

Early Mars Climate

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Summary

1) Context: History of Mars

- Different eons
- Observations
- Young Faint Sun

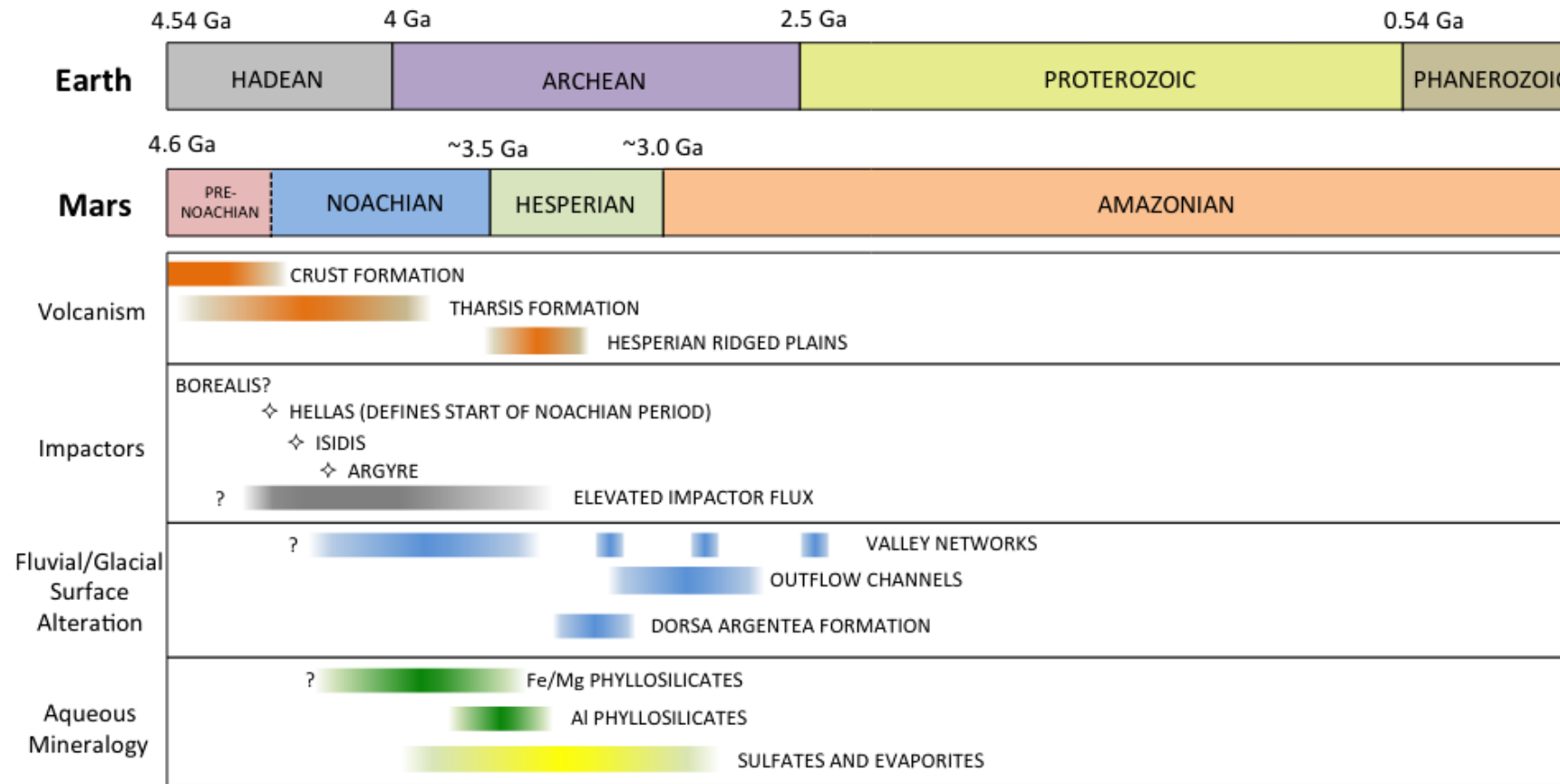
2) Noachian era:

- Atmospheric composition
- Extreme Events
- Topography & True Polar Wander
- Different Scenarios

3) Early Mars climate modeling

- What is a GCM ?
- Previous Studies
- The Mars Evolution Model

History of Mars: Timeline



Wordsworth et al. 2016

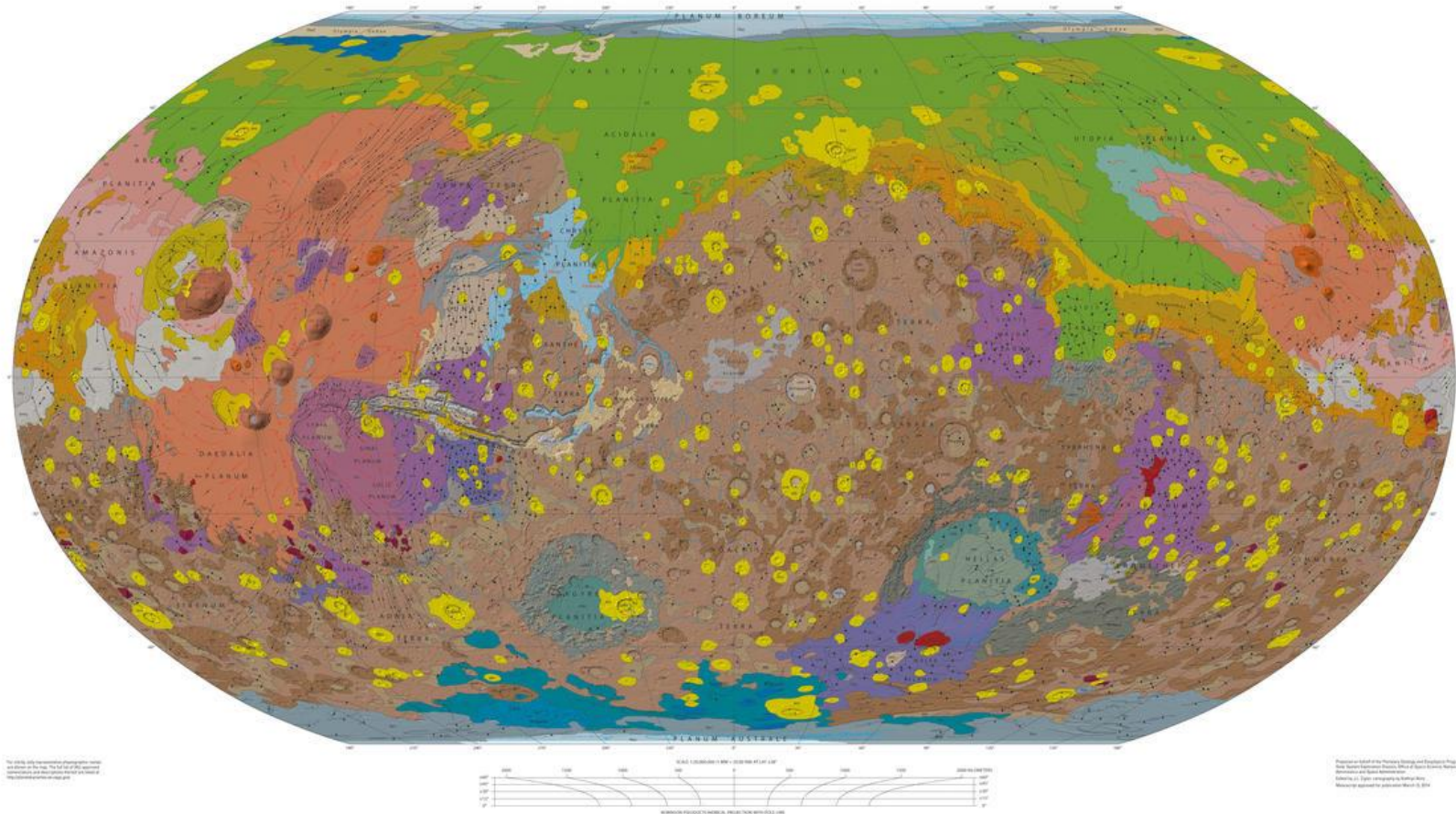
Geologic Map of Mars

Amazonian/Hesperian ?
Terrains

Tharsis buldge

Impacts

Noachian Terrains



<https://doi.org/10.3133/sim3292>

By: Kenneth L. Tanaka, James A. Skinner, James M. Dohm, Rossman P. Irwin III, Eric J. Kolb, Corey M. Fortezzo, Thomas Platz, Gregory G. Michael, and Trent M. Hare
Antony Delavault, February 2022

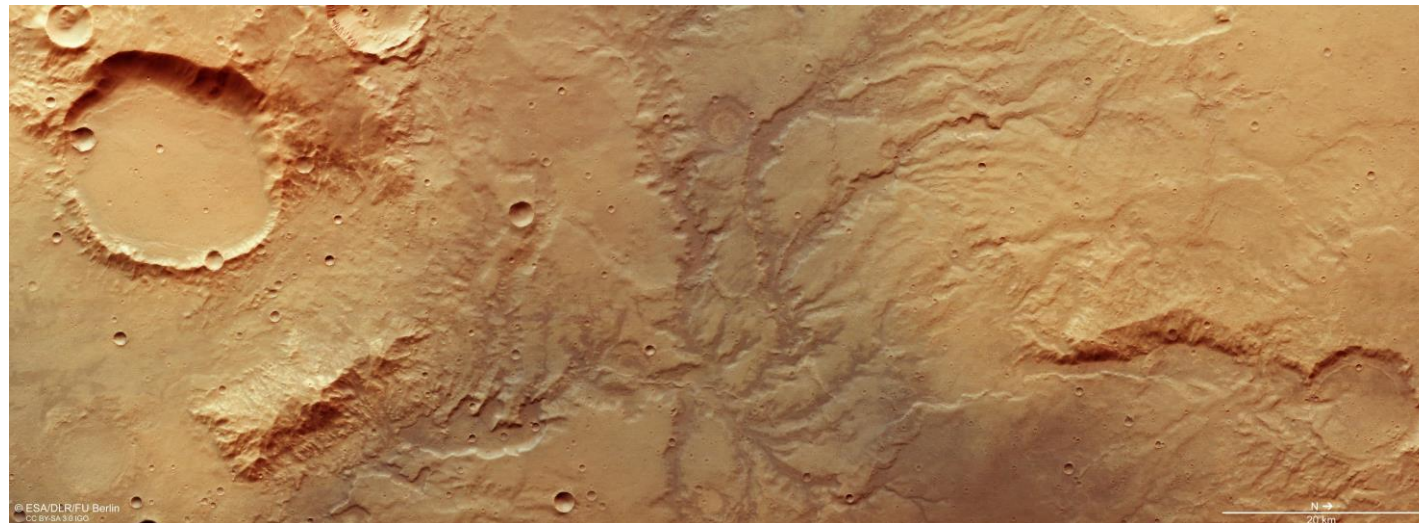
Observations



*Jezero Crater, Perseverance Landing Site
Landing Date: 18/02/2021*



*Gale crater (see Williams et al 2013)
Open/close basin lakes : Fassett and Head 2008*



*By ESA's Mars Express
9 November 2018
66°E/17°S*

Geomorphology

Mineralogy

In-situ analysis

Faint Young Sun

- ~ 3.8 Gya the Sun was 75% dimmer than today (*Cough 1981*)

Mars received $\sim 440 \text{ W.m}^{-2}$ --> BB $T^\circ = 210 \text{ K}$
>65K of GHW (x2 Earth and x9 present Mars)

- Mean semi major axis can not have changed significantly (*Laskar 2004*)

How liquid water is able to form in such conditions ?

Atmospheric Content

Mars atmospheric evolution is poorly constrained

CO₂: dominant, up to 2/3 bar ?

H₂O: initial content ?

Greenhouse gases: CH₄, SO₂, NH₃, H₂, ...

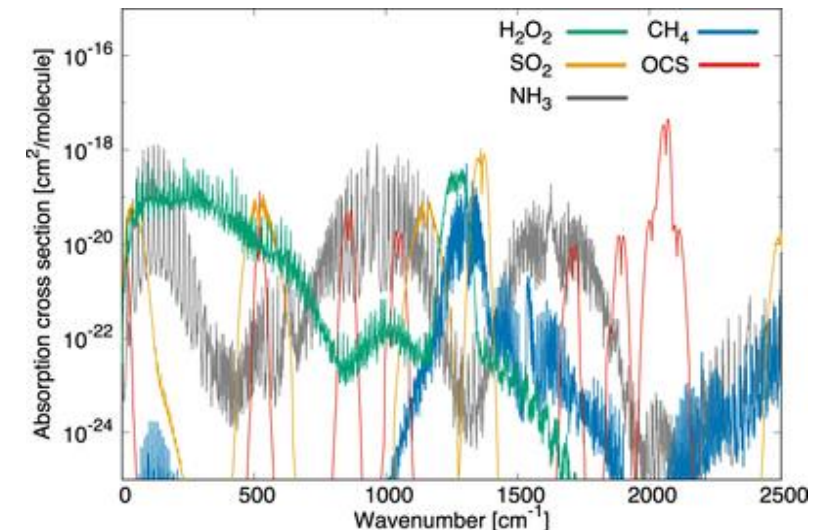
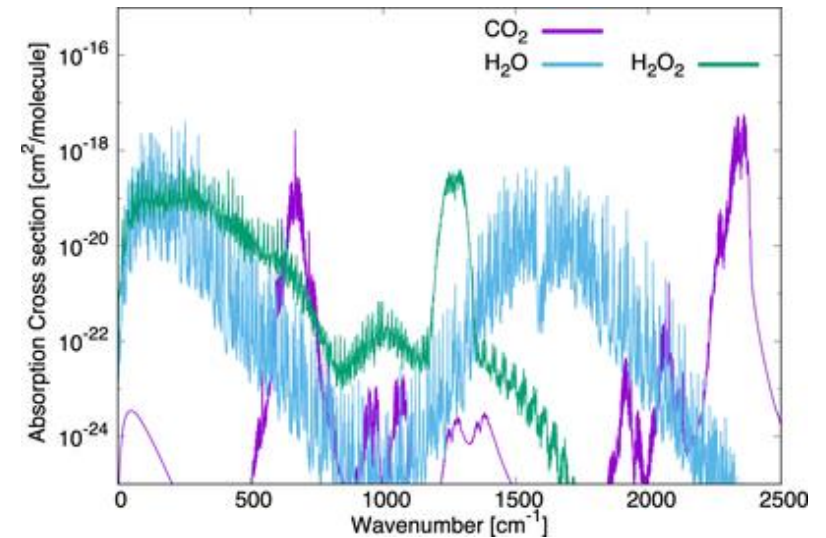
The Noachian saw an evolving atmosphere

Sources: CO₂ from crust, volcanism outgassing,...

Sinks: crust absorption, atmospheric escape,...

"Dense late Noachian atmosphere can only have been removed subsequently by surface processes" Wordsworth et al 2016

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Ito et al 2020

Extreme Events

- Impacts

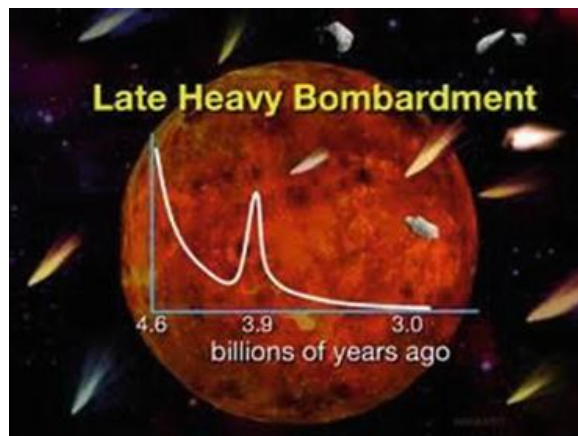
Dating from crater counting :

→ uncertainty (we need samples!)

Surface changes

Source of H₂O, CO₂, ...

Hartmann & Neukum 2001

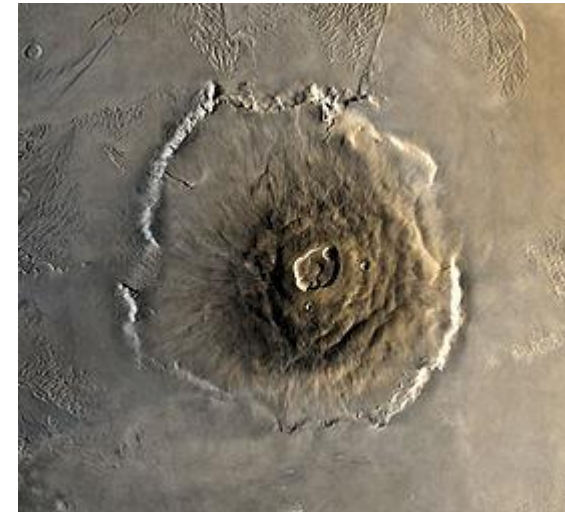


Jonas F.M. (2015) Nature of the Threat / Historical Occurrence.

- Volcanism

Tharsis bulge: True Polar Wander

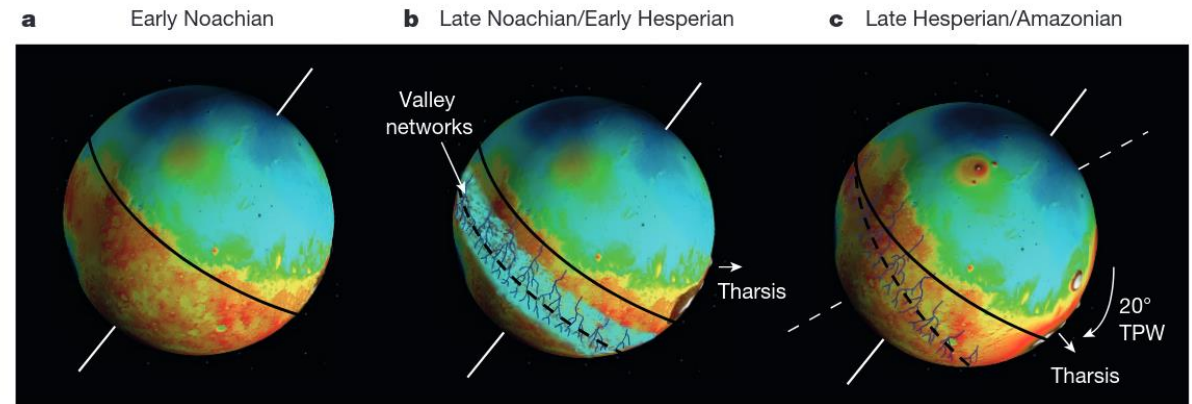
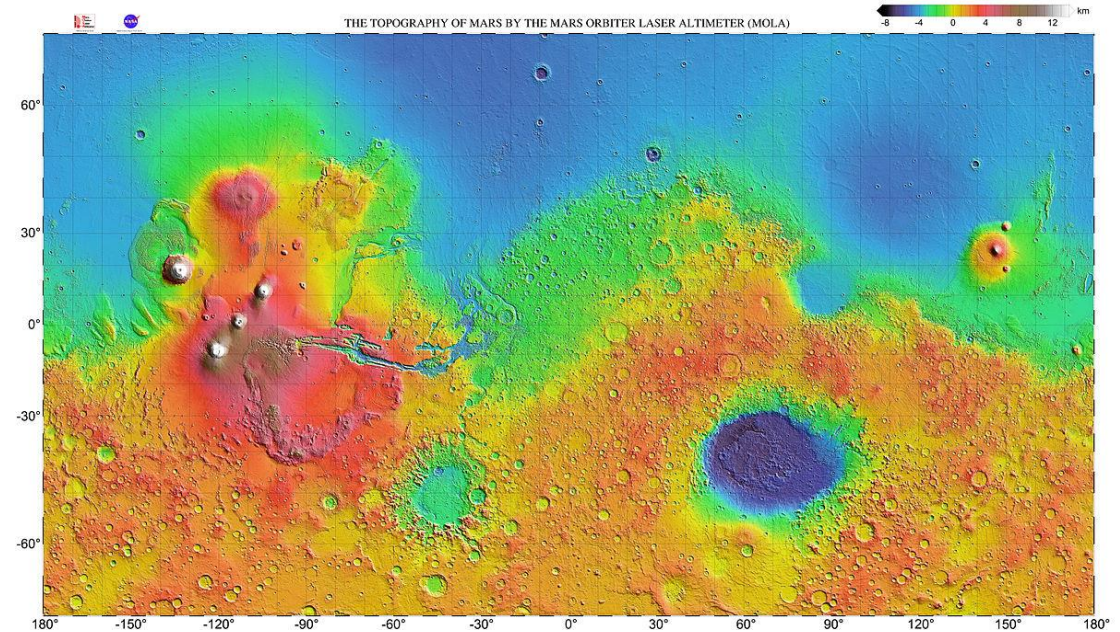
Source of CO₂, SO₂, heat...



Olympus Mons seen by Viking1 1978

Topography

- North-South Dichotomy
- Utopia basin (>4.2Gy)
- Hellas and Argyre basins
- Rising of Tharsis buldge and True Polar Wander started ~ 3.7Gy (Bouley et al. 2016)



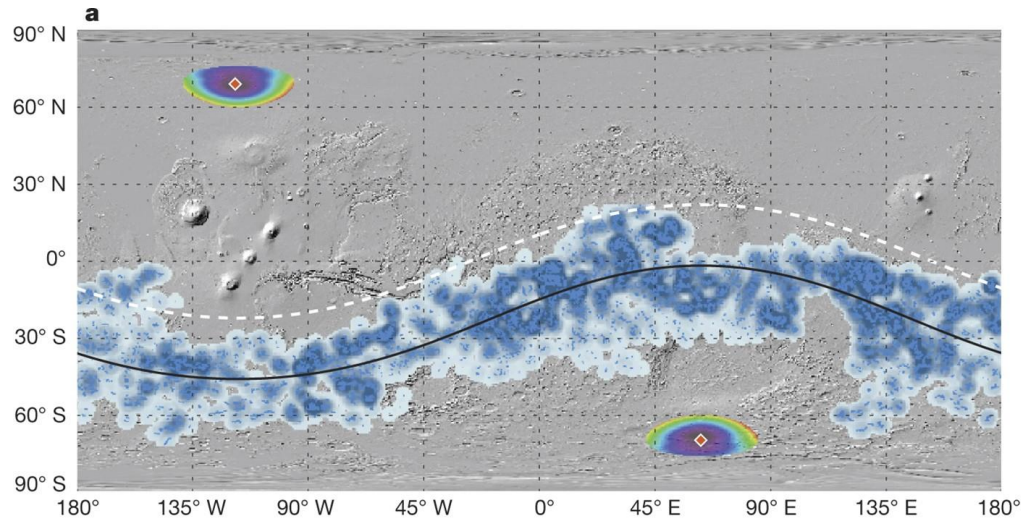
Formation of the dichotomy,
heavy bombardment,
dichotomy boundary in
equatorial position

Tharsis dome formation,
tropical precipitation with valley
networks formation

Tharsis formation causes a TPW,
valley networks on a small circle,
Tharsis bulge on the equator

Valley Networks in pre-True Polar Wander

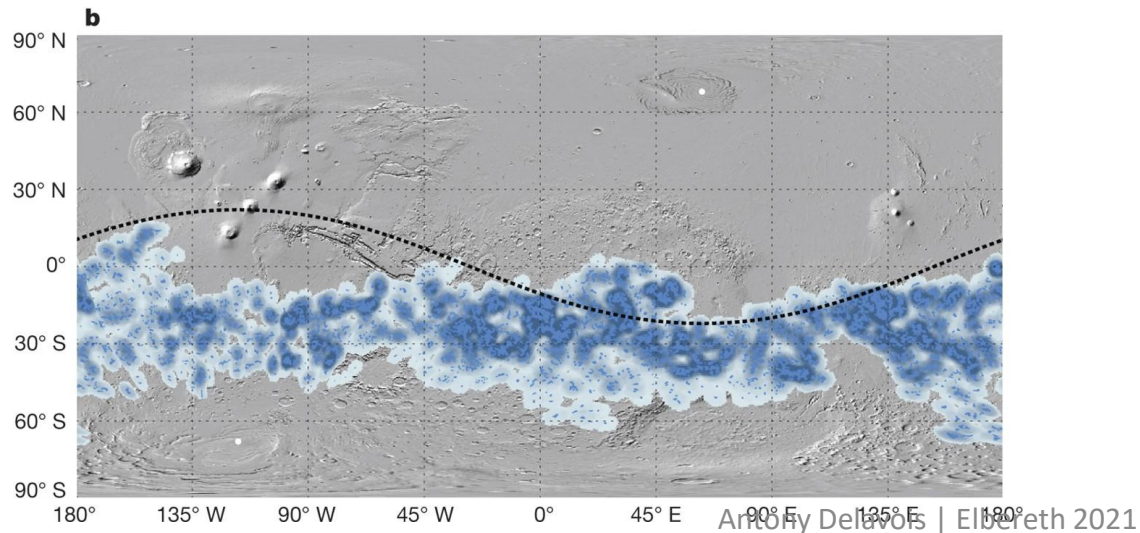
Current topo



Noachian/Early Hesperian
valley networks
distribution and density
before and after TPW.

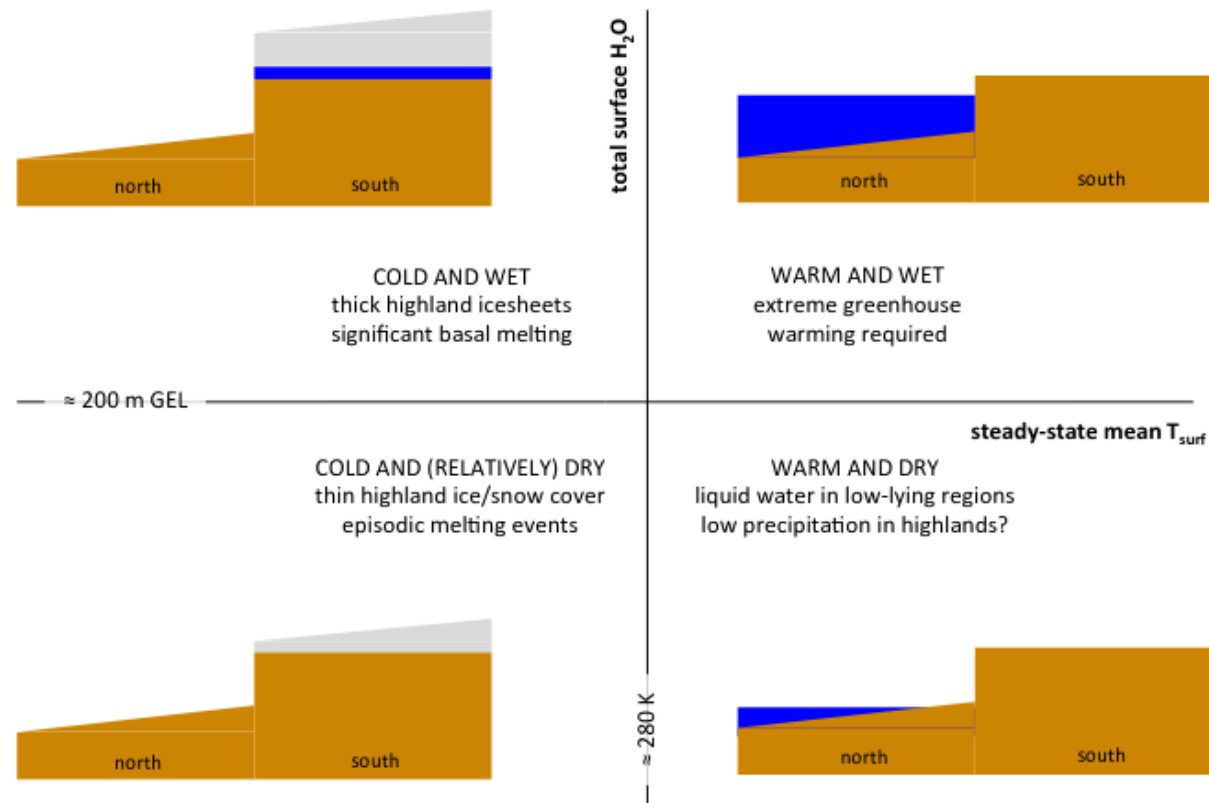
Bouley et al 2016

Pre TPW



Valley networks occur
within a latitudinal band of
 $\pm 14^\circ$ centred at 24° S

Early Mars Climate: Different Scenarios



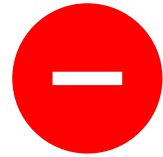
Wordsworth et al 2016

Warm and Wet Early Mars

- CH₄

- SO₂

- NH₃



Kerber et al. 2015, Tian et al 2010,...

- H₂ ?

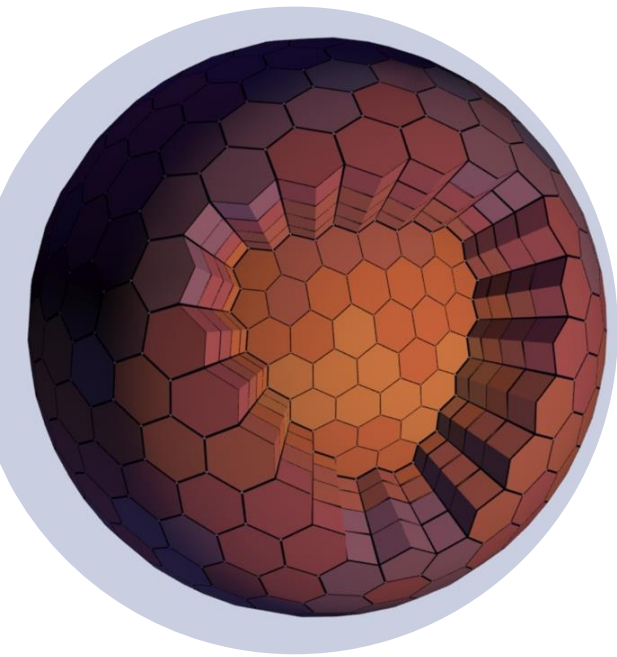


Ramirez et al 2014, Turbet et al 2020

- H₂O₂ (*Ito et al 2020*) / Supersaturated H₂O ?

Modeling the Climate of Mars: GCM

- Global Climate Models (or GCM) developed at LMD



- Dynamics: Solving Primitive Equations of Meteorology
 - Physics: Rad. transfer, turbulence, water cycle, dust cycle...
- > High computational cost : up to 30/40 years of simulation max.

- **How to properly simulate the hydrological cycle ?**

The Mars Evolution Model

- GCM asynchronously coupled to a hydrological model
--> Simulation over thousands years !

Study of lakes and rivers formation

- ERC "Mars Through Time" project leaded by François Forget



European Research Council
Established by the European Commission

Questions ?

BREAKING !!!

Mars during the New MY 36

Credits: Antoine Bierjon

