a much clearer fashion”. L12-13: Change to “..which could not previously be mapped from tomographic velocity models, is clearly identifiable in the gradient plots”. L14: Add “the” before “interpretation of..”.

P851 Caption L1: add “s” to “cross-section”. L6: Change “B” to “MB” and “NA” to “NB” to match the map labels.

P852-856: Figs 2-6: Profile letters (C, D etc) should be shown at opposite ends of the profile, along with the orientation (SW, NE etc), which is shown on some figures, not others. The captions need to explain both the stars (earthquake hypocenters, data source?) and red arrows. The red arrows pointing to gradient discontinuities do not always point exactly at these discontinuities, which is confusing. The white contours on the gradient plots need some explanation, as they all seem to be labeled zero? Some of the colours in the gradient plots do not seem to match the colour scale provided beneath them, particularly the pale greens and blues that cover most of the X and Y gradient profiles – this needs to be rectified.

References: Atwater, B.F., and Moore, A.L., 1992, A tsunami about 1000 years ago in Puget Sound, Washington, Science, v. 258, p. 1614-1617. Kelsey, H.M., Sherrod, B., Johnson, S.Y., and Dadisman, S.V., 2004, Land-level changes from a late Holocene earthquake in the northern Puget Lowland, Washington, Geology, v. 32, no. 6, p. 469-472, doi:10.1130/G20361.1.

Interactive comment on Solid Earth Discuss., 3, 839, 2011.