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Interactive comment on "ERSEM 15.06: a generic model for marine biogeochemistry and the ecosystem dynamics of the lower trophic levels" *by* M. Butenschön et al.

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ERSEM 15.06: a generic model for marine biogeochemistry and the ecosystem dynamics of the lower trophic levels

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The ERSEM model is one of the most sophisticated biogeochemical models available for shallow water ecosystems. It contains a broad range of elements (C, N, P, Si, Fe), has dynamic quotas for 4 phytoplankton types, 3 zooplankton types, bacteria mediating remineralisation, a carbon / oxygen chemistry suite, as well as a benthos with three zooplankton. There are models with more sophisticated optical sub-models, size-resolution of plankton, benthic plants and sediment chemistry (metals etc.), but in general ERSEM contains one of the broadest set of processes of any available model. The representation of bacteria in the microbial loop is, in particular, world-leading.

This manuscript describes in detail the ERSEM model with the ambitious goal to be the definitive complete mathematical description for users of this model at its present, mature state. In general the manuscript achieves this goal, although a significant number of errors appear in the text that need attention, and elements of the structure are worth considering.

I am a strong supporter of peer-review publication of this type of work and wish to provide the following comments in order to improve the manuscript. Any bluntness in the comments is due to brevity, as I understanding the challenge in achieving an error-free document with this many details. Thank you for your commitment to the thorough scientific presentation of your biogeochemical model.

Major comments on clarity.

1. It is awkward that Eqs. like (3) consider all dP/dt terms to be positive (i.e. dP/dt |pred is positive), such that it must be subtracted from growth in Eq. 3. Of course dP/dt due to predation is negative. This awkwardness is compounded later when the individual terms are calculated. For example Eq. 32 gives excretion being equal to uptake, when in fact the terms are the negative of each other. I would suggest that dP/dt |pred be negative, as well as all other loss terms. This issue comes up many times in the manuscript.

2. The symbol 'q' is overused, resulting in confusion. 'q' is used as a quota, a fraction,

and a turnover rate. In principle, it would be best to assign a symbol one class of entity to quantify, and then use subscripts and superscripts to be more specific.

3. The quotas are state variables? Wouldn't you need a set of equations to describe their advection and diffusion like Eq. 1 that conserves mass? In Section 3.2 of J. Mar. Sys. 50 (2004) 199– 222 I give a description of how conservation of mass is achieved in the advection of quotas. Is this what you do?

4. The use of calligraphic symbols for chemical elements does not abide by conventions in chemistry, although it is still clear.

5. 'Specific' is used regularly though the text, but we are not told whether it is carbon-specific etc. In a model with varying stoichiometries I think this is important. Without this I had trouble with the Eqs. on p7081, as noted below.

6. The terms lysis and mortality are used interchangeably at times. Are they the same thing in the model?

7. Primes are used in the sense of B' = B + small number, to avoid numerical integration issues. I was not confident the prime was used in consistently in the text. In any case, this is a numerical integration issue, whereas this manuscript is mostly concerned with the symbolic presentation of processes formulations. I suggest primes are removed from all equations, and an additional section added to describe any numerical approximations that are recommended for the solution of the equations.

8. The usefulness of this document would be greatly enhanced by providing a list of parameters for one of the applications given. This is particularly necessary as many of the parameters are not given units in the text. I see this as an advantage, as the model equations are therefore not presented in a specific units system. But at some point units must be given so that the consistency of the model can be assessed.

Specific major comments.

1. If Eq. 1 contains a seabed term, then Eq. 2 should have a water column term?

2. Eq. 4 – should this have an excretion term?

3. Eq. 7 will produce an undefined number when either of the limiting functions is zero.

4. Eq. 24 – I think there should be a bracket around (p-379.48)

5. I think Eq. 28 should have Prc on the nominator?

6. Eq. 27-30. To illustrate an inconsistency, imagine you have one phytoplankton species P = 1 mg C m-3, fmin = 1. fpr becomes 1, and the grazing rate is proportional to 1 x 1 / (1+1) = $\frac{1}{2}$. Now split the phytoplankton into two identical populations, indistinguishable to the zooplankton, then fpr becomes 0.5 for both, and the grazing rate is proportional to 0.5 x 0.5/(0.5+1) + 0.5 x 0.5/(0.5+1) = 0.3333. I am not sure about the definition of fpr, but the definition of fmin is problematic. This same issue is exists for benthic feeders. Here (Eq. 168) a detection capacity is assumed. The only justification I could imagine for a detection capacity is that the concentration is less than one individual. If so, then there would be a calculation that could be made to determine the value. But I don't think this is what you are trying to represent. If it is relative availability, then you could use an affinity for prey in the same manner as you consider NH4 and NO3 uptake.

7. Eq. 38 might be incomplete. The LHS implies a depth-average concentration, which would require the integral through the water column to be divided by the depth, while the RHS implies the depth integral (although the dummy variable, dz, is not given)

8. Eq. 45,46. I don't see how these equations work. If Sup is the bacteria-specific uptake rate, then Eq. 46 should be dB/dt = S B, where Sup depends on the available organic matter, not the bacterial population? In Eq. 45, should it be Rlab?

9. I am not sure of the meaning of the bold brackets in Eqs. 57 and 58, but they seem to imply multiplication of local derivatives, which I don't think is the intention.

10. P7091. Is r_decomp = r_remin by definition in the equations? If so, it would be better to have just one parameter.

12. P7105 – If alkalinity is correlated to temperature, which is non-conservative, then alkalinity will be non-conservative. Why not initialise the model with alkalinity based on T and S, and then advect total alkalinity (not just the bgc perturbations), with bgc processes as local sink/sources.

13. The equation of the vertical attenuation of light (Eq. 128) calculates light at a depth z. But the model considers discrete layers, in which case any single depth (top, centre, or bottom of the layer) does not represent the mean available light in the layer. The correct depth-averaged light within a layer is given by (Etop-Ebot)/(Kd dz) where Kd is the vertical attenuation of light coefficient, and dz is the thickness of the layer. A similar problem is described on the ROMS forum: https://www.myroms.org/forum/viewtopic.php?f=33&t=1314.

14. Eqn 245 has a parameter h with units of (mass/length)ˆ3. If you replace h with hˆ3, the units of h will be concentration, and the value will be a meaningful concentration. Same for Eq. 246.

15. Eqn 247 – is this really a 2. If so explain.

16. You could replace equation 254-255 with x./(abs(x)+hcalc) where x = omega – 1, which would be positive for calcification and negative for dissolution.

17. P7145 – So the calcification is unaffected by temperature above say 10 C? Rather than use the rain ratio, would it be easier to have an explicit calcifier.

Minor comments.

1. L10 p7083. I know what you mean, but 'enhanced inefficiency' is an oxymoron? Perhaps 'reduced efficiency' would be simpler.

2. L9, p7068 replace 'with respect to' with 'compared to'.

3. P9 'according to the internal quota and storage capacity' – are these different quantities?

4. Eq. 2 direction of z is important in this definition.

5. P7070, l12 'equations'.

6. P7071, l15 small 'P' production, radiation misspelt.

7. P7071, l20 vecu_wind is not defined.

8. P7072, l3 'numerical' misspelt.

9. P7073, l19 'as the net result'

10. P7073, l21 'predation by zooplankton'

11. P7074 l4 'for diatoms is the'

12. P7074, l10-l14 quotae? 'in unlimiting conditions at the reference'

13. P7078 l16 replace tendency with rate, and misspelling of luxury.

14. P7080 l16 – I thought 'h' was going to be for half-saturation constants? Might be worth saying that a low f means better detectability (i.e. f is actually a measure of indetectability!)

15. P7082 – internal stoichiometric quota.

16. Eq. 57 – the meaning of 'adj' is not given.

17. P7086, l15 – what is the meaning of 'at rest'

18. P7090 l4, 'excretion by zooplankton', l6 'respectively'

19. In some places (Eqs. 144,145, 152) zeta is used as the dummy variable for distance in the vertical, where z is used elsewhere. Might be clearer to stick with z.

20. P7098. L8 replace 'quota' with 'proportion' or something other than quota.

21. P7117 Eq. 158 – the use of the vertical line delimited by depths is unusual.

22. P7138 l5 ‘through’

23. P7141 replace ‘M-M constants’ with ‘half-saturation’ constants.

24. P7143 l9 – ‘nitrification’

25. P7144 l 6 Do you mean > 0 ?

26. P7155 l13-14 – check units of PAR and Ns.

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