Landing at ice exposures in the lunar polar regions

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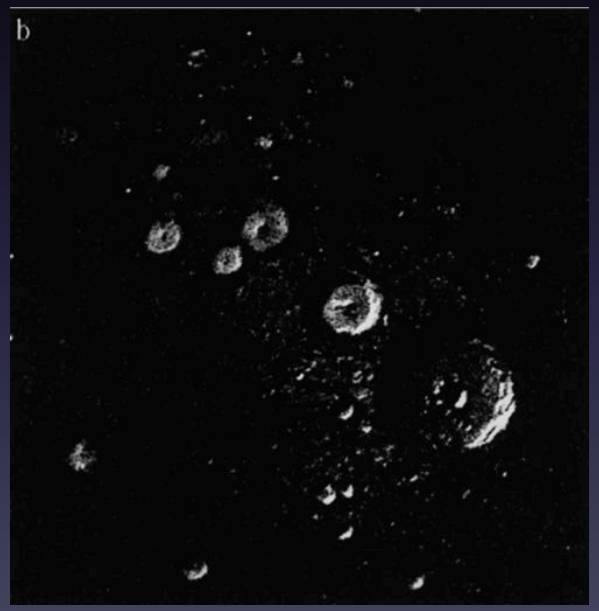
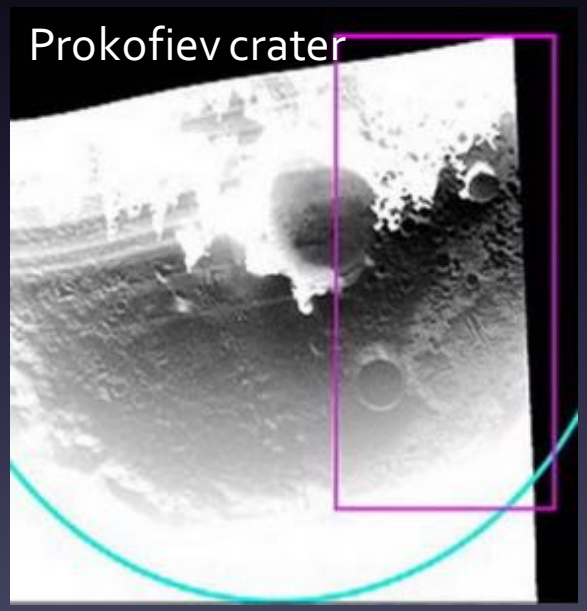
Introduction

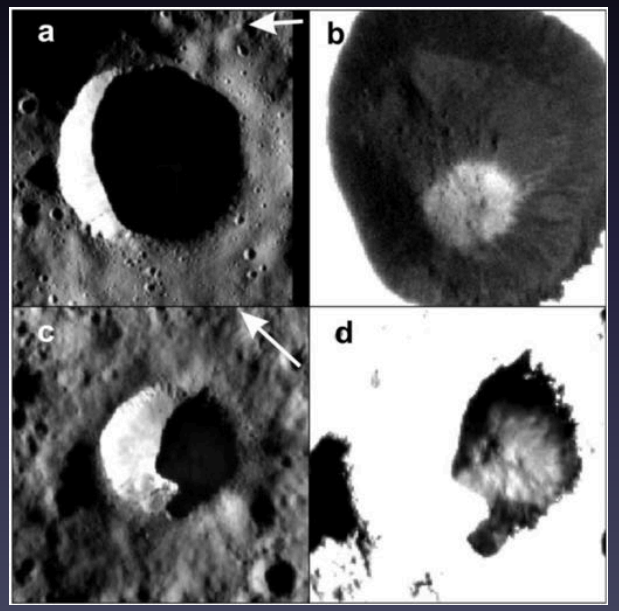
- Water ice may be allowed to accumulate at PSRs on airless bodies
  - Only few mm ice can be sublimated in billion years at temperature < 110 K (Zhang and Paige, 2009).
- Direct evidence for surface exposure ice on Mercury and Ceres was found.
  - The exposed ice is relatively pure.



Mercury NP, Radar,
Harmon et al., 2001



Mercury, MESSENGER WAC
Chabot et al., 2014

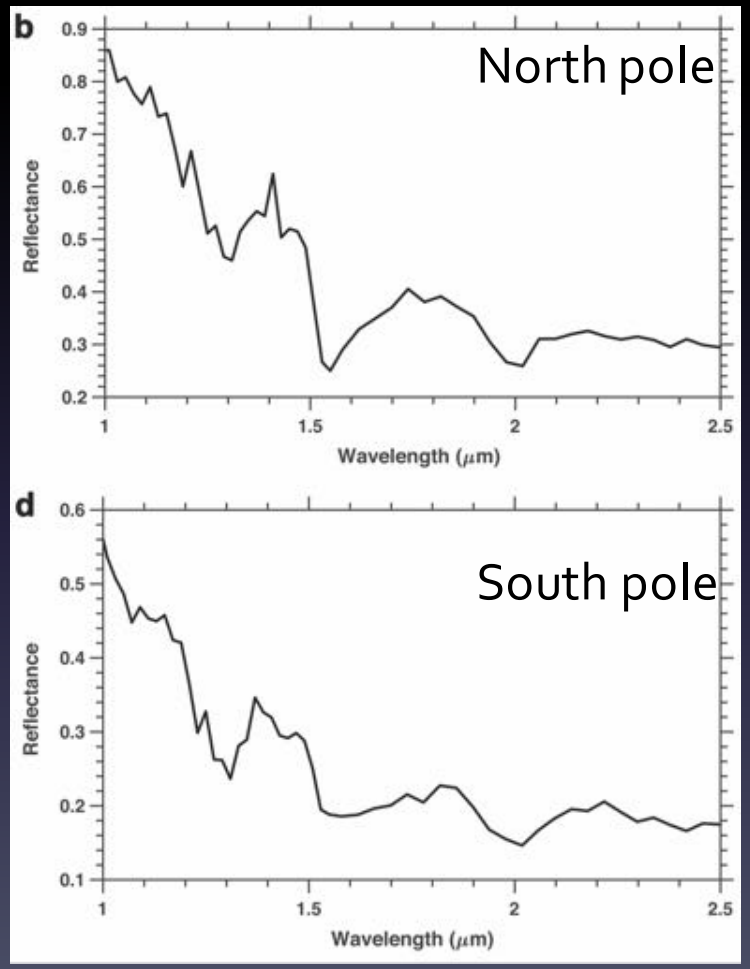


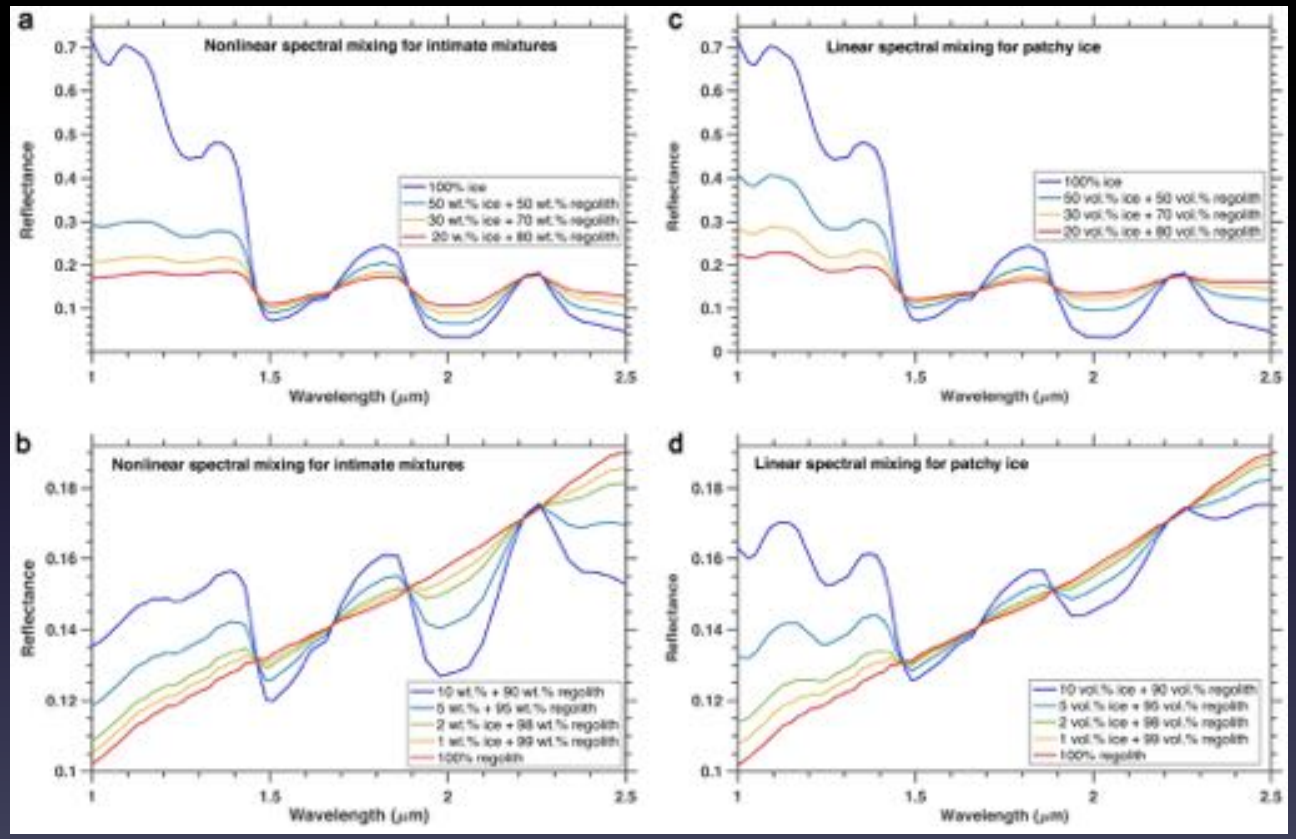
Ceres NP, Dawn FC
Platz et al., 2016

But not on the Moon…..

Introduction

- Direct evidence for the lunar surface exposed water ice in the lunar polar regions seen by the M^3
  - The abundance is lower than that on Mercury and Ceres





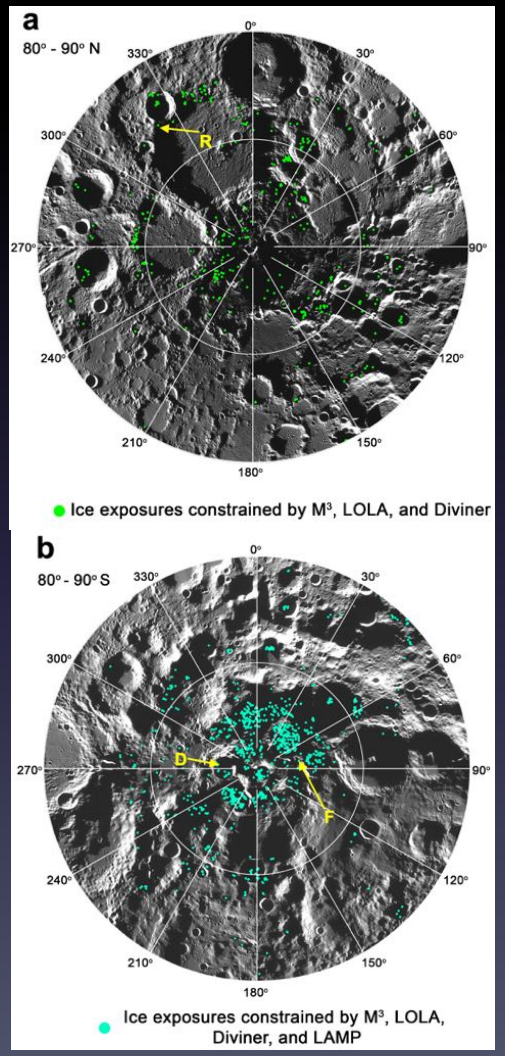
Intimate mixing, ~ 30 wt.%

Linear mixing, ~ 20 vol.%

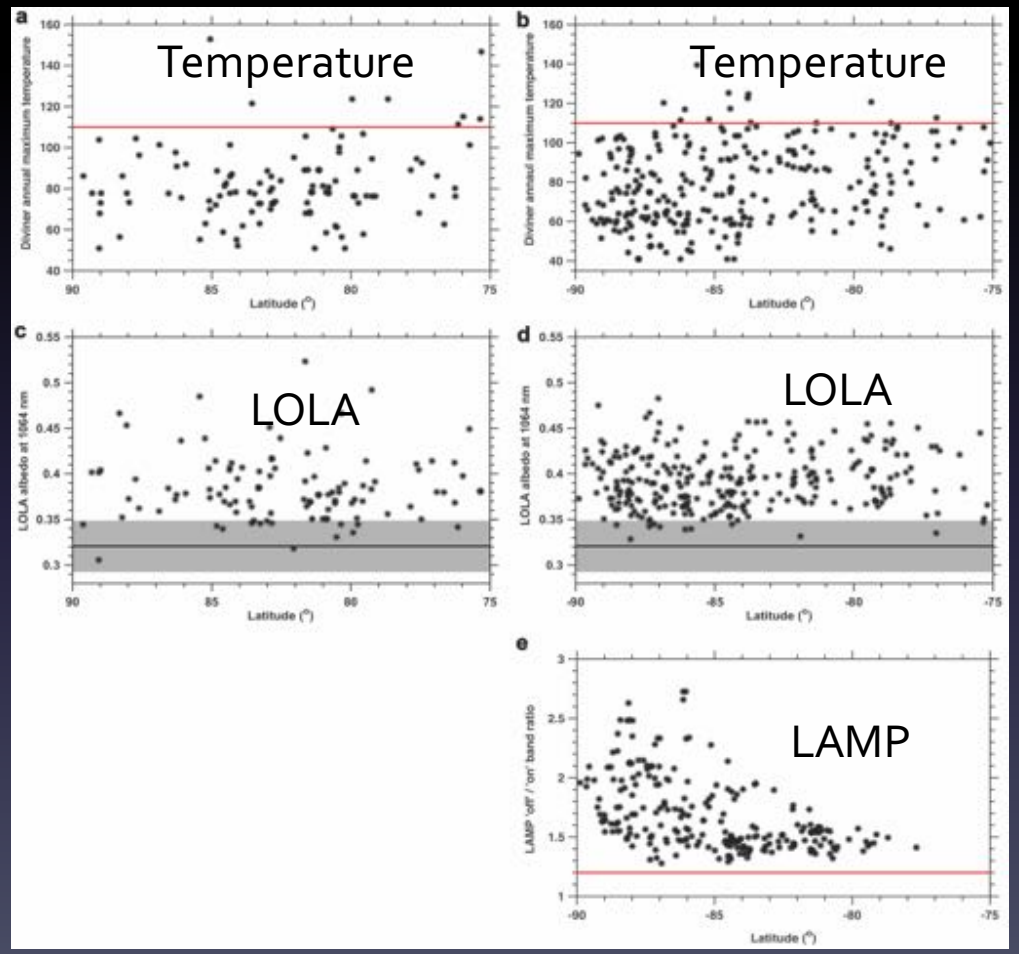
Li et al., Submitted

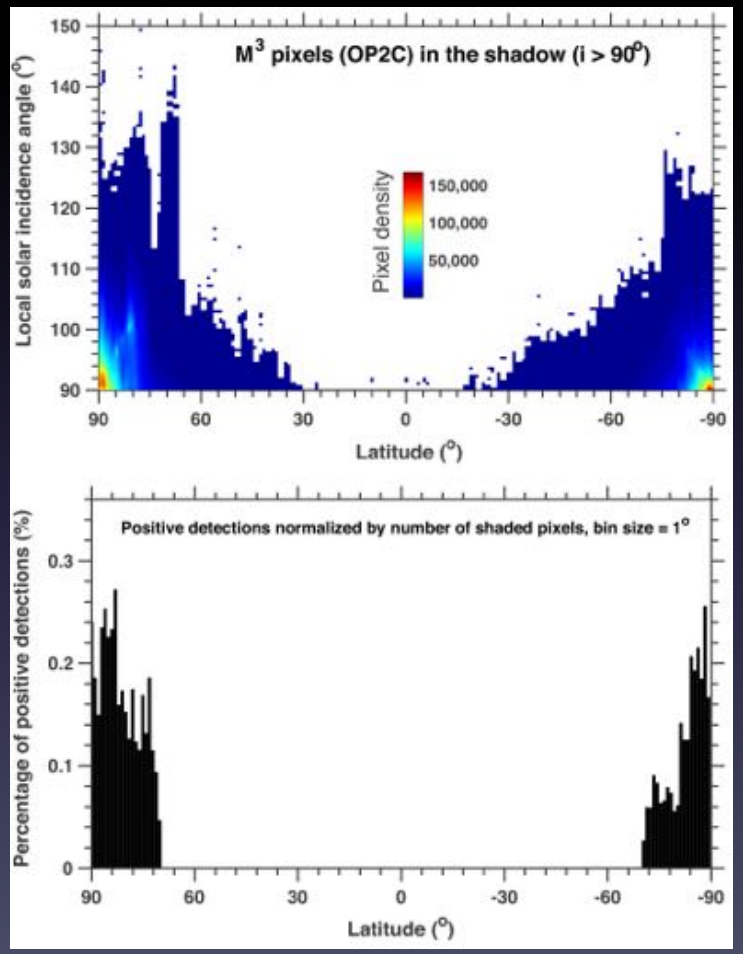
Introduction

- Consistent with high LOLA albedo, LAMP band ratios, and temperature < 110 k.
- The distribution is patchy: 3.5% of the PSRs < 110 K.



North Pole South Pole





Li et al., Submitted

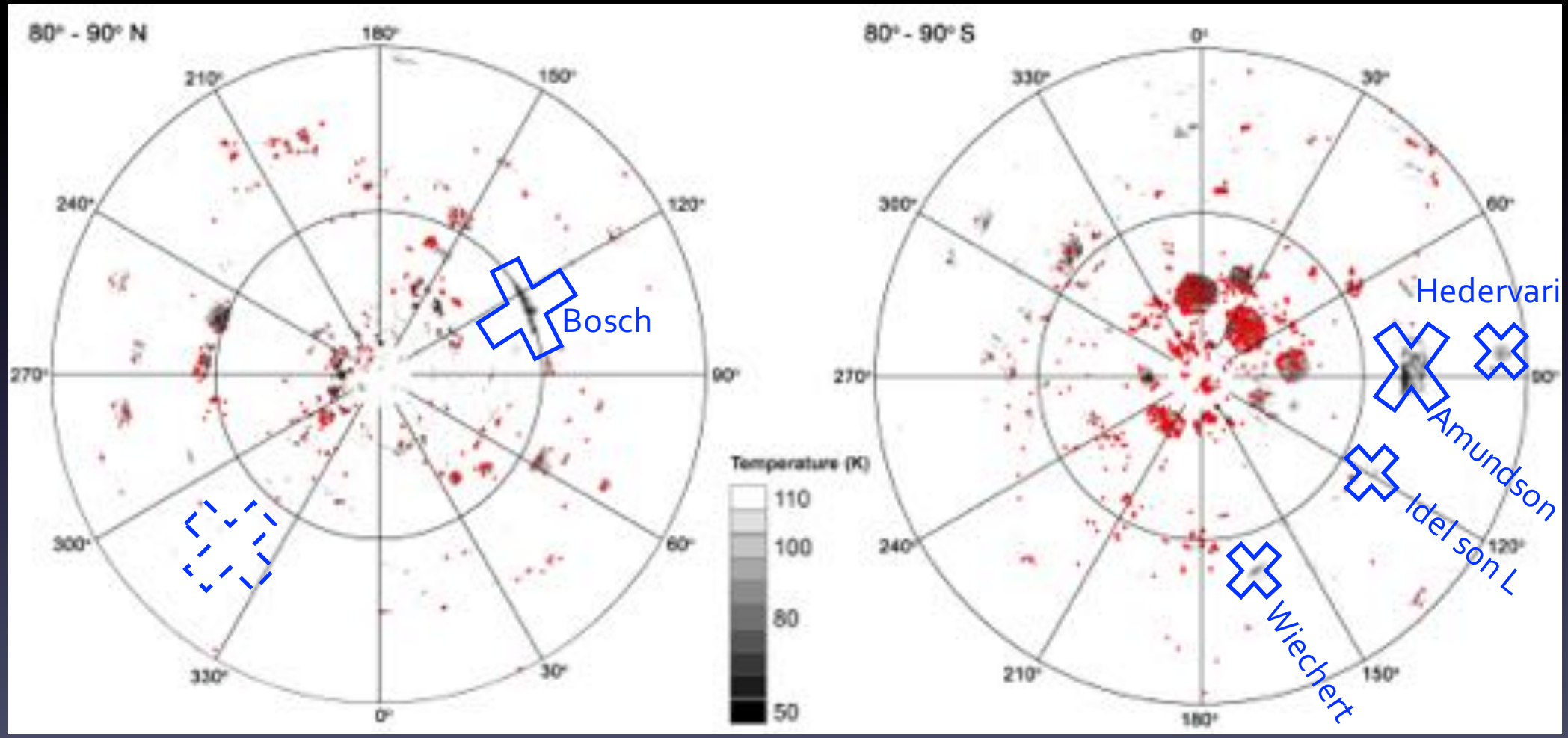
Significance of landing at ice exposures

- Water ice is the importance in situ resources for utilization for future exploration of the Moon.

- It is critical for understanding the unique processes of deposition, transportation, and retention of ice on the Moon.

The distribution of lunar surface ice

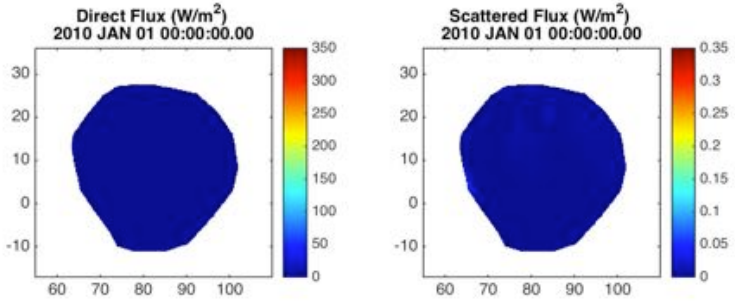
- Associated with temperature < 110 K, but not all low temperatures show ice



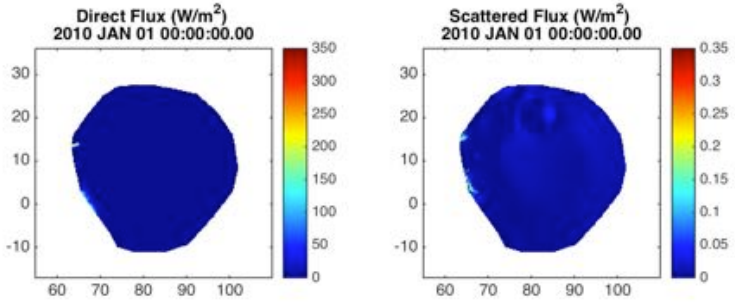
The distribution of lunar surface ice

- True polar wander?
  - Ice must be very old, and rate of supply is very low

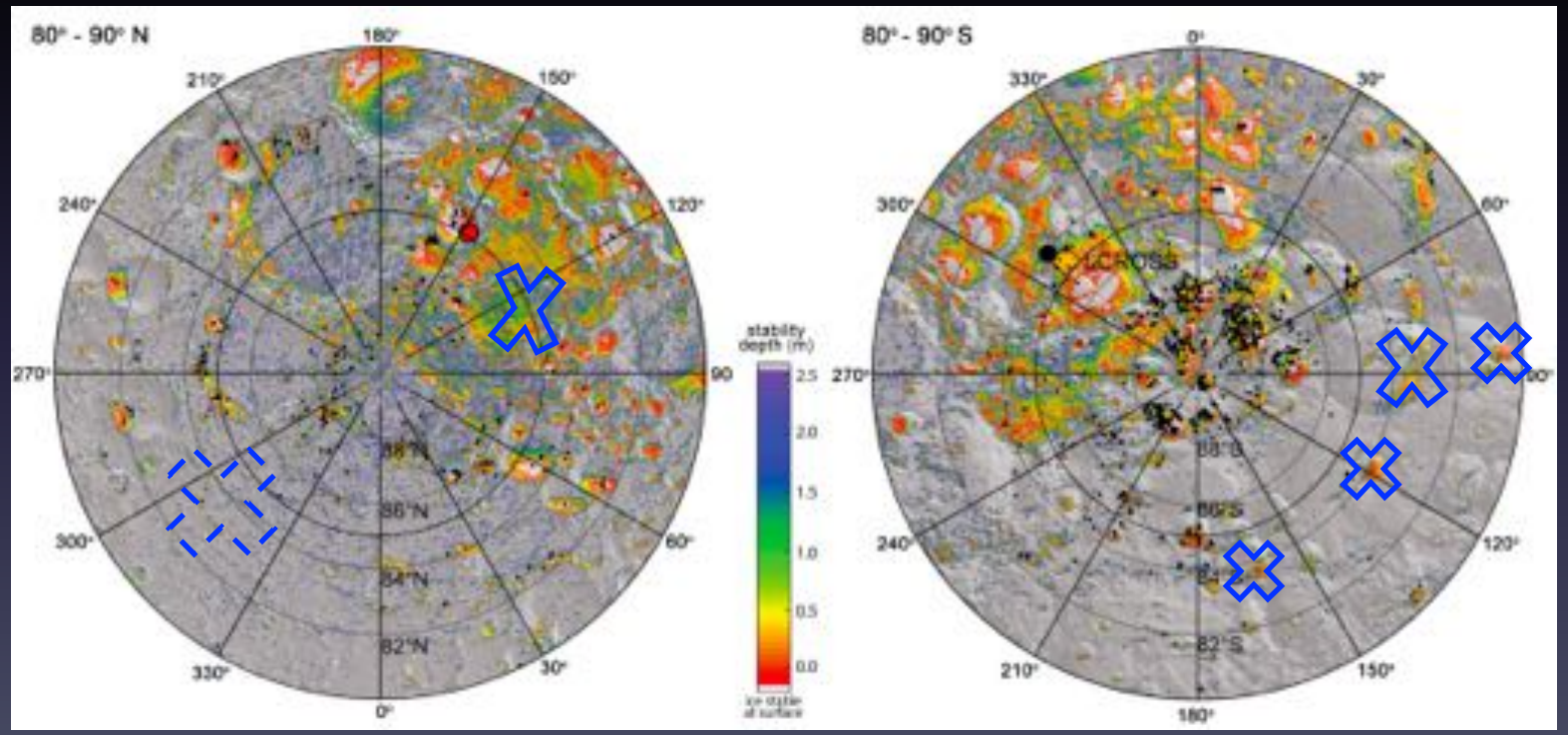
Faustini, current axis



Faustini, palaeo-axis



The stability depth of ice when the Moon was on its palaeo-axis



Siegler et al., 2016

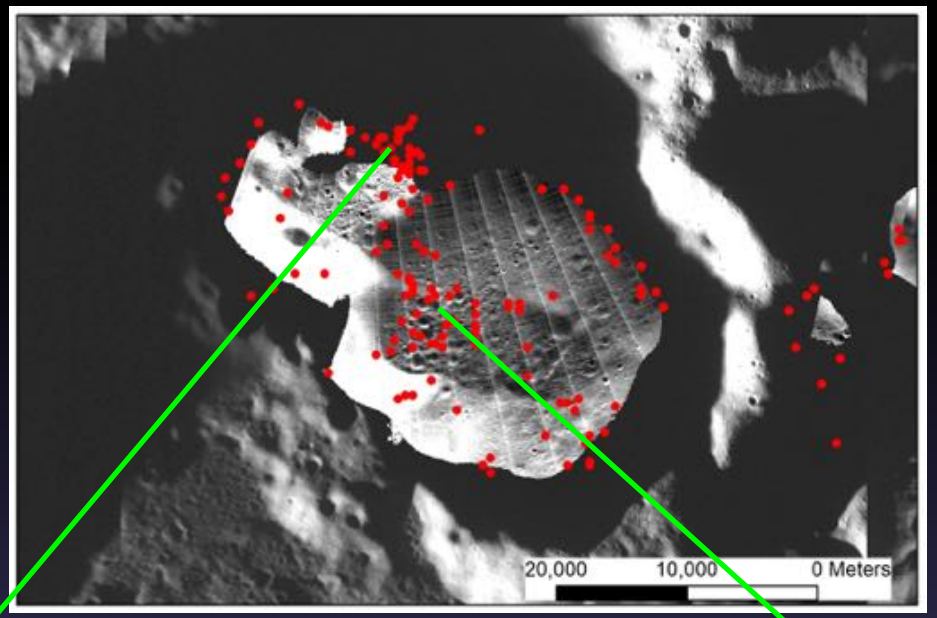
The low abundance of lunar surface ice

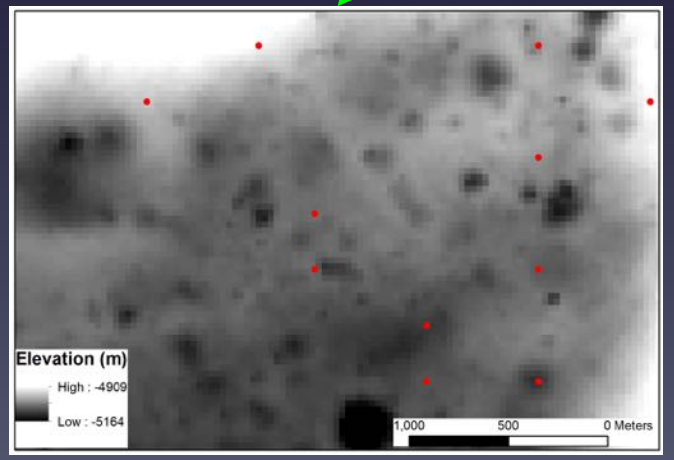
- Slow supply of water and fast overturn of the top layer by impact?
  - The top 1 m layer will be erased by impacts every around 500 million years on the Moon, 3 billion years on Mercury (Costello et al., under review).
  - Explains the patchy distribution and low ice abundance
  - More ice could be beneath the surface, > 1m?

Possible landing sites

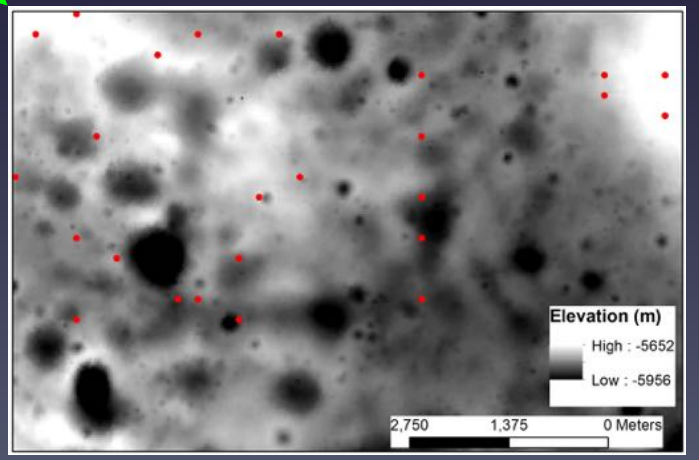
- Most ice exposures on the north pole are located at crater walls with very rough topography, min-max elevation > 4000 m.

South pole:
Sverdrup crater





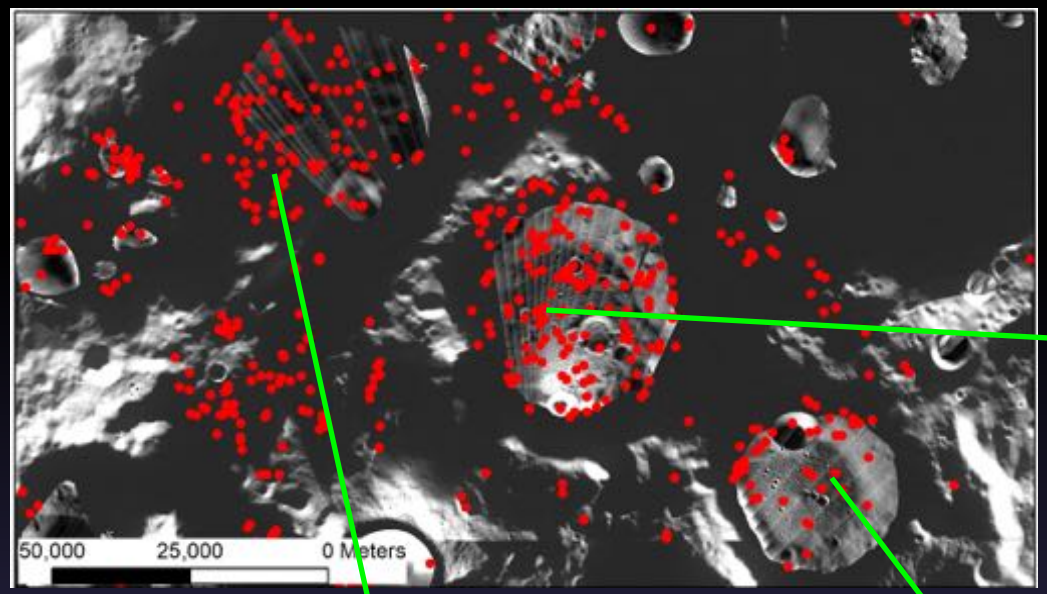
Min-Max elevation: ~250 m



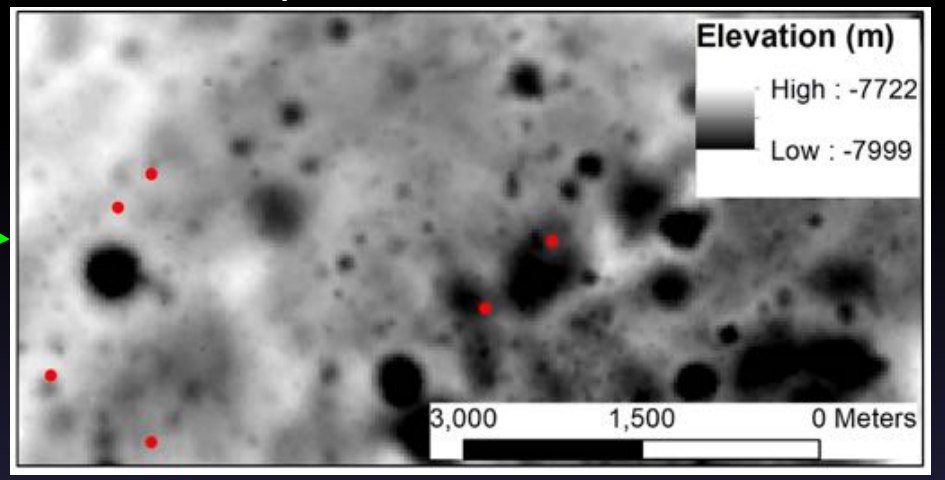
Min-Max elevation: ~300 m

Possible landing sites

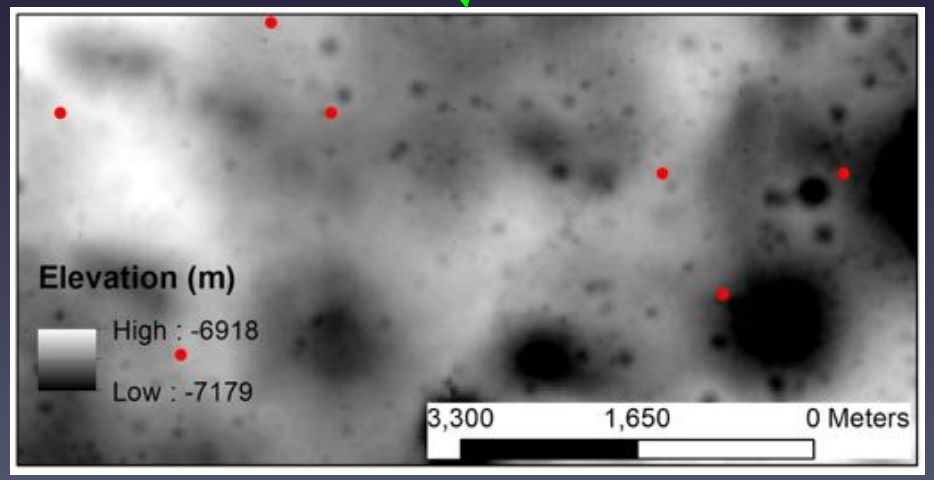
South pole:
Haworth-Shoemaker-Faustini



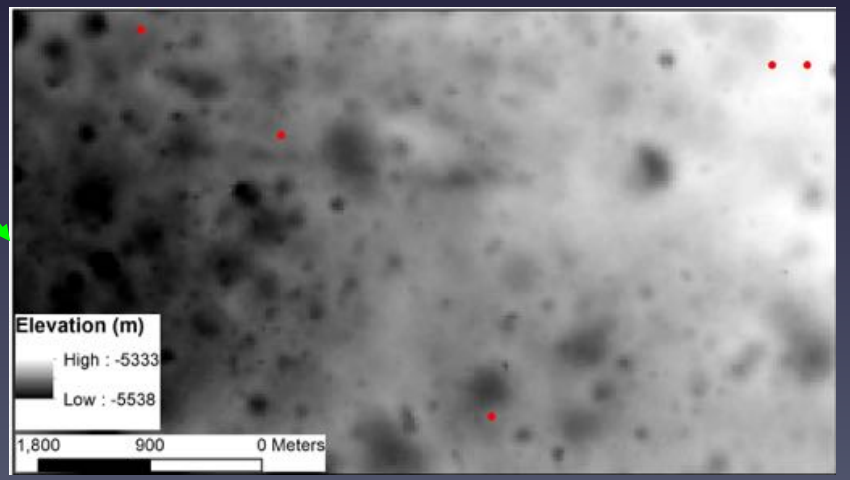
Min-Max
elevation: ~270 m



Min-Max
elevation: ~260 m



Min-Max
elevation: ~200 m



Summary

- It will help to constrain the thickness and abundance of these deposits for future in situ resource utilization.
  - Drilling > 1 m depth is required.
- Dating the age of the ice helps to test the true polar wander hypothesis. These ice might be deposited before the polar wander (> 2-3 Ga ago?)
  - If it can be done in situ, no sample return is required.
- Measuring the rate of hydroxyl or molecular water migration.
  - The migration of molecular water (if any) should be extremely slow.
  - A mass spectrometer is required.
- Testing the hypothesis about the gardening effect. It could be more water beneath the surface but mixed with regolith and the abundance is low.
  - Drilling and in situ sampling from the deep is required.