EGUsphere, referee comment RC2
https://doi.org/10.5194/egusphere-2022-15-RC2, 2022

Comment on egusphere-2022-15

Ana M. Negredo (Referee)

Referee comment on "The role of edge-driven convection in the generation ofvolcanism – Part 2: Interaction with mantle plumes, applied to the Canary Islands" by Antonio Manjón-Cabeza Córdoba and Maxim D. Ballmer, EGUsphere, https://doi.org/10.5194/egusphere-2022-15-RC2, 2022

The study by Manjon-Cabeza Córdoba and Ballmer addresses the problem of hotspots located close to (passive) continental margins, with particular emphasis in the eastern Atlantic hotspots and with a specific discussion for the Canary Islands archipelago. It represents a suitable continuation of their former work, where they found the limited capacity of Edge-Driven Convection (EDC) to generate and sustain significant melting. The present approach considers a 3D geometry and includes a mantle plume to study the interaction between the flow related to plume dynamics and shallower convection related to EDC. This approach is straightforward and the results are relevant. Overall the study deserves publication is Solid Earth after moderate revision. This revision should be focused on scientific communication rather than on modelling itself. My main concerns are mostly based on how the modelling approach (methods and setup) and results are explained and illustrated. These parts should be significantly improved. I further elaborate these ideas in the following notes that I hope will be useful during the revision.

Main comments:

1. I think that the explanation of the model setup does not allow understanding fundamental aspects of the modelling as for example the implementation of the plume thermal anomaly and the initial phases of the model evolution. The authors should clearly explain how the 'statistical steady-state' (line 98) is achieved. For example, do the authors activate first EDC and later on force plume upwelling? Or both processes are activated simultaneously instead? How is plume upwelling forced? Is equation 1 a bottom boundary condition that forces the development of a plume? I guess this is the case, otherwise, how can r_plume change every 50 timesteps without artificially perturbing the thermal distribution? I find puzzling that this update with time of r_plume does not perturb the steady-state flow and thermal fields. Similarly, which is the radius of the opening at the bottom of the model mentioned in line 97?

Also the approximations assumed (extended Boussinesq approximation, I guess, as in their former EDC study) are not mentioned.

Overall, please clearly state which are the initial and boundary conditions, explain how plume upwelling is forced and the initial evolution previous to the statistical steady-state. Below there are additional specific comments related to model setting definition.

2. I realize that illustrating the dynamics of 3D models can be very challenging, but I still consider that the quality of this fully-coupled 3D modeling is somehow obscured by the figures shown in the manuscript. Note that results are illustrated in only two type of figures, the style of figures 3, 5, 7 and the style of figures 4, 6, 8, 9. For example the interplay between EDC and plume upwelling could be better illustrated in vertical cross-sections showing the temperature, melting and velocity fields, at least for the reference case. That would alse be useful to distinguish between SSC and EDC. There are a number of statements (I list them in the comments below) that are not illustrated at all in any figure. For example, the authors mention that figures shown (Figures 3, 5, 7) refer to thermal anomalies, and that the melting areas may be deflected even more than the thermal anomaly' (lines 334-335), but this is not illustrated nor quantified by any means, which makes it difficult the comparison with the Canaries. Similarly, the important sentence: 'plume pancake may not necessarily be parallel to the plate movement' (lines 336-337), which is crucial for the comparison with the Canaries, could be shown for example on a horizontal section at the surface. I suggest adding additional figures showing for example the horizontal geometry of melting anomalies.

3. Regarding the comparison with the Canary Archipelago, the authors state that several models predict 'deflection of the plume pancake and the melting zones toward the continental margin, which would explain the shape of the whole archipelago and the geographic distribution of volcanism'. However, this deflection is of only 25-35 km, so I don't see in which sense the interaction between plume and EDC is required to explain the E-W extension of the archipelago. In this sense, perhaps a control test with a flat lithosphere would be helpful to see how the geometry of the plume pancake is affected by the mentioned interaction. This is important to support the last conclusion, which states that for the Canary Islands a plume may be rising at 200 km from the continental margin, being deflected and creating the complex age progression and widespread volcanism. I agree that the lateral deflection may explain the widespread volcanism (although the plume pancake is only deflected 25-35 km), but the age progression is not reproduced provided that this modelled deflection is towards de edge, while the Canarian volcanism becomes younger away from the edge.

Minor comments:

Lines 33-34. In the statement ‘Besides, a cogenetic relation of these volcanoes with other volcanic fields has been suggested on the basis of geochemistry (Doblas et al., 2007; Duggen et al., 2009)’, please, be more specific, which volcanic fields, which relation?

Line 46. Please, mention here the similar results found in the recent 2D study by Negredo et al. (2022; EPSL doi: https://doi.org/10.1016/j.epsl.2022.117506) which is closely related to the present work and was probably published after submission of the manuscript by Manjón-Cabeza Córdoba and Ballmer.

Line 83-84 please clarify in which sense the models are ‘bottom heated’: by means of a temperature increase or a heat flow increase…?

Line 84 better say ‘thermal distribution’ (it is a surface) instead of ‘thermal profile’

Line 88. Why is the plume located at y=660 km rather than being centered in the box, at y=1980/2=990 km. This would make sense to avoid artefacts related to the different distance to the y-normal boundaries.

Line 93. Is this temperature increase a bottom boundary condition?

Lines 135-136. this sentence ‘Plume Erosion Track (PET) that is observed in all models Ribe and Christensen (1994)’ seems ambiguous to me. Do the authors mean all models in this study? All models on plume dynamics?

Lines 136-137. The authors say ‘In the reference case (fig. 3), the PET is mostly parallel to the direction of plate motion’, but I cannot see this at all, mainly because the figure shows a snapshot in a steady-state situation, so it is difficult to see the development of a track.

Line 170. The sentence ‘Nonetheless, the base of the lithosphere is eroded more efficiently for large DeltaTplume,’ is not illustrated in any figure.

Lines 220-221. The statement ‘…another notable phenomenon occurs: vigorous SSC occurs in the plume pancake with dominant transverse rolls (i.e., perpendicular to the edge..’ as well as the description of two melting anomalies that separate and merge periodically are not illustrated in any figure.

Line 273-274. I don’t understand this sentence ‘We also find that the symmetry of the PET is higher for the cases with lower viscosity than for the case with intermediate and with high viscosity’. Symmetry with respect to what? Can the authors add any figure to illustrate this?

Lines 283-286. The authors affirm ‘On the other hand, plume pancake deflection commonly (but not always) occurs towards the edge. This prediction may explain why some hotspot tracks (such as the Canaries) do not strictly align with plate velocity, and volcanism is widespread with more activity far from the continental margin than near to it (e.g., La Palma vs. Gran Canaria)’. I agree, but this would not be consistent with volcanic islands age decreasing away from the edge in the Canaries. Can the authors explain this?

Lines 295-298. Here the authors compare model results with previous work about the interaction between mantle plume and lithospheric instabilities. In this context, a comparison with the recent 2D transient modelling by Negredo et al., (EPSL, 2022) is pertinent. The results obtained from both studies are consistent and complementary, although the sense of migration of the plume ‘pancake’ is opposed, perhaps because of the different timesteps of the simulations chosen for interpretation purposes.

Figure 3. The authors mention: ‘The purple contour outlines the region of active melting while the orange contour outlines the region of finite melt presence, including where active melt re-freezing occurs’. I don’t see these as contours, but rather as surfaces. Perhaps a vertical cross section through the plume would be useful. Why are colors al the side boundaries different from colors at the back face? Please, add orientation axis (easily added in Paraview).

List of typos:

Line 49. Say ‘these archipelagos’ instead of ‘this archipelagos’

Line 114 extra parenthesis)

Line 122 remove cf.[

Line 146 say ‘and another’ instead of ‘an another’

Line 201. ..'the dotted grey line in fig. 6' please, specify which panel.

Lines 254-256. The sentence 'Very likely, these predictions have implications for dynamic topography and swell geometry' is repeated.

Line 303 replace pyroxenite. by pyroxenite, (comma instead of point)

Line 382, remove the word 'plue' (plume, I guess)

Line 385, use lowercase E in Edge.

Figure 2. Use lowercase k for km (not Km).