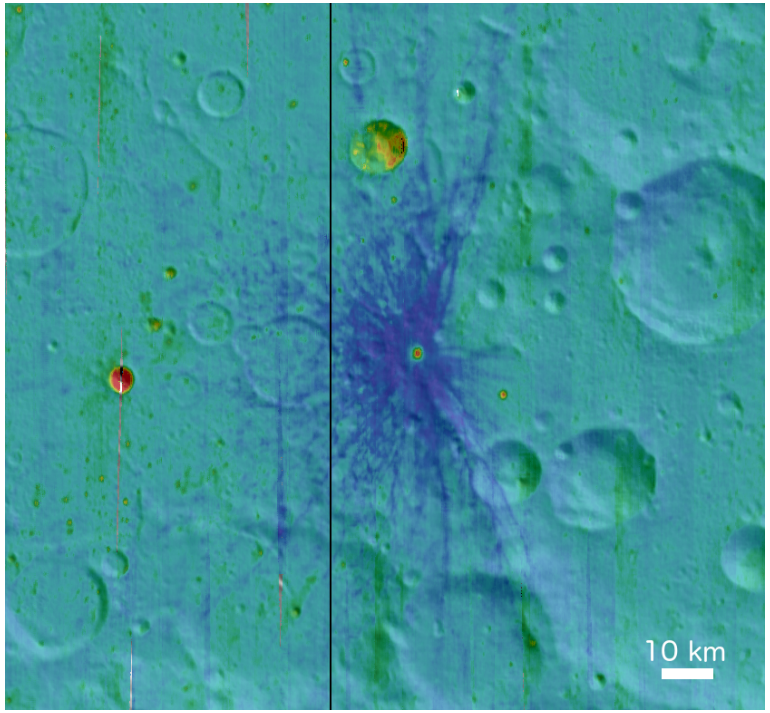
Cold Spot Formation Models



Paul Hayne[1], Oded Aharonson[2], Josh Bandfield[3], Ben Greenhagen[4], Tyler Powell[5]

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[2]Weizmann Institute of Science, Israel
[3]Space Science Institute
[4]Applied Physics Laboratory, Johns Hopkins University
[5]Case Western Reserve University

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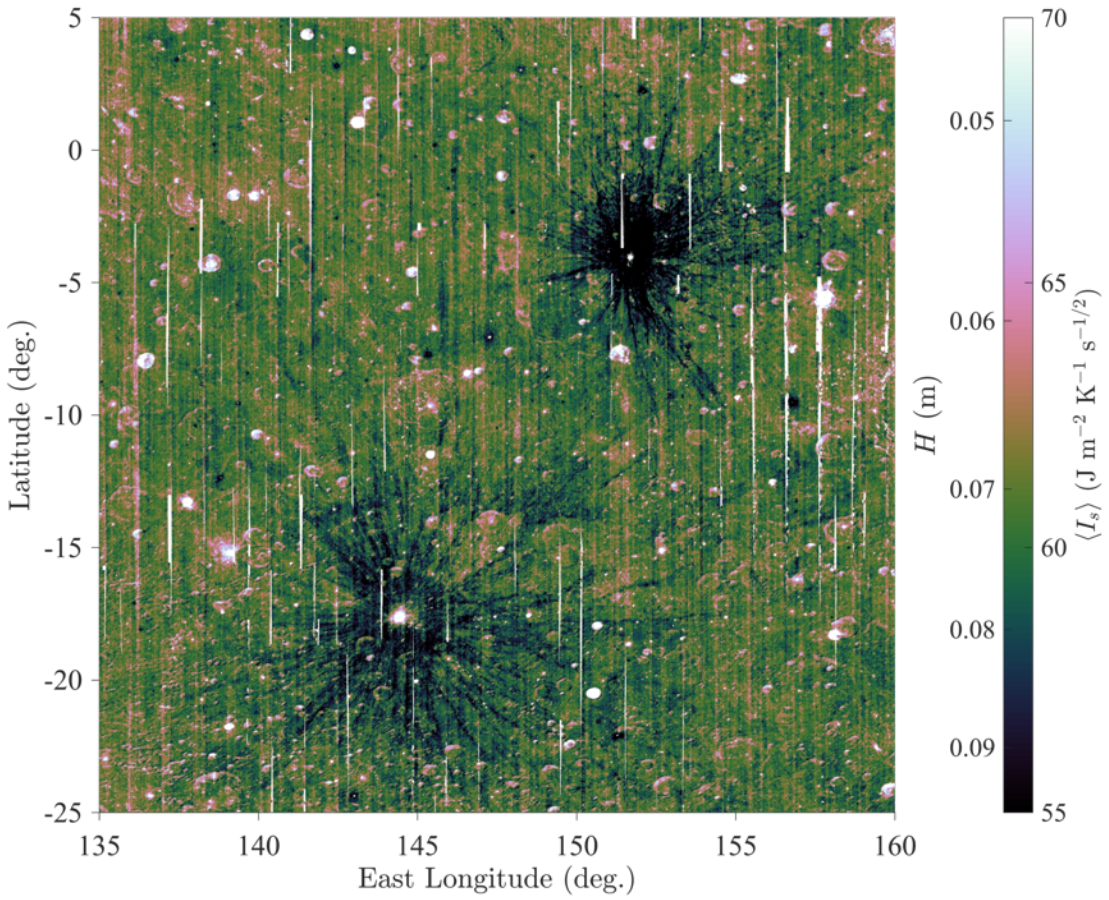
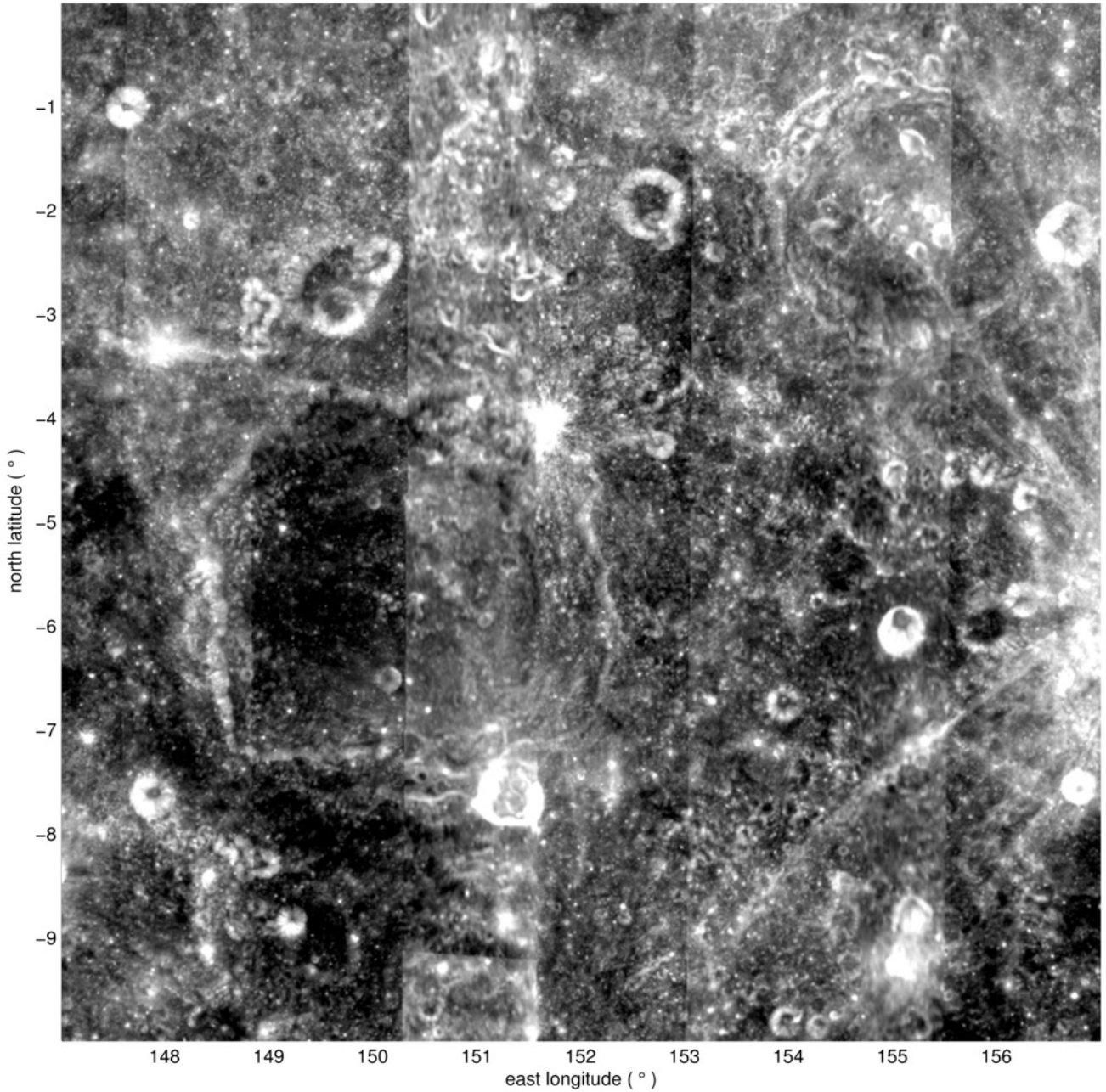
Background

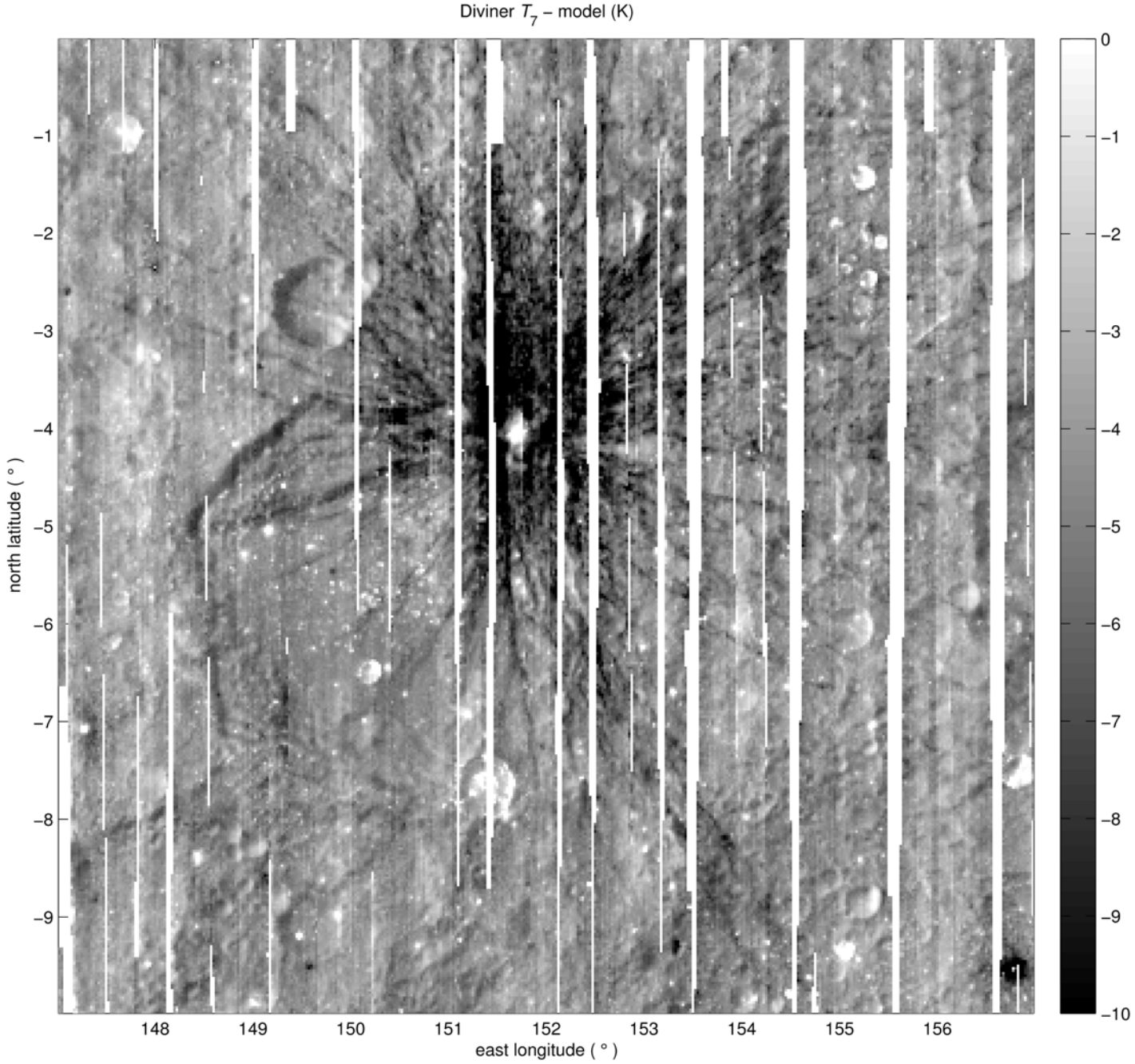
- Cold spots detected in nighttime Diviner maps
- Thousands identified (Bandfield et al., 2014)
- Population has age < 1 Myr (~100 kyr?) (Williams et al.)
- Range in size from < 100 m to 100's of km
- Proximal ejecta show evidence of granular flow
- Albedo signature not apparent over most of cold spot area

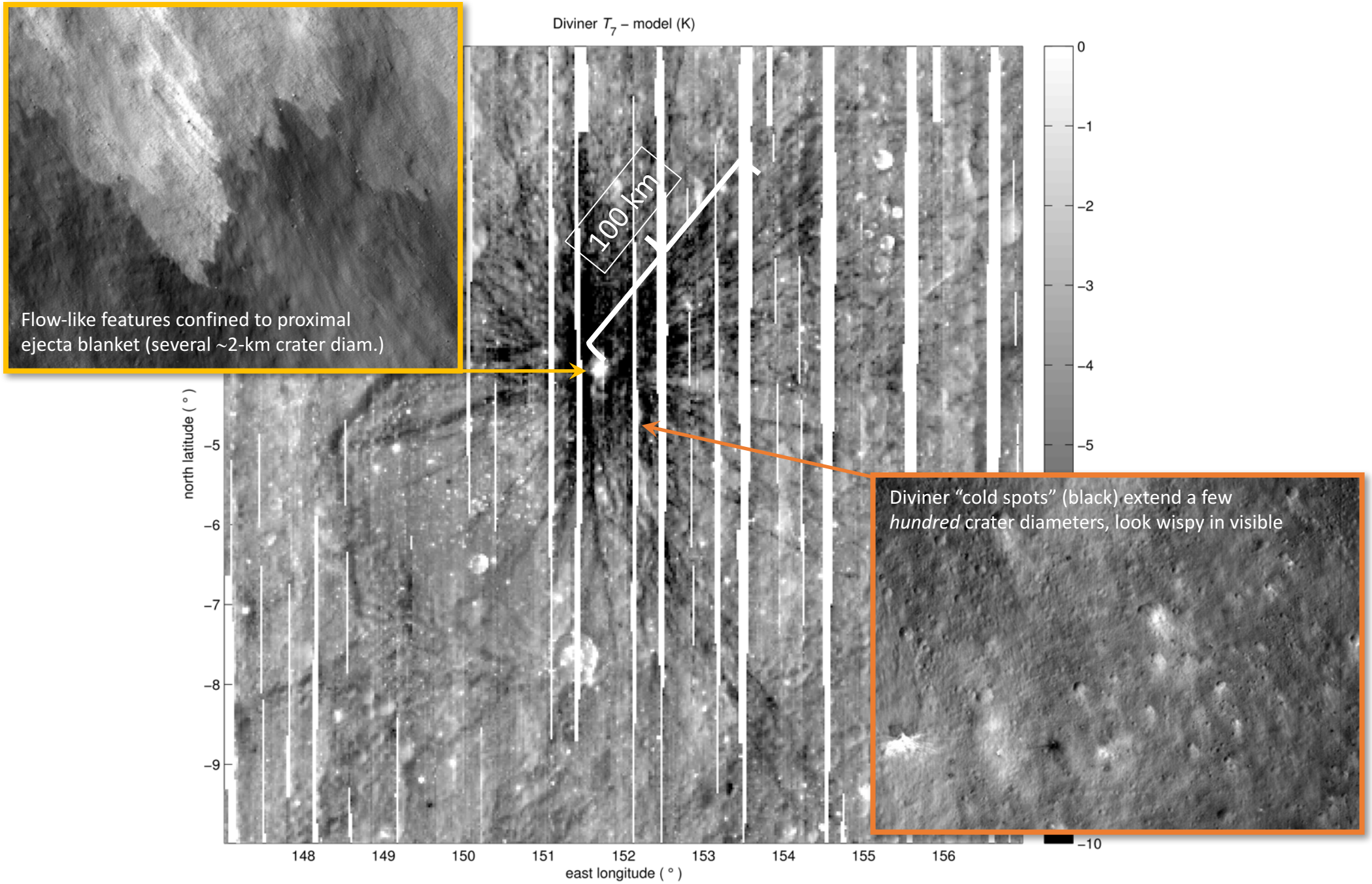


Clementine 750 nm albedo

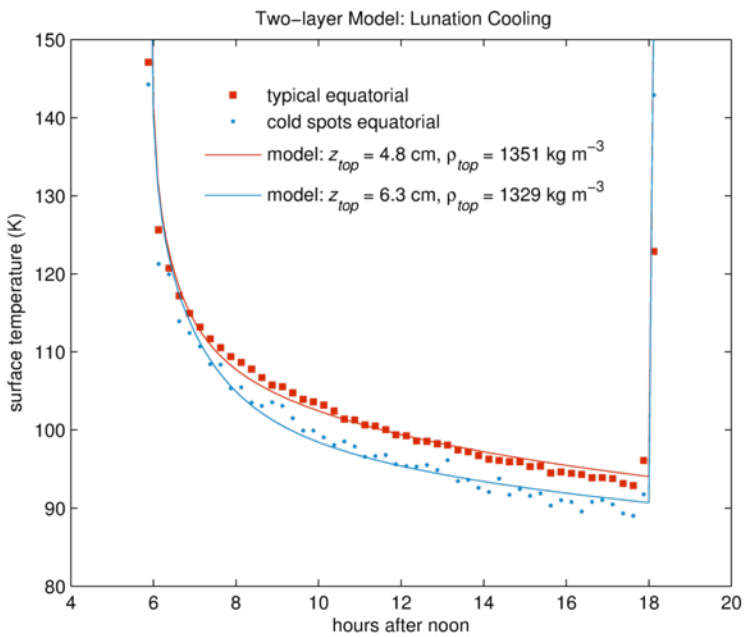


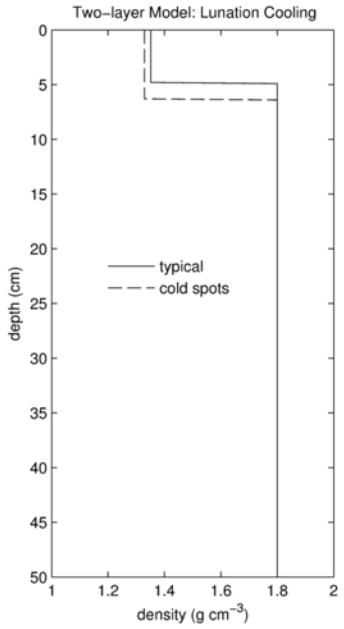
Measured nighttime temperature difference from model

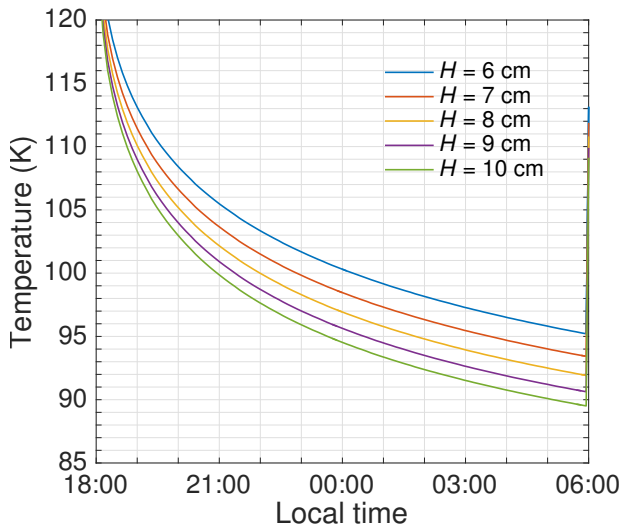



Diviner T_7 – model (K)
0
−1
−2
−3
−4
−5
−10
100 km
north latitude (°)
−5
−6
−7
−8
−9
148
149
150
151
152
153
154
155
156
east longitude (°)
Flow-like features confined to proximal ejecta blanket (several ~2-km crater diam.)
Diviner "cold spots" (black) extend a few *hundred* crater diameters, look wispy in visible

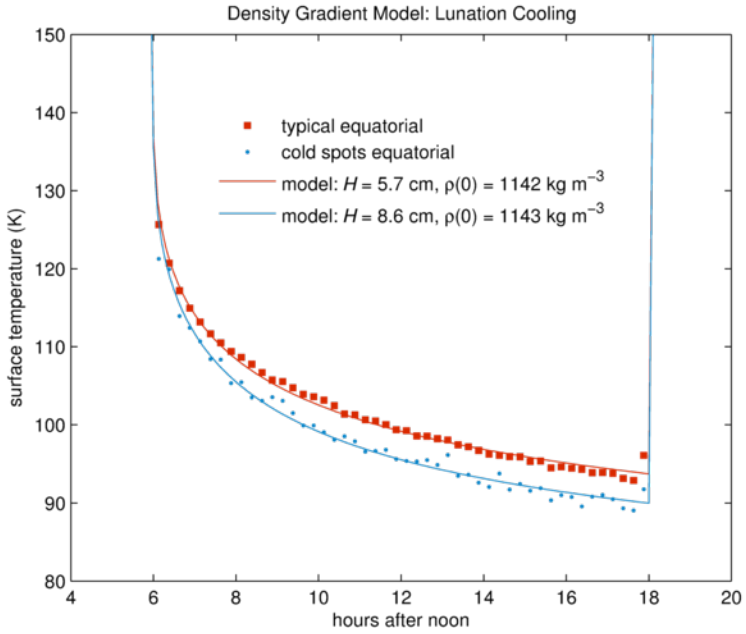
Two-layer Model

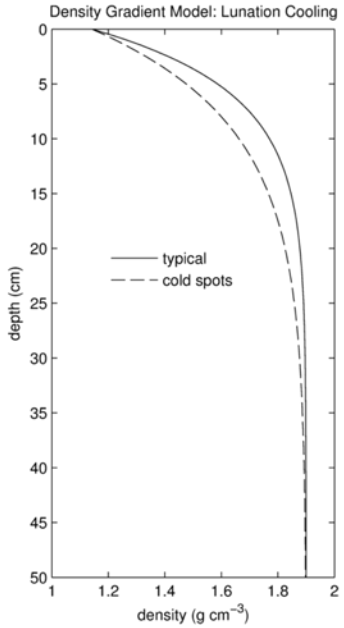


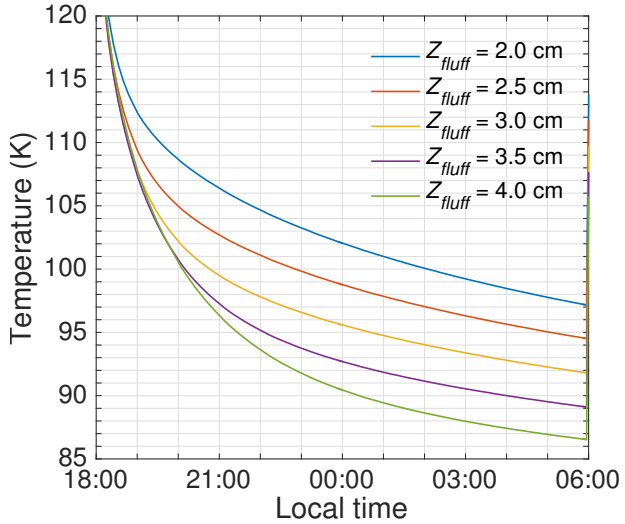




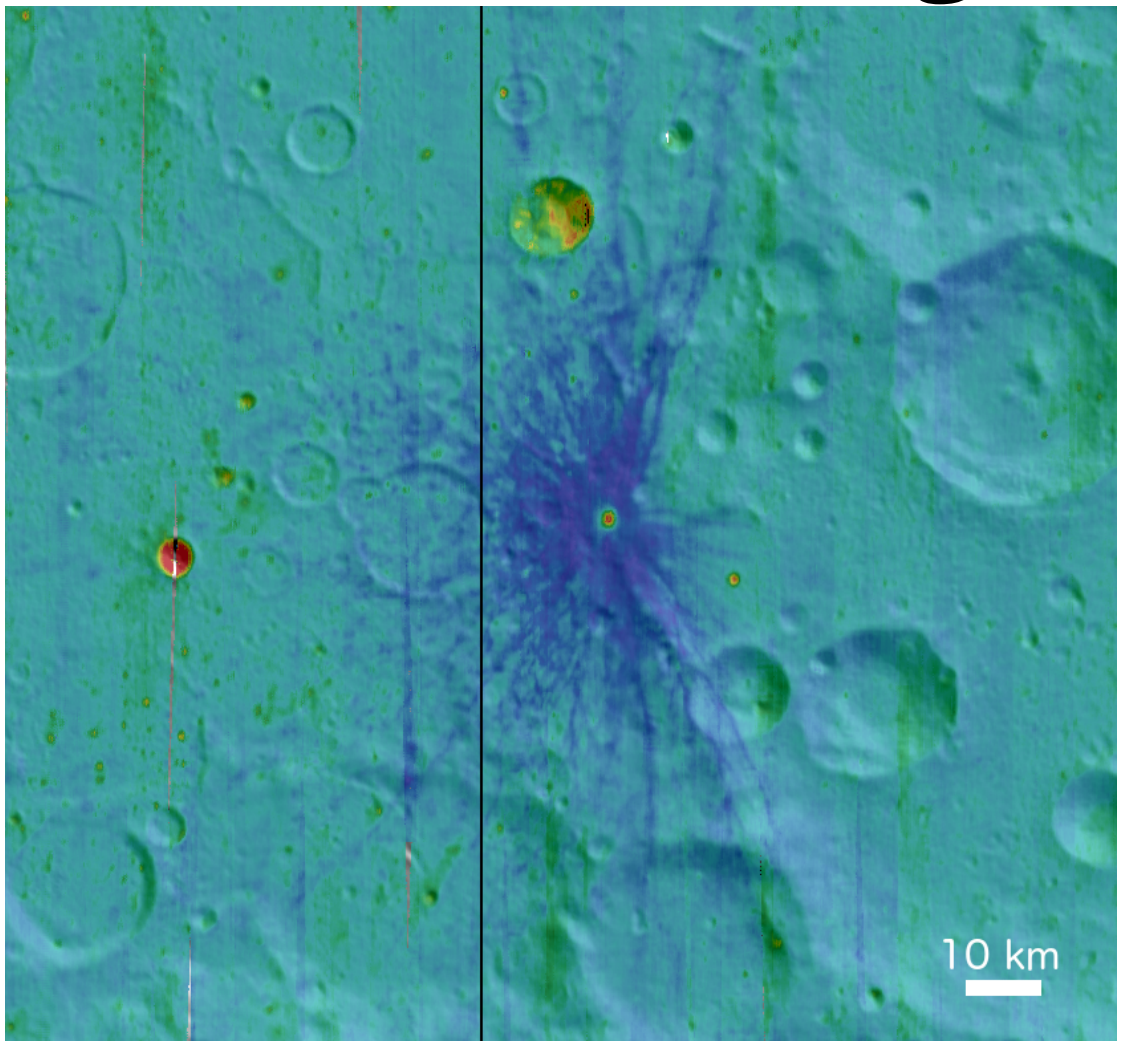
Exponential Model

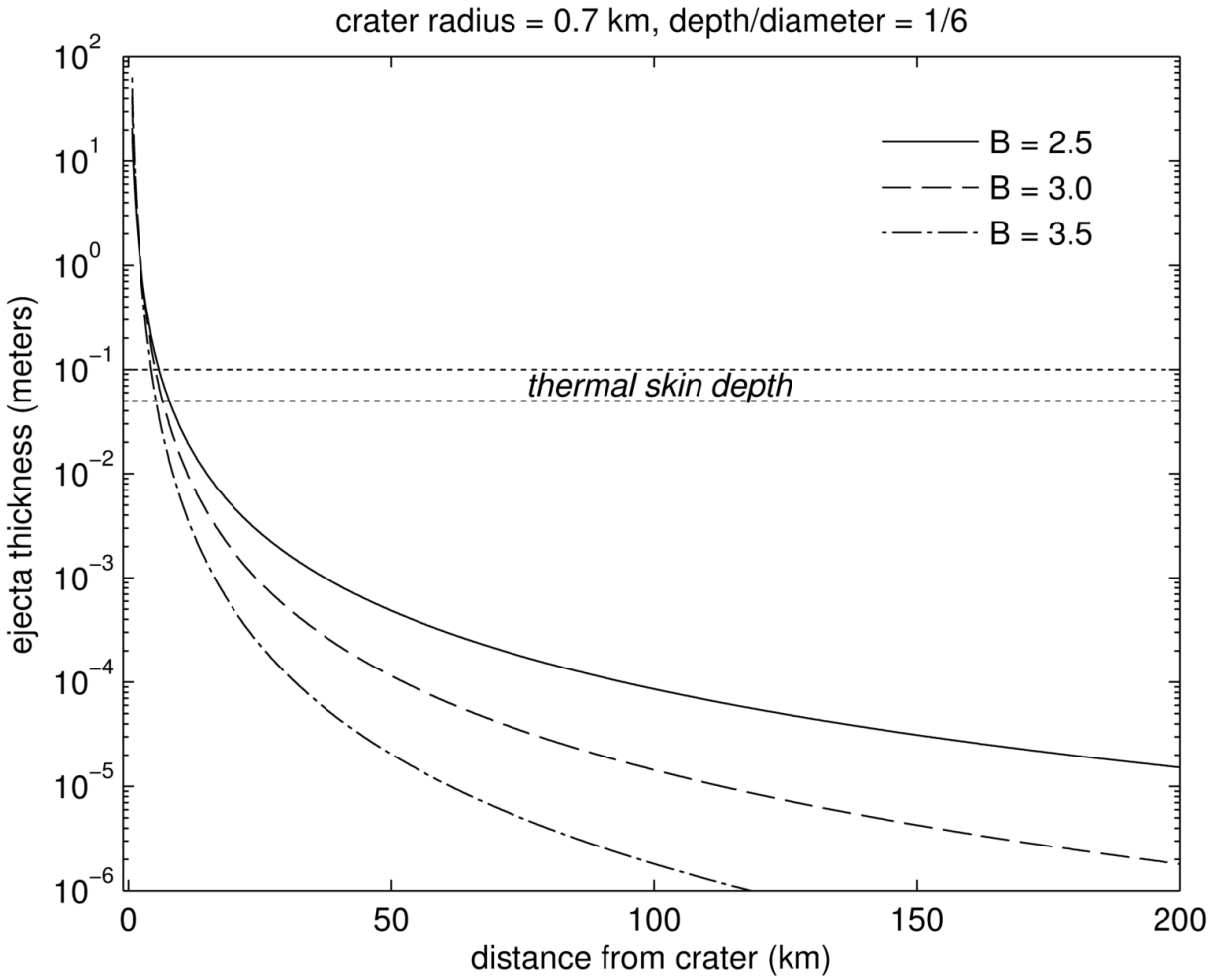




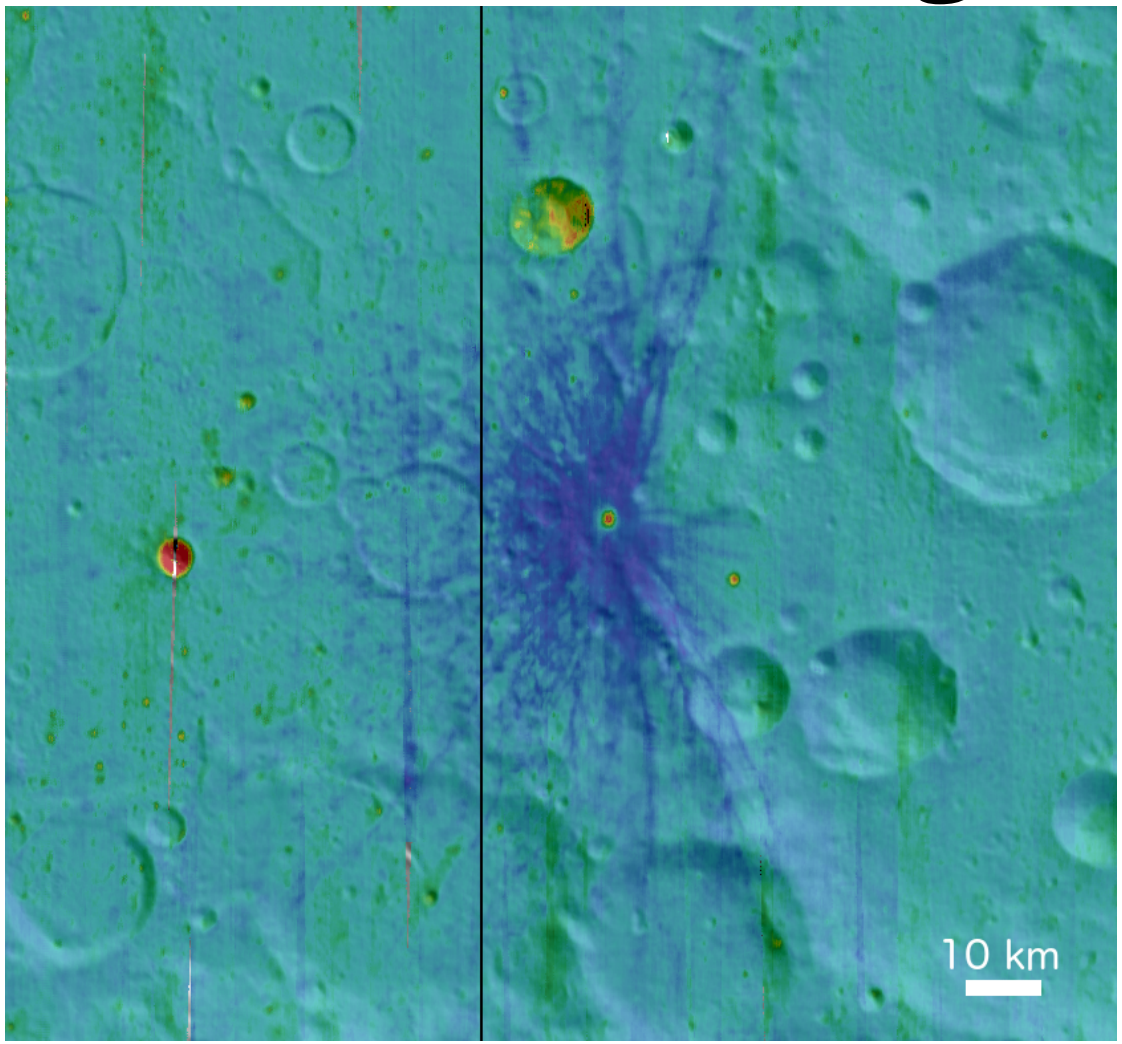


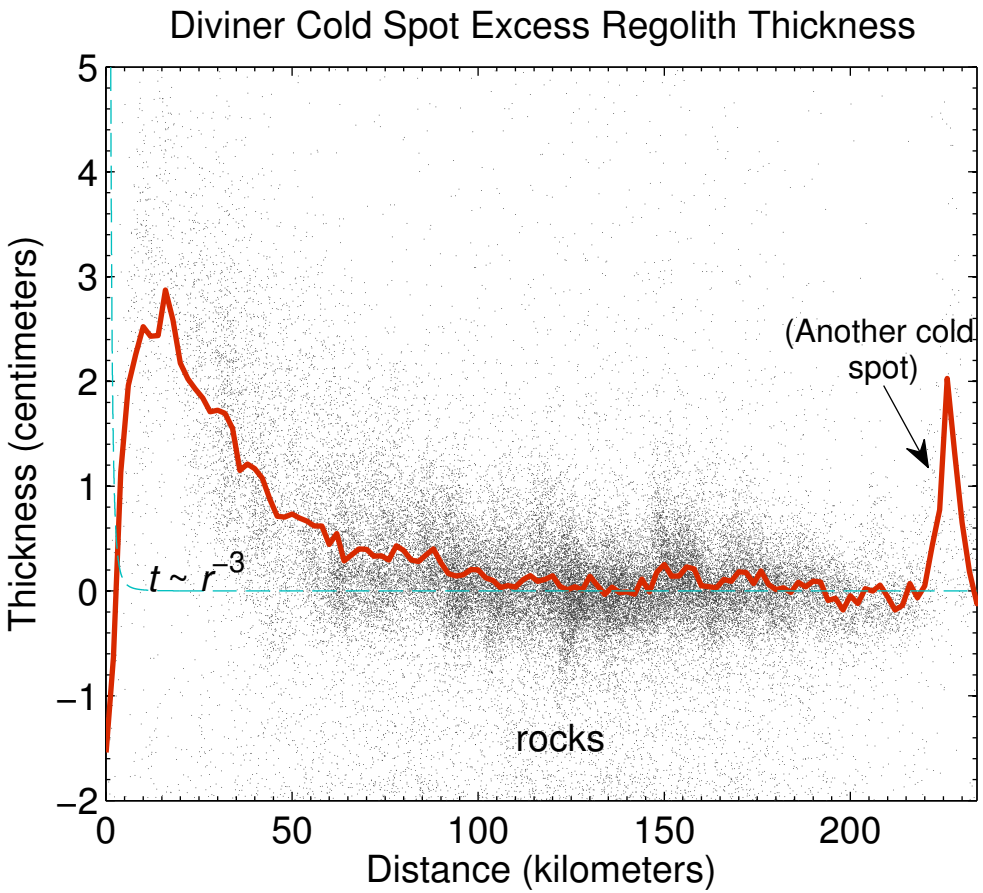
The Mass Budget Problem





The Mass Budget Problem





Proposed Cold Spot Formation Models

1. Ballistic erosion and sedimentation (Oberbeck, 1975)
2. Gas flows combined with ballistic erosion and sedimentation (Bandfield et al., 2014)
3. Seismic shaking
4. Popcorn explosions (C. Watkins)
5. Comet coma impact (M. Siegler)

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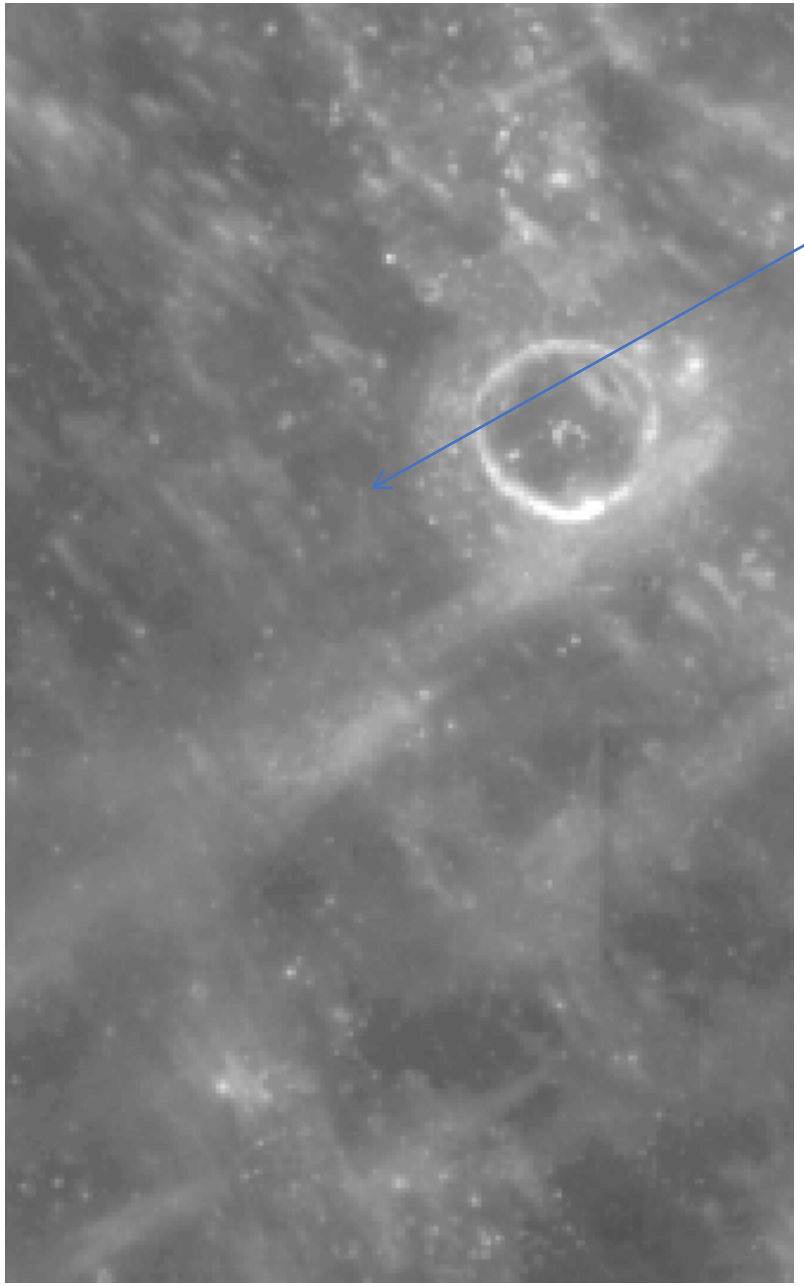
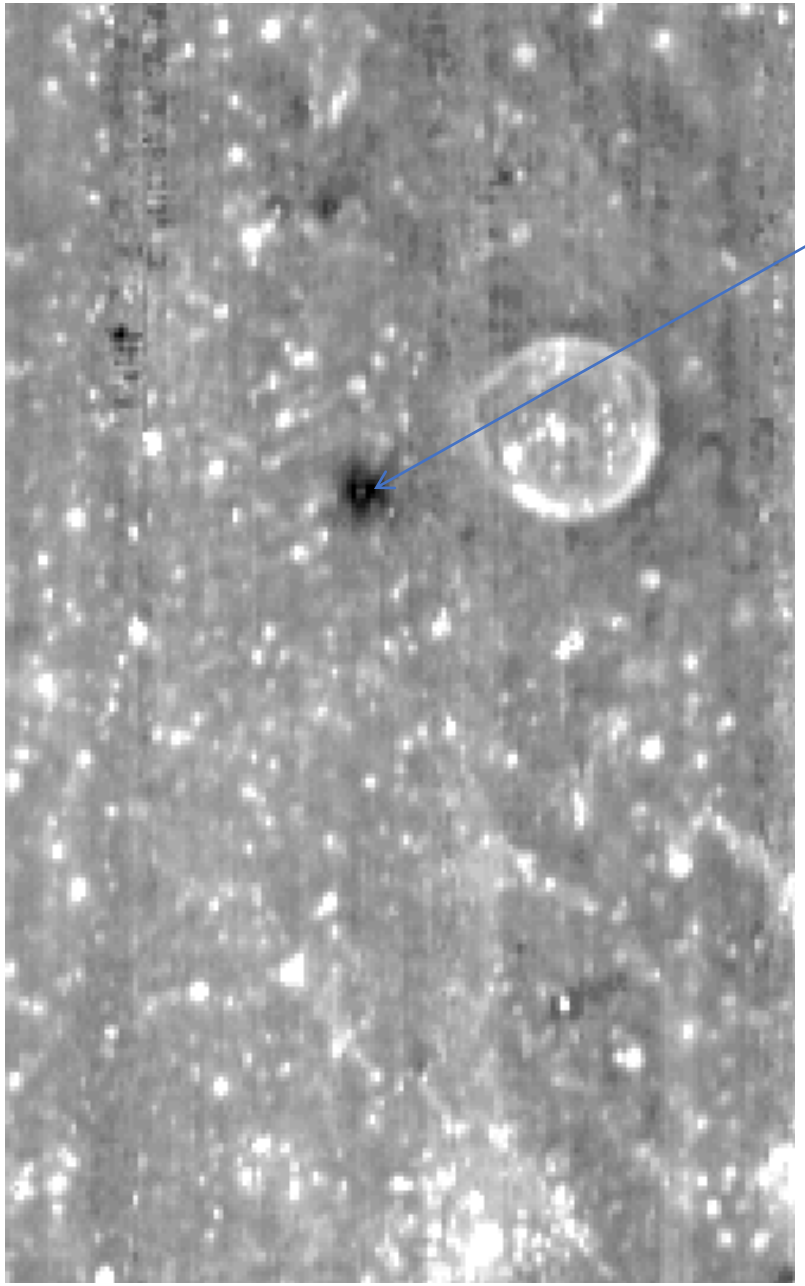
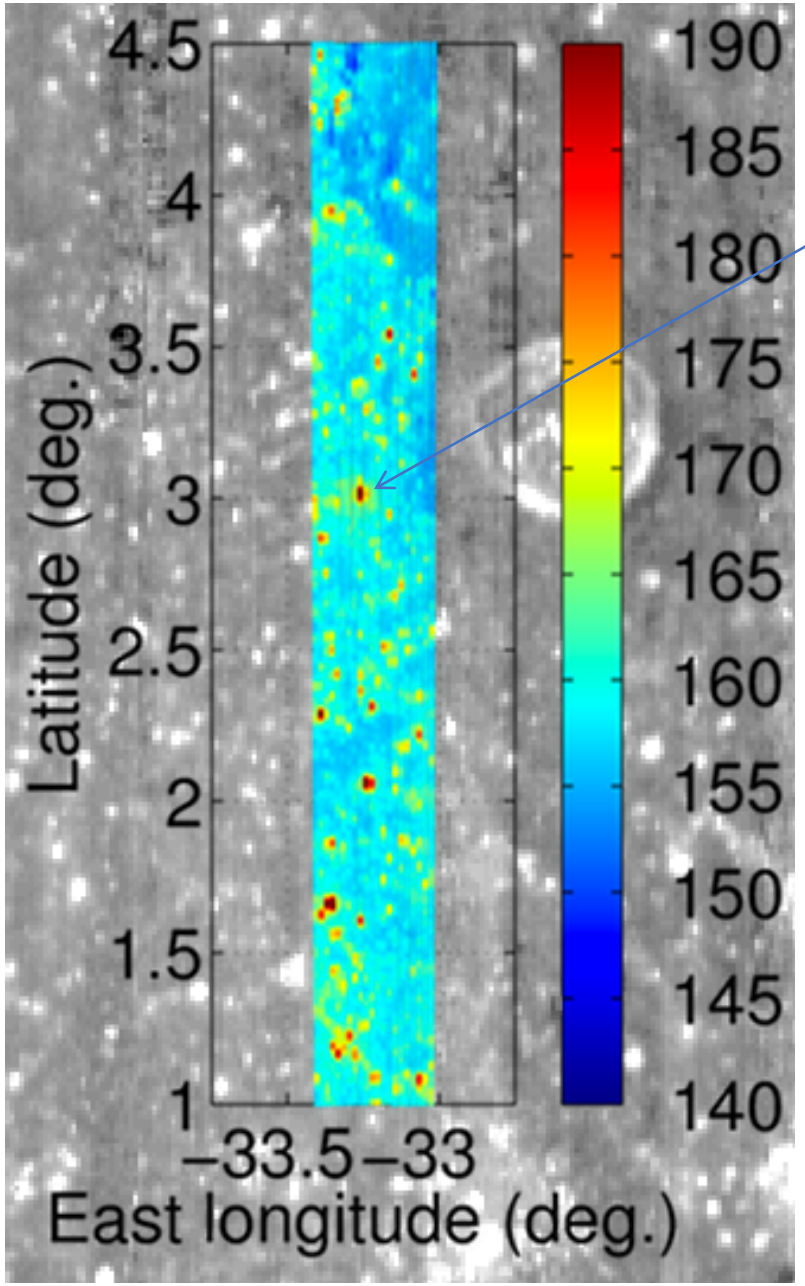
Clementine visual albedo



Diviner nighttime regolith temperature



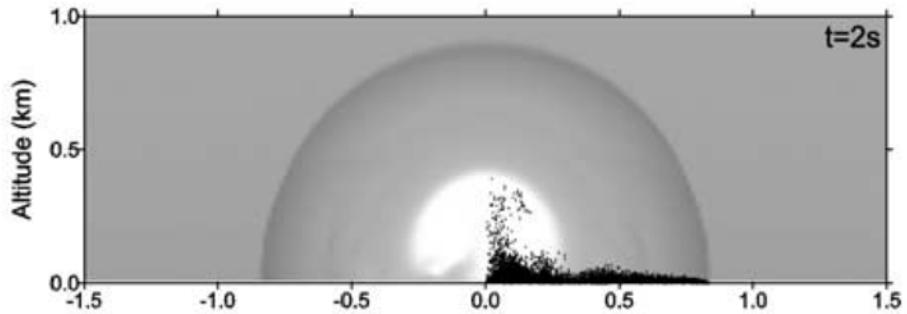
Oct. 2014 Eclipse data (color = Tb7) overlaid on regolith temp.



Cold spot

→ Implies layering (or roughness??)

Cold Spots: Model #1



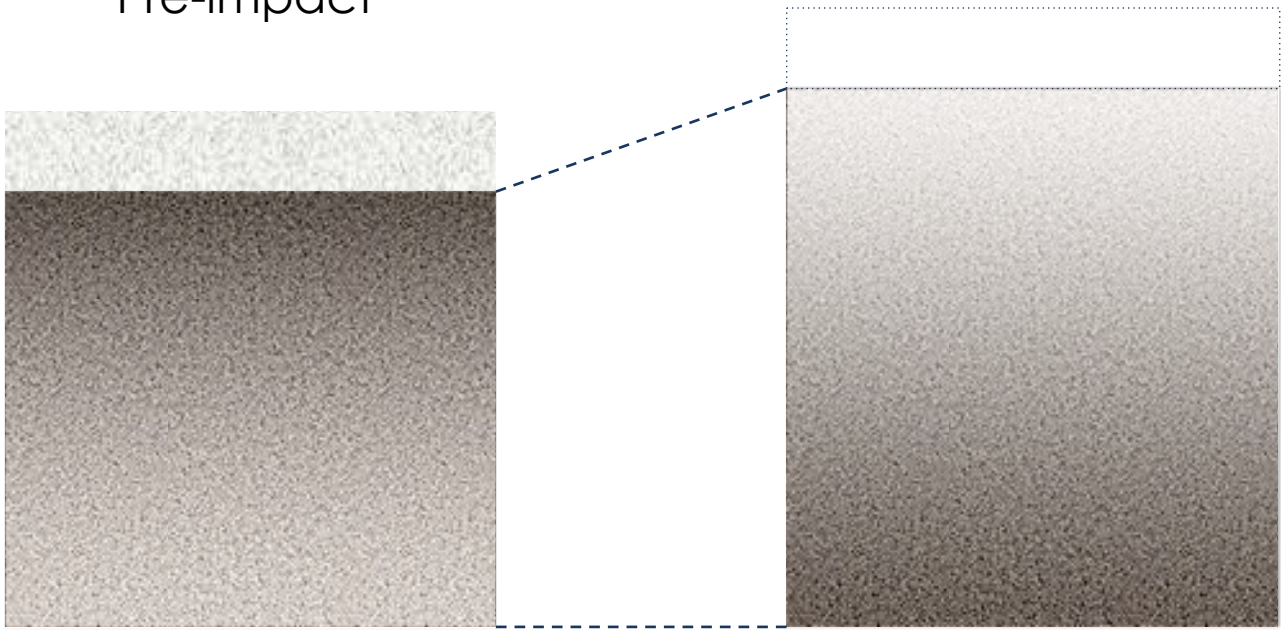
Nemtchinov et al., 2002

Pre-impact

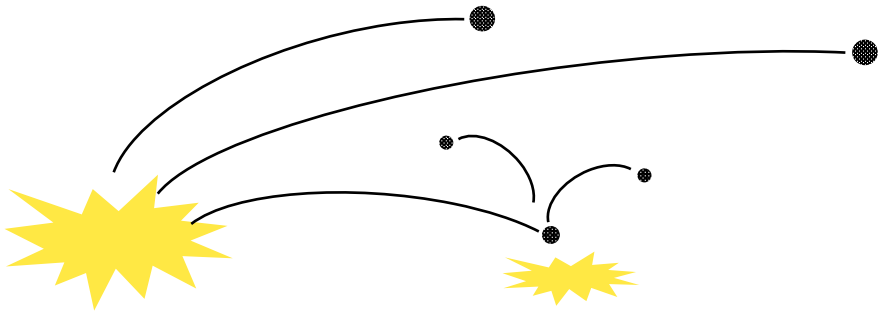
Post-impact

< 1 cm

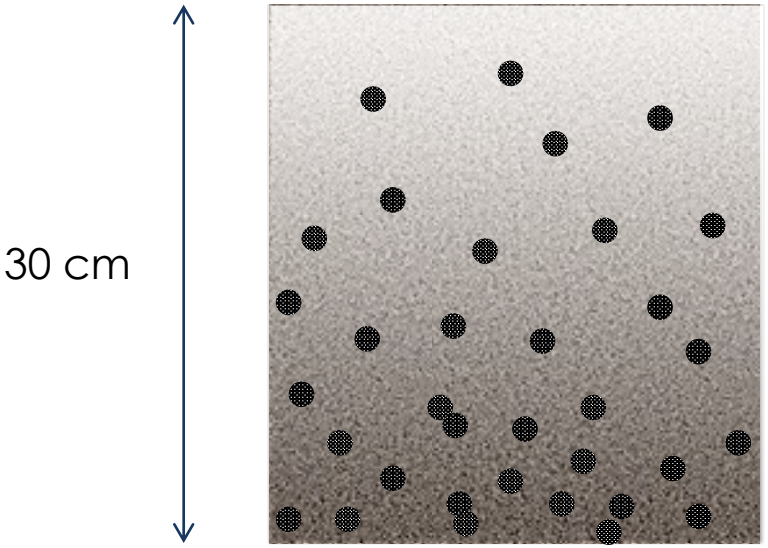
30 cm



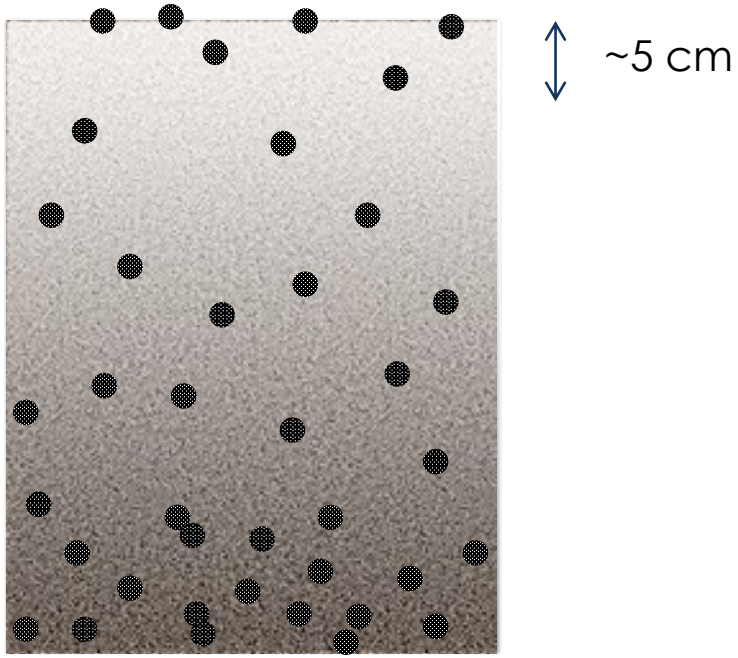
Cold Spots: Model #2



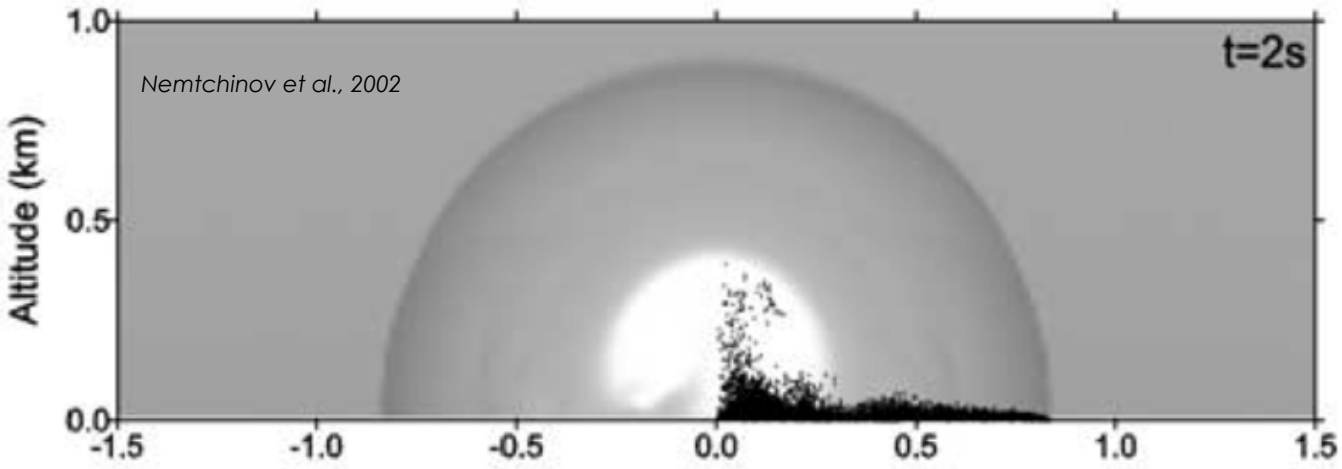
Pre-impact



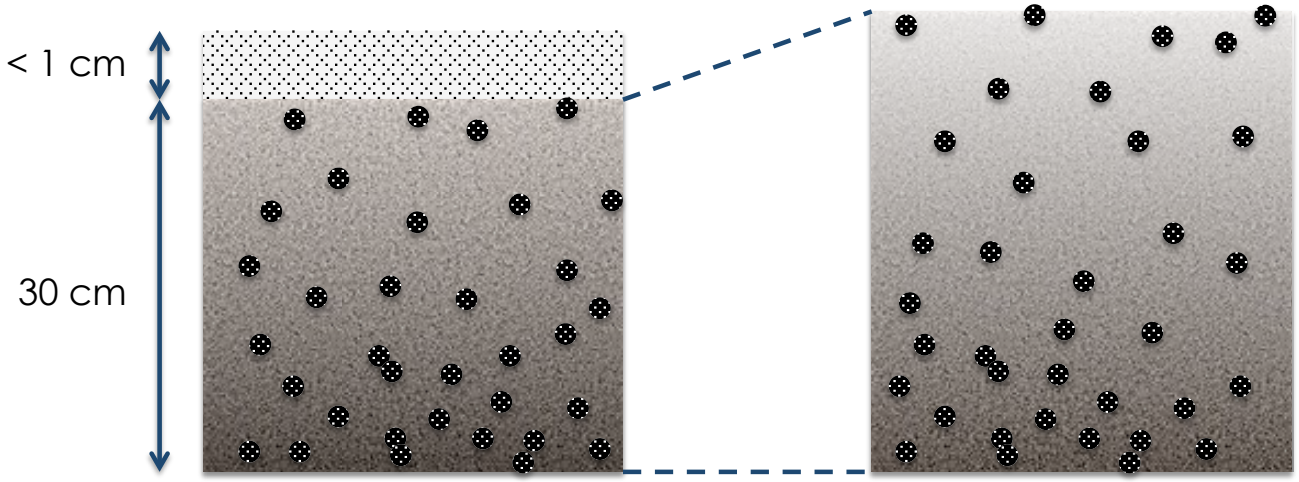
Post-impact



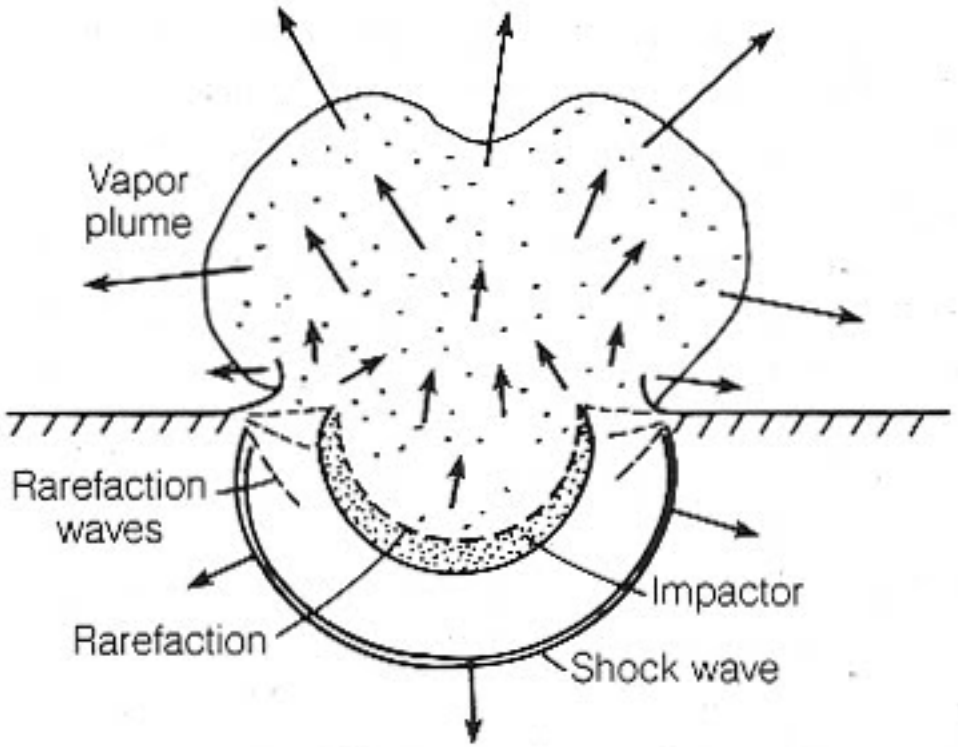
Cold Spots: Combined Model



Pre-impact **Post-impact**



Vapor Plume Model



$$S_* = \rho u_*^{\,2}$$

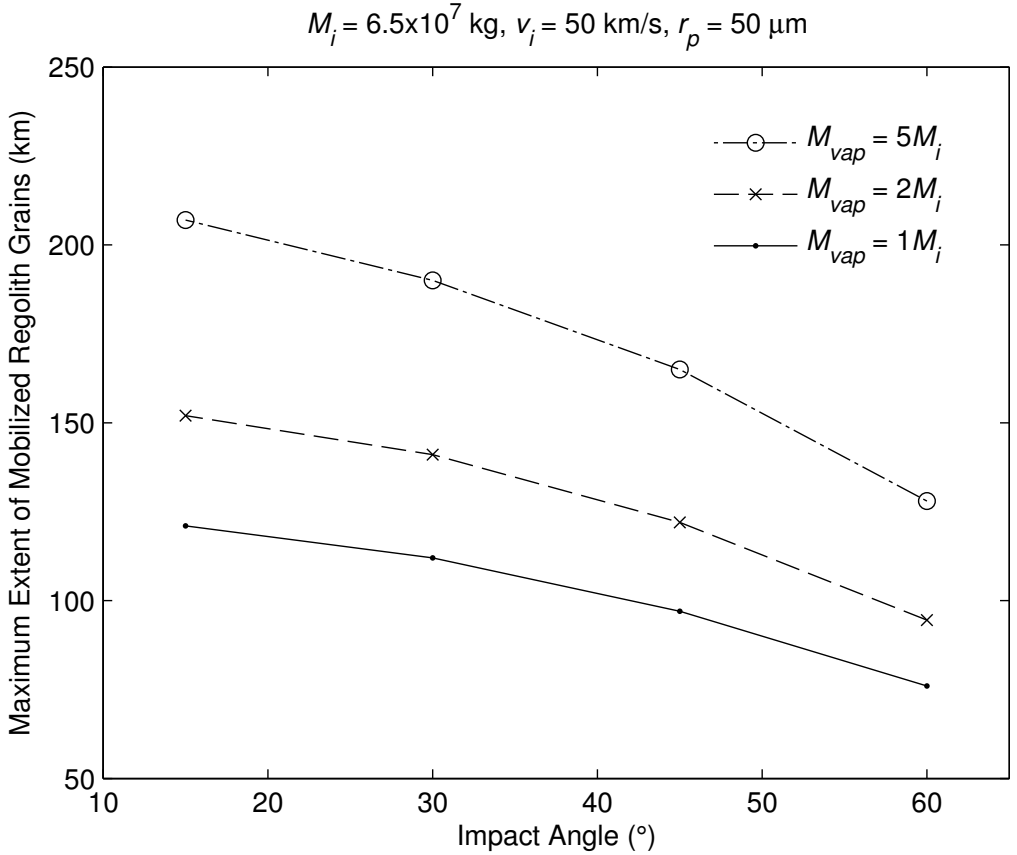
$$S_{*,t} = A^2 r_p \rho_p g$$

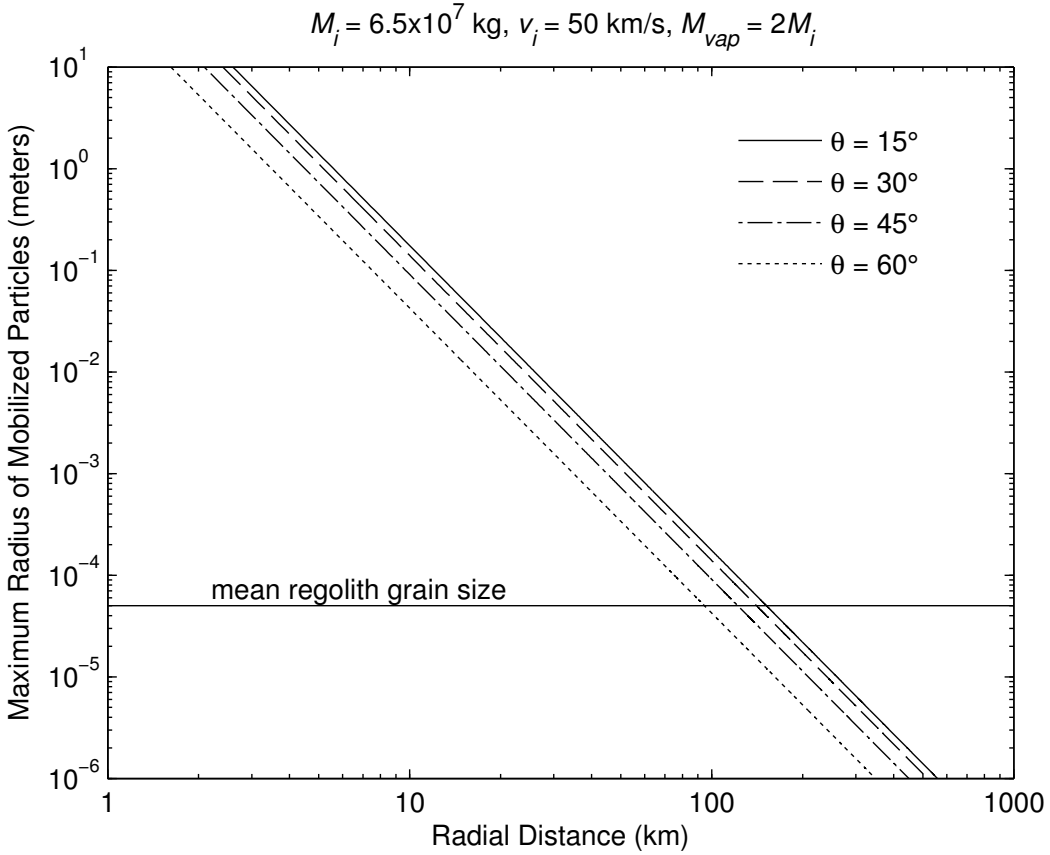
$$u(r) = u_{\max} \frac{r}{R}$$

$$u_{\max} = \frac{2}{\gamma - 1}\left[\gamma(\gamma - 1)\varepsilon_0\right]^{\frac{1}{2}}$$

$$\rho(r) = \frac{C}{R^3}\left(1 - \frac{r^2}{R^2}\right)^{\alpha} \;;\; \alpha = \frac{5+\gamma}{2(\gamma - 1)}$$

Vapor Plume Model





Summary & Future Work

- Vapor plume model can account for removal of fine-grained “fairy castle” layer to 100’s of crater radii
- Ballistic sedimentation can “fluff” regolith; model not fully working yet

- Compare to LROC “splotch” formation models (Speyerer et al.)
- Complete ballistic sedimentation model
- Roughness effects? (Rubanenko)