Brines on Mars:

Implications for Liquid Water & Planetary Protection

Edgard G. Rivera-Valentín

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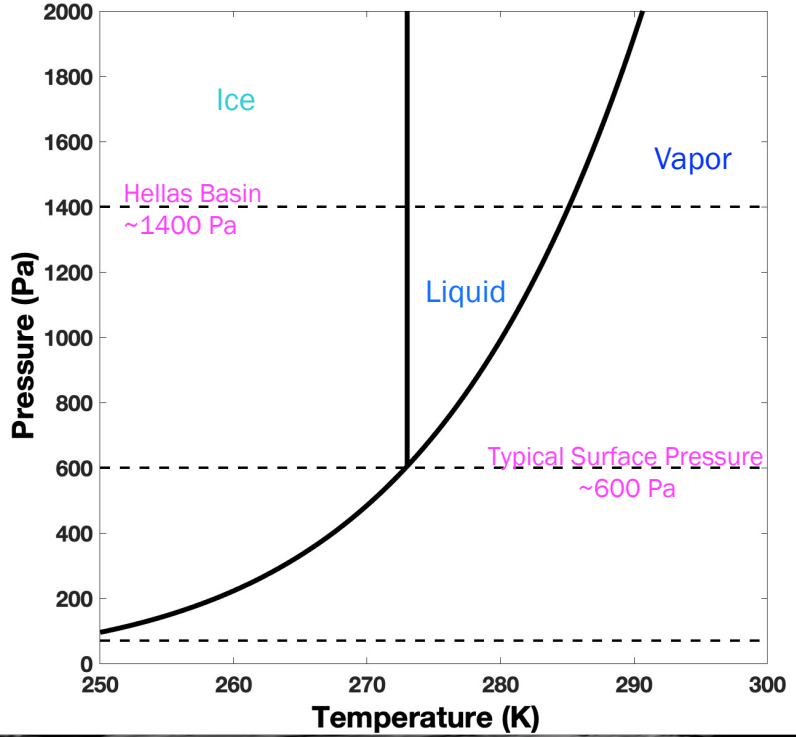
Early Thoughts on Water On Mars



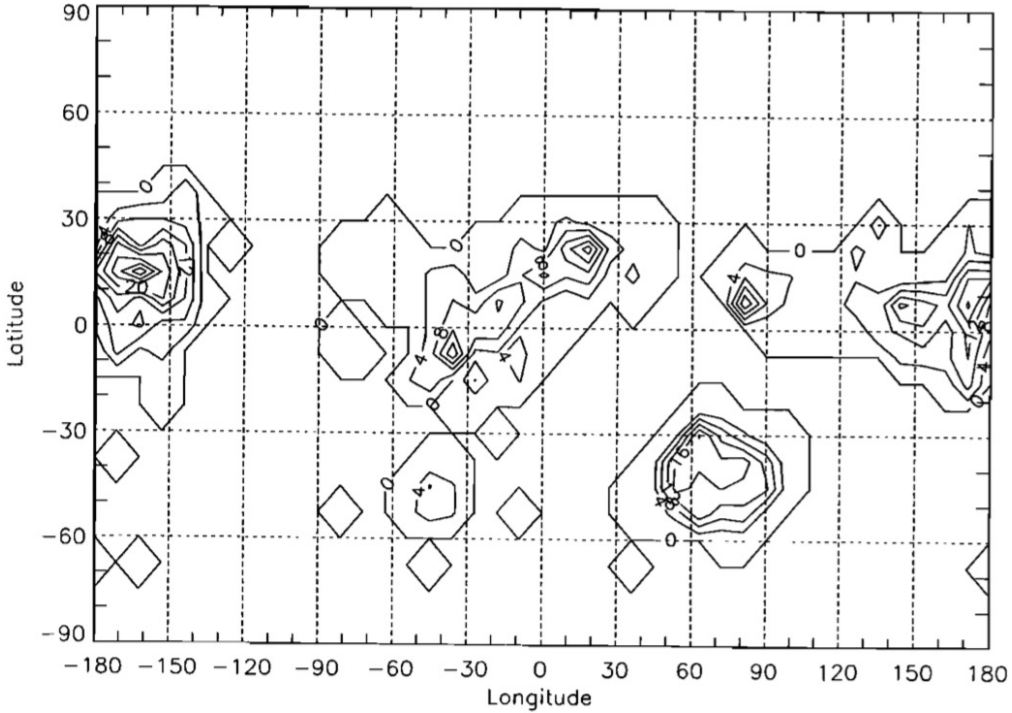


Image Credit: Figure 5; Haberle et al. (2001)

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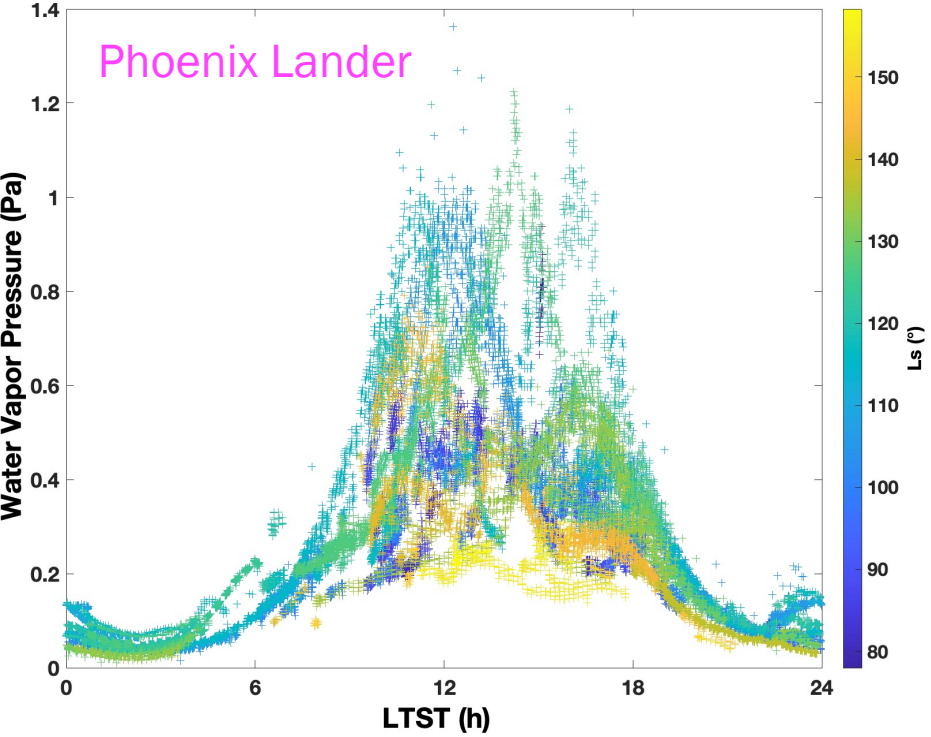
Insights From In-Situ Measurements



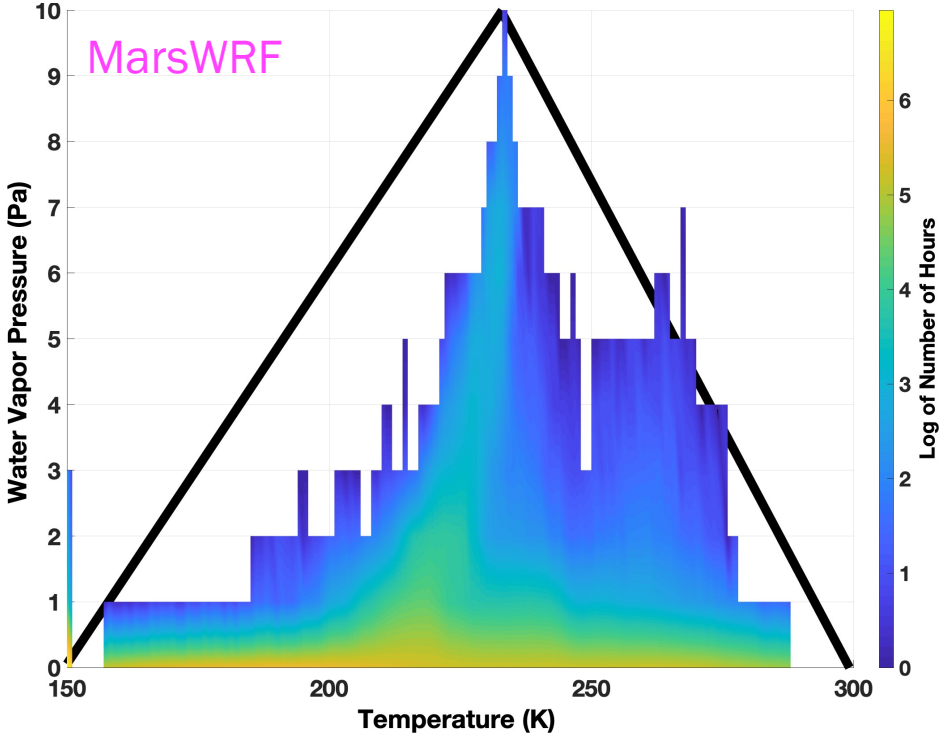


Image Credit: Extended Data Fig. 1; Rivera-Valentín et al. (2020)

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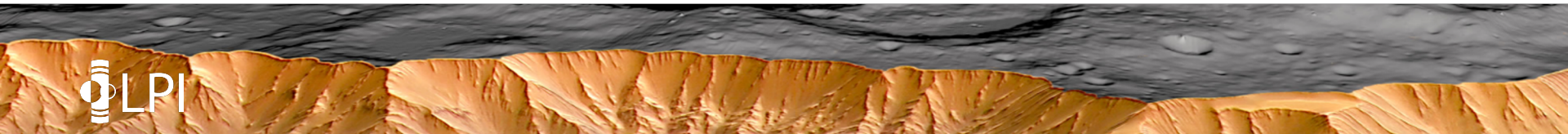
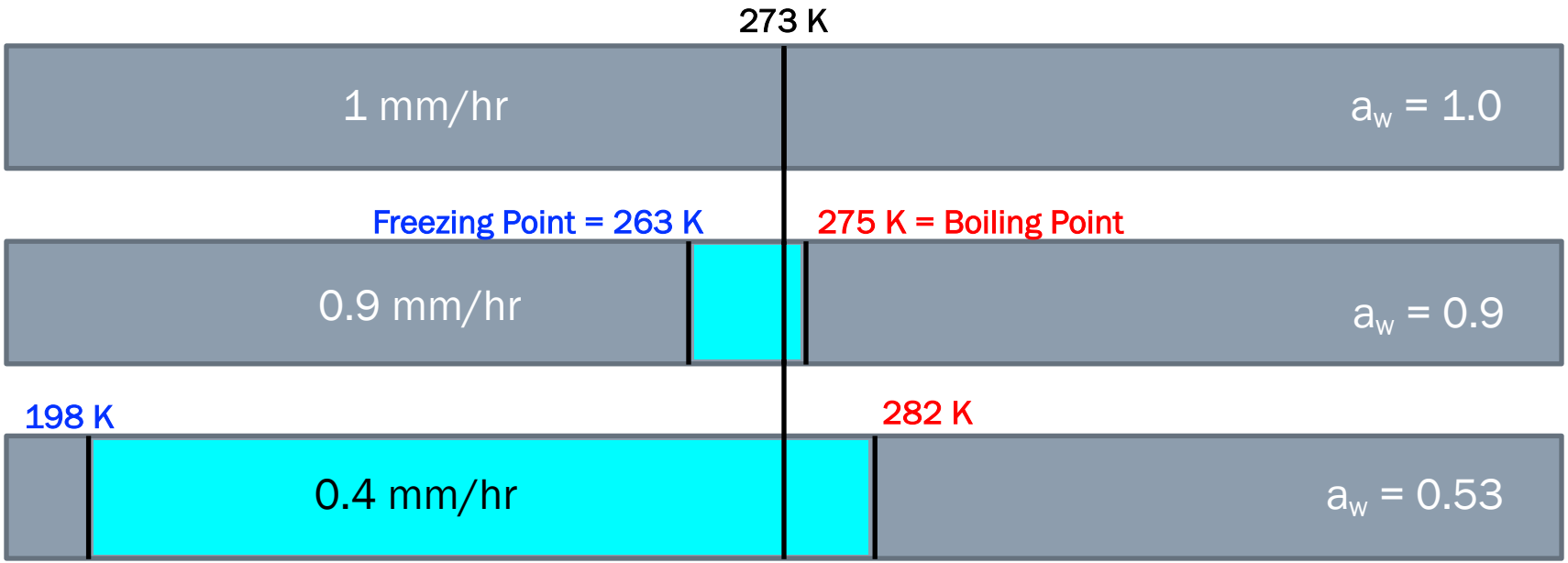
Brine Experiments

Image Credit: *C. Dundas/NASA/JPL/USGS*

University of Arkansas, University of Colorado, University of Michigan
Vincent Chevrier, Erik Fischer, Raina Gough, Jennifer Hanley, Germán Martínez, Danielle Nuding, Katherine Primm, Nilton Renno, Rachel Slank, Margaret Tolbert



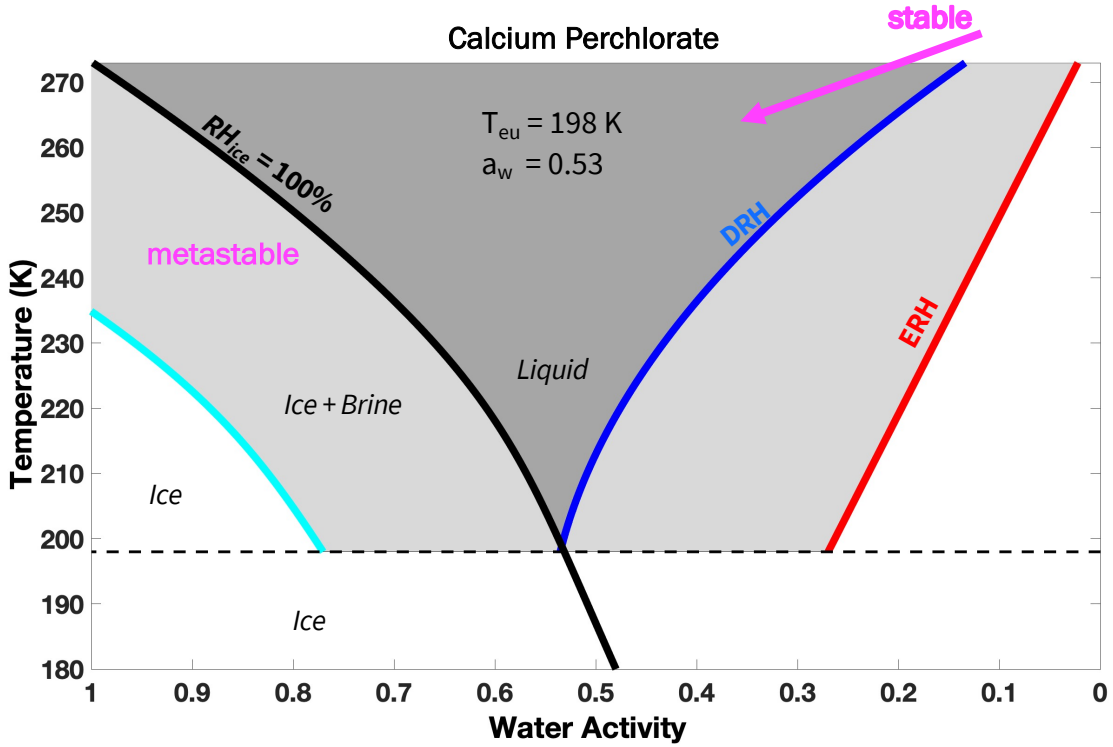
Brines & Freezing, Boiling, and Evaporation



Deliquescence

Lowell Observatory

Phase Diagram - Deliquescence



DRH = Deliquescence Relative Humidity

ERH = Efflorescence Relative Humidity

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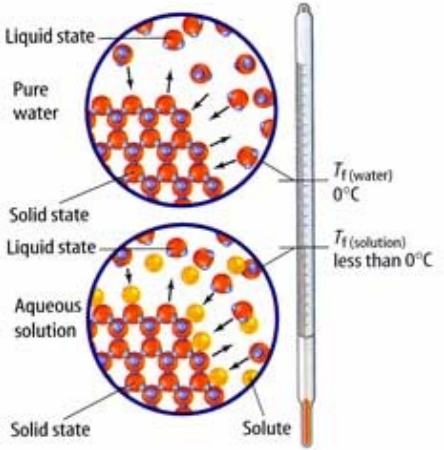
Water Activity

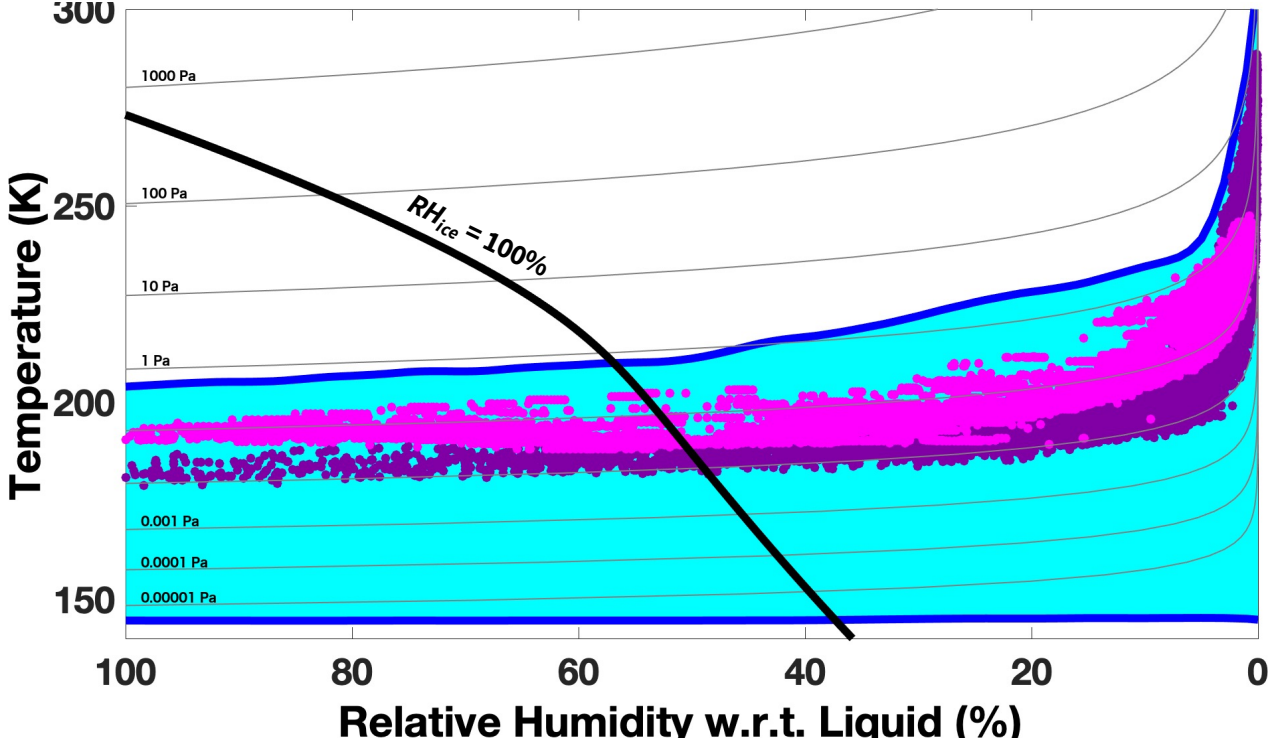
- Definition: A measure of the amount of free water molecules in a liquid.
- The Math: $aw = \frac{e_b}{e_{sat}}$



- Water activity is related to salinity (amount of salts in solution).
  - aw = 1 => pure liquid water
  - aw = 0 => pure salt

- At equilibrium with an atmosphere: $aw = \frac{e_b}{e_{sat}} = {RH_l}/{100}$

Mars Climate



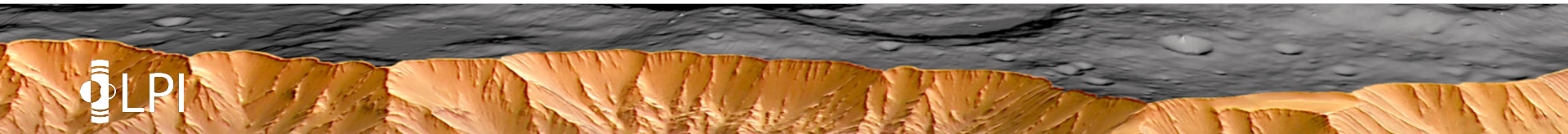
Key:

GCM Limits

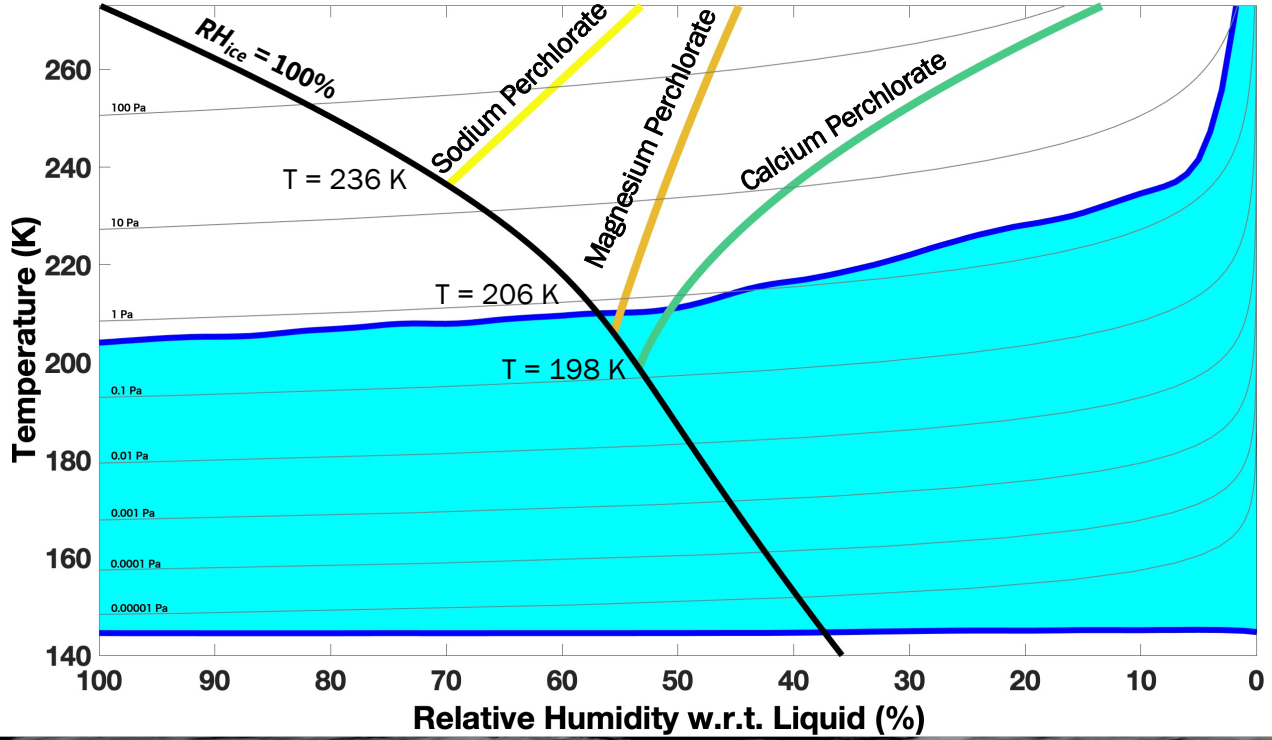
Phoenix

MSL

Mars Conditions



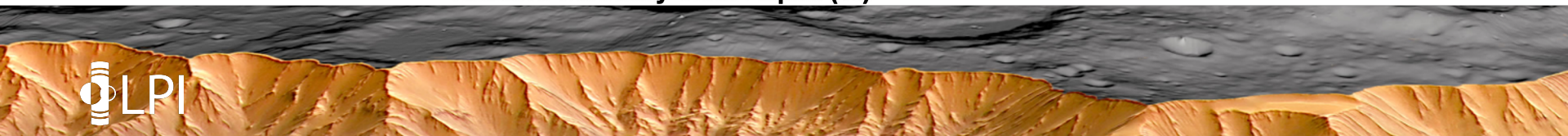
Climate Limits



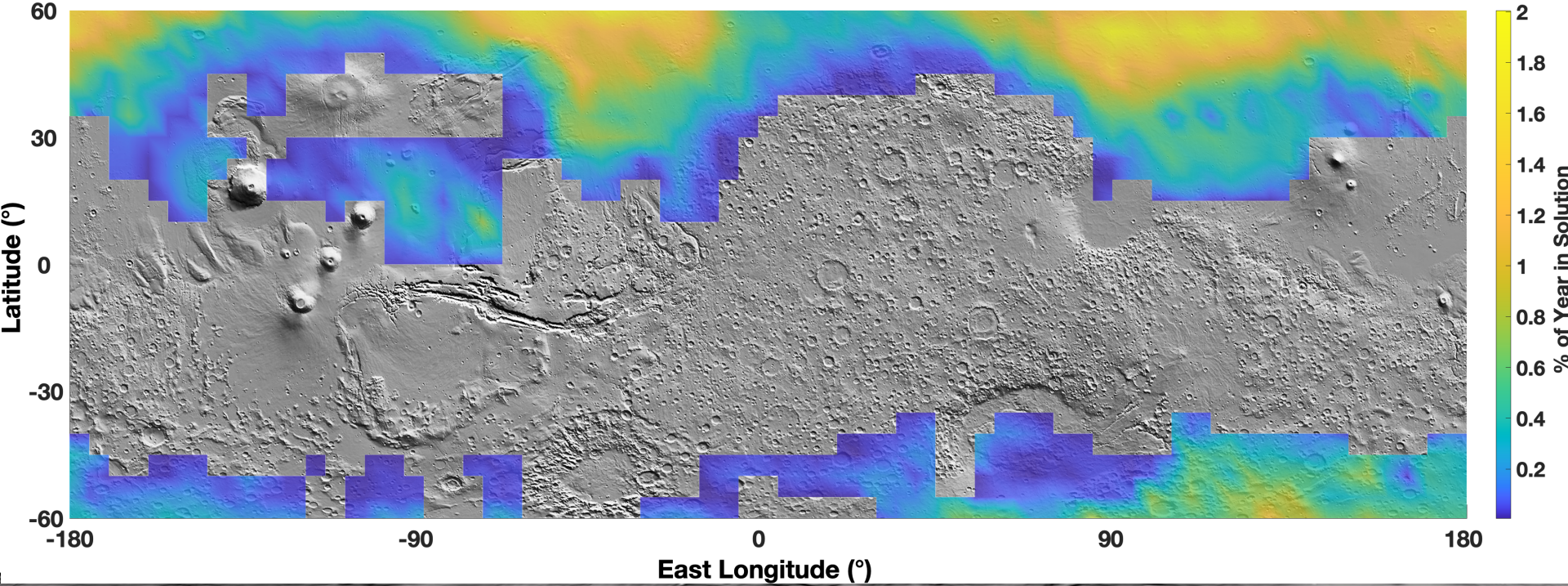
Only Brines with

T_{eu} < 210 K

can be stable



Global Model – Calcium Perchlorate



Rivera-Valentín et al. (2020) Nature Astronomy

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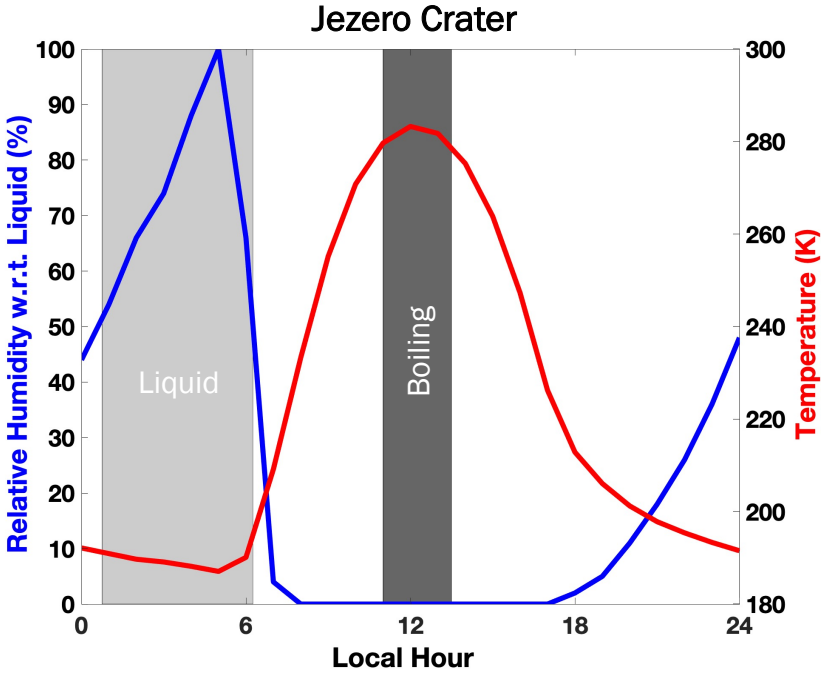
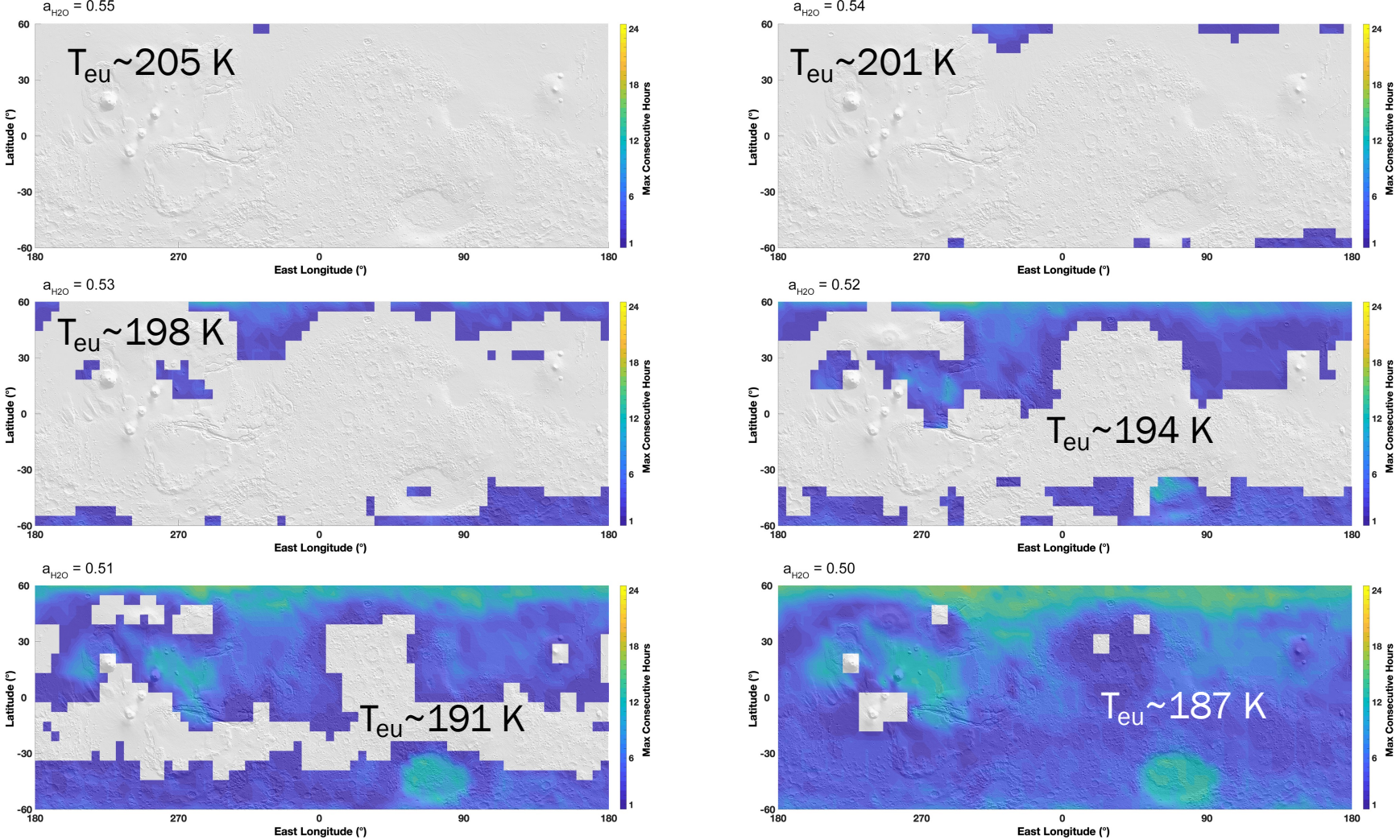
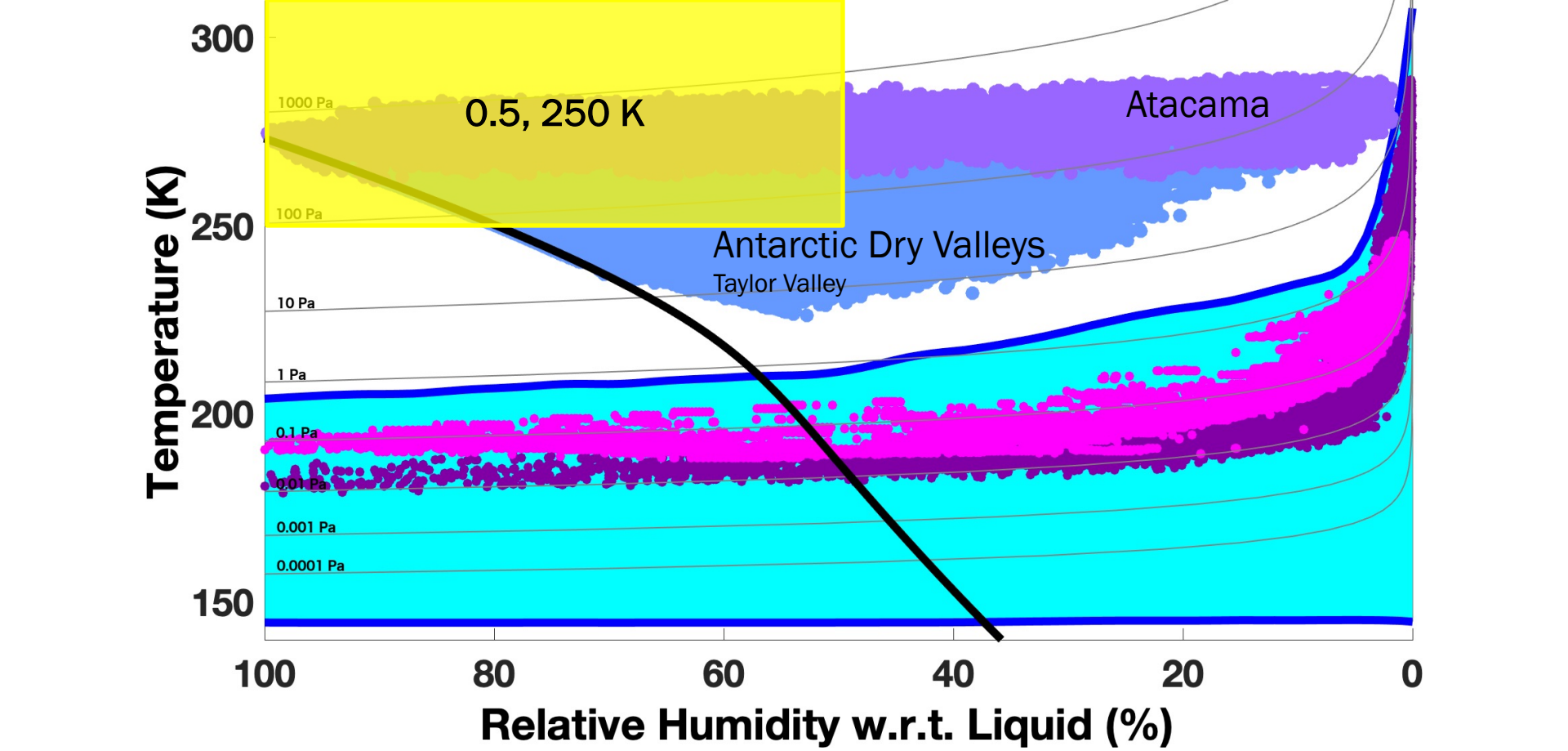
Generalizing

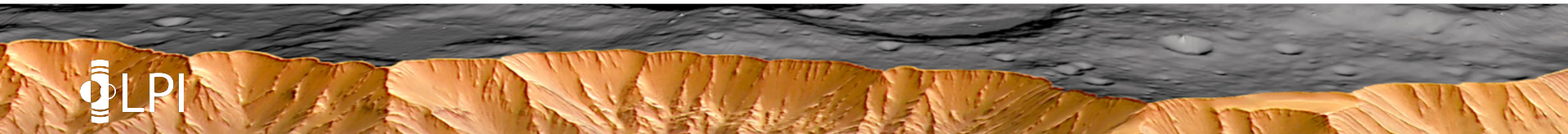
- Consider a brine with a_w = 0.5 and freezing point of 187 K
  - To avoid freezing, T > 187 K
  - To avoid boiling, $e_b < P_{atm}$
  - To avoid evaporation, $RH_l > a_w * 100$
- (e.g., Multicomponent Brines)





Chevrier, Rivera-Valentín, & Soto (2020) Planetary Science Journal


0.5, 250 K
1000 Pa
100 Pa
Atacama
Antarctic Dry Valleys
Taylor Valley
10 Pa
1 Pa
0.1 Pa
0.01 Pa
0.001 Pa
0.0001 Pa
Temperature (K)
300
250
200
150
100
80
60
40
20
0
Relative Humidity w.r.t. Liquid (%)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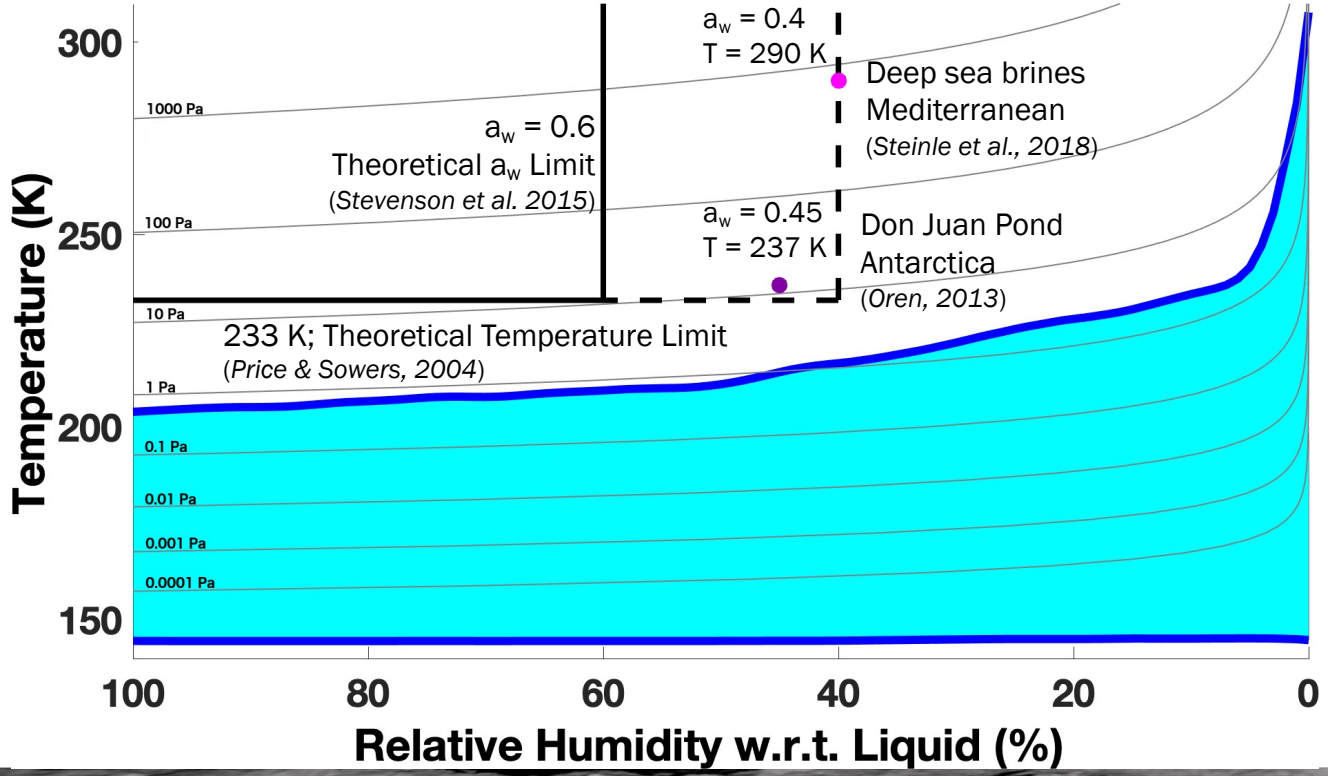
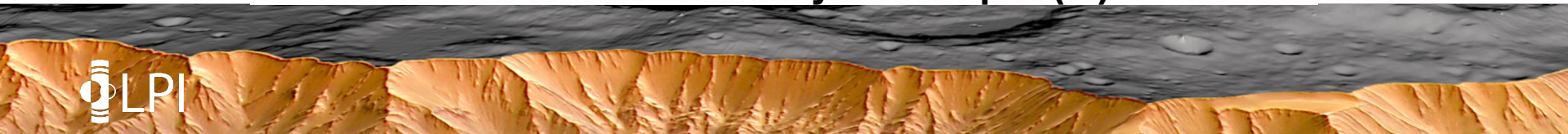
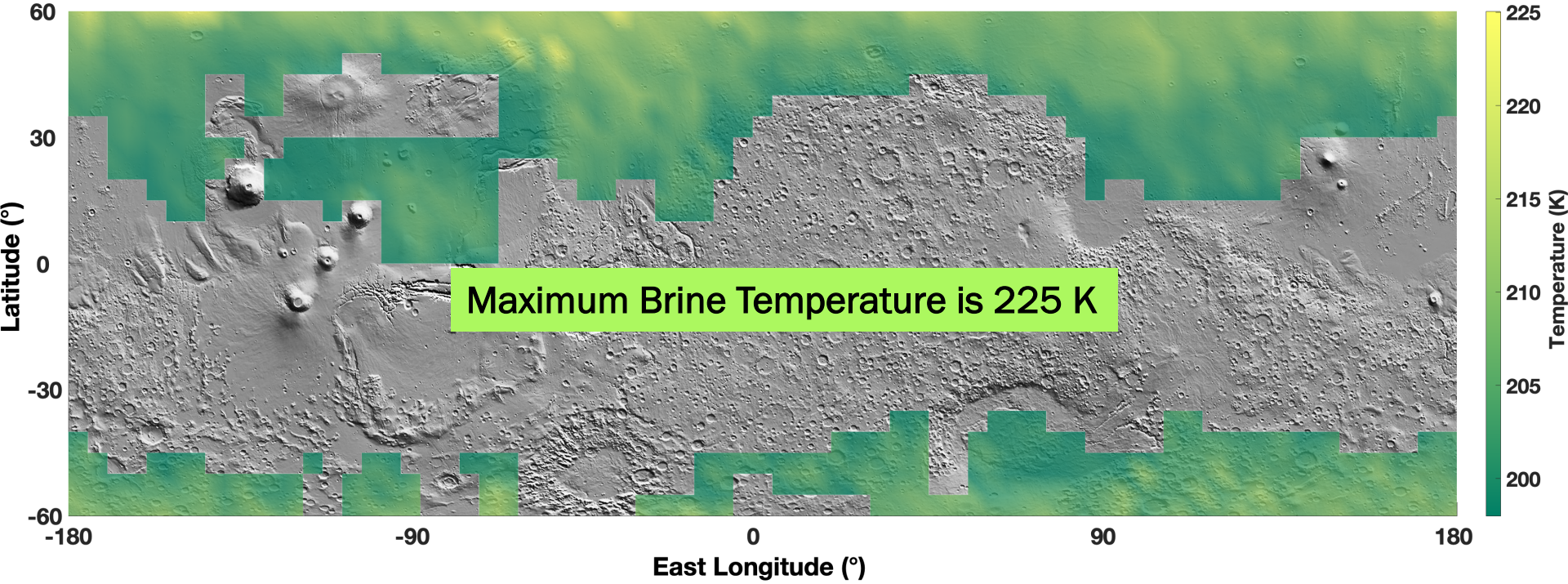
New Discoveries at New Limits!





Global Model - Deliquescence



Rivera-Valentín et al. (2020) Nature Astronomy

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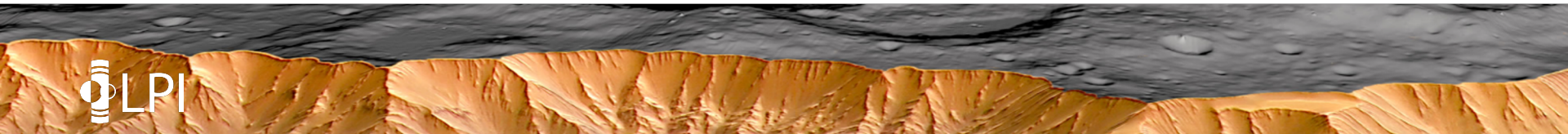
Caveats!

- Deliquescence may not be instantaneous
- Single component vs multi-component solutions
- There are other stressors for life (e.g., ionic strength, radiation)



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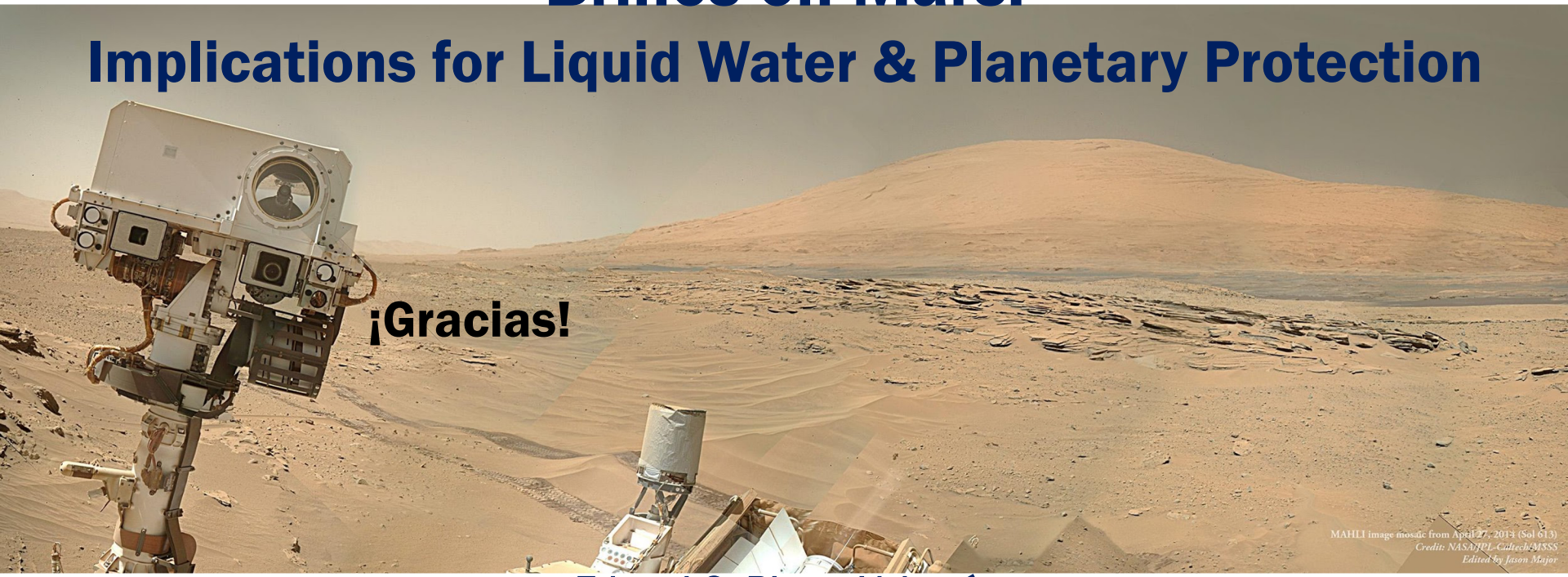

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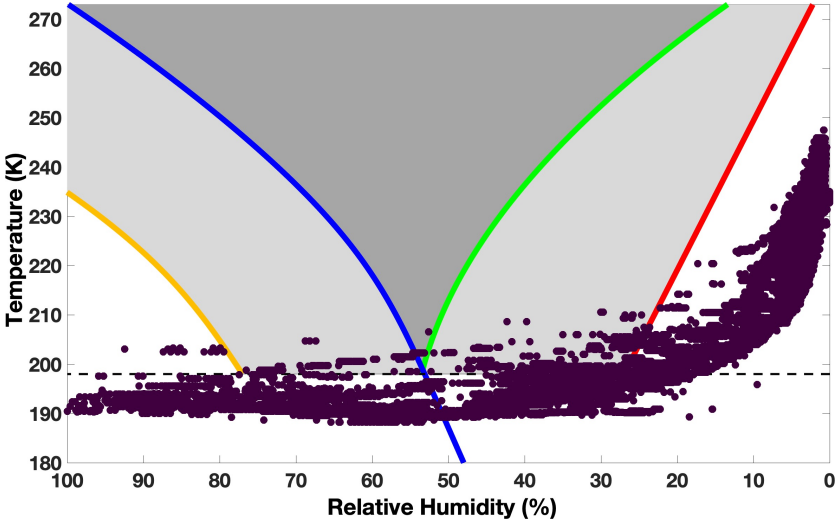
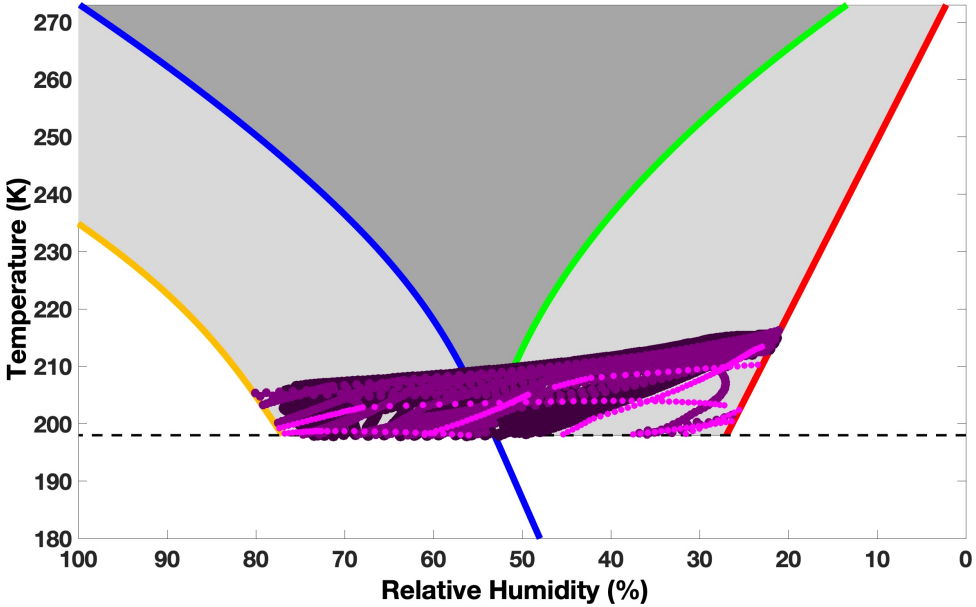
Shallow Subsurface - Phoenix

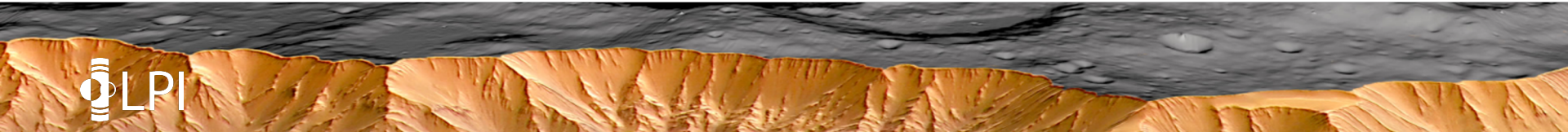


Subsurface brines can last longer (*10% of Martian year*)

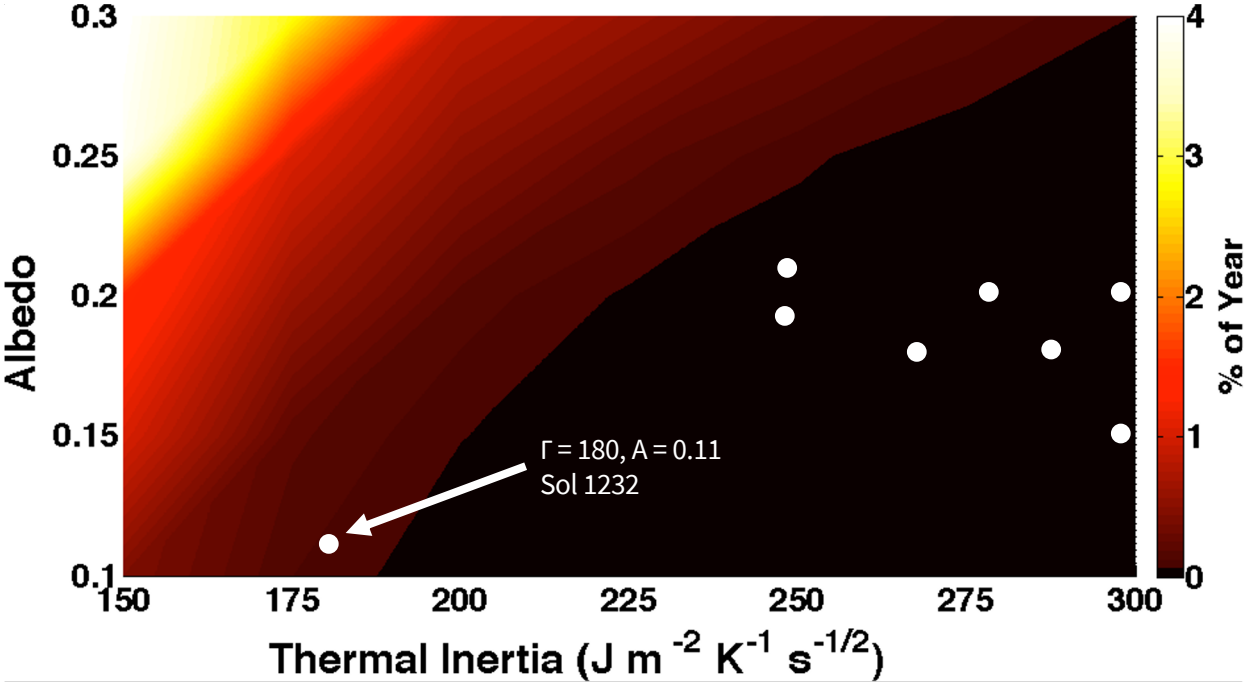
But max T = 217 K, a_w = 0.21

Max a_w = 0.8 at T = 206 K





Shallow Subsurface - MSL



Rivera-Valentín et al. (2018) JGR Planets

Experimental Constraints