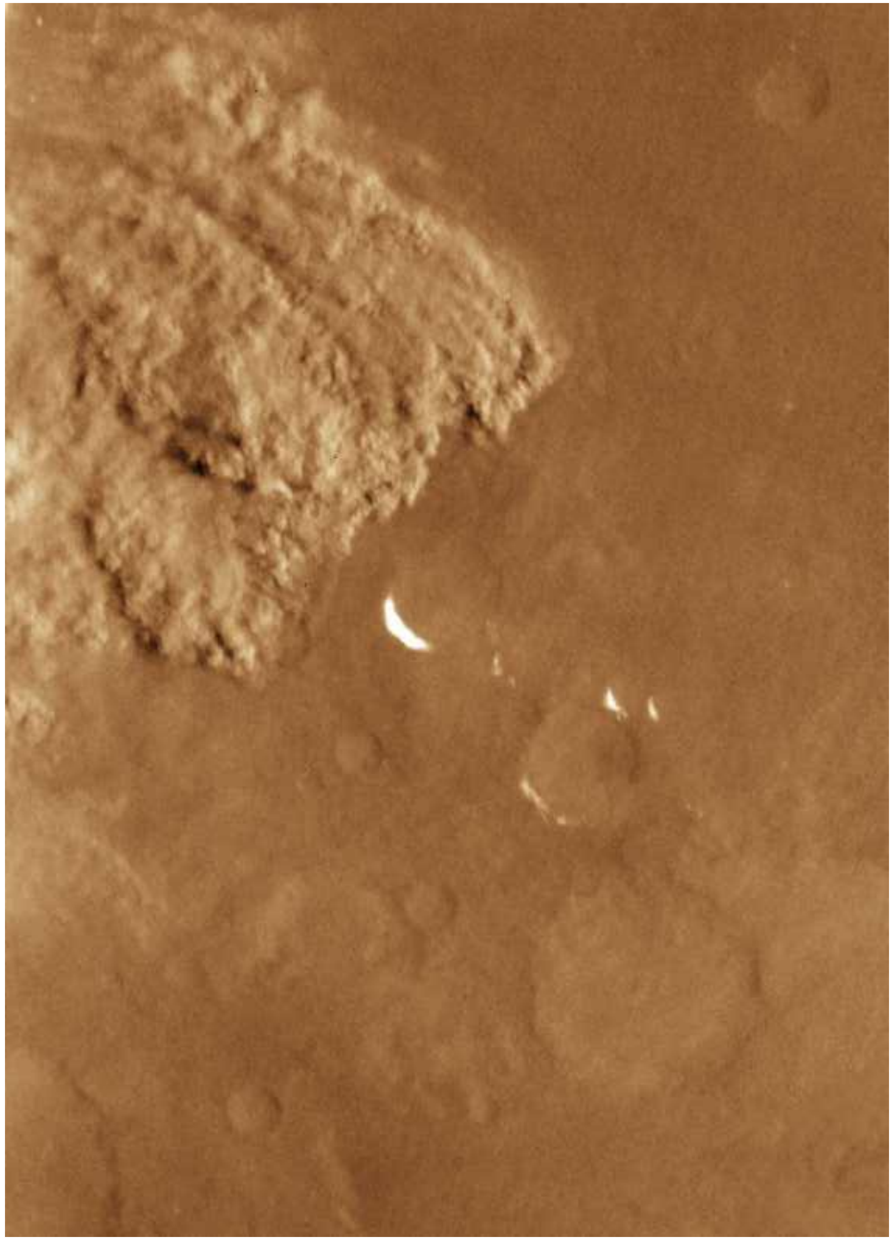


Dust-Driven Hydrogen Escape

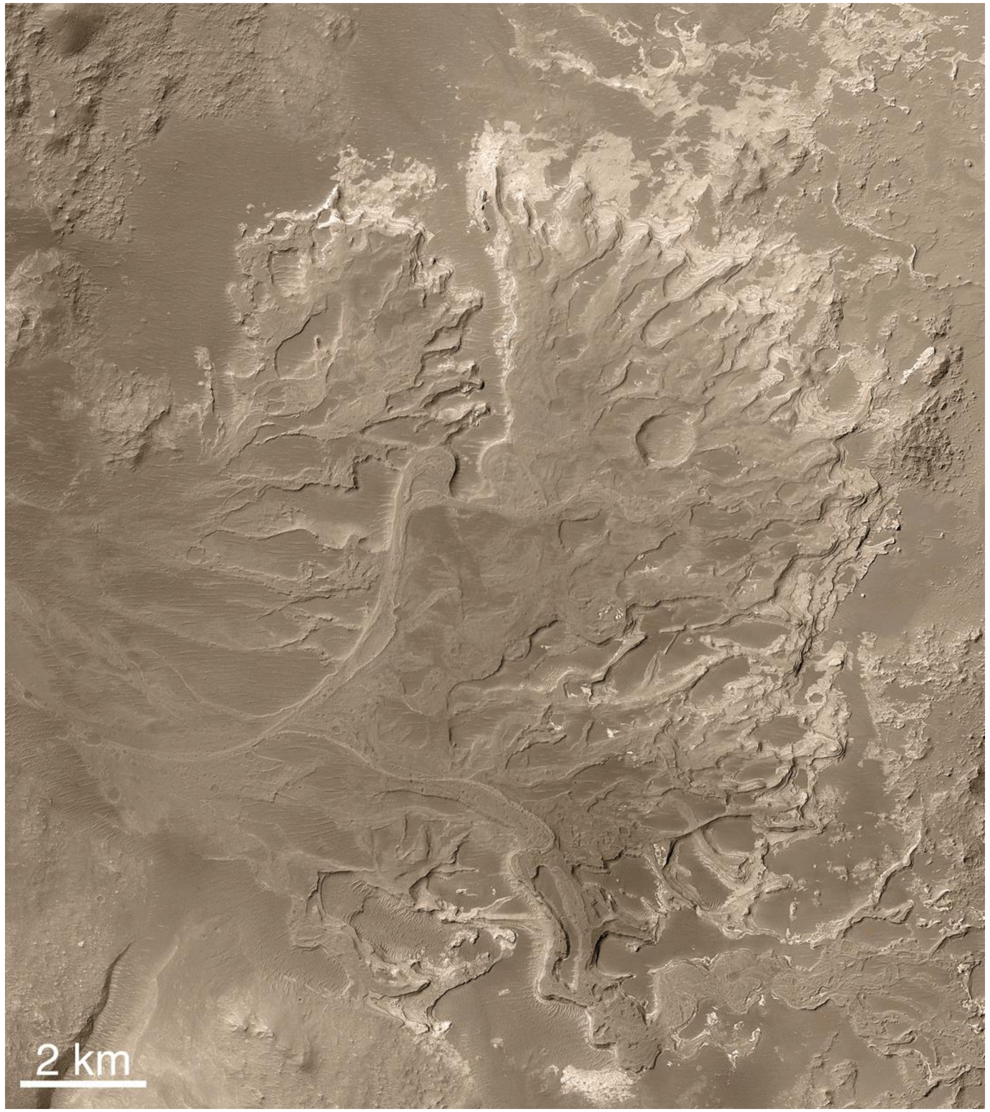
Mike Chaffin

Dave Kass, Shohei Aoki, Anna Fedorova, Justin Deighan, Kyle Connour, Nick Heavens

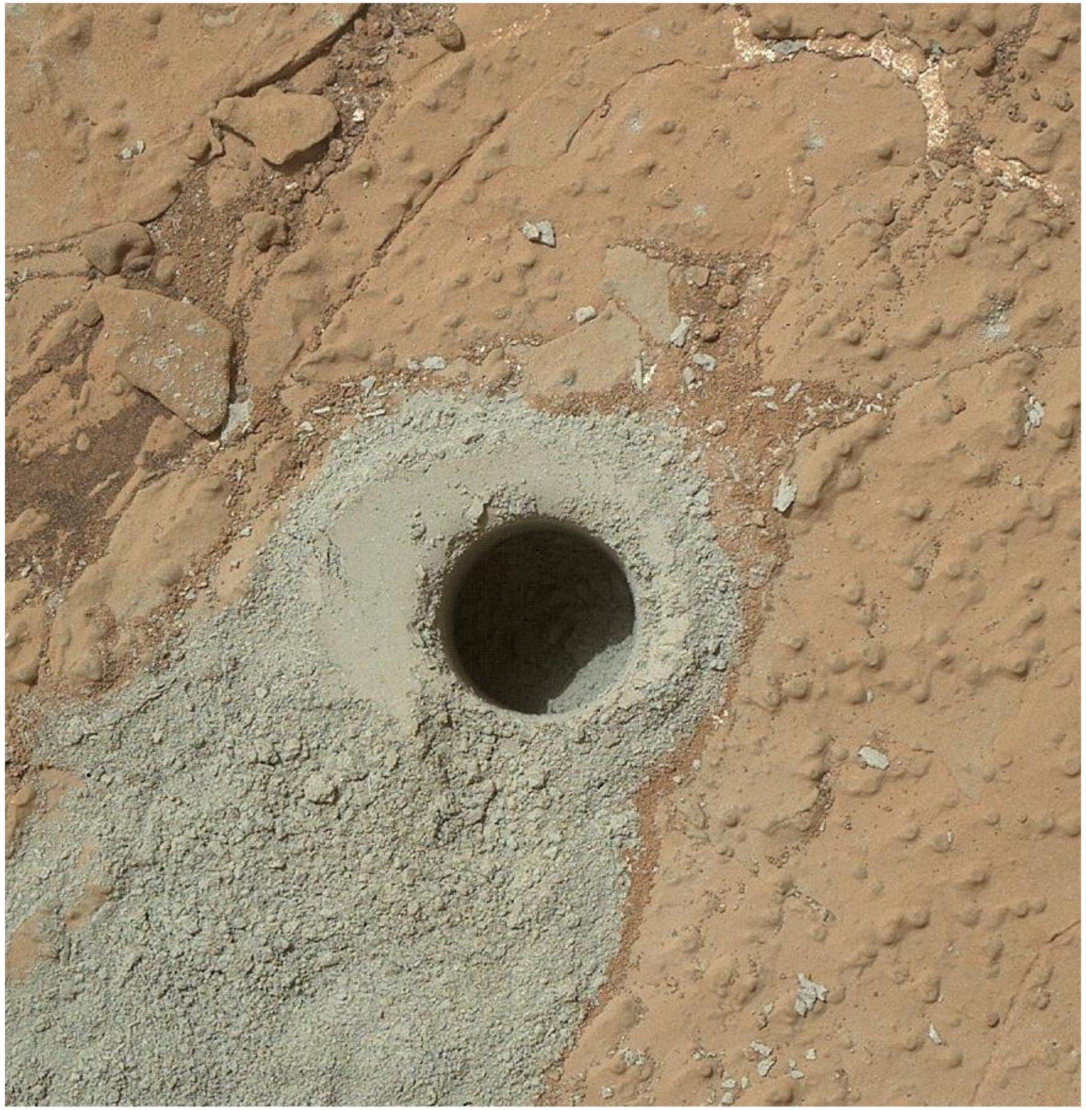
and the MRO/MCS, TGO/NOMAD, TGO/ACS, and MAVEN/IUVS teams

25 July 2019 --- 9th Mars Conference

Mars has lost water

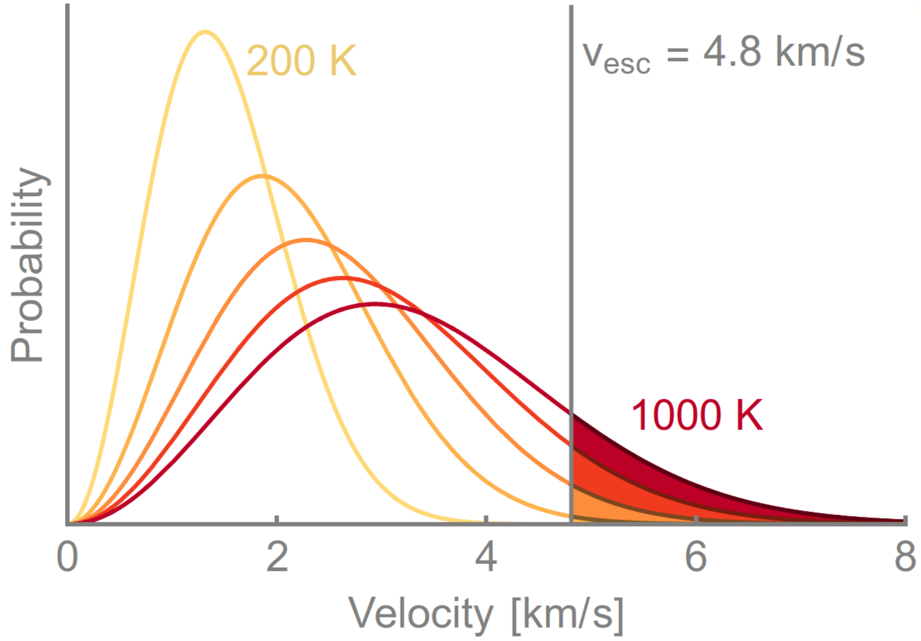


Mars has oxidized

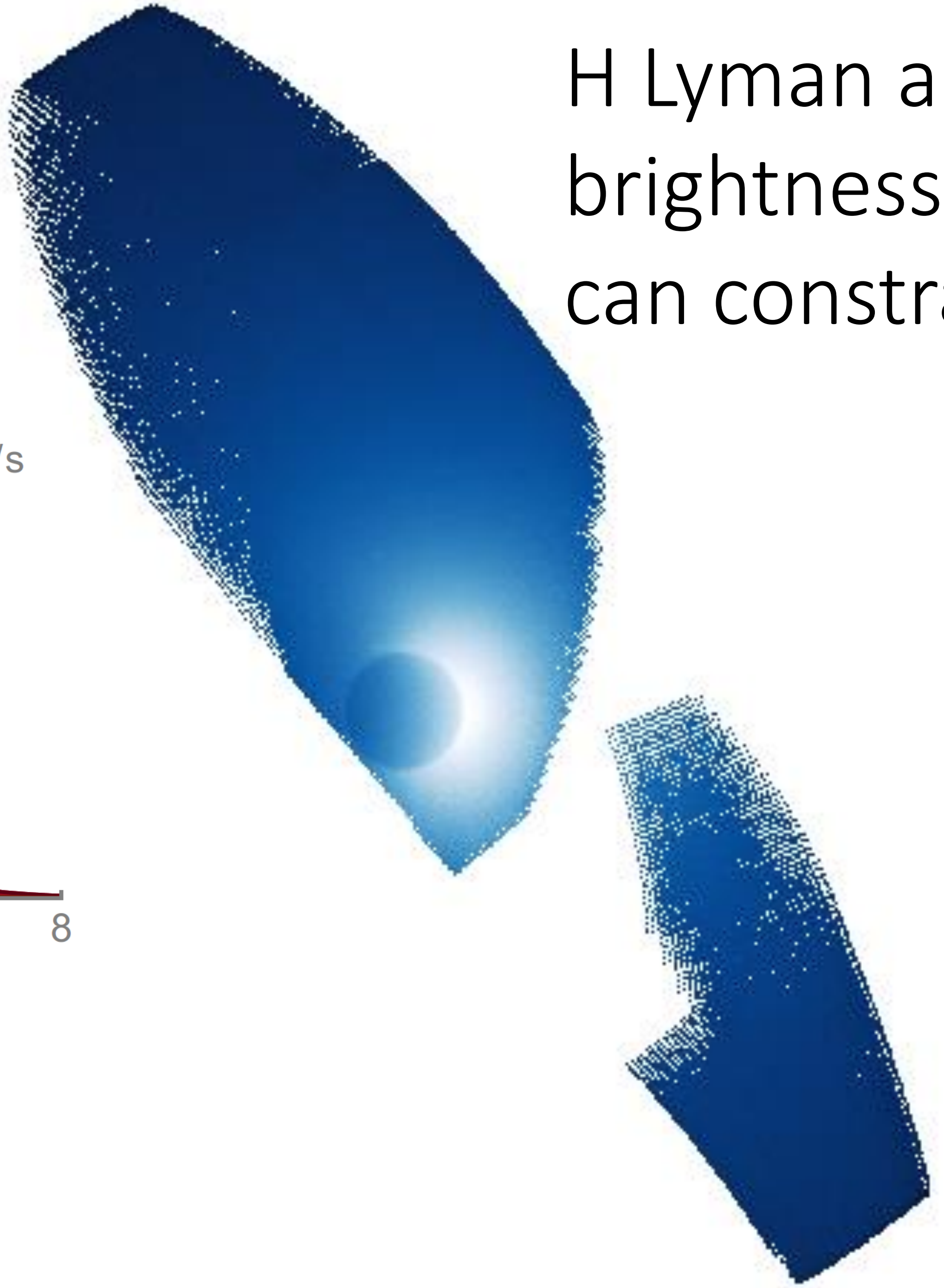


These are signatures of H escape to space.

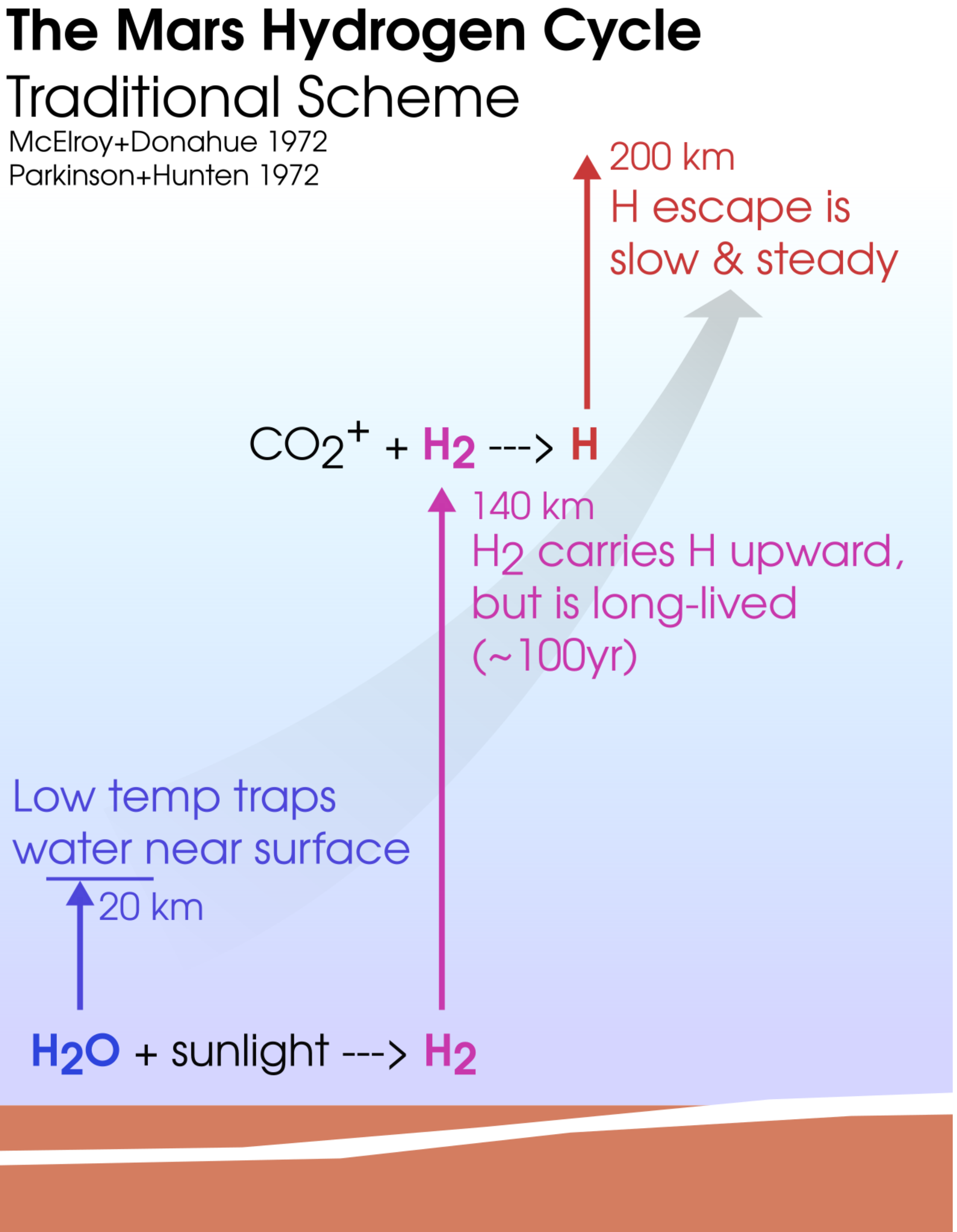
H is escaping from Mars today via Jeans escape



H Lyman alpha brightness measurements can constrain H loss



MAVEN insertion orbit image



H loss is regulated throughout the atmosphere

Thermal H velocity distribution

H cooling, exospheric transport

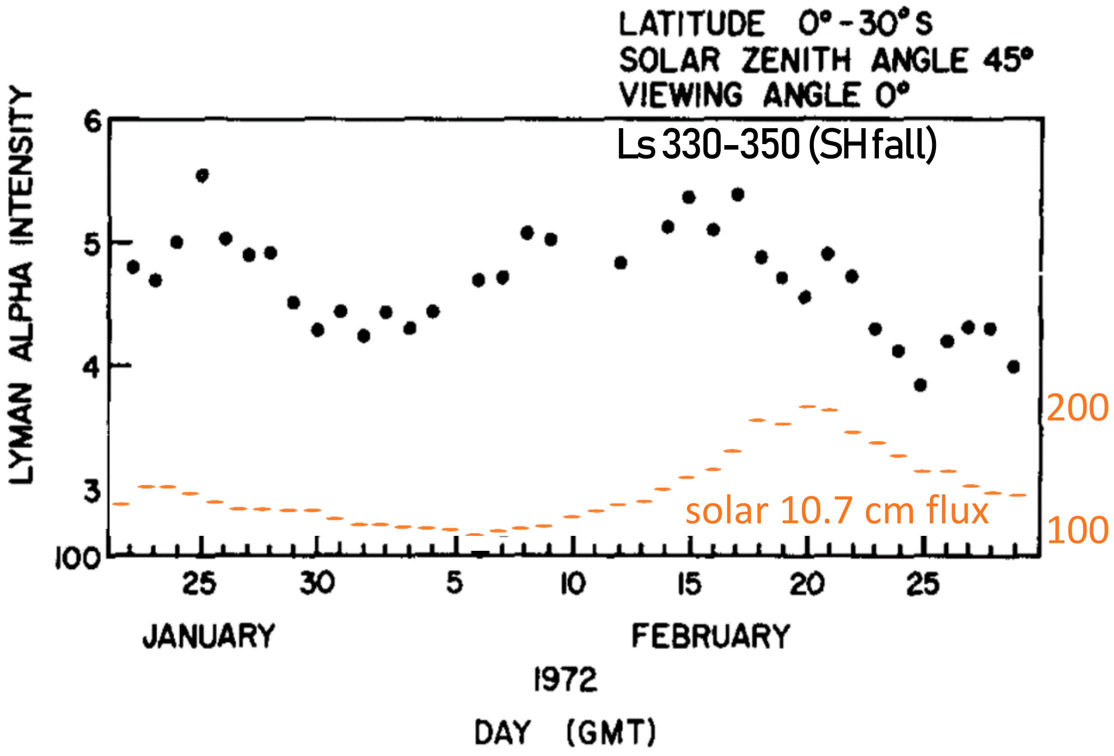
H diffusion

Dissociation

H_2 diffusion

Photochemical regulation of H_2 abundance keeps H escape = 2x O escape [McElroy 1972]

Mariner 9
the constant H loss hypothesis



What is most striking about the Mariner 9 Lyman alpha observations is not their variations, but that the observed intensities are as constant as they are. Previous to the Mariner 9 observations, it was anticipated that there might be large variations in the amount of atomic hydrogen in the Mars atmosphere (Barth, 1969; Hord *et al.*, 1970).

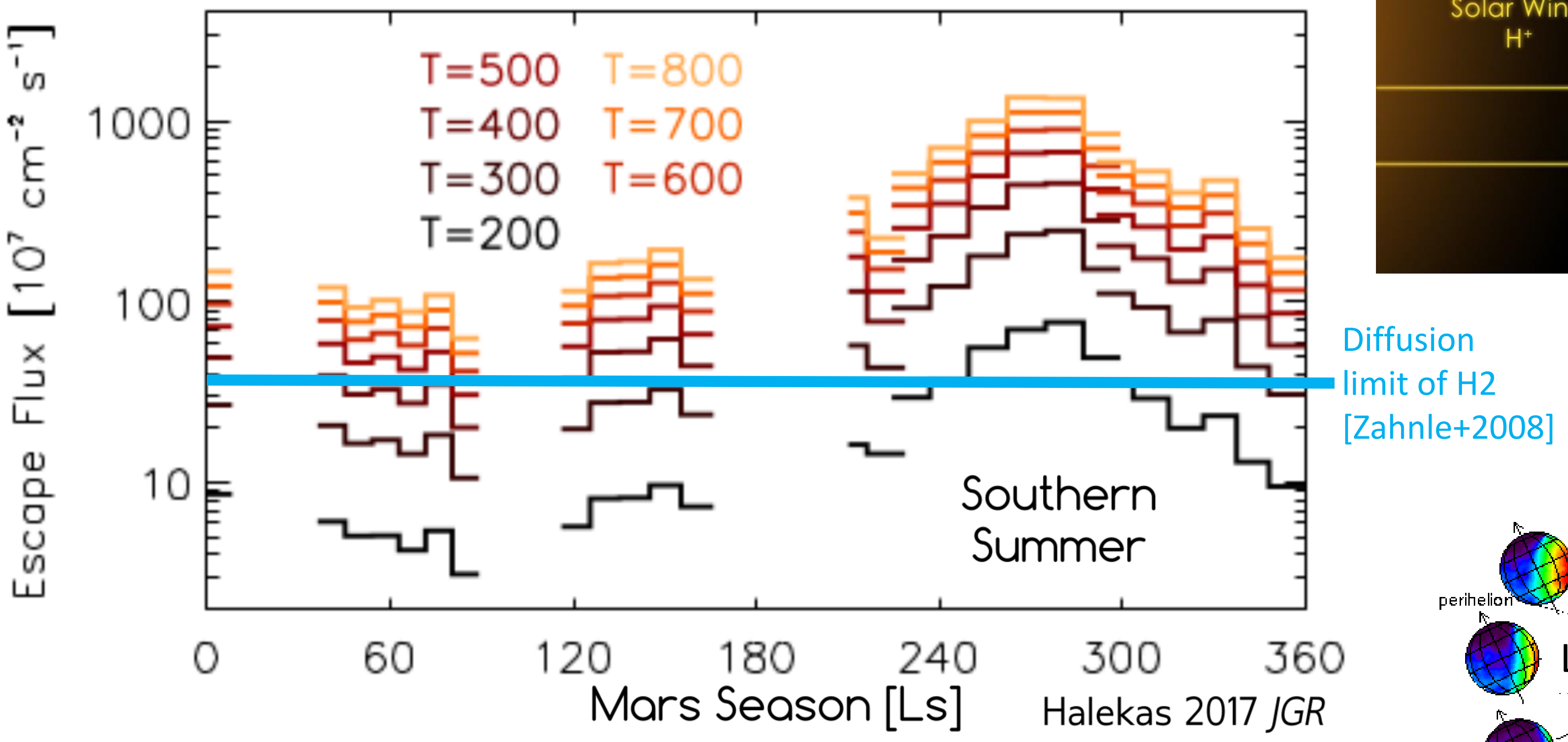
These observations suggest that there is a large buffer keeping the supply of atomic hydrogen to the exosphere relatively constant while dramatic variations are taking place in the lower atmosphere of Mars.

Barth+1972

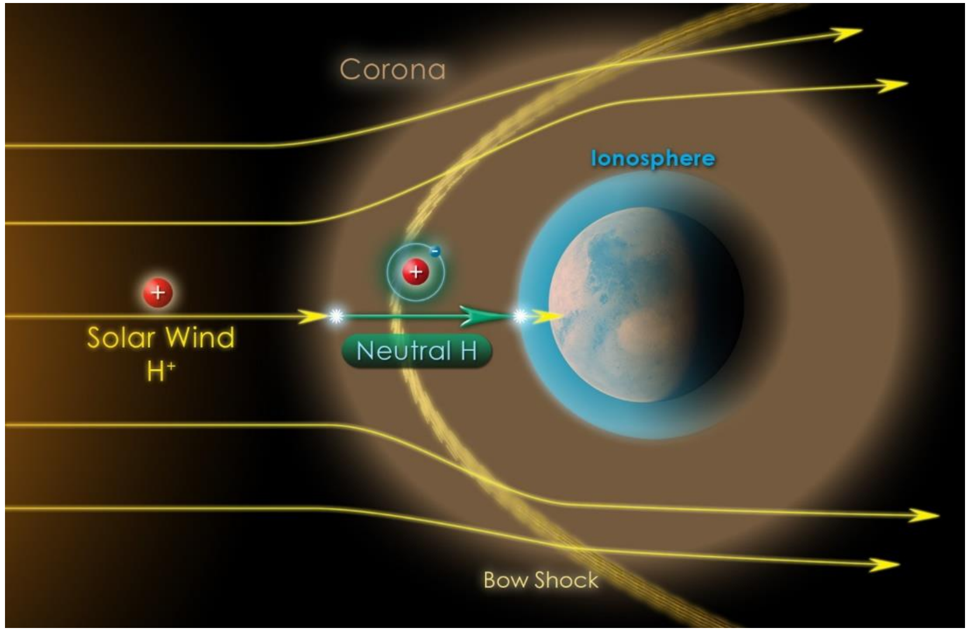
Mariner 9 observed ~25% variability in H Ly alpha brightness, concluding that H loss was nearly constant.

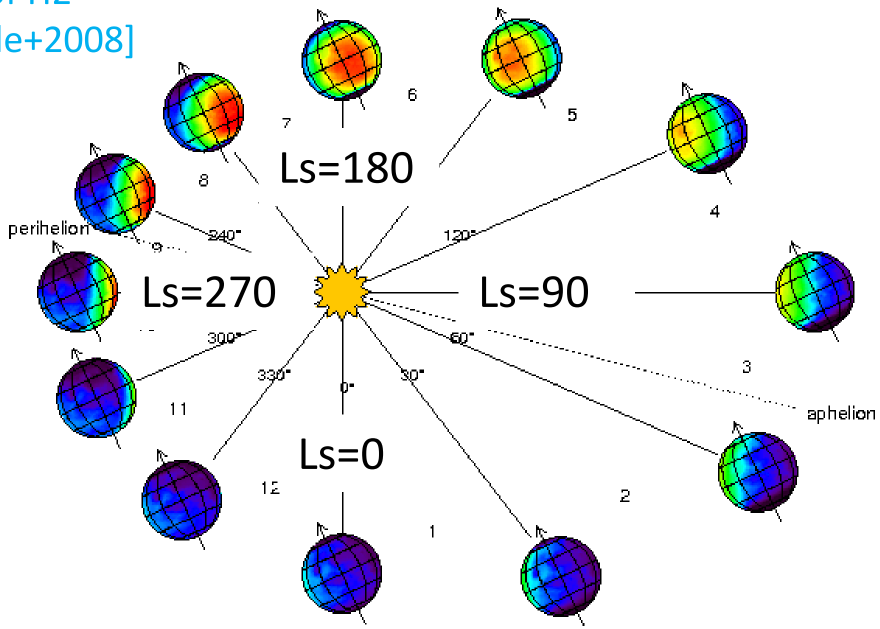
But H Ly alpha is optically thick:
10% brightness variations imply 2x variations in H loss.

Ongoing studies reveal the seasonal variability of Mars H Escape

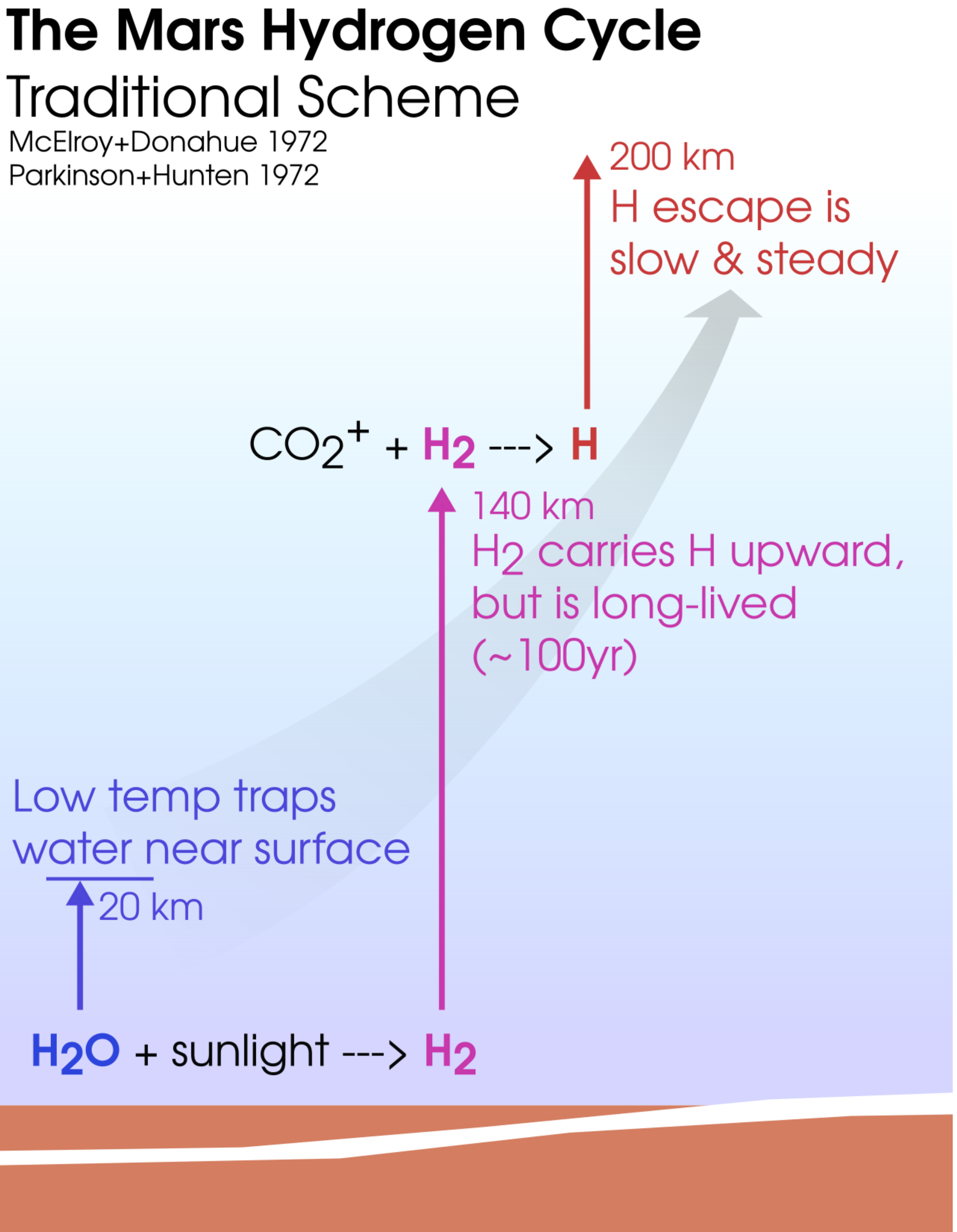


Halekas 2017 *JGR*





See also Chaffin et al. (2014) GRL
Clarke et al. (2014) GRL,
Bhattacharyya et al (2015) GRL



H loss is regulated throughout the atmosphere

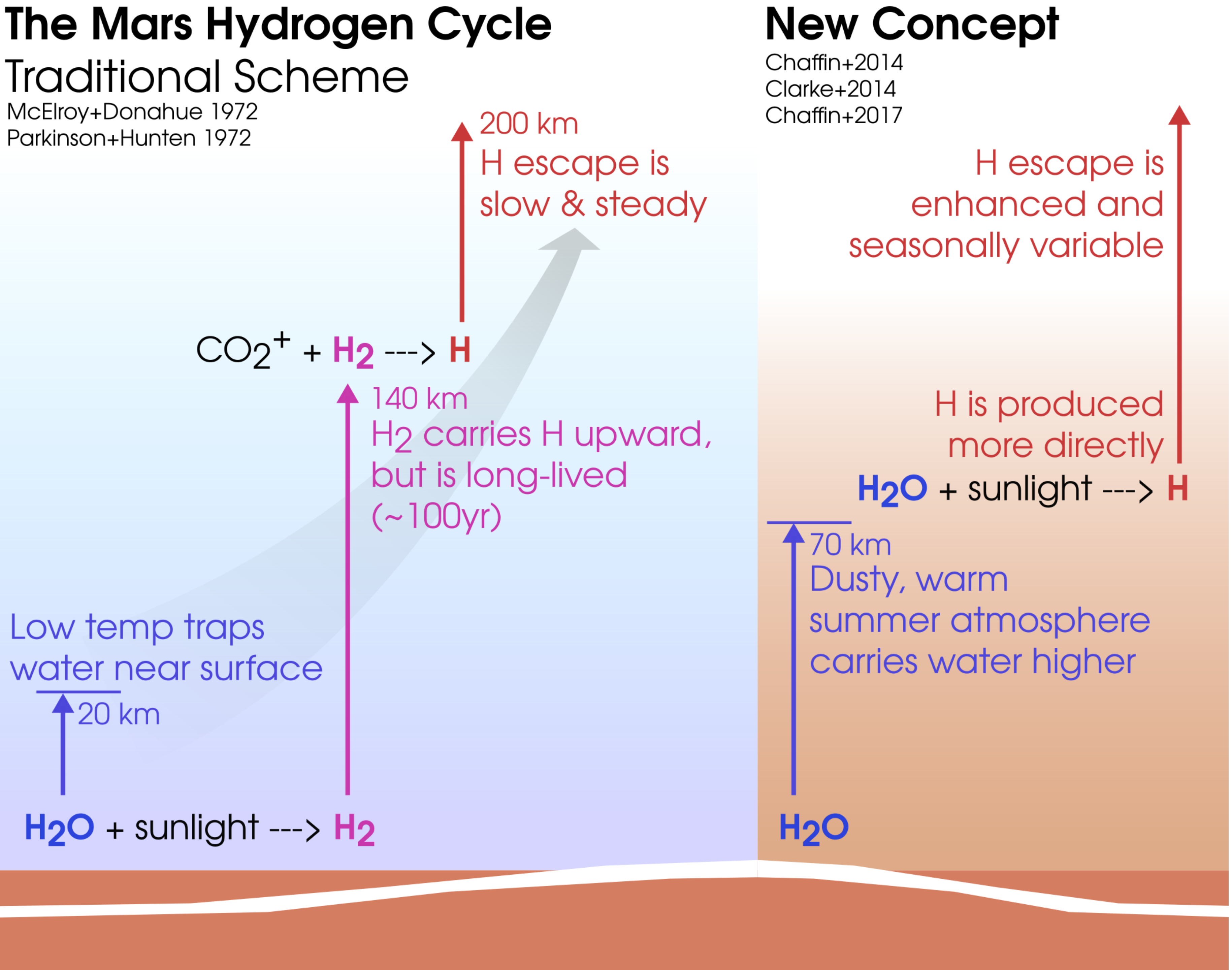
Thermal H velocity distribution

H cooling, exospheric transport

H diffusion
Dissociation

H_2 diffusion

Photochemical regulation of H_2 abundance drives H loss rate = 2x O loss rate [McElroy 1972]
(10^7 year timescale)



H loss regulation

Thermal H vel. distribution

H cooling, exospheric transport

H diffusion

Dissociation

H_2 diffusion

H_2O concentration

dust & climate cycles

Photochemical regulation

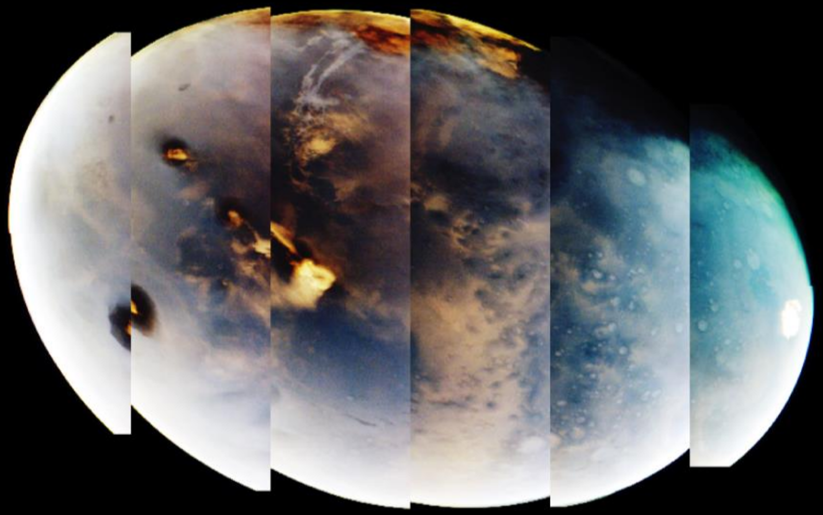
H loss rate = 2x O loss rate

(10^7 year timescale)

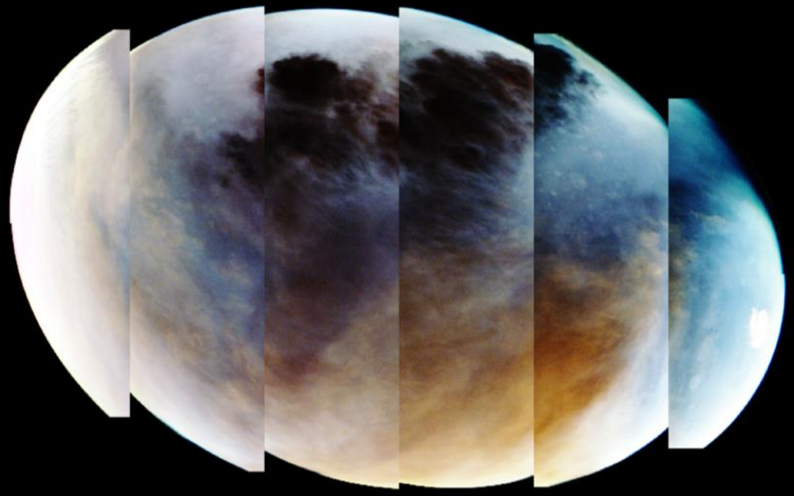
IUVS observes Regional Dust Storm Jan-Feb 2019

work by Kyle Connour

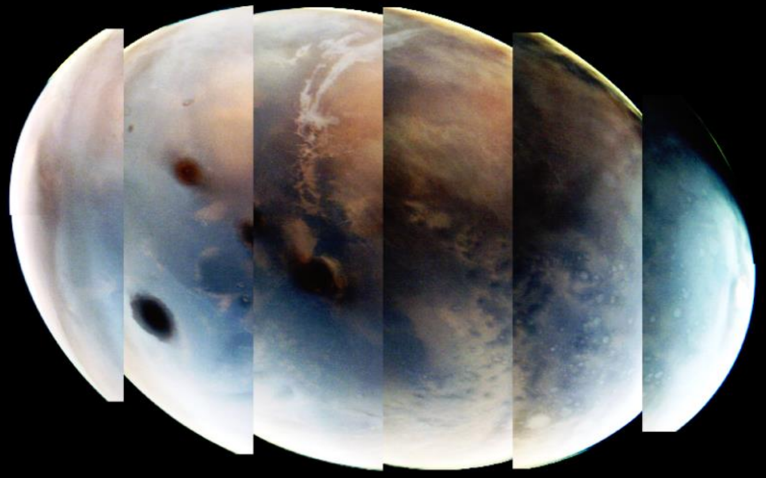
Orbit 8341 2019-01-07 15:13:46 UTC $L_s = 320$



Orbit 8356 2019-01-10 09:13:26 UTC $L_s = 321$

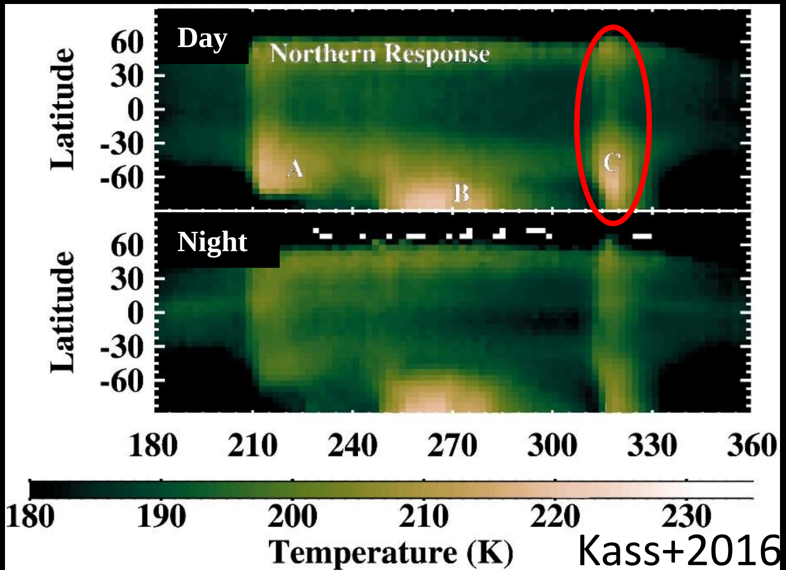


Orbit 8380 2019-01-14 18:49:49 UTC $L_s = 324$



Regional southern hemisphere dust storm occurs from 2019 Jan 7, orbit 8340, Ls~320 --- 2019 Jan 30, orbit 8380, Ls~332
.
Tharsis clouds vanish, indicating upper tropospheric heating.

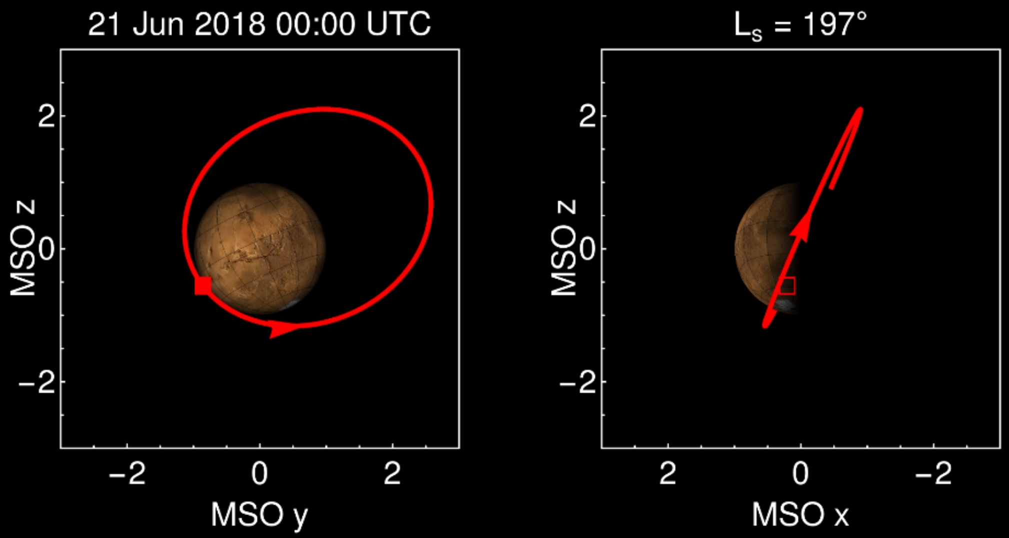
Dust storm occurs from Ls 320-330, well after perihelion and SH summer, allowing separation of dust and seasonal variation



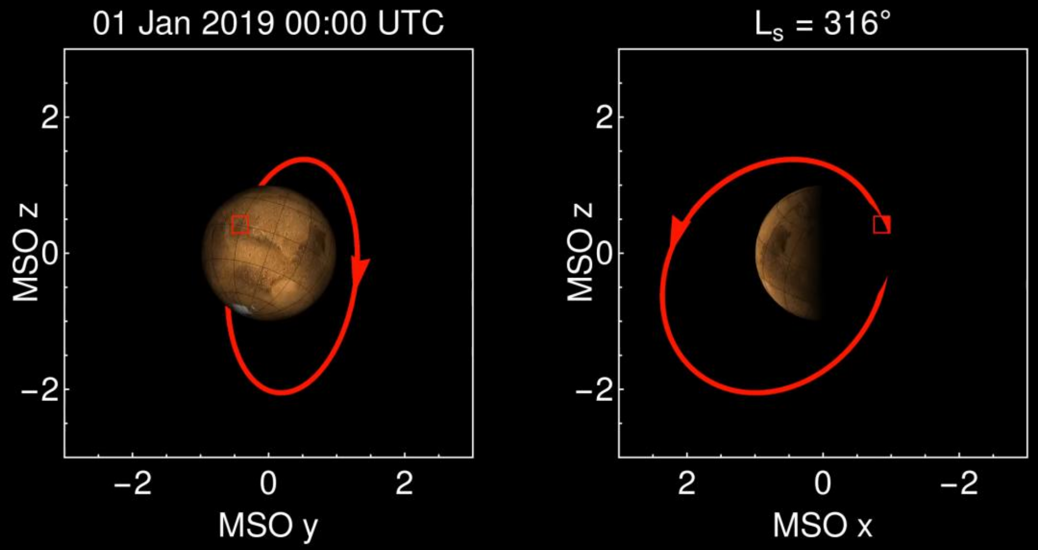
Kass+2016

Geometry of coronal scans near subsolar point at this time, unlike with previous dust events

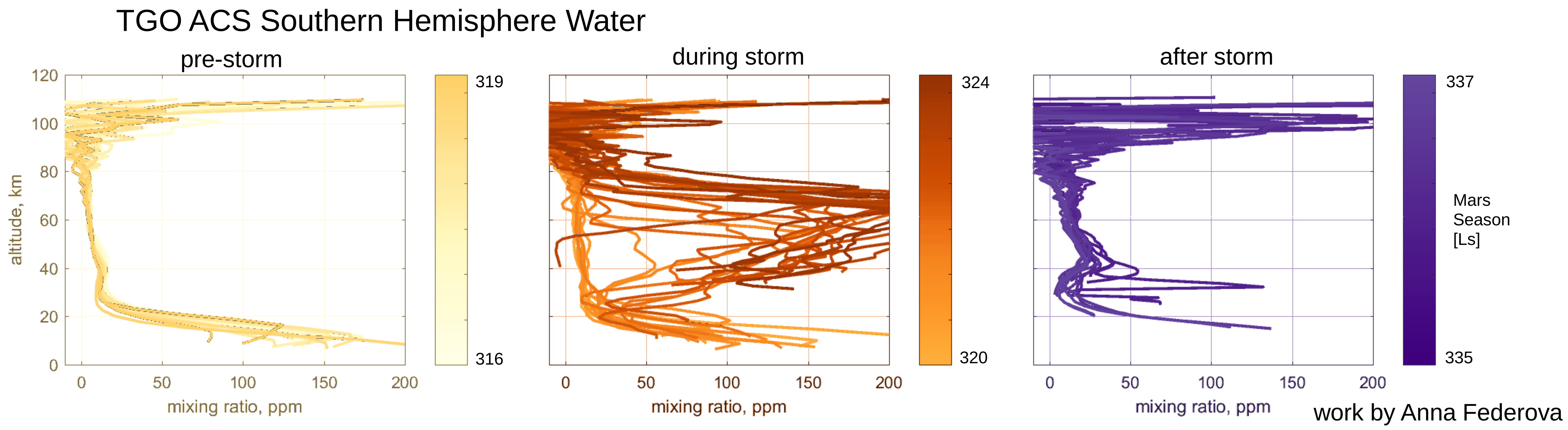
MY 34 PEDE geometry

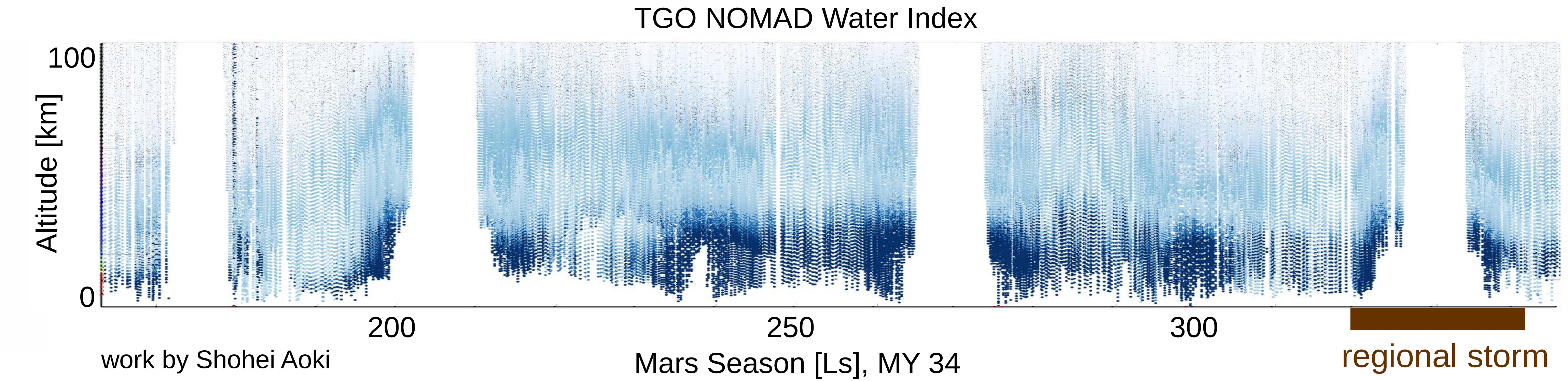


Regional dust storm Jan-Feb 2019



NOMAD and ACS profiles reveal dynamic upper atmospheric water





MRO, MAVEN, and TGO together provide unambiguous evidence of dust-induced H escape.

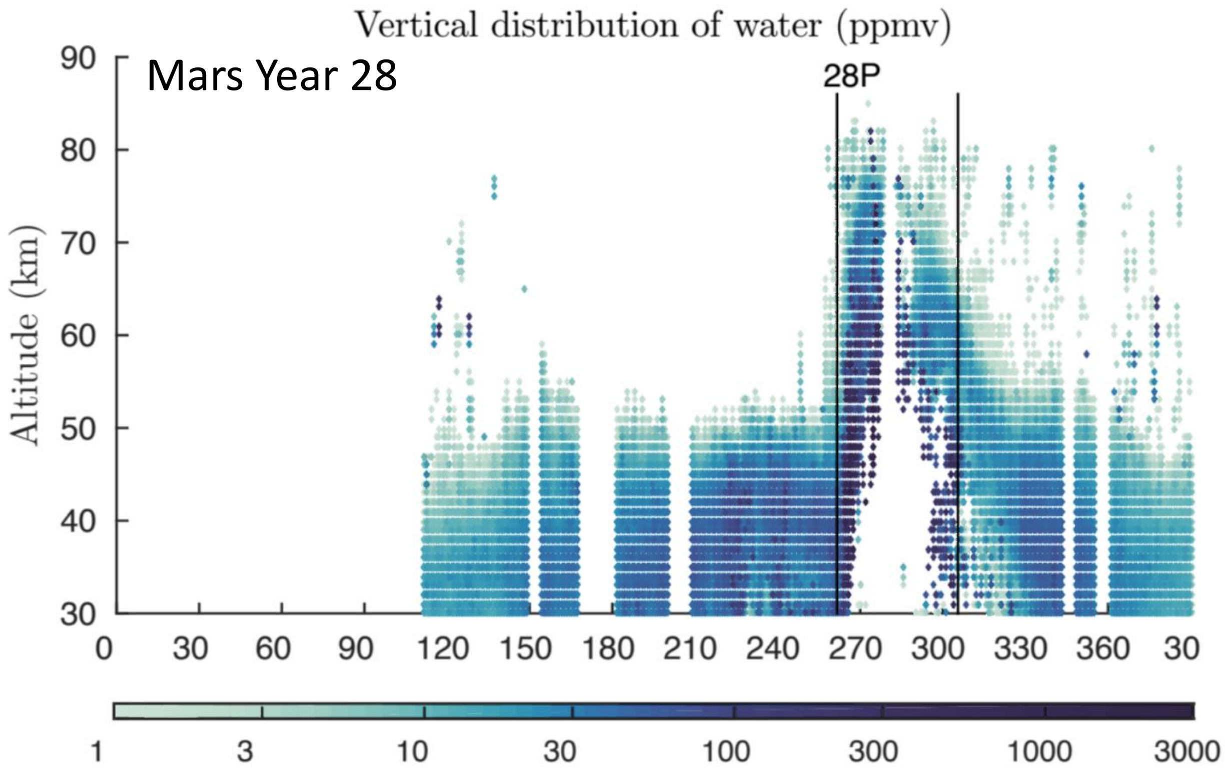
Dust in lower atmosphere
increases temperature,
inhibits ice condensation (clouds),
allows water at high altitude,
and enhances coronal H.

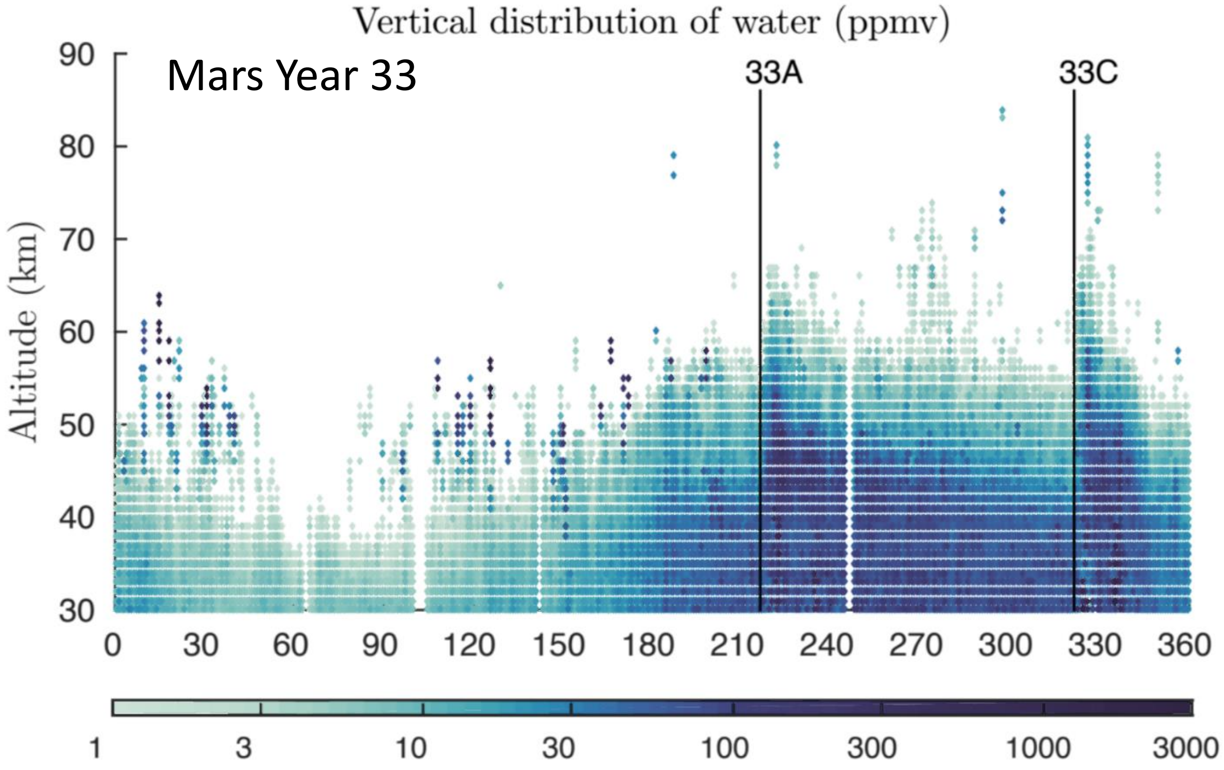
H escape increases by >2x from this event
(H retrieval ongoing).

Proton aurora also respond due to increased charge exchange in upstream corona.

Figure removed pending publication; contact michael.chaffin@Colorado.edu for a copy

Global dust storms should also affect H escape, but direct observations are scarce.





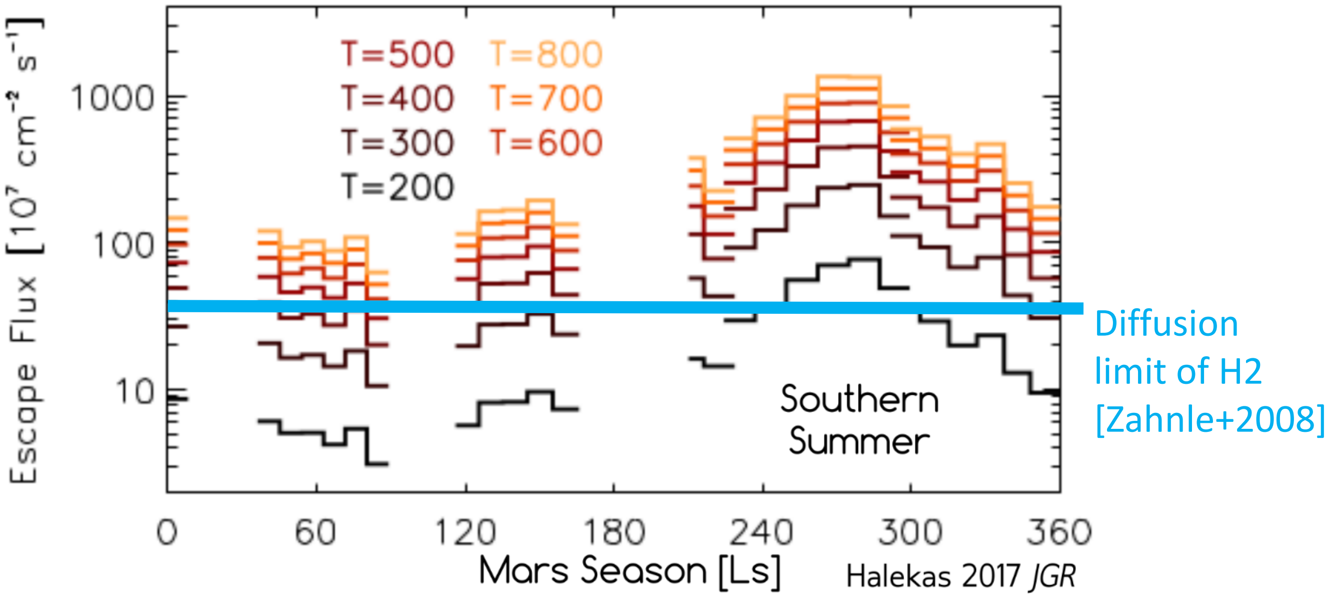
Heavens+2018
(Nature Astronomy)

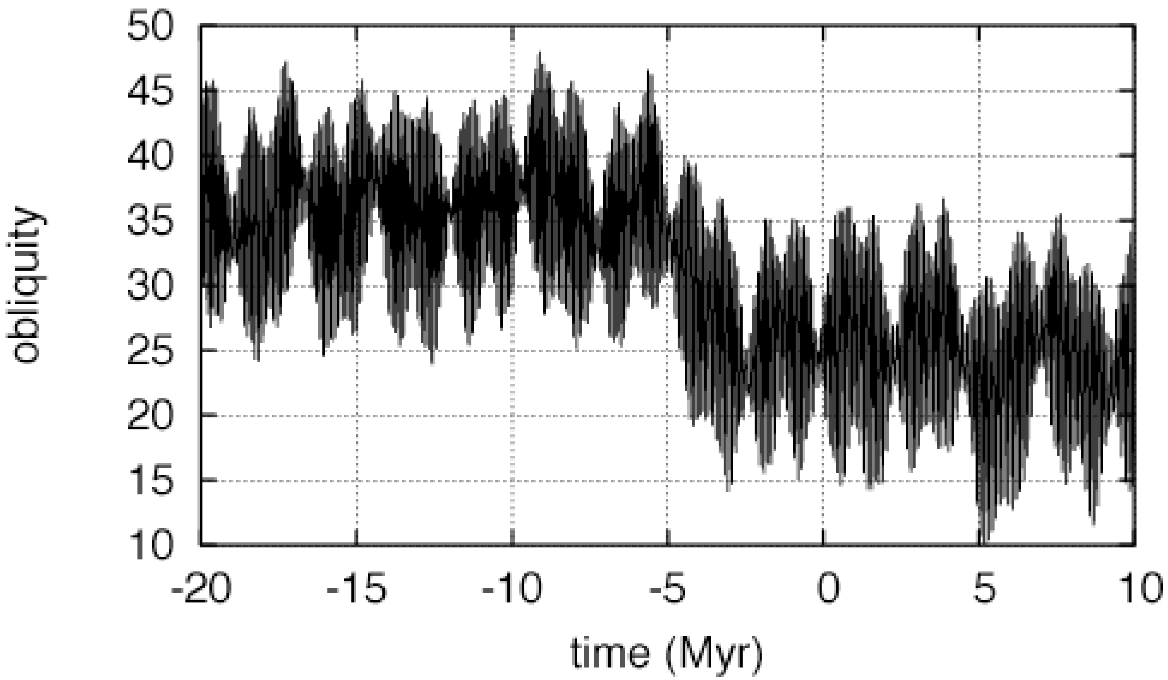
(Emirates mission may help)

Timescales

- Flare/solar impulse
- Diurnal
- Subseasonal/dust driven
- Seasonal
- Interannual
- Solar Cycle
- Dust/climate cycles

  Obliquity
- Evolutionary





Timescales

- Flare/solar impulse
- Diurnal
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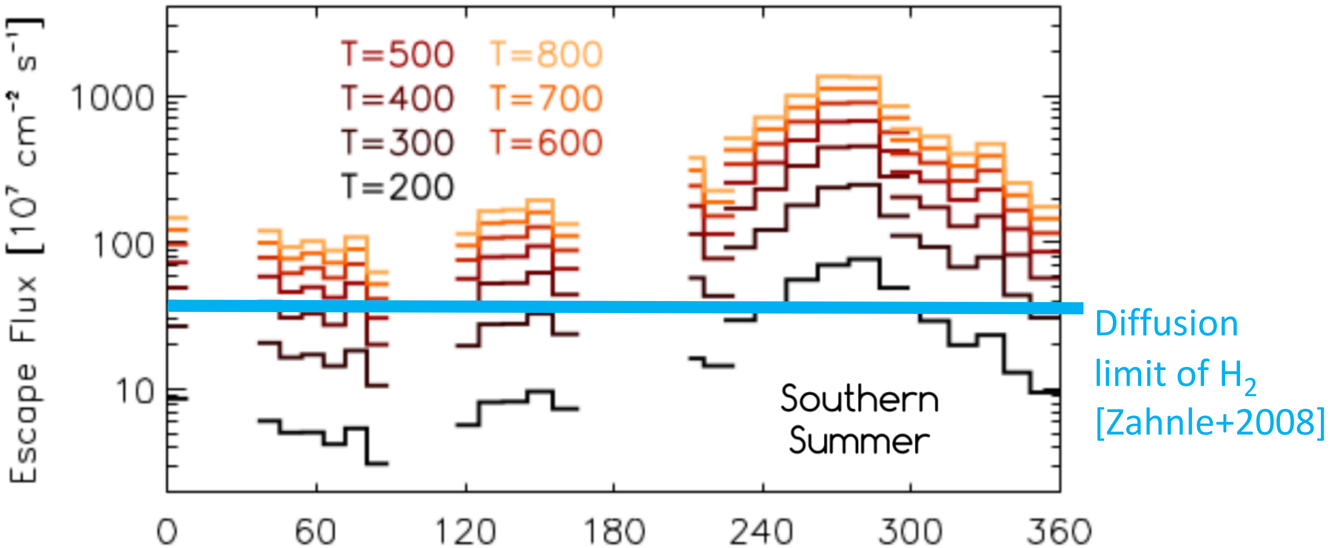
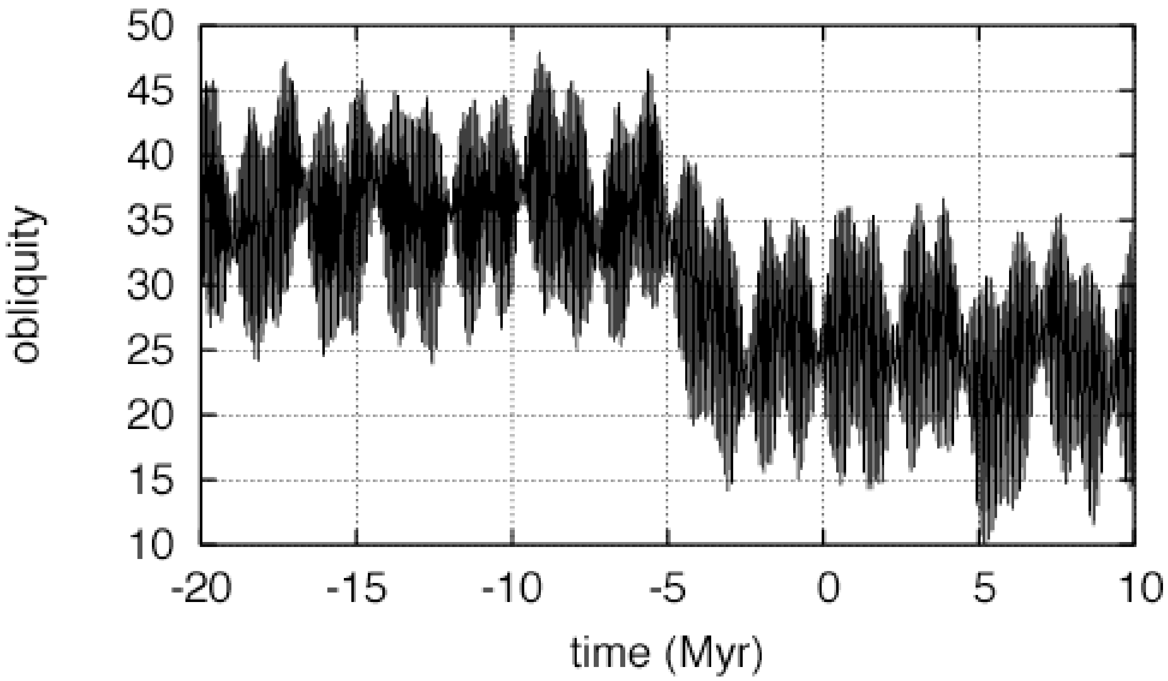
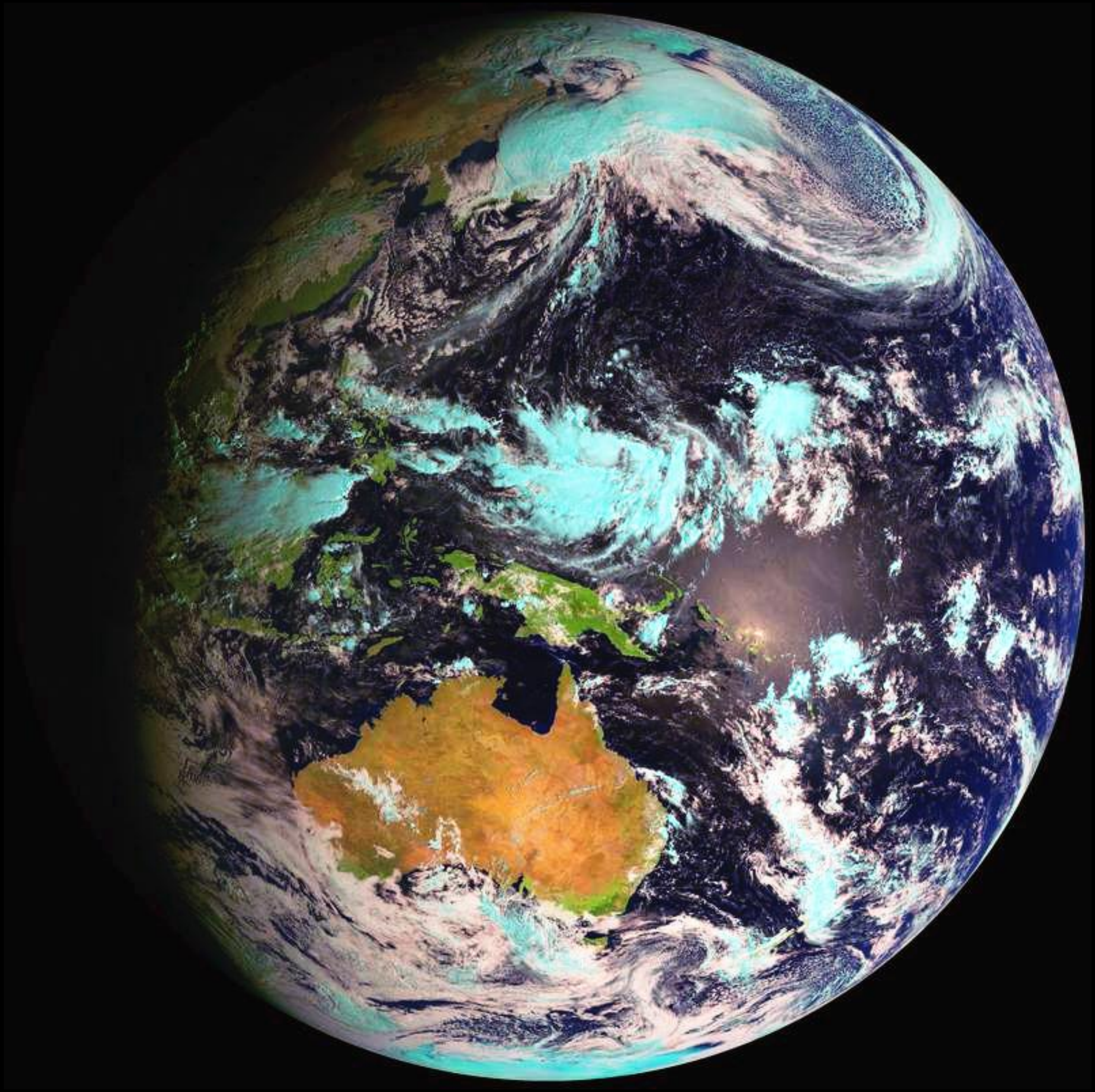
- **Seasonal**
- Interannual
- **Solar Cycle?**
- Dust/climate cycles
- **Obliquity?**
- **Evolutionary?**



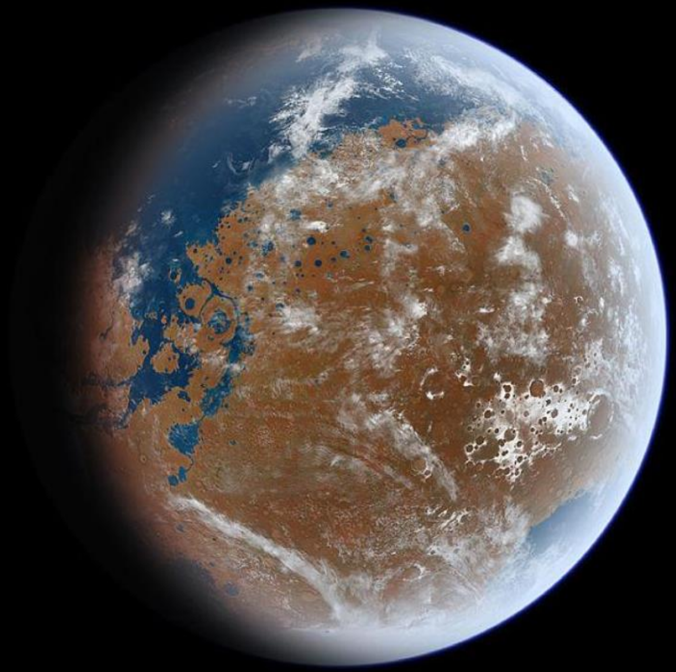
Halekas 2017 *JGR*



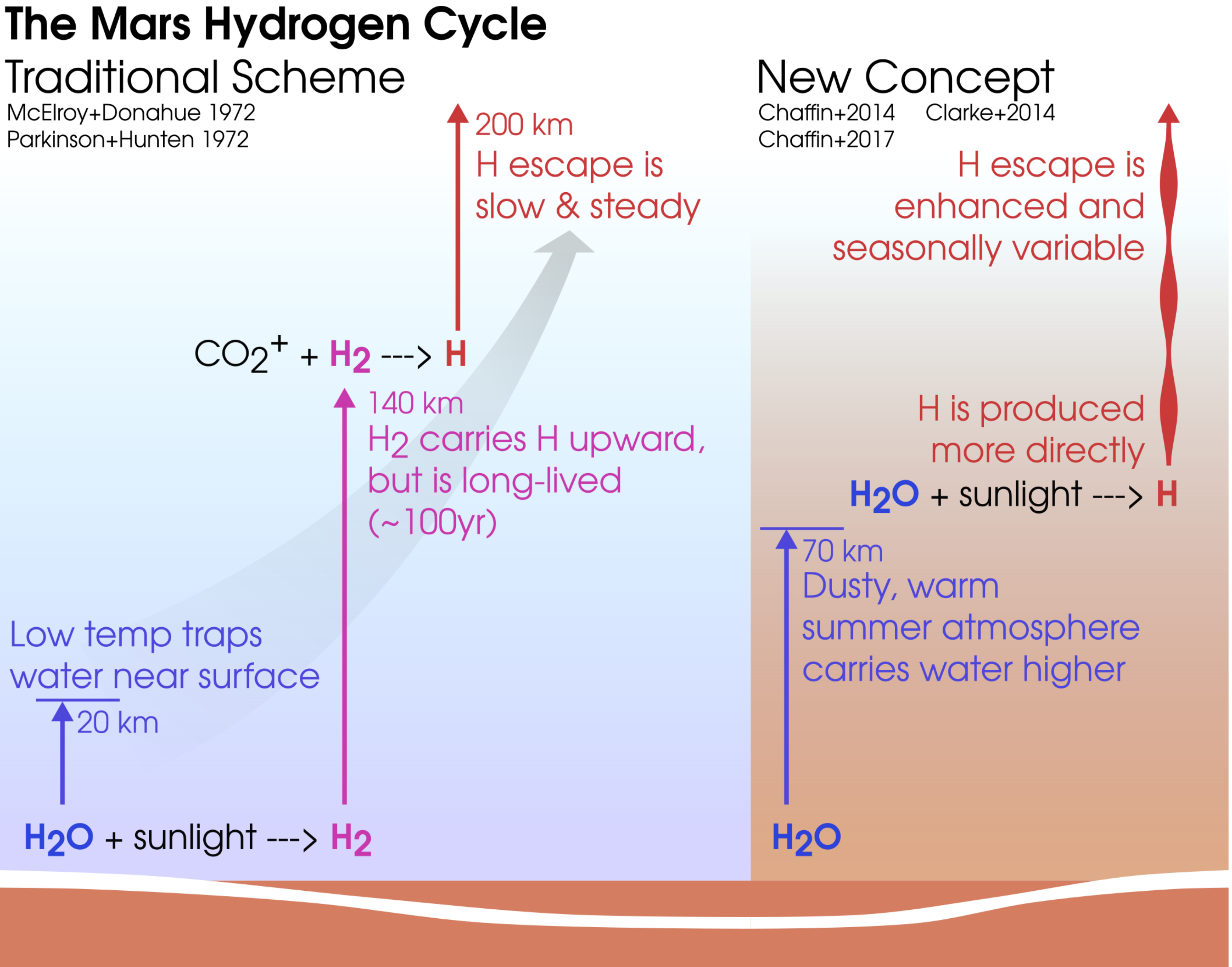


Earth’s thick atmosphere
has a more effective cold trap than Mars

Earth's thick atmosphere
has a more effective cold trap than Mars



Did early Mars' thicker atmosphere
inhibit H escape?



We are capturing most steps in the H escape pipeline in a single event for the first time.

Further analysis of timescales and magnitude of impact on upper atmospheric water and H will place new constraints on dust-induced H loss.

How might these processes change with early Martian water/dust/climate cycles and early solar EUV?