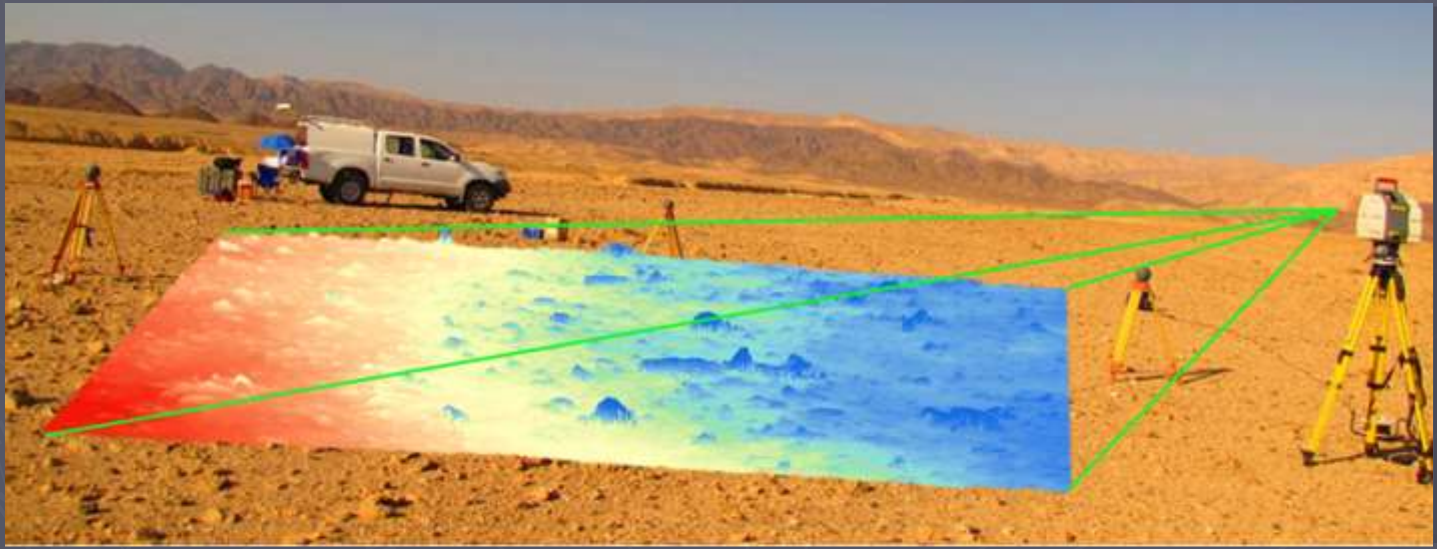
Mapping sub-pixel surface roughness using stereo imaging

Amit Mushkin, Univ. of Washington, Geological Survey of Israel

- Why look at surface roughness
- Mapping unresolved roughness from space (Earth, Mars)



Acknowledgements
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Lee Balick

Roughness –

- Scale-dependent property

- The unresolved topographic expression of the surface → below the resolution of available DEMs

Why look at roughness –

Measurable property of terrestrial surfaces that can offer quantitative insights into:

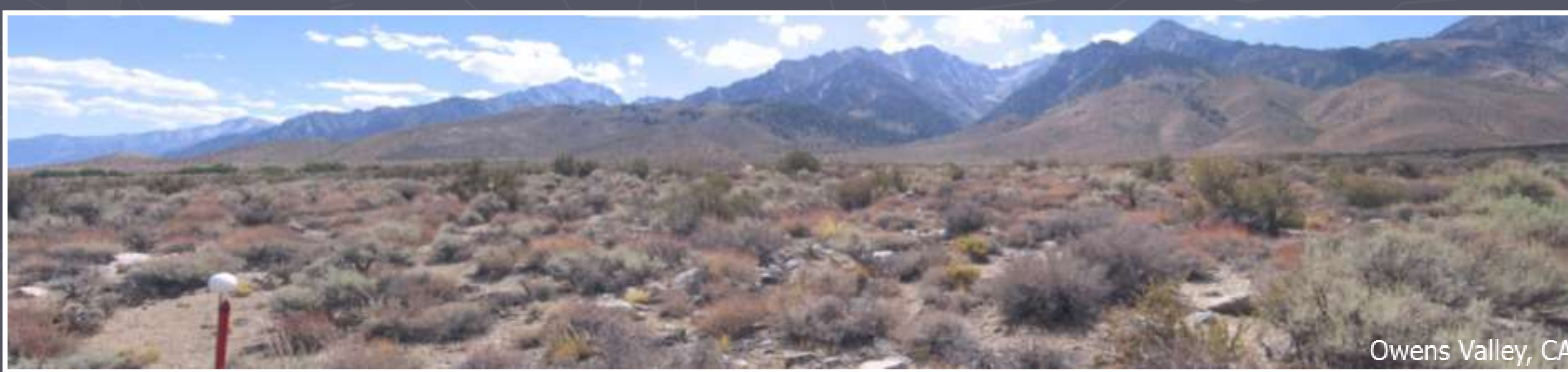
→ *Surface processes (deposition / weathering) and change*

→ *Surface age*

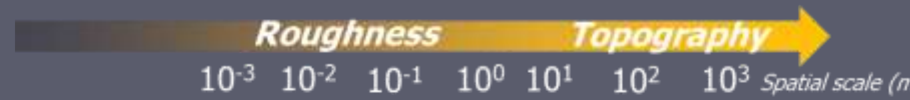
→ *Vegetation abundance and state*

→ *Landing hazards & trafficability (Mars)*

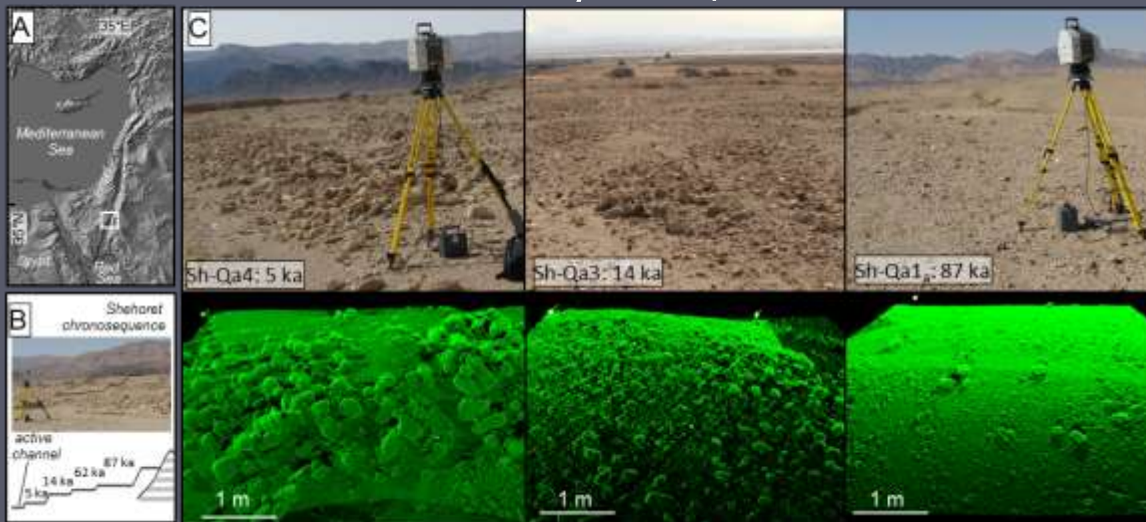
→ *Key variable in quantitative inversions of remote sensing measurements from land surfaces →VNIR, SWIR, TIR and Radar*

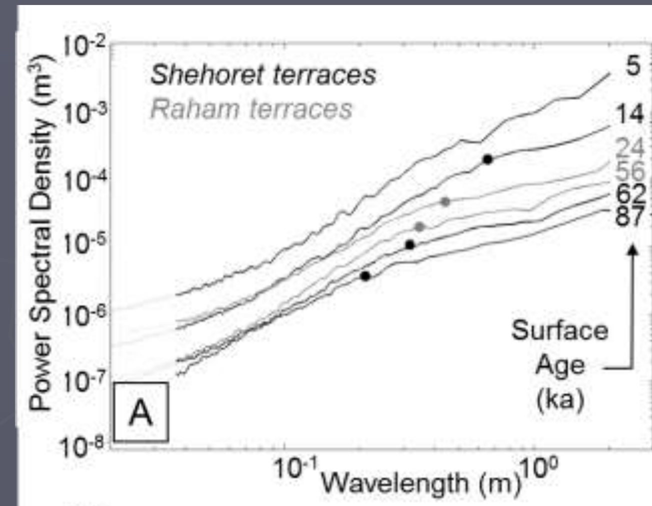


Roughness for weathering



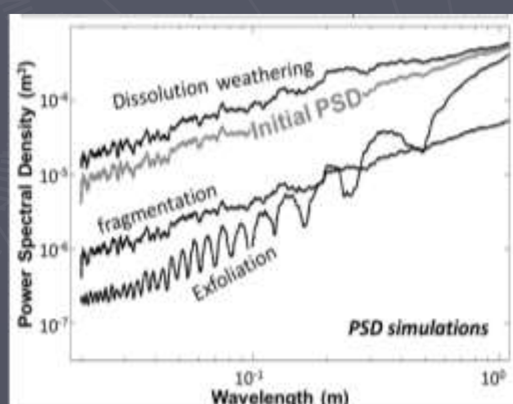
Shehoret alluvial chronosequence, southern Israel



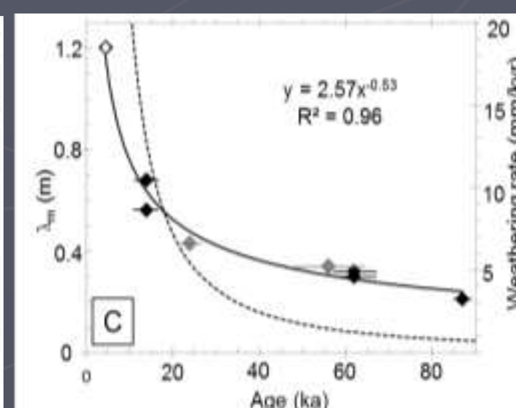


Systematic roughness evolution with time

Process



Rates

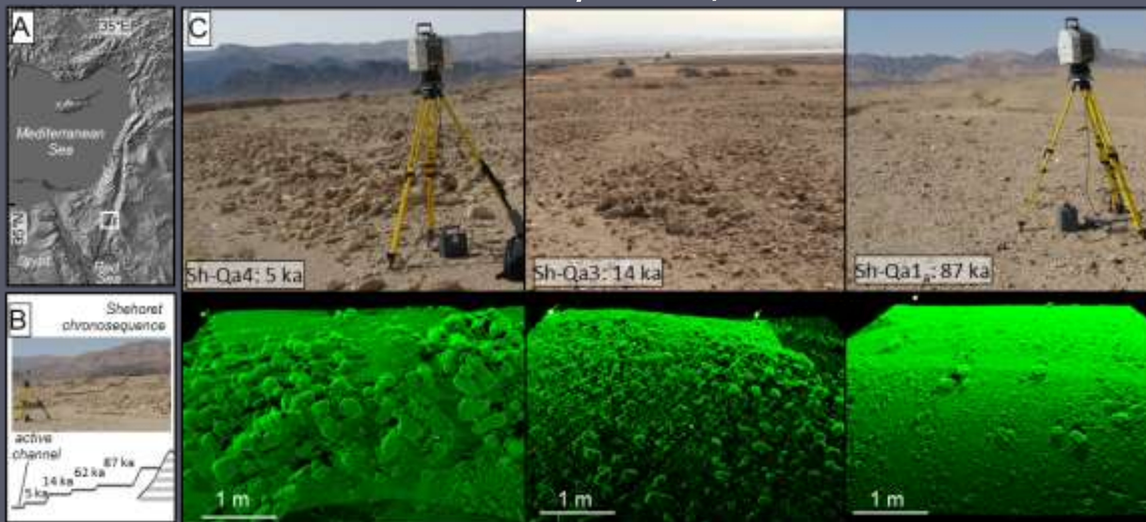


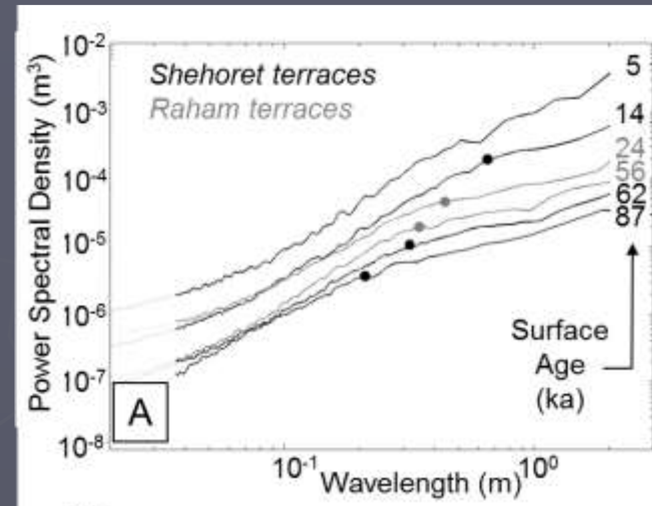
- Rock fragmentation
- Scale-dependent rates
- Non-linearly decreasing rates with time

Mushkin et al., in review

Roughness as a calibrates age proxy

Shehoret alluvial chronosequence, southern Israel

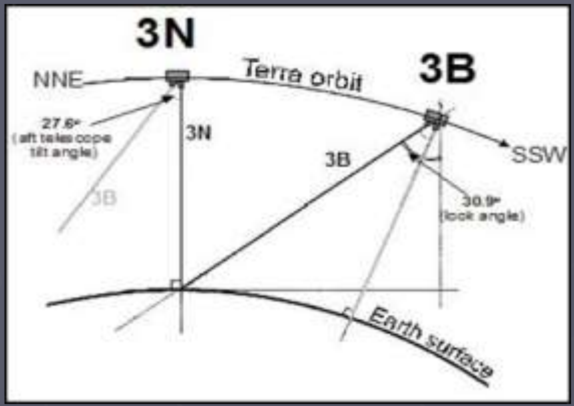




Systematic roughness evolution with time

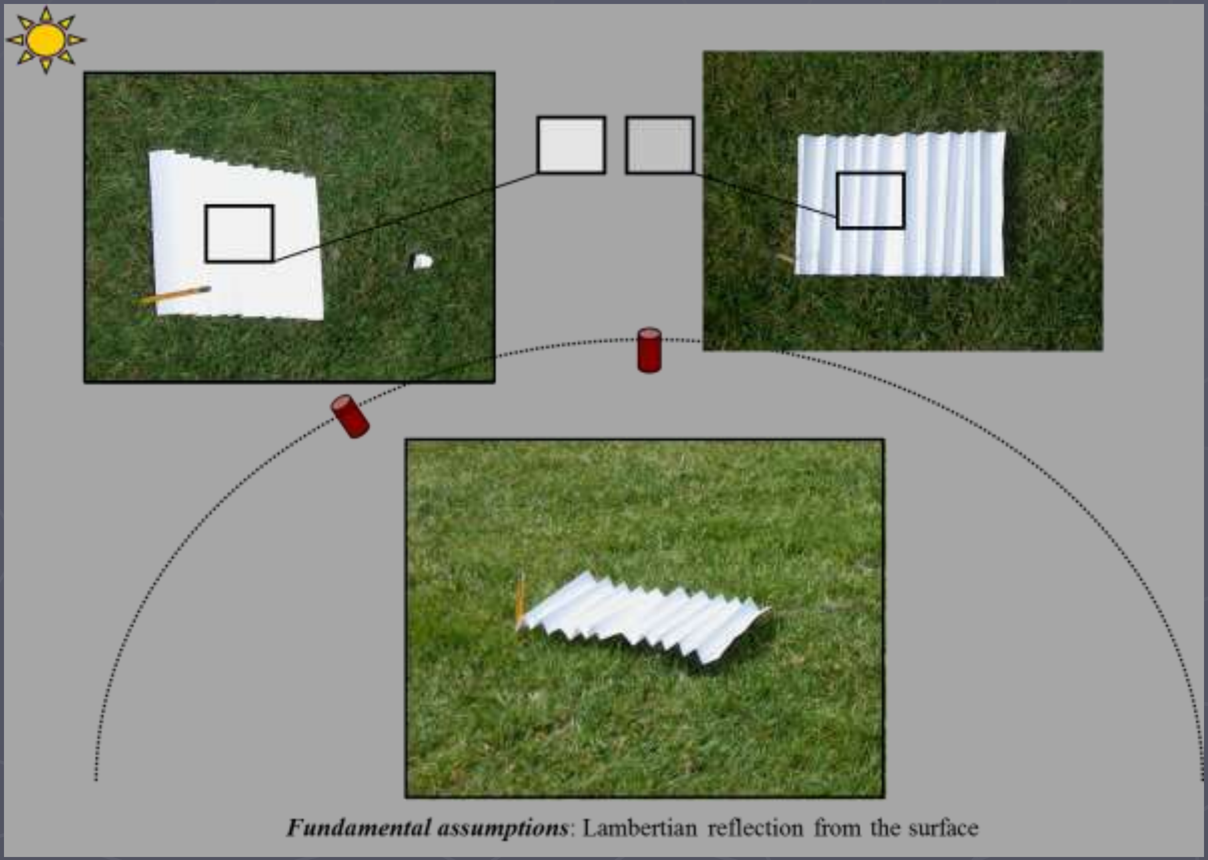
E. Trabelci, 2013 (MSc)

Sub-pixel (unresolved) roughness with ASTER stereo images



ASTER stereo imaging configuration (15 m/pixel) → 30 m/pixel DEMs

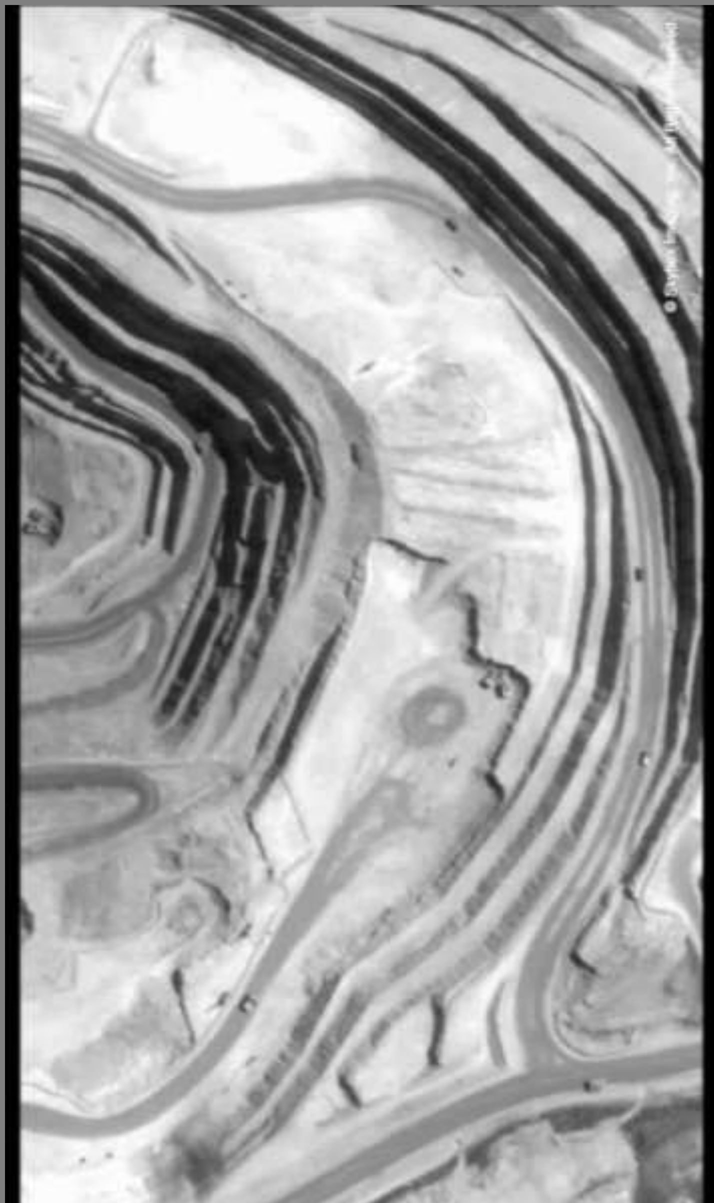
The difference between radiances at two view-angles (or illumination angles) can be used as a proxy for surface roughness

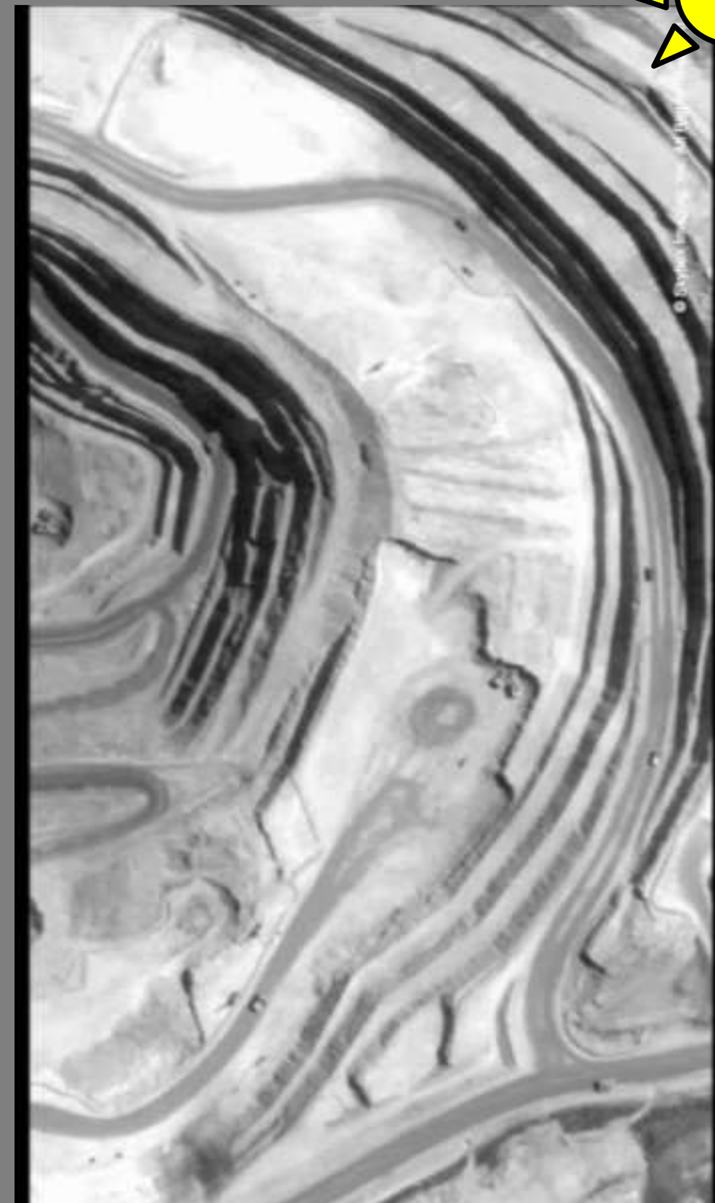


3B/3N provides a measure for the amount of unresolved sub-pixel shadowing on the surface

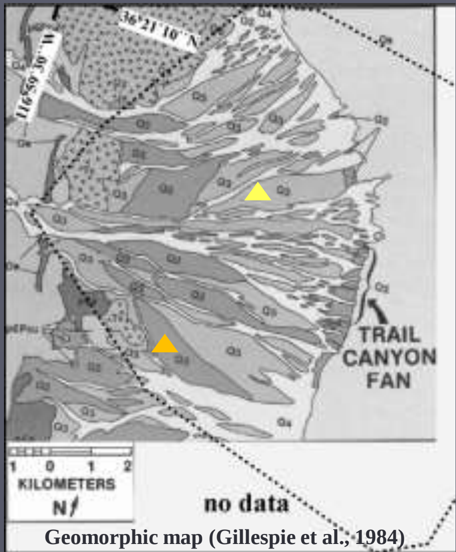
Mushkin & Gillespie, 2005; 2010

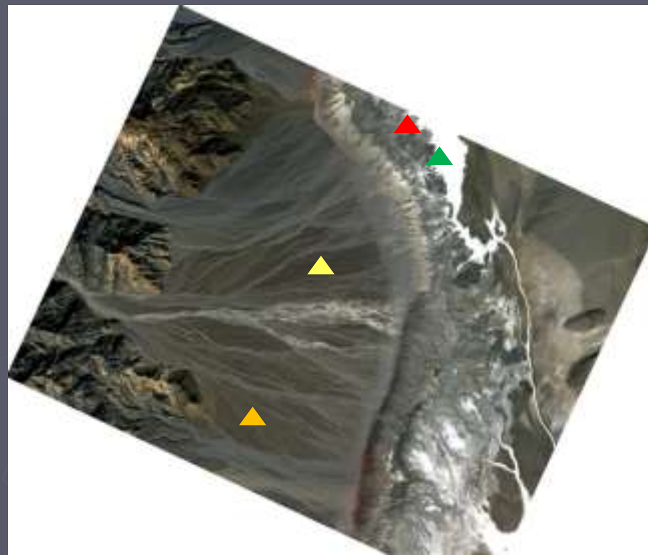
Skybox – Usak, Turkey

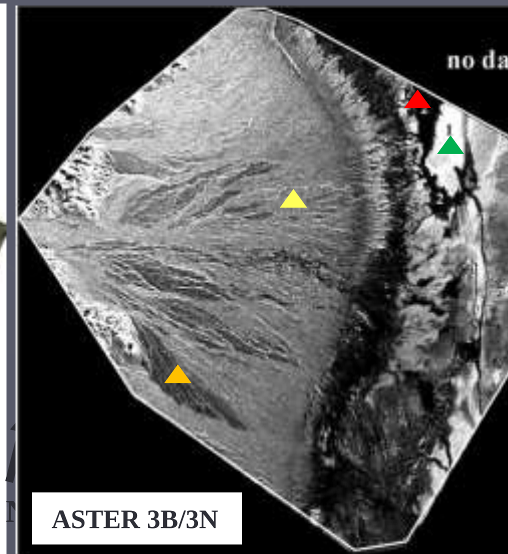


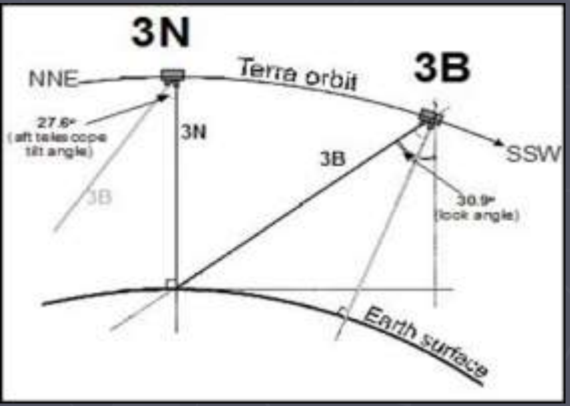


Death Valley Trail Canyon fan:

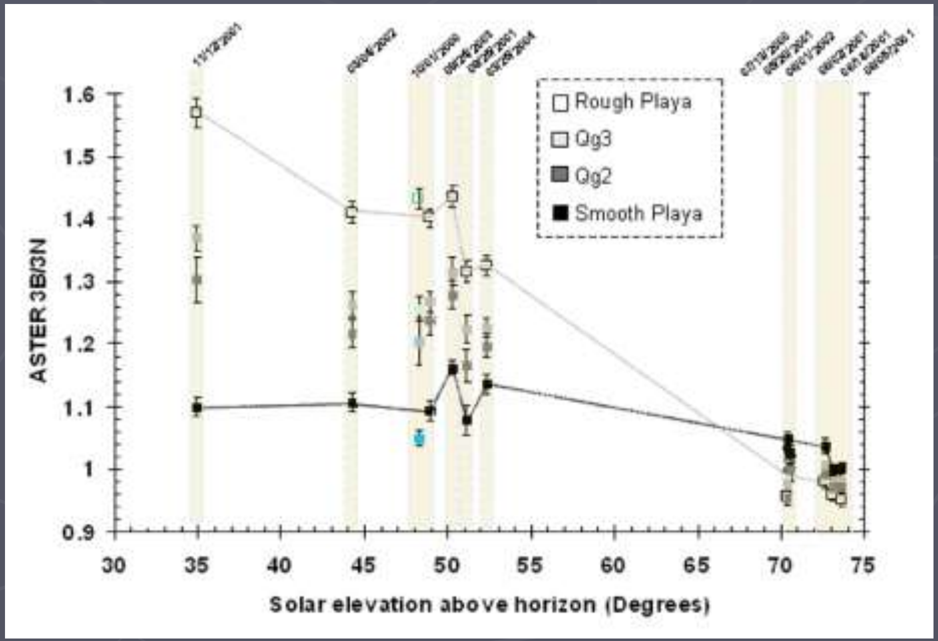








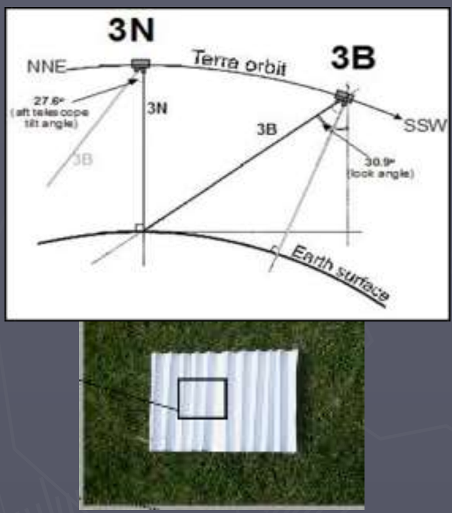
Unresolved roughness variations on the fan surfaces, and in the playa deposits are clearly identified with the 3B/3N ratio

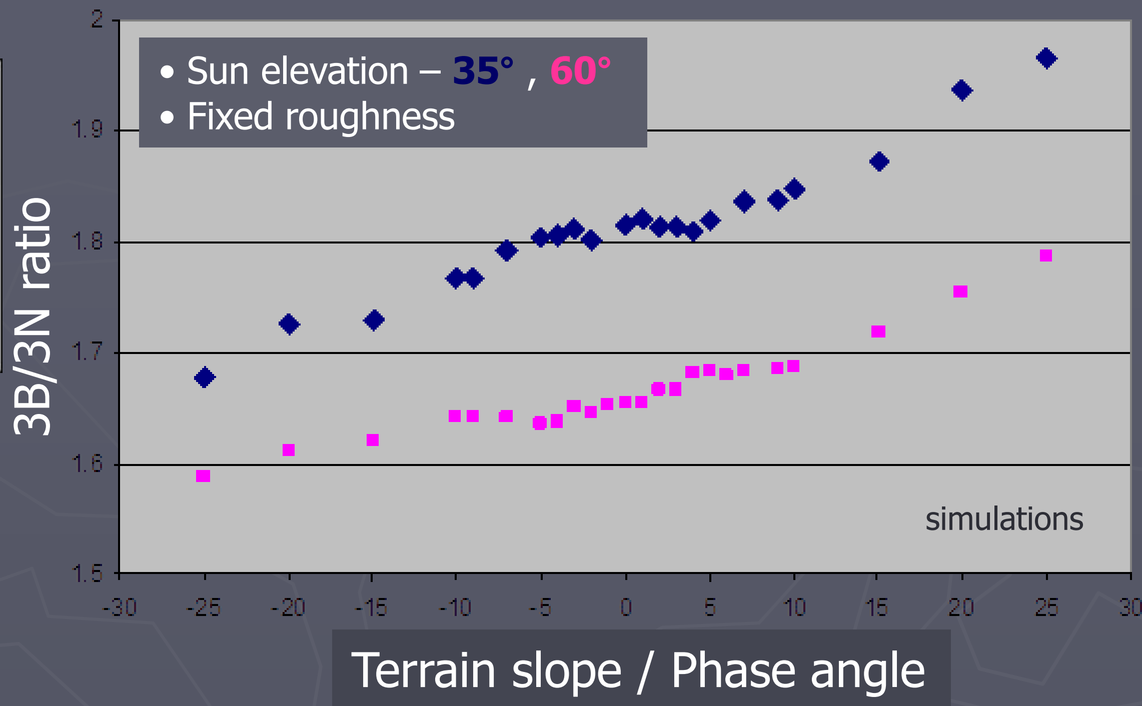


Sensitivity to solar elevation

Mushkin & Gillespie, 2005; 2010

Slope effects on 3B/3N ratios

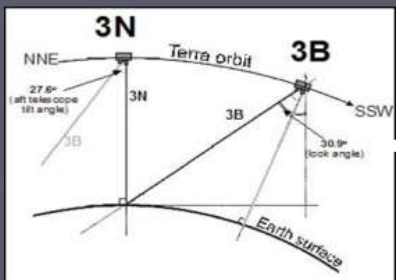


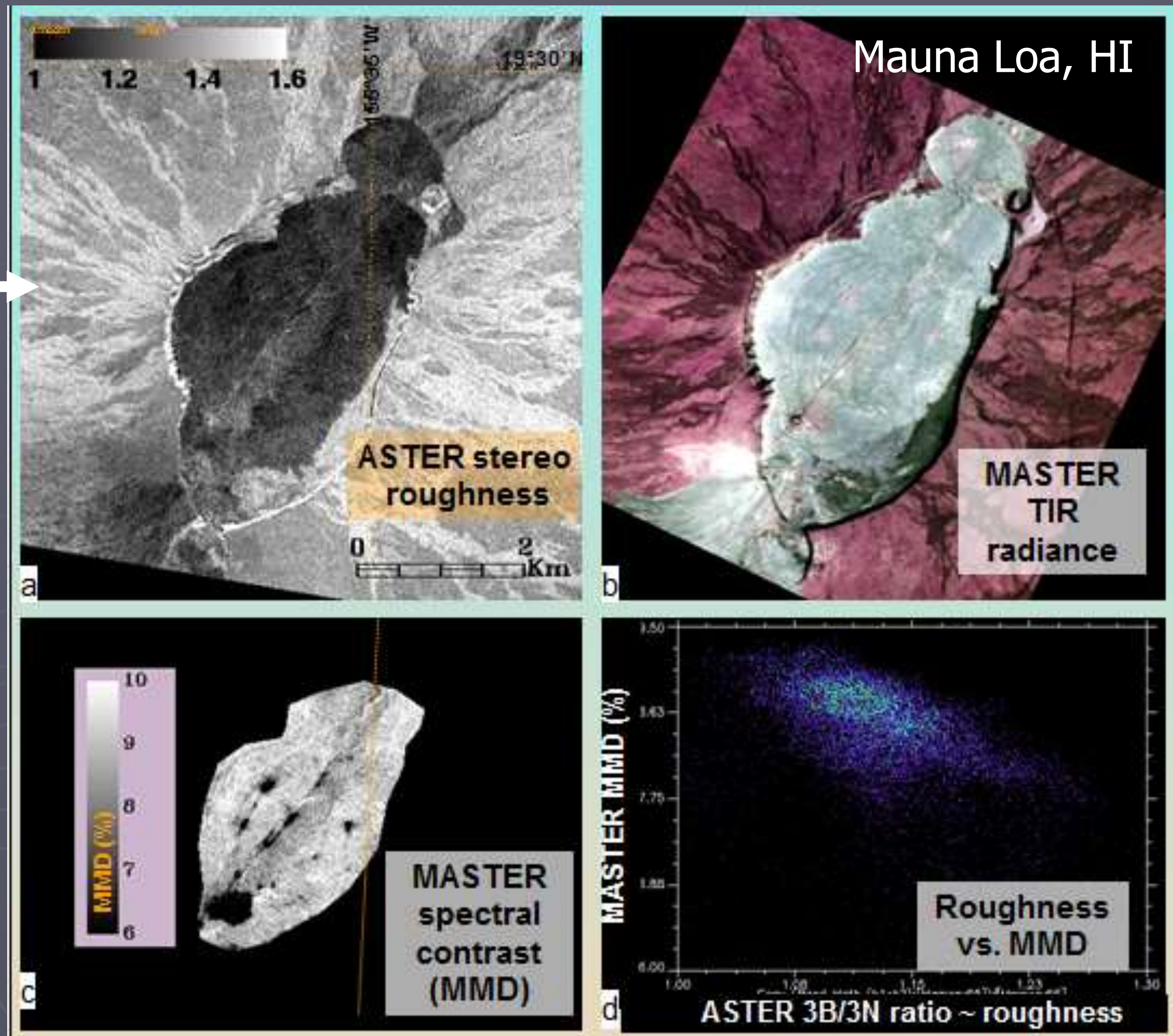


→ "Handshake" between DEM and sub-pixel roughness estimates

→ Advantage for multi-angle data – improved characterization of unresolved roughness elements

Compensating for roughness effects in the thermal infrared





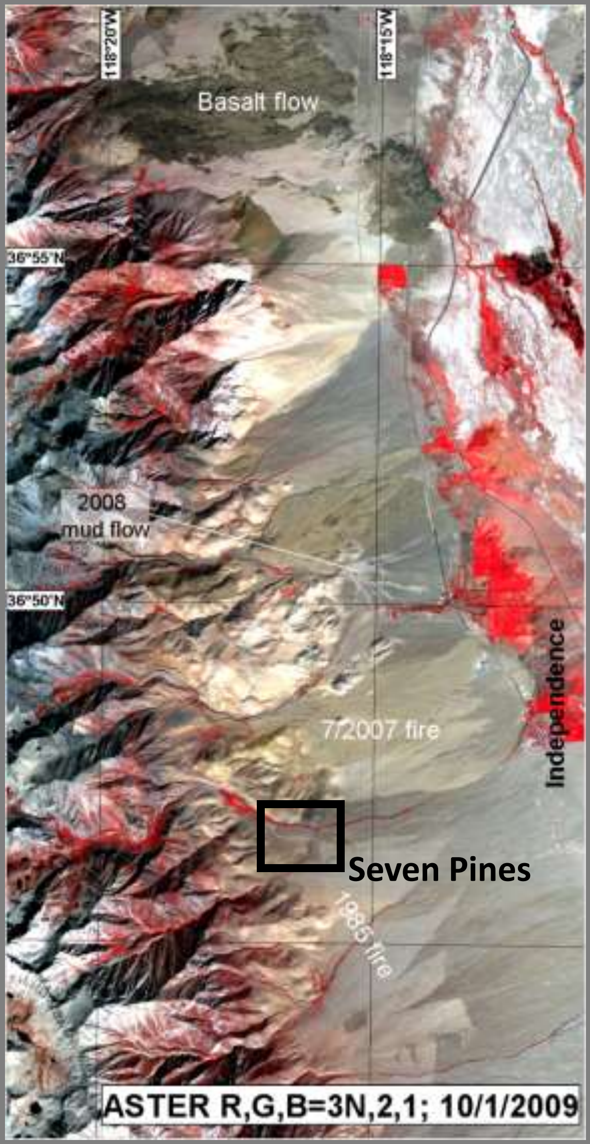
Mushkin et al., 2007

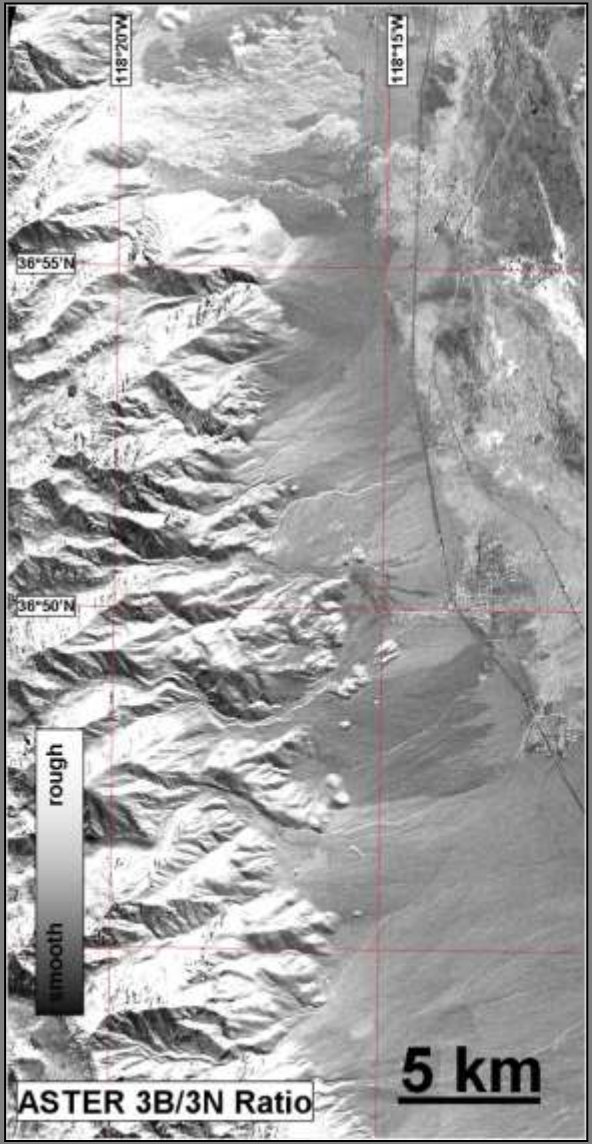
Owens Valley desert vegetation mapping

• Fire scars provide sharp, well defined transitions between different vegetation % coverage

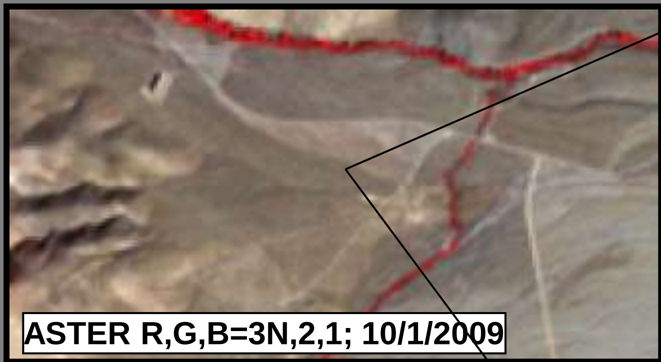
• Common geologic substrate

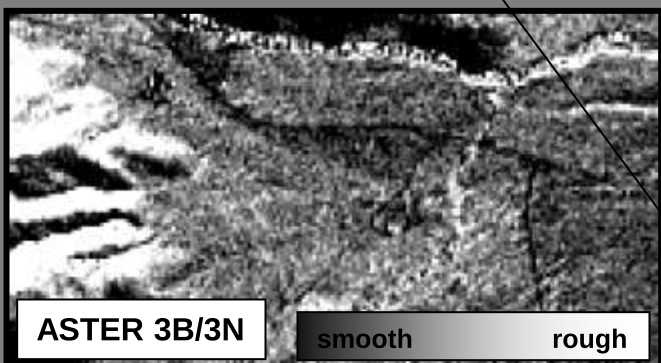
• Wide range of % vegetation coverage –
  - dirt roads ~ 0%
  - fans ~ 15-50%
  - creeks ~ 80-90%

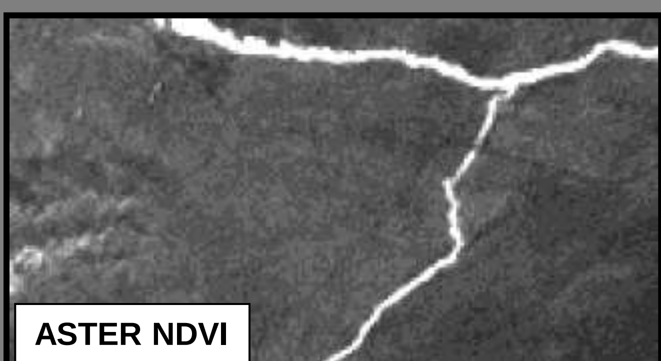


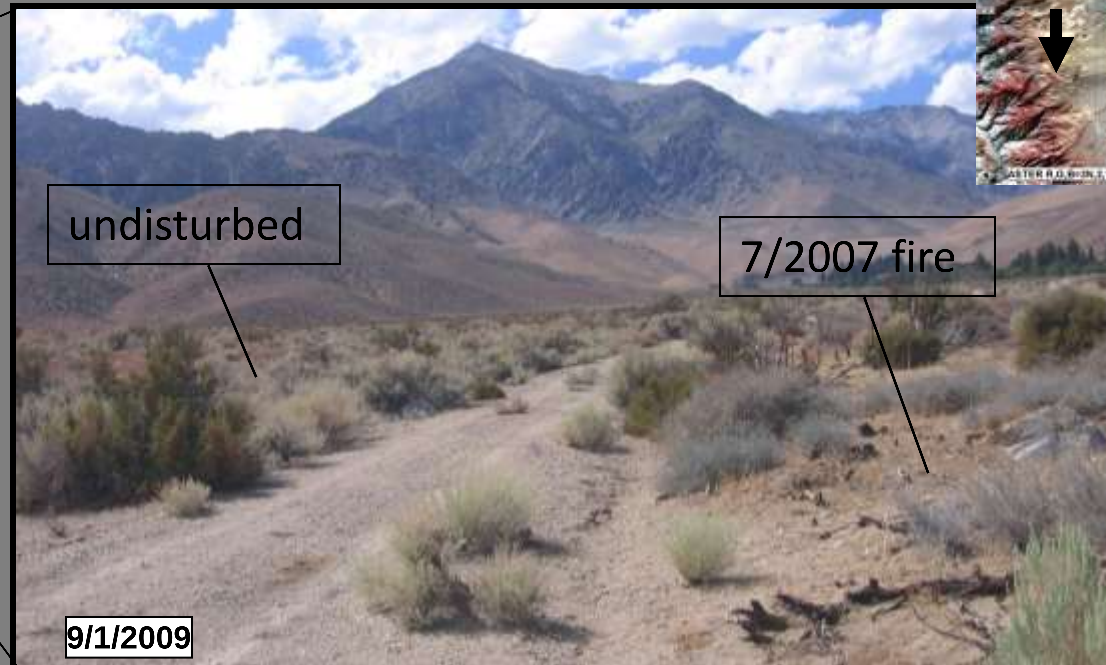


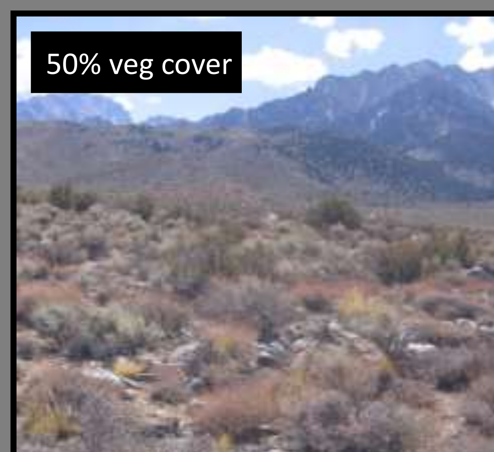
Seven Pines


ASTER R,G,B=3N,2,1; 10/1/2009


ASTER 3B/3N
smooth
rough

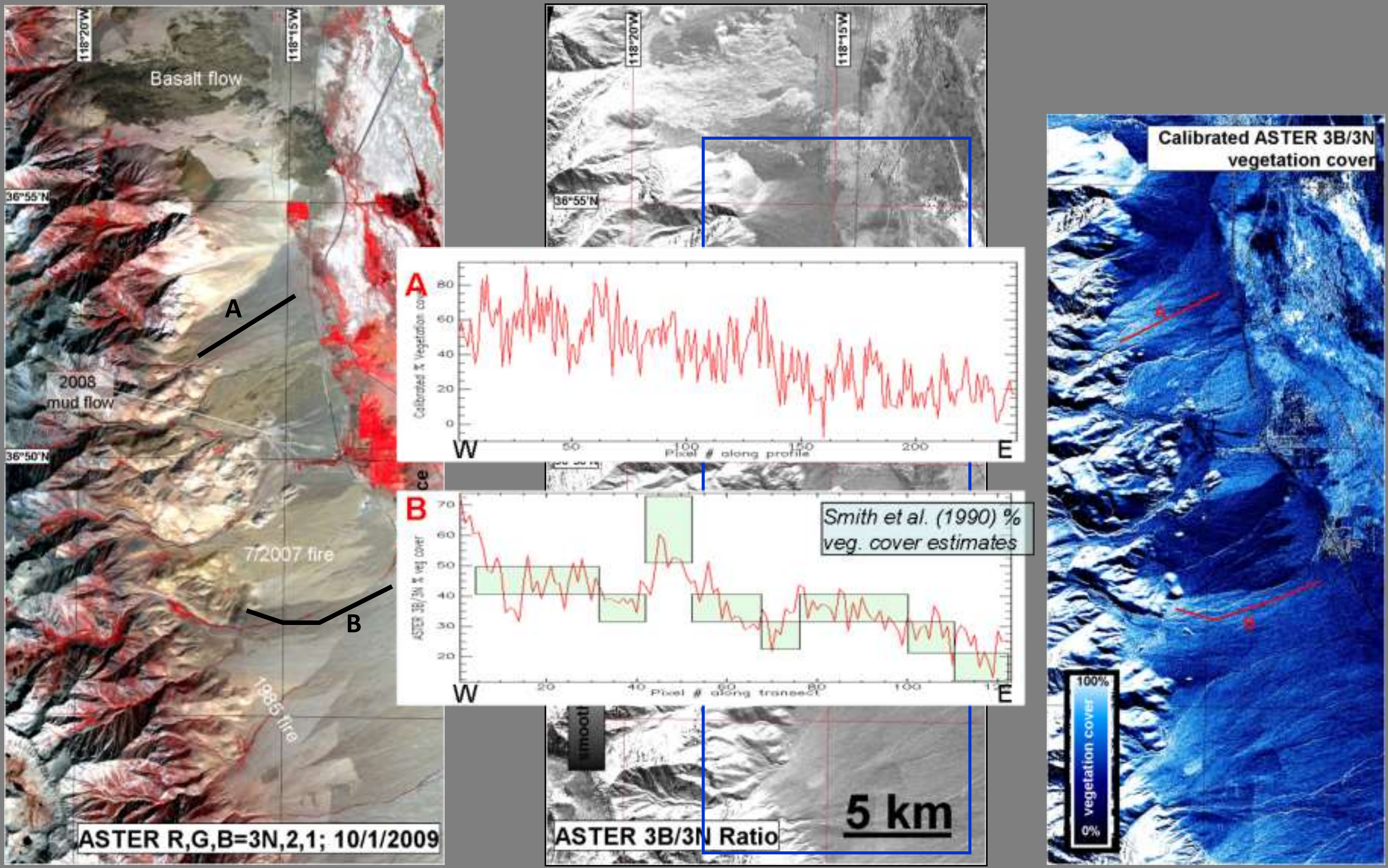

ASTER NDVI


undisturbed
7/2007 fire
9/1/2009


50% veg cover

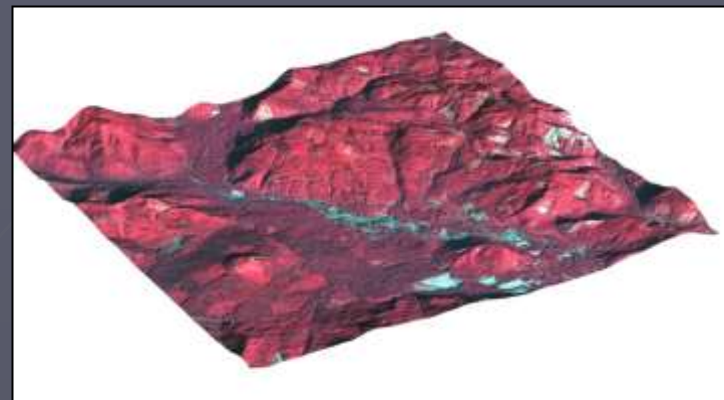

35% veg cover

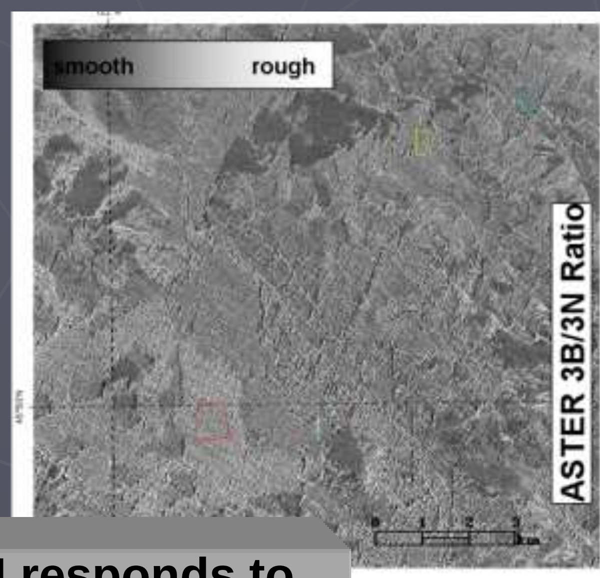
calibrated ASTER 3B/3N vegetation cover map

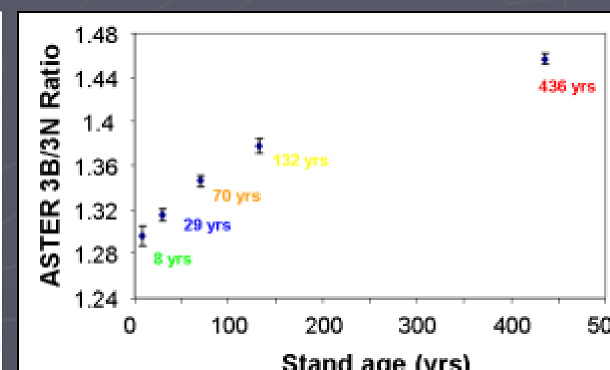


ASTER 3B/3N over Pacific NW forests

Gifford Pinchot Natl’ Forest, WA



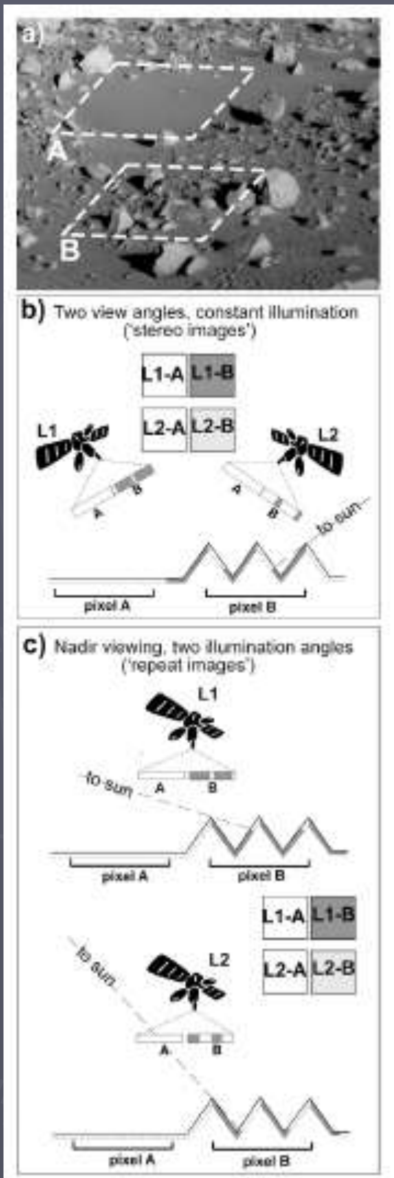




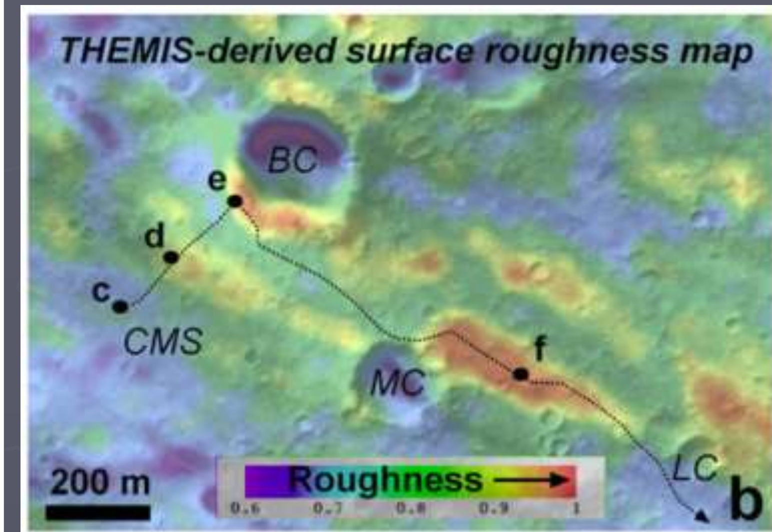
Stand ages (Roberts et al. 2004) vs. ASTER 3B/3N ratios from the images shown below. Stand ages are colored according to ROI outlines on the left

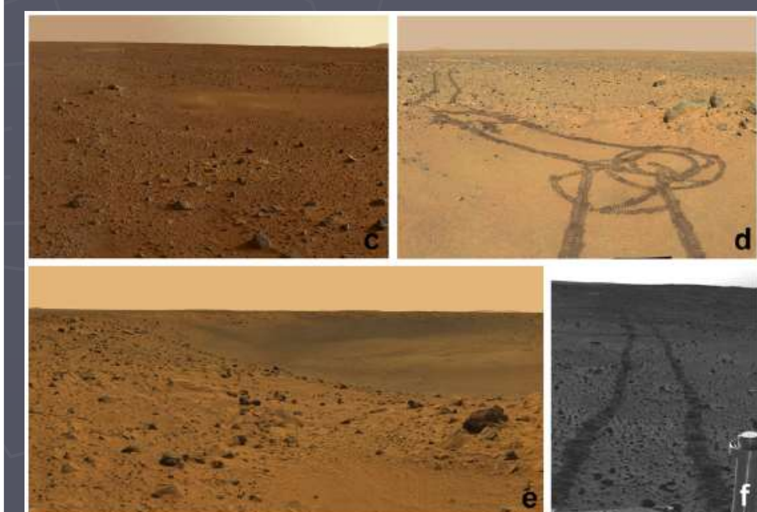
ASTER 3B/3N responds to structural stage / stand age

Unresolved roughness on Mars with stereo/repeat satellite imaging



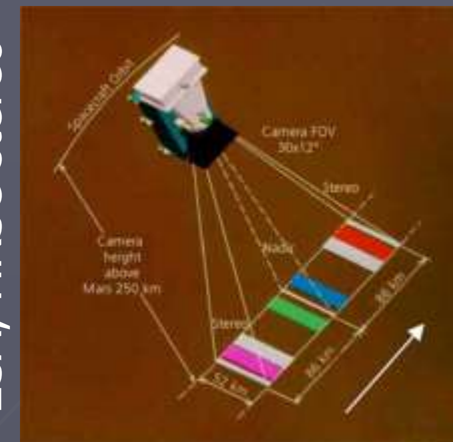
Roughness at Gusev crater

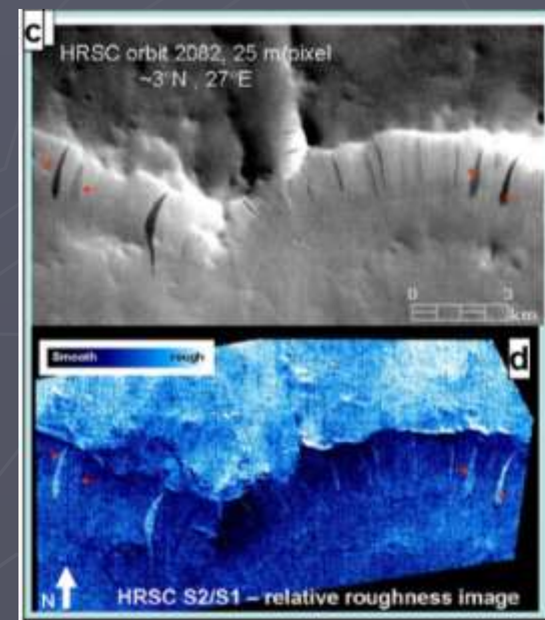




Active surface processes

ESA, HRSC stereo

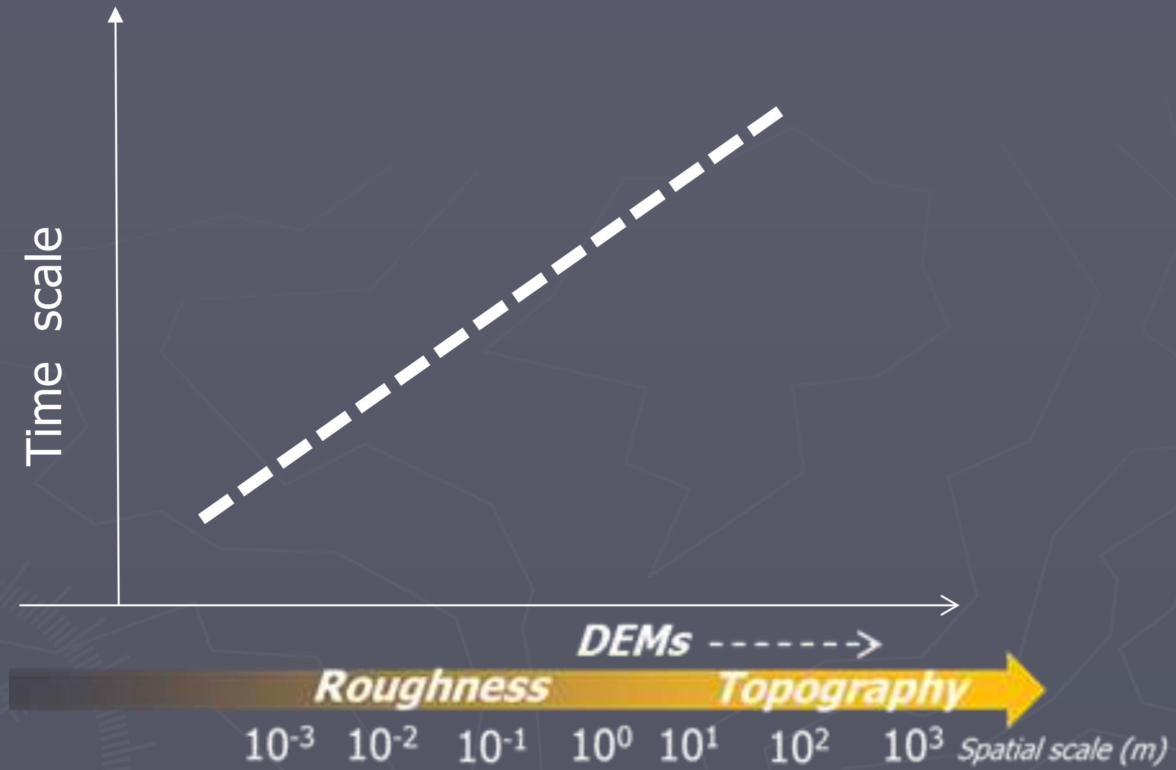




Mushkin & Gillespie, 2006, Arvidson et al., 2007

Mushkin et al., 2010

Surface processes - change detection



Surface changes at shorter length scales (e.g., roughness) are more likely to be amiable to change detection within limited observation time-windows.

Summary -

- ❑ Staring observations will be affected by sub-pixel surface roughness and associated unresolved shadows.

- ❑ Multi-angle observations provide "access" to sub-pixel surface roughness that is below the resolution of the image-derived DEM → Topography (resolved by DEMs) and sub-pixel roughness measurements complement each other in providing a more "complete" description of land surfaces

- ❑ The 'science' to be obtained from roughness measurements-
  - Surface processes on Earth and Mars (aeolian, deposition, weathering)
  - Surface age
  - Vegetation mapping
  - Change detection
  - Landing / trafficability

- ❑ The advantages of a 'staring' system for roughness measurements-
  - Low sun elevation
  - Improved constraints on the characteristics of sub-pixel roughness elements