Surface water at lunar magnetic anomalies

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Introduction

- Surface water (OH/H$_2$O) 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.

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

• Interpretation of M³ 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 M³, more correction, -> stronger water absorption
  – True temperatures for correcting M³ data are dominantly determined by time of day, albedo, and surface roughness.

• Thermal corrections of M³ 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.