EPSC Abstracts
Vol. 15, EPSC2021-133, 2021
https://doi.org/10.5194/epsc2021-133
Europlanet Science Congress 2021

Coupled models of magma oceans and their primordial atmospheres: volatile speciation, cooling history, and impact of condensables

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The earliest atmospheres of rocky planets originate from extensive volatile release during magma ocean epochs that occur during assembly of the planet. These establish the initial distribution of the major volatile elements between different chemical reservoirs that subsequently evolve via geological cycles. Current theoretical techniques are limited in exploring the anticipated range of compositional and thermal scenarios of early planetary evolution. However, these are of prime importance to aid astronomical inferences on the environmental context and geological history of extrasolar planets. In order to advance the potential synergies between exoplanet observations and inferrences on the earliest history and climate state of the solar system terrestial planets, I will present a novel numerical framework that links an evolutionary, vertically-resolved model of the planetary silicate mantle with a radiative-convective model of the atmosphere. Numerical simulations using this framework illustrate the sensitive dependence of mantle crystallization and atmosphere build-up on volatile speciation and predict variations in atmospheric spectra with planet composition that may be detectable with future observations of exoplanets. Magma ocean thermal sequences fall into three general classes of primary atmospheric volatile with increasing cooling timescale: CO, N_2, and O_2 with minimal effect on heat flux, H_2O, CO_2, and CH_4 with intermediate influence, and H_2 with several orders of magnitude increase in solidification time and atmosphere vertical stratification. In addition to these time-resolved results, I will present a novel formulation and application of a multi-species moist-adiabat for condensable-rich magma ocean and archean earth analog atmospheres, and outline how the cooling of such atmospheres can lead to exotic climate states that provide testable predictions for terrestrial exoplanets.