Geophysical Research Abstracts
Vol. 18, EGU2016-3068, 2016
EGU General Assembly 2016

Habitability constraints on water-rich exoplanets

Lena Noack (1), Dennis Höning (2), Attilio Rivoldini (1), Clemens Heistracher (3), Nastasia Zimov (3), Baptiste Journaux (4), Helmut Lammer (5), Tim Van Hoolst (1), and Jan Hendrik Bredehöft (6)

(1) ROB, Royal Observatory of Belgium, Reference systems and geodynamics, Brussels, Belgium (lena.noack@oma.be), (2) German Aerospace Center (DLR), Institute of Planetary Research, Berlin, Germany, (3) Vienna University of Technology, Austria, (4) Laboratoire de Glaciologie et Géophysique de l'Environement, Université Grenoble Alpes, Saint Martin d'Heres, France, (5) Austrian Academy of Sciences, Space Research Institute, Graz, Austria, (6) University of Bremen, Institute for Applied and Physical Chemistry, Germany

This research addresses the characterization, modelling, thermal evolution and possible habitability of water-rich exoplanets. Water is necessary for the origin and survival of life as we know it. In the search for habitable worlds, water-rich planets therefore seem obvious candidates. The water layer on such planets could be hundreds of kilometers deep. Depending on the temperature profile and the pressure gradient, it is likely that at great depths a significant part of the water layer is solid high pressure ice. Whether the solid ice layer extends to the bottom of the water layer, or if a shallow lower ocean forms above the silicate mantle, depends amongst others on the thermal state of the planet.
We therefore model the thermal evolution of water-rich planets with a 1D parameterized model. Depth-dependent profiles for thermodynamic properties as well as pressure and gravity are obtained by solving the Poisson equation for the gravity and the hydrostatic pressure equation for pre-defined mass and composition (in terms of iron, silicates and water) [1]. For density, equations of state are applied.

For the simulation of the thermal evolution of water-rich planets, several parameters (as initial temperatures or layer thicknesses) are unknown. We therefore employ a quantitatve study with more than 20'000 simulations, where we investigated which parameters have the largest influence on the appearance of a lower ocean, i.e. the possible melting of high-pressure ice by heat flowing out of the silicate mantle [2].

We find that the surface temperature has the largest influence on the thickness of water layers, for which a lower ocean can still form between the high-pressure ice layer and the silicate mantle. For higher surface temperatures, not only entirely liquid oceans are possible for deeper water shells, also a liquid ocean can form under high-pressure ice layers of hundreds of kilometer thickness (for a 1 Earth-mass planet). Deeper down, the lower ocean can still appear episodically at the water-mantle boundary (WMB).
We also investigated the main paramters influencing the existence of volcanic activity and silicate crust formation. Under deep water layers, the high pressure from the overlying water layer can inhibit melting in the mantle. The main parameters influencing the maximal water layer depth, for which melting is still possible, are indeed the parameters influencing the mantle energy budget, which are the amount of radioactive heat sources and the initial upper mantle temperature. Plate tectonics also has a strong influence on the existence of volcanism. Crustal parameters (initial thickness or heat sources enrichment factor) as well as the ice rheology (i.e. the isolating effect of the ice shell on the mantle) have only a small influence on melting processes in the interior and the formation of crust.

[1] L. Noack, A. Rivoldini and T. Van Hoolst 2015: CHIC - Coupling Habitability, Interior and Crust: A new Code for Modeling the Thermal Evolution of Planets and Moons. INFOCOMP 2015, ISSN 2308-3484, ISBN 978-1-61208-416-9, pp. 84-90, IARIA, 2015.
[2] L. Noack, D. Höning, A. Rivoldini, C. Heistracher, N. Zimov, B. Journaux, H. Lammer, T. Van Hoolst and J.H. Bredehöft: Water-rich planets: how habitable is a water layer deeper than on Earth? Submitted to Icarus.