Solid Earth Discussions

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Comment on se-2022-20

Anonymous Referee #1

Referee comment on "Plume–ridge interactions: ridgeward versus plate-drag plume flow" by Fengping Pang et al., Solid Earth Discuss., https://doi.org/10.5194/se-2022-20-RC1, 2022

This paper investigates the controlling factors in deformation regimes caused by mantle plume-ridge interaction. Using 2-d numerical models, the authors studied effect of three parameters on resultant deformation regimes: (a) spreading rate, (b) plume-ridge distance and (c) plume radius. The outcomes of this study indicate that two different responses may result from plume-ridge interaction that are ridge suction and plate drag. The controlling factor has been proposed to be the competition between plate shearing and plume spreading, which depends on plume size, plume-ridge distance and the spreading rate of the mid-ocean ridge.

The subject of the paper is very interesting and is of broad interest. However, I have some concerns about the numerical models and the interpretations of their results on which the outcomes of this paper rely. I believe some corrections are required to improve the quality of the paper. Below I listed my comments and corrections which I hope will be helpful to raise the quality of the paper.

Main comments:
1) The language of the manuscript needs to be fully checked and revised by a professional editing service or a native speaker.
2) In this study, the relation between spreading rate and age of oceanic lithosphere is ignored. Usually, higher spreading rates create younger lithospheres at a constant distance. In this study, the authors assumed that the lithospheric age is constant near the side boundaries (50 Myr). As a result, by imposing some higher velocities near the side boundaries to simulate higher spreading rates, the lithosphere becomes under extension and since the ridge is the weakest point in the system the width of ridge changes (it is clearly seen in e.g., Figs 3e,4e and 5a-b); higher rates lead to wider ridges. Could the authors explain to what extend is this assumption realistic? I think the formation of cracks in the lithosphere is the consequence of this assumption.
3) In the abstract it is written "plume migration driven by plate drag is promoted by fast-ridge spreading rate." This is true only if the plume radii are small. For large plumes the rate of spreading is irrelevant (Fig. 6). This should be mentioned here and also in discussion and conclusions.

4) Usually decomposition melting of plume head causes the formation of a plateau above the plume head. Where do plateaus form in the models? I suggest that the authors add information about where plateaus form and how thick the crust is to the manuscript. The temporal evolution of plateaus is also interesting to be investigated.
5) Lines 20-22 : "Our results highlight fast-spreading ridges exert strong plate dragging force, rather than suction on plume motion, which sheds new light on the natural observations of plume absence along the fast-spreading ridges, such as the East Pacific Rises." As I indicated above this is true only if plume radii are smaller than 250 km (based on Fig. 6). This conclusion implies that plumes in the Pacific are smaller than those in Atlantic. Are there any observations supporting this? I'm interested in a discussion about this issue in the paper.
6) Looking at distribution of plumes and their sizes in Fig.9, one cannot see any correlation between plume size with plate drag and ridge suction. Can authors comment on that? Besides, in conclusion it is written: "The plume size, that is, the plume buoyancy flux, may play a critical role in controlling the connection between the two units, compared with distance and spreading rate." Why does plume size play important role compared to the two other factors? This is not discussed in the main text.
7) Line 413- 415 : "Based on a series of numerical modeling as well as geological and geophysical observations, we predict that mantle plumes in the Pacific Ocean are more likely to be dragged away by the spreading ridge. " The authors emphasize on the fast spreading rate of Pacific ocean as a main factor for dragging plumes away from the ridges. I think the plume-ridge distance may be a main factor in this case; most of plume tails (shown as blue dots in Fig. 9a) in the Pacific ocean are located away from the ridges.
8) Line 145: Temperature of 2513 K is very high for temperature at 660 km. Considering adiabatic temperature gradient of 0.5 K km-1 and temperature of 1573 K at the base of lithosphere, temperature at the bottom of model should be ~1873 K.
9) Fig. 5: I expect the heat flux and melt are initially maximum in the area above the plume head. Then due to underplating of plume and its flowing towards ridge, the location of maximum heat flux and melt changes in time. That would be worth to show the evolution of heat flux and melt in time (similar to what is shown for surface topography in Fig. 3 and 4). For (5e-f): I suggest to show the results of plate drag model from ridge to some distances away from it , similar to what is shown in (c) and (d). I suspect that in plate drag due to imposing higher extension rate, the whole lithosphere is experiencing cracks and becomes extremely weak. Figure 5 shows the results in the early stage of deformation. Can authors provide a figure showing results at later stages?
10) I suggest to add a Table to the manuscript which describes the models, their description and their results. This helps with organising the peresntation of results in the manuscrip. For instance, in Figs 3-8 one can add the names of models to the figures and their captions.

Other comments:
Lines 13-15: These two sentences deliver the same message. Please remove one of them.
Line 36: What is Amsterdam?
Line 38: One should keep the sequence of figures in the text. Here, the authors first refer to Fig. 1b and later in the text to Fig. 1a. Please change the place of Fig1.b and Fig. 1a to be consistence with the sequence of referring to them in the text.
Line 38: "François et al., 2018" is not in the references.
Line 44: Please refer here to Fig. 1a (As I proposed above this should be Fig. 1b in the new version of manuscript).
Lines 57-60: These are conclusions of this study and should be moved to the conclusions section.
Lines64-71: Figure Caption needs some modifications. The main message of Figure 1a is to show the location and number of plumes and their responses to plume-ridge

interaction. But in the caption of Figure 1a it is written "Residual bathymetry of the ocean basins (Straume et al., 2019)". The residual bathymetry is the background color which can be referred to at the end of description of Figure 1a (not in the first line). For the description of (c) I suggest: " Sketches of ridge suction (top panel) and plate drag (bottom panel) modes."
Lines 76-77: "Colored boxes refer to the initial rock type, and corresponding newly formed molten rock types are also show in the rock boxes." It is a bit confusing what are colored boxes and rock boxes. Please modify and clarify this part. It is good to indicate here that spreading rate was simulated by imposing half-spreading rate to the side boundaries as shown by yellow arrows in the figure.
Line 108: Replace "as" by "is" and insert "is" after C and phi.
Lines 136-138: It is not clear what this sentence mean. Please modify this sentence.
Lines 147-148: This is not consistence with cooling half space. The temperature of the oceanic lithosphere tends to change linearly with depth when lithosphere is very old (older than ~80 Myr).
Line 153: "An additional velocity is imposed on both sides of the ridge to represent the half spreading rate. " Are they internal boundaries? Please explain more about it here; where are they and until which depth they extend.
Line 173: The significant surface uplift above the rising plume cannot be recognized in Figure 3a and b.
Line 181: "The mantle flow vertical velocity profiles" It is a bit confusing. The profiles shown in Fig. 3f are the horizontal component of mantle velocities along two vertical profiles. Please rephrase this part and also explain the depths which were selected for these profiles. Are they from the surface till ~250 km depth?
Lines 186-187: "The overriding plate moves slower than the ponding plume, and hence actually slows down the spreading plume branches." It is not clear what the message of this sentence is. According to model setup, since plume is located on the left side of MOR, the overriding plate motion speeds up the plume flow towards left (since the plume flow and plate motion have the same direction) and slows down the flow in the right plume branch.
Lines 187-188: "Without suction effect from the spreading center, the left plume branch flows out much slower than the right branch." Similar to what I mentioned in my previous comment, I expect faster flow towards left.
Lines 190-194: Please add a brief description of reference model here (like Figure caption of Fig. 4). "topography evolutions along the flow path of selected snapshots." Does it mean surface topography at different times? Rephrase this sentence: "Solid, dash and dotted lines are the velocity profiles of plume branches 100 km aside the plume stem and plot in (f)" Please add the scale of velocity vectors to the figures 3,4 and 5.
Line 199-201: This part refers to Fig. 5. One should keep the sequence of figures in the text. One cannot refer to Fig. 5 before explaining Fig. 4.
Line 211 : I suggest to modify this part and use the following sentence "except that in this mode a smaller plume (with radius of 100 km) interacts with a "
Fig. 5: Black curve in Fig. 5e shows the plume head location. Please add a sentence in this regard to the figure caption.
Fig. 7: It is a very complicated figure. What do the upper panels of Fig. 7a-c stand for? They show the results at different times. Are the results shown in the lower panels of Fig. 7a-c showing the results at similar times as those shown in the upper panels? The scale of Fig. 7a-c is very small and one can hardly distinguish all the curves shown in the Figure. Please make the figure bigger. I suggest to move the legend of Fig. 7a ito the right side of Figure because Fig. 7b-c also shows the results of models with different plume-ridge distances. The colors of curves for different plume-ridge distances are very similar and hard to differentiate them from each other. I suggest to change the colors. What do "plume head stage- positive spreading out" and "plume tail stage- passive flow driven by plate" mean? How are buoyancy fluxes calculated?
Line 285: Tilted plume tail cannot be recognized in Fig. 7d. I suggest to show the plume tail materials with different color than yellow.

Lines 300-312: It is hard to understand this part. Please make it more understandable for readers.
Line 322: "with i*ncreasing* spreading rate and off-axis distance"
Line 330: How does Fig. 8a indicate that fast-spreading ridge promotes plume dragging. In this figure, from three models with fast spreading rates two are representing ridge suction mode.
Fig. 8: What is the distance of plume-ridge in models shown in Fig. 8b-d? What do the dashed color curves in Fig. 8b stand for? Please explain them in the caption. The scale of figures are small. What does "plume head spreading" in Figure 8d mean? What is the effect of plume size on shear force and overpressure difference?
Lines 340-347: It is not clear how shear force and pressure difference were calculated. Please re-write this part. Was the shear force calculated for the grids in the upper part of plume head or the whole plume head? The box of 50*50 km^2 in Fig. 8a is shown only for the plume head (and not for ridge center).
Lines 353-354: "However, without plume further supplies, the overpressure difference from the plume head to the spreading center decreases slowly with time (Fig. 355 8d)." What does it mean?
Lines 360-361: "while all models gradually switch from ridge suction in the plume-head stage to dominant plate drag in the plume-tail stage" Is it valid for all models or only those representing plate drag regime?
Figure 9: What do "MAR" and "EPR" stand for? Please explain them in the caption. How did the authors obtain the plume buoyancy flux (which indicate plume size) of hotspots shown in Fig. 9?