Clutter Analysis

Jack Holt

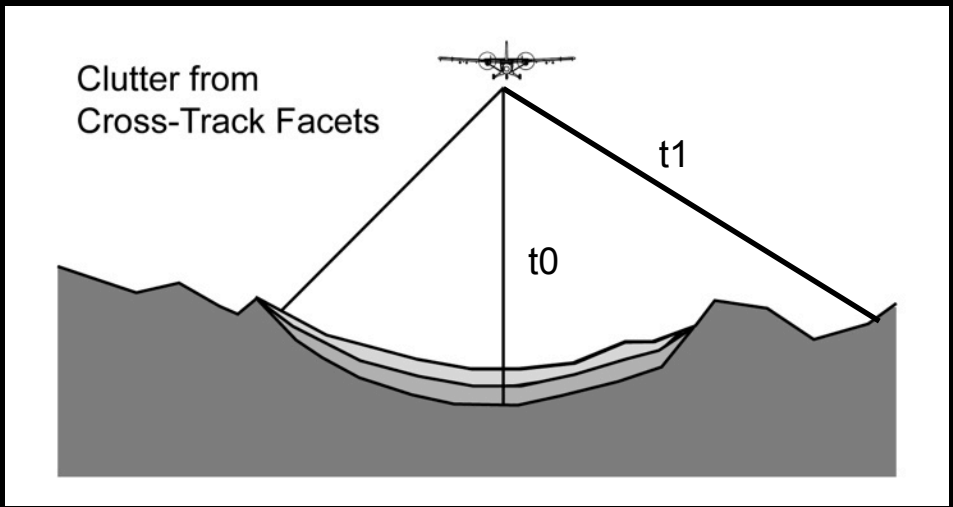
INSTITUTE FOR GEOPHYSICS

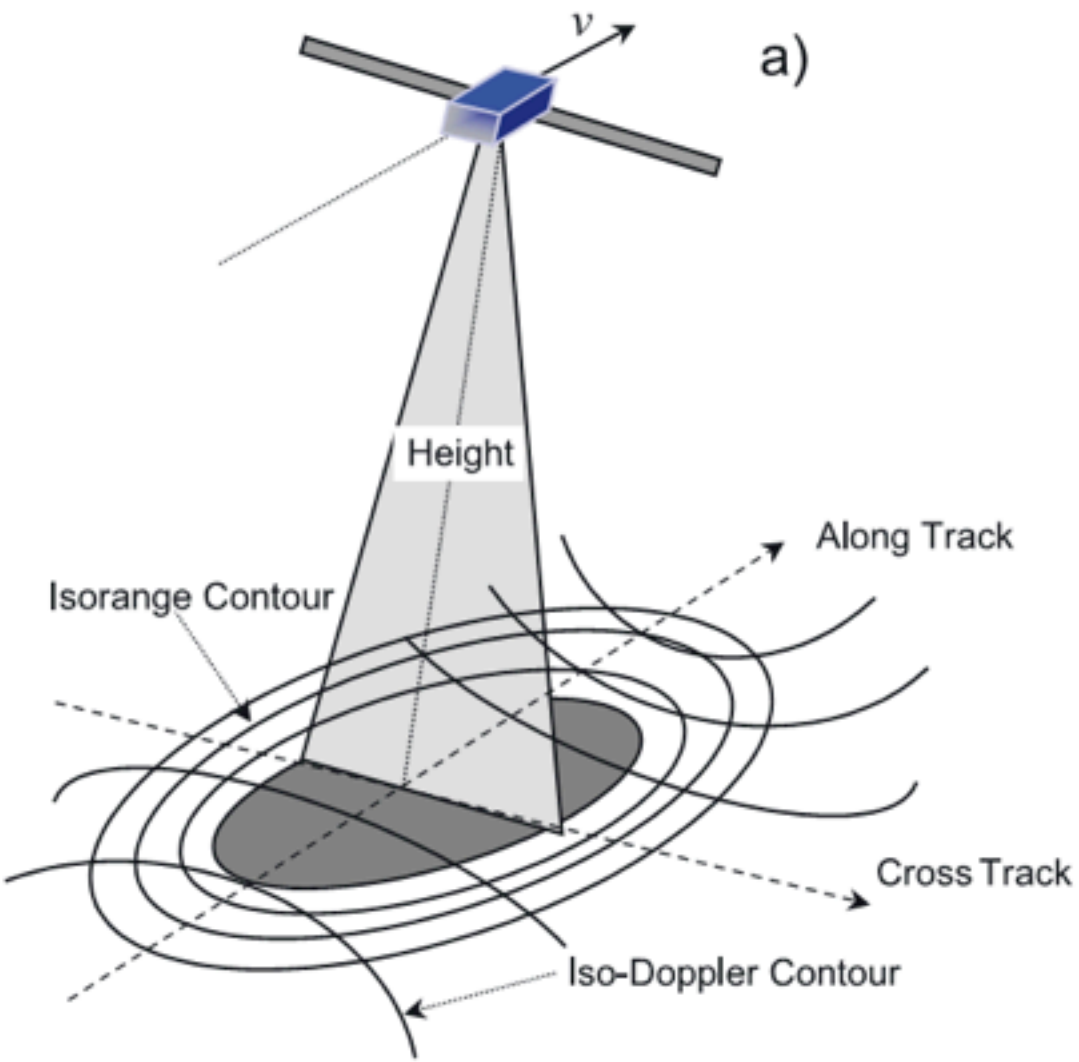
JACKSON SCHOOL OF GEOSCIENCES

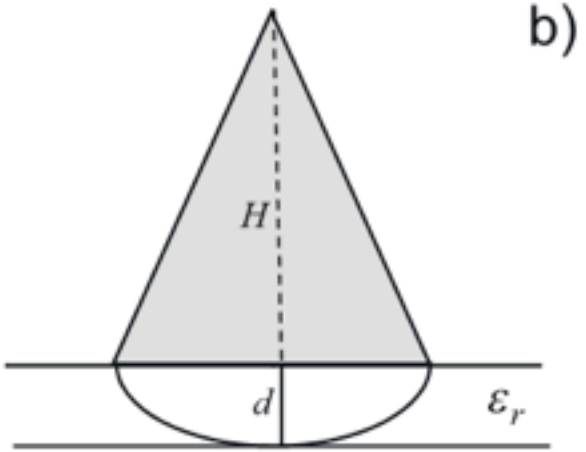
University of Texas at Austin

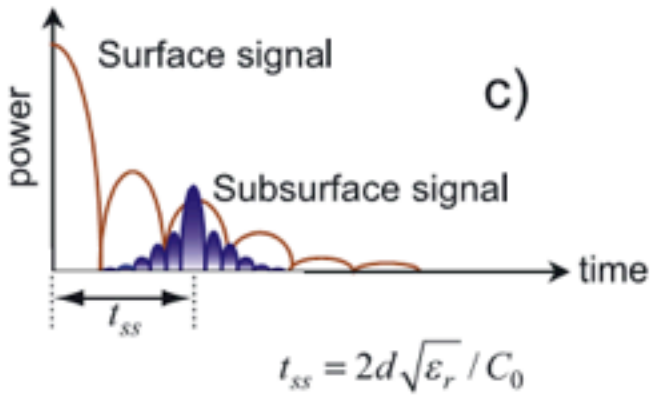
Surface Clutter - What is it?

- Reflections from off-nadir surface features (deterministic)
  - Can be interpreted as subsurface reflections due to time delays
  - Happens for any radar where you can't focus the across-track beam




a)
v
Height
Along Track
Isorange Contour
Cross Track
Iso-Doppler Contour


b)
H
d
ε_r


c)
Surface signal
Subsurface signal
power
time
t_{ss}
$t_{ss} = 2d\sqrt{\varepsilon_r}/C_0$

Clutter analysis process

1. Identify potential subsurface echoes in radar data.
2. Predict (simulate) surface echoes and compare with real data.
3. Check map view of simulation to better understand clutter sources
    1. migrate echo time delays onto surface, compare with imagery.

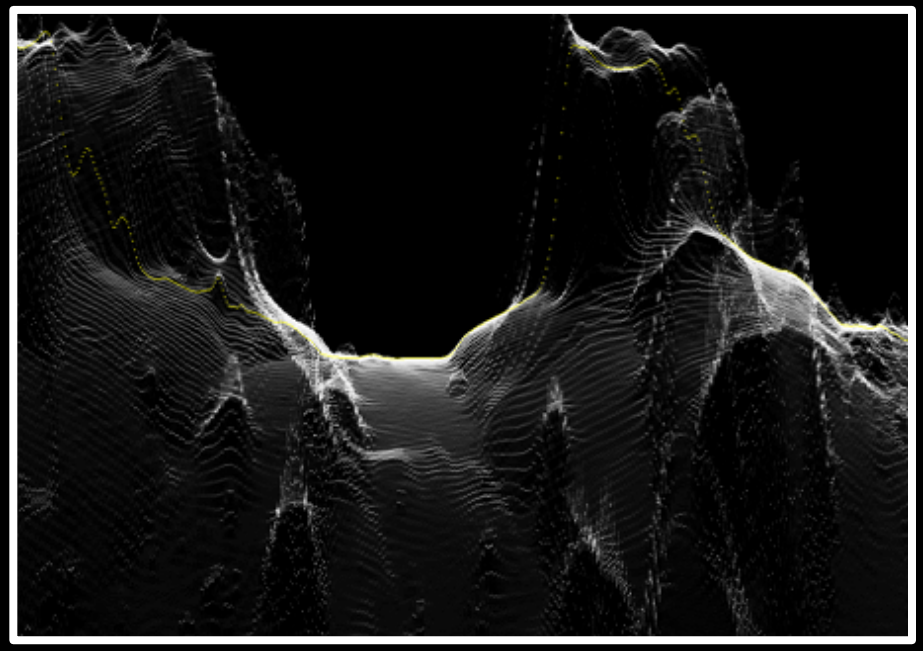
Steps 2 and 3 require a DEM of the surface.

How is clutter predicted?

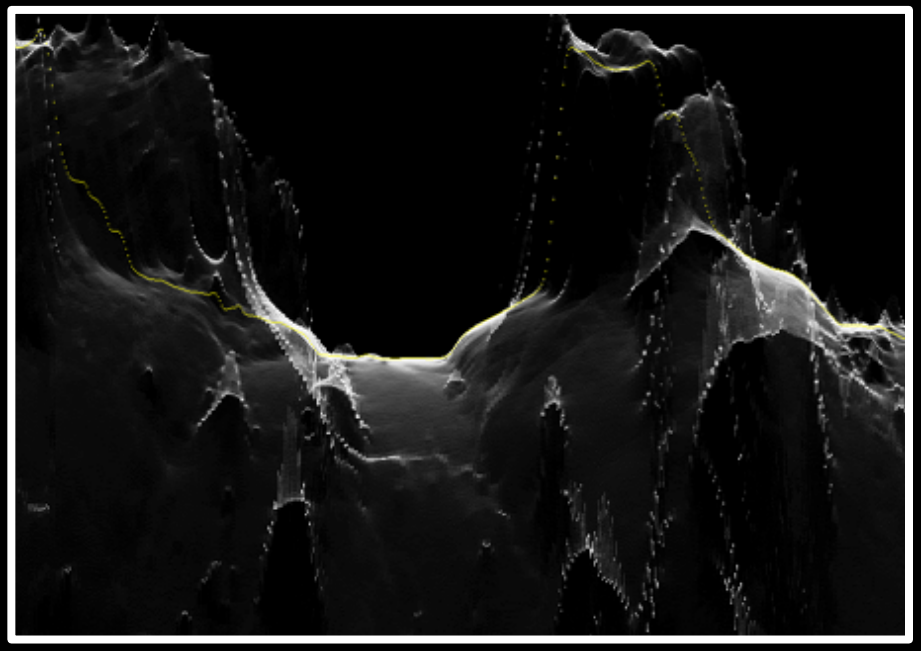
- Input 1: spacecraft trajectory
- Input 2: DEM of the surface
  - primarily MOLA
    - *~ 450 m resolution at equator, ~ 100 m near poles*
  - secondarily, HRSC (if available)
    - *~ 50 - 100 m depending on location*
- Then we run a simulator developed at UTIG
  - Incoherent, facet-based model - builds facets from DEM grid
    - *Computes power returned from each facet given orientation/area (radar cross section) w.r.t. antenna pattern at each point along track.*
    - *Assumes a combination of specular and diffuse scattering*
  - Includes along-track focusing of antenna pattern
  - See Holt et al. *JGR*, 2006

MOLA grid causes some problems

- We actually smooth it...



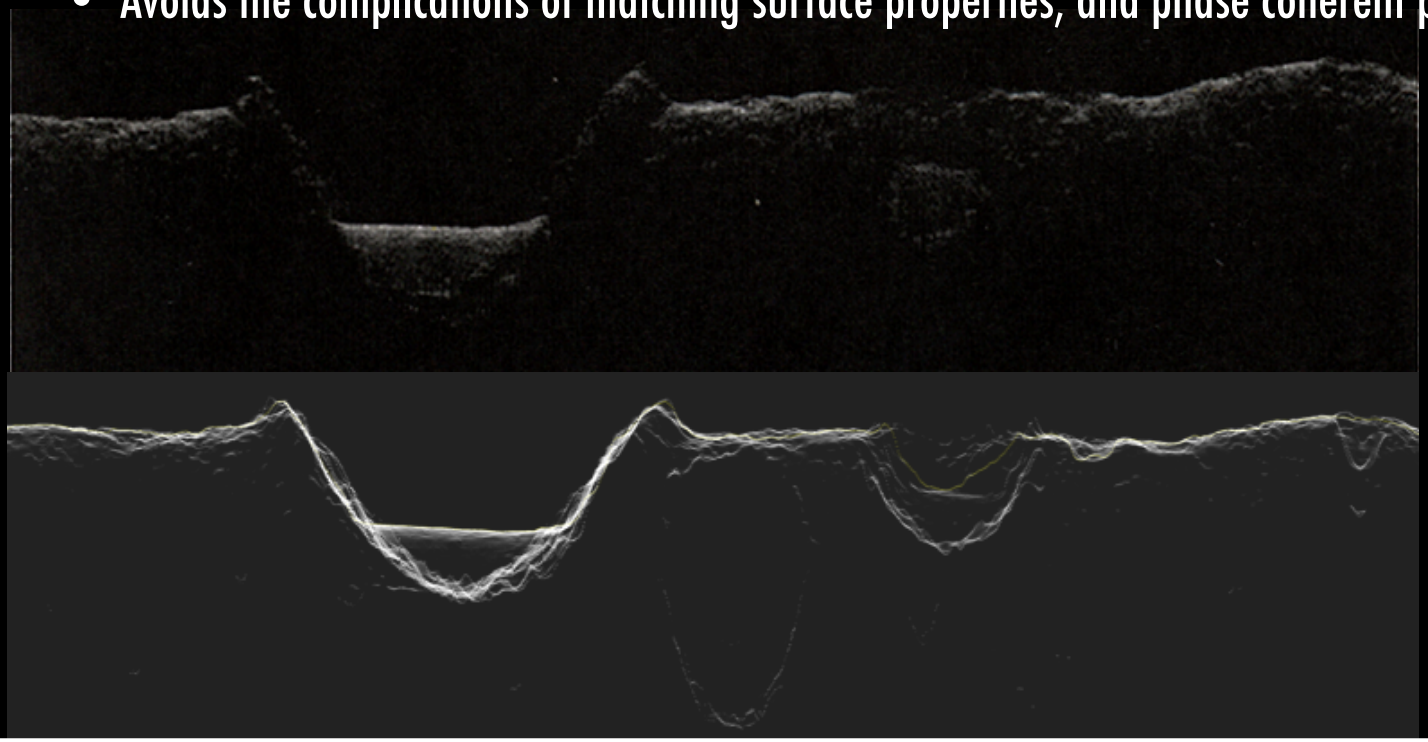
Without smoothing



With smoothing

Clutter Simulator ≠ Radar Simulator !!

- We do NOT attempt to simulate the radar data.
- Rather, we attempt to predict all possible clutter.
- This is a more conservative approach.
  - Avoids the complications of matching surface properties, and phase coherent processing.



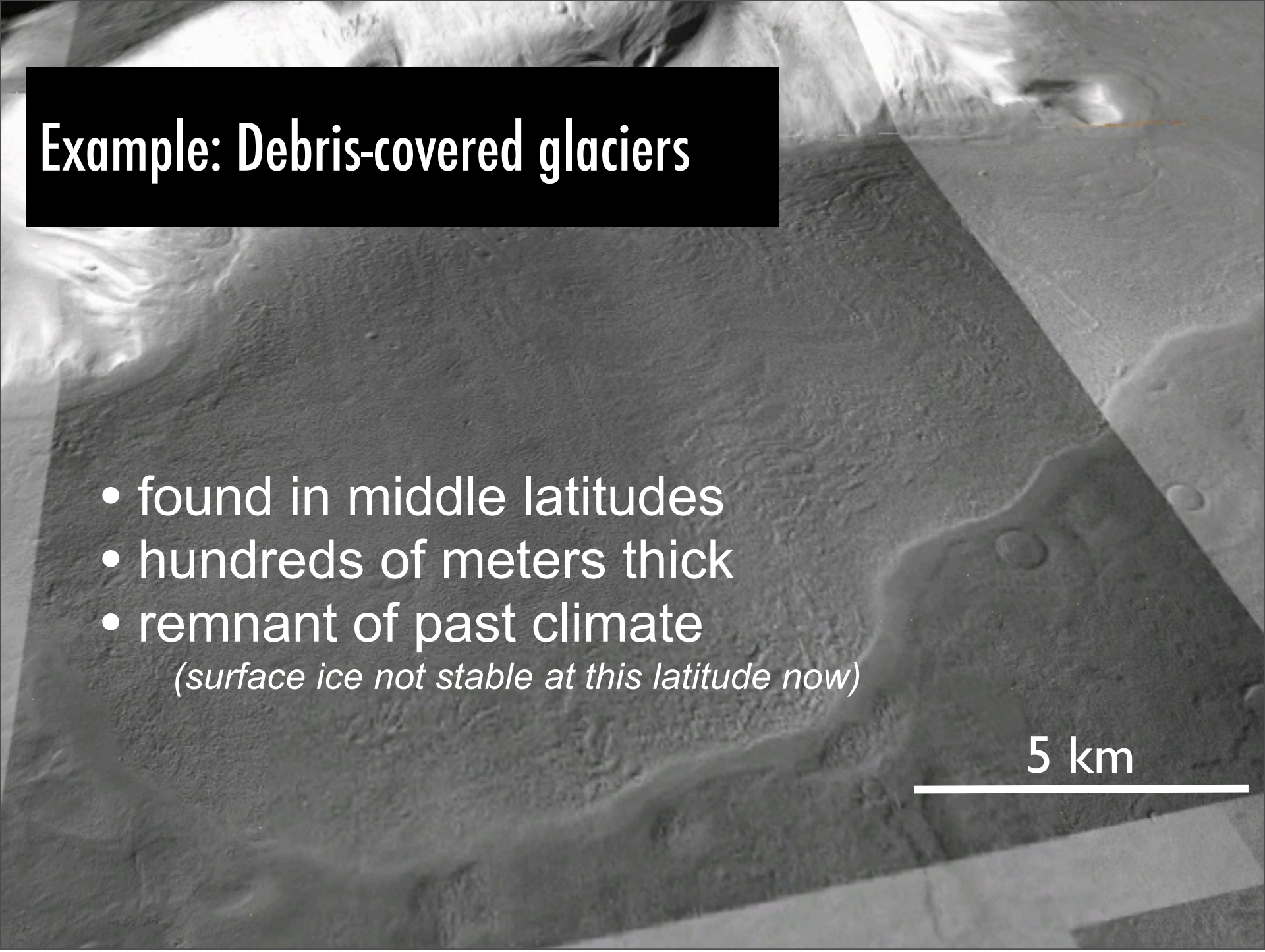
Data

Clutter Simulation

Outputs

- Cluttergram (like a radargram)
  - Left side
  - Right side
  - Combined (typically shown)
  - Includes position of nadir profile in time delay
- Echo Power Map
  - Map view of surface echo power
  - Locations of likely first echo sources

Example: Debris-covered glaciers

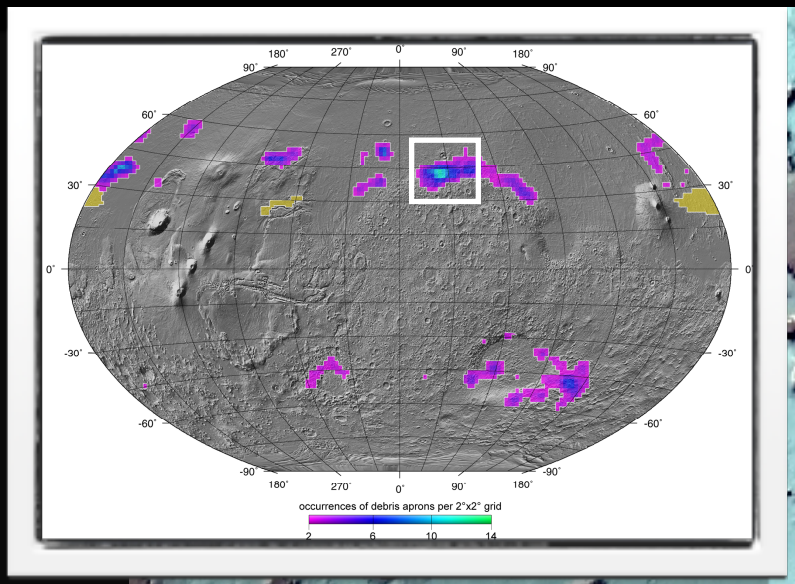


- found in middle latitudes
- hundreds of meters thick
- remnant of past climate

(surface ice not stable at this latitude now)

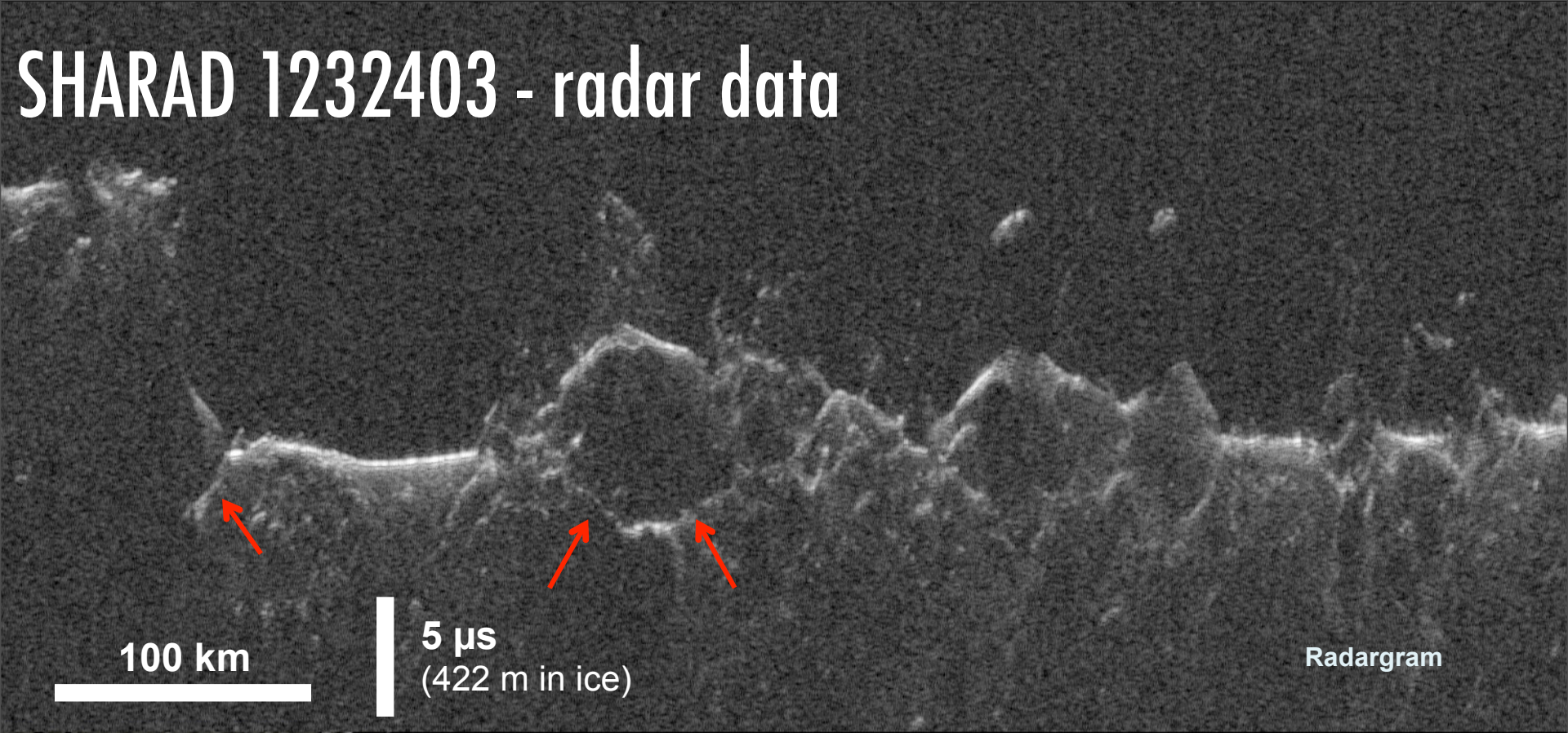
5 km

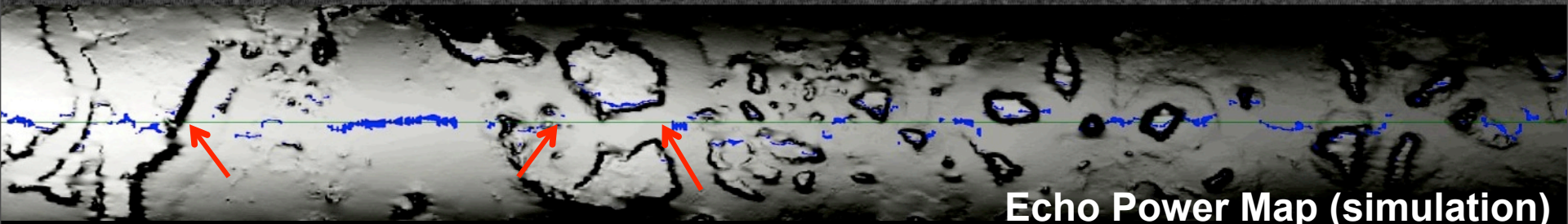
Deuteronilus Mensae region



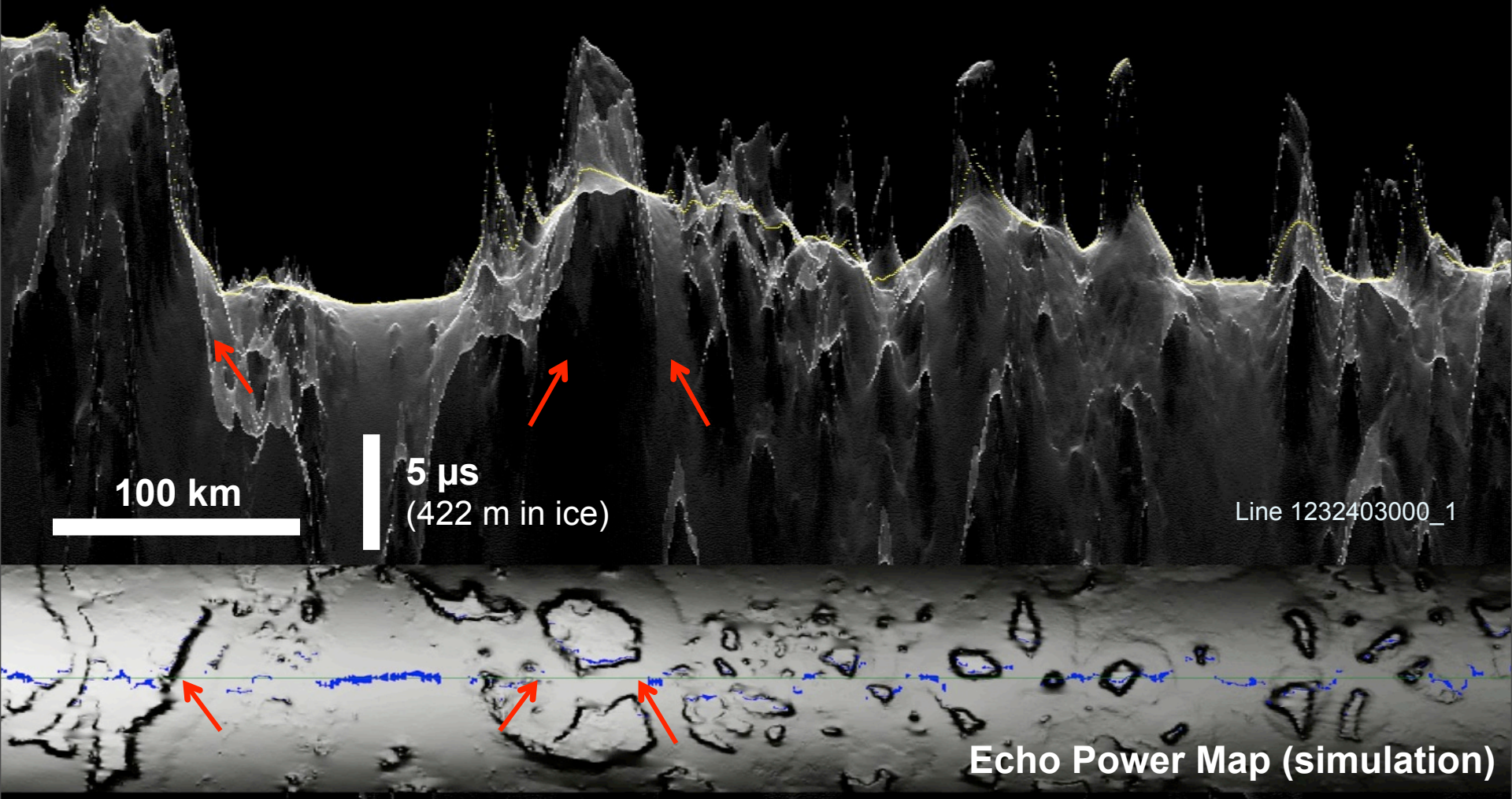
MOLA DEM

SHARAD 1232403 - radar data

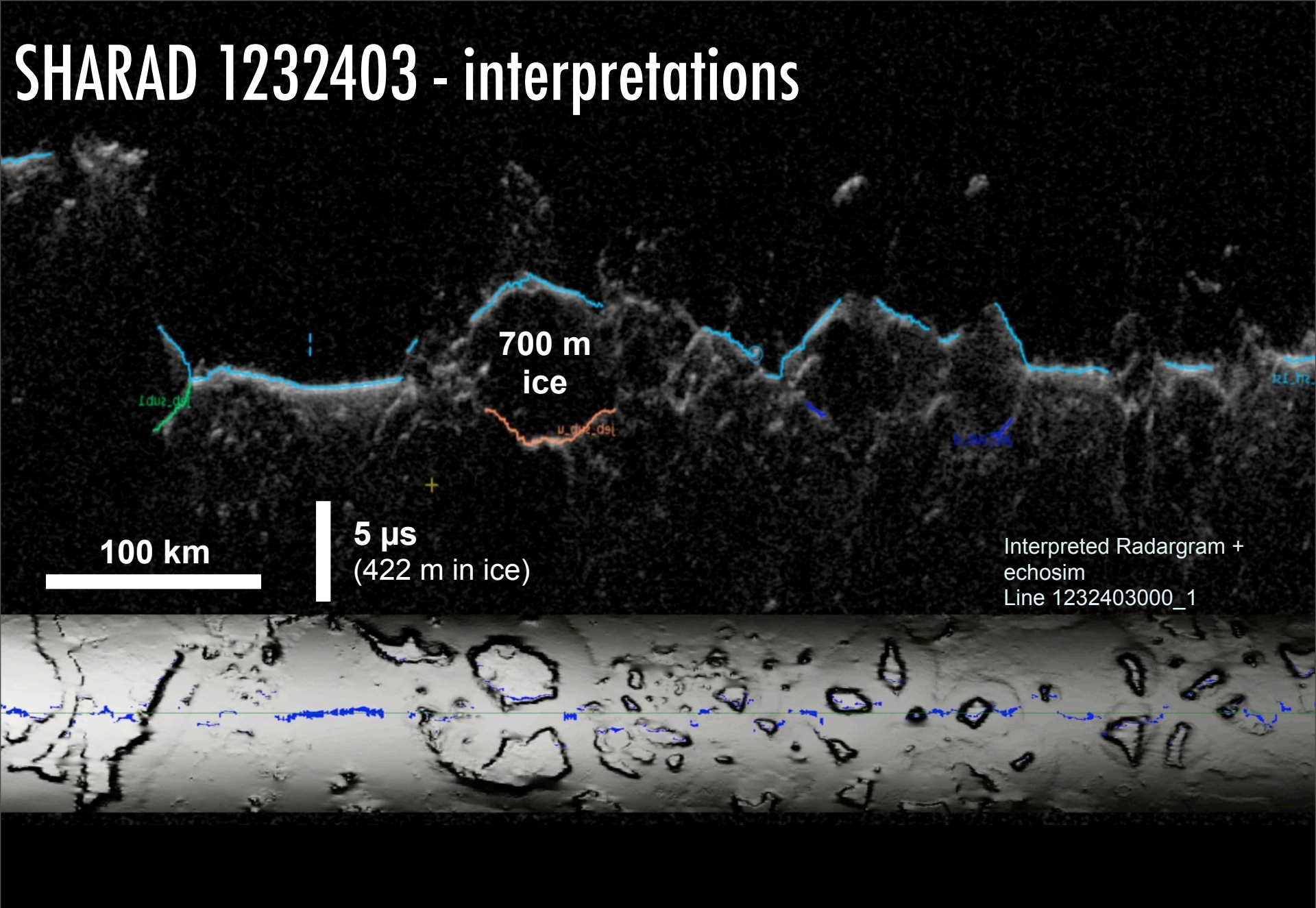




SHARAD 1232403 - clutter simulation



SHARAD 1232403 - interpretations

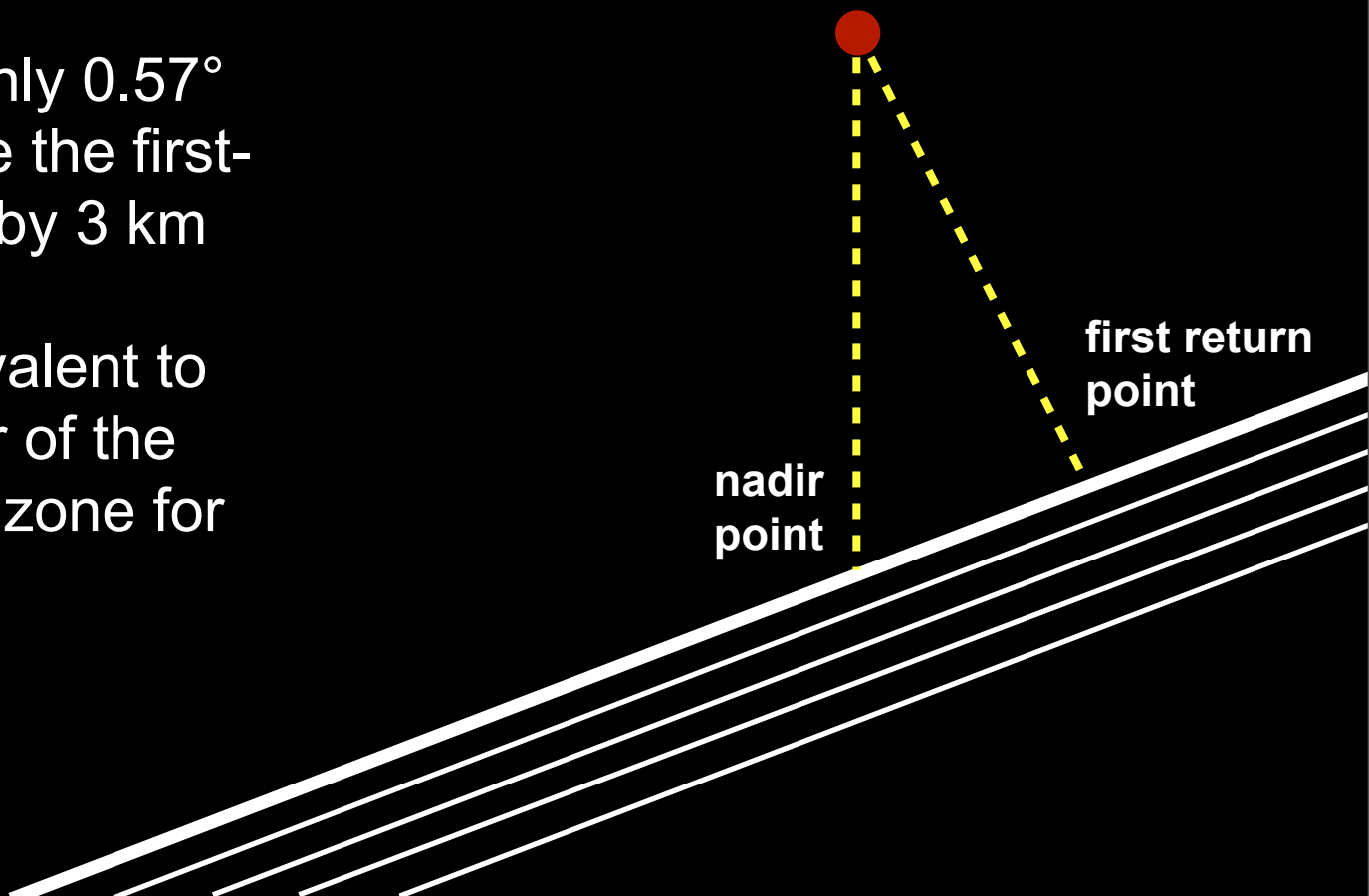


Another thing to consider: cross-track slopes

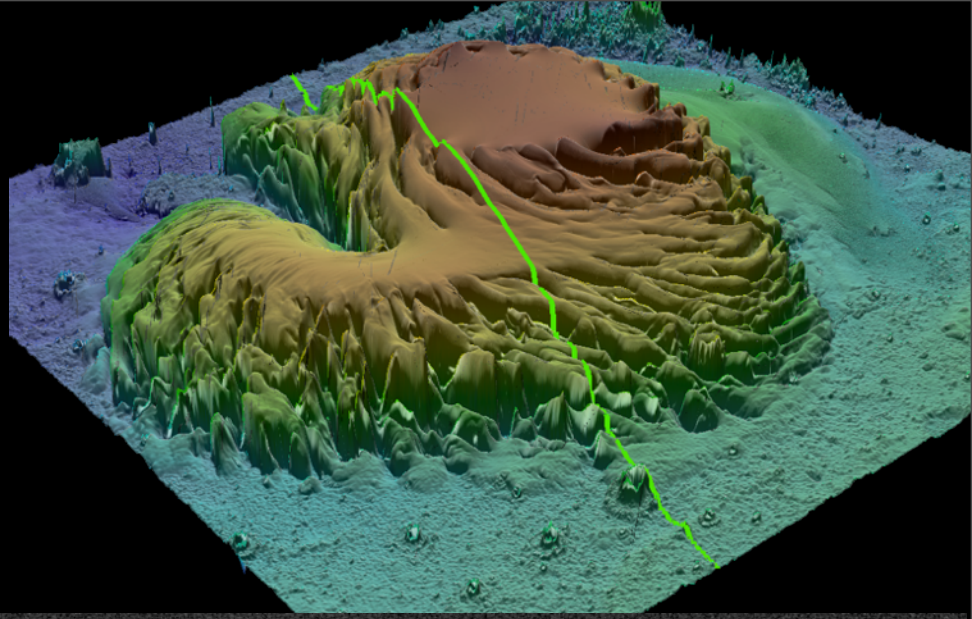
- They cause primary echoes to arise from off-nadir locations

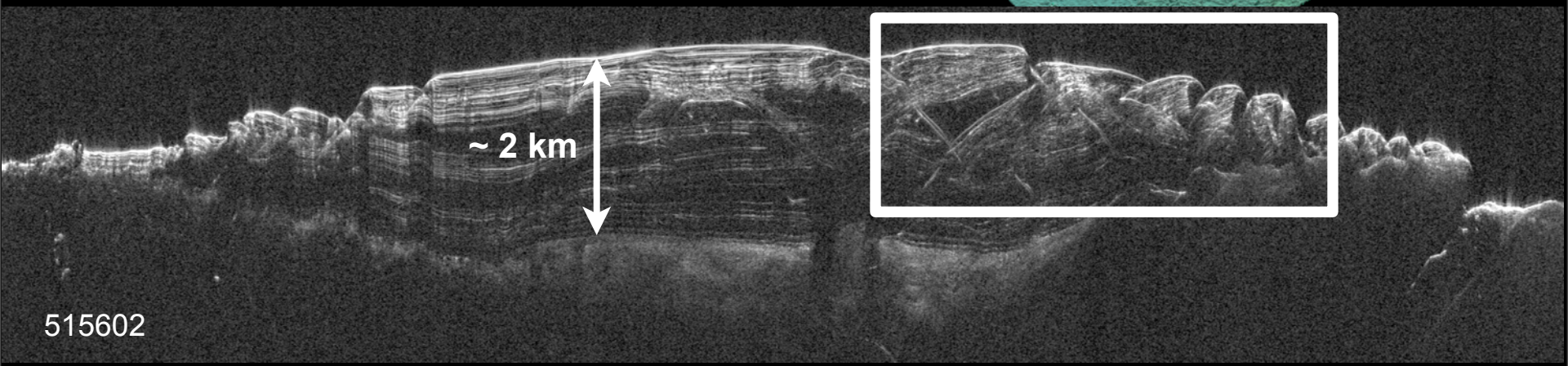
A slope of only 0.57° should move the first-return point by 3 km

This is equivalent to the diameter of the first Fresnel zone for SHARAD.



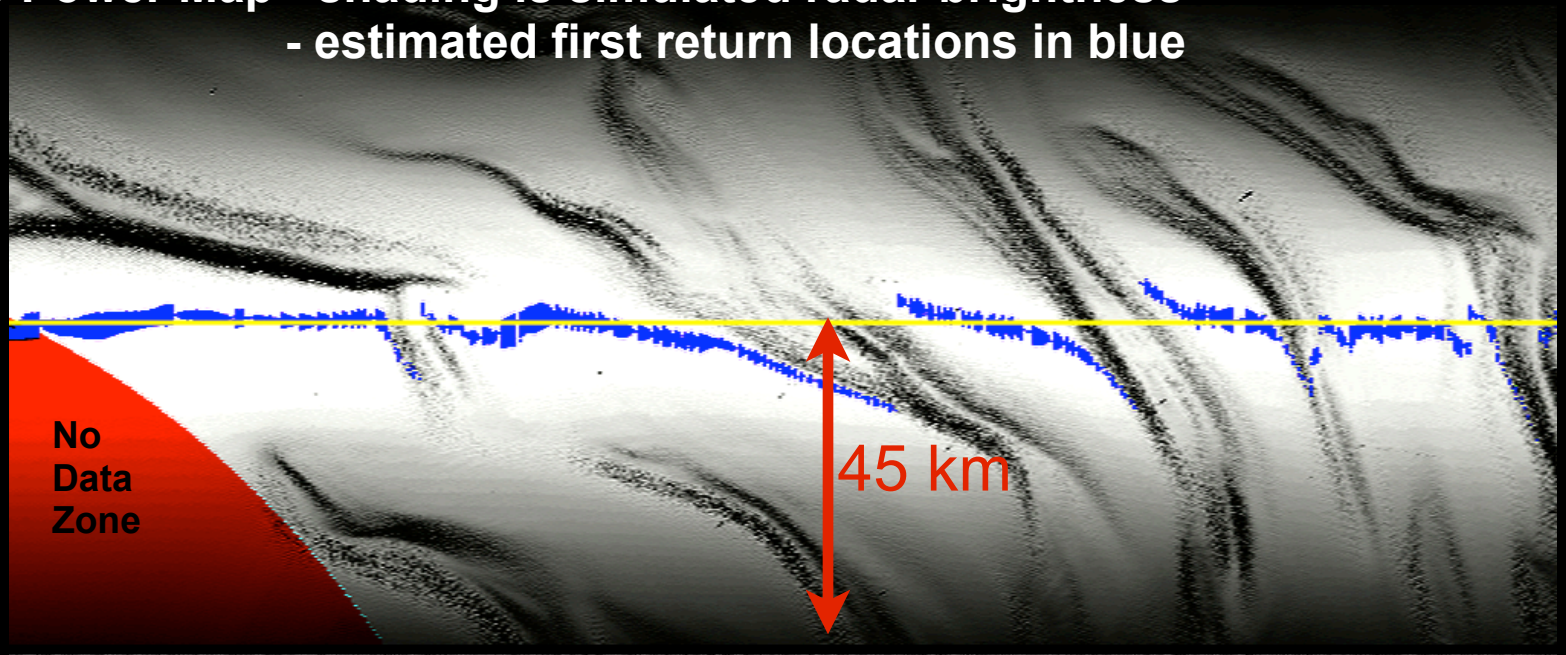
SHARAD observation across north pole





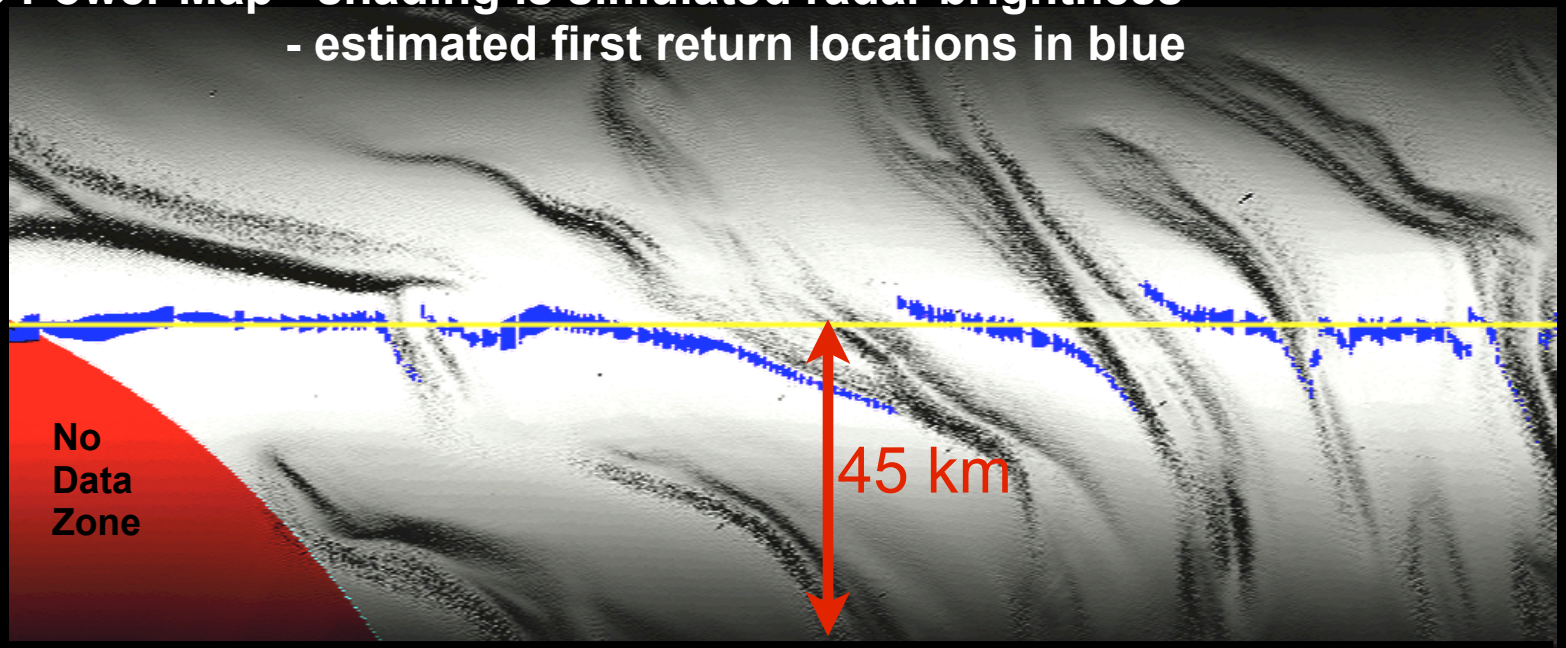
~ 1000 km across

Echo Power Map - shading is simulated radar brightness
- estimated first return locations in blue

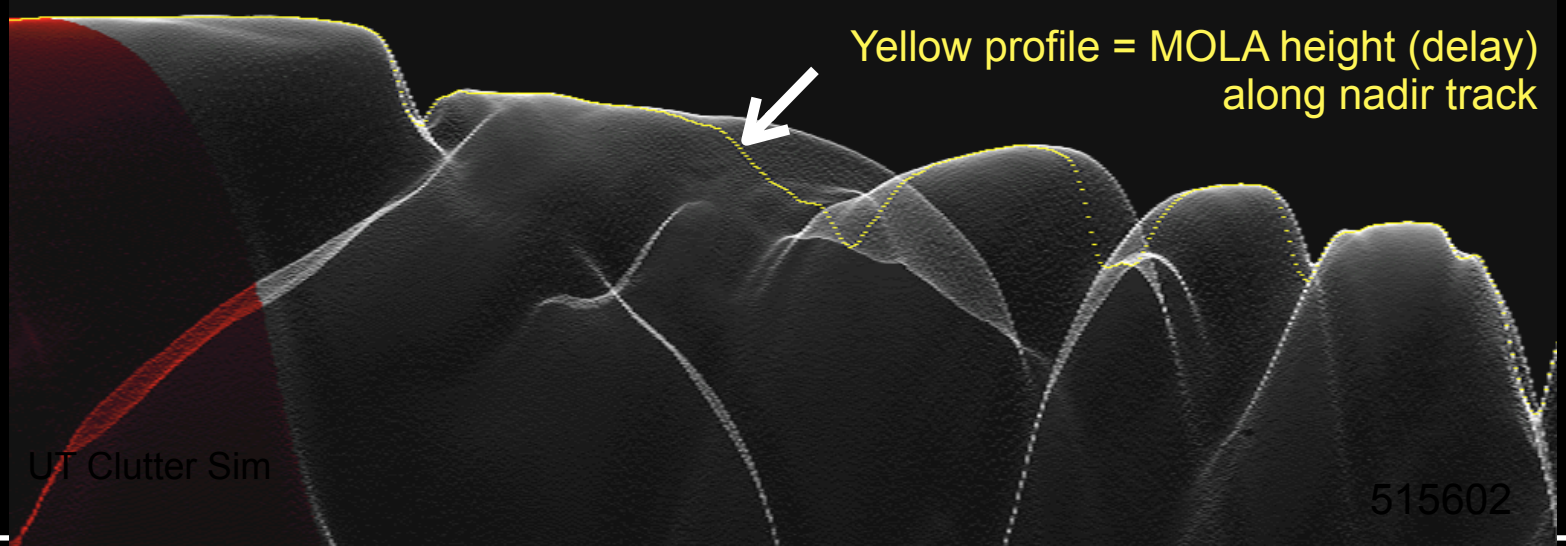


SHARAD data

Echo Power Map - shading is simulated radar brightness
- estimated first return locations in blue

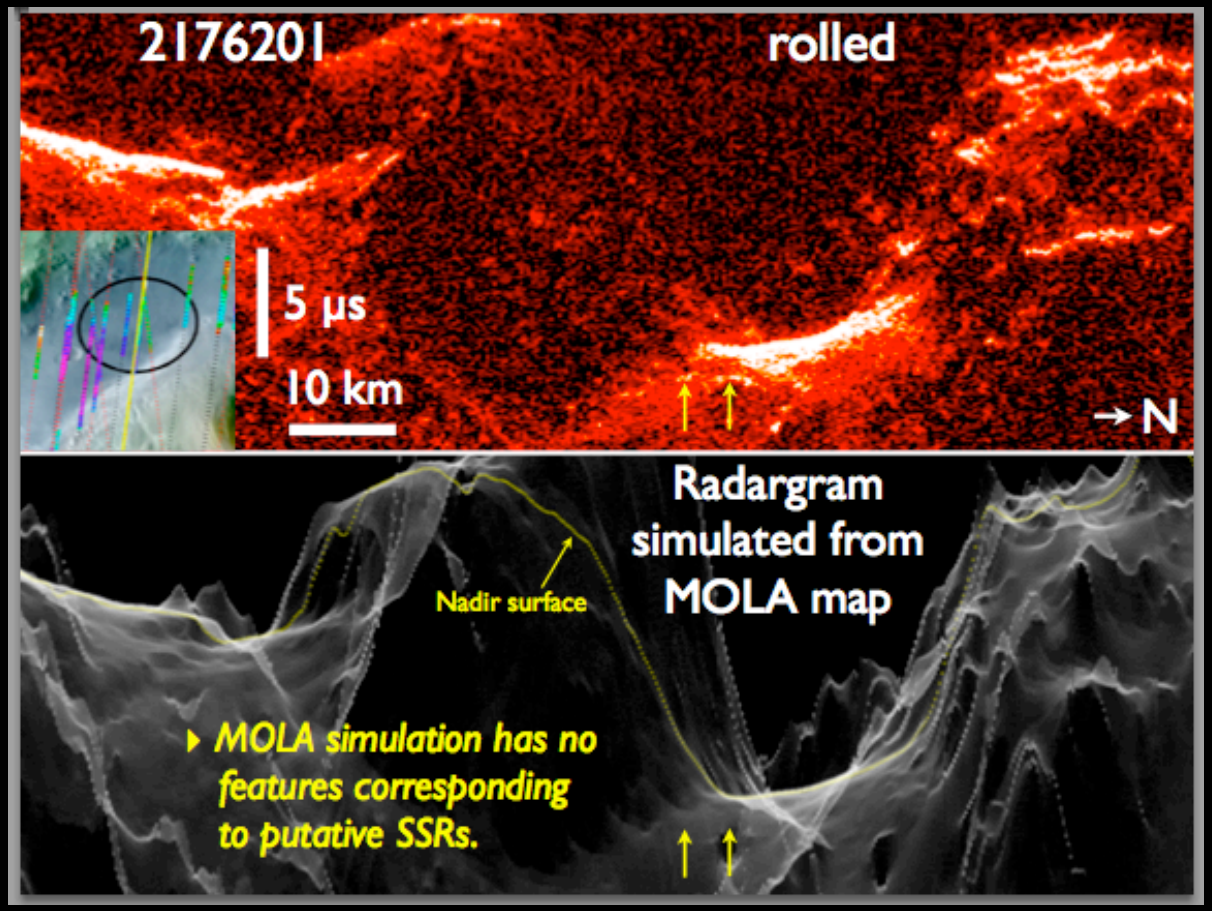


Clutter simulation, with nadir elevation profile (in yellow)



Do we need higher resolution simulations?

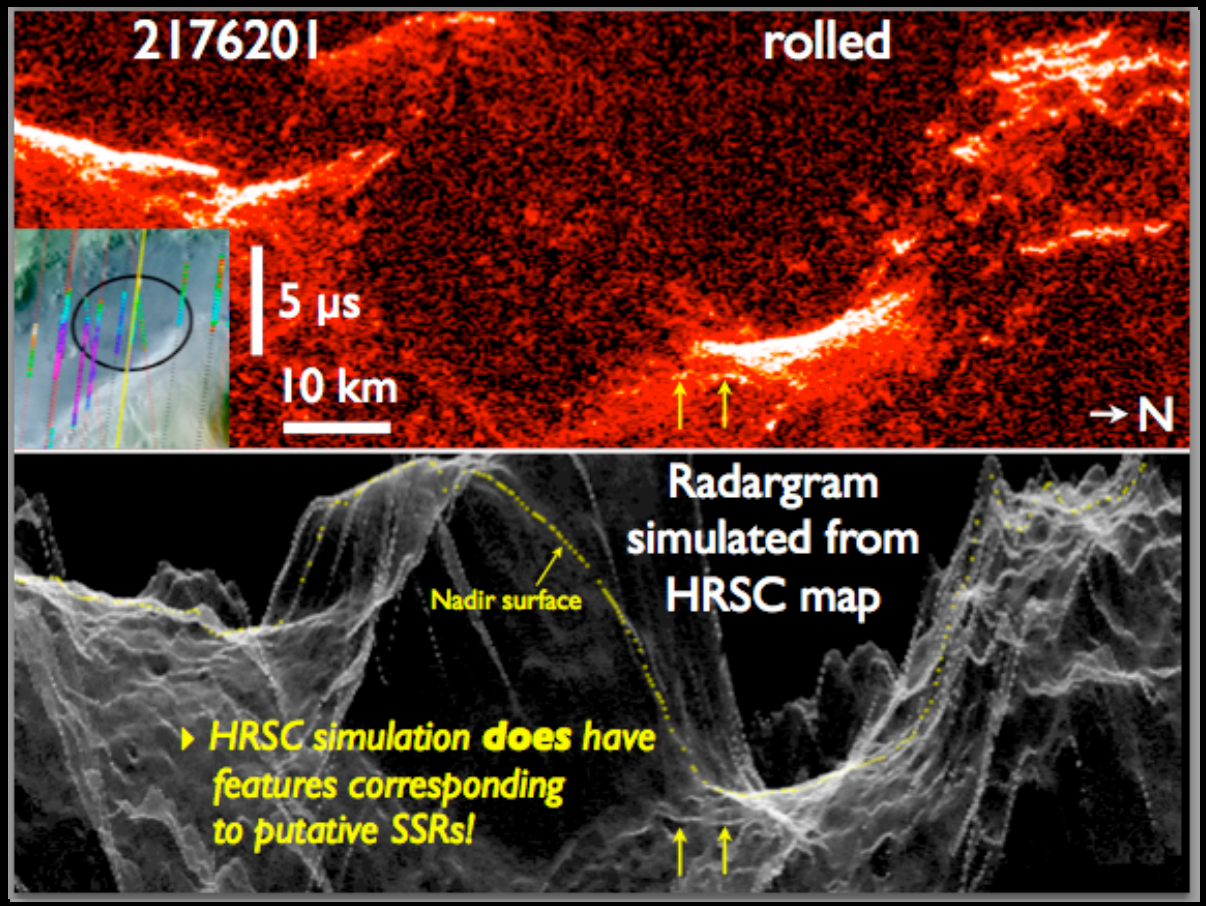
- Sometimes for very small features (few-km-scale)
  - Gale Crater example:



Putzig et al., *JGR*, in review

Using higher-resolution topography

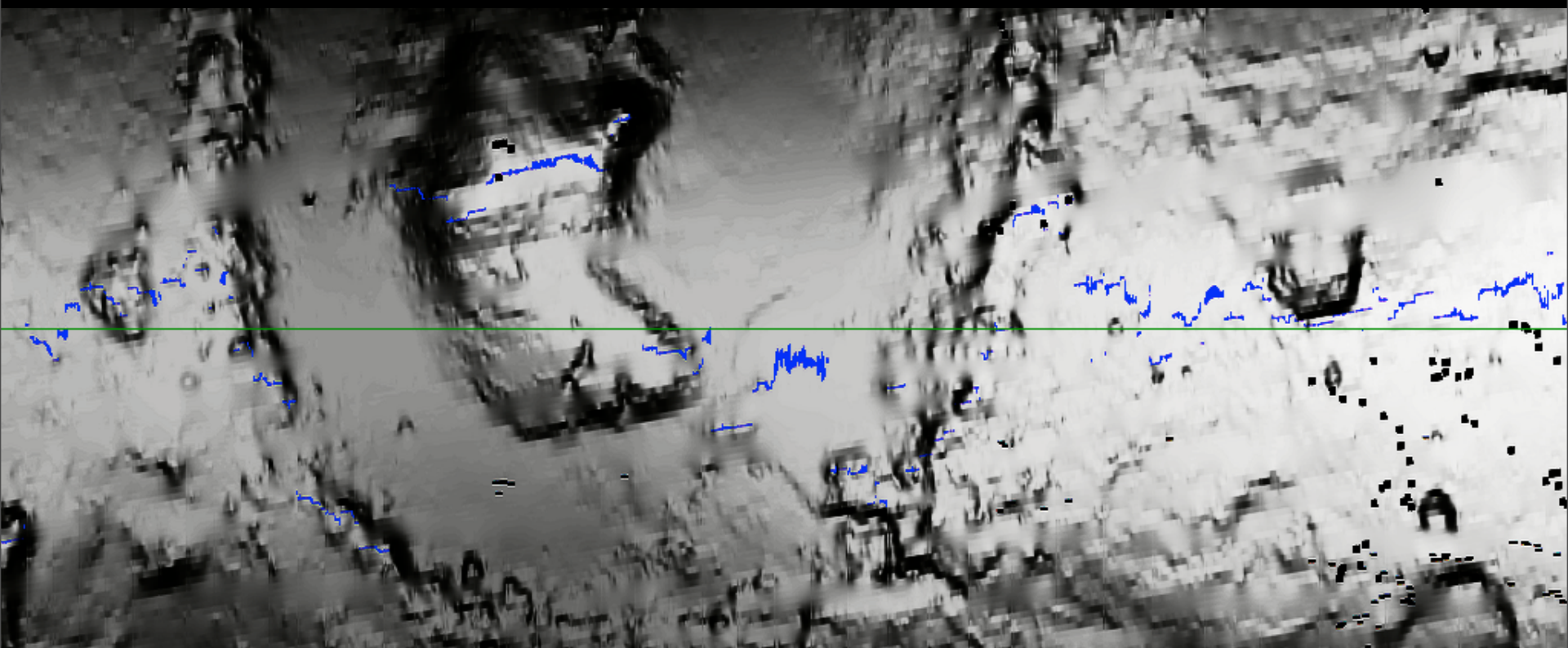
- High Resolution Stereo Camera (HRSC) on Mars Express (50 m)



Putzig et al., *JGR*, in review

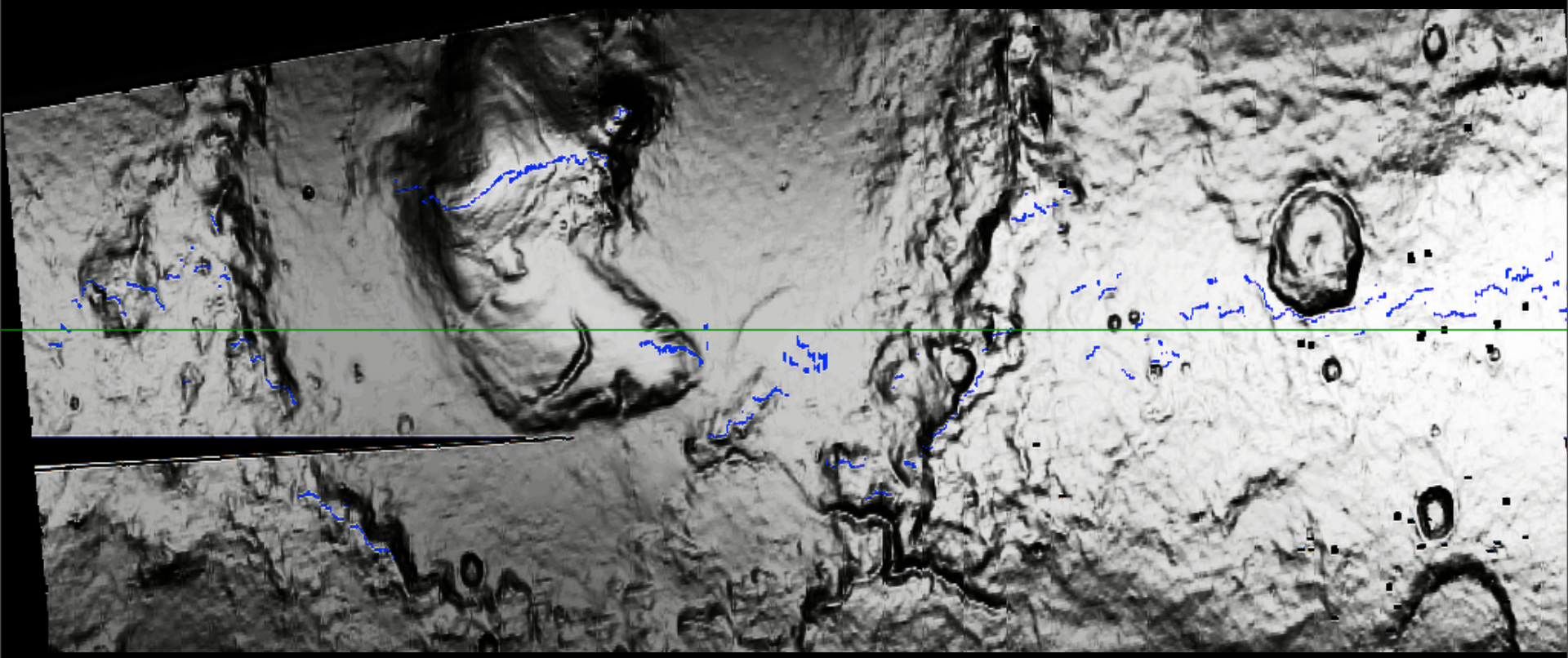
EchoPower map comparison

- MOLA (~ 300 m postings)
  - Note some problems in the gridded data which creates anomalies



EchoPower map comparison

- HRSC (~ 50 m postings)
  - Shows much more detail, potential clutter sources



In Conclusion

- Deterministic clutter can be mostly predicted with MOLA even though its horizontal resolution is >> radar wavelength.
  - More a question of the scale of features being investigated.
- Visualization of potential clutter sources can be very useful.
  - Simulated surface echo maps can help visualize clutter sources.
- Even minor surface slopes can significantly shift the location of echoes from the nadir point for orbital sounding.
  - Needs to be accounted for when reconstructing detailed subsurface layer geometry
    - *See Christian et al., Icarus, 2013.*

Availability of Clutter Sims

- Clutter sims were not part of the original SHARAD data release plan.
- Preparing to augment FPB data release on PDS with clutter sims.
  - Different versions needed for FPB, QDA/FPA, SHOC
    - *Different reference (spheroid vs aeroid) and sampling rates*
- In the meantime, they are available from UTIG on request
  - Email me for more info: jack@ig.utexas.edu
- HRSC-based clutter sims are not a "standard" product but can also be made on request fairly easily, especially if you identify the DTM.
- Echo migrations require additional work but also possible.

Acknowledgements

- NASA funding for initial clutter analysis technique development
  - Mars Fundamental Research Program
- Student participation
  - Prateek Choudhary, Sarah Christian, Charles Brothers, Jesse Berney, Enrica Quartini
- SHARAD instrument team, MRO Project (JPL)

References

Christian, S., J.W. Holt, S. Byrne, and K. Fishbaugh, Integrating radar stratigraphy with high resolution visible stratigraphy of the northern polar layered deposits, Mars, *Icarus,* 226 (2), 1241-1251, doi:10.1016/j.icarus.2013.07.003, 2013.

Holt, J.W., M.E. Peters, S.D. Kempf, D.L. Morse, and D.D. Blankenship, Echo Source Discrimination in Single-Pass Airborne Radar Sounding Data from the Dry Valleys, Antarctica: Implications for Orbital Sounding of Mars. *Journal of Geophysical Research,* 111, E06S24, doi:10.1029/2005JE002525, 2006.

Putzing, N.E., B. Campbell, R. Phillips, M. Mellon, *T.C. Brothers, and **J.W. Holt**, SHARAD soundings and surface roughness at past, present, and proposed landing sites on Mars: Reflections at Phoenix may be attributable to deep ground ice, *Journal of Geophysical Research*, in review.