A MINIMUM COMPLEXITY MODEL FOR INVESTIGATING LONG-TERM PLANETARY HABITABILITY. Toby Tyrrell[1], [1]Ocean and Earth Science, National Oceanography Centre Southampton, University of Southampton, SO14 3ZH, UK. Toby.Tyrrell@soton.ac.uk.

Introduction: In order to understand how it was possible for life to develop all the way to intelligence on Earth, it is necessary to understand how Earth's climate stayed habitable. Geological data and the continuity of life suggest that Earth's climate remained continuously habitable throughout the last 3 or 4 billion years. It is not obvious, however, how this thermal habitability was maintained. The 25% increase in solar luminosity ('Faint Young Sun paradox') might have been expected to lead to intolerable conditions [1]. In addition, the short residence time of carbon at Earth's surface (<1 million years) suggests a susceptibility to rapid climate swings and therefore a predisposition to long-term instability [2]. Silicate weathering is often proposed as a thermostat [3] but there are doubts about whether it actually acted this way.

Investigating the phenomenon of long-term habitability is challenging. Because of the timescales involved, observing the phenomenon is out of the question. Experiments are likewise not feasible. Complex climate models cannot be run for billions of years. Simpler models can, however, be used.

Model: A new, fast, minimum-complexity model will be described. It aims to represent climate feedbacks rather than the whole climate system because the feedbacks are deemed to be most critical for long-term climate evolution. Parsimony is prioritized: fundamentals necessary for simulating climate regulation (tendencies to lose or maintain thermal habitability) are included but other aspects that are not essential for this question are purposefully excluded, even where it is possible to incorporate them accurately.

The model is intended to be general rather than a model of Earth specifically. Insights into Earth's habitability are thus sought through trying to understand the behavior of a large population of potentially habitable planets.

Initial Results: Results will be presented from a first application of the model. 100,000 planets were given randomly generated climate feedbacks. They were then tested to see if they stayed habitable for 3 billion years when exposed to random perturbations (for instance asteroid impacts, supervolcano eruptions) and long term forcings (for instance stellar evolution, supercontinent cycle).

It was found that most never stayed habitable, only a small number always stayed habitable (all 100 reruns) and ~9% sometimes stayed habitable (in many cases very infrequently, e.g. on only 1 or a few out of 100 reruns). Most planets that remained habitable on a single run did not usually remain habitable. By implication, therefore, Earth's 3 to 4 billion years of habitability was most likely a contingent outcome rather than having been certain at the outset.

This modelling approach has the potential to yield insights into how Earth happened to remain habitable for so long.

References:

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