Biogeosciences
Discussions

Interactive comment on "Potential and limitations of finite element modelling in assessing structural integrity of coralline algae under future global change" *by* L. Melbourne et al.

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Review of Melbourne et. al.

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The authors build on previous 2D geometric models of coralline algae by extending these to 3D geometric models and comparing the results to a 3D model derived from a CAT scan. The paper is very well written and nicely summarises the literature. I enjoyed the paper and it

I would say this is not a confirmation of the results from Ragazzola, rather seems to be an exacting replication. The geometry of the model, the forces, the software, the parameters are all the same so, not surprisingly, similar results are obtained. My concern is the sensitivity (or robustness) of these results. Are models converged with respect to the number elements? How sensitive are the results to parameters changes?

The novel part of this work, extracting the 3D model from the CT scan, hasn't been explored as fully as one might like. It would be good see some analysis of the size, shaped and distribution of the cavities. Also, rather than presenting 3D plots of stresses identifying the locations of the maximum stresses would be much more informative - even a simple table of the top (x,y,z, stress) components would suffice.

This paper could benefit from having more detail of the models(sizes etc), estimates of uncertainty, more detailed results (where the major stresses are etc), and some guidance on how the results can be interpreted (brittleness maybe?).

1 The loadings in the model

An interesting choice has been made in the loadings. The loading is asymmetric as the forces are applied to the top-left corner over 40um strips while the opposing forces are from the bottom-left is over a 40um strip on the side but a the whole bottom surface. This results the loading being mostly compressive down the diagonal of the cube, but with some shear along the x axis. What is the ratio of the compressive to shear forces?

Is this mixing of compressive and shear forces intentional? I would imagine that main impact on the structures from wave motion would be large scale shear stresses rather than compressive ones (the fractures in the picture are lateral which suggests they are more susceptible sheer forces). Similarly, I would anticipate that borers would also predominately exert shear stresses, just on a much smaller scale.

It may be more instructive to change how the applied and constraint forces so that it better reflects the geometry of the natural environment (see figure 1). Maybe setting up two sets of loadings would be a good way to investigate the relative effects of shear and compressive loads.

2 The size of the cells

The values given in section 2.1 don't add up and the geometry specification is confusing. This is partly due to the Ragazzola paper, but the models need to be clearly specified. I've attached a figure with best that I could make of the model by examining the figures. Also it needs to be cleared noted that the in the y direction each layer has the same thickness (ie. the top and bottom surface has the same thickness as the inner ones) but in the x direction the sides (left most and right most walls) have half the thickness of the inner ones. That is, the model are not translations of a unit cells.

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3 Graph of resulting

Graphing the results makes assessment much easier. I've done a quick plot of the data as an example. Is there any different between 2D and 2D 422μatm results and the 3D compartment and 3D compartment 422μatm results? Other than a change in the 5 sig fig for the strain, these two sets of results appear identical and there is no difference between the values and nothing in the text to indicate that these are distinct results. This should be removed from the table.

4 The measured geometry

After the effort was made to create a 3D model of the actual skeleton, it would be good to have some information about the geometry of the skeleton. It is hard to judge from figure 6, but it would appear that the skeleton has a structure more like Swiss cheese than a regular lattice.

- What is the distribution of cavity sizes?

- Are the cavities more like boxes or like spheroids?

- Are the cavities regularly distributed?

- What is the distribution of distances between cavities?

- What fraction that each model fills the cell?

- What is the total surface area of each model?

I can only imagine that the a regular structure (like the compartment model) will distribute the strain very differently from a random structure (like the biologically relevant model).

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This is beyond the scope of this work, but an interesting avenue would be to take use the statistics of cavity size and distribution to generate models by removing elements from a regular lattice. With a procedural model like this the randomness could be systematically changed from regular (like the compartment model) to a swiss cheese (like the biologically relevant). This would allow the effect of disorder on stress distribution to be investigated. The same model could have the cavity size systematically increased to model the effect of OA (as done here).

5 Stress / strain

Should the total strains for each model be compared to the same total stress and the data interpreted as a linear section of a stress-strain curve? Can the results be interpreted in terms of changes in brittleness? How we sure that the data is on the linear part of the curve? For example, maybe the stresses in the perturbative regime? What would happen if the applied force is varied? I imagine that the geometry dictates the stress-strain relationship. Can the models be run with increasing loadings until a fracture occurs, or is this beyond the capability of the software?

Assuming that all the results lie on the linear section a stress-strain curve, can it concluded that the biological model has a different bulk modulus of elasticity. Even if this holds the modulus of elasticity isn't that relevant to the fracture process, which I would guess is the more relevant quantity

The von Mises is a measure of local stress, and therefore has a distribution across the model. In a fracturing process the extremes of the distribution are important, not the average of the distribution. I think it would be good to include in the table something like the 90th or 95th percentile of the von Mises stresses. Also, rather than plotting the stresses over the entire 3D model (which shows only the surface stresses) could the areas experiencing the highest stresses be identified? For example, the compartment

might have a maximum on in the middle of the left facing surface while the biological model might have a maximum in the middle of the right facing surface.

Similarly, the most informative part of the 3D stress might be a slice through the centre. The plots in paper show the stresses on the surface which are affect by the conditions - I would expect these surface layer stress to most sensitive to simulation details like size of model, while the central ones would be more stable. On the other hand, a fracture probably starts at the surface and propagates inwards, in which case the surface stress are most relevant.

What is the relationship between in the von Mises stress and the total stress? Do the von Mises stress integrate up to the total stress? Would this total stress be the force over the area of the skeleton in contact with the boundary (changing with model Figure 4b), or would it be 'bulk' area (same for all models Figure 4a)?

6 Convergence

If the model is converged with respect to mesh points the results won't depend on the number of elements - that is, it doesn't matter whether a triangular, hexagonal, random etc mesh is used the answer should be same. Comparing the results for 3D corridor with a hexagonal mesh (1×10^6 elements) with the tetrahedral mesh (2×10^6) the total strain differs by an order of magnitude. This indicates that one (or more likely both) of these models is far from convergence. What checks of convergence has been done? Without being sure that the results are converged how is it possible to compare the results of one geometry to another?

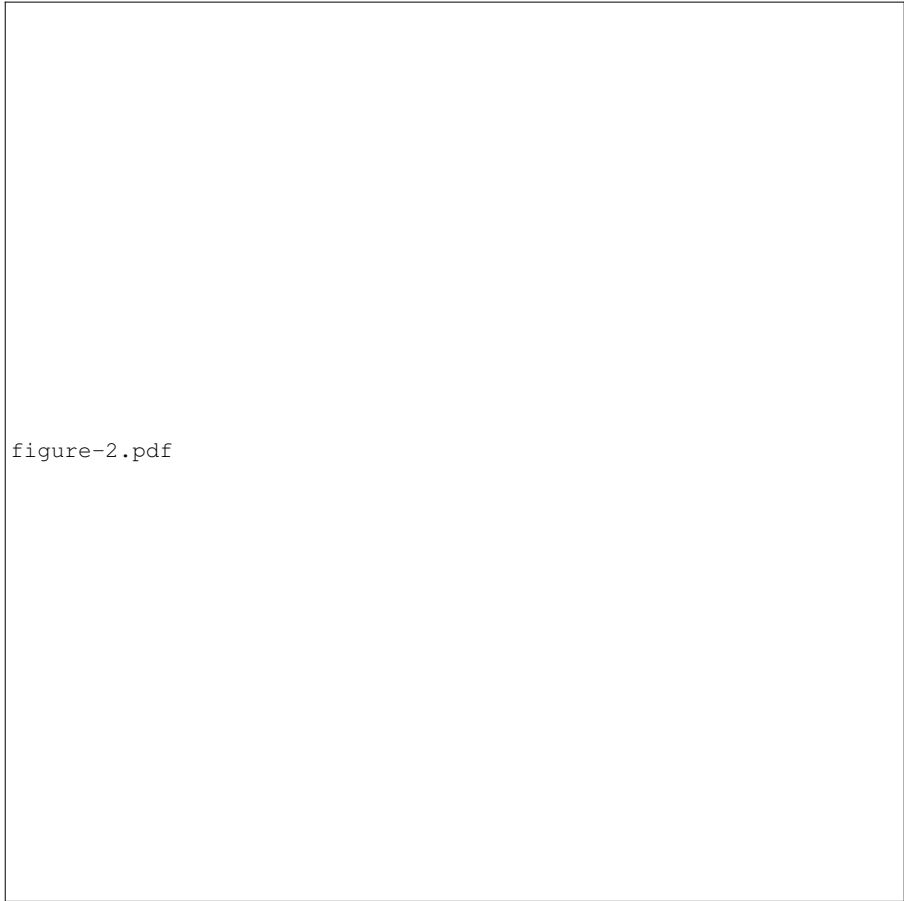## 7 Error estimates / sensitivity

Related to the last point, no uncertainties given. A simple assessment of the variation of the results with change in cell size parameters or number of grid points a rough indication of variations.
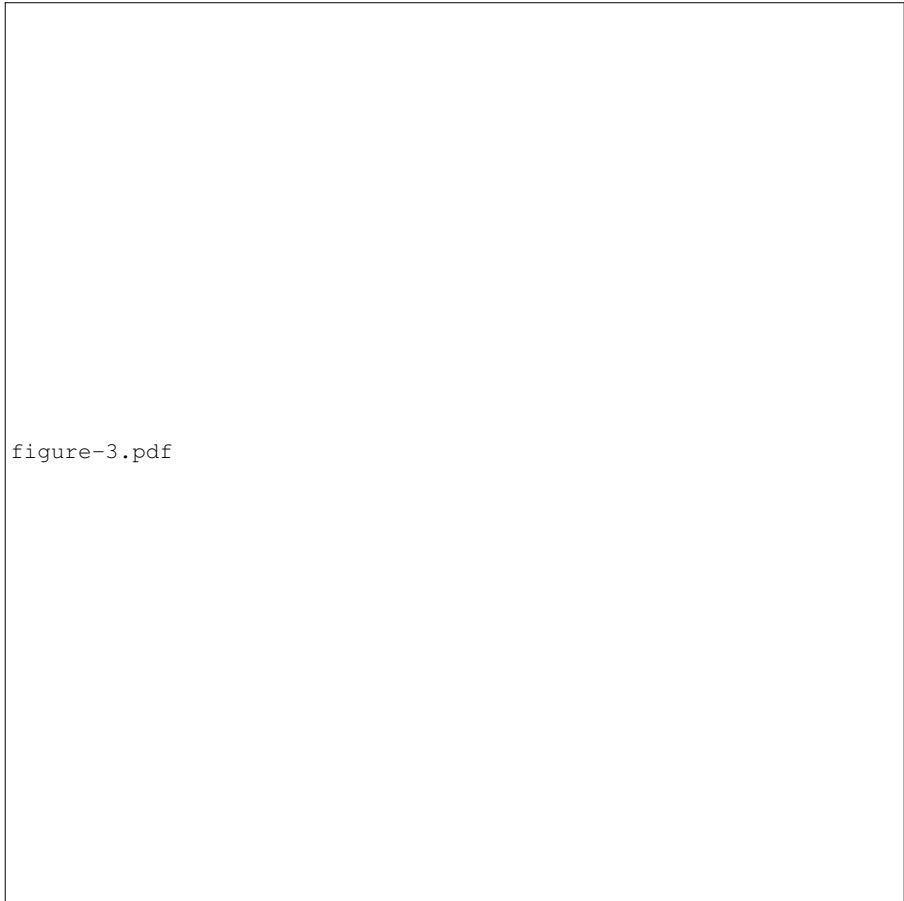
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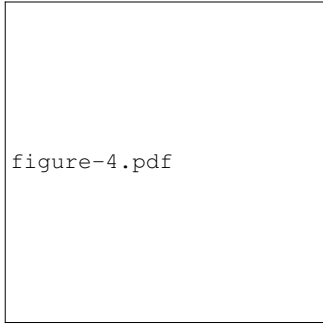
Fig. 1. Alternative setup of forces

Fig. 2. Estimated cell unit parameters.

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Fig. 3. Stress and strain in models.

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Fig. 4. Stress-strain graphs.