Surface water at lunar magnetic anomalies

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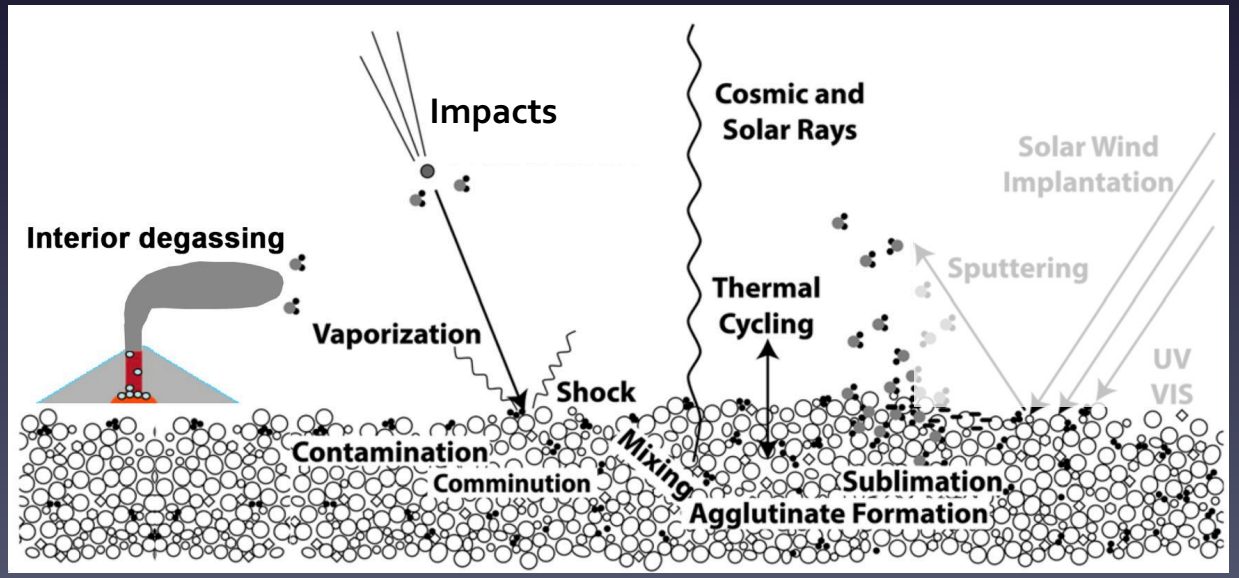
Introduction

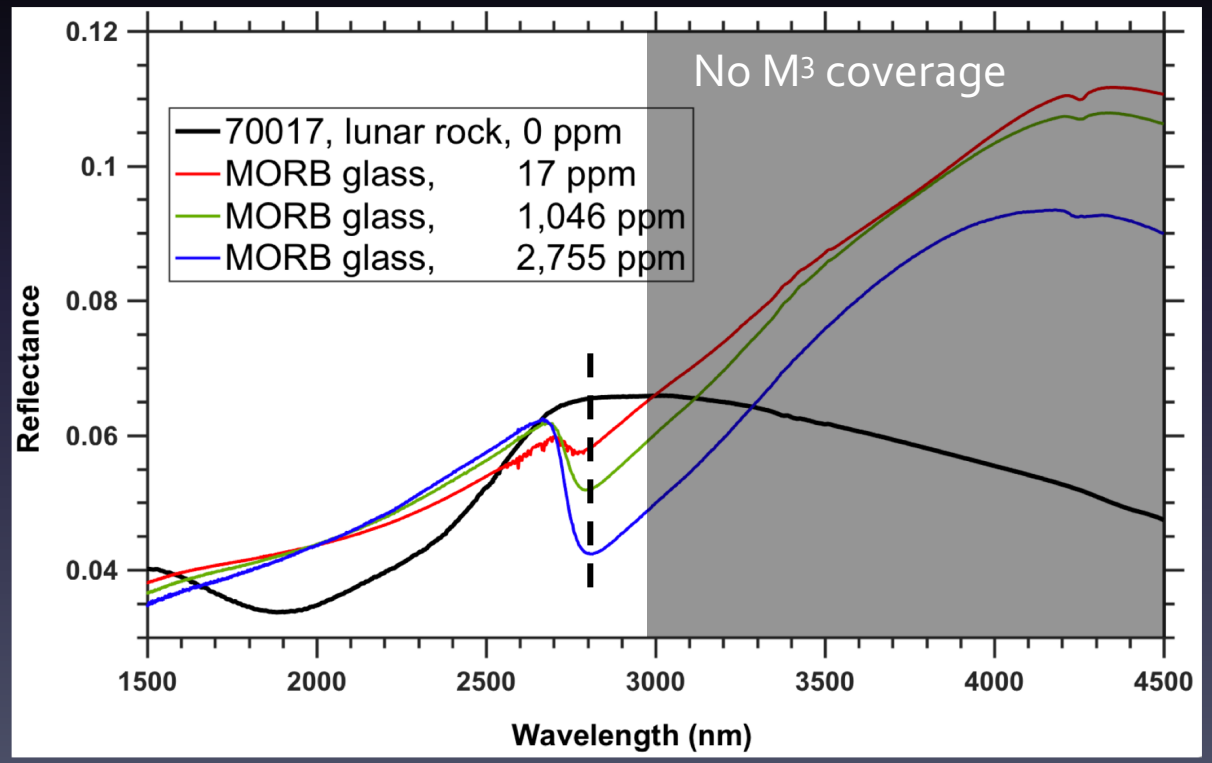
- Surface water (OH/H_2O) has been detected using orbital and ground-based IR data
  - No debate on its presence (*Pieters et al., 2009; Sunshine et al., 2009; Clark, 2009; Honniball et al., 2018; Hendrix et al., 2019*)
- Possible origins: solar wind implantation, CC and comet impact, interior degassing
  - Major contribution: solar wind (*Liu et al., 2012*)?
- Magnetic anomalies provide a natural laboratory to understand lunar water origins
  - Test if water exhibits suppression at magnetic anomalies compared with surroundings

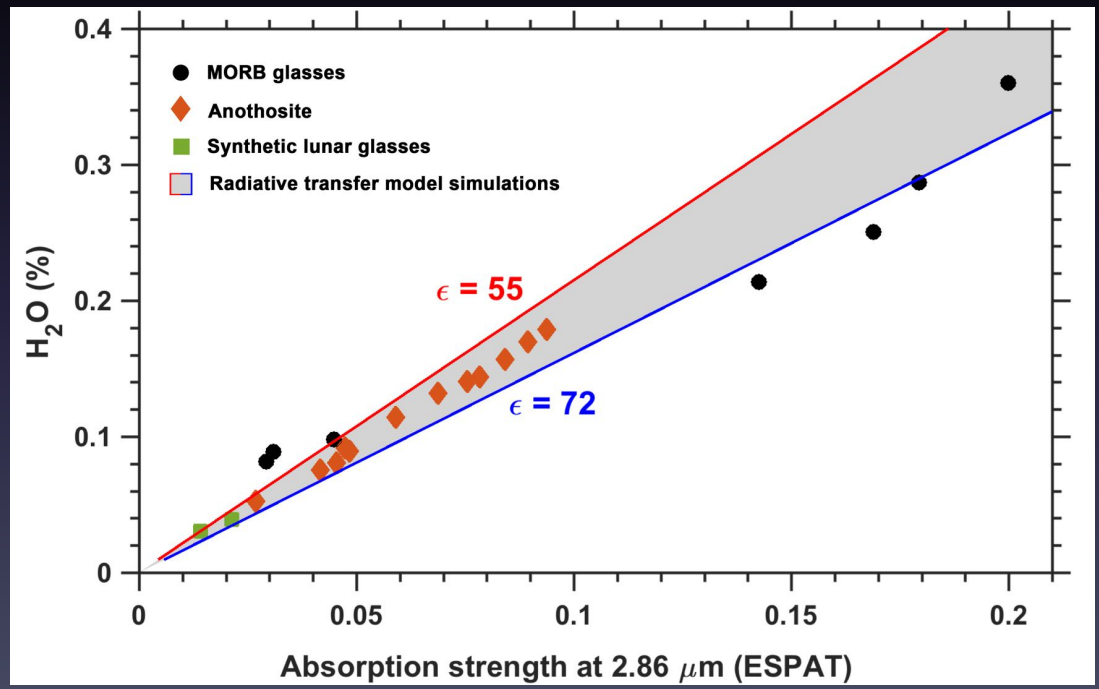


Modified from *Pieters & Noble*, 2016, JGR

Data and Methods

- Magnetic data are from *Tsunakawa et al.*, 2015, spherical harmonic degree 450, 20 km altitude.
- Absolute water content is derived from the absorption strength of the 2.86 μm band of M³ data.
- Moon Mineralogy Mapper (M³) data
  - 2 updates: five OPs vs. only OP2C; min phase pixels vs. averaging repeating pixels.

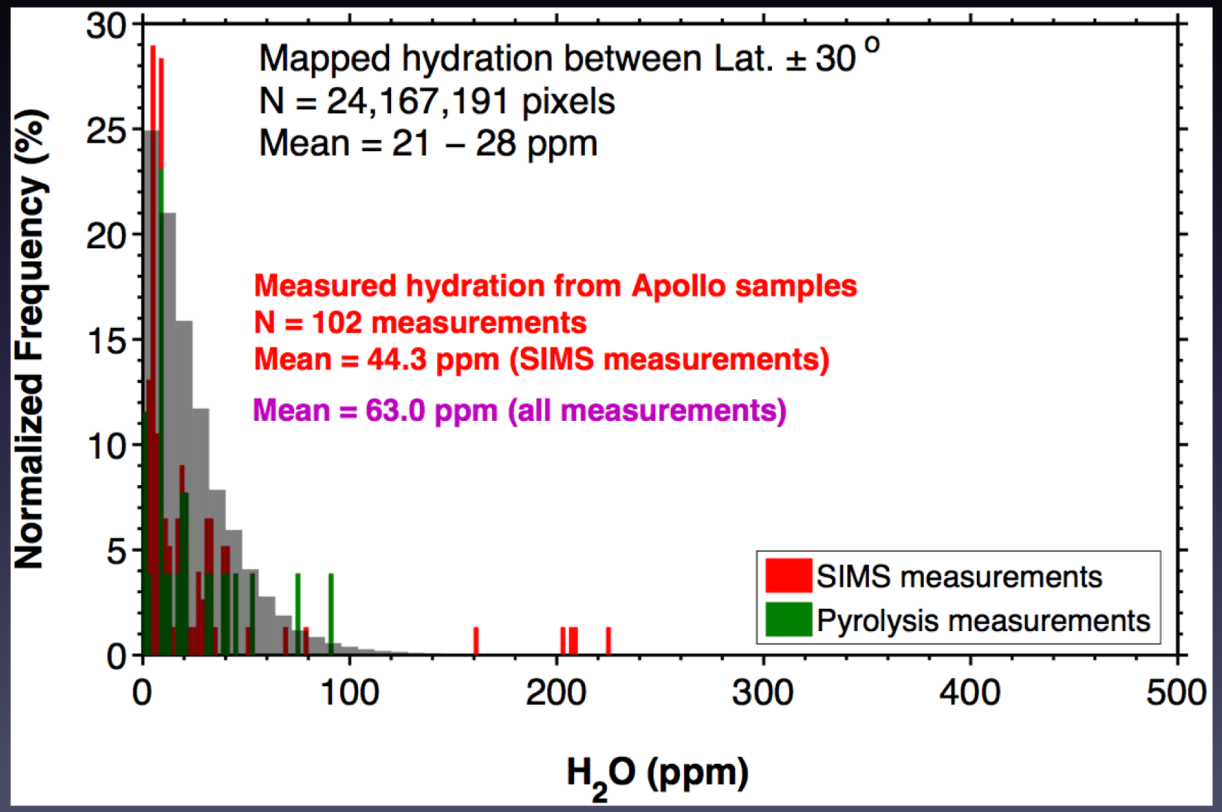




Li and Milliken, 2017, Sci. Adv.

Results

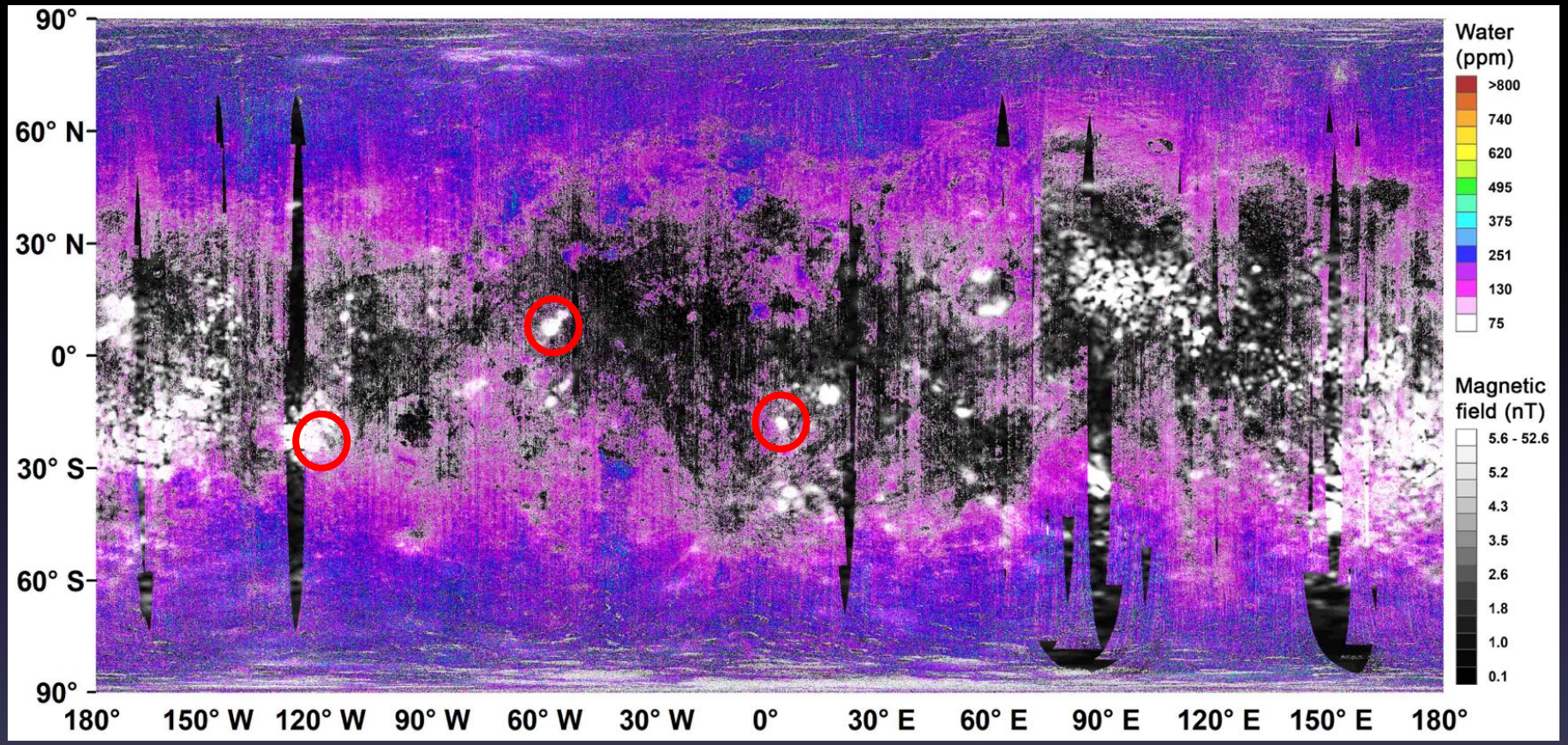
- Our model may underestimate the water content by ~20 ppm near the equator.
  - 20 ppm is added to each pixel of our water map.
- Relative variations for low water content can be better assessed.



Li & Milliken, 2017

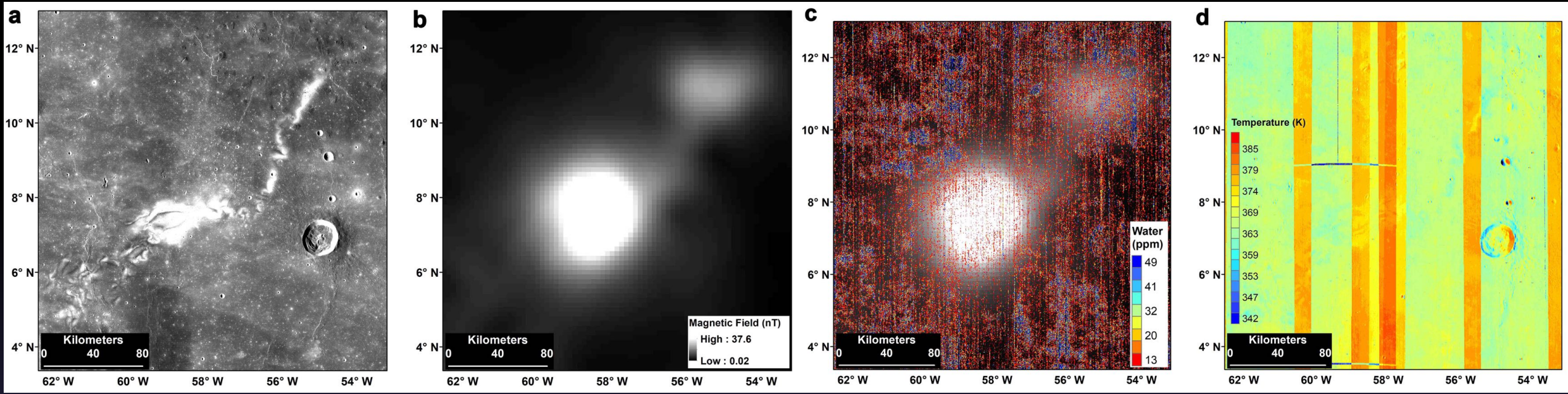
Results

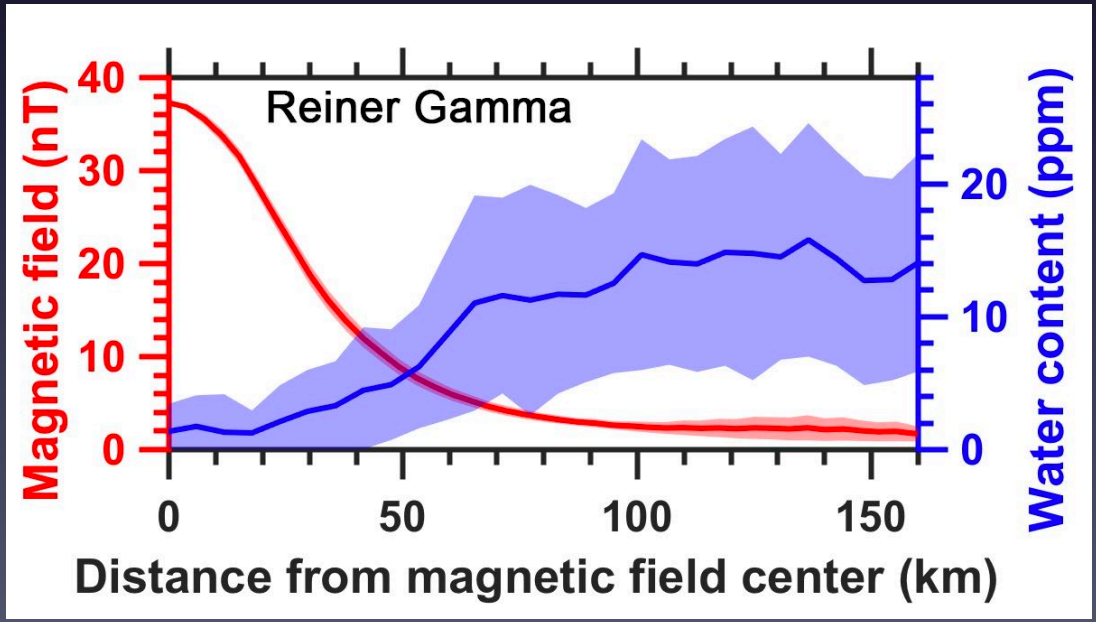
- Global water map (stretched to better present low water content) overlain on magnetic anomalies



- Strong magnetic anomalies (white color in base map) show strong water suppressions.
  - Spatial resolution of magnetic field is too low for global assessment (2 pixels per degree)
- Three regions are chosen to exam: Reiner Gamma, Airy, and Gerasimovich.

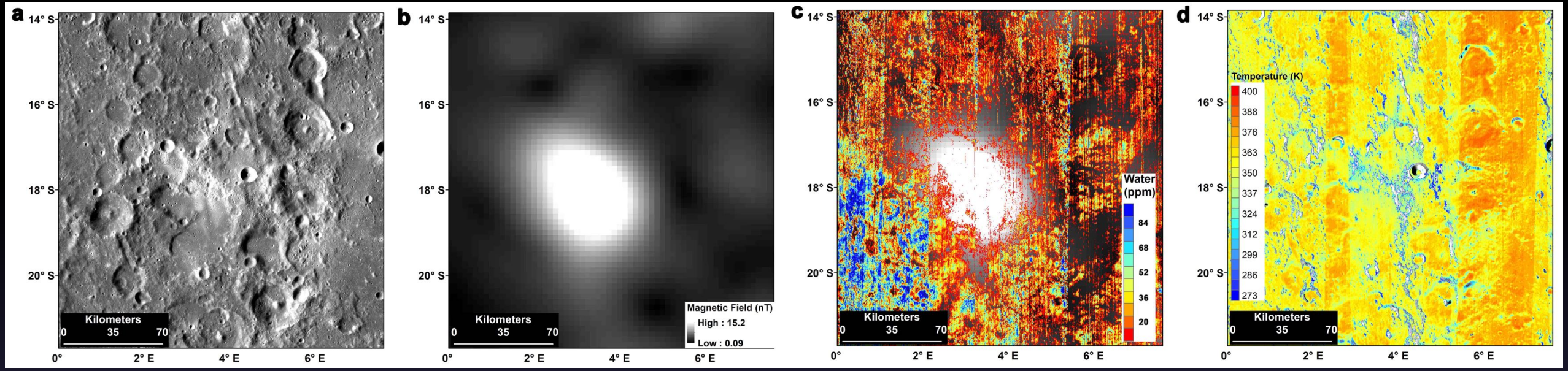
Results - Reiner Gamma

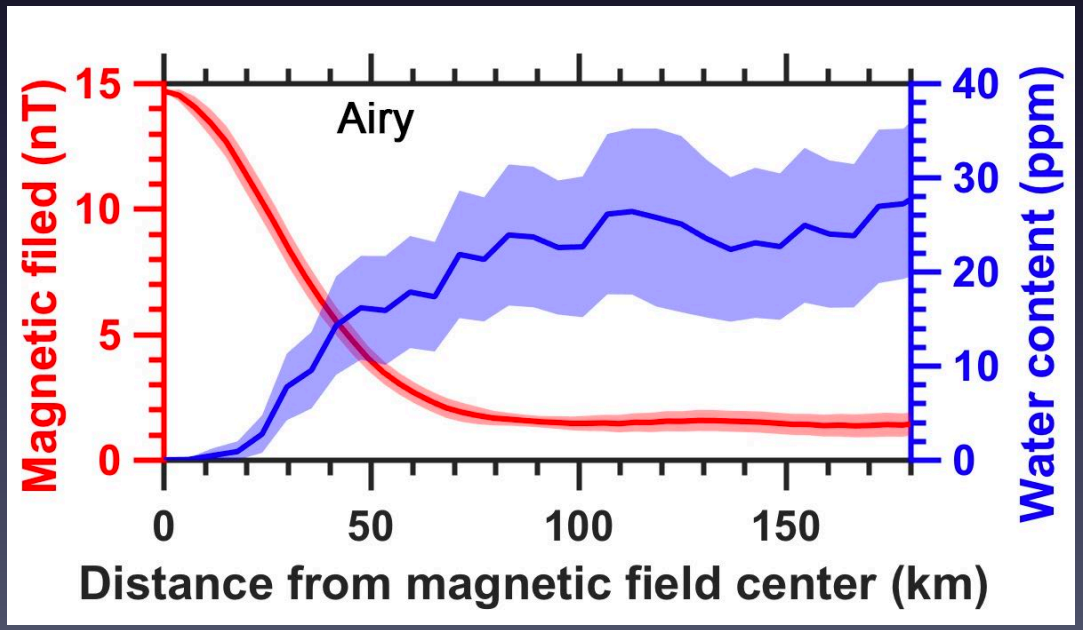




- Water suppressions correlate with magnetic anomalies, NO correlation with swirls OR temperatures.
- Water and magnetic field profiles show strong anti-correlation.

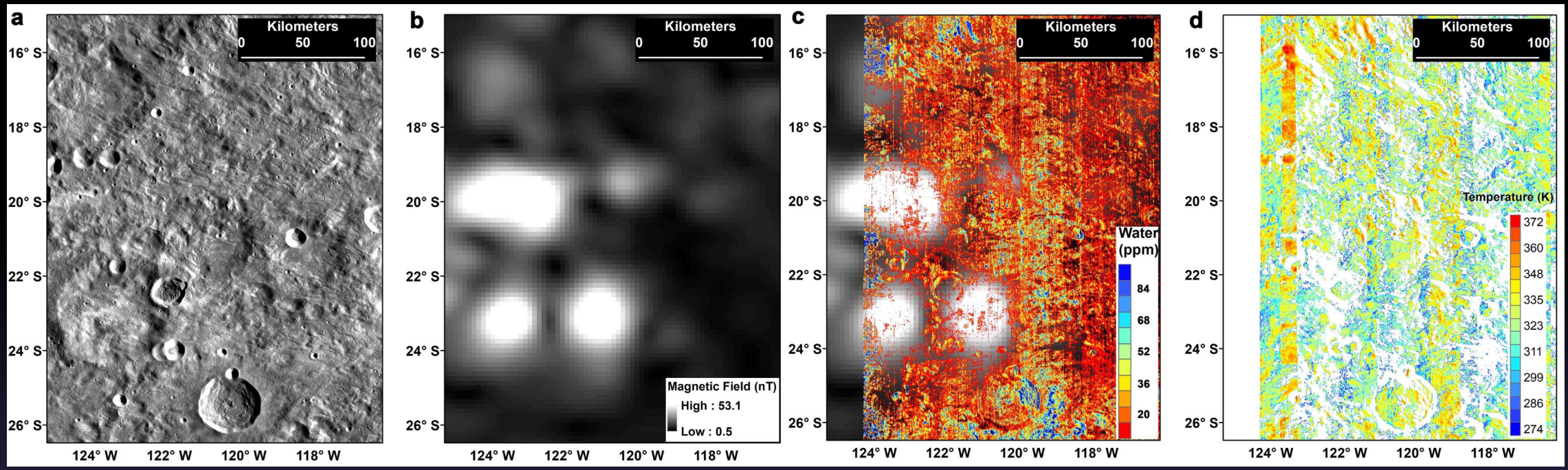
Results - Airy

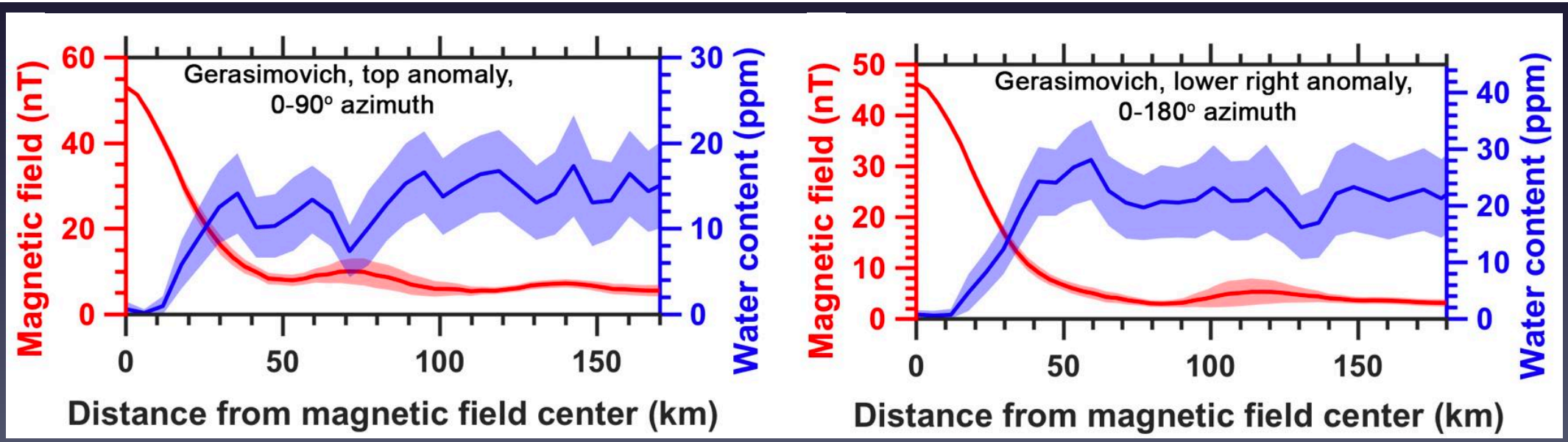




- Water suppressions correlate with magnetic anomalies, NO correlation with swirls OR temperatures.
- Water and magnetic field profiles show strong anti-correlation.

Results - Gerasimovich



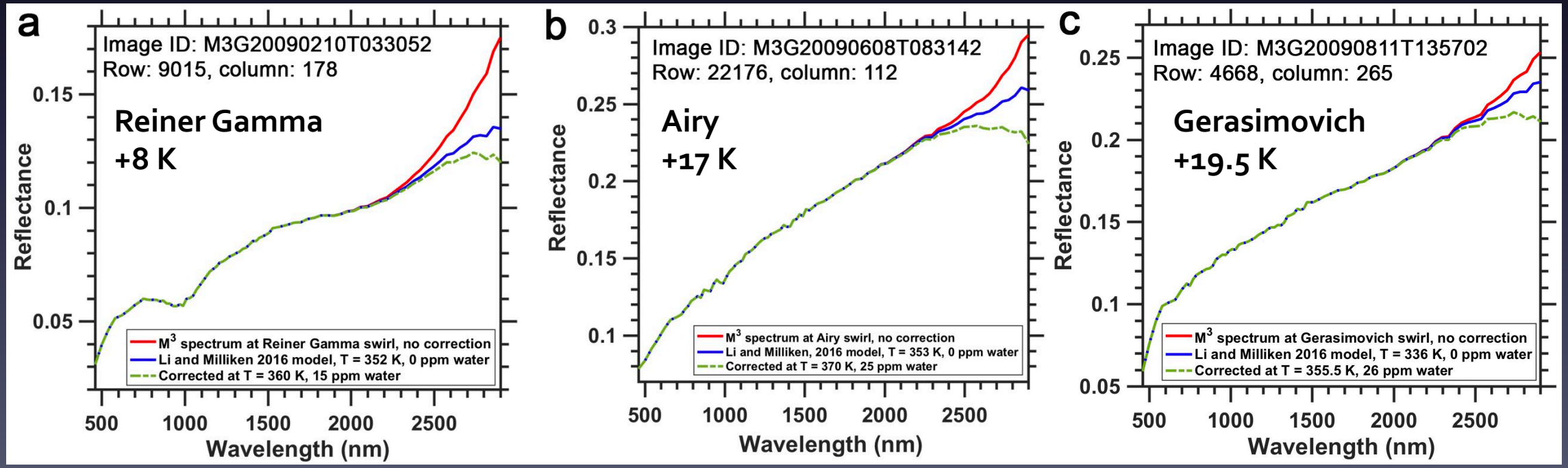


Discussion

- Interpretation of M^3 water bands is thermal model dependent (*McCord et al., 2011; Li & Milliken, 2017; Wohler et al., 2017; Bandfield et al., 2018*)
  - Higher temperature for correcting M^3, more correction, -> stronger water absorption
  - Ture temperatures for correcting M^3 data are dominantly determined by time of day, albedo, and surface roughness.
- Thermal corrections of M^3 data at magnetic anomalies and surroundings:
  - Time of day effect can be ignored.
  - Similar surface roughness has been suggested by Diviner data (*Glotch et al., 2015*)
  - Temperatures may vary with strong albedo variation (swirls).

Discussion

- Water suppressions match with magnetic field, NOT associated with temperatures.
  - Temperatures for correcting M^3 data show almost NO difference between magnetic anomalies and surroundings.
  - Water variations NOT associated with temperatures should represent true features, at least relatively.
- To show similar amount of water, ~8 – 20 k higher temperature is required at magnetic anomalies
  - No reason to believe magnetic anomalies should have much higher temperature than surroundings.



Discussion

- Magnetic field may play different roles on the formation of water and swirls
  - Swirl patterns are seen at both the strongest and a much weaker anomalies at Reiner Gamma.
  - However, the swirl pattern at Gerasimovich is not well developed, although similar magnetic field strength as Reiner Gamma.
  - Water suppression is seen at all examined **strong** magnetic anomalies.

- Need more data to understand lunar magnetic anomalies (i.e. field structure)
  - Help to understand how they affect the formation of water and swirls.

Conclusion

- Strong water suppression is seen at magnetic anomalies
  - Suggesting that magnetic field may have reduced solar wind flux and prevented the formation of water

- Magnetic field may play different roles on the formation of surface water and swirls.
  - Water suppression is seen at all examined strong magnetic anomalies.
  - However, not all strong magnetic anomalies show well-developed swirls.

- More data are required at magnetic anomalies to understand how they affect the formation of surface water and swirls.