Review of egusphere-2024-3200

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The authors present the publication and benchmark of the open source FE software package CitcomSVE 3.0, which allows to solve the GIA problem for a viscolestic continuum with lateral variations in material poperties considering elastic compressibility and the usual requirements for a GIA solver which are rotational deformations due to polar wander, geocenter motion and the sea level equation.

They benchmarked the code against a spectral 1D code following a similar benchmark of the incompressible precursor. 2.1.

The method to solve the equations for a compressible continuum with CitcomSVE2.1 was already presented by A et al. (2013) but without the SLE solver of the incompressible version and so lacking a comparable benchmark for GIA problems. Due to lack of suitable 3D benchmarks the authors were forced to test their model against the established spectral normal mode theory for 1D problems. This is in agreement with the testing of further 3D codes. To my knowledge only Martinec 2000 presented a benchmark against an analytical not spherical symmetric solution.

In summary, the presented method sounds reasonable and the results show a rather good agreement with the provided 1D solutions. Nevertheless I have a small number of suggestions which might improve the discussion and the reliability of the code:

1. discussion of spectral loads at least up to d/o 128,
2. transfer of the indepth discusssion of the applied new SLE solver into the supplement,
3. discussion also of the geoid displacement for the GIA example.

Otherwise this paper is set up clearly and I suggest its consideration for GMD.

Volker Klemann

Details

L3 Although discussed in the paper the applicability to solve the GIA problem is not stated in the title.

L34 not clear if also compressibility can vary laterally.

L38 Is the SLE solver is part of published software?

L40 Only at the end I found an explanation of what a second-order accuracy means. But, I am not convinced if this criterion holds heres see there.

L42 An assessment of the computation time is given. May be you can add that it is three times slower than the incompressible version

L70 You should add here Tanaka et al. (2011, doi:10.1111/j.1365-246X.2010.04854.x), where like in A et al. (2013), compressibility is considered. Here also see the discussion of L200ff. you should also discuss there, which codes are compressible and which are incompressible.

L115 Your code works in the Lagrangian domain. Then I would state, that the density increment is considered as being in the Eulerian domain, first as its advection in Eq. 2 is of second order, and second that in this way the Poisson equation (Eq. 3) holds. But you could also state that in case of small perturations and the resulting linearisation the Eulerian and Lagrangian density increment do not differ.

L126 The boundary condition at the CMB (Eq. 5) is important (and also goes back to Wu and Peltier 1982).

L 127 According to Zhong et al. 2003 the equation holds for an incompressilbe core.

L 132 Here and in the following I would prefer 'continuum' instead of 'medium', due the continuum mechanical formulation of the problem.

L149 Small suggestion: 'Maxwell rheology (6)' should be sufficient to write.

L156 For the time integration of the field equations you apply an explicit time differencing scheme. Is this correct? I would then specify this.

L176ff Can you state that this coincides with Tanaka et al. (2011).

L200ff You should place this discussion to L70ff.

L255ff This is a recap of Kendall et al. 2005. May be you can reduce this section and refer to them. Also in Spada and Melini (2019, doi:10.5194/gmd-12-5055-2019) a nice overview is given.
One further aspect you do not discuss is, how you treat the inner iteration between subsequent integration steps. Is this omitted here similar to Hagedoorn et al. (2007, doi:10.1007/s00024-007-0186-7), where also the field equations are solved explicitly in the time domain?

L293 The main reason to run the outer iterations is to approximate a consistent initial topography. I did not find this explicitly stated.

L298ff This first iteration is an interesting suggestions.

L304 The efficiency is not shown in the next section but later in 3.2.1. Nevertheless as stated there, I would shift this discussion to the supplement as it interrupts the benchmark discussion in this section.

L313 Why not call t his subsection 'Spectral surface load with step-function in time' ?

L317 You can also here specify that you vary the load between (1, 0) and (16, 8).

L321 Why do you considere only the cosine term and not the complete representation of the spectral load distribution?

Table 1 The reader would help if you list here the reference Maxwell time used for normalisation, also in view of Fig. 1 and the following discussion. Furthermore I wonder why the viscosity in the upper mantle is higher than in the lower mantle, this does not look like vm5a.

L335ff Can you state something regarding the radial discretisation? How many elements are considered in the lithosphere, upper and lower mantle, respectively.

With respect to the considered spectral representations did you check if the derived load love numbers deviate for different orders, I think you have checked this but it would be interesting how much they vary also in view of the spectral solutions. The reader might also wonder why the lln of (2, 1) differ so much from (2, 0). Obviously it is due to the polar motion term. You should state this here.

Figure 1. Here you chose a different nomenclature to specify the degree/order forcing. In the next you describe the (l, m) nomenclature. Easiest would be to keept it in Figure 1 but change it in Table 2 and throughout the text.

Furthermore there is a big step from degree 16 presented here to degree 128 usually considered in GIA (see Spada et al., 2011 or Tanaka et al., 2011). So it would be interesting to show the deviations also at such high degrees (see main points).

Figure 2. Form the figure and the caption it is not visible where R5 is applied. In the lower or in the upper triangle, although it should be the lower one of course.

L422 '[...] and (12) with the floating ice criterion' ?

L424 'multiple' sounds like at least 10. Also Kendall et al or other authors usually only consider 3 to 4 iterations.

L428 as stated at L304 I would shift the whole discussion of 3.2.1 to the supplement. This as you also only refer to figures there. May be you can summarise the main output there. Here it disrupts the benchmark section (see also main points).

L433 here and throughout the text I would replace 'kybp' by 'ka BP' as used in literature, see also Figure 4 vs. Figure 6.

L531 If you shifted 3.2.1 you do not have to repeat the setup of the problem here, as this as given already before.

L555 Further down you apply a nearest neighbor algorithm for the interpolation of the displacement field. Did you apply the same algorithm here or did you use a mass conserving algorithm?

Table 3. It would be great to see here also the error statistics of the RSL for the presented epochs further down.

L582 May be you can state at the beginning that in this subsection you present surface displacement rates, and RSL. What I miss is the gravity change signal at pt, as a further prominent observable (see also main points).

L627 Here you mention the gravity change and change rate of geoid height, but you do not show results, also what about RSL for this specific case?

L640ff Is the required higher resolution for (2, 1) only an observation, or can you give an explanation for this deviating behaviour? The relative difference between -120 and 0 ky is much larger for this term in comparison to the other coefficients. May be Cambiotti et al. (2010, 0.1111/j.1365-246X.2010.04791.x) helps.

Figure 6, You should discuss the offset between the FE and S solutions at the far field sites. Is this due to coastal levering especially at Geylang or mismatch in L2m1?

L691 I would not call the presented comparison 'extensive', as you discuss rather low degree spectral loads and only one GIA realisation.

L694ff I do not follow this calculus. Considering the errors in Table 3. There, from R1 to R2 the error reduces by a factor of 2, whereas you increased the number of elements by a factor of 2.7.

L699ff You can also state here that the integration time for a compressible continuum is three times larger than for the incompressible solution.