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Title: From Manhattan to Mars: Applying models of subsurface radionuclide gas seepage from nuclear testing to understand methane release from the Martian subsurface

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From Manhattan to Mars:
Applying models of subsurface radionuclide gas seepage from nuclear testing to understand methane release from the Martian subsurface

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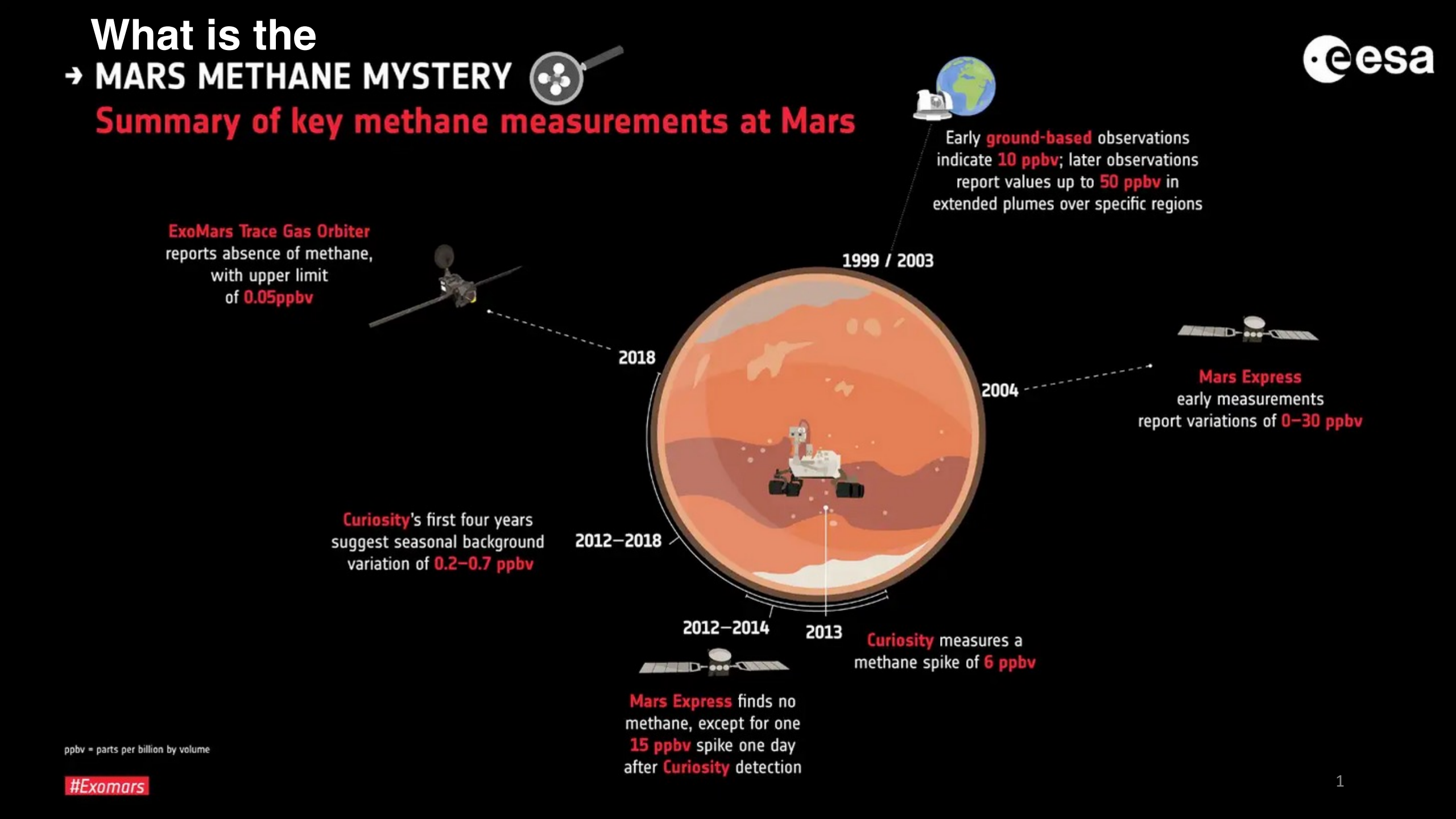
Environmental Health & Engineering Seminar
2 November 2021

What is the

→ MARS METHANE MYSTERY

Summary of key methane measurements at Mars

esa



ppbv = parts per billion by volume

#Exomars

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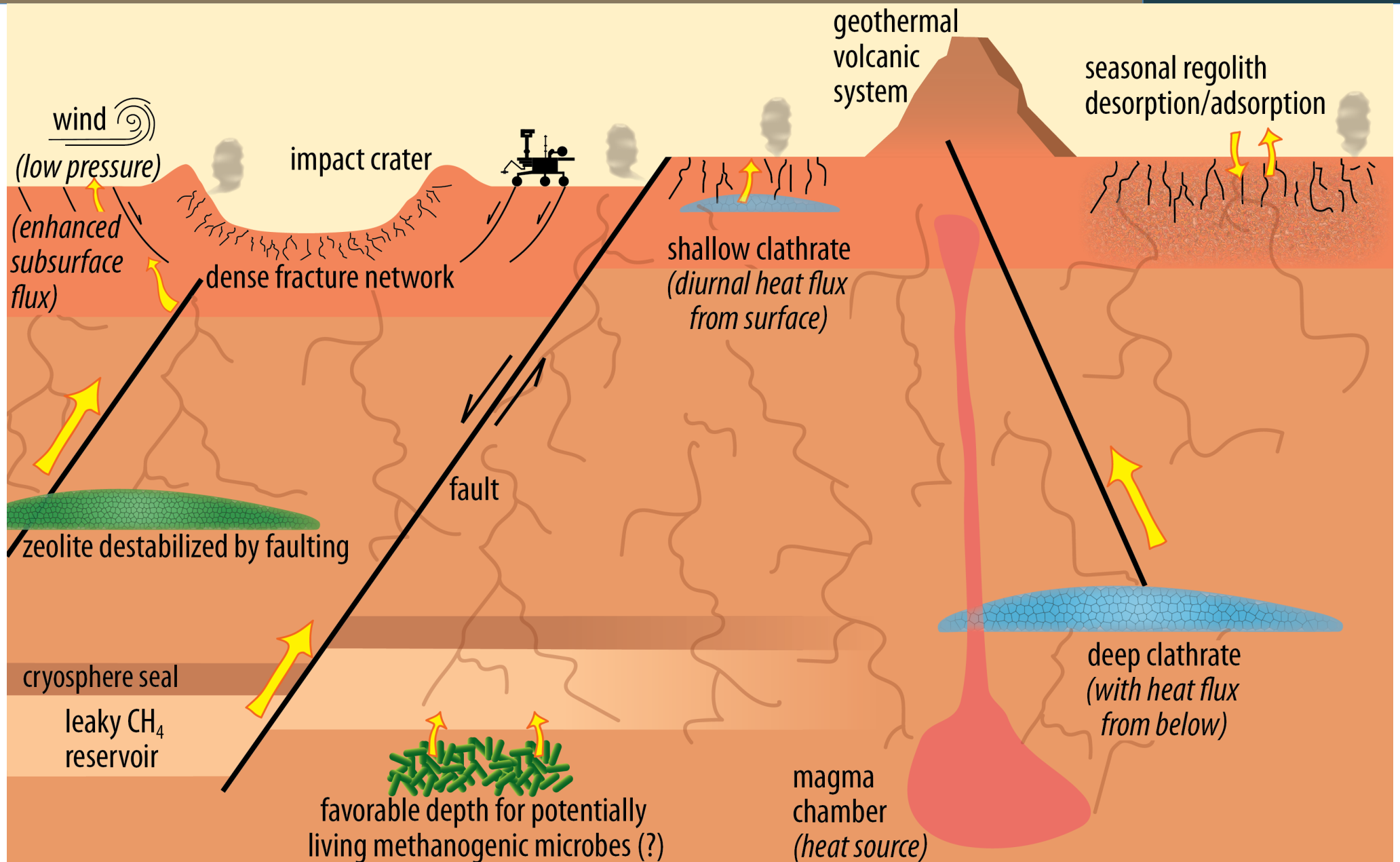
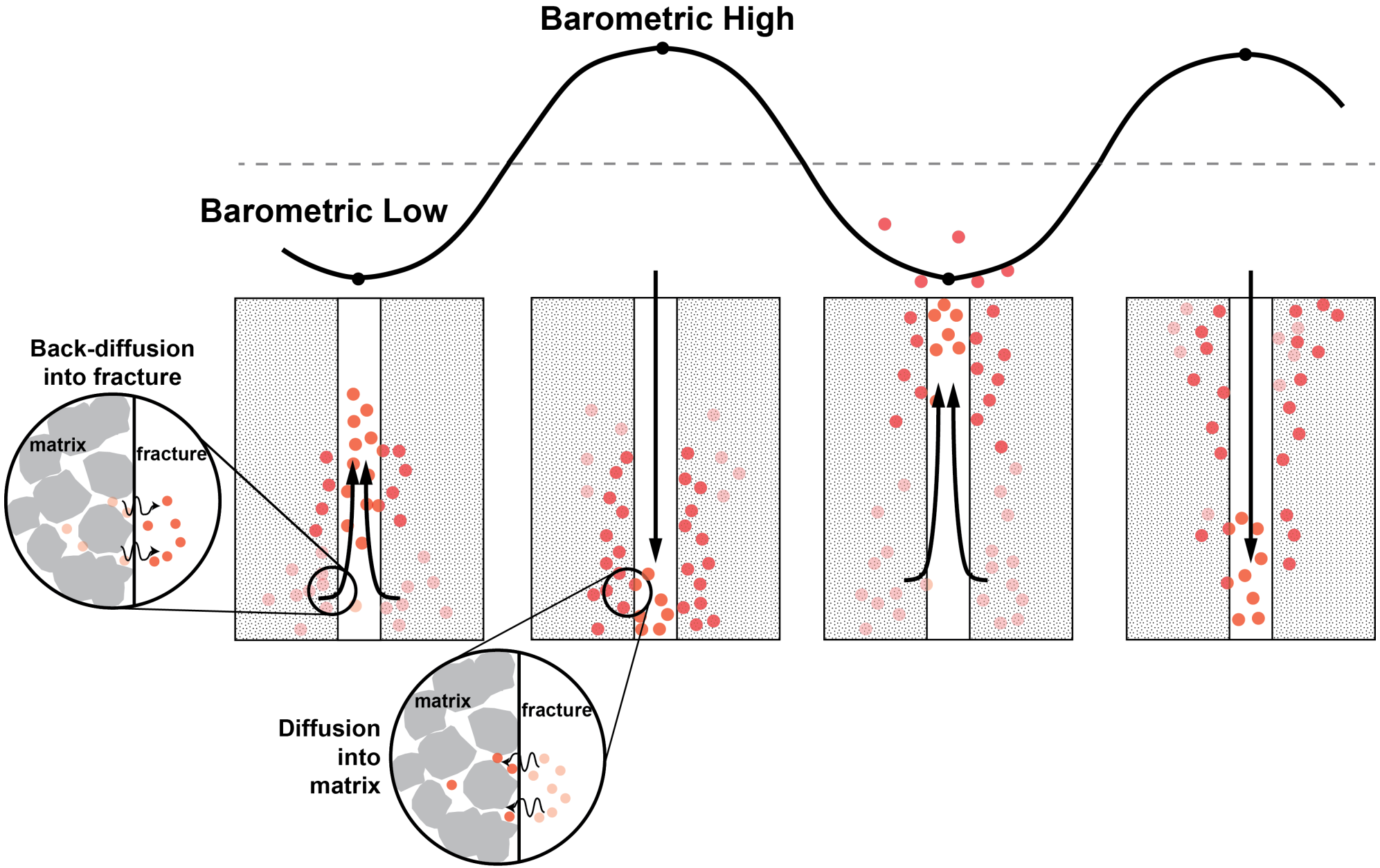


On Earth, barometric pumping enhances subsurface transport



Mars has fractures!

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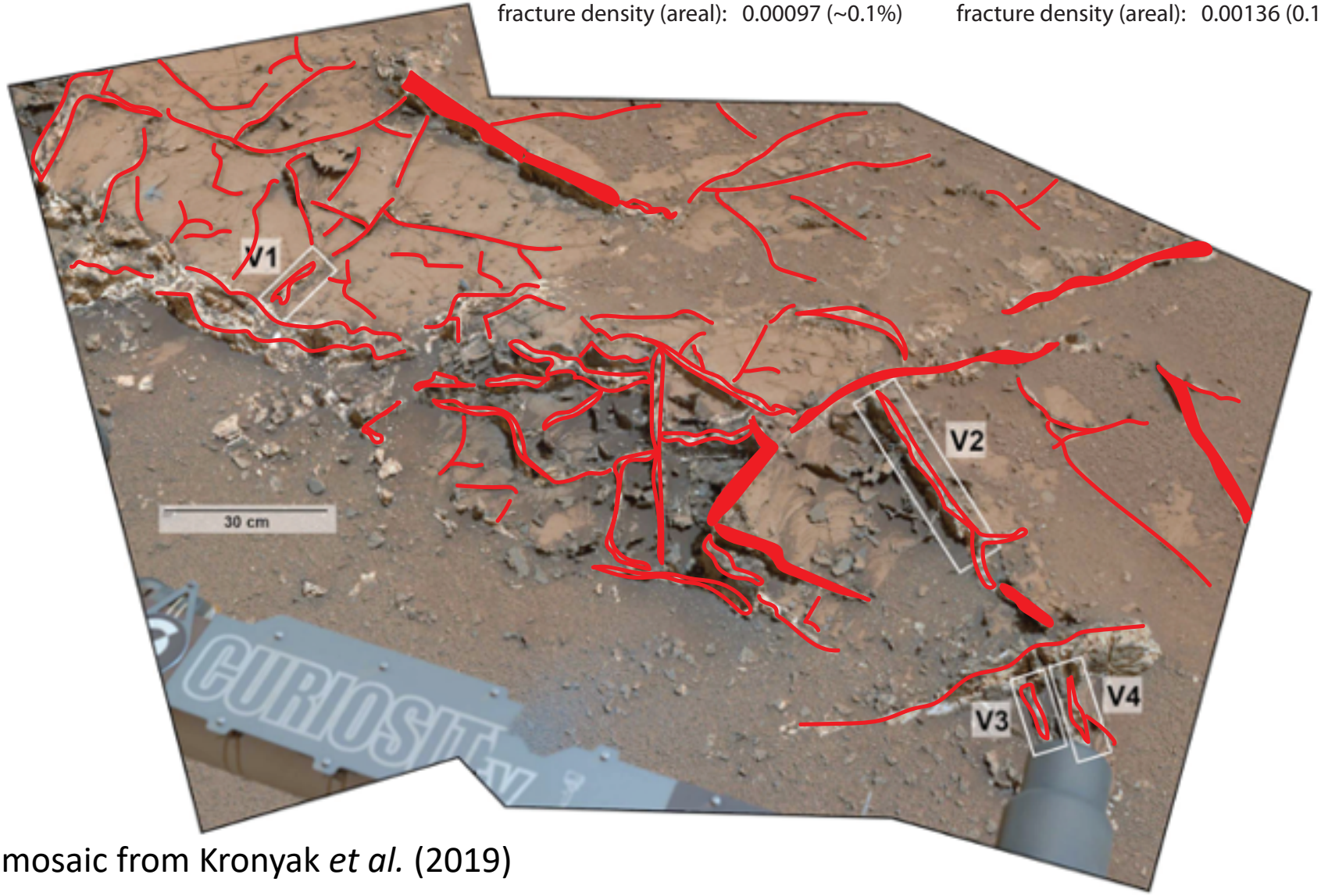
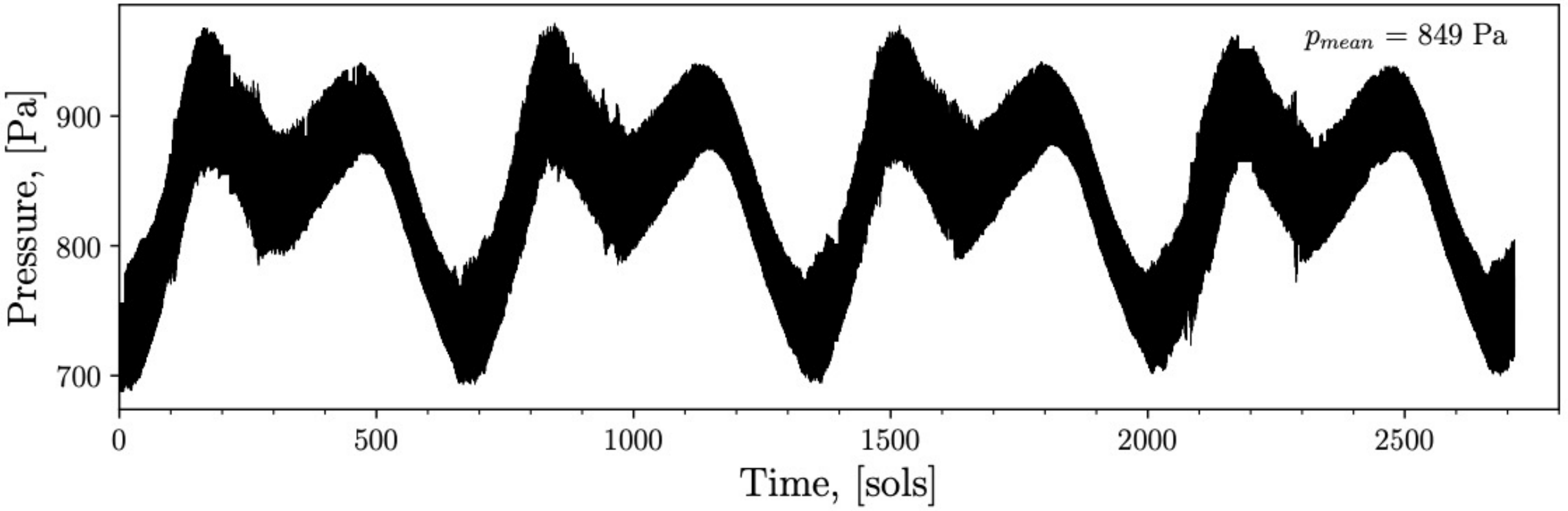
Using entire frame:
total area: 251.531 cm²
fractures: 0.245 cm²
fracture density (areal): 0.00097 (~0.1%)

Using frame of just the fractured area:
total area: 180.142 cm²
fractures: 0.245 cm²
fracture density (areal): 0.00136 (0.1%)



Curiosity Mastcam-34 mosaic from Kronyak *et al.* (2019)

Mars also has barometric fluctuations!



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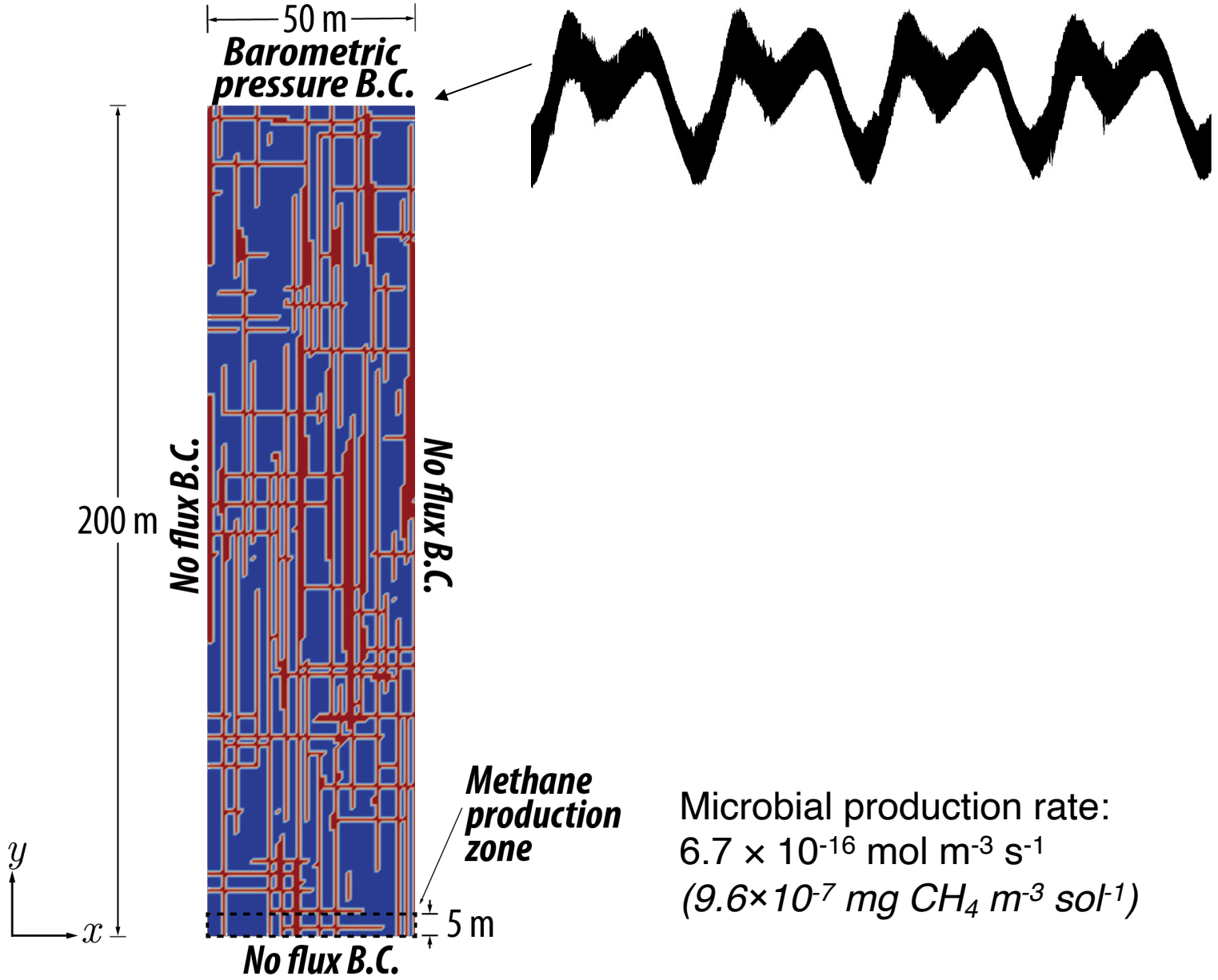
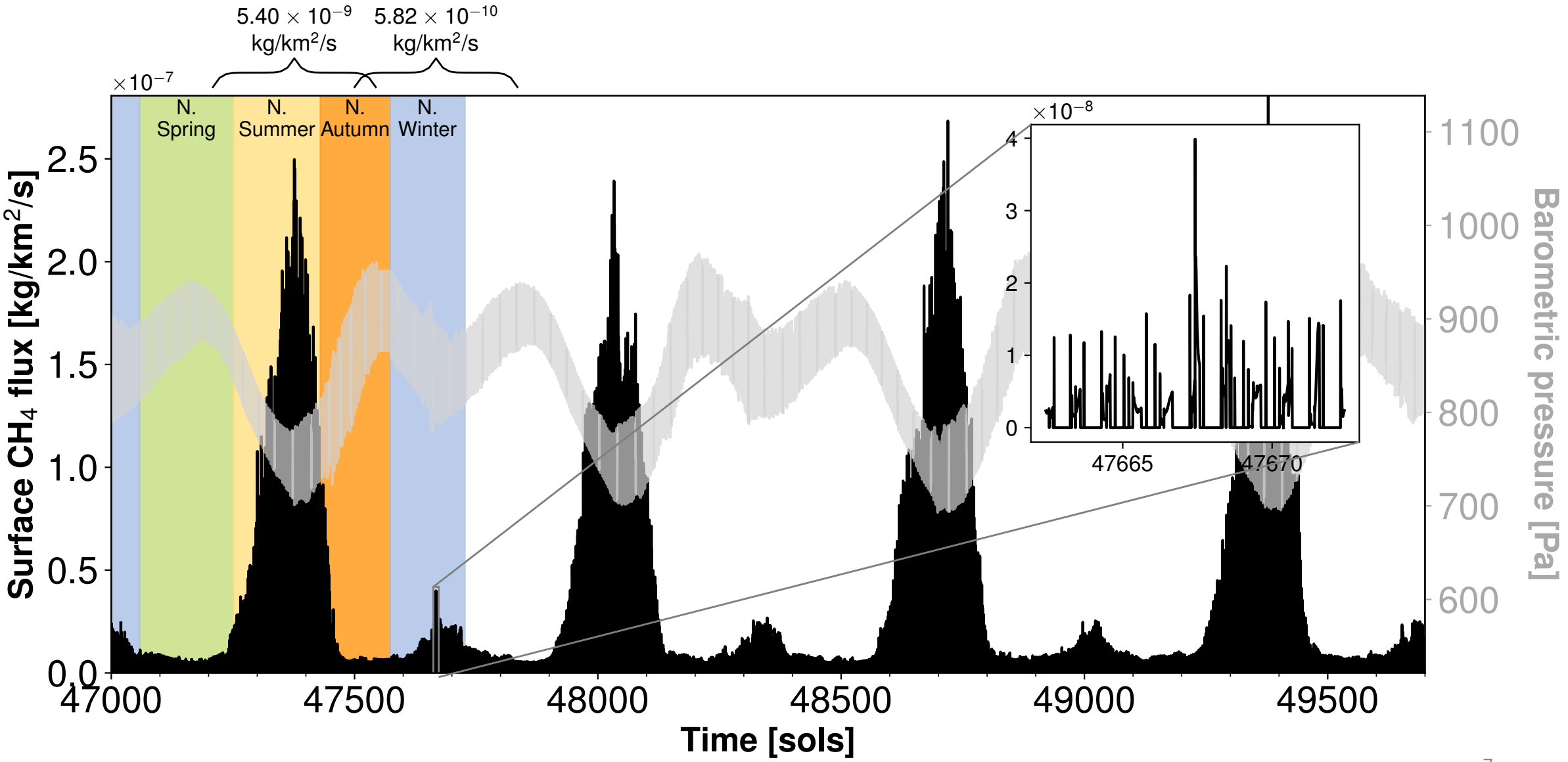


Microbial production rate:
6.7×10^{-16} mol m^{-3} s^{-1}
(9.6×10^{-7} mg CH_4 m^{-3} sol^{-1})

Significant surface CH_4 flux at steady-state



Fluxes are consistent with literature estimates

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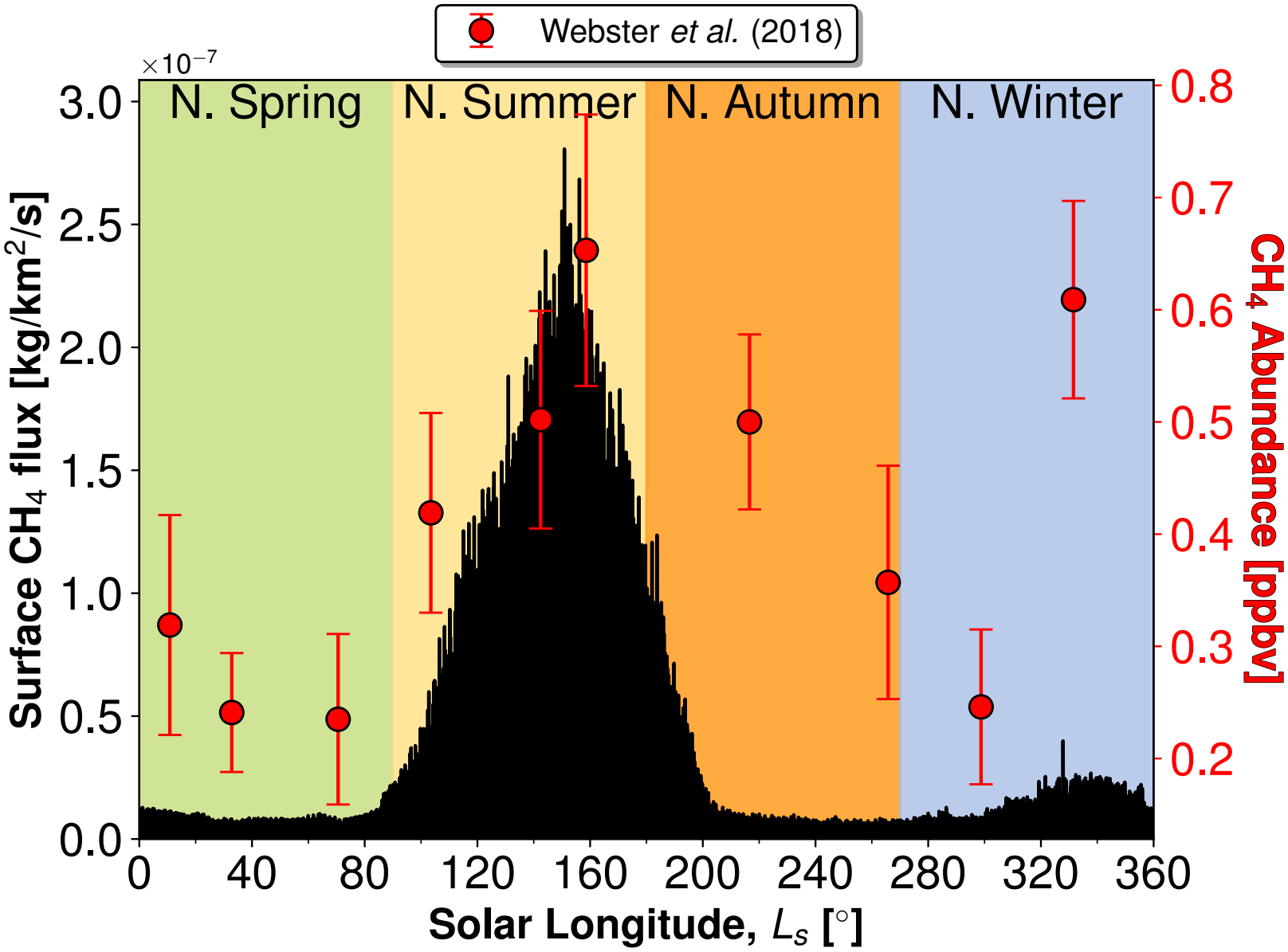
	Time-averaged flux 10^{-8} [kg·km^{-2}·s^{-1}]		
	Window duration		
Case	**58 sols**	**117 sols**	**334 sols**
base case	1.32	1.15	0.54
high k_m	1.26	1.12	0.57
low k_m	1.13	0.97	0.47
low ϕ_m	1.56	1.33	0.63
Moores, Gough, et al. (2019)			0.84*
Formisano et al. (2004)			0.002†

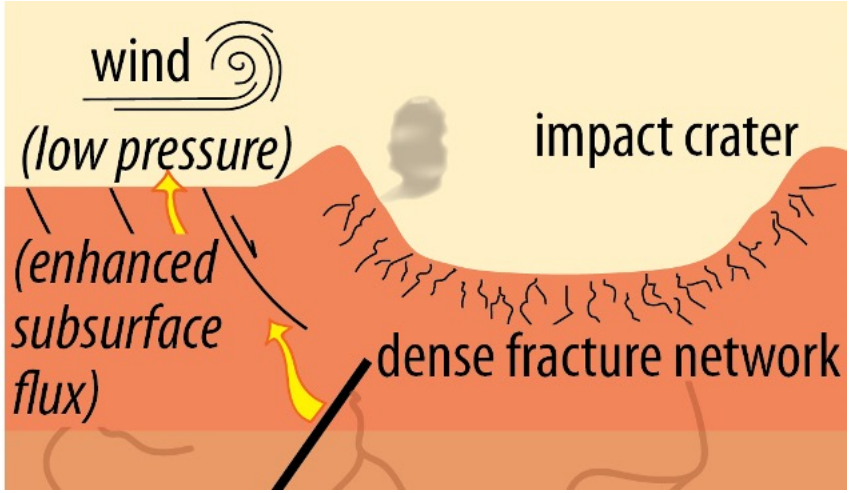
* Upper limit assuming seepage restricted to Gale Crater.
†Assuming continuous, uniform planet-wide seepage

Our fluxes reproduce seasonality of atmospheric abundance



Future work

- Investigate a wider range of methane release mechanisms
  - More advanced physics
- Develop a coupled atmosphere-subsurface model
  - Will allow us to investigate interaction between wind and topography (i.e. Bernoulli) →
  - Code will be made available as Open Source



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Extra Slides

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Future research directions

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- Extension of dominant transport frequency to fracture *networks*
- Sorption processes
- Gas flow/transport in deformable fractures
- Subsurface gas flow/exchange on Mars