

Interactive comment on “A dynamic global model for planktonic foraminifera” by I. Fraile et al.

I. Fraile et al.

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Our manuscript has received constructive interactive comments by J. Bijma, F Peeters and two anonymous reviewers. We are most grateful for their very helpful comments. Herewith, we would like to respond to the main points brought forward in the review.

Answers to the comments of referee 4:

Comment: ***‘The abstract states that the paper will “explore the response ... to different boundary conditions...”’.***

In this paper we don’t explore the response of planktic foraminifer (PF) to different boundary conditions, but we present a tool which potentially can be used for this purpose (abstract in the original manuscript, Page 4324, line 25).

Comment: ***‘(...)The authors have “coupled [ecological information] to an ecosys-***

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tem model" because the "population density [of planktic forams] depends on food". This is an ambitious task, which in the end has not been achieved, possibly because "the ecosystem model is unable to predict a bimodal pattern, related to both monsoon seasons" (page 4348).(...)'

Using an ecosystem model to provide information on food availability has several advantages. Food availability is one of the most important parameters controlling the distribution of foraminifera we coupled the foraminifera model to an existing ecosystem model (Moore et al., 2005a,b). One of the advantages of using a ecosystem model instead of direct observations for food availability (phytoplankton or zooplankton) is that the complete model (including the ecosystem and PF model) can be forced with different boundary conditions. Since our work is focused on paleoceanographic reconstructions, this approach allows to study the variations of PF through time. Despite that this ecosystem model is one of the best available at the moment for surface waters at a global scale, there are some exceptions where the model fails to reproduce phyto- and zooplankton biomass. One of the regions where the ecosystem model and observations differ significantly is the Arabian Sea. In this specific region the ecosystem model is unable to predict the observed bimodal pattern, and therefore the food availability input for the PF model is inadequate. Nevertheless, in most of the oceanic regions, the information produced by the ecosystem is a valuable for the PF model.

Comment: ***'The authors should clearly present their goals, and should also clearly present the difference of their manuscript to the paper of Žarić et al. (2006).'***

As we mention in introduction (Page 4326, line 17 in the original manuscript), the main difference between the paper of Žarić et al. (2006) and our work is that they used a static (or empirical) model whereas we use a dynamic model. Static models are based upon statistical relationship between input and output data that does not change with time. Dynamic models (systems of coupled differential equations) consider the

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processes that produce the observations, and are used to describe the behavior of the system through time (in our case the growth rate). This difference is better explained in the revised manuscript (Page 3, line 28 - Page 4, line 3).

omment: ***'The information given on the food preference of planktic foraminifers refers to selected publications, and does not represent the general trophic state of planktic forams. Pteropods and ostracods are possibly not a usual food source of planktic forams. Some spinose species can survive on animal prey for some time, but who knows if they prefer animal prey (...).'***

The information about food preference of planktic foraminifers is not precisely known at the moment, and the available data are not quantitative. We tried to compile and summarize available information about laboratory cultures and food found in the vacuoles. In the new version of the manuscript we decided to cite all the literature used for comparison. After compiling available information about the trophic state, we used a subset of this information to adjust the parameters. The tuning of the parameters for food preference is based largely on the 'carnivorous to herbivorous' level of each species. Still, experimental data provide only rough estimation for the parameters. Following the suggestion of the reviewers we tested how sensitive the model is these parameters (new section 2.6, 4.3 and Table 3). The model has four food types, which result directly from the corresponding types in the ecosystem model: diatoms and small phytoplankton (non-diatoms), zooplankton and detritus. Details about this division can be found in the paper of Moore et al. (2005a). We did not change the names to make the comparison between both models easier.

Comment: ***'N. pachyderma (sin.) can survive in sea ice, but it does not grow significantly during polar winter; N. pachyderma (sin.) is most productive during the polar summer adjacent to the ice edge. In addition, N. pachyderma (sin.) is not "the only species that grow in polar waters".'***

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We corrected the statement about *N. pachyderma* (sin.) (Page 14, line 8-10 in the revised manuscript): Although *N. pachyderma* (sin.) is the most important planktonic foraminifera living in polar waters, it is not the only species.

Comment: ***'The average biomass of planktic foraminifers (page 4336) is not easy to assess, and the statement given here is pure speculation.'***

Concerning the remark about the average biomass of foraminifera population, our ultimate aim is not to assess biomass of foraminifera, but to study the seasonal variations and its effect in paleotemperature reconstructions. For this purpose, absolute values of biomass are not relevant. We compare and discuss relative abundances between species and the season when the maximum production occurs. Following the comments of the reviewer about this point, we explain this in greater detail in the revised version (Page 5 line 23-26).

Comment: ***'Temperature does possibly control the distribution of planktic forams, but only at its extreme limits. These limits are different for different genotypes of the same morphospecies, which is mentioned for G. bulloides and N. pachyderma. The same discussion should be given for G. ruber, of which at least three morphotypes are known, as well as a number of genotypes. G. sacculifer does exist in a couple of morphotypes, which is not discussed here.'***

We discussed the different genotypes of *G. bulloides* and *N. pachyderma* because they seem to be adapted to different environments. In case of *G. ruber* and *G. sacculifer*, it is known that several genotypes exist, but there are neither clear indications so far that these are adapted to different conditions, nor is it known which types dominate where. If they don't have different environmental preferences, grouping all cryptic species as a single one does not affect the model prediction regarding relative species abundances.

Comment: ***'How do the authors know that "competition occurs between different***

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species of [planktic] foraminifera"? Is mortality really the sum of predation + respiration + competition, or rather reproduction + remineralization + predation? A reference would be helpful. In general, statements should be substantiated, and provided with proper references, which is often not the case in the manuscript presented here.'

The main parametrization of mortality is widely used to describe the pelagic system of marine environments: mortality = natural mortality + mortality due to grazing (Fasham et al., 1990, Moore et al, 2002). We defined mortality as the sum of predation, respiration and competition. Respiration refers to the 'natural physiological biomass losses', including mortality due to reproduction. To avoid misconception we decided to rename this process as `8220;death rate8221;`. A significant part of zooplankton mortality is thought to be due to predation (Hirst and Kiørboe, 2002). Competition: since our model is developed at species level we included the term 'interspecific competition'. We did not find experimental evidence which would rule out competition for 'ecospace' between foraminiferal species. Hence, from an ecological point of view, it is likely that competition exists, since ecological niches are normally dominated by few species. One must not see competition as two individuals fighting for the same shrimp but as the fact that the presence and activity of one individual influences negatively the resource availability for the other one. Foraminifera species compete for the fraction of the phyto- and zooplankton that is in a given ecosystem allocated to them. The strongest competition for resources in total would of course be with other groups of zooplankton, but the competition for the type of resources available to foraminifera would be strongest between species, as these follow the same basic strategy. Schmidt et al. (2004) stated that increased stratification creates more ecological niches and by consequence may minimize interspecific competition. Competition for an ecological niche forms the basis of much ecological and evolutionary theory, and we have no reason to rule out that competition is unimportant in foraminiferal ecology.

Comment: ***'The authors may check the manuscript for an enormous number***

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of typos and misspellings'. The typos and references are corrected and updated, respectively.

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