Modeling the Production, Delivery, and Maintenance of OH/H_2O on the Lunar Surface

Dana M. Hurley
Dana.Hurley@jhuapl.edu

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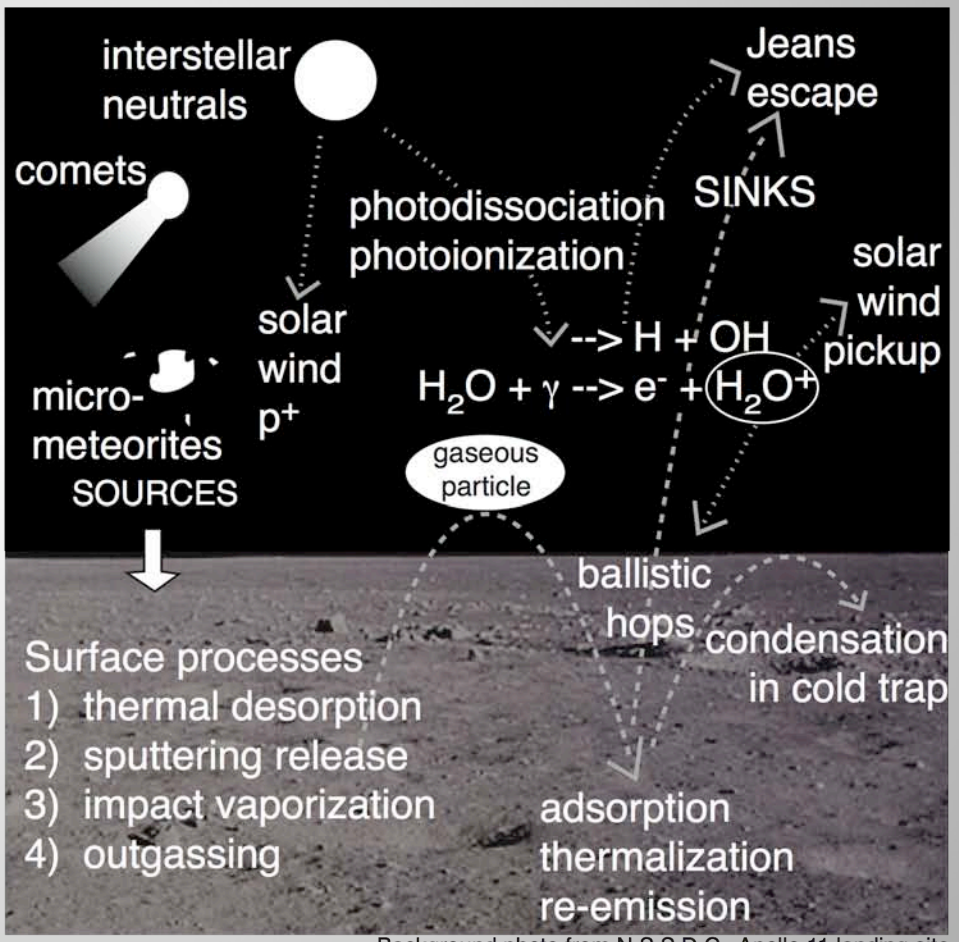
Lunar Surface-Atmosphere System

- Source rate
  - Dust, comets, solar wind
  - Distribution and velocity
- Surface stability
  - Thermal desorption
  - Photon-stimulated desorption
  - Sputtering
  - Impact vaporization
- Migration
  - Residence time
  - Lifetime
  - Surface redistribution
  - Inward migration
- Loss mechanisms
  - Photodissociation
  - Sputtering
  - Surface sinks



Background photo from N.S.S.D.C., Apollo 11 landing site

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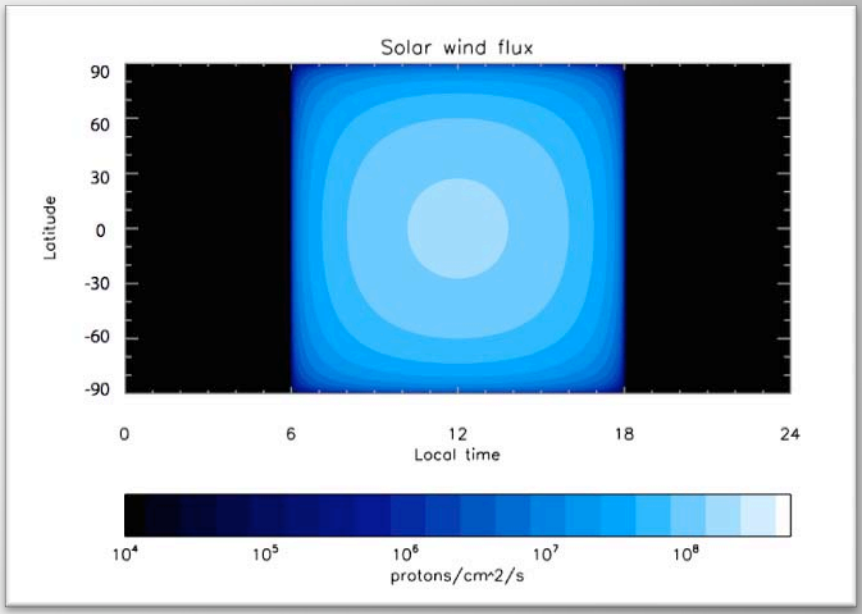
Solar Wind (SW) Delivery Rate

- SW flux falls off with solar zenith angle (SZA).
- The distribution does not match observations of high amounts at the poles.
- Converting 100% SW to H_2O for 1 lifetime:
  - Fluence of 3.4e12 H_2O/cm^2
  - Convert to global layer 10^{-10} cm.
- Assuming a weight fraction of 1000 ppm, and 100% conversion to H_2O, a thickness of 10 Å can be produced in steady state.



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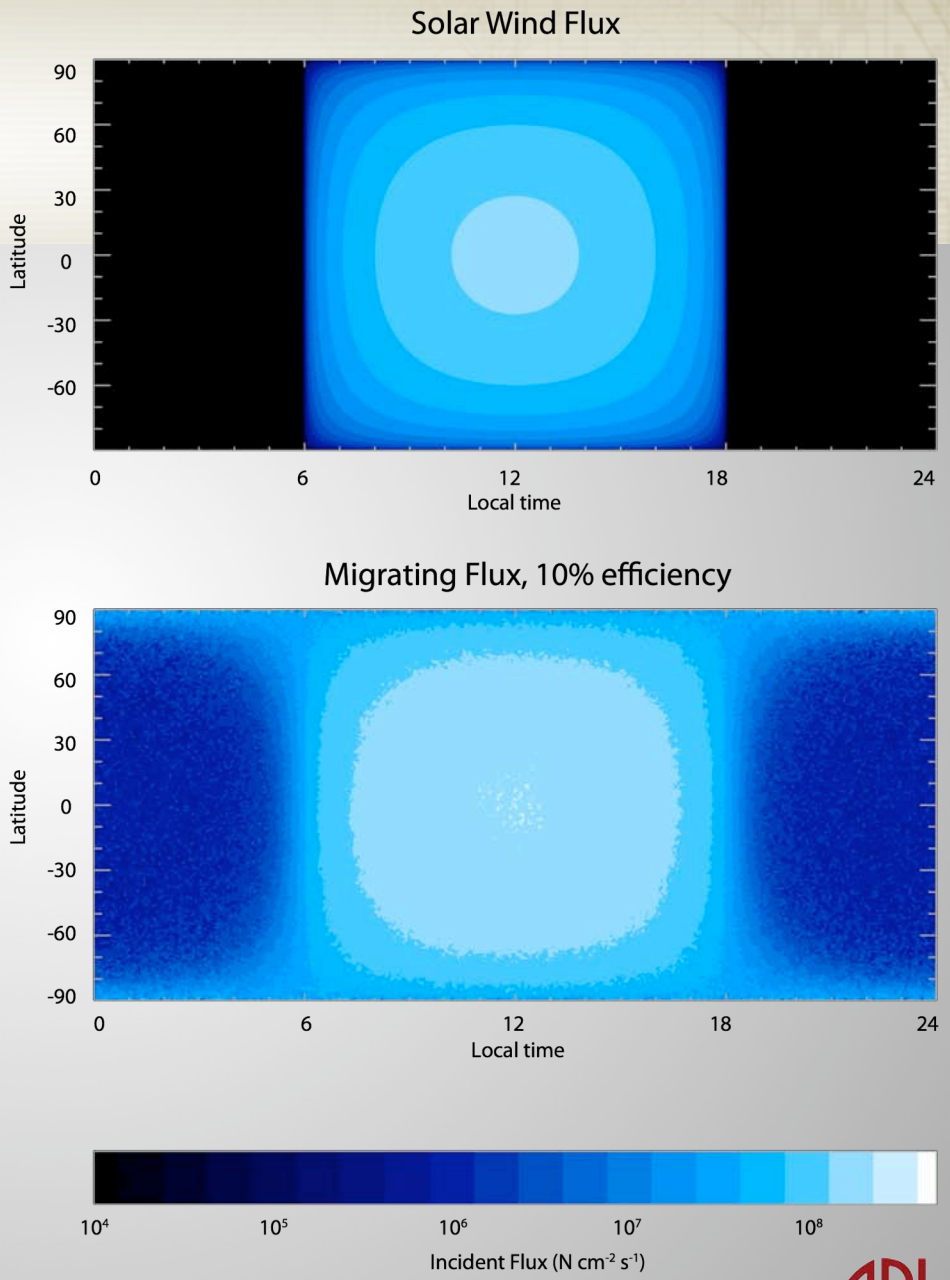
Migrating Flux

- Monte Carlo model of migration pattern of H_2O
- Each particle takes an average of 27 hops—boosts flux
- Migration redistributes particles to higher solar zenith angles
- Still have the peak flux at the equator



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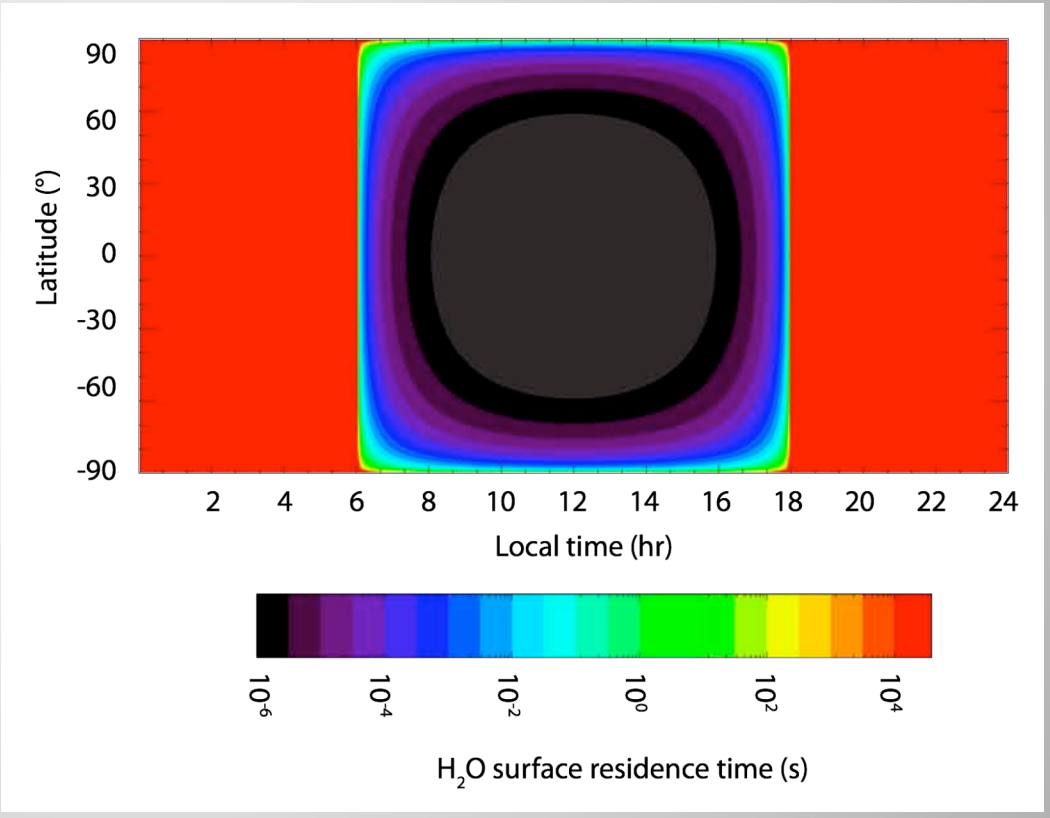
Surface Residence

- Migrating H_2O particles reencounter the surface, interact, and later thermally desorb
- Observations are of particles on the surface
- Short dayside residence times, long nightside residence time



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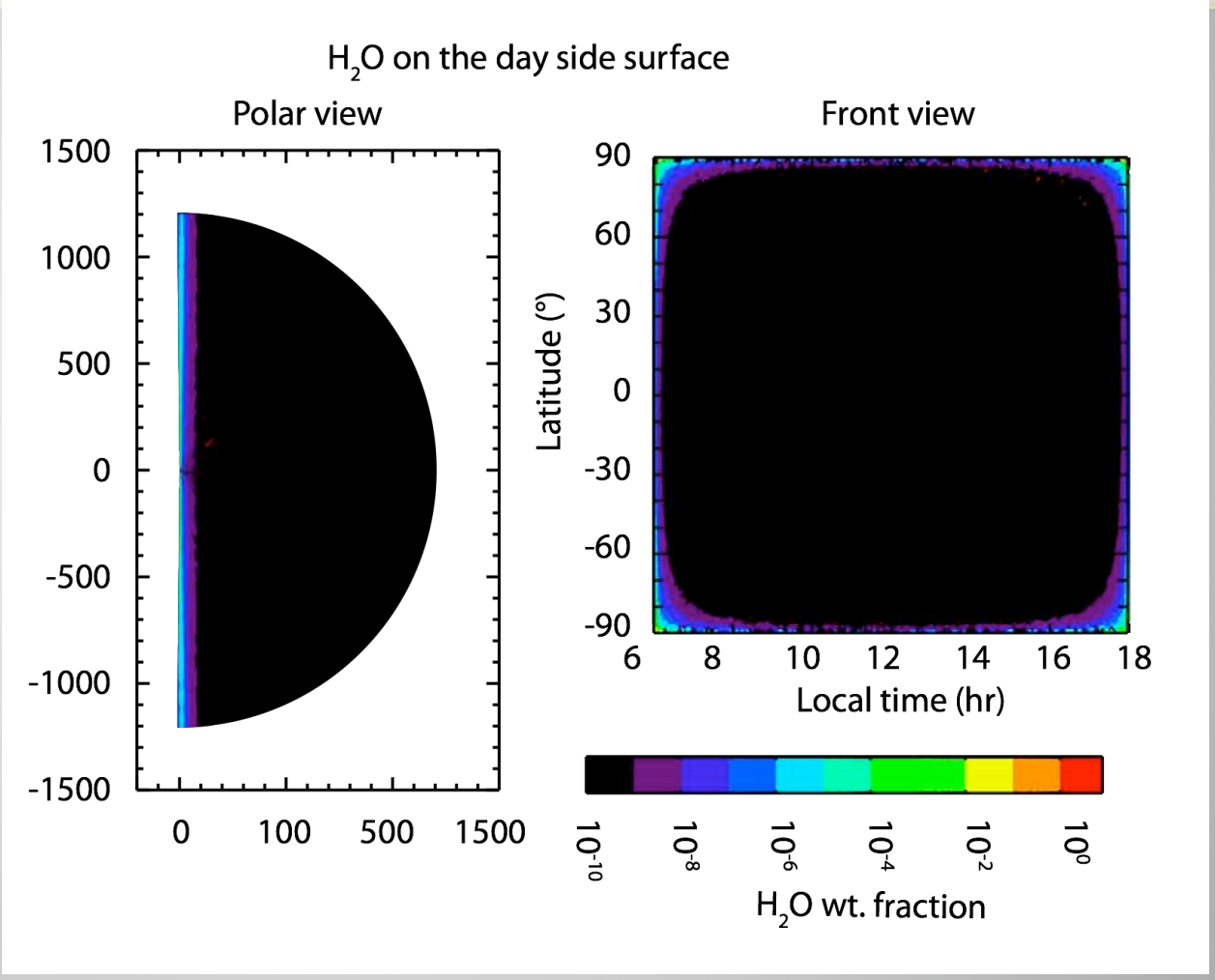
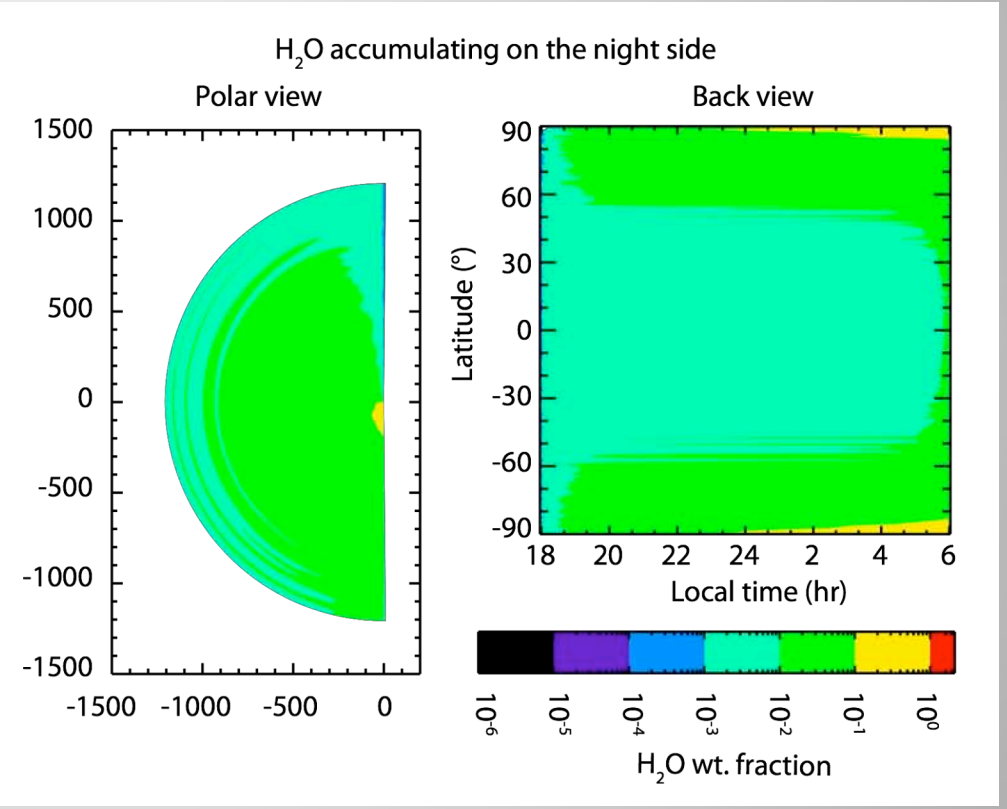
Dayside H_2O Results

- Convolve migrating flux with a surface residence time function
- Result is a distribution that has higher concentrations at high latitude
- Weight fraction predicted is too low to observe except very close to the terminator (1e-3).



Adsorption to the nightside

- Long residence time on nightside due to low UV flux and low temperature
- Depending on release conditions, ~40% of molecules get trapped on the nightside each lunation.
  - Average particle lasts 1.67 cycles
- Migration on grain surfaces into regolith is possible
  - Perhaps this sequesters H_2O released by solar wind on the last lunation to depths below UV penetration



Conclusion

- Solar wind in steady state does not reproduce observed H_2O surface density
- Micrometeoroids—source rate of 2e5 $H_2Ocm^{-2}s^{-1}$
  - Did a simulation with a more global release distribution—changes sink on nightside and surface density by 10-25% from simulations shown here
- Comets—source rate of 3e6 $H_2Ocm^{-2}s^{-1}$
  - Sporadic
- Wild speculation
  - Recent larger source (comet)
  - Seasonal sequestration
  - Thick exchange layer perpetuated by diurnal cycle
  - Complex surface chemistry/long residence times

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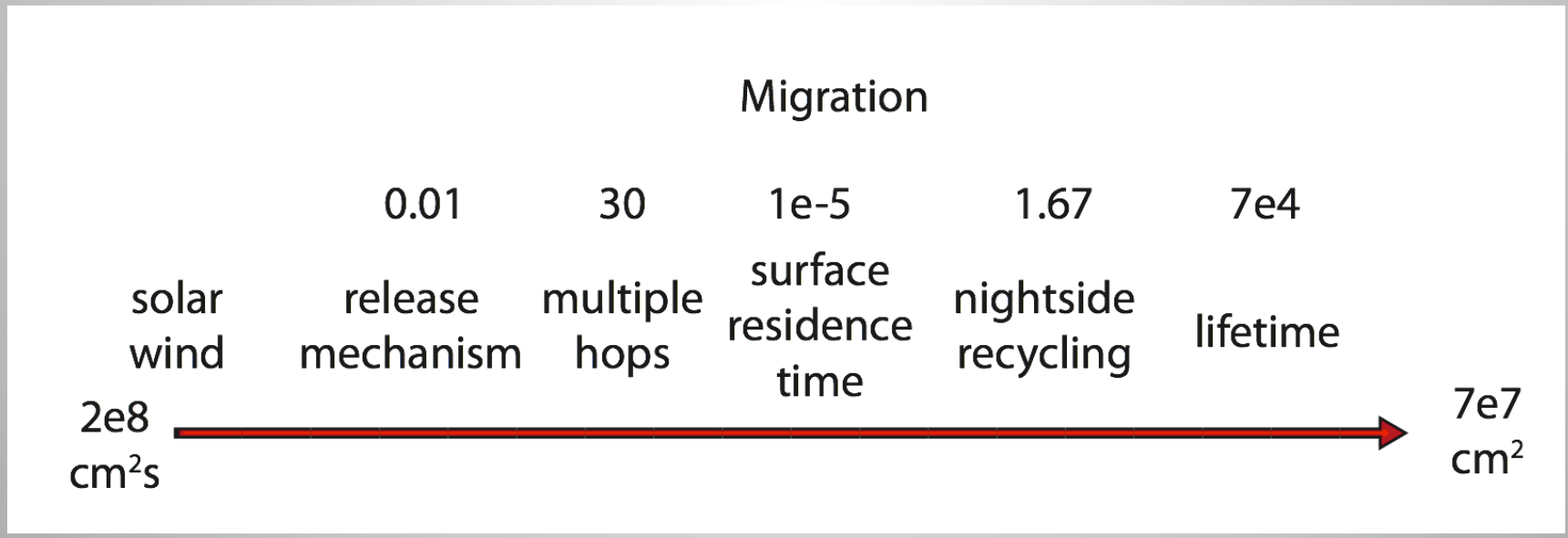
Future Directions

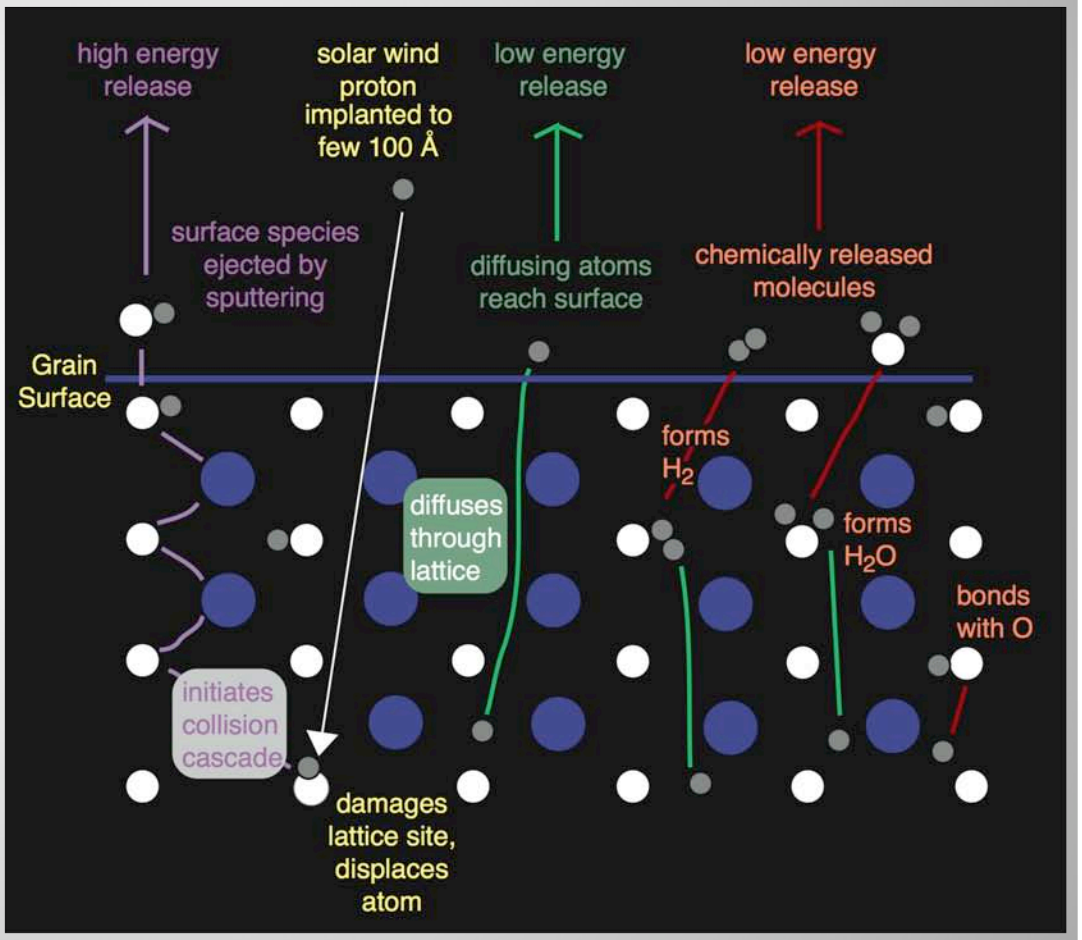
- Surface atmosphere interactions
- Regolith reservoir/depth recycling
- Stochastic sources



Backup

Solar Wind Implantation

- Solar wind protons are one possible source of hydrogen for OH/H_2O
  - Protons penetrate ~200 Å
  - Radiation damages lattice
  - Hydroxyl formation
- Lab indications are that saturation levels achieved in fluences expected in much less than the regolith turnover time
  - Mature regolith saturated?
- Perhaps there are two components, a physisorbed and a chemisorbed.



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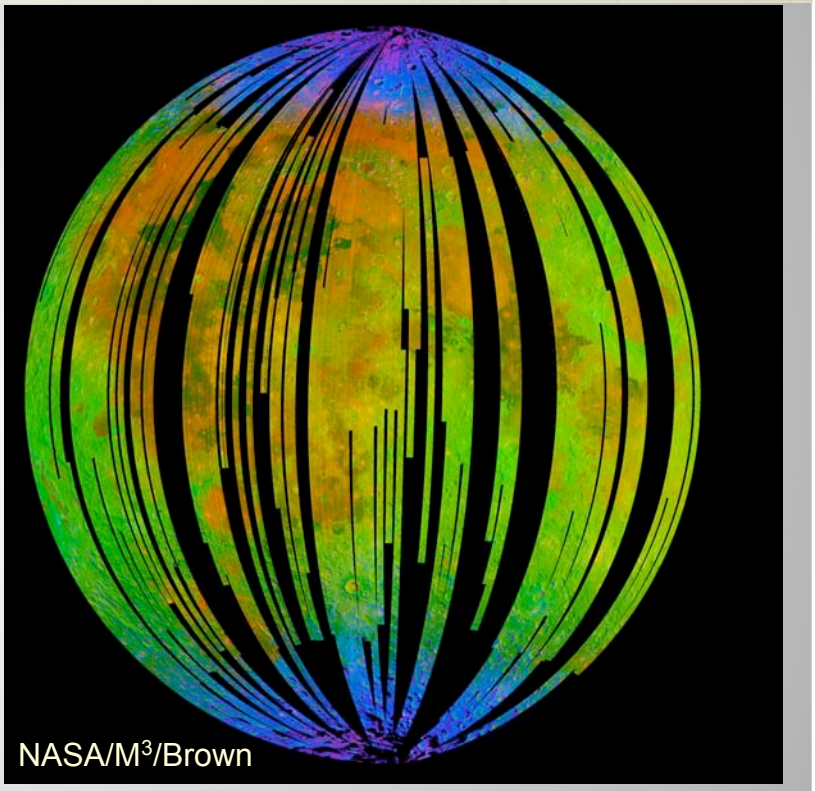
OH/H_2O Observations

Groundbreaking new observations bring new questions

- **Contents**
  - **Is it OH, H_2O, or both?**
  - **How much?**
- **Distribution**
  - **Lunar compositional dependence?**
  - **Solar zenith angle dependence?**
  - **Depth?**
- **Physics**
  - **Source?**
  - **Maintenance?**
  - **Loss?**



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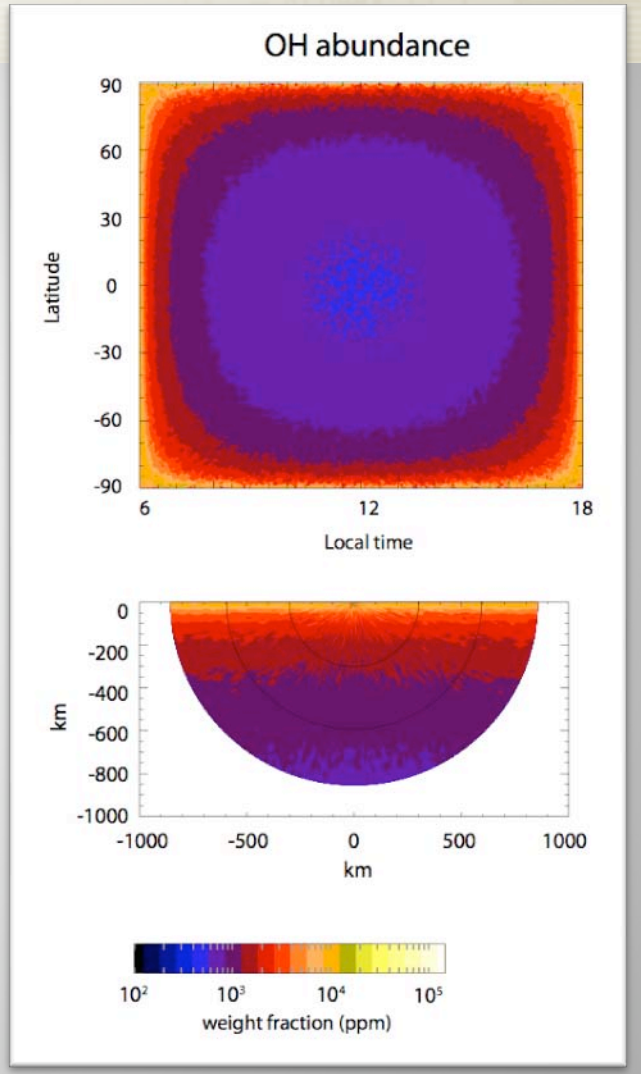
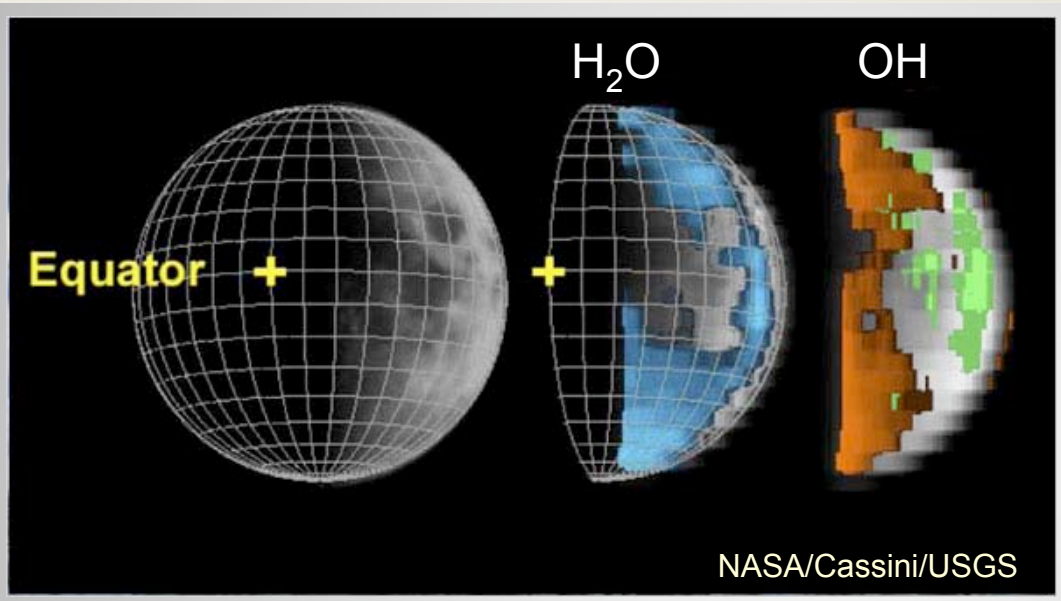
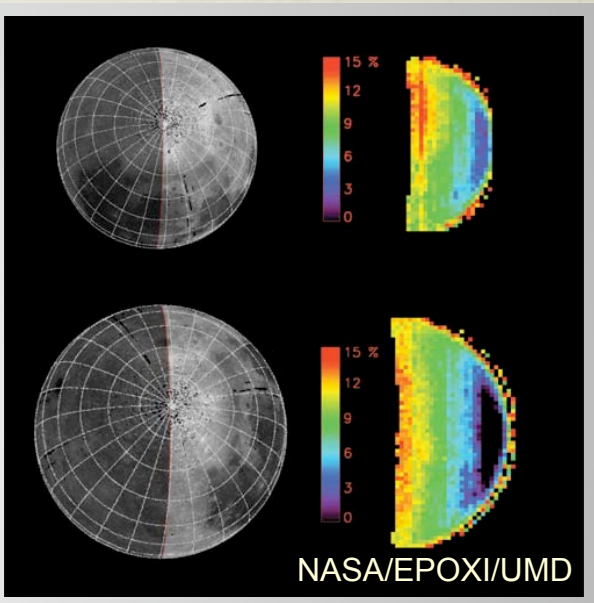
OH Simulations

- This simulation reproduces a diurnal surface density when pushed to these limits:
  - 100% efficiency of SW conversion to OH/H_2O
  - 500Å layer depth
  - Subsolar residence time of 18 hrs
  - Scales to a monolayer on 10 μm grain of 30 ppm



Spatial Distribution
Lunar OH/H_2O





- Highest concentrations are at highest latitudes (all three)
- EPOXI data indicate a diurnal signal (Sunshine et al., 2009)
- Investigate the possibilities of a diurnal signal
  - modeling the surface-atmosphere system
  - Start simple, add pieces one at a time
  - (Crider and Vondrak, 2000; 2002)

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