Upper Atmosphere, Ionosphere, Magnetosphere

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Disclaimers

- Member of MOSAIC team – not part of core study team
- MEPAG Goals Committee – Goal II (Climate) rep

All opinions presented here are independent of the above

Progress since the last Decadal Survey

Upper atmospheric drivers

- All relevant drivers measured simultaneously
- Characterized average system response to dust events and “weak to moderate” solar storms
- Discovered two ‘new’ kinds of aurora driven by particles from the Sun

Escape

- Present-day loss rates determined for H and O via all important mechanisms
- Photochemical escape dominates loss of O under present conditions
- Hydrogen escape varies seasonally, driven from below

Reservoirs

- Observed high variability throughout the entire system: “no such thing as steady state”
- Measured thermospheric winds and waves
- Characterized ionospheric structure
- Magnetosphere is a complex “hybrid” obstacle to the solar wind

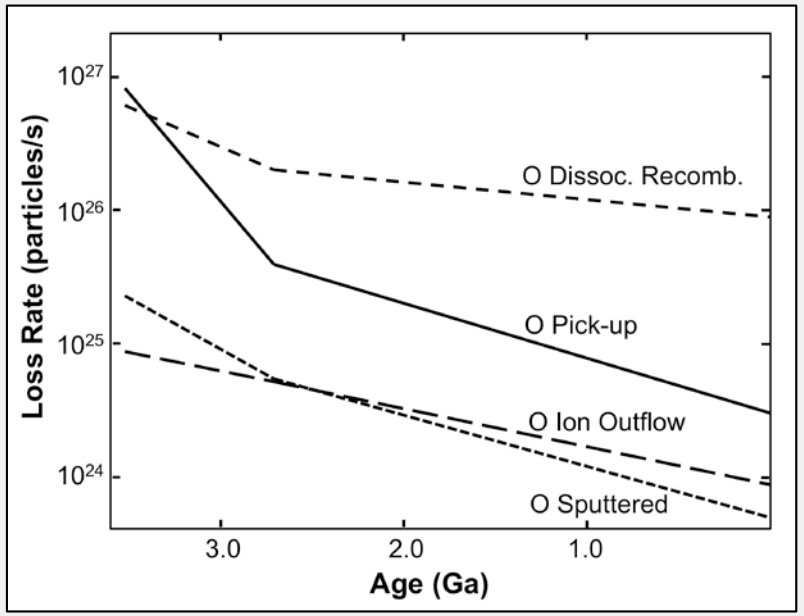
Evolution

- Escape to space has been significant over Martian history (> 0.5 bar)

Knowledge Gaps: Evolution

Blue = Gap in understanding
- Black bullets = Needs

Red = TechDev needed(?)



Chassefiere and Leblanc, 2013

Gap: High fidelity estimates of escape vs. time –and– integrated escape
- Measurements during robust solar max
- More measurements during dust storms and solar storms
- Detailed modeling (upper atmosphere only) validated by full range of observations
- Detailed modeling (entire atmosphere)

Gap: Understanding of relative importance of different loss mechanisms through time
- Same as above, but process-specific
- Modeling of “feedback” between mechanisms

Knowledge Gaps: Escape

Gap: Understanding of what limits escape for each species

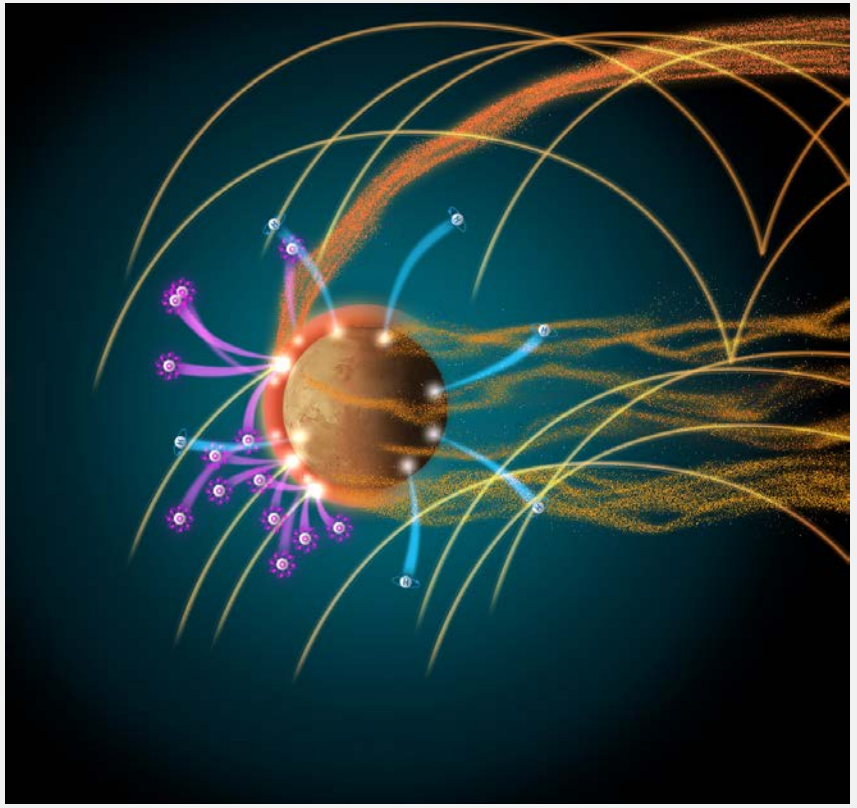
- Measurements of energy input from solar EUV and solar wind made simultaneously with measurements of escape and with estimates of supply / diffusion from below

Gap: Verification that sputtering occurs at Mars

- High altitude (> 400 km) measurements of argon (and other massive species?) at all local times, with simultaneous measurements of precipitating ions

Gap: Estimates of the escape rate of carbon

- Measured / inferred escape rates of CO_2, CO, C (both neutral and ion)



Knowledge Gaps: Reservoirs

Gap: Understanding upper atmospheric connection to the lower atmosphere

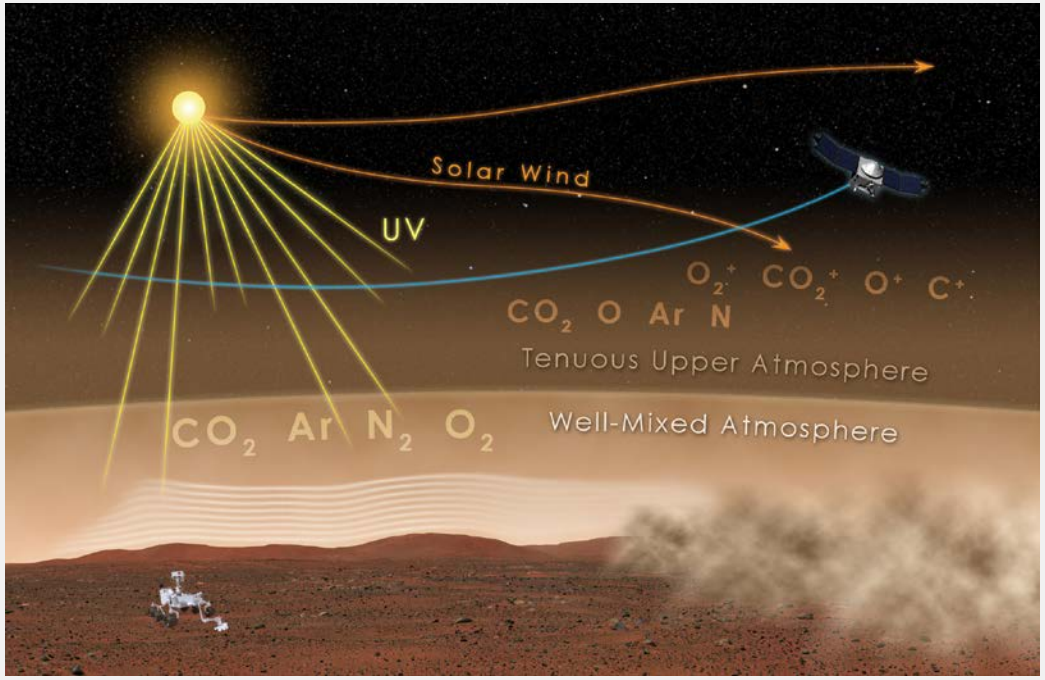
- Emirates Mars Mission results
- More dust events
- Wave measurements in the middle atmosphere

Gap: Understanding of the microphysics and electrodynamics of the magnetosphere, especially on timescales of minutes to hours

- High time resolution, fully 3D plasma observations
- Vector electric field measurements
- Multi-platform measurements (variety of options)

Gap: Compositional and thermal structure & variability of the ionosphere and thermosphere

- More in situ measurements below 150 km



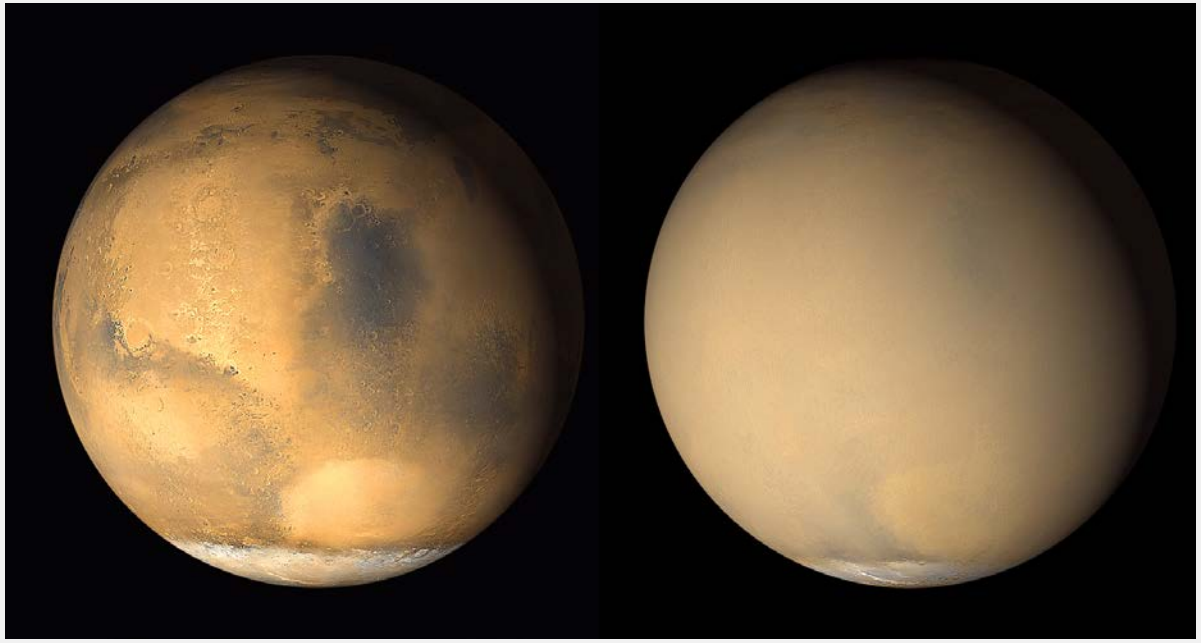
Knowledge Gaps: Drivers

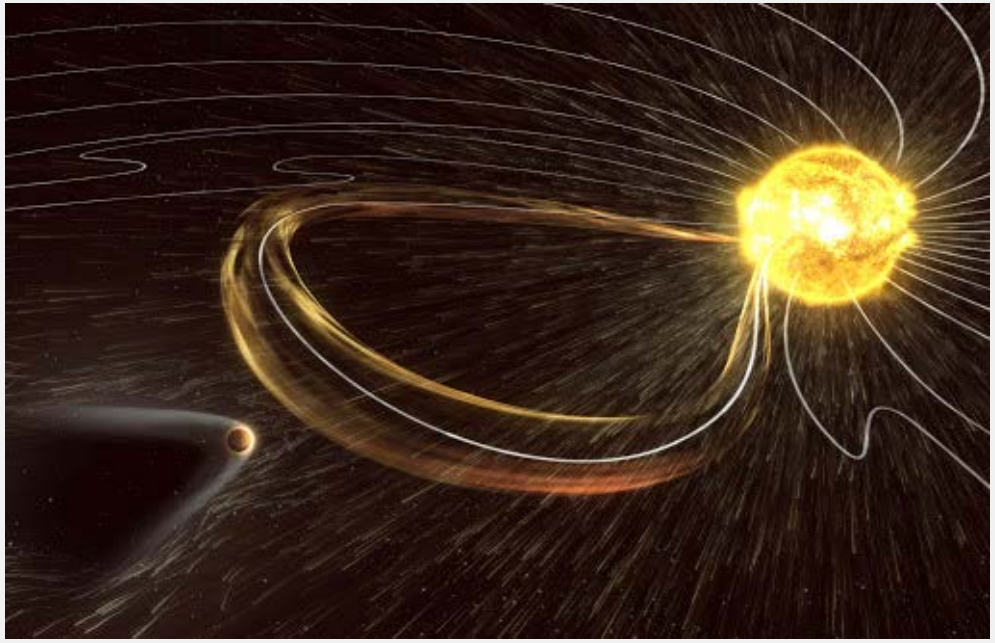
Gap: Influence of dust storms on upper atmosphere and escape

- More dust storms – please recommend for coming decade!

Gap: Influence of solar storms (flares, CMEs, SEPs) on upper atmosphere and escape

- More intense events – please recommend for coming decade!

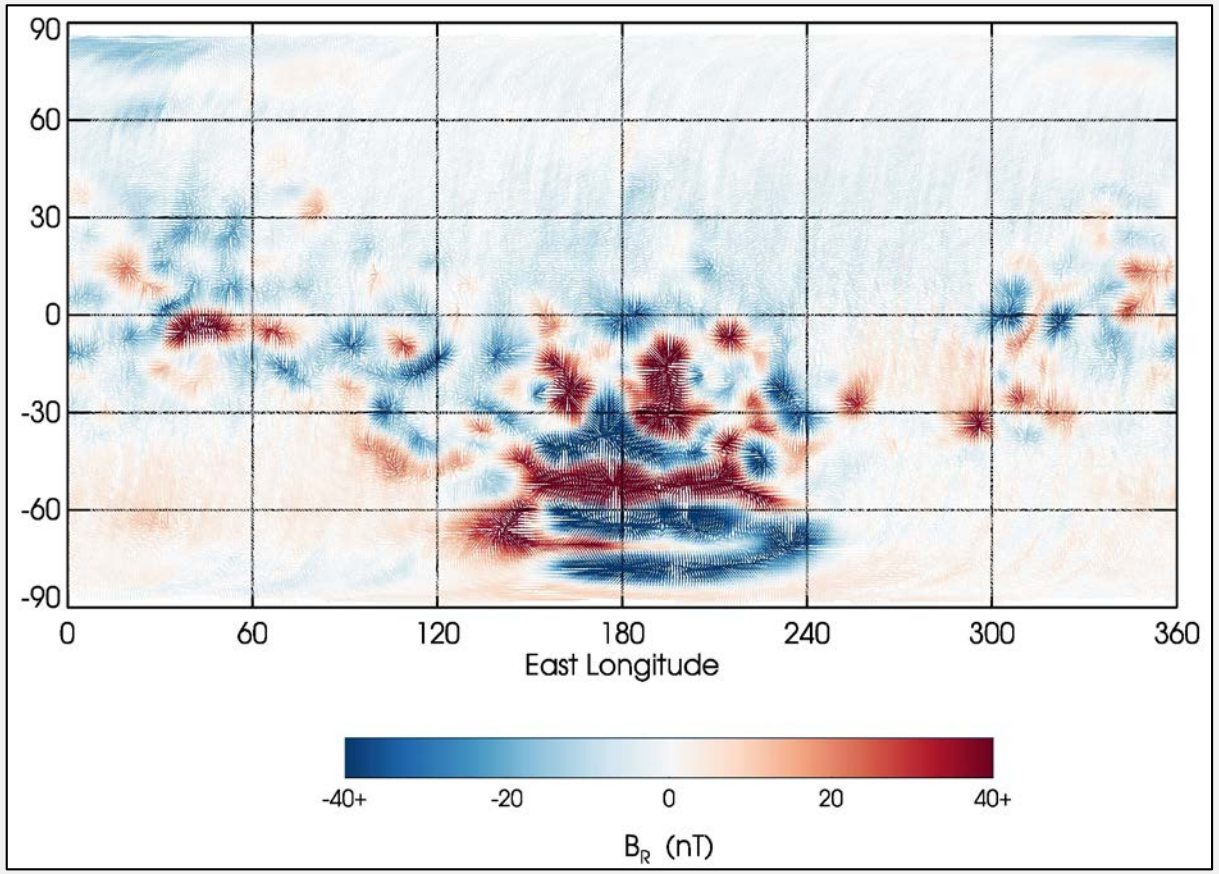




Knowledge Gaps: Crustal magnetic field influences

Gap: Influence of crustal magnetic fields on upper atmosphere and escape

- More low-altitude particle and field measurements (from above the exobase to the ionospheric main peak) in both crustal and non-crustal field regions

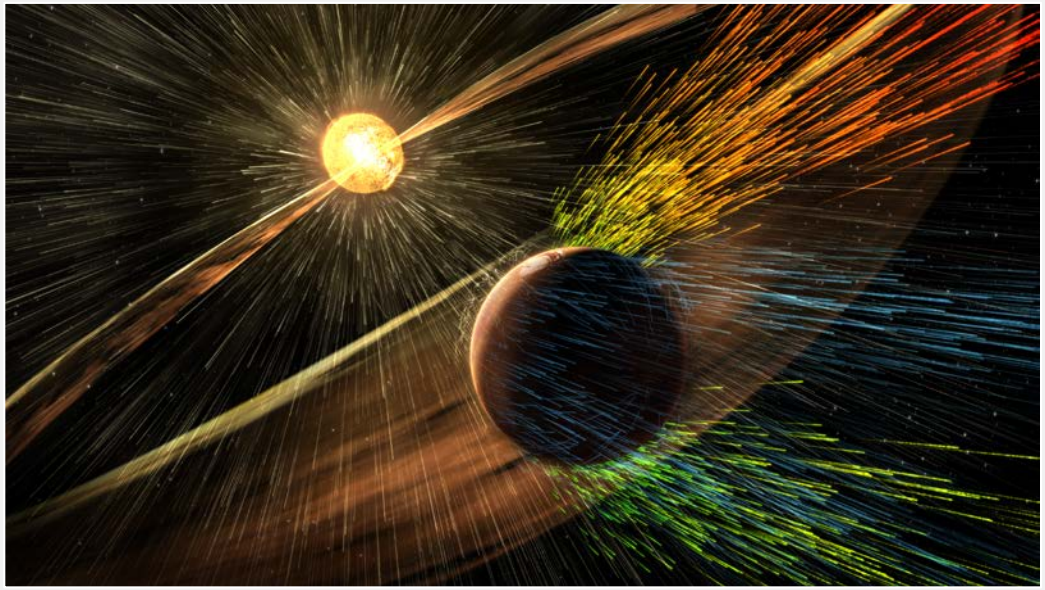


Summary

There has been much progress in the past decade

- The best dataset for planetary atmospheric escape is at Mars!

→ Mars is now the reference point for all planets



There is still much to be done

- Some knowledge gaps can be addressed through analysis of data from continuing and expected missions (e.g. MAVEN, Mars Express, EMM) and/or continued improvements in modeling
- Some knowledge gaps require new observations to be fully addressed
  (e.g. upstream monitoring, multi-platform,
  in situ < 150 km)