Using sub-pixel roughness estimates from ASTER stereo images to compensate for roughness effects in the thermal infrared

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Outline:

- ***Background*** *– roughness effects on TIR data*
  - ***Approach*** *– remote roughness estimates + radiosity model → compensate TIR data for roughness effects*
    - ***Results***

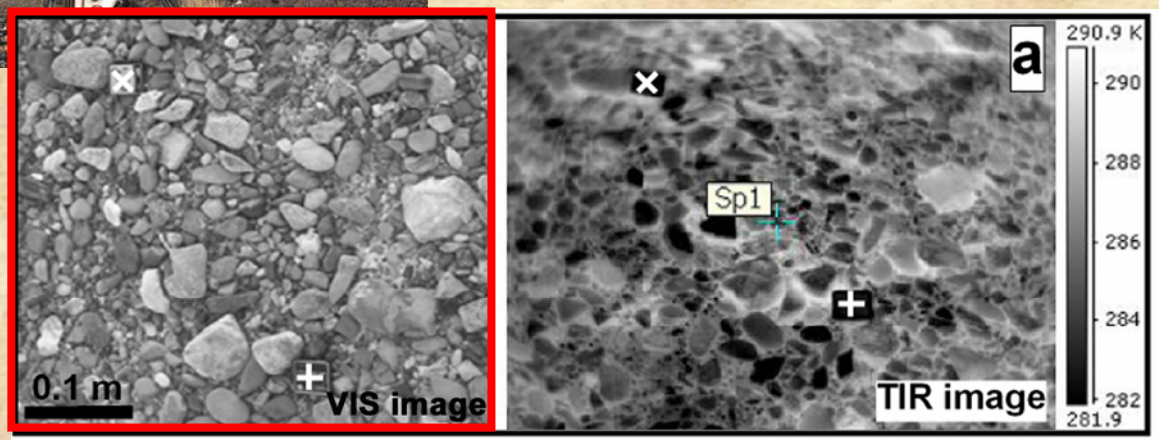
      -Remote roughness estimations (ASTER)

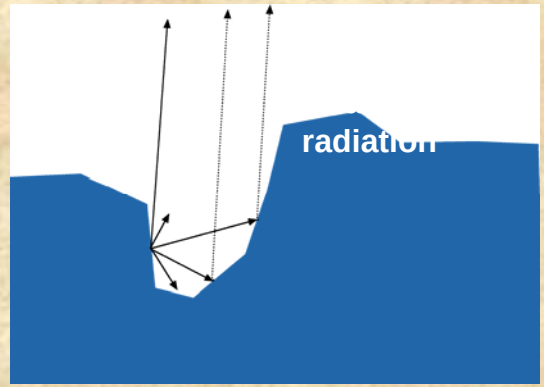
      - Basis for compensating ASTER TES emissivity retrievals

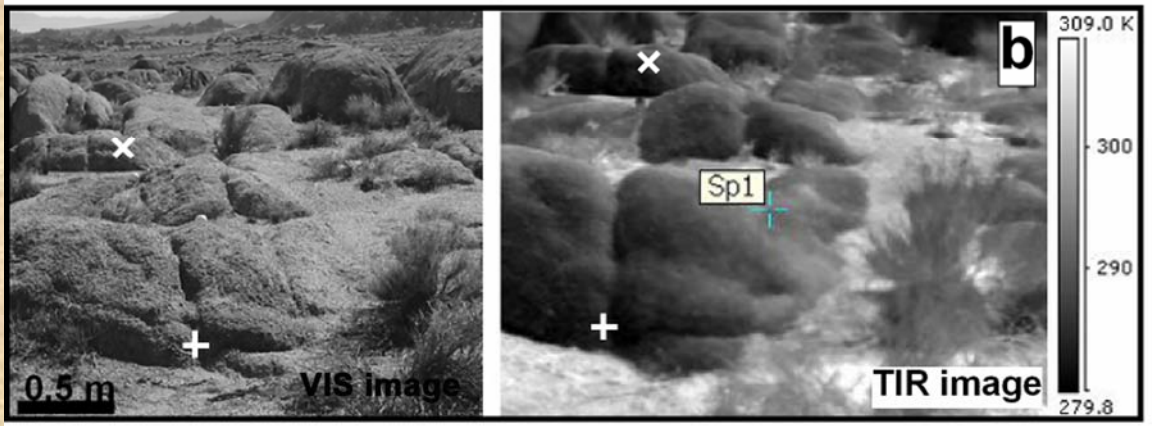
      - ***Summary & conclusions***

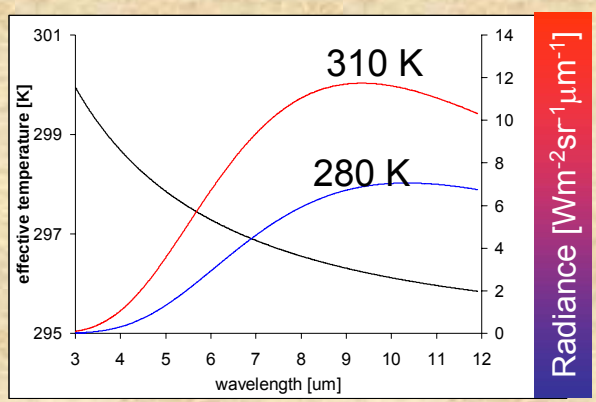
Background:

Cavity radiation & shadowing





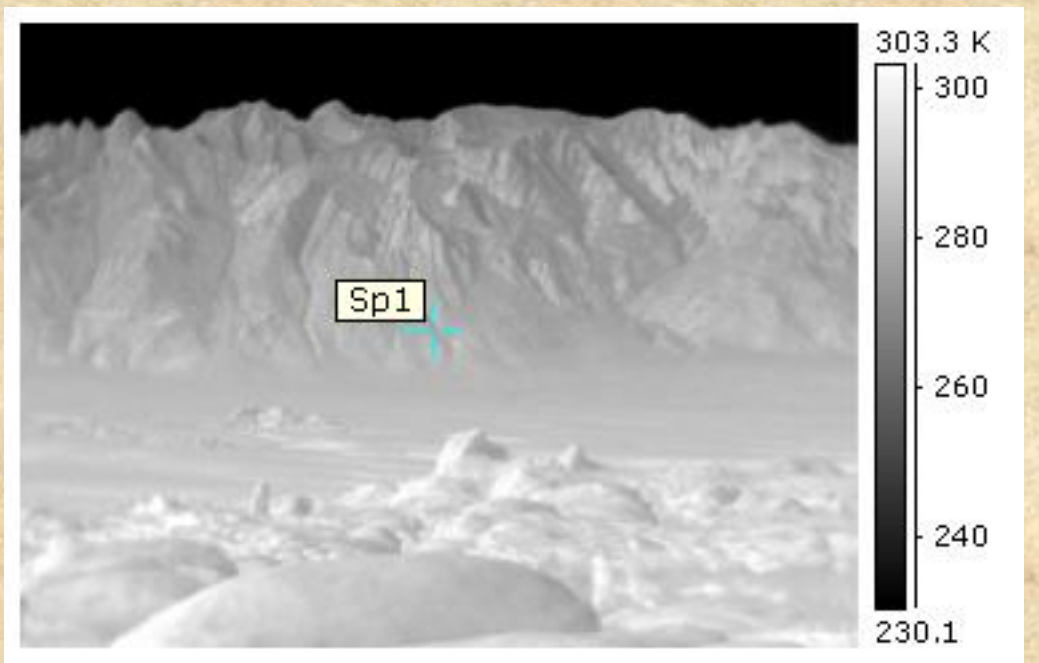




The problem:

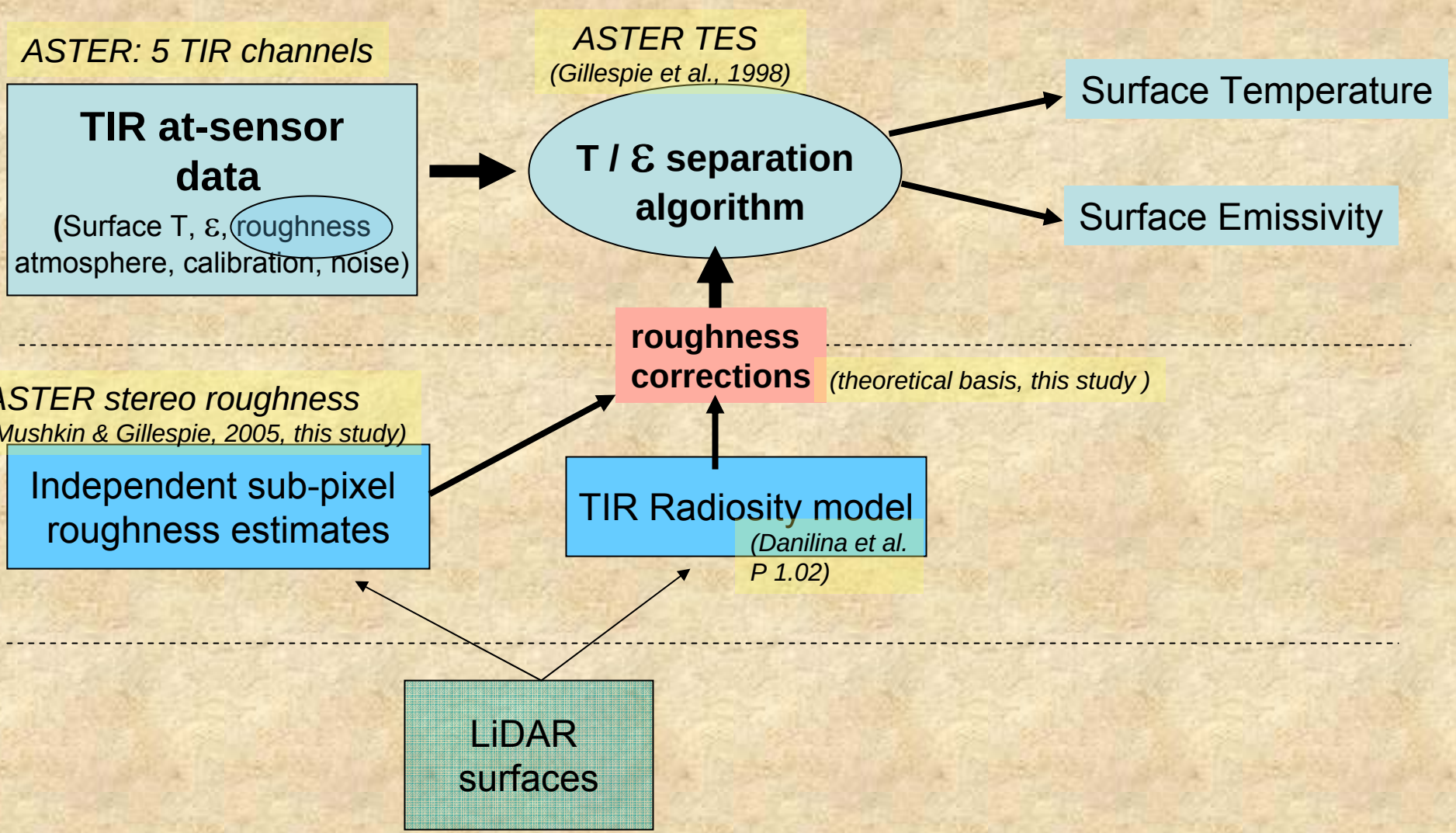
- The effects of DEM-scale topography (i.e., at the supra-pixel scale) on remote TIR measurements can be compensated using radiosity models.

- However, compensation for sub-pixel roughness effects requires quantification of the topographic expression of the surface at sub-pixel scale, i.e., surface roughness.



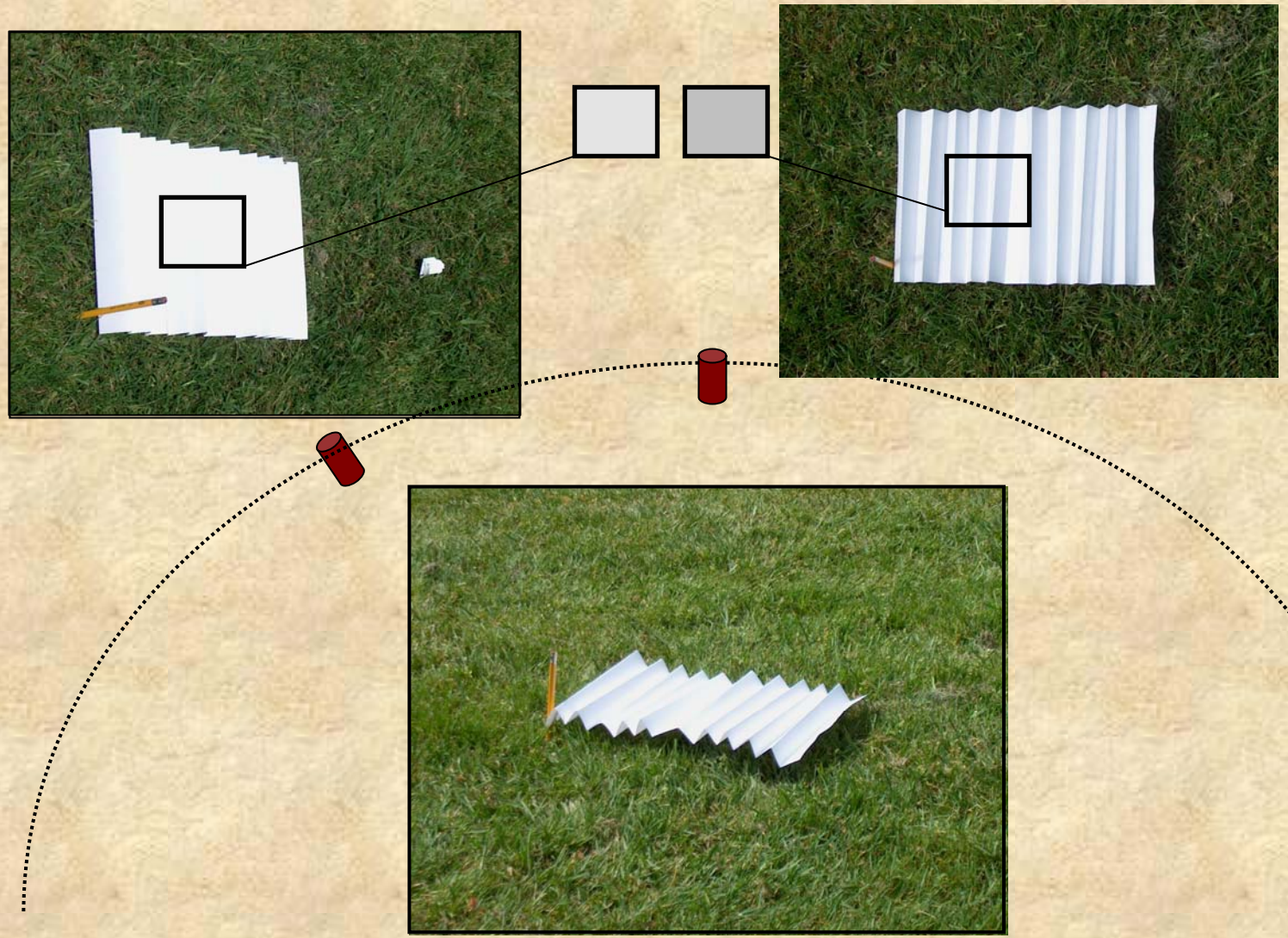
Approach:

Conceptual Flow diagram



The 'two look' approach:

The difference between measured radiances at two view-angles can be used as a proxy for surface roughness



Fundamental assumption: Lambertian reflection from the surface

ASTER data:

NASA's Advanced Spaceborne Thermal Emission Radiometer (ASTER):

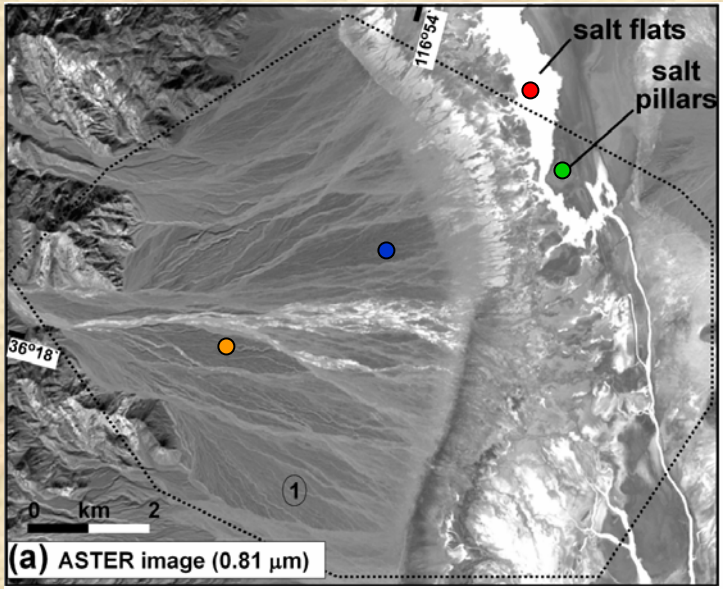
4 VNIR bands between 0.56-0.81 μm, 15 m resolution

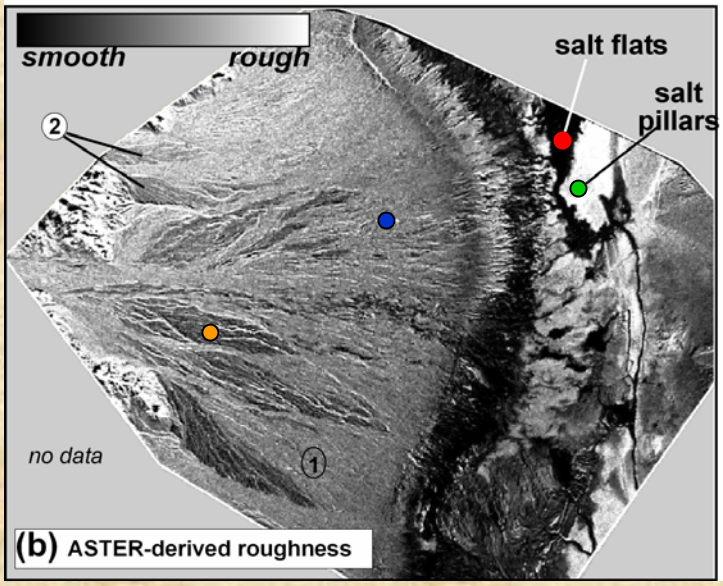
6 SWIR bands between 1.65-2.45 μm, 30 m resolution

5 TIR bands between 8.10-11.5 μm, 90 m resolution

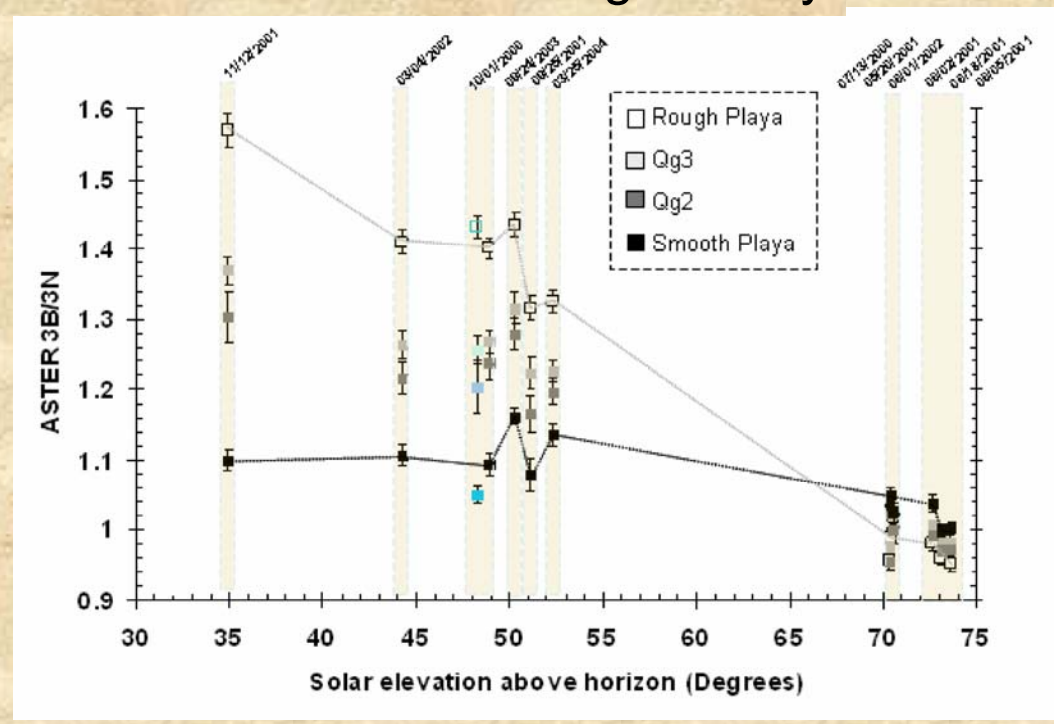
- **Stereoscopic imaging** at ~ 0.807μm (band 3)
  - viewing at nadir (3N) and 27.6^{o} backwards from nadir (3B)
    - 15m spatial resolution
      - ~65km footprint
      - 30-m resolution DEM (standard product)

ASTER stereo roughness:





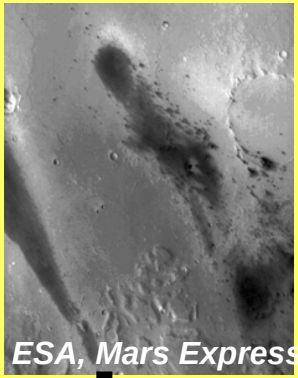
- ASTER 3B/3N ratio as a proxy for ***relative*** surface roughness (*Mushkin & Gillespie, 2005 ;RSE*)
- Independent of albedo/composition, and typical atmospheric conditions ($S^{\uparrow} << L_s$)
- Sensitive to illumination geometry



L_s: radiance at sensor , $S^{\uparrow}$: atm path radiance

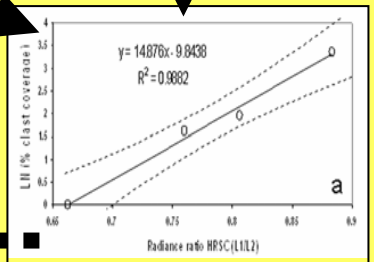
Stereo Roughness calibration:

Empirical calibration scheme: *Gusev crater*

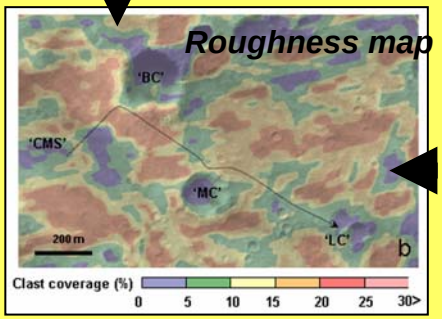


ESA, Mars Express
HRSC orbit 024

Rover ground images



Calibration curve

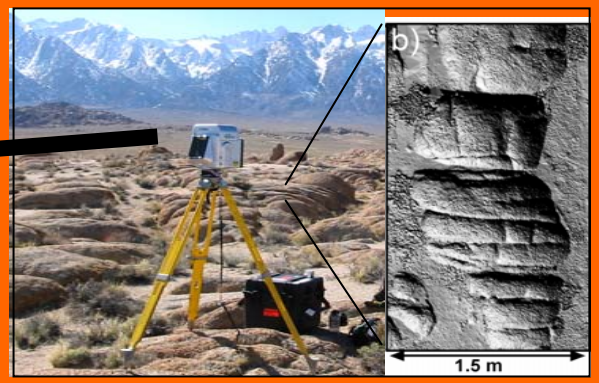


- ***Scene-specific, local calibration***
- ***problem with extrapolation to different illumination conditions***

(*Mushkin & Gillespie, in press; GRL)*

Model-based calibration scheme

Radiosity Model (vis)



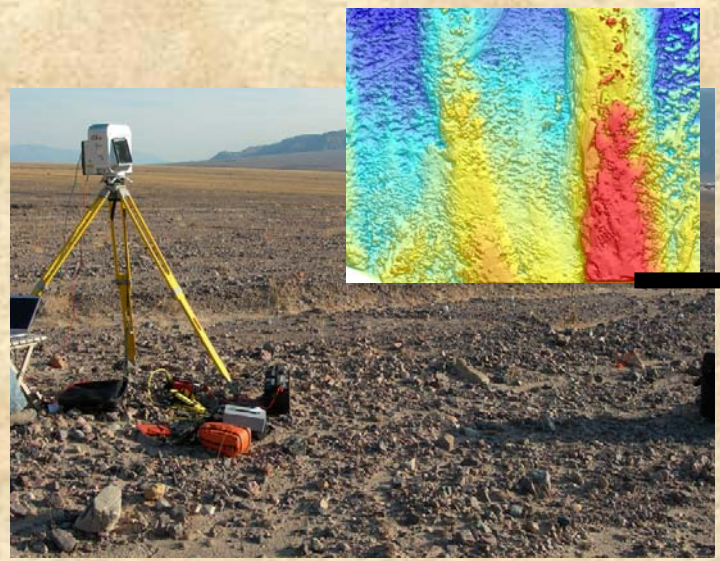
Calibration curve

ASTER Stereo data

Roughness map

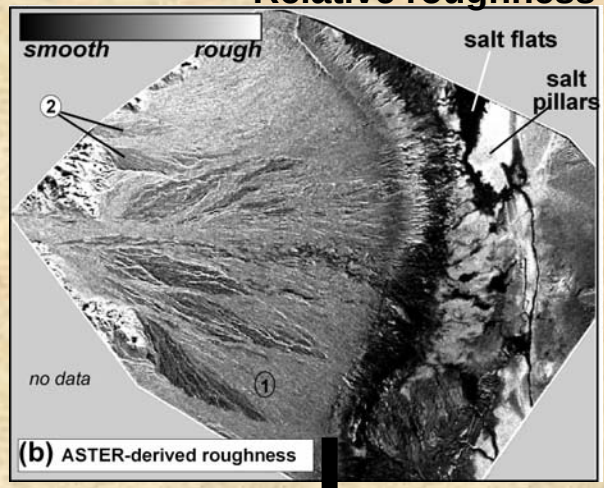
- ***illumination geometry can be adjusted in model***
- ***requires atmospheric corrections***

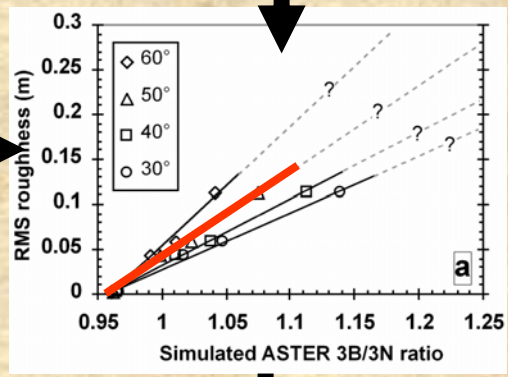
ASTER roughness calibration:



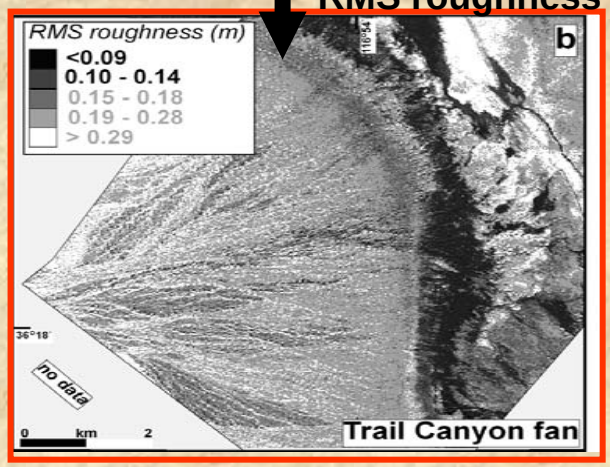
Model:
- ✓**Illumination**
- shadows
- shading
- ✓**View angles**
- sol elev
- sol azim
- orbit track
- ✓**Terrain slope** (DEM)

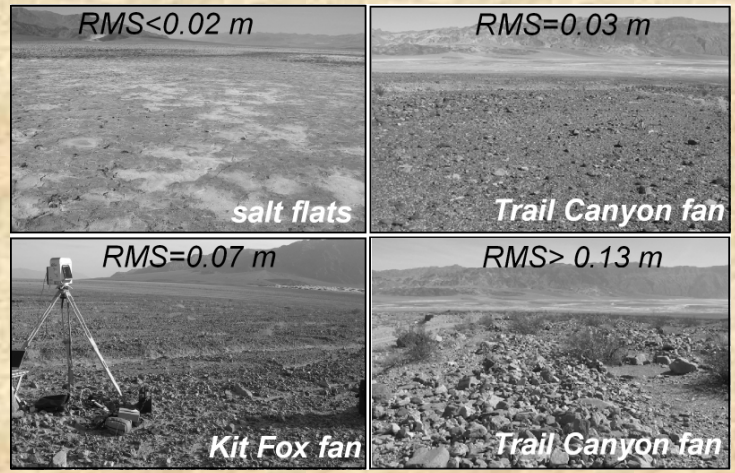
Relative roughness





RMS roughness

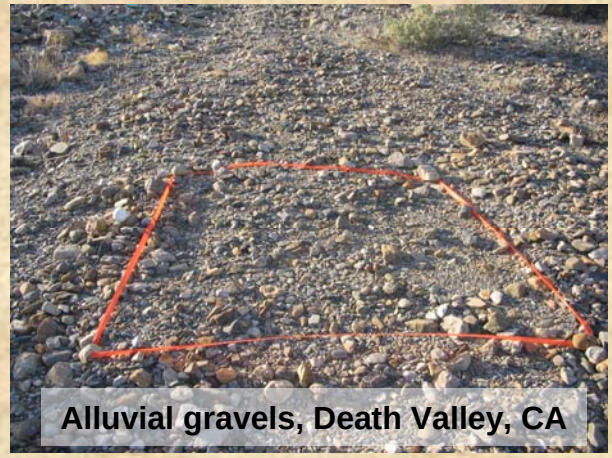




Atm. Corrections:
- ✓ **path radiance-** 'dark object subtract'
- ✓ **transmissivity-** MODTRAN (error < 2%)

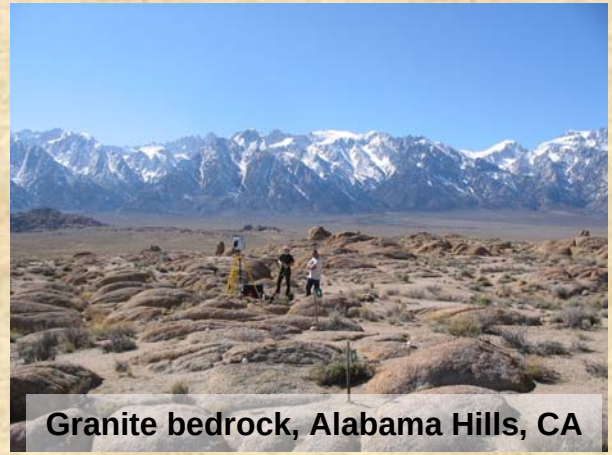
Model-based roughness calibration:

Different terrains may have different calibration coefficients -


Alluvial gravels, Death Valley, CA


Playa salts, Death Valley, CA


Basalt flow, Red Hill, CA


Granite bedrock, Alabama Hills, CA


Mars Hill, Death Valley, CA


Alluvial surfaces, southern Israel

LiDAR library for various terrains – work in progress

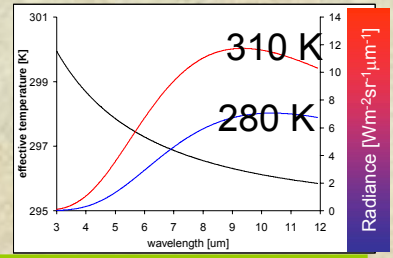
Roughness effects in the TIR:

Compensation for roughness effects on ASTER TES require a transformation function between

E_m and ε

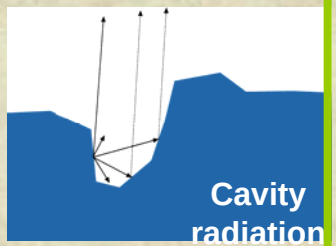
Shadowing:

$T_{eff} > T_{avg}$



Cavity rad :

Reduced spectral contrast



L_s: *radiance at sensor*

ASTER TES* *(Gillespie et al., 1998)*

ASTER 5 TIR channels

→ Assume ε_{max}

→ apparent ε_λ's

→ empirical regression MMD vs 'true' ε_{min}

→ re-scale apparent ε_λ's and Calculate T

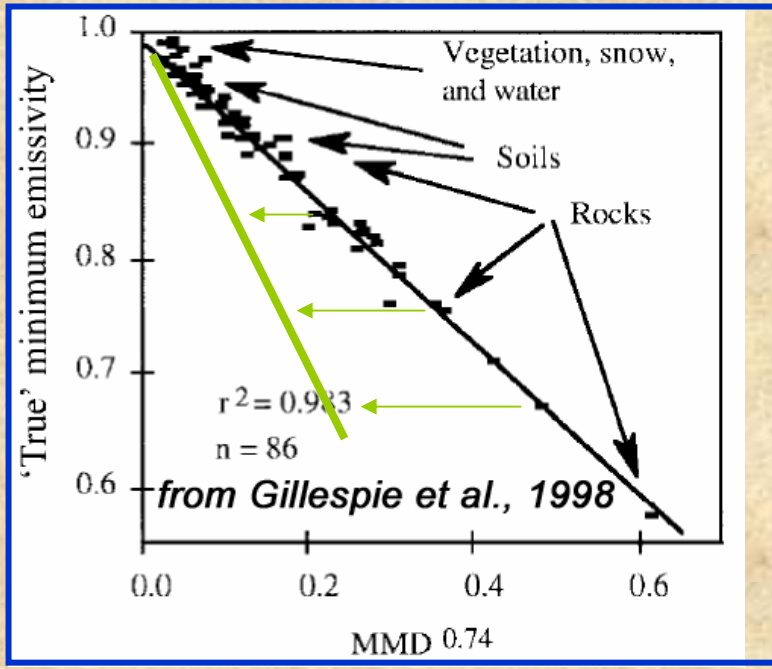
Cavity radiation:

Emmittance (E_m)= f(*emissivity, roughness*)

→ ε_{min}>'true' ε_{min}

→ Lower T_{eff}

*(Gustafson et al. P3.52)



MMD ∝ ε_{max}-ε_{min}

ASTER TES compensation for Roughness

ASTER TIR data

LiDAR surfaces

TIR radiosity Model (Danilina et al. P 1.02)

ASTER stereo roughness

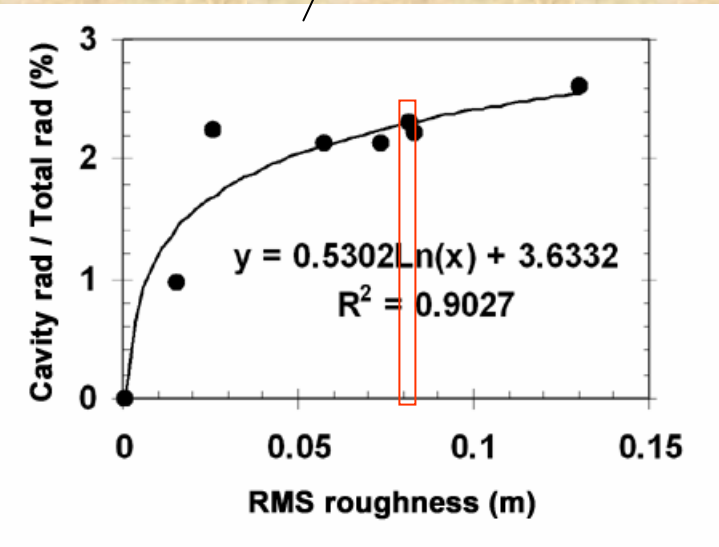
transformation function

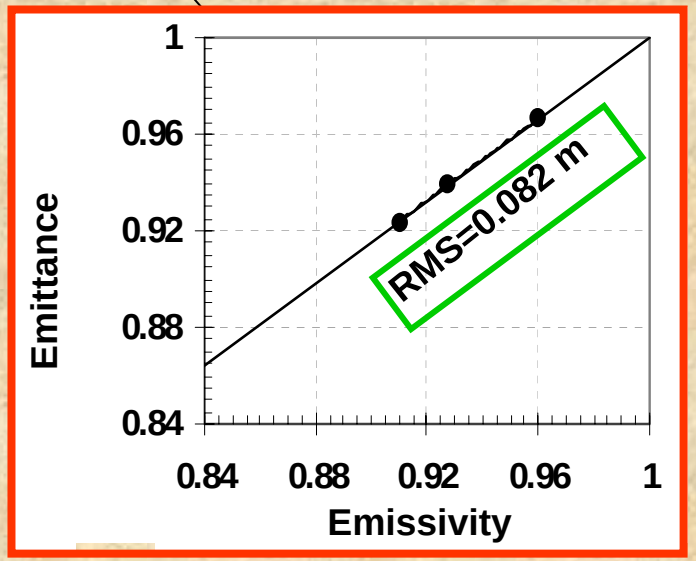
$E_{m(\lambda)} \leftrightarrow \varepsilon_\lambda$

TES algorithm

T

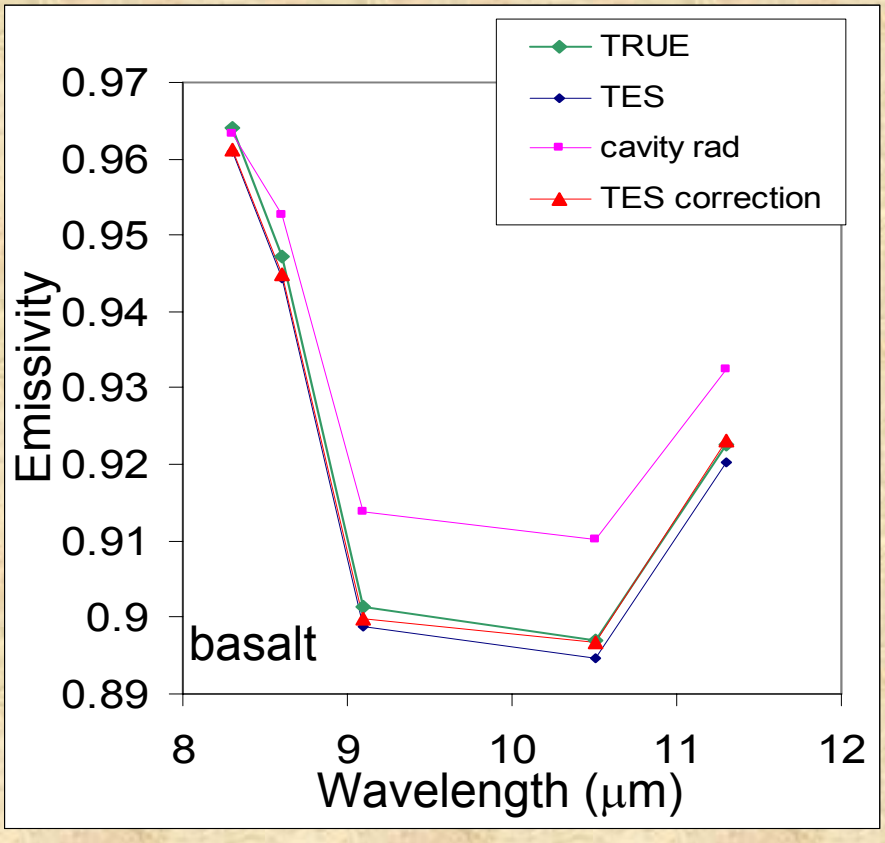
ε_λ





ASTER TES compensation for Roughness

Numerical simulation



* Spectra for “basalt1s” from ASTER spectral Library
* TES corrections include 10% random error in roughness estimation

ASTER TES compensation for Roughness

Before applying real image data:

- **Atmospheric effects**
  - **Incorporate the effects of shadows on cavity radiation**
    - **Isothermal surfaces are expected to be a 'worst-case' scenario for daytime data because the effect of shadowed cavities is be subdued. Night time data in which cavities are warmer is another story……**

Summary & Future work

Summary -

- ASTER stereo data can be used to measure sub-pixel (~15m) roughness
  - calibrations are terrain-type specific
    - theoretical basis for roughness compensation for ASTER TES emissivity retrievals

Future work –

- LiDAR library for different terrain types (in progress)
  - Incorporate solar illumination into TIR radiosity model
    - Further application and testing of roughness corrections for ASTER TIR data