



Interactive comment on “Causes and timing of future biosphere extinction” by S. Franck et al.

S. Franck et al.

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1. Our model contains more than 10 parameters that should in principle be examined in the framework of a sensitivity analysis. To scan this high dimensional space even with a Monte-Carlo-method would be a cumbersome task requiring enormous computational power. Therefore, we focused on the analysis of the model under qualitative changes of the parameterizations. E.g., Franck et al. (2002) studied the influence of different parameterizations of the hydrothermal flux and of oceanic pH. We identified the most important parameter influencing the life span - the temperature tolerance of the different life forms. A second set of values according to Schwartzman (1999), who proposed higher upper temperature limits for eucaryotes and complex multicellular life, was introduced. We find that the specific life spans of these two forms extend by some hundred million years. The ultimate life span determined by the extinction of the pro-caryotes stays remarkably constant. The revised manuscript will contain an additional figure with the results for the second parameter set. A more detailed analysis of the

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influence of the upper temperature tolerance for complex multicellular life, $T_{max,3}$, on the life span has been performed (see new figure). It is evident that the ultimate life span is almost constant at 1.6 Gyr for $T_{max,3} > 30^{\circ}\text{C}$. An investigation of the influence of P_{min} shows that the ultimate life span is extended only by 100 Myr for the minimum CO_2 pressure of 1 ppm (first parameter set). Concerning the influence of the continental growth model on the results we refer to von Bloh et al. (2003). Therein we determined three different plausible continental growth scenarios. They have only a minor influence on the results.

2. The surface temperature of the Earth is calculated with the help of a grey atmosphere model and a plausible evolution of the solar radiation. This is described in the revised manuscript in an additional section.

Concerning the loss of hydrogen via photolysis of H_2O we point to the recent discussions on escape rates of hydrogen by Tian et al. (2005). They claim that low oxygen and high carbon dioxide concentrations on early Earth yields a cold exobase, and nonthermal escape rates are limited and cannot balance the volcanic outgassing of hydrogen. We find such conditions in our model for the Archaean era. High Archaean atmospheric CO_2 levels are caused by two effects: first there is only a small amount of continental area for weathering (reduced sink of atmospheric CO_2) and second there is an intense volcanic outgassing due to higher geodynamic activity (elevated source of atmospheric CO_2). Low continental area prevents the "classic" carbonate-silicate regulation of surface temperature.

Different parameterizations of oceanic pH and hydrothermal fluxes at mid-ocean ridges have an important influence on early Earth surface temperatures. As we have shown in Franck et al. (2002) a "soda ocean" (high pH) and a so-called fast kinetics of hydrothermal reactions (Sleep and Zahnle, 2001) result in a frozen early Earth. But all temperature curves converge in the future and have minor influence on future biosphere extinctions. For this study we selected a scenario with spreading rate dependent hydrothermal reaction kinetics that yields correct present day mean global surface

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temperature.

3. We agree with the referee about the importance of biological evolution and selection on the maintenance of life. Gaian regulation mechanisms like the cloud-albedo climate feedbacks of DMS producing marine algae could stabilize the Earth temperature in the future. However, biological innovations and their impact on the Earth system are hard to quantify within the modeling framework. On the other hand, humankind could extend its lifetime on Earth by geoengineering (Hoffert et al., 2002). For example, a large mirror at the Lagrange point L1 of the Sun-Earth system could deflect partly the solar flux and stabilize the future climate (Covindasamy and Caldeira, 2000).

4. After the rise of oxygen on geological time scales methane as a greenhouse gas does not significantly influence climate on Earth and does not change the future story of our planet.

To help the reader to understand the bases of the model a revised version of the paper will contain an additional section about the applied climate model. We want to thank the anonymous referee for the constructive remarks that led to an improved manuscript version.

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