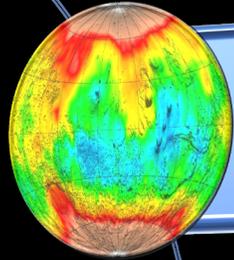
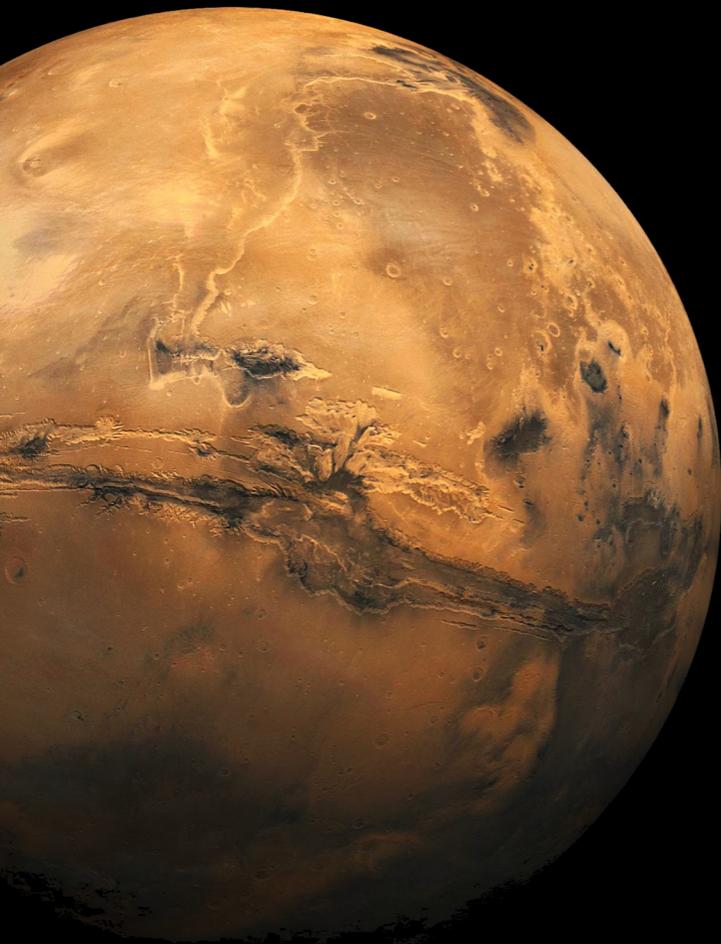


Mars Subsurface Hydrology in 4D & Implications for Extant Life

Vlada Stamenković

Jet Propulsion Laboratory, California Institute of Technology

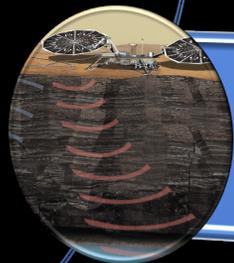
Doris Breuer (DLR), Ana Plesa (DLR), Jesse Tarnas (Brown), Jack Mustard (Brown) and from JPL: Chad Edwards, Michael Mischna, Nathan Barba, Mariko Burgin, Bob Grimm, Darmin Arumugam, Rob Beauchamp, Raju Manthena, Kalind Carpenter, Lou Giersch, Dean Wright & Seth Krieger.



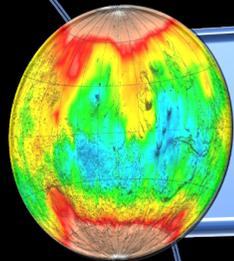
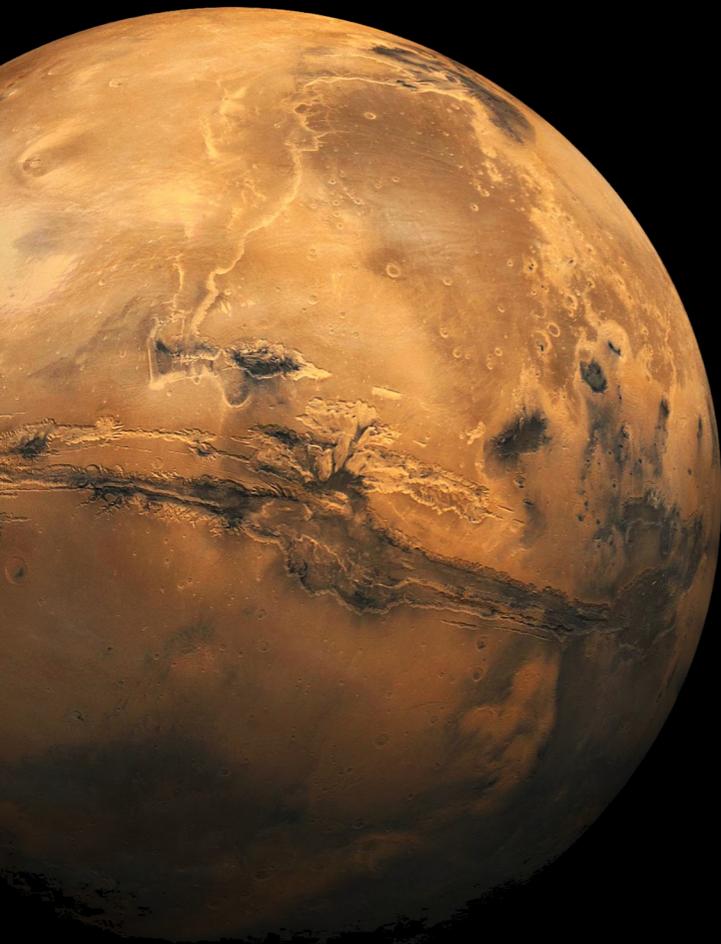
Where's the liquid water?



Tech to find it



Missions to constrain it



Where's the liquid water?



Tech to find it



Missions to constrain it

A refresher: old water...groundwater dominated???

Cementation/Alteration of Sedimentary Deposits (Noachian)

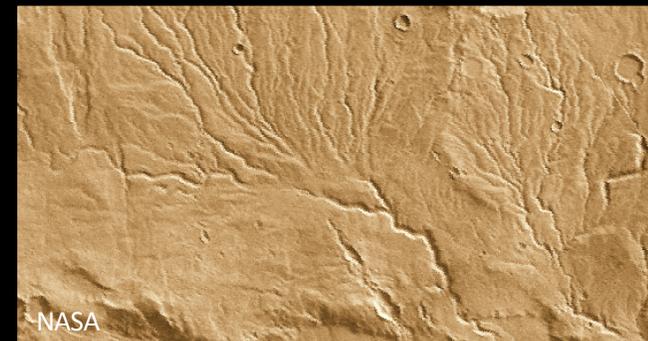


MnO₂ veins (MSL, Gale Crater)



Chaos & Outflow Channels (Hesperian-Amazonian, e.g. Kasei Valles)

Valley Networks? (Noachian-Hesperian)

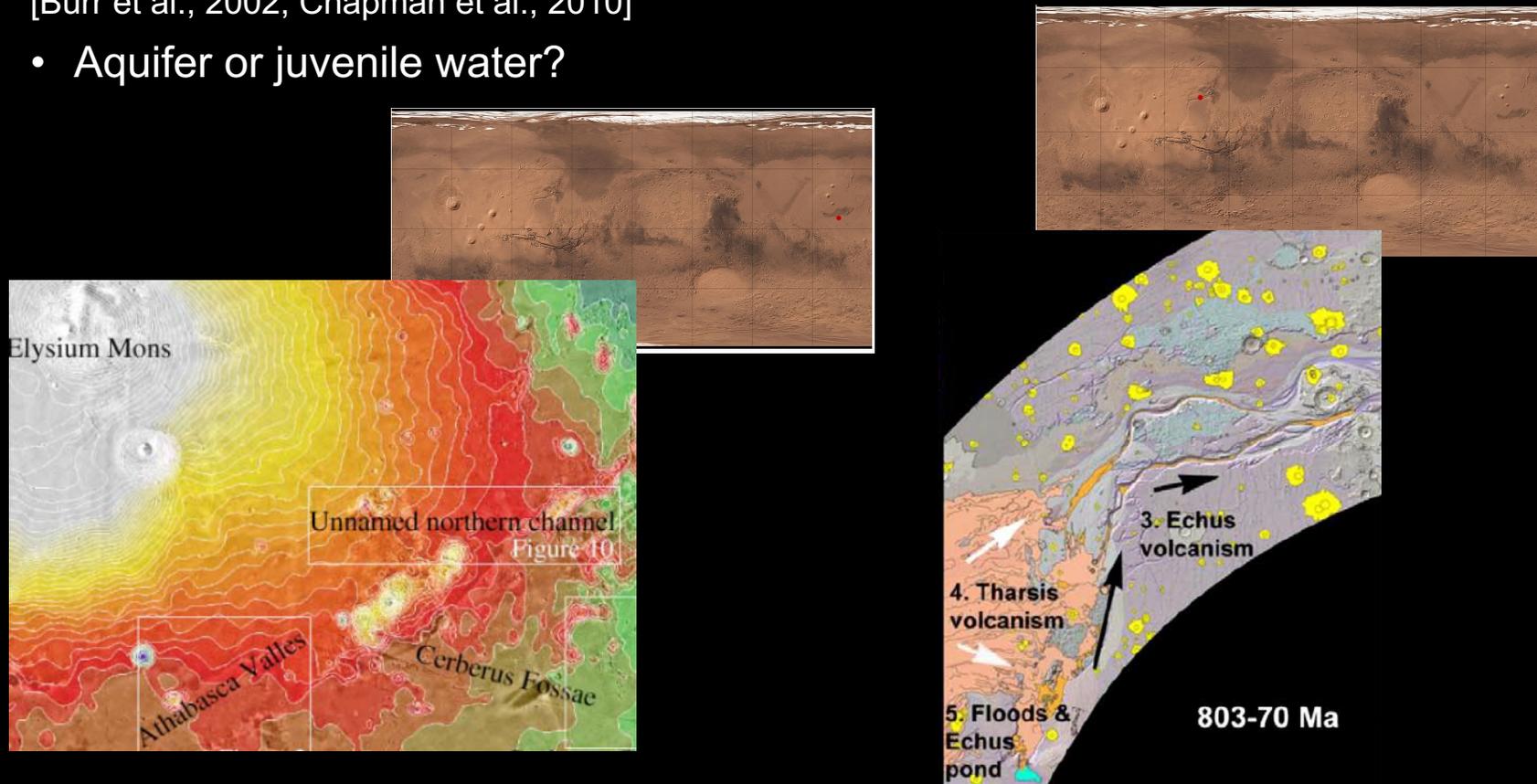


A refresher: young groundwater?

Young Outflow Channels in Athabasca and Kasei

[Burr et al., 2002; Chapman et al., 2010]

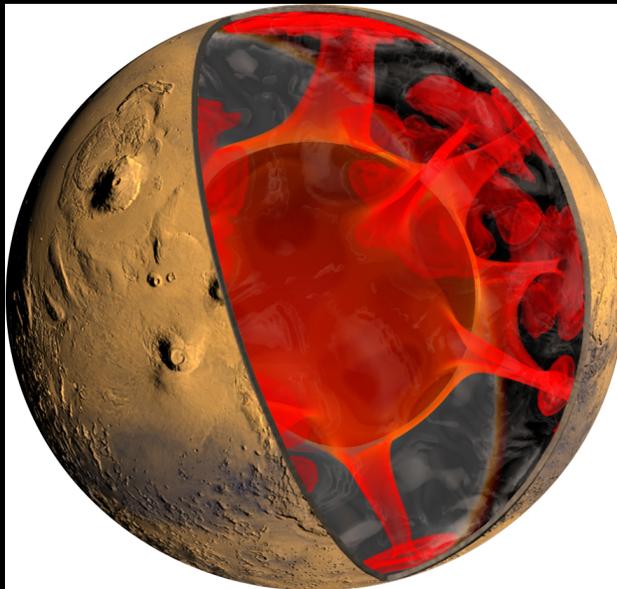
- Aquifer or juvenile water?



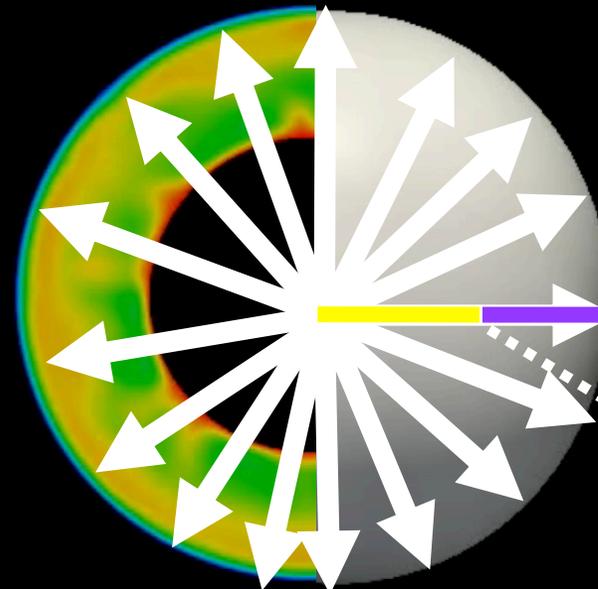
Where is the water: geodynamic evolution models

- Full mantle convection: self-consistently account for spatial convective patterns, slow
- Parametrized models: crust is major spatial heat flux modulator, fast

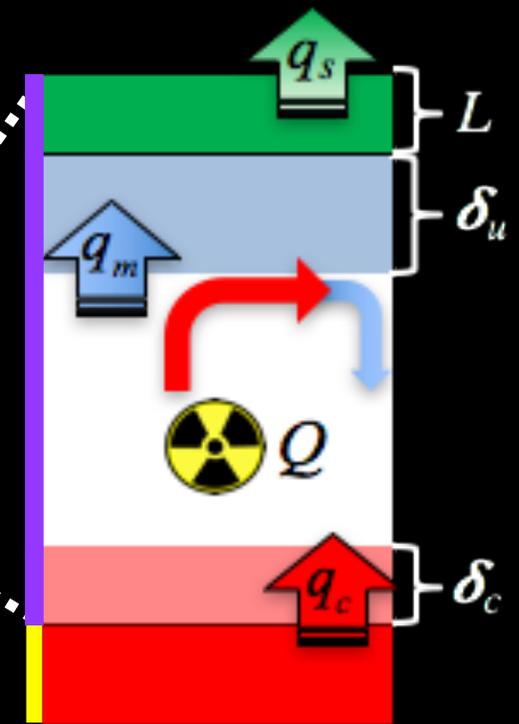
GAIA



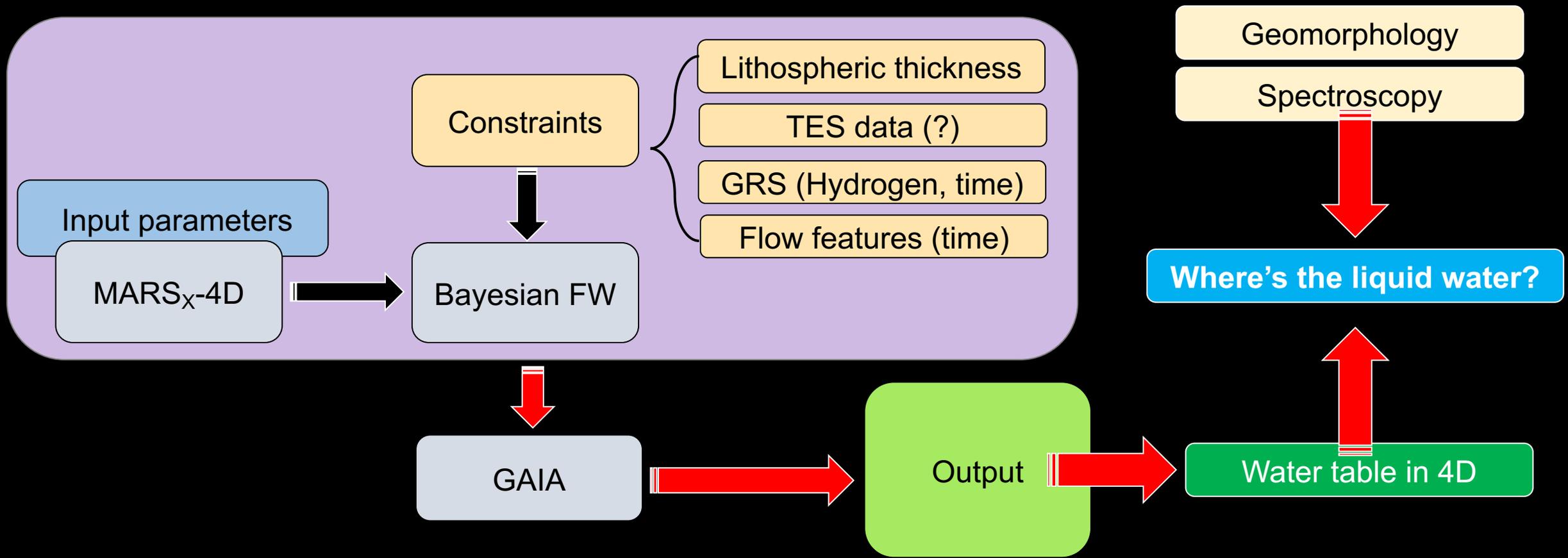
[Plesa et al., 2016]

MARS_x-4D

[Stamenković et al., in prep]



Where is the water: geodynamic evolution models



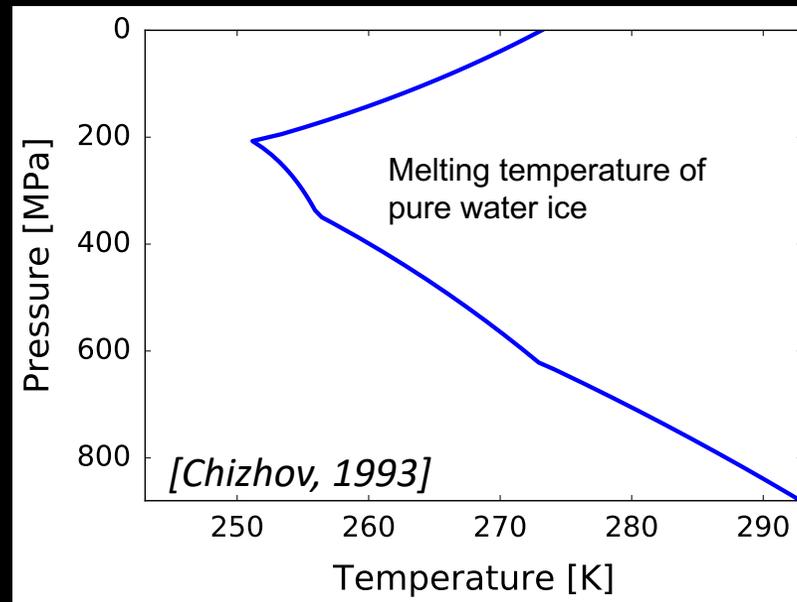
Where is the water: geodynamic evolution models

- Full mantle convection: self-consistently account for spatial convective patterns, slow
- Parametrized models: crust is major spatial heat flux modulator, fast
- We compare our subsurface temperature to the melting temperature of water ice (so far)

GAIA

MARS_x-4D

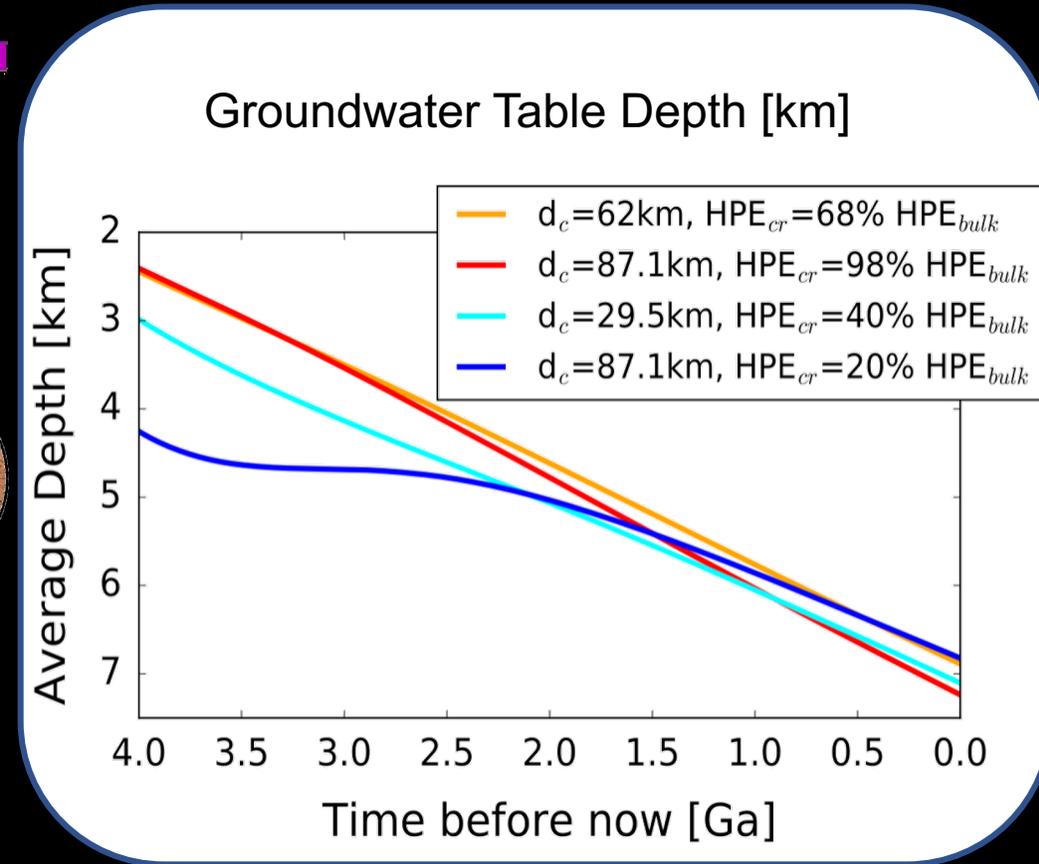
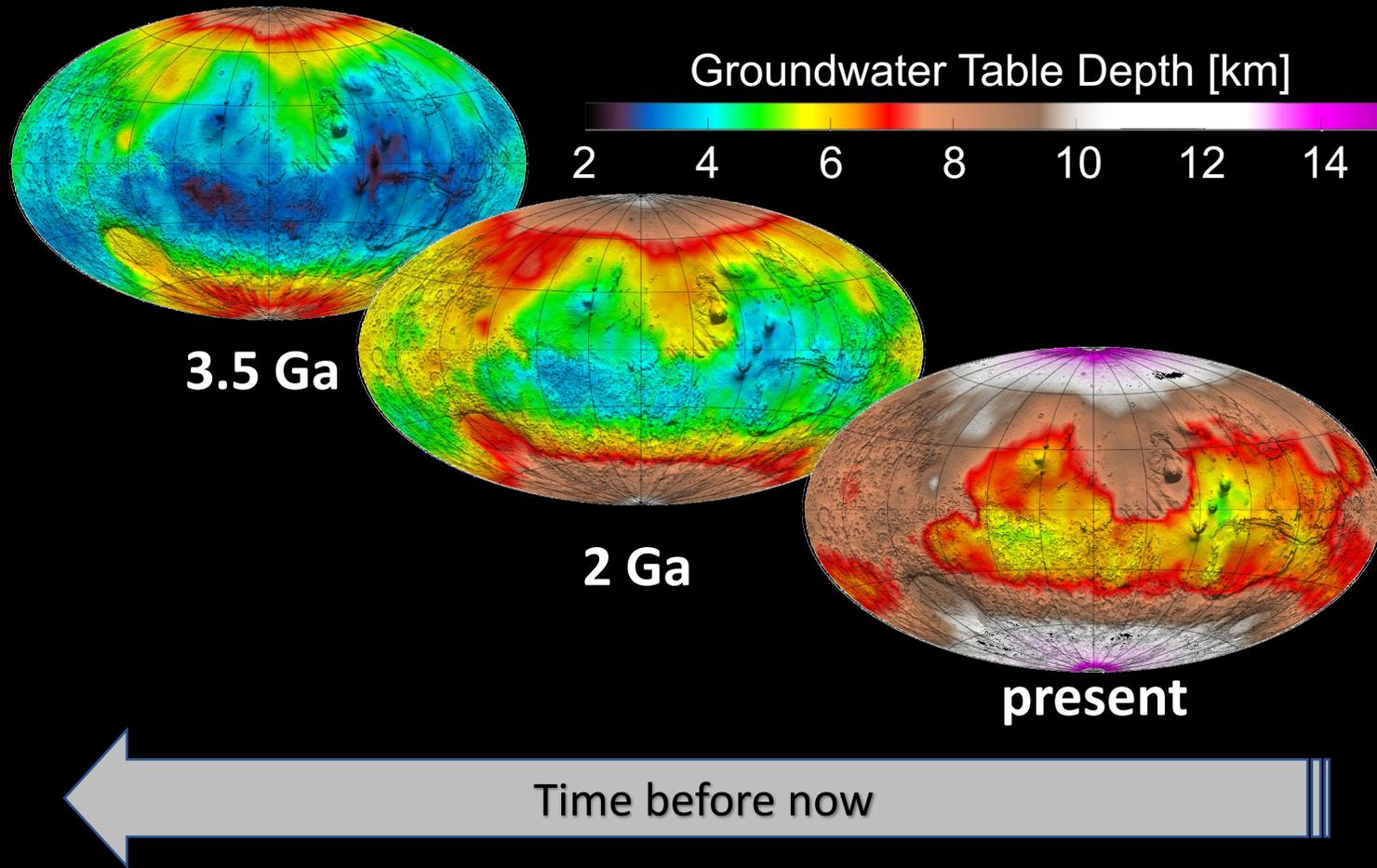
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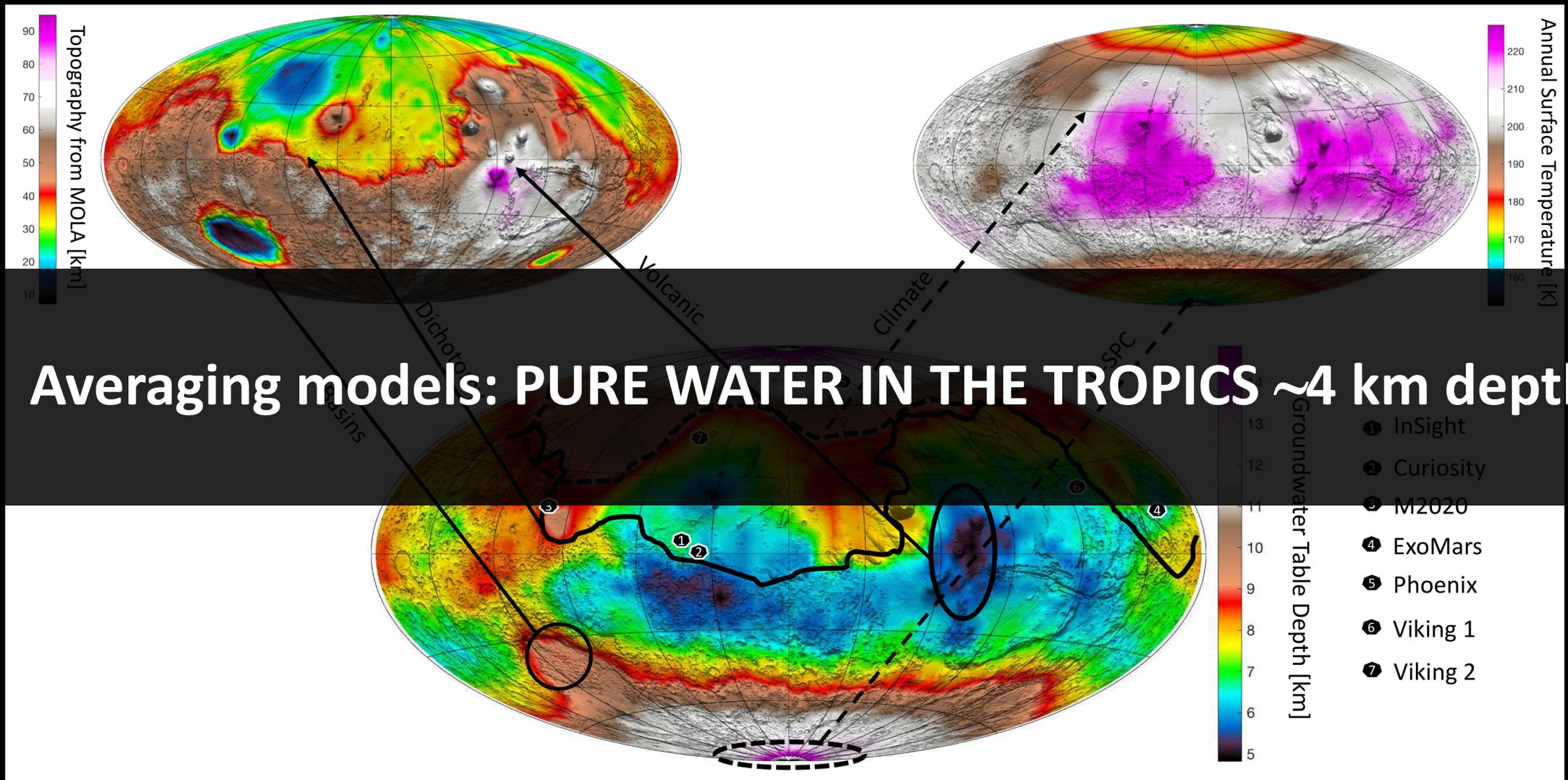
+

~~Gravity/Permeability/Porosity
(→ Flow)~~

Where is the water: across time

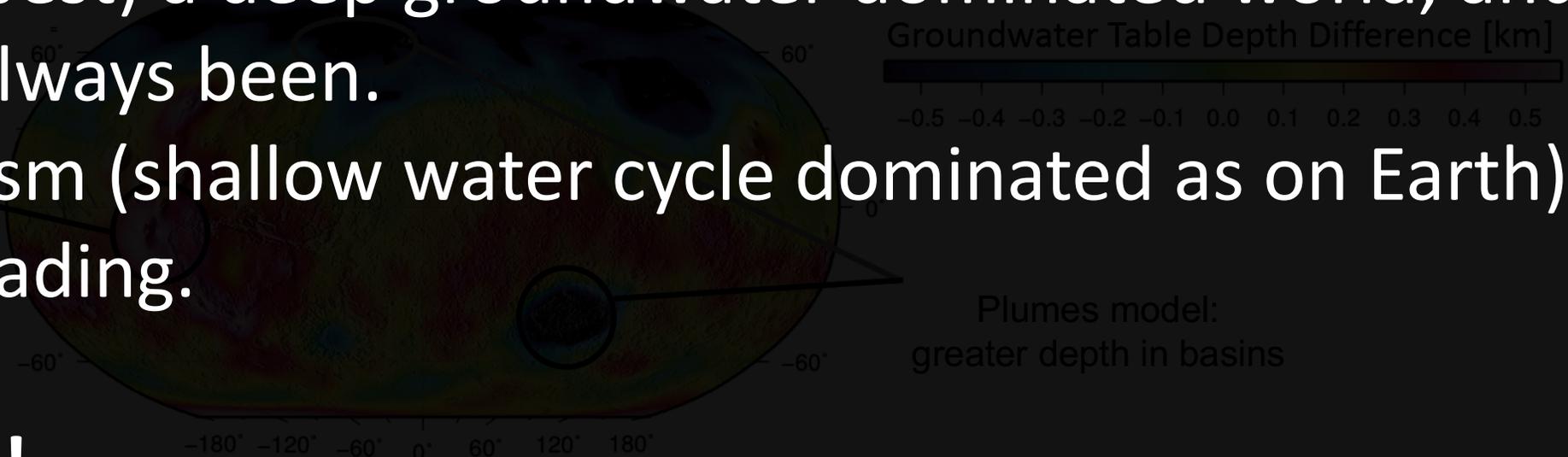


Where is the water: today in 3D



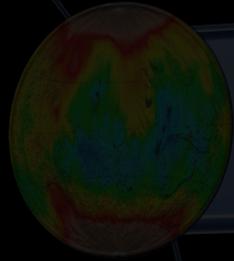
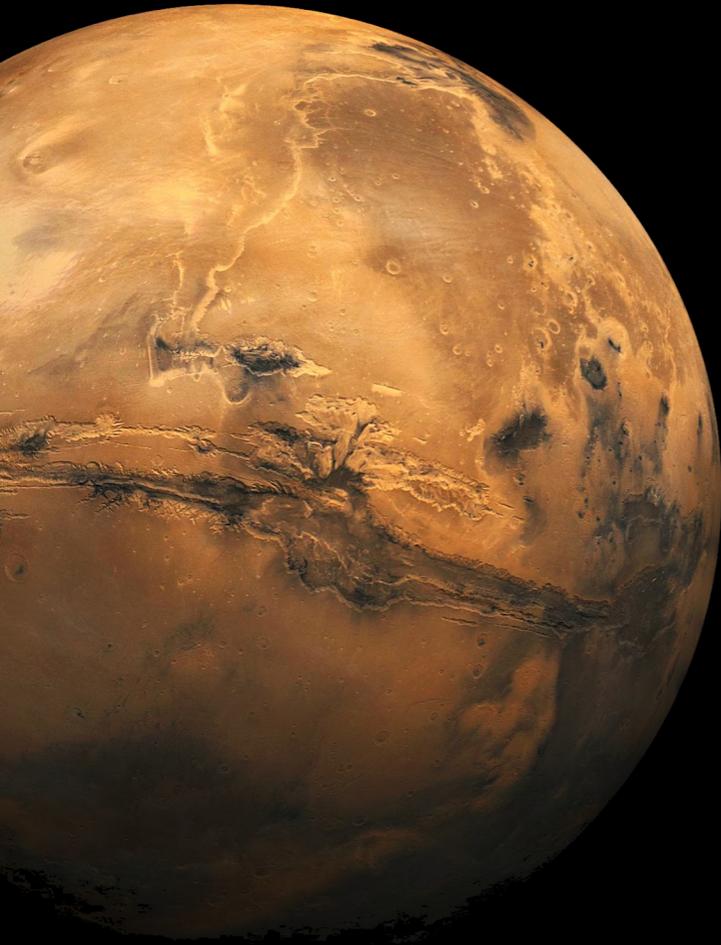
Summary

- Liquid water on Mars today is likely many kilometers deep.
- Mars is (at best) a deep groundwater dominated world, and maybe has always been.
- Geocentricism (shallow water cycle dominated as on Earth) can be misleading.



We need data!

- Technology to (finally) find liquid water.
- Missions.



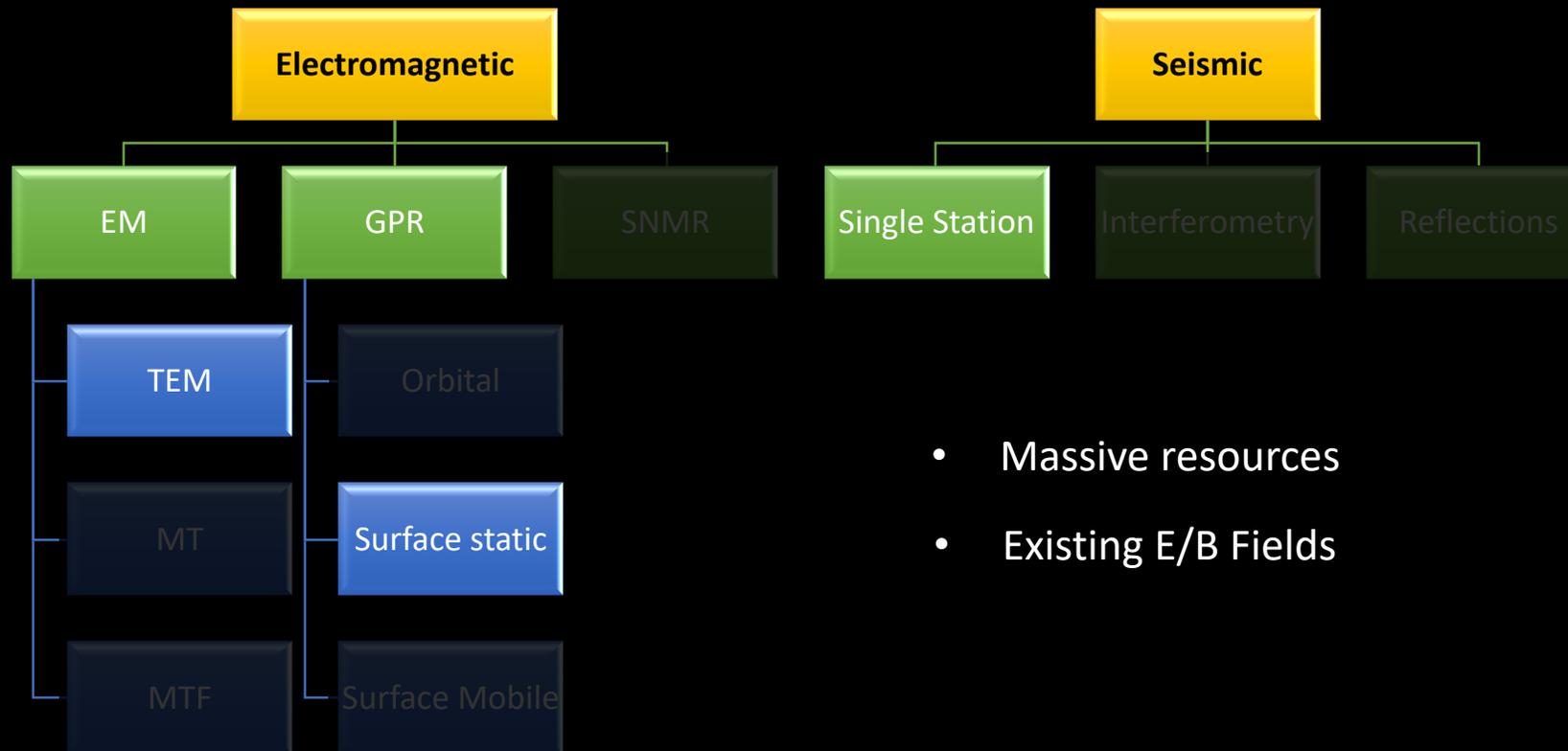
Where's the liquid water?



Tech to find it



Missions to constrain it



- Massive resources
- Existing E/B Fields

Where is the liquid water: TH₂OR (Transmissive H₂O Reconnaissance)

Stamenković +, Nature Astro (2019)



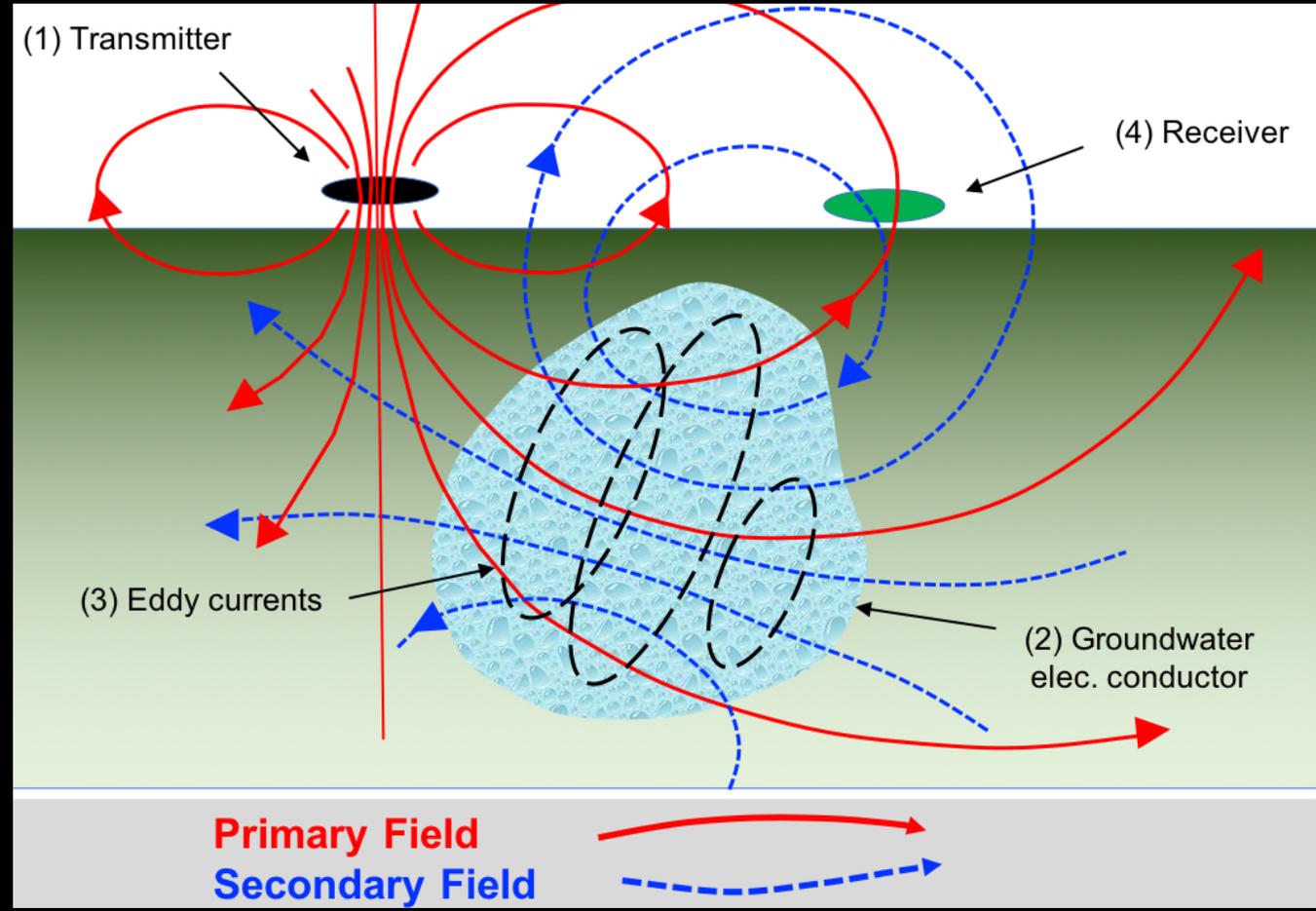
Earth

Typical Earth crust: 10^{-2} S/m
 Ocean water: 1 S/m
Contrast ratio: $\sim 10^2$



Mars

Dry Mars crust: $\sim 10^{-7}$ S/m
 Ocean water: 1 S/m
Contrast ratio: $\sim 10^7$

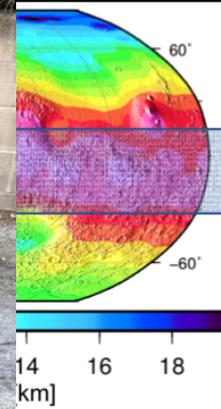
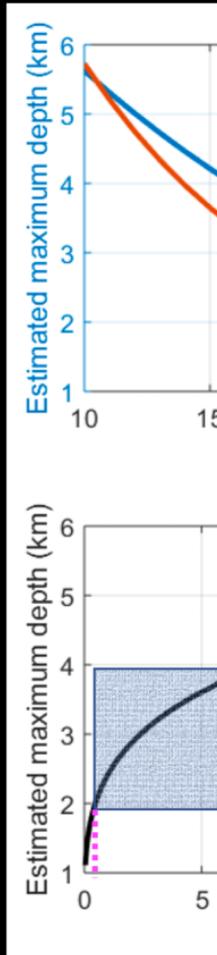


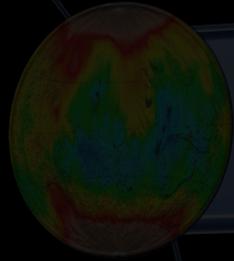
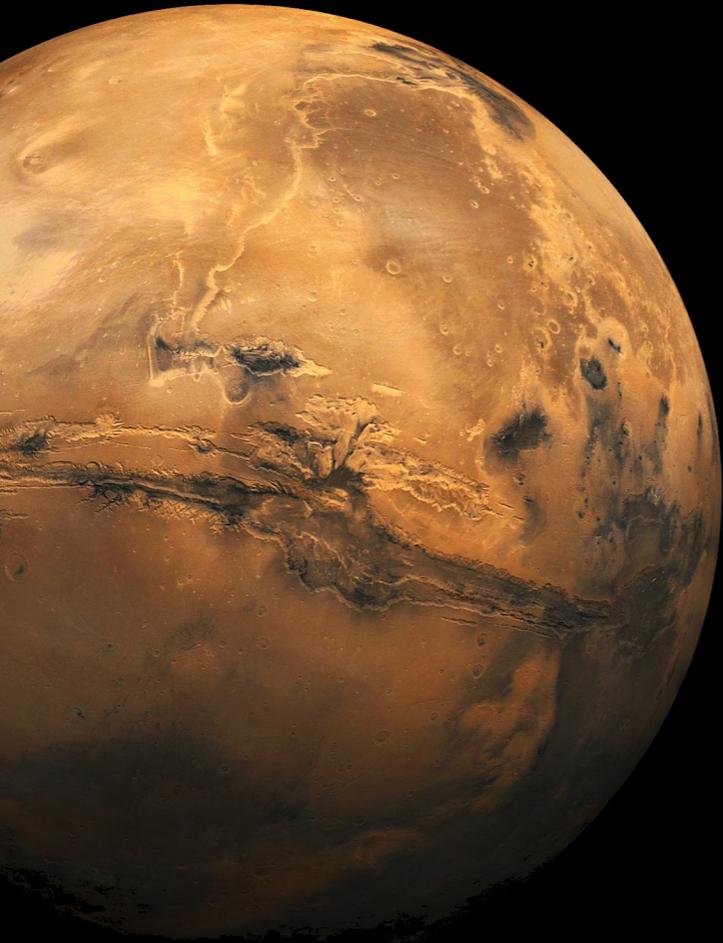
Where is the liquid water: TH₂OR Concept (Transmissive H₂O Reconnaissance)



Objectives

- Uniquely sound from the Martian surface for groundwater, expected to be at depths as large as 1-30 km, using an EM system and determine its salinity.
- Small-spacecraft compatible (<10 kg)

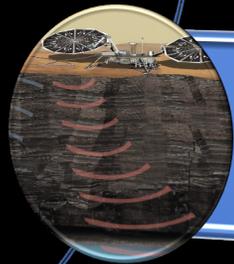




Where's the liquid water?



Tech to find it



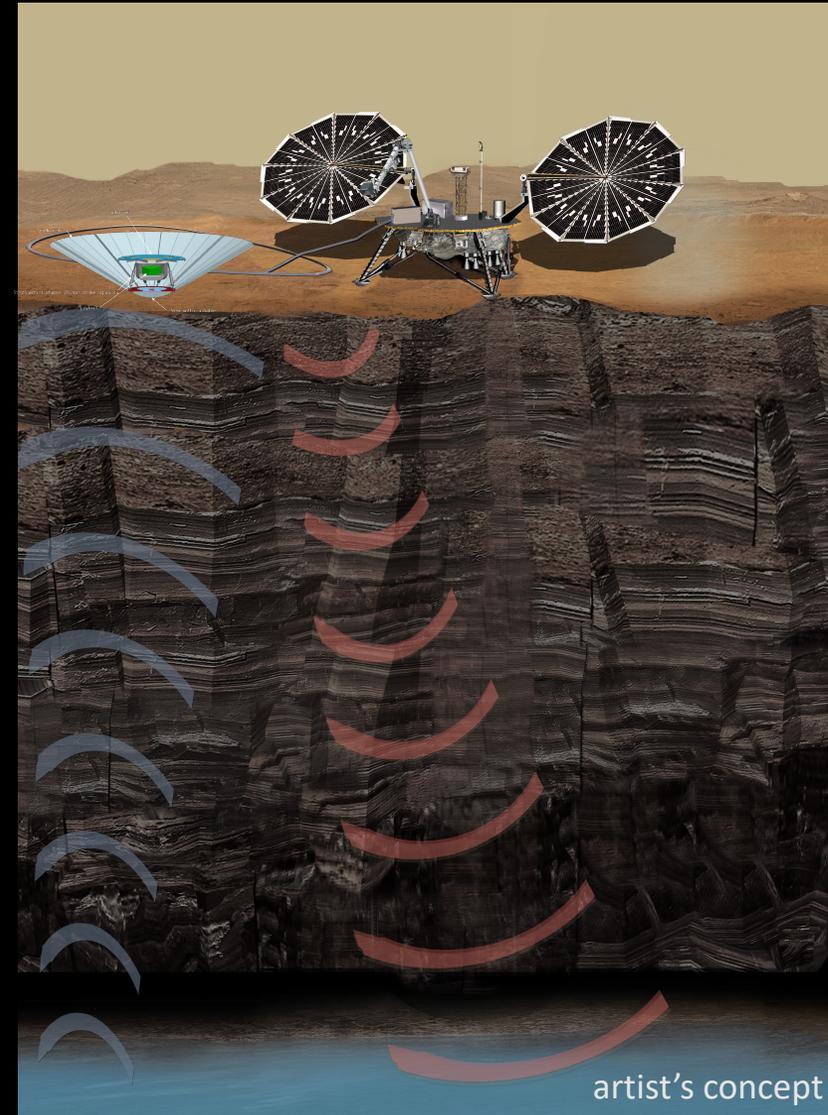
Missions to constrain it

Where is the liquid water: TH₂OR Concept (Transmissive H₂O Reconnaissance)



Objectives

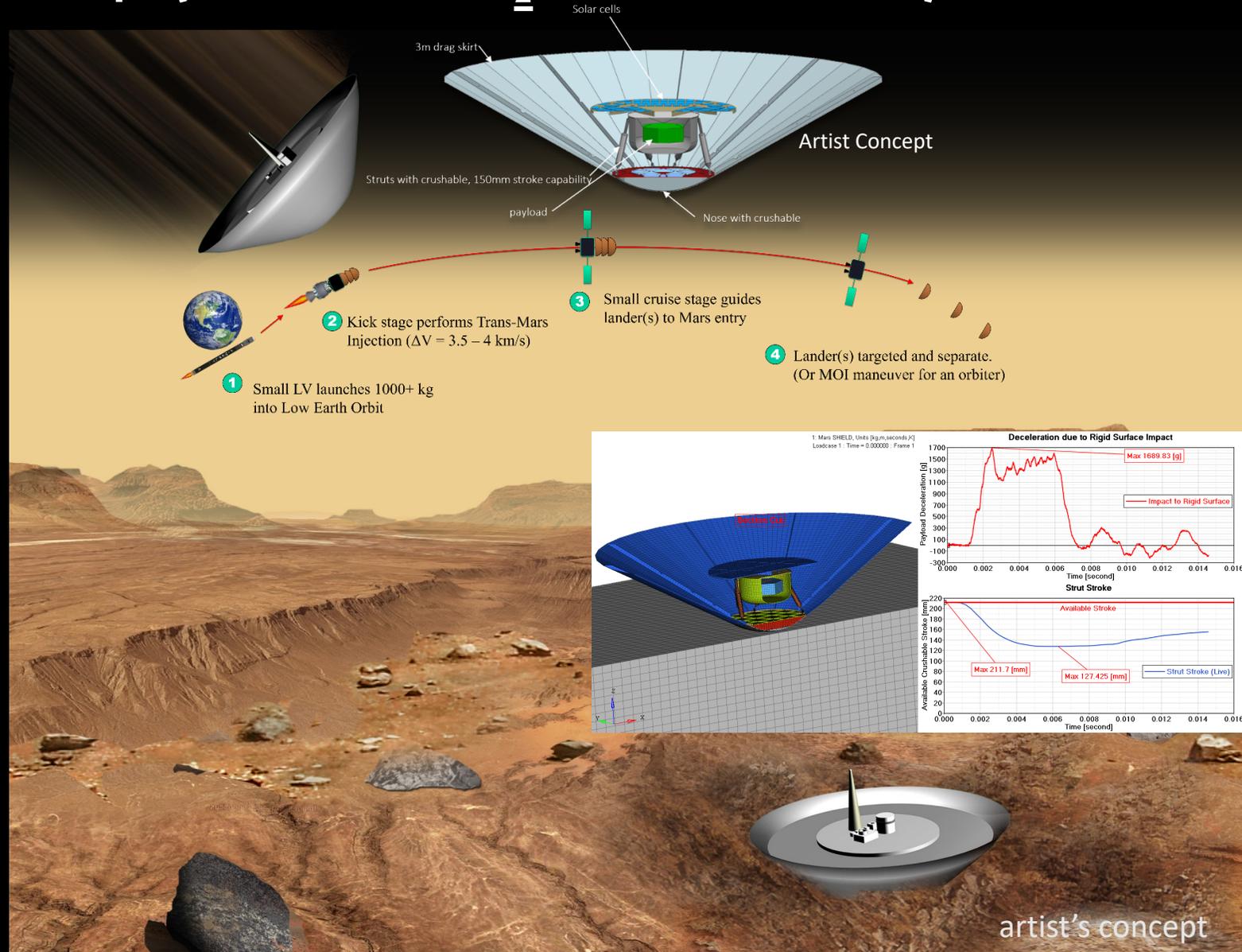
- If heritage-based system: Phoenix-type lander.
- Small-spacecraft compatible (<10 kg): SHIELD



Where is the liquid water: TH₂OR Concept (Transmissive H₂O Reconnaissance)

Small High Impact Energy Landing Device SHIELD enables the transportation of small scientific payloads affordably to the surface, such as TH₂OR.

- Landed Mass: 50 kg
- Entry speed: 60 m/s
- Impact load range 1000 g – 2000 g.
- Total science payload up to 6 kg.
- Hosted, secondary, or dedicated P/L configurations.
- Investigating options for mobility.
- Expected Mission Duration range from 90 sols to 1 Martian year (latitude dependent)



THANK YOU!



- Thermodynamics rules: Liquid water is more feasible at ~kms depth.
- Locally, shallower brines could exist.
- High water activity only possible at larger depth.
- Deep habitable zone?
- We must be careful not to be too geocentric!
- We could use low-mass instruments to sound for liquid groundwater and constrain its chemistry. → TH₂OR
- Small SHIELD crash landers and Phoenix-type architectures could be the platform.