Planetary environments where non-aqueous liquids may be present

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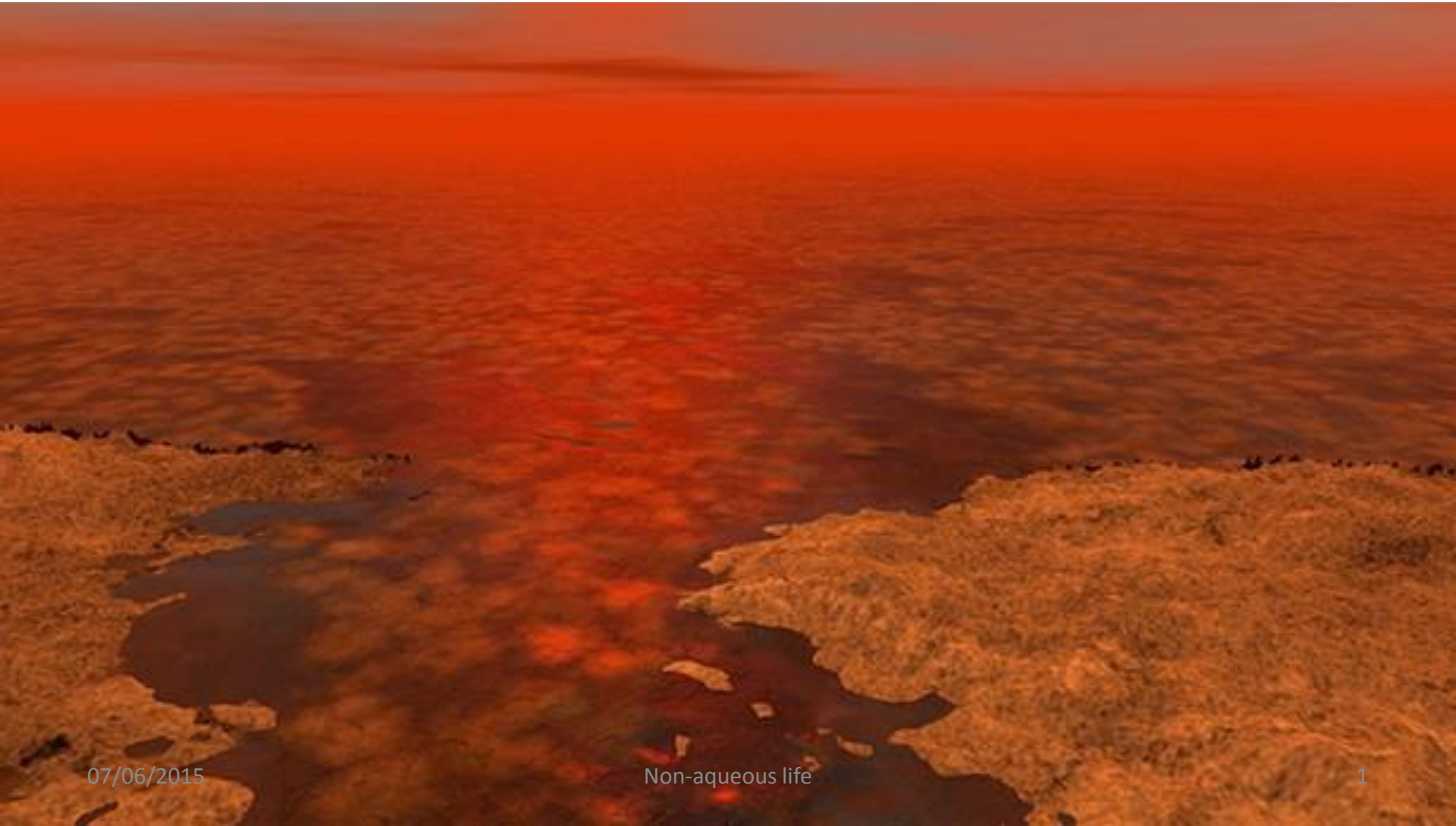
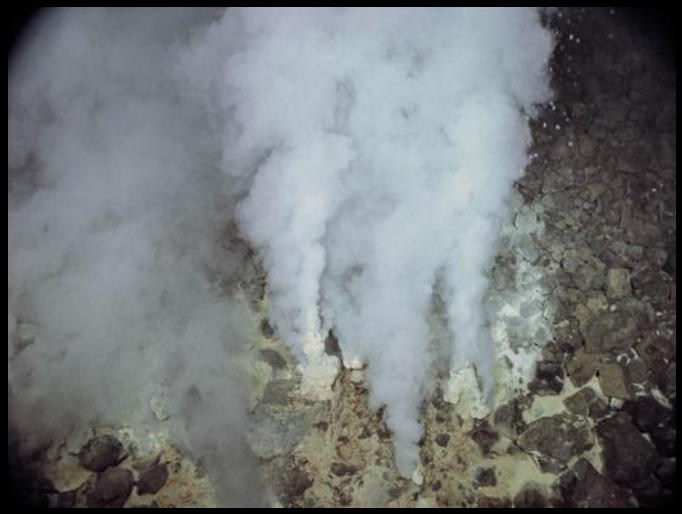


Planetary environments where non-aqueous liquids may be present

Is there life where there is water? The 'follow the water' model

Paradigm change: 'Don't follow (just) the water: Does life occur in non-aqueous media?'



Introduction

(P,T) conditions for liquids to be stable

What liquids ?

What (exo) planets or satellites ?

Conclusion

H_2O on Earth

Oceans : $1.35\ 10^{21}$ kg

Ice : $2.5\ 10^{19}$ kg

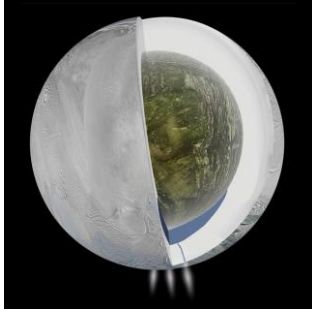
Underground water :
around $0.25\ 10^{21}$ kg

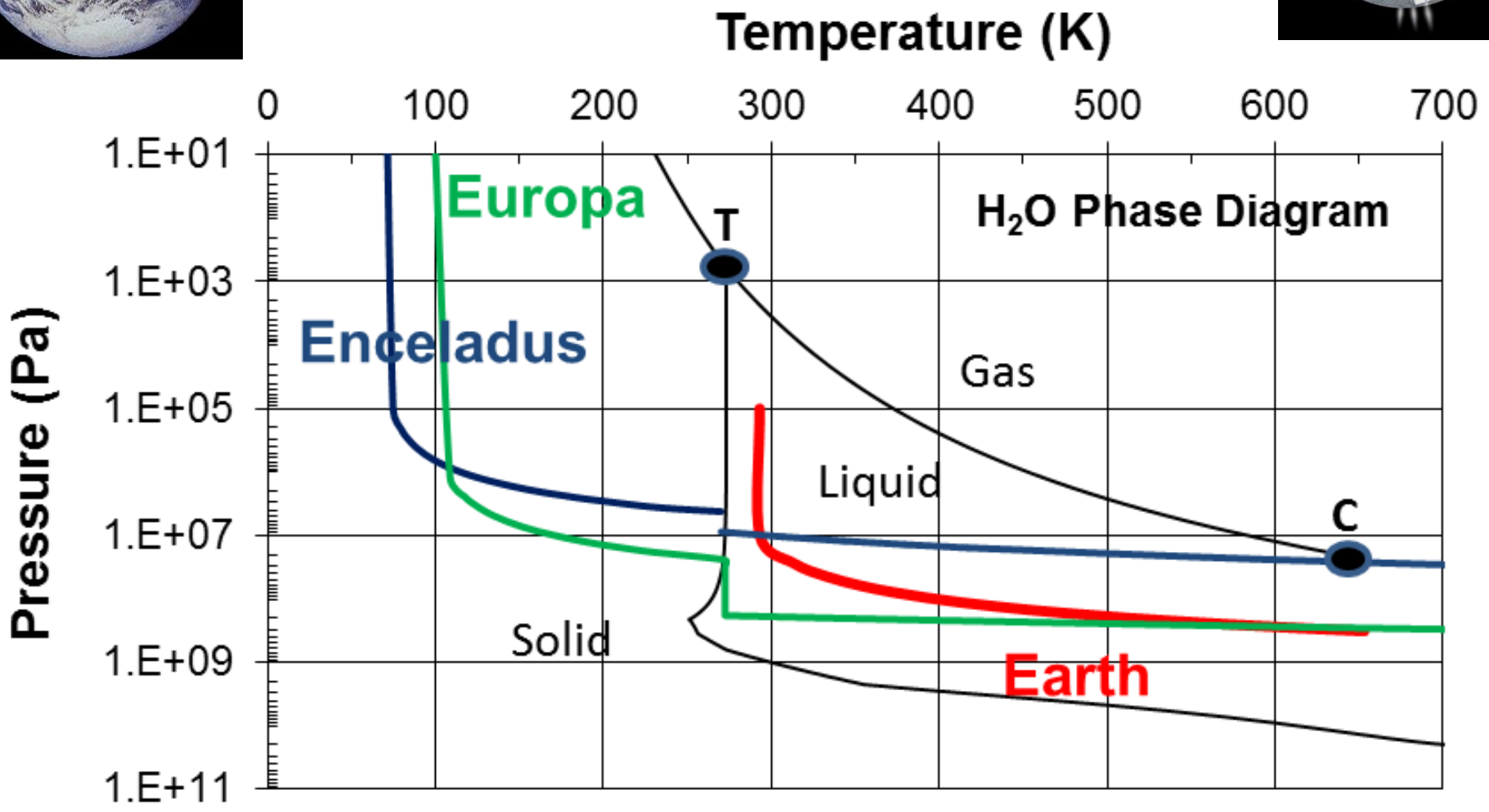
H_2O in the mantle :
0.05% * $4\ 10^{24}$ kg = $2\ 10^{21}$ kg

H_2O is about 2.5 to $5\ 10^{-4}\ M_T$

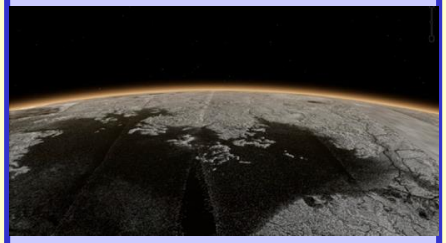
One issue is whether water comes from comets or from outgassing (volcanism)

Examples of water worlds

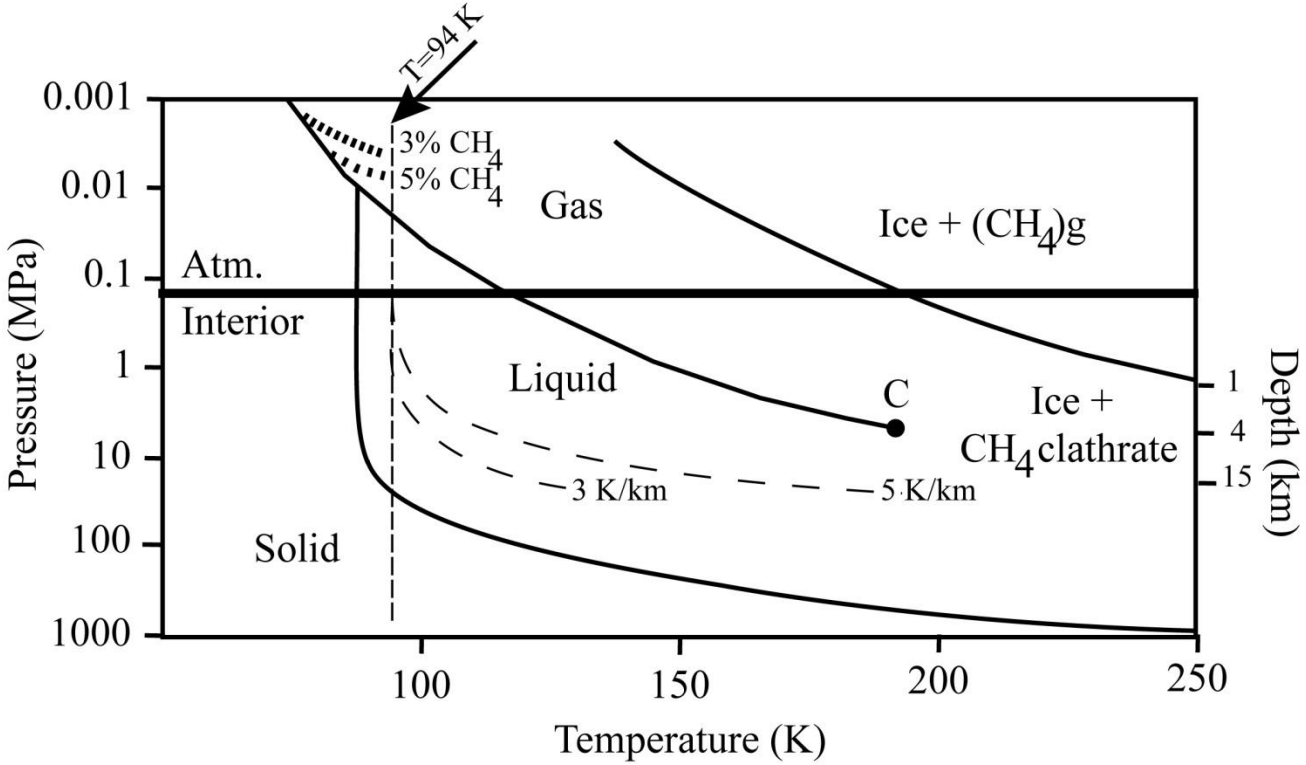


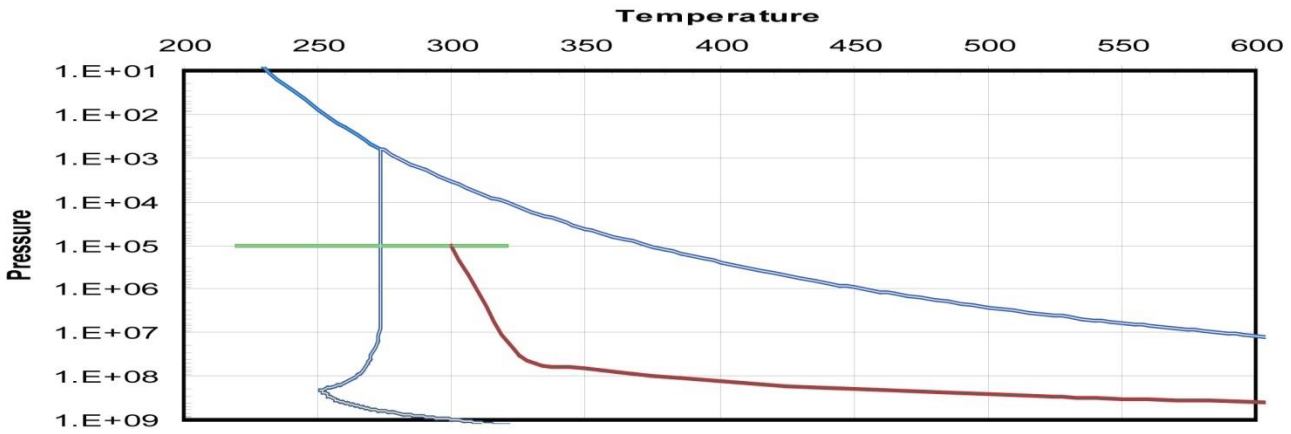


CH_4 on Titan



H_2O on Earth





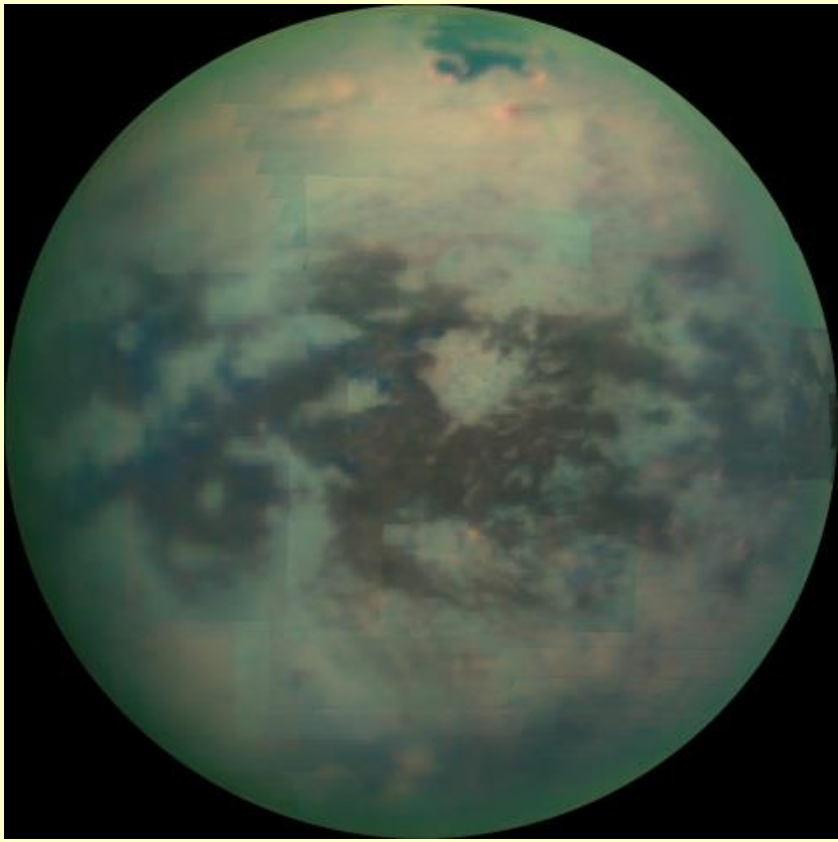
CH_4 on Titan

Atmosphere : **$1.9\ 10^{17}$ kg**

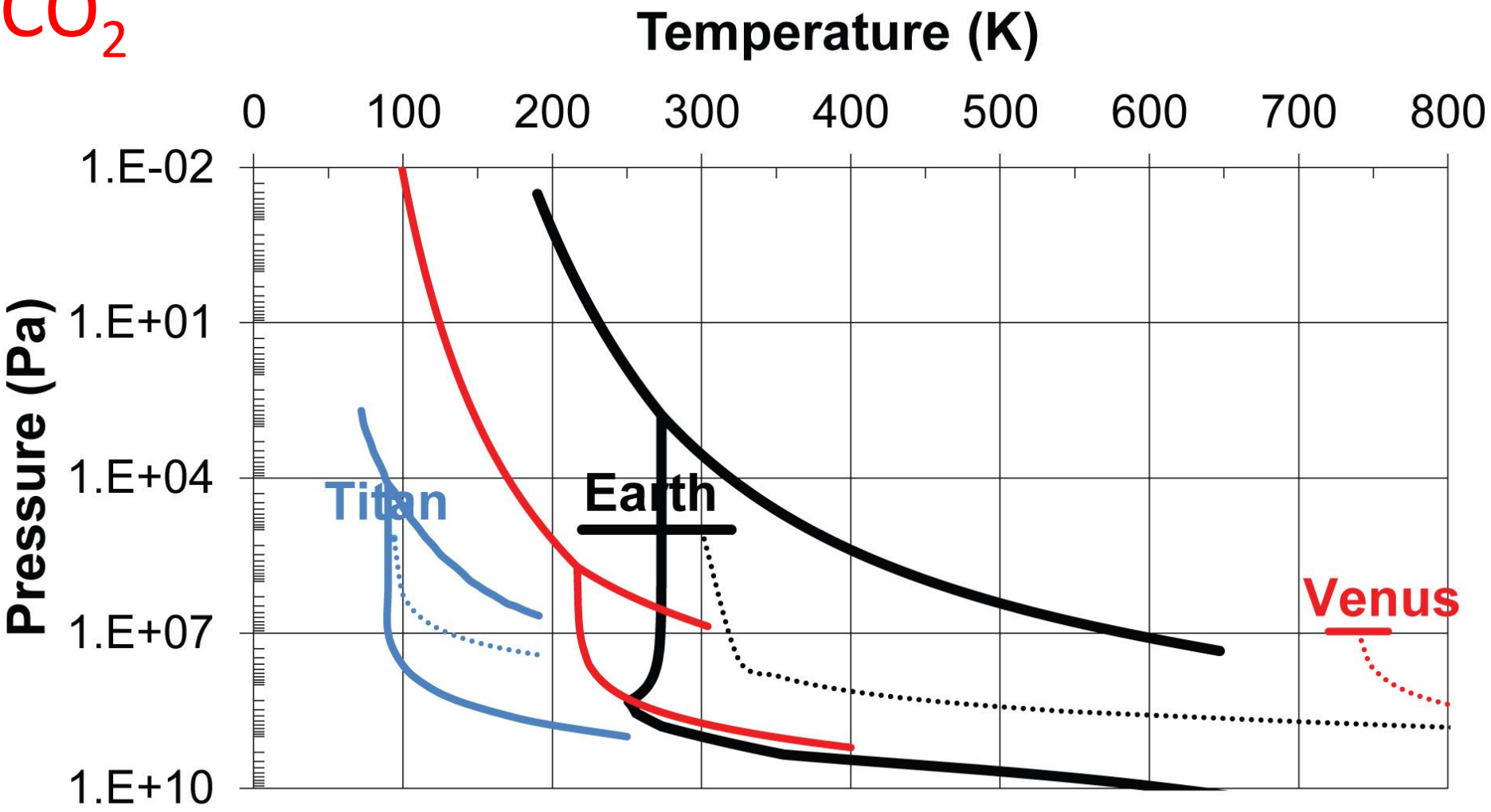
Seas: **$2.5\ 10^{16}$ kg**

Underground methane : **??**

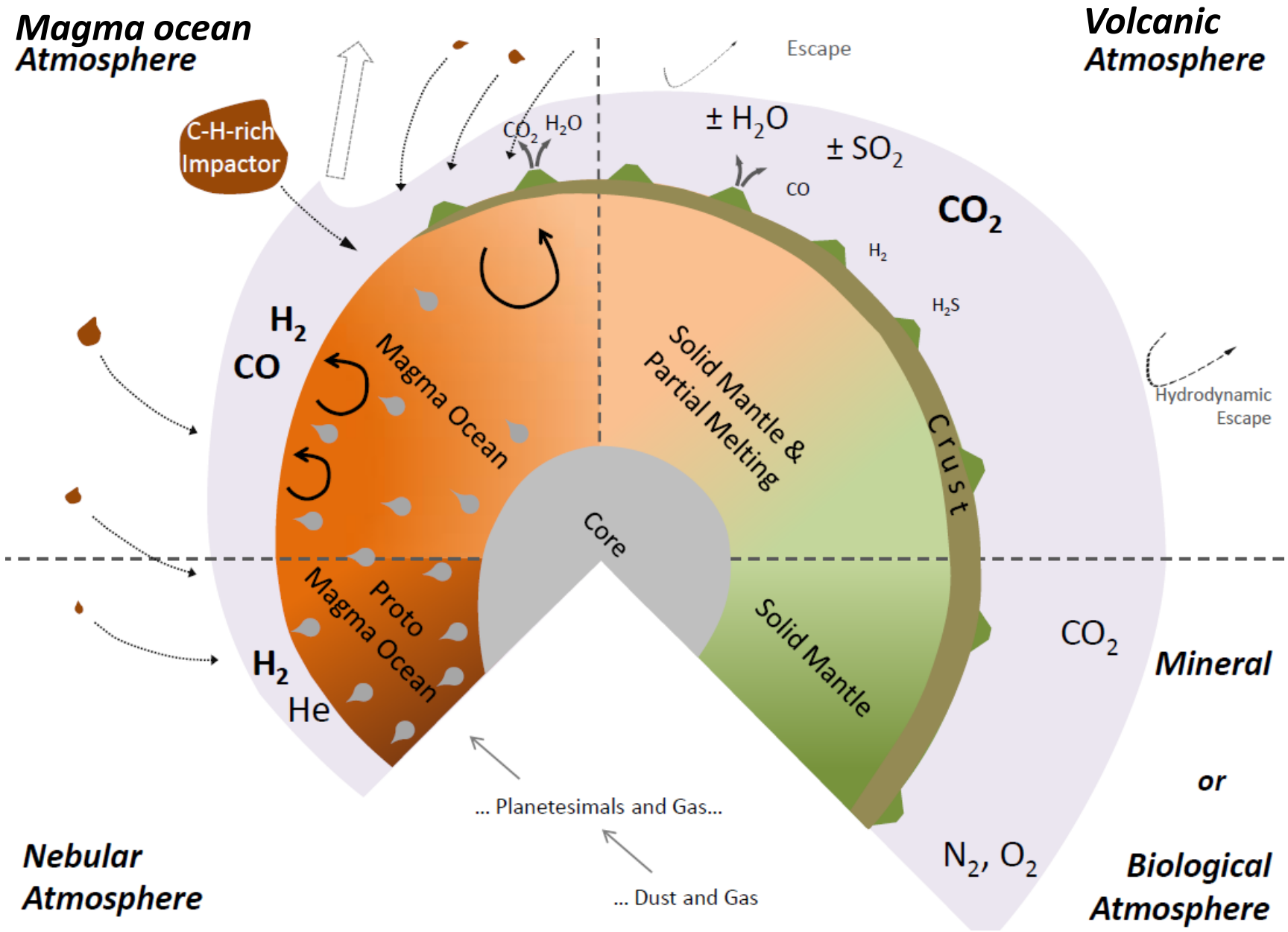
Methane is at least $2x10^{-6}\ M_{Titan}$



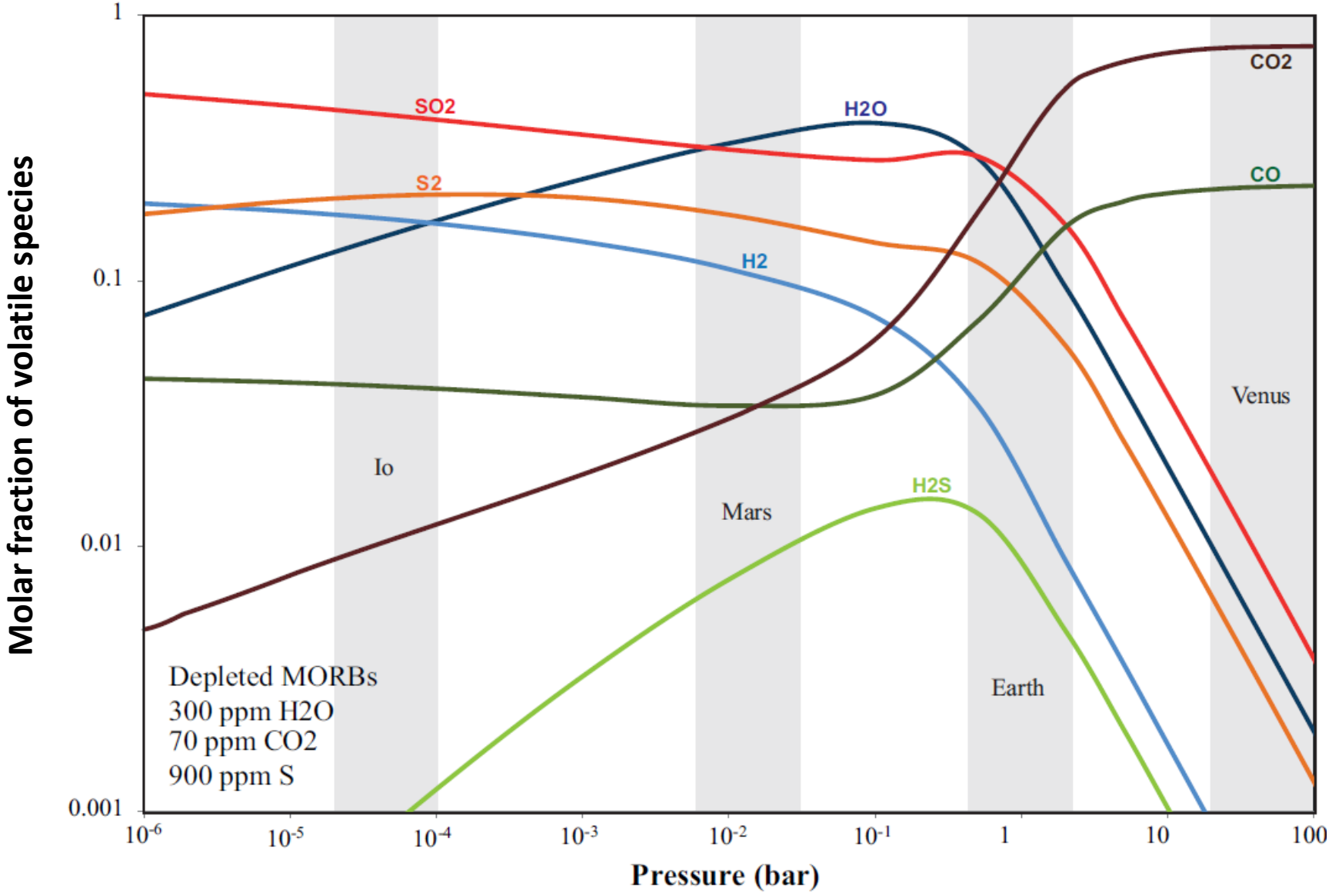
CO_2



Triple point is at low temperature and high pressure (5.2-bar). Venus' surface temperature is well above the critical point – However, exoplanets may have the right surface conditions



(from Gaillard and Scaillet, 2014)

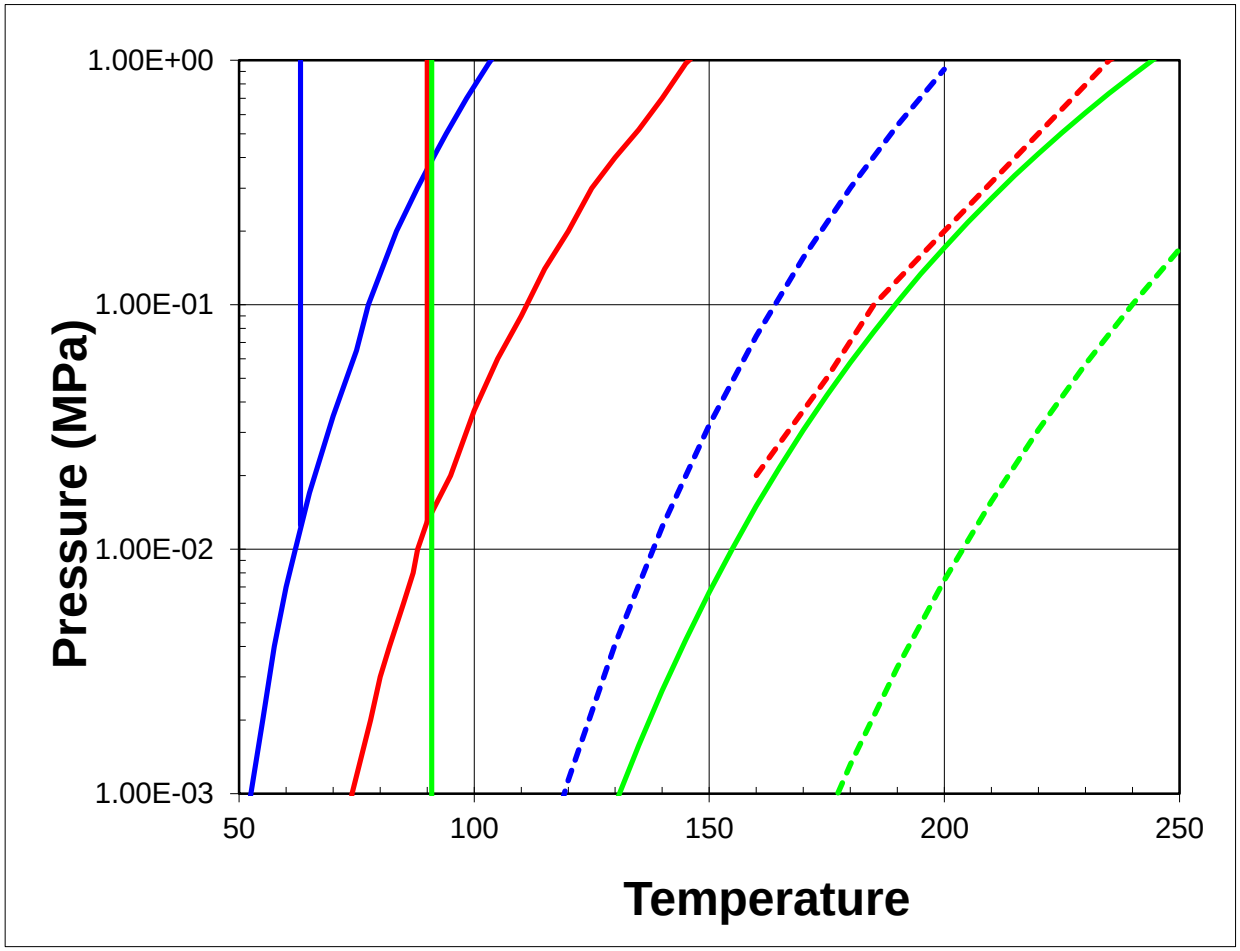


The higher the pressure, the larger the fraction of CO2 in the outgassing (Gaillard and Scaillet, 2014, A theoretical framework for volcanic degassing chemistry in a comparative planetology perspective and implications for planetary atmospheres)

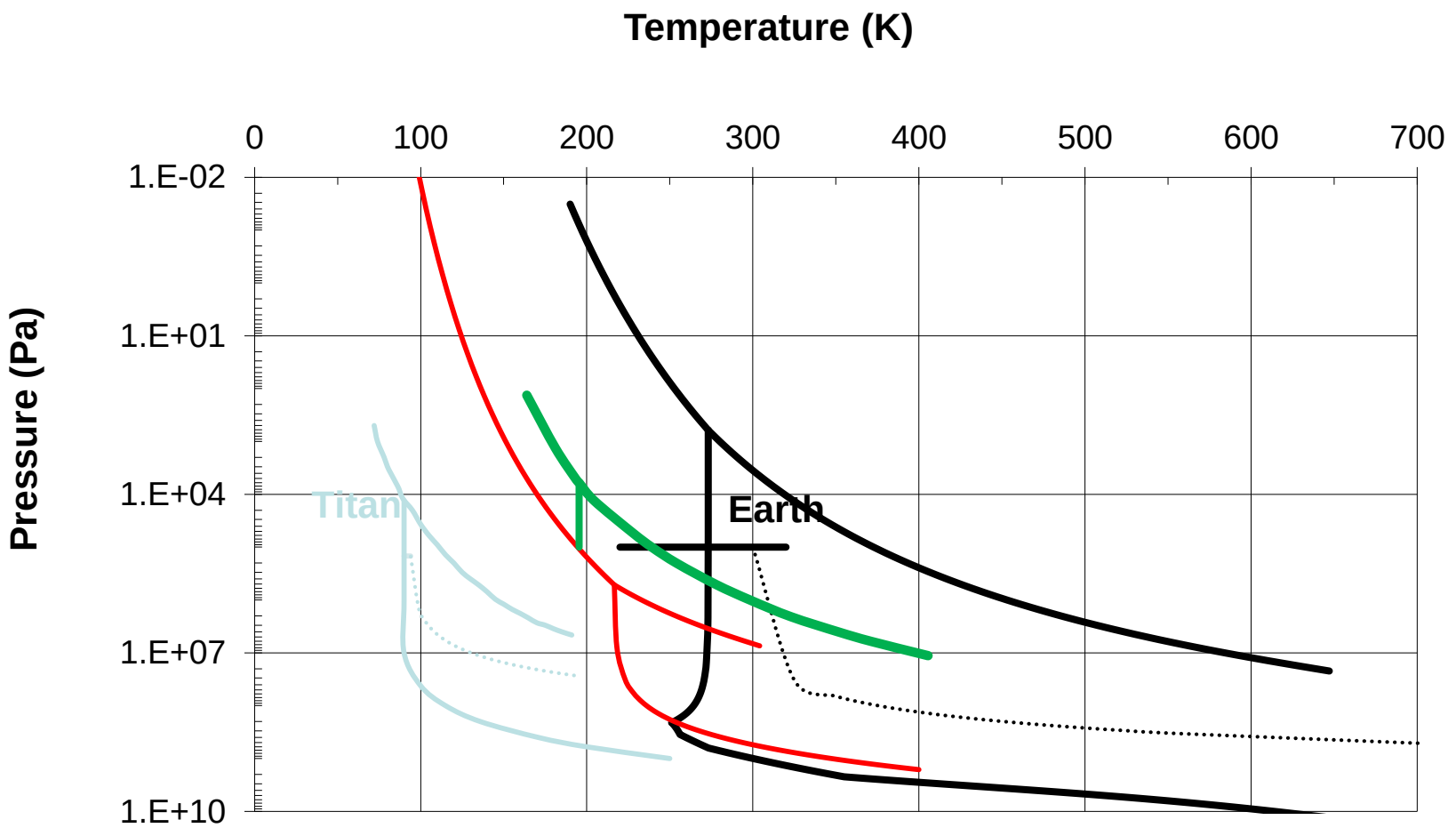
	Triple point		Critical point	
	P (Pa)	T (K)	P (Pa)	T (K)
CH_4	11,700	90.7	4,600,000	190.6
H_2O	612	273.2	22,064,000	647.1
CO_2	517,950	216.6	7,377,298	304.1

	P (MPa)	T
Titan	0.147	92
Earth	0.1	275
Venus	9.3	723

Other fluids – N2

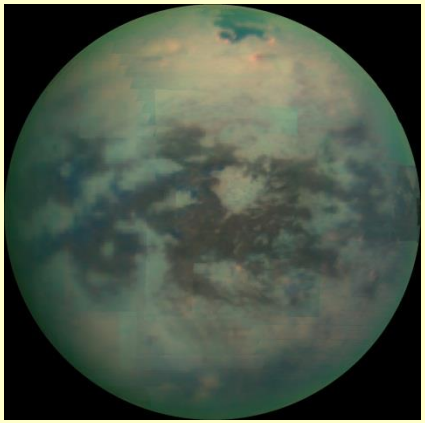


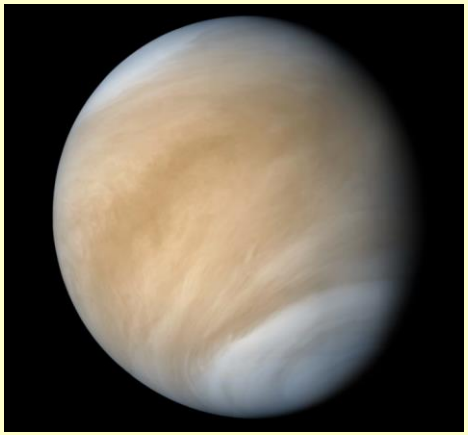
Other fluids – NH_3

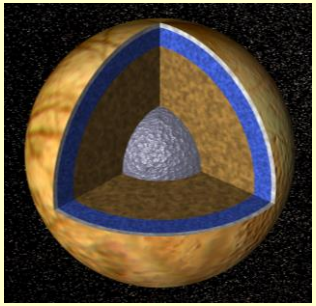


Planetary environments with liquids

H_2O **CH_4** **CO_2** **Other(s)**







The solar system provides evidence of liquid H2O, liquid CH4, and supercritical CO2.

Other planetary systems may harbor planets with other liquids such as CO2, N2, NH3

Summary and Conclusions

1. Liquids are confined in a small (P,T) range.
2. Although the case for H_2O is well documented on Earth, the origin (fraction from cometary impacts/outgassing) is still debated.
3. The preservation of liquid over geological timescales required for life to emerge and develop may require recycling between the interior and the surface.
4. Solar system exploration has revealed the presence of liquid H_2O, liquid hydrocarbons, and supercritical CO_2.
5. Other liquids such as liquid CO_2, liquid N_2, and liquid NH_3 may exist on exoplanets.
6. The case for liquid CO_2 has been supported by recent laboratory experiments