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APPLIED PHYSICS LABORATORY

Exospheric Signatures of Water Interaction with the Lunar Surface

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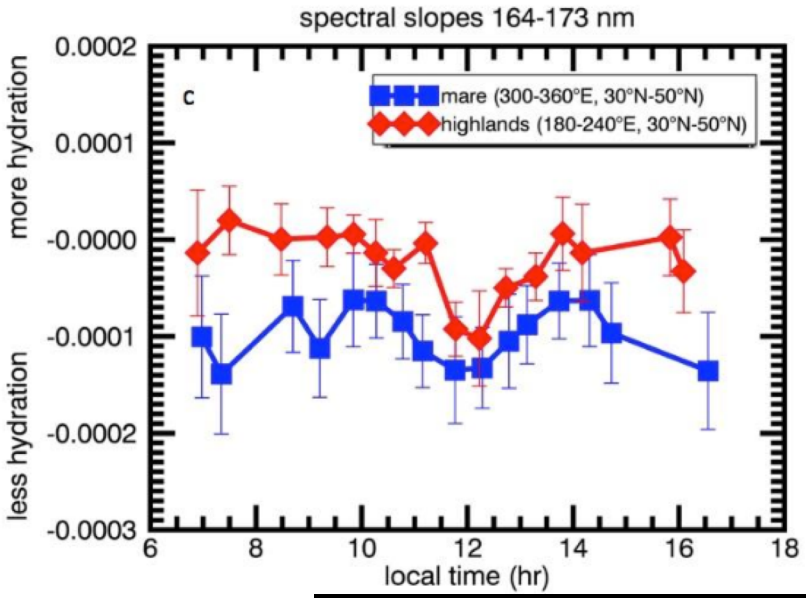
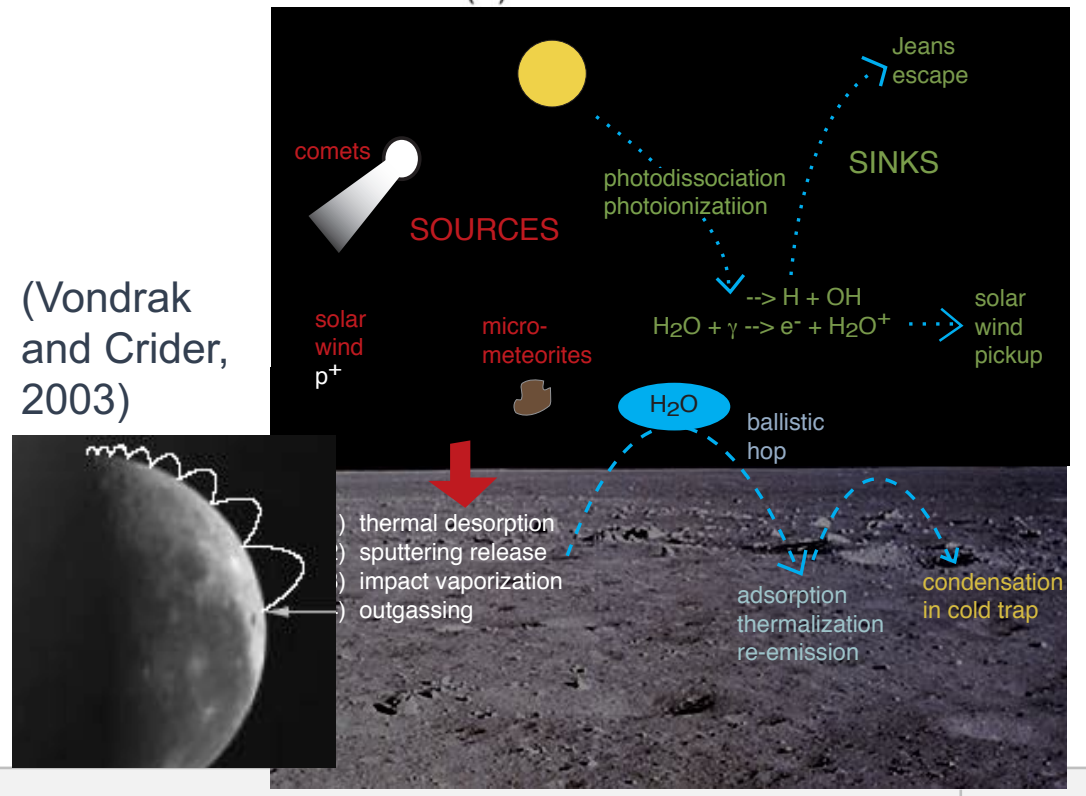
Big Questions

- What are the characteristics of the diurnal hydration on the daylit surface?
- What are the relative contributions of meteoroids and solar wind to lunar surface hydration?
- Does water migrate through the lunar exosphere to be a source of water to lunar Persistently Shadowed Regions (PSRs)? What is the efficiency?
- What is the relationship between the ongoing processes and ancient deposits in lunar PSRs?



(Hendrix et al., 2019)

(Crider and Vondrak, 2000)



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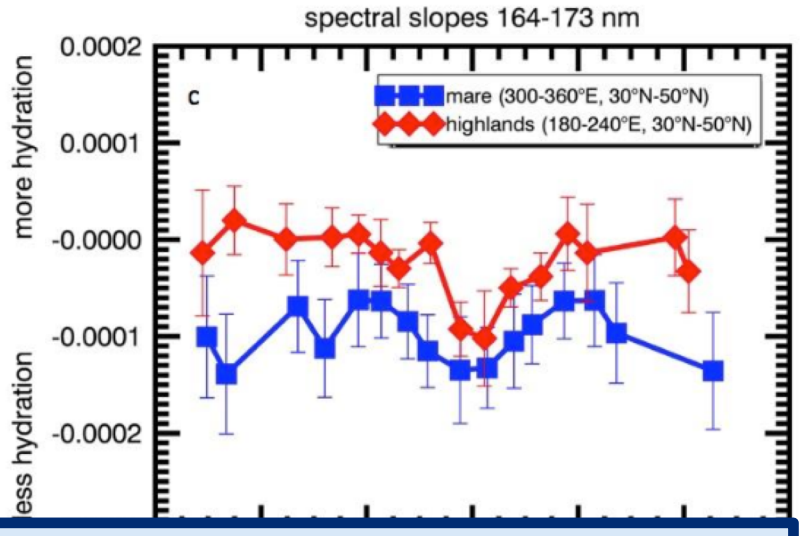

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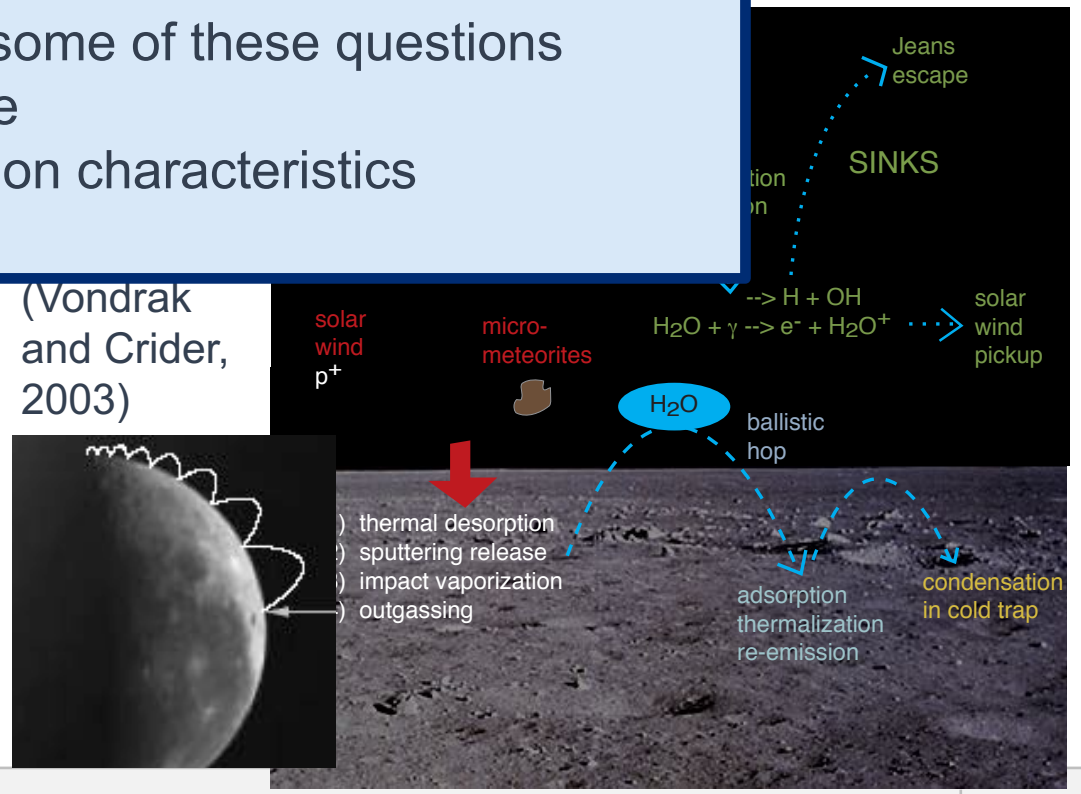


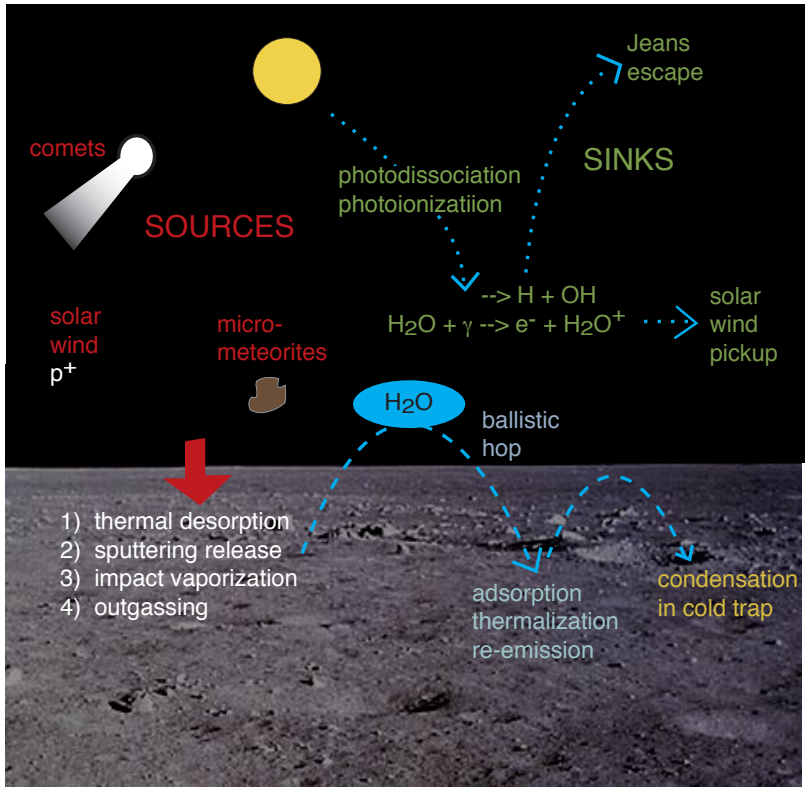
(Vondrak and Crider, 2003)

Answer—Measurements of water in the lunar exosphere could answer some of these questions

- Source and source rate
- Water-regolith adsorption characteristics
- Migration efficiency

Model

- Monte Carlo simulation with 1e6 model water molecules per second source rate
- Equation of motion under gravity
  - No collisions
  - No radiation pressure
- Sources
  - Solar wind
  - Meteoroids (Horanyi et al., 2015)
- Surface interactions
  - Activation energy sets release temperature where residence time is less than time step
  - Rerelease velocity from Maxwell-Boltzmann at local surface temperature
  - Hurley et al. (2015) surface temperature model with perturbations
- Losses
  - Crossing Hill sphere at 35 R_{Moon}
  - Photolysis (Huebner et al., 1992)
  - Landing in PSR (Mazarico et al., 2011)



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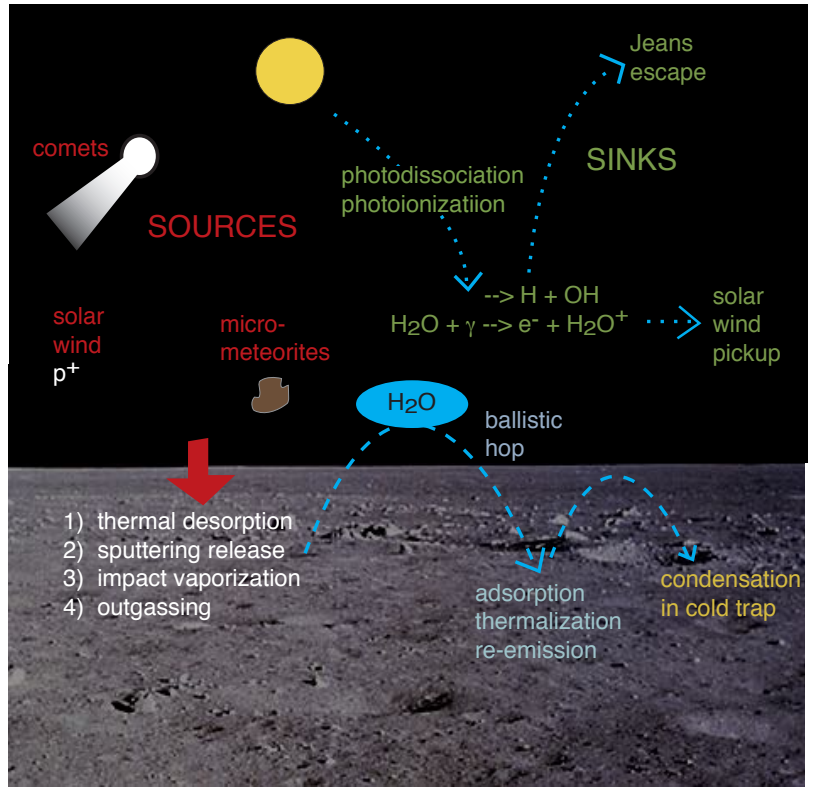


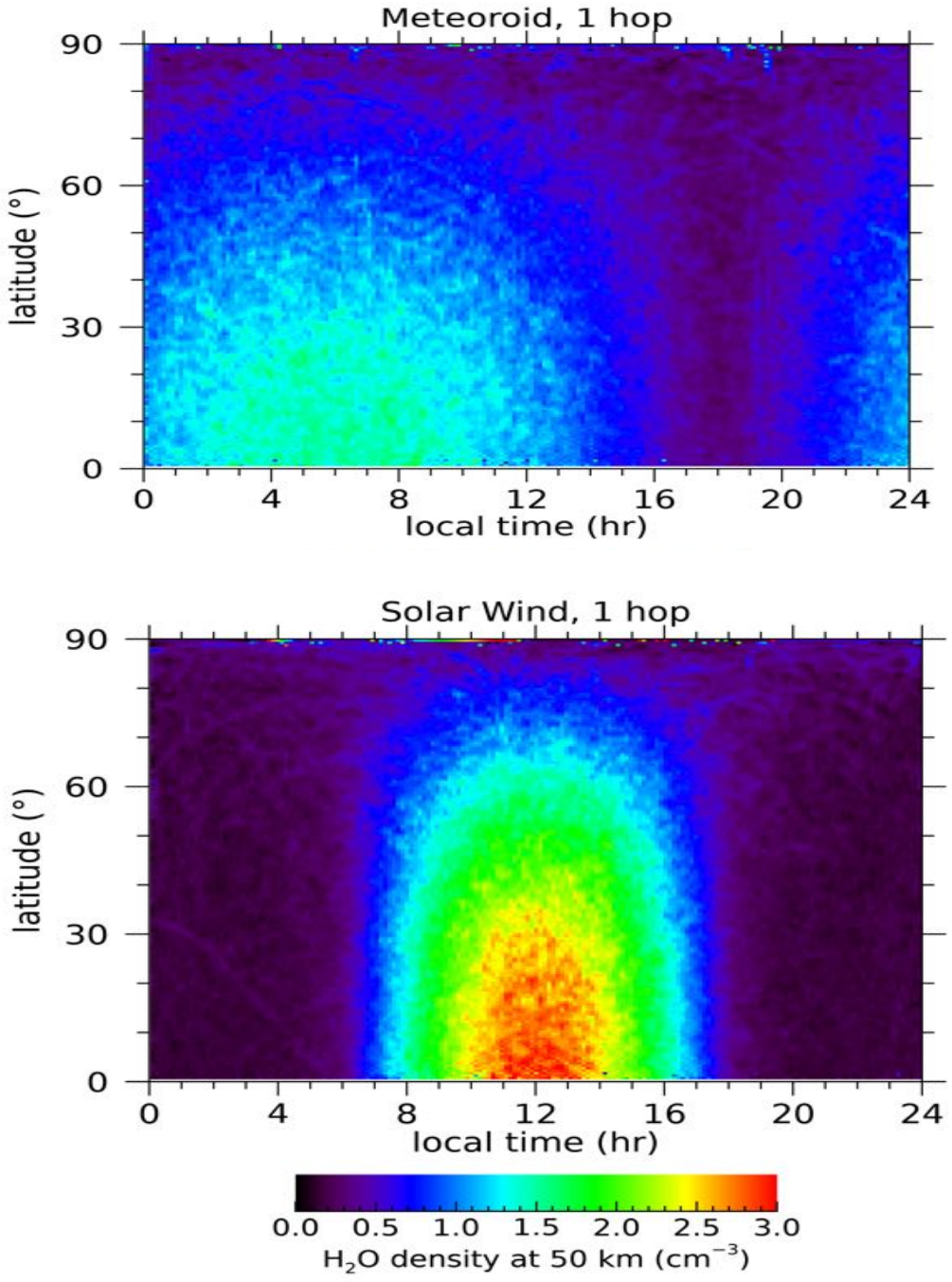
Simulated 1-Hop Exosphere

- Assume the binding energy is high and all waters that come into contact stick

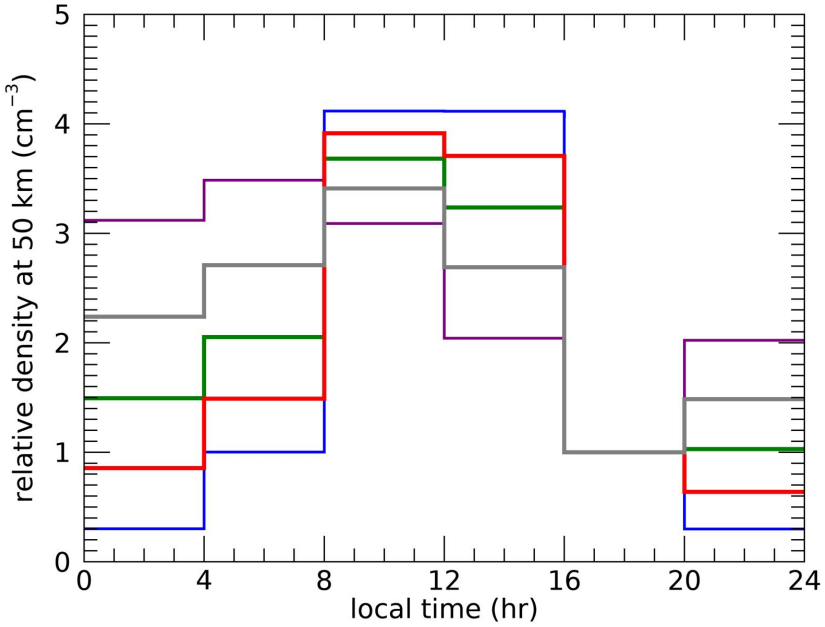
Simulated 1-Hop Exosphere

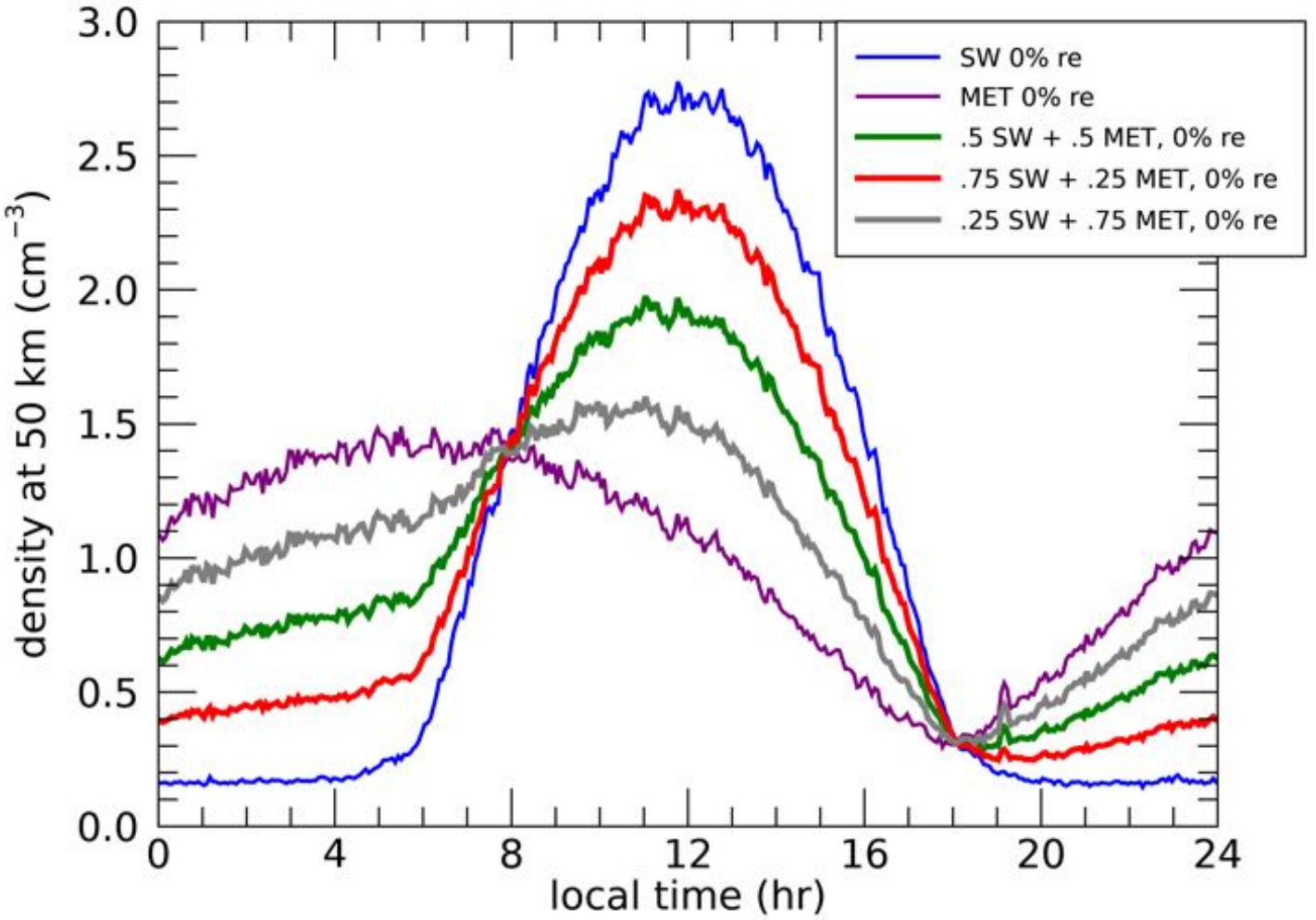
- Spatial distribution is same as spatial distribution of source
  - Peaks in morning for meteoroids
  - Peaks at noon for solar wind
- This can be a distinguishing feature to determine the relative contribution of the sources

Source	Source rate (g s^{-1})	% of inventory
Meteoroids	0.3	0.2-1.0%
Solar Wind	0.2	0.04-0.2%



1-Hop: Local Time Distribution Reveals Source



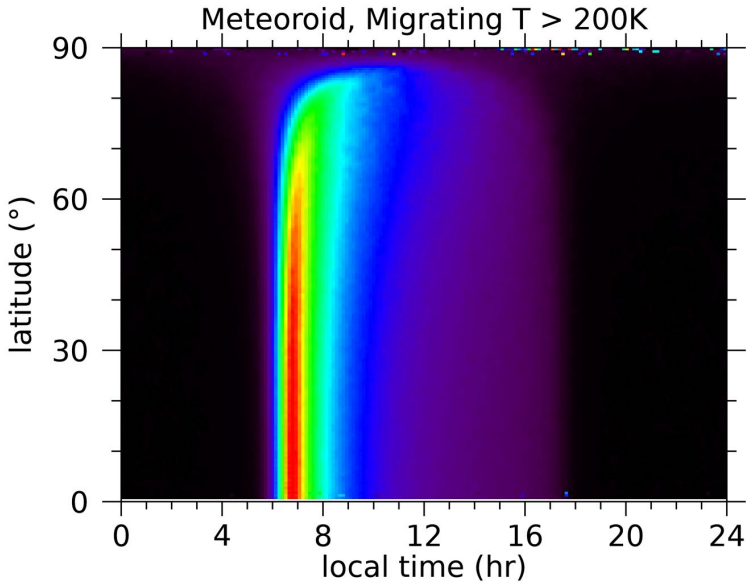


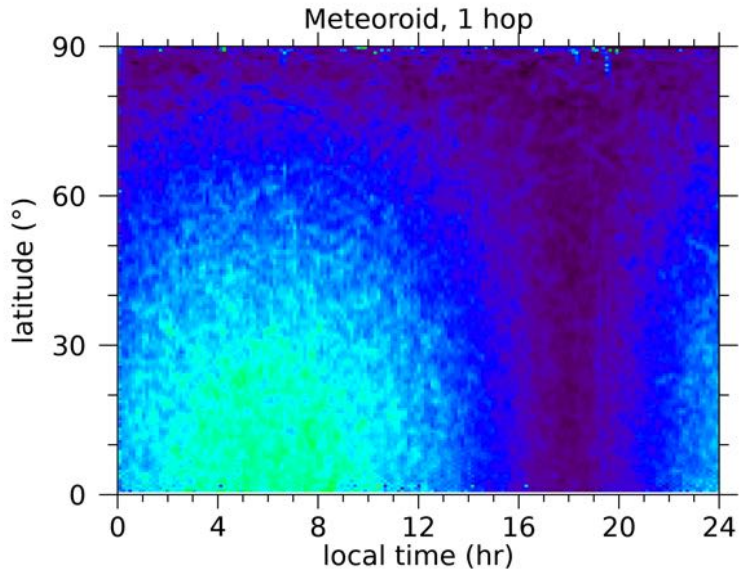
Equatorial density local time profile established relative source rate

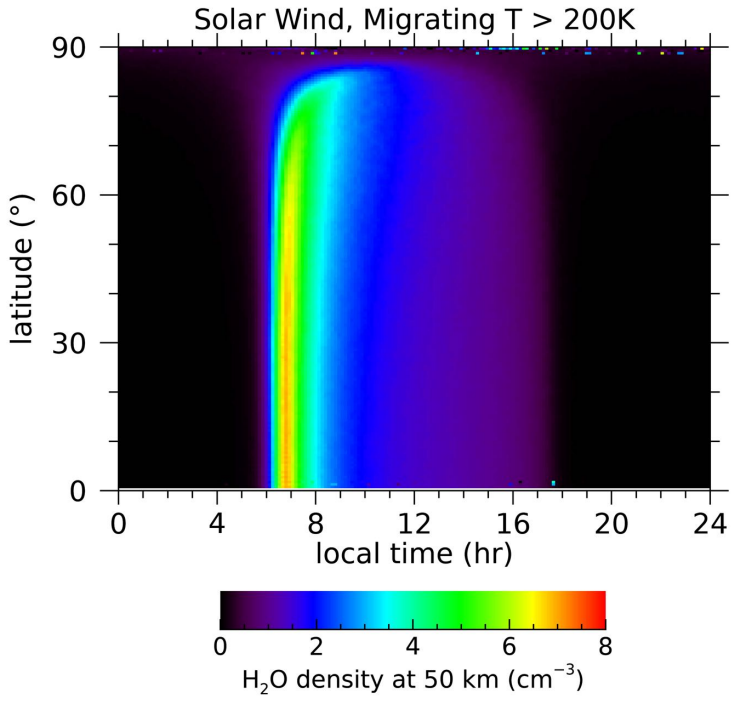
- High pre-dawn indicates meteoroids
- High mid-afternoon indicates solar wind

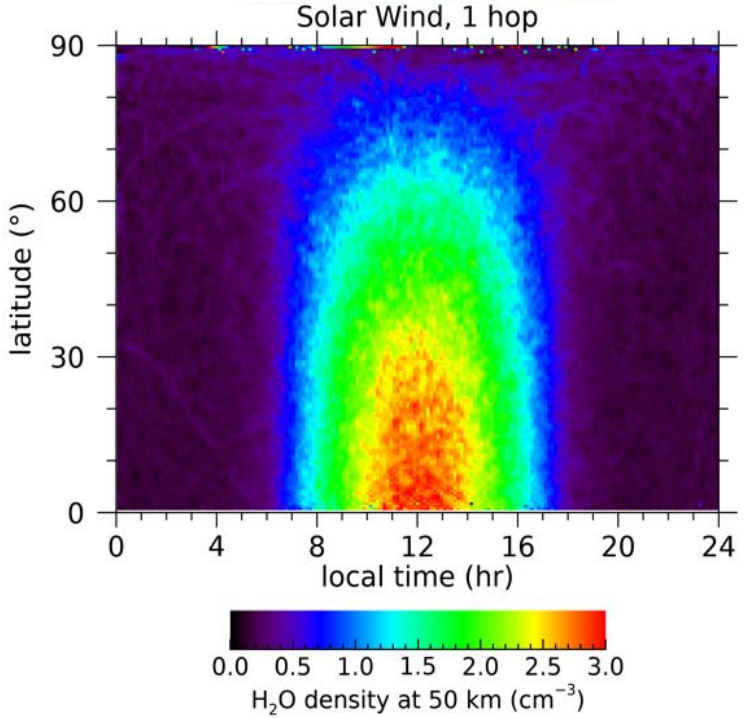
Multiple hops

- Spatial distribution of source is no longer evident
- Peak observed at low-mid latitude near dawn
- Sharp gradient on nightward side of dawn, gradual gradient across entire dayside





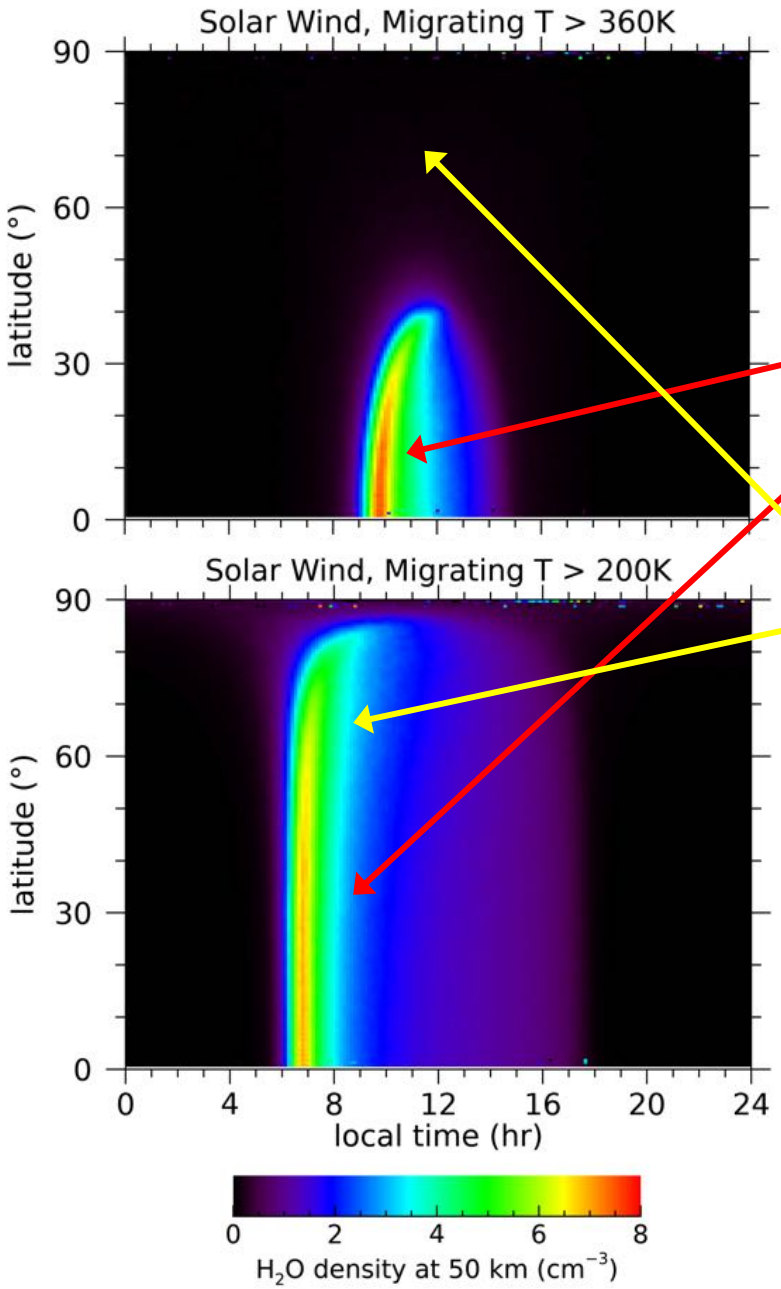




The activation energy of the surface modulates the exospheric distribution

Top run: Uses a stickier surface, release temperature is 360 K

Bottom run: Uses less sticky surface, release temperature is 200 K



Exospheric enhancement moves from 6-8 am to 9-11 am

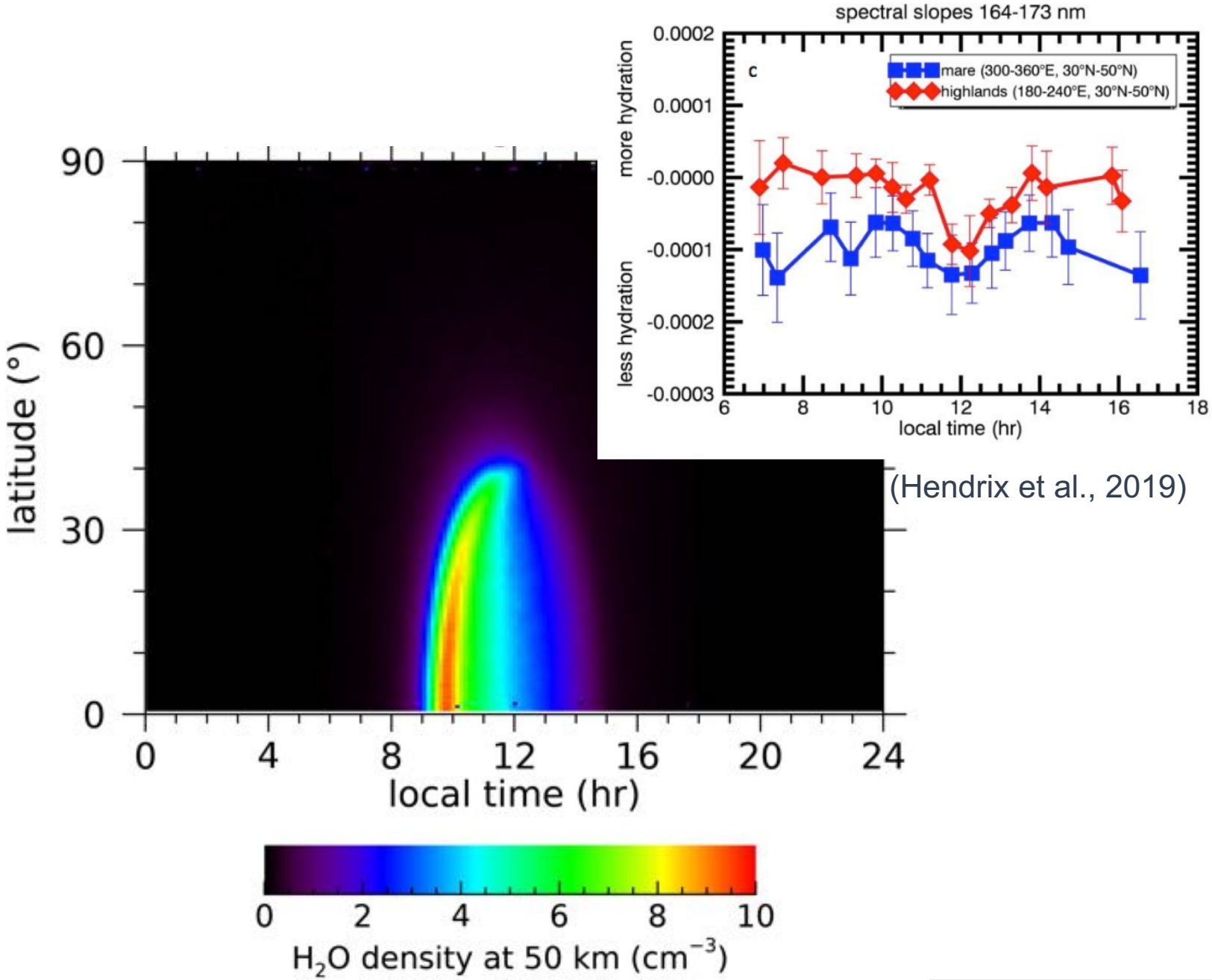
Latitude distribution changes such that little exosphere is present at high latitudes for higher activation energies.

The activation energy of the surface modulates the exospheric distribution

Stickier surface is more consistent with recent LAMP surface hydration analysis.

Source rate implied is very small fraction of ongoing sources: 0.004 gs^{-1}

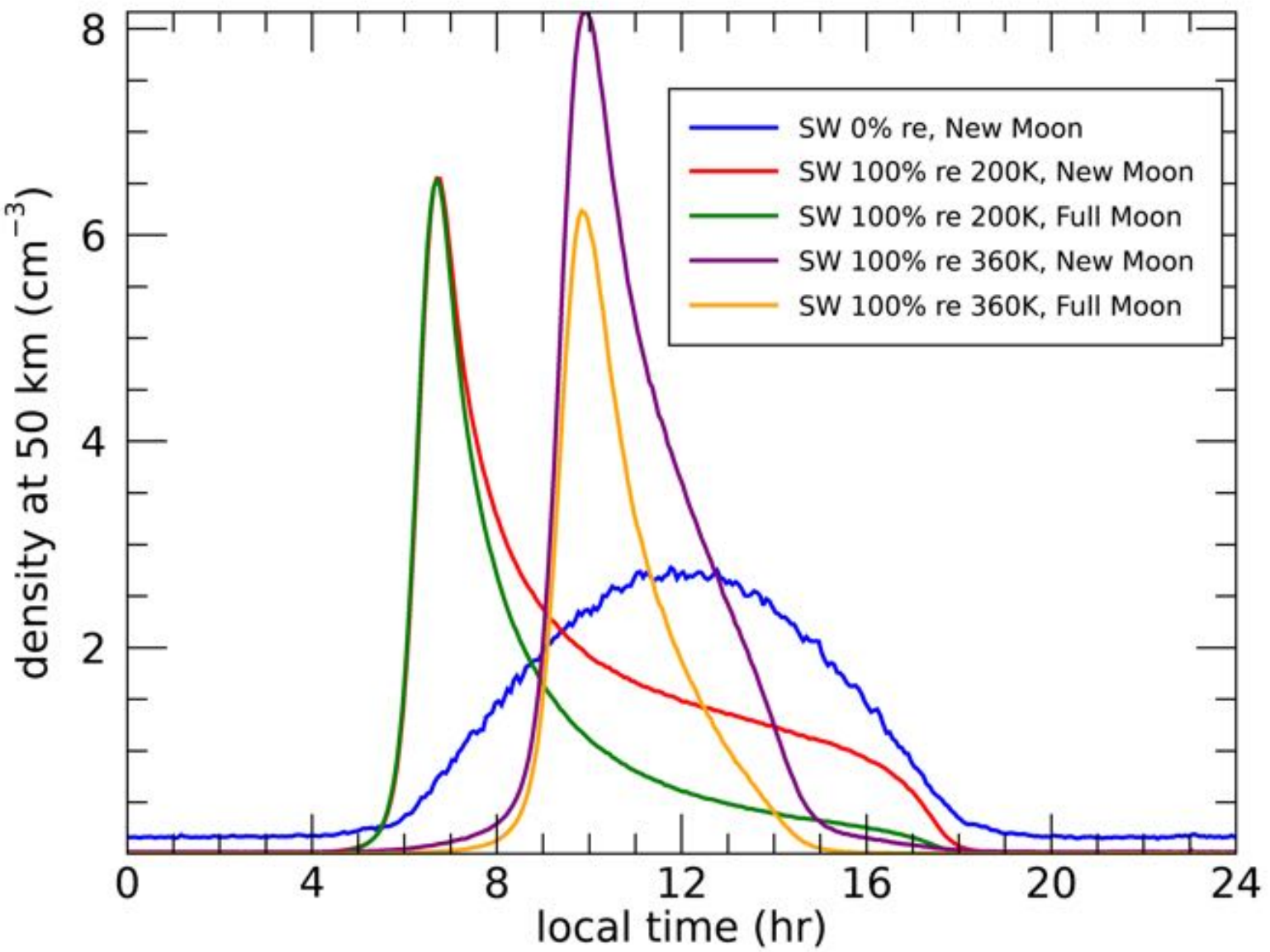
What is happening to the rest of the volatiles brought by these sources?



(Hendrix et al., 2019)

With migration, phase of Moon can reveal solar wind contribution

- Prompt solar wind source is off during magnetotail passage
- With migration, Full Moon observations include only migrating water.
- Comparisons with solar wind time can determine strength of solar wind source.



Conclusions

Lunar exospheric water measurements can address several interesting questions in lunar volatiles

- Does migration through the exosphere occur?
  - The spatial distribution in local time of the water exosphere will reveal the efficiency of migration.
- What are the contributions of meteoroids to water migration?
  - Meteoroid-released water is centered in the morning hemisphere.
  - Meteoroid streams would produce higher concentrations of water in the exosphere.
- What is the contribution of solar wind to water migration?
  - Magnetotail passages should reduce the exospheric content in the afternoon sector if prompt solar wind production is a significant contributor.
- What is the nature of the interaction between water molecules and lunar regolith?
  - The location of a “dawn enhancement” reveals the stickiness of lunar regolith.

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Conclusions

Potential Measurements

Lunar exospheric water measurements can address several interesting questions in lunar volatiles

- What are the characteristics of the diurnal hydration on the daylit surface?
  - Improved measurements of surface hydration; coordinated exosphere measurements
- What are the relative contributions of meteoroids and solar wind to lunar surface hydration?
  - Time-resolved measurements of surface hydration and sources.
- Does water migrate through the lunar exosphere to be a source of water to lunar Persistently Shadowed Regions (PSRs)? What is the efficiency?
  - Improved exospheric measurements; time-resolved PSR near-surface monitoring
- What is the relationship between the ongoing processes and ancient deposits in lunar PSRs?
  - Exploration of PSR in situ; correlation with environment