

Atmospheric speciation of rocky planets from magma ocean outgassing

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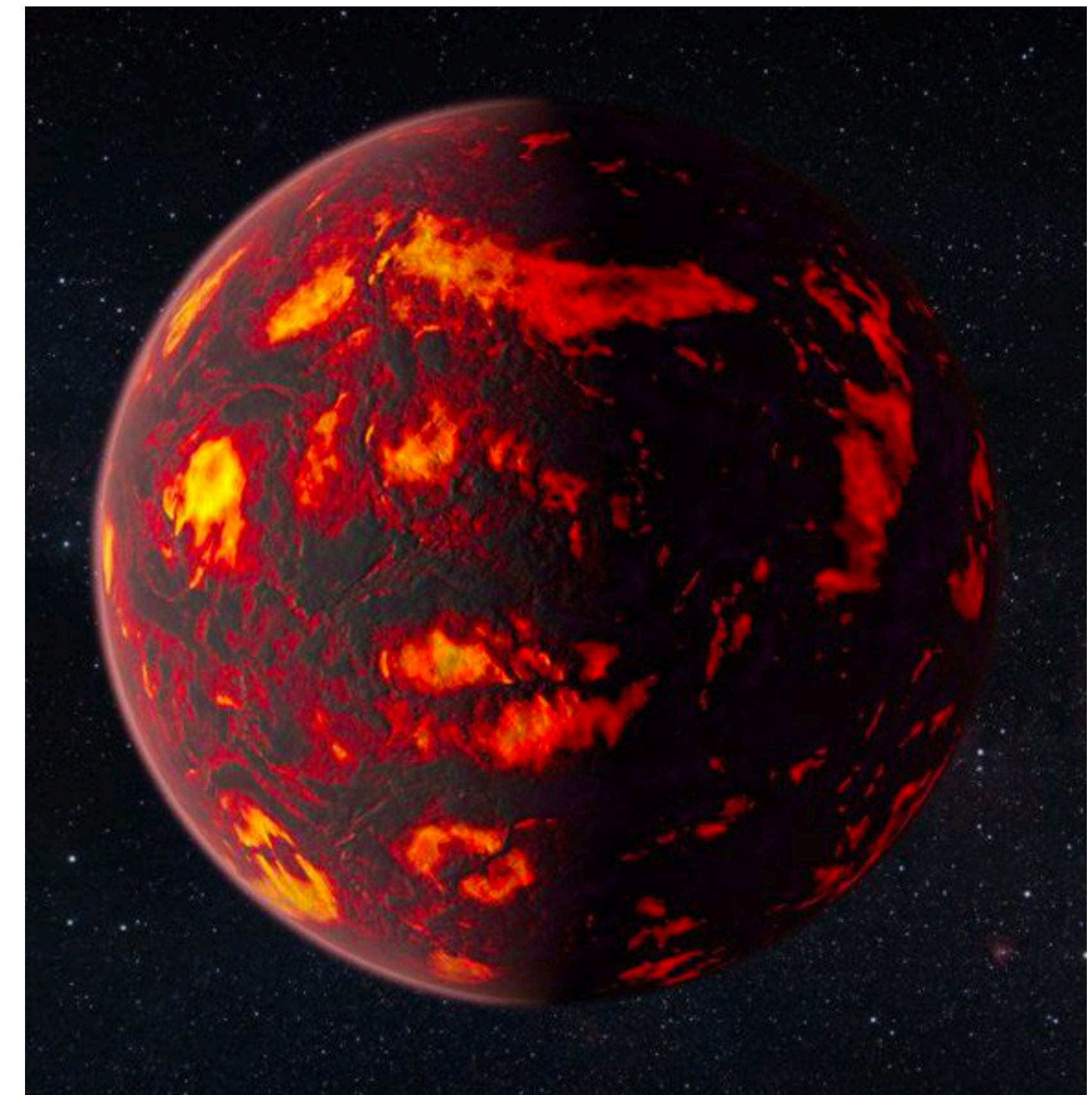
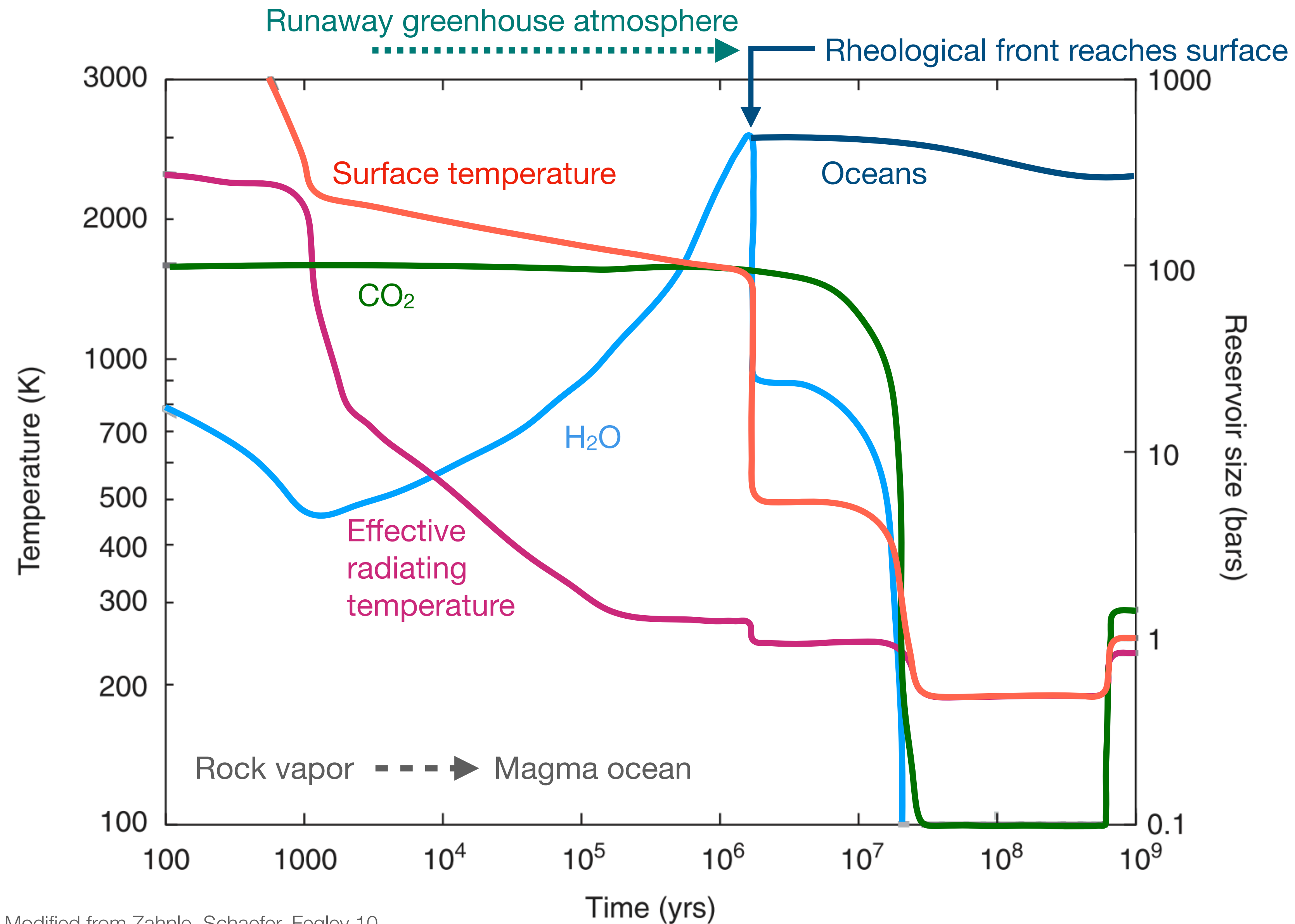


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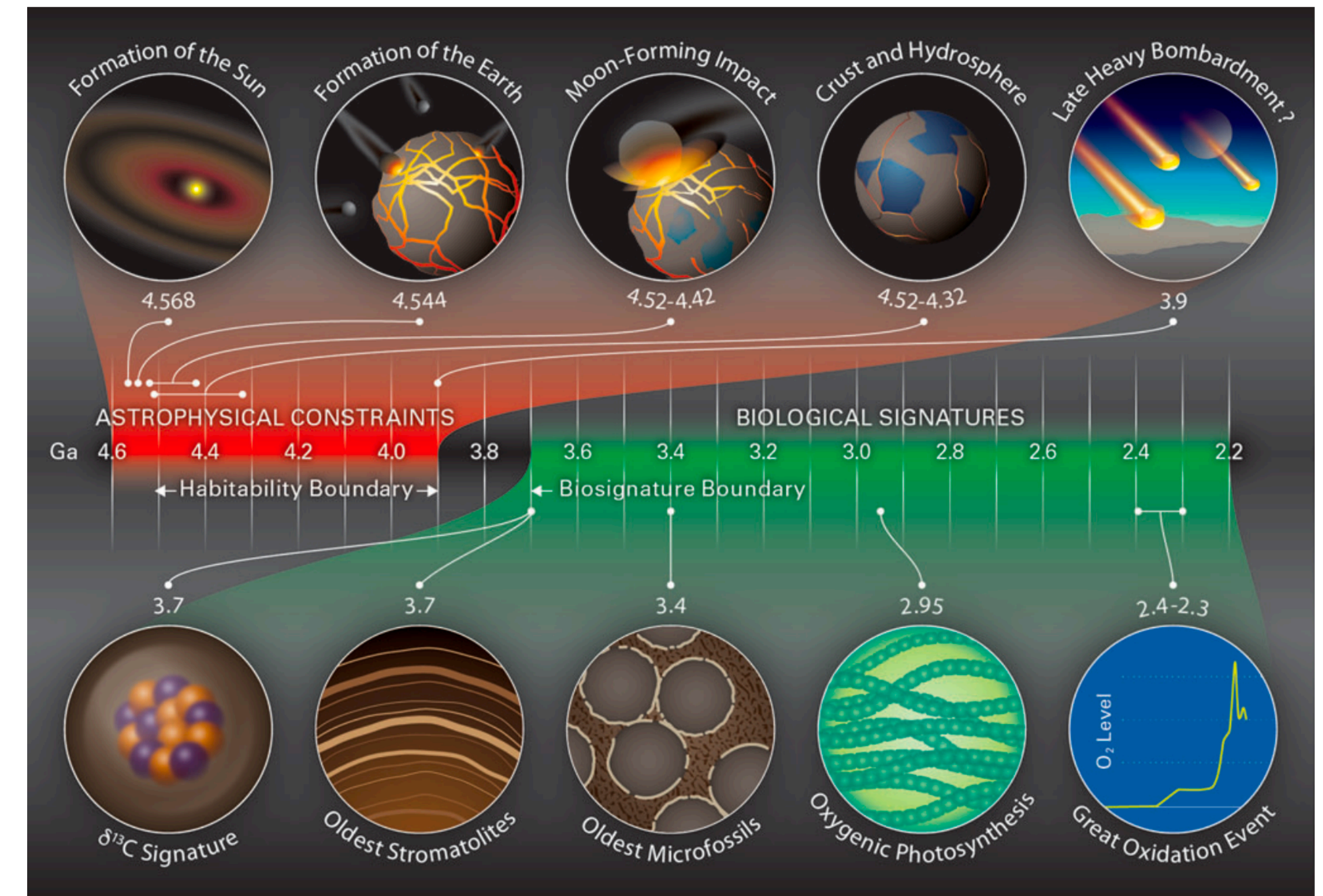
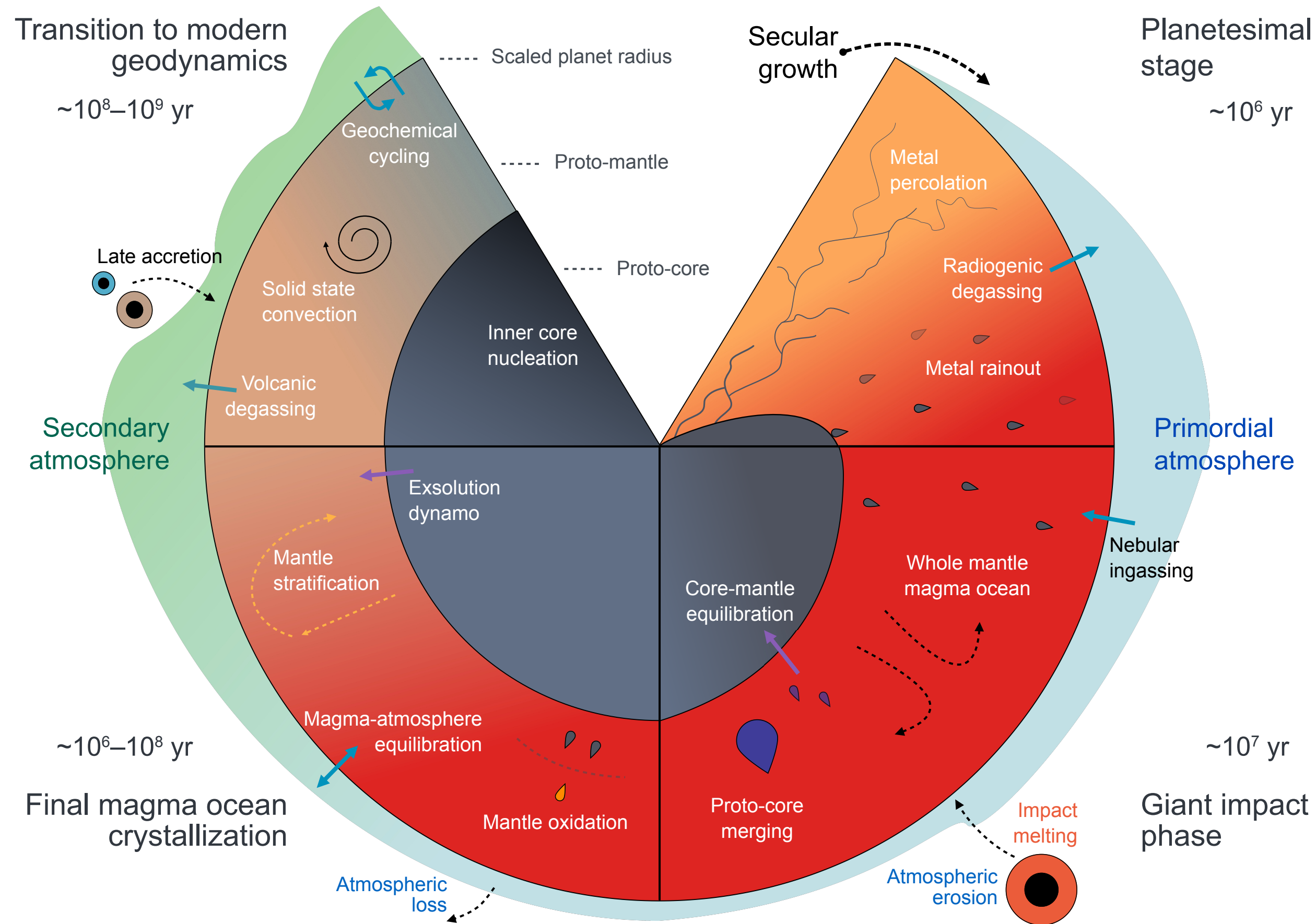


Rocky exo-planet diversity
from protoplanet solidification

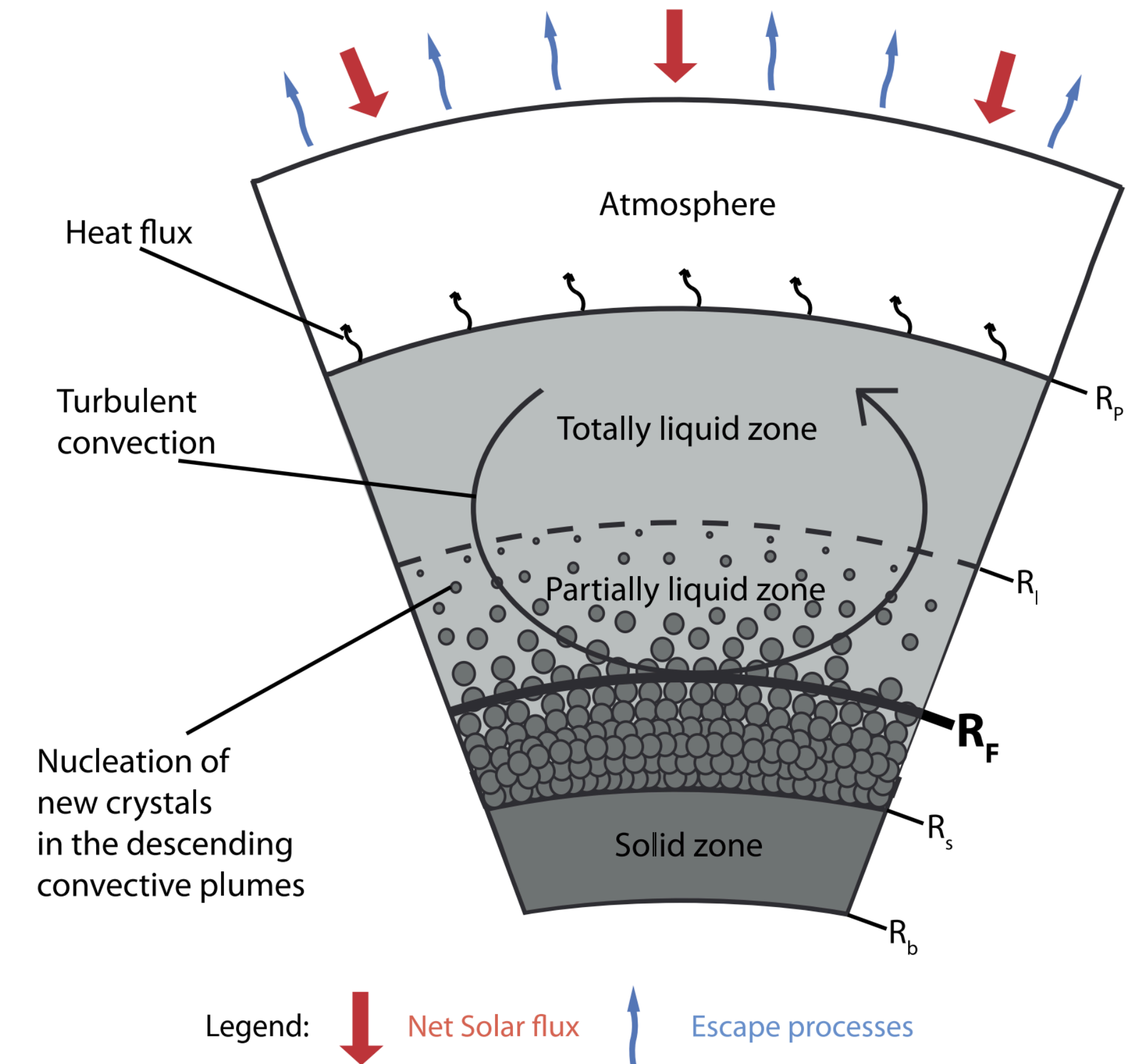
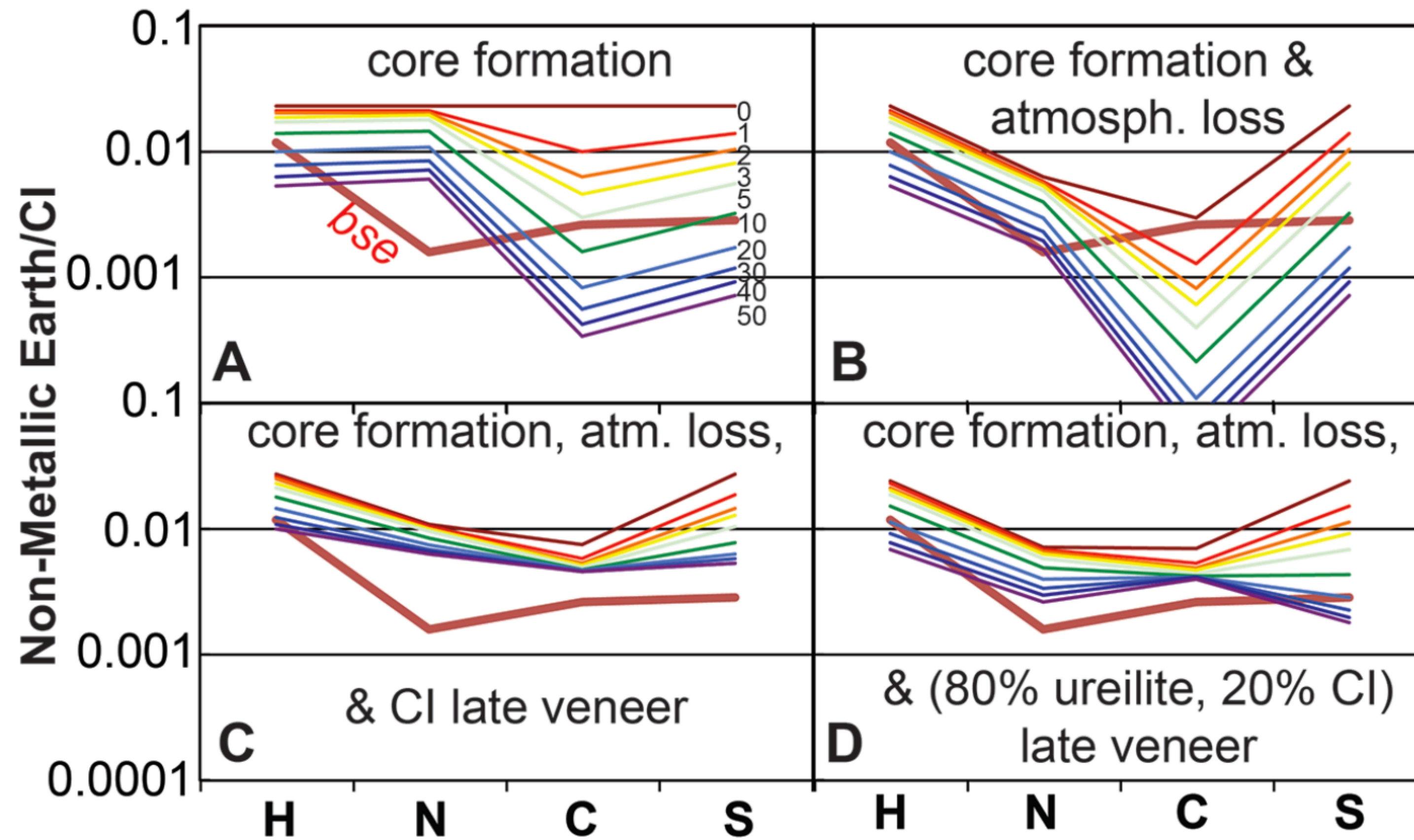
Hadean Earth: from magma- to water-oceans



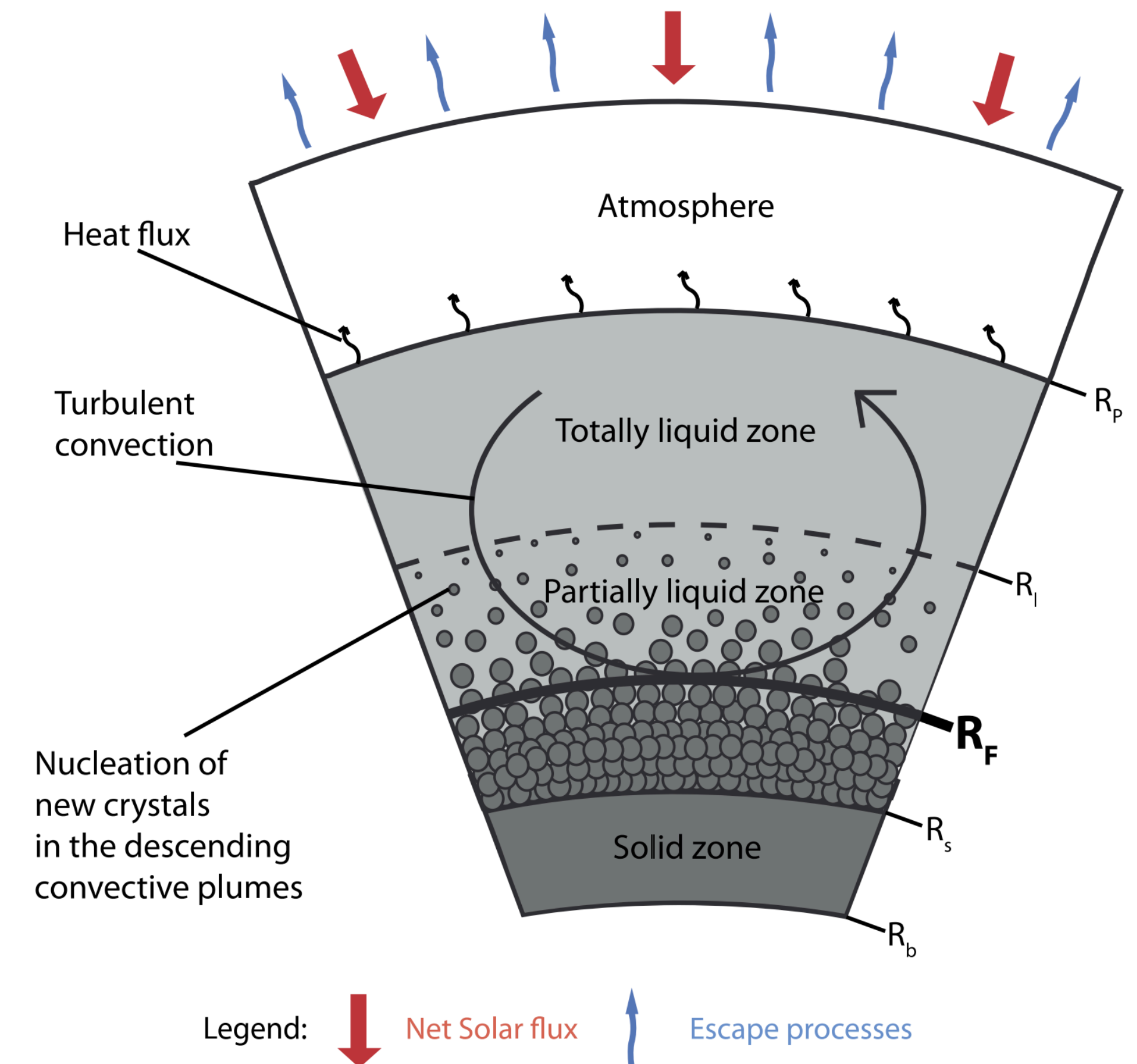
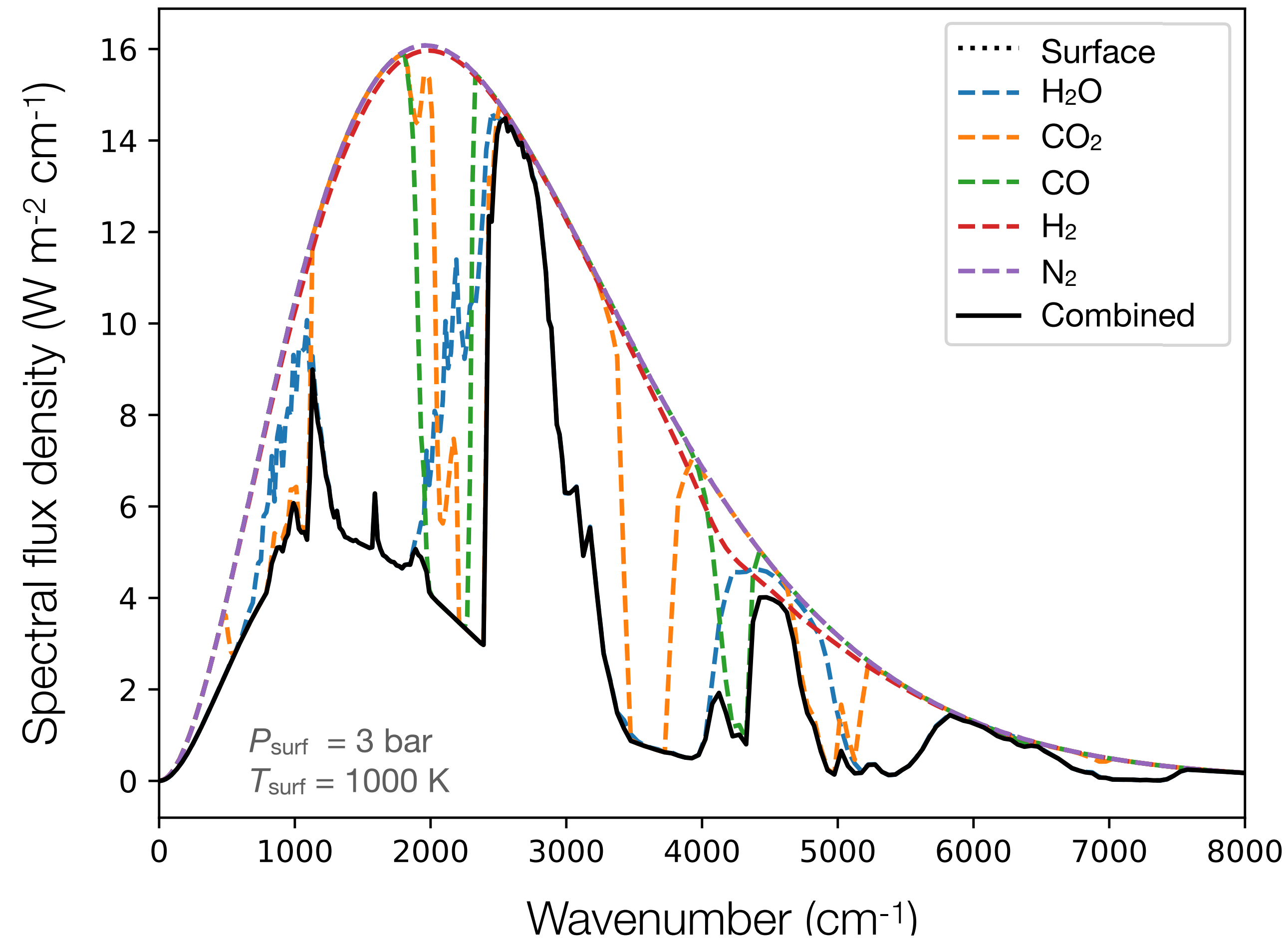
Planetary environmental conditions for OoL



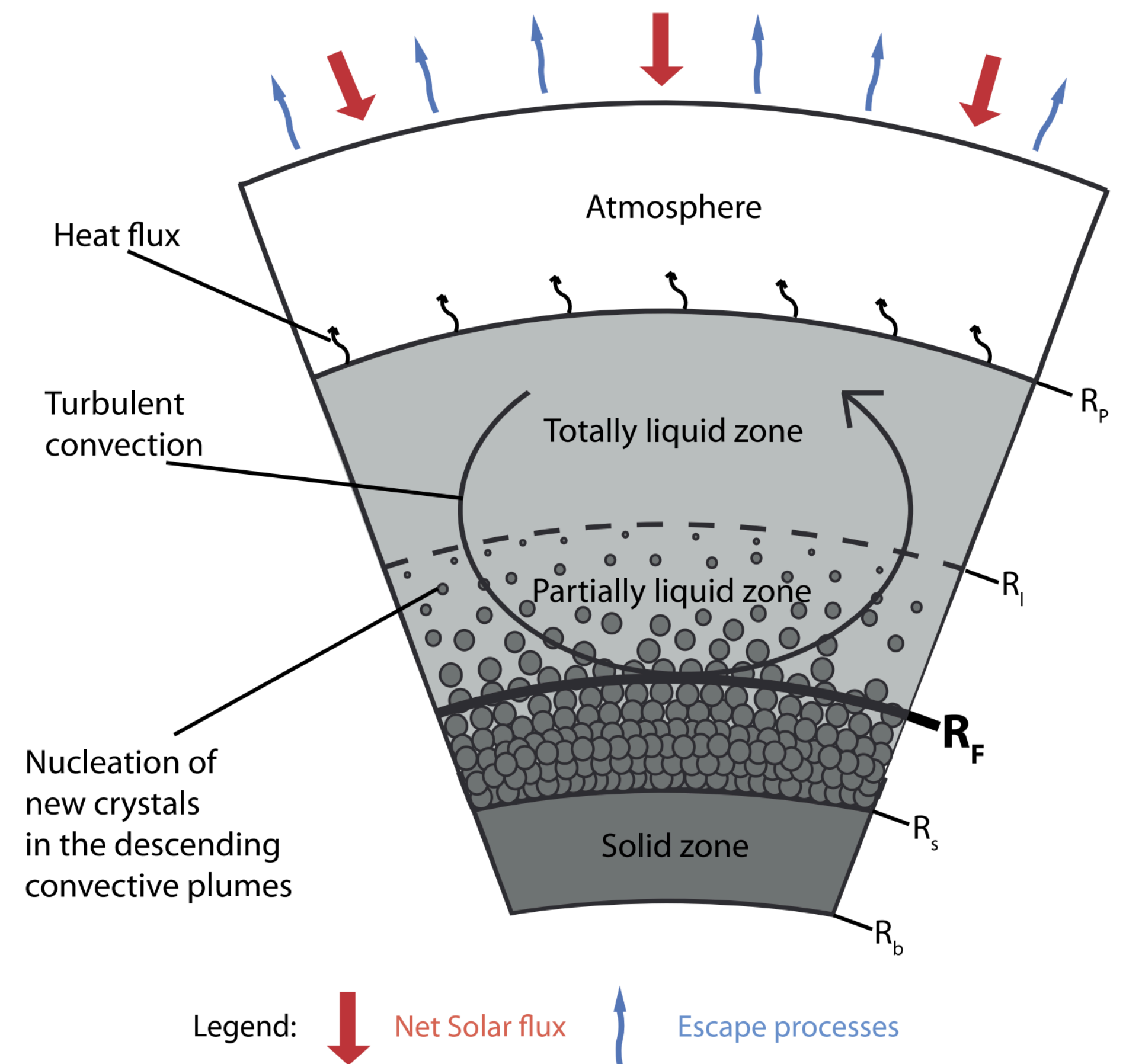
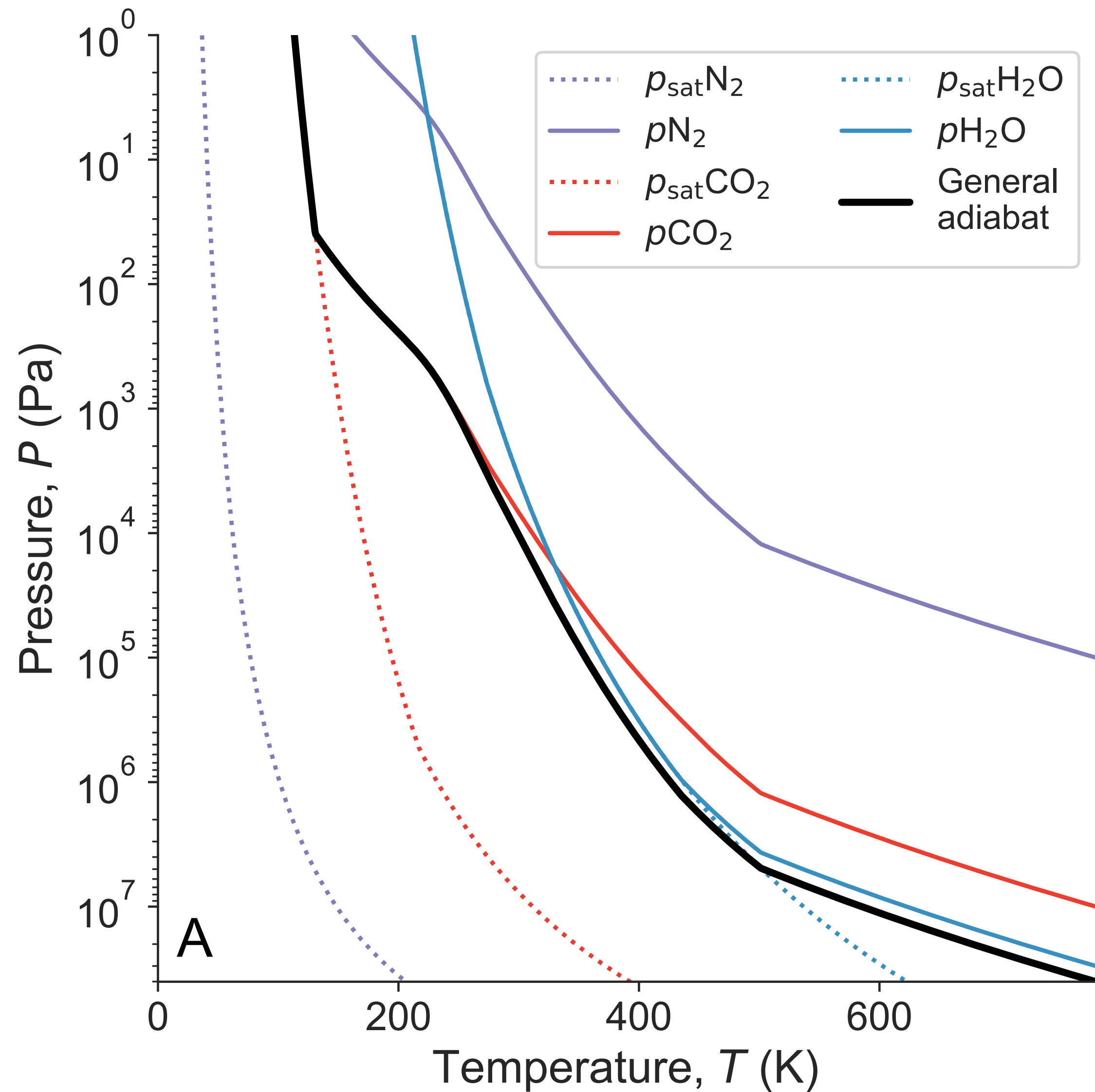
Volatile fractionation during accretion



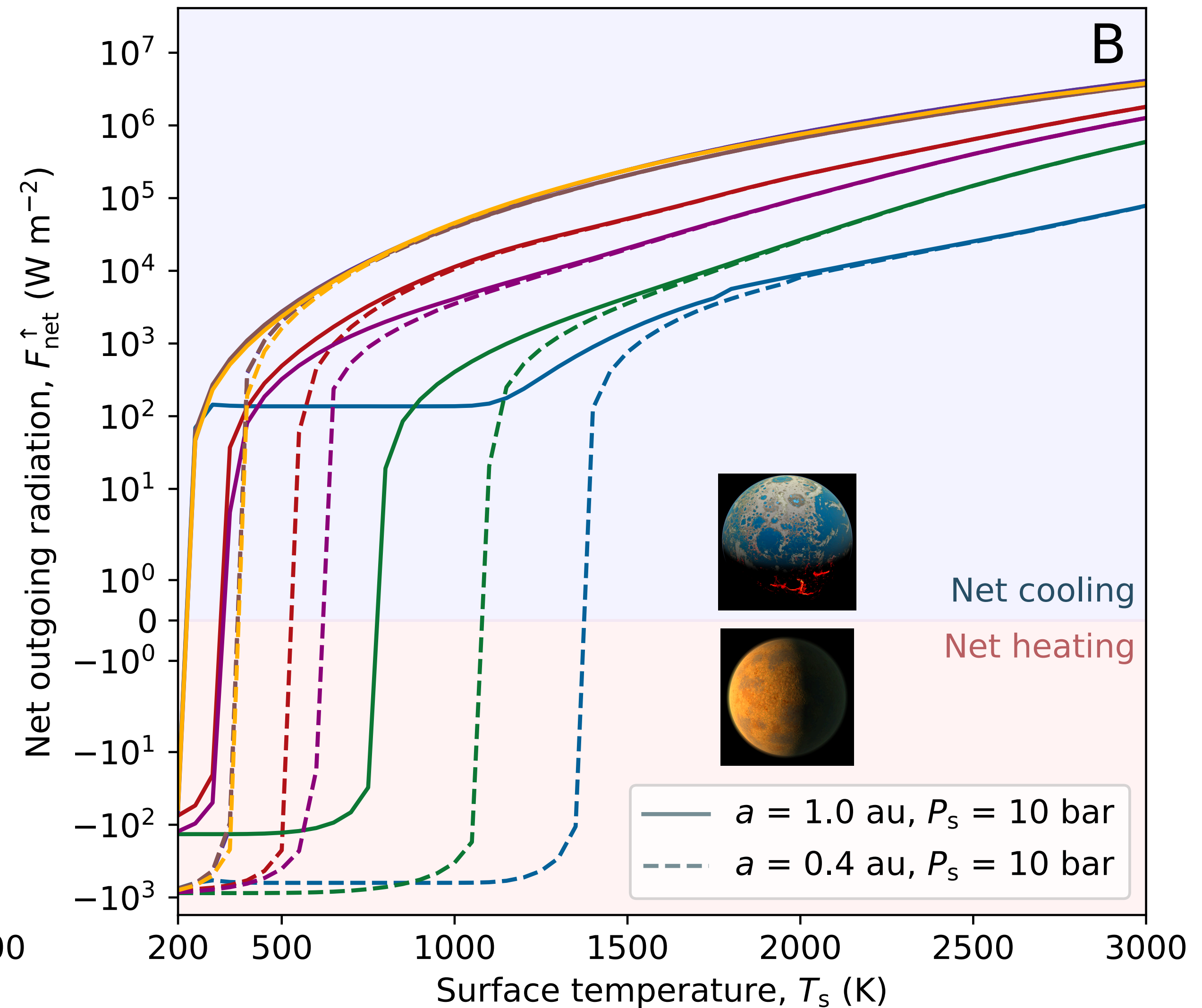
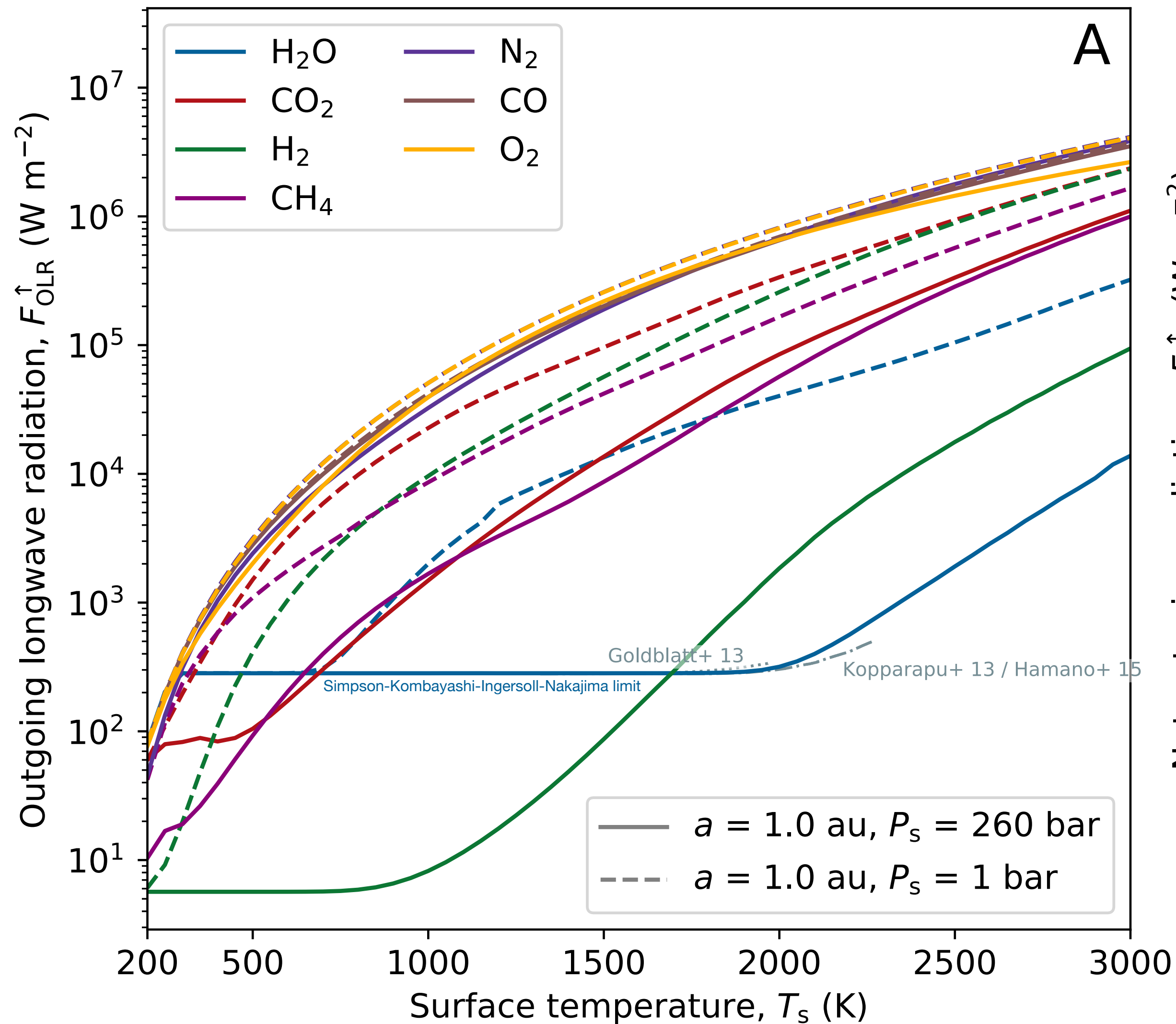
Atmospheric speciation: an open phase space



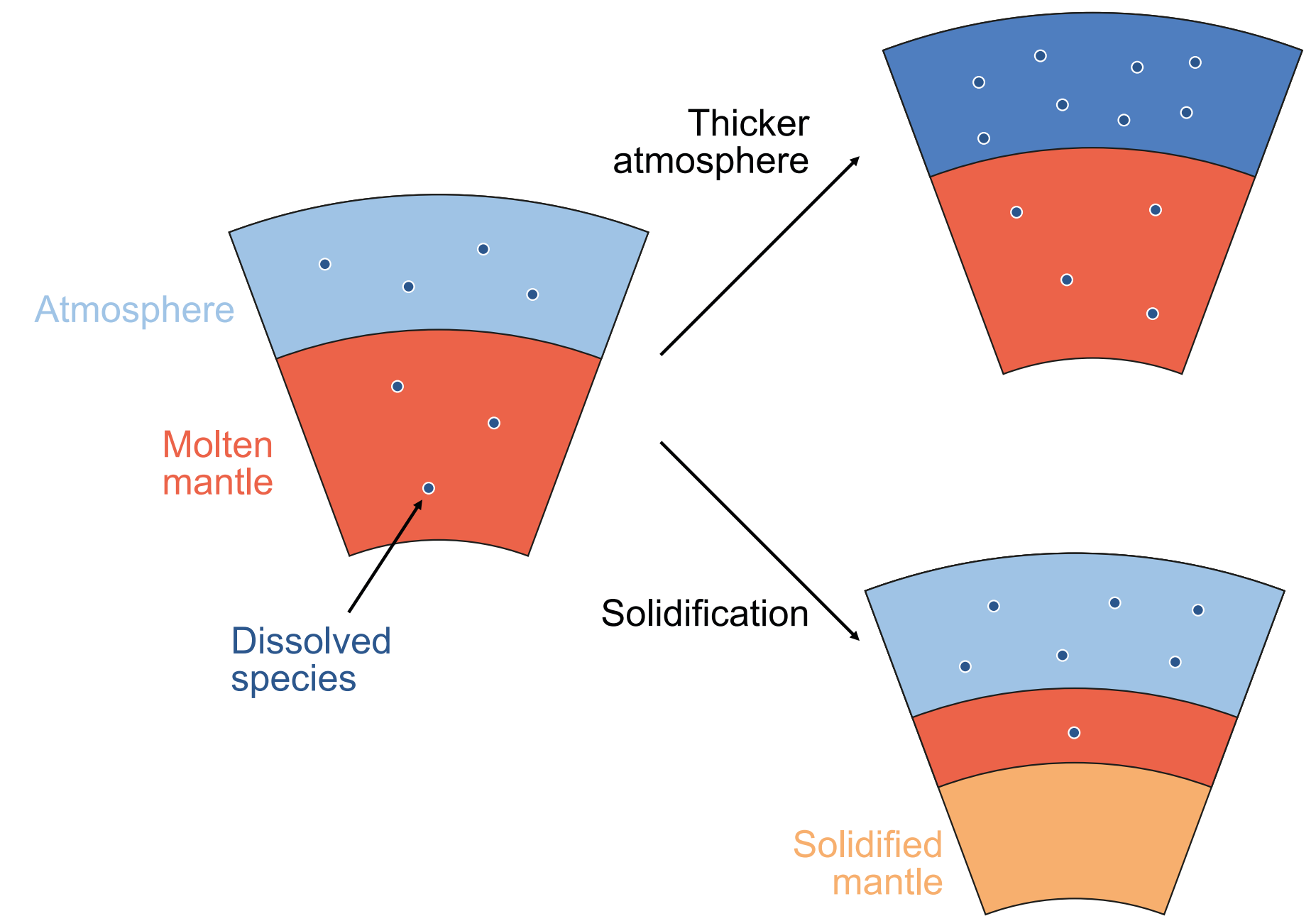
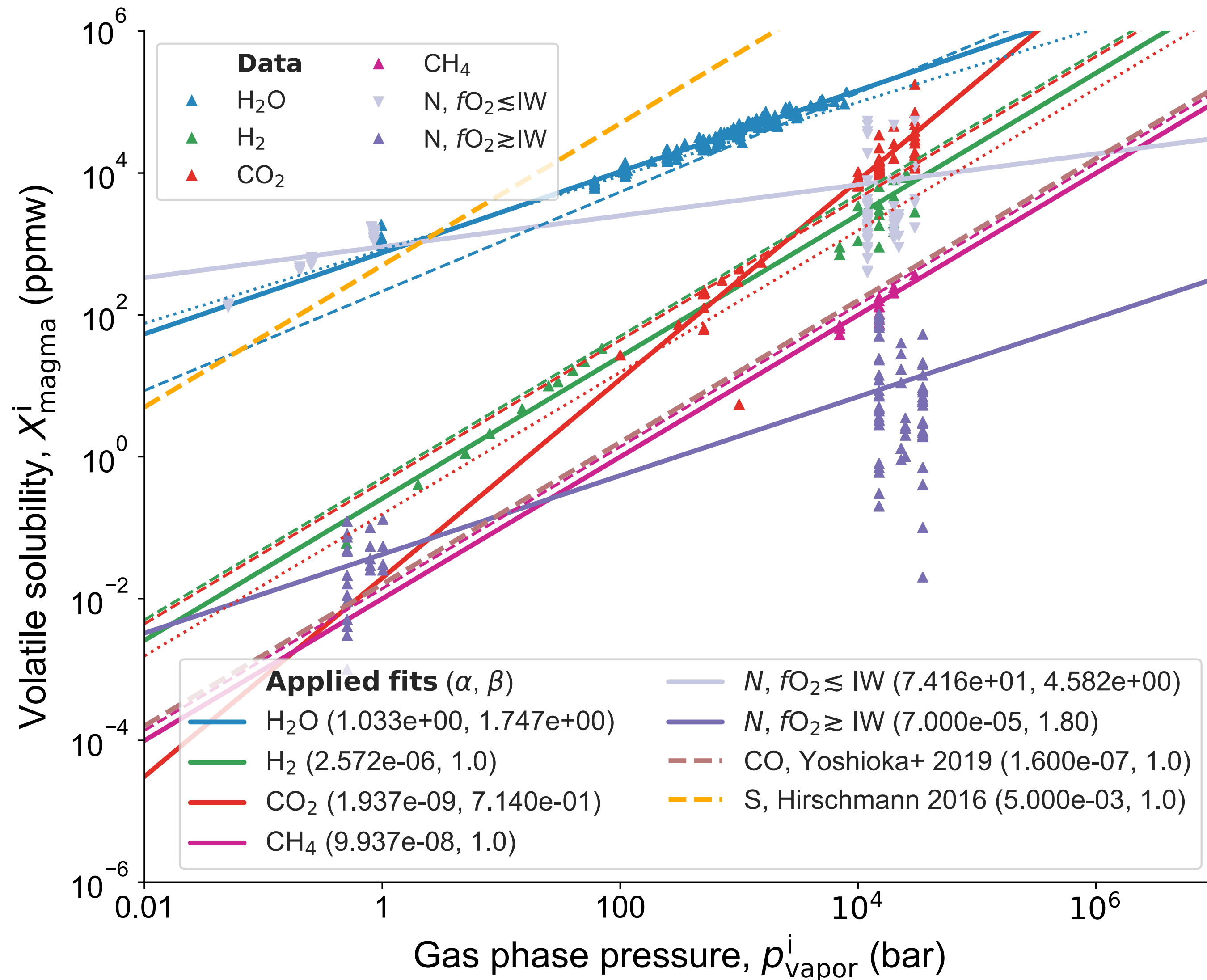
Multi-species moist adiabat structure



Heat loss or gain?



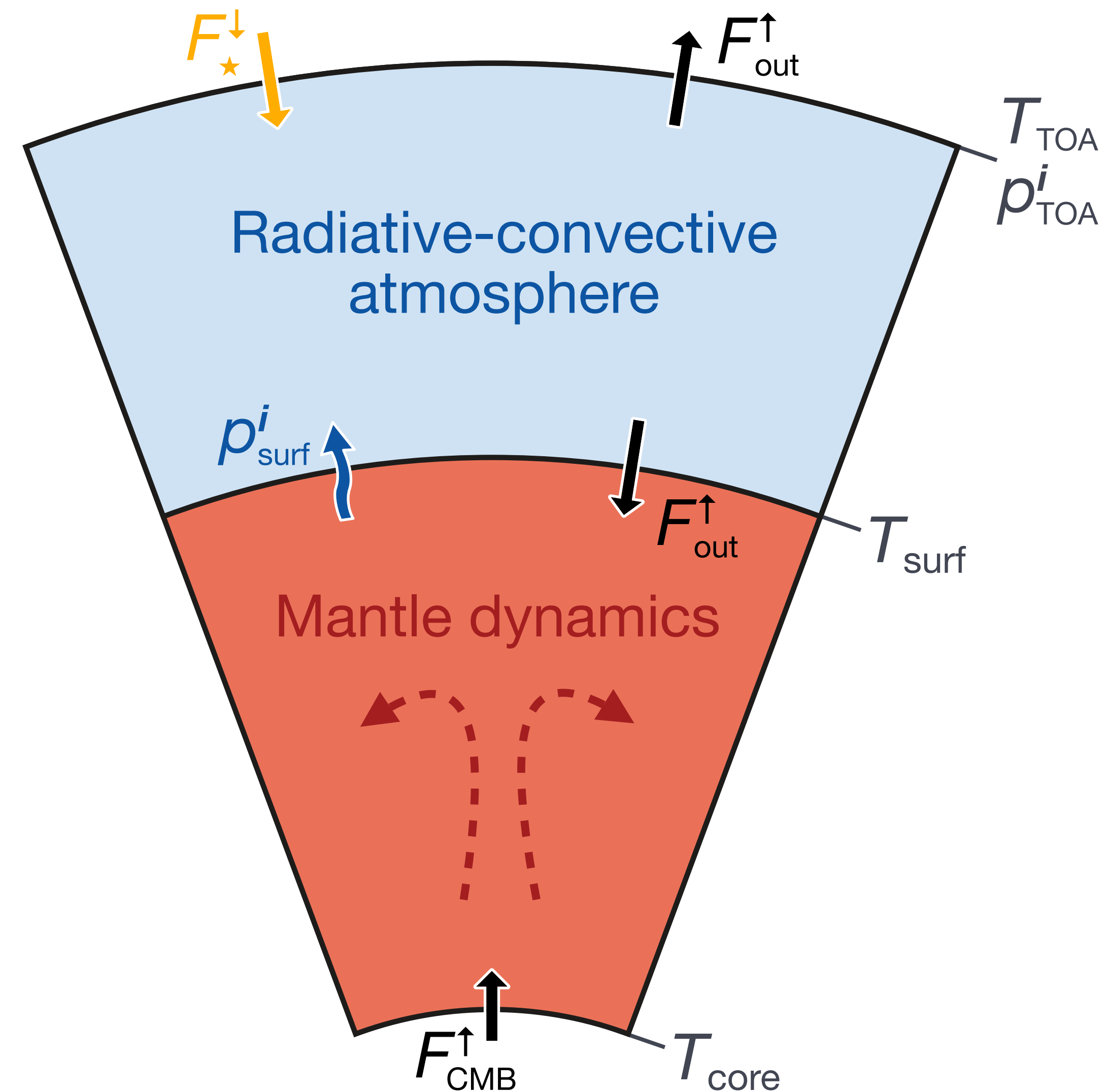
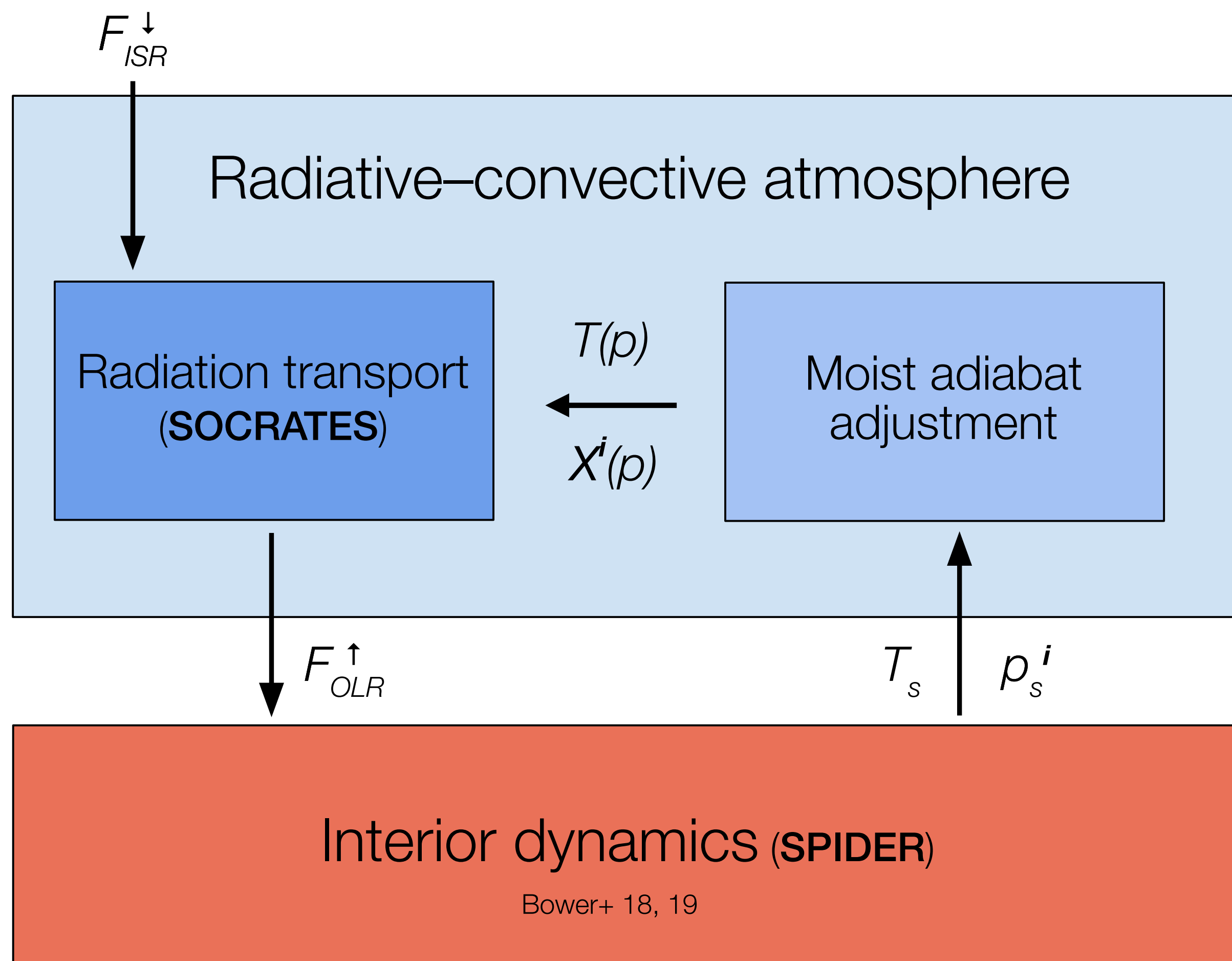
Solubility determines atmosphere pressure

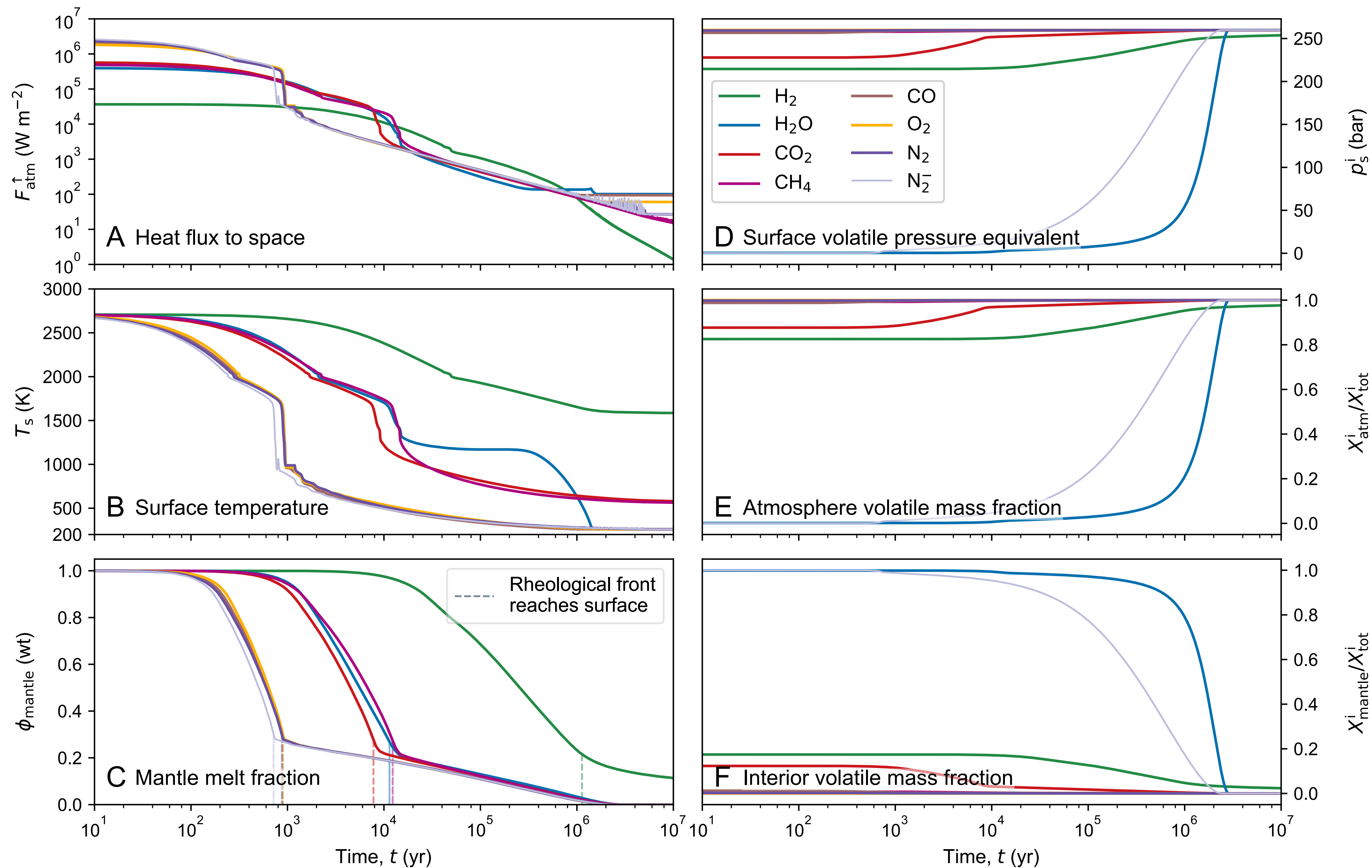


Henry's law

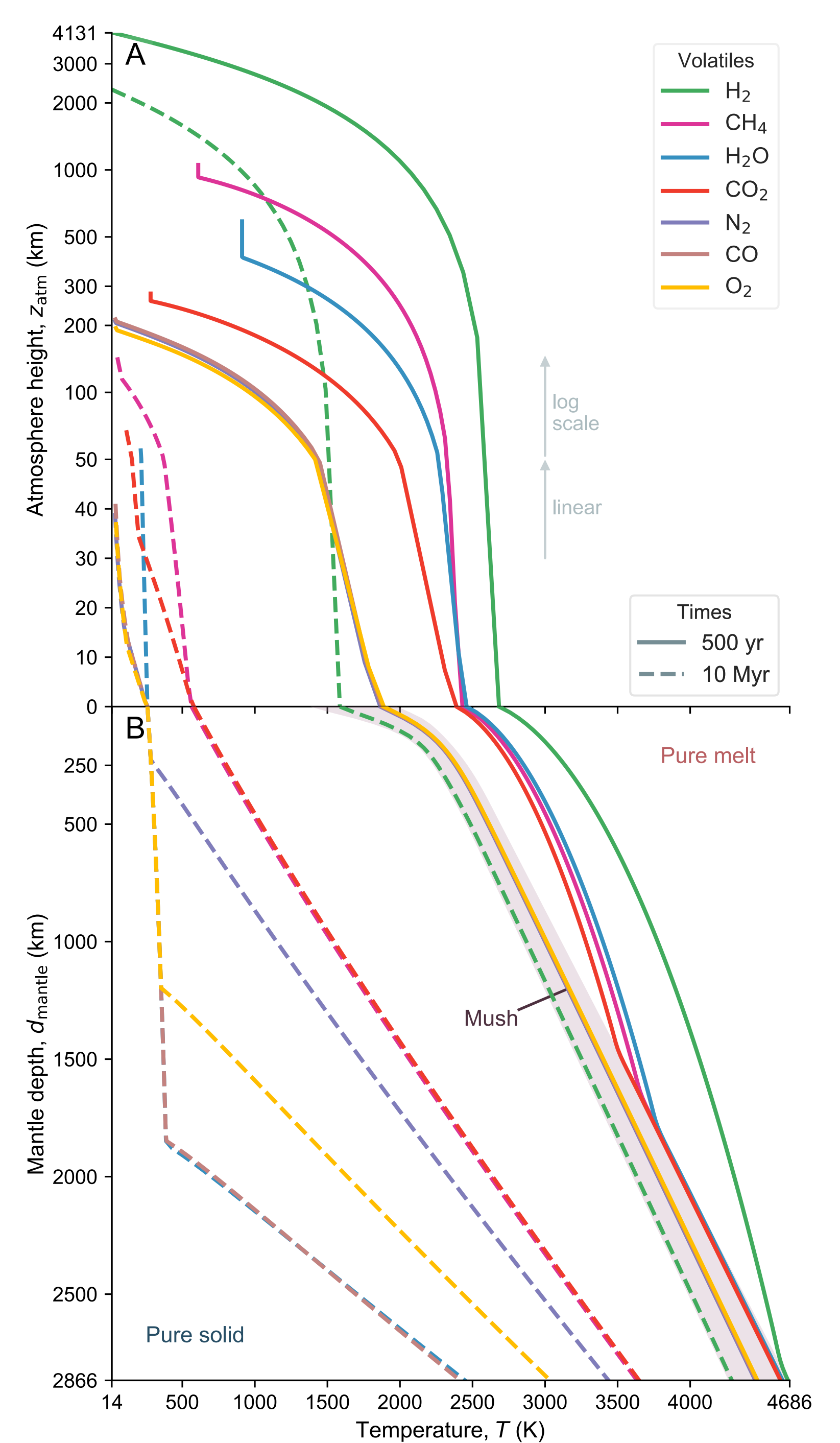
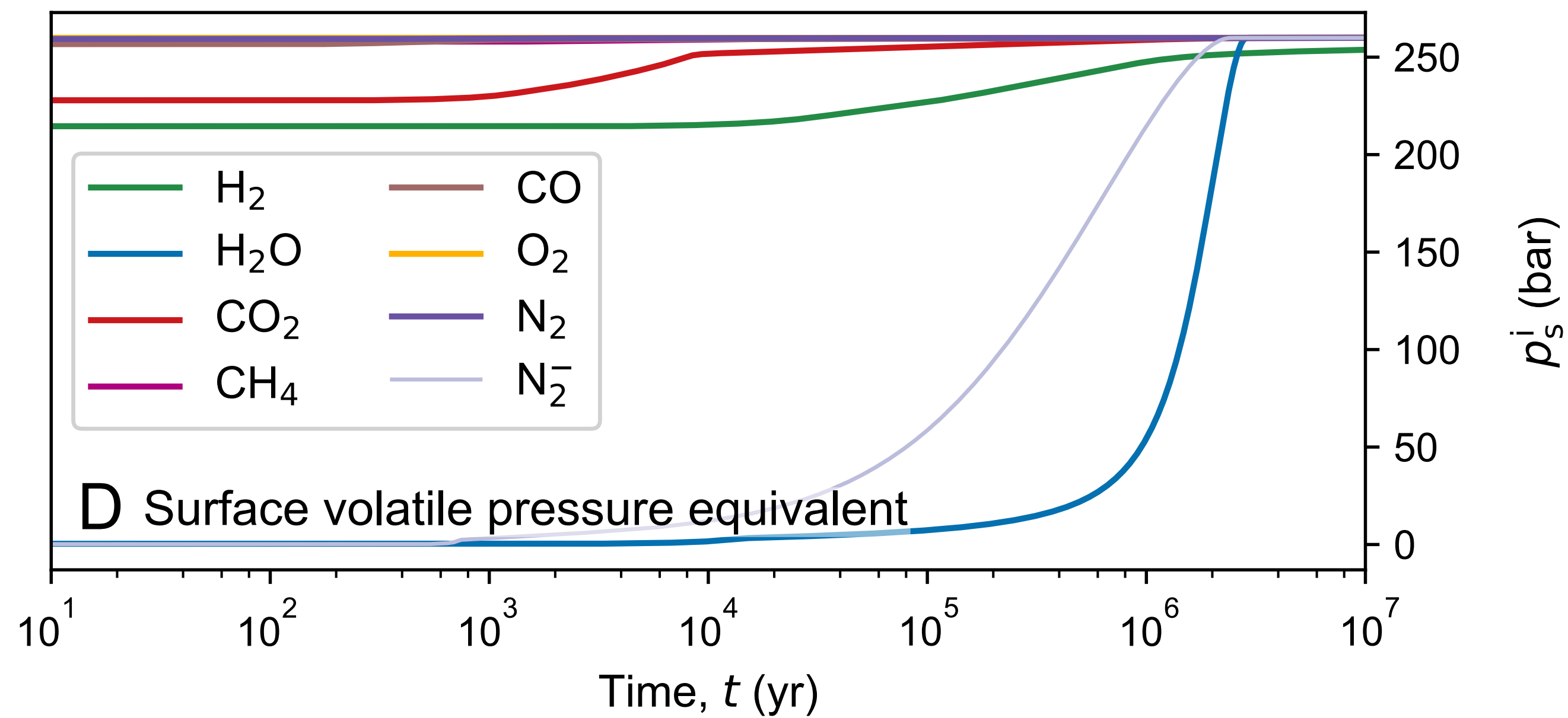
$$p_v(X_v) = \left(\frac{X_v}{\alpha_v} \right)^{\beta_v} \quad m_v^g = 4\pi R_p^2 \left(\frac{\mu_v}{\bar{\mu}} \right) \frac{p_v}{g}$$

Coupled framework

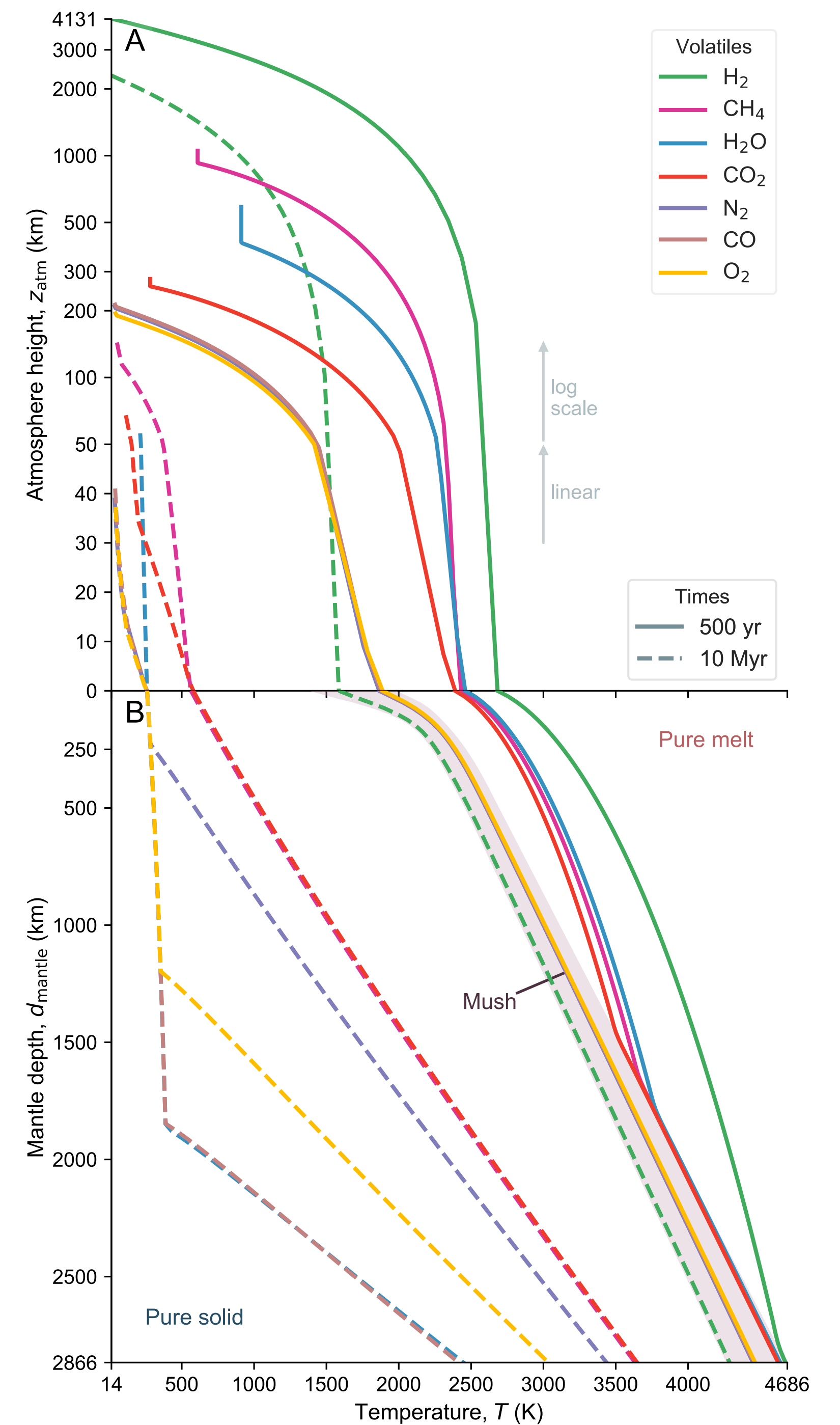
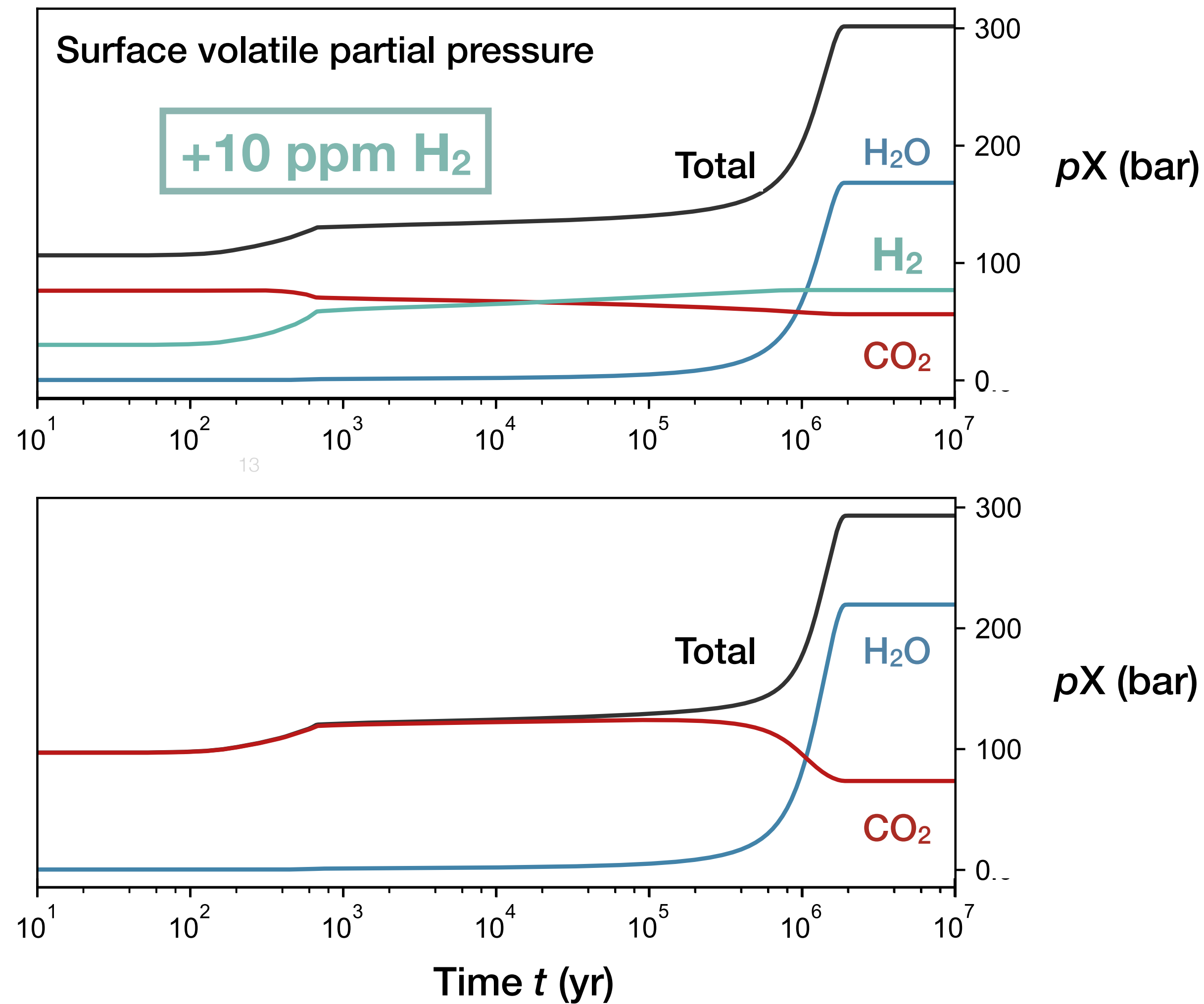




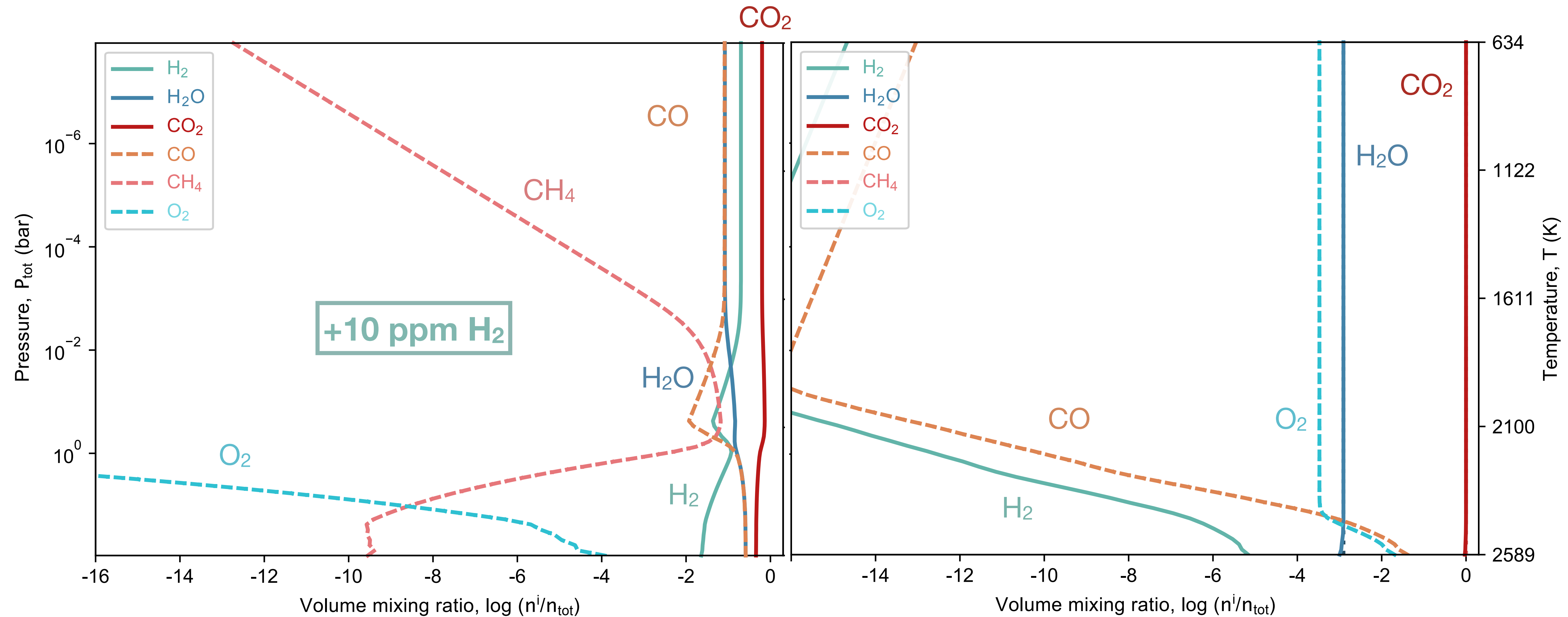
Puffy MO atmospheres



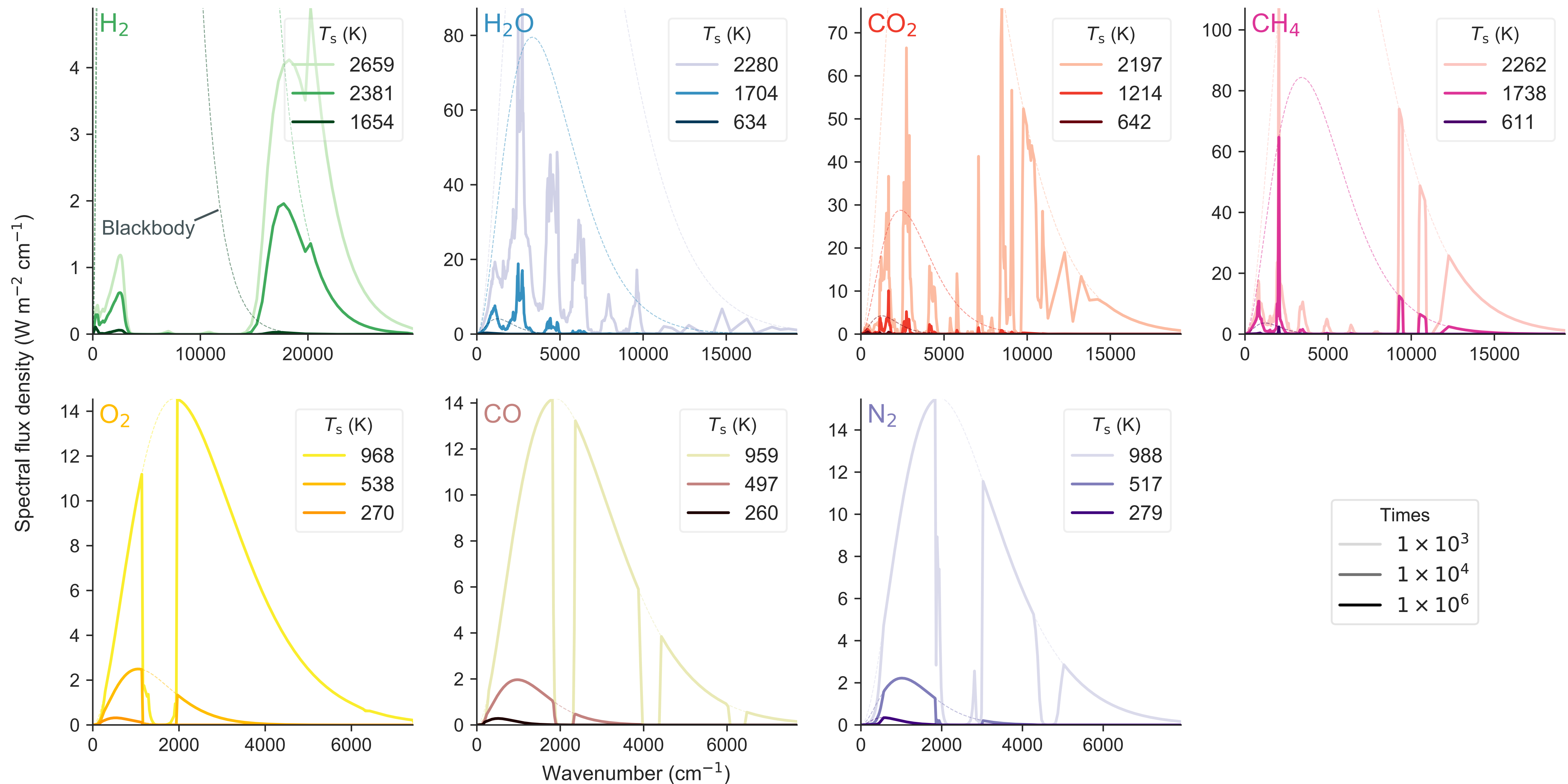
Puffy MO atmospheres



Earliest atmospheric chemistry

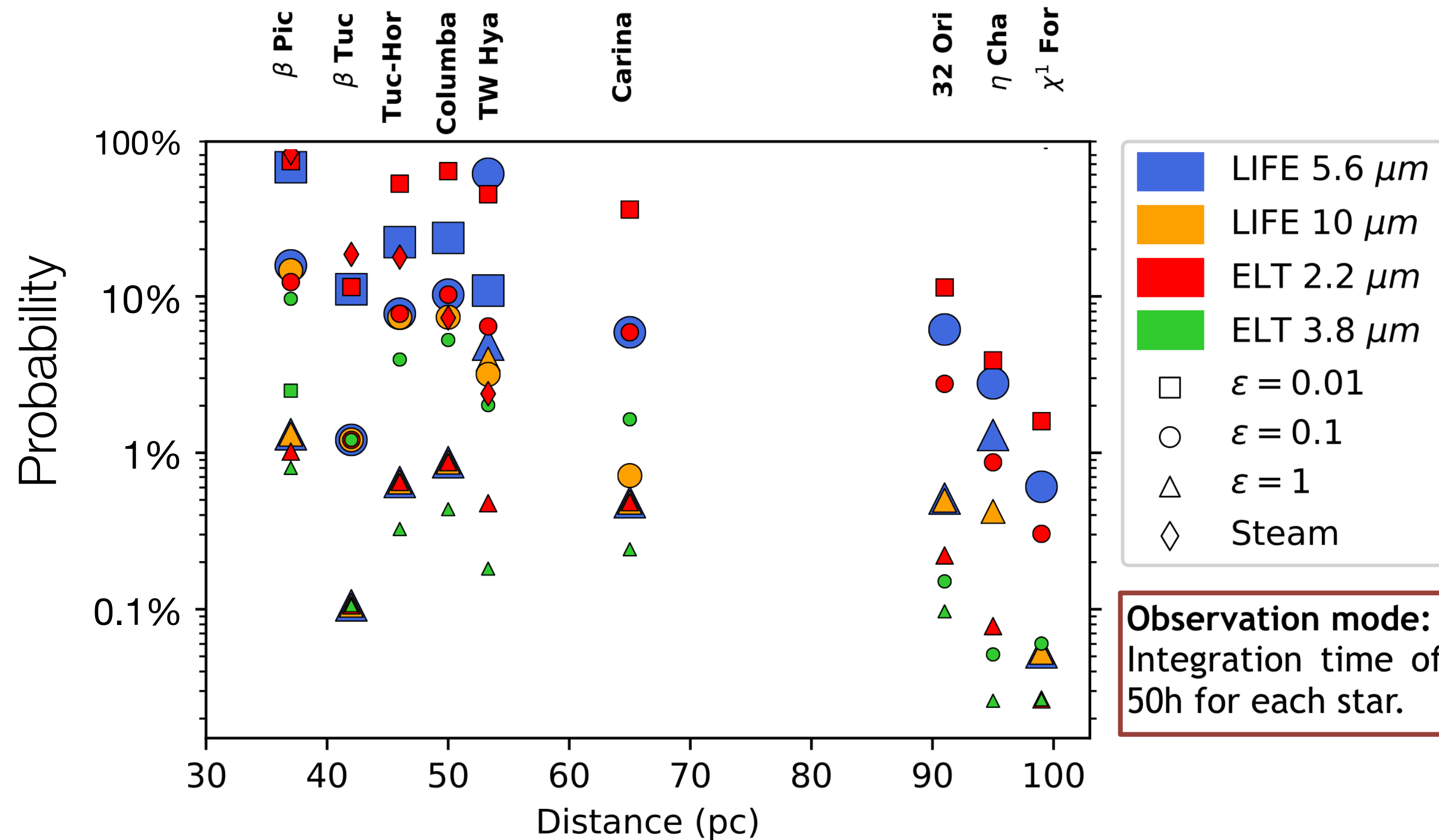


Single-species spectra

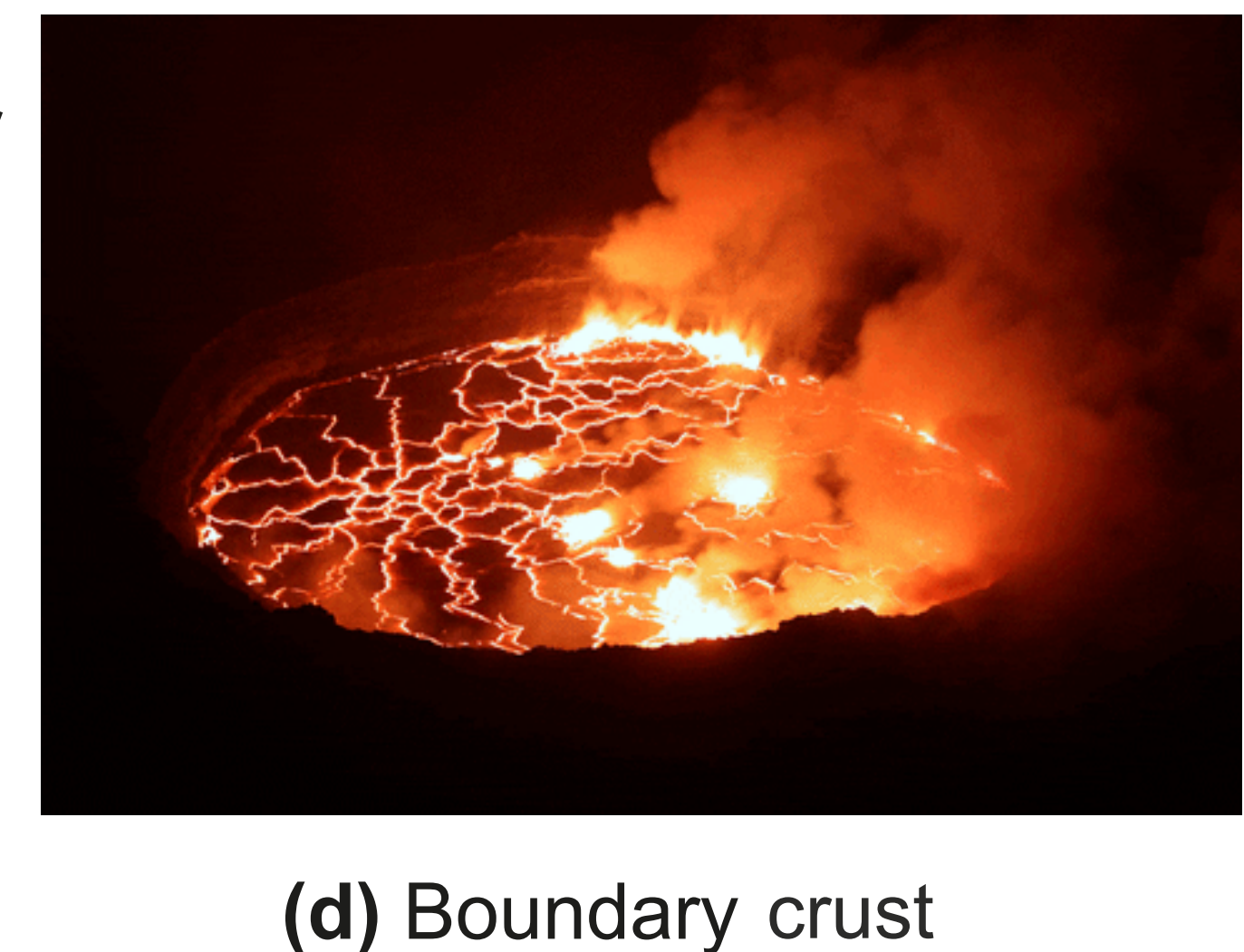
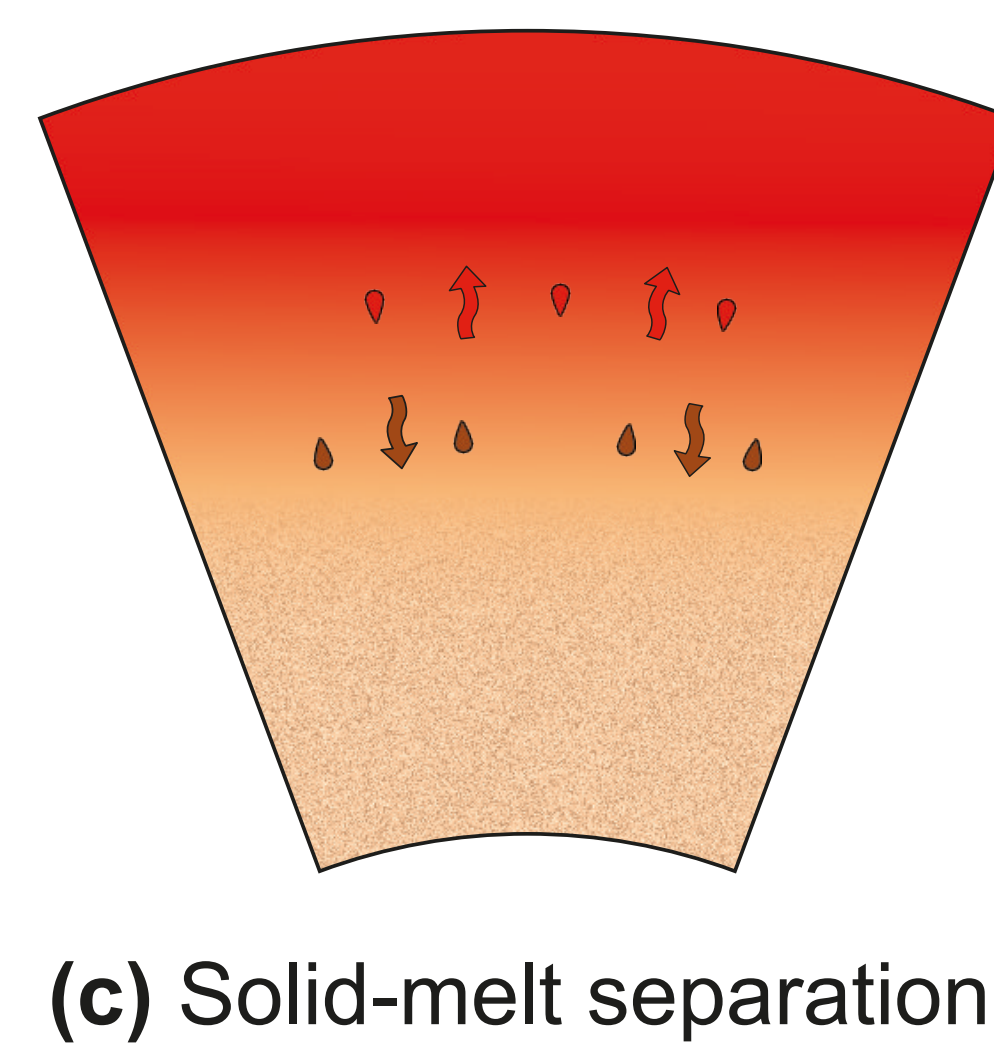
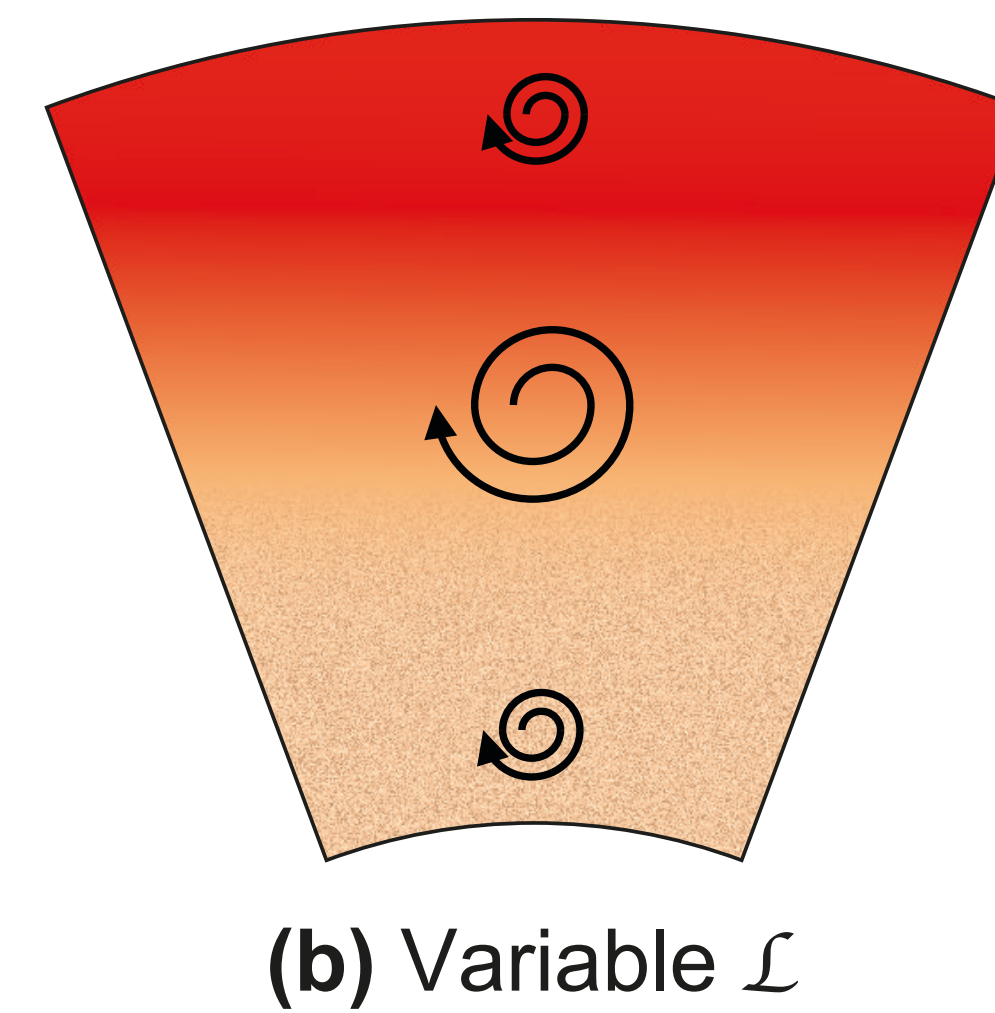
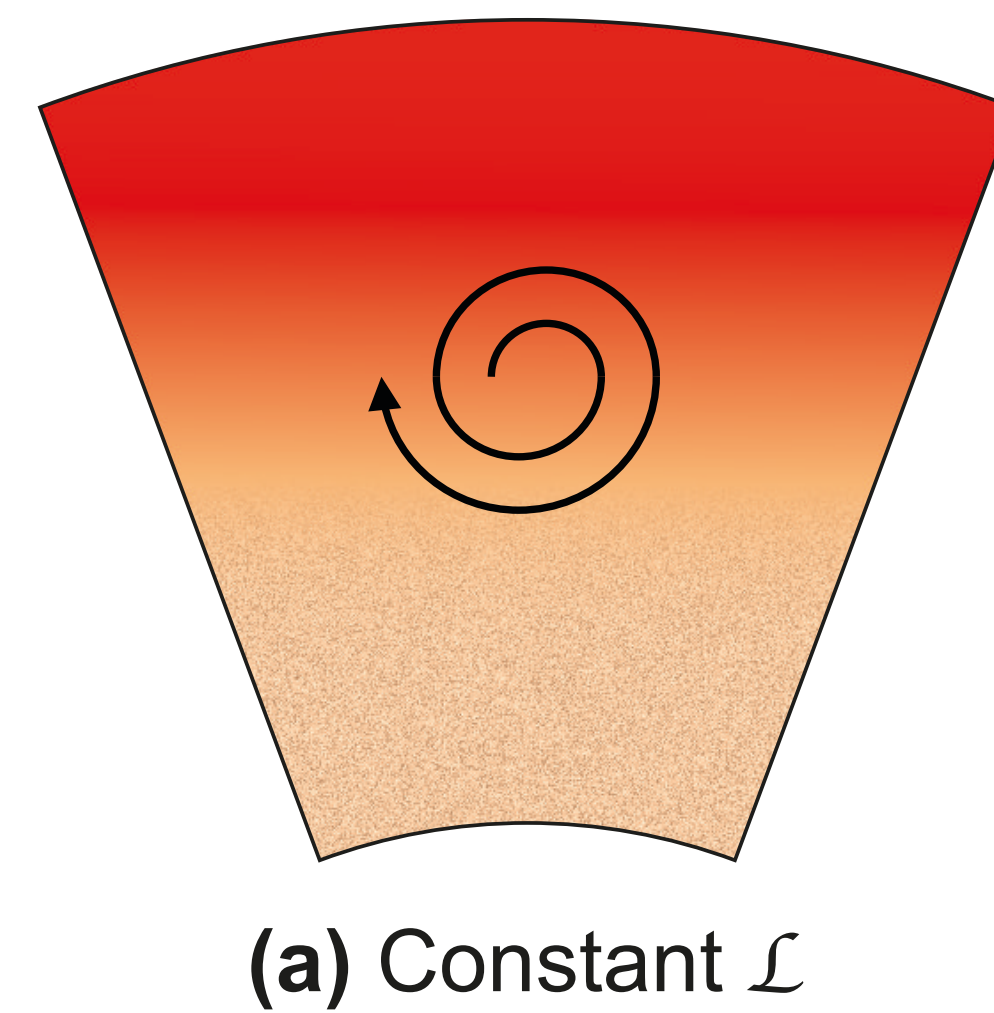
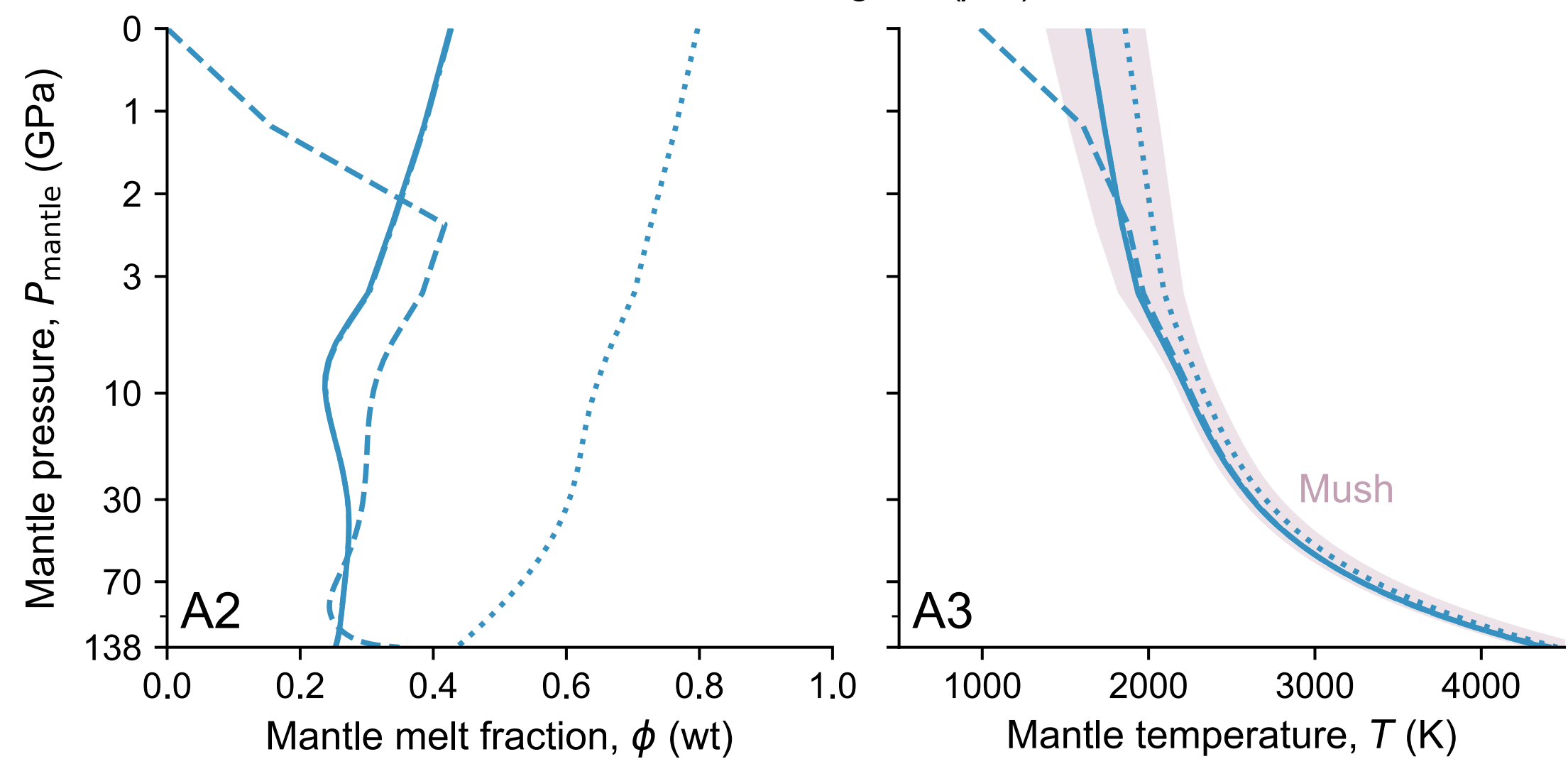
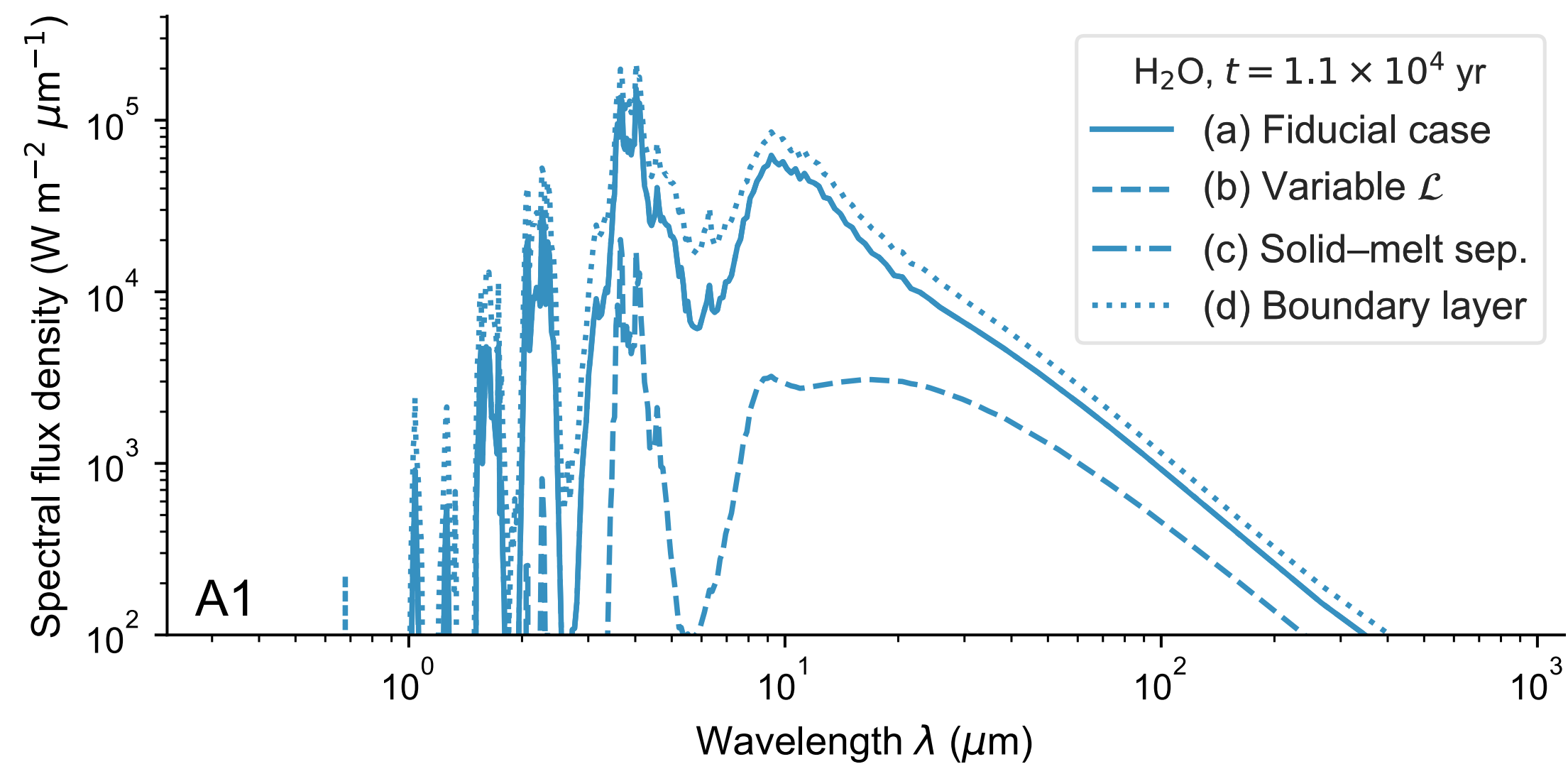


Directly image magma ocean planets?

Probability of detecting magma ocean planet
with future direct imaging facilities



Connection with interior state



Rocky exo-planet diversity from protoplanet solidification



- Magma ocean-atmosphere coupling shapes earliest atmospheric and mantle chemistry
 - ➔ Crucially defines volatile fractionation, near-surface geochemistry, and atmospheric speciation
 - ➔ Stationary + runaway MO planets may reveal diversity of early planetary environments
- Connect w/ space missions and laboratory studies
- Probe underlying distribution of ‘Hadean-like’ planets