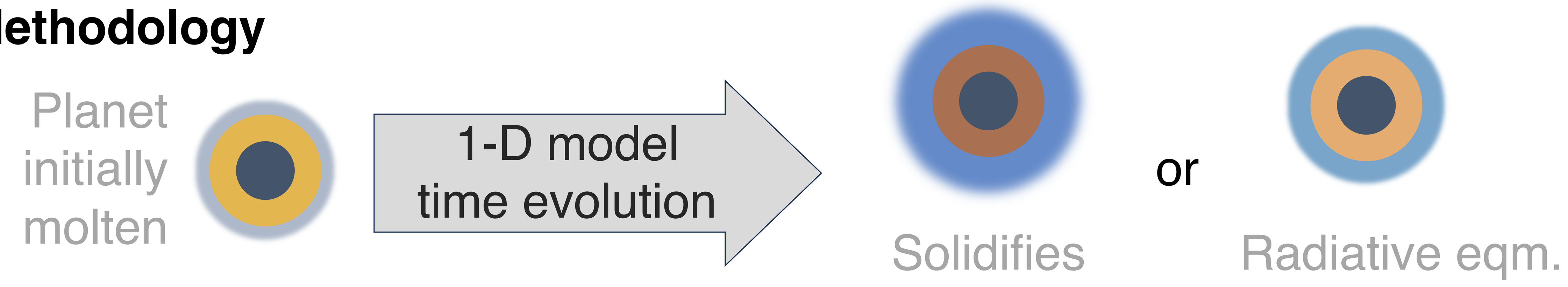
Evolution of thick atmospheres on lava worlds

Venus, Earth, and beyond

Rocky planets undergo periods with partially or completely molten mantles ("magma oceans"). Exchange of volatiles/energy between the mantle and the atmosphere sets the stage for long-term evolution.

Methodology

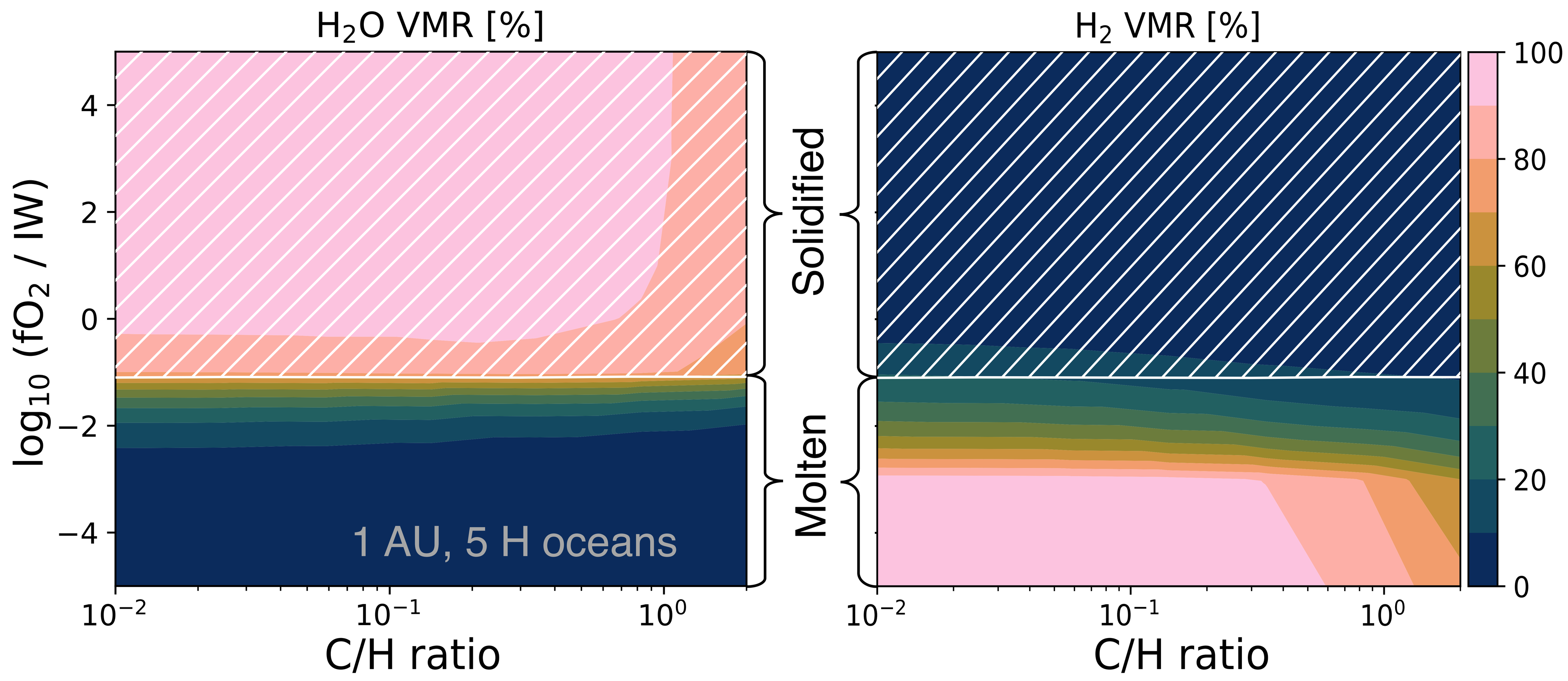


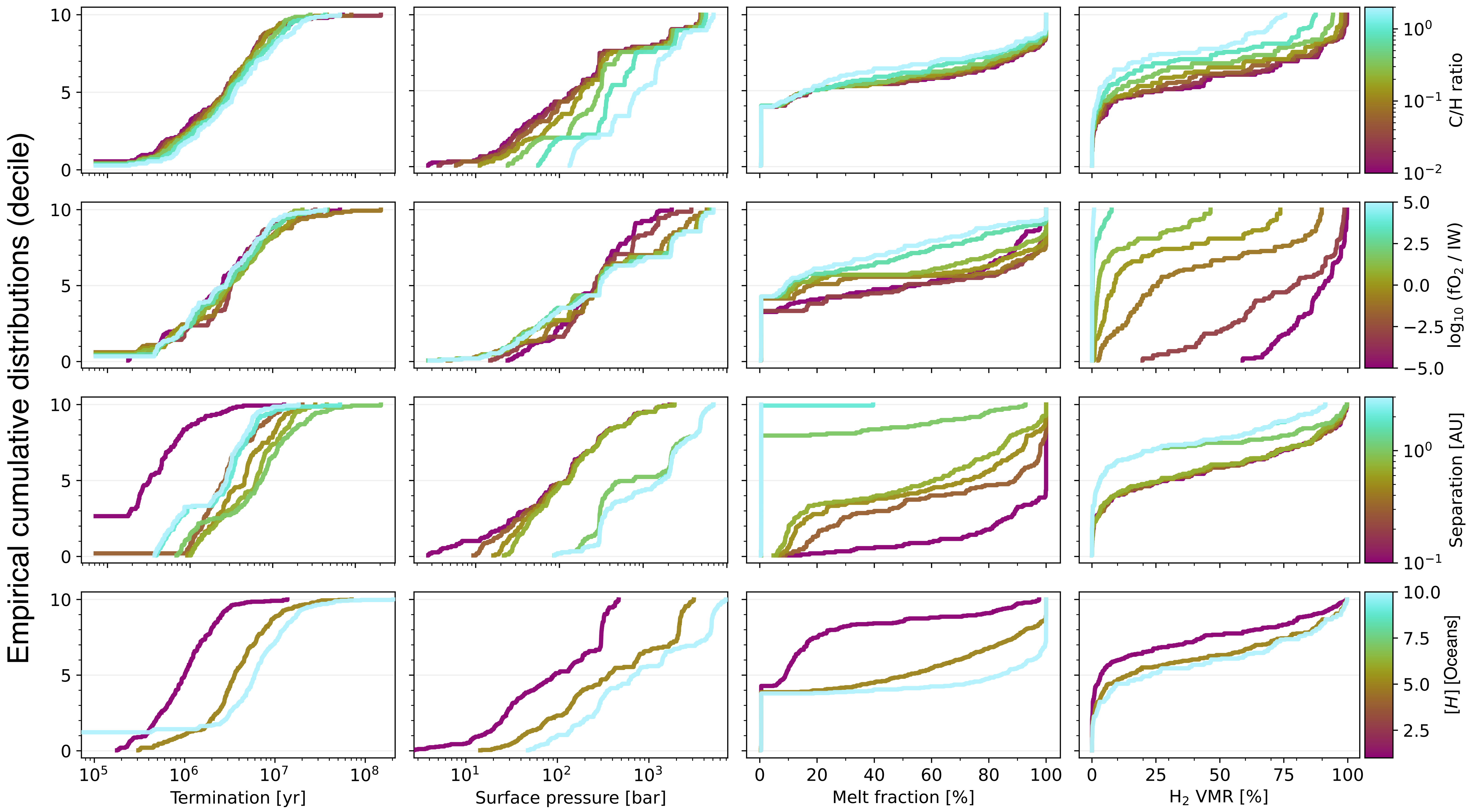
Parameter space

Separation (AU)	0.1 – 3
fO_2 / Iron-Wüstite	-5 – 5
C/H ratio	0.01 – 2
H inventory (oceans)	0.1 – 10

Results

- The post-runaway transition occurs at ~2300 K (instead of ~1800 K) when using the most complete line-lists.
- H_2 greenhouse effect limits cooling rate, extending magma ocean lifetime through collision-induced absorption.
- Small subset of cases maintain a net downward flux, resulting in hotter surfaces than the initial state.





Initialising an Earth-like planet into a fully molten state and evolving it over time using a numerical model, we have explored how different regimes arise depending on physical and geochemical properties.

- Magma oceans are as sensitive to interior properties as much as they are to incoming stellar flux.
- Solidification (or not) depends on atmospheric composition, with H_2 being the main controller.
- Water outgassing is significant at solidification, leading to thick steam-dominated atmospheres.

UNIVERSITY OF OXFORD
Harrison Nicholls
harrison.nicholls@physics.ox.ac.uk
Raymond Pierrehumbert
Tim Lichtenberg
rijksuniversiteit groningen